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GEOLOGICAL REPORT ON 1:100 000-SCALE MAPPING OF THE SOUTHEASTERN ARUNTA BLOCK, NORTHERN TERRITORY

by

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SUMMARY

A simplified working model is presented of the stratigraphic and tectonic evolution on the basement rocks in the Arunta Block, based on the concept of three broad lithological groupings, termed Divisions. For simplicity of presentation the stratigraphy of the Alice Springs area is described in terms of these three Divisions.

In the Alice Springs 1:250 000 Sheet area Division I consists chiefly of basic and acid granulites (Strangways Metamorphic Complex and its equivalents) and is interpreted as a bimodal sequence of volcanics and intrusives introduced during a phase of arrested east-striking rift development on an ensialic crust.

Later widespread subsidence resulted in two, possibly connected, east-trending troughs flanking the metavolcanic belt represented by Division I rocks. The southern trough was filled by acid volcanic and volcaniclastic rocks, now represented by well-layered quartzofeldspathic gneisses (mainly in the Wigley and Ankala Blocks), tentatively assigned to units of the lower part of Division II. In contrast, a more argillaceous sequence containing only minor volcanic rocks (Harts Range Group), and more typical of the upper part of Division II, was deposited in the northern trough preserved in the northeast of the Sheet area. The quartzofeldspathic gneisses of lower Division II in the southwest appear to be much thinner in the northeast and are present only in the adjacent Alcoota and Illogwa Creek 1:250 000 Sheet areas (eg. Entia Gneiss).

The sedimentary cycle was completed by deposition of more mature quartz sandstone and argillite belonging to Division II (eg. Iwupataka Metamorphic Complex).

Tectonism at about 1800 m.y. resulted in metamorphism up to granulite grade, widespread migmatisation, and minor granite emplacement. Metamorphism and deformation re-occurred at 1700-1600 m.y., possibly at 1500-1400 m.y., at 1100-1000 m.y., and at 400-300 m.y. Granites were emplaced during the 1700-1600 m.y., and some granite emplacement accompanied the 1100-1000 m.y. metamorphism. Overthrusting, possibly at 1600 m.y., and certainly at 300 m.y., was synchronous with metamorphism.

The Woolanga Lineament, which cuts the main east-west tectonic trend at a high angle, is thought to be a deep-crustal fracture responsible for localisation of the potassic-ultramafic Mordor Igneous Complex and the Mudtank Carbonatite during periods of stability about 1090 m.y. and 730 m.y. ago, respectively.

Arunta rocks have some potential for Oonagalabi-type Zn-Pb-Cu deposits. Various schist zones are prospective for gold, lead, copper, and possibly uranium. The zone alongside the Woolanga Lineament is a possible locus for kimberlite, which may contain diamonds, and for carbonatite which may contain economic concentrations of niobium, rare earth elements, zircon, apatite, and vermiculite. Other minerals of interest in the region include mica in the Harts Range pegmatites, and ruby, some of which is of gem quality, occurring in amphibole-plagioclase pods in the Riddoch Amphibolite Member of the Irindina Gneiss.

A: INTRODUCTION (R.D.S.)

A-1: Location and access

The Alice Springs 1:250 000 Sheet area is located between latitudes 23° and 24°S and longitudes 133°30' and 135°E, in the southern part of the Northern Territory. Alice Springs is the main township in the area; it is linked to Darwin in the north by bitumen road, and to Adelaide in the south by railway and partly sealed road. Gravel and earth roads link Alice Springs to Jay Creek, Papunya, and Yuendumu Aboriginal Settlements, and Hamilton Downs homestead in the west, Yambah and Bond Springs stations in the north, and Ross River Chalet and Ringwood, Atnarpa, The Garden and Ambalindum homesteads in the east. Daily air services operate to Alice Springs from Darwin and Adelaide, and weekly direct from Sydney.

A-2: Climate

The climate of the area is semi-arid, with a low humidity and widely varying annual rainfalls. The average annual rainfall at Alice Springs is about 250 mm, ranging from a recorded minimum of 82 mm (1965) to a maximum of 783 mm (1974). Most of the rain falls in the summer months. The potential evaporation from exposed stored water is ten times the average rainfall. In January, the normal daily maximum temperature is about 38°C and the minimum about 23°C; in July the corresponding temperatures are about 21°C and 4°C. The area has about 60 days of frost each year, and averages 300 hours of sunshine for January and 275 hours for July. Conditions are ideal for fieldwork from April to October.

A-3: Development

Alice Springs had a population of 13 400 in June 1975, and is the centre for services and supplies in the southern part of the Northern Territory. The main industries are tourism, beef cattle, government administration, and a joint Australian-USA space-tracking facility. There are smaller settlements at Ross River Tourist Chalet, and at Jay Creek and Amoonguna Aboriginal Settlements. Arltunga, now abandoned, was an important goldmining centre from 1897 to 1937, and at the turn of the century was as important as Alice Springs. Mica was mined in the Harts Range from 1890 to 1960.

A-4: Scope of this report

This report outlines the results of mapping of basement rocks in the six 1:100 000 Sheet areas that make up the Alice Springs 1:250 000 Sheet area, namely BURT, LAUGHLEN, RIDDOCH, ALICE SPRINGS, UNDOOLYA, and FERGUSSON RANGE*. An outline of the mineral deposits in the Arunta rocks within the Alice Springs 1:250 000 Sheet area is given in a separate Record (Warren, in preparation). The distribution of mapped rock units is also portrayed on the Preliminary 2nd Edition of Alice Springs 1:250 000 Geological Map (Series SF/53-14). For information on the Amadeus Basin sequence the reader is referred to Wells (1969) and Wells & others (1970). The 1:100 000 maps incorporate recent mapping by Jones (1972) on the Brewer Conglomerate, and a new subdivision of the Bitter Springs Formation based on photo-interpretation (A.J.S.). D. Clarke from the Northern Territory Geological Survey has recently subdivided the Heavitree Quartzite into members. The lithology of these members is given in this Record. They occur throughout the Alice Springs 1:250 000 Sheet area, but are not shown on the present series of maps.

Physiographic divisions of the region have been described by Perry & others (1962), and are summarised in Wells (1969). The denudation chronology in the Alice Springs area has been outlined by Mabbutt (1967, in Jennings & Mabbutt, 1967). No additional information is given in this report.

A-5: Survey method and presentation of results

Mapping was carried out from 1967 to 1975 using four-wheel drive vehicles and co-ordinated foot traverses. Mapping began in the cover rocks of the Arltunga Nappe Complex and was plotted on enlarged black and white aerial photographs. Use of coloured aerial photographs at 1:26 000 began in 1971. About 50 hours of helicopter traverses were concentrated in the inaccessible parts of the Strangways Range. Geological data and interpretation were plotted on aerial-photo overlays and then

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*Footnote: Upper case titles e.g. FERGUSSON RANGE, refer to the 1:100 000 Sheet areas throughout this report. Note that the title refers to the area of mapping and not literally to the map sheet.

transferred stereographically on to enlarged orthophoto maps supplied by the Division of National Mapping. Coloured aerial photographs of the area are also available from the Division of National Mapping. The base maps were compiled by BMR from 1:100 000 scale orthophotomap line compilations supplied by the Division of National Mapping.

Because the basement is very complex and time-consuming to map, only a few areas have been mapped in detail. For much of the detailed mapping we are indebted to a number of Ph.D. students and their supervisors. A.J. Stewart studied the central part of the Arltunga Nappe Complex under R.L. Armstrong at Yale University; M. Yar Khan mapped the Atnarpa Range in 1969-70 under B.E. Hobbs (ANU); M.J. Rickard (ANU) mapped part of the Harts Range in RIDDOCH, and supervised the work of J.L. Funk, who mapped the Arltunga Nappe Complex between Bald Hill and Jennings Gorges; B.A. Duff mapped parts of the Atnarpa and White Ranges as part of his B.Sc. Hons degree. A.F. Wilson (Uni. Qld) supervised the work of A.R. Allen, who mapped the area around Ankala Hill and the Utnalanama Range, P.J. Woodford, who mapped in the Strangways Range area west of Woolanga Bore, and S.S. Iyer, who studied the Yambah Retrograde Schist Zone. D.J. Forman (BMR) and R.D. Shaw carried out detailed mapping in the eastern part of the Arltunga Nappe Complex in 1969. The details of structural mapping in the Nappe Complex have been reported by Shaw & others (1971).

The remainder of the area was mapped mostly to reconnaissance standard, and relies heavily on photo-interpretation of coloured aerial photographs at 1:26 000 scale. The distribution of measured dips gives a good guide to the location of traverses. Particular attention was paid to the petrology of the Mordor Igneous Complex (A.P.L.), and the structural relationships between multiply folded rocks of the Cadney metamorphics north of Claraville homestead (R.D.S.). Further studies are in progress on the economically important lenses of magnesian, ferruginous, and aluminous rocks in the upper part of the Strangways Metamorphic Complex (R.G.W.).

Stratigraphic nomenclature and symbols used in this Record are those proposed for the 1st Edition series of 1:100 000 maps. Changes made between the Preliminary and 1st Edition maps are listed in Appendix C.

A-6: Explanation of the Map System

The 1:100 000 maps are principally lithological maps, and show the distribution of mappable rock types or groups of rock-types. Lithological boundaries and symbols are shown in black* on the Preliminary maps. The maps also show a proposed stratigraphic subdivision of these rocks. Red* boundaries and symbols on Preliminary maps delineate generalised "stratigraphic units". In some cases the confidence with which "stratigraphic units" can be recognised diminishes rapidly away from the reference area. The extension of "stratigraphic units" and stratigraphic correlations are, therefore, regarded as interpretative. The rocks are divided into an ascending hierarchy of stratigraphic units which have increasing formality, namely (1) rock types in undivided Precambrian (e.g. pC), (2) symbolised informal units (e.g. pCa), (3) named informal units, such as "Yambah granulite", (4) "schist zones" and (5) formations. Larger groupings of rock, namely (6) "metamorphic suites", (7) "complexes" and (8) "Divisions" decrease in formality with size, and reflect difficulties in correlation. (9) "Blocks" are used for structural and other form features such as basement-areas.

(1) In the most informal classification, rock types (a,b,f etc.) shown in black symbols and boundaries on the maps, are assigned to "pC", that is a grouping of undivided Precambrian rocks, shown in red outline. Where more than one lithological type is represented in an outcrop-area, only the first two (or rarely three) most common rock types are shown on the map. More detailed information on rock type is given in some cases in the map legend. In general, where lithological units thin beyond the limit of resolution, they have been omitted from the face of the map. Consequently, the lensing out of rock units shown on the map may be caused by the limitation of scale. In some

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*Footnote. Black and Grey are proposed instead of Black and Red for 1st edition 1:100 000 maps.

cases parallel thin units have been combined. In a few cases thin but significant units have been emphasised and thereby artificially thickened in order to retain them on the map.

(2) Where a distinct grouping of rocks has been recognised, but its relationships are uncertain, or where rock units have been lumped together simply for the convenience of mapping and description, the stratigraphic unit is given a 3 letter symbol (in RED) e.g. pGx, but is not given a name.

(3) Where a stratigraphic unit is recognised and its boundaries are clearly defined, but the internal order of superposition is uncertain because of the complex structure, an informal name is used, such as "Ongeva granulite". Such a unit is similar to the old concept of "Beds"; informality is indicated by using a lower case letter for the rock name.

(4) "Schist Zones" are treated in one of two ways:-

(i) If the mapped unit contains significant remnants of the original deformed unit, or has markedly transitional boundaries with the original unit, a structural term is used, such as West Bore Schist Zone. This usage particularly applies to cross-cutting retrograde schist zones.

(ii) If the mapped unit is clearly distinguishable from the neighbouring units, it is considered "a mappable rock unit", particularly if it is a conformable unit, and is given formal or informal stratigraphic status, e.g. Anuma schist.

(5) A unit is considered to be a formation in the formal sense of the Australian Code of Stratigraphic Nomenclature if its boundaries are defined, it consists of distinct rock types recognizable in the field, and its internal order of superposition is known or is unimportant. However, it may not be known if the unit is overturned. Formations are

distinguished by using a capital letter for the lithological part of the name, e.g. Gum Tree Granite. "Metamorphics" is used for a mixture of rock types. "Granulite" is used for mixtures of rock types (e.g. mafic and felsic granulite), 60 percent or more of which are recognisable as granulite in the field; that is, they contain metamorphic hypersthene.

(6) "Metamorphic Suite" is used as the metamorphic equivalent of "Group" for high-grade metamorphic rocks of diverse origin distinguished by some lithological feature other than metamorphic grade. As such they consist of formal or informal units, and can include unassigned rock types.

(7) "Complex" is used in the sense of "supergroup" for groupings of "suites", "formations" and informal units that together have some unifying feature, be it compositional, chemical or textural, and are also characterised by similar, usually complex, structural style. Such a 'Complex' may include anatectic igneous rocks which have had a similar metamorphic history to "stratigraphic units" in the complex.

(8) For simplicity of presentation of the regional geology, the metamorphic rocks of the Arunta Block are grouped informally into three divisions. The rocks in each division may be chronological or stratigraphic correlatives.

(9) "Arunta Block" (Noakes, 1953) is used in this Report in the sense of Arunta basement-area. The term "Arunta Complex", introduced by Mawson & Madigan (1930) for "the igneous and metamorphic rocks of the plateau-shield of central Australia", is considered superfluous because it can be divided into a number of units, or complexes, some of which also occur in the Granites-Tanami and Tennant Creek Blocks.

The nomenclature used for igneous and metamorphic rocks is mainly that proposed by Morgan (1964). However the nomenclature of metamorphic, granitic and migmatic rocks is currently under review. A glossary of geological terms is given at the end of this record to clarify the usage adopted in the text.

Grid references are given by 4 or 6-figure numbers prefixed by the 1:100 000 Sheet number given in Table A1.

Table A1: 1:100 000 Sheet Numbers

Sheet	Number
BURT	5651
ALICE SPRINGS	5650
LAUGHLEN	5751
UNDOOLYA	5750
RIDDOCH	5851
FERGUSSON RANGE	5850

Six-figure references refer to the large grey figures at the margins of the 1:100 000 Sheets, eastings being given before northings. The third and sixth digits are estimates in tenths from the grid-line to the point and specify the point to the nearest 100 m. Four-figure references are for use with 1:250 000 Sheet areas and give estimates in hundredths from the 10 000 m grid-lines. The first and fourth digit of a six-figure 1:250 000 metric grid reference (as given in the map margin) should be ignored; their function being replaced by the 1:100 000 Sheet-number. For example, The Garden homestead has a grid reference of 5751-409 248 when referred to the 1:100 000 Sheet, and 5751-4125 in the case of the 1:250 000 Sheet (not 5751-441425).

Specimen numbers listed in the text are thin section numbers unless otherwise specified and take a number of forms (e.g. 4159, 853, M3621 or 72912604). For specimens collected after 1969 the BMR registered number corresponds to this thin section number with a prefix added for the year (e.g. 75) and project (e.g. 91). For specimens collected before 1970 the thin section number and the BMR registered number do not correspond. A guide to the prefix code for registered numbers is given in Appendix I.

A-7: Previous Geological Investigations

Previous exploration and geological investigations in the region have been outlined by Forman & others (1967) and Wells & others (1970). Only an outline of work concerned with the basement or basement-cover relations is given here.

The area was first explored by John McDouall Stuart, who travelled through the western part of the region on his way northwards. His route passed west of the present site of Alice Springs (Stuart, 1865). In 1878 Henry Vere Barclay traversed north of the Hale River and discovered the Plenty River. In 1888 J. East and in 1894 Charles Winnecke explored the region between Alice Springs, the Hale River and the Harts Range.

Early geological investigations were concerned with prospecting, principally for gold at Arltunga (1889-1940) and later for mica in the Harts Range (1896-1952), and with the broad-scale subdivision of the rocks in the region. These early investigations are listed in Tables A2 and A3. The quartzites at Arltunga and Chewings Range, first described by Tate & Watt (1895), became the subject of a controversy as to whether they were both part of the basement or part of the sedimentary cover sequence. Papers concerned with this controversy are noted in Table A4. The controversy was settled by the mapping of Forman & others (1967), who showed the Chewings Range Quartzite to be part of the metamorphic basement, but the quartzite at Arltunga to be deformed Heavitree Quartzite, the basal unit of the overlying Amadeus Basin sequence.

Observations on the general geology of the region have also been made by Hills (1949), Browne (1950), Noakes (1953, 1956), Öpik (1957), and Walpole & others (1965).

A regional land research study was carried out by CSIRO in 1957 and 1958 (Perry & others, 1962). As part of the study Quinlan & Ryan reported on the geology, and Jones & Quinlan on the groundwater resources. Perry & others (1963) assessed the agricultural groundwater potential of Cainozoic sediments in the Burt Plain. Other observations on groundwater, particularly in the Alice Springs Town Basin, have been

TABLE A2. Previous Investigations of Mineral Deposits

AUTHOR	YEAR PUBLISHED	ARLTUNGA AND WINNECKE GOLD FIELDS	HARTS RANGE AND STR. MICA-FIELD
BROWN	1889 1890	Reconnaissance geological surveys of gold fields near Arltunga	
	1896	Examined gold prospects at Arltunga	Examined mica deposits in Harts Range
	1902	Reported on gold mines at White Range, near Arltunga	
	1903	Reported on new discoveries of gold in Heavitree Quartzite south of Winnecke Depot	
MATHEWS	1905a 1905b	Reported on Arltunga and Winnecke Gold fields	Reported on Harts Range mica-field
HOSSFELD	1936	Reported on Ciccone mine, Winnecke Goldfield	
	1937a	Reported on Glankroil Lead Mine, Winnecke Goldfield	
	1937b 1937c	Reported on Arltunga Goldfield	
	1940	Reported on Winnecke Goldfield	
	1954	Mentioned deposits in general report on Stratigraphy and structure of Northern Territory	

TABLE A2 (cont'd)

OWEN	1945	Notes on Pannikin Deposit, Harts Range
SULLIVAN	1942a 1942b	Notes on Harts Range mica mines and their water supply
TOMICH	1952	Brief report on Harts Range mica field
DALY & DYSON	1956	Investigation for radioactivity in Harts Range Mica Field
RYAN	1957	Report on radioactive minerals in Strangways Range in pegmatite

TABLE A3: Previous Stratigraphic Investigations of Arunta Basement Rocks

AUTHORS	YEAR PUBLISHED	DIVISION 1	DIVISION 2		DIVISION 3	DEFORMED ZONES	LATE INTRUSIVES
RENNIE	1889	Note on garnet (so called rubies from Harts Ranges)					
EAST	1889	Noted the Arunta basement on a trip to the Harts Range					
CHEWINGS	1891	Described a sequence of '...chlorite schist; granite; micaceous schist and metamorphic granite with occasional outcrops of coarse eruptive granite and other eruptive rocks...' He included these and part of the Amadeus Basin sequence in his "older rocks".					
MOULDEN	1895	Described 'altered amphibolite, altered diorite, augen gneiss and garnetiferous gneiss' from the upper reaches of the Hale River.					
TATE & WATT	1896	Distinguished between metamorphics of sedimentary, eruptive and doubtful origins, and recognised a younger division to the northeast comprised of strongly foliated gneiss, and intermediate rocks (pyroxene diorite) and a basic group (gabbro and dolerite dykes).					
MAWSON & MADIGAN	1930	Introduced term "Arunta Complex" for rocks "vastly older than Heavitree Quartzite", which they described 'as the plateau shield of Central Australia', which extended from Alice Springs for 200 mls as far as Barrow Creek.					
MADIGAN	1931 1932a 1932b 1933	Recognised an older division of gneisses			Recognised a younger unit, the "Pertaknurra", of schist, quartzite and limestone of lower metamorphic grade	Recognised Later zones of Deformation	
HODGE-SMITH	1932	Not examined	Huckitta Creek Series (schists and gneisses of both sedimentary and igneous origin)	Augen schist Ambalindum Series (altered limestone and schist)	Not examined,	Not examined	Oolgarna Acid intrusives used for Harts Range pegmatites
JENSEN	1943a 1943b 1944 1945 1947	Not examined	Gneiss and amphibolite in Harts and Strangways Ranges		referred to "Pertaknurra" as lower grade metamorphic rocks of Northern Arunta	Not examined	Studied pegmatites in Harts Range area

TABLE A3 (cont'd)

HOSSFELD	1954	recognised an older "Arunta Series" of regionally metamorphosed conglomerate, arkose, grit sandstone, mudstone, limestone, volcanics and intrusives presumed to be Early Archaean	Riddoch Series, presumed to be Late Archaean		Rocks equivalent to the Reynolds Range Group correlated with the Hatches Creek Group	mentioned pegmatites in Harts Range area
JOKLIK	1955		HARTS RANGE GROUP: Cadney Gneiss, considered to be youngest unit by Joklik (but placed in our Division 1)	Entia Gneiss (granitic gneiss)	Bruna Gneiss (megacrystic feldspar gneiss)	Irindina Gneiss (garnet-biotite plagioclase gneiss)	made an extensive study of Harts Range pegmatites

TABLE A4: Previous investigations concerning the Heavitree Quartzite

AUTHOR	YEAR PUBLISHED	HEAVITREE QUARTZITE	CHEWINGS RANGE QUARTZITE
EAST	1889	Noted unit of quartzite	
TATE & WATT	1896	Overlies rocks of a "highly metamorphic character".	Tentatively included in Heavitree Quartzite
WARD	1925	Suggested quartzite at Arltunga is Precambrian	
CHEWINGS	1891 1894 1914 1928 1935	Recognised to be infolded into basement	Recognised to be infolded into basement
MADIGAN	1932b	p.38, Considered quartzite at Arltunga to be younger than basement	
VOISEY	1939b	Assigned quartzite at Arltunga to Archaean	
JOKLIK	1955	Considered quartzite at White Range near Arltunga to unconformably underlie Heavitree Quartzite	
FORMAN, MILLIGAN & McCARTHY	1967	Quartzite at White Range shown to be deformed and metamorphosed Heavitree Quartzite	Quartzite shown to be part of metamorphic basement and to be unconformably overlain by Heavitree Quartzite.

made by Owen (1952, 1954), Jones (1957), and Quinlan & Woolley (1962, 1963, and in Wells & others, 1970). Lloyd (1965) has briefly described the Tertiary and related sediments.

In 1964 BMR (Wells & others, 1965) mapped the northwestern part of the Amadeus Basin. During the same year Forman & others (1969) mapped Heavitree Quartzite and Bitter Springs Formation folded and thrust into the crystalline basement along the margin of the Amadeus Basin, and produced the first 1:250 000 map of the metamorphic rocks, based largely on photo-interpretation. The 1964 mapping was the basis of the 1:250 000 1st edition map of Alice Springs (Wells, 1969).

A-8: Previous and Current Geophysical Investigations

A regional gravity traverse across the Amadeus Basin and Arunta Block was made by Marshall & Narain (1954), and in 1961 and 1962 the Geophysical Branch of BMR completed a regional gravity survey of the Amadeus Basin and the surrounding area (Langron, 1962a; Lonsdale & Flavelle, 1963). The surveys demonstrated very large, linear, positive and negative gravity features. Interpretation of these features has been attempted by several authors (Forman & Shaw, 1973; Anfiloff & Shaw, 1973; Mathur, 1974, 1976; Wellman, 1978).

In 1973 Anfiloff (1975) carried out a semi-detailed gravity traverse, using gravity stations at one kilometre intervals, from Mosquito Bore, westwards across the Arltunga Nappe Complex and the adjacent Arunta basement, to the central part of the Alcoota 1:250 000 Sheet area. His results indicated that the regional gravity level corresponding to uplifted rocks north of the nappe complex containing granulite facies rocks presumed to come from the lower crust is similar to levels in areas with no granulite. This suggests thrusting may have been at a low-level and confined to the upper crust.

Detailed low-level aeromagnetic surveys at a line spacing of one-tenth of a mile (160 m) were carried out over four areas considered prospective for copper in the Strangways Range and also over the area of the Mud Tank Carbonatite (Tipper, 1969). In 1972 BMR flew a detailed airborne aeromagnetic survey over four small areas of the Arltunga Nappe Complex (Taylor, 1976).

The existing total magnetic intensity map of the Alice Springs 1:250 000 Sheet area is based on data obtained by Young & Shelley (1966) as part of a study of depth to basement in the Amadeus Basin. In 1975 a regional aeromagnetic survey was flown of part of the northern Arunta basement at a height of 100 m, using a line-spacing of 1.5 km; this survey included the western part of BURT, which contains extensive Cainozoic cover.

Note added in proof:

Rb-Sr isotopic dates calculated on a Rb decay constant of 1.39×10^{-11} yr^{-1} have been recalculated using 1.42×10^{-11} yr^{-1}. In most places in the text, both dates are mentioned, and the corresponding decay constant also shown, shortened to $\lambda = 1.39$ or $\lambda = 1.42$ respectively.

A-9: Acknowledgement

The contribution of A.R. Allen represents part of a Ph.D. thesis researched at the University of Queensland under the supervision of Prof. A.F. Wilson. Allen wishes to thank Planet Metals, BMR for providing logistics during field investigations, and the University of Dundee for facilities during preparation of his contribution.

B: REGIONAL GEOLOGICAL SETTING (R.D.S.)

The Arunta Block is an irregularly-shaped basement-area which merges northwards into The Granites-Tanami and Tennant Creek Domains in central Australia. It is overlain by the Proterozoic to Palaeozoic Amadeus, Ngalia, Georgina, and Birrindudu Basins (Fig. B1).

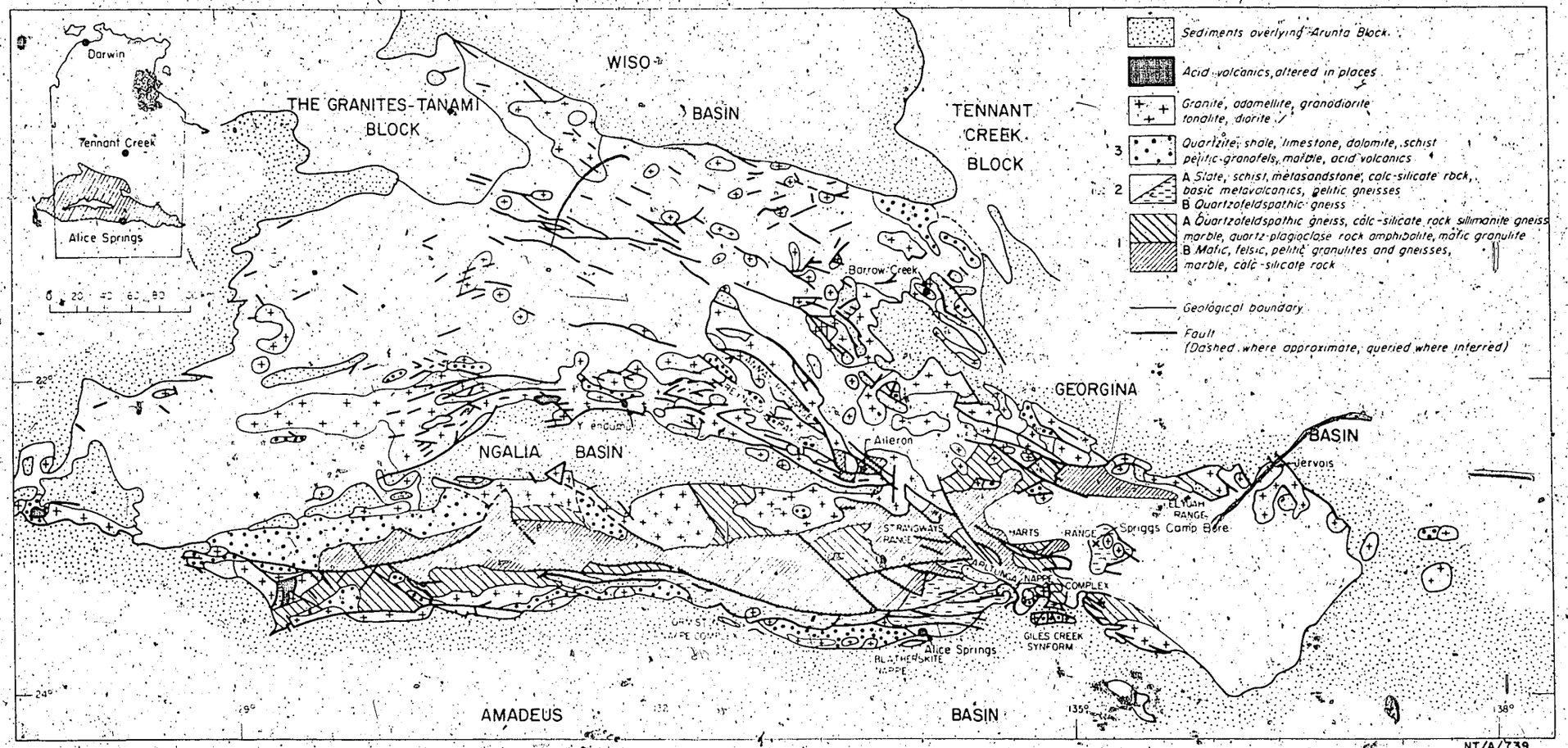
The Block comprises an early Proterozoic (or older) discontinuous sequence of sediments and volcanics, which was multiply deformed, regionally metamorphosed, and intruded by syntectonic granite in at least three separate events between 1800 m.y. and 1450 m.y. (Iyer & others, 1976; Armstrong & Stewart, 1975; Marjoribanks & Black, 1974). Post-tectonic granite intrusion, accompanied in the south by metamorphism and migmatisation, occurred at 1050-1000 m.y. (Black, 1975; Allen & Black, in press). Over-thrusting and localised amphibolite facies metamorphism occurred at 500-300 m.y. and greenschist metamorphism took place at 310-335 m.y.

The Arunta Block can be divided into three major east-trending tectonic units. These are shown in Figure B2.

The interpreted stratigraphic succession shows an overall decrease in volcanism and increase in sedimentary reworking. Three evolutionary stages are recognised and for simplicity of presentation are termed Divisions 1, 2 and 3. These Divisions should not be confused with the three tectonic units. They are recognised primarily on the basis of generalised lithological groupings of formal and informal stratigraphic units (Shaw & Warren, 1975; Shaw & Stewart, 1975; Stewart & Warren, 1977). Correlation throughout the Arunta Block is meaningful only on the scale of the Divisions. Some problems of classification still exist in the transitional stage between Divisions 1 & 2. A summary of the regional stratigraphy is given in Table B1.

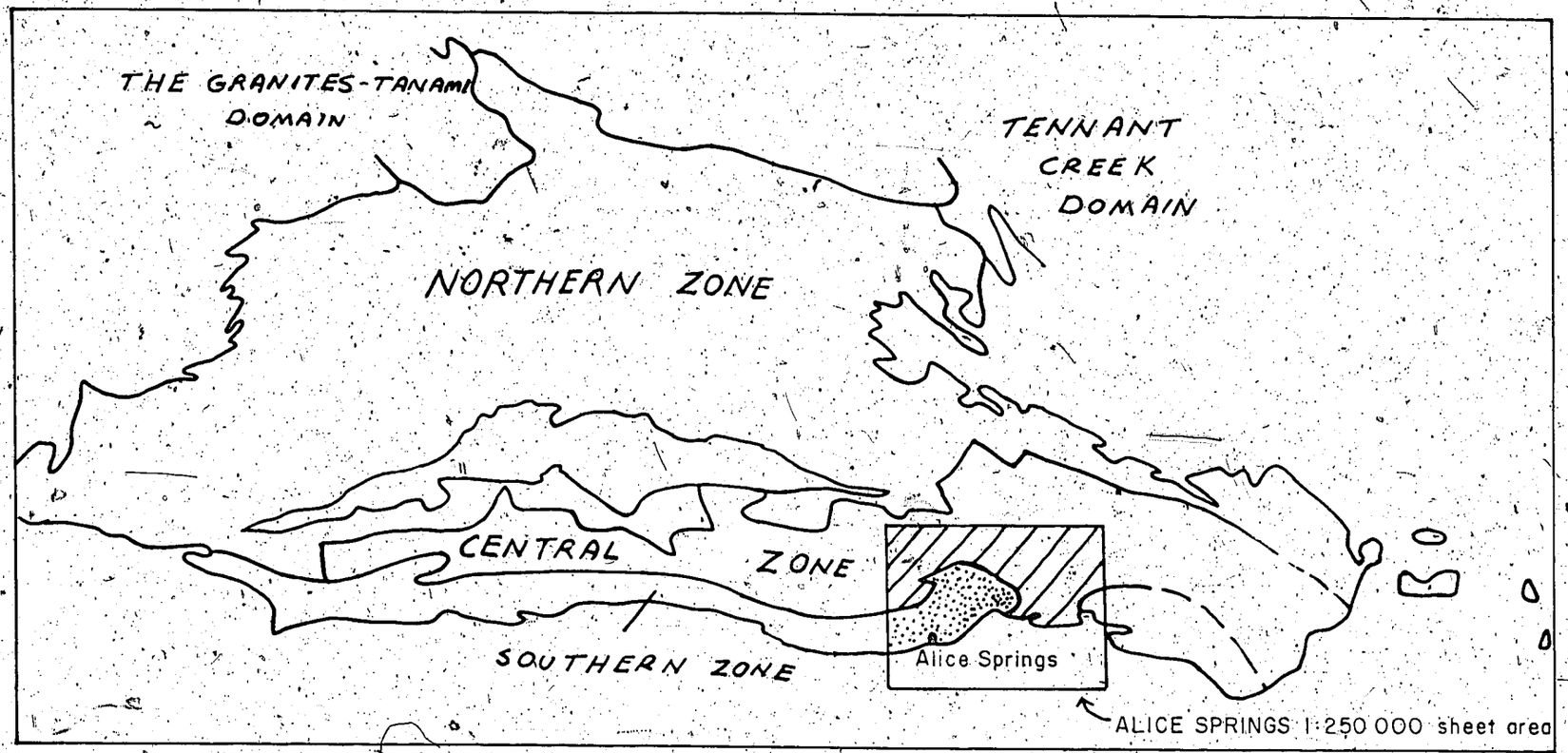
B-1: Division 1

Division 1 rocks crop out principally in the central tectonic zone (Table B1 and Figs. B1 & B2), and are characterised by felsic and mafic rocks which typically have been metamorphosed to granulite facies. These



Record 1979/47

Fig. B1 Generalised geological map of Arunta Block, showing major "stratigraphic" subdivisions (1-3) and granite



Record 1979/47

Fig. B2 Generalised tectonic zones in central Australia.

TABLE B1: Interpreted Stratigraphy of the Arunta Block

Evolutionary Stage	Age Subdivision	Southern Zone (eg. Wigley Block)	Central Zone	Northern Zone
Alice Springs Orogeny	300 - 400 m.y.	Overthrusting, localised greenschist metamorphism		
Post-tectonic intrusions	Late 700 m.y. ca. 900 m.y.	Dolerite dyke swarm, gabbro, dacite	Carbonatite	Rare dolerite dykes, troctolite plug
	Early 1200 m.y. ca.	Potassic-ultramafic intrusion with kimberlitic affinities		
Migmatisation 1100-1000 m.y.		Widespread migmatisation and local granite emplacement	Very local granite	Very local granite
At least three metamorphisms occurred between 1800 and 1450 m.y.				
Syntectonic igneous rocks	Late ie. 1700 m.y. ca.	Granites of igneous parentage, local diorite, dolerite and ultramafic rocks		Typically tin-bearing granites derived from sedimentary source rocks
	Early ie, 1800 m.y. ca.		Local anatectic granite related to granulite metamorphism	

TABLE B1 (cont'd)

Division 3		Quartzite, muscovite-biotite metasediment, staurolite-garnet-schist, metaconglomerate, quartzofeldspathic gneiss, megacrystic feldspar gneiss, megacrystic feldspar gneiss, (eg. "Iwupataka Metamorphic Complex").	Quartzite, mica schist, granule conglomerate, para-amphibolite, calc-silicate gneiss. eg. Mendip Metamorphics-Alcoota 1:250 000 Sheet area.	Quartzite, limestone, dolomite, pelite, granite porphyry, and their metamorphosed equivalents Generally greenschist facies, rarely granulite facies (e.g. Reynolds Range Group, Ledan Schist Utopia Quartzite).
Division 2A		Orthogneiss: interfingered with and includes rafts of succession of micaceous quartzose sandstone, mica schist, calc-silicate rock, and rare quartzite (Hayes Metamorphic Complex)	Pelitic gneiss, amphibolite, calc-silicate rock, rare marble and quartzofeldspathic rock. (Upper part of Harts Range Group)	Slate, schist, meta-sandstone, calc-silicate rock, intermediate and basic flows or sills, rare metamorphosed equivalents at granulite facies (e.g. Lander Rock Beds)
Division 2B		Commonly layered and migmatised quartzofeldspathic and garnet-biotite gneiss of granite to granodiorite composition, amphibolite and rare calc-silicate rock.	Granitic gneiss, leucocratic biotite-muscovite gneiss (Lower part of Harts Range Group ie. Entia Gneiss and felsic part of Delny Gneiss)	Not known in surface
Division 1A	Upper	Quartzofeldspathic gneiss, amphibolite, biotite gneiss, rare calc-silicate rock and sillimanite gneiss, hornblende gneiss in places	Calc-silicate rock, marble, cordierite, garnet and sillimanite gneisses, quartzo-feldspathic gneiss, rare felsic and mafic granulite, rare sapphirine and anthophyllite bearing rocks.	

TABLE B1 (cont'd)

Division 1B	Lower	Felsic and mafic granulite; much less common quartzo-feldspathic gneiss, cordierite gneiss, garnet gneiss; very rare calc-silicate rock and sapphirine- and anthophyllite-bearing rocks	Felsic granulite, quartzofeldspathic gneiss, mafic granulite, biotite gneiss (eg. Aileron meta-morphics)

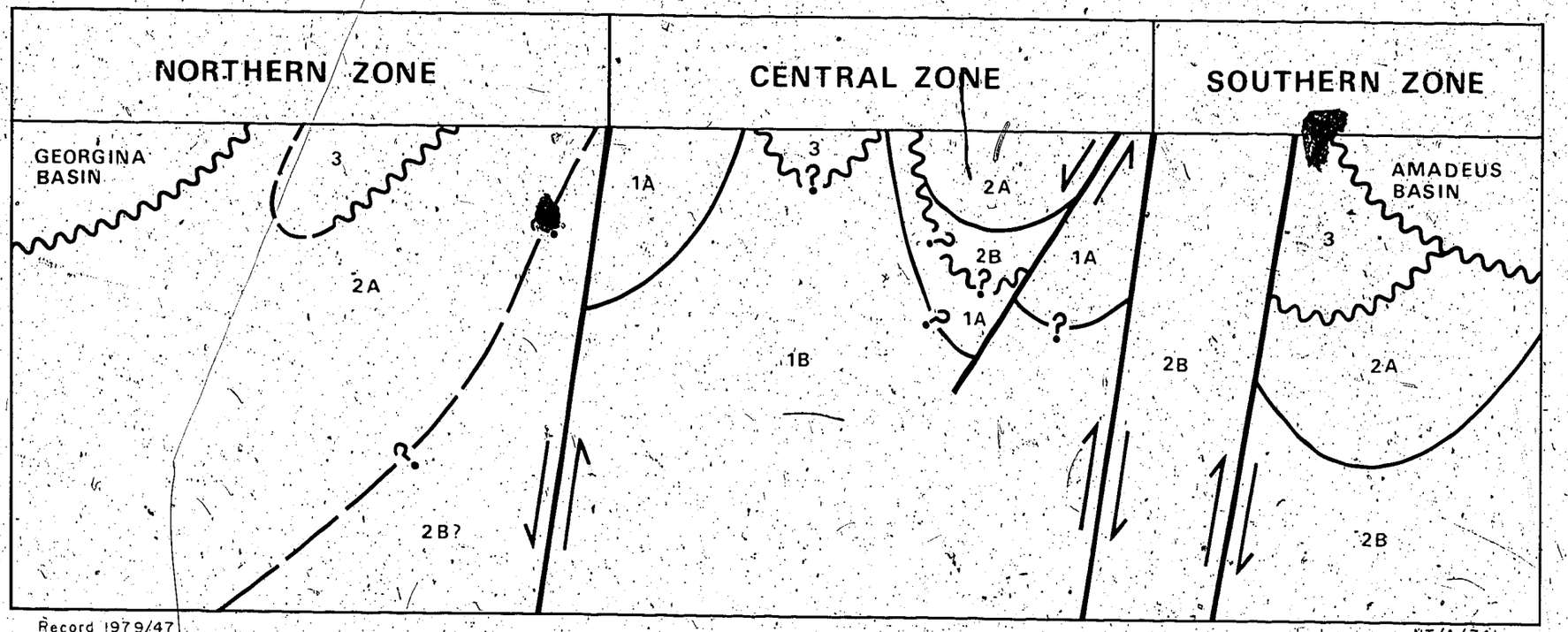
rocks crop out in linear belts corresponding to Bouguer anomaly highs. They are interpreted to be a metamorphosed sequence of acid and basic volcanics and lesser amounts of volcaniclastic rocks and small amounts of intercalated pelitic and calcareous sediments. A large proportion of the metabasic rocks is tholeiitic in composition, and occurs as both concordant and discordant bodies. Meta-anorthosite and anorthositic gabbro are present in places along the northern flank of Mount Hay range and the southern Strangways Range where they are thought to be in the lower part of the Division 1 sequence.

Rocks of Division 1 have undergone multiple folding and migmatisation, which culminated in a metamorphic event at about 1800 m.y. (Iyer & others, 1976; Black, 1975), and are considered to represent the basement to other rock sequences in the Arunta Block. They consistently overthrust Division 2 rocks of lower metamorphic grade.

Rocks in the upper part of the Division 1 (1A: Table B1 and Fig. B3) differ significantly from those in the lower part (1B). They are mainly metasediments, and include only small amounts of felsic rocks (possible metamorphosed acid volcanics and andesites) and some mafic granulite or amphibolite. Thin magnesian-rich lenses contain abundant anthophyllite, cummingtonite, gedrite, orthopyroxene and in places phlogopite and spinel. They very rarely contain sapphirine, hogbomite and kornerupine and are sparsely but widely distributed in the upper part of Division 1.

B-2: Division 2

Division 2 rocks are most extensive in the northern tectonic zone of the Arunta Block, where they consist of greenschist facies slate, schist, metasandstone, calc-silicate rock and locally intercalated intermediate and basic flows and sills (2A in Table B1, and Fig. B3). Near the Georgina Basin margin (Shaw & Warren, 1975) and in the Harts Range (Joklik, 1955) (2A, in central zone), these rocks pass into amphibolite facies rocks, and, in a restricted domain in the Reynolds Range, they pass into granulite facies rocks (Stewart & others, in preparation).



The legend for the divisions is given in figure 1 and table B1

Fig. B3 Relationship of the informal stratigraphic divisions of the Arunta Block.

Division 2 rocks in the northern and central tectonic zones (Figs. B2 & B3) consist mainly of metapelite, metapsammite and calcareous rocks which have a higher degree of sedimentary reworking, contain less felsic material, and have a smaller proportion of meta-igneous rocks than rocks of Division 1. However, in the southern tectonic zone near Alice Springs, rocks assigned to Division 2 are more quartzofeldspathic (including orthogneiss), and are thought to represent a sedimentary facies (2B) transitional with Division 1 rocks. In the upper part of this succession (2A) near Alice Springs, orthogneiss interfingers with and includes lenses of metasediment (Table B1), and is unconformably overlain by Division 3 rocks. A regional stratigraphic discordance, possibly an unconformity, separates Division 1 and 2, but the exact relationship is obscure.

The dominant Division 2 rock type is pelitic in the northern part of the Arunta Block and quartzofeldspathic in the southern part. This lithological variation may represent (1) a sedimentary facies variation, or (2) two separate sub-divisions (2A & 2B), the upper one of which thins rapidly southwards, or (3) be a function of metamorphic grade.

Division 2 rocks have been tentatively lithologically correlated with the Warramunga Group in the Tennant Creek Domain and with the Killi Killi and Mount Charles Beds of the Tanami region (Shaw & Stewart, 1975; Shaw & others, 1975). The metamorphism affecting the Warramunga Group has been dated at about 1810 m.y. by Black (1977) using the Rb-Sr total rock method.

B-3: Division 3

Division 3 rocks lie with angular unconformity on Division 2 rocks, and at one locality (near Mount Bleechmore, Alcoota 1:250 000 Sheet area) have a metamorphically discordant boundary against Division 1 rocks. Division 3 consists of weakly metamorphosed epeiric sediments (Table B1). In the Reynolds Range it consists of orthoquartzite with a basal conglomerate overlain by and interfingering with shale, lenses of limestone and dolomite, and sills and a lopolith of granitic porphyry. Near the margin of the Georgina Basin a Division 3 quartzite unit is underlain by a

Division 3 schist. Near the margin of the Amadeus Basin west of Alice Springs, Division 3 consists of a local basal metaconglomerate overlain by metasandstone, followed by quartzite intercalated with schist. The lower part of this sequence is intruded by a gneiss considered to be a metamorphosed quartz-feldspar prophyry sill.

Division 3 rocks are generally regarded as metamorphosed to greenschist facies, but in the southern part of the Reynolds Range they can be traced into granulite facies rocks. They have been correlated with the Hatches Creek Group and the Tomkinson Formations in the Tennant Creek Domain, and with the Pargee Sandstone and Mount Winnecke Formation in The Granites-Tanami Domain (Shaw & Stewart, 1976).

B-4: Igneous Rocks

Large syntectonic granite batholiths intrude rocks of all three divisions, but are most abundant in Divisions 2 and 3. Furthermore, the granites are noticeably concentrated near the margins of the younger Proterozoic-Palaeozoic sedimentary basins. They have a range of ages between 1900 and 1450 m.y. Preliminary petrological work suggests that many granites in the northern Arunta Block are similar to S-type granites in the terminology of Chappell & White (1973), whereas diorite, tonalite, granite and aplogranite of the Atnarpa Igneous Complex at the southern edge of the Arunta Block are akin to I-types (see chapter on Atnarpa Igneous Complex).

A Late Proterozoic episode of migmatisation and local granite emplacement is largely restricted to Division 2 rocks of the southern tectonic zone and has been dated at 1050-1000 m.y. (Marjoribanks & Black, 1974; Allen & Black, 1979).

Small, equant, post-tectonic intrusions include numerous gabbro bodies, dolerite dykes, dacite extrusions, a potassic-ultramafic intrusion with kimberlitic affinities (Mordor Igneous Complex) dated at 1210 ± 90 m.y. (1184 m.y., $\lambda = 1.42$) by Rb-Sr whole rock methods (Langworthy & Black, 1[illegible] and a carbonatite body dated at 730 m.y., by fission

track and Rb-Sr methods (Black & Gulson, 1978). A dolerite dyke swarm in the south of the Arunta Block, dated at about 900 m.y. (Black, personal communication, 1978), and altered but unmetamorphosed dacite extrusions at the south-western extremity of the Block are both overlain by the Heavitree Quartzite, the basal unit of the Amadeus Basin sequence. The carbonatite, potassic-ultramafic complex, and the dacite are localised near crustal dislocations postulated by Anfiloff & Shaw (1973) to correspond to the abrupt easterly and westerly terminations of the major east-trending system of gravity ridges and troughs in central Australia.

B-5: Tectonic Elements

The Arunta Block differs from much of the Proterozoic in northern Australia in the marked intensity and frequency of its deformations, and the high-grade nature of its metamorphism. In these respects it is more like the Musgrave Block and Gawler Province of South Australia.

The variations in thickness and rock types of the three major stratigraphic divisions can be related to their distribution within three major east-trending tectonic zones (Figure B2). For example, Division 2 is preserved in the central zone only at its eastern end, and Division 3 appears to rest directly on Division 1 in the northeast and in the west of the central zone. Each tectonic zone has a characteristic metal content (Stewart & Warren, 1977), metamorphic grade (Fig. B4), internal structure pattern, and styles of deformation. These differences are partly due to differences in exposed crustal level, but are also due to the fact that each zone has undergone distinct metamorphism and deformations of different ages.

The central tectonic zone (Fig. B2) is made up mostly of granulites of the Strangways Metamorphic Complex (Fig. B1), which belongs to Division 1, but it also locally contains thin sequences belonging to Divisions 2 and 3 (Figure B3). The Division 2 rocks here are mainly pelitic, and the Division 3 rocks are mainly represented by micaceous sandstone (Table B1). Granite forms a few small anatectic bodies: in the Strangways Range these are considered to be coeval with the main

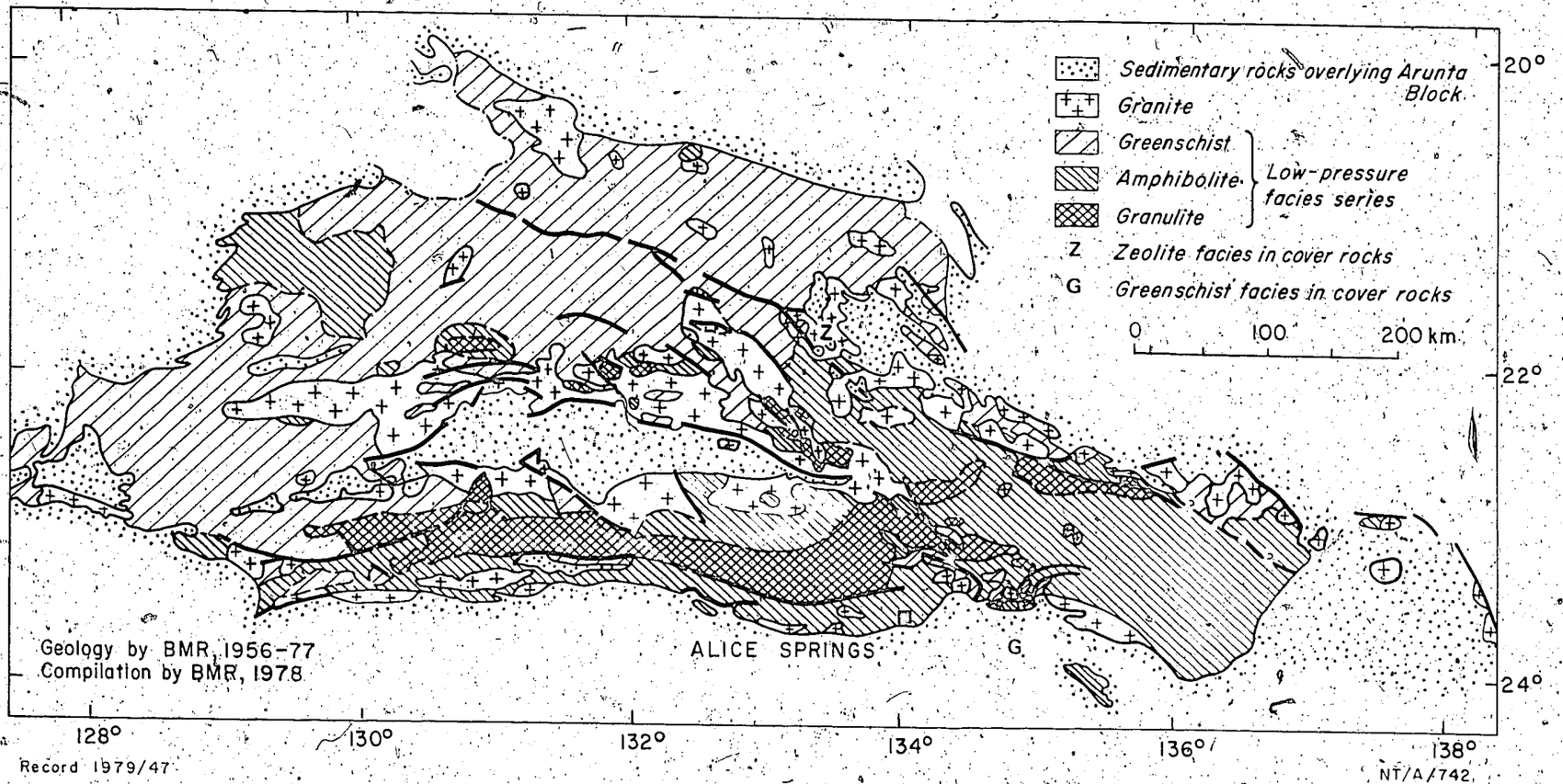


Fig. B4 Metamorphic map of Arunta Block.

granulite metamorphism which is dated at about 1800 m.y. (Iyer, Woodford & Wilson, 1976). Three phases of folding are evident in the central tectonic zone, the earliest of which commonly has northerly striking axial-plane traces. The main second phase of folding has easterly striking axial-plane traces. A third phase is developed locally. It consists of upright folds which warp the second phase recumbent folds and are accompanied by a fracture cleavage commonly trending northeastwards or eastwards (Rickard, 1975, p. 54). The main granulite metamorphism followed the third phase of folding at about 1800 m.y. (Iyer, & others, 1976).

The southern tectonic zone is separated from the central zone by a complex east-trending deformed zone shown as a fault in Figures B1 and B4. Rocks of the southern zone consist of extensively migmatised gneisses of Division 2, and are mainly of granite to granodiorite composition. Near Alice Springs the upper part of the Division 2 sequence contains metasediments (2A) and is overlain nonconformably by a sequence of metaconglomerate, pelitic gneiss, quartzofeldspathic gneiss, and quartzite assigned to Division 3. The southern zone has been metamorphosed to the amphibolite facies (Fig. B4) with the exception of lower amphibolite to greenschist facies rocks found in part of the Division 3 sequence. Two major Precambrian deformations and one in the Palaeozoic are evident. The first deformation, the Chewings phase of Marjoribanks (1975), produced isoclinal folds with a strong axial-plane foliation and lineation. Metamorphism at about 1600 m.y. (Marjoribanks & Black, 1974), mainly to amphibolite grade, is considered by Marjoribanks (1975) to be at least partly coeval with this deformation.

Syntectonic granites from the eastern part of the main segment of the southern zone (e.g. in Jennings Granitic Gneiss), dated by Armstrong & Stewart (1975) at about 1690 m.y. may belong to the same event or to a slightly earlier event. Similar granite of unknown age also occurs at the western end of the zone.

The second deformation, dated by Marjoribanks & Black (1974) at about 1050 m.y. (combined mineral and total-rock Rb-Sr isochron), was coeval with migmatisation and granite intrusion. It affected the southern zone near Alice Springs and rocks to the west at least as far as the Ormiston

area (Fig. B1). Folds produced in the highest grade rocks characteristically have mobilisate along their axial-plane structures.

Reactivation in the mid-Palaeozoic resulted in the emplacement of three thrust-nappe complexes at the southern margin of the zone (Stewart, 1967; Forman, 1971; Shaw & others, 1971; Marjoribanks, 1975). The greenschist metamorphism that accompanied this orogeny has been dated by Rb-Sr techniques at 335 and 312 m.y. (Carboniferous) by Armstrong & Stewart (1975): similar Rb-Sr mineral dates have been determined by Black & Gulson (1978).

The northern tectonic zone contains mainly Divisions 2 and 3 rocks. Division 2 here consists principally of a sequence of slate, schist and metasandstone (including Lander Rock Beds), calc-silicate rock and associated intermediate and basic flows or sills. It is unconformably overlain by quartzite and small amounts of calcareous and pelitic rocks, belonging to Division 3. Preliminary calculations on Rb-Sr data suggest that the zone was weakly metamorphosed (Fig. B4) at about 1500 m.y. (Black, BMR; 1977, personal communication). The data are still being evaluated. The zone is extensively intruded by granites especially near the margin of the Ngalia and Georgina Basins. A narrow northwest-trending upfaulted block in the Anmatjira Range (Fig. B1) consists mainly of Division 1 rocks and granite.

The structural trends in the northern tectonic zone generally follow the major faults, which trend mainly west-northwest in the east and west-southwest in the west, forming an arc convex to the north. The northern zone is basement to the Ngalia Basin, the northern margin of which became the site of major overthrust faulting during the Late Devonian and/or Early Carboniferous.

Distinct gravity signatures correspond to each tectonic zone (Fig. B2), and are of such a magnitude that they suggest that the zones continue in depth at least as far as the lower crust (Anfiloff & Shaw, 1973) and possibly as far as the mantle (Wellman, 1978). The most spectacular, a latitudinal Bouguer gravity ridge of up to +45 mGals, corresponds to the

central zone, where granulite blocks contain a significant proportion (10 to 40%) of meta-basic rock. It is this mafic component which gives the zone its high density (Mutton & others, in preparation). A similar linear positive gravity ridge but of smaller magnitude, crosses the northern part of the northern zone and may correspond to a similar granulite belt at a deeper crustal level. Parallel Bouguer anomaly troughs down to -100 mGals flank the main gravity ridge; they correspond to the granite belt surrounding the Ngalia Basin and, farther south, to the combined effect of the migmatised granitic gneisses and syntectonic granites of the southern zone, together with up to 9 km of sediment at the northern margin of the Amadeus Basin. The boundary between the southern and central tectonic zones roughly corresponds to a major deformed zone, the Redbank Zone of Marjoribanks (1975), which had been active under amphibolite facies conditions at an undetermined time (possibly at about 1600 m.y.) before the migmatisation event at about 1080 m.y. The deformed zone was also reactivated during the Devonian to Carboniferous Alice Spring Orogeny.

B-5-1: Regional tectonic model

The major gravity features outlined above have been interpreted by a number of authors (Forman & Shaw, 1973; Anfiloff & Shaw, 1973; Mathur, 1976; Wellman, 1978). The gravity features, considered as a whole, can be interpreted as indicating major density contrasts (assumed to be between 0.07 and 0.2 gm/cm^3) across the boundaries between the tectonic zones. The various gravity interpretations differ in the amount of mass imbalance ascribed to distortions of the mantle-crust boundary. It is clear that the major lateral density discontinuities, involving at least the upper crust, separate zones of different overall composition, having different metamorphic and structural histories. Gibbs & Thomas (1976) suggest that very similar gravity signatures, corresponding to province boundaries in the Canadian Shield, have formed in response to Precambrian episodes of cratonic convergence, collision and suturing.

The contrasting granite compositions from the northern and southern zones support a tectonic collision model in the Arunta Block. Granite and diorite (1700 m.y. old) in a klippe (Giles Creek Synform) that probably originated from near the central-southern zone boundary are derived

from igneous source rocks, and are similar to I-type granites in the Tasman geosyncline. In contrast, granites from the northern zone are similar to S-type granites in the Tasman Geosyncline considered to be derived by anatexis of metasediment at a much higher crustal level. However, the distinctive indicators of Palaeozoic suture zones (Dewey & Burke, 1973) are missing in the Arunta Block; obducted ophiolites, flysch nappes, and blue-schist melanges are not found. If the boundary between the central and southern tectonic zones is a suture, it may be a deeply eroded, cryptic suture, in the sense of Burke & Dewey (1973), marked by a zone of cataclasis or, if at a deeper level, mylonitisation and schist formation, separating blocks of markedly different metamorphic grade.

Several tectonic models can explain the abrupt major change in crustal composition and history displayed by the three zones of the Arunta Block. Three possibilities are:

(1) Interaction of continental and oceanic crust at about 1800-1700 m.y. However, the high proportion of rocks of granitic composition in the southern zone, and the lack of ophiolites, make this model unlikely. A modified interaction model, a short-lived narrow ocean basin which began as a rift-like structure, is discussed in more detail below.

(2) Intracontinental deformation, involving incipient underthrusting of the crust into the mantle, localised along a zone of high geothermal gradient (cf. Forman & Shaw, 1973, p. 19). This model infers incipient rifting with the introduction of tholeiitic basalts and dykes followed by overthrusting, without the formation of an ocean basin.

(3) The southern zone may correspond to a younger geosyncline in the classical sense developed against an older basement corresponding mainly to the central zone. Deep subsidence of the geosyncline may have resulted in accumulation of

radiogenic heat sufficient to melt parts of both the lower and upper crust (Schuiling 1972, a, b). This concept is supported by relationships north-northeast of Alice Springs where the overthrust boundary between the central and southern zones is a series of en-echelon faults between which Division 2 rocks appear to overlie Division 1 rocks.

The central tectonic zone has some features, particularly its high proportion of flows or dykes of tholeiitic composition, which fit the ensialic rift model of Windley (1973). On the other hand, they contain small amounts of meta-andesite, meta-anorthositic gabbro, meta-anorthosite, metatonalite, and possible metagreywacke, which point to a modern cordilleran or Andean environment. Further field work is needed to clarify the proportion of these rock types present; a major problem is that the original nature of the rocks is masked by granulite metamorphism.

Because the stratigraphic Divisions 2 and 3 can be traced across the central tectonic zone, and overlie it in places, any plate convergence must have taken place before 1700 m.y., possibly at 1800 m.y., before metamorphism of Division 2 and its intrusion by syntectonic granites. Late deformations and migmatisation at 1100 m.y., and thrust-nappe emplacement at 400-300 m.y., were localised in the same weakened southern zone. The tectonisms at 1100 m.y. and 400-300 m.y. are clearly intracratonic, because the overlying Division 3 rocks common to all three tectonic zones are close correlatives. The 400-300 m.y. event was comparatively brittle, presumably because the crust had been dehydrated and thickened by the earlier deformations.

The northern zone may also be interpreted as a younger geosyncline originally overlying but now faulted against basement of the central zone. In contrast to the southern zone, subsidence was only moderate, and regional metamorphism (1500 m.y.) generally low-grade. Granite intursion, on the other hand, was very extensive at 1500 m.y.*; 1100 m.y.* granite at Mount Boothby mirrors the coeval migmatisation in the

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*Footnote: very preliminary results by L.P. Black; subject to amendment

southern zone. The 400-300 m.y. overthrusting in the northern zone was wholly brittle, and resulted in the formation of thrust nappes at the margin of the Ngalia Basin.

It is argued here that, although there is some support in the lower part of the sequence for a plate-like boundary between the southern and central tectonic zones, this suture may have been an ensialic rift or a short lived narrow ocean basin, rather than the result of the interaction of continental crust with an extensive oceanic crust or a separate continental plate.

B-6: Amadeus Basin Sequence

The basal unit of the overlying cover sequence, the Heavitree Quartzite, rests on the Arunta basement within a few kilometers of the migmatite complex dated at 1050 m.y. near Ormiston Gorge (Marjoribanks & Black, 1974), and also rests directly on the Mordor Igneous Complex, dated at about 1200 m.y. and thought to have cooled in an intermediate-level magma chamber (i.e. 10 km+) (Langworthy & Black, 1978). This means that an enormous amount of uplift followed by erosion preceded the deposition of the Heavitree Quartzite, at about 900 m.y. Sedimentation of the platform-type was almost continuous from about 900 m.y. to the late Devonian, except for the epeirogenic interglacial Areyonga Movement in the Upper Proterozoic and mild regional uplift, termed the Rodingan Movement, possibly in the Silurian (Wells & others, 1970).

The major folding and thrust-faulting of the Alice Springs Orogeny is though to have been largely synchronous with deposition of the conglomeratic Pertnjara Group in the Upper Devonian to Carboniferous (Jones, 1972).

B-7: Cainozoic

Little deposition occurred in the region between the Carboniferous and the Cainozoic. Widespread peneplanation in the mid-Tertiary was followed by fluviatile and lacustrine deposition. Renewed tectonic activity of uncertain intensity, but involving mild folding and faulting, occurred in the later part of the Tertiary. The Quaternary was a period of renewed fluviatile deposition.

C: OUTLINE OF GEOLOGY (R.D.S.)

The following outline of the geology should be read in conjunction with the rock relationship diagrams (Figs C1, C2 & C3), the interpretative correlation chart (Fig C4), and the tables summarising the stratigraphy (Tables C1, C2, C3, C4, C5, and C6). This section emphasises interpreted stratigraphy and the reader is referred to the chapter on regional setting for a more general account, or to the bulk of the text for detailed descriptions of individual mappable units. Metamorphism and structure are treated in separate general sections. Published isotopic dates are given in Figure C3. The results of age determinations by L.P. Black (BMR) are to be presented separately in a forthcoming publication possibly in the BMR Journal of Australian Geology and Geophysics. Metamorphic unit names are those used on the latest 1:100 000 maps and on the Preliminary 2nd Edition 1:250 000 map of Alice Springs. Changes in stratigraphic nomenclature between Preliminary and 1st Edition 1:100 000 maps are listed in Appendix C.

Production of the 1:100 000 geological maps in the Alice Springs 1:250 000 Sheet area proved to be very difficult. Initially the wide variety of rock types occurring in the Sheet area were identified and their distribution delineated by extensive field checks supplemented by photo-interpretation. These rock types were then grouped into broad classifications including formal and informal stratigraphic units (see INTRODUCTION for more details). By careful study of the contact relationships a sequence of interpretative stratigraphic and intrusive events was erected. The lithological correlations that are made suggest similar geological processes, and are not necessarily time-stratigraphic equivalents. The lithological correlation chart portrayed in Figure C3 is, therefore, only one of a number of possible lithological correlations.

The units are grouped into the regional lithological Divisions 1, 2, and 3, which have been outlined in the chapter on REGIONAL SETTING.

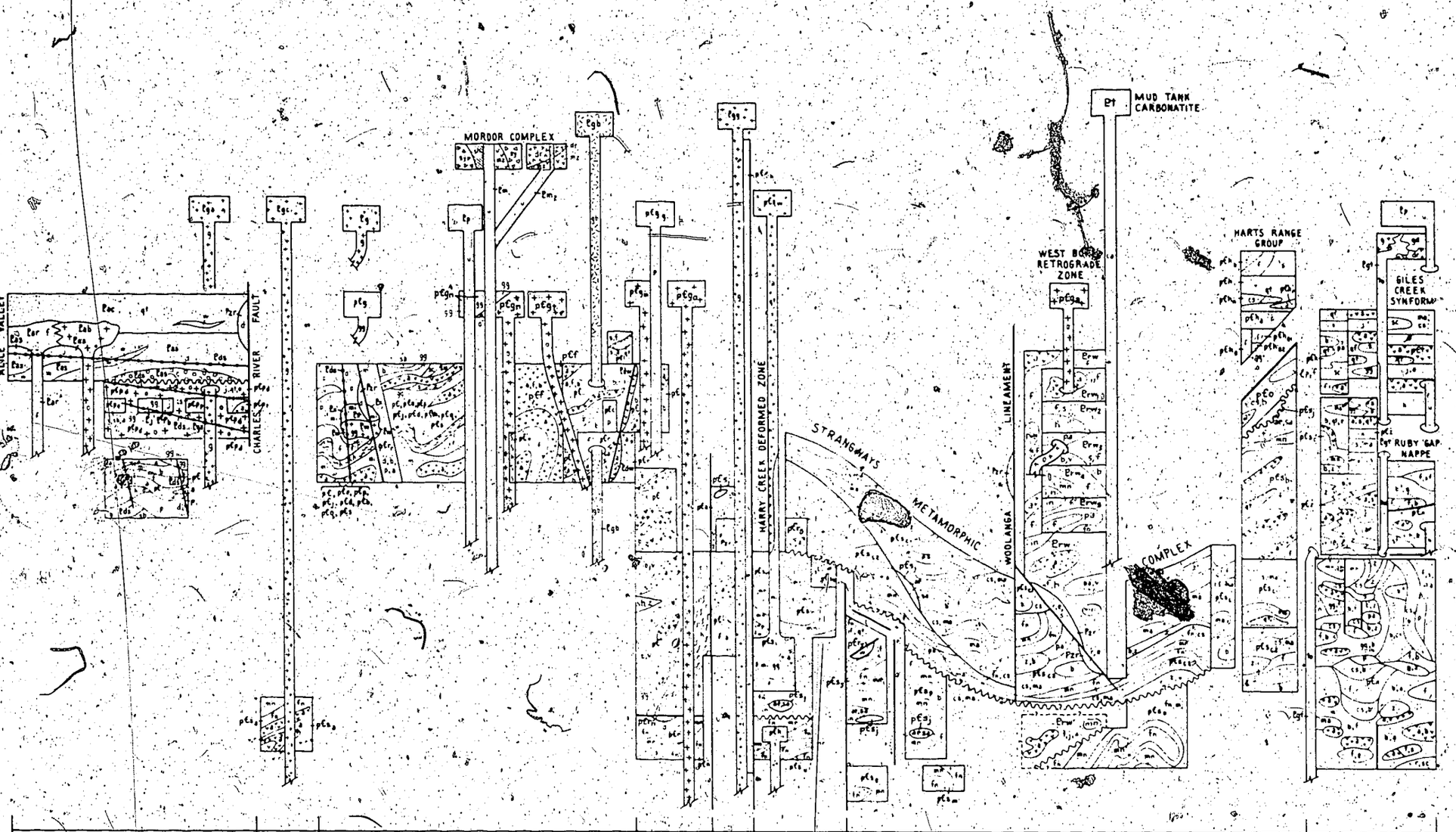

Fig. C1 ROCK RELATIONSHIP DIAGRAM OF THE ARUNTA BLOCK (Preliminary Maps)

NT/A/743

Record 1979/47

NOTE 1 Some rock types not shown because of insufficient space

2 Vertical separation of boxes indicates relative times of intrusion or dominant metamorphism
Ribbons below boxes indicate known intrusive relationships with older rocks
~~~ Unconformity, structural discordance of indefinite origin

3 Formation symbols used are those shown on the Preliminary maps

4 The Abalindum Block is to be subdivided on the First Edition maps
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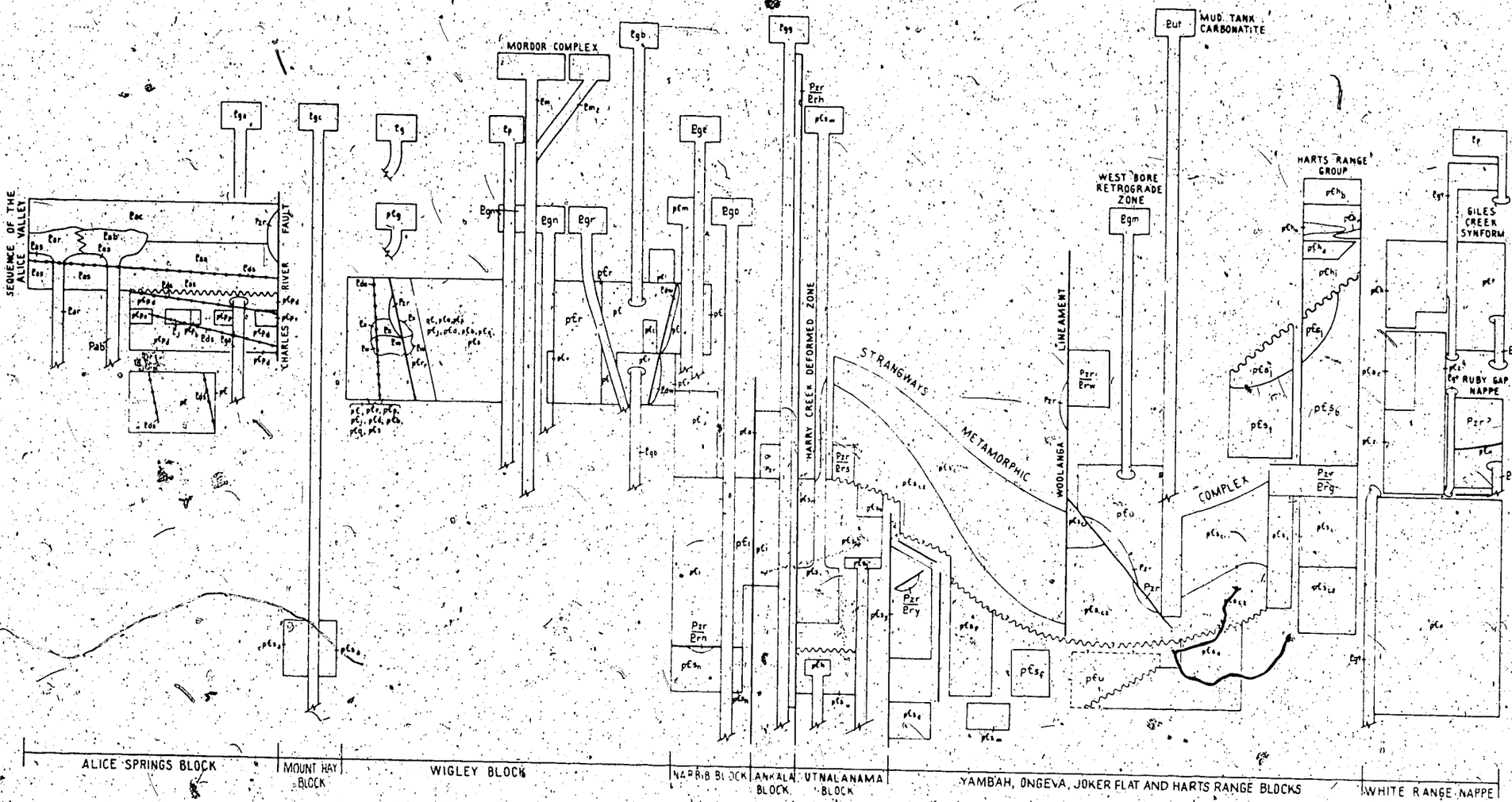

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Fig.C2 ROCK RELATIONSHIP DIAGRAM OF THE ARUNTA BLOCK (1ST Edition).

NT/A/744

NOTE Vertical separation of boxes indicates relative times of intrusion or dominant metamorphism
Ribbons below boxes indicate known intrusive relationships with older rocks
~~~ Unconformity
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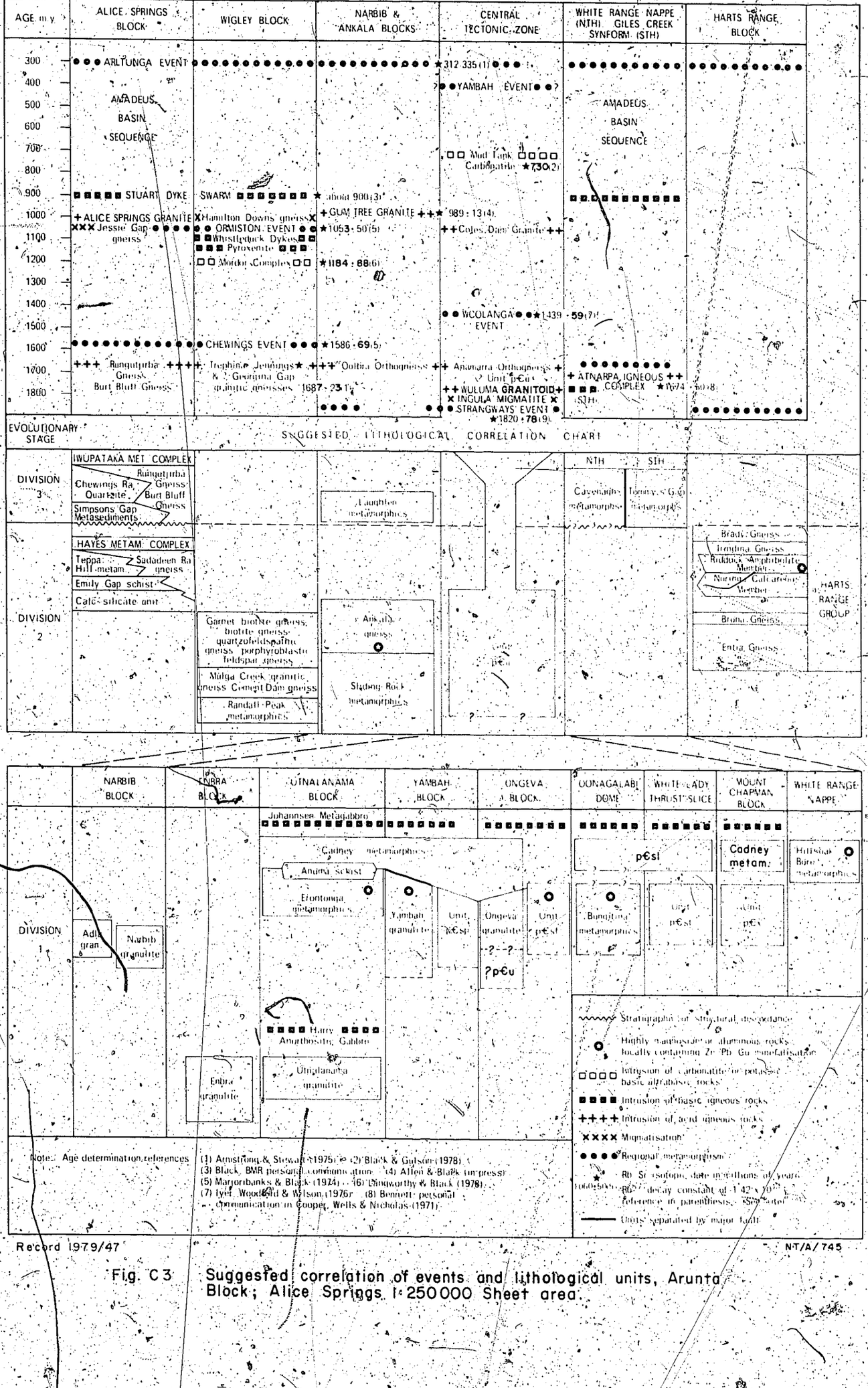

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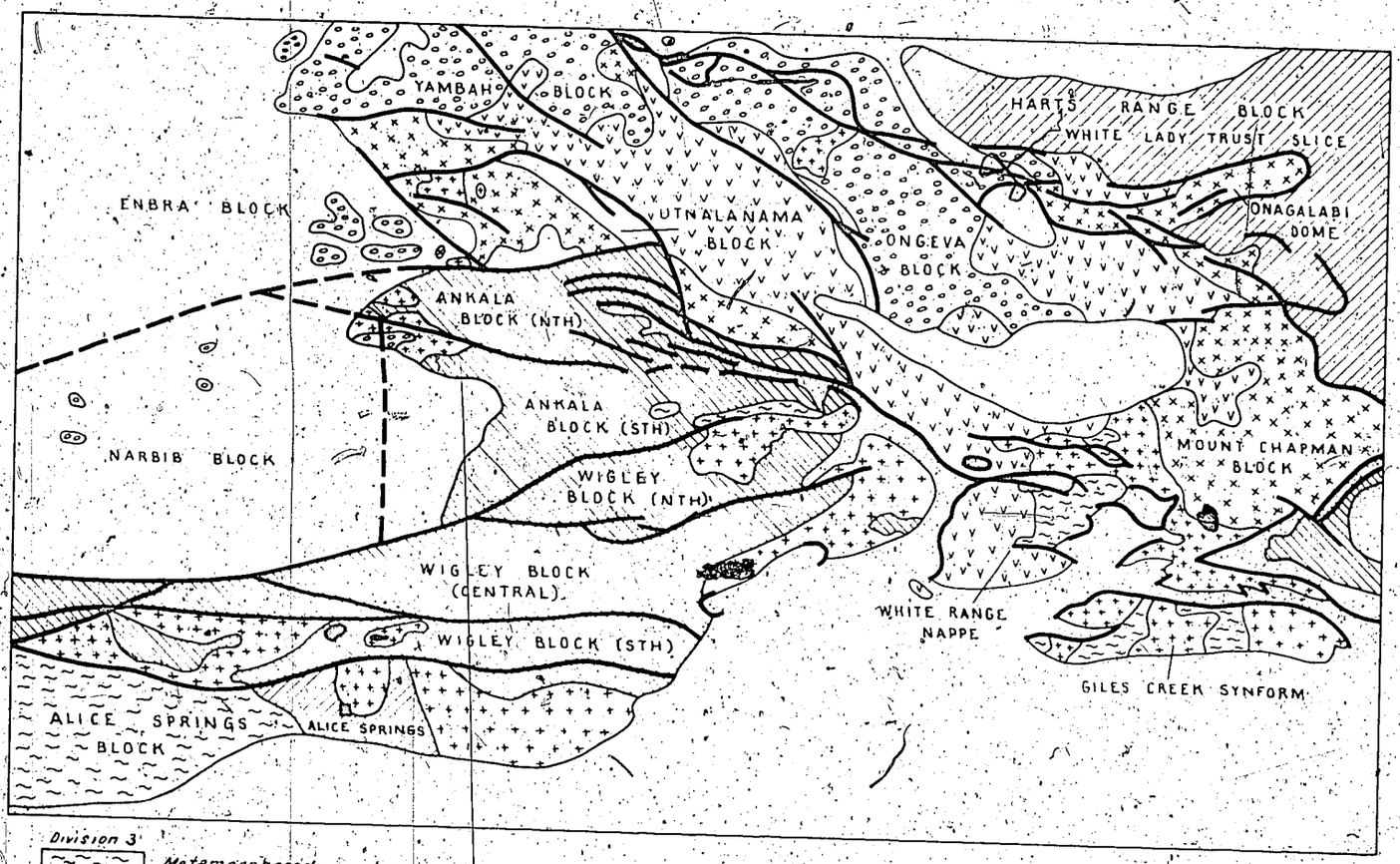
Fig. C3 Suggested correlation of events and lithological units, Arunta Block; Alice Springs 1:250000 Sheet area.



Division 3 — Metamorphosed quartose sandstone, arkosic sandstone, calcareous rocks some metamorphosed basic to intermediate igneous rocks

Division 2 — Garnet-bearing biotite-rich gneiss, granitic gneiss, amphibolite quartz-rich gneiss, calcareous rocks

Granitic to granodioritic rocks forming layered sequences

Division 1 — Dominantly calc-silicate rock, cordierite quartzite, sillimanite gneiss and other metasediments

Dominantly felsic and mafic granulite

Dominantly granulites of basic to intermediate composition

Lithological Divisions

Amadeus Basin Sequences

Basic

Granitic

Igneous

0 30 km

NT/A/746

Record 1979/47

Fig. C4 - Distribution of major lithological divisions, Arunta Block, Alice Springs 1:250 000 Sheet area.

TABLE C1. Summary of main lithological associations, Arunta Block; Alice Springs 1:250 000 Sheet area

Evolutionary Stage	Mapped Units	Characteristic rock types
Division 3	Laughlen metamorphics, Cavenagh metamorphics, Iwupataka Metamorphic Complex, and possibly Tommy's Gap metamorphics.	Metamorphosed quartzose sandstone, arkosic sandstone, pelites, calcareous marl, and limestone, acid volcanics: Tommy's Gap metamorphics are thought to be mainly derived from basic to intermediate igneous rocks.
Division 2	Hayes Metamorphic Complex, Brady Gneiss, Irindina Gneiss.	Schistose, garnet-bearing biotite-rich gneiss, biotite-bearing granitic gneiss, amphibolite, quartz-rich gneiss, calc-silicate rocks, and marble.
	Ankala gneiss, Sliding Rock metamorphics, Bruna Gneiss, Entia Gneiss, units of Wigley Block, and possibly part of unit pGu	Granitic to granodioritic rocks forming layered sequences.
Division 1	Cadney metamorphics, Hill-soak Bore metamorphics, Anuma schist	Dominantly calc-silicate rock, schistose biotite and sillimanite gneiss, and other metasediments.
	Units pGx, pGst, pGsf, and pGsp; Ongeva, Yambah, Narbib and Adla granulites, Erontonga and Bungitina metamorphics, part of Unit pGu.	Dominantly felsic and mafic granulite; some cordierite granulite, quartzo-feldspathic gneiss and amphibolite
	Harry Anorthositic Gabbro, Utnalanama granulite, Enbra granulite.	Dominantly rocks of basic to intermediate composition.

TABLE C2: PRE-CARPENTARIAN STRATIGRAPHY

Division	Grouping	Unit	Main Rock Types	Distinguishing Features	Relationship	Remarks
3	Iwupataka Metamorphic Complex	Simpsons Gap Metasediments Bas	Recrystallised micaceous and feldspathic quartz sandstone and gneiss, staurolite-garnet-two mica schist, small amount of conglomerate, amphibolite, quartzofeldspathic gneiss	Mainly metasedimentary	Intruded by Burt Bluff and Rungutjirba Gneisses. Conformably underlies Chewings Range Quartzite. Non conformably overlies Hayes Metamorphic Complex u/c overlain by the Heavitree Quartzite. Intruded by the Stuart Dyke Swarm	
		Chewings Range Quartzite Bac	Interlayered metaquartzite, muscovite-quartz schist and a small amount of staurolite-garnet mica schist	Metasedimentary; mainly massive metaquartzite	ALICE SPRINGS: underlain by the Simpsons Gap Metasediments to the S, ?underlain by the orthogneiss to the N. Intruded by the Stuart Dyke Swarm	A correlative of Bac in nose of the Blatherskite Nappe is u/c overlain by the Heavitree Quartzite
		Rungutjirba Gneiss Bar	Fine quartzofeldspathic gneiss	Fairly homogeneous massive rock	Intrudes Simpsons Gap Metasediments and possibly Burt Bluff Gneiss. u/c overlain by the Heavitree Quartzite. Intruded by the Stuart Dyke Swarm	
		Burt Bluff Gneiss Bab	Augen gneiss	Fairly homogeneous rock. Rare meta-sedimentary xenoliths	Intrudes Simpsons Gap Metasediments. u/c overlain by the Heavitree Quartzite. Intruded by the Stuart Dyke swarm	
3?	Northeastern Wigley Block	Laughlen metamorphics pCl	Muscovite-biotite schist, quartzite	Quartzite is distinctive	Thought to overlie unassigned biotite gneisses pC.	Boundaries known only from photo-interpretation
3?	White Range Nappe	Cavanagh metamorphics pCK	pCK_1: quartzofeldspathic gneiss, para-amphibolite quartzite; andalusite schist muscovite-biotite schist. pCK_2: feldspathic schist, quartz-rich metasediment, amphibolite, quartzite		No older rocks known. May be conformable with Hillsoak Bore metamorphics. Intruded by Atnarpa Ig. Complex	Correlated with Tommys Gap metamorphics. Speculatively correlated with sequence of Alice Valley

		Tommy's Gap metamorphics pCt	Hornblende gneiss, orthoamphibolite, quartz-rich metasediment, basic metavolcanics, quartzite, marble, chlorite schist		No older rocks known. Intruded by Atnarpa Igneous Complex and ultramafic rocks	Represents part of Cavenagh metamorphics carried south by nappe movement
2	Hayes Metamorphic Complex	Sadadeen Range gneiss pCpd	Porphyroblastic gneiss	Fairly homogeneous. Includes metasedimentary layers near Emily Gap schist and Teppa Hill metamorphics; rare xenoliths	Intrudes Emily Gap schist, Teppa Hill metamorphics and probably metasediments pCpb. Non conformably overlain by the Simpsons Gap Metasediments. Unconformably overlain by Heavitree Quartzite. Intruded by the Stuart Dyke Swarm	
		Teppa Hill metamorphics pCpt	Quartzose gneiss, schist, quartzite, orthogneiss, amphibolite, calc-silicate rock		Intruded by Sadadeen Range gneiss	By definition the margin of the metamorphics includes orthogneiss which is intimately interlayered with metasediments
		Calc-silicate rock pCpp	Quartz-microcline-sphene-epidote-diopside-andesine rock		Conformable with the Alice Springs Granite and the Sadadeen Range gneiss	Several m thick; may extend for about 2 km along strike
		Emily Gap schist, pCpe	Schist, metasandstone, rare amphibolite		Intruded by Sadadeen Ranges gneiss. S outcrop unconformably overlain by Heavitree Quartzite. Intruded by the Stuart Dyke Swarm	
		Metasediment pCpb	Metasediment		Through to be intruded by the Sadadeen Range gneiss. Intruded by granite and peg. veins. Apparently concordant contact with Jessie Gap gneiss	
2	Harts Range Group	Pegmatite (peg)	Zoned pegmatite		Includes both folded and unfolded types	Age uncertain
		Brady Gneiss pChb	Almandine-muscovite-biotite-plagioclase-quartz gneiss (metasediment)	Conspicuous muscovite flakes	Conformably overlies Irindina Gneiss	Described by Joklik (1955 p.74)
		Irindina Gneiss	(Sillimanite) garnet-biotite-andesine-quartz gneiss (metasediment) amphibolite quartzofeldspathic gneiss	Garnetiferous	Conformably overlies Bruna Gneiss	Described by Joklik (1955 p.68)

	Naringa Calcareous Member pCh n	Calc-silicate rock, flaggy biotite quartzite, calcareous quartzofeldspathic gneiss, marble	Calc-silicates have a well developed and continuous layering; marble is thick-bedded	Lensic member in lower part of Irindina Gneiss	
	Riddoch Amphibolite Member pCh a	Amphibolite, para-amphibolite subordinate garnet-biotite-gneiss	Commonly contains small quantities of garnet, clinopyroxene, and sphene	Lensic member in middle part of Irindia Gneiss above Naringa Calcareous Member	
	Bruna Gneiss pCh a	Megacrystic feldspar gneiss	Contains large porphyroblasts of microcline (0.5 to 4 cm +), and less commonly of plagioclase	Lensic unit conformable between Entia Gneiss and Irindina Gneiss	Described by Joklik (1955, p.66)
	Entia Gneiss pCh e (in Quartz)	Biotite-muscovite-andesine-microcline-quartz. (Granite composition) locally Kyanite-bearing	Finely layered; locally contains layers rich in hornblende and quartz	Conformably underlies Bruna Gneiss. Intruded by Inkamulla and Huckitta Granodiorites	Described by Joklik
2 Wigley Block named units	Bond Springs gneiss pCb	Leucocratic quartzofeldspathic and garnet-muscovite gneiss; lesser amounts of banded biotite gneiss, amphibolite and muscovite schist	Lighter coloured than surrounding gneisses	Structurally underlain to E and overlain to W by Unassigned gneiss, pC	
	Charles River gneiss pCq	Garnet-biotite gneiss, biotite gneiss, amphibolite, migmatite and a small amount of quartzofeldspathic gneiss	Surrounding gneisses contain less garnet	Interlayered with Old Hamilton Downs Gneiss; conformable contact with Unassigned gneiss pC and migmatised gneiss Bx. Intruded by the Stuart Dyke Swarm	
	Flint Spring gneiss pCe	Porphyroblastic and augen gneiss; small amount of quartzofeldspathic gneiss, banded biotite gneiss and amphibolite	Surrounding units have much less porphyroblastic gneiss	Conformable but gradational contact with Unassigned gneiss pC and Unnamed unit pCp	
Wigley Block unnamed units	pCd, north of Bond Springs HS	Leucocratic garnet gneiss, amphibolite		Fault bounded on most sides. N contact overlain by Quaternary sediments	
	pCj-Colyer Creek area	Leucocratic garnet gneiss, biotite gneiss, biotite garnet gneiss, amphibolite, porphyroblastic gneiss		Structurally underlies Unassigned unit pC; structurally underlain by Unassigned rocks (pC). Intruded by the Stuart Dyke Swarm	Colyer gneiss on Preliminary Map

		pCp–south of Mt Forster	Banded and laminated biotite gneiss, quartzofeldspathic gneiss and amphibolite		Bounded by Redbank Deformed Zone to N. Conformable contact with the Flint Spring gneiss	Forster gneiss on Preliminary Map
		pCs–Mt Solitaire area	Garnet–hornblende gneiss		Isolated outcrops; relationship with other units not known	
		pCr–Mordor Pound	Hornblende gneiss, quartzofeldspathic gneiss, granite	Macroscopically layered	Surrounded by Jennings Granitic Gneiss	May be K–metasomatised block of Randall Pk metamorphics
	Wigley Block Unassigned gneisses	pC on map	1. NW New Well – biotite gneiss, amphibolite, granitic gneiss 2. 9 km NW Simpsons Gap – banded biotite gneiss, amphibolite, porphyroblastic gneiss, porphyroblastic quartzofeldspathic gneiss 3. SE Painta Spring – biotite gneiss, augen gneiss, quartzofeldspathic gneiss, amphibolite small amount of biotite schist 4. Mount Lloyd Bores area banded biotite gneiss, quartzofeldspathic gneiss, sillimanite–cordierite gneiss		Faulted contacts Grades into granitic and migmatised gneiss; E boundary hypothetical. Intruded by the Stuart Dyke Swarm Grades into migmatised gneiss; structurally overlies Unassigned gneiss pC; intruded by the Stuart Dyke Swarm Conformable contact with other rocks. Intruded by the Stuart Dyke Swarm	Some migmatisation
			ALICE SPRINGS–UNDOOLYA: Extending east from Ten Mile Bore – biotite gneiss, amphibolite, quartzofeldspathic garnet gneiss, muscovite–biotite gneiss, granite gneiss, porphyroblastic gneiss, sillimanite gneiss, quartzofeldspathic gneiss garnet–biotite gneiss; migmatite		Grades into Flint Spring gneiss (pCe). Structurally underlie and overlie Bond Spring gneiss (pCb). Grades into Randall Peak metamorphics (pC). Intruded by the Stuart Dyke Swarm	Contact between pC and Randall Peak metamorphics is photo–interpreted
			LAUGHLEN: 1. Whistleduck Bore 2. South of Georgina Gap			
2	Wigley Block	Mulga Creek granitic gneiss pCm	Muscovite–biotite granitic gneiss (granite in composition)	Very leucocratic and finely schistose	Intruded by Georgina Gap granitic gneiss	Reconnaissance examination

		Randall Peak metamorphics, pCr	Mainly quartzofeldspathic gneiss and amphibolite; some mica schist and gneiss	Quartzofeldspathic gneiss definative	Intruded by Bgr and Bgn. Conformable contacts with unassigned biotite gneisses (pf); unconformably overlain by Heavitree Quartzite	Lithologically correlated with Ankala gneiss
		Cement Dam gneiss pCc	Porphyroblastic-feldspar biotite gneiss	Schistose and biotite-rich with K-feldspar megacrysts	May be related to north-eastern extension of Redbank Deformed unit	May be a structurally developed schist zone
2	Ankala Block	Ankala gneiss pCa	Quartzofeldspathic gneiss, biotite gneiss, calc-silicate rock	Felsic rocks are well layered. Unlike Utnalanoma Gneiss contains lenses of pelitic gneiss and calc-silicate rock	Appears to have a conformable contact with the Sliding Rock metamorphics at one locality, otherwise boundary is faulted sedimentary facing is unknown	Lithologically similar to both upper Division 1 and lower Division 2 rocks
1	Narbib Block	Unassigned gneiss pC	Biotite gneiss, amphibolite	Lacks garnet gneiss, hornblende gneiss and schistose biotite gneiss which are distinctive of the Sliding Rock metamorphics	Conformable contact with Sliding Rock metamorphics. Sedimentary facing unknown	Reconnaissance examination
		Sliding Rock metamorphics pCi	Biotite gneiss, and schist, garnet-biotite-gneiss, quartzofeldspathic gneiss, hornblende gneiss	The hornblende gneiss and biotite gneiss are distinctive	Conformable contact with Ankala gneiss and pC (see above)	Reconnaissance examination
1	Oonagalabi Dome	Oonagalabi metamorphics pCo (Discarded unit, incorporated into upper Bungitina Metm. (RpCsb$_2$))	Quartzofeldspathic gneiss, hornblende or clinopyroxene bearing quartz-plagioclase rock, garnet-biotite schistose gneiss, porphyroblastic feldspar gneiss, anthophyllite or cummingtonite-rich rocks	Gneisses are compositionally variable and well layered	Overlies Bungitina *metm.* with a structural discordance	Reconnaissance examination
1?	Ongeva Block (Ambalindum Block of Preliminary Maps)	Unnamed unit pCu	Quartzofeldspathic gneiss, amphibolite, rare mafic granulite felsic granulite and garnet-biotite gneiss	The high proportion of quartz rich quartzo-feldspathic gneiss	Faulted against pCrw and pCsf to North. Faulted against Cadney gneiss to the South ?unconformable on Ongeva granulite	
	Mount Chapman Block (Ambalindum Block of Preliminary Maps)	Unnamed unit pCx	pCx$_1$ Porphyroblastic-feldspar gneiss pCx$_2$ Garnetiferous and biotite-rich gneiss pCx$_3$ Quartzofeldspathic and biotite gneiss of granitic appearance pCx$_4$ Layered quartz feldspathic gneiss, marble pCx$_5$ Amphibolite, mafic granulite	Contain[illegible] proportion of quartzofeldspathic gneiss	Appears to be conformably overlain by Cadney metamorphics. The relationship with the Bungitine Gneiss has not been examined.	Reconnaissance examination

		pCx_6 Biotite and quartzofeldspathic gneiss pCx_7 Quartzofeldspathic gneiss and amphibolite			
	Hillsoak Bore metamorphics pCz	Biotite gneiss (± garnet), sillimanite gneiss, marble, calc-silicate rock, andalusite schist, amphibolite, schist, granitic gneiss		May be conformable with Cavenagh metamorphics	Correlated with Cadney metamorphics
Strangways Metamorphic Complex (late stage events)	Thuluma granitoid pCsw	Homogeneous granitic gneiss and granitoid	Homogeneity	Intrudes pCsr	Dated at 1800 m.y.
	Ingula migmatite suite pCsi	Migmatite, granitic gneiss. rare mafic granulite and calc-silicate rock	The high proportion of migmatite	Faulted against pCsr, gradational with pCsw	
	Johannsen Meta-gabbro pCsi	Plagioclase-orthopyroxene-clinopyroxene-hornblende-ilmenite granulite. Hornblende and ilmenite may be absent. Rare igneous relict textures	Thicker, more homogeneous and coarser grained than mafic gneiss in Erontonga metamorphics	Cut Harry Anorthositic Gabbro and Erontonga metamorphics. Intruded by Gum Tree Granite	
Strangways Metamorphic Complex (upper part)	Cadney metamorphics pCsc	Upper part: calc-silicate gneiss, marble and some quartzite sillimanite gneiss, and biotite gneiss Lower part: ($pCsc_2$) sillimanite-rich gneiss, mafic and felsic granulite, calc-silicate rock	The presence of calc-silicate rock is distinctive	Thought to be originally a transgressive sequence overlying parts of the lower Strangways Metamorphic Complex	Deformation and metamorphism are coeval with that in the Lower Strangways Metamorphic Complex. Separated into an upper and lower part in some 1:100 000 sheets
	(5 km southwest of Woolanga Bore) $pCsc_2$	Quartzofeldspathic, aluminous and mafic granulites	The aluminous granulites are distinctive. They are also very high in Mg and contain minerals such as sapphirine, spinel and phlogopite	Conformably overlie unnamed unit pCsp. Possible conformably overlain by the Cadney Metamorphics	Suggested unit only probably to be deleted from table
	Anuma schist pCss	Kyanite schist, staurolite schist, quartzofeldspathic gneiss, ferruginous quartzite, mica schist, marble	Kyanite, staurolite	May be conformable with Erontonga metamorphics	The only kyanite-bearing unit which is not a retrograde schist in a fault zone; a meta-sediment
	Erontonga metamorphics $pCsr_1$	Pelitic and quartzofeldspathic gneiss and granofels	Contain distinctive cordierite-bearing gneiss	Discordantly overlie Utnalanama Granulite. Conformably overlain by Cadney metamorphics	

Strangways Metamorphic Complex (lower part)	Unnamed unit pCst	Mafic granulite, quartzo-feldspathic gneiss, pelitic gneiss	Mafic bodies commonly have an ovoid shape; lacks calc-silicate rock and schist	Appears to conformably underlie the Cadney metamorphics	Reconnaissance examination
	Bungitina metam. pCsb	Laminated quartzofeldspathic gneiss, amphibolite, mafic granulite	Fine-grainsize and fine lamination of quartzo-feldspathic gneiss is distinctive	Underlies Irindina Gneiss with an apparently discordant contact. Interfingers with Gough Dam schist zone	Reconnaissance examination
	Harry Anorthositic Gabbro pCsh	Metamorphosed gabbro with anorthositic affinities	Gabbro is anorthositic	Intrudes Utnalanama granulite	
	Utnalanama granulite pCsu	Homogeneous granulite of tonalitic to dioritic composition	More massive and of more uniform composition than quartzofeldspathic gneiss of Erontonga metamorphics	Intruded by Harry Anorthositic Gabbro and Johannsen Metagabbro, discordantly overlain by Erontonga metamorphics	Interpreted by A.E.A. to unconformably underlie Erontonga Metamorphics
	Adla granulite pCsa	Retrogressed mafic granulite and felsic granulite	Garnetiferous nature of the felsic granulite	Isolated outcrops	
	Unnamed unit pCsf	Retrogressed garnet-bearing mafic granulite and mafic granulite interlayered with quartzofeldspathic gneiss, amphibolite, felsic granulite and cordierite gneiss		Faulted to the sout against pCu	Probably a correlative of the Ongeva granulite
	Unnamed unit pCsp	Quartzofeldspathic gneiss and granulite, biotite gneiss sillimanite gneiss, mafic granulite	Thought to contain only negligible amounts of cordierite bearing gneiss. Generally lacks calc-silicate rock	Conformably overlain by Cadney metamorphics	Pfitzner granulite on Preliminary map. Reconnaissance examination
	Yambah granulite	Interlayered mafic granulite, felsic granulite, cordierite granulite and cordierite quartzite with rare sapphirine-spinel-hypersthene-phlogopite rock	The interlayered nature and presence of cordierite granulite are distinctive features	Faulted against pCsr to the south	
	Narbib granulite pCsn	Mafic granulite and felsic granulite, retrogressed		Intruded by pCgo and cut by Narbib Deformed Zone	
	Ongeva granulite pCso	Interlayered mafic and felsic granulite, rare cordierite gneiss, garner gneiss	The interlayered nature and high degree of mafic granulite are distinctive	?Unconformably overlain by pCv - gradational contact with Cadney metam. to West	
	Enbra Granulite pCse	Homogeneous and unfoliated mafic granulite, rare felsic granulite	The abundant homogeneous mafic granulite is distinctive	Faulted wedge against pCi and pCsr	

TABLE C3: MID-PROTEROZOIC GRANITES AND IGNEOUS ROCKS

NAME (prefixed by pC on Preliminary Map)	ROCK TYPES	RELATIONSHIPS	AGE	REMARKS
Mordor Igneous Complex Bm_1, Bm_2	Bm_1 Syenite, monzonite, shonkinite, pyroxenite phlogopite-peridotite. Carbonate rock. Pegmatite	Intrudes granitic	1184 ± 88 (λ = 1.42)	Poss. related to Mud Tank Carbonatite see Langworthy & Black (1978)
	Bm_2 Monzonite, phlogopite-pyroxenite diorite	Intrudes granitic gneiss of pCgn		Closely related to Bm_1
Coles Dam Orthogneiss Bgo	Porphyroblastic-quartzofeldspathic gneiss	Intrudes pCsa		
Jennings Granitic Gneiss Bgn	Coarse granitic gneiss, fine granitic gneiss, quartzofeldspathic gneiss. Migmatitic in places	Generally concordant with country rocks (Randall Peak metamorphics); in places discordant and intrusive into country rocks		Syntectonic (synorogenic granite intrusive
Georgina Gap granitic gneiss Bge				Georgina Gap Granite on Preliminary Map
Anamarra orthogneiss Bgm	Porphyroblastic biotite-rich quartzofeldspathic gneiss. Homogeneous	Intrudes pCu.		
Oolbra orthogneiss Bgo	Porphyroblastic biotite-rich quartzofeldspathic gneiss. Homogeneous	Intrudes pCi and Narbib Granulite		
Trephina granitic gneiss Bgr	Biotite-granitic gneiss with sparse K-feldspar megacrysts	Intrudes unassigned gneisses (pC). Encloses a raft of Randall Peak metamorphics		
Unassigned granitic gneiss pCg	Granitic gneiss			
Atnarpa Igneous Complex Bga	Tonalite, diorite, granite, granodiorite, aplogranite	Intrudes Tommys Gap metamorphics, Cavenagh metamorphics, unnamed unit pCx. Intruded by contemporaneous ultramafic rocks		Consanguineous igneous suite formed by fractional crystallisation. High K content

TABLE C4: MIGMATITES, GRANITES AND IGNEOUS ROCKS INTRODUCED DURING THE ORMISTON PHASE OF DEFORMATION (1.2 - 1.1 b.y.)

UNIT	ROCK TYPES	DISTINGUISHING FEATURES	RELATIONSHIPS	REMARKS
Gum Tree Granite Bgg	Porphyritic biotite granite	Contains conspicuous sphene and allanite	Intrudes (1) Utnalanama granulite (2) Harry Anorthositic Gabbro (3) Erontonga metamorphics (4) Johannsen Metagabbro Cut by Harry Creek Deformed Zone	The Harry Creek Deformed Zone has been active before and after intrusion of the Granite
Unassigned granite Bg				
Alice Springs Granite Bga	Granite		Isotopic redistribution at about 1100 m.y., probably intrusive into Sadadeen Range gneiss. Intruded by the Stuart Dyke Swarm. Correlative in the nose of the Blatherskite Nappe is unconformably overlain by the Heavitree Quartzite -	
Undivided granite, Bg and pegmatite (peg) in the Alice Springs Block	Med-coarse-grained granite; pegmatitic in part	Contain garnet in places	Intrudes Simpsons Gap Metasediments, Burt Bluff Gneiss. Intruded themselves by the Stuart Dyke Swarm.	
Old Hamilton Downs Gneiss Bw	Granitic gneiss; partly migmatitic at some margins		Interfingers with Charles River gneiss; grades into pC. Intruded by the Stuart Dyke Swarm	
Jessie Gap gneiss Bj	Granitic gneiss; subordinate banded biotite gneiss, amphibolite, hornblende gneiss, augen gneiss		U/C overlain by Heavitree Quartzite. Possible confordant contact with pCpb. Grades into Unassigned gneiss (pC)	In places granitic gneiss contains small amount of sillimanite
Unnamed migmatites Bx in the Wigley Block	Migmatite, granitic gneiss, porphyroblastic gneiss, banded biotite gneiss and amphibolite	Rocks are generally all migmatised to various degrees	Gradational contact with unassigned gneiss pC and Charles River gneiss. Intruded by Stuart Dyke Swarm	

TABLE C5: LATE-STAGE IGNEOUS ROCKS

NAME	ROCK TYPES	RELATIONSHIPS	AGE	REMARKS
Mud Tank Carbonatite pCut	Carbonatite, alluvium containing magnetite, apatite, and zircon	Intrudes pCsf	720 m.y. date by fission tracks and Rb-Sr methods Black and Gulson (in prep)	Mica Rb-Sr dates give Alice Springs Orogeny dates
Stuart Dyke Swarm pCds	Dolerite, norite	Unconformably overlain by Heavitree Quartzite. Youngest intrusive event to occur in the basement	Not younger than 900 m.y. and not older than 1050 m.y.	
Unclassified gabbro Bgb	Slightly retrogressed and altered gabbro	Intrude Randall Peak metamorphics and unassigned gneisses	Post-Ormiston Metamorphic Event	South of Whistleduck Bore
Peridotite Bp	Meta-ultramafic rock, pyroxenite	Intrudes hornblende gneiss of pCv		East-northeast of Wallace Rock Yard, Haughlen
Unassigned ultramafic rocks Bp	Serpentinite, hornblendite	Intrudes Tommys Gap Atnarpa Ig. Complex, unit pCz, Hillsoak Bore mmics	1710 ± 50 m.y.	Arltunga Basin Complex
Basic hypabyssal intrusions	Amphibolite	Intrude Atnarpa Igneous Complex, Tommys Gap mmics	1710 ± 50 m.y.	Giles Creek Synform
Whistleduck Dyke Swarm Bdw	Epidote-sericite-albite amphibolite	Intrudes east-striking faults	Pre-Stuart dyke swarm	

TABLE C6: SCHIST AND DEFORMED ZONES OF PALAEOZOIC AND PROTEROZOIC AGE

UNIT	MAIN ROCK TYPES	DISTINGUISHING FEATURES	STRUCTURAL RELATIONSHIPS AND POSSIBLE AGE
Pzr	Highly schistose greenschist facies rocks, quartz veins common	Greenschist retrograde metamorphism	Cuts amphibolite facies rocks. Dated by Armstrong and Stewart (1975) by Rb-Sr method at 342-319 m.y.
Harry Creek Deformed Zone Pzr Brh	Schist, mylonite, blastomylonite	Highly deformed	Active before intrusion of Gum Tree Granite at 1000 m.y. and during early stages of the Alice Springs Orogeny
West Bore Deformed Zone Pzr Brw	Quartzofeldspathic schist, muscovite-biotite schist, biotite schist, Amphibolite Quartzite	Pronounced east-striking schistosity	Occurs at the convergence of major splay faults off the Woolanga Lineament. Possible Palaeozoic movement of an older Deformed Zone
Gough Dam Schist Zone Pzr Brg	Muscovite-biotite-schist and schistose gneiss, quartzofeldspathic schist	Amphibolite facies, pronounced schistosity	Cuts granulite units of Strangways Metamorphic Complex. Zone occurs within and alongside Cadney Fault
Yambah Schist Zone Pzr Bry	Muscovite-biotite-schist, staurolite-biotite-garnet-schist, kyanite-biotite-schist, muscovite-gneiss	Amphibolite facies, pronounced schistosity	Cuts Yambah Granulite. $^{40}Ar-^{39}Ar$ dates range from 352-388, K-Ar dates of 393 ± 9 and 369 ± 8 m.y. Rb-Sr date inconclusive (Iyre et al, 1976).
Southern Cross Schist Zone Pzr Brs	Muscovite-biotite-schist, rare kyanite schist	Amphibolite facies, pronounced schistosity	Zone occurs alongside faulted contact between Cadney metamorphics and Erontonga metamorphics
Narbib Deformed Zone Pzr Brm	Sillimanite gneiss, garnet-biotite gneiss, Deformed Rock	Cuts Narbib Granulite and pCi	Probable Palaeozoic movements. Cuts 1800 m.y. granulite
Redbank Deformed Zone Pzr Brr	Mylonitic porphyroblastic gneiss, deformed gneiss, banded biotite gneiss, amphibolite and biotite sericite schist	Cuts earlier structures; possibly related to Chewings Phase of Deformation or earlier	Early mid-Proterozoic or earlier

Division 1 rocks within the Alice Springs 1:250 000 Sheet area form the rugged terrain of the Strangways Range in the northern part of the Sheet area. They consist mainly of interlayered basic and acid granulites, and less commonly of metamorphosed calcareous and pelitic rocks. These rocks have been mostly recrystallised under granulite facies conditions. Divisions 1 and 2 are everywhere in discordant contact, which may be either a metamorphosed fault or a metamorphosed regional unconformity (Shaw & Warren, 1975; Shaw & others, in preparation).

Division 2 crops out throughout much of the northern part of the Arunta Block (Fig. 3) and is characterised by metapelitic rocks. These rocks crop out in the northeast corner of the Sheet area, but are poorly exposed. However, a sequence of mainly acid gneisses forming ridges rising 150 m above Burt Plain in the southern part of the Sheet area, thought to occupy a transitional position between Division 1 and Division 2 rocks, is here assigned to Division 2 because the gneisses differ from those of Division 1, firstly, in having a more pronounced mesoscopic layering, and secondly, in being of amphibolite rather than granulite metamorphic grade. In the adjacent Alice Springs 1:100 000 Sheet area to the southwest these well-layered acid gneisses are thought to be overlain by the Hayes Metamorphic Complex, a heterogeneous mixture of metasediments and granite gneiss, which is succeeded by Division 3 rocks (Offe & Shaw, in preparation). In the Strangways Range the contacts between Division 1 and 2 rocks are faulted.

Division 3 rocks in LAUGHLEN are confined to a small belt of narrow ridges southeast of Mount Laughlen. The Division comprises quartzite and metapelite, and appears to have been metamorphosed to lower amphibolite facies. A metaconglomerate marks the base of similar Division 3 rocks in ALICE SPRINGS, where the contact is a nonconformity (Shaw & others, in preparation; Offe & Shaw, in preparation).

C-1: Division 1

Division 1 comprises the Strangways Metamorphic Complex and units correlated with it.

The Strangways Metamorphic Complex (Table C2) is an extensive group of units which consist mainly of mafic granulite and felsic granulites or gneiss, and lesser amounts of pelitic gneiss. These rocks have undergone multiple folding followed by granulite-grade metamorphism and local migmatisation. The name was first applied by Shaw & Warren (1975) to rocks in the Alcoota 1:250 000 Sheet area, and included what were regarded as equivalent units metamorphosed to amphibolite grade. The metamorphic event which is most widespread and which characterises the complex is thought to have occurred at about 1800 m.y. (L.P. Black, 1975; Iyer & others, 1976). The Complex can be divided into a lower and upper part. The lower part of the Complex contains about 70 percent of mafic granulite; the range is from 15 to 85 percent. The upper part of the Complex is dominantly metasedimentary, consisting of calc-silicate rocks and well-layered gneisses, but also contains small amounts of mafic granulite and felsic granulite or gneiss.

The lower part of the Complex (Table C2) may be divided into two groups of units. The more basic of the two groups is regarded as the older. The younger group is more abundant and consists dominantly of felsic and mafic granulites and gneisses, and some pelitic granulites. Examples of the second group include the Narbib, Ongeva, Adla, and Yambah granulites together with the unnamed units pGsp, pGsf and pGst. The Bungitina metamorphics and unit pGx may also belong to this category, but contain a large proportion of rocks of amphibolite grade and most likely belong to the upper part of the Complex. All these units contain a high proportion of mafic granulite, and geophysical modelling of the regional Bouguer anomaly ridges suggests that they are caused by mafic granulite bodies (Mutton & Shaw, in preparation) which increase in abundance and extent with depth-to depths of 20 km or more (Anfiloff & Shaw, 1973; Wellman, 1978).

The mafic granulites fall into three distinct types:

(1) concordant bodies of olivine tholeiite composition, which are interpreted to be metabasalt. Such bodies are typically about 3-10 m thick, are continuous over

distances of hundreds of metres, and have been multiply folded along with the felsic rocks. They do not contain relict igneous structures.

(2) thick concordant and discordant bodies, thought to be sills, dykes and plugs, of metagabbro and metadolerite. The Johannsen Metagabbro is an example. Discordant bodies are a major feature of unit pGst.

(3) gneissic rocks, that are most evident in the Yambah granulite and the Erontonga metamorphics. They consist of layers 1-5 cm thick, and are considered to be mafic tuffs because they are laterally persistent, although the layering could be a metamorphic feature.

The felsic rocks are mainly of granite to granodiorite composition. They are intercalated with the mafic granulites thought to be basic volcanics or high-level intrusives in such a way that the sequence is a bimodal grouping of acid and basic volcanics similar to that occurring in the Proterozoic of the Gawler Province in South Australia. Some of the felsic rocks, however, principally those in the Utnalanama granulite, are of intermediate composition and appear to have a different origin, because they form large more homogeneous bodies.

Gneisses, thought to be possible metasediments, because of their well-layered nature, occur in the lower part of the Complex. They include cordierite granulite, cordierite felsic granulite and rare cordierite quartzite. These are the characteristic rock types of the Yambah granulite.

The upper part of the Strangways Metamorphic Complex (Table C2) contains units which are thought to be metasediments representing a shallow marine transgression which originally onlapped the units of the lower part. The first unit to be deposited was probably the Erontonga metamorphics,

which now consists predominantly of well-layered quartzofeldspathic and pelitic gneiss and granofels, rare lenses of calc-silicate, magnesian and manganiferous gneiss, and, as mentioned previously, thin intercalations of mafic gneiss. Cordierite is commonly present in the pelitic sillimanite-bearing gneiss and in quartzofeldspathic gneiss presumed to be psammitic. The cordierite-bearing quartzofeldspathic gneiss contains negligible K-feldspar, and is locally quartz-rich. In places the cordierite has been metamorphically retrogressed to garnet. Rocks interpreted to occur near the base of this transgression contain the highest potential for economic mineral deposits (see notes on Oonagalabi mineralisation).

The Bungitina metamorphics and unit pGx are considered to be correlatives of the Erontonga metamorphics. The Bungitina metamorphics differ from the Erontonga metamorphics in lacking cordierite and in containing less conspicuous garnet. Correlation with unit pGx is less certain because it has undergone extensive retrograde metamorphism.

The Cadney metamorphics, which are thought to be the top stratigraphic unit of the Strangways Metamorphic Complex in northern LAUGHLEN and RIDDOCH, because they overlie a variety of units of higher metamorphic grade, consist mainly of calc-silicate rock. The lower part of the Cadney metamorphics contains aluminous sediments, some of which are rich in sillimanite, and extensive felsic rocks of acid to intermediate composition that probably represent acid to intermediate volcanics. The Cadney metamorphics overlie the Erontonga metamorphics as well as rocks from the middle and lower parts of the Strangways Metamorphic Complex. One particularly aluminous sequence ($pGsc_3$) is akin to parts of the Erontonga metamorphics, both in composition and in its stratigraphic position underneath the more calcareous metamorphics.

The Hillsoak Bore metamorphics, which consist mainly of locally garnet- and sillimanite-bearing biotite gneiss and small amounts of marble and calc-silicate rock, interfinger with the Cadney metamorphics in the White Range Nappe. Unit pGsl is considered to be a more pelitic facies equivalent of the Cadney metamorphics which crops out in the Harts Range Block.

The main and most widespread metamorphism that affected the Strangways Metamorphic Complex resulted in ubiquitous small accumulations of mobilised migmatite as well as nonmobilised leucosome fractions. The Ingula migmatite suite and the anatectic Wuluma granitoid are large concentrations of mobilised migmatite formed as an end product of this main metamorphism.

C-2: Division 2

Division 2 rocks consist of pelitic gneisses and gneisses of granitic to granodioritic composition, and are thought to represent a higher stratigraphic level, because they either overlie the Stangways Metamorphic Complex (Alcoota 1:250 000 / and RIDDOCH) or are overthrust by it (S.E. Alice Springs 1:250 000), as is explained below. A monotonous sequence of mainly biotite-bearing gneisses extends southwards from the Ankala Block, where they are overthrust by Division 1 rocks, to the Wigley Block, and then to the Alice Springs Block, where they are overlain nonconformably by Division 3 rocks. On regional evidence Division 2 is considered to overlie the Strangways Metamorphic Complex (Division 1) in the Alcoota 1:250 000 Sheet area (Shaw & Warren, 1975), but the actual contact of these units is obscured by Cainozoic cover. In RIDDOCH the Irindina Gneiss of the Harts Range Group is considered to unconformably overlie Division 1 rocks (Cadney metamorphics and Bungitina metamorphics) although the contact is complicated by thrusting. The acid gneisses of the Ankala and Wigley Blocks are considered to represent the lower part of Division 2 (2B in Table B1), and to be lithologically similar to the Entia Gneiss, at the base of the Harts Range Group, which is also assigned to the lower part of Division 2 (i.e. 2B), as also is, tentatively the northwestern part of unnamed very complex quartzofeldspathic unit pGu from the Ongeva Block (Fig. C3).

In the Wigley, southeastern Narbib and Ankala Blocks (Figs C3 & C4) the bulk of Division 2 is made up of a monotonous sequence of extensive uniform gneisses. The gneisses are predominantly highly feldspathic (about 60% feldspar, 30% quartz) and are mainly of granite to granodiorite composition. They include some garnetiferous varieties. In addition the

sequence also includes some amphibolite, and rare metapelite and calc-silicate rock. The thickness and continuity of the well-developed gross compositional layering (from one to several tens of metres thick) in the gneisses suggests that the gneisses are derived either from acid volcanics or arkosic metasediments. A less likely possibility is that they represent sills of granite. The calc-silicate rocks and sillimanite-bearing gneiss are thought to represent metasedimentary intercalations. The amphibolite layers possibly represent meta dolerite.

The Entia Gneiss, the lowest and possibly the oldest unit in Division 2 in the Harts Range Block, does not crop out in the Alice Springs 1:250 000 Sheet area but is present in the adjacent Illogwa Creek 1:250 000 Sheet area. It is granitic and well-layered, and is considered to represent a metamorphosed sequence of arkose or, less probably, rhyolitic volcanics. It includes thin intercalations of para-amphibolite, rare marble, and, in its lower part, kyanite-bearing acid gneiss. Its upper part contains a greater proportion of minor rock types including quartz-amphibolite, a schistose biotite gneiss which contains sillimanite and garnet in places, and calc-silicate rock. It is lithologically like the Bungitina metamorphics of upper Division 1. However, the Bungitina metamorphics are considered to be unconformably overlain by the Harts Range Group, which elsewhere includes the Entia Gneiss.

Unit pGu, a predominantly quartzofeldspathic gneiss in the Ongeva Block, is thought to be partly metasedimentary because parts are quartz-rich (50%) and show well-developed compositional layering. Unit pGu is in direct contact with the Ongeva granulite, a unit in Division 1 in the lower part of the Strangways Metamorphic Complex. The lack of the intervening Cadney metamorphics indicates that this part of pGu may be a facies equivalent of the Ongeva granulite or may be older than this granulite. The discordant contact between the two units is because pGu contains one or a number of orthogneiss which intruded the Ongeva granulite and parts of pGu before metamorphism. The discordance has been accentuated by widespread retrograde metamorphism within pGu but not within Ongeva granulite. The orthogneiss in pGu is not readily separated in the field from the quartzofeldspathic gneiss which is an integral part of pGu.

The upper part of Division 2 (2A) is represented in the Harts Range by the Irindina Gneiss, which consists mainly of garnet-biotite-andesine-quartz gneiss, and the conformably overlying and lithologically similar but more quartz-rich and muscovite-bearing Brady Gneiss. The Irindina Gneiss is considered to unconformably overlie Division 1 rocks, principally the Bungitina metamorphics and the unnamed pelitic unit pCsl. The contact is partly disrupted by thrusting. In the eastern part of the Alice Springs Block the Hayes Metamorphic Complex (including Teppa Hill metamorphics) consists of orthogneiss, quartzose gneiss, schist and amphibolite, and is considered to belong to the upper part of Division 2(2A). The Irindina Gneiss contains many lenses of amphibolite, the largest of which is termed the Riddock Amphibolite Member, and also includes a unit of calc-silicate rock and flaggy biotite quartzite named the Naringa Calcareous Member. The Teppa Hill metamorphics of the Hayes Metamorphic Complex contains similar rock types: namely amphibolite, quartzite and calc-silicate rock. The Teppa Hill metamorphics are, however, much more quartz-rich than the Irindina Gneiss. The Bruna Gneiss, which underlies the Irindina Gneiss in the Harts Range, may be a metamorphosed pile of acid lavas, but probably also includes some metasediments. The Sadadeen Range gneiss, which interfingers with the Teppa Hill metamorphics in a manner suggesting an intrusive contact, may represent a metamorphosed hyperbyssal acid porphyry intrusion.

The metamorphic event affecting the Harts Range Group is of uncertain age. It may be equivalent to the Chewings Metamorphic Event dated at about 1600-1700 m.y., that affects Division 2 rocks in the Wigley Block, but a more likely possibility is that it is equivalent to the Strangways Metamorphic Event, dated at about 1800 m.y. because the history and style of folding is similar and in both cases predates the metamorphism (see Chapter on METAMORPHISM).

Problems of stratigraphic separation of Division 1 and 2 rocks

It is therefore conceivable, though unlikely, that a large part of the rocks assigned to Division 2 in the Alice Springs 1:250 000 Sheet area - principally the Ankala gneiss, Sliding Rock metamorphics and possibly the Entia Gneiss - would be better assigned to the upper part of Division 1

(i.e. 1A = 2B, Table B1). If this was the case, Division 2 rocks would be largely confined to the northern Arunta Block (Northern Tectonic Zone). Alternatively, the rocks could be regarded as a transitional group of lithologies between Division 1 and Division 2.

C-3: Division 3

After deposition of Division 2 rocks the region is thought to have become much more stable, and sediments were laid down in epeiric seas of the platform type, in the terminology of Plumb (1977): sedimentation was possibly uniform over an enormous area and typically contained a quartzite component. For this reason the upper formations of Division 3, which crop out throughout and alongside the Arunta Block, can be correlated with a greater degree of confidence. In the Alice Springs 1:250 000 Sheet area these Division 3 sediments are the Iwupataka Metamorphic Complex, the Laughlen metamorphics and possibly also the Cavenagh and Tommy's Gap metamorphics. The Iwupataka Metamorphic Complex contains a metamorphosed sequence of clean quartz sandstone, silty sandstone, siltstone and shale. The Cavenagh and Tommy's Gap metamorphics contain metamorphosed arkosic sandstone, calcareous marl and limestone; and the Cavenagh metamorphics also contains considerable quartzofeldspathic gneiss, which may represent an acid igneous rock. Acid meta-igneous rocks are also present in the Iwupataka Metamorphic Complex. The Tommy's Gap metamorphics are mainly basic to intermediate igneous rocks now represented by amphibolite and hornblende gneiss.

The basal unit in the Iwupataka Metamorphic Complex, the Simpsons Gap Metasediments, contains a basal conglomerate where it overlies the Hayes Metamorphic Complex. This conglomerate is thought to indicate a major stratigraphic break comparable to the unconformity at the base of Division 3 in the Reynold's Range (Stewart, in preparation). The Rungutjirba Gneiss is a quartzofeldspathic gneiss thought to be a metamorphosed quartz-feldspar prophyry although there are no relict igneous textures. The Burt Bluff Gneiss is a porphyroblastic-feldspar gneiss, and is thought to have intruded the Rungutjirba Gneiss before the regional metamorphism.

C-4: Mid-Proterozoic Granites and Related Igneous Rocks (Table C3)

A number of granites, considered to be synorogenic, are thought to have been intruded into the southern part of the 1:250 000 Sheet area (i.e. into the Southern Tectonic Zone of Fig. B2) at about 1700 m.y. (Fig. C3). This group of granites and granitic gneisses also includes tonalite, undeformed diorite, and granite of the Atnarpa Igneous Complex and the locally migmatitic Jennings Granitic Gneiss; both these units have been dated at about 1700 m.y. (Armstrong & Stewart, 1975; Bennet in Cooper & others, 1971). A number of very small bodies of altered ultramafic rocks (Bp) in the Giles Creek Synform are probably related to the Atnarpa Igneous Complex. Undated granites and granitic gneisses, which may also belong to the same general period, include the Anamarra and Colbra Orthogneisses, unnamed granite Bgc, and the Georgina granitic gneiss, all of which contain megacrysts of K-feldspar and the Trephima granitic gneiss, which is similar to the Jennings Granitic Gneiss. However, the Georgina granitic gneiss is localised on the eastern continuation of the Redbank Deformed Zone and, as such, has a similar tectonic aspect, and is conceivably of a similar age to the Gum Tree Granite (i.e. 1000 m.y.).

The widespread Chewings metamorphic event which preceded or was synchronous with this period of granitic intrusion, is discussed in the general section on METAMORPHISM.

The Mordor Igneous Complex, a potassic-basic complex with kimberlitic affinities, was intruded at 1210 m.y. (Langworthy & Black, 1978). It has substantially escaped the younger metamorphism outlined below. The Woolanga Lineament is thought to have been the locus for intrusion of the Complex.

C-5: Migmatites and Granites formed during the Ormiston Phase of Deformation (1100-1000 m.y. Table C4)

The Ormiston phase of deformation affected the southern Tectonic Zone (Fig. B2), which in the Alice Springs area is made up of the Wigley and Alice Springs Blocks. In the northwestern Wigley Block the event is characterised by partial migmatisation of gneisses, granite intrusion, and granitisation of quartzofeldspathic gneiss (e.g. Old Hamilton Downs Gneiss).

In the more southerly Alice Springs Block, gneisses are migmatised east of Alice Springs township (e.g. Jessie Gap gneiss), but not near Alice Springs. Here they were possibly intruded by the Alice Springs Granite during the same Ormiston deformation. The metamorphism associated with the Ormiston phase has been dated at about 1050 m.y. by Marjoribanks & Black (1974). The Gum Tree Granite was intruded into the Harry Creek Deformed Zone, which separates the Utnalalama Block from the Ankala Block, and has been dated at about 1000 m.y. (Allen & Black, 1979).

C-6: Late Stage Igneous Rocks (Table C5)

Late stage dykes intrude the Wigley, Alice Springs and Ankala Blocks. East-trending dykes, forming the Whistleduck Dyke Swarm, post-date the Trephina granitic gneiss, have been metamorphosed to the upper greenschist facies. They are intruded into faults, which are considered to post-date the Ormiston deformation. North-trending dolerite dykes, forming the Stuart Dyke Swarm, post-date all the rocks of the Wigley Block; they have been dated at about 900 m.y. (L.P. Black, BMR, personal communication, 1978).

Other mafic intrusions include slightly altered or metamorphically retrogressed gabbro, norite, and peridotite (Pgb), and an anthophyllite-rich meta-ultramafic pod (Bp) in the Wigley Block. These were intruded during the time interval 1600 m.y. to 900 m.y., probably between 1000 m.y. and 900 m.y.

The Mud Tank Carbonatite, dated at 732 ± 5 m.y. by an assessment of U-Pb zircon methods and at 735 ± 75 m.y. by Rb-Sr total rock methods, (Black & Gulson, 1978), intrudes the unnamed unit pGsf in a fault zone not far from the Woolanga Lineament, and, like the Mordor Igneous Complex, it is thought to be genetically related to this lineament.

C-7: Tectonism in the Arunta Block contemporaneous with sedimentation in the Amadeus Basin

The sedimentary history of the Amadeus Basin sequence is not the subject of the present study. Interested readers are referred to Wells & others (1967, 1970) for an outline of the stratigraphy, and to Preiss (1978) and Jones (1972) for more recent revisions on stratigraphic nomenclature.

The long period of uplift and erosion followed the Ormiston Event at 1050 m.y. and the intrusion of the Stuart Dyke Swarm at about 900 m.y. It was ended by subsidence and the formation of the Amadeus Basin sequence in which terrestrial and marine sediments were deposited. A later mild epeirogenic event coinciding with the earliest upper Proterozoic glaciation at about 700 m.y., is evidenced by a slight regional unconformity between the Areyonga and Bitter Springs Formations. This epeirogenic movement, termed Areyonga Movement, resulted in erosion of the Bitter Springs Formation, Heavitree Quartzite, and crystalline basement of the Arunta Block. Following renewed subsidence sedimentation probably became more continuous until mild regional uplift, termed the Rodingan Movement (Wells & others, 1970), resulted in a marine regression during the Silurian and early Devonian, when non-marine and shallow water sandstone were deposited.

During the Alice Springs Orogeny (400-300 m.y.) major folding and thrust-faulting of the sedimentary sequence was synchronous with the deposition of the Upper Devonian to Carboniferous Pertnjara Group (Jones, 1972). The Orogeny culminated in the Carboniferous (335-310 m.y.) as indicated by K-Ar and Rb-Sr dates on retrograde schists from the root-zone of the Arltunga Nappe Complex (Stewart, 1971; Armstrong & Stewart, 1975). During the Orogeny the Central Tectonic Zone (Figure C6) was uplifted and thrust over the Southern Tectonic Zone (e.g. Ankala and Wigley Blocks), and numerous schist zones were formed.

C-8: Schist and Deformed Zones of Palaeozoic and Proterozoic Age (Table C6)

A number of amphibolite facies schist zones in the northern part of the Alice Springs 1:250 000 Sheet area (i.e. in the Central Tectonic Zone) either cross-cut the granulite terrain or are localised at the tectonic boundary between the granulite and amphibolite facies rocks. Many of these zones contain kyanite and staurolite. The Zones include the Yambah Schist Zone, the Harry Creek Deformed Zone, the Southern Cross Schist Zone, the West Bore Deformed Zone, and the Gough Dam Deformed Zone. Within these zones the parent formations cannot be recognised. There is evidence for movement along some of the zones prior to 1000 m.y., and most, if not all, were active during the Alice Springs Orogeny. They are described further in the chapter on METAMORPHISM.

The Redbank Deformed Zone which separates the granulites of the Narbib Block (Figure C6) from the amphibolite facies rocks of the Wigley Block, differs from the schist zones described above as it consists mainly of mylonitic porphyroblastic gneiss and deformed gneiss, is partly migmatised, and is thought to be related to the Chewings phase of deformation (Marjoribanks, 1975), dated at 1590 m.y. (Marjoribanks & Black, 1974). However, biotite-sericite-schist and several narrow mylonite zones within the Redbank Deformed Zone are considered to have formed much later during the Alice Springs Orogeny.

The Narbib Deformed Zone represents a partly brittle feature developed in the upper levels of the crust during the Alice Springs Orogeny.

Greenschist Retrograde Schist Zones (Pzr), which include mylonite and quartz veins in addition to the more typical muscovite-schist and muscovite-biotite schist, form linear zones which range in thickness from a few millimetres up to at least 1 km. The zones invariably occur along faults, particularly thrust faults, which formed during the Alice Springs Orogeny. They include the schists dated at 335-310 m.y. by Rb-Sr in the Arltunga Nappe Complex (Armstrong & Stewart, 1975).

C-9: Post-Carboniferous sedimentation

There is no evidence of sedimentation from shortly after the Alice Springs Orogeny until terrestrial sediments spread over much of the Sheet area in the Early Tertiary. The Post-Carboniferous period, therefore, has probably been one of continued erosion, during which some mild epeirogenic uplifts are thought to have occurred. For instance, a mild uplift probably accompanied the onset of widespread fluviatile and lacustrine sedimentation in the early Tertiary, but this is difficult to demonstrate because the beginning of sedimentation also corresponds to a poorly documented change in climate (cf. Woodburne, 1967, p. 16).

Following a long period of deep weathering and ferricrete formation a Tertiary fluvial period commenced with the infilling of valleys in the Hale Basin and the covering of the Burt Plain with clastic fluviatile and lacustrine sediments, and some lignite. Silcrete was deposited in the upper part of this sequence due to later groundwater movements. Another period of lacustrine sedimentation resulted in deposition of calcareous sediments in the Hale Basin and in the basin south of Hale Plain. This sedimentation is equivalent to the Waite Formation in the Alcoota 1:250 000 Sheet area (Shaw & Warren, 1975). A period of mild silicification followed, producing a chalcedonic limestone.

The internal drainage system of the Burt Plain continued until a period of aridity in the Pleistocene or early Recent resulted in the formation of minor sand plains and sand dunes. The dunes are now stabilised. Alluvium is being deposited in the present drainage channels.

DETAILED DESCRIPTION OF ROCK UNITS

D-1: Division 1: Strangways Metamorphic Complex.

D-1-1: Enbra Granulite: pGse (APL)

Definition

The Enbra Granulite consists essentially of homogeneous, unfoliated, mafic granulite and small amounts of felsic granulite. It crops out as a group of low, rounded hills over an area of about 84 sq km, 1 km southwest of Snake Well. The name is derived from the aboriginal name for the type area, the Enbra Hills. The type area extends from Snake Well (5651-857355) to a prominent hill 3 km to the south (5651-857325) the abundance of mafic granulite distinguishes the unit from the Ingula migmatite suite to the north and from the more pelite-rich sequence of the Sliding Rock metamorphics to the southeast.

Relationships

The unit is entirely surrounded by Cainozoic sediment, but evidence from several scattered outcrops indicates that it is faulted against the Ingula migmatite suite to the north. This fault strikes northwest from Harry Bore and possibly extends as far as Yambah homestead. The boundary to the southeast is masked by Cainozoic sediments, but the change in rock type is so marked that this boundary may also be faulted.

Lithology

The type area consists of about 75 percent mafic granulite and 25 percent felsic granulite. The mafic granulite (4251, 4254, 4255 4553) crops out as spheroidal exposures and boulders, up to several meters across (Photo. D1). In hand specimen it is medium-grained, dark brown to black, and relatively unaltered.

Commonly, in outcrop, the rock is homogeneous and unfoliated but rarely thin compositional layering is present. The main mineral constituents of the mafic granulite (eg. 4254) are hypersthene (20%), blue-green and green hornblende (20%), spinel (4%), andesine (An_{36})

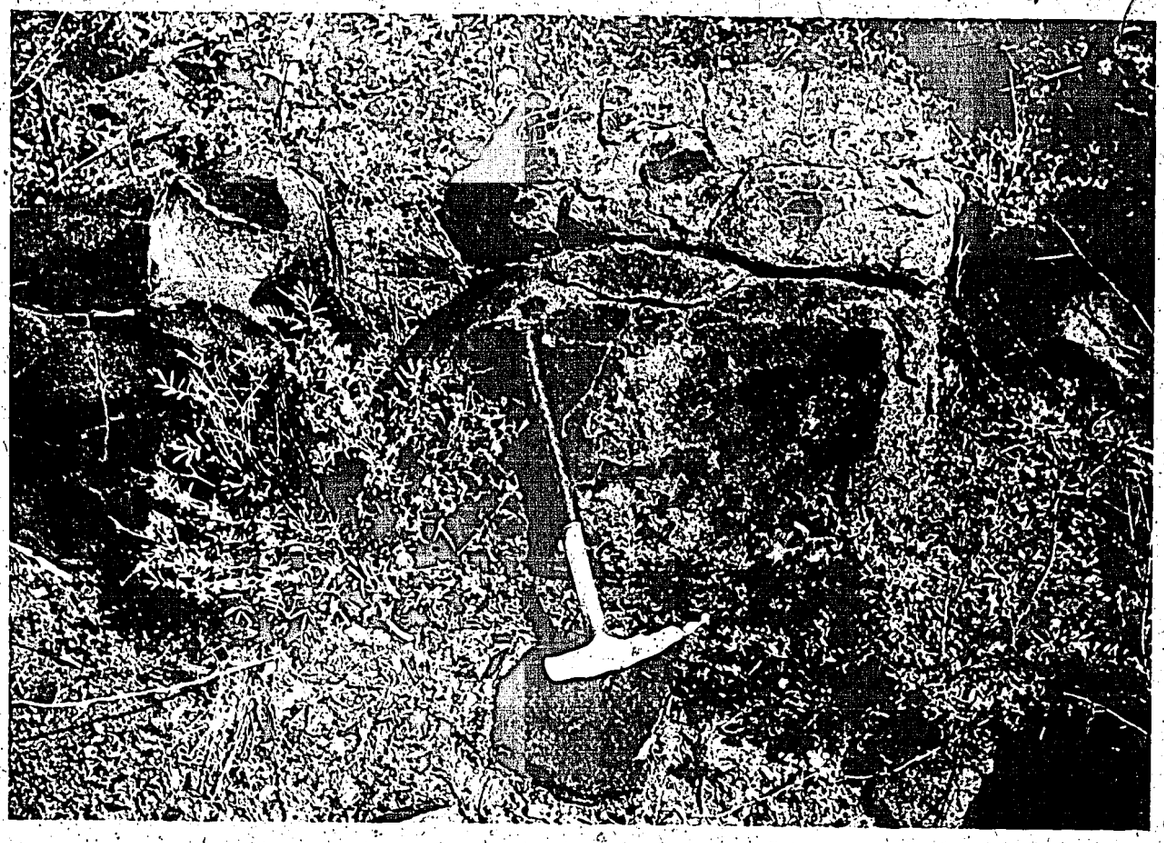


Photo D1: Typical exposure of mafic granulite showing the fine-grained, homogeneous texture.

Photo D2: Exposure of felsic granulite showing the thin compositional layering and layers of mobilisate.

(50%) and clinozoisite (6%). The rock is granuloblastic, consisting of polygonal grains up to 1.5 mm across. Hypersthene occurs in granular aggregates, up to 3 mm across, that are rimmed by hornblende. The grain boundaries are sharp, suggesting that the minerals are in chemical equilibrium. The hornblende is the product of the chemical breakdown of hypersthene, possibly during the waning stages of the granulite metamorphism. Calcic plagioclase contains zones of ovoid clinozoisite inclusions.

Green spinel, possibly pleonaste, occurs as interstitial, polygonal grains, at the triple point junctions of hornblende grains. Fine particles of opaques occur in the hornblende, commonly as linear zones adjacent to grain boundaries.

Felsic granulite (4256, 4257, 4554) crops out as lenses up to 200 meters wide intercalated with mafic granulite. The rock is typically dull red in weathered outcrop, and differs from the mafic granulite in having a faint compositional layering (Photo. D2). The layering is cross-cut by mobilisate segregations, and also by an overprinting schistosity, defined by the preferred orientation of platy biotite, which parallels the axial-plane of macroscopic folds.

The main mineral constituents of the feldspathic granulite, (4256), are garnet (20%), plagioclase (30%) and quartz (35%) with a small amount of biotite (8%), hornblende (4%) and zircon (2%). The rock is medium-grained and granulose, with sutured grain boundaries, and numerous subgrains and new-grains. Specimen 4256, could equally well be classified as hornblende gneiss (h).

Structure

The mafic granulite is homogeneous, fine-grained and on the macroscopic scale, structurally isotropic. The felsic granulite, however, is thinly compositionally layered. This layering parallels the contact with the enclosing mafic granulite and is probably a result of metamorphic differentiation. Photograph D2 shows this layering and parallel layers of

mobilisate. The bodies of felsic granulite are cut by numerous syntectonic dislocations that are oblique to the layering. The deformation related to these dislocations postdate the metamorphic differentiation because it has folded the compositional layers (Photo. D3). However, mobilisate commonly occupies thin zones within the dislocations and branches from the dislocations, into the compositional layering, suggesting that the deformation occurred in the waning stages of the metamorphism.

Origin

The mafic granulite was probably a metabasalt enclosing a small amount of metarhyolite or metasedimentary lenses.

Age and Correlation

The granulite metamorphism probably corresponds to the 1800 m.y. event affecting the Strangways Metamorphic Complex. The unit is unlike other formations of the Complex in that it has a much higher proportion of mafic granulite. The decrease in the amount of mafic rock in what are clearly the upper parts of the Strangways Metamorphic Complex has led to the suggestion that those units, such as the Enbra Granulite, which contain most mafic granulite are older.

D-1-2: Utnalanama granulite (pCsu) (A.R.A.)

*A.R. Allen prefers the non-genetic name 'Granofels' for this unit, because where retrogressed the unit does not contain granulite facies mineral assemblages.

Definition

The Utnalanama granulite is composed of homogeneous quartzofeldspathic hypersthene granofels and crops out in the foothills of the Utnalanama Range, after which it is named. The type area is 2 km west-southwest of Johannsen's Phlogopite Mine (i.e. at 5751-079307). The Utnalanama granulite is almost indistinguishable from chemically-similar hypersthene-bearing quartzofeldspathic granofels of the overlying Erontonga

Photo D3: Felsic granulite showing thin compositional layering, oblique dislocations and minor folds associated with the dislocations.

metamorphics. In outcrop, however, the Utnalanama granulite is more massive and more uniform structurally and compositionally than the quartzofeldspathic rocks of the Erontonga metamorphics which are commonly interlayered with cordierite and garnet-bearing gneisses.

Relationships

The Utnalanama granulite is the oldest rock unit in the Harry Creek area and may represent pre-existing basement to other rocks in this region. It is intruded by the Harry Anorthositic Gabbro with which it is strongly interfolded. These units are interpreted to represent a basement complex, overlain unconformably by the Erontonga metamorphics (see D-1-3), and the latter unit is regarded as a supracrustal sequence (Allen 1976).

The Utnalanama granulite is also intruded by the Johannsen Metagabbro and basic dykes which were possible feeders for the metavolcanics in the Erontonga metamorphics. Numerous younger intrusive rocks cut the Utnalanama granulite including (listed chronologically from oldest to youngest) minor bodies of a pyroxenite suite, an olivine dolerite suite, granitoid rocks correlated with the Wuluma granitoid, the Gumtree Granite and its offshoots, numerous pyroxene dolerite dykes, and granitic pegmatites. Apart from the Gumtree Granite these younger intrusives are all small bodies.

Lithology

The Utnalanama granulite is composed of coarse-grained pale grey to dark grey tonalitic-dioritic granofels. In places it is almost leucogabbroic in composition. Sharp contacts exist between the quartz-rich tonalitic phase and the relatively quartz-poor dioritic to leucogabbroic phase and in places the former intrudes or surrounds the latter. The dioritic to leucogabbroic phase is typically unfoliated, but the tonalitic fraction displays a weak foliation defined by flattened quartz grains.

The tonalitic phase consists principally of quartz and antiperthitic plagioclase (An 40), together with orthopyroxene (10%) and ilmenite (1%). The dioritic to leucogabbroic phase is composed of quartz (10%), antiperthitic plagioclase (An 40), orthopyroxene, clinopyroxene and ilmenite (1%). Zircon and apatite are abundant accessories, the first mainly in the tonalitic phase and the second mainly in the dioritic to leucogabbroic phase. Brown-green hornblende is locally present, as a primary metamorphic mineral. In retrogressed rocks orthopyroxene has been replaced by biotite, and clinopyroxene and brown-green hornblende by blue-green hornblende. Locally, small amounts of alkali feldspar are present.

Metamorphism

The Utnalanama granulite, as the oldest rock unit in the Harry Creek area, has undergone all five metamorphic episodes recognised in this region (Allen, 1976). The medium pressure granulite facies assemblages characteristic of the Utnalanama granulite were formed during the earliest syntectonic recrystallisation. The second event, also of granulite facies, resulted in major textural modifications, but only minor mineralogical changes apart from replacement of pyroxene by brown-green hornblende. These two recrystallisations, which occurred under orogenic conditions, are correlated with the mid-Proterozoic regional metamorphic episode which affected the Arunta Block (Shaw & Stewart, 1975), and have been dated at 1800 ± 27 m.y. and 1710 ± 26 m.y. by the $^{40}Ar/^{39}Ar$ method (Allen & Stubbs, in press).

The third metamorphic episode, which is mainly metasomatic in character, is responsible for the development of alkali feldspar and biotite in the Utnalanama granulite and is associated with formation of the Ingula migmatite suite and the Wuluma granitoid at the expense of plagioclase and orthopyroxene respectively (Allen, 1976). This event occurred under medium-pressure granulite facies conditions, but mineral chemistry indicates a substantial increase in pressure compared to the earlier granulite facies events (Allen, 1976). This event has been dated at 1439 ± 59, λ= 1.42 (1470 ± 60 m.y. λ= 1.39 by an Rb-Sr total rock isochron

(Iyer & others, 1976). The fourth and fifth events are related to initiation and reactivation of the Harry Creek Deformed Zone respectively (Allen & Black, 1979). The fourth event occurred under amphibolite facies conditions and has been dated at 1030 ± 22 m.y. by the $^{40}Ar/^{39}Ar$ method (Allen & Stubbs, in press) whereas the fifth event took place under epidote amphibolite facies conditions. Retrogression of pyroxene to blue-green hornblende and biotite accompanied these events. The last event is correlated with the Alice Springs Orogeny (Allen, 1976; Allen & Black, 1979).

Origin

The original nature of the Utnalanama granulite is unknown. During the first granulite facies metamorphic event, partial melting of the Utnalanama granulite occurred. The tonalitic and dioritic to leucogabbroic phases of the unit are interpreted as neosome and palaeosome respectively (Allen, 1976).

Age and Correlation

The original age of the Utnalanama granulite is also unknown. However, the Harry Anothositic Gabbro, which is intrusive into the Utnalanama granulite, and is overlain unconformably by the Erontonga metamorphics, shows evidence of crystallisation under high-pressure conditions (see D-1-3) since all three of the above units have been metamorphosed during the first granulite facies event, dated at 1800 m.y. (Allen & Stubbs, in press), the Utnalanama granulite and the Harry Anorthositic Gabbro may represent pre-Arunta basement, and the Utnalanama granulite may be the oldest unit yet recognised in the Arunta Block (Allen, 1976).

D-1-3: The Harry Anorthositic Gabbro (pGsh) (A.R.A.)

Definition

The Harry Anorthositic Gabbro* is a metamorphosed mafic igneous body with anorthositic affinities and a sheet-like or lopolithic form. The unit is intrusive into and highly interfolded with the Utnalanama granulite and crops out as a series of interconnected layers in an east-west belt just to the north of Harry Creek. The type area is 3 km west-southwest of Johannsen's Phlogopite Mine at G.R. 5751-055292 and forms an area of subdued relief in the foothills of the Utnalanama Block. The body is thought to be approximately 180 m thick, but because of its folded nature this can be an estimate only. The name is derived from Harry Creek along which it outcrops.

Relationships

The Harry Anorthositic Gabbro is a single body which, due to multiple folding displays a complex outcrop pattern consisting of a series of east-west layers which coalesce to the east and converge to the west. The body has only been found intruding the Utnalanama granulite and appears to be unconformably overlain by the Erontonga metamorphics and cut by all later intrusive igneous rocks. The inferred unconformity between the Utnalanama granulite and Harry Anorthositic Gabbro and the Erontonga metamorphics is based partly on the absence of intrusion of the Harry Anorthositic Gabbro into the latter, a criterion used by McGregor (1973) to subdivide the Archaean of West Greenland, and the presence at two localities of evidence for truncation of the Harry Anorthositic Gabbro by the Erontonga metamorphics. At the first locality (5751-082298) 1 km to the south of Johannsen's Mine the eastwards extension of the Harry Anorthositic Gabbro terminates against the Erontonga metamorphics which cut at right angles across the strata, whilst at the second locality (5751-047288) mapping indicates that one of the layers of the Harry Anorthositic Gabbro is cut by a narrow synform of the Erontonga metamorphics, but reappears on the other side of the synform. Nowhere else has structural evidence for

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*Footnote. A.R.A. prefers the name Harry Gabbro-Anorthosite for this unit

the inferred unconformity been found, although in view of the intense multiple folding which has affected these rocks this is not surprising. Thus in common with other high-grade gneiss terrains, structural evidence for the unconformity is not unequivocal.

The Harry Anorthositic Gabbro is truncated to the west by the Gumtree Granite, and to the south it is in fault contact with rocks of the Ankala gneiss within the Harry Creek Deformed Zone. Contacts with the Utnalanama granulite are usually different and typically only a generalised contact zone can be marked. Where sharp contacts do occur, no chilling of the Harry Anorthositic Gabbro against the Utnalanama granulite has been observed.

Lithology

The most common rock type of the unit is anorthositic gabbro in the classification of Buddington (1939, p19), although rock types range from pyroxenite to anorthosite; ultramafic and mafic rocks are less common than anorthositic rocks. No layering has been observed. Although mostly recrystallised under granulite facies conditions, a few uncrystallised relict igneous patches survive indicating an original igneous mineralogy of plagioclase, aluminous orthopyroxene ± clinopyroxene ± magnetite ± spinel, and a coarse ophitic fabric. Spinel is confined to the pyroxenitic end members.

Metamorphism

Two granulite facies assemblages occur:

1) Plagioclase-orthopyroxene-clinopyroxene-hornblende-magnetite ± ilmenite
2) Plagioclase-orthopyroxene-hornblende-magnetite ± ilmenite ± spinel

Retrogressive phases include cummingtonite, blue-green hornblende, epidote, sphene and rare scapolite. Microstructural features show the imprint of the same five metamorphic events recognised in the Utnalanama granulite (see D-1-2).

The body has a variable metamorphic fabric which ranges from massive unfoliated in the more mafic parts of the body to a coarse vaguely foliated fabric in the more anorthositic parts. A strong foliation associated with the Alice Springs Orogeny is developed locally.

Age and Origin

The Harry Anorthositic Gabbro predates the earliest granulite facies metamorphism (M1) dated at 1800 m.y. (Allen & Stubbs, in press), and is interpreted as older than the Erontonga metamorphics. Petrological evidence from the primary igneous relics e.g. the high alumina content of the relict igneous orthopyroxene (see Moore, 1971; Goode & Moore, 1975), the apparent absence of olivine or a primary igneous phase and the development of orthopyroxene as a liquidus phase (see Green & Ringwood, 1967a) indicates pressure conditions during intrusion of at least 10kb using Green & Ringwood's data for olivine tholeiitic compositions. Since pressure conditions during M1 have been estimated at 7kb (Allen 1976), on the basis of cordierite garnet-hypersthene assemblages in the pelitic members of the Erontonga metamorphics (see Hensen & Green, 1972), the Harry Anorthositic Gabbro would appear to have been intruded into a deep connected environment prior to uplift and erosion, and subsequent deposition of the Erontonga metamorphics. This petrological evidence supports field evidence for an unconformity between a basement complex consisting of the Utnalanama granulite and the Harry Anorthositic Gabbro possibly of pre-Arunta origin, and a supracrustal metasedimentary sequence i.e. the Erontonga metamorphics.

D-1-4: Ongeva granulite, pOso (A.P.L. & R.D.S.)

Definition

The Ongeva granulite is a highly folded sequence of interlayered mafic and felsic granulite and less abundant layers of mobilisate-rich quartzofeldspathic gneiss and cordierite granulite. The formation crops out in the headwaters of Ongeva Creek, straddling the central part of the boundary between LAUGHLEN and RIDDOCH. It is a prominent region of moderately high rugged hills that constitute the eastern extremity of the Strangways Range. The name is derived from Ongeva Creek which has its headwaters in the range. The type area is a 6 km^2 area around 5751-465330 in the centre of the formation outcrop, where tightly folded, interlayered mafic and felsic granulite are well exposed. The formation is clearly distinguished from its bordering units by the characteristic interlayered mafic and felsic granulite, and lack of calc-silicate rock.

Relationships

To the north, the formation is bounded (against the Gough Dam Schist Zone) by a splay fault of the west-northwest-striking Cadney Fault. This major zone of deformation has retrogressed the northern margin of the formation to amphibolite facies. To the east the Ongeva granulite grades into Cadney metamorphics; the boundary is defined by the presence of calc-silicate rock in the Cadney metamorphics.

The southern boundary is obscured by the overlying Cainozoic sediments of the Hale River Basin. To the southwest the formation adjoins Cadney metamorphics, and to the northwest it adjoins pGu. These units are separated by the Mount Johnstone Fault, which also cuts the Ongeva granulite. The Ongeva granulite appears to have a transitional, conformable contact with the Cadney metamorphics between 5751-415320 and 5751-426280.

The contact with unnamed unit pGu is thought to be largely intrusive in that much of the quartzofeldspathic gneiss in the south-eastern part of unit pGu is regarded as orthogneiss. The remaining part of the sequence that is not orthogneiss is thought to be a retrogressed facies equivalent of the Ongeva granulite containing a much smaller proportion of mafic rocks.

Lithology

In the type area, hornblende-hypersthene-diopside-plagioclase mafic granulite (mn) and hornblende-hypersthene-quartz-plagioclase mafic granulite (mn) are interlayered with hypersthene-plagioclase-microperthite-quartz felsic granulite (fn) and mobilisate-rich biotite-plagioclase-microperthite quartz quartzofeldspathic gneiss (f,mi). In the central part of the type-area the layers have been tightly folded, and subsequently refolded in an open concentric style about a moderately north-plunging axis. In the hinge zone of this superposed open fold an unusual discordant kernel of spinel-garnet-quartz-sillimanite gneiss (z) (3286) and garnet-sillimanite-cordierite-perthite-quartz-gneiss (3287) (i) crop out.

Away from the type area, the formation maintains the characteristic macroscopic layering and large open concentric folds. The composition of the layers remains uniform throughout the formation except for the addition of cordierite granulite, mafic calc-silicate rock, porphyroblastic gneiss, and sillimanite gneiss layers near the boundary with pGu; and the inclusion of small lenses of calc-silicate rock, garnet-quartzite, sillimanite gneiss, and marble near the transitional contact with the Cadney metamorphics. Coarse-grained granitoid is developed at 5851-505364, and layers along the northern margin are retrogressed to amphibolite facies rocks.

Mafic granulite (mn) occurs as thick continuous layers and constitutes about 50 percent of the formation throughout. It is generally interlayered with leucocratic granulite though less commonly it forms thin (3 mm to 0.5 m thick) discontinuous layers within felsic granulite. Both rock types may occur in roughly equal proportions (e.g. 678916642). In places the interlayered felsic gneiss is a typically quartz-rich (e.g. 78916638, 41). In hand specimen both types of layers are homogeneous and generally isotropic with respect to mesoscopic fabric elements, but some contain thin feldspar layers, which define a foliation parallel to S_o (probably bedding). The rocks have a slightly resinous lustre on fresh surfaces, are very tough and rust-red brown on weathered surfaces. A few mafic granulites have a quartz-rich margin near their contact with the felsic granulite. In general, the thick layers are two-pyroxene, quartz-poor mafic granulite (3281, 3289, 3290, 3292, 3296, 3298, 3299, 3301, 3302, 3305, 3306, 3341, 3344, 3347, 3348, 3367, 3370, 3392, 3398 3508, 3509, 3504, 3511, 3608, 3611, 3623) consisting dominantly of plagioclase, diopside, hypersthene, and hornblende. The granulite is granuloblastic and coarse to medium-grained, consisting of polygonal, interlocked, equant grains. In contrast, the thin layers (3369, 3371, 3396) consist dominantly of plagioclase, quartz, hypersthene and hornblende. They are granoblastic and medium-grained consisting of anhedral, lobate grains.

Four samples (3504, 3508, 3509, 3511) were submitted for whole rock analysis (see geochemical section).

The leucocratic layers can be grouped into two distinct rock types, (1) felsic granulite (fn), and (2) mobilisate-rich quartzofeldspathic gneiss (f,mi, but not distinguished on map from fn). Compositionally the two types are very similar, differing only in the presence of hypersthene in the former and biotite in the latter. In outcrop however, the abundance of mobilisate in the quartzofeldspathic gneiss (f,mi) causes it to be very slightly foliated, and forms massive and rounded exposures, clearly distinguishing it from granulite. Both varieties occur as thick, (from 5 m to 20 m) semi-continuous layers, which are intercalated with mafic granulite and crop out as crumbly, yellow-orange, moderately weathered ridges. Quartzofeldspathic gneiss commonly grades into felsic granulite.

(1) Felsic granulite (fn) (3280, 3308, 3342, 3624, 3625, 3397, 3311, 3343, 3282, 5001) is medium-grained, granoblastic and consists dominantly of quartz, microperthite, plagioclase and hypersthene together with various amounts of garnet, tourmaline and hornblende. One sample, 5002, was analysed (see geochemistry section).

(2) The mobilisate-rich quartzofeldspathic gneiss (f,mi) (3279, 3288, 3300, 3355, 3357, 3358, 3360, 3391) is coarse-grained, granoblastic and consists dominantly of quartz, microperthite, plagioclase and biotite. At 5851-505364 quartzofeldspathic gneiss grades into granitoid (3368, 3292, 3294) in the core of a tight macroscopic fold. This granitoid intrudes the western limb of the fold and is a very coarse-grained homogeneous granitic rock. It consists of megacrysts of orthoclase in a coarse-grained matrix of quartz, hornblende, biotite, plagioclase and rare hypersthene.

Slightly less massive finer-grained and more strongly foliated felsic granulite contains only a small amount of mobilisate. This mobilisate occurs as veins which are generally subparallel to a foliation defined by compositional layering, parallel to the macroscopic layering, S_o. Commonly, a progressive increase of mobilisate along strike is accompanied by a change from hypersthene to biotite as the chief mafic mineral. This indicates that the difference between the two varieties of leucocratic rock (i.e. felsic

granulite and quartzofeldspathic gneiss) may result from different water contents and consequent different degrees of melting and retrogression. The increase in mobilisate seems to be prominent in the hinge region of macroscopic folds and typically obliterates axial-plane fabric elements.

Rare layers of quartzofeldspathic gneiss (p) containing abundant megacrysts of K-feldspar form thin lenses near the boundary with pGu. Farther south, in the same area, is a thick unit of quartzofeldspathic gneiss, which grades into lesser amounts of quartzite, contains lenses of amphibolite and biotite schist.

Cordierite granulite (i) (3287, 3286, 3388, 3393, 3394, 4460, 4459) crops out in the type area, in the core of the macroscopic superposed fold and is also intercalated with mafic granulite of the northwestern margin. It consists of cordierite, sillimanite, microperthite, biotite, quartz and opaque grains and lesser amounts of hypersthene, garnet and spinel. Some varieties (3286, 4459) contain large amounts of sillimanite and grade into sillimanite gneiss (z). The cordierite is typically rimmed by small acicular crystals of anthophyllite, kyanite and quartz that possibly grew during retrogression of cordierite (Wilson, Uni. Qld, personal communication, 1977). Sillimanite gneiss also occurs near the pGu boundary and in association with calc-silicate rock near the boundary with the Cadney metamorphics. The above calc-silicate rock (cs) grades into a garnet quartzite containing minor diopside. Rare marble (ma) also occurs in the same zone.

Garnet gneiss (v) (3295, 3316, 3340, 3607, 3609, 3610) crops out as thin layers in felsic granulite. It consists of quartz, plagioclase, microperthite, clinopyroxene, biotite, garnet and hornblende.

Several small amphibolite (a) bodies (3361, 3352, 3365, 3363, 3356) crop out along the retrogressed northern margin adjacent to the Gough Dam Fault Zone. Metanorite (3395) crops out in the northwestern margin and consists of subhedral megacrysts (up to 0.5 cm long) of plagioclase (50%) and altered hypersthene (50%).

Structure

The formation is dominated by macroscopic layering S_o (layering probably coincident with bedding) defined by the interlayering of felsic and mafic granulite, which is from 5 m to 30 m thick. On the mesoscopic scale tight to isoclinal folds (F_1) occur within the layers, and are delineated by thin compositional layers S_1 that were probably produced by metamorphic differentiation. A schistosity S_2 defined by the preferred orientation of biotite is axial-plane to these isoclinal folds.

At 5751-450317 the S_o layering is tightly folded on the macroscopic scale, about an axis plunging northeast at 49° and is designated F_2. This macroscopic F_2 fold is refolded about an open concentric fold with a steeply northerly-plunging axis (F_3). This F_3 fold style occurs throughout the formation typically with a north to north-northeast plunge. Axial-plane features of F_3 folds are obscured in the hinge regions by copious mobilisate segregations, which are not aligned in the axial plane of F_3. Mineral elongation lineation, L_1, typically plunges steeply (60-70°) to the east and northeast and is probably S_1-S_2 intersections.

Geochemistry

Four samples of mafic granulite (3504, 3508, 3509, 3511) were analysed for major and selected trace elements (Appendix A1). The four samples are chemically very similar to each other and to mafic granulite 4406 from the Yambah granulite. They all resemble analyses of modern continental tholeiitic flood basalts and do not appear to have been significantly changed by element migration. Sample 3509 is slightly more siliceous, aluminous, and sodic, and less magnesian than the other rocks and may represent a more highly differentiated basalt.

One sample of felsic granulite (5002) was analysed (Appendix A2). The rock is very siliceous and similar to felsic granulite from the Yambah granulite (6007). The antecedents of these siliceous leucocratic rocks are tentatively identified as rhyolitic flows, but further study is required.

Metamorphism

The hornblende-hypersthene-diopside-plagioclase mafic granulite is typically granuloblastic (medium to coarse, polygonal, equant grains). Thus the oldest recognisable regional metamorphic conditions in these rocks were of granulite facies. Wilson (Uni. Qld., personal communication, 1977) has designated the main high temperature and pressure metamorphic event, M_1. An unusual feature of the stable M_1 assemblage is the presence of hornblende, indicating that the rocks may have been wet rather than dry during granulite metamorphism. Recognition of a second event which produced granular rims of two pyroxene new grains around the polygonal M_1 grains led to the designation of M_2 by Woodford & others (1975).

The polygonal equilibrium assemblage in the mafic rocks of the Ongeva granulite confirms a granulite facies regional metamorphism which may be M_2, but no evidence was observed for earlier metamorphism, M_1. However, granular new grains occur in 3293, 3302, 3305, 3306, 3341, 3344, 3370, 3611, 3623 and may represent incipient M_3 recrystallisation. Biotite and a second (blue-green) hornblende occur in some samples (3302, 3305, 3341) indicating that either M_3 is lower than granulite facies or that these samples are affected by incipient M_4 recrystallisation.

The northern margin of the unit is retrogressed adjacent to the Gough Dam Schist Zone. Layers of mafic and felsic granulite change along strike to amphibolite and quartzofeldspathic gneiss. Hypersthene in the felsic granulite is altered to biotite. Compositional layering is maintained and coarse-grained mobilisate segregations, typical of the felsic granulite, are easily discernible in the gneiss (3366). The complete retrogression of layers occurs over about a 20 m interval, but a curious feature is the retention of hypersthene in the mobilisate segregations over much of that 20 m.

Origin

Chemical analyses and petrographic data indicate that the formation consists of interlayered basalt and rhyolite with small amounts of psammitic and pelitic beds. The formation contains a much smaller proportion of magnesian metasediments than the Yambah granulite, but is similar in most other respects. Thus, the formation is interpreted to be a metavolcanic pile.

Age and Correlation

One sample (3366) was analysed (both whole rock and biotite) for Rb-Sr age determination but results are not yet available. The formation is correlated on composition, structure and metamorphic grade with the Yambah granulite and the unit pGsp, but because of the paucity of magnesian metasediment, may be slightly more volcanic in its antecedent character. More detailed comparison is required between the Enbra Granulite and the mafic rocks of the Ongeva granulite to establish the stratigraphic relationship of these units.

D-1-5: pGsp (R.D.S.)

(Mount Pfitzner granulite on Preliminary Map)

Definition

Unit pGsp consists principally of quartzofeldspathic gneiss, and some felsic granulite (together about 40%), mafic granulite (about 30%) and a variety of biotite gneisses, many of which contain small amounts of sillimanite or garnet. The unit forms rugged mountain ranges trending northeast, which together make up a large block of uplands west of Woolanga Bore in the northeastern quarter of LAUGHLEN. Mount Pfitzner the highest peak in the outcrop-area is about 1100 m high. On the LAUGHLEN Preliminary 1:100 000 map the unit is informally referred to as "the Mount Pfitzner granulite", but the unit is to be unnamed on the 1st edition map because it is not known in sufficient detail to be readily distinguished from neighbouring units of the Strangways Metamorphic Complex such as the Yambah granulite, so further mapping is required. The unit is distinguished from the Yambah granulite by its general lack of the cordierite-bearing gneisses. It differs from the Ongeva granulite in containing a much greater proportion of sillimanite-bearing and other aluminous rocks. Also, unlike the Yambah and Ongeva granulites, many of the quartzofeldspathic gneisses lack hypersthene. The reference section extends from Mueller Creek (GR5751-045547) southeastwards beyond Mount Pfitzner towards Woolanga Bore (GR5751-133540).

Relationships

The boundary with the overlying Cadney metamorphics to the south and east is conformable and transitional on the local scale, but regional considerations indicate a slight stratigraphic break at the top of the unit pCsp. The upper boundary is marked by the incoming of aluminous or calcareous rocks, and appears to mark a major increase in the content of metasediments.

The western boundary with the Yambah granulites is placed at the prominent and most westerly of a series of northwest-trending faults that follows Edwards Creek, because rocks containing cordierite are not known east of this fault.

Part of the northeast boundary of unit pCsp is overlain by Cainozoic deposits and as a result the relationship with unit pCu is unknown.

Lithology

The northwestern part of the reference section contains the highest proportion of mafic granulite (40%), and, for this reason, is conjectured to be the oldest part of the succession (see OUTLINE OF GEOLOGY). In this northwestern part of the section the subordinate rock types are very variable, and consist of quartzofeldspathic gneiss, biotite or phlogopite-rich gneiss, and sillimanite-bearing gneiss. To the southeast quartzofeldspathic rock becomes the dominant rock type. Some of the quartzofeldspathic rocks in the southeastern-most part of the reference section are hypersthene-bearing, and have been designated felsic granulite (fn). The overlying unit is highly aluminous containing conspicuous hypersthene and sillimanite, and has been placed in the Cadney metamorphics.

Quartzofeldspathic gneiss and felsic granulite are the principal rock types south of the reference section. In the central part of the outcrop-area a variety of rock types have been photo-interpreted, which are thought to be more biotite or phlogopite-rich because of a darker tone on the aerial photographs. At the southwestern extremity of the principal outcrop-area the gneisses are garnetiferous and migmatitic.

Mafic granulite (mn) is commonly about 100 m thick and is generally interlayered with a variety of gneisses. The mafic granulite consists of plagioclase (An_{50-60}), hypersthene, clinopyroxene, small amounts of hornblende, biotite, opaque grains, and accessory apatite. Visually estimated modes are set out in Table D-1-5A. More than half the specimens examined in thin section contain quartz (up to 20%). The texture is generally granoblastic, and less commonly granuloblastic. In the southern and eastern parts of the outcrop-area the mafic granulite shows slight recrystallisation at grain-boundaries. In these rocks hornblende is typically green and commonly slightly more abundant than in the typical mafic granulite (up to 17%), and opaque grains tend to be much finer-grained and more sparsely distributed.

Sample 3500 (GR 5751-083464) has been chemically analysed. It is chemically akin to tholeiitic basalt (Table A1, Appendix).

Amphibolite (a) consisting of plagioclase and actinolite has been recorded from the eastern boundary fault of the unit (1247A, Table D-1-5A).

Quartzofeldspathic gneiss and felsic granulite (f, fn) are interlayered with mafic granulite and are most abundant in the eastern part of the outcrop-area where they account for about 60 percent of the rocks. They form the most prominent ridges in the region, including the ridge forming Mount Pfitzner. The quartzofeldspathic gneiss appears to be predominant in the western part of the outcrop area, but felsic granulite becomes increasingly abundant towards the eastern margin of the unit. However, because felsic granulite cannot be identified by photo-interpretation the map is biased towards quartzofeldspathic gneiss. Both these rock types consist largely of plagioclase, quartz and variable amounts of perthitic orthoclase together with small and various amounts of garnet, orthopyroxene, phlogopite, biotite, clinopyroxene, sillimanite and opaque grains (Table D-1-5B). Zircon is common accessory. Rutile and monazite are accessories in some rocks in the extreme eastern and southeastern parts of the unit. The felsic rocks as a group tend to grade into sillimanite and orthopyroxene or gedrite-bearing varieties (e.g. 3723), which are more aluminous or ferruginous in composition. The gneisses are recrystallised

Tables D-1-5 A&B Visually estimated modal analysis of rocks from pGsp

Table D-1-5 A Mafic rocks (mn,a)

	1241A	1243A	1245A	1247A	3581	3582	3585	3588	3589	3590	3593	3594	3595	3596	3597	3598	3716	3717	3719	3720	3722
Plagioclase	40	50	75	55	65	57	63	74	65	75?	53	30	41	50	50	45	49	64	65	75	38
Orthopyroxene	20	20			20	25	25	5	10	10	15	30	20	27	25	20	15	10	10	8	20
Clinopyroxene	10	15				10	5	10	10	10	25	?	15	10?	2		20	20	25	1?	20
Hornblende	3	2				5	5	10		5?	3	10	5	5		5				15	17
Biotite	15	8						1		5?			5	8							3
Quartz	5		2	5	15	2		10?			2	20	1		18	10	10				2
Opaque Grains	7	5	3	tr			2				3	10	tr	tr	5	10	6	6	5	tr	tr
Epidote				tr																	
Actinolite			10	40				5						tr							
Apatite		ac					ac	ac						ac		ac		ac			
Sphene																		ac			

tr = trace ac = accessory

Table D-1-5 B Quartzofeldspathic gneiss (f) and felsic granulite (fn)

	1242	1243B	3578	3579	3581	3583	3591	3592	*3600	*3601	3602	3718	3721	*3723	*3724	W130	W312	W657	W694	W720	W543
Microcline	60																				
Perthitic orthoclase		5				2	45	45	10	40	10?	53			43	+	+	+	+	+	
Plagioclase		70	48	15	65	58	15	7	20	25	54	5	32		25	x	x	x	x	x	
Quartz	25	25	40	55	15	40	38	40	60	tr	30	40	40	40	30	+	+	+	+	+	
Garnet	10			10			1	3		1	3	2	15		4	x	x		x	x	
Orthopyroxene			12	x	20					15				15		x	x	x	x		
Gedrite														30	1						
Biotite	5	tr	15		tr			5	5		2		10			x	x	x	x	x	
Clinopyroxene				13-						5				5							
Opaque Grains			ac	7	tr		1		3	10		tr	3		2						
Sillimanite									2		1			10	tr						
Chlorite																			ac		
Muscovite	tr					tr															
Hornblende															5						
Actinolite										4											
Zircon			ac	ac		ac							ac		ac	ac		ac		ac	
Apatite					tr								ac		ac						
Sphene					-								ac								
Rutile														ac		ac					
Myrmekite		ac																			
Monazite																ac	ac		ac	ac	

* on boundary with, or in lower Cadney Metamorphics W100 etc specimen and data after P. Woodford, 1974

tr = trace ac = accessory x = minor amount + = major component

to various degrees, particularly the quartz grains. Recrystallisation is most advanced in the eastern part of the outcrop-area. One unusual type (1243) from the northern part of the unit near Mueller Creek (5751-055549) contains microcline (60%) rather than perthitic orthoclase and lacks plagioclase.

Sillimanite-bearing pelitic gneiss is interlayered with mafic granulite and quartzofeldspathic gneiss in the central-northern part of the outcrop-area and has also been photo-interpreted in the southwestern part of the outcrop-area. A typical example is specimen 3584, which consists of quartz (59%), sillimanite (20%), biotite or phlogopite (15%), cordierite (2%), gedrite? (2%), garnet (1%) and orthopyroxene (2%). Another type (1241B) contains quartz (60%), K-feldspar (10%) and plagioclase (5%), garnet (10%), sillimanite (7%), biotite (8%) and accessory opaque grains. Some of the felsic granulite of the lower Cadney metamorphics also has a similar pelitic composition (e.g. specimen 3723, Table D1-5B, 5751-100443), but is likewise not readily distinguished from other felsic granulites in the field.

Garnet-bearing biotite gneiss (v) has been mapped in the southwestern part of the outcrop-area (5751-010470 and 5751-080460) where it is interlayered with granitic and migmatite gneisses (mi) and rare lenses of mafic granulite and calc-silicate rock. It is commonly migmatitic and contains up to 15 percent garnet and from 5 to 15 percent biotite. The garnet-bearing gneiss at 5751-030485 is highly schistose and contains abundant muscovite and biotite due to retrogression.

Biotite gneiss (b) is the name used for photo-interpreted rocks that are interlayered with mafic granulite and small amounts of quartzofeldspathic gneisses in the central part of the outcrop area of unit pGsp. The rocks are recognised by their photo-colour, which is darker than that of the quartzofeldspathic gneisses.

Structure

The unit is cut by a series of northwest-trending faults, which in a few cases have thin retrograde schists localised along them. Most of the recognisable folds are synformal and trend northeasterly. It is suspected that this northeasterly trend is the final phase in a more complex folding history.

Metamorphism

Felsic granulite in the eastern part of the unit contains the assemblage perthitic orthoclase-plagioclase-orthopyroxene-phlogopite indicating that this part of the unit has been metamorphosed to well within the granulite facies. Elsewhere, orthopyroxene appears to be confined to the more pelitic of the felsic rocks (Table D-1-5B) but more sampling is needed to confirm this distribution. The mafic granulite commonly contains green-brown and green hornblende, biotite, clinopyroxene, and orthopyroxene. The green hornblende and some of the biotite are associated with recrystallisation and represent a second phase of metamorphism.

Origin

Much of pGsp is considered to be of sedimentary origin. Many of the quartzofeldspathic gneisses are thought to be metasedimentary because they appear to grade into definite sedimentary aluminous varieties. The mafic granulites are thought to be identical to that shown to have the composition of tholeiitic basalt (Wilson, 1975, p. 62).

Correlation and Age

Unit pGsp is considered to be a lithological correlative of the Yambah and Ongeva granulites.

Iyer, Woodford & Wilson (1976; pp. 219-221) suggest, on the basis of a Rb-Sr isochron defined by four points (specimens [illegible]0, W720F, W543F, W468) that the felsic granulites, which straddle the Cadney metamorphic boundary, were reconstituted during a metamorphic event (M2) which they date at 1430 ± 60 m.y. with an initial ratio of 0.731 ± 0.004. An earlier metamorphic event preserved in some of the mafic granulites of

pGsp and in adjacent Cadney metamorphics was correlated by Iyer, Woodford & Wilson (1976) with an 1860 ± 80 m.y. (M1) event inferred from Rb-Sr results on six felsic granulites from the Yambah granulite in the Yambah area. The second metamorphism (M2) is inferred by Woodford & Wilson (1976b) to correspond to widespread incipient recrystallisation evident at grain boundaries in felsic and mafic granulites in the eastern part of unit pGsp.

While R.D.S. recognises two recrystallisation events, which probably correspond to the two metamorphisms (M1 and M2), he does not consider the isotope data sufficient to allow the interpreted ages given in Iyer, Woodford & Wilson (1976) and Woodford, Mateen, Green & Wilson (1975) to be applied to unit pGsp.

D-1-6: Yambah granulite: pGsy (ARL)

Definition

The Yambah granulite is a thick, highly folded sequence of interlayered mafic and felsic granulite with less abundant layers of hypersthene-cordierite quartzite, calc-silicate rock, quartzite, and rare lenses of sapphirine-spinel-hypersthene-phlogopite granulite. The formation crops out over approximately 350 km^2 in the northeastern part of BURT approximately 75 km north of Alice Springs and forms a roughly horseshoe-shaped chain of moderately high rocky hills that constitute the western extremity of the Strangways Range. The name is derived from Mount Yambah, a prominent peak on the southern edge of the unit.

The type area is the southern slopes of Mount Strangways, 9 km north of Yambah homestead, centred on 5651-820510. A small outcrop area surrounding the Edward's Creek Prospect is also tentatively assigned to the unit. The unit is distinguished from the Erontonga metamorphics to the south, by the abundance of interlayered mafic and felsic granulite and lack of sillimanite and cordierite gneiss. It is distinguished from the unit pGsp to the east by the abundance of felsic granulite and lack of quartzo-feldspathic gneiss and the presence of cordierite-bearing gneisses. Although

the bulk composition of the felsic granulite and quartzofeldspathic gneiss is very similar, the presence of hypersthene in the leucocratic rocks of the Yambah granulite is a significant diagnostic feature.

Relationships

To the north and west of Mount Strangways the granulite is overlain by Quaternary alluvium and red earth soil, concealing its boundary with the adjacent Aileron metamorphics in the Reynolds' Range. Isolated outcrops of highly deformed, retrograde schistose gneiss, schist, and amphibolite near the northwestern edge of Mount Strangways suggest that the granulite is truncated here by a northeast-striking deformed zone. Exploratory drilling between Mount Strangways and Aileron recovered basement cores that consisted of amphibolite facies, biotite-muscovite-schistose gneiss, amphibolite and quartzite.

To the south, the granulite is bounded by the Yambah Fault, a major east-striking feature, that separates it from the northwestern extension of the Erontonga metamorphics, a sequence of garnet-sillimanite-hypersthene granulite, cordierite-hypersthene granulite and calc-silicate rock. However, at one locality (5651-960470) the southern boundary is not faulted. Here pGsy is overlain by Cadney metamorphics.

The eastern boundary is a north-northwest striking-fault that separates the unit from the unit pGsp a layered sequence of mafic granulite and quartzofeldspathic gneiss.

Lithology (see Table D-1-6A for sample numbers)

In the type area interlayered hypersthene-diopside-plagioclase mafic granulite, biotite-garnet-hypersthene-cordierite-quartz-felsic granulite and biotite-hypersthene-quartz-microperthite felsic granulite are well exposed. The layers of two pyroxene mafic granulite and felsic granulite are approximately equal in abundance, ranging in thickness from 1 m to 70 m, and are probably coincident with bedding. The granulites are folded on the mesoscopic scale about a steeply south-plunging axis and the layers are cut by an east-striking retrograde schist zone Pzr/Bry that contains kyanite, staurolite, garnet and biotite.

Table D-1-6A. Samples of rock types from the Yambah granulite, grouped lithologically

TWO PYROXENE MAFIC GRANULITE:

4095	4337	4368	4177	4304
4067	4323	4367	4181	4365
4051	4310	4438	4226	4371
4052	4452	4437	4228	
4050	4379	4087	4236	
4059	4416	4086	4237	
4057	4369	4088	AS1246	
4336	4368	4064	4321	

HYPERSTHENE-QUARTZ MAFIC GRANULITE:

4083	4312
4084	4518
4064	
4066	
4060	
4325	
4308	

FELSIC GRANULITE-MICROPERTHITE AND QUARTZ:

4068	4433	4334(r)
4094	4436	4366
4058	4422	4364
4330	6007	4440
4331	4081	
4309	4093	
4453	4085	
4439	4229	
4373	4230	
	4227	

Table D-1-6A (continued)

CORDIERITE BEARING FELSIC GRANULITE

4065	4082
4069	4063
4313	4225
4231	
4435	
4423	

CORDIERITE BEARING MAFIC GRANULITES

4326	
4327	

QUARTZITE

4339	
4372	

CALC-SILICATE ROCKS

4235	4320	4333	4516
4450	4322	4335	4517

PYROXENITE

4446	
4449	
4451	

AMPHIBOLITE

4338	4370
4329	
4324	
4441	
4329	

Table D-1-6A (continued)

SAPPHIRINE BEARING ROCKS

4417	4424	4432
4418	4425	4458
4419	4426	4374
4420	4427	4375
4421	4428	4376
4232	4429	4377
4233	4430	4378
4234	4431	

DIORITE

4089
4090
4091

MYLONITE

4092

STAUROLITE SCHIST

4061

MYANITE SCHIST

4062

FELSIC GNEISS

4176
4328
4330
4331
4332

ECONOMIC SAMPLES

4447	4449	4451
4448	4450	

The moderately high hills to the east and southeast of Mount Strangways also consist of layered mafic granulite, cordierite-bearing felsic granulite, microperthite-quartz felsic granulite and cordierite quartzite, but in addition contain small lenses of unusual rock types, such as spinel-cordierite-corundum-phlogopite-sapphirine-hypersthene granulite, diopside-scapolite calc-silicate rock, hypersthene-quartzite, pyroxenite, and a variety of retrograde schist zones.

The mafic granulite is usually homogenous on the mesoscopic scale, and isotropic; rare layers are coarse-grained with crystals up to 4 cm long. The fresh rock is brown-black and has a slightly resinous lustre; weathered surfaces are rust-red brown. Layers are usually 1 m to 20 m thick but discontinuous; necking, boundinage and attenuation of the limbs of macroscopic folds are common features (Photos D6, D7, & D8). The mafic granulite is typically fine to medium-grained and granuloblastic, consisting of anhedral, rarely polygonal, interlocked, equant grains of hypersthene, plagioclase, and either diopside or quartz and a small amount of hornblende. The abundance of diopside or quartz divides the mafic granulite into two distinct varieties; one consisting of hypersthene-quartz-plagioclase An_{50}, the other consisting essentially of hypersthene-diopside-plagioclase An_{60} with a small amount of hornblende and quartz. In the former, the quartz occurs either as large globular grains interlocked with plagioclase, as coronas rimming hypersthene, or as mymekitic intergrowths in the reaction zone between hypersthene and rare hornblende. In the latter, the quartz occurs as small interstitial grains, and the rock is dominated by large, pale green, polygonal, diopside grains. Apatite and iron oxide are common accessory minerals. Specimen 4406 has been geochemically analysed (see Geochemistry). The thin mafic layers show reaction margins up to 4 cm wide with the enclosing felsic granulite (Photos D7 & D8).

The felsic granulite can also be subdivided into two distinct rock types; one bearing garnet, cordierite quartz and microperthite, the other bearing essentially microperthite and quartz.

Photo D6: Mafic granulite boudins in felsic granulite near Mount Strangways.

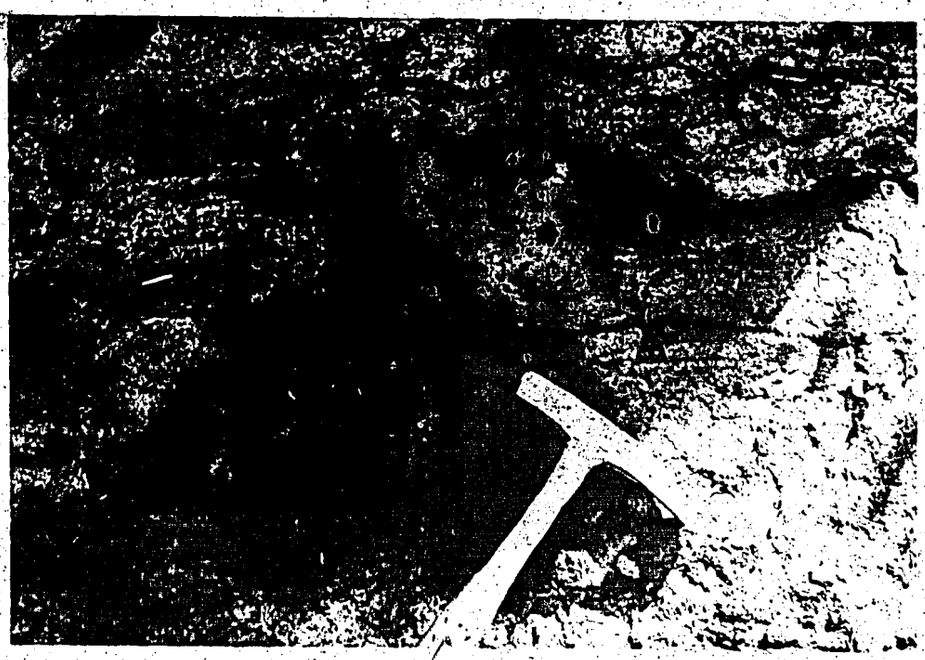


Photo D7: Reaction zones between thin mafic layers and felsic granulite.

Photo D8: Detail of thin layers showing the extensive reaction zones with the felsic granulite.

The garnet-cordierite-quartz felsic granulite is commonly inhomogeneous and anisotropic, having a penetrative foliation, S_1, defined by internal compositional layering of garnet, cordierite, biotite and mobilisate segregations, and paralleled by the preferred orientation of platy biotite. S_1, in general, parallels the macroscopic layering S_o. In outcrop the granulite is pale orange-yellow, usually medium-grained and tough. The surface of weathered outcrops is commonly pitted, slightly greasy in appearance and spheroidal. It has a small amount of mobilisate segregation, in contrast with the microperthite-quartz felsic granulite. The rock consists of biotite-hypersthene-garnet-cordierite and abundant quartz, with rare perthite and accessory zircon and iron oxide grains. The hypersthene, garnet and cordierite are commonly unaltered and occur as large, rounded embayed, anhedral grains, that enclose globular quartz grains and lie in a matrix of recrystallised quartz and tabular biotite. The hypersthene grains are strongly pleochroic from pale green to pink and up to 0.5 cm across.

The microperthite-quartz felsic granulite is homogenous on the macroscopic scale and anisotropic, consisting of biotite, hypersthene, perthite and quartz with irregular, commonly concordant, lenses and thin veinlets of mobilisate. The granulite is coarse-grained and in weathered outcrops, is yellow-orange and crumbly. It is internally contorted into disharmonic flow folds of a variety of styles.

In layers containing a large volume of mobilisate, the mobilisate is cross-cutting and the rock grades into migmatite. The granulite consists of rare large anhedral hypersthene and garnet grains set in a medium-grained, granoblastic matrix of microperthite and quartz, in approximately equal proportions, accompanied by small amounts of biotite, plagioclase, and microcline and accessory zircon and iron oxide grains. Microperthite and quartz grains are lobate or rounded and commonly have sutured boundaries. Quartz also occurs as a symplectic intergrowth with granular aggregates of garnet. Mobilisate segregations consist of coarse-grained quartz and perthite. Chemically analysed specimen 6007 is an example of this rock type.

Within the granulite mass there are several less abundant units of different composition to the mafic and felsic granulites. These include quartzite, cordierite rich quartzite, metapyroxenite, calc-silicate rock, and small lenses of sapphirine-hypersthene-spinel-cordierite-phlogopite rock and related assemblages.

Quartzite granulite crops out at two localities, one 5 km to the east of Mount Milton and the other 10 km to the west of Mount Milton. The quartzite consists of large, anhedral grains of hypersthene that have been recrystallised to small polygonal subgrains of hypersthene, and fine-grained, granoblastic quartz. Felsic granulite, cordierite-bearing felsic granulite and cordierite-bearing quartzite are difficult to distinguish in the field, and there appears to be a gradation between the latter two. Thus, the areal extent of the three rock types, particularly cordierite-bearing quartzite is not well defined.

The cordierite-bearing quartzite is a medium-grained rock consisting of globular grains of cordierite, anhedral quartz with sutured boundaries and rare microperthite. The rock also contains accessory opaque grains and abundant, fine-grained, rounded zircon. The cordierite contains dense mats of sillimanite and inclusions of zircon. The quartzite is country rock for lenses of unusual sapphirine, spinel, hypersthene phlogopite, cordierite-bearing rock. Several unusual lenses of cordierite-bearing mafic granulite crop out near Mount Yambah. These lenses consist of cordierite, hypersthene phlogopite and rare quartz.

Small plug-like bodies of metagabbro consist of subhedral laths of plagioclase An_{54}, anhedral grains of hypersthene rimmed by hornblende coronas, and rare phlogopite.

In some varieties hypersthene has been recrystallised into polygonal subgrains. Recrystallised, granoblastic pyroxenite, consisting of hypersthene, phlogopite, augite and plagioclase crops out near Yambah homestead. Small lenses of coarse-grained, hypersthene-garnet-hornblende-scapolite calc-silicate rock crop out 10 km east of New Bullock Bore and

at several localities southwest of Mount Strangways. Sapphirine has been discovered at several localities (notably at 5651-173123 and 5451-165123). Typical assemblages in which the sapphirine occurs includes enstatite or hypersthene, as coronas around spinel or as subhedral crystals. It is pleochoroic from pale pink to sky blue and has a $2V_x=50^o$ (R.N. England, Lab. Rep. 1973/57).

Anthophyllite and gedrite-bearing rocks (~~ae~~) are known principally from the Edwards Creek Prospect (5751-002553). These rocks contain large amounts of anthophyllite (up to 75% - 2647A) or gedrite (up to 100%) as well as minerals such as spinel, phlogopite, chlorite, enstatite, cordierite, garnet, and staurolite. They form small lenses seldom more than 1 m wide and several meters long. Some rocks (e.g. 2650B, H) are rich in chlorite. In specimen 2650C spinel is altered to sapphirine and in other specimens cordierite-gedrite ± orthopyroxene is altered to chlorite. Common accessory minerals include corundum, zircon, monazite, rutile and ilmenite.

Marble and calc-silicate (ma, cs, pa) discontinuous lenses accompany the anthophyllite-bearing rocks at the Edwards Creek Prospect. The marble consists of calcite together with olivine (2648B) or, in less pure portions, clinohumite, garnet, diopside, gahnite and mica. The calc-silicate rock to the south at 5751-006536 contains quartz and epidote.

Structure

The interlayers of mafic and felsic granulite are probably coincident with bedding and the foliation defined by the interlayering is designated S_o. A penetrative foliation S_1, defined by internal compositional layering, notably, of thin lamellae of mafic minerals, defines tight intrafolial folds (F_1) with limbs parallel to S_o. A second foliation S_2 defined by the preferred orientation of platy biotite, is parallel to the regional foliation S_o and axial-plane to the intrafolial folds defined by S_1. Several types of lineation e.g. compositional streaking, mineral elongation, and crenulation, have been recorded (uncommonly with two on the same surface).

Minor folds are parasitic on mesoscopic open folds (F_3) (Photo D4 & D5) in the Mount Strangways area. F_2 folds have not been measured but outcrop patterns e.g. at GR5651-814523, are indicative of F_2 folds.

In the area of the Edwards Creek Prospect rocks containing the assemblage gedrite-spinel-sapphirine and a possibly earlier assemblage of spinel, cordierite and orthopyroxene, are cross-cut by schist zones containing chlorite staurolite ± garnet and corundum. Gedrite, kyanite, cordierite and rare anthophyllite occur in a wide belt which flank the schist zones.

Geochemistry

One sample (4406) of mafic granulite and one of felsic granulite (6007) were submitted to AMDEL for major element and selected trace element analyses (Tables A1, A2, Appendix). The analysis of the mafic granulite is similar to those of modern continental tholeiitic flood basalts. The sample of mafic granulite is of hypersthene-diopside-plagioclase mafic granulite variety.

The sample of felsic granulite analysed was of microperthite-quartz-rich felsic granulite. The analysis is similar to those of present day acidic, extrusive, tholeiitic magma, possibly granophyre or rhyolite.

Origin

It is difficult to distinguish between the two varieties of mafic granulite in the field. However, it appears that the very thin (from 0.5 cm to 1 m), commonly boundinaged and isoclinaly folded mafic layers that occur within felsic granulite are hypersthene, quartz-rich mafic granulite whereas the hypersthene-diopside-plagioclase mafic granulite occurs as semicontinuous, thick (2 m to 20 m) layers. This is consistent with a sedimentary origin for the hypersthene-quartz rich mafic granulite, and a volcanic, possibly tholeiite origin for the hypersthene-diopside-plagioclase mafic granulite.

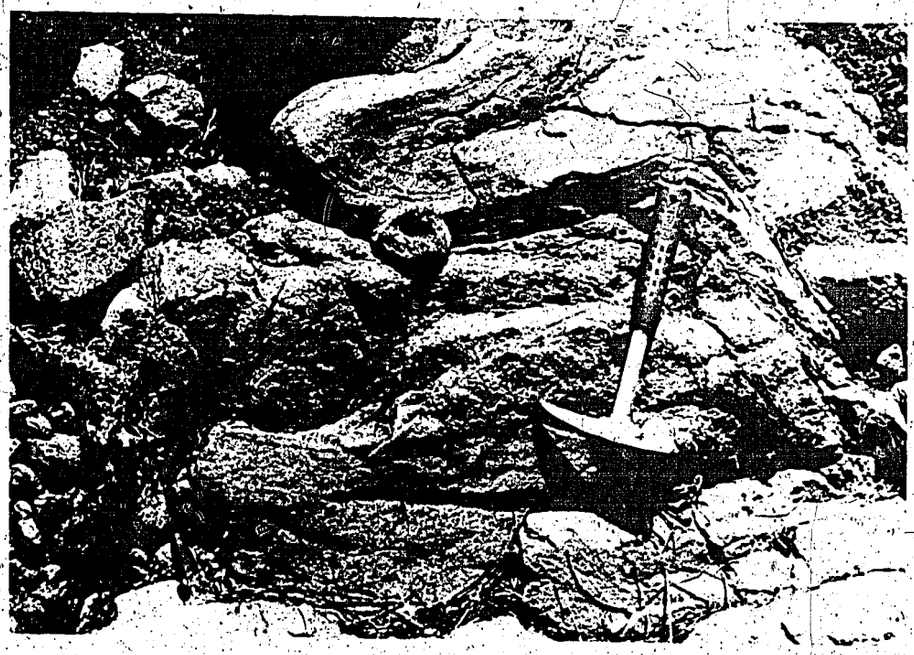


Photo D4: Minor fold in felsic granulite near Mt Strangways.

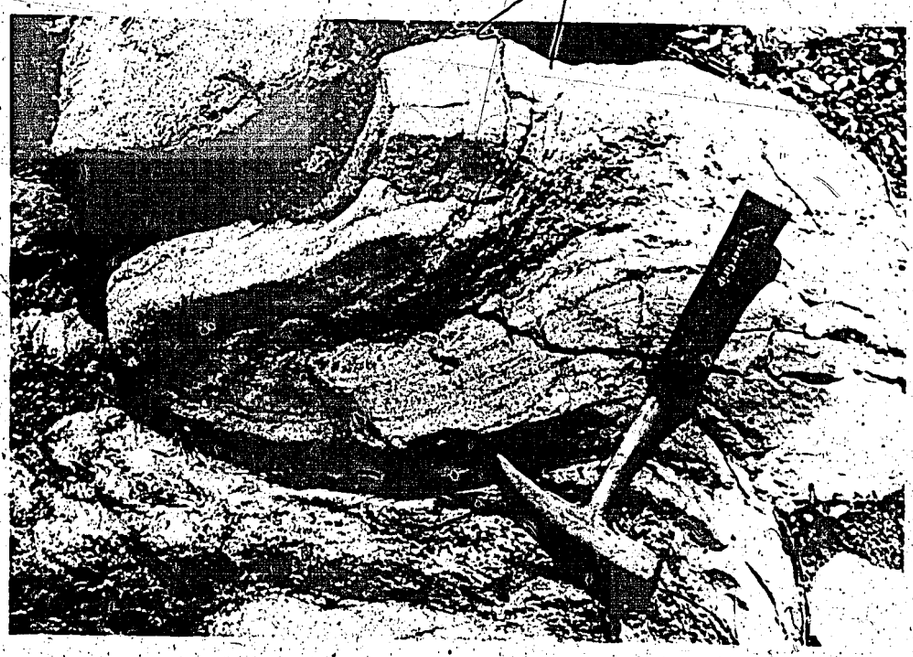


Photo D5: Detail of minor fold in photo D4 showing thin compositional layering.

The cordierite felsic granulite is gradational to cordierite quartzite and is probably of sedimentary origin. The Yambah granulite is thus considered to consist of a volcanic pile of alternating basalt and granophyre or rhyolite with less common quartzose metasedimentary layers, possibly magnesium rich, that grade in maturity up into quartzite and rare thin pelitic and calcareous lenses.

Age and Correlation

The Yambah granulite is correlated with the Mount Pfitzner granulite and the Ongeva granulite, both of which are basal formations of the Strangways Metamorphic Complex. These correlates are also made up of interlayered mafic and felsic granulite, but unlike the Yambah granulite they contain very little cordierite felsic granulite, cordierite quartzite, or quartzite. The Yambah granulite is considered, therefore, to be higher in the sequence and shows an increase in more magnesium rocks as in the Erontonga metamorphics and the lower Cadney metamorphics.

Rubidium-Strontium whole-rock isochron on felsic granulite south of Mount Strangways gives an age of about 1800 m.y. for the granulite metamorphism (Black, 1975).

D-1-7: Narbib granulite pCsn (A.P.L.)

Definition

The Narbib granulite is a small (5 km^2) unit of interlayered mafic granulite and quartzofeldspathic gneiss that crops out as a low east-northeast striking ridge along the central eastern margin of BURT, adjacent to the Narbib Deformed Zone. The name is derived from "Narbib", a sacred 'girl dreaming' aboriginal site nearby. The type section is at 5651-865215 where the mafic granulite is best exposed. The unit is distinguished from the adjacent Colbra Orthogneiss by the presence of granulite and lack of garnet, and from the Sliding Rock metamorphics to the northeast by the lack of garnet gneiss and amphibolite.

Relationships

The unit is intruded to the north and east by the Oolbra Orthogneiss and overlain to the west and south by Cainozoic sediments.

Lithology

In the type section, mafic granulite (4503, 4499, 4501) crops out as low, rounded exposures of rust-red brown boulders. It is fine-grained, equigranular granoblastic and consists of plagioclase, quartz, diopside, hypersthene and hornblende, with rare biotite and opaque minerals. The rock type (particularly 4503) is less mafic, encloses rare relict aggregates of pyroxene, and does not have the polygonal texture characteristic of the Yambah or Ongeva granulite mafic granulite.

Quartzofeldspathic gneiss from the same area (4502) is fine-grained, and consists of abundant quartz, plagioclase and opaque grains. The quartz occurs as stringers and the rock is strongly deformed. Away from the type area the rock types are similar but poorly exposed.

Structure

The unit crops out adjacent to the pseudotachylyte-bearing highly-deformed Narbib Deformed Zone and is cut by several faults arranged en echelon to this zone. The rock exhibits bent plagioclase twin lamellae and elongate quartz grains. Foliation in the type section strikes east and is either vertically or steeply southerly dipping (80°). Lineations plunge at 30° to the east.

Metamorphism

The unit has been highly deformed, and retrogressed from the granulite facies to amphibolite facies.

Age and correlation

The granulite facies metamorphism is possibly of the same age as M_1 elsewhere but no age work has been done. A recent low-level BMR aeromagnetic survey shows an area of high magnetic intensity in the

southeast of BURT, which suggests that interlayered granulite similar to the Yambah and Ongeva granulites occurs below the Cainozoic sediments. These data indicate that the small outcrop of Narbib granulite may be the northern margin of a region of interlayered granulite, adjacent to the Narbib Deformed Zone. Further work is required to confirm the correlation of the granulite with the Strangways Metamorphic Complex and to relate it to the Adla granulite and to the Mount Hay granulite that crops out to the west.

D-1-8: Adla granulite pGsa (A.P.L.)

Definition

The Adla granulite consists of poorly exposed interlayered mafic and felsic granulite, which crops out at Boen Hill and Adla Hill (whence the name is derived), in the southwest of BURT. Airphoto-lineaments and several small isolated exposures indicate that the two hills are exposures of a 10 km wide, 25 km long, belt extending from Adla Hill to Coles Dam. The type area is a small rise, at 5651-518078, 1.5 km east of Adla Hill, where interlayered garnet-felsic granulite and mafic granulite are well exposed. These rock units were mapped as garnet gneiss (v) and amphibolite (a) on the preliminary map.

Adla granulite is distinguished from rocks of the Wigley Block by its higher metamorphic grade and interlayered character. It is similar to, and may be a correlative of the Narbib granulite, but is distinguished by the presence of garnet and sillimanite, and by its high degree of migmatisation.

Relationships

A small hill at 5651-684169 exposes an intrusive contact between Bgc and Adla granulite. Elsewhere, the Adla granulite is overlain by Quaternary sediments.

Lithology

In the type area mafic granulite (4100) occurs as 10-20 m thick layers and as 5-50 cm thick lenses, both of which locally form spectacular ovoid boudins (Photo D9) and discontinuous layers, and is interlayered with mobilisate-rich garnet-bearing felsic granulite. At the type area and elsewhere (4145, 4147A, 4147B, 4152) the mafic granulite consists of quartz (25%), plagioclase (25%), hornblende (40%), hypersthene (8%), garnet (2%) and opaque grains. It is granoblastic, medium to fine-grained and only slightly retrogressed. The abundance of hornblende and quartz and the presence of garnet distinguishes it from typical mafic granulite from the Yambah granulite or Ongeva granulite.

Layers (20-30 m thick) of felsic granulite are a composite of garnet-bearing felsic granulite and massive coarse-grained mobilisate that incorporates mafic granulite boudins. Sample 4146, felsic granulite from Boen Hill, is similar to that of the type area, but does not contain sillimanite. In the Yambah and Ongeva granulites the felsic granulite contains stringers and small zones of mobilisate, whereas in the Adla granulite mobilisate dominates, and felsic granulite occurs as rafts within it (see Photo D10). Mobilisate has not been thin-sectioned, but consists mainly of coarse-grained quartz, orthoclase and plagioclase. Felsic granulite (4099) is coarse-grained, well-foliated and consists of quartz, plagioclase, orthoclase, garnet, biotite and sillimanite.

Structure

The unit is characterised by vertical lithological layering, which strikes east. This layering is probably coincident with bedding. Felsic granulite rafts have a well-defined foliation which, in general, strikes east, and which is disrupted by coarse mobilisate. Foliation in the felsic granulite is defined by fine compositional layering and by the preferred orientation of biotite. Boudinaged lenses of mafic granulite within the felsic layers parallel the mesoscopic lithologic layering and are probably thin metasedimentary layers. A steeply east-plunging lineation defined by compositional streaking was recorded at Boen Hill.

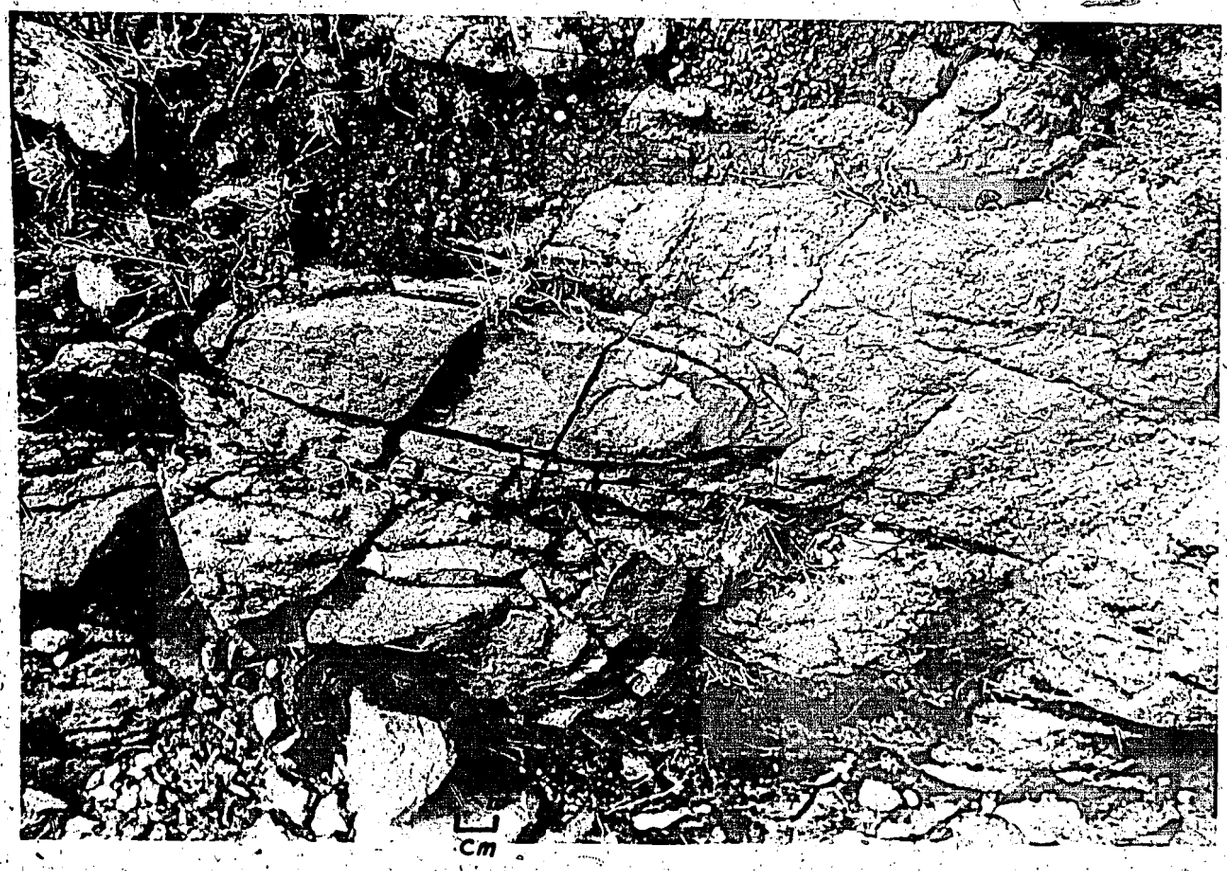


Photo D9: Mafic granulite boudin, showing metamorphic zoning, in mobilisate-rich felsic granulite.

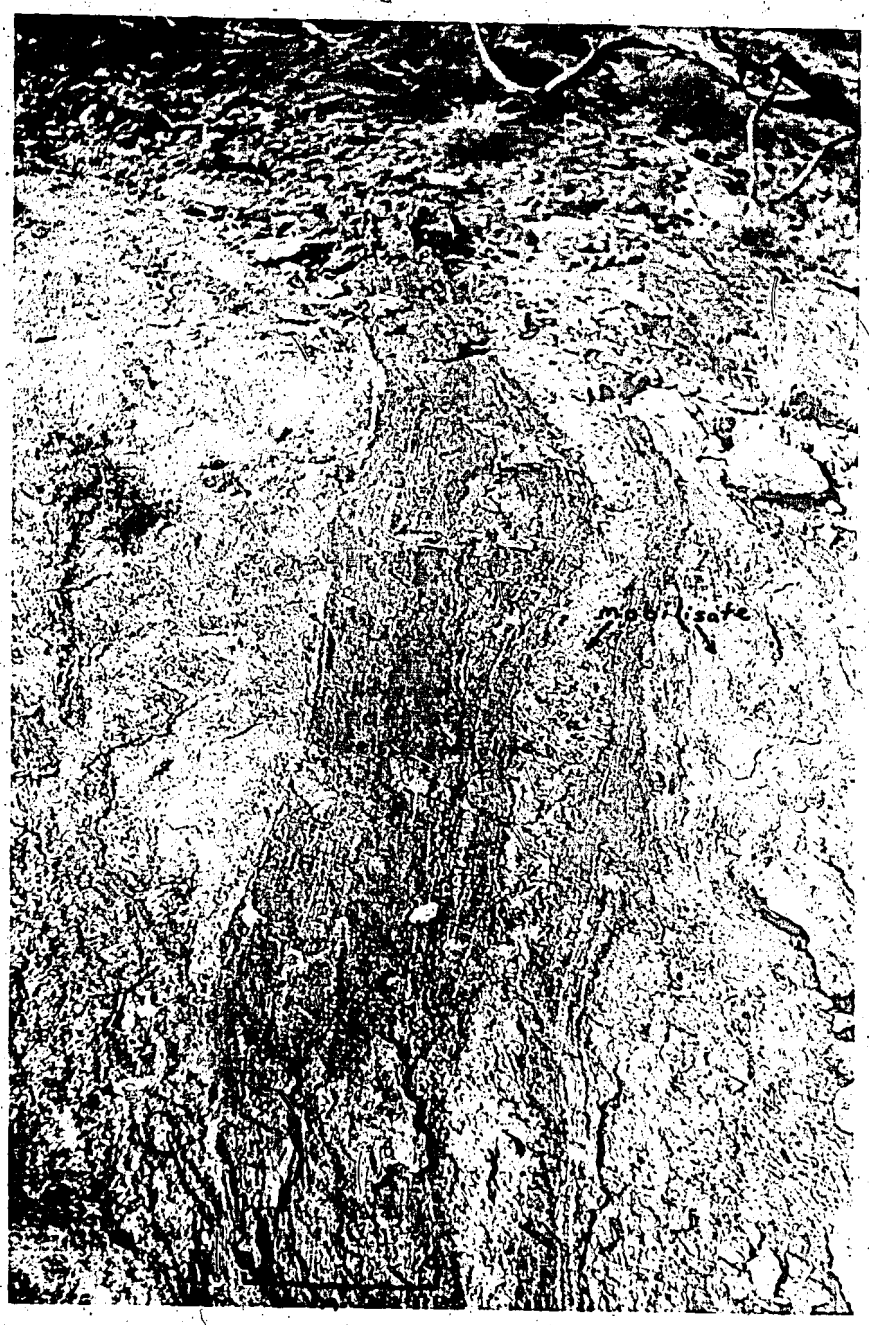


Photo D10: Well-layered, partly migmatised felsic granulite raft in mobilisate.

Metamorphism

The granuloblastic equigranular texture of the mafic granulites indicates a granulite facies metamorphism of similar metamorphic conditions to that of the Yambah and Ongeva granulites. However, the presence of garnet, abundance of hornblende in the mafic granulites, and presence of garnet and sillimanite and abundance of mobilisate in the felsic layers indicates slightly wetter conditions.

Origin

The abundance of garnet and sillimanite indicates that the felsic rocks may be metapelites. The thin boudinaged mafic layers resemble the thin mafic (metasedimentary?) layers in the Yambah and Ongeva granulites.

Age and Correlation

The unit may be a correlative of the Narbib granulite but the latter lacks garnet and sillimanite. The layered granulites at the western end of pGsf, north-northeast of Woolanga Bore, are very similar to the Adla granulite, and the two regions may be correlatives. The metapelitic nature of the felsic rocks in the Adla granulite suggest that they may be correlated with rocks from the upper part of the Yambah and Ongeva granulites, or with the Erontonga metamorphics, or with interlayered granulite members of the lower Cadney metamorphics.

No age determinations have been carried out on the unit, but it is presumed to have undergone metamorphism during the Strangways Event at about 1800 m.y. (see METAMORPHISM).

D-1-9: pGsf (A.P.L.)

Definition

Unit pGsf is a highly deformed and retrogressively metamorphosed unit consisting mainly of leucocratic quartzofeldspathic gneiss and small to rare amounts of cordierite gneiss, mafic and felsic granulite and amphibolite. The unit crops out as a narrow (2-4 km wide) belt of low hills, north of the east-striking West Bore Fault. The belt extends from Gillen Creek in the west to Ongeva Creek in the east, along the northern margin of LAUGHLEN.

The type area is 4 km southwest of 14 Mile Bore (centred on 5751-430535) where interlayered mafic granulite, quartzofeldspathic gneiss and amphibolite are well exposed. The unit is distinguished from pGu by the presence of garnetiferous mafic granulite, abundance of mafic granulite and by its interlayered character.

The unit was mapped as Brw_5 and pGsm on the preliminary 1:100 000 Sheet. Grouping of these two units and separation from pGu followed reinterpretation of the compilation of LAUGHLEN.

Relationships

The unit is overlain to the north and east by Cainozoic sediments. To the south it is bounded by the West Bore Fault against the West Bore Deformed Zone and pGu. To the west the unit is truncated by the Woolanga Lineament. Near the western end of the West Bore Fault the unit is thrust against fault slices of Heavitree Quartzite.

The unit pGsf is intruded by the Mud Tank Carbonatite and numerous pegmatite veins.

Lithology

The type area consists of interlayered mafic granulite, garnetiferous mafic granulite, quartzofeldspathic gneiss, cordierite gneiss and amphibolite. The layers are from 10 to 50 m thick, dip northeast at 70° and strike 45° and have a well-defined lineation plunging at 37° towards the north.

Leucocratic quartzofeldspathic gneiss is the most abundant rock type in the unit, constituting about 50 percent of the exposure. The gneiss consists of biotite, plagioclase and quartz, but locally contains sillimanite, muscovite, microcline, orthoclase and garnet. Magnetite, sphene, zircon, and apatite are accessory minerals. It is commonly spangled with large muscovite flakes, is medium-grained (up to 4 mm), granular, schistose and irregularly layered. The layering is defined by quartz-feldspar-rich and biotite-rich portions up to a few cm thick, and is commonly cut, at a high-angle, by a penetrative schistosity defined by the preferred orientation of muscovite and biotite.

In the southeastern part of the unit, near Blackfellows Bones Bore, the quartzofeldspathic gneiss is rich in a quartz and feldspar mobilisate and isolated zones of migmatite crop out.

Quartzofeldspathic gneiss is interlayered with a variety of mafic rocks which are variously retrogressed from granulite to amphibolite facies. Two-pyroxene mafic granulite, garnetiferous mafic granulite and amphibolite crop out as layers up to 30 m thick and are best exposed in the type area. Mafic granulite (3208) consists of hypersthene, diopside, plagioclase and rare opaque grains. The rock is equigranular, granoblastic and unaltered. Some varieties contain small amounts of orthoclase and hornblende. Garnetiferous mafic granulite mapped as para-amphibolite on the Preliminary Map consists essentially of garnet, diopside, hypersthene and plagioclase (andesine) and rare orthoclase, quartz, hornblende and opaques. Garnet occurs as rims to hypersthene grains where they are contiguous with plagioclase. A selvage of quartz and pyroxene commonly separates the garnet rim from the hypersthene. This garnet may be a product of the breakdown of plagioclase and hypersthene under high pressure, and as such it would indicate a prograde reaction not so far observed elsewhere in the Arunta Block. Alternatively, it may be a calcium garnet rim produced during retrograde metamorphism. Microprobe analyses of the garnet are required to resolve the reaction. Amphibolite, chemically identical with the garnetiferous mafic granulite (3205), crops out throughout the unit as small pods and thin layers. A spectrum of retrogression is observed in the amphibolite rocks, from mafic granulite containing a small amount of hornblende, to hornblende-plagioclase amphibolite. In all but one of the amphibolite rocks sampled, hornblende grains are blue-green and have an unusual myrmetitic intergrowth with quartz in the centre of each grain. In one sample (3203), however, the blue-green myrmetitic hornblende rims subhedral, brown to olive-green hornblende. The sample differs from the other amphibolites which seem to be direct products of retrograde metamorphism of mafic granulite.

The rare cordierite gneiss (3207) consists of biotite, orthoclase, anthophyllite, sillimanite and cordierite with accessory zircon and opaque grains. A similar cordierite granulite (in) (3255) is discussed later.

To the west of the type area quartzofeldspathic gneiss grades into biotite gneiss, felsic granulite, felsic gneiss and garnet gneiss. Biotite gneiss (3215) consists of porphyroblastic microcline (30%) and plagioclase (30%) in a matrix of biotite (10%), quartz (10%) and orthoclase (20%). Interlayered with the biotite gneiss and felsic gneiss are quartz-rich layers commonly highly deformed and muscovite-bearing.

Muscovite (30%) - quartz (70%) schist (3223) crops out together with an unusual carbonate rock (3222) on the northern side of a highly deformed lense of biotite gneiss (5751-290542). The carbonate rock contains serpentinite after olivine, in addition to muscovite, calcite and chlorite. No other carbonate rocks were observed in the unit apart from the intrusive Mud Tank Carbonatite.

Interlayered with the biotite gneiss described previously (e.g. 3215) are relict pods of felsic granulite, rare lenses of garnet gneiss and a relict pod of magnesium-rich mafic granulite and aluminous metasediments. The latter pod crops out 0.5 km south of West Bore and consists of five rock types: (1) cordierite granulite (in) containing anthophyllite (5%), biotite (5%), sillimanite (10%), hypersthene (40%), and cordierite (40%) (3255 at GR. 318524), (2) gneiss containing sillimanite (30%) and quartz (60%) together with rare muscovite and biotite, (3) chlorite schist, (4) cordierite quartzite, and (5) granulite containing garnet, sillimanite, anthophyllite, cordierite and hypersthene. One sample (4265) contains rare monazite. These magnesian rocks are similar to the unusual rocks associated with the sapphirine-bearing assemblages, which are interlayered with mafic and felsic granulites at a number of localities in the Strangways Metamorphic Complex.

Felsic granulite (3220) consists of plagioclase (15%), clinopyroxene (20%), and quartz (60%) together with accessory chlorite, hornblende (5%) and zircon. A felsic granulite having an intermediate composition (3230) crops out in the eastern part of the unit. It contains plagioclase (60%), hypersthene (20%), amphibole (10%) and quartz (10%). The garnet gneiss (3224) consists of garnet (30%) and quartz (60%) with accessory chlorite, muscovite and

orthoclase. Both of these rock types are rich in quartz, and, together with the quartz-rich schists and muscovite-quartzite, form layers in the biotite gneiss.

At the far western end of the unit, interlayered garnet-rich felsic granulite and mafic granulite crop out as an isolated hill (5751-205545). It (3229) consists of biotite, subhedral garnet, plagioclase, orthoclase and quartz and is interlayered with a felsic granulite containing hypersthene (20%), hornblende (10%), quartz (10%), plagioclase (60%) (3239) and a mafic granulite containing hypersthene (10%), diopside (10%), hornblende (30%), plagioclase (40%), and minor opaques. This outcrop is grouped with the unit because of the similarity between the garnet-rich felsic granulite and the garnet gneiss. However, Cainozoic sediments obscure the area between the outcrops.

Geochemistry

Four samples were analysed for major and selected trace elements, amphibolite 3202, garnetiferous mafic granulite 3205 and mafic granulites 3232 and 3241. Despite the difference in metamorphic grade the four analyses are very similar (Table A2 Appendix) and show the rocks to be meta basic igneous rocks with moderate amounts of alumina, iron, lime and soda. The major element abundances are similar, except for an increases in Fe/Mg, to the mafic granulites from the Yambah granulite and the Erontonga granulite and are remarkably similar to modern day Tholeiitic Flood Basalts (ref. to Turner & Verhoogen, p. 208). The trace element analyses, however, differ significantly from the Yambah and Erontonga granulites in being much lower in Ni and Cr and much higher in V, Sr, and Ba. The difference in trace elements and the higher Fe/Mg ratio indicates that the pgsf rocks are possibly more fractionated.

Specimen 3255 is a cordierite granulite which is both aluminous and magnesian (Appendix A4). It forms a conformable lens in an unusual magnesian and aluminous sequence similar to that containing sapphirine-bearing assemblages elsewhere. A felsic granulite which has an intermediate igneous composition (3230) has also been analysed (Table A2, Appendix A2).

Structure

The unit is cut by a penetrative, commonly easterly trending, steeply dipping schistosity defined by the preferred orientation of mica (chiefly muscovite). Lithologic and mineralogical layering are commonly cut at a high angle by the schistosity, thereby producing a strong lineation, L_1 (typically steeply plunging at 70° to the northeast). Two kilometres south of Joker Flat Dam (5751-406497) refolding of muscovite-rich quartzofeldspathic gneiss has produced classic refolded fold forms (see Photo D11). Saddle, and basin-and-dome structures have resulted from the interference of at least two (and it is suspected, three) phases of folding. L_1 is axial-plans to F_1 and is folded about F2 folds, which plunge at 24° towards 117°.

Origin

The unit is considered to be composed of interlayered metavolcanics and pelitic rocks that grade into reworked quartzose metasediments to the west of the type area.

Age and Correlation

The interlayering of retrogressed mafic and felsic granulites, and the similarity in chemistry and occurrence of unusual magnesium-rich mafic granulite, indicates a similarity between pGsf and the interlayered mafic and felsic granulite of the Strangways Metamorphic Complex. The granulite facies metamorphism probably corresponds to the 1800 m.y. M_1 event of the Strangways Metamorphic Complex and the retrogression is, at least in part, attributable to the introduction of water and to the amphibolite facies conditions which accompanied the formation of the Gough Dam Schist Zone. The unit is possibly a correlate of the granulites that crop out to the northeast of Gough Dam, but these have a higher proportion of mafic granulite and are not well layered.

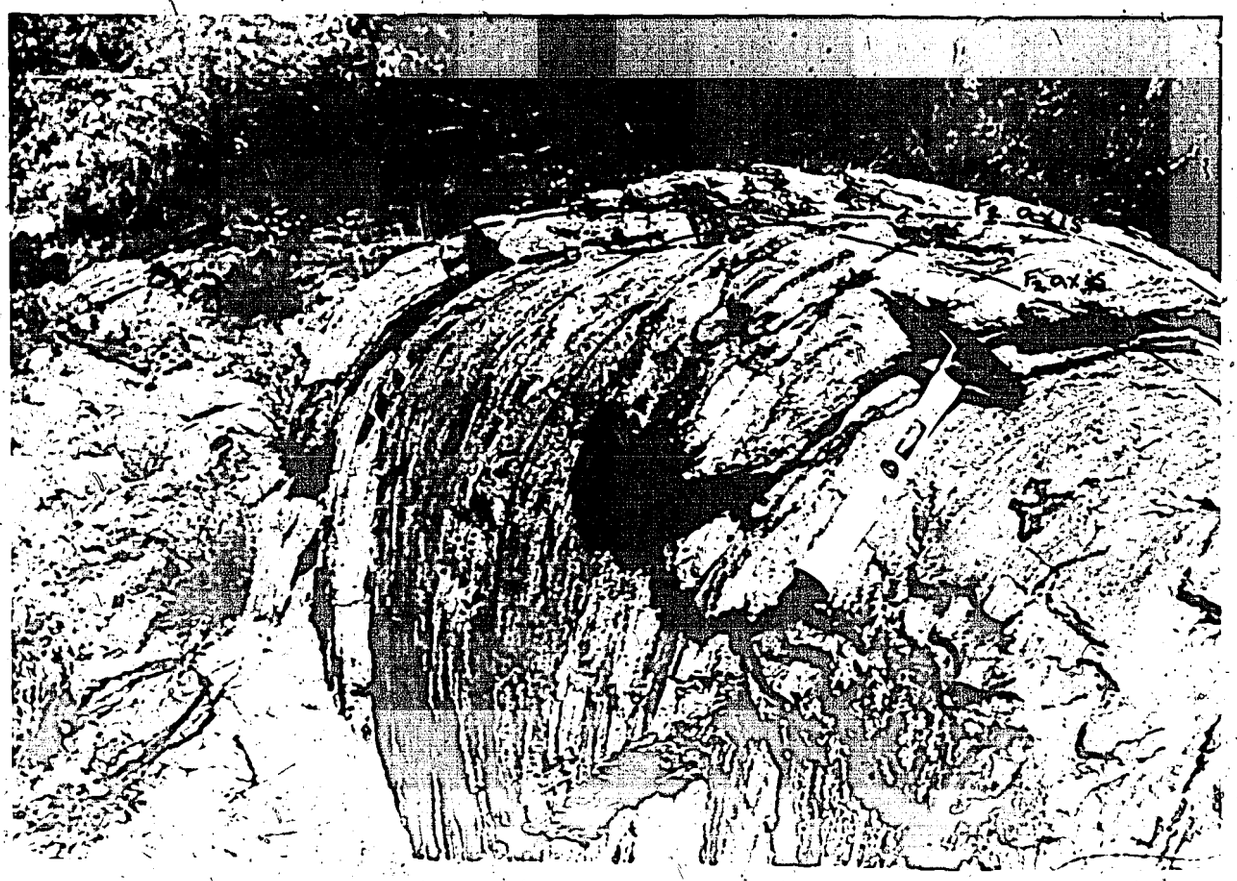


Photo D11: Refolded fold. Photo shows folding of the F_1 lineation about the arched subhorizontal F_2 axis.

D-1-10: Unnamed Unit, pGst (R.D.S.)

Definition

Unit pGst crops out in the northwestern quarter of RIDDOCH, and is made up of mafic granulite, quartzofeldspathic gneiss and lesser amounts of pelitic gneiss. It forms a belt of small, rugged hills which extends from Blackfellows Bones Mica Mine (abd) eastwards along the north side of Ongeva Creek to north of the Copper Queen Prospect. The mafic granulite and quartzofeldspathic gneiss are best exposed around and east of the abandoned Blackfellows Bones Mica Mine. The unit is grouped in the Strangways Metamorphic Complex, because it consists mainly of mafic granulite and quartzofeldspathic gneiss. However, it lacks the typical mesoscopic interlayering of mafic and felsic granulite characteristic of the Ongeva and Yambah granulites: instead, the mafic granulite bodies commonly have an ovoid to irregular shape. The unit lacks the abundant calc-silicate rock which typifies the Cadney metamorphics. The Gough Dam Schist Zone differs from unit pGst in containing predominantly schistose rocks and much less mafic rock.

Relationships

Unit pGst has a conformable contact with the Cadney metamorphics south of Old Schaber Station Well. Small lensic bodies of quartzofeldspathic and pelitic gneiss and mafic granulite persist as subordinate rock types into the nearby Cadney metamorphics. The southern boundary of unit pGst is obscured by alluvial plains, but may be a fault because of the structural discordance and abrupt change in rock type between the outcropping units.

The Pannikan Dam Fault forms the northern boundary, and brings the unit into contact with Irindina Gneiss.

Lithology

The general outcrop pattern is one of small ovoid to irregularly shaped masses of mafic granulite (3350, R4521) enclosed by quartzofeldspathic gneiss. However, in several places, the quartzofeldspathic gneiss forms elongate bodies. Pelitic gneiss, principally biotite gneiss, is photo-interpreted to form small bodies mainly in the northern part of the unit.

The proportion of mafic granulite decreases from being the dominant rock type in the west to a minor rock type in the east where it forms small bodies and layers within the quartzofeldspathic gneisses. Here, the mafic rocks are two-pyroxene granulite, amphibolite and rare garnet-epidote rock. In the same outcrop area, quartzofeldspathic gneiss and biotite gneiss form interlayers about 1 m thick. Both quartzofeldspathic and biotite gneisses are compositionally layered. Several of the quartzofeldspathic gneiss layers are cordierite-bearing, and a few are garnet-bearing. The unit contains one lens of sapphirine and kornerupine-bearing granofels enclosed in cordierite-bearing quartzofeldspathic gneiss 3 km northwest of the Copper Queen Prospect.

Mafic granulite (R4521) is fine-grained (0.5 mm) and consists mainly of plagioclase (50%) exhibiting bent twin-lamallae, and clinopyroxene (40%), together with smaller amounts of hypersthene (6%) and green hornblende (3%) distributed discontinuously along pyroxene grain boundaries, and opaque grains (1%). Specimen 3350 is medium-grained, granoblastic and consists of hypersthene (megacrysts up to 1 cm across), clinopyroxene, plagioclase, and rare quartz and opaque grains.

The quartzofeldspathic gneiss (R4659-60) is roughly of granodioritic composition, but has a high quartz content (Joklik, 1955, p. 44). The minerals in decreasing order of abundance, are: andesine, quartz, porphyroblastic microperthite, biotite, almandine, myrmekite, apatite, magnetite and sphene. A granitic variety (R4616) from 4 km north-northeast of Mount Schaber is medium to coarse-grained and contains microperthitic microcline (53%), quartz (29%), oligoclase (15%) and possible cordierite (3%).

The sapphirine-bearing and related coarse-grained rocks crop out in a small body (2760-2762), 10 m long by 3 m wide. The primary mineral assemablages contain sillimanite, kornerupine, plagioclase, orthoclase, and sapphirine, but cordierite has partly broken down through the reaction:

Cordierite = sillimanite + orthopyroxene + quartz

Sapphirine is in part pseudomorphed by phlogopite, corundum, and magnetite, presumably by reaction with orthoclase and quartz from the breakdown of cordierite. Kornerupine is in part pseudomorphed by magnesium tourmaline and sillimanite, the sodium of the tourmaline coming from plagioclase in the primary assemblages. The largest fragments of kornerupine occur in a matrix of phlogopite-kornerupine. Geikeilite, a rare magnesium iron titanate (a structural analogue of ilmenite), has been collected from float.

Metamorphism

The mafic granulites reached two-pyroxene stability, but the green hornblende at pyroxene grain boundaries indicates limited hydration, possibly at a slightly reduced metamorphic grade. Cordierite-bearing assemblages reacted to produce hypersthene-sillimanite; the reaction suggests increasing pressure.

Origin

The unit is thought to represent a mixed sequence of acid volcanics interlayered with or intruded by rocks of basaltic composition. The origin of the cordierite-bearing quartzofeldspathic gneisses and biotite gneisses is uncertain, although some may have been chloritic pelites.

Age and Correlation

The unit is correlated with the Strangways Metamorphic Complex because it contains similar rock types; that is felsic rocks and mafic granulites. Like the Bungitina metamorphics it differs from the typical units of Strangways Metamorphic Complex in that it is made up of ovoid, discontinuous rock masses.

No age determinations have been carried out on the unit.

D-1-11: Erontonga metamorphics ($pGsr^{1-3}$) (A.R.A.)

The Erontonga metamorphics crop out in three regions:

(1) the main area in the Phlogopite Mine area and eastwards to Pinnacles Bore in LAUGHLEN (pGsr1) (A.R.A.) and, in two other areas;

(2) in an arcuate belt in the central-northern part of BURT (pGsr2) (A.P.L.); and

(3) in the Winnecke Depot Creek region in the centre of LAUGHLEN (pGsr3) (A.J.S.).

The central area (1 above) includes the type-area and is described first. The adjoining areas (2 and 3 above) are described in the following sections.

(1) $pGsr^{1}$ (A.R.A.)

Definition

The type area of the metamorphics extends from 5751-072304 west of the Phlogopite Mine to 5751-089329, at the boundary with the adjoining Cadney metamorphics to the east. In this area the Erontonga metamorphics are designated pGsr1 and consist predominantly of pelitic and quartzo-feldspathic gneiss and granofels, rare calc-silicate, magnesian and manganiferous gneisses, and mafic gneiss occurring as thin interlayers within the unit. These mafic gneisses are thought to be volcanics, and account for less than 10 percent of the total outcrop-area of the unit. They are too thin to portray on the map. Unlike the mafic granulites of the Johannsen Metagabbro they contain quartz. The unit generally has strong relief; quartzose granofels and pelitic gneiss are the most resistant rock types, and form the highest ridges. The name of the unit is derived from the Erontonga Waterholes (5751-322242), situated in cordierite gneiss of the Winnecke Depot Creek area (area 3, above). In the type area, the Erontonga metamorphics differ from the adjoining Utnalanama granulite to

the south by the presence of abundant cordierite-bearing pelitic gneiss in the former; they are distinguished from the Cadney metamorphics to the north and the Ankala gneiss to the southeast by the lack of cordierite in both those units: a distinction which also applies in the other two areas to be described below.

Relationships

In the region of Johannsen's Phlogopite Mine the Erontonga metamorphics unconformably overlies the Harry Anorthositic Gabbro (see D-1-3). The Erontonga metamorphics pass northwards into the Cadney metamorphics, but the nature of this contact is unknown. R.D.S. considers the Cadney metamorphics to conformably overlie the Erontonga metamorphics with a transitional contact between the two.

The unit is intruded in chronological order by (1) numerous mafic dykes collectively termed the Johannsen Metagabbro, (2) a pyroxenite-magnetitite suite, (3) the Gumtree Granite, (4) a group of thin pyroxene dolerite dykes, and (5) coarse pegmatite dykes. To the west it passes into migmatite of the Ingula migmatite suite which, in turn, grades into the Wuluma granitoid. To the southeast the Erontonga metamorphics are truncated by the Harry Creek Deformed Zone (Brh).

Lithology

The Erontonga metamorphics consist mainly of quartzofeldspathic and cordierite-bearing pelitic rocks, and small amounts of calc-silicate, magnesian and manganiferous rocks, which together account for less than 5 percent of the formation. Apart from rare calc-silicate and magnesian rocks, all rocks of the formation contain quartz.

The unit contains two generations of migmatite. The older generation is correlated with the first regional granulite facies metamorphism and the younger with formation of the Wuluma granitoid, to which it is spatially related. The older migmatites are structurally controlled, and are not of minimum melt composition. They consist of quartz-plagioclase-garnet segregations interlayered with a palaeosome of pelitic and quartzofeldspathic gneiss. The younger migmatites are not structurally controlled,

and the neosome cross-cuts structural trends. It approaches a minimum melt composition more closely and appears to be compositionally similar to the Wuluma granitoid.

Cordierite-bearing gneisses vary considerably in mineral content depending on host rock composition. In addition to quartz and cordierite, the various assemblages developed during the earliest granulite facies metamorphism are composed of:

orthopyroxene	(1)
orthopyroxene + plagioclase	(2)
orthopyroxene + garnet	(3)
orthopyroxene + garnet + plagioclase	(4)
garnet + plagioclase	(5)
garnet + sillimanite	(6)
plagioclase	(7)

Zircon is a ubiquitous accessory, but opaque grains are absent.

The assemblages in the quartzofeldspathic rocks are less variable. In addition to quartz, plagioclase and magnetite, the rocks contain orthopyroxene and/or garnet. Biotite, although ubiquitous in both pelitic and quartzofeldspathic rocks, has been interpreted on textural grounds to have developed later than the above assemblages and is regarded as metasomatic in origin (Allen 1976). Alkali feldspar, which is rare or absent, texturally appears to have a similar origin. Plagioclase is commonly antiperthitic and grades into mesoperthite. Modal variation in the above rocks is marked.

The rare calc-silicate rocks have a diverse composition. They can be subdivided into quartz-bearing and quartz-free groups. Assemblages that developed during the earliest granulite facies metamorphism are the quartz-bearing rocks which consist of combinations of the phases:

quartz ± plagioclase ± clinopyroxene ± Mg clinoamphibole ± magnetite ± ilmenite ± sphene ± apatite ± zircon ± rutile

Quartz-free calc-silicate rocks have very similar mineral contents, but lack rutile. Hornblende and andraditic garnet which are also common, have formed during the second granulite facies metamorphism.

The magnesian and manganiferous rocks, which include the rocks exposed in Johannsen's Phlogopite Mine, contain sapphirine, gedrite, Mg-edenite, enstatite, diopside, phlogopite, spinel, Mn-garnet, and Mn-orthopyroxene. The Phlogopite Mine locality is described in more detail in the Metamorphic Section.

Retrogression of the pelitic rocks has resulted in development of a large number of minerals including sillimanite, kyanite, gedrite, aluminous anthophyllite, staurolite, garnet and aluminous biotite. Retrograde effects in the quartzofeldspathic rocks have produced cummingtonite, blue-green hornblende, biotite, white mica, garnet and sphene. In the calc-silicate rocks, blue-green hornblende, epidote, clinozoisite and sphene formed during retrograde metamorphism.

The mafic gneiss is typically interlayered with the cordierite-bearing and quartzofeldspathic gneisses, but locally shows cross-cutting relations to them. The mafic gneiss consists of quartz, plagioclase, orthopyroxene, clinopyroxene, hornblende, and accessory ilmenite. The mafic gneiss is fairly homogeneous mineralogically with only minor modal variation, although a hornblende-free and an unusual pyroxene-free hornblendic rock have been collected. Blue-green hornblende, cummingtonite, and sphene formed during retrogression. Contents with the enclosing quartzofeldspathic gneisses are commonly gradational, and the mafic interlayers are thought to be lava flows, whilst the rare crosscutting bodies may be feeder dykes.

Structure

Two generations of folding have been identified in the Erontonga metamorphics in the Phlogopite Mine area. The first folds (F_1) are intense isoclinal folds with steeply dipping east-west axial surfaces and fold axes with variable direction and amount of plunge. The second generation folds (F_2) are asymmetric, with northeast-striking axial surfaces. Inter-limb angles range from open to isoclinal and they are responsible for the

most prominent structural features seen in aerial photographs of the region, the isoclinal antiformal structures at 5751-032373 and 5651-063352. The F_2 folds plunge consistently at moderate angles to the northeast and the Erontonga metamorphics are thought to young in this direction. Numerous normal and reverse faults have formed subsequent to this folding, including the Harry Creek Deformed Zone, and the Pinnacles Fault.

Metamorphism

The five metamorphic events which are recognised in the Utnalanama granulite (see D-1-2) have also affected the Erontonga metamorphics. The earliest metamorphism is a granulite facies event, which on the criteria of the absence of olivine in basaltic rock types (Green & Ringwood, 1976) and the presence of cordierite-orthopyroxene-garnet assemblages in pelitic rocks (Hensen & Green, 1972) is of the intermediate pressure type, and pressures of approximately 7 kb have been estimated (Allen, 1976). The tonalitic composition of the older generation of migmatite correlated with this event indicates very high temperatures for this event. K/Rb ratios support this conclusion (Allen, 1979). On the basis of assemblages identified in the metapelites (Allen, 1976), the second and third metamorphisms determined in the Harry Creek area also occurred under medium-pressure granulite facies conditions, whilst the later retrogressive metamorphisms associated with initiation and reactivation of the Harry Creek Deformed Zone occurred under intermediate pressure amphibolite and epidote amphibolite facies conditions respectively (see D-1-2). The last event, which is correlated with the Alice Springs Orogeny, brought about development of blue-green hornblende and sphene in mafic layers, white mica and Mn-garnet in quartzofeldspathic rocks, garnet, kyanite, staurolite and gedrite in pelitic rocks, and blue-green hornblende, epidote and sphene in the calc-silicate layers of the Erontonga metamorphics.

Origin

The pelitic, quartzofeldspathic, and rare calc-silicate rocks of the Erontonga metamorphics are thought to represent a sequence of terrestrial or shallow water sediments and mafic lavas deposited on a basement consisting of the Utnalanama granulite and the Harry Anorthositic Gabbro. The thin mafic gneisses are interpreted to be a group of mafic

volcanics of tholeiitic affinities. Their gradational contacts with the adjacent sediments are interpreted to be the weathered tops of lava flows. Magnesian rocks at the base of the Erontonga metamorphics have chemical affinities with rocks from the Alcoota region and Delmore Downs, which have been postulated to represent metamorphosed fossil regoliths (Warren, 1975). This postulated regolith is consistent with the inferred unconformity between the Erontonga metamorphics and the underlying Utnalanama granulite.

Age and Correlation

$^{40}Ar/^{39}Ar$ apparent age spectra of a hornblende from the mafic gneisses in the Erontonga metamorphics, and, a magnesian edenite from a magnesian rock of the Erontonga metamorphics have been interpreted to indicate two metamorphic events at 1800 m.y. and 1710 m.y. (Allen & Stubbs, in press). These are regarded as the ages of the first two metamorphic events recognised in the Harry Creek area (Allen, 1976). Thus, the Erontonga metamorphics are at least 1800 m.y. old. Four phlogopite-bearing magnesian rocks from Johannsen's Phlogopite Mine have given a 1470 ± 60 m.y. Rb-Sr total rock isochron (Iyer & others, 1976) regarded as the age of the third granulite facies metamorphic event (Allen, 1976).

(2) pGsr^2 (A.P.L.)

This section of the Erontonga metamorphics occupies an arcuate belt in the central-northern part of BURT and consists dominantly of cordierite granulite with small rare pods of mafic granulite, and small lenses of garnet gneiss, and amphibolite. The cordierite granulite (4392, 4394, 4395, 4398, 4153, 4159) consists of quartz (35%), cordierite (30%), microperthite (20%), garnet (10%) and biotite (5%). It crops out as low rubbly hills of heavily-vegetated rust-red exposures.

Cordierite-rich gneiss (4512) from a raft in the Wuluma granitoid may be equivalent to rocks from pGsr^2. This gneiss contains cordierite (5%), sillimanite (16%), and small amounts of quartz, biotite, opaque grains and ?pinite alteration after cordierite. The cordierite gneiss has been chemically analysed (Table A4 Appendix).

Rare mafic granulite (4391, 4396, 4399, 4507, 4154, 4504, 4224) crops out as scattered pods in the cordierite granulite. It consists of medium-grained granuloblastic plagioclase (30%), clinopyroxene (30%), hypersthene (20%), hornblende (15%) and quartz (5%). Specimen 4224 (GR 5651-887459) has been chemically analysed (Table A2, Appendix); chemically it is similar to specimen 4406 from the Yambah granulite and shows some similarity to oceanic tholeiite. Garnet gneiss (4393) consists of quartz (45%), microperthite (35%), garnet (15%), and biotite (5%).

pGsr^2 is folded and crosscut by mobilisate veinlets associated with patches of migmatite that occur throughout the unit. Migmatite is most abundant at the far western end of the unit where cordierite-felsic granulite is dominant over the cordierite granulite. Cordierite-felsic granulite (4505) consists of antiperthite (30%), quartz (40%), cordierite (10%), plagioclase (5%), garnet (5%), biotite (10%) and small amounts of spinel and hypersthene. Specimen 4155 is an example of a layer of quartzofeldspathic gneiss (f) containing a trace of cordierite, which occurs within a unit of cordierite granulite (in). The gneiss consists mainly of quartz (20%), plagioclase (60%), and biotite (10%). The gneiss has been chemically analysed (Table 4, Appendix): it is siliceous and low in alumina, magnesia, and potassium.

The dominant fabric element is an east-striking schistosity defined by the preferred orientation of biotite. However, the orientation of this schistosity and of the minor folding is strongly influenced by ubiquitous faulting.

(3) pGsr^3 (A.J.S.)

The main rock-type in the Winnecke Depot Creek area is cordierite gneiss, accompanied by intercalated layers of sillimanite schist, para-amphibolite, calc-silicate rock, quartzofeldspathic gneiss, biotite gneiss, amphibolite, epidote-quartz rock, and garnet-biotite gneiss. The cordierite gneiss is greasy in appearance, blue or mottled blue and white, weakly foliated to massive, and composed of cordierite (commonly with yellow pleochroic haloes around grains of zircon), antiperthitic plagioclase

(andesine to sodic labradorite), quartz, biotite, sillimanite, and accessory iron oxide and green spinel (71911931, -1936, -1937). The cordierite in sample 71911936 is uniformly pleochroic from bright golden yellow to colourless. Small quantities of sericite and epidote are secondary.

Sillimanite schist forms an irregular elongate band north of Winnecke Depot Creek; the rock is fine-grained and micaceous, but has not been thin-sectioned. Para-amphibolite crops out as discontinuous north-dipping lenses on each side of the sillimanite schist. The rock is blue-grey, fine-grained, tough, and consists of sodic labradorite, clinopyroxene, small amounts of biotite and hornblende, and accessory opaque grains (71911934). A coarse pale grey leucocratic variant is composed of calcic andesine, hornblende, epidote, and sphene (71911935), and is associated with much epidosite.

The epidote-quartz rock crops out as irregular lenses, in part anastomosing, along the northern junction of the outcrop area with the adjoining Anuma Schist, and consists of abundant layers and pods of epidote-actinolite rock in mica schist and actinolite schist. None of the other rock-types in the area has been examined. Garnet-biotite gneiss (v) has been interpreted to be present as a retrogressive phase of cordierite gneiss in faulted outcrop areas bordering the Cainozoic Hale Basin.

D-1-12: Anuma schist (pAs) (A.J.S.)

Definition

The Anuma schist is an elongate body of kyanite schist and staurolite schist that crops out as low ridges from near Marbles Bore eastwards for 14 km past Winnecke Depot Waterhole to Anuma Creek (whence the name), in the centre of LAUGHLEN. The unit is easily distinguished by the abundance of kyanite and staurolite, which are prominent in hand specimen, but are absent in the neighbouring units to the north and south. The type section is a series of low ridges located south of Marbles Bore, and extends from 5751-271260 for 600 m south to 5751-271254.

Relationships

The Anuma schist adjoins epidote-quartz rock, amphibolite, and cordierite gneiss of the Erontonga metamorphics to the south; the junction is in places concordant (and conformable?) and elsewhere faulted. To the north, the schist is in fault contact with calc-silicate rock and marble of the Cadney metamorphics.

Lithology

The sequence in the type section through the Anuma schist is shown schematically in Fig. D-1-12a. The schistosity in the rocks dips everywhere steeply north, and is accompanied by a moderate to steep north-plunging lineation. The sequence begins in the south with kyanite-muscovite schist containing coarse biotite-kyanite segregations. This is overlain by staurolite-biotite-muscovite schist (about 1 m thick), laminated epidote-microcline rock (about 1 m), then by 10 m of hematite-garnet quartzite forming a ridge. This is overlain to the north by more muscovite-biotite-quartz-feldspar gneiss, mica schist containing masses of pegmatite up to 7 m across, staurolite-biotite-muscovite schist, and lastly a few metres of interbedded marble and garnet-hematite quartzite at the northern end of the sequence, which is truncated by a fault. The only rock from the type section which has been examined in thin section is one of the kyanite segregations; it consists of kyanite, biotite, quartz, muscovite, ?magnetite, and small colourless grains of corundum (70090152 = AS855).

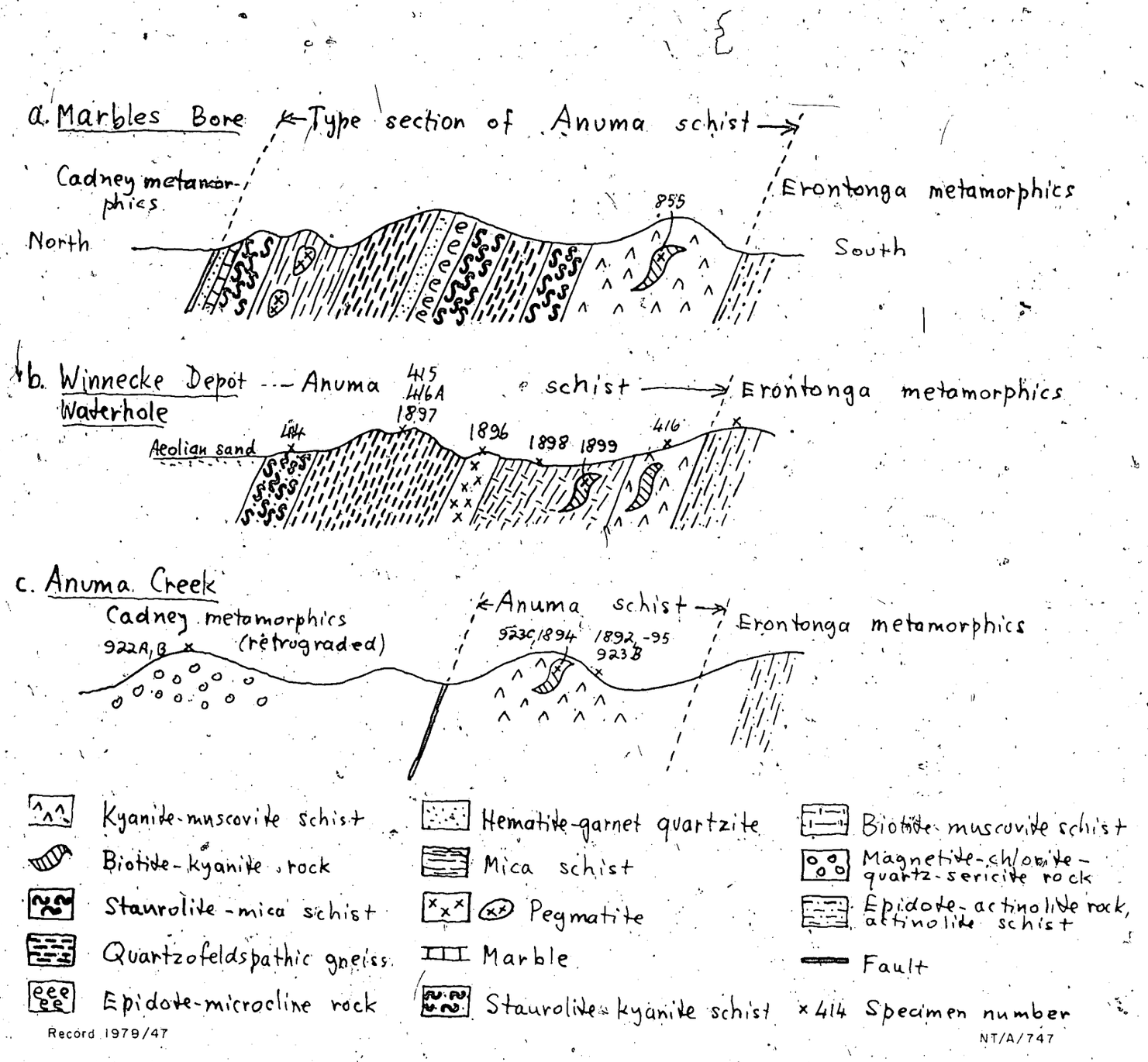


Fig. D-1-12 Diagrammatic cross-sections through Anuma schist. Thicknesses not to scale. Numbered specimens described in text.

At Winnecke Depot Waterhole, 6.5 km to the east, similar rocks form an incomplete sequence shown schematically in Fig. D-1-12b, and these have been examined petrographically. Kyanite-muscovite schist crops out at the base of the sequence, and consists of abundant coarse prismatic kyanite, muscovite, biotite, an opaque mineral (?magnetite), and rare quartz (AS416; no registration number). This rock is overlain to the north by biotite-muscovite schist, consisting of green biotite, muscovite in strongly aligned flakes, abundant ?magnetite, polygonal quartz, and rare plagioclase (71911898). Both these rock types contain segregations of coarse biotite-kyanite rock, composed of biotite, brownish kyanite in coarse prisms, ?magnetite, muscovite, quartz, and rounded zircons (71911899). The mica schist is succeeded to the north by retrogressively metamorphosed and deformed pegmatite, composed of partly recrystallised microcline, completely recrystallised polygonal quartz in elongate aggregates, strongly aligned flakes of muscovite, tiny grains of epidote, and rare yellow garnet (71911896). This is overlain by strongly foliated schistose gneiss, consisting of microcline as strained and partly recrystallised augen, myrmekitic plagioclase, muscovite, biotite, quartz, and minor secondary calcite (71911897). Several other samples from the same rock are similar in composition, but contain abundant epidote or clinozoisite, and recrystallised quartz; plagioclase forms small augen, or has also been recrystallised to a fine polygonal mosaic (70090229 = AS415; AS416A). The gneiss is in turn followed to the north by staurolite-kyanite schist (AS414; no registration number), composed of quartz (45%), biotite (20%), poikiloblastic kyanite (15%), idioblastic and poikiloblastic staurolite (10%) pleochroic from yellow to colourless, muscovite (7%), and opaque grains (3%).

At Anuma Creek, at the eastern end of the outcrop of Anuma schist, the fault along the northern side has cut well down through the sequence, and only kyanite-muscovite schist is preserved (Fig. D-1-12c). The rock consists of coarse muscovite (50%), recrystallised quartz (25%), pale green chlorite (12%) in aggregates of large kinked flakes, hematite (10%), prismatic kyanite (3%) as remnants inside aggregates of muscovite flakes, and rare zircon (71911892). Another sample (70090257B = AS923B) is similar, but lacks quartz. Sample 71911895 from the same schist lacks muscovite, and consists of biotite (40%), opaque grains (25%; ?magnetite), kinked prismatic

kyanite (20%), and subhedral greenish-blue tourmaline (15%). The schist contains prominent segregations of biotite-kyanite rock, composed of kinked biotite, deformed and twinned blades of kyanite, coarse quartz, a small amount of muscovite in cracks in kyanite, and rare corundum as coarse colourless prisms smudged in places with blue (71911894). Some segregations without kyanite consist of strained quartz and kinked chlorite only (70090257C = AS923C).

Metamorphism

The assemblages in the staurolite schist (muscovite-staurolite-kyanite-biotite-quartz) and kyanite schist (muscovite-kyanite-biotite-quartz) and ferruginous quartzite (garnet-hematite-quartz) are indicative of the middle amphibolite facies of regional metamorphism of the high-pressure type, specifically the staurolite-almandine subfacies and kyanite-almandine-muscovite subfacies of Winkler (1967). If equilibrium were attained, and the clean coarse textures in many specimens of the schists suggests that it was, then the staurolite-out isograd appears to be located in the middle of the Anuma schist, with grade increasing from north to south across the isograd.

Superimposed on the prograde regional metamorphic assemblages are younger retrograde metamorphic minerals, such as the abundant chlorite (after biotite) and sericitic aggregates after kyanite at Anuma Creek, and the epidote, clinozoisite, and fine sericite after plagioclase in the schistose gneiss and deformed pegmatite at Winnecke Depot Waterhole.

Origin

The Anuma schist is a metamorphosed sequence of iron-bearing pelitic sediments, impure quartz sand, and rare limestone near the top. The schistose gneiss at Winnecke Depot Waterhole resembles an acid igneous rock in thin section, but the strong schistosity and retrogressive metamorphism precludes absolute certainty of igneous parentage.

Age and Correlation

K-Ar isotopic dates determined by Webb & Lowder (1972) on four samples of the Anuma schist are set out in Table D-1-12A.

Sample 71911892 is retrogressively metamorphosed; it contains abundant chlorite, and the muscovite in the same rock clearly replaces kyanite. Hence, the K-Ar date of 335 m.y. indicates that the retrogressive metamorphism took place during the Alice Springs Orogeny, in the Early Carboniferous. The muscovite in sample 71911898, 10 m south of the deformed and retrograded pegmatite at Winnecke Depot Waterhole (Fig. D-1-12b) also appears to have (re) crystallised at that time, although the rock shows no retrogressive textures. The biotite dates are widely spread, as in the Arltunga area 40 km to the southeast (Stewart, 1971b). They probably recrystallised completely during the Alice Springs Orogeny, but contain various amounts of extraneous argon (cf. Armstrong & Stewart, 1975). The time of formation of the staurolite and kyanite assemblages in the Anuma schist is not known, but may have been around 1700 m.y., the general time of prograde regional metamorphism in the southeast Arunta Block.

Table D-1-12A: K-Ar isotopic dates on Anuma schist

Sample No.	Lithology	Material dated	Date (m.y.)
71911892	Kyanite-muscovite schist	Muscovite	335
71911894	Biotite-kyanite rock	Biotite	992;993
71911898	Biotite-muscovite schist	Biotite	672;674
		Muscovite	336;336
71911899	Biotite-kyanite rock	Biotite	371

The Anuma schist has no known correlative. The Yambah and Southern Cross Schist Zones, in BURT and LAUGHLEN respectively, contain similar aluminous minerals, viz., kyanite, staurolite, biotite, and muscovite, but also diopside, epidote, and hornblende at Yambah, and have clearly originated by retrogressive metamorphism along faults in pelitic, mafic, felsic, and calcic granulite and gneiss.

D-1-13: Bungitina metamorphics, pGsb (R.D.S.)

Definition

The principal outcrop area is a rugged belt of hills and ridges, some 3 km wide, which strike south-southwest from Mount Brassey in RIDDOCH (Outcrop-area 1). The metamorphics also crop out near the confluence of Florence and Maude Creeks (Outcrop-area 2), and between Muller Flat Dam and the junction of Florence Creek with the Hale River (Outcrop-area 3).

The Bunitina metamorphics consist mainly of a very fine-grained, thinly laminated, quartzofeldspathic gneiss (f) which is commonly garnetiferous (ie vf) and subordinate amphibolite (a) or mafic granulite (mn). Rarer rock types include clinopyroxene - or hornblende - bearing plagioclase - quartz rock (l), garnet quartzite (gt), biotite schist (sb), calc-silicate rock (cs) and megacrystic feldspar gneiss (p). An unusual Mg-rich unit, noted for its base-metal content, is present at the Oonagalabi Prospect. The Mg-unit includes anthophyllite rock and clinopyroxene rock.

The metamorphics are informally subdivided into presumed lower (pGsb 1) and upper (pGsb 2) units. The lower unit is more extensive, has a higher proportion of quartzofeldspathic gneiss, and contains amphibolite bodies that are commonly discordant and lensic. These amphibolite bodies are thought to be the retrogressed equivalents of minor mafic granulite elsewhere in the unit. The upper unit contains a more diverse group of rock types including those of the distinctive but rare Mg-rich unit, megacrystic feldspar gneiss, and a schistose garnetiferous biotite gneiss. Rock types common to both informal units include the distinctive quartzofeldspathic gneiss, amphibolite, hornblende-or-clinopyroxene-plagioclase quartz rock and calc-silicate rock. The later two rock types are, however, more common in $pGsb_2$ which also has much less quartzofeldspathic gneiss and amphibolite. The amphibolite in $pGsb_1$ is commonly, but not always, conformable.

The metamorphics are named after Bungitina Well (abd. GR 5851-900374), on the upper reaches of Maude Creek, 9 km south of Mount Brassey in the northeastern part of RIDDOCH.

Reference section is along Florence Creek between GR 5851-847427 and 836381.

A group of lensic bodies of quartzofeldspathic gneiss, referred to by Joklik (1955, p. 43) as the Bungitina Granodiorite (R4787, R4588) are identical to many other quartzofeldspathic gneisses in the principal outcrop area, so Joklik's unit has been extended to include all the quartzofeldspathic gneisses and subordinate mafic rocks that together had been mapped by Joklik as granitised Irindina Gneiss.

The mafic granulite and amphibolite in the principal outcrop-area have been informally referred to as 'Mount Brassey Amphibolite' by I. McCulloch (personal communication, Russgar Minerals N.L., 1973; Neilson, 1974, unpublished).

Relationships

The metamorphics are assigned to the Strangways Metamorphic Complex because it mainly consists of felsic and mafic granulite or their retrograde equivalents. They are thought to be conformably overlain by the unnamed unit pGsl, a facies equivalent of the Cadney metamorphics. However, the boundary zone is obscured by faulting. The Bungitina metamorphics are unconformably overlain by the Irindina Gneiss which belongs to the Harts Range Group. The relationship between the Bungitina metamorphics and the Naringa Calcareous Member of the Irindina Gneiss which directly overlies it is obscured by a zone of tectonic disturbance which develops into a tectonic slide. Locally, porphyroblastic K-feldspar gneiss assigned to the Bruna Gneiss, which also belonging to the Harts Range Group, overlies the Bungitina metamorphics (e.g. along Florence Creek upstream of its junction with Maude Creek). At the southwestern extremity of the principal outcrop area highly deformed Bungitina metamorphics pass progressively into the Gough Dam Schist Zone; the boundary being arbitarily defined by the incoming of muscovite and, as such is largely a reflection of metamorphic grade.

In the southern outcrop-areas the Bungitina metamorphics appear to conformably overlie the Cadney metamorphics, but this belt of Bungitina metamorphics is interpreted to be a structural repetition. The exact nature of the contacts is uncertain, but because the outcrop width is reduced to only 1 to 2 km wide north of the Muller Fault it is suspected that at least one of these boundaries is a tectonic slide. South of Muller Fault the outcrop-width is considerably thicker and the Bungitina metamorphics are still structurally underlain by the Cadney metamorphics but in this case the sequence may be overturned and unfaulted.

Distinguishing Features

The Bunitina metamorphics are distinguished from other units of the Strangways Metamorphic Complex by their high proportion of quartzo-felspathic gneiss relative to the mafic rocks, the well-layered nature of their interbeds, and their general high degree of deformation, exemplified by the lensic nature of rock units.

The Bungitind metamorphics differ from the Irindina Gneiss in containing mainly quartzofeldspathic gneiss and little of the garnet-biotite gneiss characteristic of the Irindina Gneiss. Where garnet-biotite gneiss is present, as in the presumed upper part of the metamorphics ($pGsb_1$), the biotite content is generally less than 15 percent and the garnet content less than 5 percent; whereas these percentages are generally exceeded in the Irindina Gneiss. Furthermore, the amphibolite and mafic granulite in the Bungitina metamorphics are commonly discordant whereas amphibolite in the Irindina Gneiss forms conformable, very continuous, and commonly (but not always) well-layered bodies.

Distribution of main rock types

Both informal units, $pGsb_1$ and $pGsb_2$ are recognised in three main outcrop-areas. The sequences in these areas are described below.

Outcrop-area 1: In the principal outcrop-area south-southwest of Mount Brassey in RIDDOCH, the presumed lower unit of the metamorphics ($pGsb_1$) consist mainly of a highly deformed sequence of finely recrystallised, thinly laminated, and intensely lineated quartzofeldsapthic gneiss (f), interlayered

with subordinate units of mafic granulite (mn) (e.g. M166, 2642A and B). A high proportion of these mafic bodies are cross-cutting and presumed to be meta-intrusions. A large, as yet undetermined, percentage of the mafic rocks are thought to have been retrogressed to amphibolite (a) and are intensely deformed and recrystallised.

Whereas unit $p\mathfrak{C}sb_1$ crops out as a rugged belt of hills and ridges, some 3 km wide, which strikes south-southwest from Mount Brassey in RIDDOCH the upper unit $p\mathfrak{C}sb_2$ outlines an open northeast-plunging synform, which forms a region of low subdued ridges, between 2 and 4 km south of Mount Mabel in RIDDOCH.

Photo-interpretation suggests that the basal calcareous subunit of unit $p\mathfrak{C}sb_2$ (best-known at Oonagalabi Prospect where it contains a basal magnesium-rich horizon), passes upwards into a succession of quartz-rich and biotite-rich gneisses containing decreasing amounts of calcareous material, overlain in turn by alternating lensic bodies of quartzofeldspathic gneiss and increasing amounts of amphibolite. The basal unit is a magnesium-rich, sulphide-bearing horizon (ae), referred to as "the anthophyllite horizon", but known to contain cummingtonite and gedrite, and lenses of granofels consisting of variable quantities of cordierite, phlogopite, orthopyroxene, sapphirine, corundum and garnet. The Mg-unit is overlain by a sulphide-bearing forsterite marble (ma) (2651) and calc-silicate rock (cs). Subordinate layers of amphibolite in the calcareous horizon are generally conformable. These are overlain conformably by a plagioclase-quartz gneiss (l) (eg. 2643), the layering of which is considered to be sedimentary because lamellae of small, rounded zircons are parallel to it. North of the Prospect the main rock types are garnet-biotite schist (v) and garnet-biotite schistose gneiss (v) (locally containing oligoclase and anthophyllite), and intercalated calc-silicate rocks (cs), marble (ma), and quartzofeldspathic gneiss (f). At the western extremity, 3 km south of Mount Mable, at apparently the same stratigraphic level as the garnet-biotite schist, a series of low ridges with a dark tone on the aerial photographs are made up of calcareous plagioclase-quartz gneiss (l) (3641, 3642, M171). These metasediments are flaggy, medium to dark grey, rich in quartz and contain small amounts of hornblende and clinopyroxene. Several layers of schistose biotite gneiss, a small amount of

amphibolite, and one layer, 2 m wide, or coarse-grained ferruginous quartzite are intercalated with the calcareous plagioclase-quartz gneiss (l). The apparently overlying, more prominent strike-ridge to the northwest is made up of fine-grained, strongly-lineated, quartzofeldspathic gneiss containing abundant quartz (30-50%), up to 20 percent biotite, and locally containing up to 5 percent garnet or K-feldspar porphyroblasts. North of the Oonagalabi Prospect, rocks believed to be roughly continuous with the same strike ridge consist of porphyroblastic, quartzofeldspathic gneiss (p) M169) and quartz-rich gneiss (l) M170). Rare calc-silicate lenses have been recorded from the intervening region, (e.g. M.J.R. pt. 14). The succession north of the prospect is completed by amphibolite (a) or mafic granulite (mn) interlayered with thin layers of quartzofeldspathic gneiss (f) capped by rocks photo-interpreted to be biotite schist (sb), calc-silicate rock (cs), small amounts of quartzofeldspathic gneiss (f), and rare Mg-rich rocks.

Small outcrops of Unit $p\mathfrak{G}sb_1$ also occur at the margin of the Bungitina gneiss 3 km southwest of Mount Brassey and in the upper headwaters of Muller Creek at the base of the succession.

In outcrop-area 2, located between where Florence Creek begins meandering to the southeast and Muller Creek (G.R. 5851-800340), the mafic rock content of lower unit $p\mathfrak{G}sb_1$ rises to about 40-50 percent. Here the mafic rock is largely concentrated in the eastern part of the section. The mafic rock consists of both extensively retrogressed mafic granulite (1497) and amphibolite containing relict igneous hypersthene. Subordinate amounts of garnet-bornblende gneiss (h, 881), biotite gneiss (b) and quartzofeldspathic gneiss (f) are interlayered with the mafic rocks in the eastern part. In the same area, 3 km northeast of Muller Flat Dam, a subunit of very coarse to medium-grained, biotite quartzofeldspathic gneiss (f, b) occurs west of the mafic unit. The quartzofeldspathic subunit contains numerous pegmatite segregations and encloses small lenses of mafic rock.

The upper unit $p\mathfrak{G}sb_2$ in the second outcrop-area, along Florence Creek upstream of its junction with Maude Creek, appears to structurally succeed a sequence of mafic granulite and felsic gneiss, and to be followed up-dip by porphyroblastic K-feldspar gneiss assigned to the Bruna Gneiss.

The rocks in this region are highly deformed. In this area the two units, $pGsb_1$ and $pGsb_2$, are not readily distinguished from each other.

As is the case with unit $pGsb_2$ in the outcrop-area 1, a variety of calcareous, quartzofeldspathic and biotite gneisses, representing probable metasediments, are intercalated with definite metasediments such as calc-silicate rock, quartzite and marble. Such rock types include hornblende or actinolite-bearing plagioclase-quartz gneiss (l) (2490-93, 2495) including biotite-rich varieties (b), which grade into biotite schist (sb). Quartzo-feldspathic gneiss containing porphyroblasts of garnet or K-feldspar is also present. These probable metasediments are intensely schistose and lineated, and have a medium grainsize produced by recrystallisation, possibly of an original mylonitic fabric. Farther northeast, and structurally overlying these rocks, are similar, though generally quartzofeldspathic and non-calcareous rocks, which are not obviously metasedimentary (f, sf, b). M. Rickard (personal communication ANU, 1977) regards these rocks as equivalents of the Bungitina gneiss. These quartzofeldspathic gneisses enclose discontinuous amphibolite horizons, some of which contain relict metamorphic orthopyroxene. The quartzofeldspathic gneisses also enclose patches of gneiss containing K-feldspar porphyroblasts and one bed of calc-silicate rock. Such rocks are transitional with the overlying unit of porphyroblastic gneiss and quartzofeldspathic gneiss assigned to the Bruna Gneiss.

In Outcrop area 3 a similar division of lower unit $pGsb_1$ into a mafic eastern portion and a quartzofeldspathic western portion is evident south of Muller Flat Fault. Here, 2 km south of Muller Flat Dam, the quartzo-feldspathic rock (fn?, f, mn) in the eastern portion forms a rounded plateau some 3 km across. Some, if not all, of this body is felsic granulite because all three thin-sectioned samples contain hypersthene (798, 2518, 5012). The quartzofeldspathic rock encloses small, lensic bodies of mafic granulite (2517B, 5013), and lacks K-feldspar. The succeeding unit farther east consists mainly of mafic granulite (mn) or clinopyroxene-bearing amphibolite (a) and subordinate quartzofeldspathic gneiss (f, 812) including rare garnetiferous quartzofeldspathic gneiss (vf, 2451). Small amounts of hornblende gneiss (h) and garnet-biotite gneiss (v) are also present. In many of these rocks much

of the quartz and about 15 percent of the plagioclase has recrystallised due to a second metamorphism. The boundary with overlying unit $pGsb_1$, is taken to be where amphibolite (a) and quartzofeldspathic gneiss (f) cease to be the dominant lithological-combination. Current reconnaissance mapping places this boundary just east of Florence Creek near its confluence with the Hale River.

The upper unit $pGsb_2$ in outcrop-area 3 lacks the distinctive calcareous plagioclase-quartz gneiss (l), which characterise unit $pGsb_1$ elsewhere. It is on the basis of the consistent presence of small amounts of calc-silicate rock (cs) throughout the sequence and even smaller amounts of garnet-biotite gneiss (v) (9814) in the westernmost part, that correlation with unit $pGsb_1$ is made. The succession in outcrop-area 3 contains a consistently high proportion of both quartzofeldspathic gneiss (f) (about 20%) and fine to medium-grained amphibolite (a) (5-20%). A number of these quartzofeldspathic gneisses in the eastern part of the succession (R4550, 2421) are hornblende-bearing. Various types of biotite gneiss make up the predominant rock type in the westernmost part of the sequence where amphibolite is less abundant.

In the easternmost part of the sequence, which is probably structurally the top part, gneiss containing K-feldspar prophyroblasts (p) (2421) and flaggy, two-mica schist (s) which collectively replace biotite gneiss as the main rock type. The proportion of calc-silicate rock is also increased and includes hornblende-epidote and epidote-quartz-plagioclase varieties (820).

Detailed description of rock types

The following descriptions are given in alphabetical order. Quartzofeldspathic gneiss and amphibolite, which is probably retrogressed mafic granulite, are the most abundant rock types.

Amphibolite (a) in $pGsb_1$ is thought to be widespread in the southern part of the principal outcrop-area south of Mount Brassey where deformation is most intense. The amphibolite is considered to be retrogressed mafic granulite. Specimens 6516 and 6546 for example contain relict orthopyroxene.

The interpreted extent of retrogression is supported by the relatively subdued aeromagnetic response over this region. The amphibolites are conformable with the quartzofeldspathic gneiss (f) and biotite gneiss (b). Some of the amphibolite is garnetiferous (e.g. 6523); most is foliated. It accounts for about 20% of the outcrop-area in the reference section. In rare cases the amphibolite forms layers less than 2 mm thick. Specimens 6548 and 6549 have been chemically analysed. Estimated modes for the analysed amphibolites are given in Table D-1-13D. Specimen 6544 is an unusual plagioclase-rich amphibolite containing ?scapolite.

Biotite gneiss (b) of $pGsb_2$ (e.g. 6522 A) has not been examined in detail. In a few cases the biotite gneiss forms laminae about 2 mm thick. A number of units contain traces of hornblende. Typically the biotite gneiss forms thick fine-grained, migmatitic units which are associated with quartzofeldspathic gneiss.

Calc-silicate rock (cs), more common in $pGsb_2$, is commonly garnet and diopside-rich, is commonly associated with marble, and typically forms units less than 0.5 m wide. Specimen 6531 is an unusual ultramafic variety consisting of clinopyroxene, hornblende and calcite.

Calcareous plagioclase-quartz gneiss (l) in $pGsb_2$ ranges from calcareous quartz-rich gneiss to quartz-plagioclase gneiss, and has a well-defined compositional layering suggesting that it has a sedimentary origin. Such quartzofeldspathic gneiss is typical of the two northern outcrop-areas. Constituent mineralogies are summarised in Table D-1-13A. The most common variety lacks K-feldspar, has a relatively high quartz content, invariably contains some hornblende, and rarely contains clinopyroxene. A number contain small quantities of garnet. Most consist of fine, polygonal grains and only become schistose when biotite is present or where relict quartz ribbons or super-fine laminations indicate earlier mylonitisation (2493, 2495). Several of these gneisses (e.g. 2491) contain plagioclase porphyroblasts.

TABLE D-1-13D: Estimated mineral content of mafic granulite (mn) and amphibolite (a), in unit $pGsb_1$ of the Bungitina metamorphics.

	M166	798A	2452	2455	2517B	2642A	5013	6548	6549
Symbol	mn	mn	a	mn	mn	mn	mn	a	a
Orthopyroxene	10	3		10	3	5	10		
Clinopyroxene	20	15	5	13	12	10	15		
Garnet						5			2
Hornblende	5	10	45	17	25	65	12	60	40
Plagioclase	50	61	40	53	60	20	63	38	55
Quartz	10		10	5					
Biotite			tr					2	
Actinolite	1								
Sphene									
Ti/Fe oxides	4?			2				0.05	5

Additional specimens of mafic granulite (mn) from outcrop-area 1 include, 6517, 6519, 6545, 6547, 6607, 6608B, 6609, 6616, 6617.

TABLE D-1-13A: Estimated mineral content (%) for calcareous quartzo-feldspathic gneiss (l) and related rocks (cs) in, $pGsb_2$, Bungitina metamorphics.

	881	M168	820*	2463	2464	2490	2491	2493	2495	2502	3642	3643
		l	cs	l	l	l	v	l	l	l	l	l
Quartz	50	63	30	65	55	45	43	57	57	45	52	52
Plagioclase	1	10	60	20	20	70	30	30	25	29	35	43
K-feldspar	12	–	–	1		1		2	10	1	2	
Hornblende (or Actinolite)	7	7		10	5	4		7	5	15	5	
Clinopyroxene		5									0.5	3
Garnet	3	5		1	2		2		1	3	0.5	
Biotite	25			10	15	25	25	3	2	7		
Illmenite (or magnetite)	2		tr	tr	tr	tr	0.5	tr	1		4?	2
Sphene	tr										1	1
Scapolite		15										
Epidote			7	3	2							
Calcite					1							
Chlorite										tr		

Many contain accessory sphene and illmenite.

*One uncommon variety (820), from near the end of Lizzie Creek, consists of quartz, plagioclase and epidote and is transitional to calc-silicate rock.

Additional specimens of calcareous quartzofeldspathic gneiss (l) include 6542, 6550, 6612, 6614 and 6608.

Felsic gneiss and granulite deficient in K-feldspar (fn in $pGsb_1$) crops out extensively south of Muller Fault (798B, 812, 2518, 5012). The quartz content of these rocks is between 30 and 50 percent, and the plagioclase content is consistently in excess of 40 percent (Table D-1-13B). Most contain some biotite, at least one contains garnet (2451), and three (798B, 2517, 5012) contain up to 2 percent orthopyroxene. Much of this felsic body is moderately deformed. Quartz is extensively recrystallised, and about 15 percent of the plagioclase is recrystallised around grain boundaries and shows other strain features such as bent twin lamellae.

Felsic granulite, 5012, has been chemically analysed (Table D-1-13F) and this analysis is discussed in the subsection on geochemistry.

V - see garnet biotite gneiss.

Partly metamorphosed gabbro and dolerite (in $pGsb_1$, gb, r: 880, 2494, 2496, 2500, 2503) contain ortho-and clinopyroxene, but do not have granuloblastic textures typical of mafic granulites and, in some cases, contain relict igneous textures, such as plagioclase laths (880) or minerals such as olivine (2504), which is metamorphically instable except at very high grades. The rocks are commonly recrystallised and metamorphically retrogressed to hornblende, actinolite, biotite, and rarely chlorite. These rocks are not readily distinguished on the aerial photographs, or in thin section, from the mafic granulites.

Garnet-biotite schist or schistose gneiss (v) in $pGsb_2$ is the main rock type north of the Oonagalabi prospect. Most of these rocks are transitional to garnetiferous quartzofeldspathic gneiss and have biotite contents generally between 5 and 15 percent and a garnet content less than 5 percent. Specimen 6748, with a biotite content of about 20 percent, has been submitted for chemical analysis. This schist appears to grade into quartzofeldspathic varieties (described below M167, Table D-1-13C) and the calcareous quartzoplagioclase gneiss (1) described above. Small amounts of this garnetiferous gneiss (e.g. 814, Table D-1-13C; 2458) occur in the lower part of the section in outcrop-area 3 east of Florence Creek near its junction with the Hale River.

TABLE D-1-13B: Estimated mineral content (%) of felsic granulite (fn) and related K-deficient gneiss (f) from the presumed lower unit, $p\mathfrak{E}sb_1$, Bungitina metamorphics.

	K-deficient felsic granulite and gneiss			
	789B	812	2518	5012
Garnet				
Quartz	30	50	30	47
K-feldspar	-	1	1	1
Plagioclase	67	52	62	45
Biotite	0.5	7	0.5	5
Hornblende				
Orthopyroxene			2	1
Zircon		tr		
Sphene				1.5
Opaque grains	0.5		0.5	
Epidote	1.5			1.5
Kyanite				

x = present

TABLE D-1-13F: Chemical analysis of rocks assigned to the Bungitina metamorphics.

Number				
Rock Type	Quartz-rich gneiss	Felsic Granulite	Mafic Granulite	Mafic Granulite
Grid Reference				
SiO_2	69.23	74.50	50.25	49.40
Al_2O_3	11.95	11.97	14.17	14.81
Fe_2O_3	3.20	2.05	1.79	4.28
FeO	4.42	1.28	11.40	10.50
CaO	3.19	0.74	9.83	7.84
MgO	0.01	0.53	6.30	6.76
Na_2O	3.15	1.70	2.62	2.83
K_2O	2.56	6.54	0.84	0.69
TiO_2	0.50	0.35	1.06	1.08
MnO	0.18	0.03	0.25	0.25
P_2O_5	0.06	0.05	0.10	0.09
H_2O+	0.11	0.11	0.13	0.19
H_2O-	0.11	0.09	0.07	0.11
CO_2		0.05		
Cu	10	6	30	30
Co	2	2	58	42
Ni	5	4	114	80
Cr	15	5	190	290
V	30	15	250	390
Sr	100	54	78	100
Rb	105	295	12	22
Ba	660	940	120	320
Ce	120	140	50	50
Sr	3	5	25	5
Zr	-	370	100	-
Pb		145	16	-

TABLE D-1-13C: Estimated mineral content (%) for garnetiferous gneisses (v, vf), and related rocks (h) from the Bungitina metamorphics.

Unit	pCsb$_2$				pCsb$_1$		
	6748	814	M167	6541	881	2642c	D226
Symbols	v	v	vf	vf	h	q	vf
Quartz	20	45	35	48	50	90	40
Plagioclase	44	36	45	20	1		15
K-feldspar	8	-	-	20	12	acc	25
Hornblende (or Actinolite)					7		tr
Garnet	8	3	10	2	3		5
Biotite	20	15	10	10	25		15
Illmenite (or Magnetite)					2		
Sphene					tr		
Scapolite							
Epidote		1					
Calcite							
Chlorite							tr
Zircon	tr						

Additional specimens of garnetiferous quartzofeldspathic gneiss include 6540, 6611, 6615, and 6540.

Garnetiferous quartzofeldspathic gneiss (vf) account for about 15 percent of the reference section and appear to be a variant of quartzofeldspathic gneiss (see (f) in other descriptions). Estimated modes are given in Table D-1-13C. The garnetiferous quartzofeldspathic gneiss is thought to be metasedimentary because it shows marked compositional layering, grades into quartzite, and is intercalated in places with biotite-rich gneiss (b), and calc-silicate rock (cs). Specimen 6541 from the southern part of the reference section has been chemically analysed.

Hornblende gneiss (h) in $p\mathfrak{G}sb_1$ is similar to the calcareous plagioclase or quartz gneiss from unit $p\mathfrak{G}sb_2$ (1) in that it contains hornblende and rarely garnet. It is much less abundant than the plagioclase - quartz gneiss and contains K-feldspar. It accounts for about 4 percent of the reference section. It has been studied from only one locality (881), 4.5 km northeast of the Maude-Florence Creek junction. Here, the gneiss consists (Table D-1-13C) of quartz (50%), biotite (25%), K-feldspar (12%), hornblende (7%), garnet (3%), ilmenite (2%), plagioclase (1%), and accessory sphene. The chemical analysis of specimen 881 will be discussed later. Other examples of hornblende gneiss include 6539, 6544 and 6613.

The mafic granulite in $p\mathfrak{G}sb_1$ is very consistent in mineralogy throughout all three outcrop-areas, as illustrated in Table D. Near Oonagalabi Prospect the mafic granulites show hydration of hornblende to diopside and orthopyroxene, which seems to be occurring concurrently with a reaction between hornblende and plagioclase to give garnet. Specimens 6607 and 6616 from south of the prospect also contain garnet. The plagioclase is commonly andesine-labradorite. Retrogressed mafic granulites are further described under amphibolite. Mafic granulite in the central (area 2) and southern (area 3) are moderately to strongly deformed, as evidenced by bend plagioclase twin lamallae and intense crystallisation of plagioclase around grain boundaries. Specimens 5013 and 2455 (Table D-1-13D & F) have been chemically analysed.

Mg-rich (ae) rocks of $p\mathfrak{G}sb_2$ in the vicinity of the Oonagalabi Prospect form a persistent horizon, referred to by Russgar geologists as 'the anthophyllite horizon', because they consist of either a mino-mineralic anthophyllite or cummingtonite-rich granofels. Lenses of monomineralic

cummingtonite or gedrite granofels (73912644A, 6730), and spinel-bearing granofelses, which also contain plogopite, enstatite, anthophyllite, garnet and sapphirine, occur within the horizon and especially towards its base. Other examples of this rock type include 6518, 6520, 6521, 6526, and 6529.

Marble (ma) of $p\mathfrak{C}sb_2$ from the Oonagalabi Prospect (e.g. 6530) consists of rounded, partly altered, grains of forsteritic olivine set in a matrix of calcite. It contains sulphide minerals, mainly pyrite, and an assay of a grab sample gave 0.5% Cu, 0.7% Zn, and 0.1% Pb. It also contains 1% Mn, probably present as an opaque mineral species.

Porphyroblastic feldspar gneiss (p) (2421, Table D-1-13E) of unit $p\mathfrak{C}sb_2$ occurs in all three outcrop-areas, but is most abundant in the western part of the two southern outcrop-areas (2 and 3), and is one of the principal features used to correlate outcrop-area 3 with the reference area. One extensive layer of prophyroblastic gneiss, 3 km north-northeast of the Lizzie Creek-Hale River confluence, (2421), contains rare mafic xenolith-like inclusions and is characterised by distinctive biotite clots. This gneiss is medium to fine-grained and has a granite composition. In all three outcrop-areas the feldspar porphyroblast content is distributed in an apparently random fashion. The gneisses are typically medium to thick layered. Porphyroblastic feldspar gneiss is present in $p\mathfrak{C}sb_2$, but here is a rare rock type (e.g. M142).

Quartzite (q) is a rare rock type and appears to be a variant of the quartzofeldspathic gneisses (f, l, vf) (e.g. 6612 which is transitional between q and l). The quartzite is commonly garnetiferous. (e.g. 2642C. Table D-1-13C).

Quartzofeldspathic gneiss (f) accounts for about one-quarter or more of the outcrop-area and is more abundant in $p\mathfrak{C}sb_1$. The gneiss is typically fine-grained, markedly lineated and, in places, grades into muscovite-biotite gneiss (s) biotite gneiss (b) and gneiss containing K-feldspar porphyroblasts (p see above). The gneisses form layers, tens of metres wide, which have remarkable continuity along strike. The mineral content of some

TABLE D-1-13E: Estimated mineral content of quartzofeldspathic (f) and porphyroblastic-feldspar (p) gneisses from unit $pGsb_2$ of the Bungitina metamorphics.

Symbol	R4450 (f)	2461 (f)	819 (f,r)	2421 (p)	R4588 (f)	R4589 (f)	R4587 (f)
Garnet							
K-feldspar	15	32	46	53	39.7	44	14.5
Quartz	65	25	35	35	39.4	41	35.5
Plagioclase	10	35	10	5	19.9	10	43.6
Biotite	7	7	4	4	0.8	7	5.2
Muscovite	3		2				
Hornblende		1		2			
Epidote	tr	1	2	te	0.2		0.3
Sphene	tr	tr		tr			0.1
Apatite	tr						
Magnetite	tr					0.5	0.5
Chlorite			tr				
Zircon						tr	

examples, mainly from the Lizzie Creek-Hale River outcrop-area (i.e. R4450, 2461 and 819) and 5 km south of Mount Brassey (R4589, R4788 and 6543 further SW) are summarized in Table E. As a group these quartzofeldspathic gneisses are distinguished by their K-feldspar content which ranges between 10 and 45 percent; that is they have granodiorific to granitic compositions.

The characteristic pronounced lineation and planar, laminar foliation is interpreted to be inherited from an earlier mylonitic microstructure, evidenced by relict quartz ribbons.

Metamorphism

The first recognisable metamorphism appears to have been under granulite facies conditions, and to have affected the entire outcrop-area. A second metamorphism under amphibolite facies conditions is considered to be synchronous with a major deformational phase. Deformation, evidenced in the two southern outcrop-areas by subgrain formation in quartz and bent plagioclase twins is thought to have been followed in places, particularly in the north, by extensive recrystallisation. In a few cases in the north relict quartz ribbons, in an otherwise recrystallised rock, suggest an earlier period of mylonitisation. Much of the region south of Mount Brassey, which has undergone intense and extensive deformation, is interpreted to be amphibolite facies because of its relatively slight aeromagnetic response.

East of the Maude-Florence Creek junction, recrystallisation under amphibolite facies conditions affects gabbros and dolerites which escaped the earlier granulite metamorphism affecting neighbouring mafic rocks. Thus, the amphibolite facies metamorphism is later, and is also clearly related to the Cadney and southeastern Brassey Faults, because the amount of strain indicated by the number of lensic outcrops and rootless folds, the density of secondary cross-faults, and the extent of recrystallisation increases towards these structural features.

In all three outcrop-areas of $pGsb_2$ the mineral assemblages suggest that metamorphic conditions were transitional between those of the granulite and amphibolite facies. Many of the mafic rocks are amphibolite, but many contain relict metamorphic hypersthene. The quartzofeldspathic rocks lack

hypersthene, but near the intersection of the Pannikin Dam and White Lady Faults (3642, 3643) they contain clinopyroxene. Elsewhere in $p\mathfrak{C}sb_1$, north of the Oonagalabi Prospect they are recorded to contain anthophyllite. At the Oonagalabi Prospect the presence of slightly aluminous anthophyllite in association with spinel and gedrite indicates metamorphic conditions close to the amphibolite-granulite transition. These same rocks also contain spinel, garnet and sapphirine.

Structure

F1 folds are probably represented by northerly-trending folds delineated by photo-interpretation at the southern end of the principal outcrop-area, south of Mount Brassey. Photo-interpreted tectonic slides accompanying the main episode of mylonitisation are believed to post-date F1 folding, because they truncate F1 fold trends. The broad, open synform which controls the outcrop pattern of the overlying unit of $p\mathfrak{C}sb_2$ east of Oonagalabi Prospect is interpreted to be an F2 structure. This synform may be truncated by the Brassey Fault, which is an extension of the White Lady and Pannikin Dam Faults. The main body of Bungitina metamorphics south of Mount Brassey is, thus, almost completely enveloped by faults interpreted to be tectonic slides except, in the southwestern extremity of the outcrop-area, and possibly directly northwest of the Oonagalabi Prospect.

The rapid change in outcrop width of the two southern outcrop-areas suggests their western boundary may also be a tectonic slide, but there is no direct evidence to support this idea.

Geochemistry

Three rock types considered to be typical of the Bungitina metamorphics have been chemically analysed. Specimen 881 (Tables D-1-13C & F), a quartz-rich hornblende-gneiss is chemically very like specimen 5002 from the southern margin of the Ongeva granulite and somewhat like 5012 described below. Both specimens 5002 and 881 are probable metasediments. Specimen 881 falls just in the arenite field of Garrels & MacKenzie (1971), and is similar to the arithmetic average for an eugeosynclinal sandstone given by Middleton (1960). The high Fe and relative high CaO and Na_2O together with the low Mg are consistent with a sedimentary derivation. Although Felsic

granulite, 5012, (Table D-1-13C & F) lacks K-feldspar and contains only 5 percent biotite it has a higher K_2O content than 881. Specimen 5012 is similar to the quartzofeldspathic gneiss (5021) from the lower Cadney metamorphics and likewise has a high Ba content (940 ppm). Both specimens 881 and 5012 are chemically close to the arithmetic mean of a taphrogeosynclinal sandstone of Middleton (1960) except CaO is too low by one-third. Whereas specimen 881 falls in the arenite field of Garrels and MacKenzie (1971), specimen 5012 falls in the igneous field and specimen 5012 is also similar to gneiss considered by Dougan (1976) to be originally part of a calc-alkaline volcanic suite. The origin of specimen 5012 is uncertain.

The analyses of mafic granulites 5013 and 2455 from south of Muller Fault suggests that the parent rock was a tholeiitic basalt or dolerite (Tables D-1-13D & F). In this respect they are like specimen 4406 from the Yambah granulites.

Origin

The mafic granulites and amphibolites of unit $pGsb_2$ are probably tholeiitic basalt or dolerite, as is typical of the Strangways Metamorphic Complex (see Appendix).

The quartzofeldspathic gneisses of granitic composition (f) (e.g. 4588, 4589, 4787, 4788, D266) are most likely of igneous origin, either acid flows or sheet-like granite intrusions. The felsic granulite (?fn) south of Muller Fault (7988, 5012, 2518) may also be an intrusive igneous body, possibly a charnockite, even though it is deficient in K-feldspar.

The relatively high quartz content and calcareous nature of many of the plagioclase-quartz gneiss (l) more typical of $pGsb_1$ and their well-layered nature point to a sedimentary origin for these rocks. The well-layered garnetiferous quartzofeldspathic gneiss (vf) may have a similar sedimentary origin as may the hornblende gneiss (b). The intercalated garnet-biotite schistose gneiss (v), calc-silicate rock (cs), and marble (ma) are more clearly of sedimentary origin. Some of the quartzofeldspathic gneiss (f) and pr[illegible]blastic feldspar gneiss (p), in the easternmost (?upper) part of

the succession in outcrop-area 3, have granitic compositions and may have originated from sill-like granite bodies or from acid volcanics. Many of the amphibolites could have been sills or flows, some have been plug-like gabbro bodies, although it is difficult to distinguish intrusive bodies from megaboudins. The more continuous units in the upper (structurally) part of the sequence are likely to have been basaltic sills or flows.

Age and Correlation

The age of the metamorphics is unknown. They are presumed to have been regionally metamorphosed at 1800 m.y. like other units of the Strangways Metamorphic Complex, but are thought to have undergone a later second metamorphism to account for the extremely fine recrystallised texture. The Bungitina metamorphics are most like the unit pGx which also have a large content of quartzofeldspathic rocks, and are correlated with the Strangways Metamorphic Complex. Unit pGx is extensively retrogressed to amphibolite and greenschist facies rocks. The Bungitina metamorphics are also similar to parts of the Erontonga metamorphics, although in general this unit contains considerable cordierite suggesting that it may be more magnesian. Like the Bungitina metamorphics and pGx, and unlike much of the Strangways Metamorphic Complex, the mafic rock content of the Entia Gneiss is small. On the other hand, the Bungitina metamorphics are also similar to the Entia Gneiss of the Harts Range Group, except that the interlayered mafic rocks in the Entia Gneiss appear to be hornblendic and much more quartz-rich.

Furthermore, the presumed upper unit of the Bungitina metamorphics, $pGsb_2$, is lithologically like the upper part of the Entia Gneiss (pGhi) which is well exposed to the upper reaches of Entire Creek in QUARTZ where it consists mainly of quartzofeldspathic gneiss, quartz amphibolite, hornblendite, sillimanite, muscovite-biotite and garnet-bearing varieties of pelitic gneiss, rare calc-silicate rock and marble. Similar rock types to those of unit $pGsb_2$, particularly the more quartzofeldspathic felsic garnet-biotite and biotite gneisses, and the distinctive layers of gneiss containing feldspar porphyroblasts, occur in the lower, more feldspathic part of the Irindina Gneiss, as can be seen, for example, in the upper reaches of Irindina Creek. This correlation with the Irindina Gneiss is strongly favoured by M.J. Rickard (personal communication, ANU, 1977).

R.D.S. considers that the Bungitina metamorphics are not a part of the Harts Range Group because the Irindina Gneiss of the Harts Range Group is considered to unconformably overlie the Bungitina metamorphics as outlined previously.

D-1-14: Cadney metamorphics, pCsc (R.D.S.)

Definition

The Cadney metamorphics are a spectacular succession of mainly calcareous and pelitic rocks which constitute the uppermost unit of the Strangways Metamorphic Complex. The main rock types are calc-silicate rock, marble, biotite gneiss and sillimanite gneiss. The lower part of the unit also contains quartzofeldspathic gneiss and felsic granulite.

The unit has been subdivided in LAUGHLEN. Here, the upper part of the metamorphics ($pCsc_1$ in LAUGHLEN) consists almost entirely of calc-silicate rock and biotite gneiss, and small amounts of marble and lesser amounts of quartzite. The lower part of the metamorphics ($pCsc_2$ in LAUGHLEN) typically contains calc-silicate rock and thick layers of quartzofeldspathic gneiss and felsic granulite, and very small amounts of mafic granulite. In the Strangways Range in LAUGHLEN the lower part also includes aluminous rocks rich in sillimanite.

The Cadney metamorphics crop out extensively in RIDDOCH and LAUGHLEN, principally, in the headwaters of The Tug, Cadney, and Muller Creeks in RIDDOCH, and as a sinuous belt extending east-west across the central and southern Strangways Range in LAUGHLEN. The outcrop pattern parallels that of the Arltunga Nappe Complex to the south. The metamorphics correspond to the region of lowest relative relief, second only to the Tertiary plains; the rocks mainly form rounded parallel ridges and discontinuous narrow plains up to 100 m wide. Peripheral to the main outcrop-area the region is relatively rugged consisting of scarps of up to 40 m at the unit margin. Elsewhere, the outcrop area contains minor ridges reaching 150 m high, formed principally of the more resistant quartzofeldspathic gneisses and felsic granulite of the lower part of the metamorphics.

The reference section for the Cadney metamorphics is in RIDDOCH and extends along and north of the main branch of Tug Creek from Eritjapurta Pass (i.e. "Cattlewater Pass") to the junction of Tug and Cadney Creeks, and then from Muller Bore northeastwards to the track to Bungitina Well (abd) from Muller Flat Dam. Joklik (1955a) named the unit "Cadney Gneiss" after Cadney Creek (lat. 23°14', long. 134°44'), but did not nominate a reference section. The type specimen of Cadney Gneiss described by Joklik is almost certainly part of the Cavenagh metamorphics and is discarded as a reference sample. Although the unit is characterised by calc-silicate rock and marble, it includes pelitic gneisses, so the term "metamorphics" is preferred to "Gneiss". The stratigraphic name is regarded as informal as the unit may subsequently be amenable to formal subdivision.

The Cadney metamorphics are distinguished from neighbouring units by their content of calc-silicate rock and the widespread occurrence of sillimanite-bearing gneiss. Quartzofeldspathic gneiss units are typically continuous over extensive distances; a feature which together with their chemistry (see later) is suggestive of a sedimentary derivation. Mafic granulite is an atypical rock type and normally crops out as plug-shaped bodies suggestive of an intrusive origin.

Relationships

The Cadney metamorphics is an extensive and distinctive metasedimentary unit, which wraps around a number of kernels composed principally of mafic and felsic granulite and gneiss. The overall structural trend in the Cadney metamorphics differs from that in the underlying units, but both are thought to have undergone the same phases of folding. The Cadney metamorphics consistently overlies the kernels of mafic and felsic rocks, and is thought to be stratigraphically younger because it is extremely unlikely that overturning has occurred on a regional scale. These underlying units are the Yambah granulite, Unit pGsp, the Ongeva granulite (all in LAUGHLEN), and units pGst and pGx (in RIDDOCH). The Erontonga metamorphics, which also underlies the Cadney metamorphics in LAUGHLEN, differs from the other underlying units in consisting largely of metasediments and in having a transitional contact with the Cadney metamorphics. In the White Range Nappe

south of New Gidyea Bore (abd) the Cadney metamorphics interfinger with the Hillsoak Bore metamorphics, which are also considered to be mainly metasedimentary.

A sequence comprising principally the Cadney metamorphics and both the Erontonga metamorphics and the Hillsoak Bore metamorphics is interpreted to form a transgressive sequence that overlies the lower part of the Strangways Metamorphics Complex, which in contrast to the above sequence typically consists of mafic and felsic rocks and is considered to be largely of igneous parentage. The units underlying the Cadney Metamorphics and the Erontonga metamorphics differ lithologically from each other suggesting a regional discordance at this contact. On a local scale, however, the contact typically appears to be conformable. For example, at the western contact with the Ongeva granulite in LAUGHLEN small lenses of calc-silicate rock and sillimanite gneiss, typical of the Cadney metamorphics, reoccur near the boundary as thin units in the Ongeva granulite, which is mainly a sequence of alternating felsic and mafic granulite. The felsic granulite and gneiss closest to the contact are well-layered and locally contain layers of mafic granulite from 2 to 10 cm wide suggestive of a metasedimentary origin. The eastern boundary with the Ongeva granulite in RIDDOCH is also transitional in that quartzofeldspathic gneiss, felsic granulite and mafic granulite, typical of the Ongeva granulite reoccur as minor rock types in the lower part of the Cadney metamorphics.

Distribution of rock types

Because the Cadney metamorphics are extensive and very variable, the succession in each of the following eight outcrop-areas will be outlined in turn, beginning with the reference section: (1) in central-northern RIDDOCH in the Cadney Creek catchment; (2) near Paradise Well in southeastern RIDDOCH; (3) in the White Range Nappe in southwest RIDDOCH: (4) in the Ten Mile Dam area north of The Garden homestead in LAUGHLEN: (5) between the headwaters of Muller and Gillen Creeks in northwest LAUGHLEN: (6) northwest of Southern Cross Bore in central-northern LAUGHLEN: (7) towards Mount Milton in BURT and western LAUGHLEN; and (8) west and southwest of Woolanga Bore in the northern Strangways Range in RIDDOCH. More detailed lithological descriptions of the main rock types are given in the next subsection following the outline of their distrubution.

(1) In the catchment of the Cadney, Tug and Muller Creeks in central-northern RIDDOCH the reference section for the lower part of the Cadney metamorphics extends along the north of Tug Creek from Eritjapunta Pass to its confluence with Cadney Creek. Here, the greater part of the Cadney metamorphics consists of calc-silicate rock but it also contains several persistent beds of garnet-biotite quartzofeldspathic gneiss which are generally from 100 m to 350 m thick, numerous thin beds of biotite gneiss, a few intercalations of marble, and rare lenses of mafic granulite and mafic calc-silicate rock. The quartzofeldspathic gneiss is not everywhere garnetiferous and is more abundant lower in the section near the boundary with the Ongeva granulite, whereas the biotite gneiss is more abundant in the upper part of the section.

The reference section for the upper part of the Cadney metamorphics extends from Muller Bore northeast to the track to Bungitina Well (abd) and Bullocky Dam. This section contains a small amount (about 15%) of mafic granulite which forms plug-shaped bodies interpreted to be of intrusive origin. The lower part of this reference section consists of calc-silicate rock intercalated with several units of sillimanite gneiss and garnetiferous biotite gneiss, which is also locally sillimanite-bearing. One unit (e.g. 797) contains cordierite as well as sillimanite, and a few thin marble beds are also present. The upper part of this succession contains a few lenses of quartzofeldspathic gneiss and generally lacks garnetiferous-gneiss.

(2) The Cadney metamorphics continue southwards from the reference area to south and southeast of Paradise Well in southeastern RIDDOCH, where they crop out in an arcuate belt extending from the lower reaches of Tug Creek to Mount Russell. Here, the biotite and sillimanite-biotite gneiss content of the upper unit increases and together account for up to half the upper unit in places. These gneisses also become more varied; garnetiferous types in particular become more prominent in the lower and middle part of the section. Close to Unit pGx, in the Mount Chapman area, the quartzofeldspathic gneiss (f) content increases to 20 percent although biotite gneiss is still dominant. Also about 15 percent of the biotite gneiss in the same area is muscovite-bearing (s). These gneisses are in general more felsic and may be equivalent

to the lower Cadney unit, pCsc$_2$, although if this is the case the calc-silicate content is very much reduced. An estimate of the mineral content of the rocks south of Paradise Well is given in Tables D-1-14 A & C. The calc-silicate rocks form the lower ground near the Hale River (809B, 1026, 1027, 1030). These rocks grade into quartz-rich hornblende gneiss (2502), muscovite-biotite gneiss containing epidote (815A, 815B), and muscovite-quartzite (1029). Sillimanite-bearing gneiss forms the higher ridges in the main part of the range, and it also occurs as thin interbeds in the calc-silicate rocks north of the range and as thin units in the more felsic biotite gneisses south of the main range. Mafic granulite (809A, 2512, 2514; Table D-1-14C) forms high peaks along the main range, and shows all stages of retrogression from mafic granulite to amphibolite (2410; Table D-1-14C). Most of the rocks at the western-end of this outcrop-area show some degree of retrogression to greenschist assemblages. In addition, several narrow schist zones cut the metamorphics such as the northerly trending zone at the Wheal of Fortune Gold mine (abd). Here, a hornblende-gneiss (852A) has been coverted to a rock consisting of green actinolite (25%), green biotite (10%), chlorite (2%), epidote (2%), calcite (1%), and muscovite (1%), in addition to plagioclase (27%), and quartz (20%). Similarly, retrogression of a biotite gneiss has produced epidote (10%), muscovite (15%), green biotite (3%) and chlorite (4%) and a trace of calcite as well as quartz (15%), plagioclase (53%), (852B).

(3) (by A.J.S.) One outcrop of Cadney metamorphics has been mapped in the White Range Nappe, in the southwest of RIDDOCH, immediately south of Gidyea Bore. It comprises interbedded calc-silicate rock, biotite gneiss, marble, amphibolite, quartzite, epidosite, and a single exposure of mafic granulite. The biotite gneiss is dark grey, fine-grained, and contains small coarse-grained pegmatitic patches of feldspar, quartz, and garnet. The gneiss (68110292, -0296, -0350) consists of quartz (40 to 60%), plagioclase (30 to 40%) largely replaced by coarse white mica, biotite (10 to 20%, without chlorite), garnet (2%), and microcline (1%). A darker variant (68110287, -0293 contains more biotite (25%) and also chlorite (5 to 10%); -0293 contains abundant zoisite (15%) as well. Quartzite pods associated with the biotite gneiss are similar to those in the Hillsoak Bore metamorphics; they are mottled red, white, and blue, and are composed

of quartz, red-brown garnet, and hematite (68110283). Marble forms four separate beds in the biotite gneiss, and is medium to coarse-grained, white, and massive; the southernmost lens (71911737) consists of calcite (90%) and small amounts of epidote, microcline, diopside, pale orange-brown garnet, quartz, and sphene. An impure, pelitic variety (71911746) is composed of calcite, colourless chlorite, muscovite, and quartz. Interbeds of calcareous quartzite (71911741) in the marble are composed of quartz as large flattened and partly recrystallized grains, epidote, oligoclase, yellow-brown garnet, microcline, clinozoisite, and muscovite. The single exposure of mafic granulite, from a locality 5.3 km south-southeast of Gidyea Bore, consists of calcic plagioclase, hypersthene mantled by tremolite, clinozoisite, and opaque grains (71915049).

(4) In the Ten Mile Dam area, north of The Garden homestead calc-silicate rock and marble grade to the east, firstly, into an interlayered sequence of mafic and felsic granulite and then into sillimanite gneiss, biotite gneiss and garnet gneiss adjacent to the Ongeva granulite. The felsic granulite typically consists of quartz and abundant calcic-plagioclase with lesser amounts of sillimanite, garnet, hypersthene and biotite. The mafic granulite consists of hypersthene, diopside, hornblende and plagioclase with rare biotite and quartz. Two kilometres west southwest of Ten Mile Dam mafic granulite was found to contain abundant spinel, hypersthene, diopside and opaque minerals indicating a relatively high metamorphic grade. Calc-silicate rock consists of labradorite, and rounded garnet and diopside grains in a matrix of recrystallised calcite. Scapolite, muscovite, and serpentine are rare accessory minerals.

In the southeastern part of the Ten Mile Dam area (5 km north of the Garden homestead the unit grades into biotite-gneiss, biotite-plagioclase-orthoclase-sillimanite quartzite, sillimanite $\pm$ garnet $\pm$ microcline-biotite-plagioclase quartz-rich gneiss and garnet gneiss. This sillimanite-rich sequence grades, to the east, into the Ongeva granulite.

A sample of felsic granulite which crops out as a thick unit surrounded by calc-silicate just south of Ten Mile Dam was selected for geochemical analysis (see 6006 and subsection of Geochemistry of rocks in the Cadney metamorphics (Tables D-1-14 F & G).

(5) The section exposed along the watershed between the headwaters of Muller and Gillen Creeks is taken to be the reference section in the western outcrop area, that is for the Cadney metamorphics in LAUGHLEN. Unfortunately, the section is complicated by extensive strike-faulting. The lowest part of the metamorphics (i.e. GR 5751-112321 to 5751-142351) has a transitional contact with the Erontonga metamorphics and consists of extremely sillimanite-rich biotite gneiss, interlayered with lesser amounts of calc-silicate rock, which increases in abundance up-section (i.e. northwards away from the Erontonga metamorphics).

In the middle to upper part of the metamorphics ($p\epsilon sc_2$), which is exposed mainly in the western tributaries of Gillen Creek (i.e. GR 5751-142351 to 5751-151361, quartzofeldspathic gneiss is intercalated with equal amounts of calc-silicate rock and smaller amounts of amphibolite. At this point the section is interrupted by the Southern Cross Schist Zone.

The section through the upper part of the metamorphics ($p\epsilon sc_1$) is 22 km to the east in Muller Creek (i.e. GR 5751-063425 to 5751-074445). Here, the unit consists of calc-silicate rock interlayered with minor amounts of biotite gneiss. Intervals rich in calc-silicate rock also contains thin intercalations of marble, and rare beds of feldspathic quartzite and garnetiferous quartzofeldspathic gneiss. Pods of mafic granulite are present in this area. The uppermost part of the section is partly faulted against Unit $p\epsilon sp$ (i.e. the "Mount Pfitzner granulite" in the Preliminary map).

(6) Northwest of Southern Cross Bore the lower unit, $p\epsilon sc_2$, is transitional between that of the western reference section and that near Ten Mile Dam. Sillimanite-bearing gneiss is considerably less abundant than in either area and is much more quartzofeldspathic.

(7) West of the Gillen Creek reference section (i.e. 6 above) the lower Cadney unit is compositional similar to that near Gillen Creek except close to BURT (5751-990460) where some of the sillimanite gneiss becomes cordierite-bearing.

(8) Five kilometres southwest of Woolanga Bore the lower part of the succession is transitional with the unnamed unit pesp and consists of an alternating sequence of predominantly quartzofeldspathic, aluminous and mafic granulites, and one horizon of ultramafic rocks. This sequence may eventually be separated out as a separate unit akinned to the Erontonga metamorphic as calcareous rocks are absent. Woodford (1974, and in Woodford & Wilson, 1976a) assigned these rocks to his "Western Zone Granulites". A narrow highly-deformed zone of calcareous rocks separates this "western zone" from Woodfords' "Median Zone Granulites" farther east. The median zone is a sequence of mainly felsic rocks (quartzofeldspathic gneiss and felsic granulite), but includes small amounts of mafic rock and rare aluminous rocks. The succeeding calcareous sequence to the east, "the Central Calcareous Sequence", consists of thin intercalated marble, calc-silicate rock, and less common felsic and aluminous rock types. Rare mafic layers and one large mafic intrusion (5751-187433) occur within the sequence.

Detailed lithological descriptions

The calc-silicate rock in the reference area (area 1) in RIDDOCH is pale grey, commonly medium-grained, equigranular and granuloblastic. It is typified by its regular, though lensic, layering made up of quartz and mafic-rich portions. Less common greenish layers generally contain a high proportion of epidote or diopside. Layers range from very thin laminae to layers up to 4 cm thick, and are commonly boudinaged and disharmonically folded. Typical varieties in the reference area near Tug Creek in RIDDOCH contain quartz, calcite, epidote-clinozoisite, plagioclase (commonly andesine to labradorite), clinopyroxene (typically diopside also hedenbergite), amphibole (either hornblende, tremolite or actinolite), and, in places, forsterite, scapolite, microcline, phlogopite, and garnet, and very small amounts of dolomite. Accessory minerals include magnetite, sphene, spinel, tourmaline and apatite. (5003, 5004, 5005, 5007, 5018, 5030, 5035).

The calc-silicate rock in the Tug Creek region (area 1) grades into calcareous quartzite (5010), quartz-clinopyroxene-plagioclase gneiss (5019, 5022) and impure marble (e.g. 5009). The marble (in areas 1, 4 and 6) is typically pale grey and consists mainly of calcite; dolomite is rarely present and then only in accessory amounts. Minor minerals in the marble are the same as those in the calc-silicate rock.

Sillimanite-biotite gneisses in area 1 can be recognised on the colour aerial photographs by their rich red-brown colour. In hand specimen the gneisses are steel grey to brownish grey.

Three varieties are recognised:

(1) Those rich in quartz are most common (883, 885).

(2) The second most abundant type is rich in K-feldspar (792, 793).

(3) The least common type contains cordierite (797).

All varieties contain 10 to 15 percent biotite, 10 to 15 percent sillimanite and about 15 percent plagioclase, up to 10 percent magnetite and up to 5 percent garnet. Rare types contain abundant garnet. All three types of sillimanite gneisses are generally schistose and in some places show a moderate degree of recrystallisation accompanied by partial retrogression to greenschist facies assemblages. In the cordierite-bearing type (797) matted aggregates of sillimanite and biotite occupy interspaces between rounded cordierite and plagioclase grains.

Sillimanite in pelitic rocks from area 5 in central LAUGHLEN locally accounts for up to 60 percent of the rocks (e.g. 3635) and forms a strong lineation. Other constituents of this sillimanite-gneiss include plagioclase, quartz and amphibole. Plagioclase-rich varieties of sillimanite gneiss (e.g. 3636) are similar except that they contain considerably less sillimanite and rarely contain traces of garnet. In these plagioclase-

rich rocks sillimanite and biotite generally form fine matted aggregates in the spaces between the rounded plagioclase grains. Both sillimanite gneisses contain up to 10 percent magnetite and, consequently, have a marked magnetic response. A few of these rocks contain kyanite.

Mafic calc-silicate (pa, or para-amphibolite) in areas 1 and 9 is an interesting and widespread variant of the calc-silicate rock, though generally rare. This rock is very like the quartz-clinopyroxene-plagioclase gneiss of area 1 in that it consists mainly of clinopyroxene and plagioclase, and is discussed further in the section of geochemistry.

Garnetiferous quartzofeldspathic gneiss (vf) and quartzofeldspathic gneiss (f) which crop out in area 1 are grouped collectively into two types; those containing 40 percent or more K-feldspar (824A, 902, 5021) and those containing less than 5 percent K-feldspar (825, 828, 5016, 5021). Specimen 1034 is intermediate between the two. Garnet is commonly localised in quartz-rich layers and patches. An estimate of the mode of these quartzofeldspathic rock is given in Table D-1-14B. The plagioclase is untwinned for the most part and is extensively recrystallised in narrow zones alongside faults (e.g. 5017). The K-feldspar is commonly a micro-perthite. Quartz invariably occurs in elongate aggregates of polygonal grains.

The quartzofeldspathic gneiss (f) in the Woolanga Bore area (area 9 in LAUGHLEN) includes sillimanite, garnet and rare cordierite-bearing types (z, vf, it), and is well-layered on a scale suggesting sedimentary bedding. The quartzofeldspathic gneiss, although interlayered with mafic granulites, rarely contains orthopyroxene. The normal mafic mineral is a pyrope-almandine type (pyr 30.5, alm 65.8, gross 2.7, spess 1.0 - average of 5 probe analyses, Woodford, 1974). Some felsic granulites contain almandine that formed during deformation, and this garnet is notably different in composition from the earlier pyrope-almandine type. An average of three probe analyses is pyr 17.4, alm 70.7, gross 10.2, spess 1.6 (Woodford, 1974).

rich in CaO (18.70% wt. %) as would be expected with a calc-silicate rock. The ratio of SiO_2/Al_2O_3 to $(Na_2O + CaO)/K_2O$ falls outside the extrapolated igneous trend of Garrels & MacKenzie (1971). However, the copper, cobalt and nickel contents are high (e.g. Cu = 98 ppm, Co = 64 ppm, Ni = 150 ppm, Cr = 440 ppm). A sedimentary origin is favoured for this rock, but the evidence is equivocal.

(2) Mafic granulite from the basal unit southwest of Woolanga Bore (?pGsc$_2$ on LAUGHLEN-BURT 1ST EDITION) have compositions 'more akin to primitive ocean tholeiites and are more magnesian than similar rocks analysed from the Yambah granulite' (Wilson, 1975 p. 62). A conformable lens of mafic granulite (3502-GR 5751-064422) is akin to tholeiitic basalt in composition.

(3) The felsic rocks (902A, 932A, 5017, 5021, 6006: Tables D-1-14 F & G can be grouped into two types: (i) quartzofeldspathic varieties and (ii) intermediate varieties.

(i) The quartzofeldspathic varieties are much the more abundant of the two types. The specimens analysed (902A, 5017, 5021) comes from the lower part of the Cadney metamorphics in the Tug Creek area in RIDDOCH. Specimen 5017 plots well outside the igneous field of Garrels & MacKenzie (1971) and is similar to the average eugeosynclinal sandstone of Middleton (1960), an Eocene greywacke from Washington State (Pettijohn, 1957 in Pettijohn 1963 Table 6 I) and Mesozoic greywackes from New Zealand reported by Reed (in Pettijohn 1963 Table 6, G).

Specimens 902A and 5021 differ from 5017 in having exceptionally high K_2O/Na_2O ratios (5.5 and 7.6: cf. 0.3), low CaO (0.45 and 0.32; cf. 5.66) and higher Ba (1450 and 1000 ppm; cf. 40 ppm). Sillimanite, seen in the hand specimen in 902A, suggests some phases of the rock may be more aluminous than that analysed. Specimens 902A and 5021 have significantly different FeO/MgO ratios of 2.52 and 8.98 respectively. Both specimens 902A and 5021 are chemically similar to a specimen of pink gneiss (321) from the Southern Namaqualand Gneiss Complex, South Africa, which is part of a group of gneisses that Kronner (1971) convincingly argued are meta-arkose.

Felsic granulite (Table D-1-14B) in area 1 in RIDDOCH occurs only sporadically (e.g. 887, 907) in the lower and upper units and in general, forms bodies too small to show on the map. The granulite contains plagioclase (50-60%), quartz (15-20%), hypersthene (10-20%), hornblende (-20%), biotite (5%), magnetite (up to 7%). This felsic granulite tends to be granoblastic with equant in grains and is bimodal in grain-size distribution.

Mafic granulite, although not abundant is widespread (824B, 890, 901, 2400: Table D-1-14C) in area 1 in RIDDOCH. Generally these granulites show partial recrystallisation to smaller grains and lack relict igneous features.

Biotite gneiss has been used largely as a photo-geological unit for a variety of gneisses and may include garnetiferous, sillimanite-bearing and felsic types.

The aluminous rocks are restricted to a basal unit of the Cadney metamorphics in the Woolanga Bore area (area 8 in LAUGHLEN) where they occur in lenses up to 100 m wide and contain small amounts of sapphirine. The sapphirine has typically replaced the outer rim of spinel which in places forms a symplectite in orthopyroxene. Sillimanite and plagioclase are common minerals (Woodford & Wilson, 1976a). Mineral assemblages of the aluminous rocks are given in Table D-1-14D. The basal unit containing the aluminous rocks will probably be separated out from the Cadney metamorphics by future workers when its relationship to the rest of the Cadney metamorphics and the underlying unit pCsp is better known.

The ultramafic rock associated with the aluminous rocks in area 8 (LAUGHLEN) consist mainly of hornblende and orthopyroxene, but very locally contains olivine. It grades into mafic varieties.

Geochemistry

(1) The mafic calc-silicate rock analysed (5020, Table D-1-14E) shows compositional layering on a scale similar to that of bedding and consists mainly of clinopyroxene (45%), and plagioclase (38%) which has been saussuritised and shows slight replacement by scapolite. The specimen is

TABLE D-1-14A: Visually estimated modal analysis of rocks from Cadney metamorphics south of Paradise Well

	Calc-silicate rocks				Gneisses					Sillimanite-bearing gneisses		
Specimen	809A	1026	1027	1030	2502	1029	815A	2470	1034	2513	1028	2451
Symbol	cs	cs	cs	cs	s,h	qt	s,r	s,sm	f	l	z	z
Quartz	55		30	20	60	75	30	55	51	16	20	40
Plagioclase		38	10	45	20	15	10	25	25	17	10	46
K-feldspar			46				41		15		47	
Biotite			3		6	3	10	1	5	5	15	10
Garnet	18	20		3	4	tr		tr			3	3
Hornblende			6		10							
Clinopx	5	10	3	30								
Scapolite	17	20	2									
Epidote		5				tr	6	7	2			
Muscovite			tr			7	2	12	2			
Sillimanite										5	4	tr
Cordierite										55		
Opaque Grains				1		tr				2	1	1
Sphene	tr	2	tr	tr			tr					
Apatite		tr	tr	tr	tr					tr		
Zircon									tr			
Chlorite						tr	1	tr				
Calcite	5			1								
Actinolite		5										

tr = trace

TABLE D-1-14B: Estimated mineral content (%) of quartzofeldspathic gneiss (f) and felsic granulite (fn) from the Cadney metamorphics.

Mineral	824A	825	828	887	902	907A	932	1034	5017	5021	6006
K-feldspar	58				40		5?	15		50*	
Plagioclase	6	52	55	57	4?	53	70	25	63		70.8
Quartz	29	35	32	13	36	20	15	51	30	30	13.7
Hypersthene						20					7.4
Clinopyroxene									3		3.0
Biotite	2	5	7	5	7	tr	5	5		10	5.0
Hornblende											tr
Opaque grains	1	1	1	1	tr	7	tr		1		tr
Garnet	3	4	5		13				3	10	
Zoisite/epidote								2			tr
Zircon	tr	tr	tr		tr			tr	tr?		
Chlorite			tr				tr				
Apatite							tr				
Cordierite							5				
Muscovite/sericite		3						2			
Spinel	1										
Calcite									tr?		

*Stained for K-feldspar

tr = trace

TABLE D-1-14C: Visually estimated modal analysis of mafic granulite and amphibolite from the Cadney metamorphics

Area	Tug Creek area				South of Paradise Well			
	8248	890	901	2400	809A	2512	2514	2410
Plagioclase	60	60	45	59	60	62	45	63
Hypersthene	23	5	5	10?	25	3	3	
Clinopyroxene	10	9	13	10?	2	7	35	
Hornblende	1	25	30	20	7	25	15	
Biotite	3		3		3			2
Quartz					2			10
Actinolite					0.5	1		20
Opaque Grains	2	1	4	1	0.5	2	2	
Apatite			tr		tr			
Sphene	tr							tr
Epidote								5
K-feldspar	1							
Actinolite		tr						

TABLE D-1-14D: Mineral assemblages of aluminous granulites from Woolanga Bore area, (area 8) (after Woodford and Wilson, 1976a).

	"Western Zone"								Median Zone Granulites and Central Calcareous sequence					
	15	25	109	115	120	122	580	664	405	419	420	692	712	716
Sapphirine	X		X	X	X	X	X	X	X				X	
Orthopyroxene	X	X	X	X	X	X	X	X	X				X	
Phlogopite	X	X	X	X	X	X	X	X	X	X	X	X	X	
Spinel	X		X	X	X	X	X	X		X	X		X	
Opaque Grains	X	X	X	X	X	X		X		X			X	X
Sillimanite		X	X			X			X		X		X	X
Gedrite	X	X			X	X				X	X			
Corundum	X		X	X	X	X	X					X		X
Plagioclase				X	X	X								
Garnet									X	X	X	X		
Hoghomite										X	X			X
Cordierite									X	X	X		X	
Quartz									X	X			X	
Kornerupine												X		
Tourmaline												X		
Kyanite									X	X	X			
K-feldspar									X					
Surinamite													X	

X = mineral present

TABLE D-1-14E: Chemical analysis, norm and estimated mode, mafic calc-silicate rock 74915020 from Cadney metamorphics

Chemical analysis		CIPW Norm		Estimated mode	
SiO_2	44.99	Diopside En	46.08	Hornblende	7
Al_2O_3	13.91	Olivine Fo	2.77	Clinopyroxene	45
Fe_2O_3	3.69	Zircon	0.01	Plagioclase	28
FeO	6.78	Orthoclase	1.47	Biotite	1
CaO	18.70	Albite	5.69	Calcite	1
MgO	7.23	Anorthoclase	32.97	Scapolite	5
Na_2O	1.05	Nepheline	1.79	Sphene	tr
K_2O	0.24	Magnetite	5.57	Sericite	10
TiO_2	1.11	Chromite	0.22	Epidote	1
MnO	0.20	Ilmenite	2.14	Opaque grains	2
P_2O_5	0.16	Apatite	0.38		
H_2O+	0.30	Calcite	1.04		
H_2O-	0.04				
CO_2	0.45				
	98.85		100.13		

TRACE ELEMENTS (ppm)		Average Basalt*1	Average Shale*2
Cu	98	Co 40	Co 19
Co	64	Ni 88-90	Ni 68
Ni	150	Cr 162-168	Cr 90
Cr	440	V 247	V 130
V	320		
Sr	122		
Rb	14		
Ba	50		
Ce	20		
Sr	25		
Zr	44		
Pb	240		

*1 Prinz (1967)

*2 Turekian and Wedepohl (1961)

TABLE D-1-14F: Chemical analysis of felsic rocks from the Cadney metamorphics

Specimen Number	902A (70090223)	932A (70090271)	5017 (74915017)	5021 (74915021)	6006 (74916006)
Rock	Sillimanite-garnet felsic gneiss	Felsic granulite	Garnet-clinopyrox. quartzofelds-pathic gneiss	Garnet Quartzofeld. gneiss	Felsic Granulite
Grid Ref.		5751-314298			
SiO_2	71.03	62.53	70.44	72.67	56.20
Al_2O_3	12.26	18.22	12.77	12.11	21.43
Fe_2O_3	1.01	0.47	2.51	0.79	0.70
FeO	3.33	2.97	2.79	3.61	2.62
CaO	0.45	6.24	5.66	0.32	7.50
MgO	1.72	2.91	0.87	0.49	1.56
Na_2O	1.21	3.75	2.57	0.98	4.50
K_2O	6.66	0.98	0.79	7.47	0.98
TiO_2	0.40	0.28	0.59	0.44	0.25
MnO	0.03	0.06	0.13	0.02	0.06
P_2O_5	0.05	0.08	0.11	0.05	0.06
H_2O+	0.34	0.20	0.24	0.03	0.28
H_2O-	0.14	0.12	0.08	0.07	0.06
CO_2			0.35	0.05	0.20
Trace Elements					
Cu	22	22	16	18	10
Co	6	12	2	8	14
Ni	5	23	14	14	44
Cr	25	60	5	10	45
V	30	135	35	35	75
Sr	44	420	94	34	430
Rb	230	30	28	320	10
Ba	1450	480	40	1000	340
Ce	130	20	110	180	60
Sr	0	x	15	5	5
Zn			400	430	65
Pb			125	42	420

TABLE D-1-14G: Interpretation of geochemical ratios of felsic rocks from the Cadney metamorphics

RATIO	INTERPRETATION, I = Igneous, S = Sediment, N = Not Igneous, T = Transitional geochemistry					REFERENCE
	902A	932A	5017	5021	6006	
(K_2O+Na_2O): $\frac{K_2O}{K_2O+Na_2O}$ x100	N	I	I	N	I	Hughes (1972)
log (SiO_2/Al_2O_3): log $((CaO+Na_2O)/K_2O)$	T	I	N	N	I	Garrels and MacKenzie (1971)
Niggli c: mg	S	I	?	?	I	Leake (1964)
K_2O/Na_2O	5.5	0.26	0.31	7.57	0.22	Dougan (1977)
SiO_2:Zr/TiO_2	-	-	Rhyodacite Field	Rhyodacite Field	Andesite Field	Winchester and Floyd (1976)
V	30	135	35	35	250	
Ni	5	23	14	14	28	Ni for acid igneous rocks = 5-18 ppm, Condie et al, 1970

TABLE D-1-14G (cont'd)

	902A	932A	5017	5021	6006
Comparable Analysis	Interpreted Altered Acid Volcanic (1); Interpreted Arkose (4); Arkose (6)	Hypersthene Andesite (2)	Average Eugeosynclinal (3) Sandstone	Interpreted Altered Acid Volcanic (1); Arkose (4); Arkose (6)	Average Andesite (5)
Comparable Analysis; this report	5021, 6007	6006	-	5012, 6007	932A
Interpreted Parent Rock	Altered Acid Volcanic or Arkose	Andesite	Arkosic Sandstone	Altered Acid Volcanic or Arkose	Andesite

(1) Dougan (1976): Spec. 8714

(2) Turner and Verhoogen, 1960. p. 285 Table 28, 5

(3) Middleton, 1960

(4) Kroner, 1971 Table 1. spec. 321

(5) Nockolds Av. Morgan (1964) p. Table 6, II

(6) MacKie, in Pettijohn, (1963, p. 59) Lower Old Red Sandstone

However the FeO/MgO ratio for the South Namaqualand Gneisses as a group is significantly higher (up to 21.2). A sedimentary origin is favoured for all three quartzofeldspathic varieties (9022, 5021, 5017), because their overall chemistry is more like arkose than an acid volcanic or granite. Table D-1-14G illustrates their chemical parameters and chemically classification in various schemes designed to distinguish parent rock types.

(ii) The intermediate varieties also come from the lower Cadney metamorphics, but are from the western-outcrop-area near Ten Mile Dam in LAUGHLEN. These rocks (932A, 6006) are remarkably similar to andesite (Table D-1-14G) both in total chemistry and SiO_2:Zr/TiO_2 ratio. (Winchester & Floyd, 1976).

Structure

In the Tug Creek area in RIDDOCH two sets of isoclinal folds are outlined by felsic gneiss units within a sequence of calc-silicate rock and pelite. The most widely distributed earlier isoclinal folds are regarded as F1 (local terminology for this area) and have northwesterly dipping axial-surfaces in the north of the area and northeasterly dipping axial-surfaces in the south. F1 folds are considered to have been accompanied by strong sliding because synformal structures have been obliterated. These F1 folds have been refolded about a large F2 fold which has an easterly-trending and north-dipping axial-surface. Where F2 fold hinges are very tight an axial-plane schistosity is locally developed. Both fold phases F1 and F2 are essentially reclined and coaxial; the dominant plunge being steep and to the north. An even earlier fold (F_o) has been identified from only one locality, just west of the junction of the two main branches of Cadney Creek. Here, a shallowly plunging fold is refolded by an F1 fold. Elsewhere, an earlier phase of folding is suspected from the lensic nature of the compositional layering.

In the Southern Cross Bore area in LAUGHLEN most of the mesoscopic fold axes and lineations plunge steeply to the northeast. Like the folds in the Tug Creek area the folds are cylindrical and disharmonic in style and lack an axial-plane schistosity. Sets of three superposed fold phases in which axes have a very similar orientation are exposed 7 km northwest

of Southern Cross Bore near the core of a major northeast-plunging synform. A major deformed zone along the southern margin of the Cadney metamorphics in northwest LAUGHLEN outlined by the Southern Cross Schist Zone is localised in the less competent marble-rich units of the Cadney metamorphics.

Metamorphism

In the Tug Creek area the typical granulite assemblage in the felsic rocks is plagioclase-clinopyroxene-plagioclase with or without K-feldspar and very small amounts of hornblende and biotite. Hypersthene-bearing felsic granulite is common in rocks of intermediate compositions; quartzofeldspathic gneisses containing garnet and biotite are more typical. Thin layers and pods of the two pyroxene-mafic granulite occur throughout the sequence. The calc-silicate rocks locally contain forsterite and spinel; a typical assemblage being forsterite-scapolite-garnet-clinopyroxene-calcite. Quartz and plagioclase are common additional phases. The pelitic rocks contain K-feldspar in addition to sillimanite and lack muscovite except in localised retrograde schist zones. The rocks throughout the Tug Creek area clearly belong to the granulite facies. Incipient partial melting and the widespread stability of biotite are consistent with temperatures less than 750°C (Turner, 1968).

Much the same metamorphic grade applies to the western outcrop-area. Felsic rocks in the Ten Mile Dam area (e.g. 932A, 6006) contain hypersthene and are interlayered with two-pyroxene mafic granulites here and northwest of Southern Cross Bore (e.g. 68180017). Within the calc-silicate sequence two-pyroxene granulites appear to be uncommon. Again the pelitic rocks contain both K-feldspar and sillimanite, but lack muscovite. One specimen contains andalusite (68180019). Mineral assemblages in the calcareous rocks include quartz-diopside-calcite-andesine (6718006), hornblende (green)-diopside-andesine-quartz-microcline-sphene-scapolite (67180014) and plagioclase-hedenbergite-scapolite-calcite-sphene-epidote-garnet (67180018). These calc-silicate assemblages are consistent with the higher grade part of the amphibolite facies or the lower part of the granulite facies. Near Southern Cross Bore the sequence is cut by a number of north-trending greenschist facies schist zones.

In the Woolanga Bore area (area 8) most of the rocks show the effects of deformation and recrystallisation of the primary granulite facies minerals. This phenomenon is well shown by the mafic granulites where second generation granules of pyroxenes and plagioclase are well-developed at hornblende-plagioclase interfaces. (Woodford & Wilson, 1976b). The scarcity of orthopyroxene in the felsic rocks is considered to be due to composition rather than metamorphic grade. Woodford (1974) has carried out extensive studies on mineralogy, geochemistry and metamorphism in the Woolanga Bore area.

Origin

Like the Erontonga metamorphics the calc-silicate rocks, biotite and sillimanite gneisses and small amounts of felsic rock of the Cadney metamorphics are considered to be a sequence of limy rocks interbedded with argillaceous sandstones and small amounts of arkose, thought to occur mainly near the base of the sequence (e.g. 902A, 5017, 5021). Many, but not all, of the minor mafic granulites bodies have isolated ovoid to irregular shapes that suggest an intrusive origin. The para-amphibolite lenses such as at 5020 in RIDDOCH are tentatively regarded as calcareous metasediments. The felsic granulites of more intermediate composition such as 932A, 933A, 6006 are most likely derived from andesites.

Correlation

The Cadney metamorphics are considered to occupy a unique position in the stratigraphic sequence and not to have any correlates. Because the Cadney metamorphics overlie many of the other units of the Strangways Metamorphic Complex one option is to correlate it with the Naringa Calcareous Member of the Irindina Gneiss; this correlation with the Irindina Gneiss is dubious, because the Cadney calc-silicates rocks are typically dull-grey, commonly garnetiferous, and quartz or plagioclase-rich; and in addition occur in thin-bedded to laminated lensic layers typically associated with sillimanite gneiss. In contrast to the Cadney metamorphics, the calc-silicate rocks of the Naringa Calcareous Member of the Irindina Gneiss normally occur as pale to orange-brown, thick-bedded, massive, very continuous beds in a sequence commonly containing quartzite.

Age

The granulite metamorphism affecting the Cadney metamorphics is considered to be the same as that producing the Ingula migmatite suite and the related anatectic Wuluma granitoid date at roughly 1800 m.y. (L.P. Black, BMR, personal communication, 1977).

A date of 1430 ± 59 m.y. (λ = 1.42) is inferred by Iyer, Woodford & Wilson (1976) for the metamorphic event (M2) that produced second generation granules of pyroxenes and plagioclase in the Woolanga Bore area. Their date is based on a Rb-Sr isochron defined by four points for felsic granulites which straddle the pCsp-Cadney metamorphic boundary. $^{40}Ar/^{30}Ar$ dates on rocks from the same area are inconclusive (Woodford, Mateen, Green & Wilson, 1975). Their inferred date needs to be substantiated by more Rb/Sr data.

D-1-15: Unit pCsl (R.D.S.)

Definition and Distribution

Unit pCsl is sequence of mainly schistose biotite gneiss (sb) and calc-silicate rock. Some of the schistose biotite gneiss grades into muscovite gneiss (s), and the calc-silicate rock grades into a layered amphibolite (pa). Less common rock types include marble (ma), biotite gneiss (b), quartzofeldspathic gneiss (f), mafic granulite (mn), and sillimanite gneiss (z).

The unnamed unit crops out in the southwestern part of the Harts Range Block in central-northern RIDDOCH where it extends from south of White Hill Dam to beyond Pannikin Dam.

Relationships

The unit is assigned to the Strangways Metamorphic Complex because it is considered to be a facies equivalent of the Cadney metamorphics, and because it has transitional contacts with units containing rock types typical of the Complex. It appears to conformably overlie the unnamed unit pCst in the west, and has a transitional boundary with the underlying Bungitina metamorphics in the east, although this contact is complicated by numerous strike-faults.

Unit pGsl is unconformably overlain by the Irindina Gneiss of the Harts Range Group. This contact is sharp and is marked by the incoming of abundant garnetiferous biotite gneiss which forms continuous well-layered units. In contrast, rock types in unit pGsl are lensic and are commonly folded on a small scale; a feature which is rare in the Irindina Gneiss. Discordance between the Irindina Gneiss and pGsl becomes more marked to the east, but in this region the unconformable relationship is relatively obscured by a zone of tectonic disturbance.

The unit passes southwards through a transitional metamorphic and structural boundary marked by the appearance of muscovite-bearing schists into the Gough Dam Schist Zone.

Distribution of rock types

The bulk of the northern part of the outcrop-area (between GR 5851-590465 and 710434) consists mainly of schistose biotite gneiss (sb), which grades into muscovite-bearing varieties (s), and subordinate calc-silicate rock (cs), which appears to grade into layered amphibolite (pa). Lenses of biotite gneiss (b), quartzofeldspathic gneiss (f) and rare mafic granulite (mn) occur throughout the sequence, but are more abundant near the contacts with unit pGst and the Bungitina metamorphics. Near the southwestern end Unit pGsl comprises ubiquitous calc-silicate rock (cs), small amounts of well-layered mafic calc-silicate rock (pa), muscovite-biotite-schist (s), biotite gneiss (b) and impure coarse-grained marble (ma) (including two small layers of coarse-grained quartzite (qt) within the marble), and rare mafic granulite (mn). Para-amphibolite (pa) becomes very abundant in the eastern part of the unit. Small lenses of sillimanite gneiss occur throughout the unit.

Lithology

Schistose biotite gneiss (sb) locally contains muscovite clots (s) and is very rarely garnetiferous. It is commonly either slatey or schistose. The biotite content is generally about 25 percent. The gneiss has gradational contacts with sillimanite gneiss and calc-silicate rock.

Calc-silicate gneiss (cs) commonly has a yellow-green colour due to its epidote content. It is mainly layered (0.5 cm); generally consisting quartz-rich and mafic-rich layers. A typical example e.g. (Specimen 6537; GR 5851-614-452) consists of epidote, actinolite, plagioclase and quartz, together with traces of biotite, calcite and iron-oxide grains. A less common variety consists mainly of diopside, calc-plagioclase and quartz.

Para-amphibolite (pa) grades into calc-silicate rocks such as specimen 6537 described above. The amphibolite is generally hornblende-rich, well-layered and foliated. Like the calc-silicate it has quartz-rich layers and diopside or hornblende-rich layers. Specimen 6538 (GR 5851-663414) contains about 15 percent quartz in addition to plagioclase, hornblende and magnetite, and traces of biotite. Specimen 6620 (GR 5851-676414) is very similar but also contains about 10 percent clinopyroxene.

Marble (ma) which is commonly pale grey, is present in small amounts throughout the unit as is mafic granulite (mn).

Sillimanite gneiss (z) is a rare but widely distributed rock type. For example, an isolated pod of sillimanite-garnet-biotite feldspar gneiss is exposed in a prospecting pit 700 m north of the Copper Queen Prospect. Specimen 5068 from south of Pannikin Dam contains microcline (48%), quartz (35%), plagioclase (10%), and biotite (7%). Specimen 5069, farther to the east contains cordierite (36%), which poikiloblastically encloses quartz (15%) and plagioclase (20%) in addition to containing K-feldspar (10%), biotite (10%) sillimanite (7%) and magnetite (2%).

Metamorphism

Much of the unit is at least upper amphibolite in metamorphic grade, because sillimanite-K feldspar is stable in pelitic rocks. The few rocks containing orthopyroxene near the southern and western margins of the outcrop-area indicate granulite facies conditions. Where muscovite is present it is thought to be due to retrogression possibly associated with movements on the Pannikin Dam Fault and faults at the northern and southern contacts of the unit.

Structure

The unit dips consistently northwards at a steep angle in the north and west, but strikes northerly in the southeast. Numerous shallowly plunging folds throughout the unit generally plunge in the direction of strike. Much of the northern contact is faulted, but unfaulted portions are also present.

Correlation

Unnamed unit pGsl is considered to be part of the Strangways Metamorphic Complex, and is thought to unconformably underlie the Harts Range Group. Unit pGsl is considered to be a pelitic facies equivalent of the Cadney metamorphics because it contains a number of rock types with an identical field appearance including calc-silicate rock, marble and sillimanite gneiss. These Cadney-like rock types are more abundant in the southern and presumably older part of the sequence. The Hillsoak Bore metamorphics are correlated with pGsl because they are also a pelitic facies equivalent of the Cadney metamorphics. However, the Hillsoak Bore metamorphics contain ubiquitous garnet unlike pGsl, and are also much more quartz-rich.

Age

No age determinations have been carried out on the unit.

Origin

The original sequence probably consisted of argillites, calcareous metasediments and limestones, and rare felsic volcanoclastic rocks. The form of the rare mafic granulite suggest they are probably metamorphosed gabbros.

D-1-16: Johannsen Metagabbro Dyke Swarm (pGsj) (A.R.A.)

Definition

The Johannsen Metagabbro is a suite of coarse-grained mafic dykes and small bosses which intrude the Utnalanama granulite and Erontonga metamorphics in the area west of Johannsen's Phlogopite Mine after which the dyke suite is named. The dykes radiate outwards to the north and west of the type area at GR 5751-062296 2 km to the southwest of Johannsens Phlogopite Mine.

The dykes are distinguished from the thin mafic gneiss layers in the Erontonga metamorphics by their much greater thickness, their homogeneous massive nature, their lack of foliation, their sharp contrasts and their locally discordant relationships.

Relationships

The Metagabbro dykes cut the Harry Anorthositic Gabbro, the Utnalanama granulite and the Erontonga metamorphics; and are themselves cut by the Gumtree Granite, the pyroxene dolerite dykes and coarse-feldspar pegmatite dykes. The unit consists of extremely abundant vertical dykes up to 100 m thick, which are concordant both with axial-planes of F1 folds and the related S-foliation. The dykes vary markedly in width along strike over distances of only a few metres. Commonly, the dykes bifurcate, or anastomose, and in the hinges of FI folds they widen out to form small boss-like bodies.

Lithology

The unit is compositionally homogeneous. Total rock analyses plot in the tholeiitic field of Irvine & Barager (1971), and the unit is olivine normative (Allen, 1976). The Gabbro is coarser grained than the mafic gneisses in the Erontonga metamorphics and weathers spheroidally. No chilled margins have been recognised and no igneous layering is present.

Structurally, the individual bodies are massive and non-foliated, although locally a weak foliation is defined by hornblende. Igneous textural relics are rare, but igneous plagioclase, orthopyroxene and clinopyroxene have been identified. The primary metamorphic assemblage is plagioclase-orthopyroxene-clinopyroxene-brown-green hornblende-ilmenite, although locally hornblende or ilmenite may be absent. Retrograde metamorphism results in the development of cummingtonite, blue-green hornblende, epidote and sphene.

Metamorphism

The Johannsen Metagabbro is the youngest unit in the Utnalanama Block to have undergone the initial granulite facies metamorphism. (Allen, 1976). Only rare textural relics of this event survive strong recrystallisation

during the second granulite facies metamorphism, but the S1 foliation associated with the M1 event is locally preserved. The Johannsen Metagabbro shows very good textural and mineralogical evidence for the other three metamorphic events. So, in common with the Utnalanama granulite, the Harry Anorthositic Gabbro and the Erontonga metamorphics, the Johannsen Metagabbro shows evidence for the five metamorphic events described in D-1-2.

Age and Origin

The field characteristics of the Johannsen Metagabbro is the lenticular, bifurcating and anastomosing intrusive pattern and sinuous character of the dykes (e.g. Watterson, 1968; Poole & Cresswell, 1973; Escher & others, 1976) indicate intrusion of this unit under synkinematic conditions. Other evidence, such as the unchilled margins, absence of deformation, and the total volume of mafic magma of the Johannsen Metagabbro accomodated in the Utnalanama Block is consistent with this interpretation and further indicates intrusion into hot rocks undergoing compression, i.e. synorogenic intrusion. Local development of the S1 foliation indicates intrusion during D1 and the syntectonic M1 metamorphism of the Utnalanama Block dated at 1800 m.y. (Allen & Stubbs, in press). Thus an intrusive age of approximately 1800 m.y. is postulated for the Johannsen Metagabbro (Allen, 1976).

D-1-17: Ingula migmatite suite pCsi (A.P.L.)

Definition

The Ingula migmatite suite consists of migmatite and quartzofeldspathic gneiss that enclose a number of small bodies of mafic granulite, cordierite gneiss, sillimanite gneiss and amphibolite and the Wuluma granitoid. The Wuluma granitoid is a member of the suite. The unit crops out 5.5 km south-southeast of Mount Milton in the central northeastern quarter of BURT as a region of heavily vegetated, monotonous, low, rocky hills. The name is derived from the aboriginal place name, "Ingula", the area 5.5 km north of Snake Well. The aboriginal name has been adopted as Ingula Hills the low hills on the southwestern margin of the unit. The reference section extends northwest from Salt Bush Bore

(GR 5651-930399) along a tributary of Burt Creek to GR 5651-905436. The unit is distinguished from the enclosing Erontonga metamorphics to the north, east and south by its large amount of mobilisate, granitic composition, paucity of cordierite gneiss and lack of felsic granulite. To the southwest it is distinguished from the Enbra Granulite by the latter's large amount of mafic granulite. In the southeast quarter of the suite quartzofeldspathic gneiss and migmatite are less easily distinguished from the Wuluma granitoid member because they have a gradational contact with the homogeneous, coarse-grained granitoid.

Relationships

The suite is bounded, typically by faulted contacts, to the north, east and south by the Erontonga metamorphics. Where this boundary is not faulted it is in part gradational because, although there is a distinct change in composition across the boundary, mobilisate generated in the granitic gneiss of the suite has invaded the cordierite gneiss of the Erontonga metamorphics. To the south the suite is faulted against the Erontonga metamorphics, but farther to the southeast the relationship is more complex because the suite is integral with the Wuluma granitoid. The Wuluma granitoid is interpreted to be an anatectic granite intrusive into Erontonga metamorphics. It is genetically related to the mobilisate in the migmatite of the Ingula migmatite suite. To the southwest the suite is truncated by a major northwest-striking fault. This fault is for the most part covered by Cainozoic sediment which overlies the western margin of the suite, but is exposed in three small hills 4 km north of Snake Well. Thus the western margin of the suite is faulted against the Enbra Granulite.

Lithology

The type area consists of monotonous, rocky, exposures of highly faulted migmatite and quartzofeldspathic gneiss enclosing small bodies of amphibolite, cordierite gneiss, mafic granulite, muscovite-biotite schist and garnet calc-silicate rock.

Migmatite consists of abundant coarse-grained (grains up to 5 cm across) mobilisate which encloses rafts (up to 8 m across) of poorly foliated biotite-quartzofeldspathic gneiss. The mobilisate (4343) consists of large anhedral grains of microperthite (30%), plagioclase (30%) and quartz (30%) biotite (10%). The biotite-quartzofeldspathic gneiss (4380, 4382) enclosed by the mobilisate consists of plagioclase (40%) quartz (30%) orthoclase (20%) and biotite (10%). It is fine-grained, equigranular and, in addition, rarely contains small amounts of hornblende, microperthite, muscovite and opaque minerals. The gneiss has a poor foliation defined by the preferred orientation of biotite, which generally parallels a vague compositional layering.

Cordierite gneiss (4387, 4388, 4344, 4347, 4350, 4286) occurs as small pods or lens-shaped bodies in the migmatite. It (4387) consists of coarse-grained quartz (50%), cordierite (40%), and biotite (10%).

Mafic granulite (4348, 4399, 4275, 4279, 4287) occurs as small pods and thin lenses. It consists of equigranular polygonal grains of plagioclase (40%), quartz (20%), clinopyroxene (15%), hypersthene (15%), and hornblende (10%) and is rarely mineralogically layered.

Garnet quartzofeldspathic gneiss (4384) occurs as a thin (15 cm wide) layer in migmatite and consists of fine-grained biotite (10%), subhedral garnet (15%), orthoclase (20%), plagioclase (20%), and quartz (30%) with small amounts of opaque grains (5%).

Two metagabbroic plug-like bodies occur in the type area. Sample (4386) is a fine-grained rock consisting of quartz (10%), hornblende (10%), clinopyroxene (10%), and long subhedral laths of plagioclase (70%). Sample (4274) consists of biotite (5%), hornblende (5%), clinopyroxene (10%), hypersthene (10%), quartz (35%) and small laths of plagioclase (35%).

Small amounts of amphibolite (4385, 4389, 4345) and calc-silicate rock (4285) occur as small lenses throughout the type area.

Structure

The suite is cut by numerous faults. In the rafts of quartzofeldspathic gneiss that occur within the migmatite, the foliation is defined by the preferred orientation of biotite and thin compositional layers. This foliation is commonly folded and the rafts are rotated relative to one another.

Metamorphism

The migmatisation of the probable upper amphibolite facies and pods and lenses of granulite facies are relic and show retrograde mineral facies.

Origin

The widespread migmatisation is probably related to the Wuluma granitoid but it is not clear whether the granitoid was derived by total melting of the suite or is an intrusive granite. The gradational boundaries between the two units and their similarity in composition tends to support the former.

Age and Correlation

The Wuluma granitoid has been dated at 1800 m.y. (Black, BMR personal communication 1978) but includes relic pods of granulite. Thus the migmatisation is related to the earliest metamorphism of the Strangways Metamorphic Complex but slightly post dates the granulite event dated at 1820 $\pm$ 78 m.y. λ = 1.42 (1860 m.y. λ = 1.39 Iyre & others, 1976).

D-1-18: Wuluma granitoid (pGsw) (APL) of Ingula migmatite suite

Definition

The Wuluma granitoid is a unit of granitic rocks which crop out over an area of 14 km^2 immediately south of Saltbush Bore, in the central eastern margin of BURT. The name is derived from 'Wuluma' the aboriginal rain dreaming area centred on 5651-935373 and is to be applied to the hills in the area. The type area is centred on 5651-925375 where coarse-grained granitic rock, enclosing rafts of biotite-quartzofeldspathic gneiss, is well exposed. The unit is distinguished from the surrounding Erontonga

metamorphics by its granitic composition and lack of cordierite granulite. The member is gradational with the Ingula migmatite suite, but distinguished from it by its homogeneous, coarse-grained granitic character.

Relationships

The unit is a member of the Ingula metamorphic suite, into which it grades to the northwest and west. It intrudes Erontonga metamorphics to the east and is faulted against the metamorphics to the north and south.

Lithology

The type area consists of large rounded boulders and smooth pavements of granitoid. The granitoid is homogeneous on the macroscopic scale, structurally isotropic and very coarse-grained. It commonly encloses rafts (up to 1 m thick and several metres long) of mobilisate-rich biotite-quartzofeldspathic gneiss. Granitoid (4246, 4247) consists of biotite (7%), altered plagioclase (20%), microcline (30%) and quartz (40%) together with a small amount of muscovite and opaque grains. The microcline and plagioclase occur as large (0.3-0.5 cm across) megacrysts with ragged recrystallised boundaries. These megacrysts are set in recrystallised fine-grained matrix of quartz.

Away from the type area granitoid (4248) is similar to 4246, except near the intrusive contact with Erontonga metamorphics. Near this margin coarse-grained granitoid (4508, 4509) consists of biotite (5%), plagioclase (15%), microperthite (40%), and quartz (40%). The rock is granoblastic and unaltered.

Origin

The gradational contact with the Ingula migmatite suite and similarity in composition between the granitoid and the mobilisate of the suite suggests that the granitoid was derived by total melting of the suite during metamorphism.

Age and Correlation

A sample of the granitoid from the type area was dated by the Rb/Sr whole-rock method (Black, personal communication, 1978). The intrusion is related to the earliest metamorphism of the Strangways Metamorphic Complex. It is dissimilar to the Anamarra orthogneiss and Oolbra orthogneiss because it is relatively unmetamorphosed.

D-2: Division 1: Units similar to the Strangways Metamorphic Complex

D-2-1: Hillsoak Bore metamorphics (pGz) (AJS)

Definition

The Hillsoak Bore metamorphics are the sequence of marble, calc-silicate rock, andalusite schist, amphibolite and schist, quartzite two-mica schist, granitic gneiss, biotite gneiss, sillimanite gneiss, amphibolite, quartzofeldspathic gneiss and quartz-plagioclase rock that crops out in the western part of the White Range Nappe, in the southwest of RIDDOCH and northwest of FERGUSSON RANGE. A small separate outcrop of marble and andalusite schist belonging to the unit is situated in the northeast of UNDOOLYA, immediately north of Ross River Tourist Chalet. The unit forms low scrubby hills and ridges; the marble is noted for its vicious growth of giant spinifex grass. The name of the unit is derived from Hillsoak Bore, at the western margin of the outcrop-area. In RIDDOCH, the biotite gneiss is easily distinguished from the adjoining metatonalite of the Atnarpa Igneous Complex by the non-layered and schistose nature of the metatonalite, together with its abundant muscovite and epidote. In FERGUSSON RANGE, the marble is distinguished from the adjoining unmetamorphosed carbonates of the Bitter Springs Formation by its much higher metamorphic grade.

Relationships

The Hillsoak Bore metamorphics in RIDDOCH interfinger to the east with metatonalite of the Atnarpa Igneous Complex. In FERGUSSON RANGE, the Hillsoak Bore metamorphics are overlain with an angular unconformity by the Upper Proterozoic Heavitree Quartzite to the south, and faulted against the Upper Proterozoic Bitter Springs Formation to the west.

Lithology

The type section of the Hillsoak Bore metamorphics extends from 5850-515967 for 6 km to 5850-565994, in FERGUSSON RANGE. The section begins in the west with a unit of thinly interbedded marble and calc-silicate rock apparently 800 m thick, but this figure in no way represents the true

thickness because of ubiquitous folding and boudinage (Figs D12, D15). The marble is white to pink, fine-grained, and consists of xenoblastic calcite (80%), quartz (10%), and epidote (10%), together with accessory microcline, muscovite, hematite, and chlorite (68110003(i)). Calc-silicate laminae are yellow-brown, very fine-grained, and consist of quartz, microcline, epidote, and chlorite (68110003A).

A unit of interbedded calc-silicate rock and marble overlies with apparent conformity the marble and calc-silicate unit, and is distinguished from it by a much greater proportion of calc-silicate, and by the distinctive dark brown weathering crust characteristic of calc-silicate rocks in the area. The unit is apparently about 1200 m thick, comprises interlaminated calc-silicate rock coloured in bands of green, white, and yellow, calc-silicate marble, and metapelite, and is commonly much folded. The rocks consist of assemblages in various proportions of calcite, clino-amphibole, epidote, diopside, microcline, and quartz. Symmetrical mineralogical zoning parallel to the laminae is common. One example (68110048) comprises a central marble zone (0.65 cm wide) of calcite (75%), actinolite sheathed with idioblastic tremolite (15%), microcline (5%), epidote (3%), quartz (2%), and accessory sphene. This zone is flanked on each side by calc-silicate layers (0.4 cm wide) composed of coarse poikiloblastic diopside (30%), tremolite (30%), calcite (30%), microcline (7%), quartz (2%), and sphene (1%). These zones are in turn flanked by concentrations of microcline adjoining the metapelite laminae, in places forming monomineralic layers. These metapelite laminae are of two types:

1. quartz-free laminae, consisting of muscovite (80%), chlorite (20%), and in some specimens small idioblasts of golden monazite around detrital grains of the same mineral;

2. quartz-rich laminae, consisting of quartz (40%), chloritised biotite (30%), and microcline (30%) which is again concentrated along the outer sides of the laminae against neighbouring quartz-free laminae.

Rare black laminae in the calc-silicates are rich in tourmaline. One specimen (68110186) from the northern part of the outcrop contains abundant orange garnet (andradite?).

Overlying the calc-silicate and marble unit, again with apparent conformity, is a persistent layer of friable, red-brown andalusite schist. The rock comprises abundant stubby blue porphyroblasts of andalusite up to 2.5 cm long, in a matrix of quartz, muscovite, biotite, sillimanite (concentrated along the margins of andalusite crystals), hematite, and detrital tourmaline (68110078). The andalusite porphyroblasts are crowded with small blebby inclusions of quartz, and are mantled by sericite; in places, the andalusite is completely replaced by sericite. In the small outcrop of Hillsoak Bore metamorphics immediately north of Ross River Tourist Chalet in UNDOOLYA, finely spotted schist consists of small porphyroblasts of andalusite mantled by quartz + sericite, and small idioblasts of colourless spinel in a very fine-grained groundmass of quartz, muscovite, and strongly chloritised biotite (68110003B).

An interbedded sequence about 1200 m wide of amphibolite, schist, and quartzite, succeeds the andalusite schist; the quartzite is in places repeated by folding. The amphibolite has not been thin-sectioned; it is fine-grained, foliated, and consists chiefly of actinolite, accompanied by small porphyroblasts of garnet in some specimens. Calcite coats joints and forms lenticles about 3 cm long in parts of the amphibolite. Schists in the sequence are pale, fine-grained, granoblastic to lepidoblastic, and include muscovite-biotite-microcline-quartz schist (68110005A(i)), muscovite-quartz schist (-0005A(ii)), and sericite (after plagioclase?)-microcline-quartz schist (-0184). Quartzite in the sequence occurs as pods a few metres thick. It is thin-bedded, has a characteristic variegated red, white, and blue appearance, and is composed of polygonal quartz (80%), xenoblastic calcite (5%), idioblastic hematite (5%), and accessory limonite and chlorite (68110079).

Granitic gneiss crops out in the northernmost part of the outcrop area, and comprises fine-grained granitic gneiss interlayered with coarse grained feldspathic and pegmatitic gneiss, and lesser amounts of red, tourmaline-bearing pegmatite. The rocks have not been thin-sectioned.

Two-mica schist crops out in the southeasternmost part of the outcrop area, on strike with the granitic gneiss. The rock is streaky pale brown and white, fine-grained, strongly foliated and flaky, non-layered, and weathers to pinkish-brown steeply-dipping ellipsoidal slabs. It consists of quartz (60%), muscovite (30%), and biotite (10%). A composite amphibolite-schist body within the two-mica schist consists of actinolite schist, crenulated chlorite schist, and coarse-grained massive plagioclase-hornblende amphibolite.

The biotite-gneiss is generally medium to coarse-grained, strongly schistose, and lineated. It is commonly layered, and the dark layers are usually composed entirely of coarse biotite. In places the gneiss is non-foliated, and lineated only. The rock is heterogeneous in composition, and consists of strained quartz (50 to 70%), kinked biotite (10 to 30%), containing numerous tiny grains of colourless spinel, fractured oligoclase (0 to 35%) which is partly or completely converted to sericite, muscovite (1%), and accessory microcline, broken zircon grains, and apatite. In some specimens, the biotite is weakly chloritised. Garnet is of very local occurrence; it forms dodecahedral idioblasts up to 3 cm across, and was observed only in the far southeast of the outcrop-area, in the vicinity of the outcrop of sillimanite gneiss. At specimen locality 68110111 (5850-589983), a patch of coarse biotite schist contains xenoblastic garnets up to 10 cm across. Pegmatitic layers in the gneiss at locality 68110181 (5851-544017), 2.8 km northeast of Hillsoak Bore, contain similar xenoblastic garnet concentrations, and the biotite gneiss itself contains 15 percent microcline. In the northwest of the area, 5 km west of Gidyea Bore, the gneiss (68110282; 5851-490129) is very rich in quartz (75%), plus sericite (10%) in large aggregates after Al_2SiO_5(?), chlorite (10%), biotite (3%), muscovite (1%), and oligoclase (1%). At most localities in the biotite gneiss, irregular masses a few metres across of fine-grained leucocratic biotite-bearing quartzofeldspathic gneiss are present, and are commonly accompanied by coarse pegmatite.

Sillimanite gneiss crops out as a small body straddling the eastern edge of LAUGHLEN and western edge of RIDDOCH on the southern side of the Hale Plain, and as a larger body south of Paddy's Plain, at the far southeastern end of the Hillsoak Bore metamorphics outcrop-area in FERGUSSON RANGE. The rock is essentially similar to the biotite gneiss, but in addition carries bluish-white sheafs and streaky clusters of fibrous sillimanite, forming up to 3 percent of the rock. Whitish ellipsoidal nodules of quartz + sillimanite up to 5 cm across are common in the outcrop south of Paddy's Plain. The outcrop straddling LAUGHLEN and RIDDOCH is a composite assemblage of sillimanite-biotite-feldspar gneiss, muscovite schist, and contorted feldspathic schist (68110268).

Amphibolite is most abundant in the far southeast of the outcrop area in FERGUSSON RANGE, where it forms lenses up to 2 km long in the sillimanite gneiss. However, it is also very common in the biotite gneiss, where it forms pods and masses a few metres across at almost every locality, although rarely large enough to map. The amphibolites are of three kinds:

(1) the first kind (68110074, -0112, -0115, -0120, -0138, -0142) is medium-grained, massive to weakly foliated, and composed of hornblende or actinolite (60 to 80%), sericite (10 to 40%), quartz (0 to 10%), and accessory biotite, ilmenite, and hematite. The sericite aggregates are accompanied by clinozoisite, and contain remnants of plagioclase in some specimens. Other secondary minerals include chlorite after biotite, and rims of sphene around ilmenite. Garnet occurs as idioblasts up to 2 cm across in 68110112, surrounded by white shells of sericite and clinozoisite, and forms 10 percent of this rock.

(2) The second kind of amphibolite (68110122, -0141) is coarse to very coarse-grained, massive, and consists of tremolite (50%), sericite (30 to 40%) ± clinozoisite, garnet (15%), and quartz (5%). The garnet occurs as idioblasts up to 2.5 cm across; some of them show snowball structure, and all are mantled by shells of sericite ± clinozoisite and a small amount of fine anthophyllite.

(3) The third kind of amphibolite is a body of cordierite-anthophyllite rock (68110123) in the southeasternmost part of the outcrop area. The rock is massive, medium to coarse-grained, and consists of pale brown prismatic anthophyllite (60%), cordieriet (25%) veined by pinite, sericitised oligoclase (10%), quartz (3%), accessory biotite (chloritised), rounded grains of zircon, and hematite. In the southern part of the body (68110125), oligoclase forms a much greater proportion of the rock, and in some specimens abundant grey-brown garnet is present whereas cordierite is absent. The body is cut by two black dykes (68110124) composed of anthophyllite, cordierite, garnet intergrown with quartz, biotite, sericitised plagioclase, chlorite, and opaque grains.

Quartzofeldspathic gneiss has been delineated solely by photo-interpretation, and forms four lenses disrupted by faulting from a single horizon in the biotite gneiss 5 km northeast of Hillsoak Bore, together with a larger equant mass 0.5 km west of the largest lens. A sixth body is photointerpreted 5 km southwest of Gidyea Bore.

Quartz-plagioclase rock crops out immediately west of the Cavenagh Range, and is accompanied by interbeds of amphibolite and quartzite. The quartz-plagioclase rock is fine to medium-grained, and includes a few thin pegmatitic layers of quartz, feldspar, and garnet. The typical rock (71911720) in the southern part of the outcrop comprises labradorite (An_{57}:47%), quartz (35%), brown hornblende (15%), diopside (3%), and accessory sphene. Farther north, the assemblage is clinozoisite (48 to 62%) in coarse aggregates, quartz (10 to 40%), tremolite or actinolite (5 to 10%), green-brown hornblende (0 to 10%), coarse sphene (0 to 3%) and accessory epidote and calcite (71911721, -1731, -1732). Sample -1732 also contains labradorite (An_{64}:8%), zoisite, and accessory euhedral allanite. These assemblages indicate retrogressive metamorphism of the quartz-plagioclase rock from amphibolite to greenschist facies.

At specimen locality 71911726 west of the Cavenagh Range, quartz-dolomite rock forms a concordant east-dipping vein about 25 m long and 1 m thick in the quartz-plagioclase rock, and is accompanied by

a selvedge of green chalcedony on its under side. A parallel vein of quartz-limonite rock crops out about 15 m east of the dolomite vein. Two samples of the dolomite were semi-quantitatively analysed for trace elements, and the results are set out in Table D-2-1B.

Structure

Two generations of folds are present in the marble and calc-silicate rocks of the Hillsoak Bore metamorphics. The earlier folds are tight to isoclinal (Photo D12-14), with subhorizontal axes plunging gently northwest or southeast, and axial planes parallel to the lithological layers. Later folds are kink folds, generally in parallel sets striking east and dipping about 50° south; in places the conjugate set is also present. Another major set strikes north and has a steep to vertical dip. Quartz veins in the two-mica schist are commonly tightly folded and boudinaged about steeply plunging axes with axial planes parallel to the prevailing schistosity. At one locality (5850-550952), the axial-plane schistosity is itself folded about a gently north-plunging axis. Boudins are well developed in the calc-silicate rocks (Photo D15), and range in plunge from northeast to southeast in the plane of the layering; the boudins are folded by, and hence predate, the folds in the calc-silicates.

The layered parts of the biotite gneiss are tightly to isoclinally folded in a few widely separated localities. At specimen locality 68110181 (GR5851-544017), ptygmatic folds are present in the leucocratic layers of the gneiss, and post-date the isoclinal folds. Some bodies of pegmatite in the gneiss are folded, and the hinges are commonly thickened and grade into mullions.

Metamorphism

The assemblage calcite-epidote-quartz in the marble of the Hillsoak Bore metamorphics is indicative of the greenschist or low amphibolite facies. The associated calc-silicate rocks contain these minerals together with microcline, actinolite, tremolite, diopside, and rare andradite(?), and the last two are indicative of the amphibolite facies. The assemblage in the associated schist is sillimanite-andalusite-muscovite-biotite-quartz. Hence, the rocks have been regionally metamorphosed

TABLE D-2-1B: Results (in ppm) of semi-quantitative analyses of trace elements in quartz-dolomite vein in Hillsoak Bore metamorphics (1726 A,B), and in marble veins at Tommy's Gap (1885A,B), together with average abundances in carbonatites and limestones for comparison.

Element	Sample number, preceded by 7191-				Av. abundance in carbonatites	Av. abundance in limestones
	1726A	1726B	1885A	1885B		
Nb	n.d.	n.d.	n.d.	n.d.	1951[1]	0.3[2]
Co	n.d.	n.d.	n.d.	n.d.	17[1]	0.1[1]
Ni	30	10	10	5	8[1]	20[1]
V	1000	10	n.d.	n.d.	150-300[3]	5-20[4]
Cr	20	n.d.	20	20	48[1]	11[1]
Ti	600	100	100	100	4376[5]	300[6]
Ba	100	100	n.d.	100	3583[5]	220[6]
Sr	100	100	n.d.	n.d.	3900[5]	420[6]
La	n.d.	n.d.	n.d.	n.d.	516[1]	14[7]
Pr	n.d.	n.d.	n.d.	n.d.	ca.40[8]	1.4[9]
Nd	n.d.	n.d.	n.d.	n.d.	733[10]	4.5[9]
Y	30	30	10	50	96[1]	13[7]
P	n.d.	n.d.	n.d.	n.d.	9120[5]	400[2]
Rb	n.d.	n.d.	n.d.	n.d.	ca.zero[11]	60[6]

n.d. = not detected. AMDL Report AN441/76. Emission spectroscopy.

1. Heinrich, 1966, p.225, Table 8-b (after Gold, 1963).
2. Turekian & Wedepohl, 1961, Table 2.
3. Dawson, 1966, Table 3.
4. Honjo & Tabuchi, 1970.
5. Heinrich, 1966, p.222, Table 8-2, column 5 (recalculated to element %).
6. Graf, 1960, Table 19.
7. Muir et al., 1956.
8. Heinrich, 1966, p.234.
9. Haskin & Gehl, 1962, Table 1.
10. Loubet et al., 1972, Table 1.
11. Heinrich, 1966, p.242.

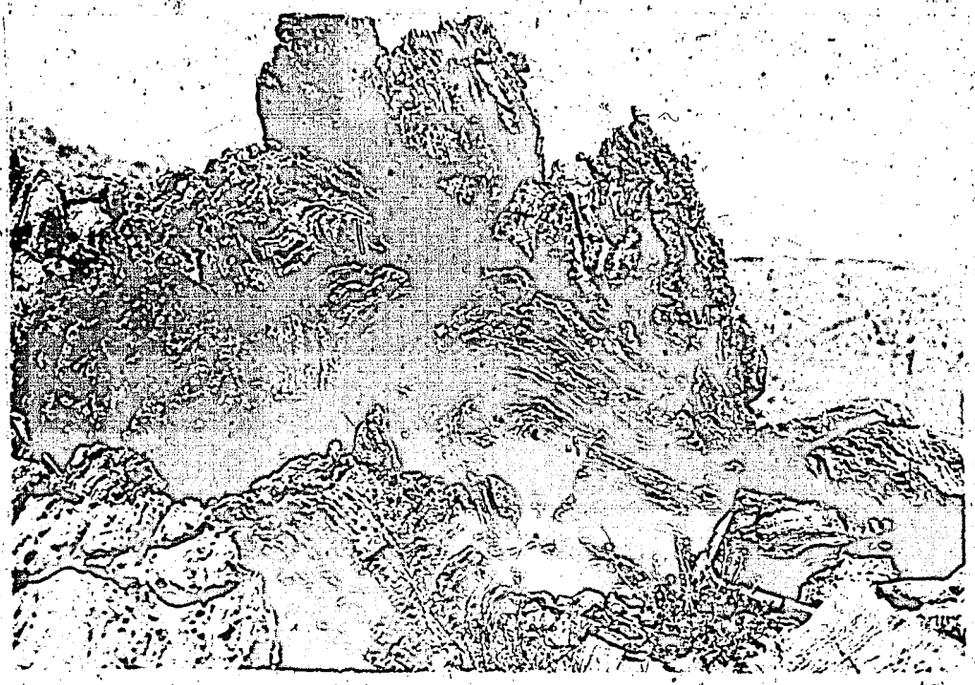


Photo D12: Tightly folded marble and calc-silicate rock of Hillsoak Bore metamorphics (3.5 km south of Hillsoak Bore). 5850-516966.

Photo D13: Isoclinally folded calc-silicate rock of Hillsoak Bore metamorphics (5 km south-southeast of Hillsoak Bore). 5850-527955.

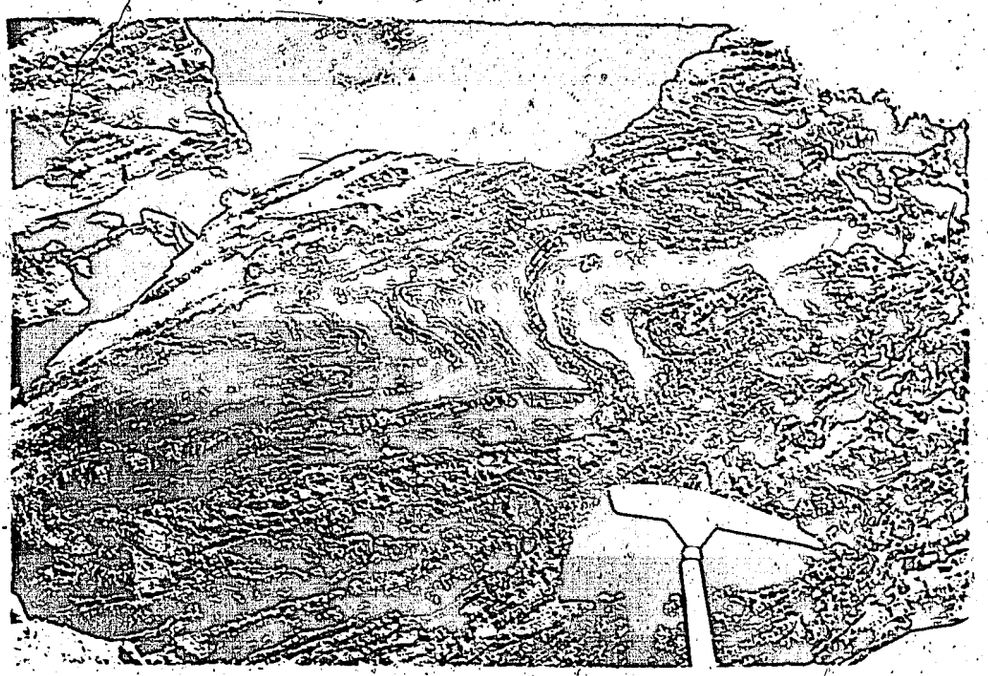


Photo D14: Tight to isoclinal folds in metapelite laminae in marble of Hillsoak Bore metamorphics (3.5 km south of Hillsoak Bore). 5850-516966.

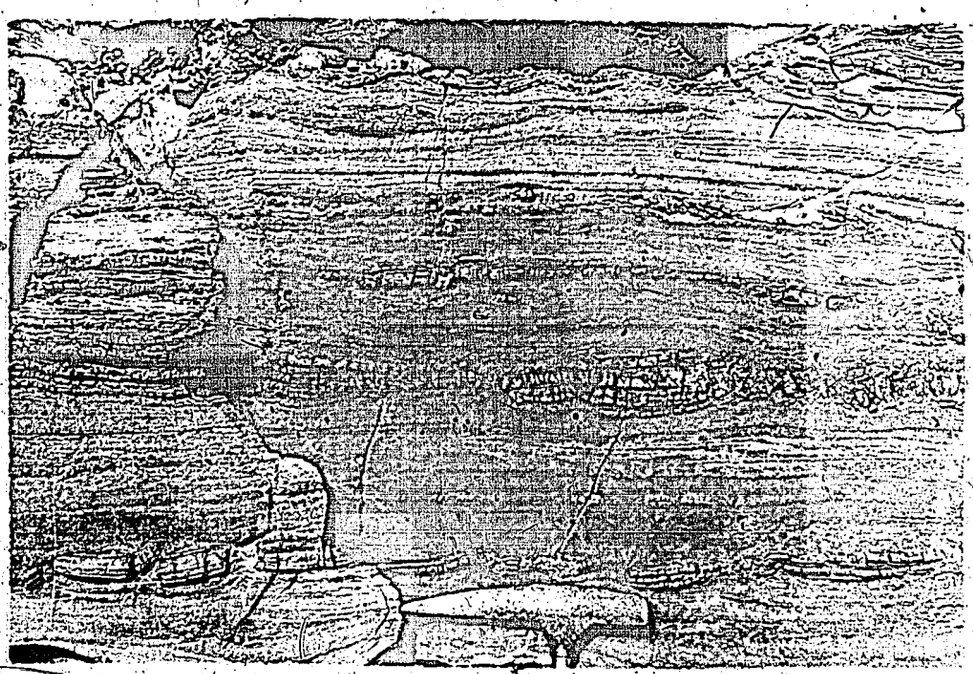


Photo D15: Boudins of calc-silicate rock in marble of Hillsoak Bore metamorphics (3.5 km south of Hillsoak Bore). 5850-516966.

under conditions transitional from low to middle amphibolite facies. The presence of andalusite, cordierite, and anthophyllite indicates low-pressure conditions.

The symmetrical mineral zonation of the calc-silicate laminae in the southwestern part of the Hillsoak Bore metamorphics is an example of small-scale metasomatic diffusion down a compositional gradient normal to the laminae (Vidale, 1969; Thompson, 1975). If one assumes that the parent sediment was a quartzose dolomitic marl between beds of mudstone or shale, the assemblage in the centre of the symmetrical layer could have formed by the reaction:

$$25CaCO_3MgCO_3 + 6KAlSi_3O_8 + 28SiO_2 + 6H_2O \rightarrow 5Ca_2Mg_5Si_8O_{22}(OH)_2 +$$
dolomite — microcline — quartz — tremolite

$$11CaCO_3 + 2Ca_2Al_3Si_3O_{12}(OH) + 39CO_2 + 3K_2O$$
calcite — epidote

In the succeeding zones, the epidote, K_2O, and some of the tremolite react thus:

$$2Ca_2Mg_5Si_8O_{22}(OH)_2 + 2Ca_2Al_3Si_3O_{12}(OH) + 12SiO_2 + 3K_2O \rightarrow$$
tremolite — epidote — quartz

$$8CaMgSi_2O_6 + 6KAlSi_3O_8 + 3H_2O + 2MgO$$
diopside — microcline

In the second variety of amphibolite west and south of Paddys Plain, the mantles of plagioclase + anthophyllite around garnet may have formed by the reaction (following Misch & Onyeagocha, 1976):

$$14(Fe,Mg)_3Al_2Si_3O_{12} + 7Ca_3Al_2Si_3O_{12} + 27SiO_2 + 6H_2O \rightarrow$$
almandine-pyrope — grossularite — quartz — water

$$6(Mg,Fe)_7Si_8O_{22}(OH)_2 + 21CaAl_2Si_2O_8$$
anthophyllite — anorthite

and in the cordierite-anthophyllite body, growth of the garnet-quartz porphyroblasts may be explained by the reaction:

$$\underset{\text{cordierite}}{3Al_3(Mg,Fe)_2Si_5AlO_{18}} + \underset{\text{anthophyllite}}{3(Mg,Fe)_7Si_8O_{22}(OH)_2} + \underset{\text{oligoclase}}{(4NaAlSi_3O_8 + CaAl_2Si_2O_8)}$$

$$\rightarrow \underset{\text{garnet}}{9(Mg,Fe)_3Al_2Si_3O_{12}} + \underset{\text{quartz}}{26SiO_2} + 3H_2O + 4Na^+ + Ca^{++} + 30^=$$

The latter reaction indicates the transition from the lowest to middle amphibolite facies of the low-pressure facies series (specifically, from the andalusite-cordierite-muscovite subfacies to the sillimanite-cordierite-muscovite-almandine subfacies of Winkler, 1967).

The partial or complete alteration of plagioclase to sericite ± clinozoisite, cordierite to pinite, biotite to chlorite, andalusite to sericite, and ilmenite to sphene all indicate a later episode of retrogressive metamorphism to low greenschist facies. The effects are visible in nearly every thin section, indicating that the retrogression, although patchy and incomplete, was very widespread.

Origin

The abundance of aluminous and calcareous minerals in the Hillsoak Bore metamorphics indicates that they were originally a sequence of limestone, dolomite and marl, pelite, and quartz sandstone that underwent low-pressure regional metamorphism. The absence of layering in the associated amphibolite suggests an origin as basic flows or sills. The absence of layering in the two-mica schist, and its field resemblance to a schistose granite suggests that it is, in fact, a retrogressively metamorphosed granite in which the original microcline has altered to muscovite + quartz, as suggested by Armstrong & Stewart (1975). The body of granitic gneiss which interfingers along strike with the two-mica schist may be the unretrogressed, although foliated, part of the original granite.

Age and Correlation

Isotopic dates on ten mineral concentrates and three whole rocks from the Hillsoak Bore metamorphics are set out in Table D-2-1A. As discussed by Armstrong & Stewart (1975), the three whole-rock samples are very enriched in rubidium, and lie well below an isochron of 1719 ± 24 m.y. obtained from samples of the neighbouring Cadney metamorphics, Cavenagh metamorphics and Atnarpa Igneous Complex. Hence, the Hillsoak Bore metamorphics are regarded as having been regionally metamorphosed at 1687 ± 23 m.y., λ = 1.42 (1719 ± 24 m.y., λ = 1.39) and then underwent later ^{87}Sr mobilisation, possibly during the Alice Springs Orogeny. Thus, the Rb/Sr whole-rock dates in the Hillsoak Bore metamorphics were rendered meaningless. Similarly, the K-Ar dates on hornblende and biotite were also probably partly reset by the same event. The two sericite K-Ar dates are distinctly different from the others, and probably result from introduction of extraneous argon into sericite formed during the Alice Springs Orogeny, as found in biotite and muscovite in retrogressively metamorphosed tonalite from the Atnarpa Igneous Complex in the northern part of the White Range Nappe (Armstron & Stewart, 1975).

The Hillsoak Bore metamorphics lithologically resemble the Cadney metamorphics - both units have a dominantly calcareous part with subordinate metapelite, amphibolite, and quartzite, and a dominantly pelitic upper part, characterised by biotite and sillimanite gneisses and subordinate quartzofeldspathic gneiss. The similarity of the two units extends to the rock-types present in small amounts - anthophyllite rocks and meta-ultrabasic rocks are associated with both. Hence, the Hillsoak Bore metamorphics and Cadney metamorphics are correlated. The Hillsoak Bore metamorphics is similar lithologically to Unit pCsl, which consists mainly of very schistose biotite gneiss and small amounts of layered amphibolite, and is also thought to be a facies equivalent of the Cadney metamorphics.

TABLE D-2-1A: Isotopic dates from Hillsoak Bore metamorphics

Sample No.	Lithology	Material Dated	Date (m.y.)	Reference
Potassium-Argon Dates				
68110074	Amphibolite	Hornblende	1660	A
68110078	Andalusite schist	Muscovite	1532	A
68110082	Two-mica Schist	Muscovite	1371	A
68110082	" " "	Biotite	1371	A
68110109	Biotite gneiss	Sericite	534	B
68110122	Amphibolite	Sericite	596	B
68110115	Coarse biotite mass in amphibolite	Biotite	1368	A
68110144	Biotite gneiss	Biotite	1377	A
68110181	Coarse biotite segregation in biotite gneiss	Biotite	1481	A
68110270	Amphibolite	Hornblende	1639	A
Rubidium-Strontium Dates				
68110082	Two-mica schist	Whole rock	1395	C
68110115	Coarse biotite mass in amphi-bolite	Whole rock	1562	C
68110144	Biotite gneiss	Whole rock	873	C

A = Stewart (1971a); B = Stewart (1971b) C = calculated from data in Armstrong & Stewart (1975)

D-2-2: Unnamed unit, pGx (R.D.S.)

Definition

Unit pGx crops out as extensive, low, generally, northeasterly-trending ridges between Mount Chapman and Ruby Gap in RIDDOCH. It is divided into seven subunits:

Subunit pGx_1 is characterised by porphyroblastic feldspar gneiss, quartzofeldspathic gneiss and calc-silicate rock, and crops out in the northeastern part of the outcrop-area.

Subunit pGx_2 is characterised by garnetiferous and biotite-rich gneiss and crops out in the area of Star and Pig Hole Creeks in the eastern part of the unit.

Subunit pGx_3 consists of homogeneous quartzofeldspathic and biotite gneiss of granitic appearance and crops out in the north of Unit pGx and in the southeast of the unit about 4 km north and northeast of Ruby Gap.

Subunit pGx_4 is similar to subunit 3, but has a much better developed layering and includes calcareous gneiss and marble beds. It crops out in the southwestern and southern parts of the Unit.

Subunit pGx_5 consists of bodies of amphibolite or mafic granulite that have a shape suggestive of an intrusive origin. It is not shown as a separate stratigraphic unit in the Preliminary Map, but simply as a rock type.

Subunit pGx_6 is a sequence of mainly biotite and quartzofeldspathic gneiss that is tentatively correlated with subunit 2. These rocks crop out farther southeast in the main outcrop-area in the core of the Ruby Gap Nappe, south of Star Creek. This unit has been changed to pGf on the Alice Springs 1:250 000 Preliminary map.

Subunit pGx_7 consists of quartzofeldspathic gneiss and amphibolite, both of which have undergone varying degrees of greenschist retrogression. The subunit is correlated with subunit 4. This unit has been changed to pGf in the Alice Springs 1:250 000 Preliminary map.

As future mapping will probably lead to formal subdivision of unit pGx, no type areas are given. The section exposed in Star Creek was used to erect the informal subunits presented here.

pGx_1 is somewhat similar to the Cavenagh metamorphics, but is distinguished from it by the presence of porphyroblastic feldspar gneiss. However, it is also similar to parts of the Hillsoak Bore metamorphics. pGx_2 is similar to garnetiferous-biotite gneiss exposed in the core of the White Range Nappe, which are tentatively assigned to the Hillsoak Bore Metamorphics, but is distinguished from them by its greater proportion of quartzofeldspathic gneiss and amphibolite. pGx_3 is similar in composition to granitic rocks from the Atnarpa Igneous Complex, but is much more gneissic and has undergone granulite facies metamorphism at its northwestern end. pGx_4 is similar to the interlayered felsic and mafic rocks of the Ongeva granulite, but is retained in Unit pGx, because it is transitional with subunit 2 and is of a distinctly lower metamorphic grade. Subunits pGx_6 and pGx_7 in the core of the Ruby Gap Nappe are correlated with subunits 2 and 4 respectively from the main outcrop-area, but are kept as separate units because the units in the Nappe are markedly allochthonous.

Relationships

In the northwest pGx, principally pGx_3, is overlain by a tongue of Cadney metamorphics south of Paradise Well. In the northeast, pGx grades across the Hale River into mafic and felsic granulites assigned to the Ongeva granulite. North of Stewart Hole Yard, pGx is interpreted to be overlain by the postulated extension of the Bungitina metamorphics. This boundary roughly follows the Hale River. The exact relationships remain problematical partly because the boundaries are obscured by weathering and a cover of aluvium, but principally because of the necessarily poorly defined nature of the rock units.

The southern and eastern boundaries of pGx is a long, narrow, curved zone of greenschist retrograde metamorphism, which corresponds to a major thrust zone in the Arltunga Nappe Complex. Rock farther southeast in the core of the Ruby Gap Nappe are tentatively correlated with subunits 2 and 3 of Unit pGx based on lithological criteria.

To the northwest in a region of low hills surrounded by alluvial flats, subunit 3 of pGx passes across the Hale River into mafic and felsic granulites assigned to the Ongeva granulite.

Lithology

Subunit (pGx_1)

pGx is characterised by resistant, scarp-forming quartzofeldspathic and porphyroblastic-feldspar gneisses, and less resistant, moderately dissected, micaceous gneisses, calc-silicate rock and marble (f, b, p, f, cs, ma). The subunit occupies two northeast-trending synforms: (1) one extends from the headwaters of Pig Hole Creek (5851-855085) towards the southeastern slopes of Mount Russell; and (2) the other is located at 5851-935130, 4-5 km southwest of Stewart Hole Well (abd.).

(1) At the base of the subunit in the upper reaches of Pig Hole Creek a unit of photo-interpreted muscovite-biotite schist, calc-silicate rock, biotite gneiss, amphibolite and marble (s, cs, b, a, ma) passes upwards into a layered quartzofeldspathic gneiss containing a few intercalations of marble and chlorite-muscovite schistose gneiss (f, r, ma). At Star Creek, in the same synform farther northeast and higher in the succession, a unit of garnet-biotite and epidote-actinolite calc-silicate rocks (cs-847, Table B), amphibolite (a-848, Table C), rare marble (ma) and photo-interpreted biotite gneiss (b, p), is overlain by a quartzofeldspathic gneiss (f, s) interlayered with a medium-grained muscovite-biotite gneiss, which contains plagioclase and microcline porphyroblasts, 1-5 mm across (p; 849, 2433; Table A).

TABLE D-2-2A: Estimated modes for quartzofeldspathic gneisses from Unit pGx.

SUBUNIT	1				2			3			4	
SPECIMEN NUMBER	849	2433	2470	2471A	845	842A	1032A	2416	2430	833B	839A	840B
SYMBOL	p	p,s	f,s	f	f	j,vf	gg,f	f	f	f	s,f	f
Quartz	30	30	55	69	30	70	56	35	35	40	30	30
Plagioclase	39	25	25	15	10	2	15	25	35	25	10?	5
Biotite	10	7	1	10	7		5	10	12	tr	8	0.5
Garnet						tr						
K-feldspar	5	3		5	53		20	25	3	36	45	59.5
Epidote/ clinozoisite	4	10	7	1		10	2	6	10	2	4	3
Actinolite				tr						tr		
Muscovite	5	25	12			15	2	4	2		3	2
Chlorite	3	2				3				2	tr	
Calcite	2	3				tr			1			
Sericite	1	tr			tr		tr		2		tr	tr
Opaque grains	1						tr		tr		tr	tr
Sphene	tr			acc							tr	
Apatite	tr											

acc = accessory

tr = trace

TABLE D-2-2B: Estimated modes for miscellaneous gneisses from Unit pCx.

SUBUNIT	1		2							3
SPECIMEN NUMBER	847	2471B	842A	2530	2532	2531	843B	844	850	2413
SYMBOL	cs	s	j,vf	v,b	z,vm	v,h	h	h	h	h
Plagioclase	56	6	2	30	5?	52	16	50	18	37
Hornblende							12			
Actinolite	10					1.5	4	15	15	16
Quartz	12	45	70	48	53	30	52		35	34
Biotite	1	13		15	6	18	1	22	20	10
K-feldspar	1						10		2	1
Garnet			tr	0.5	4	4				
Sillimanite										
Epidote/ clinozoisite	15	2	10	1		1.5	5	10	10	6
Muscovite/ sericite	3	18	15	1	27	2		3	tr	tr
Chlorite	0.5	13	3	2.5	4	1				
Opaque Grains	1.5	3		2	tr	tr			1.0	
Sphene	acc			tr	tr	tr				
Apatite	acc									
Calcite			tr							

acc = accessory

tr = trace

TABLE D-2-2C: Estimated modes for mafic rocks from unnamed unit pCx

	1032B	853	2523	2439	2431	2527	839B	840A	2411	2432	848	2435	846A	2478	843A	2529	837	842B
Clinopyroxene	25	12												20		14		
Orthopyroxene	8	6														5		
Plagioclase	53	60	55	30	40	39	5	19	13	13	23	37	40	55	35	65	6	34
Hornblende	10	10	40	25	38	40	45?		20	25	60	35	10		46	16	30	45
Biotite		0.5			1			2		5		6	3	5				0.5
Quartz			5			-	5	10	30	16	10	?	15		1		10	10
K-feldspar		10?											1?					
Opaque Grains	4	tr	tr	tr	acc	tr	4	1	tr		tr	ac	tr	tr	2	ac	ac	tr
*Actinolite/Tremolite			5	35	17	7	30	60	35	15	2	7	20	20	8		35	4.5
Epidote/Clinozoisite			6	10	4	12	3	4	2	20	2	4	1		6		15	2
Muscovite/Sericite		1.5	2		tr	2	2	3			8	4						1
Chlorite								0.5				4					1	3
Calcite			7		tr					6		3					4	
Sphene					acc				tr									
Apatite	tr																	tr
plag. bent		X	X	X		X				X					X			X
plag. sl. bent	X				X		X						X	X		X		
granoblastic			X			X		X										X
granoblastic-elongate					X						X		X					
schistose								X	X	X					X		X	
Granuloblastic	X	X		X					X					X		X		
Grainsize	m	c-m	m	m	m	m	m	m	f	m	m	m	m	f	m	m	f	m

*Actinolite used for pale green or blue green amphibole with an extinction angle less than 15°

(2) In the synform southwest of Stewart Hole Well (abd) a similar porphyroblastic feldspar gneiss to that described above (p.848, 2433) contains small amounts of hornblende and epidote. Immediately underneath the porphyroblastic-feldspar gneiss, calc-silicate rock is interlayered with muscovite-quartzofeldspathic gneiss and biotite gneiss. Farther north, at the same structural level as the calc-silicate rock there is a sequence of mainly pelitic gneisses (v, a, e; v, b, s) which includes garnet-biotite gneiss, amphibolite, biotite gneiss (2471A), biotite-muscovite schist (2471B), and quartzofeldspathic gneiss. Immediately to the north, on a low plain covered by quartz scree between the synform and the Hale River, poorly exposed muscovite-biotite (2470, f, s, Table A) and chlorite-bearing quartzofeldspathic gneisses (f, s, p. h) contain feldspar prophyroblasts in places. A few bodies of amphibolite (2478) are also exposed. These quartzofeldspathic gneisses are tentatively assigned to pCx_1 rather than a possible extension of the Bungifira metamorphics. The quartzofeldspathic gneiss continues eastwards across the Hale River.

The porphyroblastic gneiss (p; 849, 2433; Table D-2-2A) is a tonalitic gneiss, which has been largely reconstituted during greenschist metamorphism and deformation. It contains relict, irregular plagioclase and some microcline porphyroblasts in a recrystallised matrix of plagioclase, microcline, greenish-brown biotite, epidote and quartz. Biotite and epidote are concentrated in foliation planes and quartz forms thin ribbon-like layers segmented into subgrains and grains. Locally, (eg. 2433) the prophyroblastic gneiss is even more severly retrogressed and foliated, and contains abundant muscovite (25%) replacing already saussuritised plagioclase.

Quartzofeldspathic gneiss (f) in the subunit is very variable in character. That near the base of the section in Pig Hole Creek is epidote-bearing, quartz-rich, finely layered and very similar to the quartz-rich gneisses (j) of the Cavenagh metamorphics exposed at Mount Gordon. The quartzofeldspathic gneiss (f, s), which occurs higher in the section interlayered with prophyroblastic gneiss at Star Creek, is fine-grained, flaggy and contains biotite, muscovite, calcite and epidote. It

is permeated by pink quartzofeldspathic layers, generally 1 mm to 5 m wide. Similar gneisses are exposed in the plain west of Stewart Hole Well (abd); specimen 2470 (Table D-2-2A), for example, is a schistose granoblastic gneiss consisting of quartz (55%), plagioclase (25%), muscovite (12%), epidote (7%) and biotite (1%).

The calc-silicate rocks (eg. 847 Table D-2-2B) are well-layered and are considered to be mainly of sedimentary derivation. Some, however, are formed by greenschist deformation and retrogression gneisses of intermediate composition. For example, specimen 847 consists of bent and broken plagioclase grains, irregular epidote grains, poikiloblastic actinolite and polygonal quartz together with muscovite, biotite, chlorite, opaque grains and accessory sphene and apatite. Microcline is confined to distinct layers.

Biotite and garnet-biotite gneiss and biotite-muscovite schist are subordinate in subunit 1. Garnet-bearing gneiss occurs on both sides of the Hale River south of Stewart Hole Dam (abd.). In some cases, biotite clots have replaced garnet. Specimen 2471A is a fine-grained, granoblastic, schistose gneiss consisting of quartz (69%), plagioclase (15%), microcline (5%), biotite (10%), epidote (1%), traces of actinolite, and accessory apatite. Specimen 2471B is a schist, which consists of quartz (45%), muscovite (18%), biotite (13%), chlorite (13%), plagioclase (6%), epidote (2%) and opaque grains (3%).

Subunit (pGx_2)

pGx_2 is made up of a variety of biotite gneisses, including quartzofeldspathic, garnetiferous and hornblendic types including amphibolite, which form an extensive, highly dissected terrain of moderate relief between Atnarpa Creek, east of the track (abd.) to Star Creek Well, and Star Creek. Quartzofeldspathic gneisses are more resistant and generally form ridges, and amphibolite similarly forms many of the higher hills. The subunit is lithologically transitional between subunits 1 and 4.

In the eastern part of the outcrop-area in Star Creek the succession can be described in four parts beginning in the south near the Pig Hole Creek junction.

(i) Here, garnet-biotite and biotite gneiss are interlayered with amphibolite (841) and small amounts of quartzofeldspathic gneiss (v, b, a, f). The garnetiferous gneiss includes biotite-rich and quartzofeldspathic variants, some of which are quartz-rich (1-842A). Garnet porphyroblasts are commonly altered to biotite or chlorite. Amphibole is most abundant at both the southern and northern ends of the creek-section and contains numerous quartzofeldspathic layers and irregular quartzofeldspathic masses, which constitute up to 30 percent of the rock.

(ii) To the north, farther up Star Creek, the gneiss becomes more quartzofeldspathic and consist of roughly equal proportions of quartzofeldspathic gneiss (f), and schistose or strongly lineated biotite gneiss (bc,i. 10-25), a small proportion of which is garnetiferous (eg. v-2530).

(iii) The next part of the creek-section contains a small amount of hornblende-biotite gneiss (h-832B, 844), and quartzofeldspathic gneiss (f-845), in addition to the predominant biotite gneiss, which locally contains feldspar porphyroblasts. One distinct horizon of coarsely foliated biotite gneiss contains garnet and muscovite (vm).

(iv) The uppermost part of the succession is northeast of Star Creek and has been interpreted from aerial photographs to consist of a unit comprising biotite gneiss, possible calc-silicate rock and amphibolite (b, cs? a) overlain by a small body of quartzofeldspathic gneiss and subordinate amphibolite (f, a).

A similar succession to that in Star Creek is exposed in Pig Hole Creek. In the lower part of the Creek sillimanite-garnet-biotite muscovite (z, v-2532) occupies the core of a synform outlined by a unit of medium-grained, medium to thickly layered amphibolite interlayered with subordinate garnet-biotite and garnet-hornblende-biotite gneiss. All three rock types contain abundant quartzofeldspathic segregations. To the west, and

presumably underlying the amphibolite unit, is a succession of commonly garnetiferous biotite gneiss (v, b) and quartzofeldspathic gneiss (vf, f). One small exposure of ferruginous dolomitic marble occurs on a hillside east of Pig Hole Creek and small amounts of calc-silicate rock have been photo-interpreted elsewhere.

In the western part of the outcrop-area of subunit 2, the succession dips consistently to the east and is interpreted to underlie the eastern succession described above. Its rock types are transitional between those of subunits 2 and 3. At the base of the sequence, in the far west, thin layers of pale grey marble (ma) and amphibolite (a-837) are interlayered with biotite gneiss and quartzofeldspathic gneiss (b, f). A thin ridge of coarse to medium-grained muscovite-biotite quartzofeldspathic gneiss forms the western slope of the main ridge in this part of the subunit, which consists of a coarse-grained epidote-bearing quartzofeldspathic gneiss and subordinate epidote-actinolite-biotite gneiss (f, h). The eastern slopes are formed of coarse-grained muscovite-biotite quartzofeldspathic gneiss and biotite gneiss together with small amounts of chlorite-biotite schist and amphibolite (b, f etc.). In the adjoining valley to the east epidote-biotite and coarse-grained biotite quartzofeldspathic gneiss and amphibolite (f, a) crop out and are followed farther to the east by a hill-forming unit of amphibolite and biotite gneiss (a and b, a). To the north, towards Pig Hole Creek, a thin ridge of epidote-bearing quartz-rich quartzofeldspathic gneiss contains intercalations of actinolite gneiss and chlorite-muscovite-schist (2534). Similar, but more schistose, rocks continue west from here to the base of subunit 1.

Quartzofeldspathic gneiss in subunit 2 consists of both very acid rocks of possible igneous origin (f) such as specimen 845, and quartz-rich rocks (j) commonly containing garnet, thought to be metasedimentary, like specimen 842A (j, vf). Estimated modes are set out in Table D-2-2A. Retrogression of the quartzofeldspathic rocks is widespread and can be recognised in the field because of the ubiquitous epidote, muscovite, and sericite. These retrograde minerals are characteristic of the breakdown of plagioclase and are not present in perthite-rich variants like specimen

845. There, the perthite is either in large bent grains or has become finely recrystallised, in which case it is accompanied by a slightly coarser polygonal grains and subgrains of quartz. In specimen 842A calcic plagioclase has been replaced by albite, muscovite and epidote, and garnet is partly altered to chlorite.

Garnetiferous gneiss (v, z, vm) is typically biotite-rich (2530 2531) or muscovite-rich (2532). Estimated mineral contents are listed in Table D-2-2B. Specimen 2532 is also sillimanite-bearing, and specimen 2531 contains a small amount of actinolite. These gneisses are typically fine-grained, schistose, granoblastic, and contain recrystallised quartz grains.

At least two types of hornblende or actinolite-bearing gneiss (h) are present. Specimen 843B (Table D-2-2B) is a medium-grained, strongly foliated rock, and consists of elongate grains and aggregates of quartz, green-brown hornblende, partly altered to actinolite, and plagioclase, microcline, epidote and biotite. It may be a metamorphosed granodiorite or rhyodacite. Specimen 844 is a fine-grained inequigranular granoblastic actinolite gneiss which lacks quartz, and may be a metamorphosed diorite.

Subunit 3 (pGx_3) consists of schistose, commonly adamellitic granitic gneiss (gg?) and includes rocks mapped in the field as quartzofeldspathic gneiss (gg?, f-1032, 2430, 2416), biotite gneiss (gg?, b) and small amounts of biotite-actinolite gneiss (h-850, 2413) that crop out in two areas:
(1) a northeast-trending strip, about 1 km wide of low relief extending between Mount Chapman and Mount Russell; and
(2) a region of low ridges formed of similar, but more schistose and muscovite-bearing gneisses, located northwest of Ruby Gap Gorge.

In both outcrop-areas the unit is dotted with numerous pods, lenses and ovoid bodies of mafic granulite (mn) in the extreme northwest near Claraville homestead, and of amphibolite (a) elsewhere.

The main gneiss (?gg, f, b) is flaggy, of granitic appearance, very variable in colour (colour index 0 to 50) and is normally fine to medium-grained. Locally, it contains layers of biotite-schist. Small quantities of muscovite, and less commonly epidote are ubiquitous in the southeastern outcrop-area (2 above), northwest of Ruby Gap. Muscovite-bearing varieties are typically medium to coarse-grained and granoblastic.

A tentative classification as granitic gneiss (?gg) is based on its granitic mineralogical composition (adamellite to tonalite) and field appearance together with its uniform character throughout the outcrop-area. Specimens 1032A and 2416 contain roughly equal proportions of plagioclase and K-feldspar, whereas Specimen 2430 contains only negligible K-feldspar (Table D-2-2A gives estimated modes). All three rocks are granoblastic, schistose and have undergone slight retrogression to greenschist minerals such as epidote and sericite. Specimen 2430 has been chemically analysed (see following subsection).

Hornblende gneiss (h) is a comparatively rare lithological type, although widely distributed. This gneiss contains actinolite, but negligible K-feldspar, which indicates it is in the dioritic compositional range. Both specimens that have been petrographically examined (850, 2416) are schistose and have been reconstituted by greenschist retrogression. Estimated modes are given in Table D-2-2B.

Subunit 4 (pGx_4)

This subunit is, in many ways, similar to subunit 3, except that it shows more definite layering and forms topographically higher and more rugged country: (1) in the upper reaches of Atnarpa Creek east of Excelsior and Battery Wells (abandoned); (2) about 10 km northeast of Atnarpa homestead, southeast of the confluence of Pig Hole and Star Creeks; and (3) as a northeast-trending ridge southwest of Star Creek Well. The subunit interfingers and has a transitional boundary with subunit 2.

(1) East of Atnarpa Creek layered felsic gneiss is interrupted by a number of irregular masses of amphibolite. A small body of marble occurs near the boundary with subunit 2, 1.5 km southeast of Excelsior Well. Tonalite of the Atnarpa Igneous Complex, where preserved from retrogression, is considered to intrude subunit 4 along its western contact.

(2) Northeast of Atnarpa homestead, interlayered quartzofeldspathic gneiss and amphibolite interfinger with biotite gneiss of subunit 2 along their western border. The quartzofeldspathic gneiss is medium to coarse-grained, commonly biotite-bearing, but include a few horizons lacking biotite and containing muscovite or epidote. The amphibolite invariably contains quartzofeldspathic layers, which constitute 10 percent of the rock. Some show conspicuous yellowish green epidote-staining. This sequence passes northwards into layered and schistose biotite gneiss of subunit 2 near an easterly-trending fault.

(3) One range formed mainly of quartzofeldspathic rock and a small amount of amphibolite trends northeastwards towards Star Creek Well. The north end of this belt of quartzofeldspathic gneiss appears to be an over-turned antiform, the core of which contains marble (2525) and a small amount of diopside-bearing quartzofeldspathic rock (2526).

Quartzofeldspathic gneiss (833BC, 839A, 840B) contains K-feldspar in excess of plagioclase (Table D-2-2A) and has granitic composition. It is generally fine to medium-grained, granoblastic and contains saussuritised plagioclase. Specimen 833B is most deformed, as it is near the White Range retrograde schist zone; it contains bent and broken plagioclase grains, broken, slightly bent and recrystallised K-feldspar, and polygonal quartz.

Amphibolite is described separately as subunit 5,

Marble (2525) consists of polygonal medium sized grains of calcite, some antigorite (3%), which has presumably pseudomorphed olivine, and a trace of white mica.

Diopside-bearing quartzofeldspathic gneiss (2526) consists of quartz (60%), microcline (15%), plagioclase (13%), diopside (4%), epidote (4%), tremolite (3%), sericite (1%) and accessory sphene and opaque grains. This thin-section includes a patch, 1 cm across, of diopside-rock.

Subunit 5 is used for the ovoid, lenticular and irregularly shaped bodies of amphibolite and mafic granulite that have a shape suggestive of an intrusive origin. These mafic bodies are most abundant in subunits 3 and 4. Mafic granulites are preserved in the northern part of subunit 3 north of Wheal Mundi Well. One isolated body (2529) (about 2 km north of the Star-Pig Hole Creek junction) occurs as a relic in highly retrogressed rocks of subunit 2. Amphibolite, variously retrogressed to greenschist facies, occurs elsewhere. The subunit is not distinguished in the Preliminary 2nd Edition 1:250 000 map.

In thin-section mafic granulite consists of polygonal grains of orthopyroxene (5-8%), clinopyroxene (12-25%), hornblende or actinolite (10-16%), plagioclase (50-65%), and up to 4 percent magnetite (Table D-2-2C). Larger grains are commonly recrystallised to fine grains at grain boundaries. Specimen 2478 contains clinopyroxene as well as actinolite.

The amphibolite is extensively retrogressed to the greenschist facies minerals such as tremolite or actinolite (5-55%), epidote or clinozoisite (1 to 15%), muscovite or sericite (up to 4%), chlorite and calcite. As the amphibolite becomes more extensively retrogressed it becomes progressively more schistose (Table D-2-2C). Specimen 2411 has an unusually high quartz content (30%).

Subunit 6, Ruby Gap Nappe (pGf on Preliminary 1:250 000 map)

Gneiss, which is tentatively correlated with subunit 2, crops out in the core of the Ruby Gap Nappe. It dips northeasterly and extends from the fork in Atnarpa Range eastwards to Ruby Gap Yard where Star Creek enters the Hale Rivers. It is conveniently described in five units: (i-iv) occur north of a major schistose, east-northeast trending fault; and (v) occurs south of the fault.

(i) Directly underlying the Heavitree Quartzite, in the westernmost part, is a much-eroded, closely dissected unit photo-interpreted to consist of quartzofeldspathic gneiss and subordinate biotite gneiss (f, b).

(ii) The overlying unit (b, a, f) is slightly more resistant, forming moderately dissected, rounded hills. The main rock type is a biotite gneiss which is coarse-grained and strongly foliated where examined at the southeastern end of the outcrop area. Amphibolite is also common. One, a pale blue-grey amphibolite (743/15), consists of saussuritised plagioclase (54%+), actinolite (30%), quartz (8%), sericite (5%), epidote (3%), and trace amounts of chlorite and biotite. Quartzofeldspathic gneiss becomes more abundant near the northern margin of the unit. A pale-grey marble bed, 15 m wide, occurs close to the schistose fault zone, which trends east-northeast along the southern edge of the sequence (i-iv).

(iii) The next unit (f, b, h) is made up of two types of quartzofeldspathic gneiss. One is biotite-bearing and is intercalated with biotite and hornblendic gneiss and forms valleys. The other is white in outcrop, has negligible mica, and forms a prominent ridge (f); the unit is about 80 m thick. A medium-grained biotite-bearing gneiss (c.i= 10-20), which has an outcrop width up to 800 m is the main rock-type above the ridge-forming gneiss. It is interlayered with subordinate sericitic quartzofeldspathic gneiss, rare fine-grained hornblende gneiss and at one locality (e.g. 743/10; Table D-14-3B) with a strongly lineated amphibolite, which consists of actinolite (40%) and extensively saussuritised plagioclase.

(iv) The easternmost unit (b, f, r, a) (b?, gg, r, a) bordering Star Creek has not been extensively examined and is photo-interpreted to be mainly biotite gneiss together with subordinate quartzofeldspathic gneiss and small amounts of amphibolite. The southern part of the outcrop area forms moderately dissected rounded hills, not unlike those of unit (iii) above. In the north, thick quartzofeldspathic gneiss units have given rise to northeast-trending ridges. One such quartzofeldspathic gneiss (749/12A) is adamellite in composition, consisting of quartz (52%), plagioclase (23%+), microcline (20%), sericite (2%), epidote (1.5%), biotite (1%) and chlorite (0.5%). Amphibolite in the same area (749/11, 749/12B, 734/5-6) is completely retrogressed to actinolite and saussuritised plagioclase.

(v) South of the east-northeast trending fault, near Amarta Waterhole is an extensive unit of biotite-hornblende gneiss, which occurs principally along the slopes below the scarp of Heavitree Quartzite. This gneiss is not markedly foliated, and is interlayered with small amounts of biotite gneiss, hornblende gneiss without biotite, and amphibolite. As with other amphibolites in the Ruby Gap Nappe these amphibolites (e.g. 746/12) consist essentially of actinolite and saussuritised plagioclase. This amphibolite also contains microcline (5%) and quartz (5%+).

Subunit 7 (pGx_7) Ruby Gap Nappe (pGf in Preliminary 1:250 000 map)

A correlate of subunit 4, designated subunit 7, crops out in the northern part of the Ruby Gap Nappe (f, r, a; f, sf, a). Quartzofeldspathic gneiss and small amounts of amphibolite, both of which have undergone varying degrees of deformation and greenschist retrogression, crop out in the Ruby Gap Nappe north of Star Creek. In one pod of amphibolite (652), the hornblende is virtually unaltered. The quartzofeldspathic gneiss becomes progressively more schistose northwards towards the retrograde schist zone (Pzr).

Geochemistry

Specimen 2430a from subunit 7 has been analysed (Table D). An estimated mode for this gneiss is given in Table D-2-2A. The gneiss falls in the igneous spectrums of Garrels & MacKenzie (1971; i.e. ratio of log SiO_2/Al_2O_3) to log ($CaO + Na_2O/K_2O$)) and of Hughes (1972; i.e. ratio of ($K_2O + Na_2O$ to $K_2O/(Na_2O + K_2O)$). The Ni/Rb ratio also lies in the igneous field (Condie, Macke & Reimer, 1970). The analysis is reasonably similar to Nockold's average granodiorite (Table D-2-2D) and in this respect it is like specimen E5082 from an undifferentiated gneiss unit pG, near Ten Mile bore, ALICE SPRINGS.

Metamorphism

Hypersthene-bearing mafic granulite assemblages are restricted to the extreme northeast of the unit, with the exception of one relict pod (2529) located north of the Star-Pig Hole Creek junction. Relict sillimanite is present in pelitic rocks (e.g. 2532) in this same area. Specimen 2478 near Stewart Hole Yard is a clinopyroxene-bearing amphibolite. Elsewhere,

TABLE D-2-2D: Chemical Analysis Specimen 2430 from unit pGx compared with other rocks types (wt.%).

	2430	E 5082*	A*
SiO_2	67.09	69.17	66.88
Al_2O_3	15.70	14.34	15.66
Fe_2O_3	1.19	1.70	1.33
FeO	2.15	2.22	2.59
CaO	3.70	2.95	3.59
MgO	1.76	0.86	1.57
Na_2O	3.85	2.73	3.84
K_2O	2.55	3.92	3.07
TiO_2	0.37	0.57	0.57
MnO	0.05	0.06	0.07
P_2O_5	0.05	0.16	0.21
H_2O^+	0.56	0.08	0.65
H_2O^-	0.08	0.10	-
Trace Elements ppm			
Cu	10	14	
Co	2	2	
Ni	10	14	
Cr	35	15	
V	165	310	
Rb	100	185	
Ba	940	1500	
Ce	50	130	
Sc	3	5	

* E/5082 - Undifferentiated gneiss near Ten Mile Bore, ALICE SPRINGS

* A - Nockold's average granodiorite, Morgan (1964: Table 2, Column III)

amphibolite shows various degrees of retrogression to greenschist facies exemplified by the proportion of actinolite, or less commonly, tremolite. In the core of the Ruby Gap Nappe amphibolite contains either actinolite or a blue-green hornblende of low maximum extinction angle (Table D-14-3B) and is not noticeably schistose. In many of the quartzofeldspathic gneisses, sericite and epidote are recognisable in the field and are the result of saussuritisation of plagioclase during greenschist retrogression.

Structure

The most apparent mesoscopic structural pattern appears to be one of open, northeast-trending folds, which plunge gently northwards. One such antiform, 4 km southwest of Star Creek Well, has an overturned and partly faulted-out eastern limb. Elsewhere, these northeasterly folds are generally upright. They are, almost certainly, the last phase of folding.

The extent and importance of earlier folding is not clear because such folds, where observed mesoscopically, also have shallow northerly plunges. Consequently, the effect of any large earlier folds on the map pattern is not readily distinguished from that of the late open folds. Interfering folds of different fold generations occur in a creek section 1 km south of Mount Russell (east of 2411), and a reversal in the vergence (sense of asymmetry) in small-scale folds is visible at locality 2473, 2.6 km southeast of Stewart Hole Yard. Several reclined folds are considered to belong to an earlier phase of folding because they have axial-plane traces at a high angle to the trend of the large-scale northerly folds.

Mylonite has been mapped in an easterly schist zone at the base of a calc-silicate sequence 3 km west of Star Creek Well (abd). The lateral extent of this deformed zone has not been determined. Many of the mapped rock units thin rapidly along strike suggesting that boudinage and general attenuation are common.

The porphyroblastic feldspar gneiss near the top of subunit 1 possibly represents a folded deformed zone. This gneiss is very schistose, contains ragged prophyroblasts of both plagioclase and K-feldspar, and very thin, lenticular quartz aggregates, which may represent recrystallised quartz ribbons typical of mylonites.

Origin

The more micaceous, quartz-rich and garnetiferous rocks in subunits 1 and 2 are considered to be derived from argillaceous arenites. The lateral extent of the quartzofeldspathic gneisses, which are present in subunits 1, 2 and 4, suggest that they are either acid flows or arkosic sediments. The presence of marble and calc-silicate rock in subunits 1, 2 and 4 indicates a sedimentary environment for those parts of the sequence, at least.

Subunit 3 is considered to largely represent a suite of metamorphosed granitic rocks of mainly adamellite or granodiorite composition (? gg, f, b), but including a small amount of diorite composition (h). This interpretation is consistent with the one chemical analysis available. The lens of calc-silicate rock that crops out in subunit 3, 3 km northwest of Mount Chapman is anomalous; it is possible a sedimentary raft in the granite or, alternatively rocks in this region should be assigned to subunit 4.

The outcrop-shape of the amphibolites and mafic granulite of subunit 5 suggests that these rocks are metamorphosed intrusive bodies.

Correlation and age

Subunit 1 is considered the youngest, subunit 2 next-youngest and subunit 4 the oldest. Subunit 3 is interpreted to be a metamorphosed granitic rock and subunit 5 is considered to be mainly mafic intrusions. The quartzofeldspathic gneiss near the base of subunit 1, with its intercalations of marble, is superficially similar to the quartz-rich metasediments, which crop out at Mount Gordon in RIDDOCH and are assigned to the Cavenagh metamorphics.

The garnetiferous and biotite gneiss of subunit 2 is similar to gneiss tentatively assigned to the Erontonga metamorphic that crops out in the core of the White Range Nappe west and south of Paddy's Plain in RIDDOCH. The Sliding Rock metamorphics in LAUGHLEN are also very similar to subunit 2 except that they contain a much higher proportion of hornblende gneiss and amphibolite.

Subunit 4 resembles the Randall Peak metamorphics in LAUGHLEN and UNDOOLYA in that both consist basically of interlayered quartzofeldspathic gneiss and amphibolite, and subordinate biotite-gneiss.

The gneiss of granitic appearance in Subunit 3 can be compared with the Trephina granitic gneiss, which is considered to have intruded the Sliding Rock metamorphics before metamorphism.

The northwestern extension of pGx passes under the Cainozoic and Tertiary deposits of the Hale Plain where it lines up with the transitional boundary between the Ongeva granulites and the Cadney metamorphics.

No age dating has been carried out on rocks from Unit pGx.

D-2-3: pGu (Unnamed Unit) (A.P.L. & R.D.S.)

Definition

The unnamed unit, pGu, is an extensive, highly deformed, and partly retrogressed unit consisting mainly of quartzofeldspathic gneiss enclosing irregular bodies of amphibolite and rare lensic layers consisting of schist and mafic calc-silicate rock. It crops out in the Mount Johnstone Dam area, in the central northeastern quarter of LAUGHLEN. Near Mount Johnstone Dam the unit crops out as low hills and is poorly exposed, being partly overlain by a thin but extensive cover of Cainozoic sediments. To the southeast of Mount Johnstone Dam, on the southeastern margin of the Anamarra Orthogneiss, the unit includes a high proportion of quartz-rich quartzofeldspathic gneiss, which forms moderately high, rugged hills. The western and southern margins of the unit include a high proportion of felsic and mafic granulite which also form moderately high hills.

The type area is along Anamarra Creek, 2 km west of Mount Johnstone Dam, from 5751-320515 to 5751-343440. The unit pGu is distinguished from the bordering units by its high proportion of quartzofeldspathic gneiss, and irregular shaped bodies of amphibolite. It is also distinguished by its lack of calc-silicate rock, marble, and interlayered felsic and mafic granulite.

Relationships

To the northwest, pGu is faulted against the West Bore Deformed Zone (Brw). To the north it is separated from pGsf by the West Bore Fault. This fault is a major structural feature which extends, as a splay fault off the Woolanga Lineament, from 3 km northwest of Woolanga Bore across the northern margin of LAUGHLEN and possibly joins the north-bounding fault of the Gough Dam Schist Zone 1 km south of Blackfellow Bones Bore.

The Cadney Fault, the southern bounding fault of the Gough Dam Schist Zone, extends west-northwesterly from 6 km south of Blackfellow Bones Bore and crosscuts the unit pGu. Numerous splay faults off the Cadney Fault have deformed and aided retrogression of the unit, and many small schist zones within the unit are similar to sections of the Gough Dam Schist Zone.

To the southwest the unit is faulted against Cadney metamorphics (pGsc) by a second major splay fault off the Woolanga Lineament (named the Mount Johnstone Fault). The eastern margin of the unit is overlain by Cainozoic sediments but appears to pass gradationally into the Gough Dam Schist Zone. To the southeast the unit has a perplexing boundary with the Ongeva granulite (pGso). The boundary is defined by an abrupt change in structural style and metamorphic grade between the two units but does not appear to be faulted. It is thought to be a transitional contact disrupted by extensive intrusion of granitic material since metamorphosed and now represented by quartzofeldspathic gneiss.

The unit pGu is intruded by the Anamarra Orthogneiss (5751-360430) and a metagabbroic plug (5751-440431). It is a composite of the units Brw_1, Brw_3, Brw_4, the southern part of Brw_2 and parts of Brw (undifferentiated) which were defined on the preliminary 1:100 000 map. These units were grouped because of their similar quartzofeldspathic gneiss content, following reinterpretation of the compilation of LAUGHLEN. It must be noted, however, that significant compositional differences exist between the southwestern and southeastern regions (see Lithology) and consideration to subdivision of pGu should be given following further detailed fieldwork.

Lithology

The type area consists of interlayered biotite gneiss, quartzofeldspathic gneiss and amphibolite with small bodies of muscovite-biotite and sillimanite schist, garnet gneiss, migmatite and calc-silicate rock. The area is cut by numerous faults, intruded by pegmatite and extensively covered by Quaternary scree and gravel.

Away from the type area the unit maintains the high proportion of quartzofeldspathic gneiss and irregular shaped mafic bodies. However the southwestern and southeastern margins of the unit are significantly different in composition. The southwestern margin includes cordierite and mafic granulite, biotite and garnet gneiss, muscovite-quartz schist, garnet-biotite-gneiss and quartz-rich quartzofeldspathic gneiss. The southeastern margin is similar to the type area, but the quartzofeldspathic gneiss is particularly quartz-rich.

The most abundant rock type is quartzofeldspathic gneiss (3259), which, in the central area, encloses irregular amphibolite bodies and consists essentially of plagioclase (40%), orthoclase (20%) and quartz (25%) with variable, but typically small amounts of biotite and muscovite, and accessory zircon and opaque grains. In the southeastern region the gneiss encloses similar irregular amphibolite bodies and some mafic granulite and thus has the same megascopic appearance, but crops out as massive, homogeneous boulders and rounded exposures consisting of fine to medium-grained, poorly foliated, quartz-rich quartzofeldspathic gneiss (4269, 4270, 4272). This

gneiss is migmatitic in part, enclosing two generations of mobilisate; one forming thin (0.5-1 cm) discontinuous stringers, concordant with the gneissic foliation, the other forming crosscutting veinlets, 1-3 cm thick, which are axial-plane to minor folds.

Along the southeastern margin of pGu the metamorphic grade increases, and quartzofeldspathic gneiss grades into felsic granulite.

Biotite gneiss (3258, 3262) constitutes about 15 percent of the unit and occurs as thick interlayers in the quartzofeldspathic gneiss. Its occurrence is generally restricted to the central part of the unit where it crops out as low hills of schistose gneiss commonly containing distinct biotite lamellae up to 0.5 cm thick which separates 1 to 4 cm thick layers of biotite, quartz and feldspathic. One sample (3258) consists of plagioclase (45%), quartz (30%), biotite (15%), and muscovite (10%). Biotite gneiss contains a variable amount of muscovite, commonly much less than the 10 percent recorded in the above sample. In the southwestern part of the unit biotite gneiss is interlayered with mafic granulite and garnet gneiss.

Muscovite-biotite schistose gneiss crops out as thin elongate lenses adjacent to faults. The gneiss (3265, 3264, 3416, 4267, 3320, 3321, 3257) consists dominantly of quartz and muscovite, but also contains variable, but small, amounts of orthoclase and biotite.

Sillimanite schist is locally garnetiferous and grades into muscovite-biotite gneiss (78916644) and crops out in the central eastern e.g. GR 5751-425444 and southeastern parts of the unit (GR 5751-430440).

Amphibolite (3267, 3377, 3329, 3418, 3326, 3386, 4273, 3385, 3387, 4268) occurs throughout the unit as irregular, elongate bodies ranging in thickness from a few metres to tens of metres. The amphibolite crops out as homogeneous, medium-grained mafic rock composed essentially of subhedral hornblende, plagioclase and rare quartz. Some samples contain small amounts of scapolite (4273), epidote (3385), or clinopyroxene (3326). A few of these amphibolites are clearly of intrusive origin as they contain idioblastic plagioclase laths e.g. GR 5751-430413.

Garnet gneiss crops out in the southwestern region (3316, 3406), and adjacent to the western edge of the Anamarra Orthogneiss (3261). Specimen (3316) contains quartz (40%), orthoclase (30%), plagioclase (10%), biotite (10%) and garnet (10%). Specimen 3261 fortuitously does not include garnet; however clast of garnet were observed in the outcrop.

Mafic granulite (4053, 4465, 4470, 3269, 3399, 3428, 4465, 4470) and retrogressed mafic granulite (3322, 3382, 3398, 4461) constitute about 2 percent of the unit and crop out mainly in the southwestern region, along the southern margin of the unit, and adjacent to its contact with Ongeva granulite. The mafic granulite forms small irregularly shaped pods. Sample 4053 is a coarse-grained, granuloblastic rock, which consists of plagioclase (25%), orthopyroxene (25%), clinopyroxene (25%), and hornblende (25%). Incipient retrogression of mafic granulite is evidenced by alteration of pyroxene rims to amphibole (3398). Complete retrogression produced chlorite-actinolite rock such as 3382.

Mafic granulite specimen 3369 has been chemically analysed (see Geochemistry).

Felsic granulite (3417) forms massive, reddish-brown hills along the southern margin of the unit and constitutes about 5 percent of the outcrop. It consists of quartz (40%), plagioclase (40%), clinopyroxene (15%), and biotite (5%), and accessory opaque grains.

Small slices of cordierite granulite (3319) crop out immediately beneath an east-striking, northerly dipping fault (80°) that crosscuts the western region. The cordierite granulite consists of megacrysts of hypersthene (up to 1.5 cm long) (50%), in a matrix of equigranular cordierite (25%), sillimanite (10%), quartz (10%), and phlogopite (5%).

Calc-silicate rock is an uncommon lithological type that crops out in the southeastern part of the unit. This calc-silicate is commonly quartz-rich and actinolite-bearing.

Structure

The unit is extensively deformed by the east-northeast extension of the Cadney Fault, and by numerous splay faults off the bounding West Bore and Mount Johnstone Faults. Schistosity developed adjacent to many of these faults overprints earlier structures and numerous localities feature two strong, intersecting foliations. The earlier foliation is defined by compositional layering, whereas the overprinting schistosity is defined by the preferred orientation of biotite and muscovite. In biotite gneiss, at 7151-325505, compositional layers of feldspar, quartz, and biotite (layers up to 4 cm thick) are separated by biotite layers (from 0.25 to 0.5 cm thick). Both are crosscut by a schistosity defined by the reorientation of biotite. The intersection of these foliations defines a prominent lineation, which plunges at 40° to the northeast. The overprinting schistosity parallels the axial-plane of minor folds, which also plunge at about 40° to the northeast. The parallelism of schistosity and axial-planes of minor folds is in evidence elsewhere (e.g. 7151-403448) indicating that the development of the schistosity was accompanied by folding of the compositional layers. Muscovite formed by retrograde metamorphism is oriented parallel to the overprinting schistosity.

Geochemistry

One sample (3269), a mafic granulite which forms a pod-shaped body 4 km north of Mount Johnstone, was analysed for major and selected trace elements (see Table A1, Appendix). The major element analysis is very similar to that of mafic granulite from the Yambah granulite (4406) and, as with this analysis and those of mafic granulite (3205) and amphibolite (3202) from pGsf, it is similar to modern-day tholeiitic flood basalts (Turner & Verhoogen, p. 208).

The trace element abundances are also very similar to mafic granulite 4406 from Yambah and in this regard they differ from the more fractionated (i.e. low Ni and Cr and higher V, Sr and Ba) mafic granulite of pGsf.

Metamorphism

The unit consists predominantly of rocks of amphibolite metamorphic facies but includes a high proportion of mafic and felsic granulite on the southwestern margin and several isolated bodies of mafic granulite near Mount Johnstone Dam. The occurrence of isolated mafic granulite bodies suggests that the unit may have been retrogressed from granulite facies. Retrogression is also indicated by the growth of muscovite which is oriented parallel to the overprinting schistosity.

Origin

The region to the west of the type area contains abundant garnet gneiss, biotite gneiss and schist and in this respect is similar to the metampelitic rocks of the Erontonga metamorphics. The less common sillimanite gneiss and calc-silicate rock are clearly metasedimentary. To the southeast of the type area the quartzofeldspathic gneiss is notably rich in quartz and appears similar to the layered, possibly volcanoclastic quartzofeldspathic gneiss of the Bungitina metamorphics. The irregular shape of many amphibolite bodies in the unit suggests that they may be of a different origin from the well-layered mafic granulites of the adjacent Ongeva granulite.

A large part of the quartzofeldspathic gneiss in the southeastern part of the outcrop area is thought to be one or a number of orthogneisses because it has a homogeneous granitic composition, it has discordant contacts with the Ongeva granulite and because it has incorporated rafts and xenoliths of amphibolite, mafic granulite, schist and rare hornblende.

Age and Correlation

The abundance of quartzofeldspathic gneiss and inclusion of irregular shaped amphibolite bodies indicates a similarity to both the Bungitina metamorphics and the unnamed unit pGx. The metamorphic grade, composition and structural style separate the unit from the adjacent Ongeva granulite, but its stratigraphic relationship with the Ongeva granulite is problematical. The unit pGu is of lower metamorphic grade and consists of more metasedimentary rocks than the Ongeva granulite. This indicates that it is possibly younger than the Ongeva granulite i.e. younger than the

1800 m.y. granulite metamorphism of the Strangways Metamorphic Complex. If it is younger and unconformably overlies the Ongeva granulite, being a correlative of the Bungitina metamorphics, then the Cadney metamorphics, which underlie the Bungitina metamorphics are missing from the Ongeva granulite - pGu contact which is improbable. A second possibility is that the unit pGu was metamorphosed to granulite facies at 1800 m.y., as indicated by the isolated outcrops of mafic granulite, then retrogressed to amphibolite facies, and is indeed older than the Ongeva granulite or a facies equivalent of it. Much of the southeastern part of the unit is considered to be an orthogneiss which intrudes the Ongeva granulite and an earlier layered sequence of quartzofeldspathic, pelitic and calcareous rocks.

D-3: Division 2: Rocks of the Ankala and Narbib Blocks

The characteristic rock of these Blocks is a well-layered gneiss of granitic to granodioritic composition.

D-3-1: Sliding Rock metamorphics, pGi (R.D.S. & A.P.L.)

Definition

The Sliding Rock metamorphics is a sequence of hornblende-biotite-gneiss (h), garnet-biotite gneiss (v), biotite gneiss (b), quartzo-feldspathic gneiss (f), and amphibolite (a). Sillimanite-bearing gneiss (z) crops out along the southeastern margin of the unit. Granitic gneiss (gg) and rare kyanite gneiss (y) are confined to the western end of the outcrop-area. The main part of the unit forms a broad east-striking ridge which parallels Harry Creek to the north and extends from the headwaters of White Tree Creek in BURT eastwards to Turner's Prospect in LAUGHLEN. A more pelitic part of the unit to the south parallels the main ridge and has a more subdued relief. The name is derived from Sliding Rock Well (GR 5751-178214) south of Winnecke. The reference section is on the eastern side of the track from Sliding Rock Well to Randall Peak Bore (i.e. between GR 5751-193207 and 5751-178185). The common occurrence of either garnet of hornblende in the gneisses makes the unit distinctive.

Relationships

The southern boundary of the metamorphics is conformable against unassigned rocks (pG) and is marked by the outgoing of garnetiferous biotite gneiss and by an increase in the biotite content of the gneiss giving rise to rocks that have a relatively high colour index (CI = 20+). At the northwestern end of the unit the southern margin is intruded by the Oolbra orthogneiss which separates it from the Narbib granulite farther to the south.

The northern boundary is faulted against the Ankala gneiss for most of its length. South of Bald Hill Dam the Sliding Rock metamorphics may be conformably overlain by a thin unit of biotite schist, anthophyllite-bearing rock, calc-silicate rock, marble, and hematite quartzite and

sillimanite gneiss followed by a unit of migmatitic biotite gneiss and quartzofeldspathic gneiss, both of which are tentatively assigned to the Ankala gneiss.

The Sliding Rock metamorphics is separated from the Heavitree Quartzite by a zone of schist (Pzr).

Lithology

The relative proportion of rock types in the Sliding Rock metamorphics is roughly estimated from the aerial photographs to be:

Hornblende-biotite gneiss (h)	- 25%
Garnet biotite gneiss (v)	- 25%
Biotite gneiss (b)	- 20%
Quartzofeldspathic gneiss (f)	- 20%
Amphibolite (a)	- 15%
Biotite schist (sb)	- 5%
Sillimanite gneiss (z)	- 3% or less
Granitic gneiss (gg)	- 2%
Kyanite gneiss (y), magnetite-quartzite (qf), metagabbro (gb) and dolerite (do)	- rare

Estimated modes of the main rock types are set out in Tables D-3-1A, B and C.

Hornblende-biotite gneiss (h) is most common in the northern part of the metamorphics (Table D-3-1B). An excellent example can be examined in the main, or easternmost tributary of Winnecke Depot Creek (GR 5751-243198). Here, the gneiss is beautifully folded and migmatised; a lenticular leucosome portion accounts for 10 to 20 percent of the rock. Garnet is present in very small amounts and is generally retrogressed to biotite. Epidote and calcite are generally localised in minor fractures and schist zones. A typical gneiss (937) from this locality contains quartz (30%) (very variable grainsize), poorly twinned plagioclase (20%), biotite (10%), green hornblende (35%), and garnet (1%), in addition to the secondary minerals, sericite, epidote, and chlorite (total 4%).

TABLE D-3-1A: Visually estimated modes for felsic rocks from the Sliding Rock metamorphics, pGi

	Garnetiferous biotite gneiss			Biotite gneiss			Quartzofelds-pathic gneiss			Granitic gneiss						
	4102	862	4024	861	3522	754	3520	5000	863	4109	4112	4104	4111	4105	4113	4118
	v	v	v	b	b	b	f	f	f	gg	gg	gg	gg	gg	gg	gg
Quartz	45	40	39	33	35	53	40	33	27	55	60	60	50	55	50	55
Plagioclase	40	23	35	30	17	10	33	45	32	40	35	25	40	40	48	40
Garnet	5	2	9													
Hornblende										tr						tr
Biotite	10	10	16	20	15	25		10	5		5	15	10	5	2	1
Muscovite/Sericite		10				tr	3	10	3							
K-feldspar		10		15	33		23		15?							
Opaque grains			1				1									
Epidote/clinozoisite		tr		2		7		2	5							
Actinolite																
Chlorite						5			13							
Clinopyroxene										5						5
Zircon			ac													
Apatite			ac													
Sphene				tr		tr			tr	tr						
Pyrite						tr?										

tr = trace

ac = accessory

TABLE D-3-1B: Visually estimated modes for mafic rocks from the Sliding Rock metamorphics, pGi

	Amphibolite						Hornblende - biotite gneiss					Dolerite
	3515	4108	4119	3517	3518	3521	4023	937	3514	3516	3653	4101
	a/h	a	a	a	a	a	h	h	h	h	h	
Quartz	17					2	22	30	30	30	32	15
Plagioclase	50	40	40	20	30	30	29	20	40	15	37	40
Garnet							11	1	-	2	10	
Hornblende	30	60	60	60	65	61	29	35	20	10	15	
Biotite	3						8	10	10	2	10	
Muscovite/Sericite					tr			1.5	tr			
K-feldspar						2				33	5	
Opaque grains						tr	1		tr	5		
Epidote/clinozoisite	tr				5			1.5	tr		tr	
Actinolite							tr		tr			
Chlorite								1			1	20
Clinopyroxene				20		5						25
Apatite							ac					
Sphene	ac									?1		

TABLE D-3-1C: Chemical analysis of quartzofeldspathic gneiss No. 5000 from the Sliding Rock metamorphics, pGi

Specimen	5000	5002	Nockolds' average muscovite-biotite granodiorite (Morgan, 1964, Table 2, (5)
Grid Reference	5751-225197	5851-Ongeva Granulite	
SiO	73.47	75.64	70.47
Al_2O_3	13.02	10.79	15.50
Fe_2O_3	0.75	2.01	0.63
FeO	2.64	2.33	2.12
CaO	1.68	1.00	1.91
MgO	0.98	0.70	0.65
Na_2O	3.11	2.72	4.12
K_2O	2.59	3.91	3.59
TiO_2	0.36	0.29	0.30
MnO	0.05	0.07	0.03
P_2O_5	0.21	Less than 0.01	0.16
H_2O +	0.84	0.07	-
H_2O -	0.04	0.11	-
CO_2	0.10	0.20	-
Total	99.82	99.85	99.48
Cu		10	
Co	4	Less than 2	
Ni	16	20	
W	5	Less than 5	
V	Less than 5	Less than 5	
Sr	68	46	
Rb	90	85	
Ba	1150	1150	
Ce	90	100	
Sr	240	480	
Zr	65	180	

Elsewhere (e.g. 4023) the garnet content increases to about 10 percent, and the gneiss locally also contains up to 35 percent microcline (e.g. 3516, 3653). A granoblastic texture is characteristic. Blue-green actinolite is also a widespread secondary mineral (e.g. 4023, 3514).

Garnet-biotite gneiss (Table D-3-1A) is most abundant in the central zone immediately south of the hornblende gneiss as well as in the western part of the outcrop-area. A small amount of hornblende gneiss is interlayered with the garnetiferous gneiss in this central zone. The garnet is typically poikiloblastic, seldom exceeds 10 percent of the rock, and is generally localised in separate quartz-rich layers (e.g. 745, 862, 4024). Quartz and biotite contents are slightly more abundant than in the hornblende-biotite gneiss, and reach 50 and 20 percent respectively. The texture is granoblastic. Accessory minerals include magnetite, zircon and apatite.

Biotite gneiss has a very similar felsic content and texture to the above gneisses, but lacks hornblende and garnet. The biotite content varies from 10 to 35 percent. Biotite gneiss is more common in the southern part of the sequence, and includes variants which contain up to 60 percent quartz. The composition of the gneiss varies, in a broad sense from adamellite (e.g. 3522) to granodiorite (e.g. 861).

Quartz and biotite show a greater variation in grainsize than does feldspar and the quartz is commonly recrystallised at grain-boundaries. Late-stage deformation near fault zones forms schist (e.g. 754) composed of polygonal quartz, fine-grained, wispy, green-brown biotite, chlorite, sericite, epidote and rare calcite. Near these fault zones plagioclase is altered to sericite, epidote and albite, and biotite is altered to chlorite.

Quartzofeldspathic gneiss, although distinguished by its low colour index (less than 10), is granodioritic in composition (e.g. 3520, Table D-3-1A). This specimen is medium-grained, lacks biotite, contains quartz (40%), plagioclase (33%), microcline (23%), muscovite (3%), and opaque grains (1%). Specimen 863 is similar, but contains biotite. Specimen 5000, which has been chemically analysed, also contains biotite, but lacks K-feldspar

(see Table A for mode). This fine-grained (1-2 mm) granoblastic gneiss shows the effects of greenschist retrogression: plagioclase is altered to clinozoisite and muscovite; and quartz has undergone partial polygonisation to new grains and subgrains at grain boundaries.

Amphibolite can be divided into three varieties (Table D-3-1B).

The first (e.g. 3515) contains up to 31 percent biotite, 15 percent quartz, and in specimen 3515 has much more plagioclase than hornblende. This amphibolite has a mineral content transitional between that of hornblende-biotite gneiss and that of amphibolite.

The second variety contains up to 60 percent hornblende and up to 10 percent clinopyroxene (e.g. 3517, 3512). Specimen 4110 and 4120 are granuloblastic rocks that have been chemically analysed. The chemical composition and ovoid form of the outcropping bodies suggest that they are metagabbros (Table A2, Appendix).

The third and most common variety consists simply of hornblende (50-65%), and plagioclase (20-30%), in addition to accessory minerals (e.g. 3518).

Granitic gneiss (gg) (Table D-3-1A) crops out in the northwestern end of the unit and consists of coarse anhedral grains of quartz, plagioclase, biotite, and rare clinopyroxene and hornblende. The gneiss is quartz-rich, well-foliated and compositionally layered. The layering ranges in thickness from 0.5 cm to 5 cm (Photo D16), and consists of alternating quartzofeldspathic, partly crosscutting, mobilisate layers and biotite-quartz-plagioclase gneiss.

Schistose biotite gneiss (sb) is widespread throughout the metamorphics. This rock type is a variant of garnet and sillimanite-bearing biotite gneisses (i.e. v, and z). It forms east-trending belts of subdued topography.

Sillimanite-bearing gneiss (z) is an uncommon, but significant rock type, which crops out along the southeastern margin of the unit.

Rare kyanite-biotite-quartzofeldspathic gneiss (y) crops out in the nose of a large fold at 5651-962251 as a bleb-like body in granitic gneiss.

Rare dolerite (4101) consists of tabular plagioclase and chloritised clinopyroxene. It occurs as a thin dyke-like body crosscutting quartzofeldspathic gneiss 5651-928252.

A metagabbro (gb) (4126) at GR 5651-901247 and (4127) GR 5651-903250 contains relict igneous plagioclase and orthopyroxene grains, in addition to a granuloblastic matrix of plagioclase (An_{60}), hornblende, clinopyroxene, hypersthene(?), quartz and microcline. Specimen 4127 has been chemically analysed.

Geochemistry

Biotite gneiss specimen 5000 has been chemically analysed (Table C). It occurs in a zone rich in hornblende-biotite gneiss and is considered to be a related rock type. The specimen (5000) has high normative Qz (i.e. 39.62 - CIPW norm) and a K_2O/Na_2O ratio of 0.83. It shows some chemical similarity to specimen 5002 from the Ongeva granulite except K_2O is markedly lower and total iron is significantly higher (see Appendix for chemical analysis). It is also chemically similar to specimen 5082 from unit pG of unassigned gneisses south of Georgina Gap. It is also similar to Nockolds' average muscovite-biotite-granodiorite (Morgan, 1964; Table 2, Column 5). A plot of log (SiO_2/Al_2O_3) against log $(CaO + Na_2O)/K_2O$ falls within the igneous field of Garrels & MacKenzie (1971) and is consistent with a granodiorite composition. A plot of the immobile elements Zr/TiO_2 against SiO_2 when compared with the results of Winchester & Floyd (1977) for modern volcanics, suggests the gneiss may have been derived from a rhyolite or similar very acid rock. The gneiss is atypical of the unit in that it lacks K-feldspar (cf. Table D-3-1A) and the possibility that K_2O has been removed during metamorphism needs to be considered. Like specimens 5002 and 5018 it is interpreted to be a metamorphosed rhyolite or dacite.

Amphibolite specimens 4110 and 4120 have also been chemically analysed (Table A2, Appendix). They are thought to be metagabbros, having a tholeiitic composition. They are very like specimen 4127, an analysed metagabbro from the same area containing relict igneous plagioclase and orthopyroxene (Table A2, Appendix).

Metamorphism

Amphibolite specimens 3517, 3521, 4110 and 4120 contain clinopyroxene and have granuloblastic textures; and the intercalated sillimanite gneiss lacks muscovite. Mineral assemblages in the other rocks sampled are less diagnostic, but are consistent with the unit having been metamorphosed to upper amphibolite facies.

Structure

Double folds are outlined by quartzofeldspathic layers south of Harry Bore at 5751-985256 and 5651-940260, as well as southwest of Sliding Rock Well at 5751-166201. The earlier folds are tight, and, on unfolding, appear to have trended northeast; the more numerous later folds have northwest-striking axial-planes and overturned southwestern limbs. The early folds at 5751-166201 appear to have been formed before migmatisation. Here, the second generation fold plunges shallowly to the southeast. At the double-fold locality south of Harry Bore (GR 5751-985256), both fold generations plunge to the southeast at 45 to 60°. A weak axial-plane schistosity, migmatisation and numerous tight parasitic folds (Photos D16-17) accompany the second generation folds at 5651-948269.

A third phase of minor open folds and warps is specially related to a series of northeast-trending faults, which are locally accompanied by narrow retrograde schist zones containing greenschist facies minerals (5751-143207, 5751-155205, 5751-190167 and 5751-190138). The same narrow schist zones are well exposed at the Gecko and Rankin's Prospects. A very early or pre-Alice Springs Orogeny age is favoured for these schist zones, because they are transected by the wider, more pronounced east-trending schist zones known to be formed along with the Arltunga Nappe Complex during the Alice Springs Orogeny.

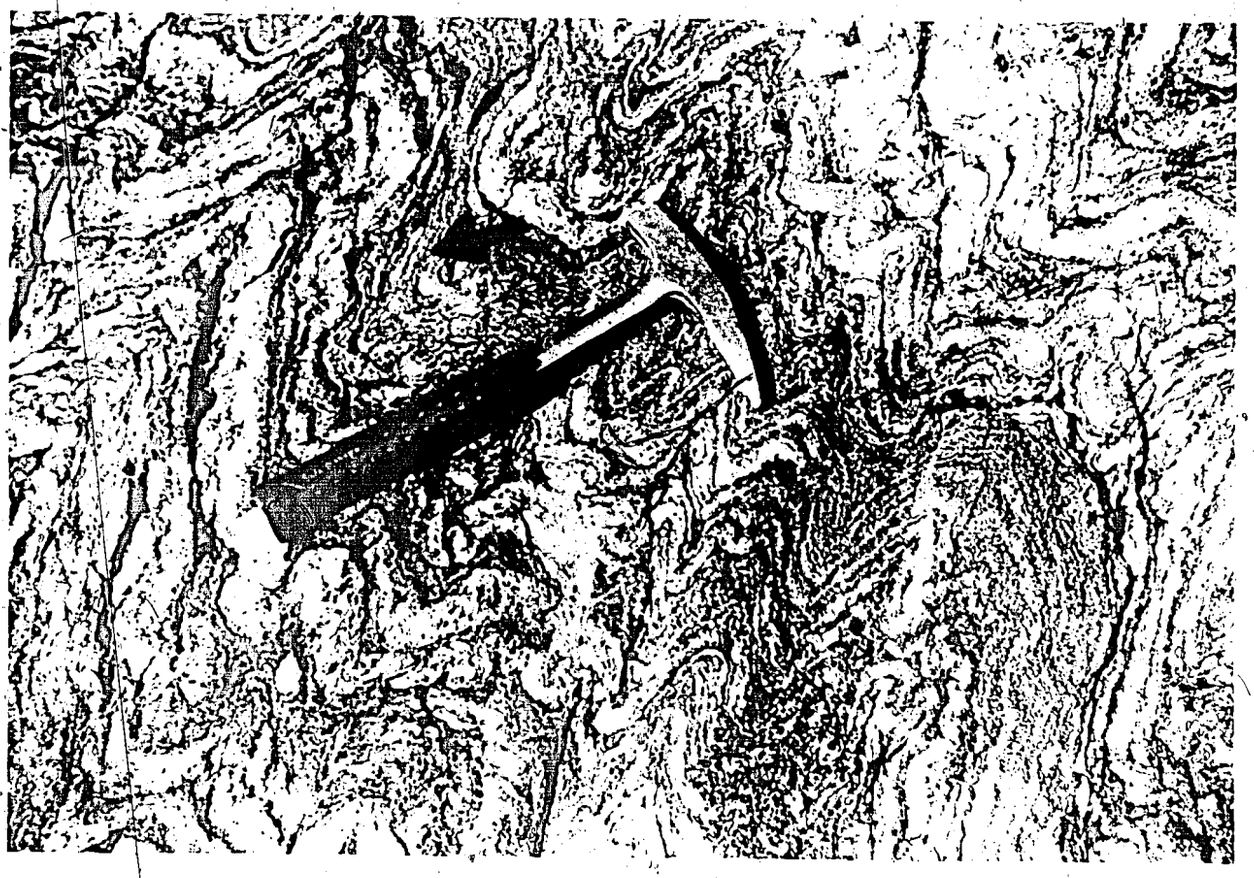


Photo D16: Tightly folded leucosome-rich granitic gneiss 4.5 km south of Harry Bore. This minor folding and migmatisation may be associated with F_2 folding.

Photo D17: Minor folding of leucosome-rich layers in granitic gneiss 2 km NW of PhotoD16.

Origin

The Sliding Rock metamorphics is interpreted to be derived from a sequence of principally acid and intermediate volcanics, and rarer basic volcanics, together with a small amount of pelite.

Correlation and Age

In the rock relationship diagram the Sliding Rock metamorphics is tentatively classified in Division 2. However, the unit has some lithological similarity to parts of the Strangways metamorphics although clearly of a lower metamorphic grade.

A stratigraphically continuous sequence can be interpreted to extend from the Ankala gneiss, through an indefinite unit (mapped as ? pGi) consisting of biotite gneiss and amphibolite, into the main part of the Sliding Rock metamorphics. Such a sequence can be compared with the lower part of the Harts Range Group, namely the Entia Gneiss, the Bruna Gneiss and the Irindina Gneiss. In this postulated correlation the more felsic and hornblende-bearing biotite gneiss of the Sliding Rock metamorphics would correspond to the upper part of the Entia Gneiss and the southern zone rich in the more pelitic gneisses and amphibolite would correspond to the Irindina Gneiss: the Bruna Gneiss being absent.

No age determinations have been carried out on this unit.

D-3-2: Ankala gneiss (pGa) (A.R.A., R.D.S.)

A.R.A. has described the type area near Ankala Hill. An outline of variationsoutside the type area is given by R.D.S.

Definition (A.R.A.)

In the type area the Ankala gneiss is composed mainly of quartzo-feldspathic gneiss (f) and lesser amounts of calc-silicate gneiss (cs) subordinate pelitic gneiss (b) two conformable mafic units (a), and rare marble (ma), metamorphosed ultramafic rock (un), quartz-hematite rock (qf) and cummingtonite-rich rock (ae).

The Ankala gneiss forms a wedge widening eastwards from its apex near Gumtree Bore (5751-041263) to the Pinnacles Fault (5751-195308) where it is offset to the south. Its southern boundary is marked by the Bald Hill Fault. It is uncertain whether the Ankala gneiss extends to the south of the schist zone (Pzr) about 5 km to the south of the Harry Creek Deformed Zone. This schist zone (Pzr) may curve round the western end of the quartzite range at Bald Hill to be intersected by the Bald Hill Fault (5751-277179 to 5751-990266) (J.L. Funk, ANU, personal communication, 1975). The intersection of the northwesterly trending Bald Hill Fault with the Harry Creek Deformed Zone cuts out the Ankala gneiss is exposed to the north of the Harry Creek Deformed Zone south of Johannsen's Phlogopite Mine (5751-079306).

The unit is named after Ankala Hill (5751-081276) 3.5 km south-east of Johannsen's Phlogopite Mine (5751-079306). The type area is taken to extend from the Ankala Hill area (5751-085284) to Gumtree Bore (5751-041263). The Ankala gneiss is distinguished from the Utnalanama granulite by its pelitic and calcareous rocks, its lower metamorphic grade, and by the more acid composition and layered nature of the quartzofeldspathic rocks. The Ankala gneiss lacks the hornblende and garnet-bearing gneisses — characteristic of the Sliding Rock metamorphics (R.D.S.).

Relationships

Along its northern margin the Ankala gneiss is faulted against the Erontonga metamorphics, the Utnalanama granulite and, at one locality, the Harry Anorthositic Gabbro; the boundary is marked by the Harry Creek Deformed Zone.

The southern boundary of the Ankala gneiss is also in fault contact separated from the Sliding Rock metamorphics by the Bald Hill Fault (A.R.A.), except for a small portion near Rankin's Copper Prospect (5751-093243) where the two units appear to be conformable (RDS). This apparently conformable contact requires verification by further field work.

Distribution outside the type area (R.D.S.)

The Ankala gneiss has been also mapped north of the Winnecke part of the Arltunga Nappe Complex and from there west to the type area (R.D.S.). Because the unit has been involved in overthrusting associated with the nappe formation it has been deformed to a schistose rock in many places. Consequently, the unit is vulnerable to weathering and occupies a low-lying belt broken by several peaks such as Mount Bartlett. In the Mount Bartlett area (GR 5751-330194) the unit contains a thick, coarse-grained diopside-marble horizon.

Southeast of Pinnacles Bore a conformable amphibolite unit enclosed in a sequence of quartzofeldspathic gneiss outlines a double fold (GR 5751-175300) (R.D.S.).

At Rankin's Prospect (GR 5751-093242), a sequence of mainly amphibolite, biotite gneiss and biotite schist assigned to the Sliding Rock metamorphics is overlain by a thin base of biotite schist, anthophyllite-bearing rock, calc-silicate rock, marble, sillimanite-scaping gneiss and haematite quartzite (R.D.S.). Both this lense and the immediately overlying unit of migmatite biotite gneiss and quartzofeldspathic gneiss are tentatively assigned to the Ankala gneiss. Further petrographic details on the succession at Rankin's Prospect are given in Table D-3-2A.

Lithology (A.R.A.)

In the type area the Ankala gneiss consists mainly of quartzofeldspathic gneiss, composed of quartz, plagioclase, alkali-geldspar, biotite, hornblende, garnet, Fe-oxide, rare cummingtonite, and abundant accessory allanite. Retrogression produced sericite, epidote and blue-green hornblende.

Calc-silicate gneiss is also abundant, particularly in the lens of Ankala gneiss north of the Harry Creek Deformed Zone, and in the main fault block west of Ankala Hill (5751-081276). These range from mafic varieties poor in plagioclase to felsic varieties rich in plagioclase. In addition, skarns are developed where offshoots of the Gumtree Granite intrude the calc-silicate rocks, and some highly garnetiferous rocks at the boundary between the lens of Ankala Block to the north of the Harry Creek Deformed

TABLE D-3-2A: Visually estimated mode for rock types from Rankins' Prospect. (R.D.S.)

(Registered specimens 70090395 - 401)

Position	Eastern Succession			Western Succession		Southern Lode			Intervening Lode Horizon						Northern Lode					
Specimen Number	395	400	401	397A	397B				397A 398A	398B	398C	399A	399B	399C	399D	399E	399F	399G	399H	
Reference (Data Cards)	A	W	X	K_1	K_2	B	C,F J	G,H	L,M	N_1	N_2	P	Q	R	S	T_1	T_2	T_3	T_4	
Rock Type Symbol	z	a?	z?	r	r	qf	qt	a	b,z?	z	v	qf	peg	cs	cs	cs	cs	cs	cs	
Quartz	15		25	40	7	x	x		60	48	20	65	x	x			x			
Copper sulphide							x					?						?		
Magnetite	2					x			2	1	30	4		x						
Diopside														x						
Cummingtonite																	x			
Hornblende		x			70			x					45		x	x		x		
Actinolite															x					
Calcite																			x	
Epidote		x	x		x							tr	x		x	x		x		
Chlorite	20			25					9		25	20	x		x	x		x	x	
Sillimanite	x		?						?	x										
Garnet	2			5						1	25	10			x					
Muscovite/Sericite	20?	x	10	20	20		x		9	25			x				x			
Biotite	30		15	10					20	25	x	tr								
Plagioclase			50					x												
Kyanite											?									
Chalcedony																			x	

NOTES: x = present, % undetermined tr = trace. Eastern succession = Possible Ankala gneiss Western succession = Probable Sliding Rock metamorphics

Zone, and the Utnalanama Block, have been interpreted as metasomatically altered fault breccias derived from calc-silicate rocks (Allen & Black, 1979). The calc-silicate rocks consist of quartz, plagioclase, clinopyroxene, hornblende, sphene (or titaniferous magnetite), abundant allanite, and rare zircon and apatite. Retrogression together with metasomatism of Gumtree Granite has formed epidote, andraditic garnet, blue-green hornblende, alkali feldspar, scapolite, and calcite.

The mafic rocks consist of plagioclase, hornblende, clinopyroxene, and sphene. Retrogression has produced blue-green hornblende and epidote. Many of the conformable mafic rocks, although widespread, are too thin to show separately and so several are lumped together on the map. A good example of a metamorphosed mafic dyke is exposed at the Gumtree Copper Prospect.

The Fe-rich rocks, composed mainly of hematite and quartz, are associated with coarse masses of cummingtonite, and are locally coated with green malachite staining. During the Alice Springs Orogeny white mica and chlorite were formed from hematite and indeterminate ferromagnesian minerals.

Pelitic and ultramafic rocks are rare. The pelitic rocks have been retrogressively metamorphosed and are now composed of quartz, chlorite, biotite and white mica. Ghosts of garnet and another aluminous mineral, (possibly kyanite) survive. The ultramafic rocks (5751-074282) are composed of colourless tschermaleitic amphibole, phlogopite, and chromite, which are partly replaced by retrogressive serpentine and chlorite.

Sillimanite-bearing gneiss (R.D.S.) (z) occurs at the conformable boundary with the Sliding Rock metamorphics at Rankin's Prospect (GR 5751-093242) where it contains abundant muscovite and biotite. The mineral content of four samples is given in Table D-3-2A (0395, 0401, 0398A, 0398B).

Magnetite-quartzite (R.D.S.) (qf) contains copper sulphides at Rankin's Prospect. The mineral content of this and adjacent rocks, including various calc-silicate rocks (cs), are set out in Table D-3-2A.

Metamorphism (A.R.A.)

Textural analysis of the Ankala gneiss indicates four episodes of metamorphism (Allen, 1976). The two earlier recrystallisations, which took place under amphibolite facies conditions, have produced fabrics comparable with those that developed during the first two recrystallisations of the rocks in the Utnalanama Block. The two episodes in both blocks have been correlated with the main regional metamorphism of the Arunta Block, (Allen, 1976).

The third episode also took place at amphibolite facies grade, and was related to the initial movements in the Harry Creek Deformed Zone which brought the Utnalanama Block up against the Ankala Block (Allen & Black, in press). This third event in the Ankala Block corresponds to the fourth event recognised in the Utnalanama Block, there being no evidence in the Ankala Block for the intervening migmatisation and metasomatic event in the Utnalanama Block. Recrystallisation in the Ankala Block during initiation of the Harry Creek Deformed Zone was minor and the main effect was minor metasomatism associated with intrusion of the Gumtree Granite, which is thought to closely postdate these movements (Allen & Black, 1979). The last event, correlated with the Alice Springs Orogeny and the reactivation of the Harry Creek Deformed Zone, occurred under epidote amphibolite facies conditions.

Origin (A.R.A.)

The Ankala gneiss is thought to be mainly a metasedimentary unit, but some of the mafic layers are interpreted as igneous in origin: the thin units are interpreted as mafic volcanics, and the thicker more massive bodies are interpreted as intrusive dykes or sills. The rare ultramafic rocks and a small proportion of the quartzofeldspathic rocks may also have an igneous origin. The hematite-quartz rocks have possibly been derived from ironstones.

Age and Correlation (A.R.A.)

The Ankala gneiss has been metamorphosed during the earliest (M1) event identified in the Harry Creek area and dated at 1800 m.y. using $^{40}Ar-^{39}Ar$ incremental heating methods (Allen & Stubbs, in press). It may represent part of the Strangways Metamorphic Complex, but was metamorphosed at a shallower crustal level than the Erontonga metamorphics and, thus, may have a younger depositional age. Metagabbro dykes in the Ankala gneiss are similar to those of Johannsen Metagabbro dyke swarm, except they are of lower metamorphic grade (i.e. lack orthopyroxene).

D-3-3: Unassigned gneisses in the Ankala Block (South) (pG), (Narbib Block in LAUGHLEN Preliminary map) (R.D.S.)

South of range of Heavitree Quartzite at Winnecke and immediately south of the east-trending belt of Sliding Rock metamorphics, and in apparent conformity with them, is a sequence of biotite gneisses, which includes up to 20 percent amphibolite and a smaller amount of quartzofeldspathic gneiss. A good reference section for this sequence is east of Mount Laughlen.

The most abundant biotite gneisses in the sequence are thought to be pelitic and include many biotite and quartz-rich varieties in addition to rare garnetiferous types. On the other hand, the quartzofeldspathic gneiss and some biotite gneisses have granitic compositions.

D-4: Division 2: Rocks of the Wigley Block, similar to Division 1 rocks. - Introduction (L.A.O.)

The Wigley Block is a mainly fault-bounded tectonic unit which extends from southeastern and southern LAUGHLEN, northern UNDOOLYA and southeastern BURT, through the northern part of ALICE SPRINGS and MACDONNELL RANGES to at least as far west as HERMANNSBURG; the western boundary of the Block has not yet been located. The west-trending Redbank Deformed Zone is the northern contact of the Wigley Block in HERMANNSBURG, MACDONNELL RANGES and ALICE SPRINGS. Northeast-trending splay-faults from the Redbank Deformed Zone define the northern boundary of the Block in BURT and LAUGHLEN. The southern fault boundary of the Wigley Block is in part the root zones for the Blatherskite Nappe (ALICE SPRINGS) and Mount Sonder Nappe (HERMANNSBURG). A migmatite front forms the boundary between the Wigley Block and Alice Springs Block in HERMANNSBURG and sediments of the Amadeus Basin unconformably overlie the Wigley Block in the east in LAUGHLEN and UNDOOLYA and also in the west in HERMANNSBURG.

The Wigley Block, as distinct from surrounding tectonic divisions, characteristically consists of migmatised gneisses and some large bodies of granite and granitic gneiss. Both the Wigley Block and the Alice Springs Block to the south are intruded by dolerite dykes and plugs of the Stuart Dyke Swarm (Bds). No dolerite dykes are known to crop out north of the Wigley Block in the southeastern part of the Arunta Block.

Gneisses of the Wigley Block are commonly highly feldspathic (about 60% feldspar, 30% quartz) and are interlayered with amphibolite; quartzite is absent and metapelite assemblages and calc-silicate rock are rare. Thus much of the Wigley Block is made up of rocks ranging from granitic to granodioritic compositions. The large-scale nature of lithological variations suggests that primary layering (either bedding or igneous sills and flows) is the precursor whereas the fine-scale layering in banded biotite gneiss is thought to be caused by metamorphic differentiation enhancing original mineralogical differences in the rock during deformation. Hence metamorphic foliation may be largely coincident with primary layering.

The regional metamorphism, which recrystallised rocks of the Wigley Block to amphibolite facies assemblages prior to the migmatisation event, has been dated from widely separated areas. A total-rock Rb-Sr date of 1586 ± 69 (1620 ± 70 m.y. λ = 1.39) (Marjoribanks & Black, 1974) has been reported from the Alice Springs Block in HERMANNSBURG. Samples from the eastern part of the Wigley Block and the nearby northern basement part of the White Range Nappe define a whole-rock Rb-Sr isochron which gives a date of 1683 ± 23 (1719 ± 24 m.y. λ = 1.39) (Armstrong & Stewart, 1975). Thus the recrystallisation which formed the gneissic fabric in the Wigley Block prior to the partial disruption and overprinting by the younger migmatite event is about 1700 m.y. in age i.e. Middle Proterozoic.

Marjoribanks (1975) used the term 'Ormiston Zone' for rocks of the Wigley Block in HERMANNSBURG, and recorded a Rb-Sr age of migmatisation at 1053 ± 49 (1076 ± 50 m.y. λ = 1.39) (Marjoribanks & Black, 1974). Biotite from granodioritic gneiss (Jennings Granitic Gneiss, Bgn) in the eastern part of the Wigley Block gave a K-Ar age of 1097 m.y. and a biotite-chlorite concentrate from partly altered "gneissic granite" (also from Bgn) gave a K-Ar age of 997 m.y. (Stewart, 1971b). A Rb-Sr whole-rock/mica isochron of 1121 m.y. (Armstrong & Stewart, 1975) was obtained from the same "gneissic granite" sample. Stewart (BMR, personal communication, 1978) considers these ages could reflect isotopic redistribution at about 1100 - 1000 m.y. The effects of this metamorphic event are also apparent in a few places in the adjoining Alice Springs Block. For example, the Alice Springs Granite (Bga) was either intruded into its present position or was isotopically disturbed at about 1100 m.y. (Compston & Arriens, 1968; L.P. Black, BMR, personal communication, 1977) and Marjoribanks (1975) reports redistribution of Rb-Sr isotopes in muscovite from the Alice Springs Block in HERMANNSBURG, an effect he assigns to the migmatite event.

In HERMANNSBURG Marjoribanks (1975) refers to the two main deformations affecting the Arunta Block as the Chewings Phase and the succeeding Ormiston Phase. In the Wigley Block in HERMANNSBURG the Chewings Phase is characterised by isoclinal folds and strong axial-plane foliation and lineation, and is considered to be partly coeval with the

Middle Proterozoic amphibolite facies metamorphism; the Ormiston Phase is characterised by folds with a wide range of style and orientation, and is accompanied by Late Proterozoic migmatisation and granite intrusion.

Layering in the gneisses is preserved as the dominant fabric element; whole sale recrystallisation may have occurred during the subsequent high amphibolite facies metamorphic event which accompanied the Ormiston Phase of deformation.

From field examination the layered migmatised gneisses characteristic of the Wigley Block are considered to be derived from a sedimentary and volcanic pile of granitic to granodioritic composition; large masses of macroscopically homogeneous granitic gneiss are considered to be derived from acid plutons. Amphibolite layers, lenses and pods in some places contain relict igneous pyroxene and are derived from basic sills or flows.

Rocks of the Wigley Block are tentatively correlated with the Division 2 of metamorphic rocks of the Arunta Block proposed by Shaw & Stewart (1975) and briefly described by Stewart & Warren (1977). One possible exception is the Randall Peak metamorphics which are characterised by quartzofeldspathic gneiss and amphibolite; rock types which may be analogues of mafic and felsic granulites of Division 1 at a lower metamorphic grade.

Only a very informal subdivision of the Wigley Block has been possible because of the gross compositional homogeneity of rocks of the Wigley Block and the gradational and commonly poorly exposed contacts between many rock types. Other rock types in the Wigley Block are referred to as Unnamed units (e.g. pGs), or Unassigned gneiss (e.g. pG), and are only briefly described.

Component units of the Wigley Block are the Bond Springs gneiss pGb, Flint Spring gneiss pGe, Charles River gneiss pGq, Unnamed unit pGd north of Bond Springs homestead, Unnamed unit pGs in the Mount Solitaire area, Unnamed unit pGp south of Mount Forster (Forster gneiss on ALICE

SPRINGS preliminary map) and Unnamed unit pGj in the Colyer Creek area (Colyer gneiss on ALICE SPRINGS preliminary map) in ALICE SPRINGS; the Randall Peak metamorphics pGr and Unnamed unit pGv in LAUGHLEN and UNDOOLYA; and Unassigned gneiss pG in ALICE SPRINGS, LAUGHLEN and UNDOOLYA; and Unnamed unit pGf on LAUGHLEN preliminary map.

D-4-1: Randall Peak metamorphics, (R.D.S.)

(includes pGf in LAUGHLEN Preliminary)

Definition

A distinctive unit characterised by quartzofeldspathic gneiss (f) and amphibolite (a) crops out as a complex arcuate pattern of ridges in an extensive area in southern LAUGHLEN and in northern UNDOOLYA south of Randalls Peak, after which the unit is named. Biotite gneiss (b) is intercalated with the quartzofeldspathic gneiss. Muscovite-biotite gneiss (s) is also a subordinate rock type in the immediate vicinity of Randall's Peak, where it forms valleys and flatter country. Other minor rock types with a more widespread distribution include hornblende gneiss (h), sillimanite gneiss (z) and megacrystic feldspar gneiss (p). The type area extends from Porters Well (GR 5751-221093) for about 4 km farther to the southwest. Sequences containing thick units of quartzofeldspathic gneiss and amphibolite are included in the Randall Peak metamorphics; the boundary is defined by the change in rock type from the last thick unit of quartzofeldspathic gneiss. The metamorphics include the unnamed unit pGf shown in the preliminary map of LAUGHLEN. The surrounding gneisses (pG) are predominantly biotite gneiss; the absence of quartzite in the Randall Peak metamorphics distinguishes the unit from the Laughlen metamorphics.

Relationships

The Randall Peak metamorphics are surrounded for the most part by unassigned biotite gneisses grouped in the undivided unit pG. Based on meagre foliation-dip information, the metamorphics consistently dip underneath the undivided unit pG and may be older.

The Trephina granitic gneiss (Bgt) has discordant contacts against the Randall Peak metamorphics and encloses a raft of the metamorphics. The Jennings Granitic Gneiss (Bgn) has some conformable contacts and some discordant contacts with the metamorphics suggesting that they are both granites which intruded the metamorphics before metamorphism.

The metamorphics are also intruded by a number of small gabbroic plugs (Bgb), which show partial greenschist retrogression.

The unit is unconformably overlain by Heavitree Quartzite at the southern tip of Georgina Range.

The western boundary of the unit is obscured by deep weathering and alluvium.

Lithology

The unit occupies an extensive area in central-southern LAUGHLEN and northern UNDOOLYA. The overall proportion of rock types in the unit has been estimated from aerial photographs to be:

Quartzofeldspathic gneiss (f)	30%
Amphibolite (a)	30%
Biotite gneiss (b)	30% or more
Muscovite-biotite gneiss (s)	5% or less
Hornblende gneiss (h), sillimanite gneiss (z) and megacrystic feldspar gneiss (p)	5%

The muscovite-biotite gneiss (s) is largely confined to the Randalls Peak area. Biotite gneiss (b) has a very variable distribution, and is most abundant in the southern part of the outcrop-area, where it is the main rock type.

The metamorphics also occur outside the principal outcrop-area as a small lens of epidote-stained feldspar amphibolite and hornblende gneiss within the Jennings Granitic Gneiss at GR 5751-450020. The amphibolite lens is surrounded by an envelope of biotite gneiss containing small quantities of hornblende, garnet and feldspar megacrysts.

Quartzofeldspathic gniess (f) is widely distributed in layers and lenses commonly about 150 m wide, which have a distinctive pale yellow-brown colour on the aerial photographs, and form low ridges. The gneissic layering is typically well-developed, very even in width, and made up of folia generally about 2-8 mm wide. The rocks are typically fine to medium-grained, but those with a high K-feldspar content tend to be medium to coarse-grained. Biotite is the main subordinate mineral and ranges from 5 to 15 percent. Rocks with a biotite content in excess of 10 percent are included because they are indistinguishable from aerial photographs from those with a colour index of less than 10. Muscovite is much less common. Garnetiferous varieties (vf) are uncommon and sporadically distributed (e.g. GR 5751-132023, 5751-185047). The quartzofeldspathic gneiss is locally migmatitic. The two specimens examined in thin section (D736, D738: Table D-4-1A) have granitic (ie, hypidiomorphic) rather than gneissic textures. Specimen D738 is adamellitic in composition, and consists of K-feldspar (35%), quartz (30%), plagioclase (24%), biotite (5%), sericite (4%) and opaque grains (2%). Specimen D738 has a granodioritic composition, and contains hornblende (2%) (Table D-4-1A).

Biotite gneiss (b) is typically medium-grained and poorly or very finely foliated, although outcrops may be notably flaggy because the foliation is very planar (ie, folia are up to 5 m wide). The gneiss is distinguished by its biotite content, which varies from 10 to 30 percent. These rocks are distinguished from the quartzofeldspathic gneiss by their darker brown colour on the aerial photographs. The gneiss is commonly migmatitic on a small-scale. Visually estimated modes are set out in Table A. A notable feature of the biotite gneiss is that K-feldspar is commonly absent or confined to a leucosome phase (eg, D710, Table D-4-1A). The gneiss contains accessory apatite and zircon in places (eg, 921D, Table D-4-1A).

South of Randalls Peak, the more leucocratic of the biotite gneisses grade into muscovite-bearing biotite schist (s) which is generally quartz-rich, has a colour index between 10 and 50, and is fine to coarse-grained. Muscovite is nearly everywhere subordinate and commonly occurs as conspicuous coarse-grained aggregates.

TABLE D-4-1A: Visually estimated modes of quartzofeldspathic gneiss (f), biotite gneiss (b), sillimanite-bearing gneiss (z) and related rocks from the Randall Peak metamorphics

Rock Type Symbol	D707 p	D736 f	D738 f	921D b	1160 b	D710 b	3614 b	D709 d	D735 z	3528 z	D737 z
Quartz	20	45	30	25	55	35	10	27	20	58	55
Plagioclase	35	27	24	50	25	45	55	15	37	15	10
Biotite	5	8	5	20	15	14	13		5	15	20
Muscovite	2								30	3	
K-feldspar	38	12	35			2	20	38			6
Hornblende							2				
Garnet									2	2	1
Sillimanite									6	5	5
Chlorite					1			10			1
Epidote/clinozoisite				tr	1	1	10				
Sericite		4	4	5	3	3					
Opaque grains		2	2							2	2
Apatite				ac	ac						
Zircon				ac	ac						
Sphene						ac					
Texture*[1]	gr	gr	gr	g	g	g		d	s	g	s

*[1] gr - hypidomorphic, g - granoblastic, s - schistose, d - cataclastic

*[2] K-feldspar is confined to a leucosome layer 2 cm wide where it accounts for 35 percent of the layer

ac = accessory

tr = trace

Megacrystic feldspar gneiss (p) is a variant of biotite-bearing quartzofeldspathic and biotite-gneisses. It is typically of very variable grainsize (fine to coarse-grained), and commonly accompanied by a pegmatitic granite phase, which in places is muscovite-bearing. Examples have been mapped at GR 5751-145015 where it is a coarsely foliated rock with a colour index of about 30; near the boundary with the Jennings Granite Gneiss (Bgn) at GR 5751-322023; and in UNDOOLYA at 5750-204846, where it contains pink feldspar megacrysts up to 5 cm across in a strongly lineated matrix of biotite, quartz and feldspar. Specimen 707 from GR 5750-204846 is of adamellitic composition, and consists of microcline (38%), plagioclase (35%), quartz (20%), biotite (5%), muscovite (2%) and accessory zircon and apatite.

Amphibolite (a) is widely distributed in layers up to 150 m wide which are typically intercalated with the quartzofeldspathic gneiss. The amphibolite is commonly fine to medium-grained, and shows a wide variety of textures (see Table D-4-1B). It typically contains about twice as much hornblende as plagioclase and 5 to 15 percent quartz. The hornblende is commonly a bluish green variety, and in a few places is completely retrogressed to actinolite (Table D-4-1B).

The amphibolite in the lens within the Jennings Granitic Gneiss at GR 5751-450020 is lineated, not foliated, and is noticeably stained with epidote (4340-42).

Amphibolite grades into biotite-hornblende gneiss (h) (Table D-4-1B, eg., 921B, 921C, 5080). A typical example (921C) contains hornblende (5%), quartz (25%), biotite (23%), plagioclase (45%) and opaque grains (2%). Garnet and sericite are locally present. Zircon is accessory. Hornblende gneiss (68110099) also occurs in the envelope of gneiss surrounding the amphibolite lens in the Jennings Granitic Gneiss at GR 5751-450020. This hornblende gneiss is medium-grained and non-layered.

TABLE D-4-1B: Visually estimated modes of amphibolite (a)* and hornblende gneiss (h) from the Randall Peak metamorphics

	912A	3533	D708	D711	D712	D722	D723	D734	921B	921C	3616	4340	4341	4342
Rock Type Symbol	a	a	a,r	a,r	aa	a	a	a	h	h	a	a	a	a
Clinopyroxene		?5												
Hornblende	60	55		60	65	50	45	60	x	4				
Plagioclase	25	32	20	10	24	34	48	37	x	45	55			
Biotite	5		1						x	23				
Quartz	10	5	5	10	10	15	5	tr	x	25				
Garnet										2				
Sericite/ Muscovite			4	10	1			1		tr				
Epidote/ Clinozoisite				10				1						
Actinolite/ Tremolite			40											
Chlorite			20							tr				
Sphene						1		1						
Zircon										ac				
Opaque Grains		3	7				2	tr	tr	2				
Apatite			3?											
Texture*		u	g	g	g	s	u	u	d					

* s = schistose
g = gneissic
b = granoblastic
u = granuloblastic

x = present
ac = accessory
tr = trace

Metamorphism

The Randall Peak metamorphics have been metamorphosed under lower amphibolite facies conditions. The pelitic assemblage sillimanite-muscovite-garnet has a sporadic, but widespread distribution. The hornblende in amphibolite and biotite-hornblende gneiss is bluish-green or less commonly green and is only locally altered to actinolite. Garnet is also sparsely disseminated in some of the quartzofeldspathic rocks. Migmatitisation is widespread in the gneisses so it is likely that temperatures were high enough to allow partial melting.

Later greenschist retrogression is evidenced by saussuritisation of plagioclase, chloritisation of biotite, and alteration of hornblende to actinolite. The blue-green hornblende may also be a retrograde mineral and belong to this later event. Epidosite and quartz veins are most abundant in those zones where greenschist retrogression is most marked, such as alongside the east-trending fault system which cuts the unit.

Structure

Foliation dips at the perifery of the unit suggest that it forms the core of a complex dome or acticlinorium.

Early folds (possible F3 as mapped in ALICE SPRINGS) trend northwest and northerly in the southern part of the outcrop-area and northeast in the northern part. These are overprinted by more open easterly-trending folds (?F4), which in many cases are localised near the east-trending faults suggesting a genetic association.

The east-trending fault system is the dominant structural feature. The localisation of greenschist retrogression alongside these faults suggest that it is an Alice Springs Orogeny event. However, there is evidence from the Whistleduck dolerite dyke swarm that the faults are much older. These dolerites are localised in the east-trending faults and are considered to have been metamorphosed at amphibolite facies before retrogression.

The northern margin of the Randall Peak metamorphics is a major fault, along which narrow zones of greenschist retrogression are also concentrated. This northern boundary fault represents an extension of the Redbank Deformed Zone, which is known to have undergone two major periods of movement; one pre-migmatisation (ie, older than 1100 m.y.); the other during the Alice Springs Orogeny (Marjoribanks & Black, 1974).

Origin

The layered nature of the quartzofeldspathic gneisses and amphibolites together with their probable meta-igneous compositions suggests that they may represent a bimodal volcanic pile very like that postulated for the Strangways Metamorphic Complex. Alternatively, the quartzofeldspathic rocks may be meta-arkose. Also, like the Strangways Metamorphic Complex, the unit contains pelitic intercalations now represented by the garnet sillimanite-muscovite-biotite gneiss.

Correlation and Age

The principal rock types are very like those of the lower part of the Strangways Metamorphic Complex except they are at a much lower metamorphic grade. The metamorphics may, therefore, belong to Division 1. On the other hand, they are part of the Wigley Block and have undergone the migmitisation characteristic of that Block which as been dated in HERMANNSBURG (some 150 km to the west) at about 1100 m.y. (Marjoribanks & Black, 1974). In addition, and unlike the Strangways Metamorphic Complex, the Randall Peak metamorphics is overlain by Heavitree Quartzite. This relationship together with its relatively low metamorphic grade (lower amphibolite facies) suggest that the Randall Peak metamorphics represents a higher structural-level in the crust than the Strangways Metamorphic Complex. This conclusion is consistent with its association with the Trephina granitic gneiss and Jennings Granitic Gneiss bodies. The Randall Peak metamorphics are correlated with the Ankala gneiss, which is lithologically similar and is also thought to represent a higher structural level than the Strangways Metamorphic Complex.

D-4-2: Flint Spring gneiss, pGe (New name) (L.A.O.)

Definition

The Flint Spring gneiss is characterised by an abundance of porphyroblastic and augen gneiss, and crops out north-northwest of the Alice Springs township in ALICE SPRINGS where it occupies an area about 7 km by 1 km of low to moderate rounded and rubbly hills. The unit is named after Flint Spring (GR 5650-783902) on Colyer Creek. The type locality is along a tributary of Colyer Creek from GR 5650-833913 to 820916. Prophyroblastic and augen gneiss occur either as a small component or are lacking in the neighbouring units.

Relationships

The eastern contact with the Unassigned gneiss (pG) and the western contact with the Unnamed unit (pGp) are both gradational and conformable with the foliation. The Flint Spring gneiss is bounded to the north and south by faults. Slightly metamorphosed norite (Bgb) forms a small rubbly outcrop within the unit and an aplite dyke, 50 cm wide, intrudes the unit (GR 5650-809913) and is itself crosscut by the country rock foliation.

Lithology

The unit consists largely of, and is typified by, porphyroblastic and augen gneiss composed of large augen and ovoids of feldspar up to 10 cm or more long, in a dark fine-grained matrix. The rest of the unit comprises quartzofeldspathic gneiss, banded biotite gneiss containing garnet in a few places, schistose biotite gneiss, and a small number of amphibolite layers and lenses. No specimens of the unit were collected.

Structure

The Flint Spring gneiss outlines a large-scale fold with a northwest-trending axial-plane trace; foliation dips about the vertical. About 2 km west of 10 Mile Bore augen and quartzofeldspathic gneiss are mesoscopically folded about a moderately plunging west-southwest axis. The axial-plane of the folds is outlined by a gneissic fabric of mineral streaking and feldspar augen orientation.

Origin and Age

The origin of the Flint Spring gneiss is uncertain. The abundance of porphyroblastic and augen gneiss within the unit suggests the unit may be at least partly of igneous origin.

The Flint Spring gneiss was probably metamorphosed during the Middle Proterozoic Chewings Phase of deformation. Effects of the Late Proterozoic Ormiston Phase of deformation are considered to be the large-scale fold; no significant recrystallisation of the Flint Spring gneiss is thought to have accompanied this folding.

D-4-3: Charles River gneiss, pCq (New name) (L.A.O.)

Definition

The Charles River gneiss typically consists of layered garnet-bearing gneiss, and amphibolite, and crops out about 9 km north of the Alice Springs township in ALICE SPRINGS. It is named after the Charles River, which crosses the unit. The type locality is about 10 km north of the Alice Springs township on the west side of the Stuart Highway (GR 5650-846882) and consists of banded garnet-biotite gneiss, quartzofeldspathic gneiss and amphibolite. Neighbouring units contain only a small amount of garnet-bearing gneiss.

Relationships

The Charles River gneiss is bounded to the north, east and south by faults. In the west the unit is interlayered with the Old Hamilton Downs Gneiss (Bw), and conformably in contact with Unassigned gneiss (pC) and migmatised gneiss of the Unnamed unit Bx. Partly metamorphosed norite (Bgb), dykes and plugs of dolerite (Bds), and pegmatite plugs intrude the unit. Outcrop areas that contain extensive mobilised fractions are regarded as part of the migmatite unit, Bx.

Lithology

The unit consists of garnet-biotite gneiss, biotite gneiss, amphibolite, migmatite, and a small amount of quartzofeldspathic gneiss.

The compositions of five garnet-bearing gneisses (v) collected from the unit are shown in Table D-4-3A. At the type locality the garnet-biotite gneiss is medium-grained and consists of plagioclase, strongly deformed quartz, biotite, garnet and accessory opaque and epidote grains. No K-feldspar was seen (73913866). The more quartzofeldspathic layers at the type locality consist of sericitised plagioclase, perthitic microcline, quartz, biotite, garnet (partly altered along fractures to chlorite), and accessory epidote (73913867). In places, the garnet is up to 4 mm across and is confined to the quartzofeldspathic layers in the gneiss.

Biotite gneiss (b) is commonly layered, with quartzofeldspathic layers about 1 to 2 cm wide. However, in places it is not layered, but contains feldspar lenses and subidioblastic grains up to 4 cm long.

Amphibolite (a) crops out as plugs, and as conformable layers up to 10 m across. Table D-4-3B lists the composition of amphibolite collected from two pods and a fault zone.

Some areas of gneiss are partly migmatised (mi), and contain layers of coarser quartz and feldspar and rare cross-cutting patches of quartzofeldspathic mobilisate.

Structure

A large-scale antiform and overturned synform plunge to the southwest. Mesoscopic folds in the unit commonly plunge to the west. The folds are open and are defined by folded gneissic layers; some biotite flakes parallel the axial plane of the folds. Narrow zones of schistose and retrogressed gneiss crop out along the major faults.

Origin

The Charles River gneiss is thought to be derived from pelitic and feldspathic psammites and mafic sills which have been intruded by plugs of micronorite.

TABLE D-4-3A - CHARLES RIVER GNEISS

GARNET-BEARING GNEISSES

Specimen No.	Field description	Feldspar	Quartz	Biotite	Garnet	Accessories
73913788	Garnet-biotite gneiss	Andesine, Kspar? } 55%	30%	15%	Small amount	Apatite, epidote, muscovite
73913797	Garnet-biotite gneiss	Plag., Microcline } 60%	35%	3%	2%	Muscovite, zircon
73913831	Garnet-biotite gneiss	Plag., Microcline } 60%	35%	5%	Small amount	Opaque grains, sericite, epidote
73913866	Garnet-biotite gneiss	Plag. 35%	35%	15%	15%	Opaque grains, epidote
73913867	Strongly deformed quartzofeldspathic gneiss	Plag., Microcline } 60%	35%	5%	Small amount	Chlorite, epidote

TABLE D-4-3B: CHARLES RIVER GNEISS

AMPHIBOLITE

Specimen No.	Field description	Amphibole	Pyroxene	Plagioclase	Quartz	Epidote/ Clinozoisite	Accessories
73913798	Amphibolite pod several metres long	Hornblende 40% (green)	Opx, Augite 20%	35%	5%	-	Small amount of opaque grains and apatite
73913936	Epidosite pod 15 cm long	Hornblende (green and blue-green), Actinolite 25%	-	15%	10%	50%	Small amount of muscovite and sphene
73913862	Black aphanitic deformed rock	Hornblende 48% (green)	-	45%	5%	Small amount	Opaque grains 5% Biotite 2%

Age

The Middle Proterozoic Chewings Phase of deformation and metamorphism is thought to have produced the lithologic layering and amphibolite facies assemblages of the Charles River gneiss; migmatisation was coeval with the later Ormiston Phase of deformation. Thus the gneiss is considered to be Middle Proterozoic or older.

D-4-4: Bond Springs gneiss, pGb (New name) (L.A.O.)

Definition

The Bond Springs gneiss is composed mainly of leucocratic gneiss, and crops out as an arc of low hills in the northeast of ALICE SPRINGS near the Bond Springs homestead (GR 5650-897960) from which it derives its name. The type locality for the unit is north of the homestead along the tributary of the Todd River (GR 5650-897964 to 897973). The unit is distinguished by its leucocratic composition and from its neighbours which are mainly composed of darker coloured gneisses.

Relationships

The Bond Springs gneiss is structurally underlain to the east and overlain to the west by Unassigned gneiss (pG) along contacts which are conformable with the foliation and are marked by a distinctive change from the darker rocks of the Unassigned gneiss (pG) to the generally lighter coloured rocks of the Bond Springs gneiss.

The Unnamed unit pGj in the Colyer Creek area, which crops out west of the Bond Springs gneiss, also contains a high proportion of leucocratic gneiss; however the stratigraphic relationship between the two units is not known. A Palaeozoic fault reactivated from the earlier Redbank Deformed Zone ($\frac{Pzr}{Brr}$) separates the Bond Springs gneiss from the Unnamed unit pGd of leucocratic garnet gneiss and amphibolite to the north. Displacement along this fault is believed to be substantial, and therefore the nature of the relationship between the two leucocratic units is not known.

Lithology

The Bond Spring gneiss consists predominantly of leucocratic medium-grained quartzofeldspathic and garnet-muscovite gneiss and a lesser amount of banded biotite gneiss, amphibolite and muscovite schist. Biotite and magnetite are common accessory minerals in the leucocratic gneiss. Muscovite schist crops out north of the homestead, is brown in outcrop, and contains a small amount of biotite, and possibly chlorite near the Redbank Deformed Zone. In the southern exposures of the Bond Springs

gneiss a few outcrops are partly migmatitic; coarser-grained quartzofeldspathic layers are concordant with the gneissosity. No specimens of this unit were collected.

Structure

The Bond Springs gneiss outlines an open macroscopic west plunging antiform. Foliation is defined by the compositional layering together with a mineral elongation, and parallels the contacts with surrounding units.

Origin and Age

The origin of the Bond Springs gneiss is uncertain. Gneiss and schist may represent psammitic and pelitic sediments and acid volcanics; amphibolite bodies may have been basic sills or flows.

The gneissic fabric is related to the Middle Proterozoic Chewings Phase of deformation and accompanying metamorphism. Overprinting this fabric in a few places is migmatite formed during the Late Proterozoic Ormiston Phase of deformation. The large-scale antiform is thought to be related to the Ormiston Phase.

D-4-5: Unnamed units of the Wigley Block

D-4-5-1: pGv: Hornblende gneiss (A.J.S.)

An unnamed unit of hornblende gneiss interlayered with quartzofeldspathic gneiss and granite forms a large curved lens in the west of Mordor Pound, between Trephina Gorge and the Georgina Range, in the southeast of LAUGHLEN. The body is 7.7 km long and 1.3 km wide at its maximum, and is concordantly surrounded by coarse granitic gneiss of the Jennings Granitic Gneiss, from which it is distinguished by its abundance of hornblende. The unit comprises variegated pink, white, and green medium-grained non-layered microcline-plagioclase-hornblende gneiss, interlayered with lenses several metres wide and tens of metres long of coarse-grained quartzofeldspathic gneiss and pink leucogranite rich in microcline. The unit may have formed as a product of potash metasomatism of a large raft of interlayered amphibolite and quartzofeldspathic gneiss of the Randall Peak metamorphics that was stoped off and engulfed by the Jennings Granitic Gneiss.

A folded layer of hornblende-gneiss and amphibolite which crops out near Wallace Rock Yark between GR 5751-327043 and 5751-337010 is tentatively included in pGv (R.D.S.).

D-4-5-2: pGs, garnet-hornblende gneiss - Mount Solitaire area, ALICE SPRINGS (L.A.O.)

This distinctive unit of garnet-hornblende gneiss crops out in the northwest of ALICE SPRINGS at Mount Solitaire and in the surrounding smaller hills. The unit is isolated by alluvial flats, and, consequently, relationships with other units are not known.

Lithology

The gneiss is homogeneous, and consists of medium-grained perthitic microcline and plagioclase (together 38%), quartz (30%), green hornblende (15%), biotite (10%), garnet (5%), apatite (2%), and accessory opaque grains (73913915). In places, the unit is layered, and comprises quartz-plagioclase layers up to 2 cm wide in melanocratic rock composed of plagioclase (33%), garnet (28%), green hornblende (22%), quartz (15%), opaque grains (2%) and a small amount of apatite and ?zircon (73913917 A & B). Granite veins cut the unit.

Structure

The foliation is outlined by lenses of deformed quartz aggregates and layers rich in garnet, hornblende and biotite, and at one locality on the north side of Mount Solitaire is tightly folded on a mesoscopic scale. A northeast-trending mylonite zone, about 1 m wide, cuts the unit about 0.5 km northwest of Mount Solitaire.

Origin

This distinctive unit of unusual composition, compared with other rocks in the Wigley Block, is similar in composition to several garnet-rich pods, which occur in the Unnamed unit south of Mount Forster (pGp) in ALICE SPRINGS and which are considered to be derived from calcareous pelite.

D-4-5-3: pGp, garnet-biotite gneiss - south of Mount Forster, ALICE SPRINGS (L.A.O.)

This unit crops out as low hills and rises, and is bounded to the south by a west-northwest trending fault and to the north by deformed gneisses of the Redbank Deformed Zone (Pzr/Brr). In the west the gneiss is overlain by alluvium and in the east is conformable against the Flint Spring gneiss pGe. In places the gneiss is intruded by pegmatite veins and quartz blows.

Lithology

The unit consists of banded and laminated biotite gneiss, quartzofeldspathic gneiss, amphibolite pods and layers, and hornblende gneiss. Garnet is common and in places the quartzofeldspathic gneiss contains feldspar prophyroblasts to 5 mm across.

No specimens of the banded and laminated garnet-bearing biotite gneiss and quartzofeldspathic gneiss were collected.

A concordant mafic lens at GR 5650-799931 consists of fine to medium-grained clinopyroxene, plagioclase, hornblende, biotite, sphene and opaque grains (73913859 A & B). Less than 1 km to the southeast, a mafic pod (73913860) crops out in garnet-biotite gneiss and consists of actinolite and subordinate tremolite (together 60%), plagiocalse (30%), quartz (5%), pyroxene (3%) and opaque grains (2%). At GR 5650-730925 the unit consists of hornblende gneiss (h) comprised of green and blue-green hornblende (35%), quartz (30%), plagioclase (20%), biotite (15%), and accessory sphene, apatite and opaque grains, and contains several garnet-rich calc-silicate pods up to 11 cm long. The pods typically consist of quartz (45%), garnet (35 to 40%), green and blue-green hornblende (20%), highly altered plagioclase (5%), and accessory opaque grains, and are rimmed by biotite-plagioclase-quartz rock (73913878).

Structure

In several places the layering is openly folded about mesoscopic fold axes plunging moderately to steeply west-northwest; the lineation parallels the fold plunge and is outlined by the intersection of the layering and the axial-plane cleavage.

D-4-5-4: pGj, leucocratic gneiss - Colyer Creek area, ALICE SPRINGS (L.A.O.)

This unit 14 km northwest of the Alice Springs township in ALICE SPRINGS, forms low rubbly hills and is composed of poorly exposed leucocratic garnet gneiss, banded biotite gneiss and amphibolite.

Relationships

To the north and west this gneiss grades into and structurally underlies an Unassigned unit of banded biotite gneiss, amphibolite and porphyroblastic gneiss (pG); to the east it grades into and is structurally underlain by another unassigned outcrop (pG) of banded biotite gneiss, amphibolite, porphyroblastic and migmatised gneiss. The gneiss in the Colyer Creek area is faulted to the northeast against the Flint Spring gneiss (pGe) and Unassigned gneiss (pG), and to the south against unnamed migmatite (Bx). Dolerite dykes (Eds) and a number of muscovite pegmatite plugs intrude the unit.

Lithology

The Unnamed unit in the Colyer Creek area is poorly exposed and has not been mapped in detail, but appears to be largely composed of fine to medium-grained leucocratic garnet gneiss, schistose biotite gneiss and biotite-garnet-gneiss. The garnet grains are up to 10 mm across. The extreme eastern part of the unit consists of banded biotite gneiss, amphibolite and porphyroblastic gneiss; garnet gneiss is not known in this area. Scattered green patches on the coloured aerial photographs suggest amphibolite may be a widespread component of the unit.

Structure

The western contact between the unit and the unassigned unit pG is thought to outline a macroscopic west-plunging antiform. In this area, the gneiss is mesoscopically folded about a moderately west-plunging axis and lineation is defined by rodding and mineral elongation parallel to this axis.

D-4-5-5: pGd, leucocratic garnet gneiss - north of Bond Springs homestead, ALICE SPRINGS (L.A.O.)

Leucocratic garnet gneiss forms a belt of low outcrops north of Bond Springs homestead (GR 5650-897960). It is bounded to the south by a west-southwest trending fault and overlain to the north by Quaternary sediments. Because no conformable relationships are seen with other units these rocks have been left unnamed. The Unnamed unit pGj in the Colyer Creek area contains similar rock types.

The unit consists of weakly foliated leucocratic garnet gneiss, and plugs and concordant layers of amphibolite. Garnet is in many cases subidioblastic and up to 2 mm across, and at several places is partly altered to biotite. Specimen 73913989 of amphibolite consists of medium-grained granoblastic brown hornblende (55%), labradorite (25-30%), clinozoisite (10-15%), light green clinopyroxene (5%), and accessory opaque grains.

D-4-6: Unassigned gneiss, pG, of the Wigley Block (L.A.O. & R.D.S.)

In a number of areas the rock types cannot be assigned to any stratigraphic grouping. These unassigned gneisses crop out in ALICE SPRINGS west-southwest of New Well (5650-573899), 9 km northwest of Simpson's Gap (5650-691812), southeast of Painta Spring (5650-669912), in the Mt Lloyd Bores and Tanks area (5650-775849) and near 10 Mile Bore (5650-845915) extending eastwards to UNDOOLYA. The unit also crops out in LAUGHLEN in the Whistleduck Bore area (5751-271054) and extends into UNDOOLYA to the south.

ALICE SPRINGS 1: Gneiss west-southwest of New Well, in ALICE SPRINGS, is faulted to the north and south and consists of biotite gneiss, amphibolite and granitic gneiss. In places garnet and feldspar porphyroblasts up to 5 mm occur in the biotite gneiss and the amphibolite contains abundant biotite (73913922). Migmatisation of the gneiss has produced local coarsening of quartzofeldspathic layers and a small amount of crosscutting mobilisate. The meso and macroscopic folds of this layered unit plunge at a moderate angle to the west.

ALICE SPRINGS 2: Gneiss about 9 km northwest of Simpson's Gap in ALICE SPRINGS is faulted to the south and grades into migmatised and granitic gneiss on other sides. The eastern boundary is hypothetical. The unit is intruded by dolerite dykes (Bds) and pegmatite veins, and contains conformable quartzofeldspathic veins.

Banded biotite gneiss, amphibolite, porphyroblastic gneiss and porphyroblastic quartzofeldspathic gneiss make up the unit. In some areas feldspar prophyroblasts are up to 5 cm long and quartzofeldspathic layers contain garnet. Only one specimen, amphibolite, was collected from the unit. It consists of medium-grained green and secondary blue-green hornblende (60%), plagioclase and perthitic microcline (together 38%), biotite (10%), apatite (2%) and a small amount of opaque grains, sphene, epidote, clinozoisite and calcite (73913959).

The rocks are layered and outline a macroscopic double fold. Lineations are caused by aligned biotite flakes and appear to define the axial plane trace of the second fold phase.

ALICE SPRINGS 3: Gneiss southeast of Painta Spring, in the northern central part of ALICE SPRINGS is faulted to the south and northeast, overlain by alluvium to the north, grades into migmatised gneiss (Bx) to the west and structurally overlies the Unassigned gneiss around Colyer Creek (pCj) to the east. The unit is intruded in a few places by dolerite dykes (Bds), pegmatite veins and patches of quartzofeldspathic mobilisate.

The unit is made up of biotite gneiss, augen gneiss (Photo D18: M/2166), quartzofeldspathic gneiss, amphibolite and a small amount of biotite schist. In places the biotite gneiss is banded with biotite-rich surfaces up to 5 mm apart. Feldspar augen are up to 7 cm long and occur within a strongly foliated matrix which in specimen 73913843 is composed of perthitic microcline and sericitised and saussuritised plagioclase (together 60%), quartz (30%), biotite (10%) and accessory apatite, opaque grains, allanite and ?garnet. In places the quartzofeldspathic gneiss contains a small amount of garnet. Specimen 73913846 consists of a boudinaged quartzofeldspathic layer within melanocratic gneiss composed of green and blue-green hornblende (65%), plagioclase and possible potash feldspar (together 15%), biotite (15%), quartz (5%) and accessory apatite and allanite.

Layers are folded on a meso and macroscopic scale, and plunge moderately to the west.

ALICE SPRINGS 4: Gneiss in the Mt Lloyd Bores and Tanks area, about 10 km northeast of Simpson's Gap in ALICE SPRINGS, is faulted to the north and south but elsewhere the contact with other rocks is conformable with the foliation/layering. A dolerite dyke (Bds) and a partly retrogressed mafic plug (Bgb) intrude the unit.

The rocks are banded biotite gneiss and quartzofeldspathic gneiss, and in the northeast include sillimanite-cordierite gneiss. In places the biotite gneiss and quartzofeldspathic gneiss contain feldspar augen up to 7 cm long, and in the northeast the quartzofeldspathic gneiss locally contains biotite and garnet. A 12 cm wide mafic lens within the quartzofeldspathic gneiss consists of fine-grained green and a small amount of blue-green hornblende (40%), garnet (20%), sericitised plagioclase (20%), quartz (15%), opaque grains (5%), and accessory biotite and apatite. Calcite lines fractures in the garnet (73913891). Sillimanite-cordierite gneiss crops out adjacent and partly interlayered with the mafic plug and consists of various amounts of feldspar, quartz, cordierite, sillimanite, biotite and garnet. Garnet is partly altered to green biotite, feldspar is saussuritised and sericitised, and cordierite is partly altered to pinite (73913889).

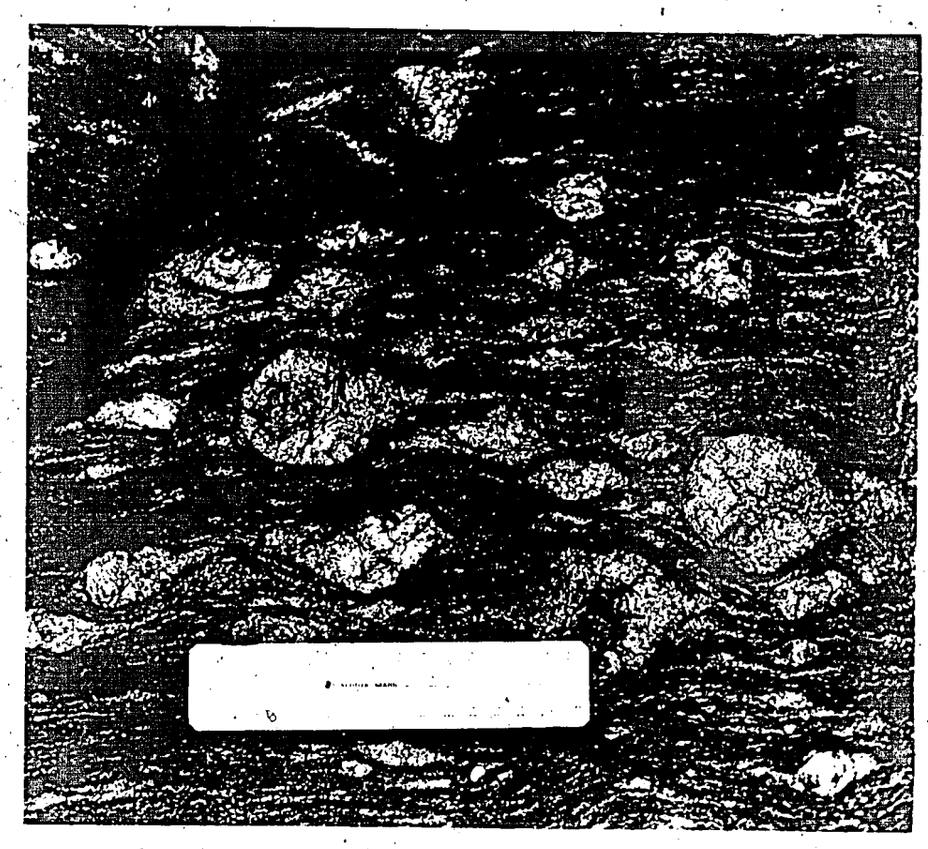


Photo D18: Augen gneiss; Unassigned gneiss southeast of Painta Spring (ruler 16 cm long). GR 5650-735881. (M/2166).

LAUGHLEN 1: Gneiss in the Whistleduck Bore area crops out in LAUGHLEN and extends to the south into UNDOOLYA as a belt separating the main outcrop area of the Randall Peak metamorphics (pCr) from an outlier of Randall Peak metamorphics (mapped as pCf on Preliminary Map) near the western tip of the Georgina Range. The gneiss consists of biotite gneiss, quartzofeldspathic gneiss and a small amount of amphibolite and rare calc-silicate rock. The biotite gneiss has a colour index of 30-60, is medium-grained, contains a mobilisate phase, is flaggy to medium-layered and is locally schistose. It typically lacks or contains little K-feldspar and is quartz-rich (e.g. 1159) like many of the gneisses in the Randall Peak metamorphics. Small amounts of muscovite and epidote in the biotite gneiss are thought to be caused by greenschist retrogression.

Amphibolite (a) plugs and layers contain varying amounts of amphibole (hornblende, actinolite and rarely tremolite), relict ?igneous pyroxene, and plagioclase (Table D-4-6A). Plagioclase grains are commonly highly altered to epidote, zoisite, clinozoisite and muscovite.

The composition of various other biotite-bearing gneisses (granitic, porphyroblastic and quartzofeldspathic gneisses) is shown in Table D-4-6B; they are consistently highly feldspathic. In places in UNDOOLYA granitic gneiss (73915725) and quartzofeldspathic gneiss (73915733 and 73915738) are weakly foliated and possibly intrude the neighbouring gneiss.

Sillimanite gneiss (z) forms a small proportion of the unit. In UNDOOLYA a schistose specimen (73915739) comprises biotite (75%), sillimanite (12%), muscovite (6%), quartz (5%), and garnet (2%).

Migmatite (mi) occurs sparsely throughout the unit. In the eastern part of the unit in UNDOOLYA granite veins and quartzofeldspathic patches transect the foliation in augen gneiss. Pegmatite veins parallel the foliation.

No specimens of quartzofeldspathic garnet gneiss, muscovite-biotite gneiss or garnet-biotite gneiss were collected from this unit.

TABLE D-4-6A: UNASSIGNED GNEISS, pG

AMPHIBOLITE

Specimen No.	Amphibole	Pyroxene	Plagioclase	Quartz	Epidote/Zoisite/ Clinozoisite/Muscovite	Biotite	Opaque minerals
73913963	hornblende; 75% (green and blue-green)	10%	15%	-	small amount	-	accessory
73913975 A	poikilitic brown amphibole with pale green rim; actinolite rims pyroxenes; 50%	opx) cpx) 30%	7%	3%	small amount	small amount (reddish-brown)	accessory
B	hornblende (green and blue-green) 80%	-	5%	15%	small amount	-	accessory
73913980	hornblende (green and blue-green), small amount of tremolite; 60%	-	-	5%	35%	-	accessory
73913981*	tremolite; 5%	-	-	-	95%	-	-
73913982*	actinolite; 55%	-	10%	-	35%	-	-
73913983*	hornblende; 55% (green and blue-green)	-	38%	-	7%	-	-
73913984*	hornblende; 30% (green)	-	10%	-	60%	-	-
73915706**	hornblende; 60% (green and blue green)	-	20%	10%	10%	-	accessory
73915740**	hornblende; 37% (green and subordinate blue-green)	-	50%	-	7%	3%	3%

* From same body

** Specimens from UNDOOLYA; all others from ALICE SPRINGS

TABLE D-4-6B - UNASSIGNED GNEISS, pG

BIOTITE-BEARING GNEISSES

Specimen No.	Field description	Feldspar	Quartz	Biotite	Accessories
73915725	Granitic gneiss	Kspar 38% Plag 30%	49%	Chloritsed biotite 3%	-
73915705	Porphyroblastic gneiss	Microcline } 64% Plag }	35%	1%	Opaque grains, apatite, zircon, allanite, muscovite
73915732	Porphyroblastic gneiss (may be unmetamorphosed)	Microcline 40% Plag 25%	20%	13%	Opaque grains 2%
73913861*	Quartzofeldspathic gneiss	Kspar } 60% Plag }	35%	5%	Opaque grains, muscovite, apatite
73915733	Quartzofeldspathic gneiss	Kspar 30+% Plag 30-%	30%	5%	-
73915738	Quartzofeldspathic gneiss	Microcline 35% Plag 28%	30%	5%	Opaque grains 2%

* Specimen from ALICE SPRINGS; all others from UNDOOLYA.

Structure

In the northeast of ALICE SPRINGS (GR 5650-930900) amphibolite outlines a tight overturned synform with a north to northeast-trending axial plane. To the north at GR 5650-945977 a photo-interpreted synform with a northeast-trending axial plane is truncated by the re-activated (during the Alice Springs Orogeny) Redbank Deformed Zone. Near 10 Mile Bore in ALICE SPRINGS the gneiss outlines a large scale open fold; the axial plane trace trends west and southwest. This westerly axis refolds the amphibolite at GR 5650-930900 and is thought to be associated with the Late Proterozoic Ormiston Phase of deformation.

Mesoscopic folds have west-trending axial planes and vary in style from ptygmatic, flow and isoclinal to open and gentle. An axial plane fabric outlined by parallel biotite flakes is commonly developed in the nose of the tighter folds.

LAUGHLEN 2: West of Georgina Gap there is a sequence of biotite gneiss (b) and less abundant hornblende gneiss (h). The sequence is markedly migmatised in places. Specimen 74915080 at GR 343418 is an example of hornblende gneiss which has been chemically analysed (see Geochemistry). The sequence is conformable with the Randall Peak metamorphics.

ALICE SPRINGS-UNDOOLYA: Gneiss near 10 Mile Bore in ALICE SPRINGS and extending eastwards to UNDOOLYA forms low to moderate rounded hills and ridges composed of biotite gneiss and amphibolite with lesser amounts of quartzofeldspathic garnet gneiss, muscovite-biotite gneiss, granitic gneiss, porphyroblastic gneiss, sillimanite gneiss, quartzofeldspathic gneiss, garnet-biotite gneiss and migmatite.

Relationships

The gneiss is fault-bounded to the north and south and to the west in ALICE SPRINGS grades into the Flint Spring gneiss (pGe), a distinctive unit mainly consisting of porphyroblastic gneiss. In ALICE SPRINGS the Unassigned gneiss structurally underlies and overlies the Bond Springs gneiss (pGb). The Unassigned gneiss grades into and is

darker in colour than the light-coloured rocks typical of the Bond Springs gneiss. In UNDOOLYA the gneiss grades into the Randall Peak metamorphics (pCr), a unit containing similar rock types to the Unassigned gneiss but containing a higher proportion of quartzofeldspathic gneiss and amphibolite. The boundary between the two units is photo-interpreted.

The Unassigned gneiss is intruded by rare dolerite (Bds) and quartz dykes and pegmatite veins.

Lithology

Specimen 74915082 from near 10 Mile Bore in ALICE SPRINGS appears in hand specimen to be typical of the biotite gneiss (b). It consists of microcline and plagioclase (together 60%), quartz (30%), biotite (10%) and accessory opaque grains, allanite and apatite. However this specimen is mylonitised and partly altered; sphene rims opaque grains and epidote replaces plagioclase.

Geochemistry

A whole rock analysis of specimen 74915082 near 10 Mile Bore in ALICE SPRINGS is similar in composition to average adamellite of Nockolds (1954) (Table A3, Appendix). Specimen 74915081 at GR 5751-401149 west of Georgina Range is a hornblende-bearing gneiss (h). Chemical analyses (Table A3, Appendix) show it has an intermediate composition.

D-4-7: Cement Dam gneiss, pCc (R.D.S.)

Definition

A small body of schistose biotite gneiss containing conspicuous megacrysts of K-feldspar crops out over a strike-length of about 7 km in a valley 1.5 km south of Cement Dam (23°24'S, 134°11'E). The type section is between GR 5751-183107 and 5751-175116 along the track between Randall's Peak and Porter's Well. The unit is distinguished by its schistose nature and the conspicuous K-feldspar megacrysts, which are absent from neighbouring units.

Relationships

The southern boundary is faulted against the Randall Peak metamorphics: the fault represents the eastern continuation of the Redbank Deformed Zone. The northeastern boundary is a fault-branch of the same deformed zone. The northern and southwestern boundaries appear to be conformable with a unit of unassigned amphibolite and subordinate biotite gneiss (pG).

Lithology

The porphyroblastic-feldspar biotite gneiss (p) is a distinctive rock containing conspicuous megacrysts of K-feldspar, in a biotite-rich matrix (up to 40 percent). The gneiss is very uniform in mineralogy. The biotite-rich matrix is medium to coarse-grained. A few layers of quartzofeldspathic gneiss (f) occur within the main gneiss.

Structure

The gneiss is a highly schistose zone and parallels the main eastern extension of the Redbank Deformed Zone which, in this case, is a fault. The schistosity generally dips about 40° northwards. In places, the schistosity is folded indicating a complex history.

Metamorphism

The gneiss is thought to have been formed under lower amphibolite facies conditions although the mineral assemblage is not diagnostic.

Origin

The highly potassic composition of the gneiss suggests that it has been derived from either pelitic metasediments or an acid igneous rock. Its highly schistose nature suggest that it may have had a structural history similar to those Schist Zones in the northern part of the 1:250 000 Sheet area that characteristically contain kyanite and staurolite (see general section on 'Metamorphism').

Age and Correlation

The age of the gneiss is unknown. It is lithologically similar to the Georgina Gap granitic gneiss. On the other hand, it may represent a schist zone such as those formed during the Yambah Metamorphic Event (see general section on Metamorphism).

D-4-8: Mulga Creek granitic gneiss, pGm (R.D.S.)

Definition

The Mulga Creek granitic gneiss forms a small plateau about 3 km across southwest of Georgina Gap, between the main ridge of Heavitree Quartzite near Mount Laughlen and Mulga Creek. The plateau is higher than the valley containing the Georgina Gap granitic gneiss, but lower than the ridges of Heavitree Quartzite forming Mount Laughlen. The type locality of the unit is at GR 5751-407149 just west of the boundary with the Georgina Gap granitic gneiss. It is distinguished from the Georgina Gap granitic gneiss by its finer-grain size and lack of K-feldspar megacrysts.

Relationships

The Mulga Creek granitic gneiss appears to have a discordant, possibly intrusive contact, with unassigned gneiss and amphibolite (pG), is intruded by the Georgina Gap granitic gneiss, and is unconformably overlain by the Heavitree Quartzite. It includes lenses of amphibolite which are thought to be derived from intrusive rocks younger than the granite, but relationships are uncertain. The metamorphic foliation is thought to post-date the time of intrusion. The granitic gneiss body has undergone green-schist retrograde metamorphism, presumably during the Alice Springs Orogeny.

Lithology and Geochemistry

Specimen 5081 consists of muscovite (2%), biotite (3%), plagioclase (45%) showing slight alteration to sericite, quartz (30%), and microcline (20%). It is fine-grained and slightly schistose. Chemical analysis of this specimen shows that it has the composition of a granite (see Appendix for analysis).

Structure

Layers of amphibolite within the granitic gneiss have been folded indicating that the gneiss has undergone a complex history.

Correlation and age

The Mulga Creek granitic gneiss is unlike other synorogenic granites such as the Trephina granitic gneiss, and is thought to be older than them because it shows evidence of deformation and folding. No age determinations have been carried out on the gneiss.

Origin

The gneiss is considered to be a deformed and metamorphosed granite, because it has a uniform granitic composition.

D-5: Division 2: Hayes Metamorphic Complex in the Alice Springs Block (L.A.O.)

Introduction

The Hayes Metamorphic Complex is defined as the granitic basement containing metasediments and amphibolite which crops out near the Alice Springs township in ALICE SPRINGS over an area of about 35 km east-west by about 10 km north-south. The name is derived from John Hayes Rockhole in the northeast of UNDOOLYA (GR 5750-331978).

The Charles River Fault is the northern boundary of the Hayes Metamorphic Complex, and the unconformably overlying Heavitree Quartzite (Buh) is the southern boundary (Photo D19). To the east the Complex is in contact with granitic gneiss (Bj) and to the west it is apparently overlain non-conformably by the Iwupataka Metamorphic Complex. Granite (Bga), pegmatite, and dolerite (Bds) intrude the Complex.

Component units of the Hayes Metamorphic Complex are the Unnamed Unit (pGpb), Emily Gap schist (pGpe), Unnamed Unit (pG pp), Teppa Hill metamorphics (pGpt), and the Sadadeen Range gneiss (pGpd).

D-5-1: Metasediment, pGpb, at the southeastern margin of Sadadeen Range gneiss (L.A.O.)

Granite and pegmatite veined metasediments crop out in ALICE SPRINGS as a north-trending belt about 300 m wide by 4.5 km long. The metasediments are apparently concordant with the Jessie Gap gneiss (Bj) to the east and the Sadadeen Range gneiss (pGpd) to the west. Exposure of this unit is generally poor.

The rocks are medium-grained garnet-biotite-quartz feldspar gneiss, schistose biotite gneiss, biotite-muscovite-quartz schist, and quartzite layers. The unit is intruded parallel to the foliation by numerous granite veins and locally by plugs of garnet-biotite-muscovite pegmatite. At GR 5650-912809 quartzose and schistose layers are mesoscopically folded about a west-dipping axial-plane.

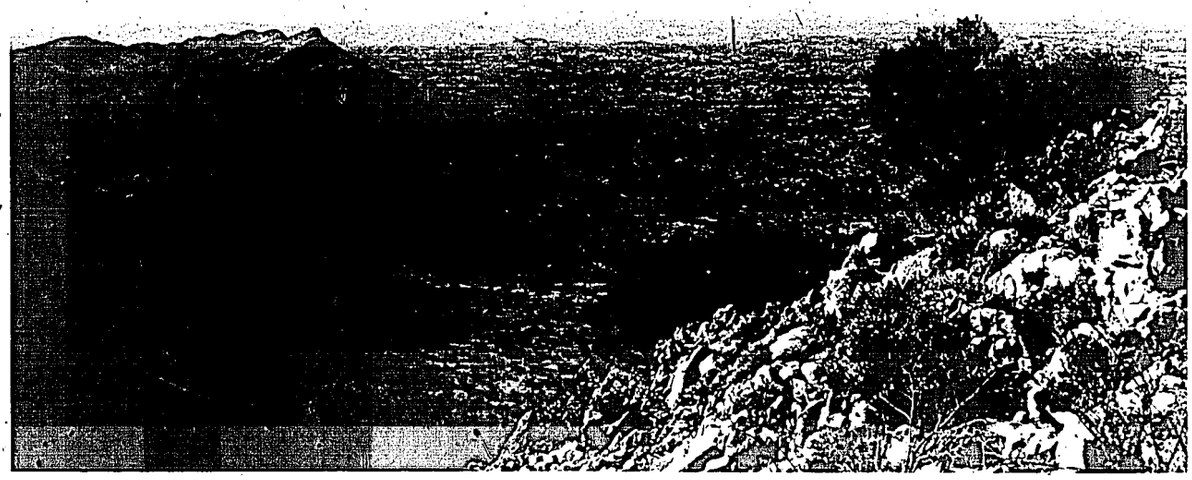
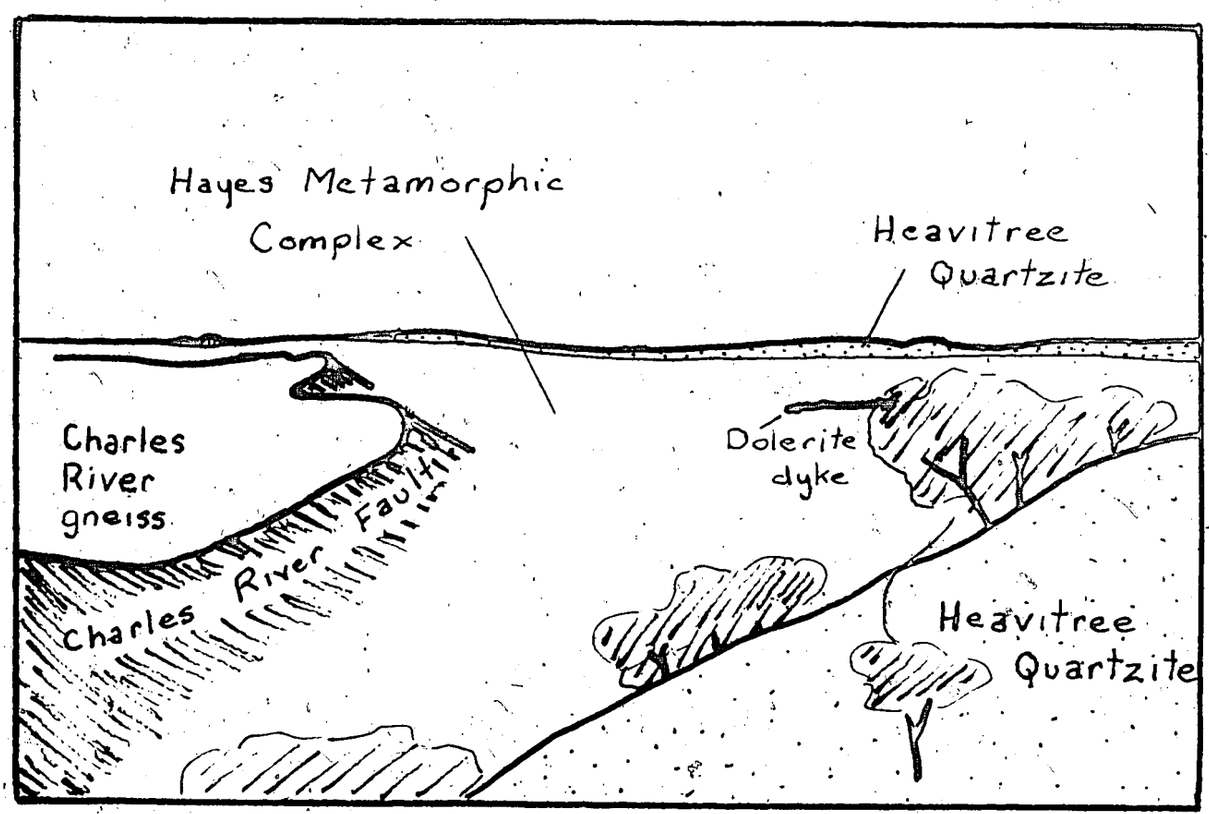


Photo D19: Charles River Fault outlined by Rungutjirba Ridge; Heavitree Quartzite at Simpsons Gap in right foreground. View to the east from GR 5650-724809. (N/2164).



D-5-2: Emily Gap schist, pCpe
(new name) (L.A.O.)

Definition

This unit consists of schist, metasandstone and rare amphibolite, and crops out as low to moderately high rubbly hills and ridges in two outcrop areas about 6 km east and 5 km southeast of the Alice Springs township in ALICE SPRINGS. The name is derived from Emily Gap, a gap in the Heavitree Quartzite (Buh) at the eastern end of the most southerly exposure of the unit. The type locality is 5 km east of the Alice Springs township at GR 5650-905800.

Relationships

Both outcrops are possibly intruded by the Sadadeen Range gneiss (pCpd) and are cut by dolerite (Bds) and pegmatite dykes. The Heavitree Quartzite unconformably overlies the southern-most exposure of the unit.

Lithology

The northern-most outcrop of Emily Gap schist typically consists of biotite-feldspar-quartz schist with some layers of medium-grained, recrystallised, micaceous-quartz sandstone and rare amphibolite. Locally the schist contains muscovite, opaque grains, and feldspar augen up to 10 mm long.

The southern-most schist zone near Mount John consists of two-mica schist, biotite schist, quartzose sericite-schist, and medium-grained, recrystallised, sericitic quartz sandstone and rare amphibolite. In places the southern schist contains hematite-bearing layers. Specimen 73913774 (GR 5650-917746) consists of muscovite (50%), quartz (30%), biotite (20%) and accessory tourmaline. The rock is fine-grained, and contains sericite-hematite spots up to 1.6 mm across, which may be alteration products after staurolite.

Granite veins are commonly interlayered with the schist. Pegmatite in the northern outcrop contains garnet.

Structure

The dominant fabric of the unit, the schistosity, is axial plane to the macroscopic folds which form the present major structures- two over turned folds within orthogneiss. The fold nose of the northern schist is strongly lineated; axial-plane schistosity intersects the folded earlier surface. The fold nose of the southern schist displays a folded foliated surface cut by axial-plane schistosity. The northern schist has a north-westerly plunging synformal axis with its axial-plane inclined at a moderate angle to the west, while the southern schist has an southwesterly-plunging, antiformal fold axis with axial-plane dipping at a moderate angle to the south. Mesoscopic overturned isoclinal folds with axial-plane schistosity are rarely preserved. Low amphibolite facies mineral growth accompanied the fabric development and may be of Middle Proterozoic age, i.e. comparable with the Chewings Phase of deformation and metamorphism defined by Marjoribanks (1975) in HERMANNSBURG to the west.

A northwest-trending fault has displaced the northern part of the northern outcrop area of schist. Crenulations occur in the southern schist zone.

Origin and Age

The Emily Gap schist is probably derived from pelite, psammitic pelite and a small amount of mafic rock of unknown origin. Assuming the schistosity formed during the Chewings Phase the unit is Middle Proterozoic or older.

D-5-3: Calc-silicate rock, pGpp,
at the southeastern margin of the Alice Springs Granite (L.A.O.)

A narrow lens of laminated calc-silicate rock crops out within the Sadadeen Range gneiss near the south-eastern margin of the Alice Springs Granite (Bga) in the central-eastern part of ALICE SPRINGS. The unit is several metres thick where examined, but may extend northwards parallel to the eastern margin of the Alice Springs Granite for about 2 km. It is conformable within the Sadadeen Range gneiss (pGpd).

The calc-silicate rock consists of fine-grained andesine (55%), iron-rich diopside (15%), epidote (15%), sphene (5%), microcline (5%), quartz (5%) and accessory apatite and medium-grained opaque grains (73913800). Laminations are outlined by feldspar elongation and trails of epidote and diopside and are roughly paralleled by quartz strings.

D-5-4: Teppa Hill metamorphics pCpt
(New name) (L.A.O.)

Definition

The Teppa Hill metamorphics are comprised of metasediments, orthogneiss and amphibolite and crop out in ALICE SPRINGS where they form low hills extending in an arc from the Charles River Fault to the Alice Springs township. The name is derived from Teppa Hill which is situated within the Alice Springs township (GR 5650-850795) and the type locality is at GR 5650-818785 to 826792.

Relationships

The Teppa Hill metamorphics have an apparently concordant contact with the Sadadeen Range gneiss (orthogneiss; pCpd) to the east, northeast, west and southwest. However, the southeast boundary is outlined by interfingering of the Teppa Hill metamorphics with the Sadadeen Range gneiss. The apparently concordant contact in detail is made up of intimately interlayered metasediment and orthogneiss; for practical purposes the boundary between the metasediment and the orthogneiss of the Sadadeen Range gneiss has been placed such that by definition the Teppa Hill metamorphics includes the minor portion of the orthogneiss which is intimately interlayered with metasediment.

Dolerite (Bds) and pegmatite dykes intrude the Teppa Hill metamorphics.

Lithology

Metasediments (j, qt, sb, cs) of the Teppa Hill metamorphics consist of interlayered fine to coarse-grained muscovite-biotite quartzose gneiss, metaquartzite, biotite and muscovite-biotite schist, muscovite schist,

and a small amount of calc-silicate rock. One specimen of quartzose gneiss was collected; 73913999A is a weakly schistose rock composed of quartz (94%), muscovite (3%), biotite (3%) and accessory apatite. The laminations and partly flaggy nature of the metaquartzite is cuased by the planar concentration of heavy minerals and/or sericite. At GR 5650-831779 muscovite-biotite schist contains white plagioclase megacrysts up to 2 cm in diameter (73913804). Specimen 73913778 from the calc-silicate layer consists of quartz (70%), poikilitic garnet (15%), epidote and clinozoisite (together 7%) agrregates, sericitised sodic plagioclase (5%) and clinopyroxene (3%).

Orthogneiss (o) is interlayered with metasediments and amphibolite and consists of schistose feldspar, quartz and biotite.

The only specimen of amphibolite (a) collected is strongly foliated, medium-grained and is composed of actinolite (70%), clinozoisite and muscovite (together 25%), quartz (about 5%) and accessory tremolite, sphene and apatite (73913805). Actinolite is partly altered to biotite.

Correlations

Both the Teppa Hill metamorphics and the Irindina Gneiss (pGhi) (in RIDDOCH, QUARTZ and LIMBLA) belong to Division two and are thus tentatively regarded as stratigraphic or lithological correlatives. Furthermore parts of the Irindina Gneiss in RIDDOCH are correlated by lithology with the Teppa Hill metamorphics. For example the basal part of the Irindina Gneiss in the Maude Creek area consists of interlayered quartzite, semi-pelites containing large feldspar porphyroblasts, and pods of epidote-garnet-diopside rock. Elsewhere in RIDDOCH, QUARTZ and LIMBLA the Irindina Gneiss consists of garnet-mica-plagioclase gneiss and a lesser amount of amphibolite, calcareous rocks, sillimanite-bearing gneiss, quartzofeldspathic gneiss and rare ultramafic rock.

Origin and Age

The Teppa Hill metamorphics are thought to be a sequence of pelitic and calcareous psammites which have been intruded by basic flows and acid igneous rock, and metamorphosed probably during the Chewings Phase of deformation. Thus the Teppa Hill metamorphics are considered to be Middle Proterozoic or older.

D-5-5: Sadadeen Range gneiss, pGpd (New name) (L.A.O.)

Definition

The Sadadeen Range gneiss is an orthogneiss which forms low rounded hills east and west of the Alice Springs township in ALICE SPRINGS, and is named after the Sadadeen Range (GR 5650-865775) on the east side of the Todd River within the township of Alice Springs. The type locality is at GR 5650-865775.

Relationships

The Sadadeen Range gneiss has concordant contacts with the neighbouring Unnamed metasediments (pGpb), Emily Gap schist (pGpe) and Alice Springs Granite (Bga). Contact with the Alice Springs Granite is in places marked by interlayered gneiss and granite over a distance of several metres. Sadadeen Range gneiss may completely envelop the Unnamed calc-silicate rock (pGpp).

The unit is interlayered with the Teppa Hill metamorphic (pGpt) and near the Emily Gap schist commonly contains schist and quartzose metasediment layers (for example 73913783); xenoliths are rare, consist of fine to medium-grained biotite gneiss (Photo D20), biotite and biotite-muscovite schist and metamorphosed magnetite-biotite and muscovite-chlorite-bearing feldspathic quartz sandstone, and probably originate from the Teppa Hill metamorphics or the Emily Gap schist.

To the west the Sadadeen Range gneiss appears to be non conformably overlain by the basal conglomerate of the Simpsons Gap metasediments (Bas); in places the foliation is at a high-angle to the conglomerate bed.

Photo D20: Xenolith within Sadadeen Range gneiss. GR 5650-767799. (M/2164).

The Charles River Fault forms the northern boundary of the unit, and west of the Alice Springs township the gneiss is cut by west trending-faults showing horizontal displacements of about 1 km.

Dolerite (Pds) and pegmatite dykes cut the Sadadeen Range gneiss and all are unconformably overlain to the south by Heavitree Quartzite (Buh).

Lithology

The gneiss is characterised by lenticular, blocky or ovoid porphyroblasts of perthitic microcline up to 8 cm in length, in a schistose matrix of biotite, quartz and feldspar (73913803). In the more schistose parts of the unit feldspar occurs as elongate aggregates. In places the unit contains a small amount of muscovite, garnet and epidote and is interlayered with granite veins and quartzofeldspathic gneiss consisting of albite, microcline, quartz, chloritised biotite, and muscovite (73913802).

At GR 5650-771800, 9 km west of the Alice Springs township, dark fine to coarse-grained gneiss adjacent to a dolerite dyke consists of garnet (45%), quartz (20%), feldspar (15%), biotite (15%), chlorite (2%) and a small amount of subhedral tourmaline, and apatite (73913812). This garnet-rich gneiss may be a sedimentary xenolith metamorphosed during the regional metamorphism.

Structure

The Sadadeen Range gneiss commonly has a schistose to flaser fabric outlined by elongate feldspar and quartz grains in a biotite-rich matrix.

At GR 5650-725795 quartz and feldspar aggregates outline tight mesoscopic fold noses with axial-plane schistosity. The intersection of the schistosity and the pre-schistosity surface defines a lineation. The gneiss is strongly lineated at the nose of the large-scale overturned synform which is outlined by the northern outcrop of the Emily Gap schist and thought to be related to the Chewings Phase of deformation.

Origin and Age

The Sadadeen Range gneiss is relatively homogeneous and in places contains layers and rare lenses of metasediment. Thus it is considered to be an acid igneous body intrusive into sediments. It is older than the Heavitree Quartzite which unconformably overlies it, the dolerite and pegmatite dykes which intrude it, and the earliest recognised deformation in the area, the Chewings Phase, which has given it a gneissic fabric. Thus the Sadadeen Range gneiss may be Middle Proterozoic or older.

D-5-6: Unassigned gneiss pG, in the eastern part of the Alice Springs Block, (L.A.O.)

Unassigned gneiss pG of the Alice Springs Block crops out in the eastern part of ALICE SPRINGS and extend into UNDOOLYA.

Relationships

The northern boundary of the gneiss is several splinter faults which join the Charles River Fault to the west and extend into the cover sediments to the east. The unit is unconformably overlain by the Heavitree Quartzite (Buh) to the east and merges with the Jessie Gap gneiss (Bj) to the south and southwest. Dolerite (Bds) and pegmatite dykes cut the unit.

Lithology

The gneiss is typically granitic or migmatitic, but also contains abundant augen gneiss, amphibolite, banded biotite gneiss and a smaller amount of hornblende gneiss, pyroxenite, quartzofeldspathic gneiss and biotite schist.

Orange, poorly foliated, medium-grained granitic gneiss at GR 5750-079802 is typical of the granitic gneiss (gg) in the unit and consists of microcline and partly sericitised and saussuritised plagioclase (together 68%), quartz (30%), chloritised biotite (2%) and small amounts of muscovite, opaque grains, epidote and ?garnet (75914707). Quartzofeldspathic mobilisate occurs as crosscutting veins and patches.

Augen gneiss (p) contains feldspar augen to 20 cm and lenticular quartz-feldspar aggregates and typically consists of potash feldspar and partly antiperthitic plagioclase (together 60%), quartz (35%), biotite (5%) and accessory opaque grains and apatite (75914710).

At GR 5750-146841 hornblende gneiss (h) contains varying amounts of plagioclase, quartz, green and blue-green hornblende, microcline and pyroxene (75914716, 17, 18). Sphene, opaque grains and apatite are accessory minerals. Feldspars are sericitised and saussuritised and 4716 shows sphene rimming opaque grains, chlorite along fractures in the opaque grains, and a small amount of actinolite.

At GR 5750-156846 the unit consists of biotite gneiss and quartz-veined medium-grained pyroxenite (u) which is composed of aggregates of granoblastic pale green clinopyroxene (98%), highly sericitised plagioclase, quartz and light green amphibole (75914720).

Structure

The foliation in the unit is outlined by layering and laminations and is locally in a mesoscopic open wave-form. In places, quartzofeldspathic veins are folded on a mesoscopic scale. Fault zones within the unit commonly consist of fractured feldspar, fractured or recrystallised strained quartz grains and epidote and chlorite (75914712, 13).

Origin and Age

The Unassigned gneiss at the eastern margin of the Alice Springs Block is migmatised and homogenised and similar to units in the Wigley Block. This area is considered to be the eastern hinge zone of the fault separating the Alice Springs Block from the Wigley Block.

Migmatisation and homogenisation of the gneisses probably occurred during the Ormiston Phase of deformation at about 1080 m.y.

D-6: Division 2: Harts Range Group - Introduction (R.D.S.)

The term, Harts Range Group, was introduced by Joklik (1955) for "that portion of the Archaeozoic Complex of Central Australia that outcrops in the Harts Range". Shaw & Warren (1975) considered it to be younger than the Strangways Metamorphic Complex on regional structural and stratigraphic criteria. Joklik named the constituent formations, which from oldest to youngest are the Entia Gneiss, the Bruna Gneiss, the Irindina Gneiss, and the Brady Gneiss - assuming the order of superposition in the Huckitta Dome to be normal. However, no facing structures are preserved.

D-6-1: Entia Gneiss, pGhe (R.D.S.)

The Entia Gneiss (pGhe) does not crop out in the Alice Springs 1:250 000 Sheet area. The lowest unit of the Entia Gneiss is a strongly deformed kyanite-bearing granitic gneiss. The next unit of the Entia Gneiss is thickest and most widespread, and consists of muscovite-biotite granitic gneiss containing thin intercalations of muscovite-biotite schist, quartz amphibolite, and, in at least one or two places, mafic calc-silicate rock and ankeritic marble. The upper unit of the Entia Gneiss is a quartzofeldspathic gneiss interlayered with subordinate quartz amphibolite, and small amounts of a number of rock types including schistose and augen-bearing biotite gneiss, sillimanite and garnet-bearing biotite gneiss, coarse-grained muscovite gneiss, quartzofeldspathic gneiss, epidote calc-silicate rock and rare marble. For a fuller description of the Entia Gneiss the interested reader is referred to Joklik (1955).

D-6-2: Bruna Gneiss, pGha (R.D.S.)

Definition

The Bruna Gneiss is characterised by abundant, very large (up to 20 cm across) feldspar megacrysts set in a matrix of granitic gneiss, which is grey and consists of quartz, feldspar, biotite, and, in places, garnet.

The unit crops out extensively in the Illogwa Creek 1:250 000 Sheet area where it forms foothills on the inner-side of the pound, corresponding to the Huckitta (Structural) Dome in the upper reaches of Entire Creek. The unit also crops out in a relatively flat area 2 km southeast of Brumby Bore in RIDDOCH, and extends from here northwards as discontinuous lenses to the confluence of Maude and Florence Creeks. In the Maude Creek area the Bruna Gneiss has been deformed into a fine-grained, platy mylonite, in which the feldspar megacrysts have been reduced to augen, and is commonly intercalated with thin quartzite.

Joklik (1955), who defined the unit, did not nominate a type area, but the upper reaches of Entire Creek provide a good reference section. The name of the unit is derived from Mount Bruna in the northwestern corner of the Illogwa Creek 1:250 000 Sheet area.

Unlike the underlying Entia Gneiss and overlying Irindina Gneiss, the Bruna Gneiss contains conspicuous feldspar megacrysts.

Relationships

The Bruna Gneiss has a transitional contact with the Irindina Creek where the contact is unaffected by thrusting as in the headwaters of Irindina Creek. The Gneiss has a conformable contact with the Entia Gneiss, but the boundary is commonly a horizon of structural detachment.

Lithology

Reference section: In the upper reaches of Entire Creek the Bruna Gneiss can be divided into three units.

(1) The basal unit is a thinly layered felsic gneiss, in which layers containing abundant K-feldspar megacrysts alternate with layers containing a moderate number of megacrysts.

(2) In the middle unit the granitic gneiss is more homogeneous, and is only slightly megacrystic in its very upper part.

(3) The upper unit contains abundant feldspar augen in addition to idioblastic porphyroblasts suggesting that at least some of the more idioblastic porphyroblasts have grown late in the history of the gneiss. A small amount of the upper unit contains garnet megacrysts and is intercalated with hornblende gneiss.

Some sliding, indicated by strike discordance, has taken place at both the upper and lower boundaries of the Bruna Gneiss.

Major lithological variants: Outside the reference section the Gneiss is made up of three major lithological types.

(1) The most abundant lithological type contains conspicuous large, poorly twinned, pink megacrysts of microperthitic microcline. These megacrysts are poikiloblastic and contain numerous inclusions of plagioclase and mafic minerals. Megacrysts of hornblende, garnet, and andesine are also present in small quantities, but are not poikiloblastic.

(2) The second lithological type is characterised by its large megacrysts of bluish grey ortholcalse, which is weakly perthitic, poorly twinned, and contains grains of altered feldspar, quartz, and hornblende. The matrix contains oligoclase-andesine, and is generally very fine-grained.

(3) The third lithological type (eg R4563) occurs in narrow layers, and consists of equal amounts of quartz, microcline, and partly megacrystic oligoclase.

Geochemistry

Joklik (1955 p. 67) gives a chemical analysis of the main lithological type (R4596), but the analysed sample lacked K-feldspar megacrysts. He pointed out that the Gneiss resembles a rapakivi granite in composition, and argued that the formation of K-feldspar megacrysts involved the introduction of potash, silica, alumina and possibly silica and the removal of iron and magnesia.

Structure

The base of the Bruna Gneiss is commonly a thrust horizon. The Gneiss shows little internal structure.

Correlation and Age

The Bruna Gneiss has no obvious correlates, and has not been the subject of age determination studies.

Origin

The Bruna Gneiss is thought by R.D.S. to be possibly a unit of metamorphosed and deformed acid volcanic, possibly ignimbrites, extruded during an interval of tectonism between the more arkosic sedimentation interpreted for the Entia Gneiss and the pelitic environment interpreted for the Irindina Gneiss. An origin as acid ignimbrites would explain the wide distribution of the Gneiss. On the other hand, Joklik considered that, although the Gneiss had the composition and appearance of a rapakivi granite, it was most likely a metamorphosed sedimentary rock based on its mineralogical composition and texture.

The contacts of the Bruna Gneiss are commonly thrusts and the formation of the large megacrysts is, in some cases at least, related to the proximity to these thrusts. Another model for the origin of the Bruna Gneiss is by mylonitisation and metasomatism of the Entia Gneiss, which has a similar granitic composition.

D-6-3: Irindina Gneiss, pGhi (R.D.S.)

Definition

The Irindina Gneiss is the most extensive unit in the Harts Range and consists mainly of a garnet-mica-plagioclase gneiss (v) which typically occupies valleys and low-lying areas in RIDDOCH and in the adjacent QUARTZ and LIMBLA Sheet areas. Amphibolite layers (a) make up a small portion of the unit and generally crop out as high ridges. The Riddock Amphibolite Member (Joklik, 1955) forms the most prominent range in the region extending eastwards from Mount Riddoch.

The Naringa Calcareous Member (Joklik, 1955) crops out extensively in the eastern part of the Harts Range principally in two areas: (1) in a low plateau between Brumby Bore and Bullocky Dam and (2) in the valley extending from Benstead Mine (abd) to Billy Hughes Bore (abd). Separate descriptions are given for both the Riddock Amphibolite Member and the Naringa Calcareous Member. Less abundant rock types in the Irindina Gneiss include megacrystic feldspar gneiss (p), sillimanite-bearing gneiss (z), quartzofeldspathic gneiss (f), and rare ultramafic rock (un) and marble (na). These minor rock types crop out principally between the Benstead Mine (abd) and Mount Palmer in RIDDOCH.

The formation was named by Joklik (1955, p. 38 and 68) after Irindina Creek, in which contacts with the underlying and overlying formations are well exposed. The valley of Irindina Creek is taken to be the type area. The overlying Brady Gneiss is a ridge-forming unit typically more quartz- and muscovite-rich than the Irindina Gneiss. The muscovite invariably forms clots; a feature rarely seen in the Irindina Gneiss. In addition, the Irindina Gneiss contains finer-grained mica flakes and has less distinct layering compared with the Brady Gneiss. In general composition, however, the two units are very similar. The underlying Bruna Gneiss is quartzofeldspathic and strikingly porphyroblastic.

Joklik's type specimen of garnet-mica-plagioclase gneiss (R4577) is not from the type area, but from 3 km west-northwest of the Last Chance Mica Mine in central-eastern QUARTZ.

Relationships

The Irindina Gneiss has a transitional contact with the underlying Bruna Gneiss in that the Irindina Gneiss contains interlayers of more felsic gneiss containing large feldspar megacrysts as the boundary is approached in the type section.

The upper conformable contact with the Brady Gneiss is sharp.

Lithology

A brief description of the type section (1) and other representative sections, in the Maude Creek area (2), the Brumby Bore area (3), and the upper reaches of Entire Creek (4), will be followed by more detailed descriptions of the main rock types. The main bodies of the Naringa Calcareous Member and the Riddoch Amphibolite are described in separate sections that follow.

(1) In the type section, the lowest part of the sequence is exposed on the southern side of Irindina Creek, and consists of schistose garnet-biotite-plagioclase gneiss and amphibolite interlayered with a slightly more felsic gneiss containing large feldspar porphyroblasts. This latter rock type resembles the underlying Bruna Gneiss, suggesting a transitional contact. The middle part of the type section consists of schistose garnet-biotite-plagioclase gneiss, and is divided into two parts of narrow lenses of Riddoch Amphibolite Member, which thickens and becomes more continuous westwards. The upper part of the type section is more quartzo-feldspathic; thick units of biotite gneiss (b) with colour indices of 20 to 40 are interlayered with quartzofeldspathic (f), gneiss (colour index) 5 to 10. This quartzofeldspathic gneiss contains layers of fine-grained amphibolite.

(2) In the Maude Creek area the Irindina Gneiss can be divided into three subunits, the order of superposition of which is ambiguous. The assumed upper unit consists of dark grey to black schist and gneiss characterised by abundant garnet porphyroblasts, i.e. garnet-plagioclase-quartz gneiss, two thin marble beds, and locally calc-silicate quartzite layers.

A middle unit consists of marble and flaggy calc-silicate rock, which is separated out as the Naringa Calcareous Quartzite Member. An upper quartzofeldspathic unit contains numerous thin layers of amphibolite.

The basal part of the Irindina Gneiss has a transitional contact with the Bruna Gneiss, and consists of interbeds of dark quartzites and semi-pelites containing big feldspar porphyroblasts, in addition to pods of epidote-garnet-diopside rock.

(3) Farther south, in the area of Brumby Bore a lens assigned to the Riddock Amphibolite Member, containing quartz and garnet, directly overlies the Bruna Gneiss. The overlying Irindina Gneiss is highly schistose and contains rare thin beds of marble and amphibolite. It becomes sillimanite-bearing up-section as the Naringa Calcareous Member is approached.

(4) In the upper reaches of Entire Creek in QUARTZ the base of the Irindina Gneiss consists of a garnetiferous biotite gneiss having a colour index of 15 to 25, which is interlayered with thin layers of amphibolite. The contact with the underlying Bruna Gneiss is probably faulted. The overlying Irindina Gneiss is similar except that it is much more schistose and biotite-rich (up to 40%) and, in places, contains muscovite, sillimanite and feldspar prophyroblasts. Upwards these schistose gneisses become intercalated with thin layers of amphibolite, rare marble and epidote calc-silicate rock. The contact with the immediately overlying Riddock Amphibolite Member is transitional. The succession above the amphibolite is not exposed.

Lithology

Garnet-biotite-plagioclase schistose gneiss (v) is the most widespread rock-type, and characterises the unit. The reference specimen of this rock type (R4577) was collected by Joklik from 3 km west-northwest of the Last Chance Mine (abd) in central-eastern QUARTZ, 2 km from a major thrust. The specimen consists of roughly equal parts of quartz, andesine, biotite; almandine (9%) forms porphyroblasts 3 mm across and is commonly felted with sillimanite fibres. Accessory minerals vary in type throughout the unit and include magnetite, sphene, apatite, zircon and rutile.

The above garnetiferous gneisses grade locally into sillimanite-bearing gneisses (z), in which the sillimanite forms up to 16 percent of the rock. Such rocks (1) make up thin rock units east, northeast and northwest of Brumby Bore, (2) form a small component in a wide belt extending from the Benstead Mine (abd) to Mount Palmer; and (3) also occur 8 km west of Kong Bore in northwestern RIDDOCH.

Megacrystic feldspar gneiss (p) also occurs sporadically in the zone extending from Benstead Mine (abd) to Mount Palmer. This rock is formed in those layers where the proportion of pegmatitic mobilisate and leucosome is high. The feldspar megacrysts are generally small and consist of microcline microperthite. In specimen R4627 (5851-000000) collected 2.5 km east-northeast of Benstead Mine (aba) conspicuous elongate megacrysts of microcline (about 4 cm x 2 cm x 1.3 cm), which partly incorporate patches of plagioclase and biotite, are set in a dark biotite-rich matrix. Specimen R4625 (5851-000000) collected 1.5 km south of the Spotted Tiger Mine (abd) consists of a fine-grained grey schistose matrix containing quartz, oligoclase, biotite, and accessory magnetite, sphene, and apatite; and megacrysts of microperthitic microcline (rimmed by myrmekite), micro-antiperthitic oligoclase, quartz and garnet (Joklik, 1955, p. 69). These megacrystic feldspar gneisses are not sufficiently abundant to be shown as a rock unit on the map.

Muscovite-bearing garnetiferous gneiss (vm) is only known from a few localities, such as 4 km southwest of Benstead Mine (abd) where it consists of quartz (50%), muscovite (24%), biotite (15%), garnet (1%), plagioclase (5%), and opaque grains (5%). Similar gneiss also occurs southeast of Naringa Well (abd).

Quartzofeldspathic gneiss (f) forms a prominent ridge extending northwest from the Rex Mica Mine (abd); and also occurs as scattered outcrops (e.g. M128) northwest of Spotted Tiger Mica Mine (abd) and a belt about 200 m wide alongside the Grand Canyon Pegmatite, 3 km south-southeast of Benstead Mica Mine (e.g. M120).

Amphibolite (a) Lenses are widely distributed throughout the Irindina Gneiss; the large majority of these are correlated with the Riddock Amphibolite Member. The lenses are thought to represent basaltic stratigraphic flows and sills of limited extent, which are concentrated in the same interval in the Irindina Gneiss. This interval has been repeated by folding. The four main outcrop-areas of amphibolite other than the Riddock Amphibolite Member are listed below.

(1) Small bodies of amphibolite and less common mafic granulite (mn) (e.g. R4510, R4492,) occur within a zone extending from the Spotted Tiger Mica Mine (abd) to Mount Painter, and in places account for 50 percent of the outcrop-area.

(2) A similar high concentration of amphibolite bodies occurs southwest of Benstead Mica Mine (abd). These two amphibolite-rich belts (1) and (2) may be continuous underneath the synformal belt of Naringa Calcareous Member which separates them.

(3) North of Pannikin Dam two amphibolite units, totalling about 300 m in thickness, are separated by a layer of quartzite and are interlayered, particularly in the lower part, with garnet-biotite gneiss, garnetiferous quartzofeldspathic gneiss, and quartzofeldspathic gneiss. The main amphibolite layer (Table A, Riddock Amphibolite Member: M173, M174) is mottled, massive, and consists almost entirely of plagioclase (65%) and hornblende (35%). The amphibolite outlines a minor synform.

(4) At Mount Ruby an amphibolite lens, about 250 m thick, is foliated and, in places, is markedly deformed. Specimen 822 consists of hornblende (55%), plagioclase (20%), clinopyroxene (10%), quartz (10%), garnet (3%), and sphene (2%). Specimen R4553 from the same lens is very similar except it contains opaque grains (1.5%) rather than sphene, biotite (1%) and trace amounts of chlorite and apatite (Riddock Amphibolite Member, Table A). This lens of amphibolite lies directly on Bruna Gneiss; the apparent absence of section between the two units is suggestive of a tectonic slide.

Ultramafic rock (un) makes up a small body which dips concordantly underneath a layer of amphibolite that outlines a small synform near the Rex Mica Mine (abd). Specimen R4483 from the lens is described by Joklik (1955, p. 57) as "a practically unaltered olivine pyroxenite, containing diopside (40%), olivine (30%), hypersthene (15%), amphibolite (5%), serpentine and accessory magnetite, pleonaste, phlogopite and apatite". Specimen M153, from the same body, consists of orthopyroxene, clinopyroxene, green pleochroic olivine, spinel, talc and accessory magnetite and chlorite.

Marble (ma) occurs as a few isolated lenses principally east of Bungitina Well (abd) and southeast of Brumby Bore. These lenses are associated with the Naringa Calcareous Member, but appear to underlie it.

Metamorphism

Rocks from the Irindina Gneiss have generally been metamorphosed to upper amphibolite facies; mafic rocks in a small region near Mount Palmer have granulite facies assemblages. A widespread, though uncommon, mineral assemblage in the pelitic rocks includes sillimanite and K-feldspar without muscovite, indicating the rocks are above the upper-sillimanite isograd. Several of the amphibolites contain clinopyroxene, but lack orthopyroxene. A few mafic rocks containing orthopyroxene indicating granulite facies conditions, occur near and southwest of the Disputed Mine (e.g. R4621-22, R4492, R4776).

Structure

The apparent simplicity of folding in the Irindina Gneiss is deceptive as the unit has undergone three-phases of folding. Multiple folding is best displayed in the Maude Creek area and has been studied by Rickard (Rickard & Shaw, 1972). First phase folds (F_1) are reclined and tend to have north-trending axial-surfaces. Second phase folds (F_2) are also reclined, but invariably have east-striking, north-dipping axial-surfaces and northerly plunges. Third phase folds commonly have north-easterly trending axial-surfaces and have a more local distribution.

Like the Bruna and Entia Gneisses, with which it is conformable, the Irindina Gneiss dips gently off the Entia Dome in QUARTZ. The large mass of flat-dipping Irindina Gneiss in the area between Bungitina Well (abd), Lizzie Bore and Lindsay Mica Mine (QUARTZ) represents the southwestern flank of the Entia Dome. Here, gently domed areas are separated by equally shallow basins. Dips rarely exceed 25°. However, recumbent folds, visible in creek beds, have axial-planes which parallel the nearly horizontal layering.

A thrust (or metamorphosed slide) is thought to separate the Naringa Calcareous Member from the main body of Irindina Gneiss along the northern and eastern boundaries in the Naringa Well area (abd). Recrystallised tectonic breccia is locally present along this contact. The high-angle, locally developed, structural discordance between the Bruna Gneiss and the Irindina Gneiss is also thought to represent local sliding. This contact is normally conformable.

Additional information on the structure of the Irindina Gneiss is given in the descriptions of the Riddock Amphibolite Member and the Naringa Calcareous Member.

Origin

The high iron content of the main gneiss, indicated by its biotite and garnet content, together with its pelitic nature, suggest that the Irindina Gneiss may represent a metamorphosed red-bed sequence. This interpretation is consistent with the interbeds of calcareous rocks.

Correlation and Age

The Irindina Gneiss is thought to be stratigraphically younger than the Strangways Metamorphic Complex. This relationship is favoured because the Irindina Gneiss conformably overlies the Bruna Gneiss which, in turn, overlies the Entia Gneiss. Moreover, the Entia Gneiss is correlated with the Bungitina Gneiss and unnamed unit pGu, both of which are correlated with rocks from the upper part of the Strangways Metamorphic Complex. The actual contact between the Irindina Gneiss and the uppermost unit of the Strangways Metamorphic Complex (Cadney metamorphics) is a thrust or recrystallised slide.

The main metamorphism affecting the Irindina Gneiss is regarded as the 1800 m.y. event which has produced granulite facies assemblages in the Strangways Metamorphic Complex.

D-6-3-1: The Naringa Calcareous Member of the Irindina Gneiss, pChn (R.D.S.)

Definition

The Naringa Calcareous Member consists of flaggy biotite quartzite (qt), calcareous quartzofeldspathic gneiss, and feldspathic calc-silicate rock which rarely grades into quartzite (f, cs, qt), thick-bedded marble (ma) and various, generally thickly-layered calc-silicate rocks (cs). Less common rock types include biotite gneiss (b) and pale grey quartzite (qt).

The principal outcrop-area of the Member is a low, extensive plateau covering about 50 km^2 between Brumby Bore and Bullocky Dam in RIDDOCH. The unit thins and steepens in dip northwards and can be traced farther northwards around an east-trending reclined fold to about 2.5 km northeast of Bungitina Well (abd) where it outlines an arrow-head fold. The Member also crops out to the northwest along the northern edge of the Riddock Amphibolite Member and extends from here as far as Pannikin Dam. A small outcrop-area occurs southeast of the Virginia Copper Prospect. The belt of calc-silicate rock and marble which extends from Benstead Mica Mine (abd) to Billy Hughes Bore (abd), is probably also an outlier of the Member.

Joklik (1955a) named the unit after Naringa Well (abd), about 6.2 km north of Brumby Bore (5851-955245), but he did not nominate a type-section which is defined in this report to extend northwest for 1.5 km from Brumby Bore. The unit includes the lithologically related marble and quartzite beds mapped by Joklik as Ail and exposed upstream of Naringa Well, structurally above the flaggy quartzite.

The distinction between the Naringa Calcareous Member and the Cadney metamorphics is discussed under Cadney metamorphics - Correlation and Age.

Relationships

The Naringa Calcareous Member is a discontinuous unit occurring in what is interpreted to be the stratigraphically lower part of the Irindina Gneiss. North of the Mount Brassey Fault, it underlies the Riddock Amphibolite Member and is separated from it by about 100 m of

garnet-biotite gneiss and interbedded calcareous rocks. This relationship continues westwards into a small synform and complementary antiform 3 km northeast of Pannikin Dam.

The Naringa Calcareous Member overlies about 100-150 m of garnet-biotite gneiss and biotite schist and rare marble, which in turn overlie the Bruna Gneiss about 8-10 km northeast of Brumby Bore. The rapid thinning of the garnet-biotite gneiss unit northwards suggests that a tectonic slide (see glossary) may be located at the base of the Member. Near Brumby Bore the section of Irindina Gneiss thickens to about 750 m as units of sillimanite gneiss, biotite gneiss and amphibolite come in at the base of the section.

Lithology

In the reference area north of Brumby Bore the Naringa Calcareous Member can be divided into four informal subunits.

(1) The structurally lowest subunit consists of a medium-grey, conspicuously flaggy, biotite quartzite (808, 2516) intercalated with biotite gneiss, which is muscovite-bearing near the base. Lenses of marble and calc-silicate rock (R4590), sporadically distributed near the base, are locally transformed into a spectacular tectonic breccia, indicating that the lower contact is probably a thrust fault.

(2) The overlying subunit consists of a calcareous quartzofeldspathic gneiss, which is schistose to flaggy and is interbedded with small amounts of quartzite. The subunit becomes more calcareous upwards and grades into calc-silicate rock (804, 805, A, B).

(3) The next subunit is a very massive, impure marble, which weathers orange-brown. It grades into the overlying subunit.

(4) The uppermost subunit contains a wide variety of rock types including quartzite, a dark grey schistose biotite gneiss, massive green hornblende-diopside calc-silicate rock and one bed of white marble.

In the upper reaches of Maude and Florence Creek the Naringa Calcareous Member consists of a remarkably even-bedded quartzite, which has a variable calc-silicate mineral content. The quartzite weathers to an unusual purplish-brown, but is greenish-grey when fresh; quartz, diopside, feldspar and biotite are its main constituents in many areas, but some areas it consists mainly of scapolite and quartz (e.g. 6625, GR 5851-801427). The flaggy quartzite passes transitionally into a coarsely crystalline, thick, blue grey to white, well-bedded marble.

In a 10 km long belt between the Benstead Mica Mine (abd) and Billy Highes Bore (abd) a calcareous meta-arenite is interlayered with small amounts of marble. The rock consists essentially of quartz, diopside, scapolite, biotite, calcite and accessory sphene, apatite, magnetite and zircon (e.g. R4610). The belt continues across the creek south of Benstead Mine (abd). Small exposures of calc-silicate rock at the base of the hill just west of Stones Bore possibly also belong to the Naringa Calcareous Member.

Calc-silicate rock is the principal lithological type petrographically examined. All specimens contain quartz, clinopyroxene and scapolite (Table D -6-1A). In specimen R4590 from south of Naringa Well (abd), hornblende and diopside are concentrated in thin alternating layers (Joklik, 1955, p. 86).

The marble is typically impure. Specimen 805 B/I from 3.5 km northeast of Brumby Bore is a coarse-grained marble and consists of calcite (57%), clinopyroxene (18%), quartz (13%), scapolite (12%), and traces of biotite and pyrite.

Table D -6-1A: Estimated modes of calc-silicate rocks from the Naringa Calcareous Member

	R4590	804A	805A	R4610
Quartz	37.7	74.5	60	36.9
Scapolite	25.0	5	3	30.4
Diopside/ Clinopyroxene	18.5	5	15	28.4
Hornblende/ Actinolite	16.1	0.5	-	
Calcite	1.0	3	20	1.7
Biotite	0.5	1	1	1.4
Plagioclase		10	-	
Sphene		+	+	1.2
Apatite	0.2			+
Zircon				+
Pyrite			+	

The flaggy quartzite varies considerably in its biotite content from 10 to 2 percent. One example (808) from just north of Brumby Bore consists of quartz (73%), plagioclase (15%), biotite (10%), garnet (2%), and accessory muscovite and zircon.

Structure

A number of major tectonic slides such as the Cadney Fault, and the Mount Brassey-Pannikin Dam Fault System are localised in the Naringa Calcareous Member. The major outcrop-area of the Member north of Brumby Bore is largely circumscribed by a thrust and this occurrence of the unit is referred to as the Naringa Thrust Slice.

The distribution of the Member is largely controlled by the major east-trending structures, which in the Maude Creek region are F_3 folds. The main outcrop areas of the Member correspond to minor antiforms which flank the main Mount Riddoch-Mount Brassey Range. The intervening region containing the principal body of the Riddock Amphibolite Member

is interpreted to be an F_3 synformal structure. The two western branches of the Y-shaped outcrop-area near the Stones and Benstead Mica Mines (abd) are interpreted to be earlier synforms (i.e. F2), refolded into a F_3 structure.

The internal structure of the Naringa Trust Slice north of Brumby Bore is problematical. The northern margin forms part of an antiformal overfold and is followed to the south by a series of small east-striking synforms and antiforms, which are disrupted by interal thrusting, but maintain moderate to shallow dips overall.

Metamorphism

The mineral assemblages in the calc-silicate rocks are characteristic of the middle part of the amphibolite facies, but are not diagnostic as such assemblages persist into the granulitic facies as in the Cadney metamorphics.

Origin

The Naringa Calcareous Member represents a metamorphosed calcareous shelf-facies. Its restriction to the western part of the Harts Range suggests that the sea shallowed to the west during deposition of the lower part of the Irindina Gneiss.

Correlation

Correlation of the Naringa Calcareous Member with the Cadney metamorphics is unlikely for reasons outlined in the section on the Cadney metamorphics.

D6-3-2: Riddock Amphibolite Member of the Irindina Gneiss, pGhr (R.D.S.)

Definition and Distribution

The Riddock Amphibolite Member consists of layered amphibolite, some massive amphibolite, and a subordinate amount of garnet-bearing pelitic and quartzofeldspathic gneisses similar to those that make up most of the Irindina Gneiss. It forms the principal ridge of the Harts Range, which is a 300 m high, 5 km wide range and extends for over 50 km from west of Mount Riddock eastwards to the headwaters of Irindina and Entire Creeks in RIDDOCH. The northern dip-slope of the range is bare and smooth, whereas the southern side of the range is generally a series of steep and more rugged scarps. The type area selected by Joklik (1955) is 2.5 km northeast of Mount Riddock, where he collected his type specimen for chemical analysis. This specimen may not be typical as much of the amphibolite which is more layered than at this locality. The unit takes the old spelling "Riddock" which is also retained by Riddock homestead. The amphibolite differs from many other of the amphibolites in the region in commonly being markedly layered, and by locally containing small quantities of garnet, clinopyroxene and sphene.

A lens of the Riddock Amphibolite Member, 1.6 km south of Bungitina Well (abd), consists of medium polygonal grains of hornblende (50%), and irregularly shaped relict grains of clinopyroxene (5%), plagioclase (43%), opaque grains (1.5%) and traces of sphene, apatite and biotite (specimen 0876, Table D-6-2A).

Relationships

The Riddock Amphibolite Member occurs towards the middle of the Irindina Gneiss. In the section exposed in Irindina Creek, the Member occupies a central position in the Irindina Gneiss. Northeast of Pannikin Dam it lies above the Naringa Calcareous Quartzite Member (pGh_n) of the Irindina Gneiss, being separated by a section of garnet-mica gneiss.

TABLE D-6-2A: Visually estimated modes, Riddock Amphibolite Member

	R4495	R4619	M126	M152	M160	M173*	876*	822*	R4518	R4553*	R4502	R4503
Plagioclase	66	35.8	54	59	50	65	43	20	42	25	68	13.5
Hornblende	30	58.2	40	37	36	35	50	55	45	60	11	9
Clinopyroxene	3	2.1		1	7		6	10		3		3.5
Garnet	+		2		7			3		tr	10	
Quartz	1	1.0						10	10	10	11	73
Sphene	tr	1.3	3	3			tr	2	2		tr	1
Opaque Grains		1.3					1		1	1		
Apatite	tr	0.3	1		tr	tr	tr		tr	tr		
Scapolite	tr	tr										
Biotite							tr			1		
Chlorite										tr		

\+ present in hand specimen tr , trace

* amphibolite layers correlated with the Riddock Amphibolite Member

Lithology

In Joklik's type area the Riddock Amphibolite Member consists of homogeneous, thick, extensive layers of amphibolite. Elsewhere, it is a sequence of layered amphibolite and garnetiferous gneisses typical of those in the Irindina Gneiss. These interlayers are most abundant at the margins of the principal outcrop-area of amphibolite, especially at its eastern and western ends. Because of poor access much of the central part of the main range has not been examined. The relatively low bulk specific gravity of the Member (2.85 ± 0.05 gcm^{-3}) determined by topographic profiling over the main range at Stones Bore (Anfiloff, 1977) suggests that up to about half the member may be gneiss (S.G. 2.70+) or a para-amphibolite of relatively low density containing a high proportion of quartz and feldspar rather than an orthoamphibolite (SG = 3.0; Parasnis, 1971). The relatively slight regional aeromagnetic response indicates that much of the unit does not have the relatively high magnetic content of the type-specimen (R4619; 1.3% magnetite, Table2B) and supports the gravity data in suggesting that much of the unit may consist of para-amphibolite, gneiss, or another rock containing little magnetite. Some units of amphibolite appear pale brown and massive on the coloured aerial photographs but this appearance is due to the high reflectivity of the exfoliation surfaces.

Amphibolite: Joklik described the type-specimen (R4619) as a medium-grained (1.5 mm) metagabbro with no lineation or foliation discernible. He considered that relics of the original texture are preserved, but his interpretation is dubious because the minerals have recrystallised. The mode and a chemical analysis of the type-specimen (R4619) are presented in Tables A and B and discussed in the geochemistry subsection and in the subsection on origin. Elsewhere in the unit much of the amphibolite contains relict clinopyroxene (e.g. 6594). Relict orthopyroxene is rare (e.g. 6551). Layered and quartz-rich varieties of amphibolite have been mapped as para-amphibolite? (pa). Throughout most of the unit the amphibolite is markedly layered, most is made up (Table D -6-2A: R4619, M126, M152, M160) of coarse polygonal to semipolygonal grains of plagioclase hornblende, and various smaller amounts of clinopyroxene, garnet and sphene.

TABLE D-6-2B: Chemical analysis, Norm and Mode Specimen R4619, Riddock Amphibolite Member (after Joklik, 1955 p.50)

Analysis wt. percent		Norm		Mode (measured, percent)	
SiO_2	50.32	or	1.73		
Al_2O_3	14.95	ab	25.15	Hornblende	58.2
Fe_2O_3	1.34	an	26.69	Andesine	35.8
FeO	9.48	di ($CaSiO_3$)	10.56	Diopside augite	2.1
		di ($MgSiO_3$)	6.00		
MgO	7.58	di ($FeSiO_3$)	4.09	Scapolite	trace
CaO	10.66			Quartz	1.0
Na_2O	3.00	hy ($MgSiO_3$)	8.00	Sphene	1.3
K_2O	0.34	hy ($FeSiO_3$)	5.54	Magnetite	1.3
H_2O^-	0.10			Apatite	0.3
H_2O+	0.14	ol ($MgSiO_4$)	3.43		100.0
TiO_2	2.08	ol (Fe_2SiO_4)	2.55		
P_2O_5	0.23	mt	1.91		
Cl	0.08				
	100.30	il	1.91		
		ap	0.39		

Apatite and magnetite are common accessory minerals. Visually estimated modes are given in Table D -6-2A. A number of amphibolite bodies (e.g. R4502, R4518) contain up to about 10 percent quartz. Although several of the thicker layers of amphibolite in the central part of the Harts Range consist of homogeneous medium-grained, recrystallised amphibolite, most of the amphibolite, including the marginal layers, are commonly layered and foliated; much of the amphibolite is also migmatitic. Many of the amphibolite bodies also contain small amounts of epidote, biotite, scapolite and hedenbergite.

Where pegmatites have permeated the adjoining Irindina Gneiss, the amphibolite adjacent to the gneiss grades into a rock consisting of monomineralic plagioclase or hornblende, which is coarse-grained and almost pegmatitic. For example, hornblende rock (un) occurs at the Virginia Prospect.

One rare but distinctive rock (hp) consists mainly of plagioclase (70%) and some hornblende (up to 25%) or clinopyroxene (up to 20%) (e.g. 6553, 6592A). It forms strike valleys with a whitish appearance on the aerial photographs in the valley west of Mount Campbell (Specimen 6592).

Subordinate rock types of the Riddock Amphibolite include garnetiferous quartzofeldspathic gneiss (vf) and garnet-biotite schistose gneiss (v). Rare sillimanite gneiss (z) is also common in the gneissic parts of the sequence.

Quartz-rich para-amphibolite (pa), which grades into quartzite (qt), is exposed over a thickness of 120 m on the western scarp of Mount Campbell (R4503, Table 2A) where it structurally overlies 120 m of pegmatised garnet-mica gneiss and is succeeded gradationally upwards by massive amphibolite. The most quartz-rich rock (qt) e.g. 6593A, B, 6592, 6593, is even-grained, schistose, and contains labradorite (13.5%), hornblende (9%), and altered pyroxene (1%), in addition to quartz. This quartz-rich lithological variant may have the same origin as layered

amphibolites such as R4502, which contains up to 11 percent quartz together with labradorite and garnet. It may also be related to labradorite-garnet-quartzite (vf, q) mapped as Irindina Gneiss 2.5 km northeast of Mount Riddock (R4511, R4790). Quartz appears to be most abundant in garnetiferous variants (e.g. 6551 (45%), 6552A (50%), 6554 (30%)), but is also abundant in highly schistose variants (e.g. 6592-3, qz = 10 to 70%).

Structure

The principal body of Mount Riddock Member is interpreted to outline an F3-synformal structure. The overall structure has been outlined in the section on the Irindina Gneiss.

Metamorphism

The rocks have been metamorphosed to the upper part of the amphibolite facies because they contain clinopyroxene, but lack orthopyroxene.

Geochemistry

Based on CaO/MgO and FeO/Fe_2O_3 ratios (Table I -6-2B) Joklik (1955, p. 50) interpreted the more massive amphibolite (R4619) to be a metamorphosed basic igneous rock having a slightly higher than normal Na_2O content. He thought the high TiO_2 content (2.08%) indicated that the unmetamorphosed rock was rich in ilmenite. Similarly, a plot of Niggli-mg against Niggli-c plot ($mg = \frac{MgO}{FeO + MnO + Fe_2O_3 + MgO}$) places the amphibolite close to that of a normal tholeiitic basalt or dolerite (cf., Leake, 1964; Kalsbeek & Leake, 1970). In addition, a plot of total iron (i.e. $FeO^* = FeO + 0.8998\ Fe_2O_3$) against FeO^*/MgO (FeO^* = total Fe expressed as FeO) falls in the tholeiitic field of Miyashiro (1974).

Correlation and Age

Small bodies of amphibolite and mafic granulite extending from the Spotted Tiger Mica Mine (abandoned) to Mount Palmer also overlie a second outcrop-area of Naringa Calcareous Quartzite Member and are correlated with the Riddock Amphibolite Member. The two small lenses of amphibolite that crop out (1) as low ridges at Mount Ruby, and (2) 1.6 km south of Bungitina Well (abd).

No age determinations have been carried out on the unit.

Origin

In a broad sense, the chemical analysis (Table D-6-2B) is consistent with derivation of the amphibolite from a basic igneous rock. However, the plagioclase-rich varieties such as R4502 and quartz-rich types such as R4503 suggest that at least some of the amphibolite is gradational in composition with metasediments. Much, if not most, of the amphibolite is markedly layered and has a variable quartz-content suggesting it may be a para-amphibolite. Some of the quartz-rich layers bifurcate suggesting that there has been some later redistribution of silica. Joklik (1955) seemed to agree with this view when he suggested that the quartz in R4503 may be metasomatic.

D-6-4: Brady Gneiss, pGhb (R.D.S.)

Definition

The Brady Gneiss consists mainly of almandine and muscovite-bearing biotite-plagioclase-quartz gneiss. It occupies the northern slopes of the Harts Range in the far northeastern corner of RIDDOCH, and in the adjacent 1:100 000 sheet areas to the north and east. The unit was named by Joklik (1955) after Mount Brady. The reference area for the unit is taken to be that surrounding the chemically analysed sample (R4631) located 1.5 km north-northwest of the Central Mica Mine (abd), that is about 6 km west of Mount Brady. The Brady Gneiss is readily distinguished from the Irindina Gneiss because it is more quartz-rich, commonly contains muscovite, and forms an elevated region.

Relationships

The Brady Gneiss overlies the Irindina Gneiss with a conformable contact. No unit is known to overlie the Brady Gneiss, except for Cainozoic cover.

Lithology

In the Brady Gneiss muscovite forms large flakes and aggregates, which emphasise the schistosity and help to distinguish the unit from the Irindina Gneiss. The Gneiss is also characterised by the wide variety of rock types that commonly occur as thin interbedded layers. Such rock types include garnet-muscovite bearing gneiss, biotite gneiss, muscovite-biotite gneiss, quartzofeldspathic gneiss and rare amphibolite. Considered as a whole, the Brady Gneiss contains less garnet and less sillimanite than the Irindina Gneiss. The garnet in the Brady Gneiss forms large megacrysts. The sillimanite occurs in felted aggregates in the garnet, or closely associated with the garnet; and is generally restricted to narrow zones. Compositional layering is better developed in the Brady Gneiss in that there is a more complete separation into mica-rich and quartz-rich layers than in the Irindina Gneiss. Joklik estimated the average mineral content of the Brady Gneiss to be 46 percent quartz, 29 percent plagioclase,

13 percent biotite, 7 percent muscovite, 2 percent almandine, accessory sillimanite and magnetite, and traces of zircon. Microcline is uncommon, but 8 percent microcline occurs in a specimen (R4632) from alongside the abandoned Harts Range Mica Depot.

Geochemistry

The chemically analysed specimen, R4631 (Joklik, 1955, p. 75), is coarse-grained, and has a marked gneissic layering. Its oligoclase is poorly twinned, its biotite is intensely pleochroic, and it contains green pleonoaste associated with garnet. Joklik regarded the analysed specimen to be a metasomatised and metamorphosed psammo-pelitic metasediment. For such a rock, the analysed specimen is high in silica, and low in alumina and potash.

Correlation and Age

The Gneiss shows some lithological similarity to the Hillsoak Bore metamorphics, but is more quartz-rich than that unit. No age determinations have been carried out on the Gneiss.

Origin

The Gneiss is thought to be a metamorphosed psammo-pelitic sediment. The Brady Gneiss is more quartz-rich than the Irindina Gneiss and consequently may represent a shallower-water facies. It also contains more quartzofeldspathic rock, the origin of which is uncertain: it possibly represents arkosic metasediment.

D-7: Division 3: Iwupataka Metamorphic Complex, Alice Springs Block, - Introduction (L.A.O.)

The Iwupataka Metamorphic Complex is defined as those metasediments and meta-igneous rocks which crop out over a west-trending length of about 100 km in the southern Arunta Block from near Simpsons Gap (ALICE SPRINGS) westward to Ormiston Gorge (HERMANNSBERG). It is named after the Aboriginal Settlement about 40 km west-southwest of the Alice Springs township (GR 5650-477683).

The Complex is fault-bounded to the north, unconformably overlain by the Heavitree Quartzite (Buh) to the south, nonconformably overlies orthogneiss of the Hayes Metamorphic Complex to the east, and grades into basement migmatite and granite to the west. Dolerite (Bds) and pegmatite dykes and in places granite, porphyry, and rare basic plugs intrude the Complex.

Members of the Complex in ALICE SPRINGS are the Simpsons Gap Metasediments (Bas), Chewings Range Quartzite (Bac), Rungutjirba Gneiss (Bar) and the Burt Bluff Gneiss (Bab).

D-7-1: Simpsons Gap Metasediments, Bas (New name) (L.A.O.)

Definition

The Simpsons Gap Metasediments crop out in ALICE SPRINGS, south of Simpsons Gap, and between the Chewings Range and the Burt Bluff Gneiss (Bab), as low to moderately high rounded hills and ridges. The unit extends to the west into MACDONNELL RANGES. The name is derived from Simpsons Gap 17 km west of the Alice Springs township. The type locality is along Jay Creek in ALICE SPRINGS between GR 5650-506767 and 513779. The basal conglomerate does not crop out at the type locality, but a good exposure can be seen at GR 5650-765782.

Relationships

East of Simpsons Gap the Metasediments overlie the Sadadeen Range gneiss (pCpb); to the south they are unconformably overlain by the Heavitree Quartzite (Buh) but to the north they are concordantly overlain by the Chewings Range Quartzite (Bac). The Metasediments are intruded by both the Burt Bluff Gneiss (Bab) and the Rungutjirba Gneiss (Bar) as seen at GR 5650-564775, where the Burt Bluff Gneiss and the Rungutjirba Gneiss interfinger with the unit and the Burt Bluff Gneiss contains a 2.5 m long sliver of recrystallised sericitic sandstone. Pegmatite, undivided granite (Bg) and dolerite dykes (Bds) also intrude the unit.

Lithology

The Simpsons Gap Metasediments consist of a thin metamorphosed cobble conglomerate at the base, overlain by recrystallised micaceous and feldspathic quartz sandstone with interlayered staurolite-garnet-two-mica schist and a small amount of amphibolite (Table D-7-1A). The basal conglomerate (Photo D21) crops out in the east where it overlies Sadadeen Range gneiss at a low angle and is composed of isolated quartzite and quartz cobbles up to 15 cm long, and locally feldspar augen up to 4 cm long, in a schistose muscovite-quartz matrix (73913817). Recrystallised hematite-muscovite-bearing sandstone, poorly sorted biotite and muscovite bearing sandstone, and small amounts of biotite-muscovite schist crop out west of the conglomerate. Between the Chewings Range and the Burt Bluff Gneiss the unit forms ridges of metamorphosed sandstone and gneiss between valleys of schist; towards the Chewings Range the unit includes interlayered white, grey and blue recrystallised quartzite up to 2 m thick. At grid reference 5650-561778 a thin pebble conglomerate (specimen 74912651) crops out and outlines the nose of an antiform. It is overlain by recrystallised sericitic sandstone, sericite schist and hematite-bearing sandstone and is underlain by fine-grained biotite and muscovite-feldspar-quartz gneiss (75910728, 74912652). To the north the quartzose beds are interlayered with garnet-biotite-muscovite schist containing subidioblastic staurolite. Locally, the garnet is idioblastic and up to 5 mm across. Southeast of Mount Lloyd the unit consists of inter-layered translucent greenish-grey

TABLE D-7-1A - SIMPSONS GAP METASEDIMENTS

Specimen No.	Field description	Quartz	Feldspar	Muscovite	Biotite	Epidote, clinosoisite	Other
73913750	Muscovite-quartz gneiss	45%	Kspar 15%	25%	Small amount	15%	Apatite, opaque grains
73913752	Recrystallised haematite-sericite-quartz sandstone	70%	-	22%	-	-	Rhomb-shaped opaque grains 8% sphene
73913821	Recrystallised quartz sandstone	75%	Plag 10%	10%	5%	Small amount	Garnet, opaque grains
73913853	Biotite-sericite quartzose gneiss	75%	Plag (more calcic than mid oligoclase) 10%	9%	6%	-	Garnet, opaque grains
73913941	Biotite-sericite-quartz gneiss	60%	-	30%	1%	-	Chlorite 8%, opaque grains 1%, apatite
73913944	Quartzite	75%	Plag 20%	Small amount	5%	Small amount	Garnet, opaque grains
73913754	Garnet-staurolite-biotite-muscovite schist	30%	Alkali feldspar 10%	45%	13%	-	Staurolite 2%, garnet, zircon
74912652	Schistose gneiss	40%	Plag 37%	20%	-	-	Sphene 1%, apatite, opaque grains
75910728	Biotite gneiss	55%	Plag) Kspar?) 39%	-	Chloritised biotite 5%	-	Sphene 1%, apatite
74912653	Schistose actinolite-quartz feldspar gneiss	49%	Sodic plag 20%	-	-	-	Actinolite 30%, sphene 1%, apatite

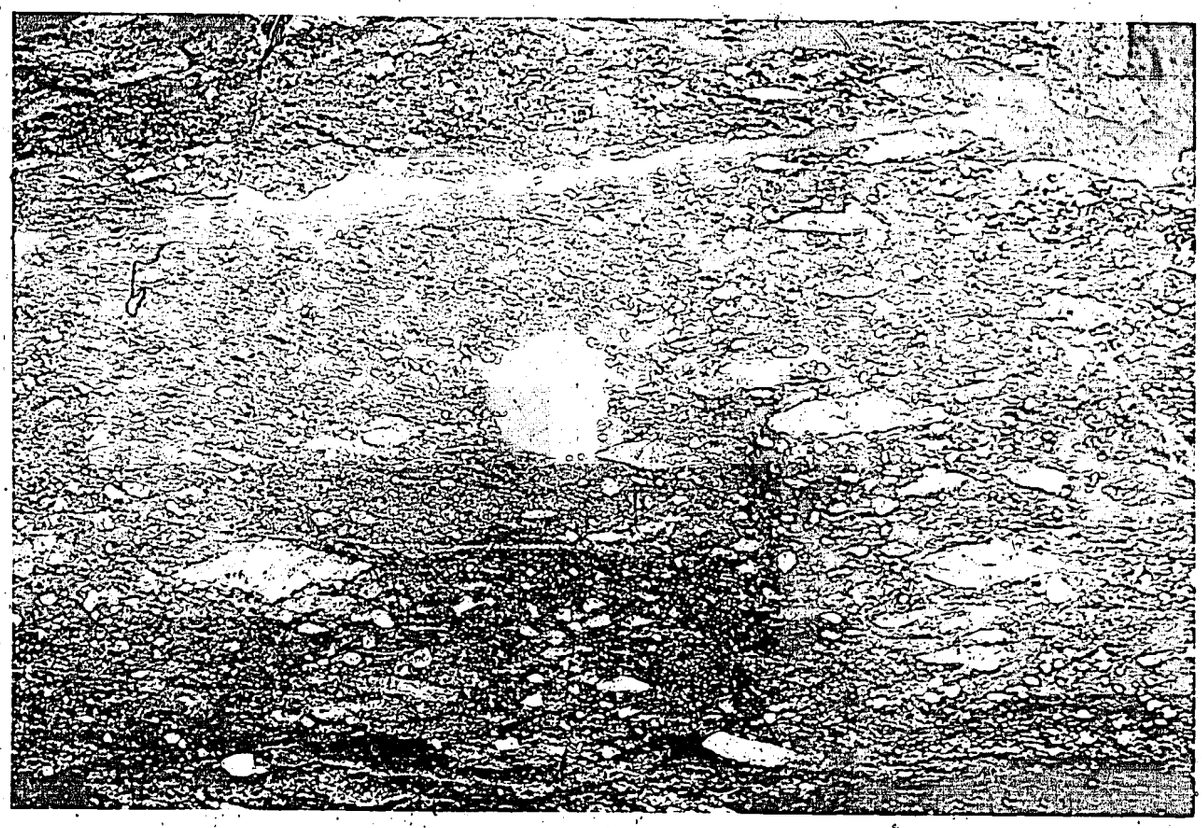


Photo D21: Pebble conglomerate at the base of the Simpsons Gap Metasediments (lens cap about 5 cm across). GR 5650-724797. (M/2164).

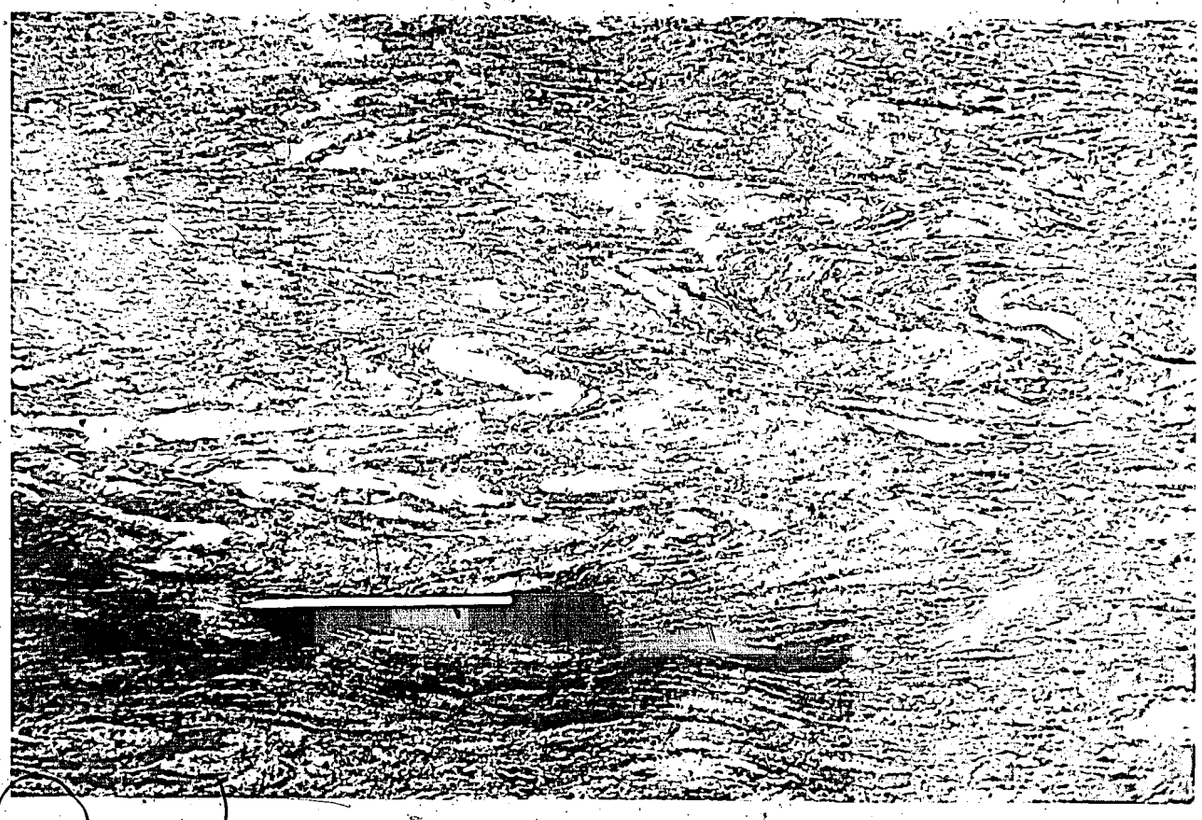


Photo D22: Tight mesoscopic folds outlined by quartz and quartz-feldspar veins (pen is 14 cm long). GR 5650-505763. (GA/8218).

fine-grained quartzose gneiss (73913944), schistose gneiss and schist. Amphibolite layers crop out west of the Sheet area. Fine to medium-grained schistose feldspar-actinolite-quartz gneiss crops out at GR 5650-569786 (74912653).

Structure

Bedding is preserved locally in both the conglomerate and the overlying metamorphosed sandstone. About 3 km east of Simpsons Gap the bedding consists of layers of cobbles. Here foliation in the conglomerate is defined by elongate phenoclasts of quartzite and quartz, and by alignment of muscovite and is discordant to the bedding.

Bedding in the metamorphosed sandstone is indicated by heavy mineral laminations and is only evident where bedding and foliation are at a high angle to each other. At GR 5650-560803, 2 km southeast of Mount Lloyd, crossbedding is visible in a quartzitic layer.

The earliest recognised folding is equated with the Chewings Phase of deformation, and appears as mesoscopic intra-folial folds formed in the schist and in folded quartz veins, and is also outlined by competent quartz-rich layers in the recrystallised sandstone (Photo D22). In a schist specimen 73913747, from the type locality (GR 5650-505768), the schistosity is axial-plane to isoclinal folds outlined by quartzose layers. Fold noses are commonly transposed and so the original layering in many places parallels the foliation.

Later folding comparable with the Ormiston Phase of deformation, is more open, ranges from mesoscopic to macroscopic scale (Photos D23-24), and refolds Chewings Phase folds. For example at GR 5650-538783 well-parted sericitic quartzose gneiss is tightly folded on a mesoscopic scale and refolded about a moderately steep east-plunging axis. At GR 5650-483767 metaquartzite is folded about gently west-southwest and moderately east-northeast plunging axes. The earlier lineation, associated with the Chewings Phase of deformation, is folded; a crenulation lineation defines

Photo D23: Mesoscopic open folds in the Simpsons Gap Metasediments at the type locality (pen is 14 cm long). GR 5650-506765. (GA/8229).

Photo D24: Mesoscopic open folds in the Simpsons Gap Metasediments. GR 5650-561798. (GA/8226).

the axial-plane trace of the later folds. Grey sericitic quartzose gneiss at GR 5650-521792 is folded about a moderate east plunging axis. The earlier folded lineation and the axial plane trace of the east plunging folds are both defined by aligned sericite flakes.

Correlation

Pelitic and semi-pelitic schists cropping out south of the Chewings Range in HERMANNSBURG (Marjoribanks, 1975) are similar in composition, metamorphic grade and the style of deformation to the Simpsons Gap Metasediments. Preliminary mapping of the basement rocks south of the Chewings Range in MACDONNELL RANGES indicates that the Simpsons Gap Metasediments may extend from ALICE SPRINGS, through MACDONNELL Ranges as far west as HERMANNSBURG.

Origin

The Simpsons Gap Metasediments are thought to represent a marine sequence deposited on crystalline and sedimentary basement of the Hayes Metamorphic Complex. A thin-near-shore conglomerate was deposited first followed by feldspathic sands and pelites. Amphibolite cropping out in this unit west of ALICE SPRINGS may have originally been basalt.

Age

The Simpsons Gap Metasediments were folded and metamorphosed to upper greenschist to low amphibolite facies assemblages during the Chewings Phase of deformation; thus the unit is Middle Proterozoic or older.

D-7-2: Chewings Range Quartzite, Bac (L.A.O.)

Definition

The Chewings Range Quartzite consists predominantly of metamorphosed quartzite and forms the Chewings Range which is a series of west-trending rugged hills and ridges which extend from about Mount Lloyd in ALICE SPRINGS westward to near Mount Giles in HERMANNSBURG. The type

locality of the Chewings Range Quartzite is along Jay Creek in the west part of ALICE SPRINGS from GR 5650-512808 to 508819. Multiple folding of the unit precludes any estimate of true thickness; apparent thickness is up to 5 km.

Relationships

Prichard & Quinlan (1962) describe the metaquartzite of the Chewings Range Qaurtzite as closely jointed, recrystallised quartzite cropping out within the Arunta Block in the southern half of the Hermannsburg 1:250 000 Sheet area. Although they considered it to be Heavitree Quartzite (Buh), M.A. Condon (personal communication in Prichard & Quinlan, 1962) noted a strong structural discordance between the quartzites on air photographs. Later mapping by BMR recognised the metaquartzite as a basement unit (Forman, Milligan & McCarthy, 1967). Marjoribanks (1975) described the Chewings Range Quartzite in his report on the structural and metamorphic geology of the Ormiston area in HERMANNSBURG.

In ALICE SPRINGS the Chewings Range Quartzite is faulted to the north against orthogneiss (?Bab) (C. Mawer, Monash University, personal communication, 1978) and may be conformably underlain to the south by the Simpsons Gap Metasediments (Bas). The Chewings Range Quartzite is terminated to the east against the Charles River Fault.

In some places in MACDONNELL RANGES to the west, the Chewings Range Quartzite extends into the basement gneiss with apparent conformity.

Because of the complex and tight nature of the early folding in the Chewings Range, it is possible that some schist horizons in the Chewings Range Quartzite may be infolded Simpsons Gap Metasediments. However until the structure of the Range is fully understood all schist horizons in the Range are mapped as part of the Chewings Range Quartzite.

North trending dolerite dykes (Bds) intrude the unit and a small amount of pegmatite is interlayered with the unit.

Lithology

The Chewings Range Quartzite consists of interlayered metaquartzite and muscovite-quartz schist, and a small amount of staurolite-garnet-mica schist layers and lenses. For convenience the unit is described as it occurs in each Sheet area; ALICE SPRINGS, MACDONNELL RANGES and HERMANNSBURG.

At the type locality in ALICE SPRINGS the metaquartzite consists of strained and fractured elongate interlocking quartz grains up to 4 mm long (about 97%), aligned muscovite flakes and lesser amounts of sillimanite, biotite, tourmaline, zircon and opaque grains (73913919, 20). Sillimanite occurs as radiating needles in quartz and also appears as needles within biotite. Staurolite-garnet schist and sericite-quartz phyllite lenses are also present at the type locality. In ALICE SPRINGS the metaquartzite is locally veined by quartz and, where faulted, typically consist of ribbons of strained quartz (90%), limonite staining (5%), muscovite (3%), and accessory tourmaline and opaque grains (73913998). Crossbedding of the metaquartzite is rarely preserved (Photo D25).

In MACDONNELL RANGES Hirsinger and Wilkie (Monash University, personal communication, 1975) recognises two main components making up the metaquartzite (1) massive coarse-grained, recrystallised quartzite and (2) quartz "phyllite". In places in the same Sheet area the Chewings Range Quartzite consists of recrystallised fine to medium-grained quartz with a small amount of kyanite, muscovite, and opaque grains.

In HERMANNSBURG Marjoribanks (1975) describes the western end of the Chewings Range Quartzite as a massive, coarse-grained, very pure metaquartzite. The margins of the unit contain muscovite and the southern contact is interlayered with mica schist.

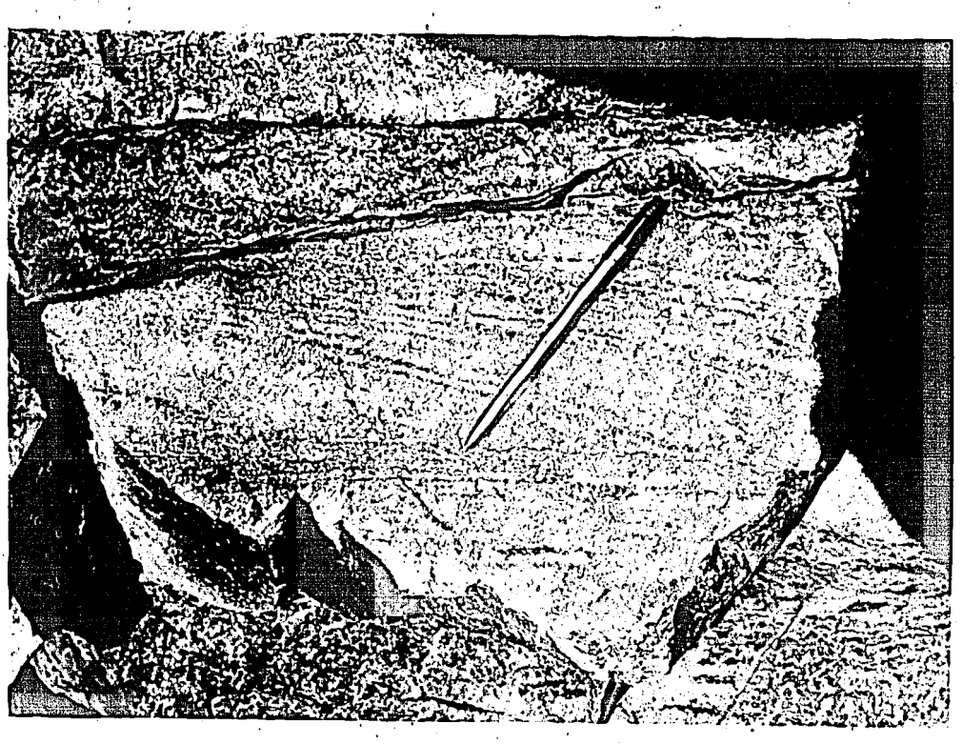


Photo D25: Crossbedded metaquartzite of the Chewings Range Quartzite (pen is 15 cm long and points to the line of truncation). GR 5650-513810) (GA/8700).

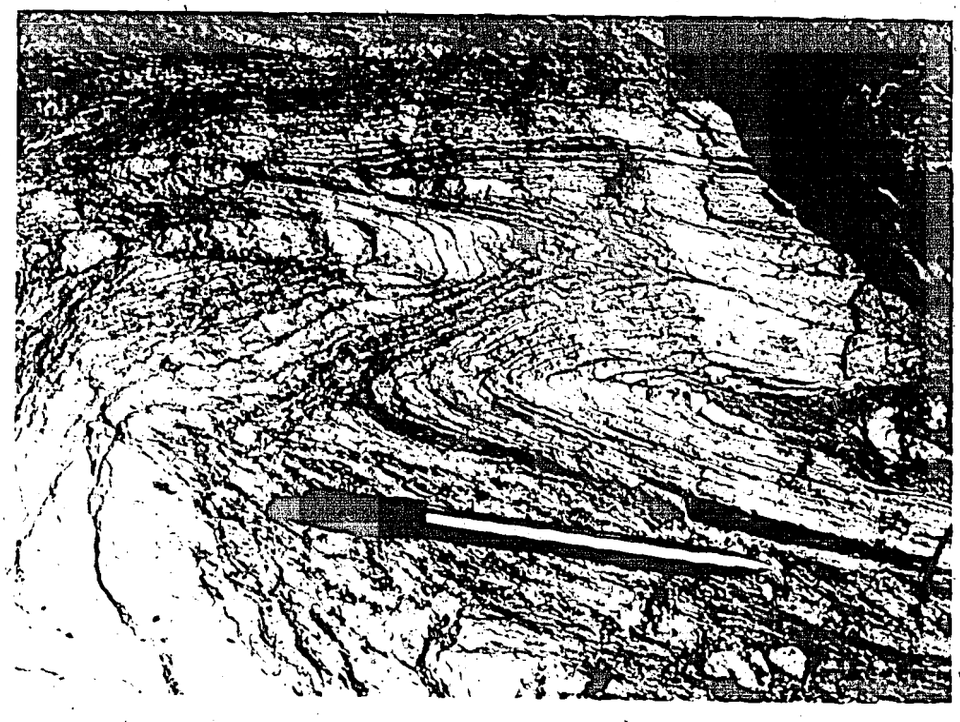


Photo D26: Isoclinal folds in metaquartzite of the Chewings Range Quartzite (pen is 15 cm long). GR 5650-514812 (GA/8697).

Structure

Marjoribanks (1975) in his report on the structural and metamorphic geology of the Ormiston area in HERMANNSBURG considers possibly four phases of deformation affected the Chewings Range Quartzite and surrounding rocks prior to the Alice Springs Orogeny. The second (Chewings Phase) and third (Ormiston Phase) phases are recognised along the length of the Chewings Range.

The Chewings Phase of deformation is characterised by tightly folded metaquartzite ranging from mesoscopic (Photo D26) to macroscopic folds with amplitudes up to 1 km (V. Hirsinger and J. Wilkie, Monash University, personal communication, 1975). In both HERMANNSBURG and ALICE SPRINGS the Chewings Range Quartzite is thought to lie within a major synformal Chewings Phase structure. Foliation of the less massive metaquartzite is defined by parting surfaces of muscovite, fractures, and colour lamination and is probably in many cases equivalent to bedding which has been transposed during the Chewings Phase of deformation. Muscovite orientation defines the axial-plane trace (lineation) of Chewings Phase folds.

The Ormiston Phase of deformation is typified by mesoscopic and macroscopic open folds which in places are seen to fold the earlier lineation.

In ALICE SPRINGS west-trending faults may repeat part of the Chewings Range Quartzite.

Correlations

Isolated metaquartzite hills 5 km south of Simpsons Gap, protrude through alluvium, are overlain by the Rungutjirba Gneiss (Bar), and are thought to be outliers of the Chewings Range Quartzite. The only sample collected from the hills is composed of finely recrystallised quartz (99%), muscovite and opaque grains (75A0723). The quartz generally has lobate grain boundaries.

Another possible exposure of Chewings Range Quartzite crops out 10 km south of Simpsons Gap in the nose of the Blatherskite Nappe. The outcrop is unconformably overlain by the Heavitree Quartzite and consists of glassy coarse-grained metaquartzite.

Origin and Age

The Chewings Range Quartzite represents a mature marine quartz sandstone containing small amounts of pelite layers near the base. It is older than the Heavitree Quartzite which unconformably overlies it and the dolerite dykes (Bds) which intrude it. Marjoribanks (1975) suggests the Chewings Range Quartzite and surrounding rocks were recrystallised under almandine-amphibolite facies metamorphic conditions at least partly coeval with the Chewings Phase of deformation. Thus the Chewings Range Quartzite is Middle Proterozoic or older.

D-7-3: Rungutjirba Gneiss, Bar (New name). (L.A.O.)

Definition

The Rungutjirba Gneiss is a distinctive, laminated fine-grained quartzofeldspathic gneiss which crops out in ALICE SPRINGS. It is exposed south of Simpsons Gap and from here bifurcates westwards towards the headwaters of Laura Creek. It forms moderately high rounded hills and is named after Rungutjirba Ridge, a conspicuous west-trending ridge passing through Simpsons Gap. The type locality is about 5 km west-northwest of Temple Bar Gap along a tributary of Roe Creek (GR 5650-670758).

Relationships

Although no crosscutting relationships are seen, the unit appears to intrude the Simpsons Gap Metasediments (Bas) and the Chewings Range Quartzite (Bac) on its eastern margin. It intrudes the Simpsons Gap Metasediments on its northern margin. Inter-fingering of the unit with the Burt Bluff Gneiss (Bab) is interpreted as an intrusive contact.

The Rungutjirba Gneiss is intruded by dolerite (Bds) and unconformably overlain by the Heavitree Quartzite (Buh).

Lithology

The quartzofeldspathic gneiss is pink or cream in hand specimen and consists typically of quartz and plagioclase augen, commonly less than 2 mm long, in a laminated, aphanitic, muscovite-quartz-feldspar matrix. Biotite and euhedral magnetite are present locally. Specimen 73913825 consists of plagioclase and few microcline grains up to 1.5 mm across, and lenses of quartz, in a finer-grained matrix of quartz, feldspar, biotite, muscovite, opaque grains and apatite. In specimen 73913763 the feldspar is partly altered to sericite and biotite is chloritised. In some areas the unit is schistose with lenticular feldspar, and epidote forms thin bands and coats slickensides. A layer of fine-grained basic rock (73913824) crops out at GR 5650-672765 and consists of laths of sericite and relict plagioclase up to 0.5 mm long in a fine-grained matrix of ?chlorite, ?sphene, opaque grains and ?hematite.

Structure

Laminations in the unit are caused by mica, quartz lenses, feldspar grains and lenticular aggregates of feldspar. At GR 5650-606788 and 650742 the gneiss is tightly to isoclinally folded on a mesoscopic scale. Large-scale folds are open and shallow plunging. Mineral streaking defines a lineation plunging roughly to the southwest or northeast.

Origin and Age

Rungutjirba Gneiss is a massive unit, thought to be derived by metamorphism and deformation of a quartz-feldspar porphyry sill or flow. It would appear to be a similar metamorphic age to other members of the Iwupataka Metamorphic Complex i.e. Middle Proterozoic or older.

D-7-4: Burt Bluff Gneiss, Bab (New name) (L.A.O.)

Definition

The Burt Bluff Gneiss is the distinctive large feldspar-bearing orthogneiss cropping out in ALICE SPRINGS between the Chewings Range and Heavitree Quartzite (Buh) and extending westwards from near Burt Bluff (after which the unit is named; GR 5650-674714), to about 5 km west of Iwupataka Native Settlement. The type area is along Jay Creek north of the Settlement. The unit forms low to moderate rounded and rubbly Hills. Its air photograph pattern, particularly north of the Settlement, is characteristic of granite terrain.

Relationships

The Burt Bluff Gneiss interfingers with the Rungutjirba Gneiss (Bar). This interfingering contact is considered more likely to be a metamorphosed intrusive contact then a tight macroscopically folded concordant contact. The Burt Bluff Gneiss contains rare xenoliths (for example at GR 5650-565776), possibly derived from the Simpsons Gap Metasediments, and is intruded by dolerite dykes (Bds) and prophyritic and mafic plugs. To the south the Gneiss is unconformably overlain by the Heavitree Quartzite.

The large feldspar-bearing orthogneiss cropping out north of the Chewings Range and extending to the west of the Sheet area, is thought to be related to the Burt Bluff Gneiss. It is fault-bounded to the south (C. Mawen, Monash University, personal communication, 1978), north and northeast, and intruded by pegmatite, granite, and dolerite (Bds).

Near the Iwupataka Native Settlement the Burt Bluff Gneiss is capped by disected sheets of red alluvium (Czc) containing rounded cobbles of quartzose rock and quartz.

Lithology

The Burt Bluff Gneiss consists typically of schistose augen gneiss and subordinate laminated even-grained granitic gneiss. Pink and white feldspar augen, up to 3 cm long are enclosed in a fine to medium-grained biotite-quartz-feldspar matrix.

Some feldspar grains are partly altered to epidote and sericite (73913743). Near faults the gneiss commonly contains joints, layers and veins, up to 10 mm wide, rich in epidote. Locally the gneiss contains clots of biotite and epidote, and in other places it passes into flaser gneiss containing muscovite. A small amount of quartzofeldspathic gneiss up to about 1.5 m thick is conformably interlayered with the Burt Bluff Gneiss. A specimen from one of these layers consists of microcline, albite, quartz, biotite, muscovite and garnet (73913739). Pegmatite and quartz veins parallel, and in some areas cut, the foliation. Xenoliths consist of fine-grained biotite-plagioclase-microcline-quartz rock (for example 73913742).

North of the Chewings Range the large feldspar-bearing gneiss consists of stubby microcline up to 30 mm long in a schistose fine to medium-grained matrix composed of quartz, altered plagioclase, microcline, chloritised biotite, muscovite, epidote and accessory opaque grains, tourmaline, apatite, sphene and zircon (73913910). Locally the unit is equigranular. Xenoliths are common, are elongate up to about 1 m, parallel to the foliation, and consist of fine-grained biotite-quartz-feldspar gneiss and muscovite-biotite schist (Photo D27-28).

Structure

The strong foliation characteristic of the Burt Bluff Gneiss is defined by elongate feldspar aggregates, recrystallised quartz lenses and biotite flakes and is thought to have formed during the Chewings Phase of deformation. The foliation was gently folded on a macroscopic scale during the Ormiston Phase of deformation. Biotite flakes outline a strong lineation which plunges roughly southwest or northeast.

Photo D27: Small xenolith within Burt Bluff Gneiss, south of the Chewings Range (pen is 14 cm long). GR 5650-568718. (GA/8708).

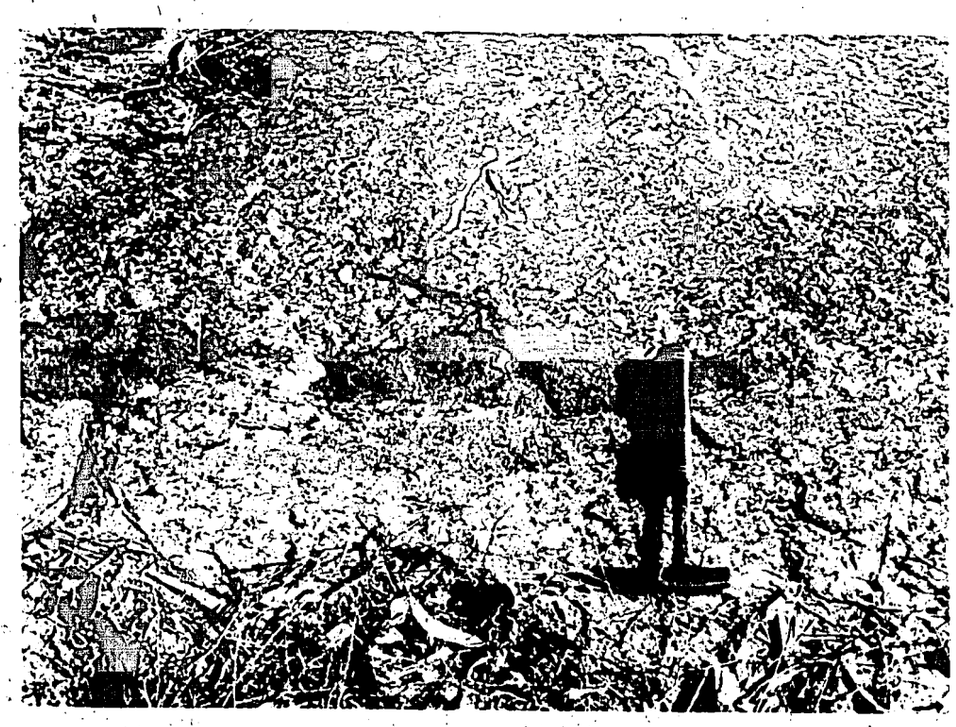


Photo D28: Large-feldspar orthogneiss (?Burt Bluff Gneiss) north of the Chewings Range containing elongate xenoliths. GR 5650-506834. (GA/8696).

Epidote veins and slickensides are common along faults.

Origin

The Burt Bluff Gneiss is a relatively homogeneous unit containing rare xenoliths south of the Chewings Range and more abundant xenoliths north of the Range (Photo D27-28). It is considered to have originally been a granite.

Age

The unit may be younger than the Rungutjirba Gneiss and the Simpsons Gap Metasediments but pre-dates the pegmatite and dolerite dykes which intrude it and the Heavitree Quartzite which overlies it. The foliation was probably caused by the Chewings Phase of deformation. Hence the unit is considered to be Middle Proterozoic or older.

D-8: Division 3: Schist and quartzite in the northeastern Wigley Block

D-8-1: Schists in the Randall Peak metamorphics

Some of the muscovite-biotite schists(s) in the Randall Peak metamorphics are lithologically like those in the Simpson Gap Metamorphics and the Laughlen metamorphics which are assigned to Division 3. However, these schists are retained in the Randall Peak metamorphics and Division 2 because they are intimately interlayered with quartzofeldspathic gneiss and amphibolite.

D-8-2: Mount Laughlen metamorphics, pGl (R.D.S.)

Definition

This unit is characterised by thin beds of quartzite, which occur in a unit consisting mainly of muscovite-biotite schist. The unit extends from directly south of Mount Laughlen (GR 5751-367152), the topographic feature after which they have been named, westwards to immediately south of Cement Dam (i.e. to GR 5751-183121). The reference area extends from 2.2 km southwest of Mount Laughlen (GR 5751-366120) to the south of Mount Laughlen (GR 5751-359143).

In addition to the presence of quartzite the unit is distinguished by the general absence of amphibolite, which is found in the somewhat similar Randall Peak metamorphics (and unit pGf on the Preliminary map of LAUGHLEN). In some places it is difficult to distinguish the metamorphics from zones of Palaeozoic greenschist retrogression (Pzr).

Relationships

The quartzite lenses overlies unassigned biotite gneiss of unit pG in Ankala Block-(South). The quartzite and schist are in faulted contact with rocks of the Wigley Block and, as such, lie north of the eastern extensions of the Redbank Deformed Zone, but they are considered to be more like the rocks of Division 3 than schistose rocks associated with the Redbank Deformed Zone elsewhere.

Lithology

The muscovite-biotite schist has a colour-index of up to 15, and rarely up to 30. It is generally medium-grained and has a well-developed gneissic layering. Felsic varieties are commonly fine-grained, contain up to 5 percent biotite, and only traces of muscovite. Muscovite-rich varieties are, for the most part, quartz-rich and grade into quartzite. For example, a typical muscovite-rich variety (3525) contains up to 30 percent muscovite and sericite, 60 percent quartz, and 10 percent albite; some varieties contain biotite or chlorite although these minerals are more commonly absent.

The quartzite is fine-grained, recrystallised, and contains small to trace amounts of muscovite and plagioclase.

Although amphibolite is generally absent one body is known in the northern-central part of the outcrop-area. This amphibolite (3658) retains primary igneous hornblende laths, and is probably a later intrusion. The amphibolite contains 10 percent quartz and the plagioclase has been saussuritised to epidote and muscovite.

Correlation and Age

The Laughlen metamorphics are assigned to Division 3, and are lithologically correlated with the Chewings Range Quartzite in the Iwupataka Metamorphic Complex.

No age determinations have been carried out on these rocks.

Origin

The Laughlen metamorphics are considered to be a sequence of metasediments because they include interlayers of quartzite, and because the schists are pelitic or psammopelitic in composition.

D-9: Division 3: Rocks in the White Range Nappe

D-9-1: Cavenagh metamorphics (pCk) (A.J.S.)

Definition

The Cavenagh metamorphics are the diverse assemblage of metasedimentary and meta-igneous rocks that crops out in the south of RIDDOCH and north of FERGUSSON RANGE. The unit is divided into two subunits: pCk_1 comprises quartzofeldspathic gneiss, para-amphibolite, quartzite, andalusite schist, and muscovite-biotite schist, and crops out in Paddys Plain and east of the Cavenagh Range. Its reference section extends from GR 5851-656015 to 5851-680034. pCk_2 comprises feldspathic schist, quartz-rich metasediment, amphibolite, quartzite, and granitic gneiss that crops out between the Cavenagh and White Ranges, and at Mount Gordon, north of Arltunga. Its reference section extends from GR 5851-704059 to 5851-696068 to 5851-705083. The two subunits are separated by a fault striking southeast from the northwestern corner of the Cavenagh Range. The quartzofeldspathic gneiss underlies Paddys Plain itself; amphibolites and schist give rise to subdued hilly terrain; and the quartz-rich metasediment and quartzite form prominent peaks and ridges, the highest of which is Mount Gordon, with a relief of 200 m above the surrounding terrain. The name of the unit is derived from the Cavenagh Range on the northern side of Paddys Plain; the Range itself is named after the pioneering family who built 'Ambalindum' homestead beside the Hale River to the north. The Cavenagh metamorphics are distinguished by their pronounced lithological dissimilarity from the metatonalite of the Atnarpa Igneous Complex to the north, and from the quartzite of the Heavitree Quartzite to the east, west, and south. To the southwest, the Cavenagh metamorphics pass beneath alluvium.

Relationships

Relationships of the Cavenagh metamorphics to other units in the Arunta Block are almost everywhere concealed by younger formations. Metatonalite of the Atnarpa Igneous Complex contains numerous rafts of amphibolite assigned to the Cavenagh metamorphics, and also surrounds

the large body of quartz-rich metasediments that forms Mount Gordon. Northwest of Arltunga, an apophysis of the metatonalite appears to intrude feldspathic schist of the Cavenagh metamorphics. Foliation trends in the quartzofeldspathic gneiss of Paddys Plain are approximately parallel to trends in biotite gneiss of the Hillsoak Bore metamorphics to the west, and so the concealed contact of the two units may be concordant and conformable. The Cavenagh metamorphics are unconformably overlain by the Upper Proterozoic Heavitree Quartzite on the western side of White Range and the eastern side of the Cavenagh Range.

Lithology

Subunit pGk_1

The reference section for subunit pGk_1 extends for 3 km across the eastern end of Paddys Plain, in RIDDOCH. At the western end, the subunit consists of quartzofeldspathic gneiss, and this is succeeded to the east by a sequence 350 m thick of para-amphibolite, chlorite schist, andalusite schist, and quartzite. The sequence has been tightly folded into a gently north-plunging synform, and is hence repeated in reverse order for a further 200 m, finishing with para-amphibolite again. The reference section then crosses a small fault, and passes eastwards through biotite gneiss, chlorite schist, a second variety of quartzite bordered to the south by amphibolite, and finishes in more para-amphibolite at its eastern end.

Quartzofeldspathic gneiss is poorly exposed as very low rubbly ridges. The rock is a non-layered heterogeneous gneiss composed of quartz, feldspar, chlorite, and sericite in different porportions from place to place. Locally the rock is brecciated and intensely quartz-veined, and contains small patches rich in chlorite.

Para-amphibolite is fine to medium-grained, weakly foliated but strongly lineated, and composed of hornblende or actinolite, plagioclase, epidote, and quartz. Various metasediments are interbedded with the para-amphibolite, and include sericite-chlorite schist, ferruginous marble, and quartzite (74915053,-5054) at GR 5851-680060 east

of the Cavenagh Range. Immediately adjacent to the Cavenagh Range, the para-amphibolite contains strongly foliated biotite schist composed of dark laminae of biotite, epidote, quartz, and monazite, and light laminae of quartz, albite, biotite, muscovite, sphene, zircon, and clinozoisite (68110017, 74915051).

Chlorite schist in the reference section consists of chlorite, quartz, sericite, biotite and rare porphyroblasts of feldspar.

Andalusite schist forms two layers conformably above and below the tight synform of quartzite in the reference section. The rock has not been thin-sectioned.

Several lenses of quartzite have been mapped in the eastern part of Paddys Plain, and another lens crops out 2 km south of the old Police Station. At locality 5851-664021 strongly lineated quartzite in the reference section outlines the tight synform described above. The rock is hard and pure, and is under and overlain by andalusite schist. One kilometre to the northeast, a second variety of quartzite is fine-grained, schistose, and includes muscovite-sericite quartzite (with associated muscovite schist), feldspar-chlorite quartzite, and chlorite-feldspar quartzite. The quartzite lens 2 km south of the old Police Station is streaky blue and white, very fine-grained, and strongly lineated.

Layered biotite gneiss forms a discontinuously exposed layer or lens in the east of Paddys Plain, and comprises alternating quartzofeldspathic and biotite-rich layers about 0.5 m thick.

Three bodies of amphibolite have been mapped in the southern part of the quartzofeldspathic gneiss of Paddys Plain, and several more crop out next to the second variety of quartzite in the reference section. Only onebody has been examined; it is very coarse-grained, massive, and consists essentially of hornblende and small amounts of quartz and plagioclase.

Schist at the extreme eastern end of Paddys Plain contains biotite, but has not been otherwise examined.

Subunit pGk_2

The reference section for subunit pGk_2 is situated east of Arltunga and the old Police Station, in RIDDOCH. At the southern end, the subunit consists of photointerpreted schist, followed to the north by feldspathic schist, quartzite, granitic gneiss, amphibolite, metatonalite of the Atnarpa Igneous Complex, and quartz-rich metasediment at the northern end.

Feldspathic schist crops out in the area extending from the old Police Station to Corbins Bluff, in the northwest of White Range. The unit also includes a subordinate amount of quartzofeldspathic gneiss, and small amounts of quartzite, marble, phyllite, amphibolite, and chlorite schist. The feldspathic schist is grey, fine-grained, granitic in composition, and strongly foliated and lineated. It consists of broken fragments of microcline, recrystallised quartz, sericite, plagioclase, muscovite, and rare biotite (74915055). The quartzofeldspathic gneiss is similar, but medium to coarse-grained and composed of quartz, plagioclase, biotite, muscovite, calcite, sphene, and ilmenite (74915056). Quartzite forms a single elongate pod at 5851-693068, 750 m southeast of the old Police Station; it is mottled red, white, and blue, and consists of quartz, garnet, hematite, magnetite, and green spinel (68110329). Impure ferruginous marble forms a poorly exposed thin layer at 5851-687067, 500 m southwest of the Police Station. Phyllite is exposed next to the east-striking fault west of the Crossroads, and is characterised by wavy foliation. Amphibolite forms a small body at 5851-688069, 300 m south of the old Police Station, and consists of actinolite, clinozoisite, quartz, ilmenite, and sphene (74915057). Chlorite schist at the same locality is composed of quartz, plagioclase, chlorite, sericite, garnet remnants in chlorite, and opaque grains (74915058).

Quartzite forms a low north-trending ridge about 1 km long midway between the Police Station and Corbins Bluff, and is tough, clean, glassy, and strongly lineated. It is underlain by cream to white coarse-grained dolomitic marble, which is strongly folded and cut by numerous veins of white quartz.

Granitic gneiss 500 m east of the old Police Station is fine to medium-grained, strongly lineated but not everywhere foliated, and ranges from leucogranite to normal granite in composition. It is imperfectly layered in some places, and elsewhere is accompanied by layers of coarse-grained pegmatitic granite and coarse tourmaline-quartz rock which is also foliated and lineated.

Amphibolite crops out mainly southwest of White Range; smaller lenses are present on the northern side of the quartz-rich metasediment ridge forming Mount Gordon, and as enclaves in metatonalite and granite of the Atnarpa Igneous Complex north of the Cavenagh Range. South and west of White Range, the rock is green, generally coarse-grained and lineated, and retrogressively metamorphosed; in places it is fine-grained and schistose. On the western side of White Range, a few metres from the overlying Heavitree Quartzite, the rock is thoroughly retrograded to chlorite schist containing blebbly concentrations of epidote. North of the quartz-rich metasediment ridge north of White Range, the amphibolite is massive except near the metasediment, where it is foliated over a width of about 2 m. On the north side of the Cavenagh Range, a sample of one of the amphibolite enclaves in the metatonalite consists of green hornblende (85%), andesine (15%) substantially altered to sericite + epidote + calcite, and accessory ilmenite rimmed with sphene (68110200).

Quartz-rich metasediment crops out on the northern side of White Range, and forms a prominent ridge northwest from there to Mount Gordon. It is incorrectly designated as Heavitree Quartzite on the First Edition (1968) of the Alice Springs 1:250 000 Geological Sheet. The rock is pale pinkish-brown, fine to coarse-grained, strongly foliated and lineated, and consists of quartz (75 to 85%) as strain-gree polygonal

grains, microcline fragments (10 to 25%), muscovite (5%), plagioclase (0 to 5%), biotite (1%), and accessory zircon, monazite, and tourmaline (68110019, -0044, -0336). Most of the muscovite in -0336 is khaki-brown, and may be a 'ferri-phengite'. Coarse aggregates of colourless muscovite (68110318) occur in the metasediment.

Deeply weathered rock occupies three areas between the Crossroads and old Mission. Rock-types observed in the areas include mica-quartz gneiss and vein quartz; in addition, very fine-grained weathered impure marble, consisting of fibrous calcite, muscovite, and elongate aggregates of strained quartz and limonite (68110302) is exposed in the most westerly area.

Structure

The Cavenagh metamorphics almost everywhere exhibit a strong north-plunging lineation (Photo D29), and generally a northerly-dipping schistosity or gneissic foliation as well (Photo D32); the only massive rocks are a few exposures of amphibolite. Quartzite pods are tightly folded around axes parallel to the general lineation. The quartz-rich metasediment of Mount Gordon exhibits reclined folds (Photo D30, D31) and superposed folds.

On the macroscopic scale, the Cavenagh metamorphics are part of the White Range Nappe of the Arltunga Nappe Complex. The two subunits are separated by a major fault striking southeast from the northwest corner of the Cavenagh Range, and this, together with the markedly different lithological assemblages in the subunits, suggests that they may be parts of two separate thrust sheets in the White Range Nappe.

Metamorphism

Most of the rocks in the Cavenagh Metamorphics show effects of retrogressive metamorphism to greenschist facies, but residual assemblages of the older facies are still preserved. The only truly pelitic rock contains andalusite + muscovite + quartz; impure quartzites

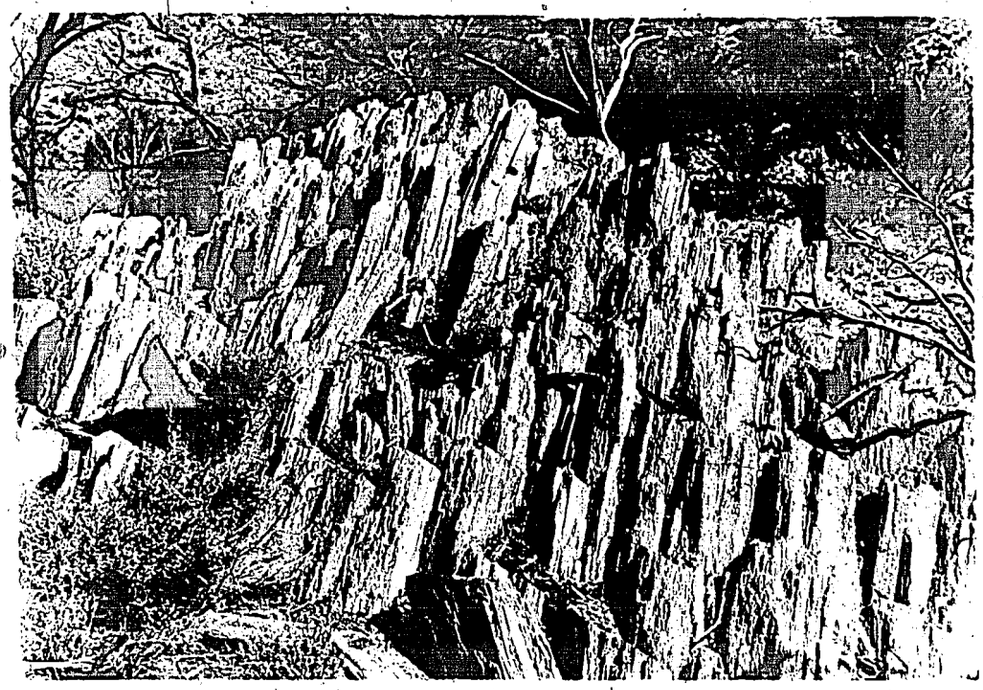


Photo D29: Strong lineation in quartz-rich metasediment of Cavenagh metamorphics, Mount Gordon ridge. 2 km east-northeast of Arltunga, GR 5851-703083. (AJS-IV, 1968, p.12, loc 516).

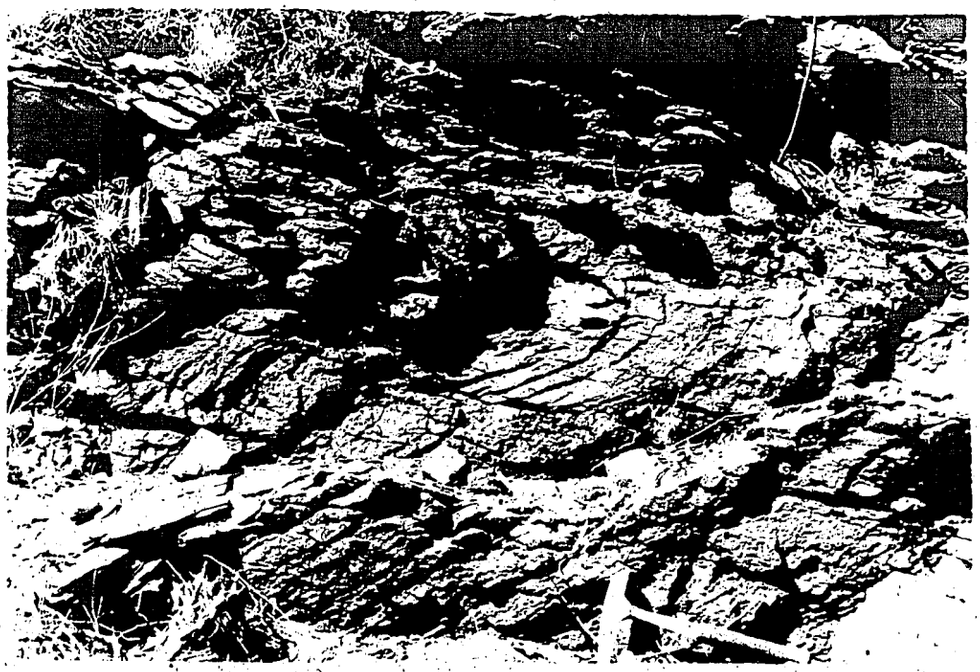


Photo D30: Reclined fold with axial-plane foliation and cleavage mullions in quartz-rich metasediment of Cavenagh metamorphics, Mount Gordon ridge, 1.5 km southeast of Mount Gordon, GR 5851-705089. (AJS-IV, 1968, p. 11, loc 512).

Photo D31: Reclined folds in quartz-rich metasediment of Cavenagh metamorphics, Mount Gordon ridge, 1.7 km east of Mount Gordon, GR 5851-708098. Scale is 15 cm long.

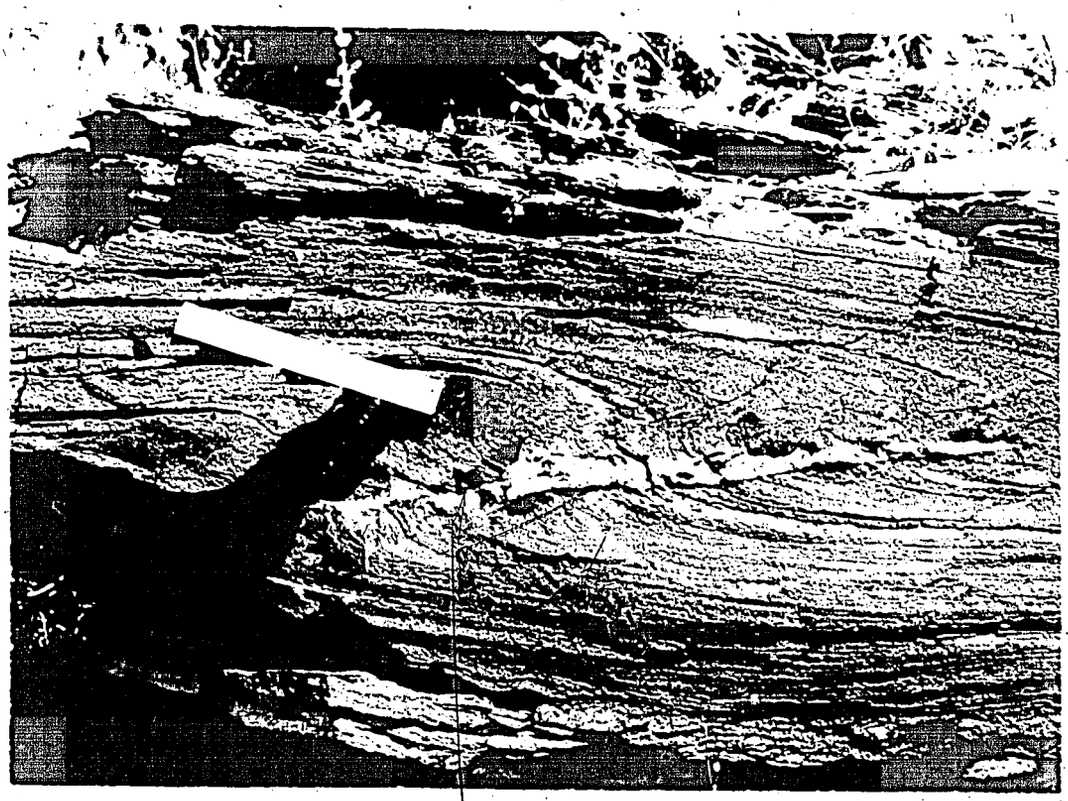


Photo D32: Folded schistosity in quartzofeldspathic schist of Cavenagh metamorphics, showing quartz vein along axial plane of reclined fold; 750 m west of the Crossroads, RIDDOCH, GR 5851-702071.

in the same area contain quartz + muscovite or quartz + feldspar. Associated para-amphibolite is characterised by hornblende or actinolite + plagioclase + epidote + quartz, and intrusive orthoamphibolite in the same area is characterised by hornblende and plagioclase. Between the Cavenagh and White Ranges, chlorite schist 300 m south of the old Police Station contains garnet remnants; feldspathic schist and gneiss and quartz-rich metasediment are characterised by microcline + plagioclase + muscovite + biotite + quartz; quartzite pods contain garnet; amphibolite consists of hornblende + andesine; and marble near the old Mission consists of calcite + muscovite + quartz. All these assemblages belong to the middle amphibolite facies of regional metamorphism. The retrogressive metamorphism is evidenced by chlorite and sericite in quartzofeldspathic gneiss, feldspathic schist, and chlorite schist in the east of Paddys Plain; calcite after plagioclase, sphene after ilmenite, and chlorite after garnet in schists between Arltunga and White Range; and sericite, epidote, clinozoisite, and calcite after plagioclase in various amphibolite bodies.

Origin

The Cavenagh metamorphics are a metamorphosed assemblage of various sedimentary and igneous rocks. Possible parent rocks may have been as follows:

Metamorphic rock	Possible parent
Quartz-rich metasediment	Psammopelite or arkosic sandstone
Para-amphibolite	Calcareous marl
Quartzite	Sandstone
Marble	Limestone and dolomite
Biotite gneiss	Pelite
Andalusite schist	Pelite
Feldspathic schist with intercalated quartzite and marble	Acid volcanics with interbedded sandstone and limestone
Quartzofeldspathic gneiss (non-layered)	Acid igneous rock (volcanic or plutonic)
Granitic gneiss	Acid igneous rock
Amphibolite	Basic igneous rock
Chlorite schist	?Retrogressively metamorphosed basic igneous rock

Age and Correlation

Isotopic dates on various rock types in the Cavenagh metamorphics are set out in Table D-9-1A. The Rb-Sr whole-rock date on sample 68110200 of amphibolite is regarded as dating the time of regional metamorphism (Armstrong & Stewart, 1975). The hornblende from the same rock, the muscovite of 68110318, and the biotite of 68110336 clearly contain various amounts of extraneous argon. Biotite of 68110318 and the khaki-brown muscovite of 68110336 have crystallised (or recrystallised) during the Alice Springs Orogeny.

The Cavenagh metamorphics are correlated on lithological grounds with the Tommys Gap metamorphics of the Giles Creek Synform, 15 km to the south; specifically, both formations contain adjoining units of amphibolite and quartz-rich metasediments, and the chief component (after quartz) in the latter is abundant microcline. However, there are also lithological differences between the two formations; quartzofeldspathic gneiss, feldspathic schist, and para-amphibolite are not known in the Tommys Gap metamorphics, and hornblende gneiss and basic volcanics are not known in the Cavenagh metamorphics.

The Cavenagh metamorphics may be speculatively correlated with the Mount Laughlen metamorphics in LAUGHLEN, which consist of muscovite-biotite schist, quartzite, quartzofeldspathic gneiss, and amphibolite, and with the Iwupataka Metamorphic Complex in ALICE SPRINGS, which consists of quartzofeldspathic gneiss, quartzite, quartz-rich metasediment, staurolite-garnet schist, and conglomerate. If this correlation can be confirmed, it would indicate that the Cavenagh metamorphics (and the Tommys Gap metamorphics) belong to Division 3 of the threefold subdivision of the Arunta Block (Stewart & Warren, 1977).

TABLE D-9-1A: Isotopic Dates from Cavenagh metamorphics

Sample No.	Lithology	Material Dated	Date (m.y.)	Reference
Potassium-Argon Dates				
68110200	Amphibolite	Hornblende	2132	A
68110318	Quartzite	Muscovite	1077	A
68110318	Quartzite	Biotite	370	A
68110336	Quartzite	Muscovite (brown)	399	A
68110336	Quartzite	Biotite	1775	A
Rubidium-Strontium Date				
68110200	Amphibolite	Whole rock	1719	B

A = Stewart (1971b)

B = Armstrong & Stewart (1975)

D-9-2: Tommys Gap metamorphics (pCt) (A.J.S.)

Definition

The Tommys Gap metamorphics are defined as the interlayered assemblage of hornblende gneiss, orthoamphibolite, quartz-rich metasediment, basic metavolcanics, quartzite, marble, and chlorite schist that crops out in the west, central, and eastern parts of the Giles Creek Synform; the three areas of outcrop are separated by two large areas of intrusive diorite of the Atnarpa Igneous Complex. The metamorphics form a closely dissected landscape of low scrubby hills, with a few higher hills of resistant orthoamphibolite, quartzite, and marble. The name is derived from Tommys Gap (GR 5850-623885), situated at the western end of the Giles Creek Synform, 15 km east of Ross River Tourist Chalet. The type area extends from Tommys Gap north for about 1.5 km to GR 5850-623903; in this area, the basic metavolcanic, marble, and chlorite schist units are well exposed, but their structural relationships are complex and not understood. The reference area for the orthoamphibolite is located at GR 5850-703924, 0.8 km south-southeast of Marmalade Dam, and for the hornblende gneiss at GR 5850-802931, 3.5 km east-southeast of Chabbana Waterholes. All the rock-types of the Tommys Gap metamorphics are readily distinguished from the surrounding rocks on lithological and compositional grounds, except for the hornblende gneiss, which is similar in composition to the neighbouring diorite of the Atnarpa Igneous Complex. However, the hornblende gneiss is compositionally layered, whereas the diorite, although displaying a preferred dimensional orientation of hornblende grains, is not layered.

Relationships

No rocks older than the Tommys Gap metamorphics have been recognised. The metamorphics are intruded by granite and hypabyssal members of the Atnarpa Igneous Complex, and adjoin diorite and tonalite of the Complex. The metamorphics are also intruded by plugs and dykes of altered ultramafic rock, by an amphibolite dyke, and by a plug of dolerite of the Stuart Dyke Swarm. The metamorphics are unconformably overlain by the Heavitree Quartzite of the Amadeus Basin sequence along the southern side of the Giles Creek Synform, and are faulted against the Bitter Springs

Formation along the northern side of the Synform. At the western end of the Synform, the rocks are inverted, and the Heavitree Quartzite dips east beneath the Tommys Gap metamorphics at about 10°.

Lithology

The Tommys Gap metamorphics are mapped as seven separate rock-types, which are, in decreasing order of areal extent: hornblende gneiss, orthoamphibolite, quartz-rich metasediment with interlayers of quartzo-feldspathic gneiss and amphibolite, basic metavolcanics (with subordinate amounts of amphibolite, ?tuffaceous metasilstone, quartzite, and calc-silicate rock), quartzite, marble, and chlorite schist.

Hornblende gneiss crops out over a large area in the centre of the Giles Creek Synform and in a small area in the southwest of the Synform, which also includes a small amount of biotite gneiss. The typical hornblende gneiss is medium to fine-grained and layered, but the unit as a whole is notably heterogeneous; grain-size, proportions of light and dark minerals, and degree of preferred orientation vary markedly. In some places the rock is coarse-grained, at others nearly massive; elsewhere again, it is lineated only. The rock consists of twinned but unzoned sodic andesine (45%) which is strained and extensively sericitised, xenoblastic hornblende (35%) pleochroic from blue-green to dark yellow-green to pale greenish-yellow, strained quartz (20%), and accessory apatite and opaque material (71911865). Secondary epidote and clino-zoisite are present in plagioclase, epidote surrounds the opaque mineral, and tremolite forms small masses at the margins of hornblende grains.

Tightly folded biotite gneiss is exposed at GR 5850-706878 (68110050, 71911864). The gneiss is a few metres thick, and bordered to the north and south by typical hornblende gneiss.

Orthoamphibolite of the Tommys Gap metamorphics is widespread throughout the Giles Creek Synform. It consists mostly of amphibolite, but small quantities of quartzite are present in the westernmost outcrop, and veins of epidote-calcite rock, quartz-feldspar pegmatite, and aplite

are present in places. The orthoamphibolite conformably adjoins the quartzite and quartz-rich metasediment of the Tommys Gap metamorphics, and crops out within the hornblende gneiss unit; orthoamphibolite is intruded by tonalite of the Atnarpa Igneous Complex in the Marmalade Dam area, and forms a swarm of angular rafts in Atnarpa Complex diorite in the centre of the Giles Creek Synform.

Amphibolite is medium-grained, weakly schistose and/or lineated, but not layered. It consists essentially of subhedral labradorite (37 to 60%) as large equant grains or smaller decussate laths, common hornblende (25 to 55%) pleochroic from bluish-green to deep yellowish-green to pale yellowish-brown, clinopyroxene (2 to 15%) substantially altered to hornblende (71911835, -1849); euhedral epidote (5%) and sphene (1%) encrusting opaque grains are present in specimen -1849, and sericite is abundant after labradorite in specimen -1835. A third specimen (-1808) comes from a small body of amphibolite enclosed by the hornblende gneiss unit of the Tommys Gap metamorphics, and in addition to hornblende and sericitised plagioclase it contains small amounts of quartz, cloudy red microcline, and abundant apatite; pyroxene is absent.

Quartzite in the westernmost outcrop area of orthoamphibolite is white, fine-grained, moderately schistose and strongly lineated (71911867). Muscovite is accessory.

Veins of epidote-calcite rock about 5 cm thick cut the amphibolite in several places; the calcite is concentrated in the centre of the veins.

Quartz-rich metasediment of the Tommys Gap metamorphics crop out over two areas in the western part of the Giles Creek Synform, and includes smaller amounts of quartzofeldspathic gneiss, hornblende gneiss, and amphibolite. Quartz-rich metasediment forms about 75 percent of the unit, and is typically medium-grained and weakly foliated. The rock forms layers 1 to 2 m thick, separated by thinner layers of hornblende gneiss. The quartz-rich metasediment (71911839, -1855) consists of quartz (80 to 85%) as approximately equant grains with curved, embayed, or lobate boundaries,

round grains of microcline (5 to 15%) which are strained, kinked, broken, and extensively sericitised, green chlorite (3%) as small oriented bent flakes, and epidote (2 to 4%). Sample -1839 also contains 2 percent actinolite altered to chlorite and epidote.

None of the other rock-types in the unit has been thin-sectioned. The quartz-feldspar gneiss is medium to coarse-grained and approximately granitic in composition; in the southern part of the larger (eastern) outcrop area it is fine-grained and contains abundant epidote. The hornblende gneiss resembles that in the centre of the Giles Creek Synform.

Basic metavolcanics occupy one area in the extreme west of the Giles Creek Synform, and another along the eastern margin of the northwest lobe of the Synform. The unit comprises amphibolite, ?tuffaceous metasiltstone, quartzite, calc-silicate rock, and chlorite schist.

Amphibolite is themost abundant rock type, and is fine-grained, massive to weakly schistose, and closely jointed. In a few places, it is coarse-grained, with augen and streaks of feldspar. The typical rock (68110103B) consists of strongly aligned prisms of hornblende (40%) pleochroic from blue-green to yellowish-green to pale yellow, oligoclase (40%), quartz (10%), ilmenite (10%), sphene (1%), and accessory apatite. Masses of fine-grained nearly monomineralic actinolite rock (71911873) occur in places; the rock consists of porphyroblasts of actinolite zoned to colourless rims of fine tremolite, and accessory sphene. Sample 71911841 from the eastern outcrop area adjacent to the fault striking southwest from Giles Waterhole has been retrogressively metamorphosed to epidote, chlorite, sphene, and leucoxene; the plagioclase remains as andesine.

?Tuffaceous metasiltstone is known only in the area north of Tommys Gap, and consists of small silt-sized polygonal grains of recrystallised quartz cemented by pale green serpentine; serpentine also forms separate lumps accompanied by hematite, colourless chlorite, and bleached biotite (68180013, -0014). Small flakes of partly bleached

biotite, and detrital grains of rutile and opaque material accompany the fine quartz. A few large grains of oligoclase veined by serpentine are present in sample -0014. These rocks may have been tuffaceous siltstone which were later retrogressively metamorphosed. Malachite is commonly present in these rocks, and has been documented by Shaw (1967) and Warren & others (1974).

Ferruginous quartzite forms small pods in the metavolcanics, and may be the remnants of complexly folded beds (Shaw, 1967). The quartzite is commonly feldspathic, and in the northern part of the area, between the two bodies of marble shown on the map, a similar quartzite is calcareous as well, consisting of (in order of increasing abundance) hematite-sphene-calcite-actinolite-microcline-quartz (68110103A). The quartzites also contain small quantities of malachite, pyrite, and arsenopyrite (Shaw, 1967).

Massive calc-silicate rock crops out abundantly in the eastern part of the meta-volcanic unit and also occurs with pods of ferruginous quartzite in the western part of the area. Assemblages include (in order of increasing abundance): hematite-calcite-quartz-epidote (68110101A), and epidote-sphene-microcline-plagioclase-quartz-actinolite (71911875).

Chloritic schist occurs at the contact of the basic metavolcanic unit and adjoining units. There are three varieties: the first, in which talc is the most abundant component, is pale grey or mottled green and grey, very soft, and composed of opaque material-chlorite-talc (68110100F) or opaque material-tremolite-chlorite-talc (71911874). The second variety, with tremolite most abundant, consists of opaque material-talc-chlorite-tremolite (71911880). The third variety, with chlorite dominant, consists of quartz-hematite-actinolite-chlorite (71911877). The mineralogical composition of the chloritic schists suggests that they have formed by retrogressive metamorphism of ultrabasic igneous rocks. On the other hand, their juxtaposition with marble, amphibolite, coppery metapelite, and ferruginous metaquartzite is reminiscent of the Oonagalabi association of

magnesian metasediments (Stewart & Warren, 1977). Hence, five samples from three hand specimens were semi-quantitatively analysed for cobalt, nickel, copper, and chromium by emission spectroscopy, and sample 71911874 was re-analysed by X-ray fluorescence; the results are set out in Table D-9-2A.

Table D-9-2A: Results (in ppm except where otherwise stated) of semi-quantitative analyses of chloritic schists from Basic Metavolcanic unit of Tommys Gap metamorphics. Co, Ni, Cu, and Cr (1) analysed by emission spectroscopy (error = ± 50%); Cr(2) by X-ray fluorescence (error = ± 20%).

Sample No.	Co	Ni	Cu	Cr(1)	Cr(2)
71911874A	30	300	25	1.5%	0.6%
71911874B	60	300	25	1.5%	0.5%
71911877A	30	100	10	100	n.d.
71911877B	10	100	10	100	n.d.
71911880	60	200	10	0.2%	n.d.

Analyst: S. Smith (BMR), September 1975.
n.d. = not determined

The results indicate that the chloritic schists are of igneous origin, and hence were presumably some sort of ultrabasic rock related to the metavolcanics. The high content of chromium in specimens 1874 and 1880 is noteworthy, and suggests that the opaque mineral in these rocks is chromite.

Quartzite of the Tommys Gap metamorphics forms six isolated outcrops in the southwestern lobe of the Giles Creek Synform. The rock forms red-brown resistant ridges of moderate relief, and was originally depicted as Heavitree Quartzite on the First Edition of the Alice Springs 1:250 000 Geological Sheet (BMR, 1968). The quartzite is pale brown to pinkish-orange, coarse-grained, strongly foliated, and weakly lineated.

It consists of quartz (60%) as large flattened and broken grains partly recrystallised to aggregates of small polygonal grains, microcline (25%), as broken, strained, and kinked fragments, bent flakes of muscovite (10%), and rare plagioclase; hematite and zircon are accessory (71911869). The brecciation of the quartzite is concentrated in a set of kink folds which fold the foliation and lineation of the quartzite.

Marble and calc-silicate marble of the Tommys Gap metamorphics crop out 1 km north of Tommys Gap, and form two separate bodies adjacent to or surrounded by basic metavolcanics. The marble is grey to grey-brown, massive, medium-grained, and consists of coarser laminae of recrystallised calcite with curved to slightly embayed grain boundaries, and finer-grained laminae of calcite with embayed to lobate boundaries, accompanied by bent flakes of muscovite, and hematite (68110025). Rare pelitic laminae consist of abundant muscovite, hematite, limonite, and very fine calcite. In places the marble contains lumps of chert and hematitic quartz.

Calc-silicate marble is present at GR 5850-632899 and is variegated red, green, and yellow, massive, and medium-grained. It consists of (in increasing order of abundance) plagioclase-hibschite-actinolite-hematite-epidote-calcite (71911876). Hibschite, the orange-red hydrogrossular garnet, also forms large monomineralic masses (whence it was identified by X-ray diffraction; 71911882) near the centre of the eastern marble body at the contact with an apophysis of the metavolcanic unit. The massive hibschite is cut by veins of very coarse calcite and hematite; individual calcite rhombohedra measure up to 11 cm across.

Chlorite schist forms a separate lenticular map-unit inside the western body of marble north of Tommys Gap. The rock is dark green and soft, and consists of quartz-hematite-chlorite (68110102).

Metamorphism

The mineral assemblages in the calc-silicate rocks of the metavolcanic unit at the western end of the Giles Creek Synform belong to the highest grade of the greenschist facies of the moderate-pressure facies series of regional metamorphism. Key assemblages include: calcite-epidote-quartz, calcite-actinolite-microcline-quartz, and epidote-microcline-plagioclase-quartz-actinolite; the assemblage plagioclase-hibschite (hydrogrossular)-actinolite-epidote-calcite is transitional into the lowest part of the amphibolite facies (Winkler, 1967). The assemblage oligoclase-hornblende in the basic metavolcanics themselves belongs to the lowest part of the amphibolite facies. In the hornblende gneiss unit in the centre of the Synform, the characteristic assemblage is andesine-hornblende. Thus, there is a rise in grade from moderate-pressure high greenschist facies transitional to low amphibolite facies in the west, to moderate-pressure middle amphibolite facies in the east. The labradorite and clinopyroxene in the orthoamphibolite bodies between the areas of basic metavolcanics and hornblende gneiss are regarded as igneous relics, and do not signify a local maximum in metamorphic grade between the oligoclase-hornblende assemblage in the west and the andesine-hornblende assemblage in the east.

Superimposed on the amphibolite-facies assemblages is a later partial retrogressive metamorphism of the low greenschist facies, indicated by the abundance of epidote (or clinozoisite) and sericite after plagioclase, tremolite at the margins of hornblende grains, epidote rims around opaque grains, sericisation or reddening of microcline, and abundant chlorite after biotite and actinolite. The retrogression, as elsewhere in the Arltunga Nappe Complex, is presumably of Carboniferous age.

Origin

Before regional metamorphism, the Tommys Gap metamorphics were essentially an interlayered assemblage of basic and intermediate volcanic rocks, ?tuffaceous silt, impure quartz sandstone containing considerable detrital feldspar, mud, and carbonate, and small amounts of limestone with

a few pelite laminae. The assemblage suggests a geosynclinal setting at the margin of an ocean basin, with basic lavas and shallow-marine sands and carbonates in the west, and intermediate to basic volcanics without associated sediments in deeper water to the east.

Age and Correlation

One sample of biotite gneiss from the hornblende gneiss unit of the Tommys Gap metamorphics (68110050 = GA 5750; 71911864) lies slightly above the isochron from which the date of 1710 ± 50 m.y. on the Arnarpa Igneous Complex published by Cooper & others (1971) was calculated (Fig. D-10-7Q). Using the initial ratio of the isochron, the biotite gneiss gives a date of about 1900 m.y.

The Tommys Gap metamorphics are correlated on lithological grounds with the Cavenagh metamorphics, 20 km to the north; the correlation is based on the similarity of the quartzite and quartz-rich metasediment units and associated amphibolites of both units.

D-10: Mid-Proterozoic Granite and Granitic Gneiss (?1.8-1.6 b.y.)

A number of foliated granites are correlated on lithological grounds with the Jennings Granitic Gneiss and are thought to have been emplaced during the Chewings Metamorphic Event (see METAMORPHISM).

D-10-1: Trephina granitic gneiss, Bgr (R.D.S.)

Definition

A biotite granitic gneiss containing sparsely disseminated K-feldspar megacrysts occupies an extensive, flat, relatively low-lying region of about 50 sq.km in the central headwaters of Trephina Creek (centred on Lat. 23°29'S, Long. 134°21'E), after which the gneiss is named. The gneiss is characterised by its uniform composition, and the presence of potassium feldspar megacrysts. Typical exposures of the unit can be examined in the area 5 to 7 km north of Whistleduck Bore (i.e. 5751-264122 to 255111).

Relationships

The Trephina granitic gneiss is considered to intrude unassigned gneisses (pG) of the northern Wigley Block. It encloses are large raft of Randall Peak metamorphics about 4 km long. Its gneissosity may be syntectonic, but is more likely to be post-tectonic as it appears to parallel that in the adjacent gneisses. The granitic gneiss is intruded by the Whistleduck Dyke Swarm, and may have been intruded by gabbroic bodies now represented by the numerous amphibolite bodies within the granitic gneiss.

Lithology

The K-feldspar megacryst content of the granitic gneiss varies from 2 to 5 percent. These porphyroblasts range up to 2 cm in length, and are set in a medium to coarse-grained, well-foliated matrix. In some places, such as along the track between Whistleduck Bore and Porters' Well, the granitic gneiss is very schistose and the biotite content reaches almost 60 percent. This schistose gneiss resembles the Cement Dam gneiss.

The granitic gneiss contains numerous bodies of amphibolite which may be up to 800 m long and up to an equal length across. One such amphibolite that was sampled (3527) is schistose, and consists of about 50 percent green hornblende and only about 10 percent plagioclase, in addition to 5 percent quartz, and lesser amounts of biotite and opaque grains. Some of this amphibolite contains garnet, and in other varieties the plagioclase is retrogressed to sericite and epidote.

Correlation and Age

The Trephina gneissic granite is grouped with the Cement Dam gneiss and the Jennings Granitic Gneiss because variants of the Trephina granitic gneiss resemble both these gneissic rocks very closely.

No age determinations have been carried out.

Origin

Unlike the Cement Dam gneiss, the Trephina granitic gneiss is more clearly a metamorphosed and deformed granite, as evidenced by its uniform composition and granitic mineralogy.

D-10-2: Oolbra orthogneiss, Bgo (A.P.L.)

Definition

Oolbra orthogneiss is a remarkably homogeneous unit on the masoscopic scale consisting of porphyroblastic schistose orthogneiss, which crops out as low hills, over an area of 40 km^2, in the central eastern margin of BURT. The name is derived from the Oolbra Dam, 5 km southwest of the unit. The unit is distinguished from the amphibolite, garnet-gneiss, and quartzofeldspathic gneiss of the Sliding Rock metamorphics, which it intrudes, by the abundance of large porphyroblasts of orthoclase. This feature, and a difference in metamorphic facies, distinguishes the unit from the retrogressed granulites of the Narbib granulite. The type area is 7 km northeast of Oolbra Dam, centred on 5651-885226.

Relationships

The orthogneiss intrudes the Sliding Rock metamorphics. It encloses fragments of, and is surrounded by, these metamorphics and the contact between the two units is extremely irregular. The orthogneiss also intrudes Narbib granulite to the southwest of the type area.

To the west the orthogneiss and rocks of the Sliding Rock metamorphics are covered by Cainozoic sediments. The abrupt termination of trends in the Sliding Rock metamorphics, however, indicates that the western boundary may be faulted against the Enbra Granulite.

Lithology

In the type area porphyroblastic schistose orthogneiss (4480) consists of large prophyroblasts of orthoclase (up to 75 mm across) (50%) (Photo. D33) in a matrix of quartz (20%), biotite (10%), plagioclase (5%), garnet (5%), orthoclase (5%), hornblende (3%), and opaque minerals (2%). The porphyroblasts are rounded and heavily fractured. Away from the type area the orthogneiss is similar to 4480. Some sample (4479, 4476) contain zones of microbreccia and others (4474, 4528, 4124) contain long ribbons of quartz. These rocks show evidence of widespread, intense deformation of the unit.

Structure

The orthogneiss has a strong penetrative schistosity defined by mineralogical layering and by preferred orientation of biotite and long ribbons of quartz. This schistosity is rarely folded about open folds that plunge at 60° towards 100° (Photo D33).

Origin

The homogeneous granitic character of the unit suggests that it is an orthogneiss.

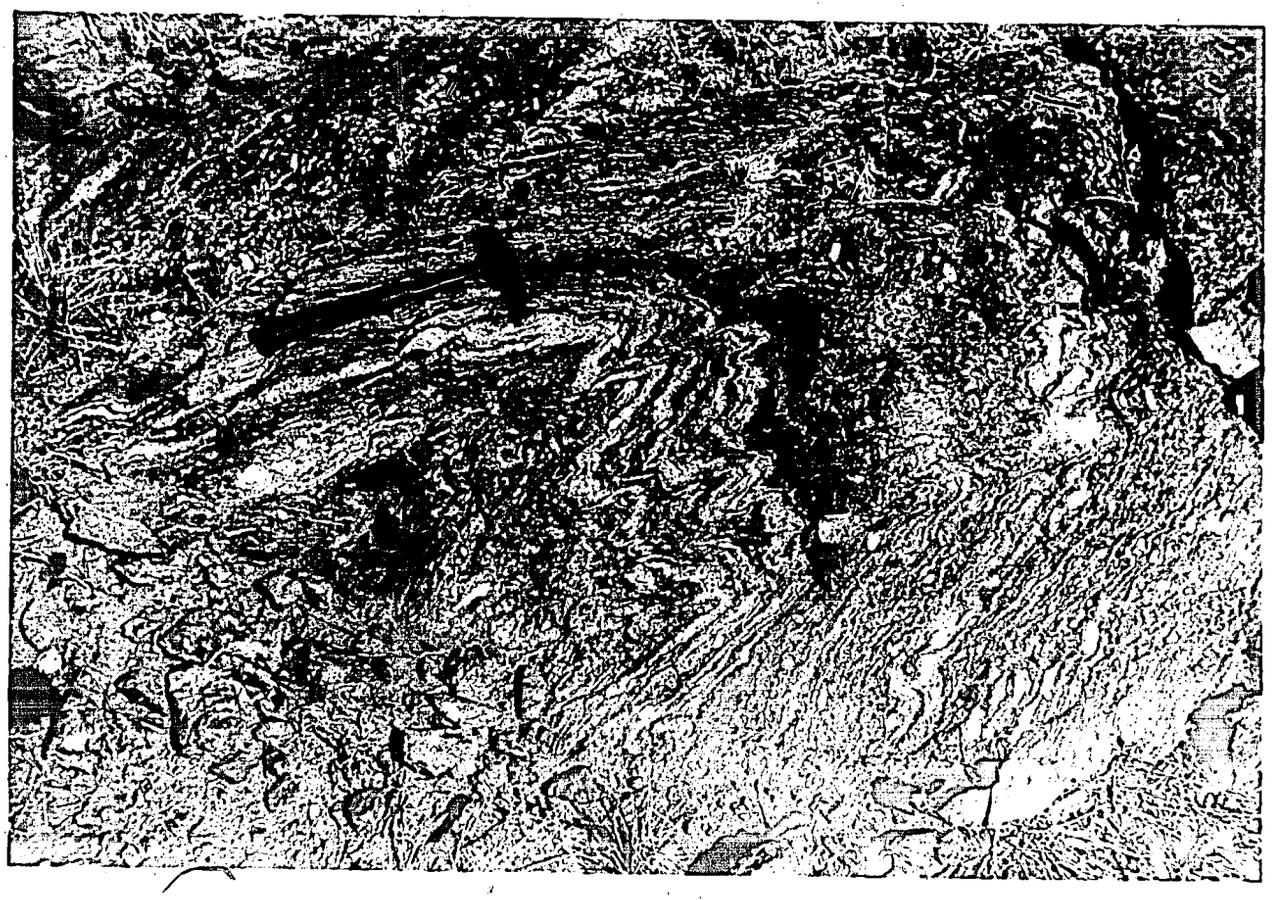


Photo D33: Rare folding of feldspathic and micaceous layers in porphyroblastic gneiss near locality 4140.

Age and Correlation

The age is unknown. The unit is correlated with the Anamarra orthogneiss. The Jennings Granitic Gneiss and the Atnarpa Igneous Complex are also similar and have been dated by Rb/Sr whole rock at 1720 and 1750 m.y. respectively (AJS this report).

D-10-3: Anamarra orthogneiss, Bga (APL)

Definition

The Anamarra orthogneiss consists of homogeneous porphyroblastic schistose orthogneiss that crops out 6 km north of Mount Johnstone, in the central northeastern part of LAUGHLEN. It crops out as a region of low relief consisting of low rounded exposures over an area of 15 km^2. The unit has a discordant lobate boundary, in part faulted on the southern margin. It extends in a narrow zone to the northeast where it is truncated by the Cadney Fault. The name is derived from the Anamarra Creek which has its headwaters in the type area of the unit. The type section is well exposed in Anamarra Creek from 5751-349432 to 5751-345424. This section consists of biotite-rich porphyroblastic orthogneiss. The unit is distinguished from the surrounding unit pGu by the abundance of large porphyroblasts of orthoclase and by the abundance of biotite.

Relationship

The orthogneiss intrudes unit pGu.

Lithology

In the type section the orthogneiss (3262) contains porphyroblasts of orthoclase (20%), in a matrix of hornblende (8%), quartz (30%), plagioclase (30%), biotite (10%) and sphene (4%). The porphyroblasts are up to 5 cm across and are commonly wrapped by biotite and elongated in the plane of the foliation. Away from the type section (3263, 3270, 3328, 3343, 3464) the orthogneiss is remarkably similar to 3262. It encloses rafts of amphibolite (3333, 3332) and one body of mafic granulite (3466).

Structure

The gneiss is strongly foliated and has a penetrative lineation, which plunges at about 70° to the northeast. The boundary of the unit is discordant to layering in unit pGu. This discordance and the circular outline of the body suggests that it was intrusive into pGu.

Origin

The structure and homogeneous granitic composition of the unit suggest that it is a granitic intrusion which enclosed rafts of pGu.

Age and Correlation

The age is unknown. However, the unit is correlated with the Oolbra Orthogneiss 50 km to the west southwest and both units are probably older than the Wuluma Granitoid (1800 m.y. L.P. Black, BMR personal communication, 1977).

D-10-4: Jennings Granitic Gneiss (Pgn) (A.J.S.)

Definition

The Jennings Granitic Gneiss is the large body of coarse granitic gneiss (gg_1, but incorrectly labelled O on LAUGHLEN Preliminary Edition) containing elongate masses of quartzofeldspathic gneiss and small masses of amphibolite that crops out in Mordor Pound, in the southeast of LAUGHLEN and northeast of UNDOOLYA. Also assigned to the Jennings Granitic Gneiss are a second body of coarse granitic gneiss between Trephina Gorge and Bulltrap Yard in UNDOOLYA, two bodies of finer-grained granitic gneiss (gg_2, but labelled gg on LAUGHLEN Preliminary Edition) in the centre of the coarse granitic gneiss adjacent to the Mordor Complex, and two elongate bodies of porphyroblastic gneiss together with amphibolite and hornblende gneiss west of the large body of coarse granitic gneiss. Other rock-types present in the unit, but too small to show on the maps, are pegmatitic granite, pegmatite, epidosite, and vein quartz. The Gneiss gives rise to gently dissected terrain of low hills and gullies separated by alluvial flats. The name is derived from Jennings Gorges, which cut the prominent ridge of Heavitree Quartzite on the eastern side of Mordor Pound; the

Gorges themselves are named in memory of Mr Peter Jennings, field assistant with the BMR party in 1972, who was killed the following year in a climbing accident in the Colombian Andes. The Jennings Granitic Gneiss is easily distinguished by its granitic composition from the mafic and intermediate rocks of the Mordor Complex. Similarly, its lack of hornblende differentiates it from the large lens (pGv) of hornblende gneiss and quartzofeldspathic gneiss striking southwest from the Georgina Range, and from the amphibolite-bearing Randall Peak metamorphics (pGr) surrounding the two bodies of porphyroblastic gneiss and the coarse granitic gneiss west of Trephina Gorge.

Relationships

The western margin of the coarse granitic gneiss in LAUGHLEN appears on the map to be grossly discordant to the Randall Peak metamorphics, and to the small body of biotite gneiss (pG) 4 km east of Wallace Rock Yard. Further, the biotite gneiss is apparently intruded by a small plug-like mass of coarse granitic gneiss at GR 5751-370016. Relationships with the teardrop-shaped body of Randall Peak metamorphics in the south-eastern corner of Mordor Pound, and with the lens (pGv) of hornblende gneiss and quartzofeldspathic gneiss southwest of the Georgina Range appear to be concordant. The western margin of the westernmost body of porphyroblastic gneiss likewise appears to be concordant with quartzofeldspathic gneiss of the Randall Peak metamorphics, and the two bodies of porphyroblastic gneiss are separated by a thin layer of hornblende gneiss (pGv), also suggesting concordance. Hence, the Jennings Granitic Gneiss is discordant with and apparently intrusive into the surrounding country rocks in some places, and is concordant with them in other places.

With regard to younger rocks, the Gneiss is intruded by syenite of the Mordor Igneous Complex, which has injected numerous apophyses into, and contains elongate rafts of, the finer-grained granitic gneiss of the Jennings Granitic Gneiss. Shonkinite, monzonite, and diorite of the Mordor Igneous Complex are in contact with, and presumably intrude, the Gneiss. The eastern part of the Gneiss is cut by two pegmatite veins which also cut the Mordor Complex and are hence younger than 1200 m.y. (Langworthy

& Black, 1978). A small lens of metamorphosed ultramafic rock (Epy) at GR 5751-375033 is concordant with the Gneiss, but presumed to intrude it. The Gneiss is unconformably overlain by the Upper Proterozoic Heavitree Quartzite.

Lithology

Coarse granitic gneiss of the Jennings Granitic Gneiss is generally medium to coarse-grained, markedly contorted, and heterogeneous. The type area extends along the unnamed creek from 5750-394006 in UNDOOLYA to 5751-400012 in LAUGHLEN, and at the western end shows excellent exposures of multiply folded migmatitic layered gneiss (Photo D34), grading eastward through agmatitic and augen gneiss (Photo D36) to non-layered weakly foliated porphyritic orthogneiss (or gneissic granite) containing enclaves of amphibolite (Photo D37) at the eastern end. The typical coarse granitic gneiss (68110096, GR 5751-397012; 72913612, GR 5751-449040) consists of quartz (10 and 20% respectively), microcline (62%, 55%), sericitised plagioclase (22%, 10%), chloritised biotite (both 3%), hornblende (2%, 7%), garnet (0%, 5%), and accessory sphene, epidote, and allanite.

Away from the type area, the coarse granitic gneiss is generally similar to that in the type area. However, granodioritic variants occur between the Georgina Range and the lens (pGv) of hornblendic rock at GR 5751-372044 (sample 68110095), and at GR 5751-419016 (sample 72913615) in the main body of coarse granitic gneiss. The two samples consist of quartz (20% and 40%, respectively), andesine (50%, 35%), biotite (15%, 20%), microcline (10%, 5%), hornblende (5%, 0%), and sphene. Folded xenoliths are present in the gneiss in places (Photo D35).

The body of coarse granitic gneiss between Trephina Gorge and Bulltrap Yard in UNDOOLYA has been sampled (70090323) at only one locality (GR 5750-257955), and is of normal granitic composition. Secondary chlorite, epidote, and sericite are prominent.

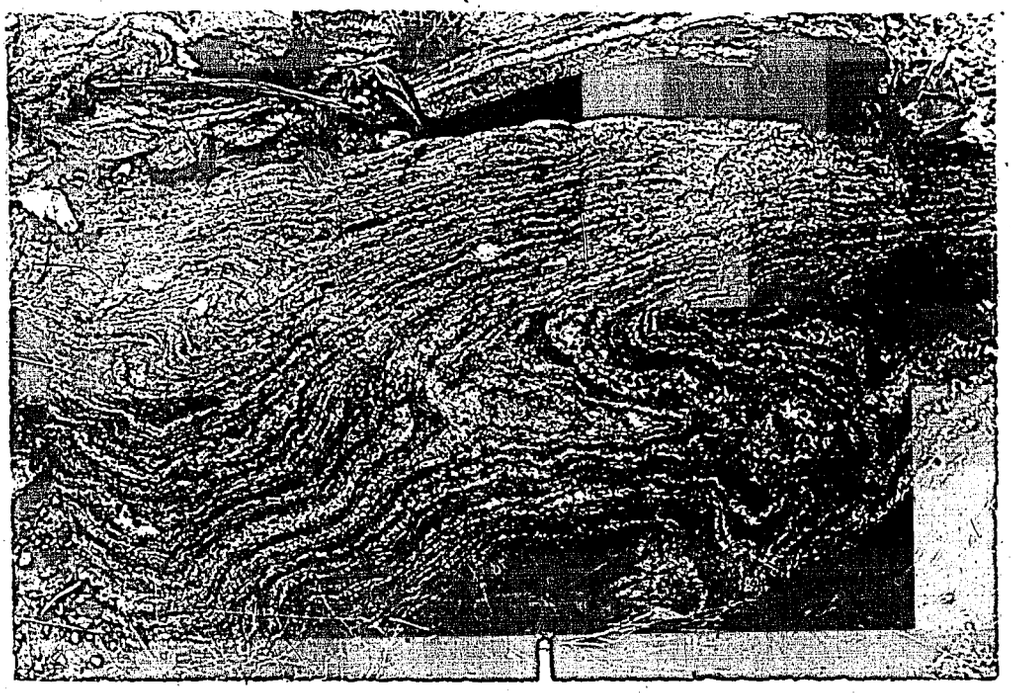


Photo D34: Multiply folded layered migmatitic coarse granitic gneiss of Jennings Granitic Gneiss, 2 km north-northeast of Trephina Gorge, UNDOOLYA, GR 5750-394006.

Photo D35: Folded xenolith in coarse granitic gneiss unit of Jennings Granitic Gneiss, 8 km east of Wallace Rock Yard, LAUGHLEN, GR 5751-411018.

Photo D36: Agmatitic augen gneiss of coarse granitic gneiss unit of Jennings Granitic Gneiss, 2 km north-northeast of Trephina Gorge, UNDOOLYA, GR 5750-394006.

Photo D37: Weakly foliated porphyritic orthogneiss (or gneissic granite) of coarse granitic gneiss unit of Jennings Granitic Gneiss, 6.8 km east of Wallace Rock Yard, LAUGHLEN, GR 5751-399021.

The fine-grained granitic gneiss in the centre of the main body of orthogneiss is leucocratic, and stands up as prominent hills above the neighbouring coarse granitic gneiss. The smaller western body (68110097; GR 5751-396035) of the two is composed of xenoblastic quartz (30%), microcline (60%), sericitised oligoclase (5%), and biotite (5%). The larger body is medium to coarse-grained (74916000 = AS3015, from 5751-442050; 74916001 = AS3016, from 5751-435060). Sample 73914144 from a raft in the syenite at 5751-434068 is a coarse-grained rock containing small lenticular mafic clots (or microxenoliths) composed of biotite, epidote, chlorite, opaque grains, sericitised plagioclase, and fresh allanite; the rock is cut by fractures filled with epidote.

The two bodies of porphyroblastic gneiss west of the main coarse granitic gneiss body are medium-grained and granitic in composition, and in one place (5751-321024) the gneiss is intruded by pink medium-grained leucogranite and porphyritic microgranite.

Amphibolite is particularly abundant in the south of the coarse granitic gneiss mass, and ranges from small inclusions a few centimetres long to mapped bodies 1 km long. The rocks are fine to medium to coarse-grained, lineated concordantly with the surrounding gneiss, but generally not foliated. The rocks are rather heterogeneous and range in composition from quartz diorite (68110092A, GR 5751-379019; plagioclase (40%), hornblende (35%), quartz (20%), biotite + chlorite + muscovite (5%), and accessory ilmenite) to nearly pure amphibole rock (68110092B; hornblende (98%), diopside (1%), plagioclase, quartz, allanite, and monazite).

Hornblende gneiss is associated with the large body of amphibolite in the west of the Jennings Granitic Gneiss, but has not been sampled.

Structure

The rocks of the Jennings Granitic Gneiss exhibit typical metamorphic foliation - both platy mica orientation and lithologic layering - and linear orientation of elongate micas, streaky mica aggregates, and hornblende prisms. The rocks are also prominently folded. The folds are generally isoclinal and of large amplitude, and their axial planes are parallel to the lithologic layering. Folds in non-layered gneiss are of much smaller amplitude, and have been formed by sinusoidal bending of the foliation along discrete zones several centimetres apart, resulting in an appearance similar to strain-slip cleavage. Many areas in the Gneiss show superposed folding (Photo D34); the various fold phases evident have not been analysed. Only a few structural measurements have been made in the Gneiss; 15 linear grain orientations in the southwestern part of Mordor Pound are concentrated around a line plunging 45° northwest (Stewart, 1971a).

Metamorphism

The assemblages garnet-hornblende-biotite-andesine-microcline in the various types of granitic gneiss, and diopside-muscovite-biotite-hornblende-plagioclase in the included amphibolite bodies are indicative of regional metamorphism under conditions of the middle amphibolite facies. In addition, all the rocks examined in thin section contain secondary minerals. Biotite in many samples is substantially altered to chlorite, and plagioclase is sericitised or saussuritised. Veins of epidote, some with aureoles of epidotised gneiss several metres wide, are common. The rocks have therefore been subjected to patchy retrogressive metamorphism under greenschist facies conditions.

Origin

The gradation from multiply folded, layered, partly migmatitic, coarse granitic gneiss through augen gneiss and agmatite to weakly foliated orthogneiss (or gneissic granite) can be interpreted as the result of regional metamorphism, metamorphic differentiation, and deformation of pelitic metasediments and/or metavolcanic rocks, culminating in partial melting. On this hypothesis, one might (but need not necessarily) expect

to find aluminous gneisses containing sillimanite, cordierite, and garnet associated with the granitic gneiss, but such is not the case. Alternatively, the transition could result from metamorphism and deformation of granite to gneiss, either at the same time as, or after, intrusion and crystallisation of the granite. The low initial ratio (0.7051) of $^{87}Sr/^{86}Sr$ given by three samples (68110095, -96, -97) of the coarse granitic gneiss indicates no redistribution of Sr after initial differentiation (or crystallisation) of the rocks (Armstrong & Stewart, 1975), and hence supports the hypothesis of origin by intrusion as a granite during active metamorphism and deformation of the region. An origin as a synorogenic granite is consistent with the partly discordant (and intrusive) and partly concordant relationships with the surrounding country rocks.

Age and Correlation

Samples 68110095, -96 and -97 lie on a Rb-Sr whole-rock isochron which gives a date of 1687 ± 23, λ = 1.42 (1719 ± 24 m.y., λ = 1.39) (Armstrong & Stewart, 1975), and for the reasons outlined in the previous paragraph, this was the time of initial differentiation and crystallisation of the Jennings Granitic Gneiss. Biotite concentrates from 68110095 and -96 have given K-Ar dates of 1097 and 997 m.y. respectively (Stewart, 1971b), and -96 also gave a Rb-Sr whole rock-biotite date of 1121 m.y. (Armstrong & Stewart, op. cit.). The removal of Ar and Sr daughters may have occurred during the Devonian-Carboniferous Alice Springs Orogeny, or it may have occurred during the thermal event at 1053 ± 50 m.y., λ = 1.42 (1076 ± 50 m.y., λ = 1.39) that formed migmatite in the Ormiston area, 100 km west of Alice Springs (Marjoribanks & Black, 1974). This late Proterozoic heating also reset mineral dates at Alice Springs, where muscovite and K-feldspar in the Alice Springs Granite gave a Rb-Sr date of 1130 m.y., and biotite in the same rock a Rb-Sr date some 10 percent less (Compston & Arriens, 1968).

The Jennings Granitic Gneiss is correlated on lithological resemblance and similarity of relationship to surrounding rocks with (1) the Tephina Granite, west of the Georgina Range, (2) the Mulga Creek Gneiss north of the Georgina Range, between Mount Laughlen and Georgina Gap,

(3) the Anamarra Orthogneiss north of Mount Johnstone (in LAUGHLEN), and (4) the Oolbra Orthogneiss (BURT). The Atnarpa Igneous Complex, which straddles the boundary of RIDDOCH and FERGUSSON RANGE, has given Rb-Sr whole rock isochron dates of 1674 ± 50 m.y., λ = 1.42 (1710 ± 50 m.y., λ = 1.39) (R. Bennett, pers. comm. in Cooper et al., 1971) and 1687 ± 23 m.y., λ = 1.42 (1719 ± 24 m.y., λ = 1.39) (Armstrong & Stewart, 1975), and is hence the same age as the Jennings Granitic Gneiss.

D-10-5: Georgina Gap granitic gneiss, Bge (R.D.S.)

Definition

A granitic gneiss, containing large megacrysts of K-feldspar up to 5 cm across, crops out over an area of about 10 sq. km along and east of the track to Whistleduck Bore south of Georgina Gap (GR 5751-410160), after which the unit is named. An apophysis is photointerpreted to extend for 6 km westwards from the southern tip of the main body along the margin of the Wigley Block. The type area is the markedly dissected region immediately south of the Gap at GR 5751-480155. Elsewhere, the granitic gneiss crops out poorly, and generally corresponds to a relatively low-lying area of subdued relief. The granitic gneiss is distinguished by its large K-feldspar megacrysts which are up to 5 cm across.

Relationships

The granitic gneiss appears to have intruded (1) the Hulga Creek granitic gneiss, (2) unassigned biotite gneiss and amphibolite (pG), and (3) the Laughlen metamorphics.

Lithology

The granitic gneiss has a biotite content of up to 20 percent, and is coarse-grained for the most part. The gneissic layering is not as markedly developed as that in other granitic gneisses in the area, and it is likely that it is a synogenic granite.

Structure

Two synclines outlined by authothonous Heavitree Quartzite flank the Georgina granitic gneiss to the west and east. These synclines are considered to be due to deformation of the relatively less competent gneisses surrounding a more competent and rigid body of granitic gneiss, and to have formed during folding of the Heavitree Quartzite in the early stages of the Alice Springs Orogeny.

The gneissosity parallels the margins of the body, which is elongate along the easternmost fault-extension of the Redbank Deformed Zone. This association suggests that it is genetically related to the Redbank Deformed Zone.

Origin

The body is considered to be a synorogenic granite intruded, during a tensional phase, into the eastern extension of the Redbank Deformed Zone. Although a gneissosity is strongly developed, the granitic gneiss is considered to be granite rather than an orthogneiss.

Age and Correlation

The age of the granitic gneiss is unknown. It is akinned to the Gumtree Granite in that (1) it is megacrystic, (2) it is not markedly gneissic, and (3) it has been intruded into a major deformed zone. It may be of a similar age (i.e. 1000 m.y.).

The granitic gneiss was probably intruded after the main period of regional folding and metamorphism of the surrounding crystalline basement because it lacks the folded amphibolite lenses that form part of the adjacent Mulga Creek granitic gneiss as well as the more distant Jennings Granitic Gneiss and Trephina granitic gneiss.

D-10-6: Unassigned granite, pCg (A.J.S.)

Several small bodies of granite crop out in the southwest of RIDDOCH and northwest of FERGUSSON RANGE. Only the largest body, 7 km east-southeast of Hillsoak Bore, and the two bodies between Arltunga and the old Mission have been visited. All three are medium to coarse-grained and leucocratic, and the two smaller bodies near Arltunga are also strongly foliated (schistose). Sample 68110331 from 1 km north of the old Arltunga Mission is a cataclastic rock, and consists of strained and broken fragments of microcline, seriate grains of recrystallized quartz, elongate aggregates of fine pale green muscovite accompanied by smudges of opaque matter (possibly remnants of biotite), and rare fragments of oligoclase. Pegmatites in the granite masses are also schistose. The two smaller bodies are evidently retrogressively metamorphosed, and muscovite in 68110331 gave a K-Ar date of 387 m.y. (Stewart, 1971b), indicating that the retrogression took place during the Alice Springs Orogeny.

D-10-7: Atnarpa Igneous Complex (Bgt) (A.J.S.)

Definition

The Atnarpa Igneous Complex is the group of plutonic igneous rocks comprising (in order of decreasing abundance) tonalite, diorite, granite, granodiorite, hypabyssal aplogranite, and other dyke rocks that crop out in the Giles Creek Synform, White Range Nappe, and Ruby Gap Nappe of the Arltunga Nappe Complex, in FERGUSSON RANGE and RIDDOCH. The Complex extends north from the Giles Creek Synform to Atnarpa homestead (whence the name is derived), along the northeastern side of White Range, then west to the northern side of the Cavenagh Range, in RIDDOCH.

The plutonic rocks give rise to a closely dissected hilly terrain of mild relief; the hypabyssal rocks form low ridges and knobs projecting about 1 m above the surrounding ground. At no one locality are all the members of the Complex exposed together, and so it is necessary to nominate four reference areas. The first is located about 3.5 km southeast of Chabbana Waterholes in FERGUSSON RANGE, and extends eastward from 5850-775905 to 5850-805905. In the eastern part of this area, good exposures of diorite containing rafts of orthoamphibolite of the Tommys Gap metamorphics are cut by the later hypabyssal members of the Complex; in the west the hypabyssal rocks become the dominant rock-type and constitute the aplogranite member of the Complex. The second reference area is at 5850-678921, 2.1 km west of Marmalade Dam, where fresh tors of tonalite contain numerous dark rounded xenoliths (Photo D38). The third reference area is 0.5 km west of Marmalade Dam at 5850-695925, where granite is well exposed on the south bank of the creek. The fourth reference area is in the northeast of FERGUSSON RANGE, at 5850-970005, where the granodiorite forms prominent hills on the east side of the Hale River.

In general, the rock types of the Atnarpa Igneous Complex are readily distinguished by their marked lithological difference from the adjoining gneisses, schists, and amphibolites of the Tommys Gap, Cavenagh, and Hillsoak Bore metamorphics, and the unnamed unit pGx. However the

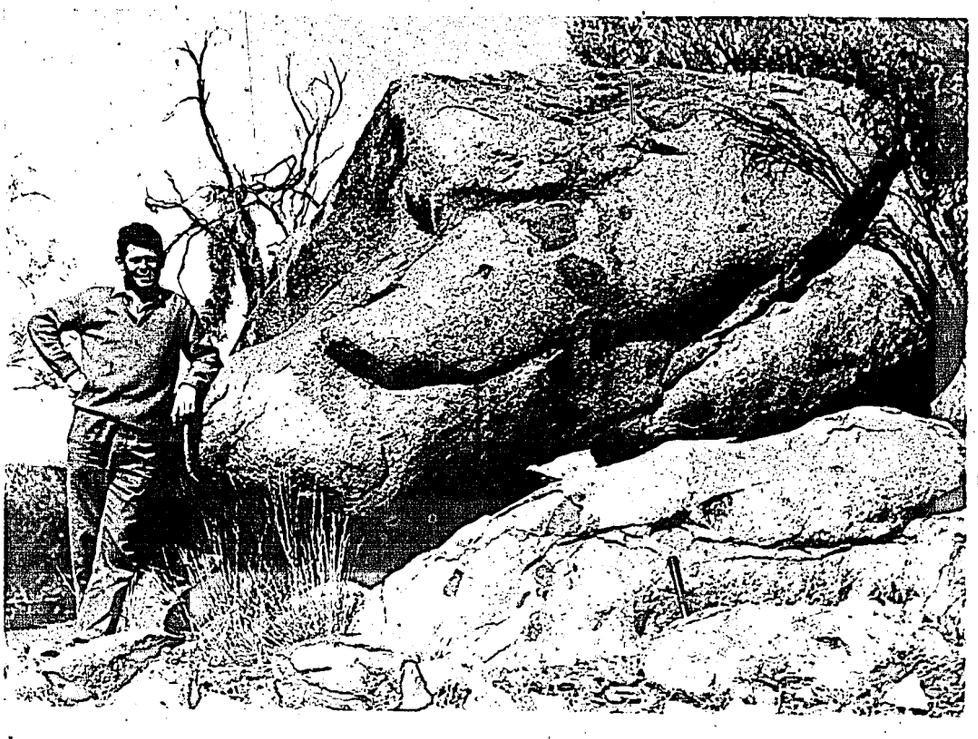


Photo D38: Reference locality (5850-680 23) for tonalite of Atnarpa Igneous Complex, showing tors of tonalite containing dark rounded xenoliths. AJS on left. 2.7 km west-southwest of Marmalade Dam, FERGUSSON RANGE.

Photo D39: Photomicrograph of metamorphosed tonalite of Atnarpa Igneous Complex, showing large grain of albite (centre), coarse white mica, and recrystallised quartz. Sample 68110040, 4 km north-east of Arltunga township, RIDDOCH. Crossed nicols. Length of field 2 mm.

distinction between diorite of the Atnarpa Complex and hornblende gneiss of the Tommys Gap metamorphics depends only on the layering in the gneiss, and the contact of the two rock-types is transitional.

Relationships

In FERGUSSON RANGE, diorite of the Atnarpa Igneous Complex encloses numerous rafts and consequently clearly intrudes orthoamphibolite of the Tommys Gap metamorphics in the central part of the Giles Creek Synform. The diorite also adjoins hornblende gneiss and quartz-rich metasediment of the Tommys Gap metamorphics, but the boundaries are inferred solely from airphoto-interpretation. The diorite surrounds and is presumably intruded by several plug-like masses of ultramafic rock in the eastern part of the Giles Creek Synform. The diorite is also intruded by dykes of amphibolite, norite, and dolerite in the central part of the Synform, and by dykes of microdiorite, microtonalite, microadamellite, microgranite, aplogranite, aplite, pegmatite, vein quartz, and quartz-calcite rock of the Atnarpa Complex itself.

Tonalite of the Atnarpa Igneous Complex adjoins orthoamphibolite, basic metavolcanics, quartzite, and marble of the Tommys Gap metamorphics, and the presence of mafic xenoliths in the tonalite indicates that it intrudes the metamorphics. In RIDDOCH, the tonalite contains a large raft of quartz-rich metasediment (the Mount Gordon ridge) and numerous enclaves of amphibolite of the Cavenagh metamorphics, sends complex apophyses into biotite gneiss of the Hillsoak Bore metamorphics, and has an irregular and apparently intrusive contact with the unnamed unit pGx. In FERGUSSON RANGE, the tonalite is intruded by dykes of microdiorite, microtonalite, aplite, pegmatite, and vein quartz of the Atnarpa Complex, and by amphibolite dykes.

Granite intrudes orthoamphibolite and basic volcanics of the Tommys Gap metamorphics, and contains several enclaves of amphibolite of the Cavenagh metamorphics. In the Ruby Gap Nappe, the westward-directed 'V' shape of the granite suggests intrusion into the adjoining gneisses of the unnamed unit pGx. The granite encloses a raft of diorite of the

Atnarpa Complex in the Ruby Gap Nappe; and in the Giles Creek Synform and west of Mount Gordon the irregular shape of the granite masses and their marked tendency to crop out within the tonalite of the Atnarpa Complex suggests that the granite intrudes the tonalite also. The westernmost body of granite in the Giles Creek Synform is intruded by microgranite, aplite, pegmatite, and amphibolite dykes, and the granite in the Ruby Gap Nappe is intruded by a swarm of pegmatite dykes.

Granodiorite of the Atnarpa Complex adjoins quartzo-feldspathic and biotite gneisses of the unnamed unit pGx in RIDDOCH, and also adjoins the large ultramafic mass in the same area. It is intruded by pegmatite dykes.

Aplogranite intrudes hornblende gneiss, orthoamphibolite, and basic metavolcanics of the Tommys Gap metamorphics, and it also intrudes several amphibolite dykes in the Giles Creek Synform.

The hypabyssal rocks intrude various units of the Tommys Gap metamorphics, the earlier members of the Atnarpa Igneous Complex as noted above, and also amphibolite dykes. Microadamellite, pegmatite, and vein quartz intrude the ultramafic mass at the eastern end of the Giles Creek Synform.

The Atnarpa Igneous Complex as a whole is unconformably overlain by the Upper Proterozoic Heavitree Quartzite along the southern sides of the Giles Creek Synform and Ruby Gap Nappe, and is faulted against Bitter Springs Formation along the northern side of the Synform. Tonalite of the Complex is faulted against Heavitree Quartzite of the Cavenagh and White Ranges.

Lithology

The Atnarpa Igneous Complex is a group of intermediate to acid plutonic and hypabyssal rocks of which hornblende-bearing diorite and tonalite make up about 90 percent; the large volume of diorite is especially notable. In contrast, the other 10 percent consists of leucocratic granitic rocks which lack hornblende, and contain very little biotite.

Diorite of the Atnarpa Igneous Complex crops out in three areas in the Giles Creek Synform, in FERGUSSON RANGE; in a small area between the Giles Creek Synform and the Ruby Gap Nappe; and in three small areas in the Ruby Gap Nappe, extending into RIDDOCH. The diorite is a heterogeneous body, and variation in mineralogical proportions is common, producing meladiorite, tonalite, adamellite, and granite. The unit as depicted on the map also includes numerous later dykes of microdiorite, microtonalite, microadamellite, microgranite, aplogranite, aplite, and vein quartz but they are too small to show except for two areas where they become the dominant rock-type (75%) and are depicted as separate bodies of aplogranite.

The typical diorite is a medium or coarse-grained black and white speckled rock with a preferred dimensional orientation of the dark minerals, thereby imparting a weak schistosity and in places a lineation to the rock. The diorite is not layered, and this is its main distinguishing feature in the field from the neighbouring hornblende gneiss member of the Tommys Gap metamorphics. The diorite is closely jointed, and the joints are commonly coated with epidote or epidosite. Small dark xenoliths have been observed at several localities in the diorite, and the large outcrop of diorite in the centre of the Giles Creek Synform contains numerous rafts up to 1 km long of the orthoamphibolite member of the Tommys Gap metamorphics.

In thin section (71911790) the eastern body of diorite in the Giles Creek Synform around Cleary Creek is found to consist of andesine (58%) which is extensively altered to sericite and epidote, hornblende (15%) pleochroic from blue-green to yellow-green to yellow, biotite (15%) much altered to chlorite, quartz (7%), epidote (5%), and accessory sphene, allanite, and opaque material. The leucocratic variants, especially in the far east of the area, include (1) tonalitic types (71911775, -1780; 68110054) in which the plagioclase is commonly oligoclase, hornblende has decreased to about 5 percent or less, quartz has increased to 30 percent, and a small amount of microcline appears, and (2) granitic and adamellitic types (71911772), in which hornblende is absent and the microcline content has increased still further.

In the central outcrop area of diorite, i.e. in the Giles Creek area, the rock is rather more melanocratic; the content of hornblende is about 25 percent, andesine is very calcic (An_{49}) and borders on labradorite, quartz is reduced to 2 or 3 percent, and biotite and microcline are absent (71911822). This rock also contains tremolite (3%) situated at the margins of hornblende grains, and epidote (4%), making the total ferromagnesian mineral content 32 percent. At many localities the diorite includes melanocratic rock of amphibolitic appearance, e.g. specimen 71911823 contains calcic andesine (An_{49}; 45%), hornblende (35%), clinopyroxene (15%), and quartz (5%), and the entire central part of the outcrop area is better described as a mixture of diorite and amphibolite in which the amphibolite forms numerous masses too small to show individually on the map. Quartz-rich variants are much less common in the central outcrop area, but mylonitic granodiorite is known at specimen locality 71911827.

Four small bodies of diorite have been delineated in the Ruby Gap Nappe, but only two have been sampled. The southern body (69090254, -0255) consists of sericite + clinozoisite (together 80%) pseudomorphous after plagioclase, actinolite (10%), epidote (5%), and recrystallised quartz (5%). The northern body (69090242) is a mafic diorite, and consists of coarse subhedral prisms of hornblende which are strained and broken, plagioclase much altered to sericite + clinozoisite, strained and partly recrystallised quartz, orthoclase, and sphene.

The small western outcrop of diorite, 5 km east of Tommys Gap, has not been visited, and is identified from airphoto-interpretation only.

Four specimens of diorite (69090238, from the small body between the Giles Creek Synform and Ruby Gap Nappe; and 71911722, -1789, -1795 from the eastern part of the Giles Creek Synform) were collected near faults, and show brecciation and complete alteration of the dark minerals to epidote and chlorite. In addition, -0238 has been substantially replaced by hydrothermal quartz and calcite. The faults displace the Heavitree Quartzite, and so probably formed during emplacement of the Arltunga Nappe Complex (of which the Giles Creek Synform is the southernmost outlier) in the Carboniferous.

Five small bodies of diorite crop out 0.5 km north of Tommys Gap along the northern side of the granite mass of the Atnarpa Igneous Complex in the southwestern lobe of the Giles Creek Synform. The largest diorite body is 1 km long, has a very irregular shape, and is almost completely surrounded by the basic metavolcanic unit of the Tommys Gap metamorphics; it also includes a block about 200 m long of basic metavolcanic rock in its western part. The smaller bodies of diorite are about 200 m long, and crop out between the basic metavolcanic unit and the granite, with the exception of the smallest diorite, which crops out entirely within metavolcanic rock. The diorite is medium-grained, speckled cream to pale greenish-yellow and black, weakly schistose but not layered. The diorite (68110100D; 71911872) is composed of partly sericitised sodic andesine (An_{35}; 64 to 72%) as mosaics of many small polygonal grains together with a few larger irregular grains, ragged grains of actinolite (20 to 30%) containing numerous small idioblasts of sphene, aggregates of chlorite and sphene after biotite (0 to 5%), isolated blebby granules of sphene (0 to 2%), and accessory amounts of microcline, quartz, apatite, zircon, and opaque material. Secondary sericite, epidote (0 to 5%) and clinozoisite are abundant, and actinolite is partly altered to tremolite in a few places. Veinlets of calcite-hematite, limonite-epidote, and limonite alone cut the rock as well.

Tonalite of the Atnarpa Igneous Complex crops out in the two western lobes of the Giles Creek Synform, and in the area east of Atnarpa homestead, in FERGUSSON RANGE; then north from there along the eastern side of White Range, and west past Mount Gordon to the northern side of the Cavenagh Range, in RIDDOCH. The rock is medium-grained, speckled in black and tints of cream, pink, or very pale greenish-yellow, and weakly to strongly schistose but nowhere layered. In RIDDOCH, i.e. in the White Range-Mount Gordon-Cavenagh Range area, the tonalite is retrogressively metamorphosed to a strongly schistose but non-layered gneiss. Like the diorite member, variation in mineral content is common, and gives rise to such lithological variants as diorite, trondhjemite, granodiorite, and adamellite. The mapped unit also includes numerous small dykes of micro-

diorite, microtonalite, aplite, and pegmatite which are too small to depict separately. Ovoid to lenticular xenoliths are seen at many exposures of the tonalite (Photo D38), and range up to 1.3 m long.

The typical tonalite in FERGUSSON RANGE, both in the Giles Creek Synform (68110065, 71911858, -1859, -1871) and in the Ruby Gap Nappe (69090239, -0240, -0251, -0264) consists of subhedral andesine (An_{45}; 55 to 70%) which is largely converted to sericite and epidote, quartz (15 to 25%) recrystallised to lobate aggregates, bent and broken microcline (5%), chloritised or bleached biotite (10%) with abundant granules of sphene, common hornblende (0 to 12%) partly altered to biotite or epidote, and discrete epidote grains (3 to 8%). Allanite, sphene, and primary muscovite are abundant accessories in -1871. The melanocratic variants include: diorite (68110063) from 4 km northwest of Atnarpa homestead, consisting of sericitised calcic andesine (An_{49}; 68%), hornblende (30%), epidote (2%), and accessory sphene, hematite, and ilmenite largely converted to leucoxene; trondhjemite (71911848) consisting of sodic andesine (An_{34}; 60%), recrystallised quartz (18%), biotite (15%), epidote (5%), hornblende (2%), and accessory allanite, apatite, sphene, and opaque grains; and granodiorite (68110062) consisting of andesine (An_{46}; 50%), microcline (20%), quartz (15%) and biotite (15%). The leucocratic variant is a granodiorite (68110028) from the northwest lobe of the Giles Creek Synform, composed of oligoclase (55%), microcline (20%), recrystallised quartz (15%), chlorite (7%) and epidote (3%).

In RIDDOCH, the tonalite is retrogressively metamorphosed to a mylonitic metatonalitic gneiss which is strongly schistose and lineated. The rock (68110037, -0038, -0039, -0041, -0045, -0198, -0243, -0340) consists of coarse cracked and broken fragments of plagioclase which is albite in all the samples except -0039 (andesine); the albite grains are crowded with randomly oriented laths of coarse white mica occupying up to 40 percent of the overall volume of the grain (Photo D39). X-ray diffraction of the white mica found that up to 35 percent of it is paragonite. Small euhedra of clinozoisite or epidote accompany the white mica in some samples. Quartz forms large strained grains, or elongate aggregates of small polygonal

strain-free grains. Biotite forms large aligned flakes, and is associated with the epidote and more white mica. Microcline occurs in small amounts in four samples, and is surrounded and embayed by the plagioclase. Accessory minerals include apatite, allanite, and hematite, and small amounts of secondary calcite and chlorite are also present. Chlorite has almost wholly replaced biotite in 68110038.

Two lithological variants (68110042, -0202) of the tonalite contain more microcline, and are granite and granodiorite in composition, respectively.

Only one xenolith in the tonalite has been thin-sectioned (71911859); it consists of a fine aggregate of oligoclase (46%) containing small idioblasts of clinozoisite, common hornblende (25%), epidote (15%), biotite (10%), quartz (3%), large grains of sphene (about 1%), and accessory euhedra of apatite.

Granite of the Atnarpa Igneous Complex crops out in FERGUSSON RANGE as irregular bodies in the two western lobes of the Giles Creek Synform; around Atnarpa homestead; and in the Ruby Gap Nappe. In RIDDOCH, irregular masses of granite have been mapped north and west of Mount Gordon. In the Giles Creek Synform, the granite is coarse-grained, speckled red and black, leucocratic, weakly schistose, but not layered. Xenoliths are rare. Thin veinlets of epidote are present at many localities, and the unit as mapped also includes a few microgranite, aplite, and pegmatite dykes. The granite consists of aggregates of many small and a few large grains of partly sericitised albite (about 35%), coarse recrystallised quartz (about 35%) in aggregates of lobate grains, large grains of microcline (about 25%) containing numerous small blebs of albite, aggregates of chlorite + sphene + magnetite after biotite (4%), and muscovite (1%) associated with the altered biotite and enclosed in the albite (68110021A, -0021B; stained specimen 71911883). Xenoliths in the granite are dark brown, fine-grained, and contain abundant biotite.

In the Ruby Gap Nappe, the granite is poorly exposed below Cainozoic gravel, and only one sample has been thin-sectioned (68110060). The rock is adamellitic in composition, and consists of strained quartz (20%), anhedral microcline (38%), sericitised plagioclase (38%), muscovite (2%), epidote (1%) as large anhedral grains, aggregates of small grains and overgrowths around opaque grains, and chlorite (1%).

In the vicinity of Atnarpa homestead, the granite is somewhat more schistose, and like the surrounding tonalite, is cataclastically deformed. The rock is again of adamellitic composition, and 4 km north-west of the homestead (68110064), it consists of partly recrystallised quartz (25%), fragments of andesine (An_{32}; 35%) with copious amounts of included white mica, microcline (30%), kinked biotite + muscovite + epidote (together 10%), and accessory ilmenite, sphene, and calcite. Granite 1 km north of the homestead is texturally and compositionally similar, but finer-grained (68110066).

In RIDDOCH, the granite is more strongly schistose, lineated, and commonly shows a fine to medium-grained augen gneiss texture. Xenoliths are very elongate parallel to the lineation, and one example has axial ratios of 1:3:36. Veinlets of epidote are common. In places, the granite has been cataclastically deformed to a fine-grained schist or phyllonite, especially along the northern margin of the quartz-rich metasediment ridge at Mount Gordon. Along this contact, the strongly schistose (or mylonitic) zone is only a few metres thick, and rapidly weakens northwards; 1.5 km to the north in the most northerly granite body (5851-715114), the schistosity is weak enough for characteristic granite tors and corestones to develop, albeit ovoid in shape. The two small bodies of granite at localities 68110243, -0245, 1 km north of White Range, are schistose leucocratic aplogranite and pegmatitic granite, respectively.

Granodiorite of the Atnarpa Igneous Complex crops out only in the Ruby Gap Nappe, and straddles the boundary of FERGUSSON RANGE and RIDDOCH. The rock is medium-grained, schistose, and consists essentially of quartz which is everywhere strained and partly recrystallised to

aggregates of small polygonal grains, andesine (An_{50}) which is slightly to copiously sericitised, strained and fractured microcline grains, biotite which is commonly kinked, chlorite, and epidote (68110061; 69090227, -0230, -0235, -0246, -0247, -0250, -0267). Hornblende is present in small amounts in two samples (-0227, -0267), and accessory minerals include allanite, apatite, and sphene. Sample 69090247 from the northern part of the body is a quartz-hornblende diorite.

Hypabyssal members of the Atnarpa Igneous Complex range from intermediate to acid in composition, and include dykes of microdiorite, microtonalite, microgranodiorite, microadamellite, microgranite, aplogranite, aplite, pegmatite, vein quartz, tourmaline rock, and quartz-calcite veins. The various lithologic types commonly occur in close association with each other. Except for some of the pegmatites and quartz veins, the dykes are generally too small to show on the map. However, in two areas aplite and aplogranite are very abundant and constitute about three-quarters of the country; these are the two areas of aplogranite shown on the map, one near the centre of the Giles Creek Synform, the other near the eastern end of the Synform. Generally the dykes are not topographically conspicuous, but a few form low ridges projecting about 1 m above the ground.

The hypabyssal rocks are generally medium-grained, tough, schistose, and range from dark grey (microdiorite) through mid grey or grey-brown (microtonalite) to light grey or grey-brown (microadamellite) and pinkish-brown or light brown (microgranodiorite, microgranite, aplogranite, and aplite). Joints in the dykes are commonly coated with epidote.

Aplogranite and aplite are the most abundant of the hypabyssal intrusions in the Giles Creek Synform. The aplogranite (71911830) is pinkish-brown, medium-grained, markedly leucocratic, and schistose, and commonly grades into schistose aplite (68110056A, -0057). At specimen locality 1832, a clean exposure of aplite intruding orthoamphibolite (Photo D40) shows strewing of the amphibole into the aplite and forming a hybrid 'quartz monzonite' (Photo D41).

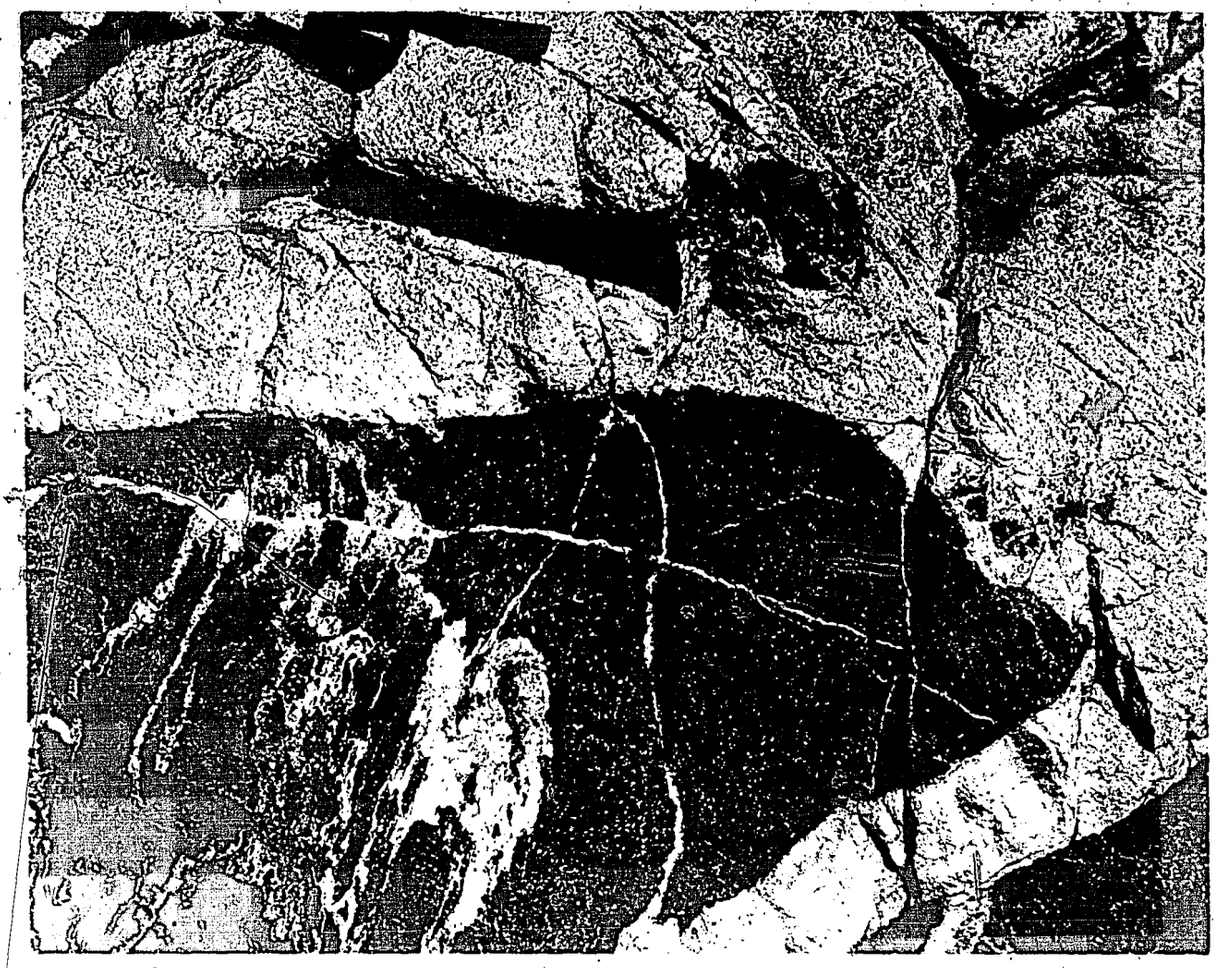


Photo D40: Amphibolite of Tommys Gap metamorphics intruded by aplite of Atnarpa Igneous Complex. Scale at top is 15 cm long. 3 km south-southeast of Giles Waterhole.

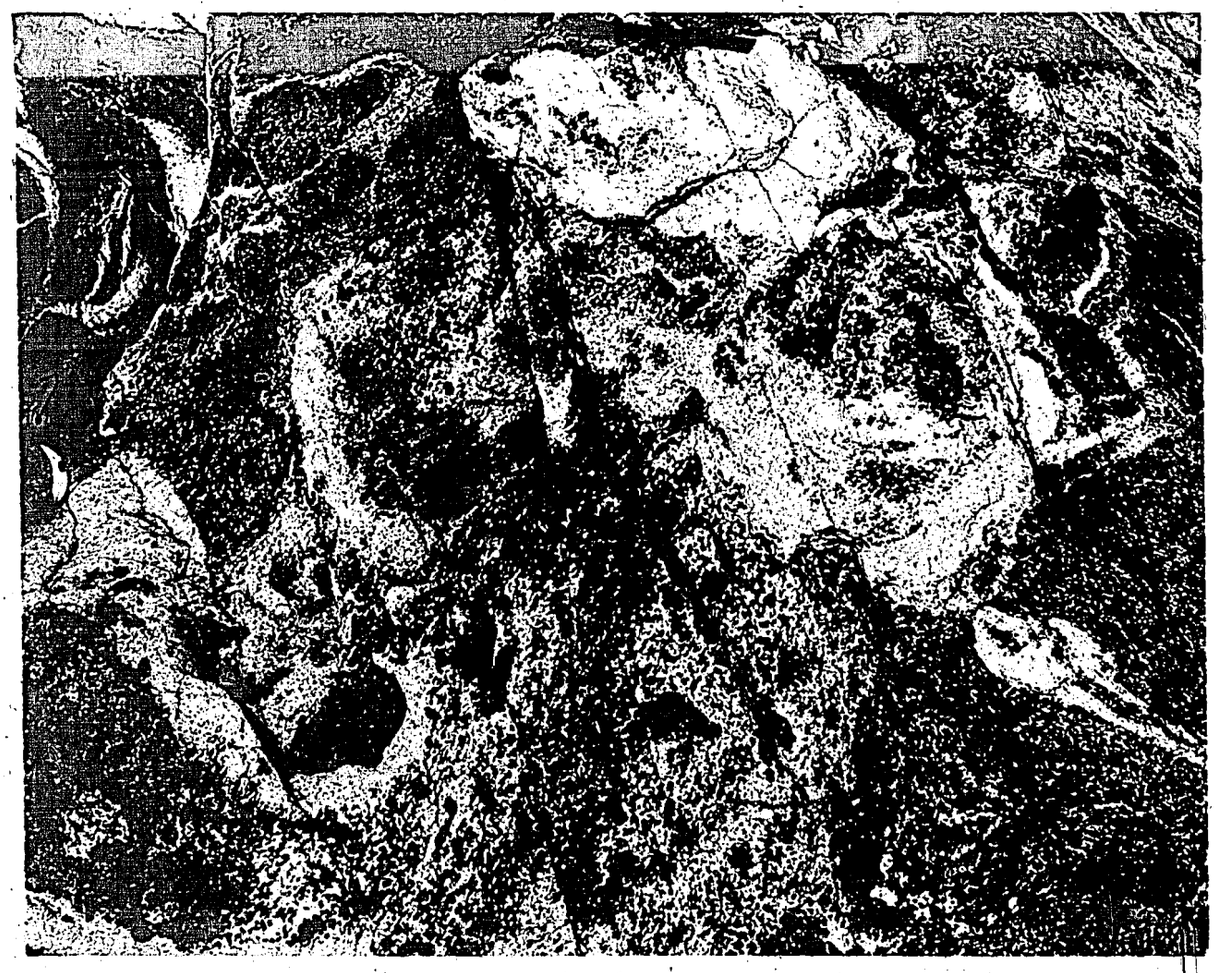


Photo D41: As above, showing xenolithic strew of amphibole and amphibolite in aplite, producing hybrid quartz monzonite. Scale at top is 15 cm long.

Visually estimated modes of the dyke rocks are set out in Table D-10-7A, and several generalisations are possible: (1) Plagioclase in microdiorite is oligoclase, in microtonalite it is andesine, in microadamellite it ranges from oligoclase to albite, and in the aplogranite and aplite it is albite; (2) biotite decreases in amount as quartz and microcline increase; (3) muscovite is most abundant in microadamellite; (4) hornblende and sphene are present only in microdiorite and microtonalite; (5) microtonalite contains little or no microcline; (6) opaque material, epidote, and allanite are most abundant in microtonalite; (7) zircon occurs only in aplogranite or aplite.

Pegmatite dykes occur throughout the Giles Creek Synform and Ruby Gap Nappe, and are generally about 1 m thick. Pegmatites are unusually abundant in the southwestern part of the eastern outcrop of diorite of the Atnarpa Complex, and here they reach several metres in thickness and form prominent pinkish-brown ridges. Several pegmatites in the large lens of orthoamphibolite 1 km west of Giles Creek are folded, e.g., at GR 5850-748900, and pegmatite masses in the area north of White and Cavenagh Ranges are coarsely foliated, lineated, and fractured. The pegmatites are composed predominantly of anhedral microcline and quartz; small amounts of albite and muscovite are present in places, and at locality 5850-824912 (71911812) the pegmatite contains abundant magnetite. Joints in the pegmatites are commonly coated with epidote. Some of the pegmatite veins have a central zone of vein quartz, and in the western part of the large eastern outcrop of hornblende gneiss of the Tommys Gap metamorphics, there are numerous roughly circular compound plugs up to about 1.5 m across consisting of an outer zone of pegmatite and a central core of vein quartz; microcline crystals at the junction of the outer zone and core are subhedral, 20 to 30 cm long, and contain abundant blades and rods of quartz ('graphic granite'). At 5850-829906 (71911811) euhedral crystals of microcline about 3 cm long are embedded in the quartz between the large subhedral graphic crystals.

TABLE D-10-7A: Modal analyses of intermediate to acid hypabyssal rocks, Atnarpa Igneous Complex

ROCK-TYPE	MICRODIORITES				MICROTONALITES				MGD[4]		MICROADAMELLITES			APG[5]	APLITES	
SAMPLE NO.	1784	1813	1845B	0055*	0056B*	0058*	1845A	1846	1798	0052*	0053*	0066*	1758	1830	0056A*	0057*
Quartz	8	5	5	30	15	35	15	20	30	30	30	15	20	20	30	38
Microcline	-	-	-	-	1	-	-	-	10	30	30	37	40	64	15	30
Plagioclase	68[8]	75[2]	65[2]	65[3]	72[3]	60[3]	65[3]	57[3]	60[2]	30[1]	30[1]	38[2]	34[2]	15[1]	54[1]	30[1]
Biotite	-	-	25	3	-	3	10	-	-	7	7	4	5	a	-	2
Muscovite	-	-	-	-	-	1	-	-	a	1	1	5	1	1	1	a
Hornblende	25	20	1	-	10	-	5	20	-	-	-	-	-	-	-	-
Sphene	2	-	2	a	a	a	2	2	-	-	-	-	-	-	-	-
Opaque	a	-	-	-	a	a	a	a	a	a	-	-	-	a	-	a
Allanite	-	-	a	a	a	a	a	-	-	a	a	-	-	-	-	-
Epidote	2	s	2	2	2	1	3	1	s	2	2	1	s	-	a	a
Sericite	s	-	-	-	s	-	s	s	s	s	-	s	s	s	-	-
Others[6]	Ch[7],A	-	A	-	A	-	-	Cl	Ch	-	A	-	T,Cl,A	Z	-	Z,A

* Preceded by 6811; all other sample numbers preceded by 7191

a - Accessory, s - Secondary, 1 - Albite, 2 - Oligoclase, 3 - Andesine, 4 - Microgranodiorite, 5 - Aplogranite

6. Less than 1 percent of Z - Zircon, T - Tourmaline, Cl - Clinozoisite, Ch - Chlorite, A - Apatite. 7. 10 percent
8. Completely altered to sericite.

Some vein quartz occurs without associated pegmatite. In general, the veins are composed purely of quartz, but in many places epidote is present as a coating on joints in the veins, or disseminated through the quartz itself. At specimen locality 71911781, vein quartz contains lumps of hematite-quartz rock after ultramafic rock, and crystals of hornblende up to 10 mm long are present in vein quartz at 5850-832905 in the hornblende gneiss of the Tommys Gap metamorphics. North of White Range, numerous white quartz veins intrude the tonalite and granite of the Atnarpa Complex, and are prominent features of the landscape. Many were mined for gold between 1887 and 1936. In addition to massive quartz, the veins generally contain pyrite. Some also carry abundant calcite and/or siderite, some are composed of quartz and calcite without pyrite (Hossfeld, 1937c), and some contain quartz, pyrite, and epidote (Stewart & Warren, 1977).

Tourmaline rock forms a black fine-grained massive dyke which intrudes the basic metavolcanic unit of the Tommys Gap metamorphics about 1 km north of Tommys Gap. The dyke is about 250 m long by 1 m thick, and crops out near the inverted Heavitree Quartzite which dips beneath the Tommys Gap metamorphics.

A quartz-calcite vein about 5 cm thick crops out at 5850-751901 (71911834) 1 km west of Giles Creek, near the contact of the large lens of orthoamphibolite of the Tommys Gap metamorphics with the diorite of the Atnarpa Igneous Complex. The vein comprises a compound outer zone of white euhedral prismatic comb quartz interlayered with grey-brown chalcedony (both between and among the prisms), and a central zone of coarse massive grey crystalline calcite containing a few small xenoliths of amphibolite. Coarse grains of chalcopyrite are present in the outer zone, and are mantled by cuprite and malachite; smaller grains consist of malachite around cuprite alone.

Chalcedony, calcite rock, and massive hematite rock form a poorly exposed low-lying north-trending elongate outcrop in the diorite member of the Atnarpa Igneous Complex at the eastern end of the Giles Creek Synform. The chalcedony is grey to green, massive, and heterogeneous. Some (71911764) is largely composed of fibrous quartz together with aggregates of sericitic muscovite (about 10%) containing numerous grains of topaz; needles of hematite (5%) and trace amounts of chlorite make up the remainder of the rock. Another sample (71911766) contains small irregular anhedra of calcite and numerous tiny grains of topaz, and sample 71911767 contains abundant calcite, mixed aggregates of chlorite + calcite + muscovite, and accessory grains of pinkish-brown tourmaline. The calcite rock (71911762, -73) is coarse-grained, massive, pink, grey, or colourless, and contains small lenticular fissure-fillings of grey-green chalcedony. The hematite rock (71911765) is fine-grained, massive, and crystalline.

Calcite-epidote veins up to 10 cm thick cut amphibolite and aplogranite at two localities (1777 and 1829, respectively). The veins comprise outer zones of epidote or epidosite and central zones of coarse white calcite.

Calcite-Granite Stockwork at Tommys Gap

Calcite rock intrudes granite of the Atnarpa Igneous Complex on the northern side of Tommys Gap, in the east bank of the creek that flows through the Gap, immediately adjacent to the ridge of Heavitree Quartzite in which the Gap is cut. The northern side of the Quartzite ridge coincides with a fault. The granite next to the fault at Tommys Gap is intruded by veins of brown calcite rock up to 6 cm thick (Photo D42). The calcite rock is medium-grained, massive, crystalline, and contains small xenocrysts up to 3 mm across of pink feldspar and white quartz; slightly larger vuggy patches of coarse white calcite are also present. In places, the veins thicken and anastomose, and enclose separate blocks of granite up to 0.5 m long (Photo D43). The rock (68110021C) consists of anhedral equant grains of calcite with straight, curved or slightly embayed boundaries. The grains are markedly deformed, and show undulatory

Photo D42: Veins of calcite rock intruding granite of Atnarpa Igneous Complex, Tommys Gap. Scale is 6 inches (15 cm) long.

Photo D43: As above; calcite encloses block of granite to right of 30 cm hammer.

extinction, polygonisation, and bent twin and deformation lamellae; a few grains are broken. Fragments of granite are present in the calcite rock and are much altered; plagioclase is almost completely converted to calcite and white mica, biotite is completely altered to chlorite, and quartz is recrystallised; microcline, in contrast, is unchanged. Separate xenocrysts of quartz show idioblastic crystal outlines against the surrounding calcite.

Some of the calcite veins are accompanied by selvedges of chert along their contacts with the granite. The chert is mottled green and brown, and contains angular fragments of white quartz and pink feldspar; thin white veinlets about 1 mm wide cross-cut the selvedges, and off-set internal laminae in the chert. The chert (68110021D, 71911886) consists of unevenly fine-grained lobate to prismatic quartz containing larger angular to subrounded xenocrysts of quartz, plagioclase, microcline, chlorite, and brown calcite. In places, the xenocrystic quartz occurs as aggregates with associated muscovite, and these may represent altered pieces of granite. The thin cross-cutting white veinlets are filled with colourless calcite and quartz. Calcite also veins and partly replaces the plagioclase xenocrysts.

The occurrence of intrusive calcite is on strike with the Woolanga Lineament, near which the Mud Tank Carbonatite is situated, 80 km to the northwest, and so the possibility existed that the intrusive calcite at Tommys Gap might also be a carbonatite. Two samples of the calcite rock were semi-quantitatively analysed for some of the trace elements known to be concentrated in carbonatites, and the results, together with data on known carbonatites and sedimentary limestones for comparison, are set out in Table D-2-1B (following Hillsoak Bore metamorphics). Clearly, the trace element abundances in the calcite veins at Tommys Gap are markedly different from those in carbonatites; the 'hallmarks' of carbonatites, viz., Nb, Ba, Pr, and Nd were not detected at all. Hence, the calcite veins at Tommys Gap are of non-carbonatite origin. R.D. Shaw has suggested that the equant shape of the calcite grains, the vuggy patches of coarse calcite, the idioblastic outlines of the quartz xenocrysts, the alteration

of plagioclase and biotite, and the cherty selvedges beside the veins indicate an origin by precipitation from hydrothermal solution. The fissures containing the calcite rock could have been produced by hydraulic fracturing of the granite by high fluid pressure of the solution. The mildly deformed state of the veins could have arisen by slight strain after precipitation of the calcite.

Geochemistry

Fifteen whole rocks from the Giles Creek Synform were analysed by Amdel for major and selected trace elements. The results are set out in Table D-10-7B in order of increasing Differentiation Index, D.I. (= normative quartz + orthoclase + albite + nepheline + leucite in weight percent; Thornton & Tuttle, 1960). As described in the section on Lithology, the diorite and tonalite map-units of the Atnarpa Igneous Complex are heterogeneous in composition, and the samples submitted for analysis were chosen so as to reflect this. Thus, the diorite map-unit is represented by five variants of strictly dioritic composition (71911773; -1780, -1790, -1821, -1872), two tonalitic variants (-1775, -1824), one gabbro (-1786), and one amphibolite (-1823) which subsequently proved to be a sample of country rock, as explained below. The mapped tonalite unit includes two truly tonalitic variants (-1858, -1871) and two dioritic variants (-1848, -1870). CIPW norms and other petrological data for the analysed rocks are set out in Table D-10-7C.

Major Elements

Variation diagrams for various oxides plotted against Differentiation Index (D.I.) are shown in Figures D-10-7 A to D. The data points show reasonably well defined trends of decreasing CaO, MgO, Al_2O_3, Fe_2O_3, total Fe as FeO, and TiO_2. Na_2O is nearly constant with respect to D.I., and K_2O shows an increase. These relatively smooth trends, together with the calc-alkaline trend to alkali enrichment on the AFM diagram (Fig. D-10-7E), indicate that the rocks from a consanguineous suite derived by fractional crystallisation of calc-alkaline magma. All but one of the Atnarpa rocks have an S.I. index ($Al_2O_3/(Na_2O + K_2O + CaO)$ after CaO is corrected for apatite) less than 1.1, and hence are I-type granitoids in the classification of Chappell & White (1974).

TABLE D-10-7B: Results of chemical analyses by ANDEL (Rept AN 3095/77) of 15 whole rocks from Atnarpa Igneous Complex. Major oxides (Results in percent) determined by X-ray flourescence and wet chemical methods. Trace elements (in ppm): Li, Co, Ni, Cu, bb atomic absorption spectrophotometry (AAS), after total solution in HF: Rb, Sn, Ba, Y, U, Th, W, Sn, by X-ray fluorescence (total values); Be, B, F by 'high-quality'; Au by fire assay and AAS

Rock Name*	amph	gb	dr	dr	dr	dr	dr	to	dr	dr	to	to	to	g	apl
Sample No.**	1823	1786	1790	1872	1821	1780	1848	1824	1773	1870	1858	1871	1775	1883	1830
SiO_2	53.2	50.6	53.4	57.5	59.1	59.8	61.2	69.2	64.1	64.4	67.9	71.2	75.3	74.5	74.9
TiO_2	0.35	0.77	0.61	0.75	0.64	0.69	0.57	0.17	0.56	0.62	0.36	0.34	0.15	0.20	0.09
Al_2O_3	12.2	19.5	19.2	18.4	18.8	16.7	16.8	12.7	15.6	16.2	14.5	14.1	13.5	12.5	13.3
Fe_2O_3	1.85	2.75	2.63	1.80	1.26	2.71	1.92	1.00	1.52	1.91	1.40	1.01	0.93	1.74	0.21
FeO	4.00	5.30	4.70	2.05	3.15	3.40	2.95	2.20	3.00	2.85	1.85	1.50	0.75	0.65	0.15
MnO	0.14	0.13	0.13	0.08	0.06	0.11	0.08	0.08	0.08	0.08	0.06	0.05	0.02	0.01	0.01
MgO(K)	9.62	3.95	3.70	3.90	2.57	3.09	2.43	0.40	2.19	1.67	1.62	1.70	1.17	0.15	0.05
CaO	12.55	8.51	8.20	7.20	6.47	6.37	5.25	3.11	3.73	4.35	3.77	4.25	1.73	0.38	0.25
Na_2O	2.60	3.30	3.45	5.25	4.44	3.50	4.30	3.10	3.41	3.80	3.79	3.77	3.04	3.44	1.94
K_2O	0.64	1.80	1.72	1.33	1.02	2.72	1.77	1.31	2.50	1.29	2.21	1.80	2.05	3.85	5.50
P_2O_5	0.11	0.35	0.33	0.21	0.17	0.34	0.17	0.05	0.11	0.17	0.12	0.09	0.04	0.04	0.02
H_2O+	1.31	1.72	1.87	1.22	0.25	0.97	1.03	1.03	0.84	1.37	1.03	1.09	0.45	0.75	0.55
H_2O^-	0.01	0.04	0.01	0.14	0.07	0.06	0.01	0.01	0.04	0.04	0.01	0.07	0.05	0.09	0.08
CO_2	0.05	0.05	0.05	0.10	0.35	0.05	0.05	0.10	0.10	0.10	0.10	0.10	0.10	0.15	0.05
SO_3	0.02	0.02	0.03	0.02	0.01	0.02	0.03	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01
Total	99.55	98.93	99.68	99.45	99.51	99.68	98.79	99.74	99.90	99.69	99.36	99.44	100.09	99.42	99.44
Li	7	40	32	5	15	27	13	10	2	17	15	30	8	10	3
Rb	4	65	55	44	65	110	48	40	40	40	40	55	75	40	130
Be	1	2	2	1	1	1	1	1	2	2	1	2	2	1	1
B	5	5	5	20	10	30	< 5	5	35	< 5	< 5	< 5	30	10	< 5
Sr	230	640	700	640	560	350	740	260	360	420	540	260	390	65	20
Ba	220	720	520	640	580	490	1300	500	1050	520	1000	620	500	40	40
Y	14	34	26	14	8	16	10	8	10	12	6	14	4	6	20
U	< 4	< 4	4	< 4	4	4	< 4	< 4	4	< 4	4	< 4	4	4	8
Th	< 4	< 4	< 4	15	< 4	6	4	< 4	8	10	16	16	6	12	44
W	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10	< 10
Co	58	42	42	38	28	48	40	58	50	30	44	50	12	12	50
Ni	100	14	20	14	26	28	24	46	30	10	18	4	6	4	2
Cu	90	35	45	12	8	16	10	8	16	14	10	8	16	6	8
Au	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005
Zn	49	90	82	49	50	80	58	50	56	50	41	47	25	35	20
Sn	4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4
F	680	900	760	480	420	660	540	400	500	660	440	400	200	160	90
K/Rb	1326	240	260	292	232	200	306	272	264	212	268	266	244	364	372
Sr/Ca x 10^4	26	105	121	120	143	107	196	71	135	140	240	102	311	218	670
Ni/Co x 10^2	172	33	48	37	93	58	60	79	60	20	41	8	12	8	4
Zn/Fe^{++} x 10^5	129	218	225	308	299	383	253	392	349	297	284	294	331	385	1600

* amph — amphibolite
gb — gabbro
dr — diorite
to — tonalite
g — granite
apl — aplite

** Number preceded by 7191

TABLE D-10-7C: CIPW norms, S-I numbers, Differentiation Index (D.I.), and other petrological data (all in weight percent) for analysed whole rocks from Atnarpa Igneous Complex.

Rock Name (abbreviated as in D-10-7B)	amph	gb	dr	dr	dr	dr	dr	to	dr	dr	to	to	to	g	apl
Sample No. (prefixed by 7191)	1823	1786	1790	1872	1821	1780	1848	1824	1773	1870	1858	1871	1775	1803	1830
Diopside	33.14	5.74	4.76	10.29	–	–	1.65	0.28	–	–	1.13	–	–	–	–
wollastonite	17.33	2.94	2.44	5.41	–	–	0.96	3.27	–	–	0.59	–	–	–	–
enstatite	12.29	1.72	1.42	4.35	–	–	0.62	3.21	–	–	0.39	–	–	–	–
ferrosilite	3.53	1.08	0.90	0.00	–	–	0.27	0.77	–	–	0.15	–	–	–	–
Hypersthene	15.02	11.65	11.72	3.40	8.74	10.54	8.55	8.38	10.02	6.77	3.00	3.13	2.33	1.12	0.22
enstatite	11.67	7.16	7.19	2.97	5.70	7.70	5.95	5.23	6.70	4.14	3.64	1.79	1.67	1.12	0.22
ferrosilite	3.35	4.49	4.53	0.42	3.04	2.85	2.59	2.15	3.32	2.63	1.42	1.33	0.68	–	–
Olivine	–	1.14	–	–	–	–	–	–	–	–	–	–	–	–	–
forsterite	–	0.67	–	–	–	–	–	–	–	–	–	–	–	–	–
fayalite	–	0.46	–	–	–	–	–	–	–	–	–	–	–	–	–
Magnetite	2.68	3.97	3.81	2.61	1.83	3.93	2.78	1.45	3.20	2.77	0.15	1.49	0.77	1.50	0.21
Ilmenite	0.66	1.46	1.16	1.12	0.65	1.31	1.08	0.32	1.00	1.18	0.68	0.65	0.28	0.38	0.17
Hematite	–	–	–	–	–	–	–	–	–	–	–	–	–	0.71	0.07
Apatite	0.26	0.83	0.78	0.50	0.45	0.43	0.36	0.12	0.33	0.43	0.28	0.21	0.07	0.14	0.05
Pyrite	0.01	0.01	0.02	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Calcite	0.11	0.11	0.11	0.23	0.60	0.11	0.11	0.23	0.23	0.23	0.23	0.23	0.23	0.33	0.11
Quartz	0.68	–	4.12	3.90	11.19	13.07	15.64	30.51	20.28	21.66	26.92	31.48	33.31	35.56	36.61
Corundum	–	–	–	–	0.65	0.24	–	–	0.66	0.51	–	0.82	1.12	1.14	1.62
Orthoclase	3.78	11.11	10.16	9.16	10.75	14.07	10.46	7.74	10.00	13.73	13.35	10.02	12.11	13.34	0.23
Albite	23.00	36.43	29.19	44.42	37.57	29.61	33.64	20.62	24.05	32.17	32.07	33.07	34.18	31.32	1.11
Anorthite	19.73	32.57	31.82	22.06	23.08	21.18	22.66	10.59	16.76	15.98	15.88	6.04	3.45	3.42	.77
Plag. An	47.28	53.40	52.16	33.18	38.09	41.70	40.10	38.17	37.02	37.12	33.13	23.07	18.39	1.01	0.61
S-I	0.44	0.88	0.89	0.79	0.99	1.00	0.94	0.81	1.03	1.02	0.95	1.01	1.12	1.099	1.04
Diff. index	26.46	39.54	43.47	57.48	59.51	59.67	59.95	65.97	66.23	67.34	72.34	81.55	85.62	92.21	7.05
Solid. indix	49.52	23.28	22.04	21.09	21.22	20.40	20.17	30.97	20.18	17.55	14.73	7.2	4.39	.26	1.83
Cryst. index	54.42	41.97	39.94	31.31	28.83	26.97	25.17	25.75	22.15	2 .24	19.28	11.44	10.31	.1	1.37
Total Fe (FeO) (F)	6.57	7.78	7.07	5.97	5.28	5.84	4.68	3.10	4.37	4.57	3.19	2.64	1.23	3.22	0.34
K_2O/Na_2O	0.25	0.56	0.50	0.30	0.41	0.78	0.44	0.41	0.84	0.80	0.80	0.61	1.0	0.38	
$K_2O + Na_2O$ (A)	3.24	5.24	5.17	6.80	6.26	6.22	5.77	4.48	6.27	6.05	6.05	6.84	6.09	7.89	10.44
'Mg' number	58.7	33.0	32.2	43.4	43.2	33.9	35.4	51.6	37.4	29.2	33.1	29.7	3 .5	10.5	20.5
Plag. name	Calc And.	Lab.	Lab.	Sod And.	Mid And.	Mid And.	Mid And.	Mid And.	Mid And.	Mid And.	Sod And.	Oli .	Oli .	Alb.	Alb.

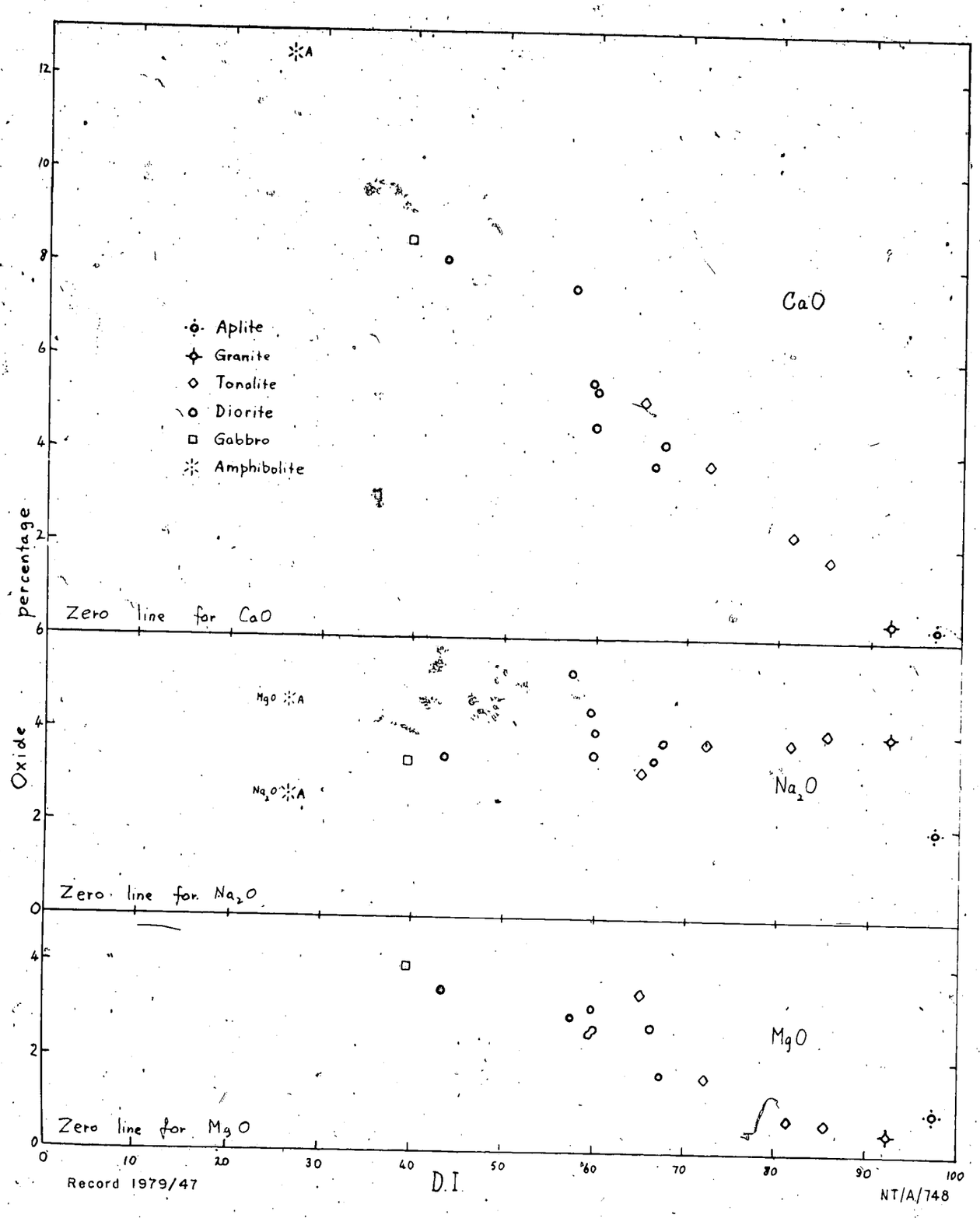


Fig. D-10-7A Variation diagram - CaO, MgO, Na_2O vs Differentiation Index for Atnarpa Igneous Complex.

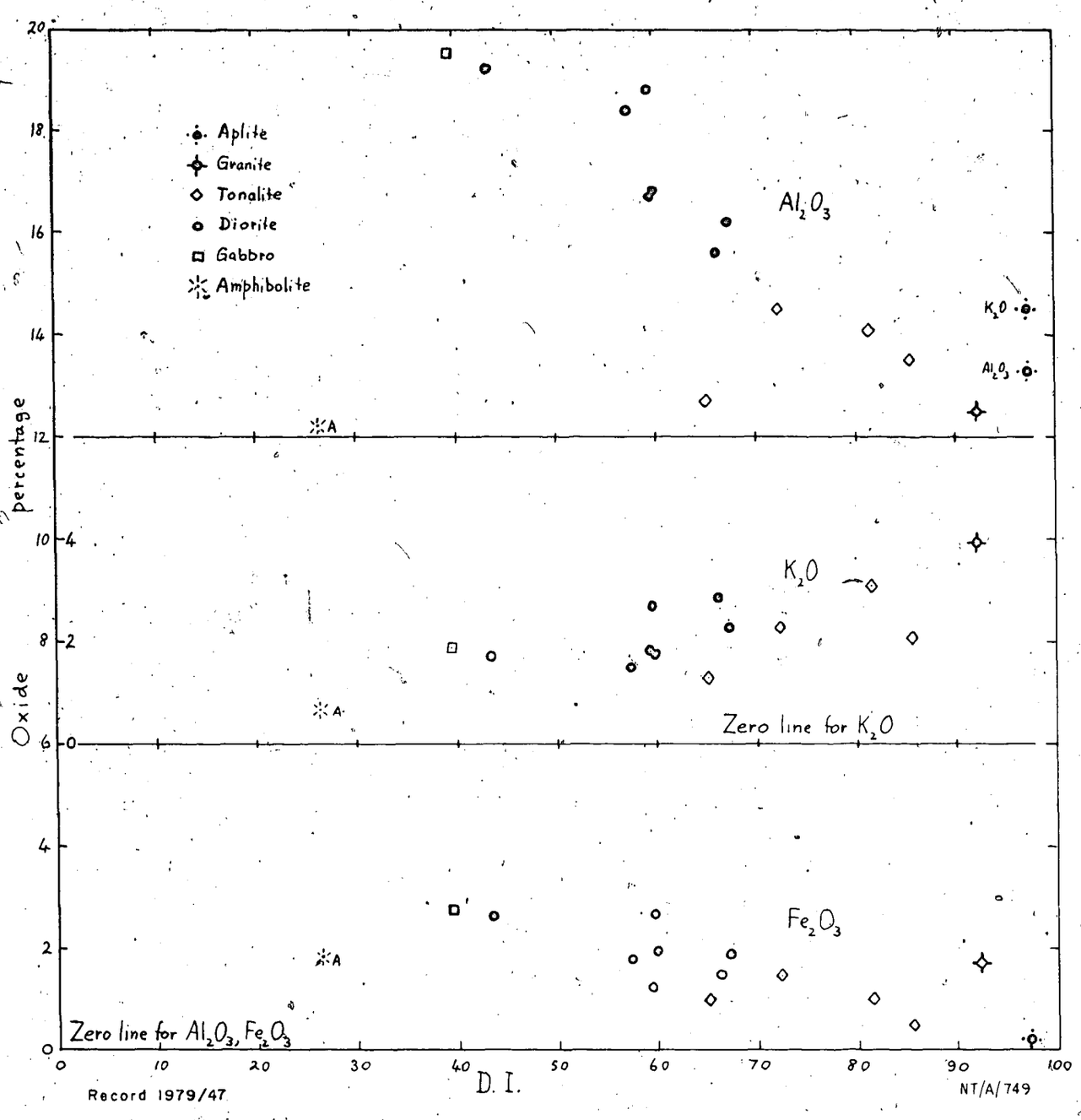


Fig. D-10-7B Variation diagram – Al_2O_3, Fe_2O_3, K_2O vs Differentation Index for Atnarpa Igneous Complex.

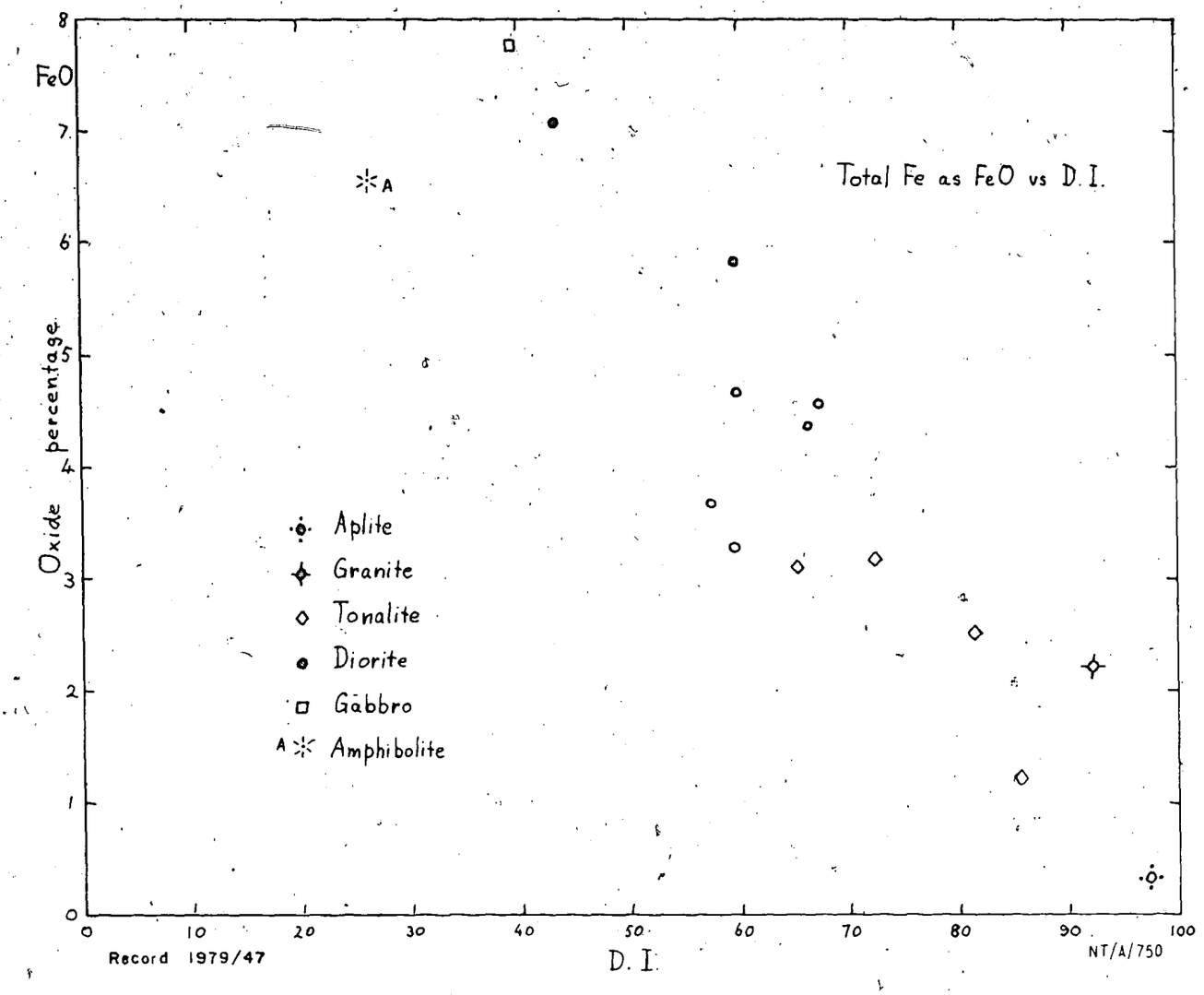


Fig. D-10-7C Variation diagram – Total iron as FeO vs Differentiation Index for Atnarpa Igneous Complex.

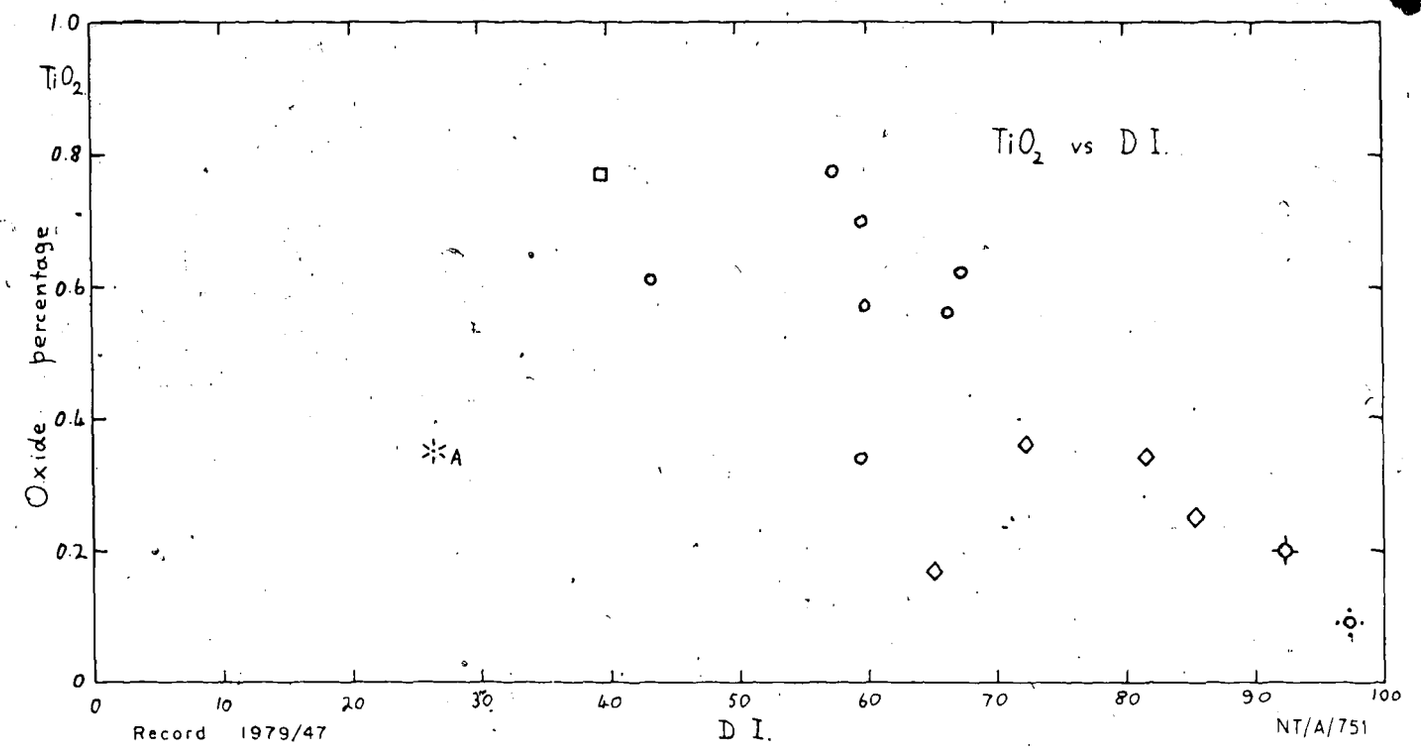


Fig. D-10-7D Variation Diagram - TiO_2 vs Differentiation Index for Atnarpa Igneous Complex.

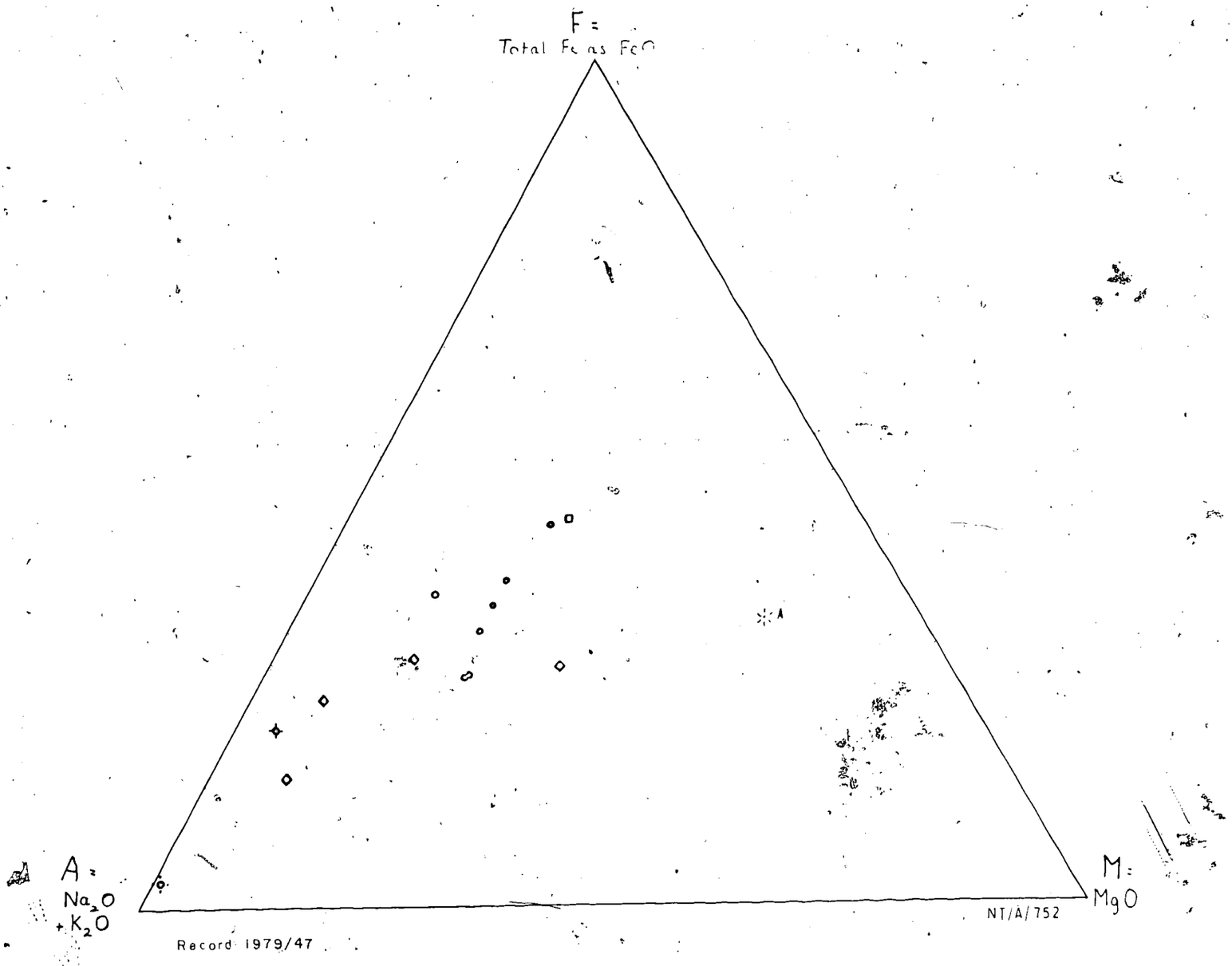


Fig. D-10-7E AFM variation diagram for plutonic and hypabyssal rocks, Atnarpa Igneous Complex.

For comparison, the rocks of the Atnarpa Complex plot among the I-types of the Kosciusko Batholith (Hine & others, in press) on Fe_2O_3 vs FeO, CaO vs SiO_2, TiO_2 vs SiO_2, and Zn vs SiO_2 plots. However, the Atnarpa rocks are much more scattered than the Kosciusko rocks on plots of Sr vs SiO_2, Ba vs SiO_2, Co vs SiO_2, and Ni vs SiO_2. They also contain considerably greater amounts of these elements than do the Kosciusko rocks, presumably resulting from their more dioritic, i.e., slightly more basic composition. However, the reason for the greater scatter of the Atnarpa data is not known.

The K_2O content of 50 diorite samples compiled by Nockolds (1954) is 1.33 percent, and for 58 quartz diorites 1.42 percent. The seven diorites and one gabbro of the Atnarpa Igneous Complex have an average K_2O content of 2.08 percent, and hence they are high-K diorites similar to those at Yeoval, N.S.W. (Gulson, 1972).

Sample -1872 from the small irregular body of diorite that crops out between granite of the Atnarpa Complex and basic volcanics of the Tommys Gap metamorphics at the far western end of the Giles Creek Synform plots near or along most of the trends in the variation diagrams. The sample is most discrepant in its high CaO and Na_2O contents and low Li, suggesting that it may have undergone some contamination by the adjoining basaltic rocks.

The most discrepant point, marked A in all the variation diagrams, is sample -1823, which is characterised by very high MgO and CaO, and by low Al_2O_3. Consequently, the norm of this sample contains unusually large amounts of diopside and hypersthene. The mode of the rock is hornblende (35%), diopside (15%), calcic andesine (An_{49}; 45%), and quartz (5%). It is the only sample from the diorite unit that does contain modal diopside, and in the field was provisionally identified as an 'amphibolite-cum-diorite'. The sample was taken from the centre of the Giles Creek Synform, where the diorite unit contains many rafts of amphibolite of the Tommy's Gap metamorphics, and so it seems that sample -1823 is from one such amphibolite

body, not from the diorite at all. The trace element abundances in this sample have been deleted when calculating the averages shown in Table D-10-7D and disoussed below.

The next most consistently aberrant sample in the variation diagrams is diorite -1848. This rock is low in lithium and boron compared to the other diorite samples, high in strontium on both the Sr vs D.I. and Sr/Ca vs D.I. plots, and very high in barium. It also has the highest K/Rb ratio of all the diorites and tonalites, but as the K_2O content is normal or slightly low compared to the other diorites, rubidium is deficient. The relationships suggest some removal of trace alkalies (Li, Rb) and boron, in exchange for introduction of alkaline earths (Sr, Ba).

Trace Elements

Average abundances of trace elements in the Atnarpa Igneous Complex, together with those for average crust, basalt, granodiorite, and granite for comparison, are shown in Table D-10-7D. Variation diagrams showing the abundance of some of the trace elements plotted against D.I. are shown in Figs D-10-7 F to N. The Complex as a whole contains normal amounts of lithium, rubidium, beryllium, boron, strontium, uranium, thorium, nickel, copper, gold, zinc, and tin. It is deficient in yttrium, and enriched in potassium, barium, and cobalt. The single sample of aplite is enriched in uranium and thorium.

Rubidium

Twelve out of the fourteen K/Rb ratios for the Atnarpa Igneous Complex are higher than the world average of 230, and two of these are higher than the normal range of 150-300 (Taylor, 1966), namely, the granite sample (-1883) and the aplite (-1830) (Table D-10-7B). Hence, these two rocks are depleted in rubidium, or enriched in potassium, or both; however, the overall rather low abundance of rubidium (Table D-10-7D) and the markedly greater content of potassium in the Atnarpa Complex whole suggests that both phenomena may have occurred in these two samples.

TABLE D-10-7D: Average trace element abundances in common crustal rocks (from Taylor, 1966) and Atnarpa Igneous Complex

Element	Crust	Basalt	Granodiorite	Granite	Atnarpa Complex
Li	20	10	25	30	16
Rb	90	30	120	150	80
Be	2.8	0.5	2	5	1.4
B	10	5	20	15	12.5
Sr	375	465	450	285	432
Ba	425	250	500	600	717
Y	30	25	30	40	16
U	2.7	0.6	3	4.8	4
Th	10	2.2	10	17	11
W	1.5	1	2	2	< 10
Co	25	50	10	1	47
Ni	75	150	20	0.5	17.6
Cu	55	100	30	10	15
Au	0.004	0.004	0.004	0.004	< 0.005
Zn	70	100	60	40	53
Sn	2	1	2	3	4
F*	-	400	520[1]	850[2]	485

* from Turekian & Wedepohl (1961)

1. 'High calcium granite'. 2. 'Low calcium granite'.

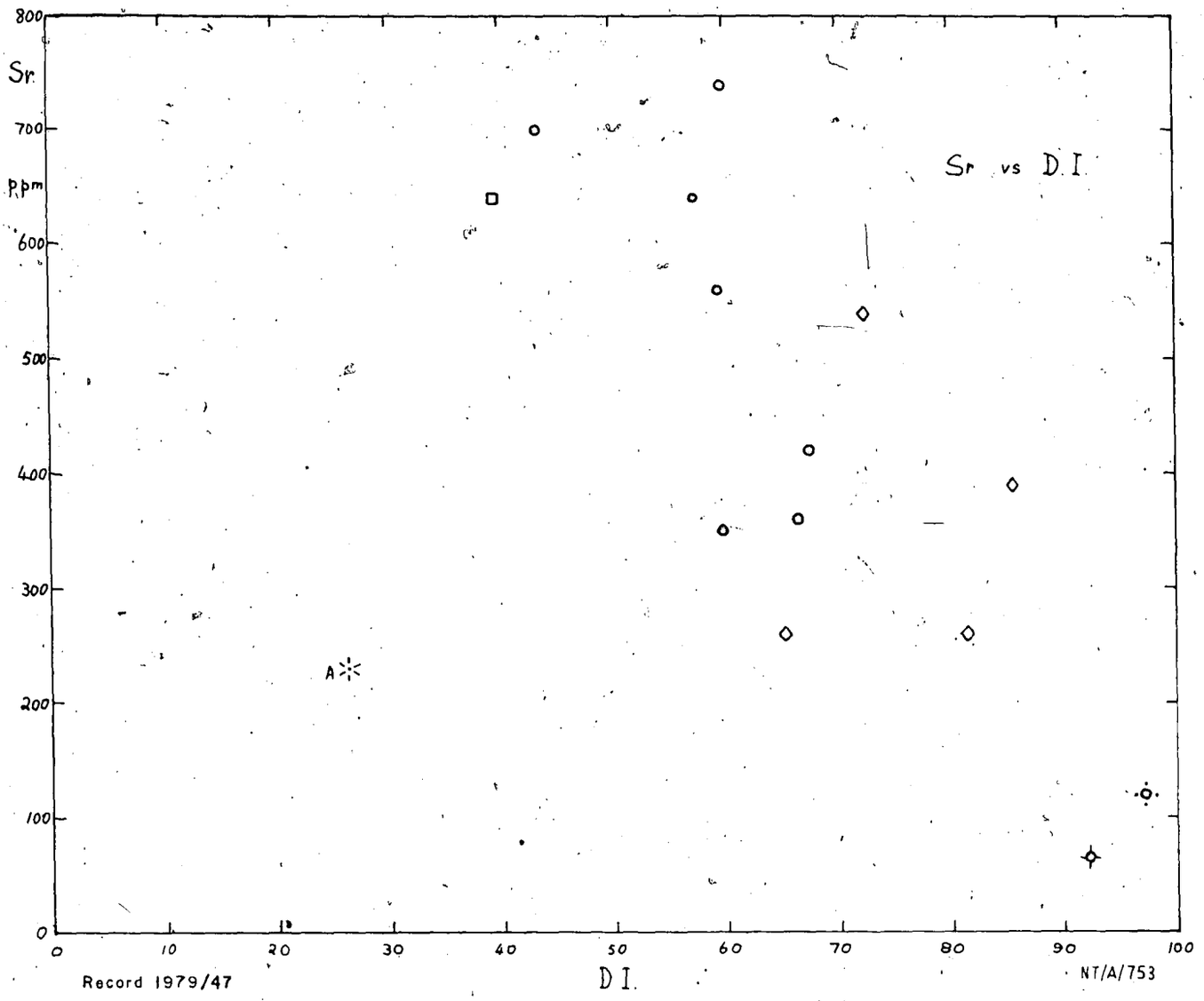


Fig. D-10-7F Variation diagram - Sr vs Differentiation Index, Atnarpa Igneous Complex.

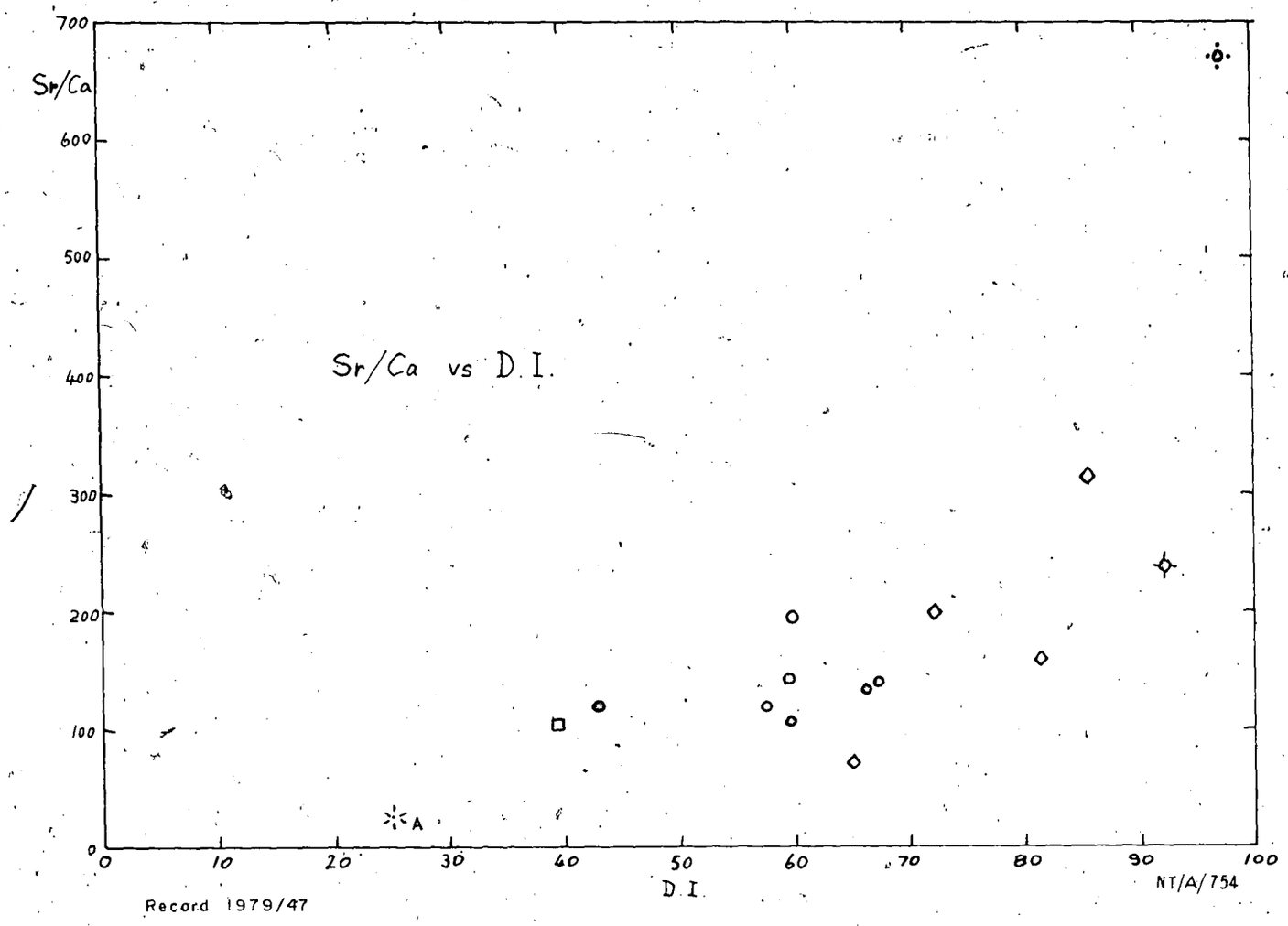


Fig. D-10-7G Variation diagram – Sr/Ca vs Differentiation Index, Atnarpa Igneous Complex.

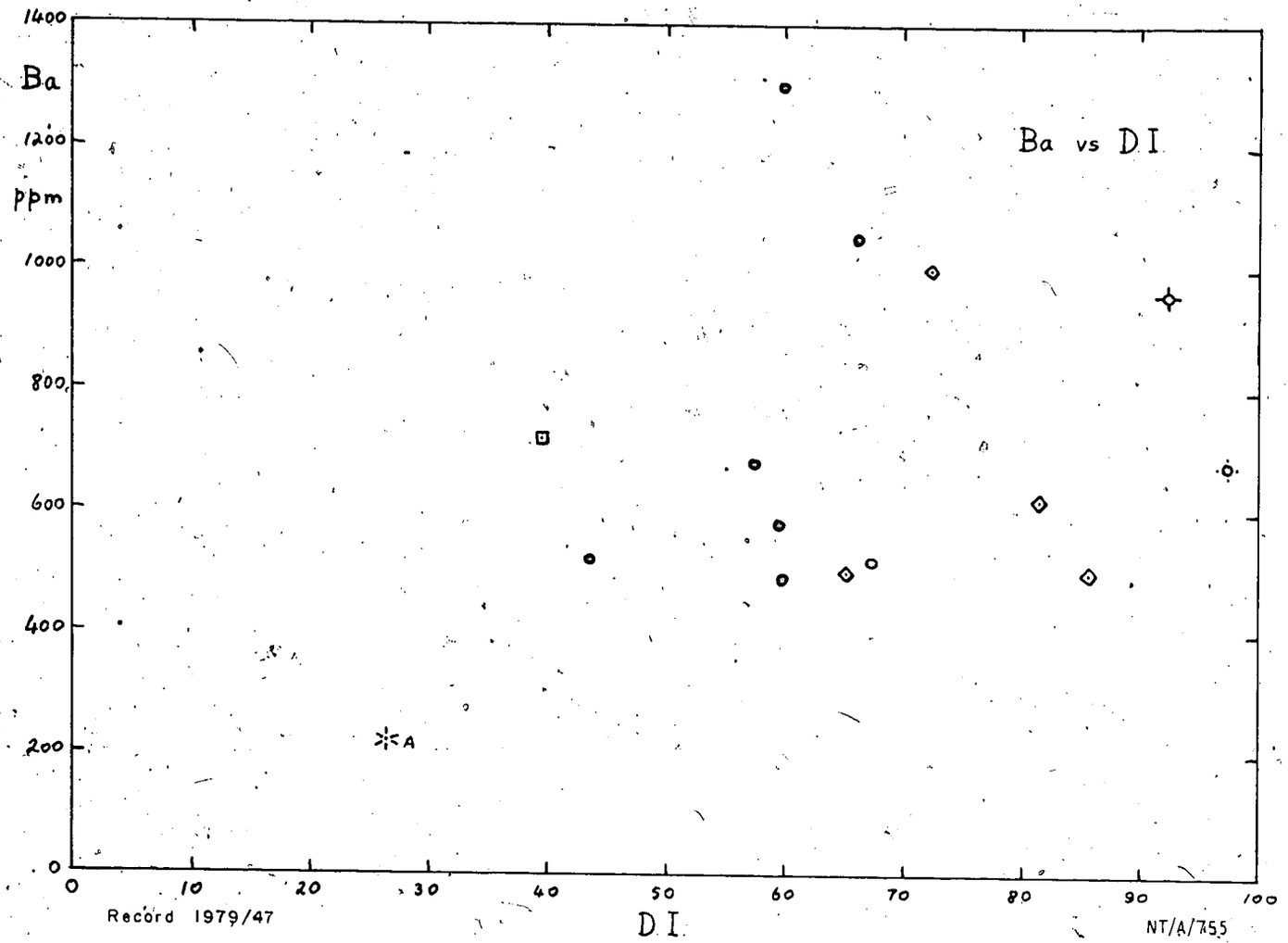


Fig. D-10-7H Variation diagram - Ba vs Differentiation Index, Atnarpa Igneous Complex.

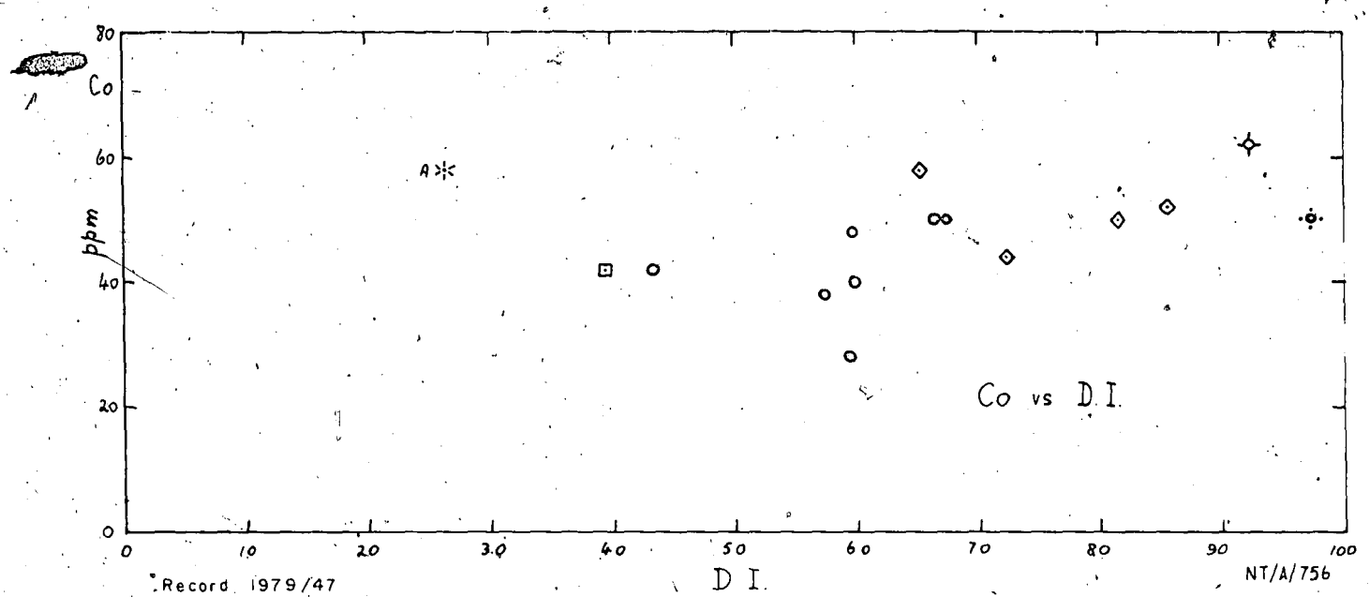


Fig. D-10-7I Variation diagram - Co vs Differentiation Index, Atnarpa Igneous Complex.

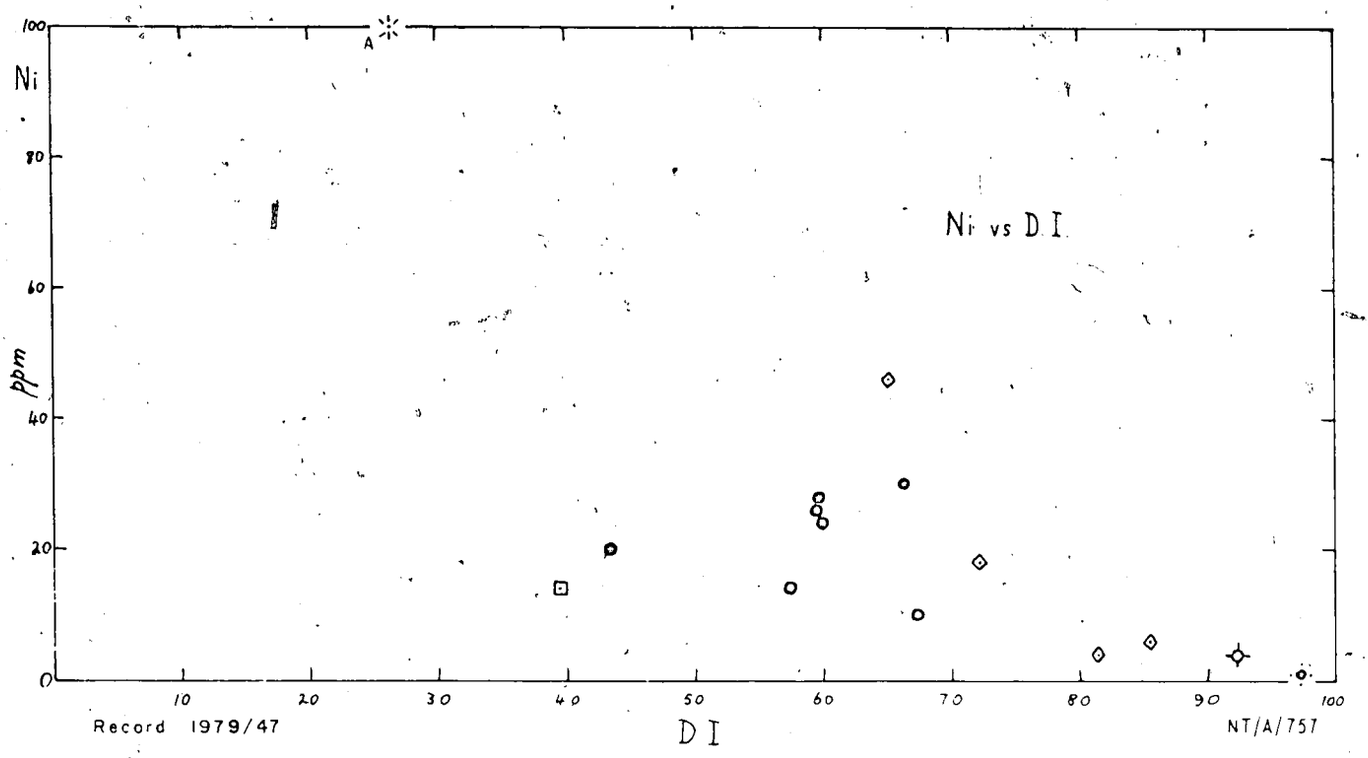


Fig. D-10-7 J Variation diagram – Ni vs Differentiation Index, Atnarpa Igneous Complex.

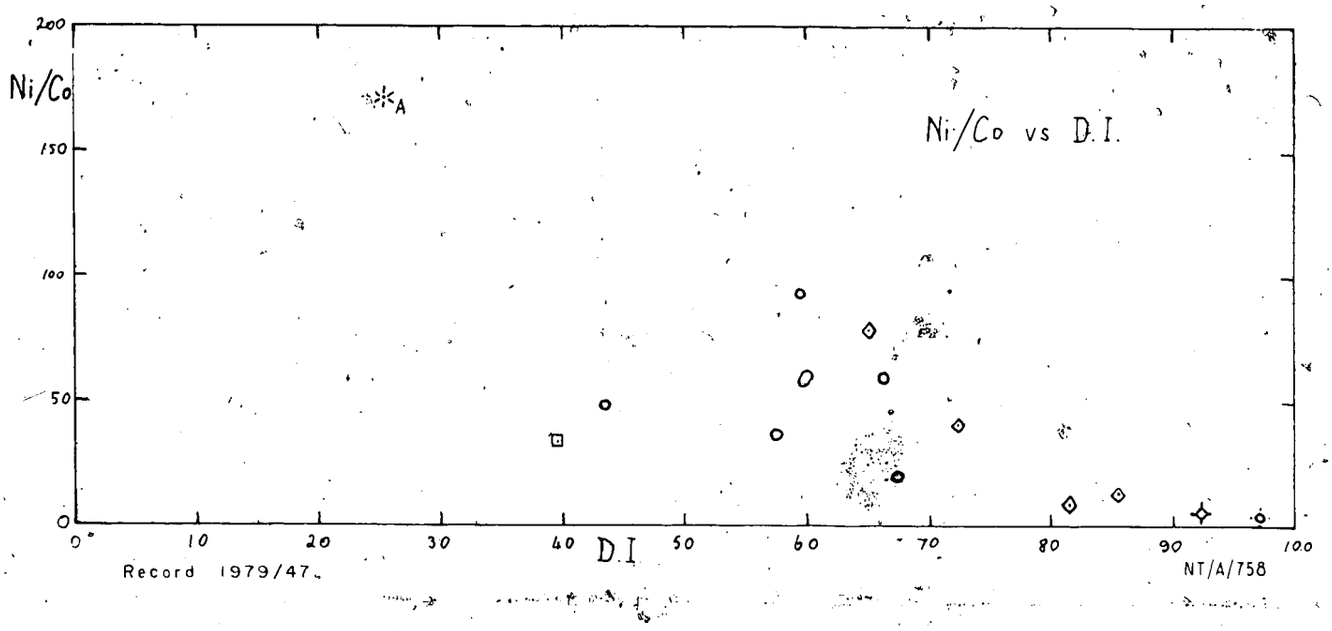


Fig. D-10-7K Variation diagram – Ni/Co vs Differentiation Index, Atnarpa Igneous Complex.

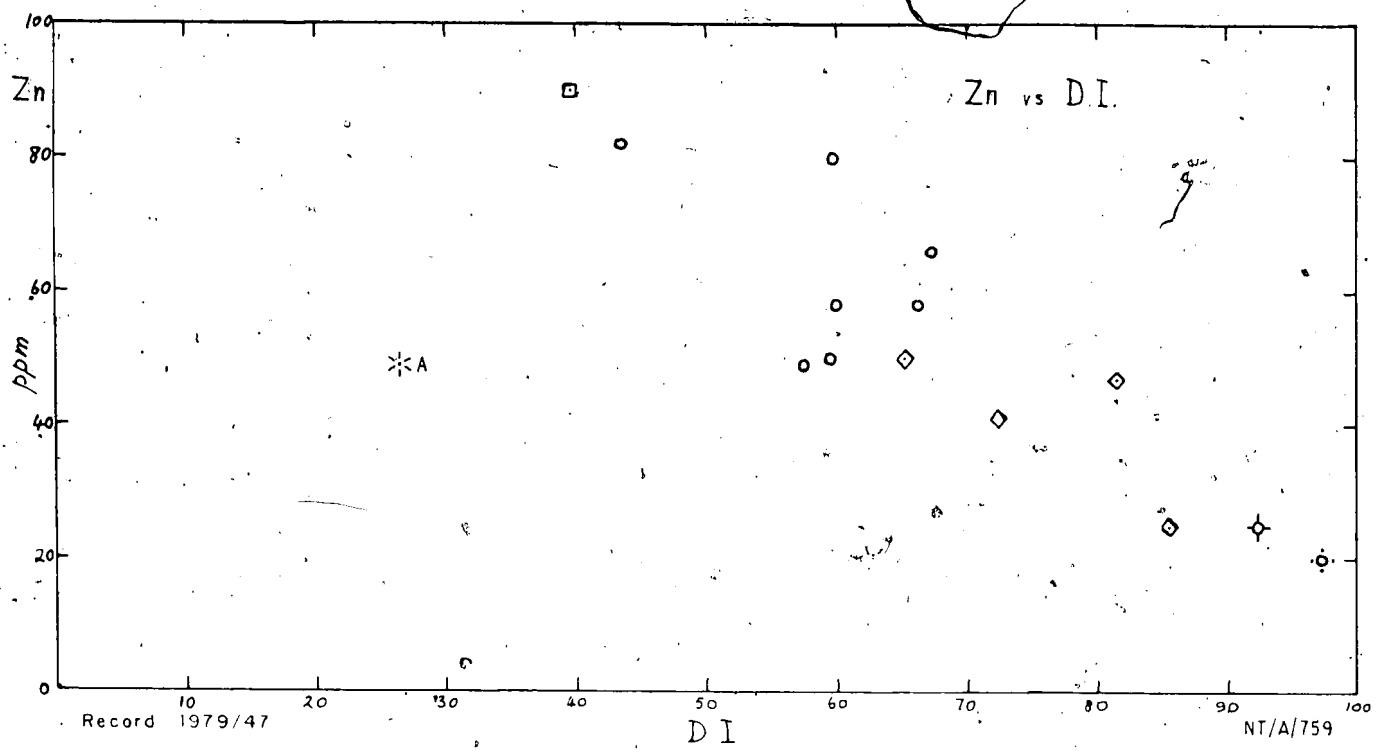


Fig. D-10-7L Variation diagram – Zn vs Differentiation Index, Atnarpa Igneous Complex.

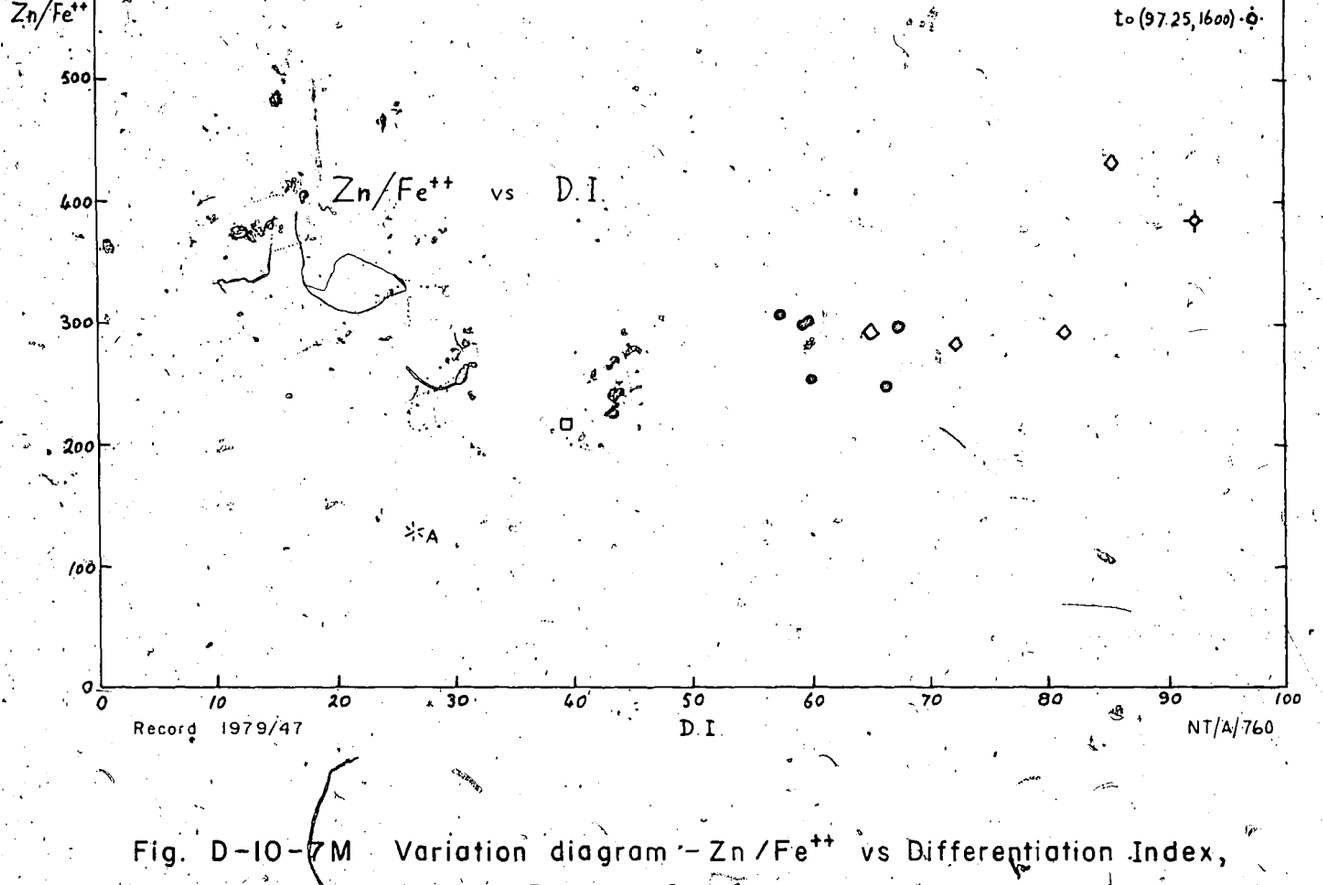


Fig. D-10-7M Variation diagram - Zn/Fe^{++} vs Differentiation Index, Atnarpa Igneous Complex.

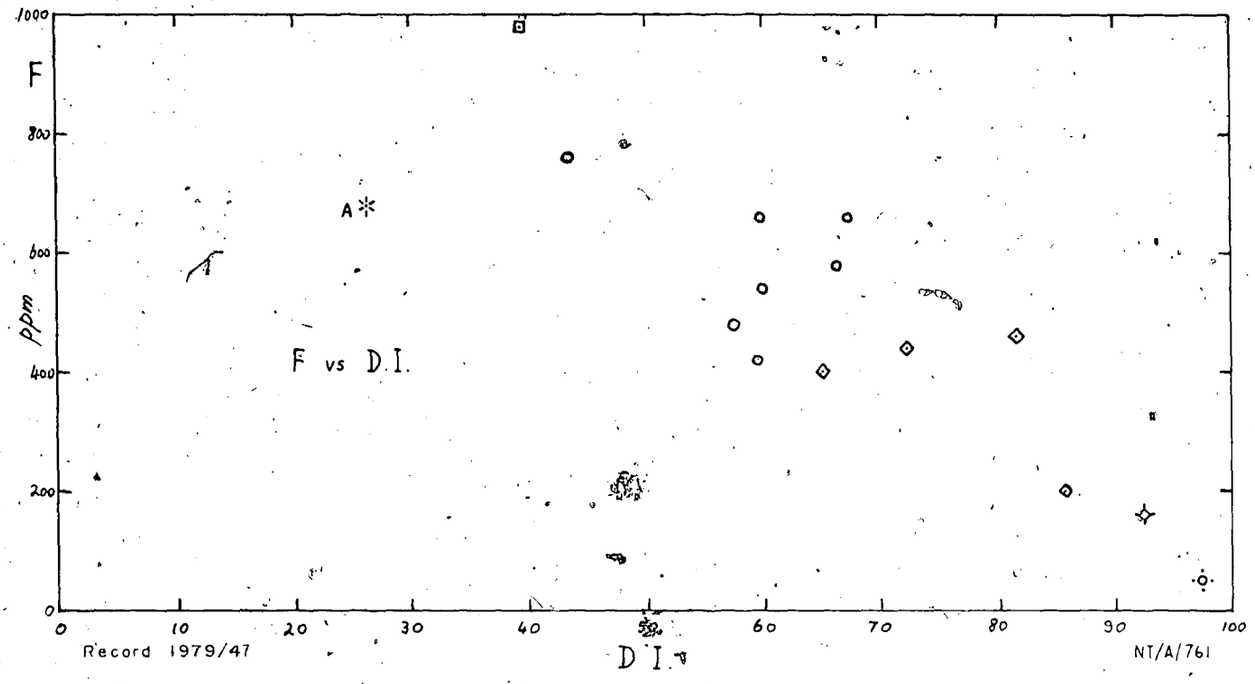


Fig. D-10-7N Variation diagram – F vs Differentiation Index, Atnarpa Igneous Complex

Strontium

Strontium shows a rather poorly defined decrease with increasing D.I. (Fig. F). The Sr/Ca ratio shows a clear increase with D.I. (Fig. D-10-7G), and the average ratios (multiplied by 10^4) for Atnarpa Complex diorite (plus one gabbro)-tonalite-granite-aplite are respectively 133-187-239-670. According to Taylor (1966), such an increase indicates that crystal fractionation operated during crystallisation of the different rock-types of the Complex.

Barium

Barium is notably enriched in the Atnarpa Igneous Complex; three samples contain 0.1% Ba or more, and the average - 717 ppm - is distinctly higher than that for average crust, basalt, granodiorite, and granite (Table D-10-7D). The sample-points are widely scattered on the Ba vs D.I. plot (Fig. D-10-7H), indicative of movement of barium subsequent to crystallisation of the rocks.

Cobalt and Nickel

Cobalt - average of 47 ppm - is rather high in the Atnarpa rocks, and the values for all the rock-types are consistently near the average for basalt and distinctly higher than those for granodiorite and granite (Table D-10-7D). Cobalt shows a slight increase with increasing D.I. (Fig. D-10-7I). In contrast, nickel values - average = 18 ppm - are close to the average for granodiorite, and show a decrease with increasing D.I. (Fig. D-10-7J). The Ni/Co ratio shows an irregular decrease with increasing D.I. (Fig. D-10-7K), indicating fractional crystallisation in the Complex (Taylor, 1966). In terms of the sequence diorite-tonalite-granite-aplite, the averages for the Ni/Co ratio (multiplied by 10^2) are respectively 51-35-6-4.

Zinc

The abundance of zinc in the Atnarpa Igneous Complex - 53 ppm - is about the same as average crust, granodiorite, and granite (Table D-10-7D). The element shows a clear decrease with increasing D.I. (Fig. D-10-7L).

The Zn/Fe^{++} ratio show a clear increase with increasing D.I. (Fig. M), again indicating the operation of fractional crystallisation (Taylor, 1966); the Zn/Fe^{++} ratios (multiplied by 10^5) for diorite-tonalite-granite-aplite are 269-325-385-1600, respectively.

Fluorine

Fluorine shows a clear decrease with increasing D.I. (Fig. D-10-7N), and a clear increase with increasing P_2O_5 (Fig. D-10-7P), suggesting that most of it is bound up in apatite. For pure fluor-apatite, the ratio of F/P_2O_5 is 0.33, but the slope of the regression line through the data points in Fig. D-10-7P is 0.2, indicating that the apatite is markedly fluorine-bearing, but contains other anions as well. The regression line intersects the F axis at around 200 ppm, suggesting that this much fluorine is not held in apatite, but resides elsewhere in the rocks.

Structure

All the igneous rocks of the Atnarpa Complex exhibit a schistosity imparted by the preferred dimensional orientation of the dark minerals, and at locality 5850-682929, the schistosity strikes perpendicular to the long axis of a large elongate xenolith, and so is not a primary magmatic flow structure. In thin section, some of the light minerals show deformation effects also; microcline is strained and broken, quartz mildly flattened, and biotite and chlorite bent and kinked. The effects are strongest in the hypabyssal members of the Complex; quartz is strongly flattened, and both microcline and plagioclase are brecciated. Hence the rocks have undergone syn- and/or post-metamorphic deformation in addition to the mineralogical changes. Structural analysis of the deformation in the Atnarpa Igneous Complex is described below in the section on 'Precambrian folding in the Giles Creek Synform'.

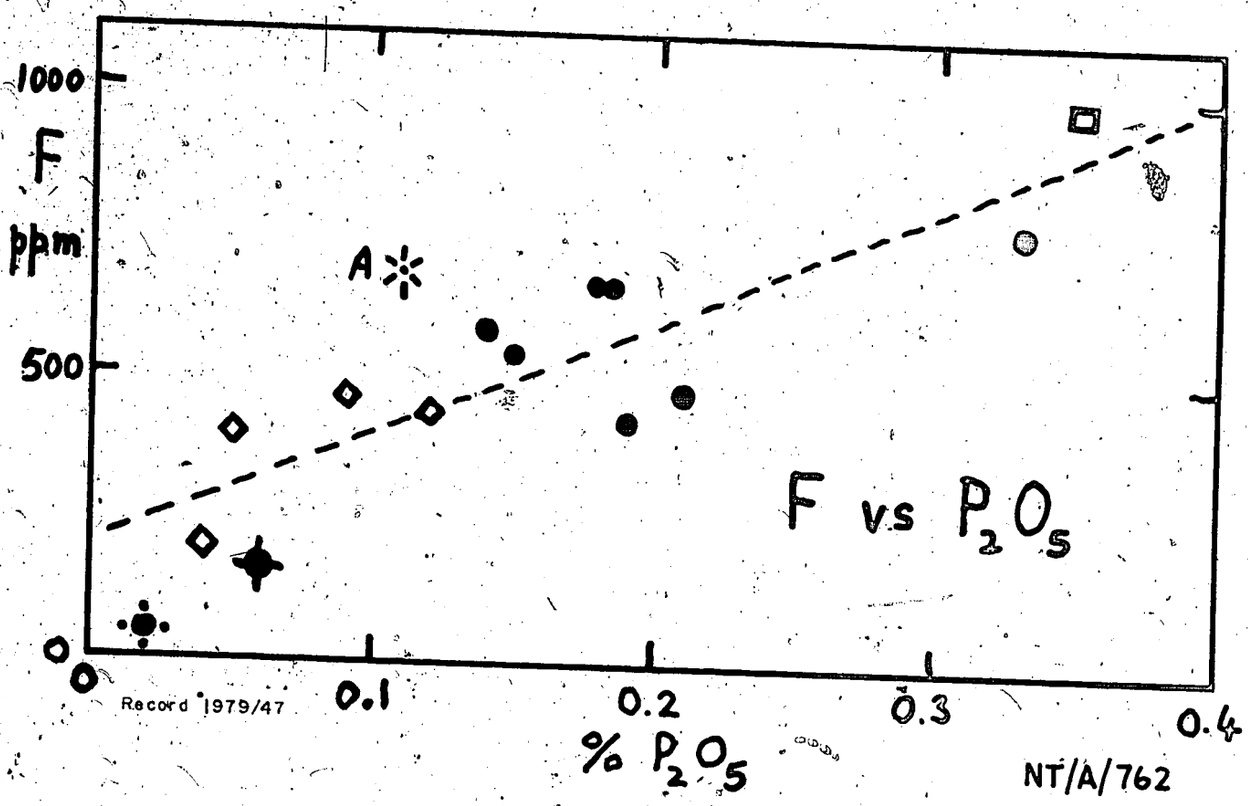


Fig. D-10-7P Variation diagram – F vs P_2O_5 Atnarpa Igneous Complex.

Metamorphism

In the Giles Creek Synform and Ruby Gap Nappe, numerous secondary minerals are present in the rocks of the Atnarpa Igneous Complex. They include: abundant sericite, epidote, and clinozoisite after plagioclase; partial or complete pseudomorphs of chlorite and sphene (± magnetite) after biotite; bleached biotite in some tonalite specimens; epidote (up to 5%) and clinozoisite in tonalite and diorite; tremolite at the margin of hornblende or actinolite; biotite and epidote after hornblende in tonalite; leucoxene after ilmenite; rare calcite after plagioclase and microcline in tonalite; recrystallised quartz in tonalite and granite; recrystallised andesine in diorite; and veins and joint-coatings of epdiosite, epidote-calcite, calcite-hematite, linonite, and linonite-epidote. The assemblage indicate that all the rocks have undergone retrogressive metamorphism of the greenschist facies.

North of White Range, the tonalite and granite of the Atnarpa Igneous Complex are thoroughly retrograded to greenschist facies assemblages, characterised by broken grains of albitised plagioclase, coarse white mica (muscovite + paragonite), epidote, clinozoisite, partly chloritised biotite, and recrystallised quartz. The albitisation of the plagioclase and formation of white mica and epidote may have taken place as follows:

$$\underset{\text{anorthite}}{6\,CaAl_2Si_2O_8} + \underset{\text{microcline}}{KAlSi_3O_8} + 3H_2O + Na^+ \rightarrow \underset{\text{albite}}{NaAlSi_3O_8} +$$

$$\underset{\text{epidote}}{3Ca_2Al_3(O(OH)Si_2O_7\ SiO_4)} + \underset{\text{muscovite}}{KAl_2Si_3AlO_{10}(OH)_2} + H^+$$

The source of the microcline was probably the tonalite itself, which in several specimens (68110040, -0041, -0045, -0198) contains irregular remnants of microcline inside albite grains. Thus, the tonalite may have been a granodiorite before the greenschist metamorphism.

Origin

The abundance of xenoliths and rafts of country rock in the diorite and tonalite members of the Atnarpa Igneous Complex, and the sharp contacts of the tonalite, granite, and hypabyssal members of the Complex against older surrounding rocks indicate the magmatic origin of the Complex. The partly observed and partly inferred order of emplacement of the members of the Atnarpa Igneous Complex, namely, diorite-tonalite-granodiorite-granite-aplogranite-hydrothermal veins, the relatively smooth trends shown by the major and most of the trace elements when plotted against Differentiation Index, and the trend to alkali enrichment on the AFM diagram all indicate that the Complex is a consanguineous suite of igneous rocks derived from a primary calc-alkaline magma that differentiated by fractional crystallisation into the various rock types observed. The rocks are I-types in the classification of Chappell & White (1974), suggesting that they are of purely igneous parentage, not melted sediments. This is supported in particular by the high cobalt content (average - 47 ppm), which is near the average for basic igneous rocks (Taylor, 1966).

The enrichment in potassium and barium in the Atnarpa Complex at first glance parallels that in the basic Mordor Igneous Complex (Langworthy & Black, 1978), which is situated 20 km to the west on the other side of the Woolanga Lineament from the Atnarpa Igneous Complex. The Mordor rocks are differentiates from an atypical part of the mantle, which by extension may also have been the source of the Atnarpa Igneous Complex. However, the fact that most of the K/Rb ratios in the Atnarpa rocks are greater than average, some markedly so, suggests that potassium may have been introduced metasomatically. This is further supported by the capricious distribution of the high barium values through the Atnarpa rocks, and by the (circumstantial) evidence for metasomatic exchange of alkalies and alkaline earths in at least one sample (-1848).

Age and Correlation

Six whole-rock samples from the Giles Creek Synform were collected for age determination in 1967, and the results of Rb-Sr analyses on these samples are set out in Table D-10-7E and shown on the normal

TABLE D-10-7E: Sample data and Rb-Sr analytical data* on rocks and minerals from the Tommys Gap metamorphics (sample 68110050) and Atnarpa Igneous Complex (remaining samples), Giles Creek Synform.

Sample Nos. ANU	Sample Nos. BMR[1]	Material dated	Rb ppm	Sr ppm	$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr$
Whole rocks						
GA5748	0049	Granite	103.6	125.8	2.390	0.7604
GA5749	0055	Tonalite	64.0	539.9	0.345	0.7114
GA5750	0050	Biotite gneiss	58.6	223.4	0.759	0.7244
GA5752	0052	Microadamellite	112.6	155.2	2.103	0.7455
GA5753	0053	Microadamellite	186.6	154.1	3.524	0.7878
GA5754	0054	Microtonalite	87.5	354.7	0.713	0.7197
Minerals						
GA5750	0050	Biotite	367.5	14.5	86.47	2.5267
GA5753	0053	Biotite	898.2	22.3	143.6	3.0815
			887.1	21.7	146.7	3.1645

* Rb and Sr contents were measured by X-ray fluorescence using calibrated standards in the whole-rock samples, and by isotope dilution in the biotite concentrates. Analyst: Miss Rosalind Bennett, BMR

1 Preceded by 6811

isochron plot in Fig. D-10-7Q. Five of the samples are from the diorite, granite, and hypabyssal members of the Atnarpa Igneous Complex, the sixth sample is from the hornblende gneiss unit of the Tommys Gap metamorphics. Four of the Atnarpa Complex samples lie within experimental error on an isochron which gives a date of 1710 ± 50 m.y. and an initial $^{87}Sr/^{86}Sr$ ratio of 0.704 ± 0.003; this is the date published by Cooper & others (1971). The fifth Atnarpa Complex sample plots below the isochron, and provides a younger age limit of 1400 m.y., using the initial ratio of the isochron, and the sixth sample, from the Tommys Gap metamorphics, plots above the isochron and provides an older age limit of 1900 m.y. using the same initial ratio also. Biotite concentrates from two of the whole-rock samples gave dates of 1500 and 1200 m.y., respectively, and so were probably affected by the Alice Springs Orogeny in the Carboniferous (Cooper & others, 1971). The Atnarpa Igneous Complex in the Giles Creek Synform was re-sampled for isotopic dating by L.P. Black (BMR) in 1973, but results are not yet available.

Two whole-rock samples (68110039, -0040) from the tonalite north of White Range lie on a Rb-Sr isochron which gives 1687 ± 23 m.y., $\lambda = 1.42$ (1719 ± 24 m.y., $\lambda = 1.39$) and an initial ratio of 0.7051 (Armstrong & Stewart, 1975), which is indistinguishable from the date of 1674 ± 50 m.y., $\lambda = 1.42$ (1710 ± 50 m.y., $\lambda = 1.39$) given by the Giles Creek Synform samples. Biotite from 68110039 gives a Rb-Sr date of 342 m.y., and biotite and muscovite from 68110040 give a Rb-Sr whole rock-mineral isochron date of 319 m.y. (Armstrong & Stewart, 1975). Four samples of white mica from the tonalite north of White Range gave K-Ar dates of 431, 401, 380, and 352 m.y., and three biotites from the same tonalite gave K-Ar dates of 889, 548, and 388 m.y. (Stewart, 1971b). The Rb-Sr mica dates give the time of greenschist facies retrogressive metamorphism as Early Carboniferous, and show that the micas contain various amounts of extraneous argon (Armstrong & Stewart, 1975).

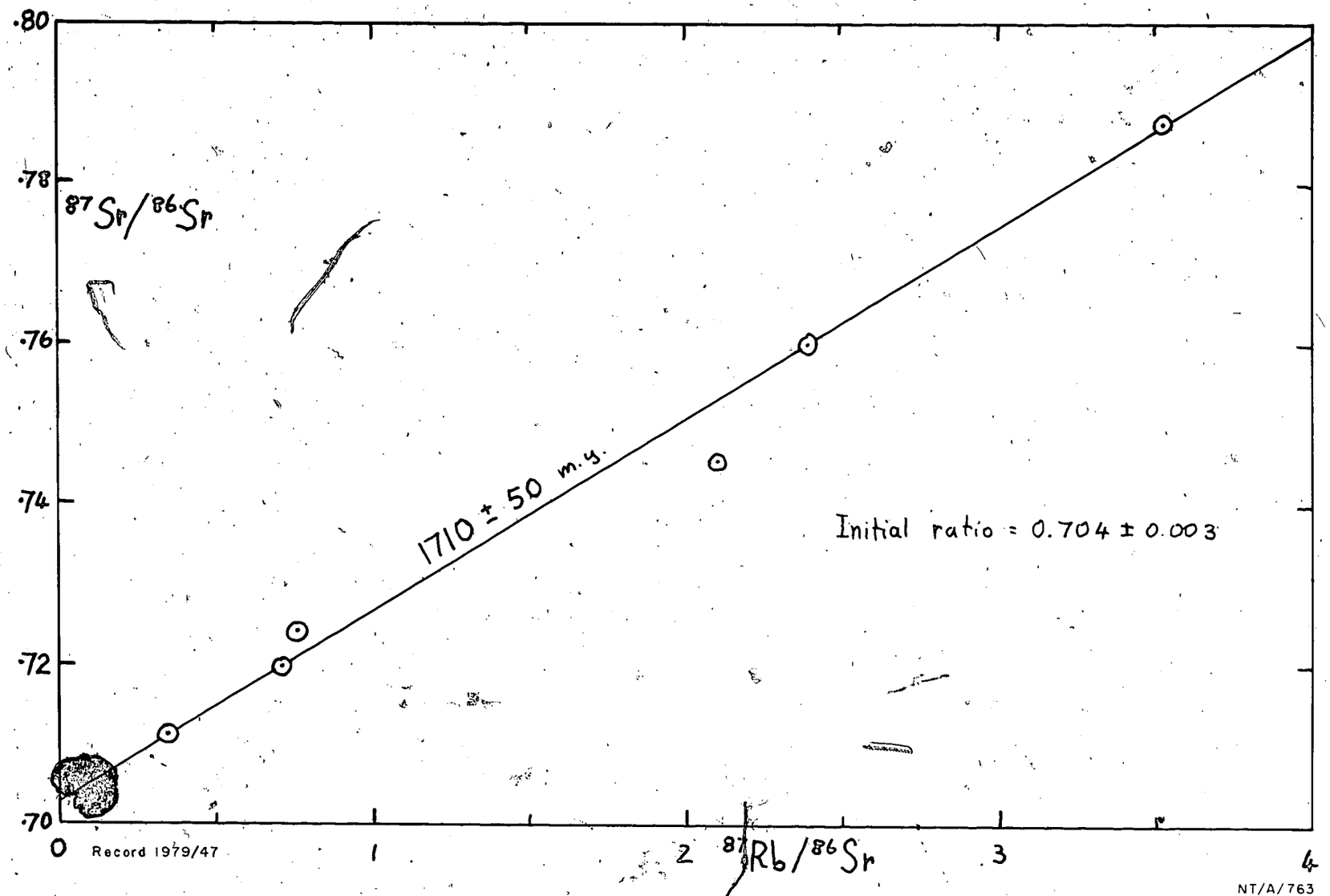


Fig. D-10-7Q Rb-Sr isochron diagram for whole-rock samples from Atnarpa Igneous Complex and Tommys Gap metamorphics, Giles Creek Synform. (See Table D-10-7E)

D-11: Mid-Proterozoic Igneous Rocks

D-11-1: Mordor Igneous Complex Bm_1, Bm_2 (A.P.L. & A.J.S.)

The Mordor Igneous Complex crops out as a large circular body in the centre of Mordor Pound (Bm_1) and as a smaller body 2 km north of Trephina Gorge (Bm_2). The former body is the main exposure of unusual mafic and ultramafic rocks and has been examined in some considerable detail by Langworthy & Black (1978). A general geological outline of the Complex is given below and the reader is referred to the above paper for detailed petrology.

(a) The main intrusive complex, Bm_1 (A.P.L.)

The main exposure of the Complex is an unmetamorphosed, roughly equant intrusion of potassic ultramafic to feldspar-rich plutonic igneous rock located 50 km east-northeast of Alice Springs, in central Australia (Fig. D-11-1A). The 6 km-diameter intrusion crops out in Mordor Pound, where it intrudes leucocratic gneiss and amphibolite of the Precambrian Arunta Block, and is almost completely enclosed by a roughly horseshoe-shaped wall of Heavitree Quartzite (basal formation of the unconformably overlying sedimentary Amadeus Basin sequence). The Complex was first examined in 1969 by Conzinc Riotinto of Australia Explorations Pty Ltd (C.R.A.), who undertook a detailed soil-geochemical, heavy-mineral, and geophysical survey of the area. Kostlin (1971) reported the occurrence of barite, brannerite, and rare pentlandite, pyrrhotite, and chalcopyrite. The soil-geochemical analyses showed low metal values, and as a result the mineral leases were allowed to expire in 1974. Scott (in Kostlin, 1971) recognised the unusual nature of the rocks, and suggested an affinity with kimberlite and carbonatite. The large (2000 gamma) magnetic anomaly indicated by reconnaissance aeromagnetic survey (Alice Springs 1:250 000 Total Magnetic Intensity Sheet (F53/B1-80)) over the Mordor Igneous Complex shows that it is a body of substantial size and magnetization. The results of detailed ground magnetic and gravity traverses by Kirton and Doe, the mapping reported by Kostlin (1971) showed that the shape of the central core of the Complex

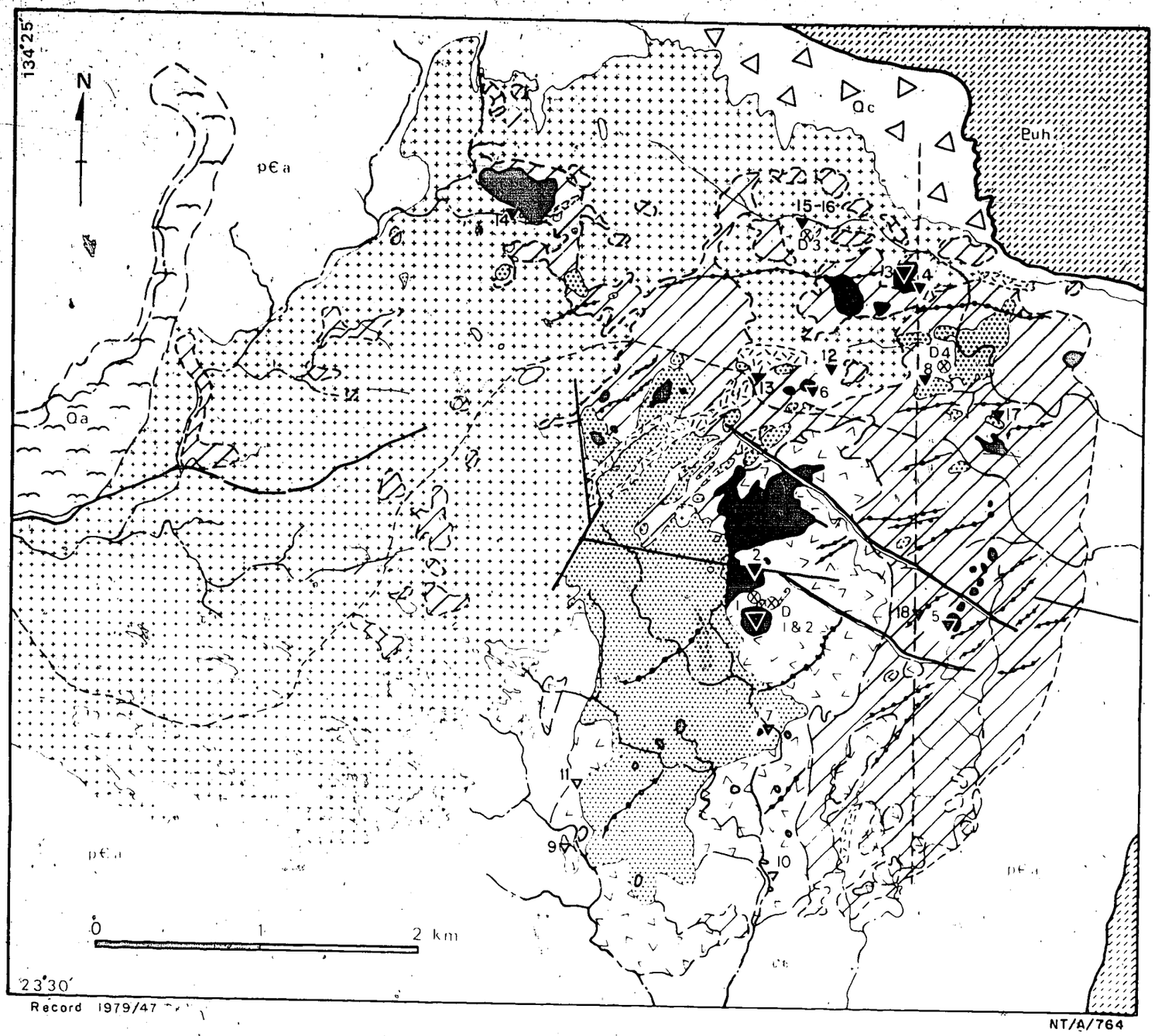


Fig: D-11-1A Geological map of Mordor Igneous Complex showing location of analysed specimens.

approximates a "vertical cylinder of diameter about 10,000 feet (3050 m) with its top surface outcropping or very shallow and its bottom surface about 20,000 feet (6100 m) deep".

A simplified geological map of the Mordor Igneous Complex is given in Fig. D-11-1A. The Complex is a consanguineous association of ultramafic, mafic and feldspar-rich plutonic igneous rocks and carbonate veins. For convenience of description the rocks may be divided into four mineralogically distinct groups.

1. Ultramafic rocks (containing greater than 70 percent mafic minerals); this group includes phlogopite dunite, phlogopite wehrlite, phlogopite lherzolite, and pyroxenite.

2. Mafic rocks (containing between 50 and 70 percent mafic minerals); this group includes phlogopite shonkinite, and melamonzonite.

3. Feldspar-rich rocks (containing less than 50 percent mafic minerals); this group includes monzonite, syenite, and pegmatite.

4. Carbonate-rich rocks.

The Complex is unaffected by deuteric alteration, and in general is well exposed; many of the contacts between units, however, are obscured by alluvium. Syenite, the principal member of the feldspar-rich group, occupies the western half of the Complex, and crops out as numerous low, rounded, weathered mounds (up to 50 m across) of coarse-grained, leucocratic, and homogeneous rock surrounded by alluvium. It is intruded by monzonite and mafic rocks (shonkinite and melamonzonite) which crop out extensively over a highly dissected area in the central part of the Complex. These are in turn intruded by numerous plug-like bodies, usually 10 to 20 m, but up to 200 m in diameter, that crop out as small conical

hills of rounded boulders, and are composed of tough, phlogopite-rich ultramafic rocks devoid of chilled margins, layering, xenocrysts, xenoliths, or brecciation. The monzonite, mafic, and ultramafic rocks are cut by numerous northeast-striking pegmatite dykes and narrow veinlets of carbonate breccia (sample 72913439).

Xenoliths are rare within the Complex; however, some small xenoliths of calc-silicate rock and microperthite-phlogopite-spinel-hypersthene-cordierite granulite occur in monzonite near its southern margin.

1. Ultramafic rocks

The ultramafic rocks are medium-grained, holocrystalline, allotriomorphic-granular, homogeneous, and rich in olivine and phlogopite. They range in composition from phlogopite dunite through hyalophane-bearing and phlogopite-rich wehrlite and lherzolite to hyalophane-phlogopite pyroxenite. Phlogopite-dunite consists of coarse serpentinised olivine, megacrysts of phlogopite (from 2 to 3 cm across), and abundant magnetite and ilmenite. Wehrlite typically contains equant, anhedral diopsidic augite, olivine (Fo_{75}), rare interstitial hyalophane and calcite, and ubiquitous poikilitic phlogopite (enclosing rounded grains of olivine and diopsidic augite). Lherzolite contains poikilitic bronzite (En_{79}) and phlogopite (enclosing olivine and diopsidic augite), equant, anhedral diopsidic augite, olivine (Fo_{75}) and interstitial hyalophane and calcite. Hyalophane-phlogopite pyroxenite typically contains more than 70 percent of diopsidic augite, megacrysts of poikilitic phlogopite and interstitial hyalophane, calcite, and rare olivine; it grades into shonkinite. Apatite, magnetite and ilmenite are common accessory minerals in all the ultramafic rocks.

2. Mafic rocks

Melamonzonite and shonkinite with allotriomorphic to hypidiomorphic-granular textures are the main mafic members of the Complex. Shonkinite, which is distinguished from peridotite and pyroxenite by an increase in the proportion of interstitial hyalophane (typically greater

than 5 percent), may be ultramafic or mafic depending upon the amount of feldspar present, and so there is a gradation between the ultramafic and mafic rocks. Melamonzonite is gradational with monzonite, but typically contains a greater amount of mafic minerals (60 to 65 percent), and less than 10 percent of orthoclase phenocrysts. Shonkinite grades into melamonzonite, but typically contains a higher proportion of mafic minerals (particularly phlogopite and olivine), and lacks orthoclase phenocrysts and oligoclase. It consists of abundant poikilitic phlogopite, orthopyroxene, rounded anhedral diopside and olivine, and interstitial barium orthoclase. Calcite, apatite, magnetite and ilmenite are accessory.

3. Feldspar-rich rocks

Monzonite is typically hypidiomorphic-granular, and consists of ubiquitous phenocrysts (from 0.5 to 2 cm long) of subhedral poikilitic orthoclase and microperthite in a medium-grained groundmass of diopside, phlogopite, oligoclase, orthoclase, and accessory calcite, apatite, quartz and opaque minerals. Less magnesian varieties of monzonite contain biotite rather than phlogopite. Syenite, the principal member of the feldspar-rich group, is coarse-grained, mesoscopically homogeneous, and hypidiomorphic-granular, and consists of euhedral to subhedral phenocrysts (up to 4 cm long) of orthoclase microperthite in a matrix of barium orthoclase, oligoclase (An_{28}), diopside, biotite, and accessory apatite, epidote and opaque minerals. The microperthite phenocrysts (in sample 73914142) comprise a host of orthoclase $(K_{0.8}, Na_{0.2})$ Al Si_3O_8, and numerous exsolved blebs of labradorite (An_{50-56}). The pegmatite dykes consist of coarse-grained plagioclase, quartz, orthoclase, and rare chlorite. Isotopic data indicate that the dykes may be comagmatic with the mafic and ultramafic rocks.

(b) Outlying intrusion near Trephina Gorge, Bm_2 (A.J.S.)

Several small peridotite plugs and numerous dolerite dykes intrude the Arunta Block. These are, however, chemically quite different from the potassic rocks of the Mordor Igneous Complex. The only known occurrence of rocks similar to those of the Complex (Bm_1) is a small highly altered body of plutonic rocks (Bm_2) that crop out in

the southwest corner of Mordor Pound, about 2 km north of Trephina Gorge (Stewart, 1971; Fig. D-11-1B). This intrusion consists of quartz diorite, monzonite, and amphibolitized ultramafic dyke-like bodies which contain several small ovoid bodies (up to 20 m in diameter) of homogeneous, medium-grained, partly altered shonkinite.

The monzonite (0087, 0089c, 4576, 4580, 4582), consists of andesine (35%), microcline (35%), hornblende (20%), biotite (6%), quartz (3%) and rare sphene, epidote, allanite, and apatite. It is a coarse-grained slightly lineated rock containing numerous spindle-shaped xenoliths of diorite.

AJS suggests the reaction:

$$3MgSiO_3 + KAlSi_3O_8 + H_2O = KMg_3AlSi_3O_{10}(OH)_2 + 3SiO_2$$

i.e. enstatite + microcline + H_2O = phlogopite + quartz for the phlogopite-rich dyke rocks enclosing the shonkinite pods. However, in Bm_1 unaltered bodies of olivine, phlogopite, bronzite, hyalophane rock have been shown (Langworthy & Black, 1978) to be in equilibrium. Thus the dyke-like bodies of phlogopite rich ultramafic rock, in Bm_2, may be similar (altered) phlogopite peridotite and the enstatite-rich pods may represent regions of only slightly different chemistry.

It is clear that the dykes, as a whole, are of unusual chemistry and are similar to the ultramafic rocks of Bm_1. Hence it is suggested that both intrusions were derived from a similar source magma enriched in large-ion-lithophile elements.

Quartz diorite (0089B, 4579, 4581, 4591) is a medium-grained rock consisting of andesine (65%), microcline (20%), quartz (5%), biotite (5%) and small amounts of hornblende, sphene, epidote, apatite and ilmenite. The diorite is intruded by the amphibolitized ultramafic dyke-like bodies. Within these dykes small ovoid bodies of ultramafic shonkinite crop out.

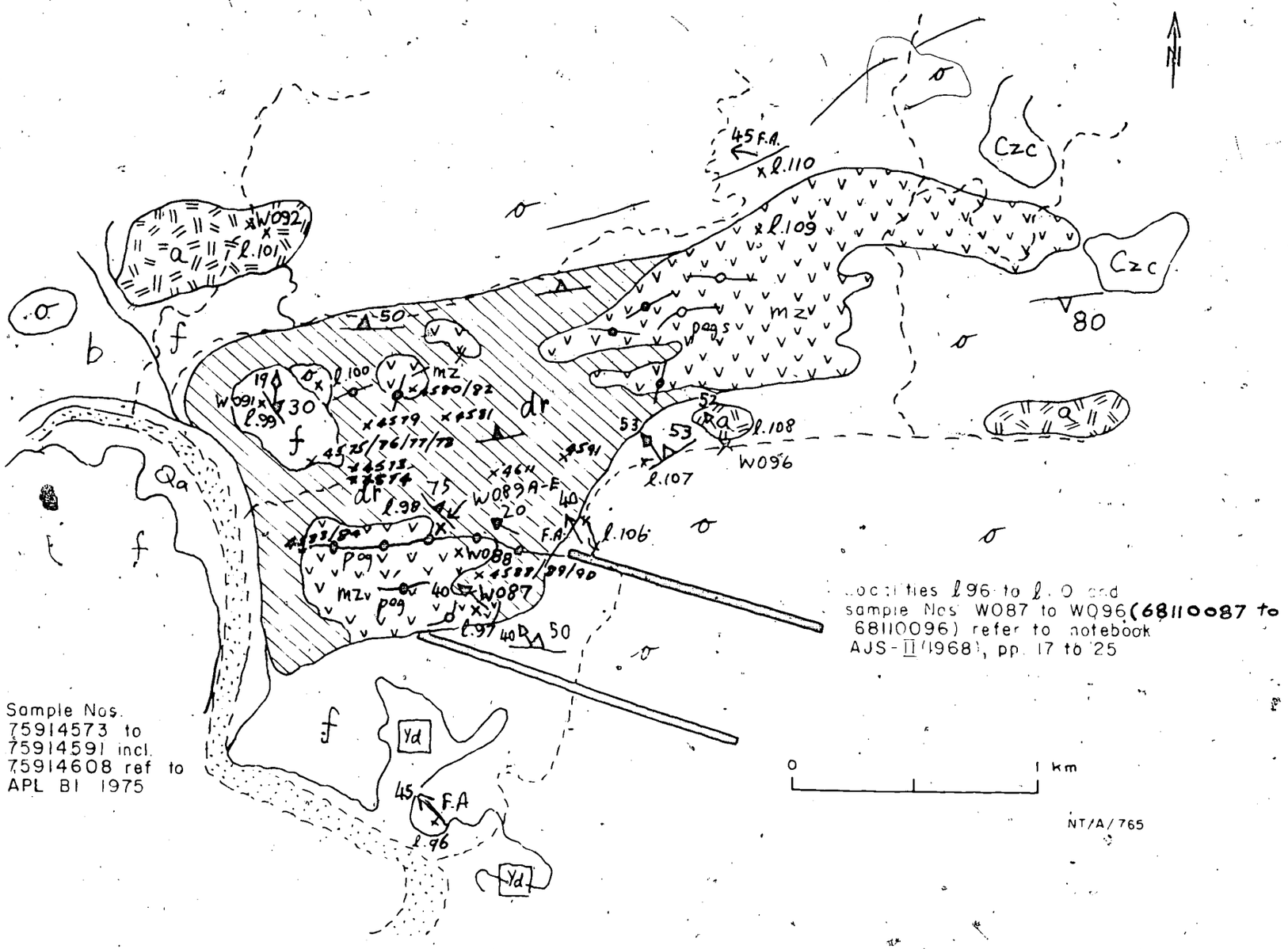


Fig. D-11-1B Geological map of Trephina Gorge offshoot of Mordor Igneous Complex.

The shonkinite consist of actinolite (60%), enstatite (20%), microcline (10%), plagioclase (6%), phlogopite (3%), and quartz (1%). Some varieties contain up to 40% biotite (or phlogopite) and the rock is similar to the phlogopite peridotite of Bm_1, however, the alteration to actinolite is a feature not observed in the Bm_1 rocks. Isotopic analysis of the shonkinite (sample 75914578) is consistent with crystallization at the same time and from the same source magma as the rocks of the Mordor Igneous Complex s.s.. Rare aplite stockworks and veinlets of carbonate-rich rock are similar to occurrences in Bm_1.

D-11-2: Unnamed Meta-ultramafic Rocks, Bp (A.J.S.)

Thirteen bodies of retrogressively metamorphosed ultramafic rock have been mapped in the southeastern part of the Arunta Block; nine (Bp_{1-9}) crop out in the Giles Creek Synform of the Arltunga Nappe Complex, two ($Bp_{10,11}$) are in the Ruby Gap Nappe, one (Bp_{12}) is in the southwestern part of the White Range Nappe (GR 5850-605975), and one (Bp_{13}) is in the autochthonous rocks west of the Nappe (GR 5751-375033).

In the Giles Creek Synform, the easternmost body (Bp_1) forms a dark conspicuous hill (5850-970905), and the westernmost body (Bp_9) crops out as a prominent knob about 5 m high and 10 m across (5850-743906). Elsewhere in the Synform, the ultramafic rocks are rather low topographic features. Two ($Bp_{8,9}$) form roughly equant bodies in the hornblende gneiss and orthoamphibolite of the Tommys Gap metamorphics, and four other similar masses ($Bp_{1,2,3,4}$) crop out in the diorite of the Atnarpa Igneous Complex. However, contacts are concealed, and evidence of the relationship between the ultramafic and surrounding rocks is lacking. The other three bodies ($Bp_{5,6,7}$) are markedly elongated in outcrop and thus appear to be dykes, and one of these (Bp_5) has a hypidiomorphic igneous texture. Hence, all the ultramafic bodies are regarded as altered plugs and dykes intrusive into the surrounding rocks. Several of the ultramafic bodies are intruded by pegmatite dykes and quartz veins, and the easternmost body (Bp_1) in the Giles Creek Synform is intruded by a dyke of micro-adamellite, and unconformably overlain by the Heavitree Quartzite of the Amadeus Basin sequence.

Six of the nine ultramafic rocks in the Giles Creek Synform are completely altered to secondary minerals, and the altered rocks can be grouped into two main types. Those of the first type are massive, medium-grained, greenish-grey (Bp_1; 71911756,-1779) or yellowish-green (Bp_9; 71911836A,-1836B), and consist mainly of antigorite and tremolite (Table D-11-2A); these are the ones that form topographically positive features. Cauliflower-like lumps of magnesite (71911760) are common on the hillside in the easternmost body (Bp_1), and at the serpentinite plug (Bp_9) the joints are filled with magnetite which is a natural lodestone, i.e., fragments of the joint-filling material have north and south magnetic poles. The second group of altered ultramafic rocks (71911782, -1797A, -1810A) are schistose, fine-grained, variegated red and grey-green, and consist mainly of calcite, chlorite, and hematite; these rocks commonly occur as fragments in vein quartz, and are topographically inconspicuous. One less altered ultramafic sample (Bp_1; 71911779) contains remnants of original clinopyroxene and brown hornblende, and one (Bp_5; 71911785) is only slightly altered and consists almost wholly of euhedral to subhedral prisms of pale green hornblende (98%); epidote (2%) occurs as small tapering grains between the hornblende prisms, and as a fine-grained cloudy alteration product in the cores of some hornblende grains; sphene is accessory. The rock appears to be an igneous hornblendite.

The small ultramafic outcrop (Bp_8) in the Tommys Gap metamorphics of the Giles Creek Synform comprises several pods about 1 m across of tough, dense, fine-grained, faintly laminated, dark brown rock. It consists of granular bright orange grossularite (or hibschite, i.e., hydro-grossular, 60%), clino-amphibole (25%) pleochroic from pale green to pale pink and much altered to quartz + limonite, hematite (10%), quartz (5%), and vivid yellow-green epidote in veinlets; sphene is accessory (71911817).

The two ultramafic masses in the Ruby Gap Nappe form prominent hills, and are closely associated with the Atnarpa Igneous Complex. The larger body (Bp_{11}), in the southeast corner of RIDDOCH, is surrounded by diorite and granodiorite of the Atnarpa Complex, and the smaller body

TABLE D-11-2A: Visually estimated modal analyses of altered ultramafic rocks, Giles Creek Synform

Map unit	Bp_1	Bp_1	Bp_2	Bp_2	Bp_3	Bp_3	Bp_9	Bp_9
Sample No *	1756	1779	1782	1797A	1807	1810A	1836A	1836B
Antigorite	50	-	-	-	-	-	73	90
Chrysotile	-	-	-	48	-	-	20	-
Serpophite	-	5	-	-	-	-	-	-
Chlorite	5	-	15	20	15	30	5	5
Tremolite	40	30	-	-	-	-	-	-
Actinolite	-	23	-	-	-	-	-	-
Hornblende	-	10	-	-	-	-	-	-
Clinopyroxene	-	10	-	-	-	-	-	-
Iron Oxide	5[H]	2	10[H]	2	15[H]	35[H]	2[M]	5[M]
Calcite	-	-	50	30	65	30	-	-
Quartz	-	-	25	-	5	5	-	-

* Preceded by 7191 H = Hematite, M = Magnetite

(Ep_{12}), 2 km northwest of Amarta Waterhole in FERGUSSON RANGE, is situated between Atnarpa Complex diorite, and hornblende and biotite gneiss of the unnamed unit pGx. The larger body (Ep_{11}) consists chiefly of serpentinite composed of antigorite, colourless chlorite, talc, tremolite, and opaque matter (69090234 = AS712/3). In contrast, a smaller outlier of the same body at the confluence of the Hale River and Star Creek is amphibole-rich, and consists of coarse prismatic actinolite or hornblende (78%), clinopyroxene (20%), and clinozoisite (2%) after plagioclase (69090245 = AS735/2). With larger amounts of clinozoisite and/or original plagioclase, the rock grades into amphibolite (69090248 = AS737/5; -0249 = AS737/6). The smaller ultramafic mass (Ep_{10}; 69090256 = AS741) is similarly amphibole-rich, and consists of coarse subhedral actinolite or hornblende, colourless chlorite, epidote, and interstitial sericite after plagioclase. The rock is a hornblendite.

The ultramafic body (Ep_{12}) in the southwestern part of the White Range Nappe forms a hill (5850-605975) about 650 m across, 3 km south of Paddys Plain. The rock is massive, mottled grey-green and brown, coarse-grained, and consists of prismatic tremolite (95%) and clinopyroxene (5%) much altered to limonite (68110114). Malachite coats slickensided joints in the body.

A prominent pod (Ep_{13} but labelled Lpy on [illegible] preliminary edition; GR 5751-375033) about 500 m long of altered peridotite crops out 4 km north of Trephina Gorge, in the autochthonous rocks west of the White Range Nappe. The rock is very tough, grey, fine-grained, faintly schistose, and consists of stubby grains of anthophyllite (60%), olivine (20%) much altered to a meshwork of iron oxide and serpophite (amorphous serpentine), enstatite (15%), bright green spinel (5%), and accessory calcite (68110093A). The pod is surrounded by a shell of hornblende gneiss several metres thick.

All the ultramafic bodies except the hornblendite dyke have undergone greenschist facies retrogressive metamorphism; the metamorphism is presumably the same one that affected the rocks of the Tommys Gap metamorphics and the Atnarpa Igneous Complex during the Carboniferous. Apart from unit Ep_8, which appears to be an iron-rich calc-silicate, the ultramafic rocks are igneous intrusions, and presumably originated from the mantle. The ones in the Giles Creek Synform were intruded after emplacement of the plutonic members of the Atnarpa Igneous Complex, but before intrusion of the hypabyssal members. Hence, they are the same age, 1710 $\pm$ 50 m.y., as the Atnarpa Complex, and the ultramafics outside the Giles Creek Synform may be of this age also.

D-12: Migmatites, granites and igneous rocks formed during the Ormiston Phase of deformation (1.1 - 1.0 b.y) (LAO) - Introduction

A period of Late Proterozoic thermal activity is recognised, and has been isotopically dated, throughout the southern Arunta Block extending from southern LAUGHLEN in the east to as far as HERMANNSBURG in the west. Basement rocks farther west than HERMANNSBURG have not been studied. This thermal event is typified by the formation of migmatites and anatectic granites and isotopic redistribution in other granitic rocks. It is considered by Marjoribanks (1975) to have accompanied the Ormiston Phase of deformation in the Wigley and Alice Springs Blocks in HERMANNSBURG. The relationship between this thermal episode and the Ormiston Phase of deformation has now been recognised elsewhere in the Wigley Block and to a lesser extent in the Alice Springs Block.

D-12-1: Jessie Gap gneiss, Ej (New name) (L.A.O.)

Definition

This unit is a granitic gneiss which crops out in the eastern part of ALICE SPRINGS and the western part of UNDOOLYA as rubbly low to moderately high, rounded hills. The unit has an even reddish-brown texture on aerial photographs. It is named after Jessie Gap, a water-gap in the Heavitree Quartzite (Euh) about 6 km south of Undoolya homestead, in UNDOOLYA. The type locality is in ALICE SPRINGS at GR 5650-968788.

Relationships

The northern part of the Jessie Gap gneiss abuts the Charles River Fault, and to the south it is unconformably overlain by the Heavitree Quartzite. The western margin of the unit is apparently concordant with metasediments (pGpb) and consists of granite and pegmatite veining the metasediments and granitic gneiss. In the northeast, it contains a greater amount of amphibolite and grades into Unassigned interlayered gneisses and migmatite. Dolerite (Eds) and pegmatite dykes intrude the unit, and veins of pegmatite, granite and aplite both parallel and crosscut the foliation.

Lithology

The Jessie Gap gneiss is typically an even-grained, medium-grained, poorly foliated gneiss of granitic composition (Table D-12-1A). In some areas it contains potash feldspar porphyroblasts up to 2 cm in length. Sillimanite occurs in specimens 75914701 and 75914711.

Towards the northeast margin the Jessie Gap gneiss consists of poorly exposed interlayered granitic gneiss, amphibolite, hornblende gneiss, and augen gneiss. Epidote forms patches in the rock and coats joint faces. In the north part of the unit, in UNDOOLYA, the gneiss contains amphibolite and both discontinuous biotite-rich layers and patches of crosscutting quartzofeldspathic mobilisate. Table D-12-1B lists the compositions of three specimens of hornblende-bearing rock collected from the north and northeast part of the Jessie Gap gneiss.

At GR 5750-031774 in UNDOOLYA medium-grained metamorphosed biotite granite crops out as isolated boulders within alluvium. These consist of perthitic microcline and strongly sericitized and saussuritised plagioclase (together 72%), quartz (25%), chloritised biotite (3%), and a small amount of chlorite (rimming and along fractures in opaque grains), allanite (partly rimmed by clinozoisite), epidote, apatite and zircon (75914703).

Metamorphosed feldspar porphyry caps a hill of granitic gneiss in UNDOOLYA at GR 5750-076753. Specimen 75914705 collected from the porphyry consists of plagioclase and poikilitic potash feldspar (together 68%), quartz (30%), opaque grains (2%) and accessory muscovite, poikilitic apatite and sphene. Potash feldspar megacrysts are up to 9 mm long.

Elsewhere the Jessie Gap gneiss rarely consists of granitic gneiss interlayered with schistose muscovite-biotite gneiss (for example 73913790), banded biotite gneiss, biotite-sericite schist and magnetite-bearing gneiss.

TABLE D-12-1A: JESSIE GAP GNEISS, Bj

Granitic gneiss

Specimen No.	Sheet area	Field description	Feldspar	Quartz	Biotite	Muscovite	Accessories
73913785	ALICE SPRINGS	Granitic gneiss	Microcline 35% Albite 35%	25%	-	5%	Opaque grains, epidote
73915704	UNDOOLYA	Porphyroblastic granitic gneiss	Microcline) Plagioclase) 69%	30%	1%	Small amount	Apatite, chlorite, epidote, ?tourmaline
75914701	UNDOOLYA	Granitic gneiss	Microcline) Plagioclase) 72%	25%	2%	Small amount	Fibrolite 1%, garnet, zircon
75914711	UNDOOLYA	Grey granitic gneiss	Kspar?) Plagiocalse) 67%	30%	3%	Small amount	Sillimanite and fibrolite, apatite, zircon, opaque grains.

TABLE D-12-1B: JESSIE GAP GNEISS, Bj,
HORNBLENDE-BEARING ROCKS

Specimen No.	Amphibole	Pyroxene	Feldspar	Quartz	Other
73915702	Hornblende 73% (green and blue-green) Cummingtonite 1%	-	Plag 7%	10%	Muscovite (after plag) 7%, epidote (after plag) 1%, opaque grains 1%, chlorite
73915703	Hornblende 35% (ranges from polygonal brownish-green grains to a small amount of blue-green grains)	Cpx 7%	Plag 50%	6%	Sphene 1%
75914706	Hornblende 15% (green and blue-green	-	Plag, Kspar? 60%	20%	Chlorite 5%, apatite, sericite, epidote, calcite.

Structure

The Jessie Gap gneiss is typically poorly foliated; at GR 5650-955783 in ALICE SPRINGS the foliation is axial-plane to mesoscopic rootless quartzofeldspathic fold noses. In some areas the foliation is folded on a mesoscopic scale. At the type locality the fold hinges are angular. Locally the unit is cut by a fracture cleavage or by a second foliation outlined by biotite segregations.

Origin

This unit is characteristically homogeneous, but in places contains amphibolite and granite, and includes what may be relict sedimentary layering, now partly reconstituted to layered gneiss.

The Jessie Gap gneiss may be derived from quartzofeldspathic sediments and small bodies of mafic rock. Metamorphism accompanying the Ormiston Phase of deformation is thought to have granitised the quartzofeldspathic rocks and possibly generated acid plugs (e.g. 75914703), flows (e.g. 75914705), dykes and veins.

Age

The Jessie Gap gneiss is considered to have been granitised during the Late Proterozoic Ormiston Phase of deformation. Late Proterozoic dolerite dykes (Bds) intrude the gneiss.

D-12-2: Pegmatite dykes, (peg), related to the Jessie Gap gneiss (L.A.O.)

Northwest-trending pegamtite dykes and a small amount of vein quartz intrudes the Emily Gap schist (pGpe), Sadadeen Range gneiss (pGpd) and the Teppa Hill metamorphics (pGpt) about 4 km east and west of the Alice Springs township in ALICE SPRINGS. The dykes are commonly up to 3 m wide and locally form low ridges about 2 km in length. Dolerite dykes (Bds) cut the pegmatite. The pegmatite consists of pink and white feldspar, quartz and muscovite; in places garnet or epidote is present.

The metamorphic event accompanying the Ormiston Phase of deformation may have homogenised the Jessie Gap gneiss (Bj) and generated the pegmatite and granite veins marginal to the gneiss, and the pegmatite dykes and quartz veins near the Alice Springs township. However because the dykes do not appear to be affected by the second major regional fold phase, which is also correlated with the Ormiston Phase of deformation, then the acid intrusions may have formed just after the Ormiston Phase of deformation. If this reasoning is valid then the pegmatite formed somewhere between about 1050 m.y. and the intrusion of the Late Proterozoic dolerite.

D-12-3: Unnamed migmatised gneiss, Bx, in the Wigley Block (L.A.O.)

Definition and Relationships

This unit of migmatised gneiss crops out as low to moderately high rounded hills in two areas north and northwest of the Alice Springs township in ALICE SPRINGS. It consists of garnet-biotite gneiss, amphibolite, porphyroblastic and augen gneiss, biotite gneiss, and granitic gneiss and is distinguished from surrounding units by its mobilisate component which generally makes up 10% or more of the rock. Where the mobilisate makes up more than about 50% of the rock the term migmatite has generally been used as the name of the rock type. The boundary between Bx and other units is transitional and poorly defined, and is based on the presence or general absence of mobilisate. The mobilisate occurs as cross-cutting and conformable layers of granitic composition, and as irregular discordant patches of even-grained granite. Granitic gneiss is partly intrusive into other rock types of the unit and near Painta Spring contains xenoliths of biotite gneiss. Dolerite dykes (Bds) intrude the unit. The type locality is at Wigley Waterhole at GR 5650-860860.

Lithology

Northwest of the Alice Springs township between Painta Spring and New Well the unit consists largely of equigranular medium to coarse-grained granitic gneiss, porphyroblastic gneiss containing feldspar megacrysts up to 6 cm across, and banded biotite gneiss. Near Painta Spring the granitic gneiss contains rafts of banded biotite gneiss and augen gneiss (Photo D44). In some places the granitic gneiss contains feldspar megacrysts up to 1 cm in length and consists of feldspar, quartz, biotite, muscovite and magnetite.

Three kilometres southeast of Painta Spring migmatite, granitic gneiss, biotite gneiss and augen gneiss form a wedge-shaped outcrop within Unassigned gneiss, pG. A specimen of the augen gneiss is strongly deformed and comprises andesine (50 to 55%), quartz (30%), biotite (10 to 15%), opaque grains (including possible pyrite grains; 3%), and small amounts of muscovite, apatite, allanite, clinozoisite and epidote (73913847). The migmatite ranges from granitic to granodioritic in composition.

South of the above mentioned wedge-shaped outcrop but north of Simpsons Gap the gneisses are migmatitic in part and consist of garnet-biotite gneiss, amphibolite (73913992), porphyroblastic gneiss containing feldspars up to 12 cm across, augen gneiss with feldspars up to 6 cm across (Photo D47) and a small amount of quartzofeldspathic gneiss (Photo D45). Migmatite and agmatite crop out within these migmatised gneisses (Photo D48).

North of the Alice Springs township at Wigley Waterhole biotite gneiss, augen gneiss and amphibolite are interlayered and veined with granite. The mobilisate fraction commonly exceeds the amount of country rock. Some parts of the granite are deformed; the only specimen examined petrographically consists of medium-grained sodic plagioclase (partly fractured, deformed twin lamellae, partly sericitised) and microcline (together 50-55%), elongate and agregates of quartz with undulose extinction (40-45%), biotite and opaque grains (together 5%) and a small amount of epidote and apatite (73913899). Part of this outcrop is fractured; epidote lines the fractures and zones of feldspathisation extend up to about 5 cm either side of the fractures.

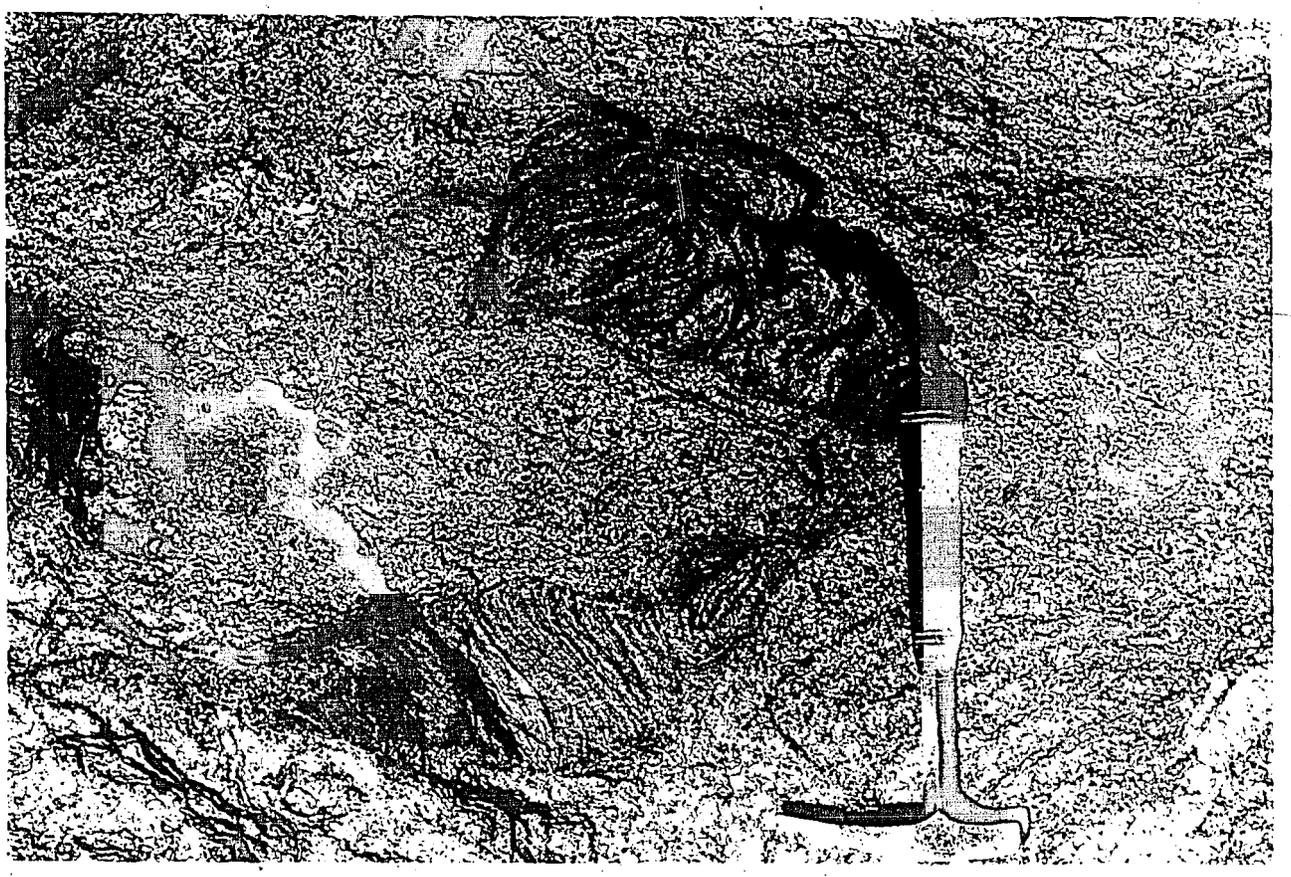


Photo D44: Xenoliths of biotite gneiss within granitic gneiss near Painta Spring, GR 5650-677909. (M/2167)

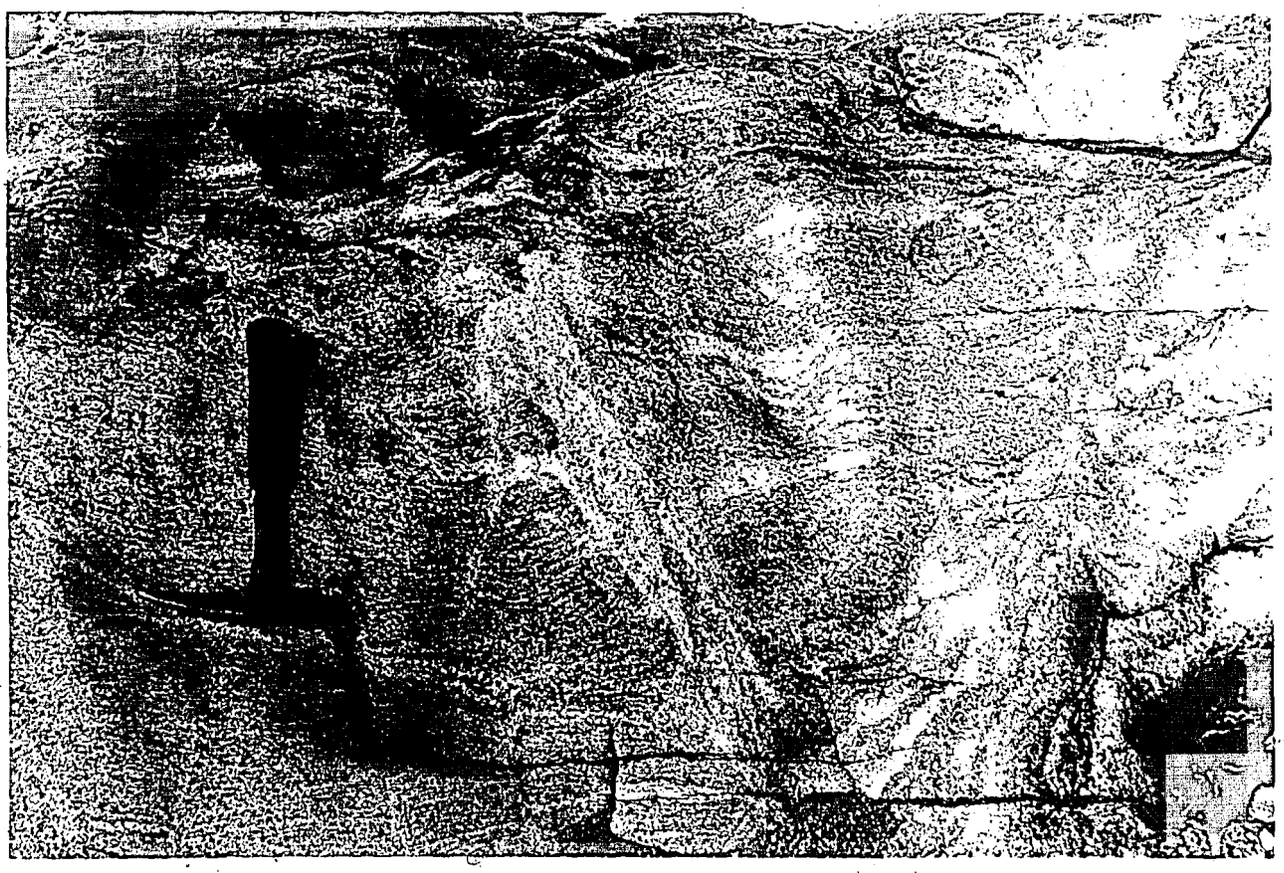


Photo D45: Quartzofeldspathic gneiss cut by granite veins. GR 5650-680829. (M/2168).

Photo D46: Mesoscopically flow-folded banded gneiss and amphibolite cut by granite veins. GR 5650-678852. (M/2168).

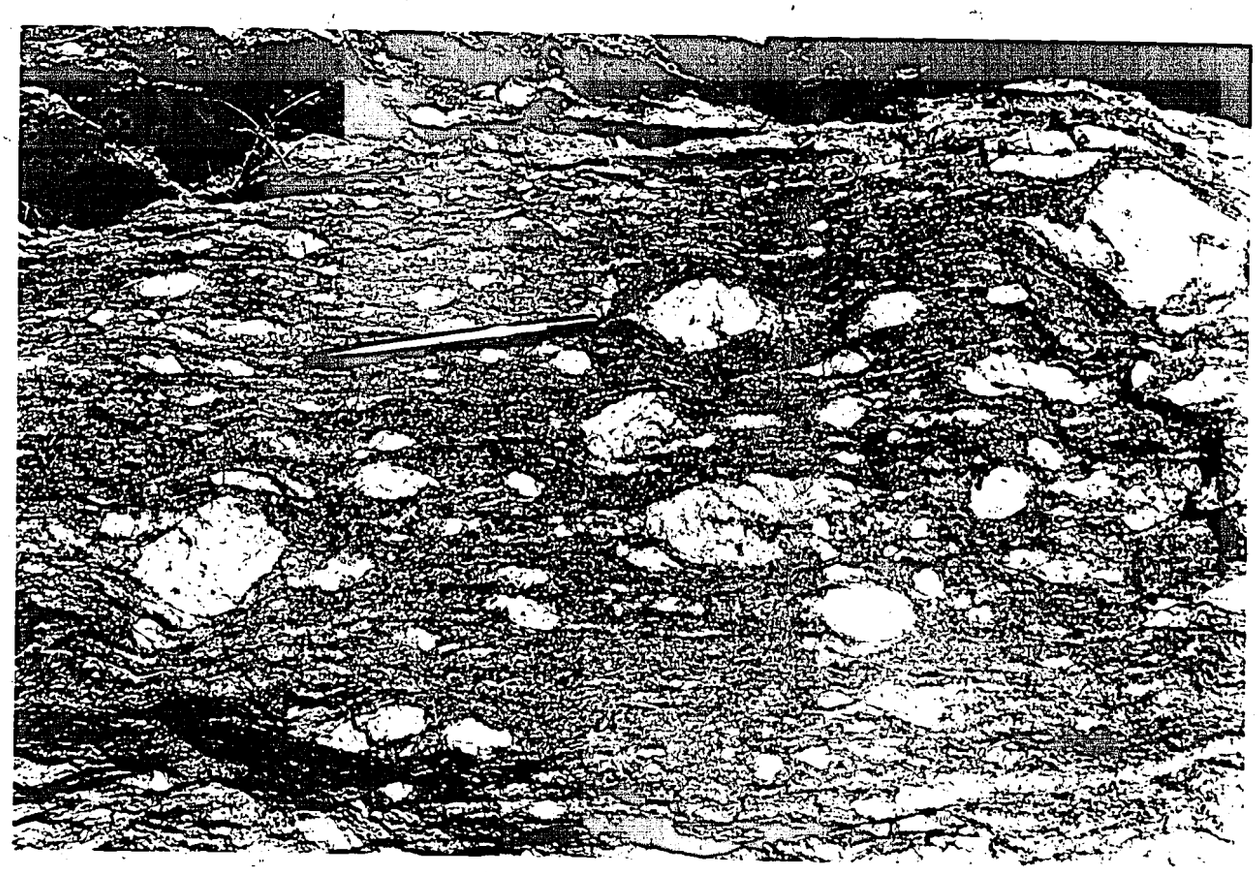


Photo D47: Augen gneiss in the Unnamed migmatised gneiss, (Bx), in the Wigley Block (pen 14 cm long). GR 5650-677859. (M/2168).

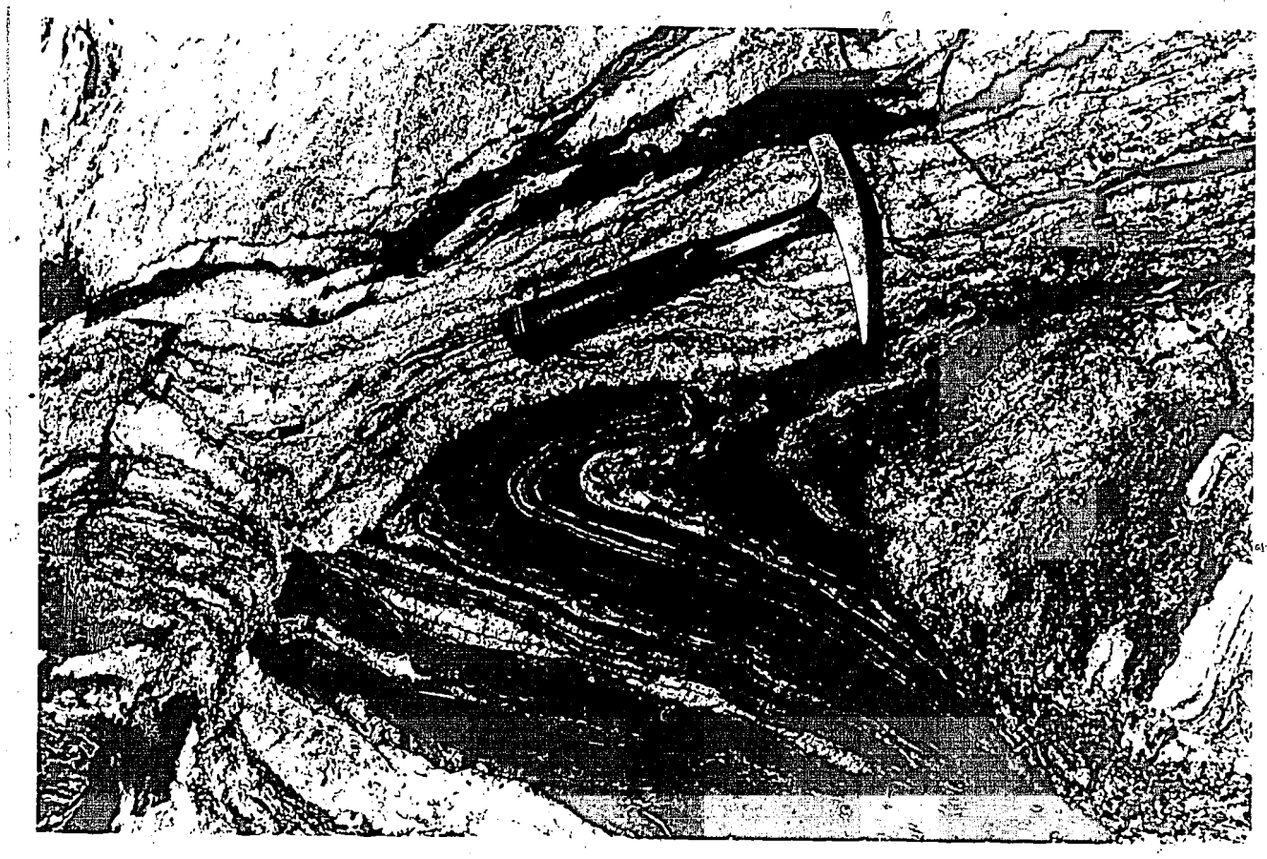


Photo D48: Migmatite; folded amphibolite layer within quartzofeldspathic mobilisate. GR 5650-678850. (M/2168).

Photo D49: Mesoscopic isoclinal folds outlined by leucocratic layer - appears to fold earlier structure. GR 5650-729871. (pen is 15 cm long). (M/2166).

Structure

Foliated amphibolite defines a macroscopic southwest plunging synform about 4 km north of Simpsons Gap. At GR 5650-729871 a quartzo-feldspathic layer is doubly folded on the mesoscopic scale; the foliation is axial plane to the isoclinal second folds (Photo D49, 50). Flow folds commonly occur in the migmatite (Photo D46); at a few localities quartzo-feldspathic material completely disrupts the layering and forms agmatite.

D-12-4: Old Hamilton Downs Gneiss, Ew
(New Name) (L.A.O.)

Definition

Granitic gneiss crops out over a wide area from near Simpsons Gap in ALICE SPRINGS westward to MACDONNELL RANGES and is named after the Old Hamilton Downs homestead near the headwaters of Jay Creek in MACDONNELL RANGES. The unit forms low to moderately high rounded hills, and the photopattern is typical of granite terrain. The Old Hamilton Downs Gneiss is distinguished from the surrounding interlayered gneisses and amphibolite. The type locality of the unit is at GR 5650-486858 along the track to the homestead.

Relationships

The Old Hamilton Downs Gneiss is cut to the northwest and south by Palaeozoic faults, interfingers with the Charles River gneiss (pGq) to the east and grades rapidly into interlayered gneiss and amphibolite (pG) to the northeast. Dolerite dykes (Eds) and rare pegmatite veins intrude the unit.

Lithology and Structure

The unit is homogeneous and medium-grained. In hand specimen, 73913997 appears typical of the granitic gneiss and consists of sericitised and saussuritised plagioclase (about 40%), quartz (30%), perthitic microcline (about 25%), green biotite (2%), and a small amount of muscovite and opaque grains. In places, muscovite is coarser-grained than the quartz and feldspar and makes up 5 percent of the rock (for example 73913913). In MACDONNELL

Photo D50: Flattened parallel fold; schistocity is parallel to the axial-plane. (pen is 15 cm long). GR 5650-729871. (M/2166).

RANGES to the west, the unit is more aptly described as muscovite gneiss. The gradational northeast margin of the Old Hamilton Downs Gneiss in ALICE SPRINGS consists in part of migmatised biotite gneiss; granite intrudes and pervades banded biotite gneiss.

The foliation of the Old Hamilton Downs Gneiss is faint and outlined by partly recrystallised lenticular quartz aggregates. Locally the unit is highly deformed and adjacent to faults consists of schistose muscovite gneiss.

Origin and Age

The Old Hamilton Downs Gneiss is considered to be an anatectic granite which has a migmatitic margin in the northeast, and possibly an intrusive contact against layered gneisses and amphibolite (pCq) to the east. Anatexis and migmatisation may be comparable in age with the regional migmatite event which affects the southwestern part of the Arunta Block and has been dated at about 1050 m.y. (Marjoribanks & Black, 1974).

D-12-5: Alice Springs Granite, Bga
(New Name) (L.A.O.)

Definition

This homogeneous body, named after the Alice Springs township, crops out north of the township in ALICE SPRINGS. Isolated granitic outcrops between the two west-trending Heavitree Quartzite Ridges south of the township may be Alice Springs Granite which has been thrust from the north as part of the Blatherskite Nappe. Typical exposure of the Granite can be seen around the Alice Springs Telegraph Station and characteristically consist of orange, rounded, bouldery hills typical of a granite terrain.

Relationships

The Alice Springs Granite has a conformable and partly interlayered contact with the Sadadeen Range gneiss (pGpd). To the north the Granite is cut by the Charles River Fault. Dolerite dykes (Bds), and at the margin, pegmatite and rare aplite dykes intrude the Granite.

Lithology

Only a brief petrographic examination of the Granite has been made. Specimen 73913999B comprises microcline (partly perthitic) and albite (together 65%), quartz (30%), greenish-brown biotite (3%), muscovite (2%) and accessory zircon, apatite and opaque grains. Biotite and albite are partly altered to chlorite and epidote respectively. In places, the granite contains white microcline laths up to 10 cm long; the matrix is medium-grained.

The marginal area of the Alice Springs Granite is in most places gneissic. In the north where the Granite is cut by the Charles River Fault the rock is brecciated, veined by epidote and consists of altered plagioclase, perthitic microcline, quartz, muscovite, chlorite and clinozoisite (73913799).

Correlation

To the south of the Alice Springs township medium, even-grained biotite-muscovite granitic gneiss and schistose granitic gneiss crop out within the nose of the Blatherskite Nappe. In places the gneiss contains feldspar megacrysts up to 4 cm long and is cut by muscovite-bearing pegmatite veins and sheared porphyry. The granitic gneiss is similar in composition to both the Alice Springs Granite and the Jessie Gap gneiss. However, the thrusting associated with the Nappe is thought to be essentially a north to south movement; hence the granitic gneiss is considered to be Alice Springs Granite which was foliated during thrusting.

Age

Forman, Milligan & McCarthy (1967) give an age of 2900 m.y. (λ = 1.39) for a sample of Alice Springs Granite collected 6.5 km north-northwest of the Alice Springs township. This date was revised to 2250 m.y.

(λ = 1.39) assuming a low initial Sr^{87}/Sr^{86} value (G.H. Riley, personal communication in Compston & Arriens, 1968), but is very imprecise as the Sr^{87} enrichment is only 3.6% (Compston & Arriens, 1968). On the basis of mineral dates Compstone & Arriens (1968) suggest the granite was affected by an isotopic redistribution event at 1130 m.y. L.P. Black (BMR, personal communication, 1977) obtained a minimum age for the Alice Springs Granite of about 1100 m.y. from muscovite assuming an initial Sr^{87}/Sr^{86} ratio of .71. Thus the Alice Springs Granite may have intruded the Hayes Metamorphic Complex or at least been warmed during the Ormiston Phase of deformation and migmatisation.

D-12-6: Undivided granite, (Bg), pegmatite, (peg), and porphyry, (po), in the Alice Springs Block (L.A.O.)

In the west of ALICE SPRINGS granite plugs intrude the Simpsons Gap Metasediments (Bas) and the Burt Bluff Gneiss correlate (Bab?) north of the Chewings Range. The granite bodies are up to 1.5 km long and are intruded by dolerite dykes (Bds). Northeast-trending pegmatite dykes intrude the Burt Bluff Gneiss north of the Chewings Range and are probably related to the granite.

The granite is medium to coarse-grained and pegmatitic in part and consists of feldspar, quartz and muscovite. Biotite occurs locally and euhedral garnets up to 7 mm across are present in a pegmatitic granite which intrudes schist and quartzose rocks of the Simpsons Gap Metasediments.

The granite intrudes open mesoscopically folded quartzose rock of the Simpsons Gap Metasediments and is itself intruded by Late Proterozoic dolerite dykes (Bds). Thus the unnamed granite intruded the Metasediments after the folding and before the dyke intrusion. If the open folds are related to the Ormiston Phase of deformation then the Undivided granite and pegmatite formed between about 1050 m.y. and the intrusion of the Late Proterozoic dolerite.

Porphyritic plugs of dacitic composition intrude the Burt Bluff Gneiss (Bab) and are partly recrystallised and retrogressed to low amphibolite facies assemblages. Specimen 73913737 (GR 5650-556718) is dark brown on the weathered surface, dark grey on fresh surfaces and consists of feldspar (some subhedral plagioclase phenocrysts: 33%), quartz (30%), biotite (15%), strongly blue-green hornblende (15%), clinopyroxene (5%), opaque grains (2%) and lesser amounts of epidote, sphene and muscovite. The clinopyroxene is partly uralitised, sphene rims some opaque grains and feldspar is partly altered to muscovite. Hornblende aggregates and plagioclase laths are up to 4.5 mm in length and matrix grains are recrystallised and fine-grained. Specimen 73913827

(GR 5650-592716) is a black and white speckled rock which in thin section is noticeably porphyritic and consists of subhedral plagioclase and a few microcline phenocrysts up to 4.2 mm long in a matrix composed of quartz, biotite, green and some very strongly blue-green hornblende, epidote, clinozoisite, opaque grains, sphene and apatite. Hornblende-biotite aggregates are up to 2 mm long, sphene rims opaque grains and plagioclase grains are commonly highly altered to epidote and clinozoisite. Matrix grains are recrystallised and fine-grained.

D-12-7: Gumtree Granite (Pgg) (A.R.A.)

A.R. Allen refers to this unit as the Gumtree Granite Suite in his publications.

Definition

The Gumtree Granite consists of a main pluton, several small satellitic bodies or apophyses, which show no surface connection to the main pluton, and numerous dykes. The main pluton is elliptical body 7 km long and 3 km wide, and crops out between Harry and Gum Tree Bores. (5651-958295 to 5751-041263). Most of the pluton is intruded into the Utnalanama Block, to the north of the Harry Creek Deformed Zone, and which intersects the southern portion of the pluton. However, some of the offshoots have intruded the Ankala Block. The Granite is named after Gumtree Bore (5951-992288). The type locality is at 5751-997282 where samples were collected for Rb-Sr age determination.

Relationships

The Gumtree Granite cuts and is thought to intrude the Utnalanama granulite, the Harry Anorthositic Gabbro, the Erontonga metamorphics, the Johannsen Metagabbro and offshoots of the Wuluma granitoid. Contact skarns have formed where offshoots of the Gumtree Granite have intruded calc-silicate rocks of the Ankala gneiss. The Gumtree Granite is thought to be contemporaneous with a swarm of pyroxene dolerite dykes.

The southern margin of the main pluton has been obliterated by intense recrystallisation within the Harry Creek Deformed Zone. The northern and eastern margins are poorly delineated because of poor exposure in the northern two-thirds of the pluton. However, a series of outcrops of a more equigranular phase appear to mark the northern margin of the pluton close to the Stuart Highway - Pinnacles road. The western part of the pluton is even more poorly exposed. The Bald Hill fault appears to truncate the pluton in the west.

Lithology

The main porphyritic phase of the Gumtree pluton, the marginal phase, and most of the offshoots are composed of biotite granite. The main pluton is markedly porphyritic, and contains abundant alkali-feldspar phenocrysts up to 3 cm in length, which are crudely aligned with both the foliation and the lineation. Marginal parts of the pluton are less porphyritic. The only variants are rare alkali-feldspar poor rocks (e.g. the fine-grained phase of the large satellite body). The primary mineralogy in descending order of abundance is microcline microperthite, quartz, plagioclase, biotite, sphene, allanite, magnetite, apatite, zircon, fluorite and tourmaline. Sphene and allanite are coarse, abundant and widespread and are characteristic of all the rock types. The other accessory minerals are much finer and of granular shape. Tourmaline and fluorite are rare and restricted to some of the dyke rocks. Some of the igneous fabrics survive, including graphic and myrmekitic textures.

The satellitic bodies are all fairly small, and range up to a few tons of metres across. The largest is located 5 km east of the main pluton (5751-074293), and separates the Utnalanama Block from a lens of the Ankala Block to the north of the schist zone. Exposures of this body are poor and contacts are not seen. The body is equigranular, but mineralogically similar to the porphyritic phase of the main pluton. Coarse and fine-grained phases display marked modal variation. In contrast to the main pluton this body is almost undeformed apart from mylonitisation around the margins.

Numerous acid dykes, usually less than a metre in width, are associated with the Gumtree Granite. The Gumtree dykes trend in three directions, one of which is parallel to the Harry Creek Deformed Zone. They are three types: (1) feldspar porphyries, (2) fine-grained aplites, and (3) pegmatites. Most of the acid dykes have intruded the Utnalanama Block. Almost all are highly deformed and most have been converted into mylonite and blastomylonite, even those most distant from the Harry Creek Deformed Zone. Only in a few places have undeformed dykes related to the Gumtree Granite been found.

Metamorphism

The Gumtree Granite has been deformed and recrystallised during the Alice Springs Orogeny (Allen & Black, in 1979). New metamorphic minerals indicate epidote amphibolite facies conditions and include white mica, epidote, manganiferous garnet, and chlorite, the last found only in the almost undeformed rock and regarded as a lower-grade mineral. Primary biotite, quartz, plagioclase and microcline microperthite have recrystallised; the secondary microcline is non-perthitic.

Structure

The main pluton is highly deformed and displays a steeply dipping east-west foliation, containing a northeasterly plunging lineation. The secondary minerals define the foliation, which wraps around the deformed phenocrysts (porphyroclasts) in the main porphyritic phase of the granite. The fabric of the offshoots range from mylonitic, where numerous highly deformed porphyroclasts have survived in a very fine-grained optically unresolvable sutured groundmass, to blastomylonitic, where the groundmass is coarser and porphyroclasts are rarer and less deformed. Ribbon quartz fabrics are also common.

Age and Origin

The age of the Gumtree Granite has been determined by the Rb-Sr whole-rock isochron method at 990 $\pm$ 13 m.y. ($^{87}Rb = 1.42 \times 10^{-11} y^{-1}$; Allen & Black, 1979). The granite is thought to be related in age to a widespread episode of migmatisation and granite emplacement, which took place in central

Australia between 1100 and 1000 m.y., e.g. the Kulgeran granites (Compston & Arriens, 1968) and the Ormiston migmatites (Marjoribanks & Black, 1974). It is thought to have originated by anatectic melting of the Ankala Block below the present level of exposure in the Harry Creek area. (Allen, in preparation).

D-12-8: Bgc, Unnamed granite (A.P.L.)

(Named Coles Dam Granite on Burt Preliminary map
mapped as Bg on 2nd Edition 1:250 000 map)

Definition

The unnamed granite, Bgc, is a homogeneous unit consisting of porphyroblastic quartzofeldspathic gneiss. It crops out over 5 km^2, 4 km west of Coles Dam, in the central southern part of BURT, and occurs as bare, rounded exposures in several isolated low hills. The name is derived from the nearby Coles Dam. The type area is a prominent hill located at 5651-672172, 4 km west southwest of Coles Dam. The unit is distinguished from the Adla Granulite to the south by the abundance of porphyroblasts, and by the lack of mafic and felsic granulite. It is isolated from other units by the Burt Plain but, in addition, differs from the Oolbra orthogneiss (the closest possible correlate) by being more quartzose, fine-grained and by containing abundant microcline and much less biotite.

Relationships

The gneiss intrudes the Adla Granulite at 5651-684170, a small isolated hill 1.5 km southeast of the type area. Elsewhere the unit is overlain by Cainozoic sediments of the Burt Plain.

Lithology

Porphyroblastic quartzofeldspathic gneiss (4150, 4199, 4198) constitutes most of the unit and is well exposed in the type area. Sample 4150 consists of small rounded porphyroblasts (1 to 2 cm across) of microcline (20%) and quartz (10%) in a matrix of medium-grained, plagioclase (25%), quartz (20%), microcline (10%), and biotite (10%). It contains accessory opaque grains and garnet. Near the trig. station, at the summit of the small hill (5651-672172), the gneiss grades into an even-grained, fine-grained variant that contains less biotite and is slightly deformed.

Away from the type area the porphyroblastic gneiss (4148, 4149) remains similar to 4150.

Structure

The gneiss has a weak foliation defined by the elongation of quartz grains. It generally strikes 070° and dips steeply (80°) to the north-northeast, has a steeply plunging mineral elongation lineation (58° to 050°).

Origin

The homogeneity, granitic composition and cross-cutting contact suggest that the gneiss is a slightly deformed and metamorphosed granite.

Age and Correlation

The age is unknown, but the relatively undeformed character suggests a similarity with the Wuluma granitoid.

D-13: Late-Stage Precambrian Igneous Rocks

D-13-1: Whistleduck Dyke Swarm (R.D.S.)

Definition

The Whistleduck Dyke Swarm is widespread throughout the Whistleduck Bore area, and is characterised by its mode of emplacement along the main east-trending faults in the region. The dykes are made up of amphibolite, which has undergone varying degrees of retrogression to greenschist facies. Specimen 3532 from GR 5750-140009 is taken to be the type specimen.

Relationships

The amphibolite of this dyke swarm occupies east-trending faults that were formed after the main episode of folding and regional metamorphism in the area. The amphibolite shows evidence, such as its medium-grainsize and granoblastic texture, that it has undergone amphibolite facies before the Alice Springs Orogeny, which commonly imparts a schistosity to the rocks. The dykes were possibly intruded after the Chewings Metamorphic Event and before the Ormiston Metamorphic Event, which is thought to be of low intensity in this region.

Lithology

Specimen 3532 consists of blue-green hornblende (30%), and plagioclase (70%), which has been retrogressed to epidote, sericite and albite.

Correlation and Age

No other basic dykes are known to have an easterly orientation. The dykes are thought to be older than the Alice Springs and Ormiston Metamorphic Events, as they show evidence of having undergone two metamorphic events.

No age determination work has been carried out on these rocks.

Origin

The amphibolite was probably originally a dolerite.

D-13-2: Basic hypabyssal intrusions in the Giles Creek Synform (A.J.S.)

Basic hypabyssal intrusions in the Giles Creek Synform in FERGUSSON RANGE are of two different types. The first comprises schistose dykes of amphibolite formed by retrogressive metamorphism of dolerite. The second type comprises massive plugs of dolerite and norite which are only slightly retrogressively metamorphosed.

Amphibolite Dykes

Amphibolite dykes are located in three widely separated parts of the Giles Creek Synform: (1) three dykes crop out in the area of copious pegmatite intrusion in the eastern part of the Synform; (2) two isolated dykes recognized solely by airphoto interpretation have been mapped in the northwestern lobe of the Synform, and (3) a swarm of amphibolite dykes crops out in the southwestern lobe of the Synform. The three eastern dykes intrude the diorite member of the Atnarpa Igneous Complex, and are closely associated with and cut by dykes of aplogranite and pegmatite. The western dykes intrude the tonalite and granite members of the Atnarpa Igneous Complex, and one amphibolite dykes intrudes the marble unit of the Tommys Gap metamorphics.

The amphibolite of the eastern dykes is medium-grained, black with subordinate white specks, and weakly schistose. It consists of oriented subidioblastic prisms of hornblende (42%) pleochroic from blue-green to dark yellowish-green to pale yellow, stubby equant grains of zoned sodic labradorite (55%) which is extensively sericitised, isolated flakes of red-brown biotite (2%) substantially altered to muscovite, sphene (1%) encrusting cores of ilmenite, and a cross-cutting veinlet of granular epidote (71911781).

The amphibolite of the southwestern dyke swarm is fine-grained, dark grey, closely jointed and in places weakly schistose; at specimen locality 71911871 (5850-659887), the schistosity in the tonalite on each side of the dyke is refracted through about 20° as it passes through the

amphibolite. The amphibolite is composed of seriate xenoblastic hornblende (70%) pleochroic from deep greenish-blue to deep yellowish-green to pale yellow, zoned andesine (22%) partly altered to sericite and clinozoisite, granular aggregates of hematite (5%), and fine polygonal quartz (3%); biotite is absent.

The mineralogical assemblage of the amphibolite dykes indicates that they were originally composed of dolerite of the tholeiitic magma-type which was subsequently regionally metamorphosed under conditions of the amphibolite facies. The sericitisation of plagioclase, alteration of ilmenite to sphene, and existence of veinlets of epidote indicate a second (retrogressive) metamorphism of the greenschist facies.

The amphibolite dykes have not been isotopically dated, but they intrude earlier members of the Atnarpa Igneous Complex, and are intruded by hypabyssal members of the Complex. Therefore, the dykes are the same age as the Atnarpa Complex i.e. 1710-1719 m.y. The dykes are both lithologically and temporally correlated with the numerous other metamorphosed dolerite dykes in the Arunta Block, but not with the dolerites of the Stuart Dyke swarm, as the latter are massive, only slightly altered, and contain abundant olivine.

Dolerite and Norite Plugs

Two plugs of dolerite and one of norite have been mapped in the central part of the Giles Creek Synform. One dolerite (5850-843908; 71911815) crops out near the centre of the largest outcrop of hornblende gneiss of the Tommys Gap metamorphics, the other dolerite (-1828) and the norite (-1825) crop out 5 km and 3 km to the west, respectively, in the central body of diorite of the Atnarpa Igneous Complex. The three plugs lie on an east-southeast line parallel to a set of major joints and faults to the east, in the eastern diorite outcrop of the Atnarpa Complex. The eastern most dolerite plug is about 200 m long and 50 m wide; the other two bodies are about 5 m across. The plugs crop out as smooth grassy areas dotted with numerous, small brown spheroidal boulders. The contacts

of the plugs with the surrounding country rocks are nowhere exposed, but it is probable that the plugs are intrusive. They are not intruded by any other rocks.

The two dolerites are fine-grained, dark grey, very tough, dense and massive, and differ slightly in mineralogical composition. The eastern dolerite (71911815) has a subophitic texture, and consists of zoned sodic labradorite (50%) as cloudy subhedral laths (some tapered) with a decussate arrangement, blobby aggregates of prismatic clinopyroxene (44%) rimmed with blue-green actinolite, opaque material (5%), red-brown biotite (1%) associated with the opaque grains, and accessory apatite and quartz-alkali feldspar micrographic intergrowth. The western dolerite (71911828) is composed of long slender laths of labradorite (55%) and intersertal aggregates of stubby grains of neutral-coloured clinopyroxene (15%), orthopyroxene (15%) pleochroic from dull red to pale green, hornblende (15%) pleochroic from brownish-green to green to brownish-yellow which appears to have formed from the clinopyroxene, and an opaque mineral (2%).

The norite (71911825) crops out as several neighbouring pods of dense tough massive rock composed of sodic bytownite (An_{71}; 40%), brownish-pink orthopyroxene (40%), clinopyroxene (10%), and actinolite (10%). The bytownite is packed with oriented tubular inclusions of ?pyroxene. The actinolite forms coronas around the orthopyroxene, is pleochroic bluish-green to green to pale yellowish-brown, and contains numerous vermiform blebs of dark green spinel. The clinopyroxene is extensively altered to brown hornblende, which in places grades imperceptibly into green actinolite, and also elsewhere forms large separate grains of its own. Apatite and an opaque mineral with associated green spinel are accessory, and several small isolated blebs of secondary talc and opaque oxide in the centres of orthopyroxene grains are probably after olivine.

The mineral assemblages and textures in the three basic plugs indicate that they are intrusive tholeiites which have all undergone partial retrogressive metamorphism to greenschist facies assemblages.

None of the three basic plugs has been isotopically dated, but because of their massive texture and mild degree of retrogressive metamorphism (presumably Carboniferous), they are correlated with the Stuart dyke swarm, which is about 900 m.y. old.

D-13-3: Unclassified gabbro, norite and pyroxenite, Bgb, south of Whistleduck Bore (L.A.O. & R.D.S.)

A small rubbly, poorly exposed, plug of partly metamorphosed norite intrudes the Flint Spring gneiss in ALICE SPRINGS (GR 5650-809912) and is composed of fine to medium-grained actinolite (35%) replacing orthopyroxene (25%), andesine (35%), reddish-brown biotite (3%) and small amounts of quartz and opaque grains (73913872).

The Charles River gneiss in ALICE SPRINGS is intruded by at least two bodies of partly metamorphosed micronorite. Eight kilometres north of the Alice Springs township (GR 5650-850857) a mafic plug consists of orthopyroxene (35 to 40%), actinolite blades with tremolite commonly in the core (35 to 40%), plagioclase (25%), biotite and opaque grains. Tremolite appears to be partly altered to carbonate (73913863). The country rock and margin of the mafic plug are foliated. Two and a half kilometres farther northeast a spotted mafic rock crops out and consists of labradorite/andesine (45%), coarse hornblende blades (30%), orthopyroxene (20%), quartz, biotite and opaque grains (73913897).

Gneiss in the Mount Lloyd Bores and Tanks area (pG) in ALICE SPRINGS is intruded by a fine-grained granoblastic mafic plug consisting of plagioclase (45%), clinopyroxene and lesser amount of orthopyroxene (together 40%), brownish-green hornblende (15%) and accessory opaque grains (73913890). Secondary green amphibole lines fractures through the rock and to a lesser extent occurs along the edges of brownish-green hornblende grains. The pyroxene and brownish-green hornblende do not appear to be recrystallised but form elongate aggregates separated by recrystallised plagioclase. Garnet-sillimanite-cordierite gneiss occurs partly interlayered with and east of the mafic plug; the mineral assemblage may be the result of thermal metamorphism caused by the mafic intrusion.

Several plugs of partly altered gabbro intrude the Randall Peak metamorphics in the southern part of LAUGHLEN (e.g. 3529, 3530, 3531) and northern part of UNDOOLYA (e.g. D5724, F729, F731). Specimen 3529 consists of bluish-green hornblende (5%) containing relict orthopyroxene and clinopyroxene (together 15%), biotite (3%), saussuritised plagioclase (45%), quartz (5%), ? clinozoisite (15%), sericite (10%), and iron oxide grains (2%). Specimen D5724 has a "granoblastic" texture and consists of labradorite (43%), clinopyroxene (26%), orthopyroxene (17%), hornblende (12%), and iron oxide grains (2%). The largest mafic plug straddles the LAUGHLEN-UNDOOLYA boundary and is about 1.7 km across. It consists of labradorite (55%), light green poikilitic actinolite up to 15 mm across (30%), clinopyroxene and orthopyroxene (together 15%), and accessory reddish-brown biotite and opaque grains. Some labradorite grains are subhedral. Specimen 3531 from the central-eastern part of the body contains highly altered olivine.,

D-13-4: Stuart Dyke Swarm, Bds (New name) (L.A.O.)

Definition and Relationships

The Stuart Dyke Swarm consists of dolerite and basalt dykes and a small number of plugs which intrude the Wigley Block and the Alice Springs Block. The dykes typically form ridges up to 7 km long and 7 m wide trending northwards in UNDOOLYA, ALICE SPRINGS and MACDONNEL RANGES and northwards and westwards in HERMANNSBURG. They appear to post-date the major metamorphic events in the basement, except the Palaeozoic Alice Springs Orogeny, and are unconformably overlain by the Heavitree Quartzite (Buh).

Lithology

Members of the Stuart Dyke Swarm are black, massive and fine to medium-grained. Samples collected from the Swarm (Table D-13-4A) typically consist of clinopyroxene and plagioclase with varying amounts of olivine, orthopyroxene and biotite. The minerals are commonly strongly altered to greenschist facies assemblages but often retain an igneous texture.

Age

The Stuart Dyke Swarm intrudes 1076 m.y. ($\lambda = 1.39$) old migmatite (Marjoribanks & Black, 1974) and is unconformably overlain by the Upper Proterozoic Heavitree Quartzite. Preliminary dating of the dykes indicates an age not younger than 910 m.y. and not older than 1050 m.y. ($\lambda = 1.39$ L.P. Black, BMR, personal communication, 1976).

D-13-5: Mud Tank Carbonatite, But (A.P.L.)

Definition

The Mud Tank Carbonatite is situated near the northern margin of the Strangways Range, close to the central northern margin of LAUGHLEN. A preliminary note of the occurrence has been published in Crohn & Gellatly (1968) and more detailed photographic and chemical data published in Gellatly (1969) and Crohn (1969) (on which much of the discussion below is based).

TABLE D-13-4A: Visually estimated modal analysis of Stuart Dyke Swarm

Specimen Number	Sheet area	Plagioclase	Pyroxene	Olivine	Biotite	Iron Oxides	Comments
73913770	Alice Springs	30% labradorite	40% cpx	30%	accessory; some probably secondary	accessory	Sub-ophitic texture. Plagioclase partly altered to sericite, and ?epidote.
73915701	Undoolya	?	35% cpx	-	-	3%	Ophitic texture. Plagioclase strongly altered to sericite and epidote. Secondary actinolite, tremolite and chlorite.
73915713	Undoolya	64% labradorite	15% cpx 3% opx	-	8%	3%	Plagioclase partly altered to epidote and cpx partly altered to green hornblende (7%)
73915729	Undoolya	?	?	-	-	-	Relict ophitic texture. Interstitial minerals strongly altered to chlorite, tremolite, and sericite.
73915730	Undoolya	46% labradorite	40% cpx	10%	-	4%	Ophitic texture.

The carbonatite intrudes rocks of the Arunta Block, which in the vicinity of the carbonatite are semi-pelitic biotite schist that are locally garnetiferous. It forms low outcrops in flat country. Three main areas of carbonate outcrop are present, aligned in a north-easterly direction and extending for about 2 km. A fourth outcrop is reported to occur a further 2 km west-southwest. Aeromagnetic results suggest that these three main outcrops represent separate plug-like masses.

Relationships

Contacts with the enclosing muscovite quartz schist are not exposed. Available evidence strongly suggests that these contacts are at least broadly concordant. Apatite and magnetite in the carbonatite is concentrated into irregular layers, veinlets and irregular masses. The carbonatite is ferruginous and are weathered in outcrops and fresh material is obtainable only from drill core.

Country rocks in the vicinity of the carbonatite outcrops were examined by Gellatly (1969) for evidence of fenitisation. Biotite schist, phyllonite and mylonite probably derived from schist and gneiss can be traced within 20 metres of the contact, but no evidence of fenitisation was noted.

Basic rocks are found as lenses (presumably xenoliths) within the carbonatite. They are amphibolite-rich rocks and show evidence of slight metasomatism.

The only alkaline rocks associated with the carbonatite crop cut as small lenses of sodic-pegmatite, generally less than 3 m long, within the carbonatite. Field relations of the lenses are uncertain because of poor exposure. These lenses may represent part of poorly exposed dykes that are considered to intrude the carbonatites.

Lithology

In hand specimen the carbonatite is composed mainly of coarse, crystalline white carbonate commonly containing biotite and with small amounts of magnetite, pale yellow-green apatite, and dark green chlorite.

In thin section the rocks are seen to consist of varying proportions of dolomite and calcite with biotite and apatite and rare magnetite, ilmenite, phlogopite, chlorite, geothite, zircon, pyrite, chalcopyrite, quartz, and rare pseudomorphs of possible pyrochlore after columbite.

Chemistry

Comparison of the Mud Tank Carbonatite with those of other areas necessitates the recognition of the variations found between different carbonatite complexes and those within individual carbonatite complexes. These depend at least partly on the stage or stages of differentiation represented in each complex. This, in turn, appears to be related at least partly to the depth of emplacement. The higher level carbonatites tend to be more highly differentiated and have higher trace element contents.

Comparison of those elements, particularly of Nb, Ba and Sr, suggest that the Mud Tank localities represent members of a poorly differentiated carbonatite-suite, and that a deep part of the original carbonatite body is exposed.

Petrology

Although zircon alone is not diagnostic of carbonatites the assemblage, apatite-magnetite-zircon is common in carbonatites, but is very rare, if not unknown, in metamorphic limestone.

The shape and distribution of calcite inclusions in dolomite suggest possible exsolution of a mixed carbonate. The zonal distribution of apatite amd magnetite crystals in the marginal parts of the dolomite grains suggest magmatic crystallisation. The size of the magnetite crystals (up to 5 cm across) is unknown in metamorphic limestones. Also the occurrence of ilmenite in the magnetite suggests crystallisation temperatures in excess of about 600°C.

Phlogopite in these rocks show reverse pleochroism with maximum absorption normal to (001). Occurrence of reverse pleochroism of phlogopite has been reviewed by Boettcher (1967), who notes that "their occurrence appears to be almost entirely restricted to carbonatites and ultrabasic rocks". The presence of possible columbite pseudomorphs after pyrochlore also suggests that these rocks may be carbonatites.

The trace element geochemistry (see table) is comparable with those from many other carbonatites and confirms that rocks are carbonatites and not metamorphosed sedimentary limestones.

Nb	20 -	450	ppm
Ba	300 -	1,000	ppm
Sr	800 -	1,500	ppm
Ti	200 - +	10,000	ppm
La	100 -	700	ppm
T	80 -	200	ppm (see Crohn, 1969)

The niobium contents of the Mud Tank rocks are comparable with those from other niobium-poor complexes such as Spitzkop, Darkainle and Sangu and very much greater than those of the Dorowa and Shawa Complexes (see Crohn & Gellatly, 1968, & Crohn, 1969).

Barium and strontium contents similarly are comparable with those of many other carbonatites, notably Tundulu, Dorowa, Shawa and Sangu, but are much less than those from high-level carbonatites (e.g. Oldoinyo lengai). Lanthinum and yttrium contents are comparable with those from other carbonatites.

Origin

The petrographic evidence for a carbonatitic origin of the Mud Tank exposures is equivocal. Petrographically similar exposures of carbonite, formed by leaching, crop out in the Mordor Complex, 50 km to the south-southeast. However, the chemistry of the Mud Tank rocks is unequivocal

evidence for a carbonatite origin. This evidence may be contracted with the depletion, in the Mordor Complex rocks, of niobium, lanthinum and yttrium which, together with strontium isotope chemistry, indicates a leaching origin of these carbonates.

Structure

The plug-like bodies are located on a major east-northeast striking fault and near the strong regional feature, the Woolanga Lineament, which may have controlled their emplacement.

Age and Correlation

Age determination results are summarized by Black & Gulson (1978), who obtained an age of about 730 m.y. for the intrusion using U-Ph zircon and Rb-Sr total rock methods. The Mordor Complex has been dated at 1184 ± 88 m.y., λ = 1.42 (1210 ± 90 m.y., λ = 1.39) thus indicating that the Mud Tank rocks are not a differentiated of the unusual potassic rocks of the Mordor Complex (Langworthy & Black, 1978). The two intrusions do have however, and are both spacially related to the Woolanga Gravity Lineament (Anfiloff & Shaw, 1976). Hence Langworthy & Black (1978) have suggested a common source rock for the two intrusions but different times of partial melting.

D-14: Rocks of Deformed and Retrograde Schist Zones

D-14-1: Rocks of Deformed Zones at the edge of Granulite Blocks

D-14-1-1: Narbib Deformed Zone, $\frac{Pzr}{Brn}$ (A.P.L.)

The Narbib Deformed Zone crops out as a west-northwest-striking fault zone from Black Tank Bore to 4 km north of Oolbra Dam. It consists of deformed major granulite deformed garnet gneiss, and mylonite. The deformed mafic granulite consists of fine-grained hornblende, clinopyroxene, plagioclase and relic grains of hypersthene. Deformed garnet gneiss consists of biotite, garnet, plagioclase, ribbon quartz and relic porphyroblasts of microperthite. This rock-type is probably deformed porphyroblastic gneiss of the Oolbra orthogneiss. Zones of mylonite define numerous faults in the deformed zone. Near the western end of the zone two parallel faults dominate the outcrop. These have extensive zones of mylonite cropping out along their length. The mylonite consists of ribbon quartz and a fine-grained recrystallised groundmass enclosing small knots of plagioclase and zoisite. Thin layers of ultramylonite occur parallel to the schistosity and small crosscutting veinlets of block (?) pseudotachylite were observed in outcrop. The zone is one of extreme deformation associated with major west-northwest-striking faulting. It cut the Oolbra orthogneiss and Narbib granulite, and deformed members of each unit are incorporated in the zone. The faults dip steeply to the northeast (80° to 32°).

D-14-1-2: West Bore Deformed Zone, $\frac{Pzr}{Brw}$ (A.P.L.)

Definition

The West Bore Deformed Zone is a 4 km wide unit of schistose rocks that crops out between Woolanga Bore and West Bore, in the central northern part of LAUGHLEN. It crops out as low hills composed predominantly of quartzofeldspathic schist, biotite schist and amphibolite. The name is derived from West Bore, which occurs at the northeastern extremity of the unit. The type area is 5.5 km east of Woolanga Bore, along an unnamed creek from 5751-229524 to 5751-223494, where well exposed quartzofeldspathic

schist, biotite schist, amphibolite and thin layers of quartzite, muscovite-biotite schist and quartzofeldspathic gneiss are cut by numerous east-striking deformed zones. pGrw is a structural unit, similar in composition to pGu, but characterized by a strong, penetrative, east-striking schistosity. It is distinguished from pGsf by the lack of mafic and felsic granulite and by the strong schistosity.

Relationships

The unit is a fault bounded block; to the southwest and southeast against pGu and to the north against pGsf. The northern boundary is the West Bore Fault, which encloses several slices of Heavitree Quartzite 2 km northeast of Woolanga Bore.

Lithology

Quartzofeldspathic schist (4494, 4495, 3238) crops out as prominent ridges of highly foliated leucocratic rock, commonly adjacent to faults. Sample 4495 consists of quartz (65%), orthoclase (25%) and plagioclase (10%). The rock contains only a very small amount of biotite; the foliation is defined by the alignment of elongate quartz grains and ribbons of quartz.

Biotite schist (3235, 3236, 3234) crops out as low hills of highly foliated rock. Sample 3234 consists of porphyroblasts (0.5 cm across) of plagioclase (20%) in a fine-grained groundmass of quartz (60%), biotite (10%), muscovite (8%) and plagioclase (2%). Small subgrains of quartz are arranged in lenticular aggregates that have a ribbon-like appearance. Polygonal 'new' grains of quartz are rare.

Muscovite-biotite schist (4403) crops out as thin, elongate bodies commonly adjacent to faults. Sample 4403 contains porphyroblasts of plagioclase in a fine-grained quartz, muscovite and biotite groundmass.

Quartzofeldspathic gneiss (3233) crops out as small, poorly foliated bodies of fine-grained biotite-plagioclase-orthoclase-quartz gneiss. Sample 3233 is slightly schistose; the foliation is defined by the preferred orientation of small biotite laths. This rock is a coarse-grained precursor of quartzofeldspathic schist.

Amphibolite (3409, 3410, 3411, 4496) crops out in the southern part of the unit. It contains two types of hornblende: the first occurs as subhedral, dark brown-green grains and is rimmed by a second, pale blue-green, anhedral variety.

In the type area quartzite occurs as narrow (from 5 cm to 0.5 m thick) discontinuous lenses.

Structure

The unit is dominated by an east to southeast-striking, steeply northerly dipping schistosity, and internal faults which parallel the northern and southern boundary faults. These faults are major splay faults off the south-southeast-striking Woolanga Lineament. They cut pGu and join the boundary faults of the Gough Dam Fault Zone, to the east-southeast. The schistosity is evidently related to the convergence of these two faults and overprints a gneissosity in rocks of similar composition of those in pGu. Thus, the unit Brw is probably a deformed part of pGu caught between the two converging faults.

Metamorphism

The retrograde, second generation of hornblende evidenced in amphibolite, and the growth and alignment of muscovite and biotite parallel to lenticular aggregates of quartz, indicate that the unit has undergone a dynamic metamorphism under low amphibolite facies conditions. One sample (0023) of kyanite-bearing schist was recorded from 3 km SE of Woolanga Bore.

Origin

The unit is so highly deformed that determination of its origin is made difficult. Nevertheless, it is similar in composition to the quartz-rich rocks of pGu in the southeastern region, and may have been a similar sequence of postulated mature sediments. The presence of thin quartzite layers in the type area supports this hypothesis.

Age and Correlation

The unit is probably a deformed part of pGu. The deformation post dates the widespread amphibolite facies metamorphism of pGu and may be related to movements associated with the Alice Springs Orogeny. This is supported by the outcropping slices of Heavitree Quartzite in the West Bore Fault, to the north of the unit, which indicate that this fault was active during overthrusting events similar to those in the Arltunga Nappe Complex known to be Late Devonian to Early Carboniferous in age (Stewart, 1971; Armstrong & Stewart, 1975). The deformed zone may be an extension of the Wallaby Knob Schist Zone which occurs in the Alcoota Sheet area to the northwest of Woolanga Bore, and also of the Gough Dam Schist Zone to the southeast.

D-14-1-3: The Harry Creek Deformed Zone (Pzr / Brh) (A.R.A.)

Definition

The Harry Creek Deformed Zone is an east-west zone of schist, mylonite and blastomylonite, 1 km wide, which extends 20 km from Harry Bore (5651-958295), eastwards to Pinnacles Bore (5751-195307), where it is offset to the south by the movements on the Pinnacles Fault. It roughly follows Harry Creek, after which it is named. In the west it is truncated near Harry Bore by the Bald Hill Fault and its westwards continuation is uncertain. The type locality (5751-070313) is 2.5 km south-southwest of Johannsen's Mine (5751-079306). The Harry Creek Deformed Zone forms a tectonic boundary between the granulite facies Utnalanama Block to the north and the amphibolite facies Ankala Block to the south.

Relationships

Associated with the Harry Creek Deformed Zone, just to the east of Harry Bore, is a small granite pluton, the Gumtree Granite and its various offshoots. The Gumtree Granite is intersected by the Harry Creek Deformed Zone and is highly deformed. Offshoots of the main Gumtree Granite pluton are found intruding both the Ankala Block and the Utnalanama Block indicating that the two blocks were in their present juxtaposition prior to intrusion of the Gumtree Granite (Allen & Black, 1979). Thus, the Harry Creek Deformed Zone is a composite zone of deformation resulting from at least two episodes of movement. The earlier movements appear to have been responsible for movement of the Utnalanama Block up against the Ankala Block, whilst later movements brought about development of the schistose character of the zone. Accordingly, the Harry Creek Deformed Zone is inferred to contain a pre-existing tectonic boundary, separating the Utnalanama and Ankala Blocks, which has been reactivated (Allen & Black, 1979).

Further support for this conclusion is given by the occurrence, to the south of Johannsen's Mine, of a small lens of the Ankala Block to the north of the schist zone. Thus, in this locality a section of the original tectonic boundary between the Utnalanama and Ankala Blocks has escaped reactivation during the later movements within the Harry Creek Deformed Zone. Significantly, along this unreactivated section of boundary unusual highly garnetiferous rocks interpreted as metasomatically-altered fault breccias (Allen & Black, 1979) have been found.

Lithology

The Harry Creek Deformed Zone is composed of schist, mylonite and blastomylonite derived from gneiss and granofels of the Utnalanama and Ankala Blocks. The gneiss and granofels pass through a zone of partial transposition and recrystallised rocks within the deformed zone.

Structure

Deformation within the zone has been intense, and has produced extremely tight steeply-plunging assymmetric folds, which verge to the east. Transposition structures define a steep foliation trending approximately east-west in the Harry Creek area, and a mineral lineation which plunges moderately to the northeast.

Metamorphism

Detailed studies of the Harry Creek Deformed Zone and the Gumtree Granite (Allen & Black, 1979; Allen, in preparation) indicate that deformation of the granite was coincidental with the development of the schistose character of the Harry Creek Deformed Zone. Assemblages containing biotite, white mica, manganiferous garnet, Mg-chlorite, epidote, blue-green hornblende, serpentine, gedrite, staurolite, kyanite and sphene are associated with this metamorphic event. Thus, mineralogical evidence indicated that reactivation of the Harry Creek Deformed Zone took place under epidote amphibolite facies conditions to be a metastable lower temperature product which has survived in a low stress environment (Allen & Black, 1979). Thus, mineralogical evidence indicates that this metamorphic episode occurred under epidote amphibolite conditions.

In unreactivated minor retrogressive zones associated with the initial movements on the Harry Creek Deformed Zone, amphibolite facies assemblages containing cummingtonite, almandine garnet and biotite are found indicating that initiation of the Harry Creek Deformed Zone took place under amphibolite facies conditions (Allen & Black, 1979).

Origin

The Harry Creek Deformed Zone is postulated to have originated as a deep-seated anorogenic wrench fault (Allen & Black, 1979). Initial movements were of a transcurrent nature with a significant vertical component and a sinistal sense. Uplift to the north has been estimated to be of the order of 5-10 km based on independent metamorphic evidence, indicating a horizontal component of movement of up to 60 km (Allen, 1978).

The Harry Creek Deformed Zone appears to have originated as a brittle structure (Allen & Black, 1979), and has the characteristics of other deep-seated anorogenic shear zones, such as those which cut the division of NW. Scotland (e.g. Sutton & Watson, 1962; Sheraton & others, 1973; Evans & Hambert, 1974).

The Harry Creek Deformed Zone has been postulated to have originated as a deep-seated shear belt of the Sutton & Watson (1962) type.

Age

The Harry Creek Deformed Zone has undergone a polyphase deformational history consisting of at least two phases of movement. The second of these has been correlated with the Alice Springs Orogeny (Allen, 1976; Allen & Black, 1979). The earlier phase of movements predates intrusion of the Gumtree Granite, and the age of the suite (990 ± 13 m.y.; $^{87}Rb = 1.42 \times 10^{-11} y^{-1}$; Allen & Black, 1979) indicates a minimum age for these movements. An $^{40}Ar/^{39}Ar$ age of 1020-1030 m.y. from biotite developed during the restricted syntectonic recrystallisation associated with these early movements (Allen & Stubbs, in press) is regarded as the age of these movements (Allen, 1976, and in preparation).

D-14-1-4: Redbank Deformed Zone, $\frac{Pzr}{Err}$ (L.A.O.)

Definition

The Redbank Deformed Zone is a west-trending zone of generally north-dipping, highly deformed rocks which extends from the northwest corner of UNDOOLYA across ALICE SPRINGS, MACDONNELL RANGES and the north-east corner of HERMANNSBURG to at least the southwest corner of NARWIETOOMA. Marjoribanks & Black (1974) originally named the deformed area in HERMANNSBURG the Redbank Zone, and described it as a major thrust-fault zone separating upthrust granulite facies rocks in the north from amphibolite facies rocks in the south. The Redbank Deformed Zone forms low to moderately high rounded hills, and commonly show a streaky appearance on

the aerial photographs. West-trending Palaeozoic faults are typified by discrete zones of mylonite and cut and may repeat parts of the Redbank Deformed Zone; in HERMANNSBURG - NARWIETOOMA the apparent thickness of the Zone is 12 km (Marjoribanks, 1975).

Relationships

In ALICE SPRINGS the boundary between the Redbank Deformed Zone and the gneiss to the south is inferred to be a Palaeozoic fault; towards the Zone pre-existing structure in the gneiss is increasingly obliterated or overprinted by a mylonitic foliation. Marjoribanks (1975) shows the southern boundary of the Redbank Zone in the HERMANNSBURG Preliminary Map as a migmatite front. In ALICE SPRINGS, MACDONNELL RANGES, HERMANNSBURG and NARWIETOOMA the contact between the Zone and the granulite facies rocks to the north is overlain by Quaternary sediments. The Zone contains several pods of relatively undeformed gneiss up to 2 km long and possibly longer.

Quartzofeldspathic mobilisate and pegmatite veins cut the mylonite layering. Discrete mylonite-filled faults cut the deformed rocks, generally trend west and are considered to have formed during the Alice Springs Orogeny.

Lithology

Rocks of the Redbank Deformed Zone in ALICE SPRINGS typically consist of mylonitic porphyroblastic gneiss, deformed banded biotite gneiss and amphibolite, and biotite-sericite schist. Porphyroblastic gneiss (p) contains ovoid feldspar up to 5 cm long in a black crytocrystalline matrix. In the northwest of ALICE SPRINGS the gneiss is composed of feldspar porphyroblasts in a fine-grained schistose matrix of strained quartz lenses and recrystallised quartz aggregates together with plagioclase, perthitic microcline, biotite, muscovite and epidote (73913931, 32). Mylonitic banded biotite gneiss (b) typically consists of plagioclase and microcline (together about 55%), lenses and aggregates of strained quartz (about 40%), biotite (about 5%), sphene, epidote, allanite, apatite and opaque grains (73913907, 926, 927). In the central northern part of ALICE SPRINGS an isolated hill consists of mylonised fine to medium-grained

gneiss which contains quartz (40%), plagioclase (30%), biotite (10%), green and a small amount of blue-green amphibole (partly altered to biotite; 7%), garnet (5%), opaque grains (3%), and accessory apatite, epidote, allanite and zircon (73913880). The Unnamed unit, pGs, at Mount Solitaire in ALICE SPRINGS is of similar composition, but is less deformed. The deformed gneisses contain relatively undeformed bodies which have compositions ranging from acid to mafic. In the northwest of ALICE SPRINGS a 10 m wide layer of mafic rock occurs within deformed gneiss and consists of andesine (50%), garnet (18%), green and a small amount of blue-green hornblende (18%), biotite (8%), quartz (5%), opaque grains (1%) and accessory apatite (73913929).

The Redbank Deformed Zone cropping out in HERMANNSBURG and NARWIETOOMA is described elsewhere (Marjoribanks, 1975).

Structure

The mylonitic foliation in the Redbank Deformed Zone in ALICE SPRINGS is caused by ribbons of strained quartz, streaks of quartz aggregates, plagioclase with bent twin lamellae, and oriented micas. At GR 5650-795934 the mylonitic foliation is axial-plane to tight mesoscopic folds. Patches of mobilisate which cut the foliation have been locally deformed by the later Alice Springs Orogeny. In the northwest of ALICE SPRINGS and about 6 km farther to the east-southeast, the foliation is mesoscopically folded about axes plunging moderately to the west. At the latter locality, (GR 5650-541898), which is an area of relatively undeformed amphibolite and biotite gneiss, an earlier tight fold is folded about a west-plunging fold axis.

Origin and Age

The Redbank Deformed Zone is highly deformed zone of rocks which has been affected in places by the Late Proterozoic Ormiston migmatite event.

The west-plunging folds in ALICE SPRINGS are also considered to be related to this event. Marjoribanks & Black (1974) suggest the Zone was initiated during the Middle Proterozoic metamorphic episode which produced granulite facies assemblages north of the Zone and amphibolite facies assemblages south of the Zone. Discrete zones of re-activation during the Alice Springs Orogeny (Part of Pzr) are indicated by mylonite and flattening of large feldspar porphyroblasts within the Redbank Deformed Zone. Biotite from a migmatite sample in HERMANNSBURG within the zone gives an age of about 400 m.y. and is considered to be a partly reset age caused by the Alice Springs Orogeny (Marjoribanks & Black, 1974).

D-14-2: Rocks in Amphibolite Facies Schist Zones cross-cutting Granulite Facies Rocks

D-14-2-1: Gough Dam Schist Zone $\frac{Pzr}{Lrg}$ (R.D.S.)
(pGrg in Preliminary Map)

Definition

The Gough Dam Schist Zone is a complex structural zone of extensive faulting, including thrust-faulting, which is bounded to the south by the east-striking Cadney Fault Zone and to the north by a series of faults, principally the White Lady Fault, and the inferred fault south of unit pGst. It crops out principally in the central western part of RIDDOCH. The Zone contains metamorphically retrograde schists which extend from the eastern branch of Cadney Creek westwards along the northern limit of the Cadney metamorphics for about 5 km into the central eastern part of LAUGHLEN. The Zone is characterised by muscovite-biotite quartzofeldspathic schist, which is thought to be derived from both granite and quartz-rich metasediments. Considerably lesser amounts of quartzofeldspathic gneiss and schist, biotite gneiss and schist, amphibolite and calc-silicate rock are also contained within the Zone. The reference area is about 4 to 8 km northwest of Mount Schaber, along the track from Eritjapuntja Pass (or "Cattlewater") to Gough Dam after which the unit takes its name. The Zone is readily distinguished from the flanking granulites by its amphibolite metamorphic grade and its pronounced schistosity.

Relationships

Near Gough Dam, the Schist Zone separates mafic and felsic granulite and gneiss, pGst, in the north, assigned to the Strangways Metamorphic Complex, from Cadney metamorphics in the south. The Schist Zone occurs within the alongside part of the Cadney Fault Zone, a major complex structural feature extending from Mount Johnstone Dam in LAUGHLEN eastwards at least as far as Lizzie Creek in RIDDOCH. The schist zone can be traced, at its widest part, along the northern flank of the main Cadney Fault. A northern branch of the Gough Dam Schist Zone merges gradually with rock of unit pGst and the southern branches rapidly becomes less schistose and change gradually into the Bungitina gneiss east of Cadney Creek. At its eastern end, near Cadney Creek, the main thrust fault breaks up into a number of splay faults, along which the schist passes into finely recrystallised quartzofeldspathic gneiss of the Bungitina metam. The principal off-shoot of the Cadney Fault continues to the southeast as far as Mount Ruby (Joklik, 1955, p. 105).

Lithology

In the reference area muscovite-biotite schist and schistose gneiss (829, 830B) grade into quartzofeldspathic schist and gneiss (830A) and enclose a few amphibolite plds. Three kilometres farther northeast, quartzofeldspathic schist, containing biotite and a small amount of muscovite, is interlayered with muscovite quartzite, calc-silicate rock, and biotite gneiss. Quartz, and less commonly epidosite, are abundant in localised patches throughout the Schist Zone.

Eastwards from the reference area the proportion of quartzofeldspathic rock increases and amphibolite bodies become very rare. In the extreme northeastern branch, south of Old Scharber Station Well, and also at the eastern end near Cadney Creek, the Schist Zones passes laterally into quartzofeldspathic gneiss. To the west of the reference area the Zone consists of interlayered schistose biotite gneiss, calc-silicate rock, quartzofeldspathic gneiss, muscovite-biotite schist and quartzose gneiss. The schistose biotite gneiss contains thin discontinuous interlayers of muscovite quartzite.

Three additional areas worthy of comparison with the reference area are: (a) south of the Copper Queen Prospect, (b) along the eastern tributary of Cadney Creek, and (c) west of the reference area.

(a) South of the Copper Queen Prospect the main rock-type is a muscovite-biotite schistose gneiss whose colour index ranges from 20 to 40. The gneiss is compositionally layered and rare layers are notably quartz-rich. Locally, the muscovite forms clots and rarely books up to 3 cm across. In the central part of the schist zone, the schist is biotite-rich. Throughout the zone small amounts of quartzofeldspathic gneiss and, less commonly, biotite gneiss, both of which contain up to 15 percent muscovite in addition to 10-20 percent biotite, crop out as narrow ridges. Calcareous rocks, including an epidote-rich calc-silicate rock and rare impure marble, crop out near the boundary with the Cadney metamorphics at the northern margin of the Zone and also as a narrow belt in the central part of the Schist Zone. A medium-grained, migmatitic quartzofeldspathic gneiss crops out sporadically along the southern margin of the schist zone. The migmatitic gneiss has quartzofeldspathic and biotite-rich phases and is commonly garnetiferous.

(b) Along the eastern tributary of Cadney Creek a similar succession of schistose gneiss and quartzofeldspathic gneiss crops out. Biotite schist is more abundant than in the succession south of the Copper Queen Prospect. In the southern part of the section, biotite schist, epidote-bearing calc-silicate rocks, hornblende-bearing gneisses and garnet-biotite schistose gneiss are abundant.

(c) To the west of the reference area, the Zone consists of interlayered schistose biotite gneiss, calc-silicate rock, quartzofeldspathic gneiss, muscovite-biotite schist and quartzose gneiss. The schistose biotite gneiss contains thin discontinuous interlayers of muscovite quartzite.

The muscovite-biotite schist and schistose gneiss range from muscovite-poor, schistose varieties like specimen 829, containing muscovite (3%), plagioclase (5%), magnetite (7%), K-feldspar (20%), quartz (35%), and biotite (30%), to more gneissic varieties such as specimen 830B, containing poikiloblastic muscovite (18%), green biotite (17%), K-feldspar (5%), and quartz (60%). Zircon is a common accessory, but traces of sillimanite, although suspected in hand specimen, were not detected in thin section.

The schistose quartzofeldspathic gneiss such as specimen (R4520) from north of Mount Schaber has the mineralogy of a alkali-feldspar granite, consisting of markedly strained K-feldspar (45%) and quartz (35%), together with oriented biotite (15%), plagioclase (5%), opaque grains and traces of muscovite. Such rocks are transitional with biotite gneiss.

A typical calcareous rock such as specimen 3644 consists of medium-grained, equant grains of quartz (25%), scapolite (25%), epidote (15%), biotite (15%), and K-feldspar (20%?).

Strongly foliated quartzose gneiss (5851-495430) characterises the southern margin of the zone near the LAUGHLEN-RIDDOCH border. This rock-type has not been sampled but has a distinct photo-pattern that clearly defines the faulted southern boundary of the Zone particularly at 5851-453440. A similar rock (3351) from 1.5 km SE of Gough Dam is medium-grained, and contains quartz (72%), muscovite (15%), biotite (10%) and opaque grains (3%).

Structure

Throughout much of the Schist Zone an intense lineation plunges consistently north-northeast at about 30° to 70°. The lineation becomes more intense than the schistosity near interpreted thrust planes (Joklik, 1955, p. 114). Elsewhere, the schistosity is more prominent than the lineation.

In the eastern tributary of Cadney Creek, where there are four subparallel faults, an intense down-dip lineation is developed. Here, the dominant dip of the schistosity is 30 to 60° towards the north. Joklik (1955, p. 106) estimates the dip of the main thrust plane in Cadney Creek to be 30° towards the north.

Origin

The schist zone is interpreted to have formed by retrograde amphibolite-grade metamorphism of a variety of gneisses and granulites. The main parent rock type appears to have been quartzofeldspathic gneiss or granulite, possibly the Bungitina metamorphics although this should have resulted in a higher proportion of amphibolite than is evident in the Schist Zone.

Age and Correlation

Amphibolite facies schist zones generally cut granulite facies terrain in the Alice Springs region, and are not known to cut rocks affected by migmatization during the Ormiston Orogenic event at about 1100 m.y.; but cut granulites dated at 1800 m.y. (Black, 1975). Thus an age between 1800 and 1100 m.y. is favoured for the Schist Zone, but an Alice Springs Orogeny age (i.e. 300 to 400 m.y.) cannot be ruled out because the final movements on the similar West Bore deformed zone overthrust the Heavitree Quartzite.

D-14-2-2: Southern Cross Schist Zone, $\frac{Pzr}{Brs}$ (R.D.S.)

Definition

The Southern Cross Schist Zone consists essentially of two roughly parallel zones of retrograde metamorphism that extend from Pinnacles Bore northwest as far as Muller Creek to the east. These schist zones are characterised by biotite-muscovite schist and subordinate muscovite-biotite schist. The schist zones are developed in the lower part of the Cadney metamorphics and consequently also contains the metamorphically retrograde equivalents of quartzofeldspathic gneiss, calc-silicate rock, and amphibolite.

Relationships

The schist zone straddles the Pinnacles Fault, and divides the Utnalanama Block into a southern and northern part, in which the rock types are noticeably different. The Schist Zone is named after Southern Cross Bore. It is essentially a structural-metamorphic feature rather than a stratigraphic unit.

Lithology

In addition to biotite-muscovite and muscovite schist, a number of small offshoots of the Schist Zone contain kyanite. Such offshoots occur (1) 1 km northeast of Pinnacles Bore, (2) along the northern margin of the smaller of the two southern branches of the Schist Zone at GR 5751-373096 and, (3) in a small outlier of the Schist Zone to the west in BURT at GR 5651-000000, where it accompanies staurolite, biotite, and garnet. Mylonite is locally present adjacent to the major northwest-trending faults which accompany the Schist Zone.

Metamorphism

The Schist Zone is considered to have formed during a medium pressure amphibolite facies metamorphism, characterised by kyanite or kyanite-staurolite, which post-dated the main granulite facies metamorphism. The age and P-T conditions of this metamorphic event, named the Yambah Event, are discussed further in the general chapter on METAMORPHISM.

Structure

In places, a marked down-dip lineation has formed in the Schist Zone close to the main accompanying faults. Although early-stage strike-slip movements cannot be discounted, it is likely that the final fault movement was an overthrust from north to south because the foliation dips about 40° north where it has been measured close to the main faults. The vertical displacement is not thought to have been very great as the same stratigraphic features are present on either side of the Zone.

D-14-2-3: Yambah Retrograde Schist Zone $\frac{Pzr}{Ery}$ (Wilson, Iyer & A.P.L.)

This schist zone has been studied by Wilson and Iyer from the University of Queensland and the reader is referred to Iyer's Ph.D thesis (pp. 82-156) and Iyer & others (1976). The schist zone crops out as a right angular intersection of two faults centred on G.R. 823498 in BURT. The schists consist of kyanite, staurolite, garnet and biotite and they cut felsic granulite of the Yambah granulite. The schists are dominantly muscovite-biotie-and quartz bearing with kyanite-staurolite, garnet, diopside-epidote and hornblende and/or chlorite layers. The chemical composition of the three analysed muscovite-biotite schists fall close to the fields of shale and greywacke (Wilson & Iyer, in preparation) and are very similar to the adjacent felsic granulites. Three of the four analysed mafic schists are more silicic than the near-by mafic granulites, although the trace element compositions of the mafic schist and mafic granulites are similar.

The aluminous schists occur as discontinuous highly deformed transposed schists. Kyanite is abundant, and blades up to 10 cm long are not uncommon. Staurolite (mostly non-twinned) is plentiful in some schists, and euhedral crystals up to 5 cm long have been found. Almandine, possibly stablized by Mn and Ca, is found in some kyanite-staurolite-biotite assemblages. Some of the highly aluminous schists contain bent needles of sillimanite as well as undeformed blades or kyanite.

The three analysed highly aluminous schists, are similar in composition. As they differ from the felsic granulites mainly in their lower SiO_2 and higher Al_2O_3, it is possible that these are "restites" following leaching of silica.

Four analyses of staurolite (Iyer, 1974) show little variation in major elements, and their average Mg values ($100\ Mg/Mg + Fe^{2+} = Fe^{3+} + Mn$) is 16.1 ± 1.4. The trace element Zn, which is common throughout the Strangways Range, is not unduly high for staurolite - the range of Zn is 496 to 4519 ppm.

Although the structural relationship of this schist belt to the granulites is uncertain, it is suspected that the schists have formed by retrogression of granulites. In several cases chemical analyses of schists and granulites are closely similar in both major and trace elements. Some schists, however have suffered K-metasomatism and silicification as well as hydration during retrogression. On the other hand, the most aluminous schists appear to have been desilicated and could be termed "restites".

The K-Ar and $^{40}Ar/^{39}Ar$ data on these schists yield Carboniferous ages of 350 m.y., and Rb-Sr analyses have so far failed to confirm this metamorphic event (Iyer & others, 1976). We (Wilson & Iyer) suspect that the Ar procedures have recorded only the latest metamorphic event. As the schists show intense deformation and polycyclic features, it is possible that the coarse kyanite-staurolite assemblages were formed considerably earlier.

D-14-3: Rocks in Greenschist (Pzr) and Mylonitic Zones formed during the Alice Springs Orogeny (L.A.O. & R.D.S.)

This unit consists of schists, ~~my~~onite and quartz veins and constitutes linear Palaeozoic fault zones throughout the Arunta Block. It is distinguished from the Redbank Deformed Zone which consists mainly of mylonitic gneisses and which is considered to have principally formed during Lower to Middle Proterozoic times. The retrograde zones vary in thickness from a few millimetres in many places to at least 1 km just south of Bald Hill in LAUGHLEN.

Many of these fault zones are considered to be re-activated from earlier basement deformed zones.

The unit typically consists of muscovite schist, biotite-muscovite schist, grey and white brittle mylonite and quartz veins. Mylonite commonly consists of a small number of feldspar grains up to 2 mm across in a schistose matrix of recrystallised and strained quartz, biotite, muscovite, epidote and clinozoisite (ALICE SPRINGS: 73913794, 796, 809). The matrix grains are generally less than .1 mm in diameter.

In the northeast of ALICE SPRINGS fine to medium-grained sericitic quartzofeldspathic schist, biotite-muscovite schist and recrystallised quartz veins are interlayered with mylonite. Mesoscopic folds occur locally and are defined by mica-rich and mica-poor layers; the mica is axial-plane to the folds.

An extensive series of retrograde schist zones extends eastwards from the Winhecke area in LAUGHLEN to the White Range area in RIDDOCH. These highly schistose and deformed retrograde rocks were first described by McCarthy (in Forman, Milligan & McCarthy, 1969). Muscovite, biotite, actinolite, calcite, quartz and epidote have recrystallised during deformation of the rocks: the mineralogy depending on the original rock composition. The quartz typically occurs as elongate aggregates. The deformation has also affected the Heavitree Quartzite and the main schistosity is a plane of flattening, which corresponds to the axial-planes of second generation folds in the quartzite. The shallow northerly plunge of these folds, which are reclined, corresponds to the direction of elongation (i.e. maximum strain) evidenced in quartz grains and pebbles. These retrograde schist zones are considered to have developed during the main phase of southward translation of the Ruby Gap, White Range and Blatherskite Nappes.

In the Ruby Gap area in RIDDOCH, within zones mapped as Pzr, quartzofeldspathic gneisses are definite schists rather than the schistose gneisses immediately to the north, and the proportion of greenschist retrograde minerals has increased (cf. Table D-14-3A and quartzofeldspathic gneiss in Table D-2-2A) commonly by a factor of two or more; the main reaction being the albitisation of plagioclase. In specimen 2435 the

TABLE D-14-3A: Retrogressed felsic rocks, Pzr; Mineralogy and microstructure (texture), Ruby Gap area

Location code	*1	*1	*2	*2	*2	*3
Specimen Number	2417	2418	2414	2535	2357	749/12A
Hornblende			4			
Biotite	5	1	5		6	1
Plagioclase	43	20?	52	44	5	23
Quartz	25	64	17	15	30	52
K-feldspar				10?	13	20
Muscovite/Sericite	10	7	5		3	2
Chlorite	5	1	2	20		0.5
Epidote/Clinozoisite	12	6	12	1	3	1.5
Actinolite			7	tr		
Feld. Matrix					40	
Sphene	tr		1			
Granoblastic elongate		x				x
Schistose	xx	xx	x	x	x	
Quartz-ribbons					xx	
Quartz-polygonal	x	x	x			
Qtz. grain boundaries embayed		x				x
Quartz grain bds. curved			x			
Qtz. sub-grains				x		x
Plag. gt. bent			x			x
Plag. bent	x			x		
Grain-size	f-m	f	f-m	m		m

*Location Code.
1. Northeast of Ruby Gap, Illogwa Creek 1:250 000 Sheet area
2. North of Atnarpa Range, RIDDOCH
3. Core of Ruby Gap Nappe, RIDDOCH

feldspars form subrounded porphyroblasts in a matrix of chlorite. Quartz is generally polygonised to a fine-grained mozaic, but alongside the main thrust-plane, 4 km northeast of Atnarpa homestead (2537), quartz forms ribbons, which bend and thin around feldspar prophyroblasts. Here, fine biotite is concentrated in the boundary between quartz ribbons, and much of the feldspar in this mylonitic rock has recrystallized to a matrix of very fine, lobate grains. In the core of the Ruby Gap Nappe, (749/2A) the feldspar has not recrystallized, but the quartz forms elongate, sutured grains showing deformation bands and fine (less than 100 um) subgrains at grain boundaries.

In the same area, the amphibolites (Table D-14-3B) are more consistently schistose or lineated compared with the amphibolites farther north, and hornblende commonly forms augen in a matrix of reduced grain size, which is fine-grained rather than the normal medium-grained. However, the proportion of tremolite/actinolite, epidote/clinozoisite, sericite/muscovite and chlorite has not noticeably increased over that in the partially retrogressed amphibolites typical of the unnamed Unit pCx.

In the core of the Ruby Gap Nappe amphibolite is almost completely retrogressed to lineated actinolite-epidote-sericite-plagioclase rock (732/10, 743/15, 749/11A,B, 749/12B, 734/5,6). Plagioclase shows all degrees of saussuritisation culminating in the formation of sutured, lobate grains of albite such as in 734/6 from near Ruby Gap Dam Yard. The actinolite tends to form idioblastic or poikioblastic grains. Like the partly retrogressed amphibolites in the schist zones these actinolite-amphibolites contain trace to negligible amounts of opaque grains, which are commonly haematite.

The Retrograde Zones represent localised zones of faulting and metamorphic retrogression within the Arunta Block during the Alice Springs Orogeny. In part these faults are root zones for a number of south thrusted nappes which involved both cover and basement rocks. The age of the Alice Springs Orogeny and, hence, the linear zones of retrogression within the basement is Carboniferous (Stewart, 1971).

TABLE D-14-3B: Retrogressed mafic rocks, Pzr;
Mineralogy and microstructure (texture),
Ruby Gap area.

*LOCATION CODE	1				2			3			
SPECIMEN NUMBER	652	2436	2438	2439	2415	734/5	734/6	749/12B2	749/11B	749/11A	743/15
Plagioclase	30?	35	22?	25	36	43	34	67.5	75	27	54
Hornblende	40	27	50	40	35						
Quartz	10	15	10	10	7?	7	1?	10			8
Biotite											tr
Actinolite/ Tremolite	2?	4	10	2	5	35	30	7	15	65	30
Epidote/ Clinoz.	10	4?	5	7	12	5	15	5	2	5	3
Musc./ Sericite	5	7	3	15	2	12	20	10	8	3	5
Chlorite	3	2	?	1	2						1
Calcite					tr						
Opaque grns.	tr	-	tr	tr	0.5		ac				ac
Sphene	tr	tr			0.5	ac	ac	0.5	tr	tr	tr
Apatite				tr				ac			ac
Granoblastic						x					
Granoblastic - elongate								x			
Schistose or Lineated	x	x	x		x		x		x	x	x
Plag. bent		x	x					x	x	x	
Hb. bent		x	x	x							
Hb. augen	x	x	x								
Grn. size	mf		m	m	mf	f	m	m	f	f	m

ac = accessory
tr = trace

*LOCATION CODE
1. Schist zone, northern Atnarpa Range
2. Schist zone, Illogwa Creek 1:250 000 Sheet area
3. Core of Ruby Gap Nappe

D-15: Amadeus Basin Sequence - Introduction (R.D.S.)

Only recent stratigraphic and photogeological studies on the Heavitree Quartzite, Bitter Springs Formation, and Pioneer Formation are included here since these changes are shown on the 1:100 000 map series.

Recent revisions to the Pertnjara Group are also included in the new series of maps and are outlined in the map commentary on the Alice Springs and Undoolya 1:100 000 Sheets by Offe & Shaw (in preparation).

D-15-1: Heavitree Quartzite, (Buh) (D. Clarke, N.T. Geological Survey)

The Heavitree Quartzite has not been subdivided in the present 1:100 000 map series. However, it is readily divisible into four members which are recognisable throughout the 1:250 000 Sheet area. Descriptions of these members from the type section of Heavitree Gap (GR 5650-847756) are included here for reference. In general the members thicken eastwards.

Undoolya Siltstone Member

The basal 6 m thick sequence of purple and green interlaminated siltstone and shale nonconformably overlies the Arunta rocks. It is regularly bedded, in thin to thick laminations, displays rare slump structures and edgewise conglomerate, and is locally finely micaceous, with a very rare trace of fine to very coarse sand grains. The following 6 m thickness is lithologically similar, but includes several very fine-grained and silty beds of sandstone infilling scour channels up to 30 cm deep and 1.5 m wide, and one 50 cm-thick laterally continuous sandstone bed. Beds comprising the overlying 4 m are not exposed, but are thought to be lithologically similar, and the total thickness of this unit, which is to be called the Undoolya Siltstone Member, is 16 m. Its upper boundary is taken at the top of the stratigraphically highest siltstone bed.

The Temple Bar Sandstone Member

The succeeding beds are mainly very fine to fine-grained, but are only moderately to poorly sorted, and are locally both silty and coarse, with rare traces of granule-sized grains. They are generally medium to thick-bedded, locally thin-bedded near the top and composed of quartz grains, but contain a characteristic trace of feldspar, which is generally weathered to white clay, in the top 27 m. Sedimentary structures that have been recorded include common current bedding displaying both trough and tabular cross-sections, two sets each of asymmetric ripple marks and dessication cracks, and one set of clay gall casts. Near the base a 'fining-upward' sequence is found in which the grainsize diminishes from coarse to very fine over a vertical distance of 4 m. This unit is 62 m thick and is informally designated the 'lower unit' of the Temple Bar Sandstone Member. Its uppermost bed is defined by the presence of scattered feldspar and coarse to very coarse quartz grains and a lower degree of sorting than is found immediately above.

The overlying beds are composed of well-sorted very fine to fine-grained quartz sand in thin to medium beds. The lower 34 m thick section is locally silty and displays several sets of current bedding with both trough and tabular cross sections, and one set each of dessication cracks and clay gall casts. The upper 16 m thick section is very well-sorted and free of silt. No sedimentary structures were observed in it. The whole unit is 50 m thick and is informally designated the upper unit of the Temple Bar Sandstone Member. Its weakly disconformable upper boundary is abrupt and clearly defined by the onset of the overlying conglomerate beds, which locally fill erosional scour channels up to 50 m deep. The Temple Bar Sandstone Member including the upper and lower units is 112 m thick.

The Fenn Gap Conglomerate Member

The overlying beds are composed of medium to thick-bedded, poorly sorted, weakly argillaceous granule conglomerate and conglomeratic sandstone, which are commonly ironstained brown, pink and purple, particularly near the base. In the lower 22 m they display common current bedding with both trough and tabular cross-sections, and two sets of clay gall casts. Grain size

'fining upward' sequences were recorded 4 to 6, 10 to 12, and 20 to 21 m above the base. Dessication cracks and clay gall casts are common in the upper 12 m, and one set each of current bedding and symmetrical ripple marks were recorded.

This sequence is 34 m thick and is to be called the Fenn Gap Conglomerate Member. Its upper boundary lies between the stratigraphically highest bed of conglomeratic sandstone and the lowest overlying bed of well-sorted, clean quartz arenite.

The Blatherskite Quartzite Member

The succeeding beds are thin to thickly bedded in the basal, 8 m, and are composed of well-sorted very fine to medium-grained quartz sand, with rare silty interbeds. They display one set each of clay gall casts, dessication cracks and symmetric ripple marks. The following medium to thick-beds are composed of very well-sorted clean fine-grained quartz sandstone, and the only sedimentary structure recorded in this 20 m thickness was a set of 'probable' asymmetric ripple marks. Together, these beds are informally known as the lower unit of the Blatherskite Quartzite Member.

The overlying 37 m thick sequence is medium to thick-bedded throughout. Near the base and near the top it is comprised of well-sorted coarse to medium-grained, clean quartz sandstone, in which several trough cross sectional current beds and one set of oscillation ripples were recorded. The middle section, from 7 to 27 m above the base, is composed of moderately sorted, very fine to medium and rarely coarse-grained quartz sandstone. Two sets of trough cross-sectional current beds, and one grainsize 'fining upward' sequence were recorded in the middle section.

These beds are succeeded by a 28 m-thick section of thin medium-bedded, and silty quartz sandstone, which varies in grainsize from silt to very coarse sand. Although locally poorly sorted, these grains are generally well-sorted into thin interbeds and interlaminae. Two sets of clay gall casts and three sets of very shallow (5 cm sets) trough cross sectional current beds were recorded. This 65-m thick sequence is informally known

as the 'upper unit' of the Blatherskite Quartzite Member, and together with the lower unit, makes up the 93 m recorded thickness of this member. The upper boundary of this member with the Bitter Springs Formation rocks is not exposed at Heavitree Gap, but has elsewhere been taken at the base of the lowest significant thickness of siltstone overlying the Blatherskite Quartzite Member.

D-15-2: Bitter Springs Formation (A.J.S.)

The Bitter Springs Formation is the sequence of stromatolitic dolomite and limestone, shale, sandstone, basic volcanics, chert, and evaporites that conformably overlies the basal unit - Heavitree Quartzite - of the Amadeus Basin. The Formation is divided into two members, the Gillen Member (Bug; lower) and Loves Creek Member (Bue; upper), and has been fully described in Wells & others (1967, 1970). Work since that time has been concerned with stromatolites in the carbonate rocks over much of the Amadeus Basin (Walter, 1972), microfossils in chert near Ross River Tourist Chalet in UNDOOLYA (Schopf, 1968), and an evaporite occurrence 10 km southwest of Ringwood homestead in FERGUSSON RANGE (Stewart, 1974; 1979). On the UNDOOLYA and FERGUSSON RANGE Sheets, the Bitter Springs Formation has been subdivided into nine photo-units, following a detailed examination of the 1:25 000 scale colour airphotos. The lithological make-up of photo-units Bug_1 through Bug_5 of the Gillen Member is known from field examination of specific localities in those units; the rock-types in photo-unit Bug_6 are deduced from general knowledge of the Bitter Springs Formation, and are tentative only, as the unit has not been examined on the ground. The three photo-units of the Loves Creek Member have been examined on the ground at locality W020, 1.5 km north of Ross River Tourist Chalet in UNDOOLYA.

From bottom to top, the nine photo-units of the Bitter Springs Formation are as follows:

Gillen Member

Bug_1-massive dolomite forming a prominent rounded ridge; siltstone known in basal part.

Bug_2-red sandstone forming valley, about 100 m thick. One specimen (WO26, GR 5850-643903, from 2.7 km northeast of Tommy's Gap) consists of a poorly sorted assemblage of angular to well rounded quartz grains coated with hematite, and accessory tourmaline with authigenic out-growths.

Bug_3-mostly dolomite, well bedded, with prominent recessive interbeds presumably composed of lutite. At western end of Giles Creek Synform, the unit forms a jumbled contorted mass of short ridges which probably represent small fault blocks; a megabreccia perhaps.

Bug_4-in FERGUSSON RANGE, mostly a recessive unit (lutite?) about 100 m thick, red, supports noticeably thick mulga (Acacia aneura). Has prominent carbonate beds at base and top, and some others interbedded in the red lutite. In UNDOOLYA, the unit is 200 to 300 m thick, appears green instead of red, and carbonate interbeds are more prominent, although the unit as a whole is still recessive and well treed. The only specimen held (WO02, GR 5750-456944, 5 km northwest of Ross River Tourist Chalet) is a fine-grained purple sandstone, and consists of angular to subrounded grains of quartz, microcline, and chert, in a granular matrix of red and black iron oxides, quartz, microcline, calcite as small polycrystalline aggregates, chlorite as a structureless cement, and a few detrital grains of tourmaline and zircon. The calcite forms deep corrosion embayments in some of the quartz and tourmaline grains, and elsewhere has formed a mineral of the epidote group by reaction with microcline.

Bug_5-this unit consists of a jumbled mass of highly contorted dolomite. Strike ridges can be traced for only about 100 m, suggesting the existence of numerous faults, and in this respect the unit markedly resembles Bug_3 at the western end of the Giles Creek Synform. The unit is characterised by a prominent pair of highly contorted carbonate beds at the top.

Bug_6-a pink recessive unit forming prominent valleys south of the Giles Creek Synform, in FERGUSSON RANGE; presumably shale. A white rock-type occupying the keel of a synform at the top of the unit may be evaporite, and is so labelled on the map.

Bug -undifferentiated; used where the rocks clearly belong to the Gillen Member and lie below the Loves Creek Member, but cannot be placed in one of the numbered sequence of photo-units.

Loves Creek Member

Bue_1-a prominent ridge-forming massive dolomite, overlain by red shale or siltstone. At specimen locality W020 (GR 5750-484917, 1.5 km north of Ross River Tourist Chalet) and elsewhere it contains numerous stromatolites, including Inzeria intia and Acaciella australica (Walter, 1972). Corresponds to the lowest 800 feet (270 m) in Fig. 7 of Wells & others (1967).

Bue_2-a recessive unit of red shale between two prominent beds of pale limestone (which are included in the photo-unit).

Bue_3-mostly red shale or siltstone, containing prominent interbeds of limestone and dolomite. The microfossils described by Schopf (1968) occur in chert in one such dolomite bed near the top of the unit at specimen locality W020.

Evaporite

In addition to the synform of possible evaporite at the top of photo-unit Bug_6 (described above), three irregularly shaped recessive areas characterised by an irregular drainage pattern of closely spaced deep narrow gullies in which white rock is exposed at the bottom are also photo-interpreted as evaporite. All three occurrences are surrounded by undifferentiated rocks of the Gillen Member (Bug), and all are situated next to the major fault (or slide) that forms the surface at the base of the large allochthonous sheet of Amadeus Basin sediments across the centre of FERGUSSON RANGE.

D-15-3: Pioneer Sandstone, Bux, (A.J.S.)

The detailed photo-interpretation of the Bitter Springs Formation revealed several exposures of an unconformity at the base of the overlying Pioneer Sandstone (revised from Areyonga Formation of Wells & others, 1967, by Preiss & others, 1978). Generally, the contact of the two formations is disconformable, and an angular unconformity was known at only one locality, '3 miles east-south-east of Shannon Bore' (Wells & others, 1977), i.e. at GR 5850-534767 in FERGUSSON RANGE. At GR 5850-700812, 3 km southeast of Box Hole Bore in the same Sheet area, the Pioneer Sandstone rests on the uppermost photo-unit, Bue_3, of the Loves Creek Member of the Bitter Springs Formation. One kilometre farther southeast along strike, the Pioneer Sandstone rests on the middle photo-unit, Bue_2, and 4 km farther southeast, the Pioneer Sandstone rests on the lowest photo-unit, Bue_1; another 3 km farther to the east, the Pioneer Sandstone rests on the Gillen Member of the Bitter Springs Formation. The Loves Creek Member in this area is about 300 m thick, from airphoto measurement, and the Pioneer Sandstone cuts down through this thickness in a distance of 8 km, giving a figure of 2° for the angle of the unconformity.

D-16: Cainozoic (B.R.S.)

Table D-16A describes the essentially conformable sequence of poorly-consolidated to moderately lithified sedimentary rocks (conglomerate, sandstone, siltstone, mudstone, lignite and chalcedonic limestone) of Cainozoic age which occur in the Alice Springs region. These rocks occupy a series of elongate intermontane basins, which are possibly fault-controlled, and in places the sediments are more than 200 m thick. Outcrops are rare, most are deeply weathered, and are mantled with widespread unconsolidated Quaternary sediments forming the rather flat landscapes of the Hale, Plenty River and Paddys Plains. These plains are partly bounded by steep, deeply dissected mountain ranges or they merge with lowlands of bedrock interspaced with flat-topped lateritic residuals.

The basement complex and Tertiary sequences appear to have undergone more than one period of chemical weathering. According to Senior (1972), laterite developed in the Arunta rocks is up to 40 m thick, and has a tri-zonal form comprising a lowermost leached zone, an intermediate mottled zone and a ferruginous top. A subsequent period of erosion stripped the laterite from most of the area, and some of the detritus was incorporated into sediments of actively downwarping intermontane basins. The Tertiary sediments were subsequently weathered and crusts of silcrete, ferricrete and some thin laterite profiles developed. Mabbutt (1965) drew attention to the laterial variation from laterite to silcrete from the centre of the margins of the Hale Plain (Garden Basin), and attributed this variation to a shallower, less fluctuating former water table in the axial region, together with possible downslope migration of iron.

A consequence of the complex weathering history is the altered mineralogical composition of much exposed rock and the destruction of fossils. As a result of the ages and relationships between Cainozoic rock units within the Alice Springs region are not known with certainty. Palaeontological evidence from adjacent areas, which appear to have a parallel history, is used here to throw some light on the most likely stratigraphic framework.

Palynology indicates that carbonaceous clay in BMR Napperby 1 is Eocene (Kemp, 1976) and lignite and sub-bituminous coal of approximately Middle Miocene age occur in the Ti Tree Basin (Galloway & Kemp, 1977). Vertebrate fossils indicate a Upper Miocene or Early Pliocene age for the upper part of the Waite Formation near Alcoota station (Woodburne, 1965). On the basis of results obtained in surrounding areas it would appear that the sedimentary sequence of the area under review encompasses the Cainozoic era, with coal swamps, fluvial and lacustrine sediments possibly originating in the Early Tertiary. Sedimentation continued intermittently, within local depressions, until the present day.

Further palynological work is being carried out on drill core from the Hale Basin (Garden Basin) using lignite and carbonaceous rock types supplied by the Northern Territory Mines Department. In addition ferruginised weathered rocks are being studied palaeomagnetically in an attempt to establish the timing of weathering events in the Alice Springs region. It is likely that the laterite profile developed on crystalline basement rocks is older than the weathered crusts (ferricrete, silcrete, chalcedonized sediments and thinner laterite) developed across rocks of all ages.

Prominent lateritic residuals, regarded by Hays (1967) as part of the Late Cretaceous or Early Tertiary Tennant Creek Surface, were palaeomagnetically sampled during 1977. Similarly, weathered rocks in the Hale Basin, possibly reflecting a Middle Tertiary weathering episode, were also collected. The two weathered rock sequences appear compatible with the Maastrichtian/Eocene and Late Oligocene/Miocene weathering events recognised by Idnurm & Senior (1978) in the Eromanga Basin of southwest Queensland.

The Cainozoic sequence (Table D-16A) is summarized from Lloyd (1968), Senior (1972), Shaw & Warren (1975). Rock unit descriptions remain unchanged since 1971, but the stratigraphic succession and age of some units has been updated in accordance with current interpretations.

A list of basement core information and total depths from a series of holes drilled along the Stuart Highway in 1973 is given in Table E5.

Table D-16A Summary of Cainozoic Stratigraphy

Age	Rock unit	Lithology	Thickness	Tectonic Events	Environment, fossils and age
RECENT	Qa	Fine and coarse clay-quartzose sand, silt and minor gravel, lacking a marked soil profile		Possible uplift in the area of the Harts, Strangways and Georgina Ranges or rejuvenation due to subsidence within the Lake Eyre Basin	Channels data from latest pluvial period - either Holocene or latest Pleistocene
RECENT and PLEISTOCENE	Ql	Calcrete; hard calcareous cements within formerly porous sediments			Humid oxidising conditions followed by aridity and aeolian activity. Development of broad sandplains with minor dunefields. Cementation of porous surface sediments and colluvium forming calcareous crusts.
	Qs, Qps	Aeolian quartzose sand (Qs); with fixed dunes (Qps)		Region tectonically stable	
	Qc	Colluvium, eluvium, scree			
	Qr	Shallow red, clayey and sandy soil i.e. "Red earth"; clayey, oxidized silty-sand			Soil produced by repeated phases of alluviation and burial related to the trapping of sheet runoff by arcuate Mulga groves. Mixed with sheet sands (Qs) suggesting that the unit began forming in the late Pliocene. For more information see Litchfield (1962).
CAINOZOIC TERTIARY	Czg	Redistributed ferricrete and quartz gravel	20 m		Transported ferruginous clastics derived from laterite profiles.
	Czc	Fanglomerate	20 m	Movement at some faults	Scree deposits flanking scarp-bounded fault lines
	Tw Waite Formation equivalents	Greenish-grey siltstone and chalcedonic limestone	20 m	Region tectonically stable	Argillaceous sediments and chemical precipitates in very quiet lacustrine environments
	Ts	Silcrete (strongly silicified quartzose sedimentary or acid igneous rocks)	3 m	Regional tectonically stable	Silicification of acid rocks in regions of restricted drainage. Possibly mid-Tertiary.
	Hale Formation Th, Thg Ulpnamba Lignite Member, Thu	Kaolinitic quartzose sandstone, siltstone and mudstone (Th), grading to coarse-grained poorly-sorted boulder conglomerate (Thg), and lignite (Thu) in subsurface	195 m in sixteen mile bore	Probable mild uplift and warping of some fault-bounded blocks	Lakes and swamps followed by river sediments grading laterally to coarse, poorly sorted clastics along intermontane margins. Lignite is possibly Eocene. Probably equivalent to the Unit Ts of the Waite Basin (Alcoota 1:250 000 Sheet)
	Arltunga Beds (Tr)	Arenaceous limestone, silicified limestone, pebbly sandstone	4 m		
	Tlf	Ferricrete		see below	see below
Upper Cretaceous to Lower Tertiary	Tln	Undivided laterite profile with well-developed ferruginous, mottled and leached zones in places grading down into unweathered rocks. Best developed on coarsely crystalline igneous rocks	± 20 m	Region tectonically stable, widespread peneplanation	Deep weathering under humid conditions. Seasonal precipitation, and fluctuating water-table, forming a trizonal laterite profile. Palaeomagnetic evidence suggests a Maastrichtian to Early Eocene weathering event (Idnurm & Senior, 1978).

E: METAMORPHISM (R.D.S.)

An outline of the classification and distribution of metamorphic facies will be followed in this section, by an interpretation of the character, age, and physical conditions of the series of metamorphic events spanning the interval 1900-300 m.y. For more details on metamorphic grade the reader is referred to Table E4 and the descriptions of the individual "stratigraphic" units.

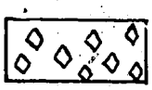
E-1: Distribution of Metamorphic Facies

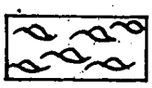
The distribution of metamorphic facies in the Alice Springs 1:250 000 Sheet area was first studied as part of the production of a metamorphic map of central Australia in the tectonic study by Forman & Shaw (1973). Earlier, Joklik (1955) made a detailed study of metamorphism in the Harts Range, but did not recognise that some regions had reached granulite facies. The distribution of metamorphic facies and key metamorphic minerals, or mineral-pairs, is given in Figures (E1 to E3) and Tables (E1 and E2) of the six 1:100 000 Sheet areas. Table E4 lists key mineral assemblages for each mapped rock unit. Table E5 lists mineral assemblages in basement cores obtained from drill holes along the Stuart Highway.

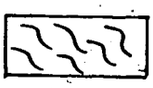
E-1-1: Granulite facies

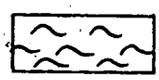
The occurrence of orthopyroxene in mafic rocks is considered to be diagnostic of the granulite facies (Turner, 1968, p. 320; Binns, 1969). No attempt has been made to map any subdivisions of the granulite facies, although a wide variation in PT conditions is evident. For example, orthopyroxene is locally present in rocks of acid and intermediate compositions, indicating metamorphism well within the granulite facies. Medium pressure and temperature conditions (greater than 9 kb and 800°C) have been demonstrated from assemblages in aluminous rocks by Vernon (1972), and by Woodford & Wilson (1976a, b) from two separate areas: one near Woolanga Bore, the other at Johannsens' Phlogopite Mine. Coexistance of

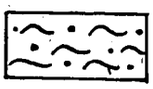
TABLE E1 REFERENCE TO METAMORPHIC MAPS

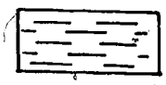

Granulite facies rocks (undivided)

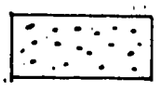

Amphibolite facies rocks (undivided)

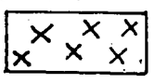

Upper amphibolite facies rocks

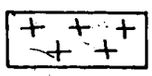

Lower amphibolite facies rock

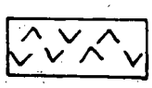

Greenschist to lower amphibolite facies rocks.


Retrograde schist zone of amphibolite facies rocks


Retrograde schist zones and localised regions of green schist facies rocks


Migmatite, granite-formed during Orimiston Event (1100 - 1000 m.y.)


Granite, granitic gneiss, orthogneiss


Basic Igneous Rock

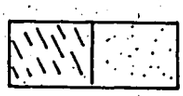

Amadeus Basin sediments

TABLE E2 METAMORPHIC MAPS- MINERAL ABBREVIATIONS

Ab	Albite (An 0-7)
Ac	Actinolite
Ad	Andalusite
Am	Almandine (garnet)
An	Andesine-oligoclase (An 17-60)
Ae	Anthophyllite
Bi	Biotite
By	Bytonnite
Ca	Calcite
Cd	Corundum
Ch	Chlorite
Cm	Cummingtonite
Co	Cordierite
Cp	Clinopyroxene
Di	Diopside
Do	Dolomite
Fo	Forsterite
Ep	Epidote, Clinozoisite, zoisite
Ga	Garnet (unclassified?
Ge	Gedrite
He	Hematite
Hb	Hornblende
Hd	Hedenbergite
Ho	Hogbomite
Hy	Hypersthene
I	Ilmenite
Ko	Kornerupine
Ks	Potassium feldspar
Ky	Kyanite
La	Labradorite
Mu	Muscovite
Op	Orthopyroxene
Oq	Opaque gneiss
Ph	Phlogophite
Pl	Plagioclase (unclassified)
Py	Pyrope (Almendinc)
Qz	Quartz
Ru	Rutile
Se	Sapphirine
Sc	Scapolite
Se	Serpentite
Sh	Sphene
Sp	Spinel (unclassified)
Sm	Sillimanite
St	Staurolite
Td	Talc
Tr	Tremolite

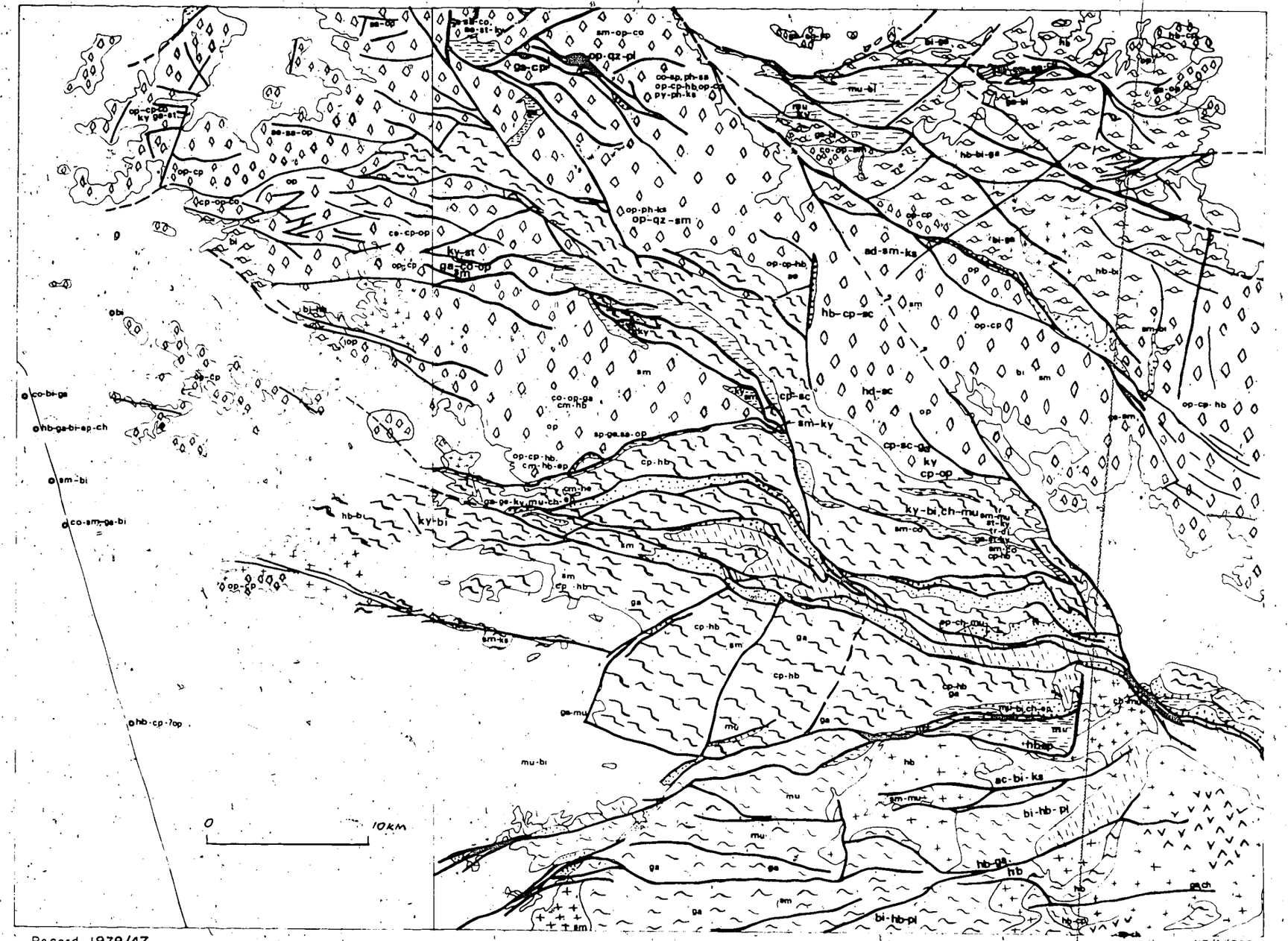


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Fig. E1 Distribution of metamorphic facies. BURT and LAUGHLEN (see table E1).

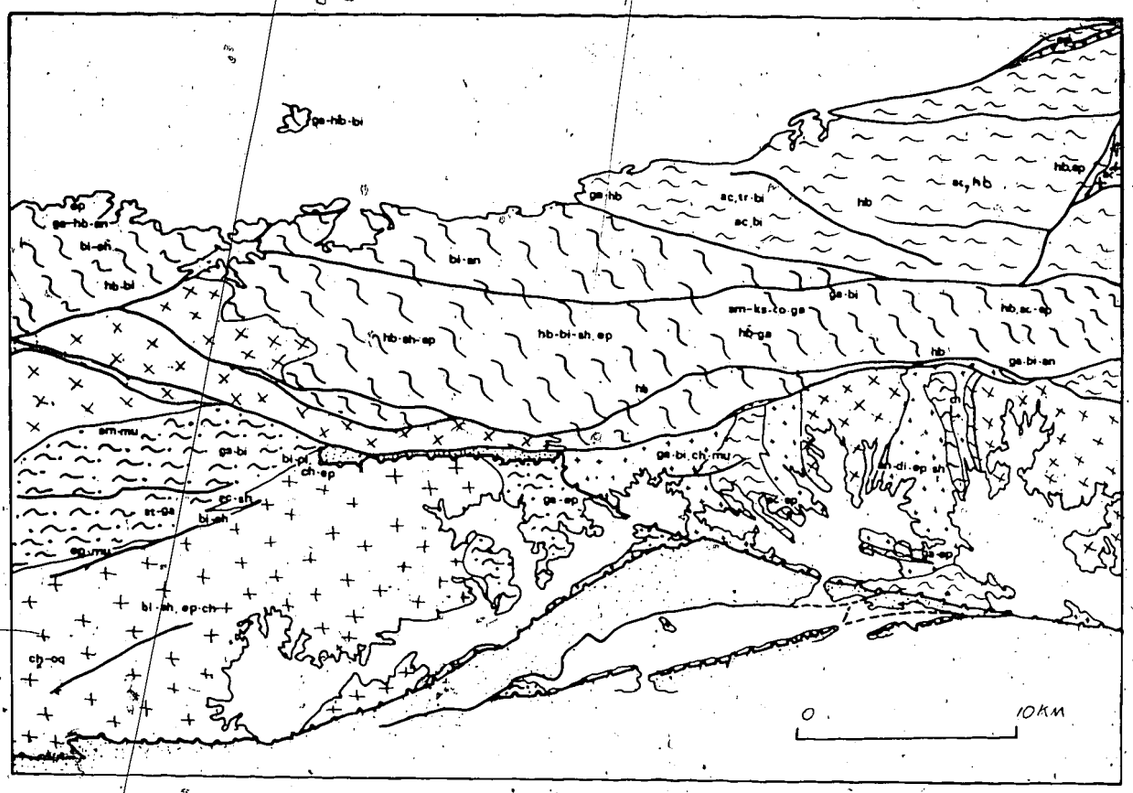
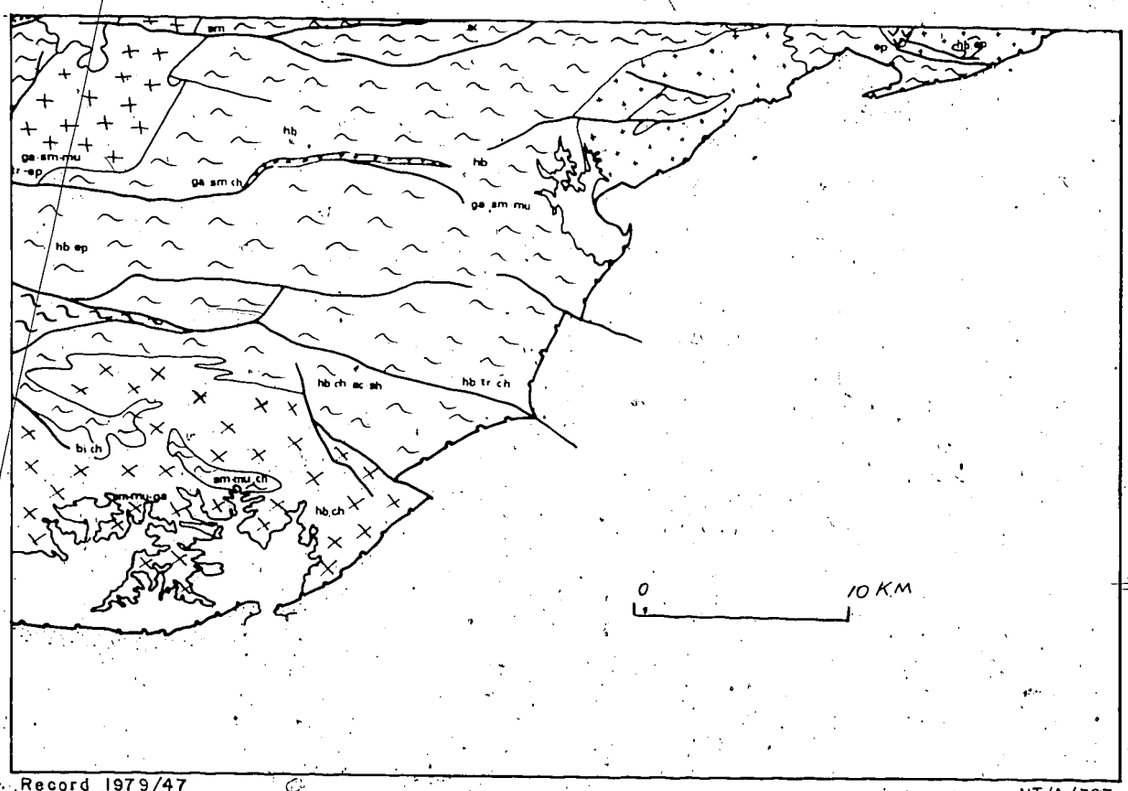


Fig. E2A Distribution of metamorphic facies ALICE SPRINGS (see table E1)



Record 1979/47 NT/A/767

Fig. E2B Distribution of metamorphic facies UNDOOLYA (see table E1)

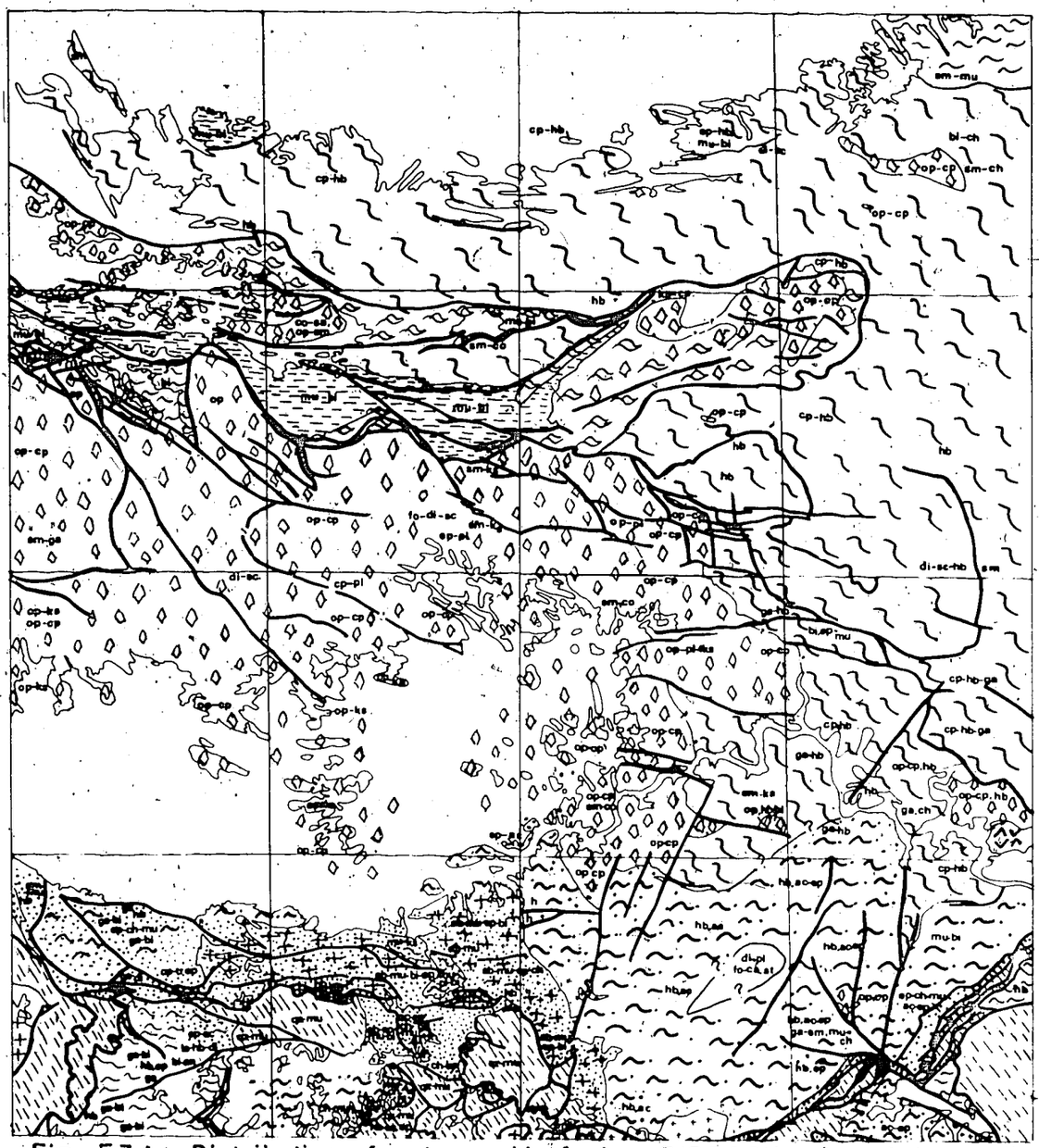


Fig. E3A Distribution of metamorphic facies ~~RIDDOCH~~ ~~(see Table E1)~~

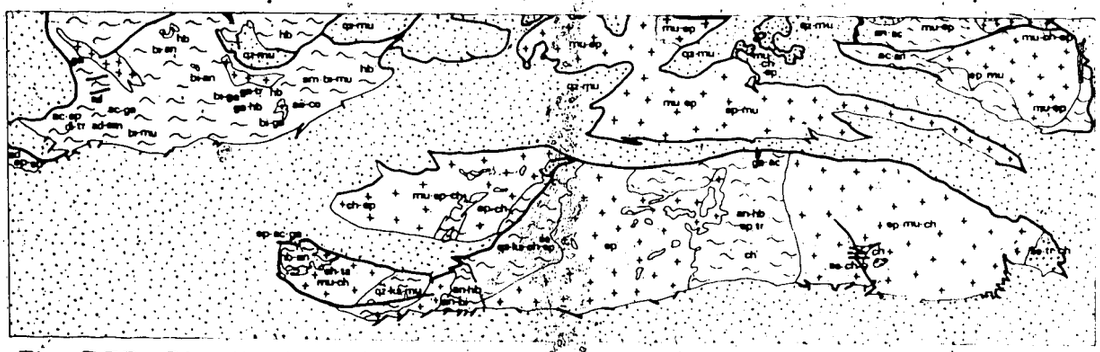


Fig. E3B Distribution of metamorphic facies FERGUSSON RANGE (see table E1)

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Amadeus Basin Sequence

0 10 KM

TABLE E3: Univariant equilibrium shown in figures E5 and E6. References are given in the Bibliography except for those marked * which are listed by Greenwood, 1976, p. 195, in THE EVOLUTION OF CRYSTALLINE ROCKS Eds. Bailey D.C., & McDonald R., 1976.

Number in Figures	Reaction	Reference
1	Kaolinite + Quartz = Pyrophyllite	Thompson, 1970a *
2	Muscovite + Quartz = Orthoclase + Al_2SiO_5	Evans, 1965; Kerrich, 1972* Chatterjee & Johannes, 1974
3A	Talc + Forsterite = Anthophyllite + H_2O	Greenwood, 1963 *
3B	Anthophyllite = Enstatite + Quartz + H_2O	Greenwood, 1963 *
4	Al_2SiO_5 polymorphs	Holdaway, 1971 *
5	Granite melting curve (i.e. Albite + Orthoclase + Quartz + H_2O)	Luth, Johns & Tuttle, 1964*
6	"Bulk composition" melting curve (i.e. Orthoclase + Quartz + H_2O)	Lambert, Robertson & Wyllie, 1969 *
7	Al_2SiO_5 polymorphs	Richardson, Gilbert & Bell, 1969 *
8	Chlorite + Kyanite + Quartz = Cordierite + H_2O	Schreyer and Seifert, 1969*
9	Fe-chloritoid + Quartz + O_2 = Fe-staurolite + Almandine + Magnetite H_2O	Richardson, 1968 *
10	Fe-staurolite + Quartz = Almandine + Al_2SiO_5 + magnetite	Richardson, 1968 *
11	Fe-cordierite = Fe-staurolite + Almandine + Quartz	Richardson, 1968 *
12	Mg Cordierite + Mg Garnet = Hypersthene + Kyanite + Quartz	
12A	Mg Cordierite + Mg Garnet = Hypersthene + Sillimanite + Quartz where $X_{CD} = 100\ Mg/(Mg + Fe^{++}) = 90+$	
12B	Cordierite + Garnet + Sillimanite + Quartz where $X_{CD} = 100\ Mg/(Mg + Fe^{++}) = 50$	Hensen and Green, 1972, 1973. Experiments under low O_2 and H_2O fugacities on silica-saturated pelitic compositions

TABLE E3 (cont'd)

Number in Figures	Reaction	Reference
12C	Cordierite + Hypersthene = Garnet + Quartz where $X_{CD} = 100\ Mg/(Mg + Fe^{++}) = 50$	
13	Cordierite + Garnet = Hypersthene + Sapphirine + Quartz	
14	Cordierite + Garnet = Hypersthene + Spinel + Quartz	
15	Talc = Amphibole + Kyanite + Quartz	
16	Appearance of orthopyroxene in amphibole + kyanite + quartz assemblage, garnet appears at slightly higher temperatures	Green & Vernon, 1974 most experiments at $P_{H_2O} = P_{TOTAL}$
17	Cordierite (+ quartz) = Aluminous Anthophyllite + Kyanite (+ quartz) where cordierite is not completely consumed	Natural rock approximating system $MgO-Al_2O_3-SiO_2-H_2O$
18	Above reaction where cordierite has completely broken down	
19	Garnet + Cordierite + Sillimanite = Spinel + Quartz	Hensen & Green, 1973. low O_2 and H_2O fugacities as for reactions 12-14
20	Incoming of garnet in quartz tholeiite with $100\ Mg/(Mg + Fe^{++}) = 40-70$	
21	Very approximate position of above reaction for alkali olivine basalt with $100\ Mg/(Mg + Fe^{++}) = 60-70$	Green & Ringwood, 1967, p. 801 and p. 807 Experimental conditions
22A	Olivine + Anorthite = Diopside + Enstatite + Spinel; and Olivine + Anorthite = Al Diopside + Al Enstatite	$P_{H_2O} \ll P_{LOAD}$
22B	Very approximate position of above reactions in alkali-olivine basalt.	Basaltic compositions

TABLE E4: SUMMARY OF METAMORPHIC MINERAL ASSEMBLAGES IN EACH MAPPED UNIT

* Composition

A = Aluminous or magnesium-rich (e.g. spinel ± anthophyllite ± gedrite ± orthopyroxene ± phlogopite rocks.

C = Calcareous gneiss, calc-silicate rock, impure marble

F = Felsic rocks, generally containing K-feldspar, mainly consiting of quartz and feldspar.

G = Granite, granodiorite, tonalite

I = Rocks of intermediate composition e.g. meta-andesite, metagreywacke

M = Mafic rock e.g. mafic granulite, amphibolite

P = Pelitic or aluminous rocks, meta-psammopelites

e.g. garnet-sillimanite-plagioclase-quartz gneiss

Q = Quartzite, ferruginous quartzite

S = Meta-psammite, quartz-rich meta-arenite

U = Meta-ultramafic rock

** Metamorphic Events

P-St = Pre-Strangways Event,

St = Strangways Metamorphic Event

Ch = Chewings Metamorphic Event

Wo = Woolanga Metamorphic Event

Wo1 = As above, early

Wo2 = As above, late

Or = Ormiston Metamorphic Event

Ya = Yambah Event

Ar = Arltunga Event

UNIT	COMPOSITION*	KEY MINERAL ASSEMBLAGES	EVENT**	METAMORPHIC FACIES	REMARKS, REFERENCES
Greenschist Retrograde Schist Zones, Pzr	F,G	Partial to complete alteration of 1. Plagioclase to sericite + epidote/clinozoisite + albite ± calcite	Ar	GREENSCHIST	Shaw et al., 1971; also this Record
	A	2. Biotite to chlorite			
	G	3. Hornblende to actinolite			
		North of White Range, RIDDOCH: Tonalite completely retrogressed to biotite + muscovite + epidote + albite		MIDDLE GREENSCHIST	Stewart, 1971a, & b
		The retrogression which also affected many of the individual units is described in detail below			
Harry Creek Deformed Zone, Pzr/Brh	I,G	1. Minerals in Zone marginal to Utnalanama Block: biotite, white mica, Mn-garnet, Mg-chlorite, epidote, blue-green hornblende, serpentine, gedrite, staurolite, kyanite, sphene.	?Ch	EPIDOTE AMPHIBOLITE	Allen and Black, in prep.
	G	2. Minerals in schistose part of Gumtree Granite: biotite, epidote, white mica, Mn-garnet ± chlorite	Ar		
West Bore Deformed Zone, Pzr/Brw	P	Kyanite + muscovite + biotite + quartz		LOWER AMPHIBOLITE	68180023, this report Spec. 4403
	P	Muscovite + biotite + plagioclase + quartz	Ar		
	M	Blue-green hornblende rimming dark-brown hornblende + plagioclase	Ar		

Yambah Schist Zone, Pzr/Byr	P	Kyanite + staurolite + biotite	Ar	ALMANDINE AMPHIBOLITE FACIES, STAUROLITE ALMANDINE SUBFACIES	Iyer, Woodford, & Wilson, 1976; Iyer and Wilson this report
	P	Muscovite + biotite + quartz ± garnet	Ar		
	C	Diopside-epidote-rich layers			
	M	Hornblende-rich layers			
	M	Chlorite-rich layers	Ar		
Southern Cross Schist Zone, Pzr/Brs	P	Muscovite + biotite + quartz (Est)		"AS ABOVE"	
	P	Kyanite + muscovite (Est)	?Ch,	"AS ABOVE	
	P	Kyanite + staurolite + biotite - quartz (Wst)	?Ar	STAUROLITE ALMANDINE SUBFACIES	Spec. 3546
Narbib Deformed Zone, Pzr/Brn	P	Garnet + biotite + quartz		UPPER AMPHIBOLITE	
	P	Sillimanite + biotite + quartz			
Laughlen Metamorphics, pCl	P	Biotite + muscovite + sericite + plagioclase + quartz	Ch		This Record. Specs. 3525, 3658
IWUPATAKA METAMORPHIC COMPLEX	S	Garnet + biotite + muscovite + sodic plagioclase + quartz	Ch	AMPHIBOLITE	L.A.O.
Simpsons Gap Metasediments, Bas	S	Biotite + muscovite + plagioclase + quartz	Ch	AMPHIBOLITE	L.A.O.
	P	Garnet + albite + biotite + muscovite + quartz + staurolite	Ch	AMPHIBOLITE	This Record
	P	Epidote + K-feldspar + muscovite + quartz		U. GREENSCHIST TO AMPHIBOLITE	
	C	Sphene + actinolite + sodic plagiocalse + quartz	Ar	UPPER GREENSCHIST	
Chewings Range Quartzite, Bac	Q	Muscovite + quartz ± sillimanite	Ch	AMPHIBOLITE	(L.A.O.) this Record MacDonnell Ranges
	Q	Muscovite + quartz ± kyanite	Ch	AMPHIBOLITE	
Rungutjirba Gneiss, Bar	F	Muscovite + quartz + andesine + K-feldspar	Ch	AMPHIBOLITE	(L.A.O.) this Record
Burt Bluff Gneiss, Bab	F	Biotite + quartz + sodic plagioclase + microcline	Ch	AMPHIBOLITE	(L.A.O.) this Record

Tommys Gap Metamorphics, pCt	C	Calcite + epidote + quartz, calcite + actinolite + microcline + quartz, epidote + microcline + plagioclase + quartz + actinolite, plagioclase + hibschite + actinolite + epidote + calcite	Ch	UPPER GREENSCHIST (West.) to MIDDLE AMPHIBOLITE (East.)	This Record (AJS)
	M	Oligoclase + hornblende (West) Andesine + hornblende (East)			
	C,M	Retrograde reactions:			
		biotite goes to chlorite, actinolite goes to chlorite, opaques go to epidote, hornblende goes to tremolite, plagioclase goes to epidote ± clinozoisite ± sericite	Ar	GREENSCHIST	This Record
Cavenagh Metamorphics, pCk	P	Andalusite + muscovite + quartz	Ch	MIDDLE AMPHIBOLITE	1719 m.y. Rb-Sr WR age on amphibolite, (Armstrong & Stewart, 1975)
	M	Hornblende + plagioclase + epidote + quartz			
	C	Calcite + muscovite + quartz			
	S	Quartz + microcline + muscovite + plagioclase + biotite			
		Quartz + garnet			
		Retrograde reactions:			
		hornblende → actinolite ilmenite → sphene garnet → chlorite plagioclase → sericite ± clinozoisite ± epidote ± calcite	Ar	GREENSCHIST	
Unnamed unit, pCd	F, M	Garnet Hornblende + labradorite + clinozoisite	C	AMPHIBOLITE	
		Retrograde reactions:			
		garnet → biotite			

HAYES METAMORPHIC COMPLEX					
Metasediment, pCpb	S	Biotite + feldspar + quartz ± garnet	Ch	AMPHIBOLITE	no thin section
Emily Gap schist pCpe	P	Muscovite + biotite + quartz	Ch	AMPHIBOLITE	
	M	Hornblende? + plagioclase	Ch	AMPHIBOLITE	no thin section
Calc-silicate rock pCpp	C	Epidote + diopside + andesine + quartz + microcline + sphene	Ch	LOWER AMPHIBOLITE	
Teppa Hill metamorphics pCpt	S	plagioclase + epidote + garnet + quartz	Ch	UPPER GREEN-SCHIST TO AMPHIBOLITE	
	Q	Muscovite + quartz	Ch		
	P	Muscovite + quartz + biotite + K-feldspar + sodic plagioclase	Ch		
	M	Actinolite + clinozoisite + muscovite + quartz ± tremolite ± sphene	Ar	UPPER GREENSCHIST	
	C	Clinopyroxene + sodic plagioclase + epidote + clinozoisite + garnet + quartz	Ch	LOWER AMPHIBOLITE	
Sadadeen Range gneiss, pCpd	F	Biotite + quartz + plagioclase + microcline	Ch	AMPHIBOLITE	
HARTS RANGE GROUP					
Brady Gneiss, pChb	S	Quartz + oligoclase + biotite + muscovite + almandine	St	AMPHIBOLITE	Spec. R4631 Joklik, 1955 p. 75
	S	Quartz + microcline + biotite + muscovite + sphene	St	AMPHIBOLITE	Spec. R4632
	P	Quartz + biotite + muscovite + sillimanite + plagioclase	St	AMPHIBOLITE	Spec. R4653 & Joklik, 1955 p. 74
	M	Garnet + hornblende + labradorite + quartz + magnetite + sphene	St	UPPER AMPHIBOLITE	Spec. R4655
	C	Quartz + calcite + clinozoisite + diopside + scapolite + sphene	St	AMPHIBOLITE	Spec. 4656

Irindina Gneiss, pChi	M	Hypersthene + clinopyroxene + plagioclase + hornblende (brown). Plagioclase (An55) + diopside + almandine + quartz + magnetite + biotite	St	GRANULITE	R4510, R4621-22, R4492, R4776 Joklik, 1955
	M	Clinopyroxene + hornblende + plagioclase + garnet + quartz + sphene	St		822, this Record
	U	Orthopyroxene + clinopyroxene + olivine + spinel + talc + magnetite (+ chlorite)	St	GRANULITE	M153, R4483
	P	Quartz + andesine + biotite + garnet ± sillimanite	St	AMPHIBOLITE	R4577; Joklik, 1955
Riddock Amphibolite Member, pChi (of Irindina Gneiss)	M	Clinopyroxene + hornblende + plagioclase + quartz + sphene (+ scapolite)	St	UPPER AMPHIBOLITE	R4619, Joklik, 1955
		Garnet + hornblende + garnet + sphene	St	AMPHIBOLITE	M162 this Record
Naringa Calcareous Member, pChn (of Irindina Gneiss)	C	Quartz + scapolite + diopside + hornblende + calcite + biotite ± plagioclase	St	AMPHIBOLITE	R4590 Joklik (1955) 804A, this Record
Bruna Gneiss pChd	F	Plagioclase (An40) + microcline + quartz + biotite + hornblende + magnetite + sphene + almandine	St?	AMPHIBOLITE	R4596 Joklik, 1955 p. 67
Entia Gneiss, pChe	F	Quartz + andesine + microcline + biotite + muscovite + magnetite	St?	AMPHIBOLITE	R4559 in QUARTZ Joklik, 1955, p. 53
	P?	Kyanite + biotite + quartz + muscovite (+sericite)	St?	AMPHIBOLITE	R4557, as above
WIGLEY BLOCK					
Unnamed unit, pCs	C	Garnet + hornblende + quartz + microcline + plagioclase	Ch?, Or	AMPHIBOLITE	L.A.O., this Record

Charles River gneiss, pCq	I	Garnet + biotite + quartz + plagioclase ± microcline (partly migmatised). Slight retrogression of: Garnet to chlorite plagioclase to epidote	Ch?, Or Ar	AMPHIBOLITE GREENSCHIST	As above As above
	M	Hornblende + plagioclase	Ch?, Or	AMPHIBOLITE	As above
Flint Spring gneiss, pCe	I	Biotite + quartz + feldspar ± garnet	Ch	AMPHIBOLITE	As above
	M	Hornblende + plagioclase	Ch		
Unnamed unit, pCd	F	Garnet + quartz + feldspar slight retrogression: garnet → biotite	Ch Ar	AMPHIBOLITE	As above
	M	Hornblende + plagioclase, slight retrogression of: plagioclase to clinozoisite	Ch Ar		
Bond Springs gneiss, pCb	F	Quartz + feldspar ± garnet ± muscovite ± biotite	Ch?, Or	AMPHIBOLITE	As above
	I	Biotite + quartz + feldspar	Ch?, Or		
	M	Hornblende + plagioclase	Ch?, Or		
Unnamed gneiss, pCj	F	Garnet + quartz + feldspar	Ch?, Or	AMPHIBOLITE	As above
	I	Biotite + quartz + feldspar ± garnet			
	M	Hornblende + plagioclase			
Unnamed gneiss, pCp	I	Biotite + quartz + feldspar ± garnet	Ch?, Or	AMPHIBOLITE	As above
	F	Quartz + feldspar	Ch?, Or	AMPHIBOLITE	
	M	Hornblende + plagioclase	Ch?, Or	AMPHIBOLITE	Some relict igneous opx
	C	Plagioclase + hornblende + garnet + quartz	Ch?, Or	AMPHIBOLITE	
	M	Actinolite + tremolite + plagioclase + quartz + opaque grains	As	GREENSCHIST	As above

Unassigned gneiss, pC	I	Biotite + quartz + microcline + plagioclase ± garnet	Ch?, Or	AMPHIBOLITE	As above
	M	Hornblende + plagioclase			Some relict igneous opx
		Some marked retrogression of hornblende to actinolite or tremolite; plagioclase to epidote or zoisite or clinozoisite + sericite or muscovite	Ar	GREENSCHIST	As above
WIGLEY BLOCK	P	Sillimanite + garnet + muscovite + biotite + plagioclase + quartz	Ch?	LOWER AMPHIBOLITE	
Randall Peak metamorphics, pCr	P	Muscovite + biotite + quartz			
	M	Hornblende)blue-green or green) + plagioclase + quartz			
		Retrograde reactions; hornblende to actinolite	Ar		
		plagioclase to sericite + epidote			
ANKALA BLOCK	M	Clinopyroxene + hornblende + plagioclase ± sphene ± quartz	Ch?	MIDDLE TO UPPER AMPHIBOLITE	Spec. 935A
Ankala gneiss, pCa	M	Hornblende + biotite + plagioclase + quartz			
	A	(Blue-green) hornblende + epidote	As?		
	A	Cummingtonite + hematite + ?K-feldspar	As?		
	C	Epidote, andraditic garnet, blue-green hornblende, alkali feldspar, scapolite, calcite	As?		retrogressed metasomatic skarn
Sliding Rock metamorphics pCi	M	Clinopyroxene + hornblende + plagioclase ± quartz	Ar?	MIDDLE TO UPPER AMPHIBOLITE	
	M	Hornblende + plagioclase (N.W.)			
	P	Garnet + biotite + quartz + plagioclase			
	P	Sillimanite + garnet + muscovite + plagioclase + muscovite			

Unit pCu	M	Orthopyroxene + clinopyroxene + plagioclase + hornblende	St	GRANULITE	Relict pods in S.W. plus isolated bodies
	F	Clinopyroxene + biotite + plagioclase + quartz	St		
	P	Hypersthene + cordierite + sillimanite + quartz + phlogopite			
	P	Muscovite + biotite + plagioclase + quartz	Ch/ Ar?	LOWER AMPHIBOLITE	Muscovite aligned parallel to overprinting schistosity
	M	Hornblende + plagioclase ± quartz ± scapolite ± clinopyroxene ± epidote			
	M	Chlorite + actinolite + ? plagioclase			
	F	Textural evidence only	P-St?	UNKNOWN	Quartz ribbons largely recrystallised
STRANGWAYS METAMORPHIC COMPLEX					
Bungitina metamorphics $pCsb_2$	A	Enstatite + phlogopite + anthophyllite + sapphirine + spinel	St?	UPPER AMPHIBOLITE to LOWER? GRANULITE	
	A	Cummingtonite — rock			
	C-S	Plagioclase + quartz ± clinopyroxene ± garnet ± hornblende ± scapolite ± K-feldspar			
Bungitina metamorphics $pCsb_1$	F	Textural evidence only	P-St	UNKNOWN	Quartz ribbons, largely recrystallised
	P	Kyanite recorded at one locality	St		- M.J.R. (ANU) M163
	F	Orthopyroxene + biotite + K-feldspar + quartz + plagioclase	St	GRANULITE	Specs. 2518, 5012 this Record
	M	Orthopyroxene + clinopyroxene + hornblende + quartz + plagioclase (± actinolite)	St		M166 M.J.R. (ANU)

	M	Hornblende or actinolite inferred from field descriptions	?	AMPHIBOLITE	inferred 5 km SE of Oongalabi Prospect. Needs field checking
Hillsoak Bore metamorphics, pC	C	Calcite + epidote + quartz	Ch	GREENSCHIST to LOWER AMPHIBOLITE	A.J.S., This Record: Rb-Sr age inferred to be 1719± 24 m.y.
	C	Calcite + actinolite + tremolite + microcline + epidote + quartz	Ch	AMPHIBOLITE	
	C	Diopside + tremolite + calcite + microcline + quartz			
	C	Actinolite + calcite + epidote + andradite + quartz			
	P	Sillimanite + andalusite +	Ch	SILLIMANITE CORDIERITE-ALMANDINE SUBFACIES OF AMPHIBOLITE FACIES; LOW P SERIES	Winkler, 1967 A.J.S. this Record
	A	Cordierite + anthophyllite ± oligoclase ± garnet	Ch		
	M	Actinolite ± garnet			
	M	Tremolite + garnet			
	P	Garnet + biotite ± sillimanite + oligoclase + quartz			
		Retrograde reactions of:			
	P	Plagioclase to sericite ± clinozoisite			A.J.S. This Record
	P	Cordierite to pinite	Ar	GREENSCHIST	
		Biotite to chlorite			
		Andalusite to sericite			
	M	Ilmenite to sphene			
		Western area - RIDDOCH			
	M	Hypersthene + clinopyroxene + plagioclase + hornblende ± biotite	St		
Cadney metamorphics, pCsc	F	Quartz + plagioclase + ortho-pyroxene + biotite	St	GRANULITE	
	P	Sillimanite + garnet + biotite + K-feldspar plagioclase + quartz			

C	Forsterite + scapolite + garnet + clinopyroxene + calcite	St		
	Eastern area - PINNACLES BORE - WOOLANGA BORE			
M	Hornblende (Mg value 52-78) + orthopyroxene (Mg value 54-73) + clinopyroxene (Mg value 66-78) + plagioclase (An 52-92) (2)	St	GRANULITE - age: 1860± P=8.5-9 kb T=700°-750°C	Primary metamorphism PT conditions by Woodford and Wilson, 1976b. PT variations basis of partition data p. 30-33.
P	Cordierite + orthopyroxene ± quartz (1,2)	St	LOW PRESSURE GRANULITE	(1) Woodford et al., 1975;
P	Orthopyroxene - spinel (2)			(2) Woodford and Wilson, 1976b
P	Cordierite - quartz - sillimanite ± kyanite (1)			(3) Iyer et al., 1976
P	Orthopyroxene + cordierite + spinel (2)			(4) Shaw, 1970
P	Cordierite + garnet + sillimanite(2)			
C	Olivine + diopside + orthoclase - phlogopite + spinel + calcite - dolomite (3)	St		
P	Sillimanite + phlogopite + bytownite + orthoclase - andalusite (4)	St		
C	Hornblende + diopside + andesine + quartz - microcline - scapolite (4)	St		
C	Mg-Calcite + dolomite (2)			
F	Garnet + phlogopite (2)			
M	Hornblende + plagioclase fine, recrystallised grains of clinopyroxene + plagioclase ± magnetite ± ilmenite	Wo1	GRANULITE i.e. 900°C. 11.5 K6	New Pyroxenes higher in Al and Mg/(Mg+Fe) & new plagioclase normally more sodic (Woodford and Wilson, 1976b): due to an increase in P and possibly T
A	Sillimanite + orthopyroxene + quartz (from cordierite)	Wo2A	Woodford and Wilson 1976 (a,b,&c)	

	A	Surinamite + quartz + cordierite + sapphirine + orthopyroxene + phlogopite spinel + sillimanite	Wo2B	T 900°C P 9Kb or less. Sapphirine, hogbomite and kornerupine formed from ?spinel late in the Woolanga event under low-grade Granulite to Upper Amphibolite Facies	Woodford & Wilson, 1976a Spec. W712
	A	Kyanite + quartz + cordierite hogbomite + garnet + phlogopite + spinel + gedrite	Wo2B		
	A	Corundum + opaque grains + phlogopite + plagioclase + sillimanite + orthopyroxene	Wo2B		Woodford & Wilson, 1976c: Kornerupine (Specs W356 & 692) formed in phlogopite dominated metasomatic zones in stages of two metamorphisms. They tentatively suggest an equilibrium temp. cf. 620-640°C based on Fe-Mg partition data for garnet-phlogopite (Woodford & Wilson, 1976c; Spec. 355)
	U	Tourmaline + kornerupine + garnet + phlogopite + corundum ± spinel ± magnetite ± ilmenite	Wo2B		
	U	Pleonaste-bronzite-hornblende	Wo2B		
	C	Very local, crosscutting garnet-wollastonite veins	?	AMPHIBOLITE	Woodford et al., 1975
Unit pGx	M	Orthopyroxene + clinopyroxene + hornblende + plagioclase	St	GRANULITE to UPPER AMPHIBOLITE	mainly in Nth.
	P	Sillimanite + garnet + biotite	St		
	C	Diopside + plagioclase + microcline + quartz			

	M	Actinolite - plagioclase - epidote (or clinozoisite) - sericite ± calcite	AS	GREENSCHIST	This Record
	P	Sericite + epidote + chlorite + plagioclase + biotite + quartz	AS		
Adla Granulite pCsa	M	Hypersthene + garnet + hornblende (40%) + plagioclase quartz	St	UPPER AMPHIBOLITE TO GRANULITE	Specs 4100, 4145
	F	Sillimanite + garnet + biotite - quartz + orthoclase + plagioclase quartz	St		Spec. 4099
Anuma Schist, pCss	P	Muscovite + staurolite + kyanite + quartz + biotite	Ch	MIDDLE AMPHIBOLITE (Staur.-Alm. subfacies to Ky-Alm-Musc subfacies)	(AJS) this Record; Winkler, 1967
	P	Muscovite + kyanite + biotite + quartz			
	Q	Garnet + hematite + quartz Retrogression of: Biotite to chlorite Kyanite to sericite			
Johannsen Metagabbro, pCsj	M	Rare textural relics of this event are thought to survive	P-St	?	Allen, 1976; Allen this Record
	M	Plagioclase + orthopyroxene + hornblende)brown-green) ± ilmenite	St	GRANULITE	Allen, 1976; Allen this Record
	M	Retrograde minerals: green hornblende, cummingtonite	Ya?	EPIDOTE AMPHIBOLITE	Allen, 1976; Allen, this Record
	M	blue-green hornblende, epidote sphene	Ar?		Allen, 1976; Allen, this Record
Erontonga Metamorphics, pCsr	M	Orthopyroxene + clinopyroxene + hornblende + quartz + plagioclase + ilmenite	St	GRANULITE	Allen, 1976; Allen, this Record
	P	Cordierite + quartz ± orthopyroxene ± plagioclase ± garnet ± sillimanite ± biotite	St/ ?Wo	GRANULITE	Allen, 1976; Allen, this Record

A	Quartz + Cordierite + Hypersthene ± Mg Biotite + sillimanite	St	GRANULITE	Vernon, 1972; Phlogopite mine area
C	Quartz + plagioclase + clino-pyroxene + Mg Clinoamphibole + magnetite + ilmenite	St	GRANULITE to UPPER AMPHIBOLITE	Allen, 1976; Allen, this Record
	PHLOGOPITE MINE AREA:			
A	Gedrite anthophyllite + orthopyroxene ± magnetite ± spinel	St	GRANULITE	Hudson & Wilson, 1966
A	Spinel - gedrite ± phlogopite	St	GRANULITE	
U	Pyroxene - spinel - clinopyroxene ± gedrite ± forsterite	St	GRANULITE	Iyer, et al., 1976
	PHLOGOPITE MINE AREA			
U	Sapphirine(1) replaces spinel, gedrite and an early phlogopite; (2) is associated with pargasite, Mg-cordierite, and highly calcic plagioclase (3) It is of two ages	?St, Wo	GRANULITE TO UPPER	Wilson, I.G.C., Sydney (1976) Section 14.
U	Zinc hogbomite is (1) co-facial with sheridanite - chlorite and (2) replaces spinel - phlogopite	Wo	GRANULITE TO UPPER AMPHIBOLITE	Wilson, I.G.C., Sydney (1976)
U	Olivine-pyroxene			
A	Later Stage hydration reactions in country rock consisting of Quartz + Sill. + Hyper. ± Biot. ± Cord.	?St	LATE STAGE GRANULITE REACTIONS	Vernon (1972), Reaction possibly involves addition of water to system: P 10 kb + T = 800°C. The result has been refined by the experimental work of Green & Vernon (1974) T=750 to 820°C & p=8-9.5 kb
	1. Cordierite + H_2O gedrite + kyanite + quartz			
	2. Al hypersthene + H_2O aluminous anthophyllite	?St		

	M	Blue-green hornblende + epidote + plagioclase	Ar?	EPIDOTE AMPHIBOLITE	Allen, 1976; Allen, this Record
	P	Biotite + Mn garnet + kyanite + staurolite	Ya	EPIDOTE AMPHIBOLITE	Allen, 1976; Allen, this Record
Unit pCst	M	Green hornblende + clinopyroxene + hypersthene + plagioclase ± quartz	St	GRANULITE	This record
	A	Kornerupine + cordierite + sapphirine + plagioclase + orthoclase	St		
	A	Above assemblage partly breaking down to sillimanite + orthopyroxene + quartz + phlogopite + corundum + magnetite: also geikeilite	St? or Wo?	GRANULITE	This Record
Harry Anorthositic Gabbro, pCsh	M	Plagioclase + orthopyroxene + hornblende + magnetite ± clinopyroxene ± ilmenite ± spinel	St	GRANULITE	Allen, 1976; Allen, this Record
	M	Retrograde reaction of: 1. Orthopyroxene to cummingtonite 2. Clinopyroxene to blue-green hornblende + epidote 3. Ilmenite to sphene	Ar	LOWER AMPHIBOLITE	Allen, 1976; Allen, this Record
Utnalanama Granulite, pCsu	I	Quartz + antiperthitic plagioclase + orthoclase + clinopyroxene + ilmenite	P-St St	GRANULITE	1800± 27 m.y. $^{40}Ar - ^{39}Ar$, Allen & Stubbs, in press
	I	Mainly textural change to above assemblage	St	GRANULITE	1710± 26 m.y. $^{40}Ar - ^{39}Ar$ Allen & Stubbs, in press
	I	K-feldspar + biotite	Wo?	GRANULITE	localised, probably metasomatic
	I	Retrograde reactions: clinopyroxene hornblende orthopyroxene biotite	Ar	AMPHIBOLITE	Allen, 197 ; Allen, this Record

Unit pCsp	M	Hornblende (green-brown) + clinopyroxene + orthopyroxene + plagioclase ± quartz ± biotite	St	GRANULITE	This Record
	F	Orthopyroxene + biotite + quartz + perthitic orthoclase ± garnet	St	GRANULITE	in West; W130, W312, W694: Woodford & Wilson (1976a)
	S	Sillimanite + biotite + quartz - plagioclase + perthitic orthoclase ± garnet	St	GRANULITE TO UPPER AMPHIBOLITE	Specs. 3600; 3602
	P	Clinopyroxene - sillimanite - orthopyroxene - quartz	Wo?	GRANULITE	Spec. 3723 similar to assemblage in Woodford & Wilson (1976a)
	M	Green hornblende + biotite, accompanied by recrystallisation	Wo?	AMPHIBOLITE	
Unit pCsf	M	Hypersthene + diopside + plagioclase	St	GRANULITE	This Record.
	M	Garnet + diopside + hypersthene + andesine ± orthoclase ± quartz ± hornblende	St		Spec. 3208 garnet rims hypersthene where it is contiguous with plagioclase
	A	Cordierite + sillimanite + anthophyllite + orthoclase + biotite	St?	UPPER AMPHIBOLITE TO GRANULITE	Spec 3207
	I	Hypersthene + hornblende + quartz + plagioclase	St	GRANULITE	
	I	Clinopyroxene + plagioclase + quartz ± hornblende (±chlorite)	St	GRANULITE	Spec. 3220
	F	Biotite + plagioclase + quartz ± sillimanite ± muscovite ± K-feldspar ± garnet	St? Ya?	AMPHIBOLITE/ GREENSCHIST	
	F	Muscovite + biotite + quartz	Ya?	GREENSCHIST/ AMPHIBOLITE	This Report
	Q	Muscovite + quartz	?	GREENSCHIST/ AMPHIBOLITE	
	P	Kyanite in biotite schist	Ya		Field determination

Yambah granulite, pCsy	M	Hypersthene + plagioclase (An50-60) ± diopside ± quartz ± hornblende (brown)	St	LOW TO INTERMEDIATE PRESSURE GRANULITE	A.P.L. this Record; Pressure est. by Iyer et al. 1976, after Green & Ringwood 1967
	F	Garnet + cordierite + quartz + hypersthene ± microperthite ± biotite ± phlogopite	St	GRANULITE	Iyer et al., 1976, 1860 ± 50 m.y. Rb-Sr isochron on 6 felsic granulites
	C	Hypersthene + garnet + hornblende + scapolite	St	GRANULITE	
	A	Sapphirine + enstatite ?+ spinel	St?	GRANULITE TO UPPER AMPHIBOLITE	A.P.L. this Record
Narbib granulite pCsn	M	Hypersthene + diopside + hornblende + plagioclase + quartz ± biotite (relict igneous pyroxene)	St	GRANULITE TO AMPHIBOLITE	Spec. 4499, This Record
Ongeva granulite, pCso	F	Hypersthene + plagioclase + quartz + microperthite ± garnet ± hornblende ± tourmaline	St	GRANULITE, garnet suggest medium to high pressure	A.P.L. this record
	M	Hornblende + hypersthene + diopside + plagioclase	St	GRANULITE	As above
	P	Cordierite + sillimanite + microperthite + biotite ± quartz ± hypersthene ± garnet ± spinel	St	AMPHIBOLITE TO GRANULITE	As above
	M	Recrystallisation of above	Wo?	?GRANULITE	
	M	Biotite + blue-green hornblende	Ar?	EPIDOTE AMPHIBOLITE	A.P.L. this Record
	P	Cordierite + anthophyllite ± kyanite ± quartz	Ya?	?UPPER AMPHIBOLITE	
Enbra Granulite, pCse	M	Hypersthene + hornblende + (blue-green) + andesine + spinel	St		Spec. 4251 This record
	I	Garnet + biotite + hornblende + plagioclase + quartz	St		Spec. 4256
		Retrograde minerals: ? blue-green hornblende, clinozoisite	Ar?		This record

TABLE E5: Basement cores from 1973 Cainozoic Drilling Program, Burt Plain.

Drill hole	Depth	Lithological Symbol	Basement Core
BMR, Alcoota 14	23 m, 75 ft	f	75900060. Rock contains biotite, plagioclase, orthoclase (microcline) and quartz; accessory opaque grains and zircon; gneissic texture: possible metasediment. Upper amphibolite-granulite metamorphic grade.
BMR, Alcoota 15	5 m, 17 ft	vf,z	75900061. Gneiss contains sillimanite, garnet, biotite, oligoclase, microcline and quartz; accessory opaque grains, zircon and monozite; gneissic texture. Metasediment. Upper amphibolite-granulite metamorphic grade.
BMR, Alcoota 16	100 m, 329 ft	pa,r	75900062. Biotite-quartz-epidote-hornblende rock cut by quartz-biotite schistose zone and calcite filled vein. Hornblende is pale green-brown, altered at margins to green-blue. Metacalc-silicate rock. Probable upper amphibolite-granulite facies retrogressed to upper greenschist-lower amphibolite, cut by schistose zones and tension fracture.
BMR, Alcoota 17	46 m, 150 ft (Basement not intersected)	-	No thin section. Core of chalcedonic / opaline quartz, microcrystalline carbonate.
BMR, Alice Springs 5	23.5 m, 77 ft	a	75912800. Rock contains opaques grains biotite, quartz, plagioclase (An45), and hornblende. Hornblende is deep green-brown. Granulite texture metabasic igneous rock. Upper amphibolite-granulite metamorphic grade.
BMR, Alice Springs 6	39 m, 128 ft	r,p	75912801. Weathered megacrysts of (perthitic) microcline, coarse muscovite in schistose groundmass of quartz, sericite and biotite; accessory epidote, tourmaline, zircon. Deformed rock - probably metasediment or augen gneiss.
BMR, Alice Springs 7	88 m, 288 ft	f,z	75912802. Gneiss containing sillimanite, biotite, garnet, quartz, orthoclase, and ?cordierite; accessory zircon and ?monozite. Granulose texture. Upper amphibolite-granulite. Felsic gneiss.

TABLE E5 (cont'd)

Drill hole	Depth	Lithological Symbol	Basement Core
BMR, Alice Springs 8	25.5 m, 84 ft	mn	75912803. Diopside-orthopyroxene-hornblende-andesine granulite; accessory opaque grains and ?rutile. Hornblende is green-brown and confined to one part of the slide. Metabasic rock. Granulite facies.
BMR, Alice Springs 9	107.5 m, 352 ft	vf,if	75912804. Gneiss containing sillimanite, biotite, cordierite, plagioclase, garnet, perthitic orthoclase and quartz; accessory sphene, zircon, opaque grains and ?diopside. Granulose texture. Metasediment. Upper amphibolite-granulite.
BMR, Alice Springs 10	92 m, 302 ft	vf,if	75912808. Gneiss containing sillimanite, cordierite, biotite, garnet, sodic plagioclase, quartz and perthitic orthoclase; accessory opaque grains, zircon and apatite. Granulose texture. Metasediment. Upper amphibolite metamorphic grade.
BMR, Alice Springs 11	58.5 m, 192 ft	i,f	75912805A, B. Gneiss containing sillimanite, biotite, cordierite, plagioclase, quartz and perthitic orthoclase; accessory zircon. Granulose texture. Possible metasediment.
BMR, Alice Springs 12	66.5 m, 218 ft	vf	75912806. Gneiss containing biotite, garnet, plagioclase, orthoclase and quartz; accessory zircon and opaque grains. Granulose texture. Metaigneous felsic rock? Upper amphibolite-granulite.
BMR, Alice Springs 13	18.5 m, 60 ft	vf,if	75912811. Gneiss containing garnet, biotite, cordierite, plagioclase, perthitic orthoclase and quartz; accessory zircon and monazite. Gneissic texture. Probably metasediment. Upper amphibolite-granulite.
BMR, Alice Springs 14	85 m, 279 ft	pa	75912812. Rock containing biotite, diopside, hornblende, plagioclase quartz and about 1% apatite, 2% opaque grains; accessory sphene. Granulose to gneissic texture. Possibly meta-calcsilicate. Upper amphibolite.
BMR, Alice Springs 15	79.5 m, 260 ft	-	Did not reach crystalline basement

TABLE E5 (cont'd)

Drill hole	Depth	Lithological Symbol	Basement Core
BMR, Alice Springs 16	8 m, 26 ft	fn	75912807. Granulite containing orthopyroxene, plagioclase, orthoclase and quartz; accessory opaque grains, biotite, hornblende, apatite and zircon. Granulose texture. Granulite, slight retrogression.
BMR, Alice Springs 17	107 m, 350 ft	fn	75912809. Gneiss containing biotite, antiperthite, perthitic orthoclase and quartz; accessory opaque grains, zircon and monazite. Granulose texture. Granulite grade. Meta-igneous rock.
BMR, Alice Springs 18	83 m, 272 ft	r,cs	75912813. Layered rock. One part of section is much more quartz-rich than the other; actinolite is confined to the other. Mineral constituents are garnet, biotite, low Ca-plagioclase, chlorite, epidote, quartz and actinolite. Calcareous metasediment. Crosscutting vein of calcite. Partly superimposed schistose fabric, partly relic granular texture. Retrogressed to greenschist from ?amphibolite grade.
BMR, Alice Springs 19	83 m, 272 ft	qt, w, x?	75912810A; B. Core A contains muscovite, opaque grains and quartz (99%). Core B contains staurolite, opaque grains, quartz muscovite, and ?clay minerals after andalusite. Metasediment. Schistose fabric. Staurolite-amphibolite grade.
BMR, Alice Springs 20	70 m, 230 ft	mn,r	75912814. Granulite containing diopside, iron-rich orthopyroxene, biotite, garnet, quartz, hornblende and plagioclase (low Ca). Crosscutting fracture filled by calcite and limonite. Granulose fabric. Upper amphibolite retrogressed from two-pyroxene high pressure granulite.
BMR, Alice Springs 21	10 m, 32 ft	mn	75912815. Granulite containing biotite, quartz, hypersthene, diopside, hornblende, plagioclase (An50-60); accessory apatite and opaque grains. Metaigneous rock. Gneissic fabric. Upper amphibolite prograding to granulite.
BMR, Alice Springs 22	71.5m, 235 ft	f	75912816. Gneiss containing biotite, sodic plagioclase, quartz, perthitic orthoclase; accessory opaque grains, zircon, and monazite. (Metaigneous rock). Granulose fabric, with superimposed polygonization and straining of quartz. Upper amphibolite.

TABLE E5 (cont'd.)

Drill hole	Depth	Lithological Symbol	Basement Core
BMR, Alice Springs 23	52 m, 170 ft	vf	Core not thin-sectioned. Identified in field as garnet-biotite felsic schistose gneiss.
BMR, Alice Springs 24	75 m, 245 ft	a,r	75912818. Gneiss containing augen of plagioclase, relict brown hornblende in schistose ground mass of biotite, quartz, blue-green hornblende; accessory opaque grains white mica and zircon. Small grains of brown mineral, possibly haematite. Metaigneous rock. Schistose fabric. Lower amphibolite retrogressed from upper amphibolite-granulite.

hornblende and both ortho- and clinopyroxene in textural equilibrium over wide areas is indicative of the hornblende - granulite subfacies (Turner & Vergoogen, 1960), and suggests that conditions were transitional towards the amphibolite facies (Turner, 1968). This interpretation is consistent with the common occurrence of biotite with orthopyroxene.

Granulite facies rocks form a belt which trends eastwards across the northern part of the Alice Springs 1:250 000 Sheet area, north of the Harry Creek Deformed Zone and the Hale Plain. Two small granulite outcrop-areas occur south of this belt in the Narbib Range and in the Adla Hills in the western part of the 1:250 000 Sheet area.

E-1-2: Amphibolite Facies

Amphibolite facies rocks are the most abundant of the three facies, and account for most of the southern part of the Arunta Block in the 1:250 000 Sheet area. The first appearance of hornblende is taken as the lower boundary of the amphibolite facies. Mafic, quartzo-feldspathic, and calc-silicate rocks at this grade have proved difficult to subdivide on a regional basis. Pelitic rocks, although better indicators of metamorphic conditions, are not sufficiently widely distributed to serve in subdividing all the amphibolite facies rocks. In some cases, upper-amphibolite facies rocks are recognised by either the coexistence of clinopyroxene with hornblende in amphibolite, or the coexistence of sillimanite with K-feldspar in pelitic rocks. The coexistence of sillimanite with muscovite in pelitic rocks is taken to indicate middle to lower amphibolite facies conditions. Elsewhere, the amphibolite facies has been left undivided on the maps (Figs. E1 to E3). Where amphibolite-facies schist-zones have developed by retrogression of granulite facies rocks they have been shown on the maps as a special category.

E-1-3: Greenschist Facies

Greenschist facies rocks are largely confined to east-trending (and a few northerly trending) retrograde schist-zones. These schist-zones are closely related to faults, and are considered to have been formed during the Alice Springs Orogeny. Rocks belonging to the upper part of the "Iwupataka Metamorphic Complex" are an exception and grade from lower amphibolite facies rocks into greenschist facies rocks.

E-1-4: Drilling Program - Basement Rock types and metamorphic grade of rocks under Cainozoic cover of Burt Plain (R.D.S.)

Twenty-four holes, 20 in the Alice Springs 1:250 000 Sheet area and 4 in the adjacent southwestern corner of the Alcoota 1:250 000 Sheet area (the location of these holes are shown on the BURT and ALICE SPRINGS Preliminary maps) were drilled during the 1973 field season. The drilling was designed to provide samples of crystalline basement from beneath the Tertiary-Quaternary cover of the Burt Plain. Cores of crystalline rocks were recovered from all except two holes Alcoota 17 terminated in ?calcrete at 150 feet and Alice Springs 15 was abandoned at 260 feet without reaching crystalline basement. The cuttings, collected in intervals of 10 feet, have not been logged. Table E5 contains details of the basement cores obtained.

The drilling revealed a basement topography with some relief which has been infilled by Cainozoic alluvial sediments. The Burt Plain is therefore a bajada, rather than a pediment plain, with respect to the Strangways and MacDonnell Ranges.

E-2: Metamorphic Events

A series of metamorphic events have been recognised, the interpreted distribution of which is shown in Figure E4 and indicated in Table E4. Each event has been assigned a name and a reference area, which is chosen to correspond with an area where age determination work has been carried out.

The following metamorphic events are proposed:

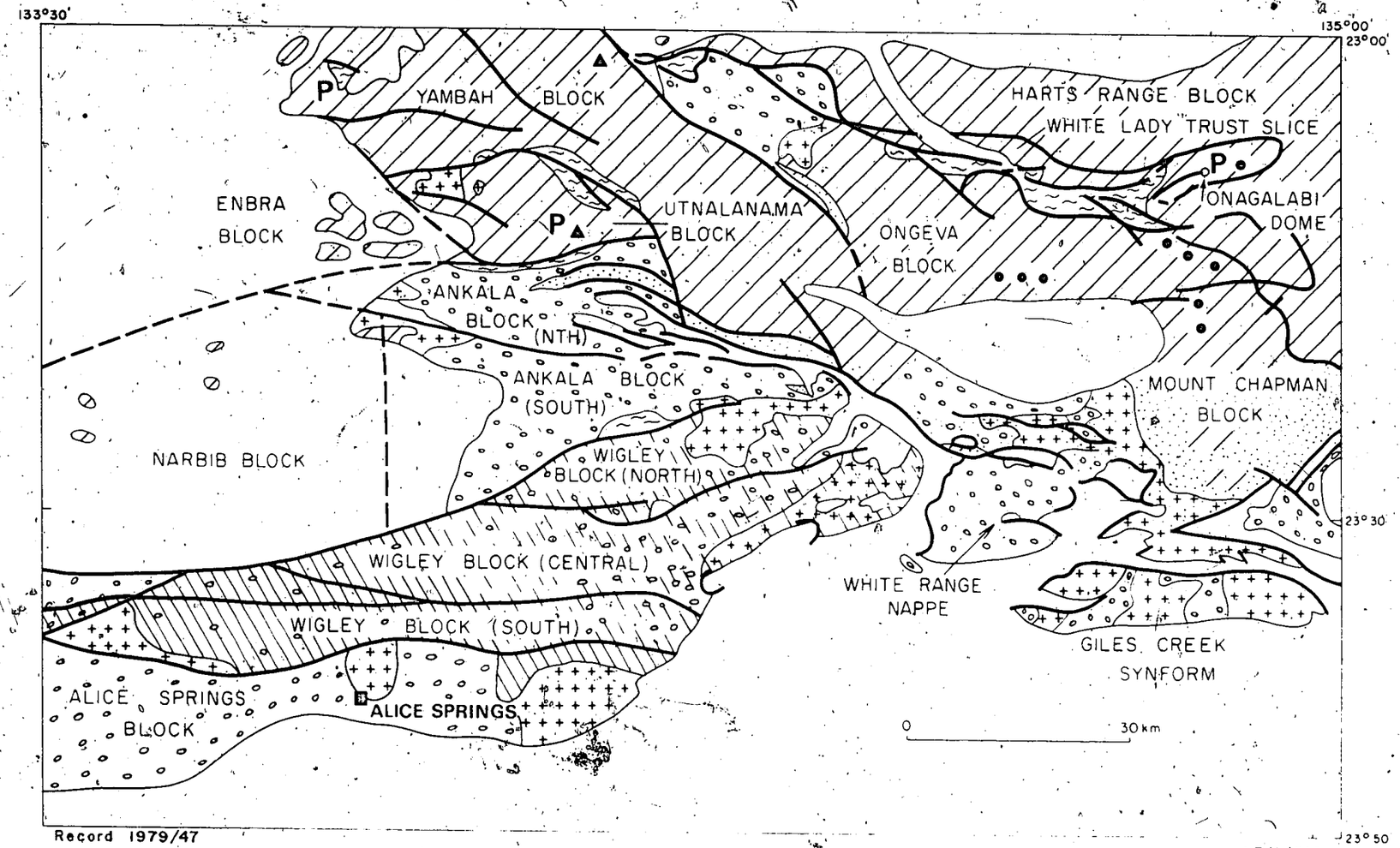
NAME	SYMBOL	AGE
Pre-Strangways Metamorphic Event	P-St	Greater than 1820
Strangways Metamorphic Event	St	about 1800 m.y.
Chewings Metamorphic Event	Ch	about 1600, possibly extending to 1650-1700 m.y.
Woolanga Metamorphic Event	Wo.	about 1450 m.y.
Ormiston Metamorphic Event	Or	1050-1000 m.y.
Yambah Metamorphic Event	Ya	Uncertain: possibly 500-350 m.y. (but there is evidence of earlier movements)
Arltunga Metamorphic Event	Ar	about 335-310 m.y.

These metamorphic events commonly, but do not necessarily, correspond to deformational events. Future work will not doubt result in clarification and subdivision of these events, but it is hoped these proposed names can be retained for the metamorphism recognised in the specified type-areas. Granite intrusion occurred during the later stages of the Strangways, Chewings and Ormiston Events.

E-2-1: Pre-Strangways Metamorphic Event (P-St)

Definition

Although on present evidence a Pre-Strangways metamorphic event is tenuous, such an event is suspected, based on textural evidence, in three areas (Figure E4). (1) In the Yambah granulite in the Yambah area, elongated plagioclase grains appear to predate the granuloblastic texture



P Pre-Strangways Event, >1800 m.y.

Strangways Event, about 1800 m.y.

Chewings Event, 1600 - 1700 m.y.

▲ Woolanga Event, about 1450 m.y.

Ormiston Event (Rb-Sr Tr age reset), 1050 - 1000 m.y.

Ormiston Event, low grade (ie. Rb-Sr mineral age reset)

Yamba Event, Proterozoic / 500 - 350 m.y.

Arltunga Event, 335 - 310 m.y.

● Recrystallisation, age unknown

Granite, granitic gneiss, granitoid

Proterozoic and Phanerozoic cover

Fault

Boundary

Fig. E4 Interpreted metamorphic events, southeastern Arunta Block; Alice Springs 1:250 000 Sheet area

characteristic of the Strangways Event (A.F. Wilson, University of Queensland, personal communication, 1976). (2) In the Bungitina gneiss in RIDDOCH, quartz-ribbons have been recrystallised during a later event which was possibly the Strangways Event, as this is typified by polygonal textures. (3) In the units exposed in Johannsen's Phlogopite Mine area, kinked pyroxenes, containing coarse exsolution lamellae, predate unstrained pyroxenes, containing very narrow exsolution lamellae, which are in equilibrium with brown hornblende. (Allen, 1979). The unstrained later fabric is correlated with the Strangways Event, although there is a discrepancy in ^{40}Ar - ^{39}Ar age as discussed below.

Physical conditions and age

The main feature of this event is the highly elongate shape of mineral grains, which indicates that metamorphism was coeval with deformation. The event is thus inferred to be older than the 1820 m.y. Strangways event (see next section). However, it may be merely the precursor to and much the same age as, the Strangways Metamorphic Event.

Allen & Stubbs (in press) propose a ^{40}Ar - ^{39}Ar age of 1800 m.y. for this event based on spectral data. The ^{40}Ar - ^{39}Ar ages are consistently less than the Rb-Sr ages for what appears to be the same event, possibly because the Rb-Sr and Ar-Ar equilibria are reset at different temperatures.

E-3-2: Strangways Metamorphic Event (St)

Definition

This event characterises the granulite facies rocks of the Strangways Metamorphic Complex. The diagnostic mafic assemblage is hornblende (brown or green-brown)-clinopyroxene-orthopyroxene-plagioclase. The granuloblastic texture of these mafic rocks is diagnostic. In ideal cases, the aggregates are perfect examples of "foam" microstructures (Smith, 1964), as they consist of polygonal grains with straight or slightly curved grain-boundaries, and 120° - triple point intersections. Such texture are thought to be produced by late-stage secondary grain

growth (Cotterill & Mould, 1976) under essentially hydrostatic conditions. At the time of formation of these granuloblastic textures no significant deformation (stress) could have been active. These textures are an important criteria enabling the distinction of the Stranways Event from earlier and later events. A weak mineral lineation and crude layering in mafic granulite may result from a slightly earlier stage: (?P-St). To date, no amphibolite lower grade rocks have been identified which unequivocally belong to the Strangways Event. However, upper amphibolite facies rocks in the Harts Range locally grade into granulite facies and appear to have undergone the same phases of folding as the rocks in the Strangways Range. Consequently, these rocks in the Harts Range are tentatively included in the Strangways Event.

Typical assemblages in pelitic gneisses occurring alongside mafic granulites are:

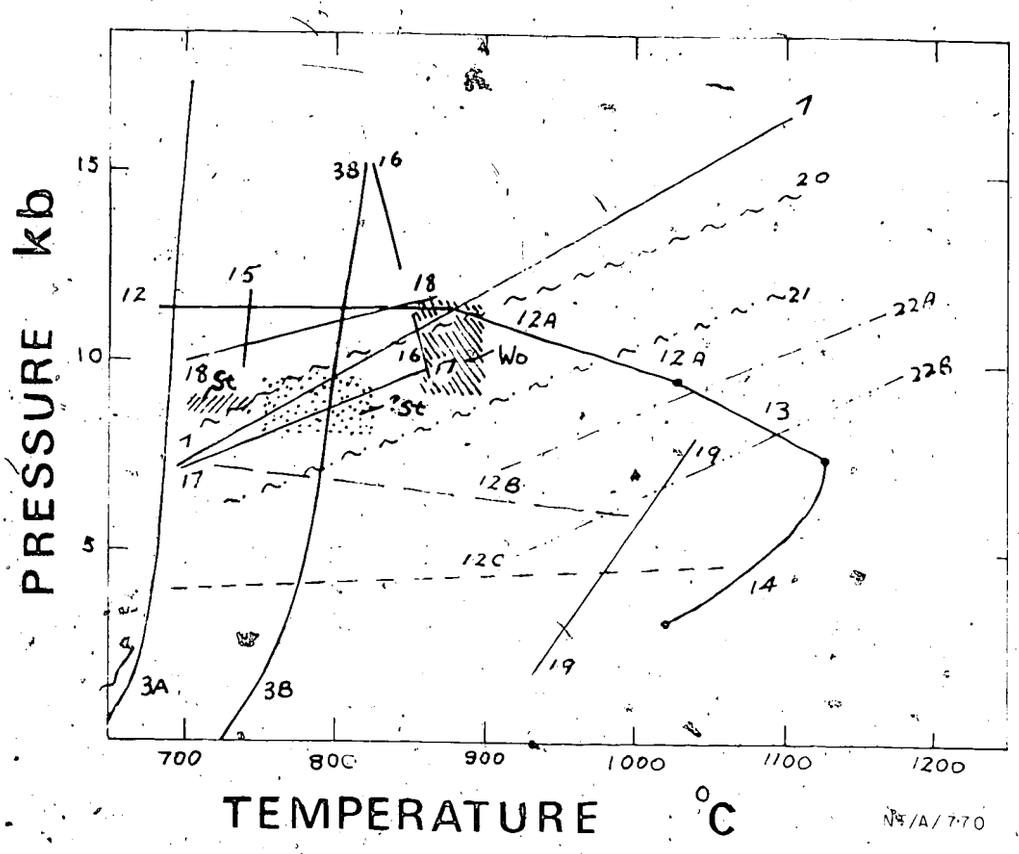
1. Cordierite + orthopyroxene + quartz ± garnet (Woolanga area)
   Cordierite + orthopyroxene + quartz ± garnet ± plagioclase (Johannsen's Phlogopite Mine area).
2. As above ± microperthite ± biotite (Yambah granulite)
3. Cordierite ± sillimanite (or kyanite) ± quartz (Woolanga area)
4. As above ± microperthite ± biotite ± hypersthene ± garnet (Yambah granulite)
5. Orthopyroxene + spinel ± cordierite (Woolanga Bore area)
6. Cordierite + quartz + garnet ± plagioclase ± sillimanite (Phlogopite Mine area).
7. Sillimanite + orthopyroxene + quartz ± kornerupine (Wilson, 1978a).

Woodford & Wilson (1976c) consider that metasomatic zones formed during this event are dominated by coarsely mesoperthitic K-feldspar and lesser amounts of quartz and phlogopite, and, in some rocks, garnet.

Physical conditions (Pressure)

An evaluation of assemblages given below suggest that the granulites were formed near the boundary between intermediate and high pressure granulites (using the classification of Ringwood & Green, 1967). The typical assemblage in rocks of basaltic composition in the Strangways Range, plagioclase + hypersthene + clinopyroxene + hornblende + quartz, has formed under conditions between the reaction - olivine + anorthite = diopside + enstatite + spinel (Reactions 22A and B in Figure E5 and Table E3) and the reactions related to the incoming of garnet, principally orthopyroxene + calcic plagioclase = garnet + clinopyroxene + quartz (20 and 21 in Figure E5 and Table E3). The P-T conditions for these reactions have been experimentally determined by Green & Ringwood (1967) for conditions $P_{H_2O} \ll P_{Load}$. Many of the mafic granulites from the Strangways Range are chemically equivalent to slightly undersaturated, olivine-normative, tholeiitic basalts. Consequently, the assemblage diagnostic of intermediate pressure granulites is effectively lowered by about 2 kb, relative to the pressure conditions for quartz-tholeiite used by Ringwood & Green in erecting the granulite pressure-classification. The effect of increased P_{H_2O} and the role of hornblende are difficult to assess from the experimental data.

Cordierite hypersthene-bearing gneisses which are intercalated with the mafic granulites of the Strangways Range may indicate low pressure granulite, as suggested by De Waard, (1965), and Ringwood & Green (1967). However, the position of cordierite breakdown is critically dependent on the cordierite $Mg/(Mg + Fe^{2+})$ value (Hensen & Green, 1973, p. 161) and possibly also on the water content of the cordierite. High $(Mg/(Mg + Fe^{2+}))$ values in the phlogopite mine area have been demonstrated by Vernon (1972) and Green & Vernon (1974), and probably occur elsewhere in the Strangways Range (Green & Vernon, 1974). Assemblages containing Mg-rich cordierites may persist to about the boundary between intermediate and high pressure granulites (Figure E5). The local presence of garnet in mafic assemblages clinopyroxene + orthopyroxene + hornblende + plagioclase also suggests that conditions approached the intermediate to high-pressure boundary.



Estimated P-T Conditions

Vernon, 1972; Vernon and Green, 1973: Strangways Event, Phlogopite Mine area.

Woodford and Wilson, 1976 a, b, c: Strangways Event, Woolanga Bore area.

Woodford and Wilson, 1976 a, b: Maximum P T conditions for Woolanga Event

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Fig. E5 Univariant phase boundaries for reactions given in Table E3

Physical conditions (Temperature)

Coexistence of hornblende and orthopyroxene in textural equilibrium is characteristic of the hornblende granulite subfacies (Turner & Verhoogan, 1960), and suggests that conditions were transitional towards the amphibolite facies (Turner, 1968). Binns (1969, p. 342) found that orthopyroxene appears in place of hornblende in basic rocks at $770 \pm 10^{\circ}C$ at 1-3 kb P_{H_2O}, where $P_{H_2O} = P_{total}$ and extrapolation of these results suggests that at 3-8 kb orthopyroxene appears at about 780°-$830^{\circ}C$, and possibly at a higher temperature at 8.5 to 9 kb. Such breakdown of hornblende to give orthopyroxene requires that excess silica be present. The abundances of hornblende in textural equilibrium with orthopyroxene suggests that a temperature exceeding $850^{\circ}C$ is unlikely. For rocks in the Woolanga Bore area Woodford (1974), and Woodford & Wilson (1967b) estimate the pressure to be in the range 8.5 - 9 kb and the temperatures to be in range $700^{\circ}C$ to 750° based on the accompanying pelitic and quartzofeldspathic assemblages and on partition data, particularly Al and trace element data. This is consistent with the local presence of kyanite in place of sillimanite.

Assemblages containing sillimanite, K-feldspar and quartz, but lacking muscovite, are widespread at the periphery of the region affected by the Strangways Event (e.g. in Cadney metamorphics) and suggest that in these regions (1) pressures were greater than 2.5 kb, as sillimanite rather than andalusite is stable, and (2) temperatures exceeded $600^{\circ}C$ (Evans, 1965). (Reaction 2 Table E3 and Figure E5). The widespread formation of migmatite having granitic composition and the presence of Mg-biotite also indicates temperatures in excess of $600^{\circ}C$ (Curve 5, Figure E6, Table E3).

Age

Woodford, Mateen, Green & Wilson (1975) using the $^{40}Ar - ^{39}Ar$ step-wise heating isochron method, obtained a minimum date of metamorphism of 1706 ± 78 m.y. on mafic rocks from the Woolanga Bore area. The mafic rock analysed (H84) had the diagnostic assemblage hornblende + orthopyroxene + clinopyroxene + plagioclase. Allen & Stubbs (in press)

have determined a $^{40}Ar - ^{39}Ar$ age of 1800 ± 27 m.y. ($\lambda = 1.42$) for what is possibly the same event in the Harry Creek area. Iyer, Woodford, & Wilson (1976) determined a Rb-Sr total rock age of 1820 ± 78 m.y. from 6 felsic granulites closely associated with mafic granulites, having the same assemblage as H84, in the Yambah area. The Rb-Sr values were too low in their mafic rocks from the Yambah area to give a meaningful age. Preliminary Rb-Sr results by Black (BMR) from the Wuluma granitoid, considered to be result of ultrametamorphism and anatexis coeval with the Strangways Event, favours an age of about 1800 m.y. (data still being evaluated). The apparent discrepancy between the Rb-Sr and one of the $^{40}Ar - ^{39}Ar$ dates may be due to the decay constants used; and the fact that Rb-Sr and Ar-Ar equilibria have different closing temperatures. The use of the Ar-Ar dating technique in high-grade terrains is still at an experimental stage.

E-2-3: Chewings Metamorphic Event (Ch)

Definition

The reference rock for this event is a weakly-layered and lineated leucocratic gneiss dated by Marjoribanks & Black (1974). This gneiss (the "Potrock" gneiss, locality 865 in HERMANNSBURG) which is a typical premigmatite gneiss from the Chewings Range Zone of Marjoribanks (1975), is composed of quartz, microcline, oligocase, biotite and muscovite. During the Chewings Metamorphic Event the minerals crystallised parallel to F2 axial-structures (formed during the main phase of folding associated with this event), but the granoblastic and polygonal texture of quartz and feldspar indicates that either crystallisation of these minerals continued after the regional stress has somewhat subsided, or that the rocks were affected by static metamorphism during a later event possibly the Ormiston migmatite event (Marjoribanks, 1975, p. 18). The main metamorphism, however, was partly coeval with the main deformation, and resulted in the crystallisation of oligoclase-andesine, and locally in rocks of suitable composition, almandine - staurolite and hornblende. Marjoribanks (1975) correlate the main deformation in the Redbank Deformed Zone with the Chewings Phase of deformation.

The Chewings Metamorphic Event can be traced eastwards at least as far as the Alice Springs Township (Figure E5). Assemblages in the Chewings Range Quartzite near the boundary between ALICE SPRINGS and MACDONNELL RANGES consist of muscovite + quartz + sillimanite + kyanite, and intercalated pelitic rocks locally include the assemblage garnet ± muscovite ± staurolite ± biotite. As is the case to the west, the assemblages are indicative of the almandine amphibolite facies. However, some upper greenschist facies rocks may also be present.

The main metamorphic event in the White Range Nappe and Giles Creek Synform, to the east is also correlated with the Chewings Range Event. Metamorphic assemblages in this eastern region are indicative of a low-pressure series ranging from upper greenschist to almandine amphibolite facies, including the sillimanite + cordierite + almandine Subfacies of Winkler (1967) (Table E4: Hillsoak Bore, Cavenagh and Tommy's Gap metamorphics). Key assemablages are:-

(1) Andesine - muscovite - quartz (Cavenagh metamorphics)
(2) Sillimanite - andalusite - muscovite - biotite - quartz (Hillsoak Bore metamorphics)
(3) Cordierite - anthophyllite (Hillsoak Bore metamorphics).

Physical conditions

In the eastern area it can be assumed that the reaction between muscovite and quartz to produce sillimanite and K-feldspar (Reaction 2, Figure E5 & Table E3) has not occurred, even in the highest grade part. Here, andalusite does not appear to coexist with K-feldspar indicating that pressures were in excess of about 3 kb. The physical conditions envisaged are similar to those in the southern Abukuma Plateau in Japan (Tagiri, 1971; in Miyashiro, 1975) and in the Mount Lofty Ranges of South Australia (Offler & Fleming, 1968, p. 260). It is likely that pressures were just above the curve for the formation of cordierite (Reaction 8, Figure E6 & Table E3) and just below the curve for the

breakdown of andalusite to form sillimanite, i.e., a little less than 4-5 kb (Curves 4 & 7 Figure E6 & Table E3). The presence of migmatite containing stable muscovite suggests a maximum temperature of 650°C if the rocks are saturated in H_2O (Intersection of curves 2 & 5, Figure E6).

To the west, closer to the type locality in HERMANNSBURG muscovite is widespread, and staurolite, sillimanite and kyanite all appear stable: kyanite, however, is extremely rare. Pressures were probably just above the triple point of the system Al_2SiO_5 (i.e. just greater than 4-5 kb), although the stability of staurolite (Hoscher, 1969; Richardson, 1968 - Reactions 9 to 11, Figure E5 & Table E3) and the apparent lack of migmatite suggest that pressures could have been higher. Temperatures were possibly about 600°C (Fig. E5).

Age

A Rb-Sr total rock date of 1586± 70 m.y. (λ = 1.42) (1620± 70 m.y., λ = 1.39) has been obtained for the event by Marjoribanks & Black (1974) for the type-specimen in HERMANNSBURG. In the eastern area, Armstrong & Stewart (1975) obtained a Rb-Sr total-rock date of 1687 ± 23 m.y. (λ = 1.42) (1719± 24 m.y., λ = 1.39) for the rocks from the northern part of the White Range Nappe (4 samples) and the eastern Wigley Block (3 samples). The synorogenic Atnarpa Igneous Complex, which intrudes rocks of the White Range Nappe and Giles Creek Synform, gives a Rb-Sr total rock date of 1674± 50 m.y. (λ = 1.42) (1710± 50 m.y., λ = 1.39), (Bennet in Cooper & others, 1971). The Jennings Granitic Gneiss probably has a similar age and origin (see note in this Record); the total rock age was not resent by the younger Ormiston event.

E-2-4: Woolanga Metamorphic Event (Wo)

Definition

This event is characterised by the growth of phlogopite, and the alteration of minerals such as spinel to form sapphirine in those aluminous rocks which also contain orthopyroxene ± gedrite (Woodford & Wilson, 1976a; Iyer, Woodford & Wilson, 1976a). The minerals hogbomite, kornerupine and surinamite were also probably formed during this event

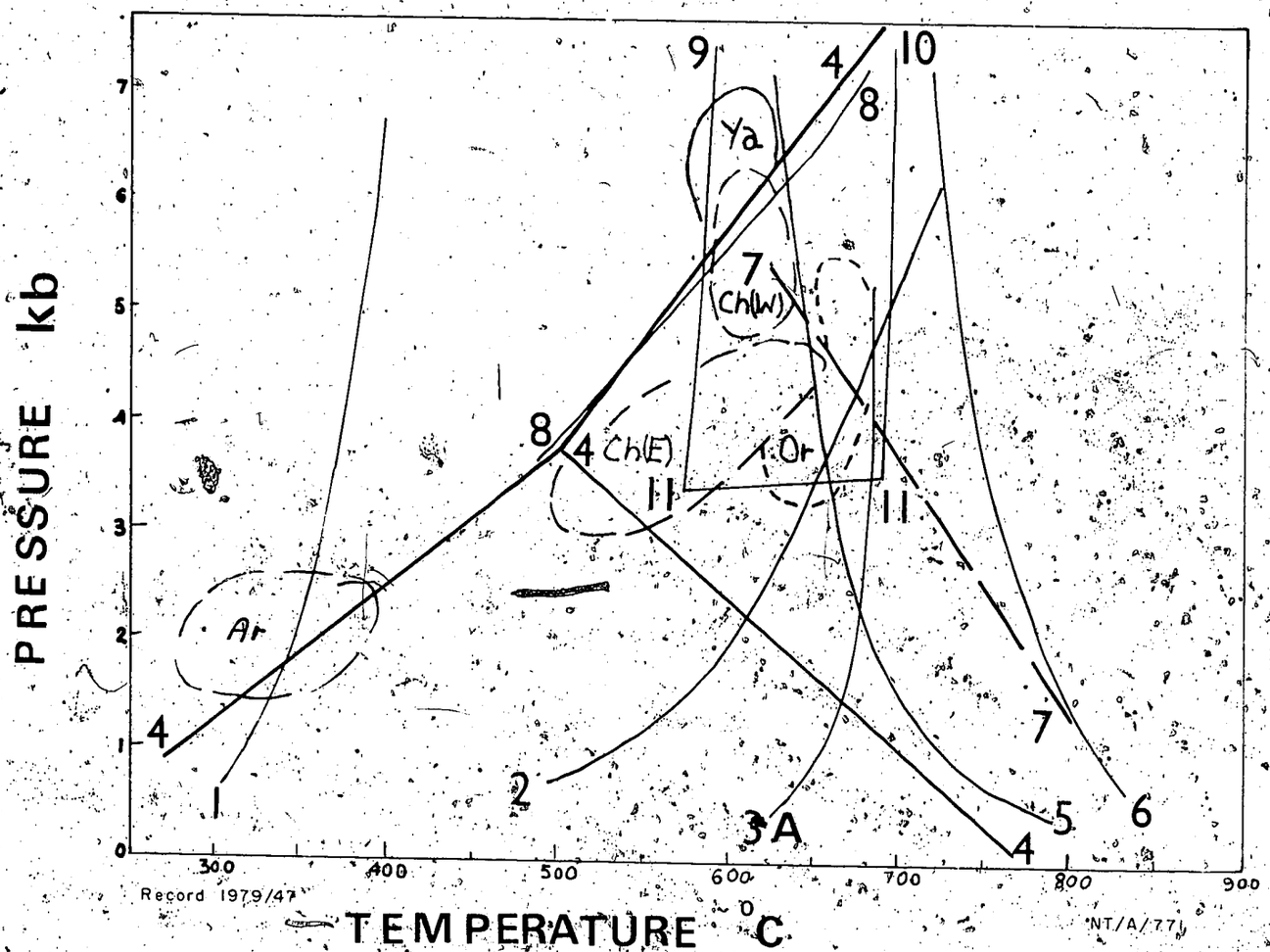


Fig. E6 Univariant equilibria listed in Table E3

Ch(E) Chewings Metamorphic Event (Eastern Region)
Ch(W) Chewings Metamorphic Event (Western Region)
Or Ormiston Metamorphic Event
Ya Yambah Metamorphic Event
Ar Arltunga Metamorphic Event

(Woodford & Wilson, 1976a, c : högbomite due to alteration of spinel; kornerupine due to potash-rich metasomatism in zones now containing phlogopite, garnet, spinel and corumdum and surinamite as inclusions in cordierite (Woodford & Wilson, 1976a), have also observed sapphirine rims on spinel to be, in turn, rimmed and intergrown with sillimanite which is in contact with an sillimanite-orthopyroxene intergrowth. This sequence of minerals suggests that the sapphirine may have formed at the same time as the assemblage sillimanite-orthopyroxene-quartz.

Woodford & Wilson (1976b) link the formation of the above aluminous assemblages with the formation of small granules of orthopyroxene and clinopyroxene at interfaces between larger brown-green hornblende and plagioclase grains which were formed during the Strangways Event. The pyroxene granules are richer in Al and have higher Mg/(Fe + Mg) ratios than their counterparts formed in the Strangways Event.

Vernon (1972) has described the hydration of cordierite to form gedrite-kyanite-quartz and the kydration of aluminous hypersthene to form aluminous anthophyllite in pelitic gneiss from the Johannsen's Phlogopite Mine area. The initial assemblage, quartz + cordierite + hypersthene ± biotite ± sillimanite, is similar to the assemblage sillimanite + orthopyroxene + quartz described by Woodford & Wilson (1976a) from the Woolanga Bore area, and may represent the same event.

Physical conditions

The association between sapphirine and sillimanite-orthopyroxene intergrowths suggests that PT conditions for sapphirine formation were similar to those for the rare assemblage sillimanite-orthopyroxene-quartz, which, on experimental grounds, indicates a maximum temperature of 900-1000°C (Hensen & Green, 1973), assuming low oxygen and water fugacities and that the assemblages is due to the reaction: Mg-cordierite + Mg garnet = orthopyroxene + sillimanite + quartz (see Table E3). Using this and related assemblages, such as rare assemblages containing kyanite, Woodford & Wilson (1962c) estimate conditions of 9 kb - 11.5 and 850 to 900°C.

The cordierite breakdown reaction can explain the assemblage cordierite + quartz ± orthopyroxene ± plagioclase ± garnet ± sillimanite ± biotite recorded from the Erontonga metamorphics in the Phlogopite Mine area (Table E3). Moreover, the relatively high Al and Mg/(Mg + Fe) contents of pyroxene equated with the Woolanga Event suggest higher temperatures and possibly pressures than during the Strangways Event (Woodford & Wilson, 1976b). Hogbomite and kornerupine have wide stability ranges and may have formed under low-grade granulite conditions or at an unspecified level of the upper amphibolite facies. Woodford & Wilson (1976c, p. 590) suggests an equilibration temperature of 620-640°C based on Fe-Mg partition date for garnet and phlogopite which coexist with kornerupine.

Vernon (1972) estimated a confining pressure of 10 kb or more and a temperature of about 800°C for the breakdown reactions involving cordierite and hypersthene. He points out that the reactions may have proceeded more in response to addition of water to the system rather than to a major change in P-T conditions.

Age

A Rb-Sr total rock age of 1439 ± 59 m.y. λ = 1.42 (1470 ± 60 m.y., λ = 1.39) has been determined by Iyer, Woodford & Wilson (1976) using three samples containing phlogopite + sapphirine + orthopyroxene + spinel ± gedrite, and one sample containing orthopyroxene + cordierite + quartz + phlogopite. This 1400-1500 date is supported by a K-Ar date of 1380 ± 60 m.y. on a large phlogopite from the Phlogopite Mine (D.C. Green, personal communication in Iyer, Woodford & Wilson (1976), and by a date of 1470 m.y. obtained by Woodford, Mateen, Green & Wilson (1975) on two phlogopites (580 & 53) in a spinel - sapphirine - orthopyroxene - clinopyroxene - phlogopite rock using the ^{40}Ar - ^{39}Ar stepwise heating isochron method. This 1400-1500 m.y. date needs to be confirmed by dating related metamorphic assemblages other than those containing phlogopite, such as those resulting from the breakdown of cordierite, because the Ar-Ar is regarded as experimental in such complex high-grade rocks.

E-2-5: Ormiston Metamorphic Event (Or)

Definition

This event is characterised by the formation of migmatite and anatectic granites, and by isotopic Rb-Sr redistribution in older rocks. It is the principal metamorphism evident in the Wigley Block. During this Event quartz, biotite, and muscovite began to recrystallise locally parallel to the axial-plane structures of coeval folds (F3 in Wigley Block, and a mobilisate phase was introduced into axial-plane structures (Marjoribanks, 1975). Specimen 72933001, a migmatite from within the migmatite complex, is taken to be the type specimen (see section on age below. The assemblage typical of these rocks in the reference area is quartz + oligoclase (or andesine) + biotite, which is stable over a wide range of metamorphic conditions. In the Wigley Block in ALICE SPRINGS common assemblages are garnet + hornblende + quartz + microcline + plagioclase, and green hornblende + plagioclase. The assemblage garnet + biotite + sillimanite + quartz + feldspar, and sillimanite + muscovite + quartz + feldspar are present locally; the assemblage + garnet + biotite + sillimanite + cordierite + quartz + feldspar occurs at one locality (D889, GR 5650-809895) in the central-southern part of the Wigley Block but may be the result of contact metamorphism (see D-13-3, p331).

Physical conditions

Maximum PT conditions of about 650°C and 5-6 Kb are suggested by assemblages that include garnet, cordierite and sillimanite, based on the semi-quantitative mineral stability relations deduced by Hess as outlined by Kiyashiro (1975, p. 81). These conditions agree well with the melting temperature of granite in the presence of an aqueous fluid at a pressure of 5-6 Kb (Miyashiro, 1975, p. 22 after Wyllie & Tuttle, 1961; Yoder & Tilley, 1962). Such conditions would correspond to a theoretical depth of about 20 km, assuming a normal geothermal gradient (30°C/km).

Age

A Rb-Sr total rock age of 1053± 50 m.y. λ = 1.42 (1080± 50 m.y. λ = 1.39, Sr^{86}/Sr^{87} = 0.734± 0.005) was determined by Marjoribanks & Black (1974, p. 296) for the type specimen of the Event (72933001, RWM 502). A specimen of migmatite from within the Redbank Deformed Zone yielded on age of 1194± 230 m.y. λ = 1.42 (1220± 230 m.y., λ = 1.39), Sr^{86}/Sr^{87} = 0.717± 0.006 (Specimen 72933000, RWN 502). Marjoribanks & Black consider that a more precise estimate of the Ormiston Metamorphic Event, is obtained when the analysis of the included muscovite is regressed with the total rock points from the type-specimen (72933001), is 1053± 12 m.y. λ = 1.42 (1076± 12 m.y. - old decay constant λ = 1.39), but they suggest a deviation of ± 50 m.y., to allow for any slight geological perturbations.

The type specimen of the Chewings Metamorphic Event (RVM 865, 72933002) is 4 km or less from the migmatite front of the Ormiston Event, and its mineral age was reset by the Ormiston migmatisation, although the total rock Rb-Sr age shows no sign of modification by this migmatite event (Marjoribanks, 1975, p. 18). Even allowing for a drop of temperature away from the migmatite front to 400°C at the RWM 865 locality it is conceivable that the recrystallised feldspar and quartz recorded by Marjoribanks (1975, p. 17 and 18) belongs to the Ormiston rather than Chewings Event.

E-2-6: The Yambah Metamorphic Event (Ya)

Definition

A number of amphibolite facies schist zones in the northern part of the Alice Springs 1:250 000 Sheet area either cross-cut the granulite terrain or occur at a tectonic boundary between granulite and amphibolite facies rocks. These zones, many of which contain the index minerals kyanite and staurolite, characterise the Yambah Metamorphic Event. The type locality for this Event is taken to be the Yambah Schist Zone, $\frac{Pzr}{Bry}$, in the northwestern Strangways Range, which clearly formed by retrogression of the adjoining granulite facies rocks. The

key mineral assemblage is kyanite + staurolite + biotite, although the assemblage muscovite + biotite + quartz ± garnet is more widespread. Rare layers in the zone are rich in either diopside and epidote or hornblende and chlorite.

A number of other similar schist zones, which consist essentially of muscovite-biotite schist and schistose gneiss, are also thought to have formed during the Yambah Event. One of these, the Harry Creek Deformed Zone, separates the granulites facies rocks of the Utnalanama Block from the amphibolite facies rocks of the Ankala Block. It contains gedrite, staurolite and kyanite in addition to minerals characteristic of the epidote amphibolite facies (Table E4). Of the other zones the staurolite - kyanite locality are present in the Southern Cross Deformed Zone, and one kyanite locality is known in the West Bore Deformed Zone, contains one but no kyanite localities are known in Gough Dam Schist Zone. In the Yambah Schist Zone, kyanite, staurolite and garnet form idioblastic crystals which are disseminated in the micaceous schist, grow across the schistosity, and appear in equilibrium with the biotite and muscovite.

Physical conditions

The Yambah Schist Zone is thought to have formed under temperature conditions just above the staurolite stability, (Hoschek, 1969; Richardson, 1968, Curve 9, Fig. F) and at a lower temperature than the curve for muscovite breakdown given by Evans (1965, Curve 2, Fig. F) that is, at about 550 to 650°C. The pressure conditions are above the Al_2SiO_5 triple point (Curves 4 & 7, Fig. E6) at a temperature at which both kyanite and staurolite are stable, i.e., slightly greater than 5-6 kb. The Harry Creek and Southern Cross Schist Zones were probably formed under similar PT conditions (i.e. amphibolite facies). The conditions of formation of the West Bore Deformed Zone and the Gough Dam Schist Zone are less definite and may extend into the PT conditions of the greenschist facies.

Age

The age of the Yambah Metamorphic Event is equivocal: two events may be involved. ^{40}Ar-^{39}Ar dates in the range 349-393 m.y. (5 determinations) and two K-Ar dates of 393 ± 9 m.y. and 369 ± 8 m.y. from the Yambah Schist Zone (Iyer, Woodford & Wilson, 1976) show that the Yambah Schist Zone was at least strongly affected, if not actually formed, by retrogression of the adjoining granulite during the Devonian, possibly during an early phase of the Alice Springs Orogeny. Rb-Sr data collected by Iyer and co-workers failed to confirm this metamorphic event. The idioblastic relationship of the kyanite, staurolite and garnet to the dominant micaceous schistosity suggest that these minerals are the same age or younger than the mica; the age of which probably controls the ^{40}Ar-^{39}Ar and K-Ar dates.

The Harry Creek Deformed Zone, on the other hand, has clearly undergone two periods of deformation: firstly, medium-pressure granulites were brought into juxtaposition with upper amphibolite facies rocks, before intrusion of the Gumtree Granite at (989 ± 13 λ = 1.42, 1010 ± 13 m.y. λ = 1.39) (Allen & Black, 1979); a later deformation, thought by Allen to be predominant, is correlated with an early phase of the Alice Springs Orogeny dated by ^{40}Ar-^{39}Ar methods at 430-500 m.y. (Ordovician) by Allen & Stubbs (in press).

The West Bore Deformed Zone was also active after 1000 m.y., probably during the Alice Springs Orogeny, as it has a faulted contact against the Heavitree Quartzite.

In summary, the age of the Yambah Metamorphic Event is equivocal. Although many of the schist zones were metamorphosed above the closing temperature for K-Ar equilibrium biotite (about 300°C) an early phase of the Alice Springs Orogeny (500-350 m.y., i.e. Ordovician to Devonian), they may be reactivated Proterozoic schist zones of uncertain age. The schist zones are very similar to the Redbank Deformed Zone, which separates granulites from amphibolites and may have been formed during the Chewings

Event (1586 ± 69 λ = 1.42-, 1620 ± 70 m.y. λ = 1.39) (Marjoribanks, 1975). However, Allen (in preparation) has textural and ^{40}Ar-^{39}Ar evidence to suggest that the analogous Harry Creek Deformed Zone was first initiated just before the Ormiston Event, i.e., 1100-1000 m.y. ago.

While the age of the Yambah Metamorphic Event is uncertain, it is possible the main assemblages were formed in an event which was a precurson to the Arltunga Metamorphic Event.

E-2-7: Arltunga Metamorphic Event (Ar)

Definition

The Alice Springs Orogeny was accompanied by the formation of extensive narrow schist zones of greenschist/lower amphibolite facies rocks produced by metamorphism of Palaeozoic sediments and retrogression of older previously metamorphosed rocks. The type-samples for this metamorphic event (W39 and W40) are from a deformed and retrogressively metamorphosed body of tonalite 4 km south of Claraville homestead (GR 5851-741122 and 5851-721116). Extensive retrogression has resulted in the conversion of andesine to albite + epidote + white mica (75 percent muscovite and 25 percent paragonite), and the recrystallisation of quartz. Relics of high-grade minerals are comparatively rare. The equilibrium assemblage is quartz + muscovite + albite + epidote + biotite.

In places chlorite or partly chloritised biotite is present instead of biotite.

Retrograde schist zones, typified by muscovite and muscovite-biotite schist containing greenschist facies assemblages, crop out at Winnecke, Arltunga, and north of the Atnarpa and Amarata Ranges. These schist zones follow the main thrust zones of the White Range and Ruby Gap Nappes and lie just to the north of the main outcrop belt of Heavitree Quartzite. Other narrow more mylonitic zones are localised along the Charles Creek Fault and faults associated with the Redbank Deformed Zone.

Three types of retrograde metamorphism are present within the Nappe Complexes (including White Range and Ruby Gap Nappes), indicating a progression in metamorphism with increasing depth.

(1) In the front of the White Range Nappe, and in the basement core of the Ruby Gap Nappe, patchy metamorphism, in which a proportion of the minerals in the rock are pseudomorphed, belongs to the lowest part of the greenschist facies. Chlorite has partly replaced biotite, and calcic plagioclase is either altered to sericite and clinozoisite/epidote, or, rarely, completely replaced by them plus albite. Original igneous and high-grade metamorphic textures are still preserved.

(2) A dislocation or dynamic metamorphism rather than a regional metamorphism is typically localised near thrust-faults, particularly within the Ruby Gap Nappe. Original textures are partly reconstituted. Quartz grains, particularly those in the matrix, are partly polygonised, and original feldspar crystals are commonly fractured or bent. In some cases a schistosity has formed, outlined by chlorite and sericite. Plagioclase is partly saussuritised to albite, sericite and clinozoisite/epidote. Biotite is partly or completely altered to chlorite. Hornblende (in amphibolite) is partly altered to blue-green hornblende or tremolite/actinolite.

(3) In the rear of the Arltunga Nappe Complex, particularly in the White Range area, retrograde effects are pervasive. Here, the texture has been largely to completely reconstituted. The characteristic new minerals are albite and clinozoisite/epidote, and new biotite is also present locally, e.g., north of White Range, indicating metamorphism at least to the middle part of the greenschist facies (i.e., above the biotite isograde). In the Charles River Fault mylonite was formed during this event along with the assemblage quartz + biotite + epidote + clinozoisite + muscovite + plagioclase + microcline.

Physical conditions -

Metamorphic conditions appear to have varied from the very lowest greenschist facies in the cover rocks, where kaolinite occurs alongside sericite, up to the biotite isograd (middle greenschist facies) within the retrograde zones in the basement.

It is estimated that only about 2.5 km of sediment was preserved at any one time over the area which later became the Arltunga Nappe Complex, because the region was partly emergent during the period between the Upper Proterozoic glaciations and again during the Silurian Rodingan Movement (Wells, Forman, Ranford & Cook, 1970). It is unlikely, therefore, that pressure exceeded 2 kb even if the zone was overlain by a thick overthrust wedge of basement rocks.

The kaolinite may be primary; if so its presence with quartz suggests temperatures below 350°C (Curve 1, Figure E6 & Table E3, given by Thompson, 1970a). According to Turner (1968), at a pressure of 2 kb the greenschist facies starts with the appearance of chlorite and sericite at about 250°C, and biotite first appears at about 400°C.

Age

Retrogressively metamorphosed micas from the type locality for this event have given Rb-Sr dates of 335 m.y. $\lambda = 1.42$ (342 m.y., $\lambda = 1.39$) (whole-rock - biotite isochron) and 312 m.y. $\lambda = 1.42$ (319 m.y., $\lambda = 1.39$) (whole-rock - muscovite - biotite isochron) (Armstrong & Stewart, 1975).

F: STRUCTURE - Introduction (R.D.S.)

As outlined in the section on REGIONAL SETTING the rocks in the Alice Springs 1:250 000 Sheet area are divisible, on the basis of tectonic history, into two parts (Fig. B2); (1) the Central Tectonic Zone characterised by mafic and felsic rocks, which have been folded then metamorphosed to granulite facies at about 1800 m.y.; and (2) the Southern Tectonic Zone typified by quartzofeldspathic and biotite gneisses, folded and metamorphosed to amphibolite facies, firstly at 1600-1700 m.y., and in the western part again at 1100-100 m.y. (The Northern Tectonic Zone does not crop out on the Alice Springs Sheet area). The two tectonic zones are subdivided into a series of structural blocks as shown in Figure E4 and in the tectonic sketches accompanying the maps. The boundary between the two Tectonic Zones largely corresponds to a series of major deformed zones, namely the Redbank Deformed Zone, the Harry Creek Deformed Zone, and deformed zones associated with the White Range Nappe and the Ruby Gap Nappe (which merges with the Illogwa Creek Schist Zone). Along these deformed zones rocks of the Central Tectonic Zone have been thrust over rocks of the Southern Tectonic Zone, initially in the Proterozoic, possibly during the Chewings phase of deformation at about 1600 m.y., and again in the Palaeozoic during the Alice Springs Orogeny at 400-300 m.y. A series of northwesterly transcurrent (strike-slip) faults appear to have accompanied the overthrusting. These transcurrent faults appear to have moved the Central Tectonic Zone progressively southwards by a series of right-lateral (dextral) displacements with the maximum displacement corresponding to the central part of the Arltunga Nappe Complex (i.e. White Range Nappe and Giles Creek Synform). The Arltunga Nappe thus appears to have been formed by a combination of both thrust-faulting and transcurrent faulting. Faulting, however, continued, particularly along pre-existing faults over a long time span. Faulting principally occurred in the Palaeozoic, but extended locally into the Tertiary.

In the following outline the general structure and folding history is described for the individual structural blocks. The numbering of fold-phase strictly applies to one particular block, but the numbering system applies in a speculative manner to the whole tectonic zone.

F-1: Folding: Precambrian Folding in the Central Tectonic Zone (R.D.S.)

The sequence and deformation and folding in the Strangways Metamorphic Complex which accounts for most of the northern tectonic unit, is summarised in Table F1. The principal regional granulite metamorphism, termed the Strangways Event, is thought to have reached a peak during and following F3 folding, because this folding appears to localise small anatectic granite bodies, and because many of the rocks, particularly massive folded layers of mafic granulite, have a granuloblastic texture indicating near hydrostatic stress conditions.

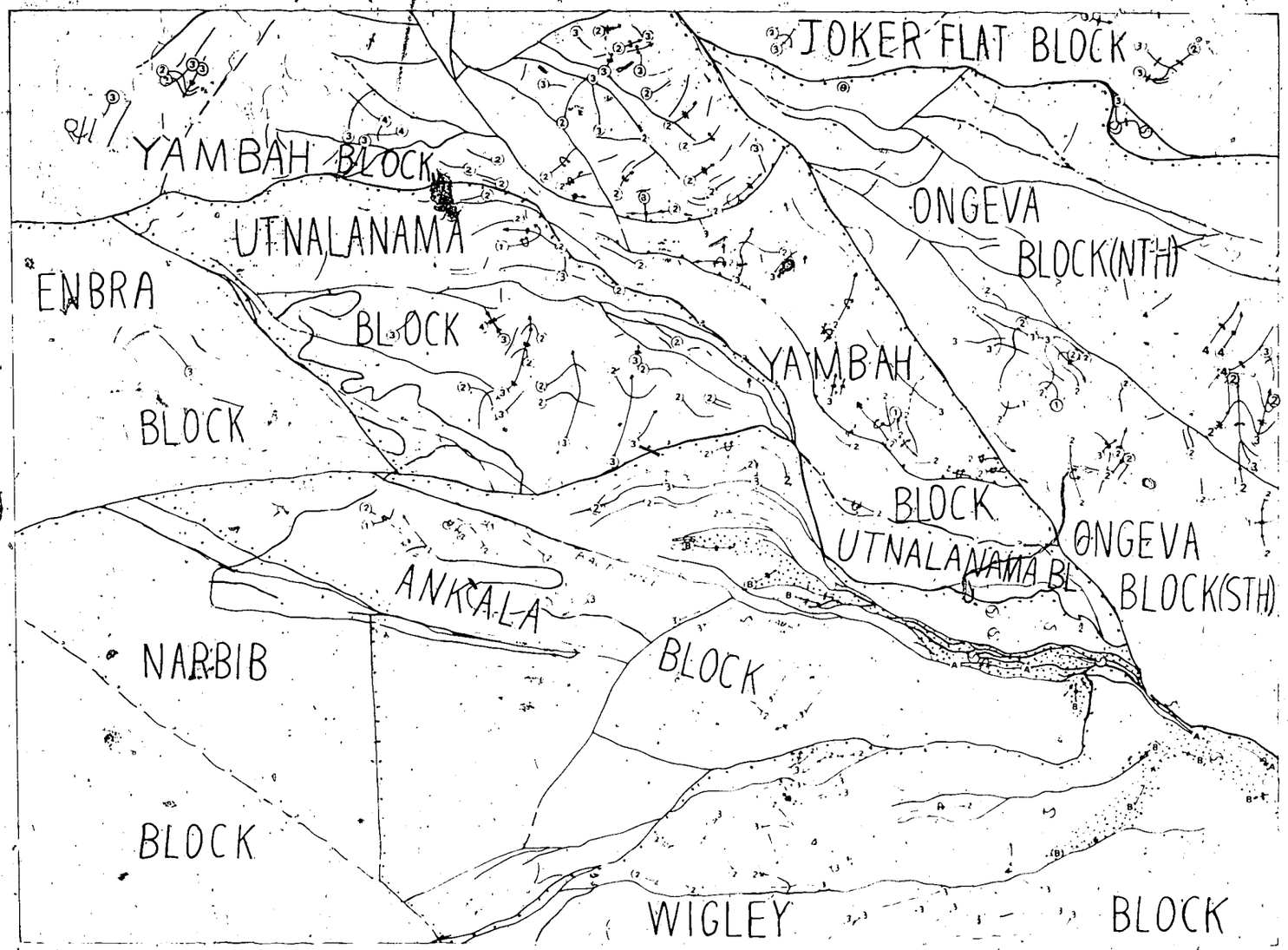
In the first recognisable folding episode the strata were isoclinally folded (F_1), particularly in the east, and then tightly refolded about steeply north-dipping east-west trending axial-surfaces (F_2), before being folded into more open north-trending folds (F_3) of a more variable trend. (e.g. northern part of Fig.F1). The F_1 folds are attenuated, commonly rootless, and recognised in only a few areas. An axial-plane F_1 foliation is not evident, but this may be due to the high degree of attenuation, the difficulty of identifying F_1 fold closures, and the fact that the metamorphism outlasted the folding.

F_2 folds form macroscopic features in the eastern part of the Sheet area. F_2 folds are generally more open than F_1 structures; they are reclined, and have moderate to shallow northerly plunges and overturned southern limbs. Except in the tightest F_2 fold-hinges, there is no axial-plane schistosity.

Lineations, marked by alignment of minerals such as hornblende, sillimanite and diopside, or by a mineral streaking (e.g. quartz aggregates), are widespread. Their geometry has been studied stereographically in the adjacent Riddoch 1:100 000 Sheet area (Rickard, 1975), where they lie in a broad girdle that approximates the F_2 axial-plane. At present it is not possible to differentiate between F_1 and F_2 lineations, but most are thought to be F_2 features.

TABLE F1: STRUCTURAL ELEMENTS FORMED IN THE NORTHERN TECTONIC ZONE BEFORE OR DURING THE STRANGWAYS METAMORPHIC EVENT

Deformation	Fold Phase	Axial-Plane Schistosity	Lineation	Comment
Do	No folds recognised			Gneissosity formed
D1	F1- Typically intrafolial isoclinal folds which fold mesoscopic layering. Slight thickening in hinge in some cases	S1- Moderately well-developed axial-plane schistosity, typically defined by the preferred orientation of biotite in felsic granulite.	L1- Moderately to strongly developed.	Main lineation commonly belongs to this deformation.
D2	F2- Tight, typically east-trending folds, commonly with steep or overturned southern limbs and little thickening in the hinges.	S2- Outlined by metamorphic differentiation and most common in the hinge-region of large folds.	L2- Slight lineation in many areas.	Tectonic sliding typically developed late in this deformation.
D3	F3- Open, concentric folds of very variable orientation, but typically north or northeast trending. No thickening in fold hinge.	S3- Axial-plane schistosity rarely developed.	L3- Lineation rarely evident	Migmatisation resulting in anatectic granitoid bodies thought to have developed at a late-stage in this deformation.
	F4- Folds very like F3 described above, but thought to have been formed slight later		As above	As above



Northern and southwestern Sheet area – Granulite and retrogressed granulite

Southern part of Sheet area - Amphibolite facies rocks

Amadeus Basin Sequence

Cainozoic sediments

Boundary between Structural Blocks, dots on down-throw side of fault

Fold Phases - Northern area

Fold Phases - Southern area

Early ... and late ... folds formed during the Alice Springs Orogeny

Locality of superimposed folds (other details as in map legend),

Fault

Tectonic Slide

Fig. F1 Fold phases BURT-LAUGHLEN area

F_3 folds have a patchy distribution. They are more open, upright-folds, and are locally accompanied by a rough fracture cleavage which parallels F_3 axial-planes. The trend of these F_3 folds varies widely, even between adjacent folds, the most common trend being northeast. F_3 folds are widespread in the Yambah, Ongeva, Utnalanama, and Mount Chapman Blocks.

F_4 folds are recognised locally. They are open northeasterly trending features.

The Entia Dome, a major structure in the adjacent Illogwa Creek 1:250 000 Sheet area, is considered to be a younger structure possibly related to the intrusion of the Huckitta and Inkamulla Granodiorites.

The individual structural blocks are described in more detail below.

F-1-1: Enbra Block (A.P.L.)

The Enbra Block is a wedge-shaped block bounded to the south by the western extension of the Harry Creek Deformed Zone and to the north by a major fault extending from Harry Bore to Yambah homestead. The western limit of the block is unknown. The block has several open macroscopic folds that plunge steeply to the west-northwest. These folds are defined by small, rare bodies of felsic granulite.

The amount and extent of folding within the block is not readily apparent because of the massive homogeneous nature of the abundant mafic granulite.

F-1-2(a): Utnalanama Block (South) (R.D.S.)

A.R. Allen considers that the repetition of linear outcrops of the Harry Anorthositic Gabbro within the Utnalanama granulite is due to early east-west open folding of a gabbro sill. The east-west trend of these folds would suggest they may be F_2 structures. A similar open F_2 syncline has been identified at 5751-057335, and is inferred by Allen to explain the repetition of lithological units to the northwest, at 5751-025365. The generally easterly trend of these rocks in the Utnalanama Block is overprinted by a series of open synclines and anticlines which are regarded as F_3 folds. A number of granitoid bodies elongate in a north-south direction may have been formed during or just before the F_3 folding.

F-1-2(b): Utnalanama Block (North) (R.D.S.)

This block is dominated by faults. A maze of faults cut the homogeneous migmatite terrain of the Ingula migmatite suite and the remainder of the block is cut by numerous faults related to the two major boundary faults.

F-1-3: Yambah Block (East and West) (R.D.S. & A.P.L.)

In the Yambah Block the Cadney metamorphics wrap around units of the middle and lower Strangways Metamorphic Complex. F_2 folds in the Cadney metamorphics are commonly reclined, have overturned southern or western limbs, and follow the main structural trend, striking easterly throughout most of the Block, but northerly in the central part, forming a large "S" shaped structure. Trends are only slightly offset by a fault interpreted to be the geological expression Woolanga Gravity Lineament (described later).

The main folds in the unit pGsp are open and plunge shallowly to the northeast. These folds are interpreted to be late F_2 or possibly F_3 folds. In the Yambah granulite at least three types of folds, representing three folding events, are recognised (Fig.F1): small intrafolial folds, which are thought to represent F_1; macroscopic open folds, F_3, which are well exposed at Mount Strangways where they have north-northeasterly striking axial-planes and appear to plunge steeply to the south; and almost isoclinal folds, F_2, which are refolded by the open F_3 folds. Boudinage of mafic layers is common on the limbs of the F_2 folds, and is responsible for much of lensoid outcrop pattern.

A major zone of deformation about 4-5 km wide occurs at the boundary of the Yambah and Utnalanama Blocks. The zone is marked by several major faults, tight to isoclinal folds of possible F_2-age, a tectonic slide indicated by fold-discordance, and several schist zones.

F-1-4: Ongeva Block (A.P.L. & R.D.S.)

The Ongeva Block is divided into a northern and a southern part, each of which has a distinctive structural style.

The northern part is made up of unit pGu and the West Bore Deformed Zone. Here pGu represents a major zone of retrograde schists, and is cut by numerous faults. Many of the faults are related to the West Bore Fault, the Mount Johnstone Fault, and the Cadney Fault. Several localities in the schist zone exhibit two lineations (commonly compositional streaking and mineral elongation), and minor folds are ubiquitous. However, a regional east-striking schistosity, commonly defined by the preferred orientation of muscovite and biotite, obscures major folds. The West Bore Deformed Zone is a region of intense east-striking schistosity resulting from the convergence of West Bore Fault and a parallel fault to the Mount Johnstone fault.

The southern part of the Ongeva Block is made up of interlayered mafic and felsic granulites which have been folded in at least three phases (Fig. 4). The first phase (F_1) is represented by tight intrafoliad folds, the axial-planes of which strike parallel to the compositional layering. The second phase folds (F_2) are tight macroscopic folds which have axial-planes striking northerly and easterly. These F_2 folds have been folded about a third phase of northerly and west-northwesterly striking open folds (F_3). The axial-planes of this third phase fan in strike direction from north to northeast, and the folds plunge steeply north. Although prominent structures on aerial photographs, these folds have no axial-plane fabric elements to aid structural analysis. They are symmetric concentric open folds which appear to have formed immediately before or during the granulite metamorphism, while the rocks were plastic. A fourth phase of northeasterly striking folds, F_4, appears to be developed locally.

F-1-5: Mount Chapman Block (R.D.S.)

The Mount Chapman Block is made up largely of unit pGx and is characterised by northeast-plunging open folds which are tentatively assigned to F_3. There is evidence of an earlier period of reclined folding and local strike faulting or sliding, (see unit description at pGx). The southwestern boundary of the Block appears to be an intrusive contact with the Athapapa Igneous Complex, but the alignment of this boundary with the Cattlewater Fault to the north suggest that the boundary and the Fault are genetically related features. The boundary with the Harts Range Block is interpreted to be a thrust-fault. Further field work is needed to confirm the extent and nature of the faulting.

F-1-6: Tug Creek Block (R.D.S.)

The Tug Creek Block is separated from the Harts Range Block by the Cadney Fault Zone. In Tug Creek region two sets of isoclinal folds are outlined by quartzofeldspathic gneiss units within a sequence of calc-silicate rock and pelitic gneiss. The most widely distributed earlier isoclinal folds are regarded as F_1 and have northwesterly dipping

axial-surfaces in the north of the area and northeasterly dipping axial-surfaces in the south. F_1 folds were accompanied by strong sliding because the intervening synformal structures are absent and presumably have been obliterated. These F_1 folds have been refolded about a large F_2 fold which has an easterly-trending and north-dipping axial-plane. Where F_1 fold hinges are very tight, an axial-plane schistosity, S_1, is locally developed. Both fold phases F_1 and F_2 are essentially reclined and coaxial; the dominant plunge is steep and to the north. An even earlier fold (F_0) has been identified at one locality (GR 5851-709321), just west of the junction of the two main branches of Cadney Creek. Here, a gently plunging fold is refolded by an F_1 fold. Elsewhere, an earlier phase of folding is suspected from the lensic nature of the compositional layering.

The structural pattern outlined by F_1 and F_2 folds in the Tug Creek Block is a type-three pattern, as described by Ramsay (1967). Such a pattern is consistent with the flow direction of the superimposed movement being at a high angle to the axial-surface of first folds (F_1), the axis of which is positioned close to the axis of the second folds (F_2) (Ramsay, 1967, pp. 520-530). Although at least two phases of folding can be recognised, the folding is regarded as one of synchronously refolded folds in the sense of Wynn-Edwards (1967).

F-1-7: Joker Flat Dam Block (A.F.L.)

This block is bounded to the south by the West Bore Fault. It has a poorly defined northern margin. It is a zone of regional retrograde metamorphism with an overprinting east-striking schistosity. Early folding is preserved in the extreme northeastern corner of the unit, where tight macroscopic folds plunge moderately to the east. Late folds associated with movements on the West Bore Fault are well exposed 2.5 km south of Joker Flat Dam at GR 5751-391499. Here up to four folding events are superimposed and classic interference folds are exposed (see unit description of pGsf).

F-1-8: The White Lady Block (R.D.S.)

The White Lady Block is largely straddled by the Pannikin Dam Fault in the north and is bounded by the White Lady Thrust in the south. It represents the faulted margin of the Harts Range Block. Both the faults are largely photo-interpreted and their extent and magnitude needs to be confirmed by further field work. The Block consists mainly of highly foliated calc-silicate rock and schistose gneisses that trend east to northeast.

F-1-9: Oonagalabi Dome (R.D.S.)

Finely foliated and intensely lineated rocks of the Bungitina metamorphics are enveloped in the Pannikan Dam Thrust-Fault to form a dome-like structure protruding into the Harts Range Block. The thrust fault is folded in the geometry of a reclined fold, the thrust being overturned along the southern boundary of the Bungitina metamorphics. The lineation plunges at moderate to steep angles to the north-northeast. The tectonic unit tapers westwards and becomes progressively more intensely schistose and lineated until it merges with Gough Dam Schist Zone.

Northerly-trending F_1 folds are delineated by photo-interpretation at the southern end of the Dome. The broad, open synform, which controls the outcrop pattern of unit $pGsb_2$ northwest of Oonagalabi Prospect, is interpreted to be an F_2 structure. This synform appears to be truncated by the Pannikin Dam Fault.

F-1-10: Harts Range Block (R.D.S.)

Folding in this block has been described by Joklik (1955). More recently, folding in the Maude Creek areas has been studied by M.J. Rickard (ANU) (Rickard & Shaw, 1972; Rickard, 1975).

The principal outcrop of the Riddock Amphibolite Member, which forms the backbone of the Harts Range, is interpreted to be an F_2 synformal structure. The two western branches of the Y-shaped outcrop-area near the Stones and Benstead Mica Mines (abd) north of the main range, are interpreted to be earlier synforms, refolded into an F_2 structure.

The flat-lying Irindina Gneiss at the eastern margin of the 1:250 000 Sheet area represents the edge of the Entia Dome developed farther east.

In the Maude Creek area, F_1 folds form small isoclines in the gneissic layering. Larger mappable F_1 folds are thought to have been north-trending recumbent folds which have been tilted into reclined folds. For example, the repetition of the Naringa Calcareous Member (of the Irindina Gneiss) in the arrowhead-like structure 7 to 9 km southeast of Mount Brassey is caused by F_1 folding, although it is not possible to determine the fold closure. No obvious axial-plane structures were produced during F_1 folding, but in some early fold closures a mineral lineation is present. F_2 folds trend easterly, and have overturned southerly limbs. They vary from tight to open structures, and, rarely, develop an axial-plane schistosity in fold cores. Small F_2 folds, show wide variations in plunge from reclined to horizontal, but lie within a consistent regional north-dipping axial-plane. In the arrowhead structure 7 to 9 km southeast of Mount Brassey, numerous near-recumbent folds have disharmonic relations between isoclines; and more open folds are complicated by attenuation, boudinage, and diapiric intrusion of marble. A larger, near-recumbent F_2 fold is outlined by the flaggy biotite quartzites of the Naringa Member at GR 5851-813362 (where the old Claraville-Lizzie Bore track crosses Maude Creek). This structure refolds an extremely attenuated first generation fold. F_3 folds in the Maude Creek area are more open upright structures in which a poor fracture cleavage is developed, in places, parallel to the axial-planes. At the Maude Creek crossing and also west of Billie Hughes Mica Mine (abandoned), the axial-planes of these third generation folds trend northeast, whereas in the arrowhead-structure southeast of Mount Brassey they trend east and gently warp F_2 recumbent folds.

Rickard (1975; and in Rickard & Shaw, 1972) presents stero-plots of poles to bedding and gneissosity; these lie in a broad girdle about a gently to moderate northeasterly axis. In addition to the broad girdle, a secondary spread of poles forms a partial girdle about an E-W axis, thought to represent a second-fold generation. Where distinguishable, F_1 and F_2 axes tend to correspond to northerly girdle and the partial E-W girdle respectively. All fold axes and lineations, irrespective of age or type, lie in a broad girdle defining a moderate to gentle northward-dipping plane that probably represents the axial-plane of the second phase folds, because F_2 appears to be the more intense and widespread macroscopic fold phase.

F-1-11: Naringa Thrust Slice (R.D.S.)

A thrust or metamorphosed slice is thought to separate the Naringa Calcareous Member from the main body of Irindina Gneiss in the Harts Range Block along most if not all of the northern and eastern boundaries in the Naringa Well area (abd). Recrystallised tectonic breccia is locally present along this contact.

F-1-12: The White Range Nappe (A.J.S.)

In the southern part of the White Range Nappe (Fig. F2), i.e. south and west of Paddys Plain, 115 poles to metamorphic foliation form two great-circle girdles on an equal-area stereographic plot; one girdle has a pi-axis plunging 30° northwest, the other a pi-axis plunging 50° east. In the same area, 57 lineations and 35 mesoscopic fold axes are clustered about a subhorizontal northwest trend, and most of the folds are upright. Pi-diagrams depicting these data are shown in Stewart (1971a) and Shaw & others (1971). The pi-axis plunging east at 50° is regarded as the axis of the later macroscopic folds in the trends of foliation in the area (Fig. F3).

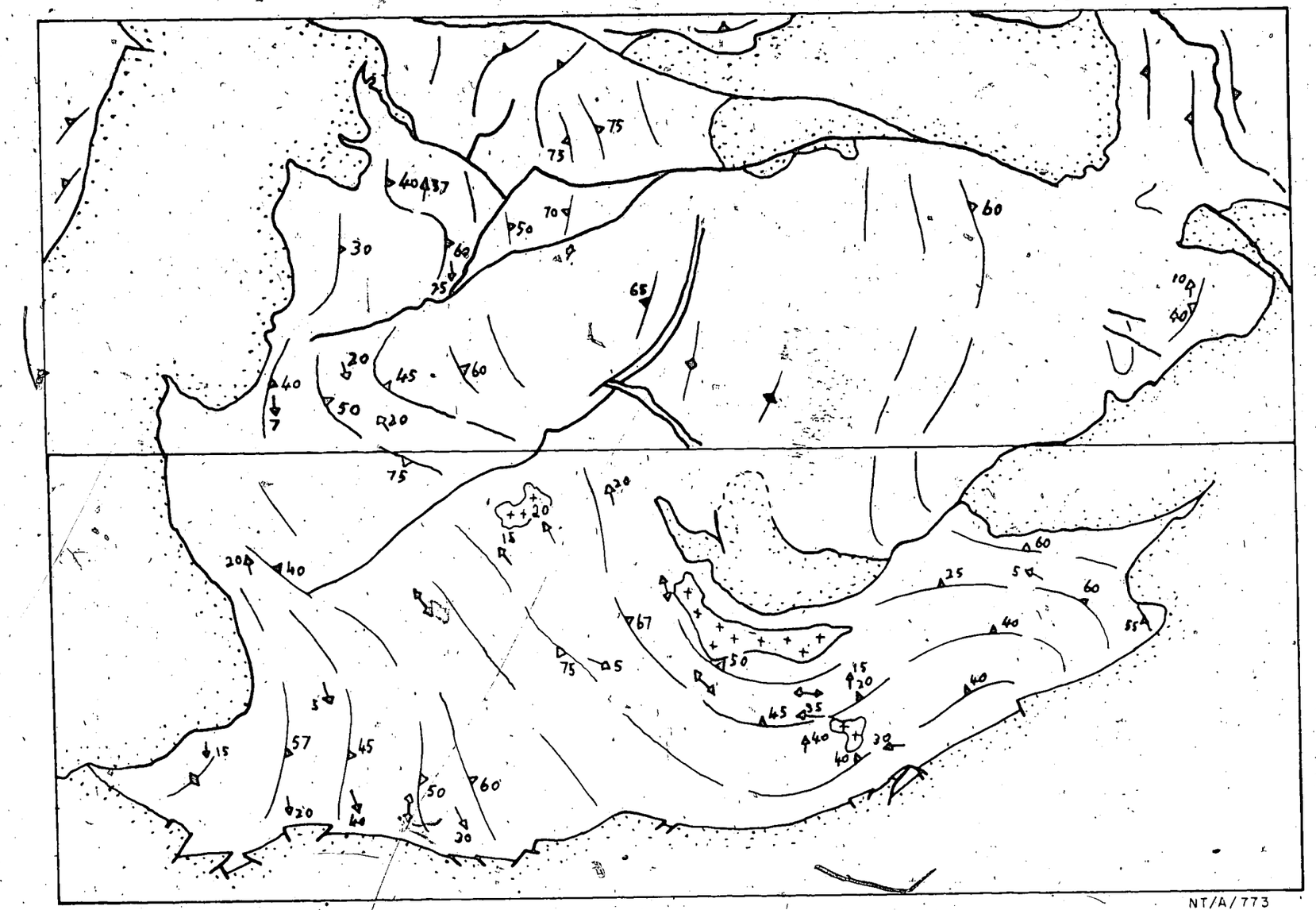


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Fig. F2 Generalised structural map of southwestern part of White Range Nappe

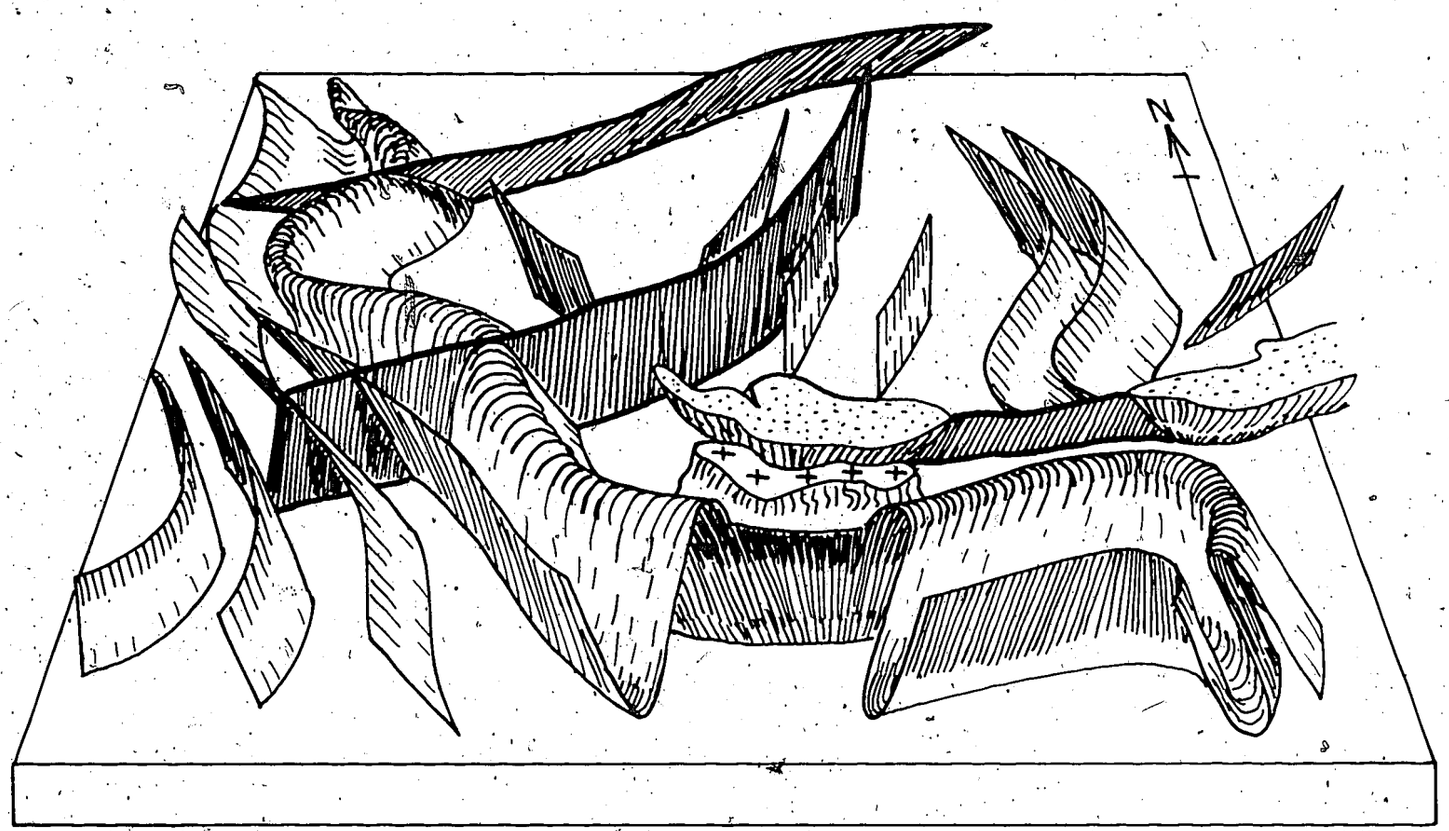

Fig. F3 Perspective sketch of form surfaces of foliation in Hillsoak Bore metamorphics. Faults (thicker outline), granite mass (crosses) and Heavitree Quartzite synforms (dots) also shown. Diagrammatic.

In the northern part of the Nappe, the basement rocks are much more schistose than those in the southern part, and normally massive rocks such as pegmatite, vein quartz, and some amphibolites, are foliated and lineated concordantly with the surrounding schist and gneiss. Foliation, lineation, fold axes, and axial planes are homotactic with those in the neighbouring Heavitree Quartzite, and hence formed in the Palaeozoic during the Alice Springs Orogeny. An analysis of the Palaeozoic folding is presented in Stewart (1971a) and Shaw & others (1971).

F-1-13: The Giles Creek Synform (A.J.S.)

A generalised structural map of the Tommys Gap metamorphics and Atnarpa Igneous Complex in the Giles Creek Synform is shown in Figure F4. It is evident from the bends in the trends of foliation, and from the arching of lineations, that more than one episode of deformation has taken place here. Because of insufficient structural measurements, no structural analysis using stereographic diagrams is presented. However, the following points can be made:

Foliation in most of the large eastern body of hornblende gneiss and amphibolite of the Tommys Gap metamorphics dips generally east, and lineation plunges moderately north-northeast (Fig. F4). In the northwest of this body, though, the foliation dips steeply north-northwest and the lineation plunges down-dip. These differences can be explained by an antiformal fold moderately plunging to the east (Fig. F5). In the small western body of hornblende gneiss and the two nearby masses of quartz-rich metasediment and amphibolite the foliation dips southeast: this may be related to the north-northwest-dipping foliation by overturning along strike (Fig. F5). (The restoration assumes that separation of the two regions of metamorphics by intrusion of the Atnarpa Igneous Complex was not accompanied by any rotation or deformation of the metamorphic rocks).

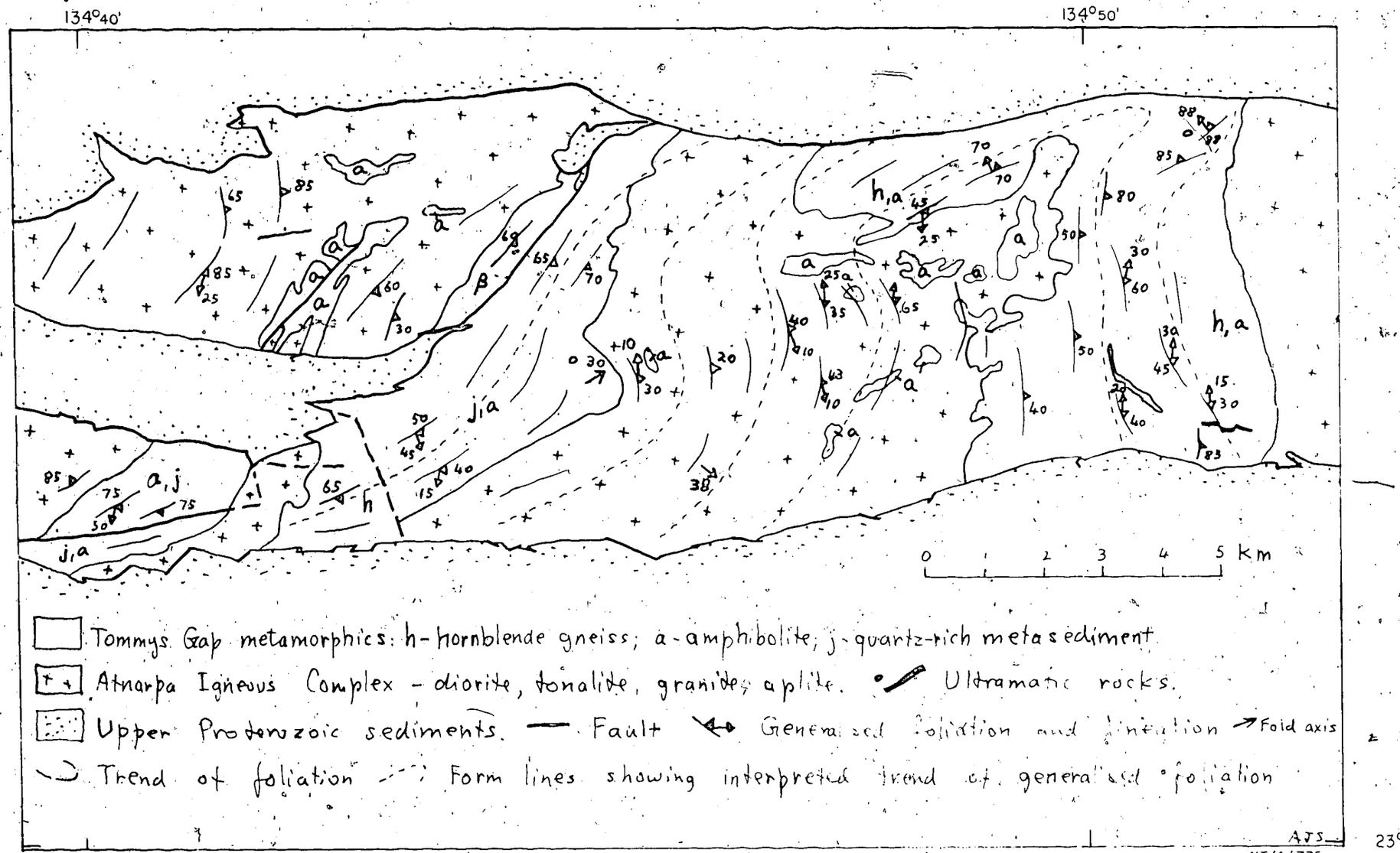

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Fig. F4 : Generalised structural map of part of Giles Creek Synform

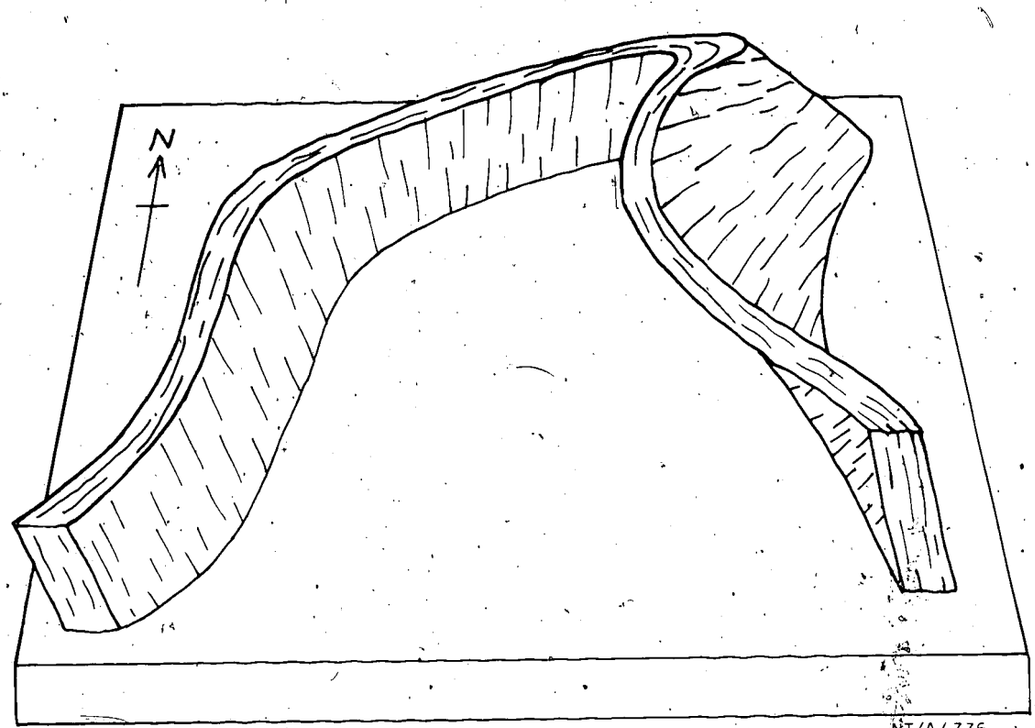

Fig. F.5 Perspective sketch of form surface of foliation in Tommys Gap metamorphics. Lineation form lines on foliation also shown. Diagrammatic.

The plutonic rocks of the Atnarpa Igneous Complex have an east-dipping schistosity which is strongest in the Giles Creek area and in the northwest lobe of the Giles Creek Synform (Fig. F4). In the Giles Creek area, the schistosity is macroscopically folded around an antiformal axis plunging moderately to the east. Lineations in the southern part of this area plunge gently south, and in the northern part, gently north. Hence, the lineation is not homotactic with the lineation in the adjoining hornblende gneiss to the east (Fig. F4). As the plutonic rocks intrude the hornblende gneiss, the lineation in the plutonic rocks is probably the younger of the two. A similar east-plunging antiform is apparent from the trends of the schistosity in the southwest lobe of the Synform (Fig. F4).

From these observations, the following sequence of deformational events can be deduced:

1. Deformation and metamorphism of the Tommys Gap metamorphics, producing foliation and a moderate north-plunging lineation in the plane of the foliation.

2. Tight folding of the foliation and lineation about moderately east-plunging axes.

3. Intrusion of the Atnarpa Igneous Complex.

4. Deformation of Atnarpa Igneous Complex, forming foliation and shallow-plunging lineation; no mesoscopic effects on Tommys Gap metamorphics.

5. Warping of the foliation and lineation in the Atnarpa Igneous Complex about moderately east-plunging axes; this episode tightened the fold in the eastern body of hornblende gneiss, and gently warped the foliation in the large body of quartz-rich metasediment.

F-2: Folding: Precambrian Folding in the Southern Tectonic Zone (R.D.S.)

The Southern Tectonic Zone (see CHAPTER on REGIONAL GEOLOGICAL SETTING) comprises amphibolite facies rocks assigned to Division 2 and 3. It can be divided into three parts:

(1) The Alice Springs Block which is dominated by the Chewings phase of deformation and is the lowest metamorphic grade;

(2) The Wigley Block which is dominated in the west by the Ormiston phase of folding and widespread migmatisation, and in the east by granites thought to be related to the Chewings phase of deformation; and

(3) In the North of the Zone, the Narbib and Ankala Blocks, which show transitional features common to the Northern Tectonic Zone. They are separated from the Northern Tectonic Zone by the Harry Creek Deformed Zone.

F-2-1: Alice Springs Block (L.A.O.)

At least three and possibly five periods of deformation can be identified throughout the Alice Springs Block. These were first recognised in HERMANNSBURG by Marjoribanks (1975) who named them as follows:

Pre-Chewing Phase	D_1 F_1 S_1 L_1
Chewings Phase	D_2 F_2 S_2 L_2
Ormiston Phase	D_3 F_3 S_3 L_3
Mount Giles Phase	D_4 F_4 S_4 L_4
Alice Springs Phase	D_5 F_5 S_5 L_5

(where D is deformation, F folding, S surface, and L lineation). The subscripts denote the sequence of the structural elements. Marjoribanks (1975) also recognised that whereas D_2, D_3 and D_5 were widely developed outside the Alice Springs Block, D_1 and D_4 appear to have no regional significance. Metamorphisms associated with D_2, D_3 and D_5 have been dated

at 1586 ± 69 m.y., λ = 1.42 (1620 ± 70 m.y., λ = 1.39). 1053 ± 49 m.y., λ = 1.42 (1076 ± 50 m.y., λ = 1.39) (Rb/Sr whole-rock methods; Marjoribanks and Black, 1974) and 335,312 m.y., λ = 1.42 (342, 319 m.y., λ = 1.39) (Rb/Sr whole-rock-mineral method; Armstrong & Stewart, 1975).

Pre-Chewings Phase. In HERMANNSBURG and ALICE SPRINGS, marginal to the Chewings Range Quartzite, a lineation (L_1) outlined by mineral elongation and fine mullion structures is folded by Chewings Phase folds (F_2). The foliation surface folded by F_2 in the Chewings Range Quartzite and the Emily Gap schist is thought in most cases to parallel bedding S_1.

Chewings Phase. This phase is typified by tight folding of S_1, with recrystallisation and formation of a strong axial-plane fabric (S_2). Mineral elongation on S_2 outlines L_2 (the intersection of S_1 and S_2), which is parallel with the F_2 fold axis. The metasedimentary rocks of the Chewings Range lie in a refolded F_2-synform in HERMANNSBURG (Marjoribanks, 1975) and ALICE SPRINGS. In the east of ALICE SPRINGS the Emily Gap schist defines a macroscopic F_2-synform and antiform within orthogneiss. The limbs of the fold are highly schistose (S_2) and lineated (L_2); the fold noses are outlined by a foliated gneissic layering (S_1) cut at a high angle by axial-plane schistosity (S_2), or by strongly lineated (L_2) rock.

Ormiston Phase. Marjoribanks (1975) recognises this phase in HERMANNSBURG as large-scale east-plunging similar folds. Axial-plane fabrics (S_3) and lineations (L_3) do not appear to be strongly developed. In ALICE SPRINGS mesoscopic and macroscopic F_3 folds are typically open with east-plunges and have little noticeable development of S_3 and L_3. The earlier surface (S_2) and lineation (L_2) are folded by F_3 folds. The surface extent of the Chewings Range Quartzite is controlled by both F_2 and F_3 structures.

Mount Giles Phase. This phase has been recognised in HERMANNSBURG as open south-facing, asymmetric buckle-folds with axial-plane traces trending west and swinging to the northwest. The folds are of limited extent and are outlined mainly by the competent Chewings Range Quartzite

(Marjoribanks, 1975). In ALICE SPRINGS this phase of deformation is not obvious. The apparent flexure of the two F_3 fold axes in the Burt Bluff Gneiss and Rungutjirba Gneiss at about GR 5650-620760 may be caused by gentle folding about a north-northwest trending D_4 fold axis.

Alice Springs Phase. This deformation caused retrogression, refoliation and mylonitisation along narrow zones within the basement. The northern fault boundary of the Alice Springs Block in ALICE SPRINGS is the root zone of the Blatherskite Nappe, southwest of the Alice Springs township, which has been described by Stewart (1967) and Clarke (in Wells, 1976). The upper (northern) plate has moved at least 14 km south-southwestwards, the distance between the root zone of the fault and the repeated stratigraphy (Clarke in Wells, 1976).

Structural analysis

The Alice Springs Block in ALICE SPRINGS has been divided into five sub-areas (Figs F6 and F7) based on the orientation of poles to S_2.

Sub-area A shows the effect of F_3 folds. Poles to foliation form a broad great circle scatter with pi-axis plunging gently to the east. This roughly agrees with mesoscopic F_3 folds in this sub-area, which generally plunge moderately to about 070°. F_2 lineations plot on a great circle, suggesting a similar-style of folding (Ramsay, 1960).

Sub-area B shows steeply dipping easterly-trending foliation with a consistent B_2 lineation orientation, and may represent the limb of an F_3 fold.

Sub-area C shows the effect of F_3 fold axes which have near horizontal to gently southwest-dipping plunges. Poles to foliation outline a great circle. The lineations form a scatter in the southwest quadrant and to a lesser extent the northeast quadrant of the stereographic projection. The scatter may be caused by the presence of two lineations, L_2 and L_3.

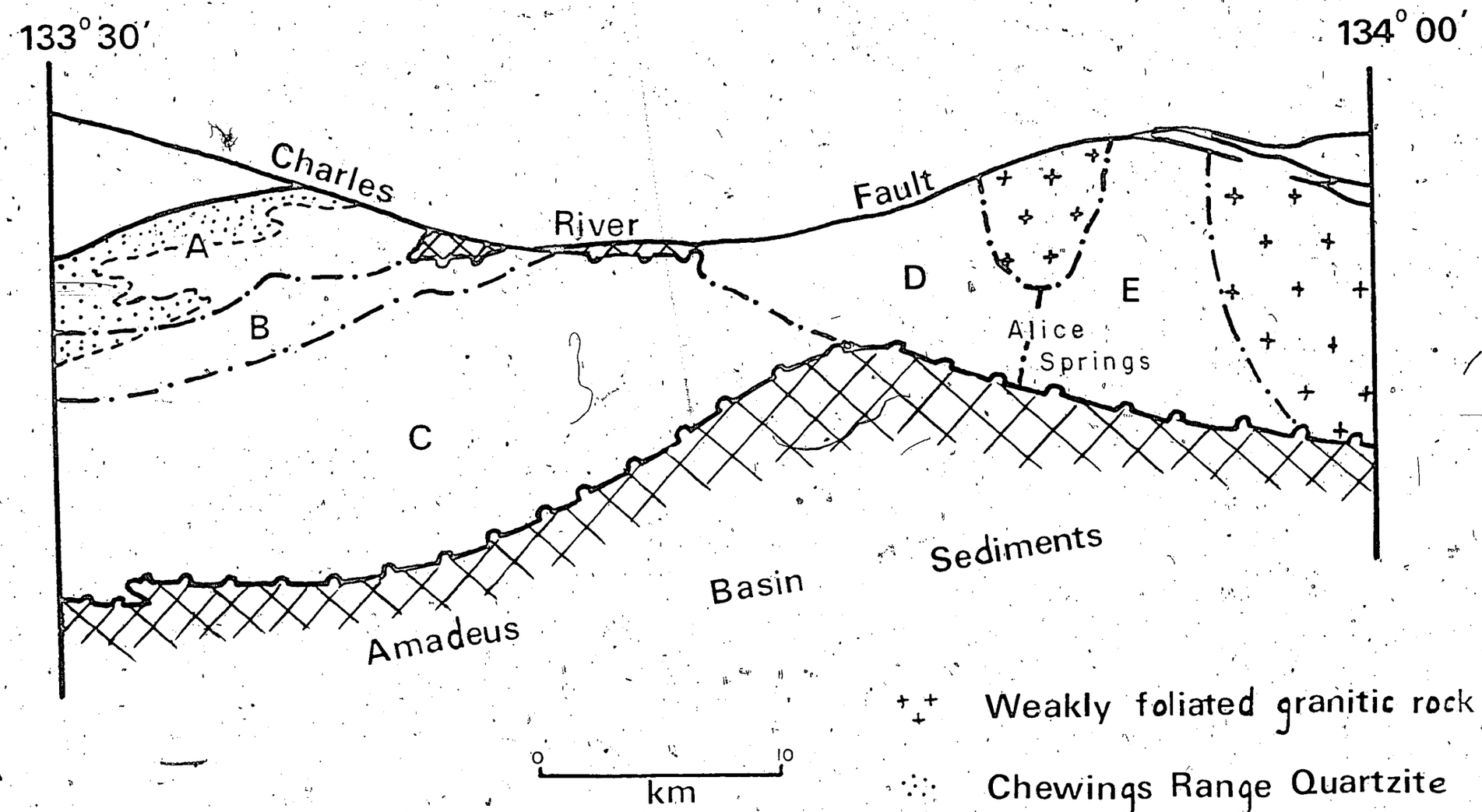

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Fig. F6 Structural domains in the Alice Springs Block in ALICE SPRINGS

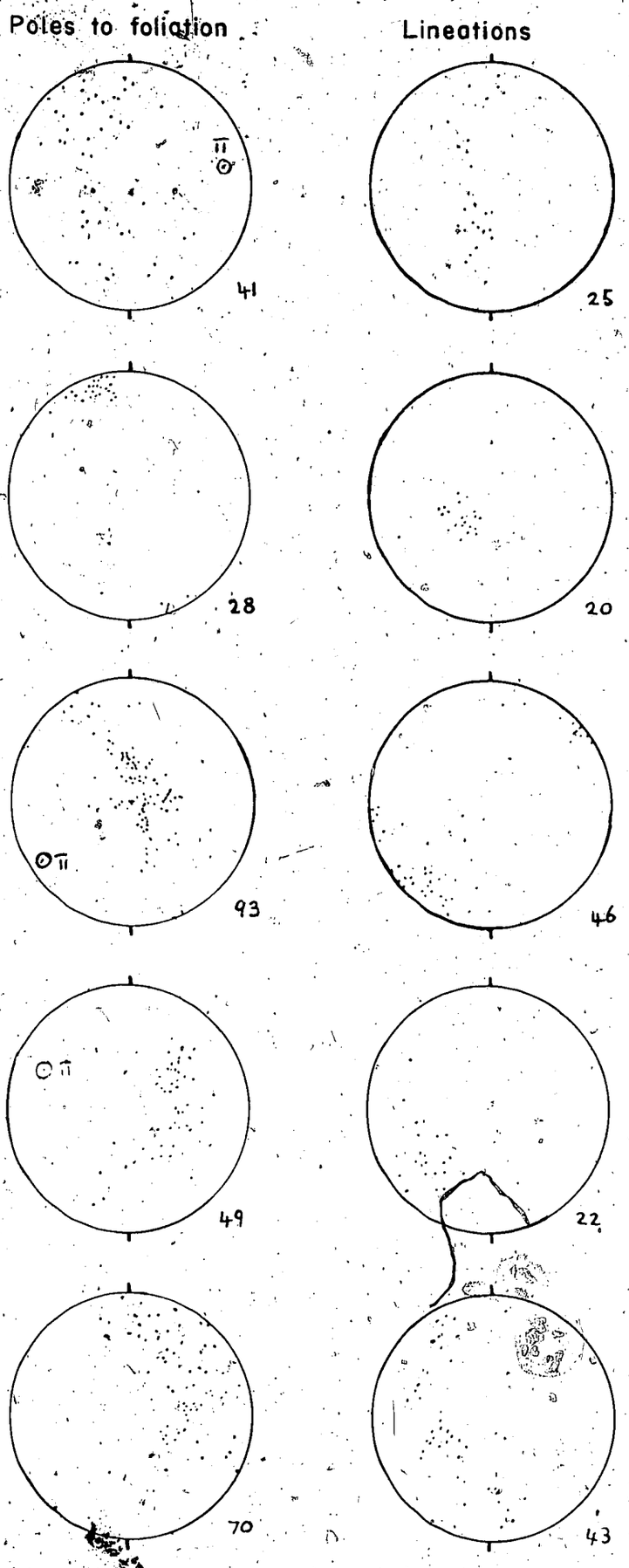

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Fig. F7 Orientation diagrams for a part of the Alice Springs Block

Sub-area D shows a partial great circle scatter of poles to foliation such that the pi-axis is gently plunging to the northwest. Lineation orientation is mainly confined to the southwest quadrant of the stereographic net but roughly outlines a great circle, suggesting a similar style of folding (Ramsay, 1960).

Sub-area E shows a diffuse pattern of poles to foliation. This scatter may be due partly to the difficulty in distinguishing in the field between S_1 and S_2. Lineations form a great circle scatter and suggest that F_3 folding may be of a similar style (Ramsay, 1960).

F-2-2: (a) Wigley Block (south) (L.A.O.)

The structural history of the Wigley Block was first described by Marjoribanks (1975) in his report on the Ormiston area in HERMANNSBURG. The same abbreviations and order of structural elements as defined by Marjoribanks (1975) will be used here.

Chewings Phase	D_2 F_2 S_2 L_2
Ormiston Phase	D_3 F_3 S_3 L_3
Alice Springs Phase	D_5 F_5 S_5 L_5

where D is deformation, F folding, S surface and L lineation. There is also some evidence, in ALICE SPRINGS in the Wigley Block, that indicates a deformational event prior to the Chewings Phase, and another event later than D_2 but earlier than the Ormiston Phase.

The structure of the Wigley Block is treated in two parts. Firstly a summary is given of the structural styles of deformation of the Wigley Block as reported by Marjoribanks (1975) in HERMANNSBURG; secondly the deformation of the Wigley Block in the Alice Springs 1:250 000 Sheet area is recorded and compared with the styles of deformation in HERMANNSBURG.

(1) In the Ormiston area (HERMANNSBURG) the earliest recognised deformation in the Wigley Block, the Chewings Phase (D_2), is characterised by isoclinal folds which have a well-developed axial-plane foliation and a lineation. The deformation was accompanied by amphibolite facies metamorphism (Marjoribanks, 1975). Marjoribanks (1975) suggests that major thrusting (Redbank Deformed Zone) commenced at this time.

The Ormiston Phase (D_3) is typified in HERMANNSBURG by folds having varying styles and orientations, and it was accompanied by migmatisation. Quartzofeldspathic mobilisate veins commonly parallel the axial-plane of F_3 folds; axial-plane schistosity and a lineation parallel to the fold axis, outlined by biotite flakes, are present locally. The general plunge of F_3 folds in HERMANNSBURG is moderate to the north.

Thrust faults and narrow zones of refoliation and retrogression are assigned to the Alice Springs Phase of deformation.

(2) In the eastern part of the Wigley Block in ALICE SPRINGS, four and possibly five deformational phases are recognised. Of these, three are correlated with the events recorded by Marjoribanks (1975) in HERMANNSBURG.

Pre-Chewings Phase

The only evidence for this early deformational event was found at 5650-729871 where an interference pattern on the limb of a mesoscopic F_2 fold suggests either an earlier fold structure or buckling and flattening of the limb during the development of the F_2 fold.

Chewings Phase

In ALICE SPRINGS this event has only been recognised on the mesoscopic scale. At 5650-826918 quartzofeldspathic layers several centimetres across in Flint Spring gneiss (pGe) outline a tight F_2 fold whose axis plunges at about 60° to 260°; the axial-plane is defined by the preferential alignment of biotite flakes and feldspar augen (Fig. F8). Within the unnamed unit Ex at 5650-729871, quartzofeldspathic layers are isoclinally folded about F_2 axes plunging at a moderate angle to

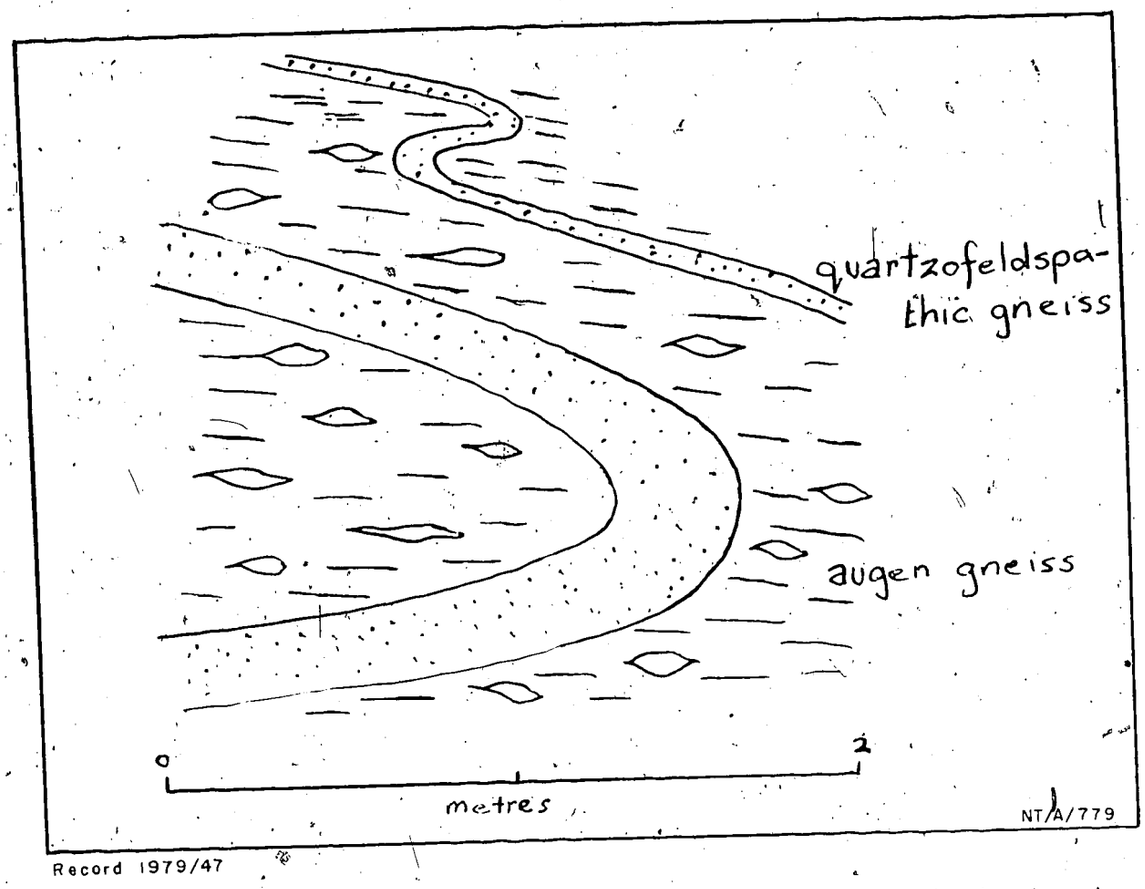

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Fig. F8 Sketch of mesoscopic Chewings Phase fold; strongly developed axial plane schistosity. GR 5650-826918

about 255°; the axial-planes are outlined by a schistosity which intersects the limbs of the folds to form a mineral elongation lineation. Both these examples of mesoscopic F_2 folds have a strong axial-plane schistosity and one has a strong lineation. They are comparable with the structural features assigned to the Chewings Phase of deformation by Marjoribanks (1975) in the Ormiston area.

Deformational event after Chewings Phase but prior to Ormiston Phase

This event is thought to be responsible for several macroscopic folds which occur in ALICE SPRINGS and these folds are designated F_2/F_3. All three examples of macroscopic folds that clearly postdate F_2 and predate F_3 plunge generally southwestwards. The foliation/layering F_2 is folded, and hence the folds post-date the Chewings Phase of deformation. Two of the folds (At 5650-620850 and 5650-930910) are folded about west-plunging F_3 axes and the axial-plane trace of the third example (At 5650-700860) appears to be cut by migmatite associated with D_3. Thus, the folds pre-date the Ormiston Phase of deformation (D_3). Other southwest trending folds at 5650-488878, 5650-830875 and 5650-725905 are overturned to the south. These folds may also be related to this 'intermediate' phase of deformation.

Ormiston Phase

Macroscopic structures considered to be F_3 folds commonly have west-trending axial-planes and plunge to the west or southwest. These include an upright synform at 5650-620850, which refolds layered biotite gneiss and amphibolite and contains migmatised and granitic gneiss (Lw) in its core, and a synform at 5650-930910 outlined by amphibolite.

At 5650-920870, a lineation defined by mineral elongation is folded about an F_3 axis. The folded lineation may be L_2, representing the intersection of the dominant foliation (schistosity) S_2 and the earlier surface S_1.

Mesoscopic F_3 folds are generally open but range from gentle and open to isoclinal and ptygmatic in style; they include flow folds in migmatised rocks. The folds plunge moderately west. In fold noses biotite flakes and fracture cleavage commonly outline the axial-plane. In some places quartzofeldspathic mobilisate veins are aligned parallel to the axial-plane.

At 5650-897860 two lineations, both defined by mineral elongation, have been recorded. As has been reported in HERMANNSBURG (Marjoribanks, 1975), the Chewings Phase of deformation is responsible for one of these, a strong L_2 lineation. However, local recrystallisation in the noses of mesoscopic west-plunging F_3 folds has also produced a later lineation, L_3.

Both lineations L_2 and L_3 may also be preserved elsewhere in the Wigley Block, but they have not been distinguished on a regional-scale. Many lineations parallel the fold axis of macroscopic F_3 folds, but in places such as at 5650-920870 the lineations show a scatter about the F_3 axis, (see above), thus indicating not all lineations are L_3.

Alice Spring Phase

Thrusting and associated faulting and retrogressive metamorphism affect the Wigley Block in the Alice Springs 1:250 000 Sheet area forming discrete zones of mylonite and schist. These are related to the Alice Springs Phase of Deformation (D_5). Associated mineral streaking outlines a strong lineation in mylonite of Pzr, and is axial plane to rare mesoscopic folds.

The Redbank Deformed Zone is markedly lineated. This lineation is thought to be mainly a D_2 structure. Narrow belts of mylonite within the Zone are thought to represent reactivation during the Alice Springs Phase. The lineation commonly present in these mylonite belts is thought to be a D_5 structure. At 5650-795933 a layer of quartzofeldspathic gneiss within the Zone outlines a mesoscopic fold; mineral elongation here outlines a strong lineation which is caused by the intersection of the axial-plane schistosity and the folded layer, and is considered to be L_2.

F-2-2: (b) Wigley Block (north and central) (R.D.S.)

Early folds, (which are possibly F_2 in the terminology of Marjoribanks, 1975) trend northeast in the central part and easterly in the northern part of the Block. These folds have overturned southern limbs and fold the main foliation. They do not have an axial-plane schistosity. These folds are overprinted by more open easterly trending folds (F_3). In some cases these folds are localised near the major east-trending faults which typify the northern and central parts of the Wigley Block. This special relationship suggest the folds and faults are genetically related. Greenschist retrogression is localised along these faults, suggesting fault movement during the Alice Springs Orogeny. However, the Whistleduck Dyke Swarm intrudes some of these faults, indicating that the faults predate the dykes.

F-2-3: Narbib and Ankala Blocks (R.D.S. & A.P.L.)

Narbib Block (A.P.L. & R.D.S.)

The Narbib Block is made up of east and northeast-striking interlayers of felsic and mafic granulite which crop out south of the Narbib Range, and in the Adla Hills immediately west of the map area. The total magnetic intensity pattern suggests that similar granulites occur between the two outcrop areas but are separated by a minor northwest-trending fault. The magnetic pattern in the southwestern corner of the Sheet area is much less disturbed than in the granulite areas indicating the presence of less magnetic rocks, possibly quartzofeldspathic gneiss similar to that in the Wigley Block assigned to Division 2.

Ankala Block (R.D.S.)

The Ankala Block is comprised mainly of quartzofeldspathic gneisses metamorphosed to the upper amphibolite facies. It is separated into a northern and southern part by the Bald Hill Fault. The two parts are grouped together because they are thought to form part of a conformable sequence of similar metamorphic grade and because the Arltunga Nappe Complex is thought to hinge in the western part of the Block.

In the northwest end of the northern part of the Ankala Block large isoclinal east-striking, north-plunging reclined folds (F_2) are overprinted by very broad, open F_3 folds. Elsewhere, most recognisable folds are associated with a marked schistosity and were formed during the Palaeozoic Alice Springs Orogeny.

In the southern part of the Block F_1 isoclinal reclined folds appear to have a more northerly strike but a similar plunge to later F_2 reclined folds which strike east-southeast and plunge northeast. A third phase, F_3, of minor open folds and warps is specially and possibly genetically related to a series of northeast-trending faults.

F-3: Faulting: Major Faults - Introduction (R.D.S.)

Rocks of the Alice Springs region have undergone a long and complex history of faulting. The major faults commonly strike easterly, either east-northeast or east-southeast, and are flanked on one side by major schist zones (Figs. C4, E4). These faults are either localised at the boundary between granulite facies rocks and amphibolite facies rocks or cut the granulite facies terrain. One exception is the Charles Creek Fault which separates the Alice Springs and Wigley Blocks. A description of these major faults is followed by brief comments on the minor faults. The Arltunga Nappe Complex is outlined as an example of the thrust nappes that formed during the Alice Springs Orogeny. Possible expressions of the Woolanga Gravity Lineament are discussed.

F-3-1: Harry Creek Deformed Zone (R.D.S.)

The Harry Creek Deformed Zone dips at about 40 degrees to the north and separates the Utnalanama Block, which has been metamorphosed to the granulite facies, from the Ankala Block which has only been metamorphosed to the amphibolite facies. The Gum Tree Granite, intruded at about 1000 m.y., is localised in the Fault Zone indicating that the zone is older than 1000 m.y.

The zone probably corresponds to in age to the last granulite metamorphism in the Utnalanama Block. The Harry Creek Deformed Zone is displaced southwards by a meridonal fault at Pinnacles Bore. East of this point the Harry Creek Deformed Zone merges with the retrograde schist zone of the Arltunga Nappe Complex (Pzr). This Zone is discussed further in Allen & Black, (1979).

F-3-2: Redbank Deformed Zone

The Harry Creek Deformed Zone is considered analogous to the Redbank Deformed Zone, in the southwest of the 1:250 000 Sheet area, which separates granulites of the Mount Hay area from migmatite gneiss of the Wigley Block, and on the adjacent Hermannsburg 1:250 000 Sheet area corresponds to the central part of the steep Bouguer Anomaly gradient of 150 mGal over 5 km. The recurrence of granulite south of the Narbib deformed zone and the presence of rocks marginal to granulite facies at the eastern end of outcrop in the Narbib Block, both south of the Harry Creek Deformed Zone, indicates that fault displacements along the Redbank Deformed Zone are of a much lower order in the Alice Springs 1:250 000 Sheet area than in the Hermannsburg 1:250 000 Sheet area; this is in accord with the much reduced gravity gradient which is about 50 mGals over 50 km.

F-3-3: Cadney Fault Zone (R.D.S.)

The Cadney Fault Zone is a major complex structural feature extending from Mount Johnstone Dam in LAUGHLEN eastwards at least as far as Lizzie Creek in RIDDOCH. The main fault is an north-dipping thrust fault. Schist adjacent to the fault is intensely lineated in places e.g. (in the eastern tributary of Cadney Creek).

F-3-4: Gough Dam Schist Zone (R.D.S.)

In the northeast the Cadney Fault Zone is flanked by the Gough Dam Schist Zone. The main fault is interpreted to be a thrust which separates the Harts Range Block and the Oonagalabi Dome. A strong schistosity and lineation in the adjacent gneisses increase in intensity towards the fault. The schistosity, and probably also the fault, dips northwards at 30° to 60°. The Harts Range Group is thought to be overthrust onto the Cadney metamorphics. There may also be a considerable strike-slip displacement, but the amount of displacement is uncertain because the stratigraphic units cannot be unequivocally correlated across the main fault.

F-3-5: West Bore Fault (A.P.L.)

The West Bore Fault separates the amphibolite facies rocks of the northern Ongeva Block from the granulite facies rocks of the Joker Flat Dam Block. It is flanked on its western end (near Woolanga Bore) by the West Bore Deformed Zone, which is probably the eastwards continuation of the Wallaby Knob Schist Zone (mapped in the Alcoota 1:250 000 sheet area) offset by the Mount Johnstone Fault.

The West Bore Fault dips steeply to the north and extends from Woolanga Bore eastwards to Joker Flat Dam where it turns sharply south. It is marked by en echelon faults and a 500 m wide zone of highly deformed rock.

F-3-6: Mount Johnstone Fault (R.D.S.)

This fault extends from Woolanga Bore in LAUGHLEN southeastwards, separating the Cadney metamorphics from the Ongeva granulite and the West Bore Schist Zone. It may be an expression of the Woolanga Gravity Lineament described below. However, it appears to extend no farther than a point about 15 km north-northeast of 'The Garden' homestead. Metamorphic retrogression to the greenschist facies occurs along this fault, suggesting some movement during the Alice Springs Orogeny.

F-3-7: Pannikan Dam Thrust (R.D.S.)

This fault separates the Strangways Metamorphic Complex from the Harts Range Group, and it extends eastwards from its apparent hinge zone near Pannikan Dam in RIDDOCH.

North of the Oonagalabi Prospect, the fault appears to become a zone of high strain, but farther east and southeast it developes into a major tectonic slide (zone of detachment). This slide continues to the southeast and then swings west and becomes overturned together with the boundary between the Strangways Metamorphic Complex and the Harts Range Group.

F-3-8: Narbib Fault Zone (R.D.S.)

This deformed zone is a series of faults separating the Narbib Block from the Ankala Block to the north in BURT. Within this zone the rocks consist of cataclasite, partly deformed garnet biotite gneiss, and rare relict mafic granulite.

F-3-9: The Woolanga Lineament (R.D.S.)

The Woolanga Lineament is a gravity feature, defined but unnamed by Anfiloff & Shaw (1973), marking a relatively sharp change in Bouguer anomaly values, at the eastern end of the Papunya Gravity High. It is also evident in the BMR 1:250 000 total magnetic intensity map.

The Woolanga Lineament is possibly expressed at the surface as two parallel faults extending for 50 km from west of "The Garden" homestead to Woolanga Bore. The more westerly fault roughly coincides with a positive aeromagnetic trend-line; Tipper (1966) considers that it may be filled with veins containing magnetic minerals.

The Woolanga Lineament was possibly the locus for varied igneous intrusions, including the Mordor Igneous Complex at about 1200 m.y. (Langworthy & Black, 1978); volcanic pipes and fissures which fed the spilitic basalt of the Bitter Springs Formation, and the Mud Tank Carbonatite. These igneous rocks are of types consistent with the concept that the Woolanga Lineament was a deep-seated crustal dislocation. The Woolanga Lineament also corresponds to a probably Cainozoic structural feature which has controlled the present topography and is expressed as a narrow valley. This feature is evident on ERTS satellite imagery. The Woolanga Lineament is roughly paralleled by others less well-defined, gravity features. One of these, about 150 km to the east, may be seismically active (Denham in Dooley, 1973).

F-4: Faults: Minor Fault Systems (R.D.S.)

Widespread groups of minor faults in the central Tectonic Zone (i.e., north of the main thrust zone of the White Range Nappe) commonly have northwesterly trends. One of the most important is a west-northwest-trending group of roughly parallel faults related to the Southern Cross Schist Zone. These separate cordierite-rich rocks of the Strangways Metamorphic Complex to the south from cordierite-poor rocks to the north. A closely spaced network of northwest-trending faults developed north of the Southern Cross Schist Zone is absent south of the Schist Zone. The first period of faulting, which trends northwest, is correlated with the formation of the Southern Cross Schist Zone which is of uncertain age.

In contrast, faults in the Southern Tectonic Zone, south of the Harry Creek Deformed Zone, have mainly easterly trends. A number of these faults are infilled with dolerite that has been metamorphosed, indicating that they are younger than the main folding episode, but older than the last Precambrian regional metamorphism.

F-5: Faults: Palaeozoic Nappes

F-5-1: Arltunga Nappe Complex (R.D.S.)

In the Arltunga Nappe Complex a series of thrust nappes involving displacements of up to at least 10 km southwards have been demonstrated from basement-cover relationships. The Complex is comprised of the Ruby Gap Nappe, the Trephina Gorge Structure, the overlying White Range Nappe, and the Giles Creek Synform forming a klippe at the front of the nappe complex. The White Range Nappe is underlain by the Ruby Gap Nappe of uncertain displacement (Forman, 1971; Stewart, 1971a; Shaw, Stewart, Yar Khan, & Funk, 1971). A southwards displacement of at least 2 km and possibly 14 km is indicated for the Blatherskite Nappe at Alice Springs (Stewart, 1967; Clark, 1975). All the nappes of the Complex are on the northern margin of the Amadeus Basin. The large displacements suggest that part of the steep Bouguer anomaly gradient to the north of this margin may be caused by Middle to Late Palaeozoic thrust faulting concomitant with greenschist retrograde metamorphism; such metamorphism is particularly well-developed near the thrust faults in the Arltunga Nappe Complex.

The Arltunga Nappes are thought to have formed principally by thrust faulting in the western, southern, and eastern parts of the Complex, and by penetrative deformation under conditions of increased metamorphic grade in the central and northern parts. Major thrust surfaces probably originated near the basement-cover contact, migrated upwards, and joined a major decollement in the Bitter Springs Formation. Once a large thrust sheet, consisting of a layer of crystalline basement overlain by Heavitree Quartzite, began moving over the lower part of the autochthonous Bitter Springs Formation, a series of thin slices of upper Heavitree Quartzite (Buh_3), and the immediately overlying Bitter Springs Formation, may have been stripped away in scraper or bulldozer fashion from the autochthon below the main thrust sheet, thus forming subsidiary thrust sheets (each resting on its own thrust fault) beneath the main thrust sheet. A good example is the imbricate thrust zone at the base of the Ruby Gap Nappe.

The thrust sheets were subsequently folded about east-west axes, and in front of the Nappe Complex were rotated. R.D.S. considers that the Giles Creek Synform also formed by sliding, and then rotated bodily as it plunged down into the incompetent sediments of the autochthonous Bitter Springs Formation in front of the earlier formed parts of the White Range Nappe. Thrusts in the cover in front of the Giles Creek Synform were formed later, probably due to gravity sliding.

The main region of penetrative deformation in the Arltunga Nappe Complex is in the northern part of the White Range Nappe, particularly in the Arltunga Goldfield-White Range area, where overfolding may well have predominated over overthrusting. Deformation processes in this region are described by Stewart (in Shaw & others, 1971); they show marked contrasts with processes in the southern part of the nappe. The fault along the northern side of the Giles Creek Synform can be interpreted as the surface at the base of a thrust nappe, rather than as the thrust-out middle limb of a large recumbent fold that was subsequently refolded; the overturning of the cover rocks of the synform would be caused by drag along the thrust surface. In the southern part of the western lobe of the White Range Nappe (i.e., between Bitter Springs Gorge and Arltunga Bore), Stewart has found that the basement rocks were only slightly metamorphosed, and underwent negligible deformation during the Alice Springs Orogeny. A major thrust-fault is present at the western end of this basement core of the White Range Nappe.

Emplacement of the White Range Nappe began by thrust-faulting (sliding), and was accompanied in its later stages by the formation of upright to south-verging east-west folds. The north-dipping penetrative schistosity and retrogression of the central and northern parts of the nappe developed after the early sliding, and were accompanied by the formation of the reclined shallowly north-plunging folds that have axial-planes parallel to their schistosity. If it is assumed that the schistosity of the deformed zones (in the northern parts of the White Range and Ruby Gap Nappes) formed during one episode, the birth of the Ruby Gap Nappe appears to have taken place after that of the White Range Nappe, probably at the same time as east-west south-verging folds in the

autochthon below the Ruby Gap Nappe and north-south recumbent folds in the allochthon of the nappe itself formed during southward sliding. The east-west upright folds and kink bands throughout the Nappe Complex formed after the main stages of emplacement in both the White Range and Ruby Nappes. The east-west folds in the western part of the Nappe Complex are tighter than those in the east.

An important meridional fault is developed in the Pinnacles Bore area, and was possibly active during the time of nappe formation. This fault dips steeply eastwards and separates two major blocks of Cadney metamorphics in the Southern Cross Bore area. A shorter, parallel fault lies about 1.5 km to the east near the Polly Boy Mine. A zone of quartz-filled shears and fractures carrying copper minerals extends from the Centralian No. 9 Copper prospect northwards to Ciccone's Shafts, parallel to the main fault. Wide-zones of greenschist facies retrograde metamorphism is localised along these faults and for this reason these faults are considered to have developed during the Alice Springs Orogeny.

Although a southwards horizontal displacement of about 10 km is indicated by the width of the White Range Nappe, the Bouguer anomalies in the region of overthrusting are comparatively flat. Modelling by Anfiloff (1976) indicates that the main thrust is almost horizontal and shallow such that the lower crust was involved very little; or if the faults were steep any mass excesses in the upper crust induced by upward displacement of the dense lower crust was obliterated by later processes such as granite emplacement.

In the area which later became the Arltunga Nappe Complex, only about 2.5 km of Upper Proterozoic and Palaeozoic sediment was preserved at any one time, largely because the region was emergent for short intervals during the Upper Proterozoic glaciations, and up to 3 km was removed by uplift during the Silurian Rodigan Movement (Wells & others, 1970). Furthermore, the P-T conditions indicated by the presence of metamorphic sericite coexisting with kaolinite in the Heavitree Quartzite confirms that overthrusting took place at relatively shallow depths, possibly only 2-3 km. The thrust faults followed pre-existing deformed zone (e.g. Harry

Creek Deformed Zone) which separated granulites from amphibolite facies gneisses, and broke through the Heavitree Quartzite, before sliding along decollement surfaces in the Bitter Springs Formation. The P-T conditions in the Heavitree Quartzite and adjacent rocks and the mapped rock relations indicate that the thrust slices containing Heavitree Quartzite and basement rocks did not penetrate the sedimentary sequence above the Bitter Springs Formation.

During the Alice Springs Orogeny the crust is interpreted to have been comparatively brittle, and consequently high pressures were produced at comparatively shallow depths. As pointed out above, biotite and muscovite formed at a depth of less than 3 km in the Arltunga Nappe Complex (Forman & Shaw, 1973; Shaw & others, 1971). There was no magmatic activity during the orogeny (Wells & others, 1970), with the possible exception of pegmatite emplacement in the Harts Ranges at the eastern end of the southern Arunta Block (Black, BMR, personal communication, 1975). By the time the orogeny took place, the lower crust may have become comparatively dehydrated, and thus less amenable to partial melting (Brown & Fyfe, 1972). Such dehydrated crust would also be expected to have a greater strength (Robertson, 1970). Forman & Shaw (1973) suggest that during the orogeny the displacements on the main faults separating the sedimentary basins from the granulite blocks were of such magnitude that a small quantity of crust was slightly underthrust into the mantle, due to compressive stresses. Once the compressive stresses waned, the underthrust crustal slab would tend to rise to an equilibrium position, producing uplift. However, during uplift (and also during the preceding overthrusting) the lower crust was not necessarily involved. As a result of the uplift, the more dense granulite block, previously stabilised in the upper crust, was uplifted, and the less dense adjacent graphitic rocks remained more or less in place. Some partial melting may have taken place at the base of crust. Duff & Langworthy (1974) suggest that the central Australian part of the Australian craton underwent recurring meridional compression during the mid-Proterozoic and Palaeozoic induced by periods of more rapid, intermittent drift of the large Gondwanide plate. One of these pronounced periods of compression is thought to have culminated in Alice Springs Orogeny.

F-5-2: Nappes in the Amadeus Basin Sediments (A.J.S.)

Wells & others (1970) showed in their Figure 66 Stewart's interpretation of the lateral extent of several thrust nappes in the northeastern part of the Amadeus Basin. The 'interpretation' of the extent of the nappes was little more than geological speculation at the time, and involved joining together many known faults in the Bitter Springs formation to form two much more extensive and quite separate faults which on the map closed around on themselves and appeared as slides at the base of two separate nappes or klippen. A third lower nappe was shown between the two upper klippen. The detailed colour airphoto-interpretation of the Bitter Springs Formation has confirmed the existence of the hitherto postulated slide forming the northern edge of the northernmost klippe; the fault (slide) has been traced from Williams Bore in UNDOOLYA past Trephina Gorge, Bitter Springs, Ross River Tourist Chalet, Box Hill Bore, to Pulya Pulya Dam in FERGUSSON RANGE, a total distance of 90 km. The slide is shown on the 1:500 000 scale 'Generalised Geological and Tectonic Map' on each of these two 1:100 000 Preliminary Sheets at the base of the 'Upper Allochthonous Sheet' (dense red dot screen) of Amadeus Basin sediments. Two kilometres northwest of Acacia Well in UNDOOLYA, the slide is subhorizontal, and erosion has cut tectonic windows through the allochthonous dolomite of the Gillen Member of the Bitter Springs Formation and revealed authochthonous red shale and limestone of the Loves Creek Member of the Bitter Springs Formation below.

Detachment Fault at the front of Arltunga Nappe Complex

Detailed photo-interpretation of the Bitter Springs Formation has also led to the recognition of a major detachment surface or slide at the front of the Arltunga Nappe Complex. Such a fault was depicted by Forman (1971, Fig. 7d) in his cross-section showing the final stage in development of the Nappe complex, but its location was not known on the ground. The fault now recognised extends from Bitter Springs southeastwards past Ross River Chalet, where it disappears beneath the allochthonous sheet of Amadeus Basin sediments for 2 km; it reappears at the junction of the UNDOOLYA and FERGUSSON RANGE map sheets, then splits into two subparallel

faults about 1 km apart extending east from Ross River Chalet for 9 km. The two faults turn sharply south in the area between the Giles Creek Synform and the White Range Nappe, coalesce into one fault 3.5 km west of Tommys Gap; this single fault strikes east-southeast for a further 12 km parallel to and about 1 km south of the Heavitree Quartzite along the southern edge of the Giles Creek Synform. The fault cannot be traced on the airphotos any farther to the east because the Bitter Springs Formation has been deeply weathered in this area, and as a result details of its stratigraphy and structure are no longer visible on the colour airphotos. The slide is shown on the 1:500 000 'Generalised Geological and Tectonic Map' of FERGUSSON RANGE at the base of the 'Allochthonous Bitter Springs Formation of the Arltunga Nappe Complex'.

Autochthonous Bitter Springs Formation between Arltunga Nappe Complex and Amadeus Basin Nappes

The area of highly contorted Bitter Springs Formation (Gillen Member, Bug_5) between the slide at the base of the allochthonous Amadeus Basin sediments and the slide at the base of the Arltunga Nappe Complex is regarded as autochthonous. In the area immediately northeast of Box Hole Bore, the outcrop of autochthonous Gillen Member (Bug) broadens considerably, and it is here, and only here, that photo-unit Bug_6 has been recognised.

Injected Tongues of Bitter Springs Formation

Several dyke-like tongues of Bitter Springs Formation have been photo-interpreted to cut at a high angle across the strike of adjoining sediments. The largest and best known occurrence was mapped by Wells & others (1967, Fig. 12), and is situated 4 km east of Allua Well, in FERGUSSON RANGE. A second occurrence is located 4 km east of Colleen Dam, in UNDOOLYA. Two further, and smaller occurrences have been found by photointerpretation; these are located 2 km west and 3 km southeast (respectively) of Tommys Gap, in FERGUSSON RANGE.

G: GLOSSARY OF GEOLOGICAL TERMS

Amphibolite (a) is used for rocks that consist essentially of hornblende and plagioclase. Hornblende contents vary between 30 and 80 percent. Quartz is less than 10 percent. The term has been extended to cover rocks containing actinolite instead of hornblende, in cases where relict hornblende is also present.

Anthophyllite or cummingtonite-bearing rock (ae) is used for magnesian, quartz-undersaturated rocks, which contain a high proportion of anthophyllite, cummingtonite, gedrite, or similar minerals such as grunerite.

Biotite gneiss (b) is a very general field term used for gneisses containing quartz, feldspar, and 10 percent or more of biotite. Many of these gneisses are of granodiorite composition, but some of the gneisses, particularly the more biotite-rich varieties, are considered to be pelitic metasediments. Biotite gneiss includes "banded gneiss" where layers of different composition or texture alternate. Rocks have been photo-interpreted to be biotite gneiss (b) where they have a brown photo-colour as distinct from the pale brownish-yellow photo-colour, which is diagnostic of quartzofeldspathic gneiss. Photo-interpretation does not give a precise indication of colour index and photo-interpreted quartzofeldspathic gneiss will be found in some cases to have a colour index in the range 10 to 15.

Carbonatite (ca) is used for a carbonate rock of apparent magmatic origin having a high content of Ba, Sr and rare-earth elements (Gary & others, 1973).

Calc-silicate rocks (cs) is a gneiss or granofels consisting of calcium-bearing silicates such as diopside, plagioclase, epidote, grossularite, formed by metamorphism of an impure marble or calcareous metasediment (Gary & others, 1973).

Coarse-grained refers to grain sizes in the range 5-30 mm.

Cordierite gneiss and sillimanite-cordierite gneiss (i) are used in this report for granular rocks containing cordierite, or cordierite and sillimanite. Other minerals present commonly include antiperthitic plagioclase, quartz, and biotite.

Cordierite-felsic granulite (if) is used in this report for rocks similar to the cordierite gneiss defined above, but containing small amounts of hypersthene, and more feldspar and quartz than cordierites. They commonly have a colour index of 10 to 20, but include rocks with a colour index of less than 50.

Cordierite granulite and cordierite quartzite (in) are used in this report for cordierite-rich granular rocks which also contain subordinate quartz and K-feldspar (mainly microperthite). Garnet, hypersthene, and biotite are minor minerals that together rarely exceed 20 percent of the total rock. This rock type grades into quartzite.

Deformed rock (d) is a very general field term used for a variety of deformed rocks such as mylonite, cataclastic rock, and highly foliated gneiss and schist. These rocks commonly occur close together and are not easily separated in mapping.

Dolerite (dl) is the medium-grained equivalent of gabbro. It usually has an ophitic texture and is used in the same sense as 'diabase' is commonly used in North America (Joplin, 1968).

Dolomite (dm) is a carbonate sedimentary rock consisting mainly of the mineral dolomite (i.e. more than 50 percent by weight) (Gary & others, 1973).

Diorite (dr) is a medium- to coarse-grained igneous rock typically containing oligoclase or andesine. Hornblende and/or biotite are the chief mafic minerals. Such rocks are usually associated with granodiorite, tonalites and quartz diorites, or form small discrete masses (Streckeisen, 1967, 1973).

Dunite (u) is a peridotite in which the mafic mineral is almost entirely olivine (Gary & others, 1973). Accessory chromite is not present in the Sheet area as is commonly the case.

Epidote rock or Epidosite (e) is used for rocks rich in epidote. These typically consist of epidote, quartz, and, in some cases, chlorite. Generally, these rocks have been produced by retrograde metamorphism (Gary & others, 1973).

(f) - see Quartzofeldspathic gneiss

Felsic granulite (fn) is a field term used for hypersthene-bearing rocks which have a colour index of less than 50. "Felsic" is used as the opposite of "mafic" for probably meta-igneous rocks having mainly light-coloured minerals in the mode (Gary & others, 1973). Most of the felsic granulite in the Sheet areas are acid in composition, but a few are intermediate and some rare examples are pelitic. A large number of these felsic granulites are thought to be meta-acid volcanics.

Granite (g) is used for rocks of both granite and adamellite composition, having a mafic content of about 10 percent, and a hypidomorphic texture. Potash feldspar forms more than 40 percent of the total feldspar; the remaining feldspar is a sodic plagioclase, commonly oligoclase. Other minerals include biotite, muscovite, and hornblende. Some metamorphically retrogressed equivalents are included in the same category.

Fine-grained refers to a grain size less than 1 mm, but resolvable.

Gabbro (gb) is a coarse-grained rock in which alkali feldspar is less than 10 percent of the total feldspar; plagioclase is generally An_{50} or greater; and the colour index is generally greater than 30. - Gabbro contains more clinopyroxene than either the pyroxene or olivine, and quartz is less than 10 percent (Streckeisen, 1967, 1973). As mapped, gabbro includes partly altered or metamorphically retrogressed varieties where relict igneous textures dominate the rock.

Granitic gneiss (gg) is a field term used in the report for macroscopically heterogeneous gneiss of broadly granitic mineralogy. The rock is commonly texturally or compositionally layered on a small-scale.

Granitoid (gt) is used in the report for macroscopic bodies of granite composition, but allotriomorphic texture (Gary & others, 1973). The term includes rocks which grade into migmatite.

Granofels is a term for all metamorphic rocks that have a granular texture, but do not necessarily belong to the granulite facies (Goldsmith, 1959). In the report the use of 'granofels' is generally restricted to rocks of lower metamorphic grade than granulite except for the special case of the Utnalanama granulite, which is partly retrogressed from the granulite facies.

Granulite (fn, mn, if, in) is a field term used for hypersthene-bearing metamorphic rocks (White in Mehnert & others, 1972). The granulites may or may not contain hornblende. In the Sheet areas, the rocks are invariably granular, commonly a granuloblastic variety, but include rare foliated and lineated varieties.

Granoblastic is a texture (microstructure) consisting of a mosaic of anhedral grains (Collerson, 1974).

Granuloblastic is a texture (microstructure) characterised by grains having smooth boundaries and forming polygonal grains. It is a special case of a granoblastic texture (Spry, 1969 p. 159; Binns, 1964).

Gneiss is a medium- to coarse-grained, irregularly layered (banded) and foliated rock in which the schistosity is commonly poorly defined because of the preponderance of quartz and feldspar over micaceous minerals. (cf. Joplin, 1968).

Hornblende gneiss (h) is a field term used in the report for rocks containing hornblende in addition to biotite, quartz, and feldspar. Such gneisses are commonly of intermediate composition. Quartz contents commonly vary between 15 and 50 percent. Plagioclase is generally much more abundant than potash feldspar.

(i) (if) & (in) see cordierite gneiss, cordierite-felsic granulite, and cordierite granulite respectively.

(j) See quartzofeldspathic gneiss - (ii) layered quartz-rich variety.

Marble (ma) is a metamorphic rock composed mainly of calcite. In the Sheet areas dolomite is generally rare or absent. Minor minerals present include diopside and grossularite.

Mafic granulite (mn) is a nongenetic field term used for hypersthene-bearing metamorphic rocks in which the colour index exceeds 50. In the Sheet areas most of the mafic granulite are basic rocks of tholeiitic composition having a granuloblastic texture. Such mafic granulites characteristically consist of hypersthene, diopside and plagioclase with small amounts of hornblende and quartz. A small proportion of mafic granulites consist of the assemblage: hypersthene-quartz-plagioclase (An_{50}) and have pelitic or intermediate-igneous compositions.

Medium-grained refers to grain sizes between 1 and 5 mm.

Migmatite (mi) is a composite rock composed of igneous or igneous looking and metamorphics materials, which are generally distinguishable megascopically (Dietrich, 1960 p. 50; Gary & others, 1973).

(mv) is the symbol used for garnetiferous mafic granulite.

Monzonite (mz) is a general term used for rocks containing 33-65 percent orthoclase or microcline, and an equal or lesser amount of plagioclase, plus 10 to 40 percent mafic minerals. Quartz is less than 10 percent and, in the Sheet areas, is commonly absent, (Moorhouse, 1959).

Mylonite (m) is used in the sense of Lapworth (1885) for a fine-grained layered rock but without the genetic coonotation that mylonites are a product of brittle deformation (Bell & Etheridge, 1973).

Orthogneiss (o) is used in the Sheet areas for macroscopically homogeneous gneiss having granite, adamellite or granodiorite composition. Feldspar megacrysts and xenoliths are abundant in many cases. The orthogneiss is commonly foliated.

Peridotite (u) is an igneous ultrabasic rock containing between 30 and 90 percent olivine, no quartz, and only very minor feldspar (Streckeisen, 1967, 1973). Mafic minerals such as pyroxene, amphibole and mica are possibly also present.

Porphyroblastic-feldspar gneiss (p) is used in the Sheet areas for quartzofeldspathic gneiss, biotite gneiss, or biotite schist containing megacrysts of feldspar, regardless of the origin of the feldspar. Augen gneiss is included in this rock type.

Mafic calc-silicate (pa) is used in the Sheet areas for calc-silicate rocks having a relatively high colour index (e.g. 20 or more); and for uncommon amphibolites which are layered, quartz-rich or have some other unusual feature.

Pegmatite (peg) is coarse-grained rock of generally granite composition that forms dykes, lenses, or veins (Gary & others, 1973).

Pyroxenite (u) is an ultramafic igneous rock containing up to 30 percent olivine where greater than 50 percent of the remainder is pyroxene (Streckeisen, 1976).

Quartzofeldspathic gneiss is of two varieties, symbolised f and j.

(i) Type-f is a field term used for granular gneisses having a colour index of about 10 or less that form layers or lensic bodies. They have a distinctive brownish-yellow colour on coloured aerial photographs. The

principal minerals are quartz and feldspar (Turner, 1968). Such rocks may include metamorphosed acid volcanics, sandstone, arkose, siliceous tuff, and granite. These rocks are similar to leptite; a Fennoscandian term for meta-acid volcanics (Sedeholm, 1935). They are typically granitic, adamellitic, or granodioritic in composition. Many are thought to be metamorphosed acid volcanics, but such an origin is difficult to prove.

(ii) Type-j is reserved for layered, quartz-rich varieties (50% or more quartz) which include rocks having possibly metasedimentary features such as laminae or rounded zircon grains, as well as rocks of uncertain origin.

Quartz-magnetite and hematite quartz rock (qf) are used for layers and lenses of quartzite containing either magnetite or hematite. These rocks commonly occur alongside magnesian rocks containing minerals such as cummingtonite and anthophyllite. The magnetite-quartz rocks are thought to be derived from cherts and other iron-rich sediments.

Quartzite (qt) is composed essentially of recrystallised quartz. Sandstone and chert are possible parent rocks.

Retrogressed rock (r) is a field term for a wide variety of retrogressed rocks which have been remetamorphosed generally at the greenschist facies. It is a convenient way of grouping together rocks of very variable texture and degrees of retrogression. Common retrograde minerals include sericite, epidote, albite, chlorite, and actinolite. A number of more specific symbols are used where large bodies have similar composition and textures (e.g. the various schists - see below).

Schist (s, sb, sc, sf) is a cleaved or schistose rock in which the individual grains are visible to the naked eye. The schistosity is caused by the preferred orientation of flaky or prismatic minerals. The schistosity is penetrative (Turner & Weiss, 1963).

The symbol s is used for schist and schistose gneiss containing both muscovite and biotite whereas the symbol sb is used for biotite schist or schistose gneiss, and sc is used for the retrogressed equivalents of amphibolite which commonly contain actinolite, tremolite, or chlorite. The symbol, sf, is used for highly schistose quartzofeldspathic rocks.

Sa is a symbol used for sapphirine-spinel-phlogopite-bearing rocks. In most cases the size of the outcrops have been artificially enlarged in order to show them on the map.

Shonkonite (sh) is a dark-coloured syenite composed mainly of clinopyroxene and orthoclase, and possibly, but not necessarily, containing olivine, hornblende, biotite and nepheline (Gary & others, 1973). Dark minerals commonly exceed 50 percent (Moorhouse, 1959).

Syenite (sy) is an igneous rock containing alkali feldspar (commonly orthoclase, microcline, or perthite), a small amount of plagioclase (less than about 15 percent), one or more mafic minerals, and quartz, if present, only as an accessory (Gary & others, 1973).

Tectonic slide is a fault formed in close connection with folding, which is broadly conformable with a major geometric feature (either fold or axial-plane surface) of the structure, and which is accompanied by thinning and excision of members of the rock-succession affected by the folding (Fleuty, 1964). Slides are common in moderate to high-grade metamorphic terrains and are marked by the intense development of foliation rather than by a zone of extensive crushing brecciation.

Ultramafic rocks given the symbol u, include dunite, peridotite and pyroxenite defined earlier.

Un is the symbol used for meta-ultramafic rocks such as meta-anorthosite, meta-pyroxenite, meta-dunite and meta-anorthositic gabbro. All these rocks are not necessarily metamorphosed igneous rocks. Those of Johannsen's Phlogopite Mine, for example, are possibly metamorphosed calc-silicate-rocks or otherwise metamorphosed alteration products formed during volcanism or later hydrothermal processes.

V is the symbol used for biotite gneiss, previously defined, where it contains garnet. It is a useful field classification. In some of the adjacent Sheet areas the symbol vf is used for garnet-bearing quartzofeldspathic gneiss, but in the 1:100,000 map of the Strangways Range Region these rocks were generally incorporated in quartzofeldspathic gneiss (f).

W is a symbol used for schist or gneiss containing staurolite. (If staurolite-bearing rocks also contain kyanite, the symbol, y, is used).

Y is used for kyanite-bearing gneiss and schist.

Z is the symbol used for gneiss containing sillimanite with or without garnet. Many of these rocks contain abundant magnetite and have a strong response on airborne magnetic maps. The symbol, i, is used for rocks containing both cordierite and sillimanite.

Fig. G ROCK TYPE SYMBOLS FOR ARUNTA BLOCK 1:100 000 SCALE

Qa	Fine and coarse clay-quartzose sand, silt and minor gravel lacking a marked soil profile, alluvium
Ql	Calcrete
Qs,Qps	Aeolian quartzose sand (Qs); with fixed dunes (Qps)
Qc	Colluvium, eluvium, scree
Qr	Shallow red, clayey and sandy soil; clayey oxidised silty-sand
Czc	Fanglomerate
Ts	Silcrete
Tss	Undifferentiated slightly lithified clastics below silcrete
Tw	Greenish-grey siltstone and chalcedonic limestone
Th,Thg,Thu	Kaolinitic quartzose sandstone, siltstone and mudstone (Th), grading into coarse grained poorly sorted boulder conglomerate (Thg) and lignite (Thu) in subsurface
Tr	Arenaceous limestone, silicified limestone, pebbly sandstone
Tla	Undifferentiated deeply weathered rock (ferricrete, laterite, minor silcrete)
Tlf	Laterite profile with well developed ferruginous, mottled and leached zones grading down into unweathered rock

CAINOZOIC ROCK SYMBOLS APPLY TO SHEETS IN THE ALICE SPRINGS 1:250000 SHEET AREA

a	Amphibolite
ae	Anthophyllite or cummingtonite-bearing rock
apl	Aplite
av	Garnet amphibolite
b	Biotite gneiss C.I.>10
c	Conglomerate
ca	Carbonatite
cs	Calc-silicate rock
d	Undifferentiated deformed rocks eg. mylonite, cataclastic, highly foliated rock
dl	Dolerite
dm	Dolomite
dr	Diorite
e	Epidote rock, Epidosite
ev	Evaporites
f	Quartzofeldspathic gneiss, C.I.<10
fn	Felsic granulite, C.I.<50
g	Granite, adamellite, includes retrogressively metamorphosed equivalents
ga	Anorthositic gabbro
gb	Gabbro, partly metamorphosed gabbro
gd	Granodiorite, includes retrogressively metamorphosed granodiorite
gf	Granofels
gg	Granitic gneiss
gt	Granitoid
h	Hornblende gneiss
hf	Hornfels
i	Cordierite gneiss, sillimanite-cordierite gneiss
if	Cordierite-felsic granulite
in	Cordierite granulite, cordierite quartzite
iv	Cordierite-garnet rock
j	Quartz-rich metasediments
k	Greywacke
l	Plagioclase-quartz rock
ls	Limestone
m	Mylonite
ma	Marble
mi	Migmatite
mn	Mafic granulite, C.I.>50
mt	Unclassified metamorphic rock
mv	Garnetiferous mafic granulite
mz	Monzonite
n	Norite, partly metamorphosed norite
o	Orthogneiss
p	Porphyroblastic-feldspar gneiss
pa	Mafic calc silicate rock, para-amphibolite, quartz-amphibolite, thinly layered amphibolite.
peg	Pegmatite
po	Porphyry
ps	Conglomeratic sandstone
q	Vein quartz
qf	Quartz magnetite rock, hematite-quartz rock
qt	Quartzite
r	Metamorphically retrogressed rock, generally greenschist facies
rh	Rhyolite
s	Muscovite-biotite schist or gneiss
sa	Sapphirine-spinel-phlogopite bearing rocks
sb	Biotite schist
sc	Chlorite schist, tremolite actinolite schist
sf	Felsic schist
sh	Shonkinite
sm	Muscovite schist, sericite schist
ss	Sandstone
sv	Garnet schist
sy	Syenite
t	Siltstone, shale, slate
to	Tonalite, includes retrogressively metamorphosed tonalite
th	Trondhjemite
tr	Tructolite
ts	Silty sandstone
u	Ultramafic rock, dunite, peridotite, pyroxenite
un	Meta-ultramafic rock
v	Garnet biotite gneiss
vf	Quartzofeldspathic garnet gneiss
vm	Garnet-muscovite gneiss
w	Staurolite schist
x	Andalusite gneiss or schist
y	Kyanite gneiss or schist
z	Sillimanite-bearing gneiss, garnet-sillimanite gneiss
α	Intermediate volcanics
β	Basic volcanics
γ	Acid volcanics

BIBLIOGRAPHY

ADAMS, C.F., 1967 - Annual Report 1966-67. Mines Branch, Northern Territory Administration, Darwin.

ALLEN, A.R., 1979 - The metamorphic evolution of the Arunta Block in the Harry Creek area, southeastern Strangways Range, Northern Territory. Ph.D. thesis, University of Queensland (unpublished).

ALLEN, A.R., 1978 - Brittle Deformation in Granulite Facies Rocks 1. The Harry Creek Deformed Zone, Arunta Block, central Australia - a brittle shear zone. Geological Society of London, Tectonic Studies Group Annual Meeting, Liverpool, December 1978 - Abstract.

ALLEN, A.R., & STUBBS, D., in press - An ^{40}Ar - ^{39}Ar Investigation of a complex terrain in the Arunta Block, central Australia - Lithos.

ALLEN, A.R., 1979 - Metasomatism of a Depleted Granulite Facies Terrain in the Arunta Block, Central Australia. Contributions to Mineralogy and Petrology, 71, 85-98.

ALLEN, A.R., (in press) - The origin and mechanism of intrusion of the Gumtree Granite Suite, Arunta Block, Central Australia - a fault controlled granitic suite.

ALLEN, A.R., & BLACK, L.P., 1979 - Deformational history of the Harry Creek Deformed Zone, a retrograde schist zone in the Arunta Block, Central Australia. Journal of the Geological Society of Australia, 26, 17-28.

ANDREWS, E.C., 1937 - The structural history of Australia during the Palaeozoic. Journal of the Royal Society of New South Wales, 71, 118-187.

ANFILOFF, W., & SHAW, R.D., 1973 - The gravity effects of three large uplifted granulite blocks in separate Australian shield areas. Proceedings of Symposium on Earth's Gravitational Field and Secular Variations in Position. Sydney, 1973, 273-289.

ANFILOFF, W., 1976 - Arltunga Nappe detailed gravity survey, Northern Territory 1973. Bureau of Mineral Resources, Australia, Record 1975/178 (unpublished).

ANFILOFF, W., 1976 - Automatic density profiling across two-dimensional topography. BMR Journal of Australian Geology & Geophysics, 1, 57-61.

ANON, 1941 - Report for period ended 31st December 1940. Aerial Geological & Geophysical Survey of Northern Australia.

ANON, 1962 - Sedimentary basins and palaeontology sections summary of activities 1962. Bureau of Mineral Resources, Australia, Record 1962/175 (unpublished).

ANON, 1966 - Annual Summary of Activities, 1966, Common Services Section - Geological Branch. Bureau of Mineral Resources, Australia, Record 1966/195 (unpublished).

ANON, 1967a - Annual Summary of activities, geological branch, 1967. Bureau of Mineral Resources, Australia, Record 1967/134 (unpublsihed).

ANON, 1967b - Geophysical Branch summary of activities, 1967. Bureau of Mineral Resources, Australia, Record 1967/152 (unpublished).

ANON, 1970 - Annual Summary of Activities, Geological Branch 1970. Bureau of Mineral Resources, Australia, Record 1970/81 (unpublished).

ANON, 1971 - Geological Branch. Summary of activities 1971. Bureau of Mineral Resources, Australia, Record 1971/103 (unpublished).

ARMSTRONG, R.L. & STEWART, A.J., 1975 - Rubidium-strontium dates and extraneous argon in the Arltunga Nappe Complex, Northern Territory. Journal of the Geological Society of Australia 22, 103-15.

BAILEY, D.F. & MACDONALD, R. (Eds), 1976 - THE EVOLUTION OF THE CRYSTALLINE ROCKS. Academic Press, London.

BANKS, J.E., 1964 - Mineral reconnaissance in the Amadeus Basin, Northern Territory, Australia. Report for Magellan Petroleum Corporation (unpublished).

BARLOW, B.C., 1966 - Georgina Basin Reconnaissance Gravity Surveys using Helicopters, Northern Territory and Queensland 1960-1961. Bureau of Mineral Resources, Australia, Record 1966/147 (unpublished).

BARNES, G.W.A., 1978 - Phyllosilicate from the Mud Tank Carbonatite, Arunta Complex, Central Australia. Bureau of Mineral Resources, Australia. XRD Laboratory Report 78/1363 (unpublished).

BARRACLOUGH, D., 1976 - Interim report on the Mordor alkalic ring complex. Geological Survey of the Northern Territory, Record 6.5-75/26 (unpublished).

BEHY, H.J., DEN TEX, E., DE WAARD, D., MEHNERT, K.R., SCHARBERT, H.G., SOBOLEV, V., WATZNAUER, A., WINKLER, H.G.F., WYNNE-EDWARDS, H.R., ZOUBER, V., ZWART, H.J., 1971 - Granulites. Results of a discussion. Neues Jahrbuch fur Mineralogie, Monatshefte.

BELL, A.D.M., 1953 - The Pinnacles Copper area, Northern Territory. Bureau of Mineral Resources, Australia, Record 1953/17 (unpublished).

BELL, T.H., & ETHERIDGE, M.A., 1973 - Microstructure of mylonites and their descriptive terminology. Lithos, 6, 337-48.

BHANDARI, N., BHAT, S.G., LAL, D., RAJOGOPALAN, G., TAMHANE, A.S., & VENKATAVARADAN, V.S. - Fission fragment tracks in apatite: Recordable track lengths. Earth & Planetary Science Letters 13, 191-9.

BERTHELSEN, A., 1960 - Structural studies in the Precambrian in Western Greenland. Geologiske Undersøgelse-Grønlands, Bulletin 25.

BLACK, L.P., & GULSON, B.L., 1978 - The age of the Mud Tank Carbonatite, Strangways Range, Northern Territory. BMR Journal of Australian Geology & Geophysics 3(3), 227-232.

BLACK, L.P., 1975 - Present status of geochronological research in the Arunta Block. In PROTEROZOIC GEOLOGY 1st Australian Geological Convention, Adelaide, South Australia, May, 1975. Geological Society of Australia. Abstracts.

BLACK, L.P., 1977 - A Rb-Sr geochronological study in the Proterozoic Tennant Creek Block, Central Australia. BMR Journal of Australian Geology & Geophysics, 2, 111-122.

BINNS, R.A., 1964 - Zones of progressive regional metamorphism in the Willyama Complex, Broken Hill district, N.S.W. Journal Geological Society of Australia, 11, 283-330.

BINNS, R.A., 1969 - Hydrothermal investigation of the amphibolite-granulite facies boundary. Special Publication of the Geological Society of Australia, 2, 341-344.

BOWMAN, H.E., 1963a - Seismic survey report on the Todd River area, Northern Territory, Australia. Report for Flamingo Petroleum, by Namco International Incorporated (unpublished).

BOWMAN, H.E., 1963b - Supplemental seismic survey report on the Area 'C', Alice Springs, Northern Territory, Australia. Report for Exoil by Namco International Incorporated (unpublished).

BROKEN HILL PTY CO. LTD 1977 - Exploration licences 1341 and 1342 Strangways Range and "Hale River" Arunta Complex, NT, Final Report. Broken Hill Pty. Co. Ltd Aust. Exploration Dept. Open File Rep. Mines Branch Darwin.

BROWN, H.Y.L., 1889 - Government Geologist's report on a journey from Adelaide to the Hale River. South Australian Parliamentary Paper, 24.

BROWN, H.Y.L., 1891 - Reports on coal-bearing areas in the neighbourhood of Leigh Creek. South Australian Parliamentary Paper, 158.

BROWN, H.Y.L., 1892 - Further geological examination of the Leigh Creek and Hergott Districts. South Australian Parliamentary Paper

BROWN, H.Y.L., 1895 - Government Geologist's report on exploration in the Northern Territory. South Australian Parliamentary Paper, 82.

BROWN, H.Y.L., 1896 - Reports on Arltunga Gold Field, etc. South Australian Parliamentary Paper, 127.

BROWN, H.Y.L., 1902 - Report on the White Range goldmines, Arltunga Goldfield. South Australian Parliamentary Paper, 76.

BROWN, H.Y.L., 1903 - Report on the gold discoveries near Winnecke's Depot, etc. South Australian Parliamentary Paper, 59.

BROWN, B.D., 1973 - Final Report Exploration Licence No. 805 - Harry Creek. Kewanee Australia Pty Ltd Open File Report. Mines Branch, Darwin, Northern Territory.

BROWNE, W.R., 1950 - Metallogenic epochs and ore regions in the Commonwealth of Australia. Journal of Royal Society of New South Wales, 83, 96-115.

BROWNE, W.R., - Petrological report on rock specimens from Central Australia. Unpublished consultants report, Technical Files, Bureau of Mineral Resources, Australia.

BRUNNSCHWELLER, R.O., 1961 - Later Proterozoic (Assyntian)-mountain building in Australia. Eclogae Geologicae Helvetiae, 54, 335-349

BUDDINGTON, A.F., 1939 - Adirondack igneous rocks and their metamorphism. Geological Society of America, Memoir 7.

BUREK, P.J., WALTER, M.R., & WELLS, A.T., 1979 - Magnetostratigraphic tests of lithostratigraphic correlations between latest Proterozoic sequences in the Ngalia, Georgina and Amadeus Basins, Central Australia. BMR Journal of Australian Geology & Geophysics 4, 47-55

CHAPPELL, B.W., & WHITE, A.J.R., 1974 - Two contrasting granite types. Pacific Geology, 8, 173-174.

CHATTERJEE, N.D., & JOHANNES, W. 1974 - Thermal stability and standard thermodynamic properties of synthetic $2M_1$ - muscovite $KAl_2(AlSi_3O_{10}(OH)_2)$. Contributions to Mineralogy and Petrology, 48, 89-114

CHEWINGS, C., 1891 - Geological notes on the Upper Finke basin. Transactions of the Royal Society of South Australia, 14, 247-255.

CHEWINGS, C., 1894 - Notes on the sedimentary rocks of the MacDonnell and James Ranges. Transactions of the Royal Society of South Australia, 18.

CHEWINGS, C., 1914 - Notes on the stratigraphy of Central Australia. Transactions of the Royal Society of South Australia, 38, 41-52.

CHEWINGS, C., 1928 - Further notes on the stratigraphy of Central Australia. Transactions of the Royal Society of South Australia, 52, 62-81.

CHEWINGS, C., 1931 - A delineation of the Precambrian plateau in central and north Australia, with notes on the impingent sedimentary formations. Transactions of the Royal Society of South Australia, 55, 1-11.

CHEWINGS, C., 1935 - The Pertatataka Series in central Australia, with notes on the Amadeus Sunkland. Transactions of the Royal Society of South Australia, 59, 141-163.

CLARKE, D.B., 1975 - The Hale River Basin; Alice Springs 1:250 000 Sheet area SF 53-14, N.T. Report No. 1 Preliminary Review. Northern Territory Geological Survey Report G.S. 75/13.

COLLERSON, K.D., 1974 - Descriptive microstructural terminology for high-grade metamorphic tectonites. Geological Magazine 111, (4), 313-318.

COMPSTON, W., & ARRIENS, P.A., 1968 - The Precambrian geochronology of Australia. Canadian Journal of Earth Sciences, 5, 561-583.

CONDIE, K.C., MACKE, J.E., & REIMBER, T.D., 1970 - Petrology and geochemistry of Early Precambrian greywackes from the Fig Tree Group, South Africa. Geological Society of America Bulletin, 81, 2759-2776.

CONDON, M.A., 1958 - Geological notes, inspection trip, 1958. Bureau of Mineral Resources, Australia, Record 1958/106 (unpublished).

CONDON, M.A., 1962 - Notes on field trip, 1962. Bureau of Mineral Resources, Australia, Record 1962/173 (unpublished).

COOK, P.J., 1971 - Illamurta diapiric complex and its position on an important central Australian structural zone. American Association of Petroleum Geologists Bulletin, 55, 64-79.

COOPER, J.A., WELLS, A.T., & NICHOLAS, T., 1971 - Dating of glauconite from the Ngalia Basin, Northern Territory, Australia. Journal of Geological Society of Australia, 18 (2), 97-106.

COTTERILL, P., & MOULD, P.P., 1976 - RECRYSTALLISATION AND GRAIN GROWTH IN METALS. Surrey University Press, London.

CRESPIN, I., 1948 - Micropalaeontological examination of specimen from Bond Springs Station, about 16 miles west of 16-mile Government bore, Alice Springs, Northern Territory. Bureau of Mineral Resources, Australia, Record, 1948/63 (unpublished).

CRESPIN, I., 1949 - Micropalaeontological examination of samples from bores at Bond Springs, west of Alice Springs, Northern Territory. Bureau of Mineral Resources, Australia, Record 1949/62 (unpublished).

CRESPIN, I., 1950 - Report on Micropalaeontological examination of samples from the 16 Mile Government Bore, west of Alice Springs, Northern Territory. Bureau of Mineral Resources, Australia, Record 1950/48 (unpublished).

CROHN, P.W., 1962(a) - Annual report 1960 - 1961. Resident Geological Section, Northern Territory. Bureau of Mineral Resources, Australia, Record 1962/10 (unpublished).

CROHN, P.W., 1962(b) - Annual report: July 1st 1961 - June 30th 1962. Resident Geological Section, Northern Territory. Bureau of Mineral Resources, Australia, Record 1962/156 (unpublished).

CROHN, P.W., 1963 - Annual Report Resident Geological Section, Northern Territory. July 1, 1962 - June 30, 1963. Bureau of Mineral Resources, Australia Record 1963/168 (unpublished).

CROHN, P.W., 1971 - Investigations at the Strangways Range Carbonatite Locality, Northern Territory, 1969 - 1970. Northern Territory Geological Survey, Record 6.5, 1971/1 (unpublished).

CROHN, P.W., & GELLATLY, D.C., 1968 - Probable carbonatites in the Strangways Range area, central Australia, Bureau of Mineral Resources Australia, Record 1968/114 (unpublished).

CROHN, P.W., & GELLATLY, D.C., 1969 - Probable carbonatites in the Strangways Range area, central Australia. Australian Journal of Science, 31, 335-6.

DALWITZ, W.B., 1966 - Notes on specimens from a drill hole at Harry's Creek Strangways Range, Northern Territory Mineral Occurrence File, Resident Geologist's Office, Mines Branch, Alice Springs, Northern Territory (unpublished).

DALY, J., 1951 - Report on radiometric investigations at the Queen Mine, Harts Range, N.T., Bureau of Mineral Resources, Australia, Record 1951/27 (unpublished).

DALY, J., & DYSON, D.F., 1956 - Geophysical investigations for radioactivity in the Harts Range area, Northern Territory, Bureau of Mineral Resources, Australia, Report 32

DAVIDSON, A.A., 1900 (?) - Report on the White Range properties, Arltunga Goldfield by the Central Australian Exploration Syndicate, Limited. (unpublished).

DAWSON, J.B., 1966 - Oldoinyo Lengai - an active volcano with sodium carbonatite lava flows. In TUTTLE, O.F., & GITTINS, J. (Eds.), CARBONATITES, Interscience, New York. 155-168.

DAY, T.E., 1916 - Report and plans of exploration in central Australia. Bulletin of Northern Territory of Australia, 20.

DE WAARD, DIRK, 1965 - A proposed subdivision of the Granulite Facies. American Journal of Science, 263, 455-461.

DIETRICH, R.V., 1960 - Nomenclature of migmatitic and associated rocks. Geotimes, Jan-Feb., 4(5), 1960.

DODSON, R.G., 1968 - Resident Geologists - Northern Territory, Annual summary of activities. January 1st 1967 - December 31st 1967. Bureau of Mineral Resources, Australia Record 1968/27 (unpublished).

DOUGAN, T.W., 1976 - Origin of trondhjemitic biotite-quartz-oligoclase gneisses from the Venezuelan Shield. Precambrian Research, 3, 317-342.

DOUTCH, H.F., 1968 - The Ninth International Congress of Soil Science, Adelaide, August 1968. Bureau of Mineral Resources, Australia, Record 1968/108 (unpublished).

DUFF, B.A., 1973 - The structural geology of the Arltunga region, central Australia. Bureau of Mineral Resources, Australia, Record 1973/10 (unpublished).

DUFF, B.A., & DANGWORTHY, A.P., 1974 - Orogenic zones in central Australia: intraplate tectonics? Nature, 249, 645-647.

DUNN, J.A., 1947 - Possibilities of developing the Harts Range mica belt. Bureau of Mineral Resources, Australia, Record 1947/89 (unpublished).

DYSON, D.F. & WIEBENGA, W.A., 1957 - Final report on geophysical investigations of underground water, Alice Springs, Northern Territory, 1956. Bureau of Mineral Resources, Australia, Record 1957/89 (unpublished).

EAST, J.J., 1889 - Geological structure and physical features of central Australia. Transactions of the Royal Society of South Australia, 12, 31-53.

ELLIS, H.A., 1937 - Report on some observations made on a journey from Alice Springs, Northern Territory to the country north of the Rawlinson Ranges in Western Australia, etc. Geological Survey of Western Australia, Annual Report, 1936.

ESCHER, A., JACK, S., & WATTERSON, J., 1976 - Tectonics of North Atlantic Proterozoic Dyke Swarms. Philosophical Transactions of the Royal Society of London, A280, 529-539.

ESKOLA, P., 1952 - On the granulites of Lapland. American Journal of Science, Bowen Volume, p. 113.

ETHERIDGE, R., 1892 - On a species of Asaphus from the lower Silurian rocks of central Australia. South Australian Parliamentary Paper 23.

ETHERIDGE, R., 1893 - On additional Silurian and Mesozoic fossils from the lower Silurian rocks of central Australia. South Australian Parliamentary Paper 23.

ETHERIDGE, R., 1893 - On additional Silurian and Mesozoic fossils from Central Australia, South Australian Parliamentary Paper 52.

EVANS, C.R., & LAMBERT, R., ST. J., 1974 - The Geology of the Lockinver District Southerland, the type area of the Inverian metamorphism. Journal of the Geological Society of London, 130, 125-150.

FANDER, H.W., 1971 - Petrographic description of hand-specimens. Job. No. CMS 71/4/42 by Central Mineralogical Services Pty Ltd for Rusgar Minerals NL. (unpublished).

FEHR, A., 1966 - Petrological study of Cambrian sediments in Alice No. 1 well, Amadeus Basin, Northern Territory. Bureau of Mineral Resources, Australia, Record 1966/5 (unpublished).

FLEUTY, M.J., 1964 - Tectonic Slides. Geological Magazine, 101, 452-456.

FORMAN, D.J., 1965 - The geology of the south-western margin of the Amadeus Basin, central Australia. Bureau of Mineral Resources, Australia, Report 87.

FORMAN, D.J., 1968 - Palaeotectonics of Precambrian and Palaeozoic rocks of central Australia. Ph.D. Thesis, Harvard University (unpublished).

FORMAN, D.J., 1971 - The Arltunga Nappe Complex, MacDonnell Ranges, Northern Territory, Australia. Journal of the Geological Society of Australia, 18 (2) 173-82.

FORMAN, D.J., MILLIGAN, E.N. & McCARTHY, W.R., 1967 - Regional geology and structure of the north-eastern margin of the Amadeus Basin, Northern Territory. Bureau of Mineral Resources, Australia, Report 103.

FORMAN, D.J., & SHAW, R.D., 1973 - Deformation of crust and mantle in central Australia. Bureau of Mineral Resources, Australia, Bulletin 144.

FRUZZETTI, O., 1969a - Geological notes on Harry Creek Copper Prospect, Strangways Range, Northern Territory, Report Resident Geologists Office for Mines Branch, Northern Territory Administration, Alice Springs (unpublished).

FRUZZETTI, O., 1969b - Geological notes on Coles Hill Copper Prospect, Strangways Range, Northern Territory, Report Resident Geologists Office for Mines Branch, Northern Territory, Administration, Alice Springs (unpublished).

GALLOWAY, R.W., & KEMP, E.M., 1977 - Late Cainozoic Environments in Australia. Bureau of Mineral Resources, Australia, Record 1977/40 (unpublished).

GARRELS & McKENZIE (1971) in COOPER, N.J., & WILKINSON, P., 1975 - The Moine Thrust and Moine Nappe at Loch Eriboll, Sutherland. Scottish Journal of Geology, 11(4) 339-359

GARY, M., McAFEE, Jr. R., & WOLF, C.L. (eds) 1972 - GLOSSARY OF GEOLOGY. American Geological Institute, Washington.

GELLATLY, D.C., 1969 - Probable carbonatites in the Strangways Range area, Alice Springs 1:250 000 Sheet area, SF 53/14: Petrography and Geochemistry. Bureau of Mineral Resources, Australia, Record 1969/77 (unpublished).

GELLATLY, D.C., 1972 - The petrology of the Strangways Range carbonatite. Geological Society of Australia, Specialists Group meetings, Canberra, Feb. 1972, Abstracts J 10.

GEOLOGICAL SOCIETY OF AUSTRALIA, 1971 - Tectonic map of Australia and New Guinea, 1:5 000 000, Geological Society of Australia, Sydney.

GEPP, H., 1937 - Report on 1937 visit of inspection to the areas being surveyed in North Australia by the Aerial Geological and Geophysical Survey of North Australia. Report Aerial Geological & Geophysical Survey of Northern Australia.

GIBB, R.A., & THOMAS, M.D., 1976 - Gravity signature of fossil plate boundaries in the Canadian Shield. Nature, 262 (5565) 199-200.

GILES, E., 1889 - AUSTRALIA TWICE TRAVERSED, Sampson Low, London, 2 vols.

GOLDSMITH, R., 1959 - Granofels, a new metamorphic rock name. Journal of Geology, 67, (1), 109-110.

GOODE, A.D.T., & MOORE, A.C., 1975 - High pressure crystallisation of the Ewarera, Kalba and Gosse Pile intrusions, Giles Complex, Central Australia. Contributions to Mineralogy and Petrology 51, 77-97.

GOODEVE, P.E., 1961 - Rawlinson Range - Young Ra[illegible] magnetic survey reconnaissance, W.A., 1960. Bureau of Mineral Resources, Australia, Record 1961/137 (unpublished).

GRAF, D.L., 1960 - Geochemistry of carbonate sediments and sedimentary carbonate rocks. I-IV Illinois State Geological Survey Circular, 297, 298.

GRAINGER, D.J., 1968 - Notes for tour 11. Ninth International Congress of Soil Science, Adelaide, August, 1968.

GREAVES, G.J.G., & BAKER, S., (compilers) 1962 - Records of the Geological Branch Laboratory, July-December 1961. Bureau of Mineral Resources, Australia, Record 1962/41 (unpublished).

GREEN, D.H., & VERNON, R.H., 1974 - Cordierite Breakdown under High-Pressure, Hydrous conditions. Contributions to Mineralogy and Petrology, 46, 215-26.

GREEN, D.H., & RINGWOOD, A.E., 1967a - The Genesis of Basaltic Magmas. Contributions to Mineralogy and Petrology, 15, 104-190.

GREEN, D.H., & RINGWOOD, A.E., 1967b - An experimental investigation of the gabbro to eclogite transformation and its petrological implications. Geochemica et Cosmochimica Acta, 31, 707-833.

GULSON, B.L., 1972 - The high-K diorites and associated rocks of the Yeoval Diorite Complex, N.S.W. Contributions to Mineralogy and Petrology, 35, 173-192.

HAIGH, J.E., 1971 - Strangways Range geophysical survey, Northern Territory. Bureau of Mineral Resources, Australia, Record 1971/18 (unpublished).

HALDANE, A.D., 1964a - Spectrochemical analysis of samples from the Hale River Field Party. Bureau of Mineral Resources, Australia, Laboratory Report (unpublished).

HARLTON, B.H., 1964 - Tectonic framework of Eola and Southeast Hoover Field and West Timbered Hills area etc. American Association of Petroleum Geologists Bulletin, 48, 1555-1567.

HASKIN, L., & GEHL, Mary A., 1962 - The rare-earth distribution in sediments. Journal of Geophysical Research, 67, 2537-2541.

HAYS, J., 1967 - Landsurfaces and laterites in the north of the Northern Territory. In JENNINGS, J.N., and MABBUTT, J.A., (eds) LANDFORM STUDIES FROM AUSTRALIA AND NEW GUINEA. 144-81. Australian National University Press, Canberra.

HEINRICH, E.W., 1966 - THE GEOLOGY OF CARBONATITES, Rand McNally, Chicago.

HENSEN, B.J., & GREEN, D.H., 1972 - Experimental study of the stability of cordierite and garnet in pelitic compositions at high pressures and temperatures II. Compositions without excess alumino-silicate. Contributions to Mineralogy and Petrology, 35, 331-354.

HENSEN, B.J., & GREEN, D.H., 1973 - Experimental study of the stability of cordierite and garnet in pelitic compositions of high pressures and temperatures III. Synthesis of experimental data and geological applications. Contributions to Mineralogy and Petrology, 38, 151-166.

HERD, R.K., 1972 - The petrology of the sapphirine-bearing and associated rocks of the Fiskenaesset complex, West Greenland. Ph.D. Thesis, University of London (unpublished).

HILLS, E.S., 1946 - Some aspects of the tectonics of Australia. Journal of the Royal Society of New South Wales, 79, 67-91.

HINE, R., WILLIAMS, I.S., CHAPPELL, B.W., & WHITE, A.J.R., in press - Geochemical contrasts between I- and S-type granitoids of the Kosciusko Batholith. Journal of the Geological Society of Australia.

HODGE-SMITH, T., 1932 - Geological and mineralogical observations in central Australia. Record of Australian Museum, 18, 415-442.

HOLDAWAY, M.J., & SANG MAN LEE, 1977 - Fe-Mg cordierite stability in High-Grade Pelitic Rocks based on experimental, theoretical and natural observations. Contributions to Mineralogy and Petrology, 63, 175-198.

HONJO, S., & TABUCHI, H., 1970 - Distribution of some minor elements in carbonate rocks, 1. Pacific Geology, 2, 41-79.

HOPKINS, R.M., 1962 - Stratigraphic measurements, Amadeus Basin, Report for Magellan Petroleum Corporation (unpublished).

HOPKINS, R.M., 1964 - Reconnaissance geology of part of the Phillipson Pound area. Report for Magellan Petroleum Corporation (unpublished).

HOSCHEK, G., 1969 - The stability of staurolite and chloritoid and their significance in metamorphism of pelitic rocks. Contributions to Mineralogy and Petrology, 27, 208-232.

HOSKING, A.J., 1972 - Authorities to Prospect 3427 and 3428 (Southern Cross 1 and 2 Prospects) ASARCO Australia Pty Ltd., Report. Open File Report, Mines Branch, Darwin, Northern Territory (unpublished).

HOSSFELD, P.S., 1936 - The Ciccone Mine, Winnecke Goldfield, eastern MacDonnell Ranges. Aerial Geological & Geophysical Survey of Northern Australia, Northern Territory, Report 22.

HOSSFELD, P.S., 1937a - The Glankroil Mine, Winnecke Goldfield, eastern MacDonnell Ranges district. Aerial Geological & Geophysical Survey of Northern Australia, Northern Territory, Report 39.

HOSSFELD, P.A., 1937b - The White Range Goldfield, eastern MacDonnell Ranges district. Aerial Geological & Geophysical Survey of Northern Australia, Northern Territory, Report 28.

HOSSFELD, P.S., 1937c - The Eastern portion of the Arltunga area, eastern MacDonnell Ranges district. Aerial Geological & Geophysical Survey of Northern Australia, Northern Territory, Report 20.

HOSSFELD, P.S., 1940 - The Winnecke Goldfield, eastern MacDonnell Ranges district. Aerial Geological & Geophysical Survey of North Australia, Northern Territory, Report 40.

HOSSFELD, P.S., 1941 - Limestone deposits near Alice Springs, Central Australia. Aerial Geological & Geophysical Survey of Northern Australia, Northern Territory, Report 49.

HOSSFELD, P.S., 1954 - Stratigraphy and structure of the Northern Territory of Australia. Transactions of the Royal Society of South Australia, 103-161.

HUDSON, D.R., & WILSON, A.F., 1966 - A new occurrence of sapphirine and related anthophyllite from central Australia. Geological Magazine, 103, 293-8.

HUGHES, C.J., 1972 - Spilites, keratophytes and the igneous spectrum. Geological Magazine, 109, (6), 513-527.

IDNURM, M., & SENIOR, B.R., 1978 - Palaeomagnetic ages of weathered profiles in the Eromanga Basin, Queensland. Palaeogeography, Palaeoclimatology, Palaeoecology, 24, 263-277.

IRVINE, T.W., & BARAGER, W.R.A., 1971 - A guide to the classification of common volcanic rocks. Canadian Journal of Earth Sciences, 8, 523-548.

IVANAC, J.F., 1971 - A.P. 2037 - Rankin's Prospect. Central Pacific N.L. report for March, 1971. Geological Survey of Northern Territory, Mines Branch, Open File CR74/63 (unpublsihed).

IYER, S.S., 1974 - Granulites and associated schists from northern Strangways Range central Australia: Geochemical and isotopic studies. Thesis, University of Queensland, (unpublished).

IYER, S.S., WOODFORD, P.J., & WILSON, A.F., 1976 - Rb-Sr isotopic studies of a polymetamorphic granulite terrain, Strangways Range, central Australia. Lithos, 9, 211-224.

JACCARD, J.P., 1961 - Geological reconnaissance in the Amadeus Basin. Report for Conorada Petroleum (unpublished).

JENNINGS, J.N. & MABBUTT, J.A., 1967 - (eds) LANDFORM STUDIES FROM AUSTRALIA AND NEW GUINEA. Australian National University Press, Canberra.

JENSEN, H.I., 1943a - Report dated 18 April 1943 (unpublished). Files, Resident Geologist's Office, Mines Branch, Department of Energy and Mines, Alice Springs, Northern Territory, Australia.

JENSEN, H.I., 1943b - Johannsen's Phlogopite Mine, Strangways Range. Bureau of Mineral Resources, Australia, Report. (unpublished).

JENSEN, H.I., 1955 - The geology of central Australia. Proceedings of the Royal Society of Queensland, 56, 85-94.

JENSEN, H.I., 1947 - The origin, distribution and mode of occurrence of mica in central Australia. Proceedings of the Royal Society of Queensland, 57, 37-52.

JEWELL, R., 1960 - Great Artesian Basin, aeromagnetic reconnaissance survey 1958. Bureau of Mineral Resources, Australia, Record 1960/14 (unpublished).

JOHANNSEN, A., 1938 - A DESCRIPTIVE PETROGRAPHY OF THE IGNEOUS ROCKS, VOL. IV. University of Chicago.

JOKLIK, G.F., 1953 - The Harts Range Mica Deposits. In GEOLOGY OF AUSTRALIAN ORE DEPOSITS (1st ed.) Fifth Empire Mining & Metallurgical Congress Melbourne, Volume 1, 336-43.

JOKLIK, G.F., 1955a - The geology and mica-fields of the Harts Range, central Australia. Bureau of Mineral Resources, Australia, Bulletin 26.

JOKLIK, G.F., 1955b - The mica-bearing pegmatites of the Harts Range, Central Australia. Economic Geology, 50 (b), 625-49.

JONES, B.G., 1972 - Upper Devonian to Lower Carboniferous Stratigraphy of the Pertnjara Group, Amadeus Basin, Central Australia. Journal of Geological Society of Australia, 19(2) 229-250.

JONES, N.O., 1957a - Preliminary report on the groundwater reserves of the Alice Springs area. Bureau of Mineral Resources, Australia, Record 1957/6 (unpublished).

JONES, N.O., 1957b - Initial geological report on the Wigleys Gorge dam site Northern Territory, Bureau of Mineral Resources, Australia, Record 1957/13 (unpublished).

JONES, N.O., 1957c - Report on the examination of beryl prospects, Harts Range, Northern Territory, Bureau of Mineral Resources, Australia, Record 1957/28 (unpublished).

JONES, N.O., 1959 - An outline of the water resources of central Australia. Bureau of Mineral Resources, Australia, Record 1959/77 (unpublished).

JONES, N.O., & QUINLAN, T., 1962 - An outline of the water resources of the Alice Springs area. In PERRY & others (1962), 150-162.

JOPLIN, G.A., 1968 - A PETROGRAPHY OF AUSTRALIAN METAMORPHIC ROCKS. Angus & Robertson, Sydney.

KALIX, A., FORMAN, D.J., & DERRICK, G.M., 1970 - Sillimanite and related minerals in Australia, Australian Mineral Industry Quarterly Review, 22 (3).

KALSBEEK, F., & LEAKE, B.E., 1970 - The chemistry and origin of some basement amphibolites between Ivigtut and Frederikshab, southwest Greenland. Grønsland Geologiske Undersogelse, Bulletin 90.

KEMP, E.M., 1976 - Early Tertiary pollen from Napperby, central Australia. BMR Journal of Australian Geology & Geophysics, 1, 109-14.

KING, L.C., 1950 - The cyclic land surfaces of Australia. Proceedings of the Royal Society of Victoria, 62, 79-95.

KINGDOM, E., 1977 - Construction materials in the southern Northern Territory - a preliminary compilation, March 1977. Northern Territory Geological Survey Report G.S. 77/15.

KINGDOM, E., WOOLLEY, D., & FAULKS, I., 1967 - Water Bore locations in Central Australia. Bureau of Mineral Resources Australia, Record 1967/83 (unpublished).

KIRSCHVINK, J.L., 1978a - The Precambrian - Cambrian boundary problem: magneto stratigraphy of the Amadeus Basin, Central Australia. Geological Magazine, 115, (2), 139-150.

KIRSCHVINK, J.L., 1978b - The Precambrian - Cambrian boundary problem: palaeomagnetic directions from the Amadeus Basin, Central Australia. Earth and Planetary Science Letters, 40, 91-100.

KLOOTWIJK, C.T., in press - Early Palaeozoic palaeomagnetism in Australia III: Middle to Early-Late Cambrian results from the Amadeus Basin, Northern Territory. Tectonophysics.

KOSTLIN, E.C., 1971 - A.' to P. 2373 - Georgina Range, NT. Memorandum to CRA Exploration Pty Ltd (unpublished).

KRONER, A., 1971 - The origin of the Southern Namagual and Gneiss Complex, South Africa in the light of geochemical data. Lithos, 4, 325-44.

KURYLOWICZ, L.E., OZIMIC, S., McKIRDY, D.T., KANTSLER, A.J., & COOK. A.C., 1976 - Reservoir and source rock potential of the Larapinta Group, Amadeus Basin, central Australia. The APEA Journal, 16 (1), 49-65.

LABONNE, B., (Compiler) 1972 - Miscellaneous chemical, petrographic and mineragraphic investigations carried out in the geological laboratory. Bureau of Mineral Resources, Australia, Record 1972/72 (unpublished).

LACROIX, A., 1941 - Les gisements de phlogopite de Madagascar et les pyroxenites qui les renferment. Annls. Geol. Serv. Mines Madagascar Fasc. II

LANGRON, W.J., 1962a - Amadeus Basin reconnaissance gravity using helicopters. Bureau of Mineral Resources, Australia, Record 1962/24 (unpublished).

LANGRON, W.J., 1962b - Amadeus Basin, gravity measurements along seismic traverses, Northern Territory, 1961. Bureau of Mineral Resources, Australia, Record 1962/169 (unpublished).

LANGRON, W.J., 1966 - Regional gravity traverses, northern Australia. Bureau of Mineral Resources, Australia, Record 1966/123 (unpublished).

LANGWORTHY, A.P., & BLACK, L.P., 1975 - Mordor Complex, a potassic, intermediate to ultrabasic intrusion with kimberlitic affinities, central Australia. In PROTEROZOIC GEOLOGY - Abstracts of First Australian Geological Convention, Adelaide 1975, Geological Society of Australia.

LANGWORTHY, A.P., & BLACK, L.P., 1978 - The Mordor Complex: a highly differentiated potassic intrusion with kimberlitic affinities in central Australia. Contributions to Mineralogy and Petrology, 67, 51-62.

LAPWORTH, C., 1885 - The Highland controversy in British geology. Nature 32, 558-559.

LEAKE, B.E., 1964 - The chemical distinction between ortho- and para-amphibolites. Journal of Petrology, 5 (2), 238-254.

LESLIE, W., 1964 - Geological report on the Amadeus Basin, Northern Territory Operational geology, French Petroleum Co. (Aust.) Pty Ltd., R.G. 305 (unpublished).

LESLIE, W., 1965 - The Upper Palaeozoic deposits of the Amadeus Basin. French Petroleum Company (Australia) Pty Ltd., R.G. 308 (unpublished).

LITCHFIELD, W.H., 1969 - Soil surfaces and sedimentary history near the MacDonnell Ranges, Northern Territory. C.S.I.R.O Soil Publication, 25.

LONSDALE, G.F., & FLAVELLE, A.J., 1973 - Amadeus and south Canning Basins reconnaissance gravity survey using helicopters, Northern Territory and Western Australia. Bureau of Mineral Resources, Australia, Record 1963/152 (unpublished).

LYONS, M., & CHARCHALIS, N., 1975 - Strangways Range, NT. Exploration Licences 57 and 58 Final Report. Planet Metals Ltd Report. Open File Report. Department of Mines and Energy, Northern Territory of Australia, (unpublished).

MABBUTT, J.A., 1967 - Denudation Chronology in Central Australia, Structure Climate and Landform Inheritance in the Alice Springs area; in LANDFORM STUDIES, Eds. J.N. JENNINGS & J.A. MABBUTT. Australian National University Press, Canberra.

MACGREGOR, J.R., 1973 - The Early Precambrian Gneiss of the Godthoab District, West Greenland. Philosphical Transactions of the Royal Society of London, A273, 343-358.

MACKENZIE, D.H., & GOW, N., 1975 - Relationship between ore, banded iron formation and Potosi gneiss at Broken Hill. In PROTEROZOIC GEOLOGY - Abstracts of First Australian Geological Convention, Adelaide, 1975. Geological Society of Australia. p. 51.

MADIGAN, C.T., 1932a - The geology of the western MacDonnell Ranges, Central Australia. Quarterly Journal of the Geological Society of London, 88(3), 672-711.

MADIGAN, C.T., 1932b - The geology of the Eastern MacDonnell Ranges. Transactions of the Royal Society of South Australia, 56, 71-117.

MADIGAN, C.T., 1933 - The geology of the MacDonnell Ranges and neighbourhood central Australia. Australian Association for the Advancement of Science - Report 21, 75-86.

MADIGAN, C.T., 1944 - CENTRAL AUSTRALIA, D.U.P. Melbourne.

MAJORIBANKS, R.W., 1975 - Structural and metamorphic geology of the Ormiston area. Bureau of Mineral Resources, Australia, Record 1975/13 (unpublished).

MARJORIBANKS, R.W., 1976 - The relation between microfabric and strain in a progressively deformed quartzite sequence from central Australia. Tectonophysics, 32, 269-293.

MARJORIBANKS, R.W., & BLACK, L.P., 1974 - Geology and geochronology of the Arunta Complex, north of Ormiston Gorge, central Australia. Journal of the Geological Society of Australia, 21, 291-300.

MARSHALL, C.E., & NARAIN, H., 1954 - Regional gravity investigations in the eastern and central Commonwealth. University of Sydney, Department of Geology and Geophysics, Memoir 1954/2.

MATHUR, S.P., 1974 - A proposal for deep seismic sounding and associated gravity survey in Central Australia. Bureau of Mineral Resources, Australia, Record 1974/69. (unpublished).

MATHUR, S.P., 1976 - Relation of Bouguer anomalies to crustal structure in south-western and central Australia. BMR Journal of Australian Geology & Geophysics, 1, 277-286.

MATTHEWS, W.H., 1905b - Report on the Arltunga and Winnecke's gold fields, and Harts Range mica-fields. South Australian Parliamentary Paper, 75.

MATTHEWS, W.H., 1905a - Report on the MacDonnell Ranges mining district. South Australian Parliamentary Paper 50.

MAWSON, D., & MADIGAN, C.T., 1930 - Pre-Ordovician rocks of the MacDonnell Ranges (Central Australia). Quarterly Journal of the Geological Society of London, 86, 415-429.

MICHOUD, P., EYSSAUTIER, M., & GATES, A., 1964 - Field report, Hale River. Report for Australian Aquitaine Petroleum, 10 (unpublished).

MIDDLETON, G.V., 1960 - Chemical composition of sandstones. Geological Society of America, Bulletin 71, 1011-1026.

MIRAMS, R.C., COATS, R.P., & DALGARNO, C.R., 1964 - Report on visit to Amadeus Basin, September, 1964. South Australian Department of Mines, Regional Mapping section, RB59/99, G.S. 2995 (unpublished).

MISCH, P., & ONYEAGOCHA, A.C., 1976 - Symplectite breakdown of Ca-rich almandines in upper amphibolite-facies Skagit Gneiss, North Cascades, Washington. Contribution to Mineralogy and Petrology, 54, 189-224.

MIYASHIRO, A., 1961 - Evolution of metamorphic belts. Journal of Petrology, 2, 277-311.

MIYASHIRO, A., 1974 - Volcanic rock series in island arcs and active continental margins. American Journal of Science, 274, 321-355.

MIYASHIRO, A., 1975 - METAMORPHISM AND METAMORPHIC BELTS. Allen & Unwin, London.

McCOLL, D.C., & WARREN, R.G., 1979 - The first discovery of ruby in Australia. Australian Mineralogist, 26, 121-125.

MOORE, A.C., 1971 - The mineralogy of the Gosse Pile ultramafic intrusion, Central Australia, II Pyroxenes. Journal of the Geological Society of Australia, 18, 243-258.

MOORE, A.C., 1973 - Carbonatites and kimberlites in Australia: A review of the evidence. Minerals Science and Engineering, 5, 81-91.

MOORE, A.C., & GRAY, C.M., 1973 - Carbonatites of the Strangways Range, central Australia; evidence from strontium isotopes. Journal of the Geological Society of Australia, 20, 71-3.

MOORE, D.H., in preparation - The Mud Tank Vermiculite Prospect, Alice Springs 1:250 000 Sheet area. (SF53/14). Northern Territory Geological Survey, Report (unpublished).

MOORE, D.H., & WOYZBUN, P., in preparation - Investigation on the Harry Creek Copper-Zinc Prospect. Northern Territory Geological Survey, Report G.S. 77/19 (unpublished).

MOOREHOUSE, W.W., 1959 - THE STUDY OF ROCKS IN THIN SECTION. Harper & Row, New York.

MORGAN, W.R., 1961 - The petrography of some metamorphic rocks in the Bitter Springs and Ruby Gap areas near Alice Springs, Northern Territory. Bureau of Mineral Resources, Australia, Record 1961/132 (unpublished).

MORGAN, W.R., 1964 - The nomenclature of igneous and metamorphic rocks. Bureau of Mineral Resources, Australia, Record 1964/182 (unpublished).

MORLOCK, J.S., 1971 - The Phlogopite Mine base-metal prospect, Strangways Range, Alice Springs 1:250 000 Sheet area, SF 53-14, Northern Territory. Resident Geologist's Office, Mines Branch, Department of Energy and Mines, Alice Springs Northern Territory - Report (unpublished).

MOSS, F.J., 1963 - Alice Springs (Farm Area) seismic refraction survey Northern Territory 1961. Bureau of Mineral Resources, Australia, Record 1963/6 (unpublished).

MOSS, F.J., 1966 - Ooraminna seismic survey, Amadeus Basin, Northern Territory, 1962. Bureau of Mineral Resources, Australia, Record 1966/57 (unpublished).

MOULDEN, J.C., 1895 - Petrographic observations on some South Australian rocks. Transactions of the Royal Society of South Australia, 19, 70-78.

MUIR, A., HARDIE, H.G.M., MITCHELL, R.M., & PHEMISTER, J., 1956 - The Limestones of Scotland. Memoir of Geological Survey of Great Britain. Special Report, Mineral Resources, 37.

MURRAY, W.R., 1907 - Journal of the government prospecting expedition to the south-western portions of the Northern Territory, by F.R. George, and to the Buxton and Davenport Ranges, by W.R. Murray. South Australian Parliamentary Paper 50.

MUTTON, A., SHAW, R.D., & WILKES, P., in preparation - Ground geophysical and geological investigations in the Southern Arunta Block, Northern Territory. Bureau of Mineral Resources, Australia, Record (unpublished).

MUTTON, A., & SHAW, R.D., 1979 - Physical property measurements as an aid to magnetic interpretation in basement terrains. Bulletin of the Australian Society of Exploration Geophysicists 10(1).

NOAKES, L.C., 1953 - The structure of the Northern Territory with relation to mineralisation. In GEOLOGY OF AUSTRALIAN ORE DEPOSITS. Fifth Empire Mining & Metallurgical Congress Publications, 1, 284-296.

NOAKES, L.C., 1956 - Upper Proterozoic and sub-Cambrian rocks in Australia. In EL SISTEMA CAMBRICA, SU PALEOGEOGRAFIA Y EL PROBLEMA DE SU BASE. 20th Internation Geological Congress, Mexico, 2, 213-38. Reprinted in Bureau of Mineral Resources, Australia, Bulletin 49.

NOCKOLDS, S.R., 1954 - Average chemical compositions of some igneous rocks. Geological Society of America, Bulletin 65, 1007-1032.

OLDERSHAW, W., (Compiler) - 1963 - Laboratory chemical, petrographic and mineral investigations July to December, 1962. Bureau of Mineral Resources, Australia, Record 1963/55 (unpublished).

OFFE, L.A., & SHAW, R.D., in preparation - Commentary on the Alice Springs Region 1:100 000 Map. Bureau of Mineral Resources, Australia.

OFFLER, R., & FLEMING, P.D., 1968 - A synthesis of folding and metamorphism in the Mt Lofty Ranges, South Australia. Journal of Geological Society of Australia, 15 (2), 245-266.

OPIK, A.A., 1952 - Discovery of fossiliferous Upper Cambrian in Central Australia. Bureau of Mineral Resources, Record 1952/17 (unpublished).

OPIK, A.A., & others, 1957 - Cambrian geology of Australia. Bureau of Mineral Resources, Australia, Bulletin 49.

OWEN, H.B., 1943 - Microscopic examination of mica from "Rex" Mine, Northern Territory. Bureau of Mineral Resources, Australia, Record 1943/44 (unpublished).

OWEN, H.B., 1944 - Report on occurrence of apatite on Alcoota Station, Alice Springs District, Northern Territory. Bureau of Mineral Resources, Australia, Record 1944/44 (unpublished).

OWEN, H.B., 1945 - Notes on the Pannikin and Elbow Mica Deposits, Harts Range, Northern Territory, Bureau of Mineral Resources, Australia, Record 1945/5, (unpublished).

OWEN, H.B., 1952 - Notes on water supply at Alice Springs. Bureau of Mineral Resources, Australia, Record 1952/21 (unpublished).

OWEN, H.B., 1952b - Report on geological investigations of underground water resources at Alice Springs. Report for Northern Territory Administration by Bureau of Mineral Resources, Australia (unpublished).

OWEN, H.B., 1954 - Report on geological investigations of underground water resources at Alice Springs, Report for Northern Territory Administration by Bureau of Mineral Resources (unpublished).

PAGE, R.W., (Compiler), 1968 - Catalogue of radiometric age determinations carried out on Australian Rocks in 1966. Bureau of Mineral Resources, Australia, Record 1968/30, (unpublished).

PARASNIS, D.S., 1971- Physical properties for rocks and minerals. ABEM Geophysical Memorandum 4.71 Atlas Copco, Bromma, Sweden.

PARK, R.G., & CRESSWELL, B., 1973 - The dykes of the Laxfordian Belts. In PARK, R.G., & TARNEY, J. (eds) - THE EARLY PRECAMBRIAN OF SCOTLAND AND RELATED ROCKS OF GREENLAND. University of Keele. 119-130.

PARKINSON, W.D., VAN DER WAAL, C.A., BROOK, J.A., CLEARY, J.R., & PINN, J.D., 1958 - Magnetic observatories operated by the Bureau of Mineral Resources, Geology and Geophysics, during the International Geophysical Year, 1957-58. Bureau of Mineral Resources, Australia, Record 1958/53. (unpublished).

PELTOLA, ESKO, 1978 - Origin of Precambrian copper sulphides of the Outokumpu District, Finland. Economic Geology, 73(4), 461-477.

PEMBERTON, R.L., CHAMBERS, S.S., PLANALP, R.N., & WEBB, E.A., 1963 - Well completion report, Exoil Alice No. 1. Report by E.A. Webb, Consulting Geologist (unpublished).

PERRY, R.A., & Others, 1962 - Lands of the Alice Springs area, Northern Territory, 1956-57. CSIRO, Australia, Land Research Series 6.

PERRY, R.A., QUINLAN, T., JONES, N.O., & BASINSKI, J.J., 1963 - Preliminary assessment of ground water suitable for irrigation in the Alice Springs area, and its agricultural significance. CSIRO, Australia, Division of Land Research Regional Survey Technical Paper 21.

PETTIJOHN, F.J., 1963 - Chemical composition of sandstones - excluding carbonated and volcanic sands. In Data of geochemistry, 6th ed. United States Geological Survey Professional Paper 440-S.

PHILLIPS, K.M., 1959 - Geology of the area between the Amadeus and Southern Georgina Basins, Northern Territory, Report for Frome-Broken Hill, 400-G-32 (unpublished).

PIRSSON, L.V., 1895 - in Petrography of the Igneous Rocks of the Little Belt Mountains, Montana. 20th Annual Report United States Geological Survey, 1900.

PLAYFORD, E.C., 1920 - Chief Warden, Northern Territory, report to Secretary, Home and Territories Dept. (unpublished in BMR files).

PLAYFORD, G., JONES, B.G., & KEMP, E.M., 1976 - Polynological evidence for the age of the synorogenic Brewer Conglomerate, Amadeus Basin, central Australia. Alcheringa, 1, 235-243.

PLUMB, K.A., 1979 - Tectonic evolution of Australia. Earth Science Reviews, 14, 205-249.

POLDERVAART, A., 1967 - Basalts: The Poldervaart Treatise on Rocks of Basaltic Composition. Interscience Publication, New York.

POJETA, J. Jr., & GILBERT-TOMLINSON, J., 1977 - Australian Ordovician pelecypod molluscs. Bureau of Mineral Resources, Australia, Bulletin, 174

POJETA, J. Jr., GILBERT-TOMLINSON, J., & SHERGOLD, J.G., 1977 - Cambrian and Ordovician rostroconch molluscs from northern Australia. Bureau of Mineral Resources, Australia, Bulletin 171.

PONTIFEX, I.R., 1964a - A mineralogical examination of an iron carbonate from Southwest of Mud Tank, Alcoota, Northern Territory, Bureau of Mineral Resources, Australia, Laboratory Report (unpublished).

PONTIFEX, I.R., 1964b - Minerographic examination of a magnetite sample from southwest of Mud Tank, Alcoota, Northern Territory, Bureau of Mineral Resources, Australia, Laboratory Report (unpublished).

PONTIFEX, I.R., 1965 - A mineralogical investigation of an analcite-rich sediment from 16 miles north of Alice Springs, Northern Territory, Bureau of Mineral Resources, Australia, Laboratory Report (unpublished).

PREISS, W.V., WALTER, M.R., COATS, R.P., & WELLS, A.T., 1978 - Lithological correlations of Adelaidean glaciogenic rocks in parts of the Amadeus, Ngalia, and Georgina Basins. BMR Journal of Australia Geology & Geophysics, 3, 43-53.

PRICHARD, C.E., & QUINLAN, T., 1962 - The Geology of the southern half of the Hermannsburg 1:250 000 Sheet. Bureau of Mineral Resources, Australia, Report 61.

PRINZ, M., 1967 - Geochemistry of Basaltic Rocks. Trace Elements. In Hess, H.H., and Poldervaart, A., (eds) BASALTS Vol. 1. Wiley Interscience, New York, 271-323.

QUILTY, J.H., & MILSOM, J.S., 1964 - Simpson Desert aeromagnetic survey, 1962. Bureau of Mineral Resources, Australia, Record 1964/115 (unpublished).

QUINLAN, T., 1959 - An outline of the geology of the Alice Springs area. Bureau of Mineral Resources, Australia, Record 1959/40 (unpublished).

QUINLAN, T., 1962 - An outline of the geology of the Alice Springs area. In Perry & others (1962), 129-145 (see above).

QUINLAN, T., 1967 (a) - The Alice Springs Town Basin: a case history. Bureau of Mineral Resources, Australia, Record 1967/47, (unpublished).

QUINLAN, T., 1967 (b) - Criteria for the design and evaluation of mathematical models for the Alice Springs Town Basin. Bureau of Mineral Resources, Australia, Record 1967/69 (unpublished).

QUINLAN, T., & WOOLLEY, D.R., 1962 - The occurrence of groundwater in the Alice Springs town basin. Bureau of Mineral Resources, Australia, Record 1962/75, (unpublished).

QUINLAN, T., & WOOLLEY, D.R., 1963 - Completion report on bore 62/9, Alice Springs Town Basin. Bureau of Mineral Resources, Australia, Record 1963/147 (unpublished).

QUINLAN, T., & WOOLLEY, D.R., 1967 - The occurrence of groundwater in the Alice Springs Town Basin. Bureau of Mineral Resources, Australia, Bulletin 89.

RADESKI, A.M., 1962 - Regional gravity survey, central and northern Australia, 1959, Bureau of Mineral Resources, Australia, Record 1962/6 (unpublished).

RAMSAY, C.R., & DAVIDSON, L.R., 1970 - The origin of scapolite in the regionally metamorphosed rocks of Mary Kathleen, Queensland, Australia, Contributions to Mineralogy and Petrology, 25, 41-51.

RANFORD, L.C., COOK, P.J., & WELLS, A.T., 1966 - Geology of the central part of the Amadeus Basin, Northern Territory, Bureau of Mineral Resources, Australia, Report 86.

RANNEFT, T.S.M., 1963 - Amadeus Basin petroleum prospects. Journal of Australian Petroleum Exploration Association, 1963.

RENNIE, E.H., 1889 - On some so-called South Australian Rubies. Transactions of Royal Society of South Australia, 11, 17-18.

RICKARD, M.J., 1975 - The structure of the Harts Range, Northern Territory. In PROTEROZOIC GEOLOGY - Abstracts of First Australian Geological Convention, Adelaide, South Australia, May 1975. Geological Society of Australia.

RICKARD, M.J., & SHAW, R.D., 1972 - Preliminary interpretation of the basement structures north of the Arltunga Nappe Complex. Joint Specialists meetings, Canberra, 1972. Geological Society of Australia.

RIDLER, R.H., & SHILTS, W.W., 1974 - Exploration for Archaean polymetallic sulphide deposits in permafrost terrains. Geological Survey of Canada, Paper 73-74.

RILEY, C.H., 1968 - Revision of granite ages in the Northern Territory, Australia. Geological Society of America, Special Report 115, 184.

ROBERTS, W.M.B., 1957 (?) - Examination of mineral specimens from Strangways Range, central Australia. Bureau of Mineral Resources, Australia, Technical Files Report, (unpublished).

ROBERTS, W.M.B., (Compiler) 1961 - Miscellaneous, petrographic and mineragraphic investigations for the period January-March 1958. Bureau of Mineral Resources, Australia, Record 1961/139 (unpublished).

ROBERTSON, I.D.M., 1973 - The geology of the country around Mount Towla, Gwanda District. Bulletin Geological Survey of Rhodesia, 68.

ROCHOW, K., 1960 - The occurrence of opal in Rosewalls Quarry, Alice Springs. Report of Resident Geologist, Alice Springs, (unpublished).

ROCHOW, K., 1962 - An investigation of the Harts Range and Plenty River mica mines, Bureau of Mineral Resources, Australia, Record 1962/34 (unpublished).

RYAN, G.R., 1957 - Report on a radioactive find in the Mount Johnstone area, Strangways Range, Northern Territory, Bureau of Mineral Resources, Australia, Record, 1957/85 (unpublished).

RYAN, G.R., 1962 - The mineral deposits of the Alice Springs area. In Perry et al. (1962), 147-149. General report on lands of the Alice Springs area, Northern Territory, 1956-57. CSIRO, Australia, Land Research Series 6.

SANGSTER, D.F., 1972 - Precambrian volcanogence massive sulphide deposits in Canada: A review. Geological Survey of Canada, Paper 72-22.

SANGSTER, D.F., & SCOTT, S.D., 1976 - Precambrian strata-bounded massive Cu-Zn-Pb sulphide ores of North America; in WOLF (ed) HANDBOOK OF STRATA-BOUND STRATIFORM ORE DEPOSITS Volume 5. Elsevier, Amsterdam.

SCANVIC, J.Y., 1961 - Report on photo-interpretation of the Amadeus Basin. Report for Bureau of Mineral Resources, Australia by Institute Francais Petrole, AUS/31, (unpublished).

SCHMERBER, G., 1966 - Petrology of surface samples from the Amadeus Basin, Northern Territory. Bureau of Mineral Resources, Australia, Record 1966/206 (unpublished).

SCHOPF, J.W., 1968 - Microflora of the Bitter Springs Formation, Late Precambrian, central Australia. Journal of Paleontology, 42, 651-688.

SCHOPF, J.W., & BLACIC, J.M., 1971 - New micro-organisms from Bitter Springs Formation (late Precambrian) of the north-central Amadeus Basin Australia. Journal of Paleontology, 45, 925-960.

SCHRUILING, R.D., 1972a - Oceanisation - geothermal models. Geologie en Mijnbouw, 51, 546-547.

SCHRUILING, R.D., 1973 - Active role of continents in tectonic evolution - geothermal models. In K.A. DE JONG & R. SCHOLTEN (eds) GRAVITY AND TECTONICS Wiley, New York.

SEDERHOLM J.J., 1935 - SELECTED WORKS: GRANITES AND MIGMATITES. Wiley, New York.

SEIBERT, F., 1974 - Stability of sapphirine a study of the aluminous part of the system $MgO-Al_2O_3-SiO_2-H_2O$. Journal of Geology, 82, 173-204.

SENIOR, B.R., 1972 - Cainozoic laterite and sediments in the Alcoota Sheet area, Northern Territory, Bureau of Mineral Resources, Australia, Record 1972/47 (unpublished).

SHAW, D.M., 1956 - Geochemistry of Pelitic Rocks. Part III: Major Elements and General Geochemistry. Bulletin of the Geological Society of America, 67, 919-934.

SHAW, R.D., 1967 - Tommy's Gap Copper Prospect, Northern Territory, Resident Geologist's Office, Alice Springs - Report (unpublished).

SHAW, R.D., 1970 - Geology and copper deposits of the Pinnacles Bores area, Strangways Range, Northern Territory. Bureau of Mineral Resources, Australia, Record 1970-115 (unpublished).

SHAW, R.D., & MILLIGAN, E.N., 1969 - Illogwa Creek, Northern Territory - 1:250 000 Geological Series. Bureau of Mineral Resources, Australia Explanatory Notes SF/53-15.

SHAW, R.D., & STEWART, A.J., 1973 - Regional geology of the Precambrian Arunta Block. Bureau of Mineral Resources Australia, Record 1973/94 (unpublished).

SHAW, R.D., & STEWART, A.J., 1975 - Towards a stratigraphy of the Arunta Block. In PROTEROZOIC GEOLOGY 1st Australian Geological Convention, Adelaide, South Australia, May 1975. Geological Society of Australia, Abstracts.

SHAW, R.D., & WARREN, R.G., 1975 - Alcoota, Northern Territory, 1:250 000 Geological Series, Bureau of Mineral Resources Australia, Explanatory Notes SF/53/10.

SHAW, R.D., & STEWART, A.J., 1976 - Arunta Block - Regional Geology. In KNIGHT, C.L., (Ed.), ECONOMIC GEOLOGY OF AUSTRALIA AND PAPUA NEW GUINEA: 1 METALS. Australasian Institute of Mining and Metallurgy - Monograph Series 5, 437-42.

SHAW, R.D., STEWART, A.J., YAR KHAN, M., & FUNK, J.L., 1971 - Progress reports on detailed studies in the Arltunga Nappe Complex, Northern Territory, 1971. Bureau of Mineral Resources, Australia, Record 1971/66 (unpublished).

SHAW, R.D., WARREN, R.G., SENIOR, B.R., & YEATES, A.N., 1979 - Geology of the Alcoota 1:250 000 Sheet area. Bureau of Mineral Resources, Australia, Record 1975/100, BMR Microform MF107 (unpublished).

SHERATON, J.W., TARNEY, J., WHEATLEY, J.J., & WRIGHT, A.E., 1973 - The Structural history of the Assynt district. In PARK, R.G. & TARNEY, J., (Eds). THE EARLY PRECAMBRIAN OF SCOTLAND AND RELATED ROCKS OF GREENLAND University of Keele, 31-44.

SHIRLEY, J.E., 1966 - Gravity meter measurements in connection with the western Pacific calibration line (Australian segment), 1965. Bureau of Mineral Resources, Australia, Record 1966/160 (unpublished).

SMITH, C.S., 1964 - Some elementary principles of polycrystalline microstructure. Metallurgical Reviews, 9(33), 1-48.

SMITH, K.G., VINE, R.R., & WOOLLEY, D.R., 1960 - Geology of the Huckitta area: Second progress report, Bureau of Mineral Resources, Australia, Record 1960/66 (unpublished).

SMITH, K.G., 1963 - Hay River, Northern Territory - 1:250 000 Geological Series, Bureau of Mineral Resources, Australia, Explanatory Notes SF/53-16.

SMITH, K.G., 1964 - Progress report on the geology of the Huckitta 1:250 000 Sheet, Northern Territory. Bureau of Mineral Resources, Australia, Report 67.

SMITH, K.G., & MILLIGAN, E.N., 1964 - Barrow Creek, Northern Territory, 1:250 000 Geological Series. Bureau of Mineral Resources, Australia, Explanatory Notes SF/53-6.

SPITZ, G., & DARLING, R., 1975 - The Petrochemistry of altered volcanic rocks surrounding the Louvern Copper Deposit, Val d'Or, Quebec. Canadian Journal of Earth Science, 12, 1820-1849.

SPRIGG, R.C., 1962a - Progress exploration in the Simpson Desert of central Australia. Journal of Australia Petroleum Exploration Association.

SPRIGG, R.C., 1962b - Review report on the geology of O.P. 57, Simpson Desert, Northern Territory. Report by Geosurveys of Australia (unpublished).

SPRIGG, R.C., 1963 - Geology and petroleum prospects of the Simpson Desert. Transactions of Royal Society of South Australia, 86, 35-65.

SPRY, A., 1969 - METAMORPHIC TEXTURES. Pergamon Press, Oxford.

STAMATELOPOULOU - SEYMOUR, K. & MOLLEAN, W.H., 1977 - The geochemistry of possible metavolcanic rocks and their relationship to mineralisation at Montaubar-Les-Mines, Quebec. Canadian Journal of Earth Sciences, 14, 2440-2452.

STANTON, R.L., 1972 - ORE PETROLOGY. McGraw Hill, New York.

STANTON, R.L., 1976 - Petrochemical studies of the ore environment at Broken Hill, New South Wales: 4 - environmental synthesis. Institute of Mining and Metallurgy, Transactions 85, B221-233.

STEIGER, R.H., & JÄGER, I., 1977 - Subcommission on geochronology: Convention on the use of decay constants in geo-and cosmochronology. Earth and Planetary Science Letters, 36, 359-62.

STELCK, C.R., & HOPKINS, R.M., 1962 - Early sequence of interesting shelf deposits, central Australia. Journal of Alberta Society of Petroleum Geology, 10, 1-12.

STEWART, A.J., 1967 - An interpretation of the structure of the Blatherskite Nappe, Alice Springs, Northern Territory. Journal of Geological Society of Australia, 14(2), 175-85.

STEWART, A.J., 1969a - Completion report, B.M.R. Alice Springs No.3 (Ringwood) Bureau of Mineral Resources, Australia, Record 1969/7 (unpublished).

STEWART, A.J., 1969b - Progress report on the Arltunga Nappe Complex. Bureau of Mineral Resources, Australia, Record 1969/71 (unpublished).

STEWART, A.J., 1971a - Structural evolution of the White Range Nappe, central Australia. Ph.D. thesis, Yale University. University Microfilms Inc., Ann Arbor, Michigan.

STEWART, A.J., 1971b - Potassium-argon dates from the Arltunga Nappe Complex, Northern Territory. Journal of the Geological Society of Australia, 17, 205-211.

STEWART, A.J., 1974 - Petrographic and geochemical study of the Ringwood evaporite deposit. Bureau of Mineral Resources, Australia, Record 1974/145 (unpublished).

STEWART, A.J., 1979 - A barred-basin marine evaporite in the Upper Proterozoic of the Amadeus Basin, central Australia. Sedimentology, 26, 33-62.

STEWART, A.J., OFFE, L.A., GLIKSON, A.Y., & WARREN, R.G., in preparation - Geology of the Reynolds Range, Mount Peake, Tea Tree, and Aileron 1:100 000 Sheet areas, Arunta Complex, Northern Territory. Bureau of Mineral Resources, Australia, Record (unpublished).

STEWART, A.J., LANGWORTHY, A.R., WARREN, R.G., OFFE, L.A., GLIKSON, A.Y., WELLS, A.T., Le MESSURIER, P., & GARDNER, J.E.F., 1976 - Precambrian structures and metamorphic rocks of central Australia and Tennant Creek, Northern Territory. 25th International Geological Congress Sydney, Australia, 1976, Excursion Guide 47C.

STEWART, A.J., & WARREN, R.G., 1977 - The mineral potential of the Arunta Block. BMR Journal of Australian Geology & Geophysics, 2, 21-34.

STILLWELL, F.A., 1943 - Mineragraphic investigations of samples from the Strangways Range. CSIRO Mineragraphic Report (unpublished).

STRACKE, K.J., 1974 - Final report of Exploration Licences Nos. 811 and 812, Southern Cross Bore and Sixteen Mile Bore, Northern Territory. Report to Stockdale Prospecting Ltd (unpublished).

STRECKEISEN, A.L., 1976 - To each plutonic rock it's proper name. Earth Science Reviews, 12, 1-33.

STUART, J.McD., 1865 - EXPLORATIONS IN AUSTRALIA, THE JOURNALS OF JOHN McDOUGALL STUART DURING THE YEARS 1858-1862, ETC. 2nd edition. Saunders, London.

SULLIVAN, C.L., 1942a - Brief notes on the Harts Range Mica Mines which may be capable of being re-opened. Bureau of Mineral Resources, Australia, Record 1942/3 (unpublished).

SULLIVAN, C.J., 1942b - Report on the water survey of the Harts Range mica field. Bureau of Mineral Resources, Australia, Record 1942/38 (unpublished).

SUTTON, J., & WATSON, J.F., 1950 - Pre-Torridonian history of the Loch Torridon and Scourie areas in the Northwest Highlands. Quarterly Journal of Geological Society of London, 106, 241.

SUTTON, J., & WATSON, J.V., 1962 - Further observations on the margin of the Laxfordian complex of the Lewisian near Loch Laxford, Sutherland. Transactions of the Royal Society of Edinburgh 65, 89-106.

TATE, R., 1880 - Rock formations and minerals in vicinity of Peake, central Australia. Transactions of the Royal Society of South Australia, 3, 1879-80.

TATE, R., 1896 - Palaeontology. In SPENCER, B. (ed). REPORT ON THE WORK OF THE HORN SCIENTIFIC EXPEDITION TO CENTRAL AUSTRALIA. Melbourne; Melvin, Mullen & Slade, London, 3, 97-116.

TATE, R., & WATT, J.A., 1896 - General Geology. In SPENCER, B. (ed). REPORT ON THE WORK OF THE HORN SCIENTIFIC EXPEDITION TO CENTRAL AUSTRALIA. Melbourne. Melvin, Mullen & Slade, London. 3, 26-75.

TATE, R., & WATT, J.A., 1897 - Report of the physical geography of central Australia. In WINNECKE, C. (1897), JOURNAL OF THE HORN SCIENTIFIC EXPEDITION, 1894, 68-86, South Australian Government Printer, Adelaide.

TAYLOR, D.J., 1959 - Report of examination of fossils collected from the MacDonnell Ranges, Northern Territory. Report for Frome-Broken Hill, 4300-G-22 (unpublished).

TAYLOR, R.J., 1976 - Arltunga detailed airborne magnetic and radiometric survey, Northern Territory, 1972. Bureau of Mineral Resources, Australia, Record 1976/50 (unpublished).

TAYLOR, S.R., 1966 - The application of trace element data to problems in petrology. Physics and Chemistry of the Earth, 6, 133-213.

THOMAS, N.M., 1956 - Review of the geology of the Amadeus Basin. Report for Frome-Broken Hill, 4300-G-11 (unpublished).

THOMPSON, A.B., 1975 - Calc-silicate diffusion zones between marble and pelitic schist. Journal of Petrology, 16, 314-346.

THOMPSON, B.P., 1950 - Baldiseri Copper Prospect. Northern Territory, Zinc Corporation Ltd. Memo, 151 (unpublished).

THORNTON, C.P., & TUTTLE, O.F., 1960 - Chemistry of igneous rocks, I: Differentiation index. American Journal of Science, 258, 664-684.

TIETKINS, W.N., 1891 - JOURNAL OF THE CENTRAL EXPLORING EXPEDITION. South Australian Government Printer, Adelaide.

TINDALE, N.B., 1931 - Geological notes on the Iliaura country north-east of the MacDonnell Ranges, central Australia. Transactions of the Royal Society of South Australia, 55, 32-38.

TIPPER, D.B., 1969 - Strangways Range detailed aeromagnetic survey, Northern Territory. Bureau of Mineral Resources, Australia, Report 136.

TOMICH, S.A., 1952 - Brief report on an investigation of mines in the Harts Range and Plenty River Mica fields, Northern Territory, Bureau of Mineral Resources Australia, Record 1952/8 (unpublished).

TRUMPY, D., & TISSOT, B., 1963 - Recent developments of petroleum prospects in Australia. Report for Bureau of Mineral Resources, Australia by Institute Francais AUS/87 (unpublished).

TUOMINEN, H.V., & MIKKOLA, T., 1950 - Metamorphic Mg-Fe enrichment in the Orijarvi region as related to folding. Bull. Comm. geol. Finlande 150, 67-72.

TUREKIAN, K.K., & WEDEPOHL, K.H., 1961 - Distribution of the elements in some major units of the earth's crust. Geological Society of America, Bulletin 72, 175-192.

TURNER, F.J., 1968 - METAMORPHIC PETROLOGY. McGraw Hill, New York.

TURNER, F.J., & VERHOOGEN, J., 1960 IGNEOUS AND METAMORPHIC PETROLOGY. McGraw-Hill, New York.

TURNER, F.J., & WEISS, L.E., 1963 - STRUCTURAL ANALYSIS OF METAMORPHIC TECTONITES. McGraw-Hill, New York.

TYRELL, G.W., 1926 - PRINCIPLES OF PETROLOGY. Methuen, London.

VERNON, D.G., 1972 - Reaction involving hydration of cordierite and hypersthene. Contributions to Mineralogy and Petrology, 37, 125-137.

VIDALE, R.J., 1969 - Metasomatism in a chemical gradient and the formation of calc-silicate bands. American Journal of Science, 267, 857-874.

VOISEY, A.H., 1939a - Notes on the stratigraphy of the Northern Territory of Australia, with special reference to the Jurassic System. Journal of the Royal Society of N.S.W., 72, 136-159.

VOISEY, A.H., 1939b - A contribution to the geology of the Eastern MacDonnell Ranges, central Australia. Journal of the Royal Society of N.S.W., 72, 160-174.

WALPOLE, B.P., ROBERTS, H.G., & FORMAN, D.J., 1965 - General geology and structure of the Northern Territory in relation to mineralization. In GEOLOGY OF AUSTRALIAN ORE DEPOSITS, 2nd edn. Eighth Commonwealth Mining & Metallurgical Congress, 160-7.

WALPOLE, B.P., & SMITH, K.G., 1961 - Geology of Proterozoic granites in Northern Territory, Australia. Part 2: stratigraphy and structure. Geological Society of America, Bulletin 72, 663-668.

WALTER, M.R., 1972 - Stromatolites and the biostratigraphy of the Australian Precambrian and Cambrian. Palaeontology, Special Paper 11.

WARD, L.K., 1925 - Notes on the geological structure of central Australia. Transactions of Royal Society of South Australia, 49, 61-84.

WARREN, R.G., 1974 - Gneiss of the Oonagalabi Group of Deposits, Arunta Complex, Central Australia. M.Sc. Thesis, University of London., (unpublished).

WARREN, R.G., 1975 - A metamorphosed regolith from the Arunta Block, central Australia. In PROTEROZOIC GEOLOGY - Abstracts of First Australian Geological Convention, Adelaide, 1975, Geological Society of Australia.

WARREN, R.G., 1979 - Sapphirine-bearing rocks with sedimentary and volcanogenic protoliths from the Arunta Inlier. Nature, 125, 711.

WARREN, R.G., in preparation - The mineral deposits in the Arunta Block in the Alice Springs 1:250 000 sheet area. Bureau of Mineral Resources, Australia, Record (unpublished).

WARREN, R.G., STEWART, A.J., & SHAW, R.D., 1974 - Summary of information on mineral deposits of the Arunta Complex, Alice Springs area, Northern Territory, Bureau of Mineral Resources, Australia, Record 1974/117 (unpublished).

WARREN, R.G., STEWART, A.J., & SHAW, R.D., 1975 - Arunta Block - mineralisation. In KNIGHT, C.L. (Ed.). ECONOMIC GEOLOGY OF AUSTRALIA AND PAPUA NEW GUINEA: 1. METALS. Australasian Institute of Mining & Metallurgy, Monograph Series, 5, 443-447.

WATERHOUSE, F.G., 1863 - Features of country on Stuart's Track across Australia. South Australian Parliamentary Paper 125.

WATTERSON, J., 1968 - Plutonic development of the I'ordeq area, South Greenland. Part II, Late Kinematic basic dykes. Meddelelser om Grønland Bd 185, 104pp.

WEBB, A.W., & LOWDER, G.G., 1972 - K-Ar dating rocks from the Arunta Complex. Australian Mineral Development Laboratory MP2236/72 (unpublished).

WEBER, B., 1975 - Preliminary Report on the KM 249 Bridge Site investigation. Northern Territory Geological Survey Report G.S. 75/18.

WELLMAN, P., 1976 - Gravity trends and the growth of Australia: A tentative correlation. Journal of Geological Society of Australia, 23, 11-14.

WELLMAN, P., 1978 - Gravity evidence for abrupt changes in mean crustal density at the Junction of Australian crustal blocks. BMR Journal of Australian Geology & Geophysics, 3, 152-162.

WELLS, A.T., 1969 - Alice Springs, Northern Territory - 1:250 000 Geological Series. Bureau of Mineral Resources, Australia Explanatory Notes SF/53-14.

WELLS, A.T., STEWART, A.J., & SKWARKO, S.K., 1966 - The geology of the southeastern part of the Amadeus Basin, Bureau of Mineral Resources, Australia, Report 88.

WELLS, A.T., RANFORD, L.C., COOK, P.J., & FORMAN, D.J., 1967 - The geology of the Amadeus Basin, Central Australia. Bureau of Mineral Resources, Australia, Record 1967/92 (unpublished).

WELLS, A.T., RANFORD, L.C., STEWART, A.J., COOK, P.F., & SHAW, R.D., 1967 - Geology of the northeastern part of the Amadeus Basin. Bureau of Mineral Resources, Australia, Report 113.

WELLS, A.T., FORMAN, D.J., RANFORD, L.C., & COOK, P.J., 1970 - Geology of the Amadeus Basin, Central Australia. Bureau of Mineral Resources, Australia, Bulletin 100.

WELLS, A.T., 1976 - Geology of the Late Proterozoic-Palaeozoic Amadeus Basin. 25th International Geological Congress, Excursion Guide 48A.

WILSON, A.F., 1974 - The mineral potential of granulite terrains and other highly metamorphosed segments of the Earth's Crust. Centenaire de la Societe Geologique de Belgique Geologie des Domaines Cristallins, Liege, 1974, 301-321.

WILSON, A.F., 1975 - Aspects of the geochemistry and petrology of the mafic granulites of the Arunta, Musgrave, and Fraser Blocks. In PROTEROZOIC GEOLOGY - Abstracts of First Australian Geological Convention, South Australia, 1975 Geological Society of Australia.

WILSON, A.F., 1978a - Large crystals of Kornerupine from a new locality in the granulites of the Strangways Range, central Australia. Neues Jahrbuch fur Mineralogie, Monatsheffe, 116, 249-256.

WILSON, A.F., 1978b - Hydrous cordierite with isotopically light oxygen from granulites, Strangways Range, Central Australia. Mineralogical Magazine, 42, 89-92.

WILSON, A.F., COMPSTON, P.M., JEFFERY, P.M., & RILEY, G.M., 1960 - Radioactive ages from the Precambrian rocks in Australia. Journal of Geological Society of Australia, 6(2), 170-195.

WILSON, A.F., & BAKSI, A.K., 1978 - Unusually light oxygen in granulites from the Strangways Range, Central Australia. In STABLE ISOTOPES IN EARTH SCIENCES, DSIR Bulletin 220.

WILSON, I.H., 1978 - Volcanism on a Proterozoic Continental Margin in Northwestern Queensland. Precambrian Research, 7, 205-235.

WILSON, I.H., DERRICK, G.M., & HILL, R.M., 1972 - Copper mineralisation (excluding Mount Isa) in the Precambrian Cloncurry Complex of northwest Queensland, Australia. 24th International Geological Congress; Section 4, 234-240.

WINCHESTER, J.A., & FLOYD, P.A., 1977 - Geochemical discrimination of different magma series and their differentation products using immobile elements. Chemical Geology (20), 325-343.

WINDLEY, B.F., 1973 - Crustal development in the Precambrian. Philosophical Transactions of the Royal Society of London, A273, 321-341.

WINKLER, H.G.F., 1967 - PETROGENESIS OF METAMORPHIC ROCKS (Second edition) Springer Verlag, New York.

WOODBURNE, M.O., 1967 - The Alcoota fauna, Northern Territory. Bureau of Mineral Resources, Australia, Bulletin 87.

WOODFORD, P.J., 1974 - Polymetamorphism in granulites from the northeastern Strangways Range, central Australia. Ph.D. Thesis. University of Queensland. (unpublished).

WOODFORD, P.J., MATEEN, A., GREEN, D.C., & WILSON, A.F., 1975 - $^{40}Ar/^{39}Ar$ Geochronology of a high-grade polymetamorphic terrain, northeastern Strangways Range, central Australia. Precambrian Research, 2, (1975) 375-396.

WOODFORD, P.J., & WILSON, A.F., 1976a - Sapphirine, hogbomite, kornerupine, and surinamite from aluminous granulites, north-eastern Strangways Range, central Australia. Neues Jahrbuch fur Mineralogie (Monatshefte), H 6, Stuttgart, 1976.

WOODFORD, P.J., & WILSON, A.F., 1976b - Chemistry of coexisting pyroxenes, hornblendes and plagioclases in mafic granulites, Strangways Range, central Australia. Neues Jahrbuch fur Mineralogie (Abh.), 128, 1-40, Stuttgart, 1976.

WOODFORD, P.J., & WILSON, A.F., 1976c - Kornerupine in metasomatic zones, Strangways Range, Central Australia. Mineralogical Magazine, 40, 589-94.

WOOLLEY, D.R., & ROCHOW, K.A., 1963 - Preliminary examination of McIntyre's adit and nearby workings, Excelsior Lease, White Range Goldfield. Bureau of Mineral Resources Australia, Record 1963/15 (unpublished).

WOOLLEY, D.R., & ROCHOW, K.A., 1965 - Mineral deposits in central Australia. In GEOLOGY OF AUSTRALIAN ORE DEPOSITS, 2nd edition. Eighth Commonwealth Mining and Metallurgical Congress, 1, 186-193.

WULFF, G.E., 1960 - Geology of the south-eastern part of the Amadeus Basin. Report for Frome-Broken Hill, 4300-G-29 (unpublished).

YEATES, A.N., 1971 - Shallow stratigraphic drilling, Hay River and Alcoota areas, Northern Territory. Bureau of Mineral Resources, Australia, Record 1971/120 (unpublished).

YOULES, I.P., 1963 - Arltunga (lead) In Monthly Report of Northern Territory for July 1963.

YOULES, I.P., 1965 - Mount Skinner Copper deposit. Report Resident Geologists Office, Northern Territory Administration, Alice Springs (unpublished).

YOULES, I.P., 1966 - Diamond drill report, Undoolya Gap copper prospect. Report Resident Geologists Office, Northern Territory Administration, Alice Springs (unpublished).

YOULES, I.P., (no date) - Report on Copper Queen, Harts Range. Report in mineral data files, Resident Geologist's Office, Northern Territory Geological Survey, Alice Springs. (unpublished).

YOUNG, G.A., & SHELLEY, E.P., 1977 - The Amadeus Basin airborne magnetic and radiometric survey, Northern Territory, 1969. Bureau of Mineral Resources, Australia, Report 187.

APPENDICES

TABLE A1: Geochemical analyses of two-pyroxene-plagioclase ± hornblende mafic granulite (mn)

		A	B	L	N	O	P	Q	T	U	V	W	Z	C
Sample Number *		73914406	73914224	72913504	72913508	72913511	72913241	72913232	72913205	72913269	72913500	72913502	71912455	74915013
Locality Grid Ref. **		B938507	B907459	L447239	R516276	R516235	L192546	L235548	L448533	L343418	L083464	L064422	R867246	R810247
Stratigraphic Unit		pCsy	pCsr	pCso	pCso	pCso	pCsf	pCsf	pCsf	pCu	pCsp	pCsc	pCsb	pCsb
Rock Type Symbol		mn	mn	mn	mn	mn	mn	mn	mn	mn	mn	mn	mn	mn
MAJOR OXIDES	SiO_2	47.42	47.67	46.99	46.42	48.92	47.42	47.30	48.70	49.55	48.33	48.57	49.40	50.25
	Al_2O_3	15.19	13.21	14.62	16.16	14.54	14.08	15.25	12.80	13.95	14.45	15.19	14.91	14.17
	Fe_2O_3	2.82	3.23	3.49	3.08	2.62	2.92	2.82	2.38	2.63	1.83	1.22	4.28	1.79
	FeO	9.15	10.70	11.00	8.00	10.40	13.20	7.81	14.60	10.00	11.10	8.10	10.50	11.40
	CaO	12.47	11.02	11.12	14.70	10.01	11.15	14.23	10.72	13.09	10.43	11.92	7.84	9.93
	MgO	7.66	8.92	7.99	7.76	9.02	6.20	8.65	4.94	6.89	7.83	10.40	6.76	6.30
	Na_2O	1.80	1.77	1.38	1.77	1.70	1.95	1.54	2.21	1.55	1.70	0.98	2.83	2.82
	K_2O	0.24	0.63	0.65	0.08	0.21	0.36	0.15	0.37	0.36	0.85	0.30	0.69	0.74
	TiO_2	0.95	1.11	1.09	0.87	0.90	1.43	0.69	1.67	0.93	1.24	0.38	1.08	1.08
	MnO	0.23	0.24	0.23	0.21	0.19	0.26	0.20	0.29	0.23	0.22	0.19	0.25	0.25
	P_2O_5	0.05	0.07	0.14	0.03	0.05	0.12	0.02	0.15	0.01	0.11	< 0.01	0.09	0.10
	H_2O^+	0.23	0.19	0.21	0.41	0.26	0.13	0.34	0.03	0.41	0.24	0.90	0.19	< 0.13
	H_2O^-	0.17	0.19	0.05	0.05	0.02	0.09	0.12	0.09	0.01	0.02	0.02	0.11	0.07
	CO_2													
	$S(SO_3)$													
		98.57	98.95	97.16	99.54	99.25	99.34	99.16	98.94	98.44	98.35	98.19	98.14	99.67
TRACE ELEMENTS	Cu	98	50	62	118	106	62	120	54	128	76	6	30	30
	Co	58	64	64	56	64	64	60	58	62	58	54	42	50
	Ni	80	135	100	65	65	35	90	13	100	130	200	80	114
	Cr	190	310	105	380	125	45	200	20	430	340	550	290	190
	V	410	490	460	430	430	530	410	610	550	410	320	390	250
	Sr	95	70	120	120	160	160	100	175	85	94	85	100	78
	Rb	2	4	14	< 2	10	4	2	3	4	38	8	22	12
	Ba	< 10	70	660	30	110	50	20	120	40	200	100	320	120
	Ce	20	20	20	< 20	20	< 20	< 20	50	< 20	40	< 20	50	50
	Sc	15	8	5	3	5	15	10	8	8	5	5	5	25
	Zr													100
	Pb													16

FOOTNOTE ** L = LAUGHLEN 1:100 000; B = BURT 1:100 000; R = RIDDOCH 1:100 000

TABLE A1 (Cont)

	A	B	L	M	O	P	Q	T	U	V	W	Z	6
Sample Number	73914406	73914224	72913504	72913508	72913511	72913241	72913232	72913205	72913209	72913500	72913502	71912455	74915013
Locality Grid Ref. **	B936507	B887459	L447839	R516276	R516235	L192546	L235548	L449533	L343418	L083404	L064422	R507246	R510247
Stratigraphic Unit	pCay	pCar	pCsc	pCsc	pCsc	pCsf	pCsf	pCsf	pCu	pCsp	pCsc	pCsb	pCsb
Rock Type Symbol	mn	mn	mn	mn	mn	mn	mn	mn	mn	mn	mn	mn	mn
Diopside Dx	24.61	23.12	1..31	30.17	15.61	21.43	29.70	24.29	26.79	18.25	19.80	10.61	19.98
Hypersthene	13.99	16.57	21.39	0.46	26.60	16.03	8.59	22.92	8.00	21.94	29.19	25.74	18.41
Olivine Fo_x	5.51	1.41	4.07	11.10	3.97	4.45	7.27		10.91	4.56	1.42	0.30	4.39
Quartz								0.37					
Corundum													
Zircon													0.02
Orthoclase	1.45	3.00	4.10	0.19	3.00	2.17	0.91	2.26	2.19	3.22	1.67	4.20	5.09
Albite	15.49	15.17	11.78	15.09	13.51	14.62	13.10	17.89	13.35	14.04	6.50	24.26	22.45
Anorthite	33.32	26.57	32.49	36.20	30.50	20.32	34.00	24.15	30.39	24.78	37.06	25.95	24.72
Nepheline													
Leucite													
Magnetite	43.5	4.97	5.32	4.79	4.03	4.51	4.33	3.77	4.14	2.89	1.96	0.47	2.74
Chromite	0.1	0.10	0.02	0.19	0.06	0.02	0.10	0.01	0.22	0.17	0.20	0.15	0.10
Ilmenite	1.64	2.14	2.06	1.07	1.73	2.74	1.33	3.21	1.80	2.40	0.74	2.08	2.04
Rutile													
Apatite	0.12	0.17	0.34	0.07	0.12	0.29	0.05	0.36	0.12	0.27	0.02	0.22	0.24
Calcite													
Mg-No.	60.52	59.60	56.45	63.38	60.74	45.59	66.40	37.64	60.79	55.72	69.77	53.46	49.65
Plagioclase An_x	68.21	63.66	73.39	70.58	67.70	63.42	72.45	56.10	69.62	67.05	91.34	51.68	52.40
Density	3.04	3.13	3.12	3.09	3.04	3.14	3.09	3.15	3.12	3.09	3.09	3.07	3.06
Solidification Index	35.94	35.33	32.80	37.51	37.04	25.17	41.25	20.16	27.41	33.59	49.72	26.98	27.45
Differentiation Index	16.94	18.57	15.94	15.58	18.20	18.79	14.09	21.33	15.54	19.86	10.37	28.54	27.53
K_2O/Na_2O	0.13	0.36	0.47	0.05	0.36	0.18	0.10	0.17	0.23	0.50	0.31	0.24	0.32
Total iron	11.69	13.01	14.14	10.77	12.76	15.83	10.35	10.74	12.37	12.75	9.20	14.35	13.01
K/Rb													

CIPW NORM

RATIOS

FOOTNOTE ** L = LAUGHLEN 1:100 000; B = DART 1:100 000; R = RIDDOCH 1:100 000

TABLE A2: Geochemical analyses of amphibolite (a), calc-silicate rock (cs), microperthite-quartz felsic gneiss (fn_1), hypersthene-plagioclase-quartz felsic granulite (fn_2), and metagabbro (gb)

	R	C	D	E	F	G	H	S	-	P
Sample Number	72913230	7291[illegible]7	7291[illegible]006	73914126	73914127	73914110	73914120	72913202	R4619	744915020
Locality Grid Ref **	L23[illegible]47	B824511	L29[illegible]32	B901247	B903250	B958262	L445548	L445548	R	R652328
Stratigraphic Unit	pCsf	pCsv	$pCsc_2$	pCi	pCi	pCi	pCi	pCsf	pCha	pCsc
Rock Type Symbol	fn_2	fn_1	fn_2	gb	gb	a	a	a	a	cs
SiO_2	53.3[illegible]	76.50	56.20	53.40	49.56	47.74	47.80	48.64	50.32	44.99
Al_2O_3	14.60	11.20	21.43	14.37	14.00	16.07	16.45	13.95	14.95	13.91
Fe_2O_3	3.9	1.51	0.70	3.52	1.63	2.11	1.74	3.34	1.34	3.69
FeO	8.35	1.60	2.42	9.15	12.90	7.40	7.40	1.60	9.48	6.78
CaO	9.67	1.31	7.30	7.04	10.34	14.95	13.90	10.51	10.66	18.70
MgO	7.43	0.25	1.56	3.22	6.10	9.43	7.20	5.60	7.50	7.23
Na_2O	0.53	2.51	4.50	2.00	2.01	2.14	2.44	2.19	3.00	1.05
K_2O	0.06	1.38	0.28	1.73	0.30	0.31	0.16	0.51	0.34	0.24
TiO_2	0.84	0.33	0.24	1.40	1.41	0.73	0.67	1.44	2.08	1.11
MnO	0.22	0.35	0.06	0.19	0.23	0.20	0.18	0.20	-	0.20
P_2O_5	0.05	0.02	0.04	0.34	0.23	0.01	0.05	0.14	0.23	0.16
H_2O^+	0.42	0.08	0.28	0.24	0.09	0.[illegible]	0.[illegible]	0.49	0.14	0.30
H_2O^-	0.11	0.08	0.06	0.14	0.15	0.04	0.01	0.15	0.10	0.04
CO_2		0.05	0.20						-	0.45
$S(SO_3)$										
	99.51	99.07	99.22	99.04	99.14	98.80	98.60	98.81	100.30	98.84
Cu	10	4	10	42	80	38	44	60		98
Co	46	1	14	30	50	58	56	54		64
Ni	85	10	44	58	60	95	120	25		150
Cr	150	5	45	30	95	350	320	40		440
V	340	5	75	250	370	450	330	600		320
Sr	110	40	430	100	120	100	100	170		122
Rb	2	175	10	60	8	0	3	4		14
Ba	110	940	340	1050	220	50	70	400		50
Ce	< 20	90	60	90	60	< 20	< 20	30		20
Sc	20	< 3	5	10	10	5	6	10		25
Zr		400	65							44
Pb		28	420							240
Diopside En_x	8.54		0.31	0.21	18.20	33.77	29.37	20.85	20.47	46.08
Hypersthene	25.30	2.50	7.94	17.02	26.60			20.57	13.05	
Olivine Fo_x						7.83	11.18		6.34	2.77
Quartz	15.89	40.82	7.03	14.27	1.55			1.17		
Corundum										0.01
Zircon										
Orthoclase	0.40	26.35	6.17	10.62	[illegible].80	1.89	0.99	3.26	2.01	.47
Albite	4.52	23.17	39.58	17.13	17.17	16.90	19.92	18.84	25.38	5.69
Anorthite	37.60	0.05	36.72	25.77	28.53	33.91	34.10	27.09	26.33	32.37
Nepheline						0.83	0.99			1.79
Leucite										
Magnetite	0.07	2.19	1.09	5.28	2.85	3.32	2.73	5.20	1.94	5.57
Chromite	0.08		0.02	0.03	0.05	0.18	0.16	0.02		0.22
Ilmenite	1.61	0.63	0.49	2.69	2.70	1.41	1.30	2.78	3.95	2.14
Rutile										
Apatite	0.12	0.05	0.15	0.82	0.55	0.10	0.07	0.34	0.55	0.38
Calcite		0.11	0.45							1.04
Mg-Fo	61.64	20.98	51.51	38.57	45.76	60.79	63.45	46.27	58.79	65.55
Plagioclase An_x	89.26	22.22	48.13	60.06	62.43	66.75	63.96	58.98	50.92	85.27
Density	3.05	2.69	2.76	2.96	3.11	3.05	3.03	3.12	3.04	3.12
Solidification Index	36.69	2.42	15.06	16.41	26.36	34.96	38.01	24.10	34.87	38.07
Differentiation Index	20.81	88.32	52.78	42.23	20.61	19.61	21.20	23.28	27.39	8.95
K_2O/Na_2O	0.11	1.75	0.22	0.87	0.15	0.14	0.07	0.23	0.11	0.23
Total Iron	11.83	3.04	3.25	12.32	14.55	9.30	8.97	14.61	10.69	10.10

MAJOR OXIDES

TRACE ELEMENTS

CIPW NORM

RATIOS

FOOTNOTE ** L = LAUGHLEN 1:100 000; B = BURT 1:100 000; R = IDDOCH 1:100 000

TABLE A3: Geochemical analyses of quartzofeldspathic gneiss (f), granitic gneiss (gg) and granite (g).

	Z	1	3	4	5	7	9	*	+	x	/	(	)	$
Sample Number #	70090270	71912430	74915000	74915002	74915012	74915017	74915021	74915080	74915081	74915082	R4559	R4596	R4631	R4559
Locality Grid Ref **	L306302	R876134	L241198	R516242	R810247	R638281	R653331	L343418	L401149	A648917	QUARTZ	QUARTZ	QUARTZ	QUARTZ
Stratigraphic Unit	pCsc	pCx	pCi	pCsc	pCsb	pCsc	pCsc	pC	pCm	pC	pChe	pCm	pChb	B i
Rock Type Symbol	fn_2	f(r)	f	f	f	f	f	f	f	f	f	f	f	f
SiO_2	62.53	67.09	73.47	75.64	74.50	70.44	72.67	60.71	74.16	69.17	75.67	63.80	77.56	63.38
Al_2O_3	16.22	15.70	13.02	10.79	11.97	12.77	12.11	14.66	13.62	14.34	14.45	16.00	10.64	18.50
Fe_2O_3	0.47	1.19	0.75	2.01	2.05	2.51	0.79	1.93	0.64	1.70	0.37	1.06	0.23	0.80
FeO	2.97	2.15	2.64	2.33	1.28	2.79	3.61	6.33	0.81	2.22		4.32	3.09	2.70
CaO	6.24	3.70	1.68	1.00	0.74	5.66	0.32	5.12	0.87	2.95	1.77	3.64	2.02	5.34
MgO	2.91	1.76	0.96	0.70	0.53	0.87	0.49	2.79	0.34	0.86	0.18	2.03	1.41	1.55
Na_2O	3.75	3.85	3.11	2.72	1.70	2.52	0.98	2.26	3.02	2.73	2.94	2.19	1.34	3.34
K_2O	0.98	2.55	2.59	3.91	6.54	0.79	7.42	2.35	5.10	3.92	4.44	5.13	2.26	3.44
TiO_2	0.28	0.37	0.36	0.29	0.35	0.59	0.44	1.13	0.02	0.57	0.08	0.78	0.37	0.54
MnO	0.06	0.05	0.05	0.07	0.03	0.13	0.02	0.13	0.02	0.06				
P_2O_5	0.08	0.05	0.21	< 0.01	0.05	0.11	0.05	0.28	0.07	0.16	0.06	0.29	0.22	0.26
H_2O^+	0.20	0.56	0.89	0.07	0.11	0.24	0.03	0.99	0.70	0.40	0.03	0.37	0.17	0.24
H_2O^-	0.12	0.08	0.04	0.11	0.09	0.08	0.07	0.09	0.08	0.00	0.12	0.35	0.74	0.08
CO_2			0.10	0.20	< 0.05	0.35	0.05	0.05	0.05	0.10				
$S(SO_3)$														
	99.81	99.11	99.82	99.85	99.94	99.85	99.00	99.76	99.27	99.27	100.11	99.96	100.05	99.17
Cu	22	10	8	10	6	16	18	34	8	14				
Co	12	2	4	< 2	< 2	< 2	8	24	< 2	< 2				
Ni	23	10	16	20	4	14	14	38	24	14				
Cr	60	35	5	< 5	5	15	10	60	5	15				
V	135	165	5	< 5	15	35	35	200	35	60				
Sr	420	390	68	46	54	94	34	260	68	310				
Rb	30	100	90	85	295	28	320	125	250	185				
Ba	480	940	1150	1150	940	40	1000	780	520	1500				
Ce	20	50	90	100	140	110	180	100	70	130				
Sc	x	3	3	< 3	5	15	5	10	< 3	5				
Zr			240	480	370	400	430	290	105	290				
Pb			65	180	145	125	42	50	46	85				

MAJOR OXIDES

TRACE ELEMENTS

FOOTNOTE ** L = LAUCHLEN 1:100 000; B = BURT 1:100 000; R = RIDDOCH 1:100 000

TABLE A3 (Cont)

	#	Z	1	3	4	5	7	9	*	+	x	/	(	)	∅
	Sample Number	70090370	71912430	74915000	74915002	74915012	74915017	74915021	74915080	74915081	74915082	R4559	R4596	R4631	R4559
	Locality Grid Ref. **	L306302	R876134	L241198	R516242	R810247	R638281	R653331	L343418	L401149	A848917	QUARTZ	QUARTZ	QUARTZ	QUARTZ
	Stratigraphic Unit	pCsc	pCx	pCi	pCsc	pCsc	pCsc	pCsc	pC	pCm	pC	pCle	pChe	pChb	Bri
	Rock Type Symbol	fn_z	f(r)	f	f	f	f	f	f	f	f	f	f	f	f
	Diopside En_x	0.56	0/28		0.57		3.50		0.06						
	Hypersthene	11.80	6.73	6.17	3.69	1.45	2.75	0.56	15.55	1.83	4.88	0.45	10.91	8.46	7.27
	Olivine Fo_x														
NORM	Quartz	17.58	23.51	39.62	37.22	37.06	40.28	34.93	20.69	34.77	30.14	37.72	18.96	53.56	16.26
	Corundum			2.70		0.88		2.02		1.78	0.70	1.74	0.93	2.67	0.20
	Zircon			0.04	0.79	0.06	0.07	0.07	0.05	0.02	0.05				
CIPW	Orthoclase	6.09	15.73	15.97	27.90	39.23	4.72	44.84	14.56	30.87	24.25	26.24	30.54	13.47	20.35
	Albite	32.16	33.02	26.54	22.67	14.38	21.81	6.36	19.48	25.85	23.44	24.88	18.66	11.43	28.29
	Anorthite	30.31	18.06	6.41	3.04	3.05	21.04	0.56	23.71	3.61	13.25	8.39	16.28	8.66	24.83
	Nepheline														
	Leucite														
	Magnetite	0.75	1.83	1.10	2.89	2.98	3.67	1.17	2.94	0.96	2.53		1.55	0.34	1.16
	Chromite	0.03	0.02		0.02		0.01	0.01	0.03		0.01				
	Ilmenite	0.54	0.71	0.69	0.54	0.66	1.12	0.84	2.19	0.04	0.12		1.49	0.71	1.03
	Rutile														
	Apatite	0.19	0.12	0.50	0.02	0.12	0.26	0.12	0.08	0.17	0.39	0.08			
	Calcite			0.23	0.45	0.11	0.80	0.11	0.12	0.12	0.23	0.14	0.69	0.53	0.62
	Mg-No.	63.61	59.36	39.35	34.90	42.49	35.75	19.50	44.02	42.82	40.87	100.0	45.60	44.88	50.60
	Plagioclase An_x	48.51	35.36	19.45	11.82	17.48	49.09	10.34	54.90	12.26	36.12	25.22	46.60	43.10	46.74
	Density	2.77	2.74	2.75	2.71	2.68	2.78	2.71	2.87	2.68	2.72	2.65	2.78	2.77	2.74
RATIOS	Solidification Index	26.26	15.30	9.55	6.00	4.38	9.13	3.69	17.82	3.43	7.52	2.27	13.78	16.93	13.10
	Differentiation Index	55.83	72.26	82.13	87.79	90.68	66.81	85.13	54.72	91.49	77.83	88.64	68.16	78.46	64.91
	K_2O/Na_2O	0.26	0.66	0.83	1.44	3.85	0.31	7.57	1.04	1.69	1.44	1.61	2.34	1.69	1.03
	Total iron	3.39	3.22	3.32	4.14	3.13	5.05	4.32	8.07	1.39	3.75	0.33	5.27	3.30	3.42
	K/Rb														

FOOTNOTE ** L = LAUCHLEN 1:100 000; B = BURT 1:100 000; R = RIDDOCH 1:100 000

TABLE A4: Geochemical analyses of cordierite–sillimanite gneiss (i), cordierite quartzite (in_1), cordierite granulite (in_2), garnet–biotite quartzofeldspathic gneiss (f), and muscovite–biotite–clinozoisite–hornblende gneiss (h).

		I	J	K	L	Y	X
	Sample Number	73914512	73914155	72913255	72913509	70090223	70090201
	Locality Grid Ref **	B953379	B957420	L318524	R518272	R687300	R815325
	Stratigraphic Unit	pCsw	pCsr$_2$	pCsf	pCso	pCsc	pCsb
	Rock Type Symbol	i	f(in_1)	in_2	in_2	vf	h
MAJOR OXIDES	SiO_2	58.02	72.85	47.99	51.13	71.03	69.23
	Al_2O_3	21.80	12.58	16.58	18.40	12.26	11.95
	Fe_2O_3	3.09	1.86	1.13	3.72	1.01	3.20
	FeO	5.70	2.47	9.25	5.10	3.33	4.42
	CaO	0.51	3.31	0.43	11.17	0.45	3.19
	MgO	3.32	0.93	20.00	4.61	1.72	0.10
	Na_2O	1.22	3.05	0.32	2.98	1.21	3.15
	K_2O	4.20	1.03	1.45	0.58	6.66	2.56
	TiO_2	0.81	0.65	1.16	0.97	0.40	0.50
	MnO	0.08	0.04	0.03	0.17	0.03	0.18
	P_2O_5	0.06	0.08	0.05	0.14	0.05	0.06
	H_2O^+	0.41	0.26	0.63	0.32	0.34	0.11
	H_2O^-	0.17	0.22	0.06	0.08	0.14	0.11
	CO_2						
	$S(SO_3)$						
		99.40	99.33	99.09	99.38	98.62	98.76
TRACE ELEMENTS	Cu	4	10	6	4	22	10
	Co	28	8	30	36	6	2
	Ni	55	5	70	65	5	5
	Cr	130	70	230	100	25	15
	V	170	95	430	300	30	30
	Sr	55	105	11	280	44	100
	Rb	150	28	80	5	230	105
	Ba	980	660	190	150	1450	660
	Ce	150	180	60	50	130	120
	Sc	8	3	10	10	8	3
CIPW NORM	Diopside En_x				15.86		4.23
	Hypersthene	15.05	4.30	64.75	8.88	9.10	3.06
	Olivine Fo_x						
	Quartz	25.91	42.23	3.61	3.12	33.08	33.29
	Corundum	14.52	0.55	14.01		2.26	
	Zircon						
	Orthoclase	25.57	6.52	8.83	3.52	40.77	15.67
	Albite	10.43	26.06	2.75	25.44	10.41	27.01
	Anorthite	2.18	16.09	1.84	35.42	1.95	10.89
	Nepheline						
	Leucite						
	Magnetite	4.60	2.77	1.86	5.58	1.50	4.72
	Chromite	0.07	0.04	0.12	0.05	0.01	0.01
	Ilmenite	1.55	1.25	2.24	1.86	0.77	0.96
	Rutile						
	Apatite	0.14	0.19	0.12	0.34	0.12	0.14
	Calcite						
RATIOS	Mg-No	50.96	40.18	79.41	61.73	47.96	3.88
	Plagioclase An_x	17.28	38.17	40.07	58.20	15.79	28.74
	Density	2.98	2.75	3.31	2.95	2.74	2.78
	Solidification Index	18.94	9.96	62.21	27.13	12.35	0.74
	Differentiation Index	61.91	74.81	15.19	32.08	84.25	75.98
	K_2O/Na_2O	3.44	0.34	4.53	0.19	5.50	0.81
	Total iron	8.48	4.14	10.27	8.45	4.24	7.30
	K/Rb						

FOOTNOTE ** L = LAUCHLEE 1:100 000; B = BURT 1:100 000; R = RIDDOCH 1:100 000

B1. Guide to Prefix Codes for Registered Numbers

Range of Nos.	Prefix Code for Map	Registered No. or Prefix	Author and Survey
4000 - 5000	R	-	Joklik, (1955); Harts Range
400 - 453			Forman, Milligan & McCarthy (1967)
	W	68110	A.J. Stewart, Arltunga Nappe Complex
	Y	68180	A.J. Stewart, Altunga Nappe Complex.
0 - 23		6718, 6818	R.D. Shaw, (N.T. Mines Branch, 1968) Pinnacles Copper Deposit area.
518 - 524		6807	D. Gellatly, (Record 1969/77) - Mud Tank Carbonatite.
524 - 783		6909	Forman & Shaw (1973); metamorphic Map of Central Australia.
		69090369-0389	D. Gellatly, Mud Tank area.
P1 - P20	P	70090275-393	R.D. Shaw, Johannsen's phlogopite Mine.
791 - 1275		7009001-0036, 1152-1250	R.D. Shaw, Arltunga Nappe Complex. Results in Forman & Shaw (1973).
1700 - 2000	Z	7191	A.J. Stewart, Arltunga Nappe Complex, Giles Creek Synform.
1300 - 1599		7191	J. Funk (ANU) - Western Arltunga Nappe Complex; M.J. Rickard (ANU) - Harts Range.
1600 - 1699		7191	M.J. Rickard (ANU) - Harts Range.
2000 - 2300		7191	M. Yar Khan (ANU) - Arltunga Nappe Complex Arltunga Range.
2400 - 2608		7191	R.D. Shaw, Arltunga Nappe Complex, Star Creek, North of Claraville homestead.
7071 - 7080		71917071-80	S. Smith and W. Dallwitz.

B1. (cont'd)

Range of Nos.	Prefix Code for Map	Registered No. or Prefix	Author and Survey
7092 - 7111		7092 - 7111	Chemical analyses, Johannsen's phlogopite Mine.
3200 - 3472		7291	A.P. Langworthy, N.E. LAUGHLEN
3500 - 3735		7291	R.D. Shaw, LAUGHLEN
4000 - 4049		7291	A. Allen (Uni. Qld), S.W. Johannsen's Phlogopite Mine
5610 - 5690		7291	J. Funk (ANU) Georgina Gap area, Arltunga Nappe Complex.
2611 - 2782		7391	R.G. Warren, Oonagalabi Mineralisation.
4050 - 4557		7391	A.P. Langworthy, BURT.
3736 - 3999	D	7391	L.A. Offe, ALICE SPRINGS.
	E	7491	L.A. Offe, ALICE SPRINGS.
4700 - 4731	F	7591	L.A. Offe, ALICE SPRINGS.
4560 - 4561		7591	A.P. Langworthy
	M	ANU Collection	M.J. Rickard (ANU), Harts Range.

B2. Analysed rocks from the Mordor Igneous Complex described by Langworthy & Black (1978).

Registered Number	Grid Reference	Rock Type	Mapped as
72 91 3434	476 086	Hyalophane-phlogopite Iherzolite	
7291 34 35	475 087	As above	
7291 3438	475 081	Phlogopite hypersthene shonkinite	
7291 3441	476 076	Phlogopite Iherzolite	
7291 3446	465 061	Phlogopite shonkinite	
72 91 3450	465 069	Phlogopite wehrlite	
72 91 3452	465 073	As above	
7391 3439	473 068	Calcite-rich serpentinised breccia	
73 91 4142	470 085	Syenite	
73 91 4182	468 082	Shonkinite	
73 91 4204	465 053	Melamonzonite	
7391 4213	453 058	Monzonite	
7491 3017	465 083	Granite pegmatite	
7491 3018	465 083	As above	
74 91 4193	480 078	Phlogopite-quartz-calcite rock	
74 91 6008	469 092	Quartz-chlorite-calcite rock.	
75 91 4560	469 092	As above, (drill core)	
75 91 4602	452 054	Melamonzonite	
75 91 4607	452 095	Barite Rock	

B3. Chemically analysed samples plotted on a 1st edition BURT-LAUGHLEN map and discussed in text.

Registered Number	Grid Reference	Rock Type		Unit
70090270 (As 932A)	306 302	Felsic granulite (Intermediate composition)	(fn_2)	Cadney metamorphics
72913202	448 548	Amphibolite	(a)	pGsf
72913205	448 533	Garnetiferous mafic granulite	(mv)	pGsf
72913230	236 547	Felsic granulite (Intermediate composition)	(fn_2)	pGsf
72 91 3232	235 548	Mafic granulite	(mn)	pGsf
7291 3241	192 546	Mafic granulite	(mn)	pGsf
7291 32 69	343 418	Mafic granulite	(mn)	pGu
7291 3500	083 464	Mafic granulite	(mn)	pGsp
72 91 3502	064 422	Mafic granulite	(mn)	Cadney metamorphics
7291 3504	447 239	Mafic granulite	(mn)	Ongeva granulite
7391 4110	958 262	Amphibolite	(a)	Sliding Rock metamorphics
7391 4120	972 266	Amphibolite	(a)	As above
73 91 4126	901 247	Metagabbro	(gb)	As above
73 91 41 55	937 420	Quartzofeldspathic gneiss	(f)	Frontonga metamorphics
73 91 4224	887 459	Mafic granulite	(mn)	As above
7491 5080	343 418	Hornblende gneiss	(h)	pG, undivided

B4. Specimens plotted on 1st edition BURT-LAUGHLEN map. The specimens were collected in 1978 (not discussed in text) and submitted for analysis, but results are not available.

Registered Number	Grid Reference	Rock Type	Unit
7891 6500	075 306	Cordierite-felsic granulite (if)	Erontonga metamorphics
7891 6507	405 318	Garnet-hornblende quartzofeldspathic gneiss (f,cs)	Cadney metamorphics
7891 6509	424 393	Quartzofeldspathic gneiss (f)	pGu
7891 6510	416 386	K-feldspar-quartz-scapolite rock (f,cs?)	pGu
7891 6511	416 386	(Garnet)-biotite quartzofeldspathic gneiss (f)	pGu
78 91 65 13	421 370	Migmatitic quartzofeldspathic gneiss (f,mi)	Ongeva granulite
78 91 6514,15	421 370, 425 370	Quartzofeldspathic gneiss (f)	As above
78 91 6576	076 308	Mafic granulite (mn)	Erontonga metamorphics
7891 6577	079 307	Cordierite felsic granulite (if)	As above
7891 6590	994 559	Quartzofeldspathic gneiss (f)	Yambah granulite
7891 6642	434 288,	Scapolite calc-silicate rock (cs)	Ongeva granulite
7891 6643	430 413	Orthoamphibolite (a)	pGu
7891 6650	432 413	Quartzofeldspathic gneiss (granitic) (f)	pGu

C. Revisions to Stratigraphic Nomenclature between Preliminary and 1st Editions 1:100 000 maps.

1ST EDITION MAP		PRELIMINARY MAP		REMARKS
NAME OF UNIT	SYMBOL	NAME OF UNIT	SYMBOL	
	Tw	Waite Formation	Tw	Symbol Tw used for correlates of Waite Formation
Silcrete	Ts	Silcrete	Tls	Age uncertain
Hale Formation	Th	Arlunga Beds	Tr	
	Thg	Sandstone	Ts	Boulder Conglomerate
Mordor Igneous Complex	Bm_1, Bm_2	Mordor Complex	Bm_1, Bm_2	
Harry Creek Deformed Zone	Pzr Brh	Harry Creek Deformed Zone	pGr_h	
West Bore Deformed Zone	Pzr Brw	West Bore Retrograde Zone	BrW, Brw_2	Most deformed part of Retrograde Zone retains name
Southern Cross Schist Zone	Pzr Brs	Southern Cross Schist Zone	pGr_s	
Narbib Deformed Zone	Pzr Brn	Narbib Deformed Zone	pGr_n	
Redbank Deformed Zone	Brr	Redbank Deformed Zone	pGr_r	

C. Stratigraphic Revisions (continued)

Georgina Gap granitic gneiss	Bge	Georgina Gap Granite	pGgg	Granite has gneissic fabric
Jennings Granitic Gneiss	Bgn	Jennings Granitic Gneiss	pGg_n	
Anamarra orthogneiss	Bgm	Anamarra Orthogneiss	pGg_a	
Oolbra orthogneiss	Bgo	Oolbra Orthogneiss	pGg_o	
Trephina Granitic gneiss	Bgr	Trephina Granite	pGg_t	
Laughlen metamorphics	pGl	Mount Laughlen Metamorphics	pGl	
Iwupataka Metamorphic Complex	Bab, Bar, Bac, Bas	Sequence of the Alice Valley	Bab, Bar, Bac, Bas	
Hayes Metamorphic Complex	pGpd pGpt pGpp pGpe pGpb	Hayes Complex	pGpd pGpt pGpp pGpe pGpb	
	pGj	Coyler Gneiss	pGj	Changed to unnamed informal status
	pGp	Forster Gneiss	pGp	As above

C. Stratigraphic Revisions (continued)

Mulga Creek granitic gneiss	pGm	Mulga Creek Gneiss	pGg_m	
Ankala gneiss	pGa	Ankala Gneiss	pGa	
Sliding Rock metamorphics	pGi	Sliding Rock Metamorphics	pGi	
Randall Peak metamorphics	pGr	Randall Peak Metamorphics	pGr	now incorporates unnamed unit pGf
		unnamed unit	pGf	
	pGu	West Bore Retrograde Zone	Brw_1 Brw_3 Brw_4	
Ingula migmatite suite	pGsi	Ingula Migmatite Complex	pGs_i	
Wuluma granitoid	pGsw	Wuluma Granite	pGs_w	
Johannsen Metagabbro Dyke Swarm	pGsj	Mafic granulite (mn)	pGs_r	mapped as mafic granulite (mn). in Erontonga Granulite, pGsr
Hillsoak Bore metamorphics	pGz		pGsc, pGr_s	Previously mapped as part of Cadney Gneiss and Southern Cross Schist Zone
Cadney metamorphics	pGsc	Cadney Gneiss	pGs_c	Joklik (1955)
Anuma schist	pGss	Anuma Schist	pGs_s	
Erontonga metamorphics	$pGsr_1$, $pGsr_2$, pGr_3	Erontonga Granulite	pGs_r	$pGsr_1$ is the type area at granulite facies; $pGsr_2$ is in N.W. (i.e. BURT) is at granulite facies but more pelitic; $pGsr_3$ is in S.E. LAUGHLEN and is at Amphibolite facies

	pGsf		Brw$_5$	Partly retrogressed rocks recognised as part of Strangways Metamorphic Complex
Narbib granulite	pGsn	Narbib Gneiss	pGn	Considered to be part of Strangways Metamorphic Complex
Yambah granulite	pGsy	Yambah Granulite	pGs$_y$	
	pGsp	Mount Pfitzner Granulite	pGs$_p$	Not mapped in sufficient detail to warrant formal status
Ongevea granulite	pGso	Ongeva Granulite	pGs$_o$	
Harry Anorthositic Gabbro	pGsh	Harry Anorthositic Gabbro	pGh	A.R.A. prefers name 'Harry Gabbro-Anorthosite'.
Utnalanama granulite	pGsu	Ultralanama Granulite	pGs$_u$	A.R.A. prefers name 'Utnalanama Granofels'.
Adla Granulite	pGsa	Adla Gneiss	pGs$_a$	