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REGIONAL GEOLOGY AND STRUCTURE OF THE NORTH-EAST MARGIN, AMADEUS BASIN, NORTHERN TERRITORY

PART I

by

D.J. FORMAN & E.N. MILLIGAN

PART II (PETROLOGY)

by

W.R. McCARTHY

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REGIONAL GEOLOGY AND STRUCTURE OF THE NORTH-EAST MARGIN, AMADEUS BASIN, NORTHERN TERRITORY

PART I

SUMMARY

The north-eastern margin of the Amadeus Basin contains outcrops of the Heavitree Quartzite and Bitter Springs Formation of Upper Proterozoic age resting unconformably on the crystalline Arunta Complex 'basement'. The Bitter Springs Formation is in turn overlain with disconformity and slight unconformity by an essentially conformable sequence of about 14,000 feet of marine Upper Proterozoic, Cambrian and Ordovician sediments. The orogeny which produced the moderate grade metamorphic rocks of the Arunta Complex has been named the Arunta Orogeny and the orogeny which deformed the Precambrian and Palaeozoic rocks under low grade metamorphic conditions has been named the Alice Springs Orogeny.

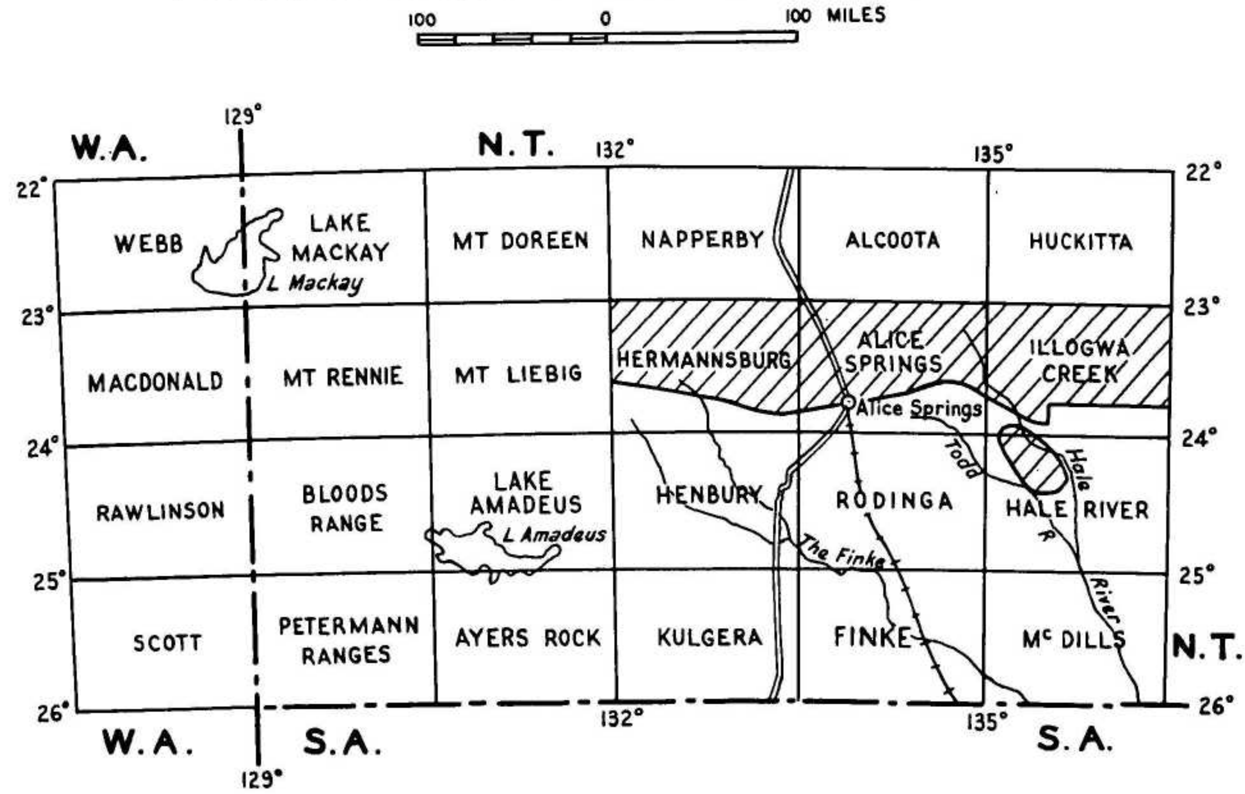
The Alice Springs Orogeny has caused upwarping and the development of two nappe complexes - the Arltunga Nappe Complex and the Ormiston Nappe Complex - along the margin of the Amadeus Basin and folding and thrusting of the sediments over two decollement surfaces within the Amadeus Basin. The decollement surfaces developed in incompetent evaporitic beds within the sedimentary succession. At the commencement of the orogeny late in the Ordovician the sea receded from the area and the Mereenie Sandstone was deposited during the Ordovician to Devonian under predominantly continental conditions. The main climax of the Orogeny occurred in the Devonian when the continental clastic sediments of the Pertnjara Formation were deposited and folded.

Within the Nappe Complexes the Arunta Complex and the Heavitree Quartzite have moved southwards up to 15 miles over the incompetent Bitter Springs Formation into the Amadeus Basin. The Arunta Complex has suffered deformation and retrograde metamorphism which is described in part II.

During the Mesozoic, flat lying sandstone and siltstone were deposited in the south-east of the area marginal to the Great Artesian Basin. The ?Tertiary sediments are lacustrine and fluviatile deposits with a laterite or duricrust profile within the sequence. The Quaternary sediments include red-brown alluvium, red earth soils and aeolian sands.

FIG. 1

1:250,000 SHEET INDEX AND LOCALITY MAP



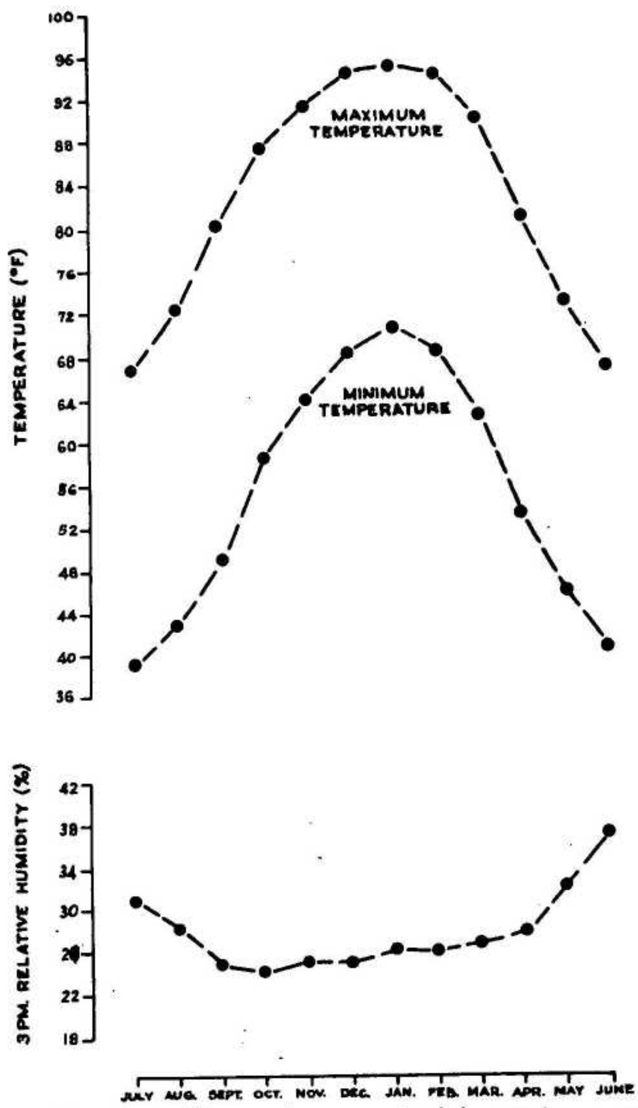
LOCALITY MAP

Bureau of Mineral Resources, Geology and Geophysics, March 1965

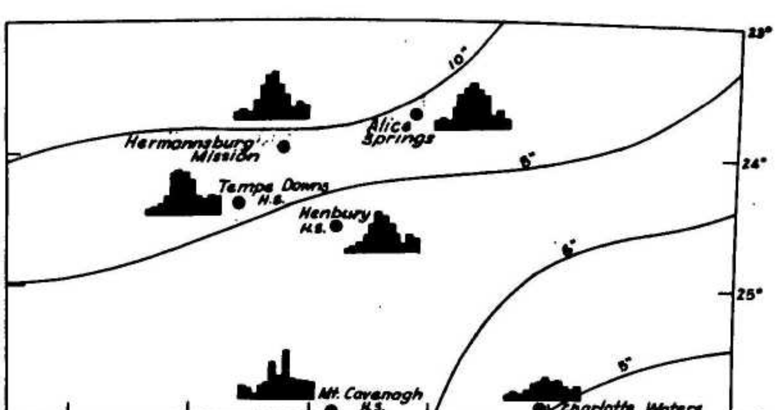
To accompany Record 1965/44 *NT /A/92*

FIG 2

TEMPERATURE, RELATIVE HUMIDITY & RAINFALL (ADAPTED FROM CSIRO 1962)



Mean monthly maximum and minimum temperatures and 3p.m. relative humidity for Alice Springs



Isohyets and histograms of annual rainfall distribution (July to June) at recording stations.

INTRODUCTION

The area described in this report (see Fig. 1) was mapped as part of the regional survey of the Amadeus Basin.

Access

The area is accessible by graded roads from the main Adelaide-Alice Springs-Darwin road (see Fig. 3) and by numerous graded roads and vehicle tracks, usually in poor condition. Parts of the more rugged terrain are inaccessible, or almost inaccessible, to Landrover vehicles. Access to the Simpson Desert was by helicopter but the northern and western side of the area is served by dirt roads from Nummery, Limbla, Indiana, White Quartz Hill and Plenty River Downs Station homesteads; the desert country can be negotiated by Landrover.

Climate

Figure 2 gives the mean monthly maximum and minimum temperatures and 3 p.m. relative humidity for Alice Springs. Isohyets and histograms of annual rainfall distribution at Alice Springs and surrounding recording stations are also given. The area is subject to droughts and the combination of drought, overgrazing and strong prevailing south-easterly winds can produce severe dust storms.

Development

The area has been developed for cattle grazing. On the Hermannsburg, Alice Springs and Illogwa Creek Sheet areas, totalling about 20,000 square miles, there are about 25 station homesteads, but several of these are only inhabited in good seasons. From each station homestead there is a network of tracks to the cattle watering points on the station. The cattle water from bores, dams, wells and waterholes. There are a number of unsuccessful bores in the area and these generally have a rough track leading to them.

The western side of the Hermannsburg Sheet area lies within a native reserve and Hermannsburg, Jay Creek and Amoonguna are native settlements. The natives in the area are no longer truly nomadic and most of them live on the settlements, at Alice Springs or on the station property at which they are employed. The natives and the settlements have developed a considerable local industry in native paintings and artifacts.

Alice Springs, in the centre of the area, is the only town. The population is about 3,500 but this figure increases during the winter months when tourism reaches a peak. Alice Springs is the terminus of the railway line from Adelaide and is connected to Darwin by a sealed road (the Stuart Highway). The Adelaide to Darwin air service passes through Alice Springs. The area about Alice Springs is served by Connellan Airways which flies a regular run to most of the stations in the area and provides transport to tourists.

The pleasant winter climate and the spectacular scenery throughout most of the area have lead to the development of a rapidly growing tourist industry centering about Alice Springs.

Alice Springs is a centre for the Royal Flying Doctor Service and a telegram and medical service to and from outlying areas, is available. The Department of Health provides medical and dental services to outlying areas in conjunction with the Royal Flying Doctor Service.

The Northern Territory Administration has established branches of Animal Industries, Water Resources, Mines, Agricultural, Lands and Survey and Social Services. The Bureau of Mineral Resources provides geologists to the Northern Territory Administration for assistance in the development of the mineral and water resources of the

Northern Territory. C.S. & I.R.O. Division of Land Research and Regional Survey has until recently maintained a regional office in Alice Springs to examine methods of pasture improvement and to conduct experimental work on small catchments. The Commonwealth Department of Works is the prime Commonwealth contracting authority in the construction of roads, aerodromes, housing and essential services.

The Division of National Mapping of the Department of National Development is responsible for the compilation of topographic maps at photoscale and their production at 1:250,000. Surveyors from the Department of the Interior have provided levels for use by the Bureau of Mineral Resources in geophysical surveys.

The mining centres of Winnecke, Arltunga and White Range are now abandoned as are the mica mines in the Harts Range area. The Harts Range Police Station is maintained on Mount Riddock Station near the north-eastern corner of the Alice Springs Sheet area.

Survey Method

Mapping was carried out by Landrover traverses from base camps at Arltunga on the Alice Springs Sheet area and Boggy Hole Bore on the Hermannsburg Sheet area.

Nine one-day helicopter traverses were made from Arltunga and White Quartz Hill Station homestead.

The geology was plotted on aerial photographs at a scale of about 1:46,000. The geology was transferred to transparent controlled slotted template assemblies which were reduced photographically to a scale of 1:250,000.

PREVIOUS INVESTIGATIONS (E.N.M.)

The area was first visited by the explorer Stuart, in 1860 (Stuart, 1865).

Probably in 1888, East (1889) made observations on the geology between Alice Springs and the Harts Range. He noted the Arunta Complex, Heavitree Quartzite and Bitter Springs Formation but did not name them. He described the "zigzag contortions of striking aspect in the Bitter Springs Formation near Bitter Springs".

In 1888 and 1890, H.Y.L. Brown (1889, 1890) made a reconnaissance survey of the gold fields near Arltunga and in 1902 he made a detailed survey of the gold fields (Brown, 1902, 1903). He recognized that the plutonic rocks were overlain by sediments of possible Cambrian age.

Fossils were first found in the Amadeus Basin by Brown and Thornton in 1890, probably near Tempe Downs (Brown, 1892; Etheridge, 1892). Etheridge reported on additional fossils in 1893.

In 1894, Tate and Watt (1896), geologists of the Horn Expedition to Central Australia, collected many fossils from the Larapinta Group and gave their age as Ordovician. They placed all the sedimentary rocks in the Ordovician system. Ward (1925) followed this proposal and suggested a Precambrian age for the ore-bearing quartzites at Arltunga.

Chewings (1891, 1894, 1914, 1928, 1935) made his first visit to the area in 1891. He proposed a Cambrian and Ordovician age for the sedimentary rocks and suggested that the basal members of these sediments (in particular the Arltunga-White Range and Chewings Range quartzites) were infolded and partly assimilated in the older basement.

Investigations by Mawson and Madigan (1930) in 1927 and Madigan (1932a and b, 1933) from 1929 to 1931, showed that the sedimentary succession could be divided into several units and that these ranged from Upper Proterozoic to Permian age. Madigan (1932a) proposed a subdivision of the rocks into Archaean (Arunta Complex), Upper Proterozoic (Pertaknurra and Pertatataka Series), Cambrian (Pertaoorrta Series) and Ordovician (Larapintine Series).

Hodge-Smith (1932) visited the area in 1929 and proposed a division of the Arunta Complex into six units and postulated at least one unconformity within the complex.

Ellis (1937) visited the area in 1936. He correlated the quartzite in the Petermann Ranges and Rawlinson Range, with the Pertaknurra quartzite at Heavitree Gap, near Alice Springs. He also observed the concordance of strike of the Heavitree Gap quartzite with that of the Arunta Complex and concluded that this quartzite, as well as the Winnecke - Arltunga quartzites, were part of the Arunta Complex.

During the years 1935 to 1941, geologists of the Aerial, Geological and Geophysical Survey of Northern Australia (A.G.G.S.N.A.), principally Voisey (1939) and Hossfeld (1936, 1937a, b and c, 1940 and 1954), investigated mineral occurrences in the area and recorded observations on the regional geology. In particular, they recognized structural and lithological differences between the Heavitree Quartzite and the White Range Quartzite and included the latter in the Arunta Complex.

Other observations on the geology of the region were made by Jensen (1945), Hills (1946), Browne (1950), Noakes (1953, 1956), Öpik (1956) and Walpole et. al. (1965), but the first comprehensive regional map was made in 1951 by Joklik (1955), during his survey of the Harts Range mica fields. Joklik subdivided the Arunta Complex into several units, separating intrusive and metamorphic rocks of different grade, and revised the nomenclature of Madigan (1932a) to conform to the Australian Code of Stratigraphic Nomenclature. He emphasized the differences between the Heavitree Quartzite and the White Range Quartzite, but proposed for the latter a Lower Proterozoic age and considered it to lie unconformably on the Arunta Complex and unconformably under the Heavitree Quartzite.

Officers of the Bureau of Mineral Resources, engaged in a search for radioactive minerals, made the next contributions to the geology, and some of their findings have been recorded in Daly (1951) and in Ryan (1957). Wilson, Compston, Jeffery and Riley (1960) and Walpole and Smith (1961) reported on the results of radioactive age determinations in the area.

In 1956, Prichard and Quinlan (1962) began a regional mapping programme of the Amadeus Basin at 1:250,000 scale by mapping the southern half of the Hermannsburg Sheet area. Wells, Forman and Ranford (1965a, 1965b), Forman (1965), Ranford, Cook and Wells (1965) and Wells, Stewart and Skwarko (1965c) continued this programme into neighbouring areas to the west and south during the years 1960 to 1963. An initial photo-interpretation of the region was carried out in 1960 by the Institute Francaise du Petrole (Scanvic, 1961).

Quinlan (1962) and Ryan (1962) reported on the geology; Mabbutt (1962) on the geomorphology, and Jones and Quinlan (1962) on the ground water resources of the area as part of a regional land research study by the Commonwealth Scientific and Industrial Research Organization in 1957 and 1958. Perry, Quinlan, Jones and Basinski (1963) made an assessment of the ground water potential of the area with regard to its agricultural significance. Other observations on ground water, particularly in the Alice Springs Town Basin, have been made by Owen (1952, 1954), Jones (1957) and Quinlan and Woolley (1962, 1963).

An early regional gravity traverse into the Amadeus Basin was made by Marshall and Narain (1954). In 1961 and 1962, the Geophysical Section of the Bureau of Mineral Resources completed a regional gravity survey which includes the area (Langron 1962, Lonsdale and Flavelle 1963).

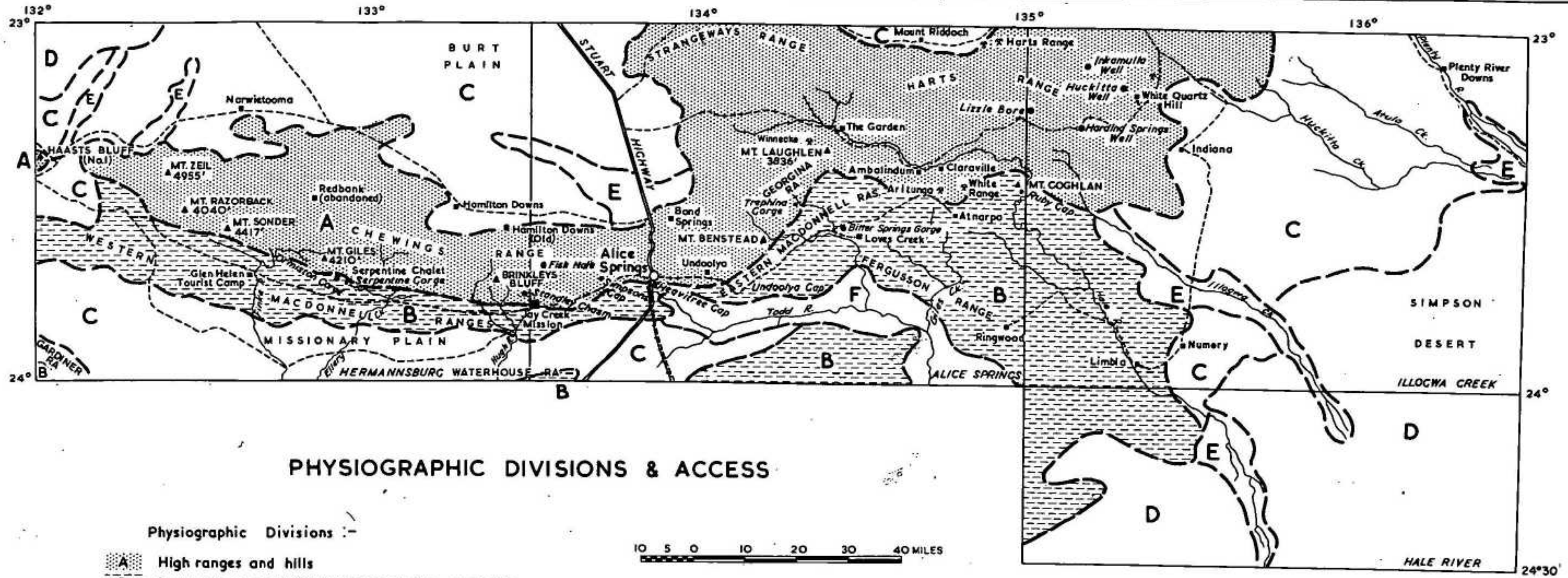
Aeromagnetic surveys within the area are as follows: Total magnetic intensity maps at 1:250,000 of Hale River (G53/B 1-19) and southern half of Illogwa Creek (F53/B 1-7). Both compiled from an airborne magnetic survey of part of the Simpson Desert made in 1962 by Aero Service Limited (Quilty and Milsom, 1964) under contract to the Bureau of Mineral Resources. A map (F53/B 1-19) of the northern half of the Illogwa Creek Sheet area at 1:250,000 showing total magnetic intensity profiles and geology prepared by the Bureau of Mineral Resources. Some reconnaissance aeromagnetic profiles to the west of Alice Springs have been reported by Goodeve 1961.

Seismic surveys have been carried out by the Bureau of Mineral Resources: Dyson and Wiebenga (1957), Turpie and Moss (1963) and Moss (1964).

During 1956 to 1960, Frome-Broken Hill Co.Pty Ltd. made an appraisal of the petroleum potential of the Amadeus Basin, and as part of this programme, Thomas (1956) reviewed previous geological work and McLeod (1959) reported on the north-eastern part of the Amadeus Basin.

Jaccard (1961) has made a geological reconnaissance of the Amadeus Basin for Conorada Petroleum Corporation.

FIG 3



PHYSIOGRAPHIC DIVISIONS & ACCESS

Physiographic Divisions :-

A	High ranges and hills
B	Low ranges and hills with intervening sand plain
C	Sand plain with some dunes and low outcrop
D	Sand plain with longitudinal dunes
E	Alluvial flood plains with some claypans
F	Gibber or alluvial plains with mesas and low hills

10 5 0 10 20 30 40 MILES

LEGEND

Atnarpa ■	Homestead
	Highway
	Road
	Railroad
Winnecke	Abandoned mining field

McNaughton (1962) made an assessment of the petroleum prospects of Oil Permits 43 and 46 in the Amadeus Basin for Magellan Petroleum Corporation, and Hopkins (1962), of this company, has measured numerous stratigraphic sections in the Amadeus Basin. Banks (Magellan Petroleum Corp.) has made a reconnaissance study of the Basin (Banks, 1964). Morgan (1961, 1963) described rock specimens from within the Arltunga Nappe Complex and made a petrographic study of a sample of spilite from the Bitter Springs Formation, which was recovered in Ooraminna No.1 well.

Lloyd (1965) has described the ?Tertiary geology of the area.

Wells _et_. _al_. (1965d), are currently preparing a report on the area to the south of the area described in this report.

Geochemical sampling within the Hale River drainage basin on the Alice Springs Sheet area and the Alice Valley of the Hermannsburg Sheet area was carried out concurrently with the geological investigation in this report but the preliminary results are not encouraging.

PHYSIOGRAPHY (E.N.M.)

The area has been divided into six physiographic regions (Fig 3). (See also C.S. & I.R.O., 1962).

High ranges and hills : This region comprises extensive ranges with intermontane basins and minor alluvial pockets. The sharpest topography is formed by quartzite ridges which reach heights of over 4,000 feet above sea level. Most of the crystalline and metamorphic rocks have subdued relief; an exception is Mount Zeil, in the west of the area, which at 4,955 feet above sea level, is the highest mountain in the area.

Low ranges and hills with intervening sand plain : This region comprises low but sharp ridges, rarely over 500 feet high, aligned with long, narrow valleys.

Sand plain with some dunes and low outcrop : This region comprises extensive plains of low relief, 1,800 to 2,300 feet above sea level in the north, and below 1,000 feet in the south-east. These plains are composed of alluvial outwash and some wind blown sand.

Sand plain with longitudinal dunes : Extensive dune fields are developed in the Simpson Desert. The dunes are mostly stabilised by vegetation and are linear, and parallel over many miles. They are oriented with the prevailing winds (north-north-west in the south-east and westerly in the north-west) and have gentle slopes on the west and south sides and steeper slopes on the east and north. The swales are flat or broadly concave with firmer surfaces and minor areas of hard ground.

Alluvial flood plains with some claypans : These border the rivers and comprise active flood plains encroaching on the sane plain and dune fields.

Gibber or alluvial plains with mesas and low hills : These occur south of Ringwood Station in the alluvial plain of the Todd River. They comprise wide plain areas with discontinuous strike ridges and some low rounded hills.

STRATIGRAPHY

On the north-eastern margin of the Amadeus Basin the crystalline igneous and metamorphic rocks of the Arunta Complex are overlain unconformably by the Heavitree Quartzite of Upper Proterozoic age. The Heavitree Quartzite is the basal formation of the Amadeus Basin sequence and is overlain by a generally conformable sequence of Upper Proterozoic, Cambrian and Ordovician sediments. The Cambrian and

Ordovician sediments. The Cambrian and Ordovician sediments are overlain with a regional unconformity by Ordovician-Devonian sediments which are overlain with regional unconformity by Devonian to ?Carboniferous sediments.

Mesozoic sediments occur in the south-east of the Illogwa Creek Sheet area in the Great Artesian Basin. Continental Tertiary and Quaternary sediments occur unconformably over the older sediments in much of the area.

In the area dealt with in this report only the Arunta Complex, Heavitree Quartzite, Bitter Springs Formation and some Mesozoic, Tertiary and Quaternary sediments were mapped. The remainder of the sedimentary succession and part of the Bitter Springs Formation is the subject of a separate report (Wells et. al., 1965d).

PRECAMBRIAN (E.N.M.)

Arunta Complex

Definition : Mawson and Madigan (1930) introduced the term Arunta Complex for the crystalline igneous and metamorphic rocks of the MacDonnell Ranges which were '....vastly older than the Heavitree Gap Quartzite.'

Chewings (1891) had proposed an order of succession in these rocks, from north to south, on the south side of the MacDonnell Ranges. This was '...chlorite schist; granite; micaceous schists and metamorphic granite with occasional outcrops of coarse eruptive granite and other eruptive rocks; quartzite; metamorphosed clays and shales interstratified with yellow and blue crystalline limestone.' It is evident that Chewings included Upper Proterozoic rocks in his 'older rocks'.

Moulden (1895) published the first petrographic observations on the Arunta rocks. He described 'altered amphibolite, altered diorite, augen gneiss and garnetiferous gneiss' from the upper reaches of the Hale River.

Tate and Watt (1896) observed that the Heavitree Quartzite rested with a marked angular unconformity on rocks of a 'highly metamorphic character'. They distinguished between metamorphics of sedimentary origin, those of eruptive origin and those of doubtful origin. They included in the first division the quartzites in the Chewings Range, but admitted that the stratigraphic position was doubtful. The third division comprised strongly foliated gneiss, acid-intermediate rocks (pyroxene diorite) and a basic group (gabbro and dolerite dykes).

Later workers recognized that a correlation of the structurally deformed and metamorphosed quartzite outliers in the Arunta Complex with the Upper Proterozoic Heavitree Quartzite introduced considerable implications with regard to the age, tectonic history and mineralisation of the Complex. Chewings (1928 p.63) stated that '...the Heavitree Gap and the Arltunga quartzites belong to a formation (Cambrian?) that was largely faulted down into and interfolded in and with the pre-Cambrian.' This was indicated, according to Chewings, as only one thick quartzite band had been observed infolded in the pre-Cambrian; more than one would be expected if the quartzite was an integral part of the tightly folded Arunta Complex.

Madigan (1932b, p.38) stated that '...the investigations...show clearly that this quartzite, together with portions of the still higher limestones, have been caught up in the later disturbances which the Arunta Formations have undergone.' Some of these limestones have been shown by later work to be part of the Arunta Complex.

Hodge-Smith (1932) followed the views of Chewings and Madigan. He proposed a classification of the Arunta Complex into:-

(i) Oolgarna Acid intrusives (upper unit)

(ii) The Everard Range Granite

(iii) The Ambalindum Series (altered limestone and schist)

(iv) The Augen Schist

(v) The Huckitta Creek Series (schists and gneisses of both sedimentary and igneous origin).

These rocks have been included by Joklik (1955) in his Harts Range Group; the Augen Schist is the Bruna Gneiss and the Ambalindum Series and Huckitta Creek Series are included, at least in part, in the Irindina Gneiss.

Voisey (1939) referred the Arltunga-White Range quartzites to the Archaean and contrasted their structural complexity with the relatively undeformed Heavitree Quartzite, which rested with 'violent unconformity' on the Arunta Complex. He listed the numerous characteristics that distinguish the two quartzites. These were :-

Heavitree Quartzite	Arunta Quartzite
orange-yellow, forming red-brown ranges.	pale yellow, forming white or light coloured hills.
massive.	streaky, rough fractures on schistosity planes.
uniform physical characteristics.	grades into schist along strike.
continuity of outcrop; underlying limestone and overlying Arunta unconformably.	lenticular bands associated with schist and gneisses.
gold absent.	gold occurrences.

Jensen (1945) listed some rock types in the Arunta Complex including gneissic and 'gneissed' igneous rocks, some of which were formed from basic tuffs. He recognized a younger formation of quartzite, slate and schist, unconformable on the gneiss, and composed of 'remnants' of the Pertaknurra Series.

Hossfeld (1954) divided the Arunta Complex into two divisions. The older rocks (originally conglomerate, arkose, grit, sandstone, mudstone, limestone, volcanics and intrusives regionally metamorphosed, granitised and intruded by basic dykes) he considered to be Lower Archaean. He named these the Arunta Series. The rocks of the Harts Range, in which granite-gneisses were absent, he named the Riddock Series and referred them to the Upper Archaean. The White Range Quartzite and 'associated rocks' he considered to be probably Middle Proterozoic in age.

Joklik (1955) mapped the rocks comprising Hossfeld's Riddock Series. He called these the Harts Range Group and proposed a subdivision into five units. These were (oldest first):-

Entia Gneiss - acid mica-quartz-feldspar gneiss, in places kyanite rich and including narrow bands of amphibolite.
Bruna Geniss - conspicuously porphyroblastic in potash feldspar.
Irindina Gneiss - garnet-mica-feldspar gneiss; some sillimanite-garnet-mica-feldspar gneiss; and the Riddock Amphibolite.
Brady Gneiss - garnet-mica-feldspar gneiss with bands and lenses of quartzite, metamorphosed calcareous sediments and amphibolite.
Cadney Gneiss - most commonly fine-grained quartzo-feldspathic gneiss.

All formations of the Harts Range Group contained bands, lenses, plugs, dykes, sills or other masses of metamorphosed basic igneous rocks. Some were contemporaneous with the Riddock Amphibolite, others were younger than the Cadney Gneiss, none were younger than the acid and intermediate plutonic rocks and associated pegmatites and aplites. Four of the largest of these acid intrusives were named the Inkamulla Granodiorite, the Huckitta Granodiorite, the Bungitina Granodiorite and the Schaber Hornblende Granite.

The Entia Gneiss occupies an area of 300 square miles in the western Harts Ranges. It is intruded by the Huckitta and Inkamulla Granodiorites, and is overlain by the Bruna Gneiss. A specimen collected by Joklik (R4559) is characteristic of the gneiss and is composed of approximately equal parts of quartz and microline with somewhat less andesine and 1.7% mica. The fabric is granoblastic and all minerals in the rock are fresh and completely recrystallised. Joklik suggests that the unusual association of large proportions of free quartz and microperthitic microcline with subordinate andesine indicates that the rock is a hybrid, and that andesine is a relic of the original composition of the rock before the metasomatic introduction of potash and soda. Its chemical composition is characteristic of palingenetic granites which are formed by the soaking of granitic material into more basic rocks.

This is the most intensely metamorphosed formation in the Harts Range Group but kyanite and sillimanite are generally absent, indicating a high potassic composition. This potash has been introduced during a later metamorphism when kyanite in the kyanite-bearing Entia Gneiss has been retrogressively metamorphosed to sericite. This kyanite-bearing Entia Gneiss is believed to have been formed by metasomatic replacement of the country rock by solutions rich in aluminia and silica from the Huckitta Granodiorite.

The Bruna Gneiss has three major variants:-

(a) gneiss containing large porphyroblasts of poorly twinned pink microperthitic microcline,

(b) gneiss with bluish-grey orthoclase,

(c) even grained acid gneiss.

(a) The large porphyroblasts of potash feldspar contain numerous remnants of plagioclase and femis minerals and probably grew by the dissolution of the previous constituents, whereas the prophyroblasts of andesine and hornblende are not poikiloblastic; the previous constituents are aligned against the borders of the porphyroblasts and have probably been forced aside by the crystalloblastic strength of the porphyroblasts.

Joklik gives a comparison of analyses of the total rock and the 'matrix' of a porphyroblastic gneiss which indicates that the formation of the porphyroblasts of the potash feldspar involved the metasomatic introduction of potash, alumina and possibly of silica, and the removal of iron and magnesia. The porphyroblasts of garnet, plagioclase and hornblende were probably formed by internal metamorphic differentation. The Bruna Gneiss closely resembles the rapakivi type granite in chemical composition and appearance, but its mineralogical composition and microscopic structure establish its sedimentary-metamorphic origin.

(b) The large porphyroblasts of the second variety consist of sparsely perthitic and very poorly twinned potash feldspar containing flakes and grains of more or less altered feldspar, quartz and hornblende. The matrix is generally intensely crushed; the feldspar is oligoclase - andesine.

(c) The third variety of the Entia Gneiss occurs in narrow bands. A typical specimen (R4563) contains equal amounts of quartz, microcline and oligoclase; the last mentioned is partly porphyroblastic.

The Irindina Gneiss is characterized by the absence of potash feldspar. A specimen (R4577) collected two yards from a large thrust fault was composed of approximately equal amounts of quartz, andesine and biotite (about 30%) and 9% of almandine forming porphyroblasts 3mm in diameter, commonly felted with thin sillimanite fibres. In certain bands, where pegmatite injection and migmatisation are particularly intense, small porphyroblasts of microperthitic microcline are present. Where the feldspathisation is most intense, large porphyroblasts of microcline are formed. Specimen R4267 is porphyroblastic in microcline in a very dark biotite rich matrix; the borders of the porphyroblasts are also lined with myrmekite indicating again that potash introduction was followed by replacement by soda.

Joklik regards the garnets as concretions of unassimilated relics of sedimentary schist and gneiss.

Sillimanite bearing Irindina Gneiss is locally common, the sillimanite averaging 16%. The rock generally contains abundant concordant veins of quartz and plagioclase, and small ellipsoidal segregations of feldspar, both indicative of migmatisation.

The Irindina Gneiss contains several beds of garnet quartzite which Joklik suggests are derived from an iron bearing kaolinitic sandstone. The almandine grains are rounded, intensely crushed and often poikiloblastic about quartz; the quartz forms cracked and strained anhedral grains.

The granitised Irindina Gneiss is a very quartzo-feldspathic gneiss generally found associated with granite injection. A specimen of granitised gneiss (R4616) is coarsely granular, practically structureless and contains 53% microperthitic microcline, 29% quartz and 15% oligoclase.

According to Joklik the original rock was probably a psammo-pelitic sediment, metamorphosed, and then crushed and granitised by the metasomatic introduction of K_2O and SiO_2 and the expulsion of FeO, MgO, some Al_2O_3 and Na_2O. Most of the albite of the original feldspar was either replaced by microcline or taken up in solution later to form microperthite. Finally, myrmekite developed at most boundaries between oligoclase and microcline, and microcline was replaced in part by albite veins. Joklik's observations on specimens R4788 and R4616 showed that granitisation was associated with intense crushing. The quartz, microperthitic microcline, and to a lesser extent albite-oligoclase, form fresh irregular porphyroblasts; the remainder of the rock is fine-grained, severely crushed and strained.

Joklik records calcareous granulites and gneisses and metamorphosed limestones in the Irindina Gneiss, although he admits that some of these have been almost completely decarbonated by silica metasomatism.

The essential feature of the Brady Gneiss is that mica, although not necessarily present in large proportions, occurs as large flakes that emphasize the schistosity. Mineralogically, it has extraordinarily high silica and low alumina. Joklik suggests that quartz and plagioclase were introduced metasomatically. It also contains less garnet and less sillimanite than the Irindina Gneiss - garnet as large porphyroblasts and sillimanite as felted aggregates either in the garnet or closely associated with it. The segregation of mica rich and quartz-feldspar rich bands is more complete in the Brady Gneiss than in the Irindina Gneiss. As in the Irindina Gneiss, primary potash feldspar is uncommon; the normal low potash of the gneiss has prevented microcline formation and the excess aluminium has been bound in the high proportion of almandine. Sillimanite bearing Brady Gneiss is generally restricted to narrow zones of rock which are more intensely metamorphosed than the neighbouring rock.

The grade of metamorphism of the Cadney Gneiss decreases southwards away from the great thrust fault system which runs east-west from near Mount Schaber to Mount Ruby. Joklik has described three specimens from metamorphosed tuffaceous sediments that are representatives of the greenschist, albite-epidote-amphibolite, and amphibolite facies. Another specimen from the Cadney Gneiss was identified by Joklik as a schist in the biotite zone which had been retrogressively metamorphosed to chlorite zone grade. The rock was composed of small augen of quartz, biotite and feldspar in a matrix of sericite, chlorite and feldspar.

Calcareous granulites and gneisses and metamorphic limestones are common in the Cadney Gneiss.

The Inkamulla Granodiorite is an acidic to intermediate plutonic rock. The colour, texture and general appearance are difficult to distinguish from those of the Entia Gneiss which surrounds it. The femic composition of the Granodiorite varies from hornblende to biotite from the centre to the margins of the intrusion; this change is accompanied by an increase in the size of the quartz and feldspar crystals. Oligoclase is the main feldspar; non-microperthitic microcline is subordinate, and hornblende, epidote and iron rich biotite make up the femic constituents. The marginal phase of the granodiorite consists of quartz, oligoclase and biotite.

The Huckitta Granodiorite is petrographically similar to the Inkamulla Granodiorite but biotite is the main ferro-magnesian, indicating a lower lime content.

The BungitinaGranodiorite is a small boss of diorite, but the mineralogical composition varies considerably between the centre and the margin. A specimen collected by Joklik from the centre of the intrusion was composed of large crystals and porphyroblasts of oligoclase and unstrained quartz in an almost mylonitic mesostasis of predominantly feldspar, severely strained quartz and biotite. A specimen collected by Joklik from the margin of the intrusion illustrated the marked separation into a mesostasis and a porphyritic phase. Most of the rock consists of a fine-grained partly mylonitic mass of quartz and alkali feldspar, with very few large remnants of original crystals; the intergranular boundaries are sutured and feldspar intergrowth is common.

The variations of the composition within the Bungitina Granodiorite were attributed by Joklik to the effects of the granitisation of the surrounding Irindina Gneiss. A residual fraction rich in alkalis and silica could, then, have been mobilised, and been the cause of the 'granitisation' of the intrusion margin and the surrounding gneiss.

The Schaber Hornblende Granite forms an outcrop of about a square mile at Mount Schaber and is surrounded by granitised Cadney Gneiss. The granite is cut by a pronounced regular joint pattern and is markedly lineated. The most conspicuous features of the rock are the porphyroblastic development of the feldspars, the introduction of free quartz, the granulation at the edge of the porphyroblasts, the exsolution phenomena of the alkali feldspars and the development of myrmekite, which suggests that a rock of average granitic composition crystallised first and was later attacked by residual fluids rich in alkalis and silica.

A few other smaller intrusive bodies of granite and granodiorite and some aplite dykes also occur. Pegmatites are common, and occur in rocks of all the subdivisions of the Harts Range Group, but less commonly in amphibolites and metamorphosed calcareous sediments, which are more resistant than others to pegmatization, feldspathization and migmatization.

Joklik believed the pegmatites were emplaced toward the end of the same diastrophism as that in which the granodiorites and the granites were introduced, and the pre-existing rocks of the Harts Range Group were metamorphosed, feldspathized and granitized.

The pegmatites consist essentially of quartz, feldspar and mica, with minor amounts of accessory minerals. In the Harts Range structure associated with the Inkamulla and Huckitta Granodiorites, the composition varies, in general from potassic at the core, to calc-alkaline at the margin. The pegmatites in the Entia and Bruna Gneiss generally consist of potash feldspar and quartz, and are mostly poor in mica; most pegmatites in the Irindina and Brady Gneiss contain plagioclase, quartz, subordinate potash feldspar and abundant mica.

There are, then, two main groups of pegmatites, one predominantly potassic and the other predominantly calc-alkaline; where dykes of these two groups are associated, the potassic pagmatite commonly cuts the calc-alkaline pegmatite and is clearly the younger.

Joklik has divided the metamorphic basic igneous rocks into 6 classes:-

(i) The Riddock Amphibolite
(ii) concordant bands and lenses of amphibolite
(iii) basic granulites
(iv) hypersthene rich intrusions
(v) non-feldspathic intrusions
(vi) low grade metabasites

The most widespread of these is the Riddock Amphibolite. The main constituents are hornblende, diopsidic augite and plagioclase. Garnet is common, epidote, biotite, scapolite, hedenbergite, magnetite, apatite and sphene occur in lesser quantity. The relative amounts of the constituents varies considerably near contacts with the country rock. For example, the relative proportions of plagioclase and hornblende varies between the extremes of 100% hornblende and 100% plagioclase. Pegmatitic amphibolite occurs in places where there are acid pegmatites in the adjacent country rock and in extreme cases, pegmatitic amphibole is converted to hornblende pegmatite.

Prichard and Quinlan (1962) outlined the distribution of the Arunta Complex in the Hermannsburg 1:250,000 Sheet area and made special mention of 'metamorphic recrystallized quartzites' outcropping in the Chewings Range and north of Goyder Pass. They correlated this quartzite with the Heavitree Quartzite, basing their conclusions on the structural position of these metaquartzites in the Ormiston Gorge - Mount Sonder region. They also admitted the possibility of other Arunta metaquartzites occurring in the Sheet area.

In the present study, some of the quartzite referred to by Prichard and Quinlan near Ormiston Gorge was found to be Heavitree Quartzite and some to be part of the Arunta Complex. An angular unconformity between the two has been demonstrated at a place where Condon (1962) had deduced from air photo interpretation, a strong structural discordance. At this locality, Heavitree Quartzite (with basal conglomerate) dips 25° north and overlies quartzites interbedded in gneisses which dip 45° west.

Other unconformities between quartzite and Arunta Complex were recognized in the Chewings Range, namely at a locality four miles east of Mount Giles, and at Brinkley's Bluff. These can also be interpreted as due to structural causes, but the possibility of a post-Arunta (and perhaps pre-Heavitree) quartzite existing in the Chewings Range cannot be disregarded. Further some of the Chewings Range quartzites are associated with shale, quartz-sericite phyllite and schist, lithologies developed in the basal Bitter Springs Formation at Ormiston Gorge. This suggests that some of the Chewings Range quartzite between Mount Giles and Mount Lloyd may be Heavitree Quartzite. However most of the quartzite in the Chewings Range is intruded by pegmatite and dolerite dykes which the Heavitree Quartzite appears to overlie unconformably. Also fold structures in the quartzite are identical with structures in the gneiss which is unconformable beneath the Heavitree Quartzite.

Similar problems of stratigraphy had revolved around metamorphosed quartzites (White Range Quartzite, of Joklik) in the east of the Alice Springs 1:250,000 Sheet area. The present survey demonstrated that in all cases the White Range Quartzite was Heavitree Quartzite.

In the present survey, no further stratigraphic interpretation was attempted in the Arunta Complex. However, observations in the Illogwa Sheet area have established that quartz-biotite gneiss and schist, biotite-feldspar-quartz gneiss, quartz amphibolite, quartz-sericite schist, metaquartzite, schistose quartz conglomerate, tourmaline-quartz rock and epidote-quartz rock outcrops and underlies most of the sand cover in the Illogwa Sheet area east of the extent of the Arunta Complex rocks mapped by Joklik. For the most part, they appear to be of a lower grade of metamorphism than most of the previously mapped Arunta rocks; for the purposes of the present survey, they have been mapped as Arunta Complex.

Dolerite Dykes

The Arunta Complex is intruded by slightly altered dolerite dykes between the Georgina Range on the Alice Springs Sheet area and the western side of the Hermannsburg Sheet area. The dykes are up to 50 feet wide and trend mainly in a north-south direction except to the north-west of Ormiston Gorge where the trend swings to westerly. One fault trending east from Deep Well Bore, 22 miles north-east of Alice Springs, contains a ?dolerite filling which is sheared and brecciated.

Dolerite intrudes amphibolite of the Arunta Complex, two miles north of Gumtree Bore, and 34 miles north-north-east of Alice Springs. The dolerite is intruded by parallel dykes of schistose, white and grey, quartz-feldspar porphyry with feldspar phenocrysts up to one inch across.

The dykes intrude the Arunta Complex and the quartzite of the Chewings Range but they are not known to intrude the Heavitree Quartzite. At one locality, two miles east-north-east of Serpentine Gorge, a clastic dyke from the base of the Heavitree Quartzite may intrude a parallel trending dolerite dyke. Dolerite dykes have been traced up to the unconformity at the base of the Heavitree Quartzite but no unconformity has been seen in these areas of poor exposure.

UPPER PROTEROZOIC

Heavitree Quartzite

The Heavitree Quartzite was named by Joklik (1955) and Heavitree Gap may be inferred as the type locality.

The Heavitree Quartzite is predominantly medium-grained silicified quartz sandstone which unfonformably overlies the Arunta Complex and is overlain conformably by the Bitter Springs Formation. It contains subordinate

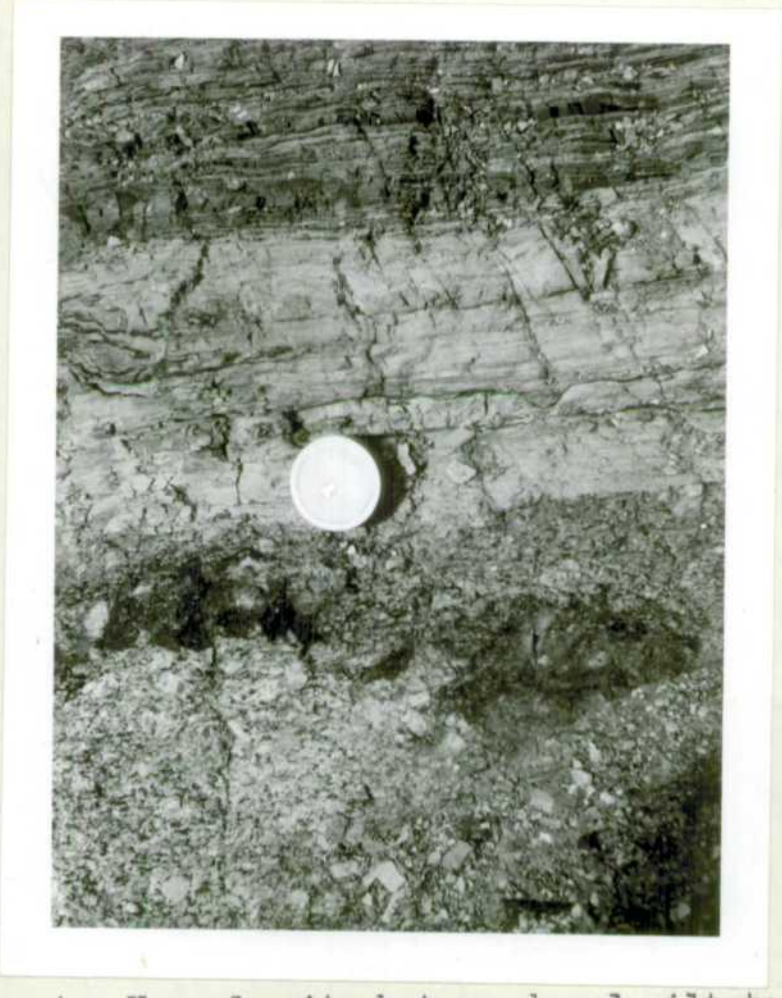


Figure 4. Unconformity between basal siltstone of the Heavitree Quartzite and gneiss of the Arunta Complex at Heavitree Gap. Marked by lower edge of the tobacco tin. Neg. No. G.7454.

amounts of coarse quartz sandstone, pebbly sandstone and siltstone. It extends almost continuously along the northern margin of the Amadeus Basin from the western side of the Hermannsburg Sheet area, across the Hermannsburg and Alice Springs Sheet areas to about one quarter of the way across the Illogwa Creek Sheet area.

The Heavitree Quartzite also crops out in an anticline in the north-western corner of the Hale River Sheet area and the south-western corner of the Illogwa Creek Sheet area. The Quartzite crops out as a prominent ridge or range usually with a gentle dip slope and a steep escarpment slope.

The unit is about 1440 feet thick at Ellery Creek Big Hole (Madigan, 1932a, 1944, and Prichard and Quinlan, 1962) and 600 feet thick at Heavitree Gap (Joklik, 1955 and Madigan, 1932a). The Quartzite appears to thicken to the east in the Alice Springs and Illogwa Creek Sheet areas, but appears to thin to about 600 and 1100 feet in the Hale River Sheet area (MacLeod, 1959).

The complicated structure and, in some areas, the metamorphism of the Heavitree Quartzite and the older Precambrian rocks lead to some doubt as to the original nature of their contact. During this survey it was established that the Heavitree Quartzite overlies moderate grade metamorphic rocks of the Arunta Complex unconformably throughout most of the area (fig.4). In the areas where the Heavitree Quartzite is infolded with the Arunta Complex the relationship between the Heavitree Quartzite and the adjacent schists is conformable on the overturned limb. However it may be deduced that the conformable schists were derived from the older unconformable high grade Precambrian rocks by retrograde metamorphism during the infolding (See McCarthy, Part II).

The basal beds are the most variable. At most localities they are abundantly cross bedded and contain white, medium-grained, gritty and pebbly sandstone with abundant coarse laminae and variable quantities of arkose and purple micaceous greywacke. At a few localities there is a basal conglomerate containing angular and subrounded fragments of the underlying Arunta Complex. Up to 30 feet of siltstone occurs at the base at localities in the Heavitree Range between Heavitree Gap (Fig.4) and Ellery Creek Big Hole.

Prichard and Quinlan (1962) recognized three members in the Hermannsburg Sheet area. The basal member comprises 700 feet of a medium to coarse quartz sandstone commonly cemented to quartzite. The middle member, about 200 feet thick, consists of coarse-grained siltstone containing about 40 percent of medium to coarse quartz grains. The top member is medium-grained sandstone generally silicified to quartzite, and includes pure yellow-brown argillaceous quartz siltstone up to 100 feet thick below the topmost quartzite bed. This member is about 500 feet thick at Ellery Creek.

No siltstone was seen within the Heavitree Quartzite on the eastern side of the Alice Springs Sheet area and on the Illogwa Creek Sheet area. The quartzite is commonly silicified and crossbedded and contains some thick gritty beds. Ripple marking and synaeresis cracks were seen at several localities.

In the Hale River Sheet area the Quartzite consists of white, pale grey and yellow-brown, coarse-grained, finely conglomeratic quartz sandstone which contains subangular to subrounded grains in laminae, thin beds and cross laminae. Some ripple markings are present. There is also a considerable proportion of red, medium and coarse-grained, ferruginous and kaolinitic, gritty sandstone which contains poorly sorted and subrounded quartz grains. In places in this area the Heavitree Quartzite has been tectonically stripped off the Arunta Complex and doubled up farther along the strike as the result of a decollement. In these areas the Bitter Springs Formation rests directly on the Arunta Complex.

The Heavitree Quartzite has been metamorphosed in the Arltunga Nappe Complex and in the Ormiston Nappe Complex. In these structures the Quartzite has been most highly deformed where is its overturned (See McCarthy, Part II). Near the front of the structure the quartzite is shattered, brecciated and silicified but deeper in the structure the quartzite has a faint to strong schistosity and may be partially or completely recrystallized to sericite bearing quartzite and schistose quartzite (See McCarthy, Part II).

The quartzite is not known to be intruded by pegmatite veins or dolerite dykes or granite. It overlies the Precambrian metaquartzite of the Chewings Range unconformably.

Four miles east of Serpentine Gorge on the Hermannsburg Sheet area a dyke of quartzite extends downwards from the base of the Heavitree Quartzite into the Arunta Complex. The quartzite dyke may cut a dolerite dyke.

The age of the Heavitree Quartzite is probably Upper Proterozoic.

Bitter Springs Formation

Joklik (1955) named the thick formation of dolomite which crops out at Bitter Springs Gorge, the Bitter Springs Limestone. He gave no section or thickness. Prichard and Quinlan (1962) mapped the same unit in the Hermannsburg Sheet area and measured a sequence of approximately 2500 feet of dolomitic limestone and siltstone at Ellery Creek.

Banks (1964) suggested an informal subdivision of the Bitter Springs Limestone into three units: Ellery Formation, Bitter Springs Formation and Gillen Formation. Wells et al., 1965d revised the name of Joklik's Bitter Springs Limestone to the Bitter Springs Formation and subdivided it into two members; the Loves Creek Member at the top and the Gillen Member at the bottom. The type locality was changed from Bitter Springs Gorge to Ellery Creek and Prichard and Quinlan's section was adopted as the type section.

The Gillen Member (Wells et al., 1965d) overlies the Heavitree Quartzite conformably and consists mainly of dolomite with lesser amounts of siltstone, sandstone and shale. The dolomite is generally dark bluish-gray with thin beds and laminae. It is commonly closely jointed and has a blocky outcrop. A few stromatolites are present. The siltstone is laminated and white, greenish-brown or reddish brown. Some beds are micaceous. The shale has predominantly green, micaceous laminae. The sandstone is predominantly white, fine-grained and contains closely jointed, medium-sized beds. In the Illogwa Creek Sheet area there is a considerable proportion of very coarse sandstone. The name is derived from Mount Gillen, four miles west of Alice Springs.

The Loves Creek Member (Wells et. al., 1965d) lies conformably on the Gillen Member and consists mainly of dolomite with limestone, calcareous siltstone, chert and basic volcanic rocks. The dolomite is pink, yellow to grey-brown and is fine-grained with thin beds. Stromatolites of several types are common. The limestone crops out as thick bedded, white and grey beds 10 to 20 feet thick. Stromatolites are abundant. The siltstone is generally reddish-brown, calcareous and medium bedded. The chert probably formed by silicification of siltstone. The basic volcanics occur in the east of the area and are known at a number of levels throughout the member. The name is taken from Loves Creek which joins the Ross River five miles west of the Ross River tourist chalet in the Alice Springs Sheet area. The type locality is at Ellery Creek.

Bitter Springs Formation in the Arltunga Nappe Complex

The Gillen Member and the Loves Creek Member were not differentiated in the Arltunga Nappe Complex because of the complicated folding and thrusting. It is probable that only the Gillen member is exposed in the deeply infolded area of the Nappe Complex. The Bitter Springs Formation is metamorphosed within the Nappe Complex to phyllite and slate. Beneath the Giles Creek Synform the Formation is tightly folded (Fig.16) but the main metamorphic effect is brecciation and a weakly developed fracture cleavage. The degree of metamorphism increases northwards from the Synform to phyllite grade in the Winneke Gold Mining area and the Ruby Gap Gorge area. (See rock specimen descriptions in McCarthy, Part II).

Bitter Springs Formation in the Ormiston Nappe Complex

The Bitter Springs Formation is isoclinally folded and metamorphosed to slate and phyllite in the deeply infolded areas of the Ormiston Nappe Complex. The Ormiston Nappe contains a core of phyllite derived from siltstone of the Bitter Springs Formation. Slate and phyllite is found derived from the basal siltstone of the Bitter Springs Formation and from siltstone interbeds within the Heavitree Quartzite in the Mount Razorback Nappe, south of Mount Razorback, and at Redbank Gorge. Brecciation and crushing and development of fracture cleavage is apparent in carbonate of the Bitter Springs Formation near the Nappe Complex.

Figure 5. Worm trails in laminated red sandstone and white claystone of ?Mesozoic age, 40 miles south-south-east of Plenty River Downs Homestead. Neg. No. G/7389.

Bitter Springs Formation within the Amadeus Basin

Until McCarthy (Part II) examined sections from the Ooraminna No.1 bore the Bitter Springs Formation was believed to be unmetamorphosed within the Amadeus Basin.

The metamorphism described by McCarthy may be regional or it may be due to the decollement within the formation. Thermal metamorphism by the spilite flows which occur over 1000 feet higher in the bore does not appear a logical explanation for the metamorphism described.

MESOZOIC (E.N.M.)

Flat lying sandstone and lutite which outcrop in the south-eastern sector of the Illogwa Creek 1:250,000 Sheet area are tentatively referred to the Mesozoic. They overlie unlateritised Arunta Complex schists and have a ferruginous capping. No diagnostic fossils have been found.

A section measured in these rocks is as follows (commencing at the top of the section):

20 feet: red-brown poorly sorted muddy sandstone, with occasional laminae of mottled white and purple claystone and scattered pebbles of Arunta Complex rocks.

15 feet: white ?gypsiferous shale and variegated pink and white claystone.

6 feet: yellow, micaceous fine-grained sandstone interlaminated with red-brown, medium-grained, quartz sandstone and white and yellow, siliceous claystone with worm trails and burrows and rare traces of shelly fossils.

Similar sediments have been described by previous authors in neighbouring areas: Öpik (in Sullivan and Öpik, 1951) and Wells, Stewart and Skwarko (1965c) have described the Lower Cretaceous Rumbalara Shale, which outcrops in the Finke 1:250,000 Sheet area and which includes white kaolonitic rock, procellanite, yellow ochre, red and grey sandstone and fragmental Pelecypoda.

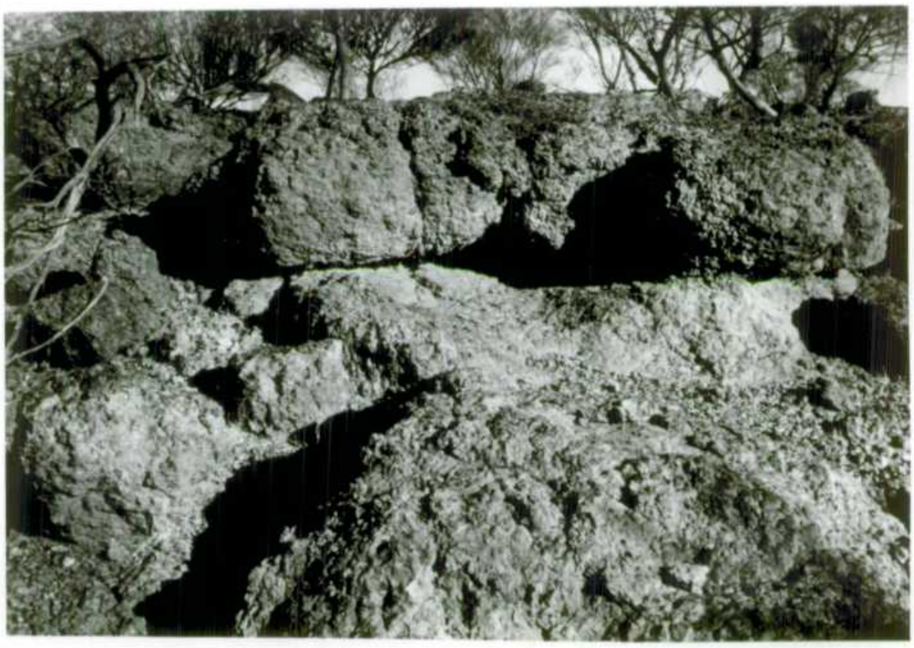


Figure 6. Six feet of laterite developed on highly weathered Precambrian schist, ten miles east of Gidyea Bore, Illogwa Creek Sheet area. Neg. No. G/7369.

Crespin and Evans (1962) identified Lower Cretaceous foraminifera and microplankton in variegated pink, yellow, cream and grey mudstones from a bore 20 miles east of the outcrops in the Illogwa Creek Sheet area. Smith (1963) recorded outcrops of thin bedded coarse-grained sandstone with pellets of siltstone and interlaminated sandy siltstone in the vicinity of this bore. Skwarko (B.M.R. Pers. Comm.) has recognized lithologic similarity between outcrop of Mesozoic De Souza Sandstone in the Hale River 1:250,000 Sheet area, and the sandstone with work trails from the south-east Illogwa Sheet area. The De Souza Sandstone underlies the Rumbalara Shale at Colson's Point in the Finke Sheet area.

The lithologic similarity to Mesozoic sediments, and the flat attitude of the beds, suggests that the south-east Illogwa Sheet outcrops are Mesozoic; no finer time allocation can be made.

?<u>TERTIARY</u>

Tertiary sediments crop out extensively in the Illogwa Creek Sheet area and in low lying areas of the Alice Springs and the Hermannsburg Sheet areas.

In the Illogwa Creek Sheet area the Tertiary sediments may be subdivided into three units. At the base about six feet of brown pisolitic laterite (Fig.6) rests upon highly weathered, decomposed and iron stained rocks of the Arunta Complex. The laterite is overlain by about 12 feet of red-brown, medium-grained argillaceous sandstone with irregular thick beds; this sandstone is overlain by about ten feet of chert. The outcrops are extensive and are up to 30 miles long and 20 miles wide. The Tertiary sediments and chemical weathering products must have been developed on a mature but uneven surface as Woolley 1963 states that there is about 100 feet of section exposed about four miles farther north. Woolley describes a sequence with white and cream clay at the base of the exposed section overlain by poorly bedded cream argillaceous limestone with some well bedded brown limestone and a hard chalcedonic cap. Woolley has suggested from surface and subsurface information that these Tertiary sediments were deposited in northwesterly trending valleys.

Tertiary sediments crop out in the valley containing the Arltunga airstrip and Arltunga Bore and in the valley containing the Garden, Amablindum and Claraville Homesteads. The deposits have been described by Madigan (1932a), Joklik (1955) and Lloyd (1965).

Madigan used the name Arltungan Beds to include all the Tertiary rocks in the area to the east of Alice Springs. Smith, Vine and Woolley (1960) and Smith (1964) revised the name to Arltunga Beds. As the deposits at Arltunga (the type locality) are lacustrine and fluviatile deposits, they were never physically continuous with other deposits of Tertiary age and the name Arltunga Beds should be restricted to the deposits at Arltunga.

Lloyd reported [illegible] feet of gastroped, ostracod and charophyte bearing arenaceous limestone overlying the Arunta Complex at the Arltunga Airstrip. In a low mesa half a mile farther south similar gastropods occur in a silicified limestone overlying poorly sorted pebbly sandstone which in turn overlies mottled Arunta Complex. Madigan (1932a) reported osmundaceous plant stems, from these deposits.

Lloyd described the deposits between Claraville and Amablindum Stations as a sequence of over 75 feet of flat lying white, green and brown, soft, calcareous clastic sediments overlain by 15 feet of red-brown poorly sorted coarse sandstone and conglomerate capped by chalcedonic limestone. Madigan (1932a) reported plant stems like Chara and small bivalves, possibly Corbicula from these deposits. Madigan also mentions a 12 foot seam of highly pyritic lignite which was found in well sinking at a depth of 26 feet on the south bank of the Hale River, five miles west of Ambalindum Homestead.

Extensive ?Tertiary deposits are known north of the Harts Ranges on the Alcoota Sheet area and on the Alice Springs Sheet area. A bore has been sunk near Mount Riddock Homestead to a depth of 600 feet through fine alluvium without striking rock. It is not known how much if any of the section penetrated is of Tertiary age.

Tertiary sediments are believed to extend over a large area of the Burt Plain beneath the cover of Quaternary sediment. Surface outcrops include a white sandstone dipping off Precambrian basement four miles north-east of Bond Springs Homestead and (Perry et al., 1963) 30 feet of chalcedony overlying weathered Precambrian rocks near Hamilton Downs Homestead. However most of the succession, which is up to 640 feet thick (Hossfeld, 1954), is known only from shallow bores most of which do not penetrate the full section. Few adequate bore logs are available but Perry et al., (1963) suggest that the oldest beds are fawn to dark grey sandy silt and clay with thin beds of sand. These sediments are generally separated from the younger Tertiary sediments by an ancient deep weathering profile. Consequently a division of the sediments is possible between those older than the laterite and grey billy in the area and those younger. The older sediments contain lignite, plant fragments, and fresh water gastropods. At Alcoota, to the north of the area, and Phillipson Pound, to the south of the area, there is an assemblage of vertebrate remains including crocodiles, turtles and other reptiles, birds, and marsupials including diprotodonts. The sediments were clearly deposited in a lacustrine and fluviatile environment during a period of rainfall higher than that of the present arid phase.

Piedmont deposits of sandstone and conglomerate adjacent to the high ranges and hills in the Hermannsburg Sheet area (Prichard and Quinlan, 1962) may have been deposited during the same pluvial period.

The age of the younger sediments is either late Tertiary or Pleistocene (Lloyd, 1965).

QUATERNARY

The Burt Plain in the west and the northern margin of the Simpson Desert in the east of the area are occupied by extensive tracts of superficial red-brown, aeolian sand, alluvium and red earth soils. Intermontane valleys filled with alluvial gravel, sand, silt and clay occur within the main areas of outcrop of the Arunta Complex and the Arltunga Nappe Complex. The deposits and their hydrological significance are described in Perry et. al., (1963).

The sand dunes and wind derived sand plains are stable under the present climatic environment and are fixed by a cover of spinifex and small shrubs. The alluvium and red earth soil is commonly covered with a light to dense growth of mulga or gidyea. Alluvium is being deposited under present day conditions in the intermontane valleys and in and near the channels and floodout areas of the streams. Perry et al. (1963) consider much of the area covered by sand and soil is probably underlain by Pleistocene wash and alluvium and that their deposition has been continuous since the Tertiary, although deposition at any one place has been intermittent.

T. Quinlan (B.M.R. Pers. Comm.) states that the boundary between the Quaternary and ?Tertiary sediments is known only from bore holes. The Quaternary sediments are of alluvial origin and comprise red-brown silty sand and gravel whereas the ?Tertiary sediments of lacustrine origin comprise

Figure 7. Isoclinal folding (A-F^1) in Precambrian quartzite of the Chewings Range at Ellery Creek. Axes of the folds plunge in a northerly direction parallel to the lineation in the quartzite. Neg. No. G/7458.

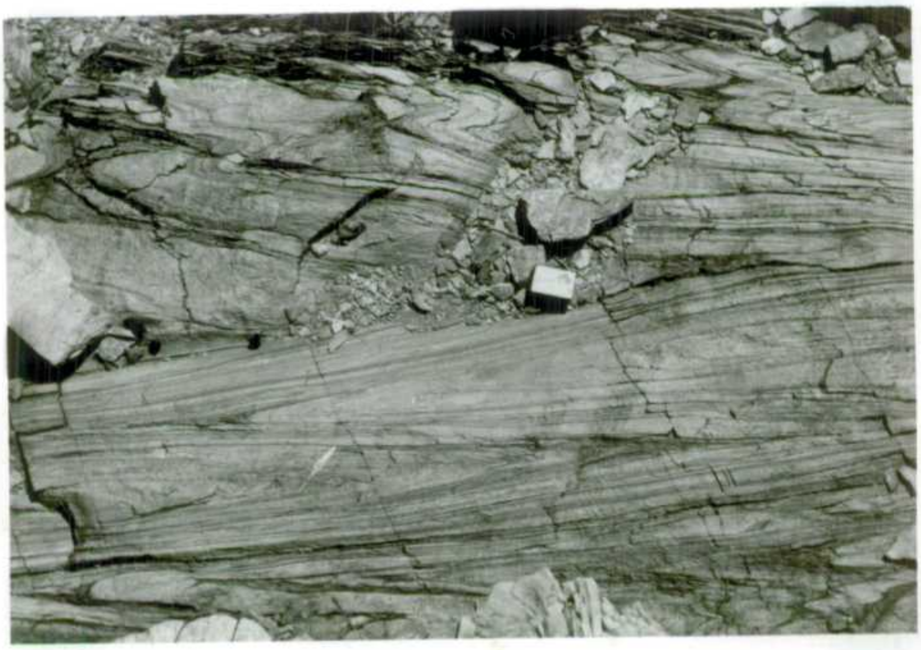


Figure 8. Isoclinal folding (A-F^1) in Precambrian quartzite at the Chewings Range at Ellery Creek. Fold axes dip steeply and plunge to the north. Neg. No. G/7457.

mottled white, grey, black, orange, fine-grained, sandy clay and clay with thin beds of lignite. The Quaternary alluvial sediments attain a maximum thickness of 180 feet at the Harts Range Police Station bore. The aeolian sands form a much thinner cover.

STRUCTURE

At least two orogenies are evident in the area of the north-east margin of the Amadeus Basin. The older, the Arunta Orogeny, took place before deposition of the Amadeus Basin sediments and caused the deformation and moderate and high grade metamorphism of the Arunta Complex. The younger orogeny probably commenced late in the Ordovician and reached a climax, in the Devonian. This orogeny, the Alice Springs Orogeny, caused the development of nappes in the Arunta Complex, Heavitree Quartzite and Bitter Springs Formation along the margin of the basin, and thrusting and folding of the Amadeus Basin sediments over two decollement surfaces. The structure of the area is illustrated in the tectonic map (Plate 5).

ARUNTA OROGENY

Joklik (1955) referred to this orogeny informally as the epi-Archaeozoic orogeny. However there is no proof either of the age of the orogeny or the age of the rocks that it affected except that they are older than the Heavitree Quartzite of probable Upper Proterozoic age.

The Arunta Orogeny is here defined as the orogeny which folded and metamorphosed the Arunta Complex before the Heavitree Quartzite was deposited. During the orogeny the Arunta Complex was isoclinally folded about north-south axes. The present attitude varies between steep and recumbent (see Figs. 7, 8) and was tightly refolded about steeply dipping east-west axes (see Fig.9).

Figure 9. Chevron folds with steeply dipping east-west trending axes (A-F^2) in Precambrian quartzite of the Chewings Range at Ellery Creek. Neg. No. G.7455.

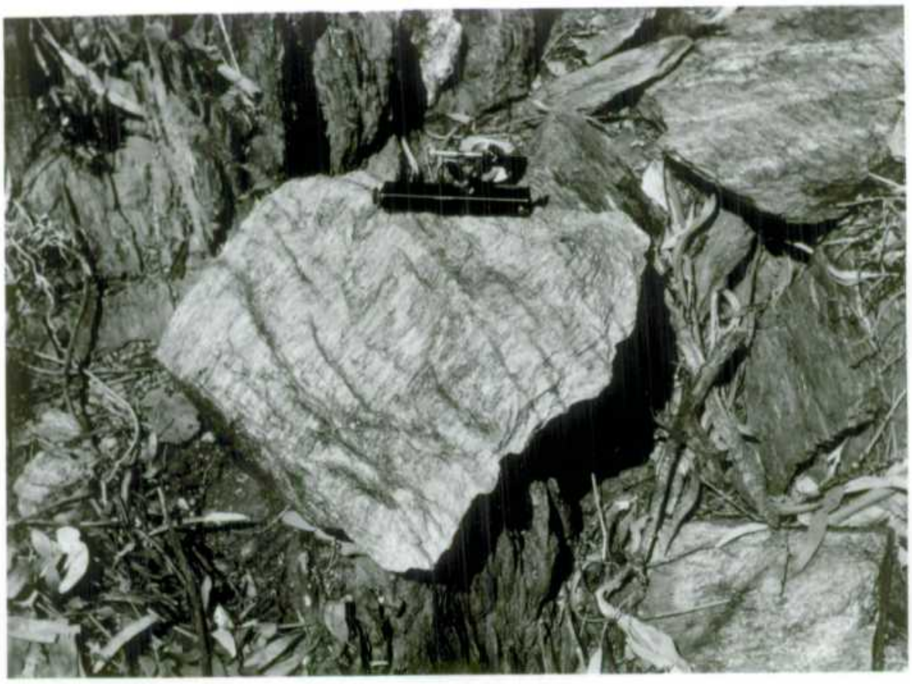


Figure 10. Chevron folding (A-F^2) in mica-quartz schist of the Chewings Range, one mile east of Ellery Creek. The chevron folds clearly refold the lineation developed parallel to A-F^1. Neg. No. G/7364.

During the earlier folding high grade metamorphic minerals such as staurolite, kyanite, almandine and sillimanite grew parallel to the axes of the north-south folds. This lineation was refolded but not everywhere destroyed by the east-west folding (see Fig.10) and the development of an east-west lineation. The structures are well developed in metaquartzite and gneiss at Fish Hole in the eastern end of the Chewings Range on the Alice Springs Sheet area.

Metamorphic lithologies developed during the orogeny include metaquartzite, marble, calc-silicate rock, schist, schistose gneiss, porphyroblastic augen gneiss and amphibolite. North of Ormiston Gorge these are intruded by pegmatite and dykes, irregular masses and veinlets of leucocratic, medium-grained biotite bearing granite. The granite may have been sweated out of the adjacent gneisses as it contains coarse feldspar xenocrysts clearly derived from the adjacent porphyroblastic augen gneiss.

It is not clear whether the banding which has been folded by the north-south isoclinal folding (A.F.[1]) in the metaquartzite, marble and calc-silicate rocks was original bedding or a pre-existing metamorphic foliation or schistosity. However it is quite clear that an older foliation has been folded in the schistose gneiss and gneiss. Hence it is possible that the Arunta Orogeny was preceded by an earlier period of folding and metamorphism. It is also possible that the earlier foliation developed mimetically at an early stage of the Arunta Orogeny.

The Arunta Orogeny is most clearly developed north of the Heavitree Range and north and south of the Chewings Range where the effects of the younger Alice Springs Orogeny are less severe. The Orogeny has also played a large part in the development of the crystalline rocks in the Harts Range area, north of the Winnecke and White Range gold mining fields, and north of Atnarpa Homestead, Ruby Gap Gorge and Aremra Bore. This area has also suffered the most intense deformation during the Alice Springs Orogeny and it is difficult to separate the structures of the orogenies.

ALICE SPRINGS OROGENY

The term Alice Springs Orogeny was introduced by Forman (1965) for the orogeny which accompanied and followed the deposition of the Pertnjara Formation. It occurred in the Devonian and caused recumbent folding of the Bitter Springs Formation and older rocks along the northern margin of the Amadeus Basin, and decollement sliding and folding of the sediments over the Bitter Springs Formation.

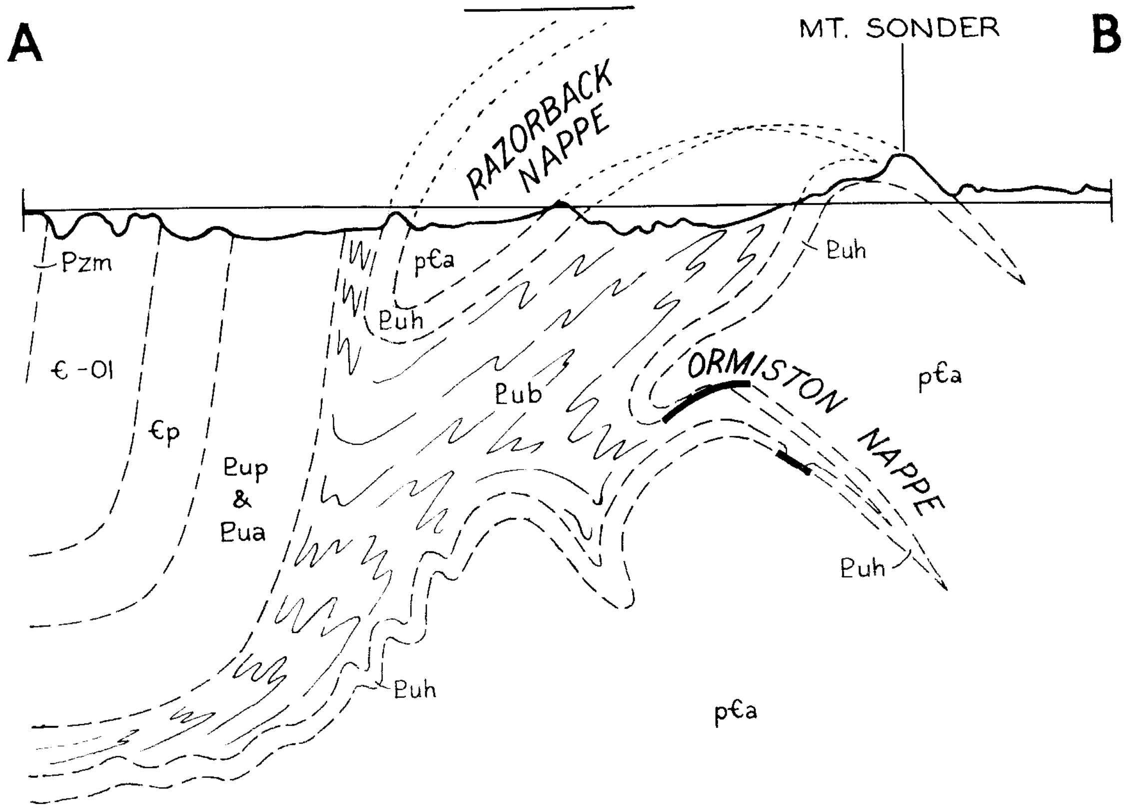
The orogeny caused the development of at least two nappe complexes: the Ormiston and the Arltunga Nappe Complexes. The term nappe refers to a recumbently overfolded body of rock in which the reversed limb has been partly or largely replaced by a thrust. A nappe complex contains two or more of these nappes piled one on the other.

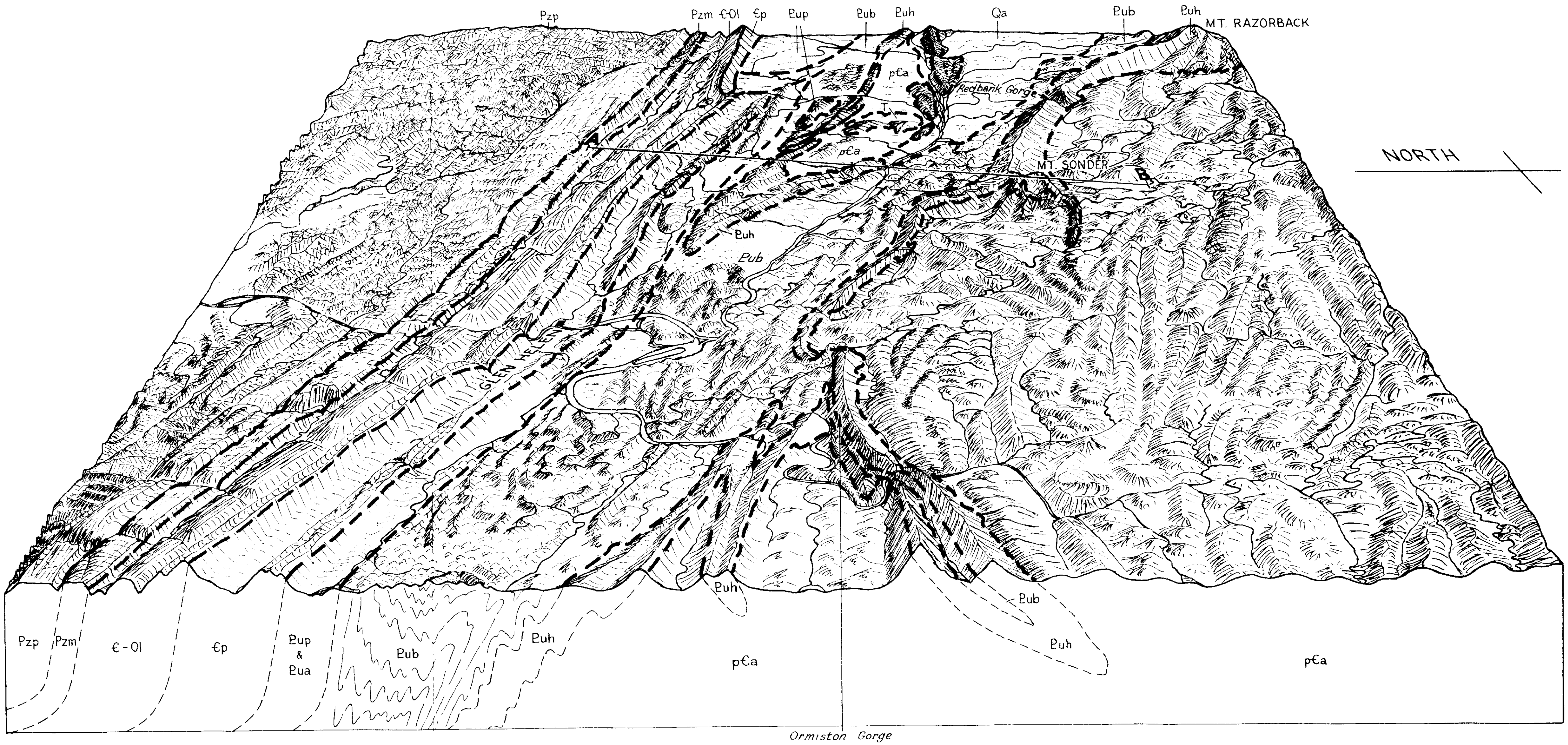
The nappe complexes developed after the Upper Proterozoic, Cambrian and Ordovician sediments had been deposited in the Amadeus Basin. The sediments younger than the Upper Porterozoic Bitter Springs Formation were squeezed out of the nappes by the highly plastic Bitter Springs Formation and were forced southwards over a decollement surface within it (D1). Another decollement surface or plane of weakness (D2) developed in the Cambrian sediments during this movement and sediments ripped off the decollement surface D1 were thrust higher up the section in places, and came to rest on the upper decollement surface D2.

The decollement thrusting was accompanied and followed by tight and isoclinal folding mainly over the deeper decollement surface.

Fig. 11

ORMISTON NAPPE COMPLEX





SCALE

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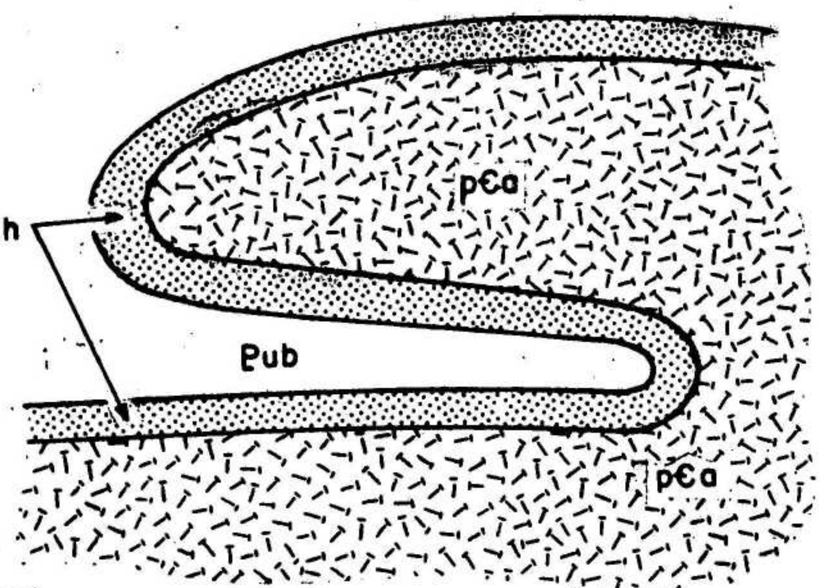
Figure 12. View of the synclinal core of the Ormiston Nappe looking westerly along the Chewings Range from eight miles east-north-east of Ormiston Gorge. The Bitter Springs Formation crops out in the valley and Heavitree Quartzite crops out in the ridges on each side of the valley. Arunta Complex occurs to the north of the range. Neg. No. G/7498.

Figure 13. Heavitree Quartzite in Ormiston Nappe (beneath Landrover) dipping under hills of schist and gneiss of Arunta Complex. Neg. No. G/7368.

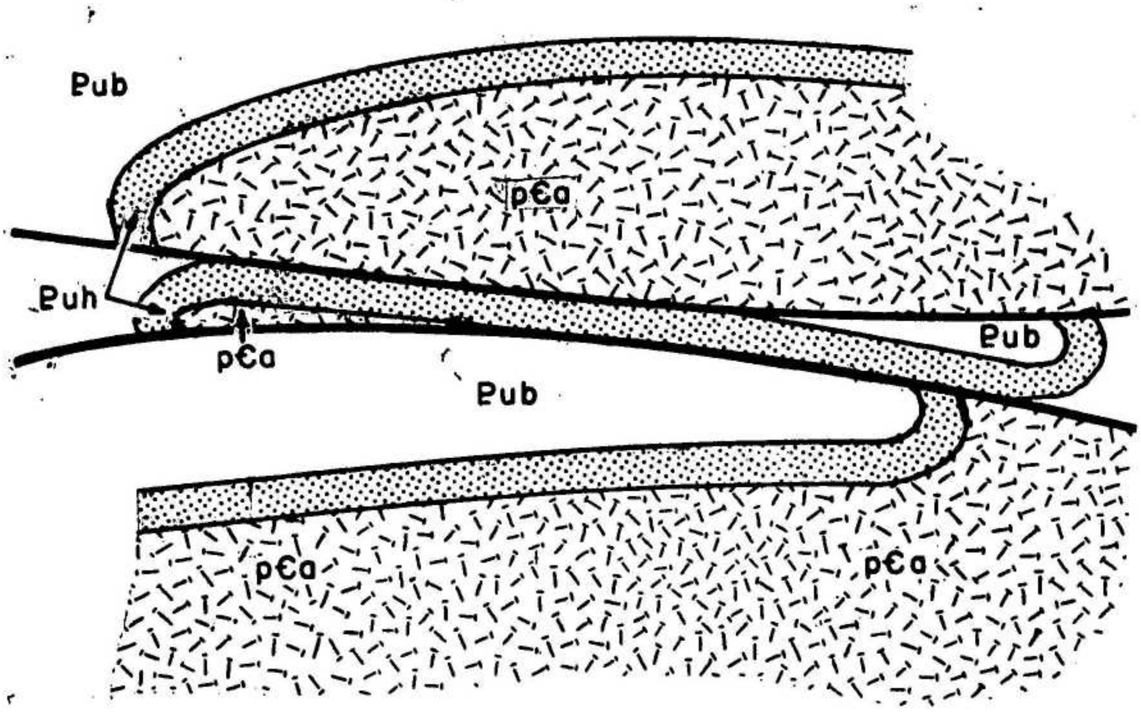
FIG 14

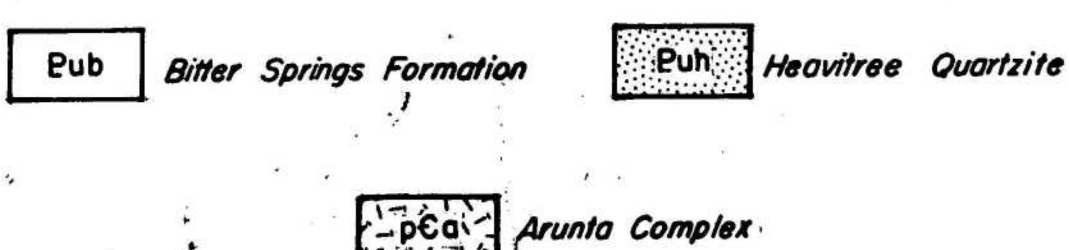
ALTERNATIVE INTERPRETATIONS OF THE HEAVITREE QUARTZITE REPETITION —ARLTUNGA NAPPE COMPLEX—

(a) Recumbent Fold.



(b) Overthrust





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Ormiston Nappe Complex

The Ormiston Nappe Complex is exposed on the Hermannsburg Sheet area in the Ormiston Gorge and Mount Razorback area and comprises the Ormiston Nappe and the Mount Razorback Nappe (Figure 11). Another nappe or series of nappes may be present farther west.

Ormiston Nappe: The synclinal core of the Ormiston Nappe is exposed at Ormiston Gorge and for about ten miles to the east-north-east along part of the Chewings Range (Figs, 11,12 and Plate 5).

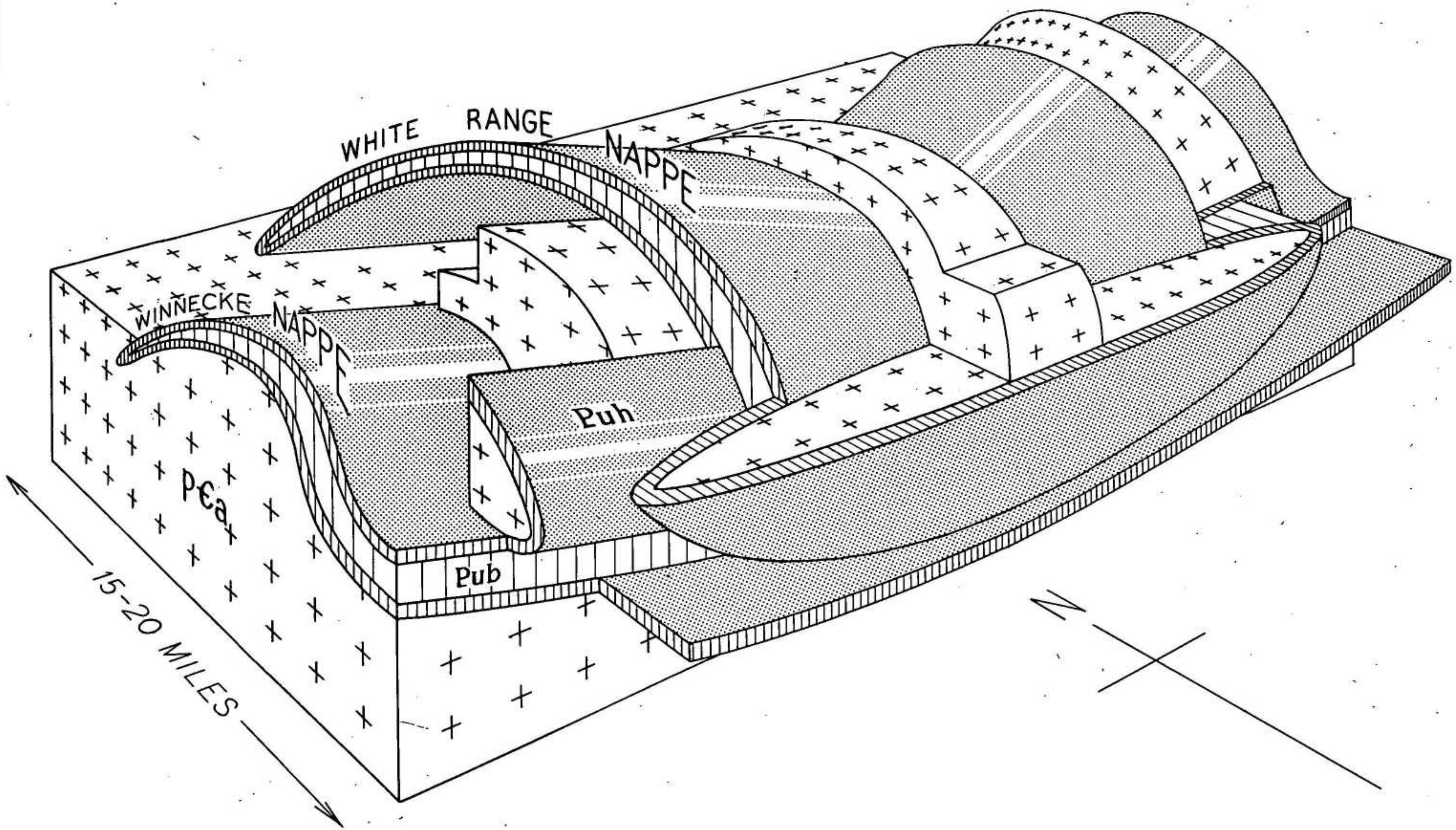
The core is northerly dipping and contains Heavitree Quartzite resting unconformably on the Arunta Complex and overlain by slate and phyllite of the Bitter Springs Formation. The Bitter Springs Formation is in turn overlain by schistose quartzite and quartzite of the Heavitree Quartzite dipping north beneath conformable schist derived from the Arunta Complex (Fig.13). The repetition of the Heavitree Quartzite appears to be due to folding rather than thrusting (Fig.14) and the metamorphism and shearing has taken place largely on the inverted middle limb (McCarthy, Part II). Two miles to the west of Ormiston Gorge, the Quartzite has been replaced by a thrust and the Arunta Complex sits directly on the Bitter Springs Formation. Two miles to the north-east of Ormiston Gorge, the Heavitree Quartzite has been sheared out of the normal bottom limb of the fold and the Bitter Springs Formation rests directly on the Arunta Complex.

Isoclinal folds occur in the Bitter Springs Formation, the Heavitree Quartzite and the schist derived from the Arunta Complex. The folds in the Heavitree Quartzite and Bitter Springs Formation at Ormiston Gorge plunge northerly and westerly. North of Ormiston Gorge the Heavitree Quartzite dips beneath conformable schist derived from the Arunta Complex (Fig.13, specimens 450-454). The quartzite and the schist

Figure 15. Recumbent fold in Heavitree Quartzite eight miles south of Haast Bluff No.1. Neg. No. G/7371.

Figure 16. Recumbent folding in the Bitter Springs Formation near Bitter Springs Gorge. Neg. No. G/7367.

Fig. 17



ARLTUNGA NAPPE COMPLEX

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have a prominent northerly lineation and at least one northerly plunging isoclinal fold is preserved in the schist.

Mount Razorback Nappe: The overturned limb of the Mount Razorback Nappe crops out between Mount Razorback and Mount Sonder (Fig.11). The Heavitree Quartzite is schistose, strongly folded (Fig.15) and dips beneath schist derived from the Arunta Complex. The schistose quartzite and the schist have a prominent northerly mineral lineation. The Bitter Springs Formation crops out beneath the overturned quartzite and is isoclinally folded (as in Fig.16) about axes with a westerly trend. The Bitter Springs Formation has a slaty cleavage parallel to the fold axes. The core of the nappe is eroded south of Mount Razorback and Mount Sonder but the front of the nappe crops out four miles farther south in the Boomerang Bore area. The nappe is overturned or overthrust for a distance of eight miles across the strike.

All the sediments of the Amadeus Basin which crop out south of the Nappe Complex are near vertical and in some areas overturned a few degrees from vertical. The sediments form a simple homocline except in the Goyder Pass area where the bottom layers appear to have thrust upwards into the sequence to form a trapdoor type of diapiric structure (McNaughton et. al., 1965).

Arltunga Nappe Complex

The Arltunga Nappe Complex contains the two largest nappes known on the northern margin of the Amadeus Basin - the Winnecke Nappe and the White Range Nappe. The Nappe Complex crops out for 80 miles along the strike and 20 miles across it. The nappes have a core of metamorphic rocks (Arunta Complex) and an envelope of Heavitree Quartzite and Bitter Springs Formation. In some areas the Heavitree Quartzite has been replaced by a thrust on the inverted middle limb. The Complex is shown in Figure 17.

The metamorphic affects on the Heavitree Quartzite, Bitter Springs Formation and Arunta Complex within the Nappe Complex is described by McCarthy in Part II.

Winnecke Nappe: The synclinal core beneath the Winnecke Nappe crops out in an arc extending from Bald Hill and the Winnecke gold mining area to Bitter Springs Gorge (see Plates 2 & 5). The core plunges easterly beneath the Arunta Complex and portions of it re-appear at the surface again. at the Arltunga gold mining field due to a reversal of plunge. From the Arltunga area the synclinal core plunges easterly again and reappears from beneath the Arunta Complex in the Mount Coughlan-Ruby Gap Gorge area (Plates 2 & 3). In the normal limb at the base of the synclinal core the Heavitree Quartzite is little altered (see specimen descriptions 426 & 446) and rests unconformably on gneiss, amphibolite, schist and thin quartzite of the Arunta Complex (specimens 427, 428, 429, 430). Four miles east of Mount Laughlan the Quartzite has been thrust out and the Bitter Springs Formation rests directly on brecciated Arunta Complex (see specimen descriptions 429-431). The Quartzite is overlain by carbonate, shale and siltstone of the Bitter Springs Formation which has been little altered in some areas and converted to slate, phyllite or schist in others (see specimen descriptions 431, 441, 442, 449). The Bitter Springs Formation in turn is overlain in most places by highly contorted, brecciated and schistose Heavitree Quartzite (see specimen descriptions 420, 422, 432, 444, 444a) which is overlain directly by conformable schists derived from the Arunta Complex (see specimen descriptions 420-425). The assumption is made that this uppermost Heavitree Quartzite is overturned and hence repeated by isoclinal folding because of the reversed order of lithological units (Fig. 14). The unconformity at the stratigraphic base of the quartzite

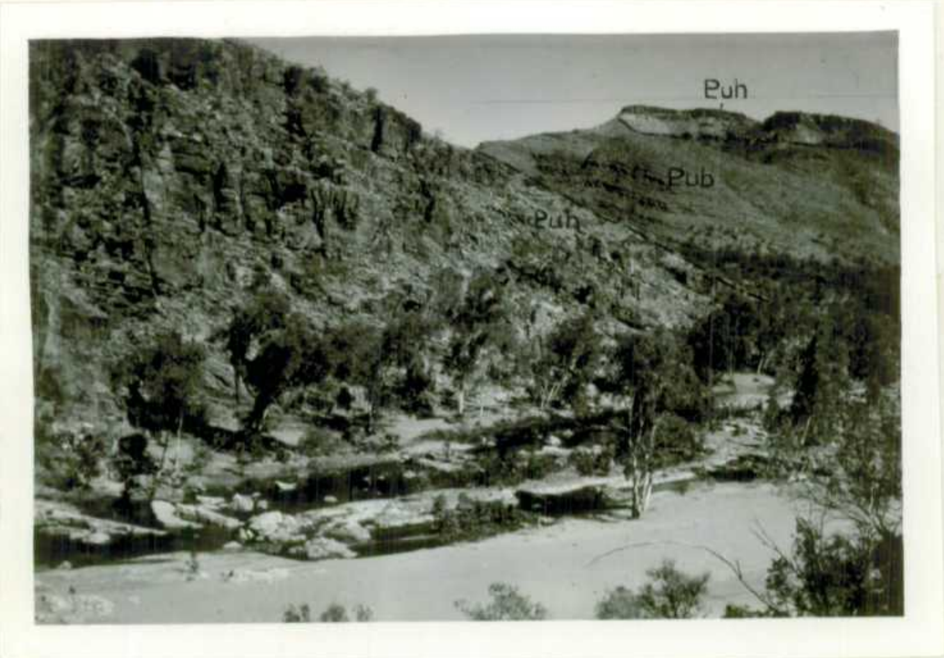


Figure 18. Repetition of the Heavitree Quartzite in the Winnecke Nappe two miles south-south-west of Ruby Gap Gorge. Photo taken looking westerly. In the foreground is Westerly dipping Heavitree Quartzite, overlain by the Bitter Springs Formation in the middle distance and Heavitree Quartzite again at the top of the hill in the distance. Neg. No. G/7357.

Figure 19. Recumbent folding in carbonate of the Bitter Springs Formation. Exposed in the bank of the Hale River two miles south-south-west of Ruby Gap Gorge (Place of collection of AS 449). Neg. No. G/7375.

is not preserved and crossbedding or other sedimentary structures which might indicate facing have been obliterated. In any case the intense isoclinal and recumbent folding in this limb would probably make such a facing meaningless.

Figure 14b shows schematically how the repetition could be explained by overthrusting. Consideration of the scale of the structure over many miles and the actual distribution of the rock units involved suggests the interpretation is wrong. Carbonate bearing schists do crop out over the Quartzite two miles west of Ruby Gap Gorge (shown ?.Bub on map) but the exposure is not typical of the Bitter Springs Formation and is most probably a carbonate from within the Arunta Complex. The Heavitree Quartzite has been sheared out and Arunta Complex overlies the Bitter Springs Formation at four localities. Two of the larger thrusts are exposed three miles east of Bitter Springs and six miles south of Ruby Gap Gorge.

The "front" of the Winnecke Nappe crops out as the prominent Heavitree Quartzite ridge to the east of Bitter Springs. The front then plunges subsurface below the Atnarpa area and reappears in the Heavitree Quartzite ridge through which the Hale River flows at Amarata waterhole. Figure 18 shows repetition of the Heavitree Quartzite in the synclinal core of the nappe one mile south-south-west of Ruby Gap Gorge. Figure 19 shows the recumbent folding of the Bitter Springs Formation exposed between the two quartzite ridges at the same locality.

The Winnecke Nappe is overlain by the synclinal core of the White Range Nappe.

<u>White Range Nappe</u>: The synclinal core of the Nappe crops out in White Range and in the range to the east of Atnarpa Homestead. The core crops out again south of Atnarpa in the quartzite ridges containing Chabbana Waterholes and is

buried farther south beneath the Giles Creek synform (see Fig.17 and Plate 2). The front of the Nappe occurs along the east-west quartzite ridge south of Tommys Gap dam. The top of the White Range Nappe is eroded.

The assumption has again been made that the repetition of the Heavitree Quartzite in the synclinal core of the nappe has been caused by recumbent folding and that therefore the rocks overlying the core are overturned (Fig.14a). This overturning has been proved at only one locality, two miles north-east of Atnarpa Homestead where the conglomerate at the base of the Heavitree Quartzite is preserved beneath the overlying Arunta Complex. Figure 14 compares the recumbent fold interpretation with a complex overthrust interpretation. The overthrust interpretation does not match the known distribution of rock units and is not preferred here.

Some thrusting has occurred on the overturned middle limb of the Nappe. The Heavitree Quartzite is considerably thinner or absent in these areas.

The Heavitree Quartzite and the Bitter Springs Formation are little altered near the front of the White Range Nappe but become progressively more highly metamorphosed deeper in the structure (Part II - specimens 441-442). The Arunta Complex has suffered retrograde metamorphism particularly near the overturned limb (see specimen descriptions 403, 405 in Part II).

Giles Creek Synform: The Giles Creek Synform (Fig.17 and Plate 5) forms the front of the White Range Nappe. It contains a core of Arunta Complex and an envelope of Heavitree Quartzite and Bitter Springs Formation. Plunges at the western end of the structure and overturning along its southern margin show that the structure is synformal and that the Arunta Complex is underlain by the Heavitree Quartzite and the Bitter Springs Formation. The body of rock can also be described as a nappe-outlier or klippe. A similar body of rock occurs 11 miles to the east-south-east on the Illogwa Creek Sheet area, north of Oolera Spring but this is probably a continuation of the Winnecke Nappe. (See cross section A-B-C. Plate III).

<u>Atnarpa Antiform</u>: The Atnarpa Antiform is a structure over 80 miles long which trends due east-west through the centre of the Arltunga Nappe Complex. (Plates 2, 3 & 5, Fig. 17). Its strike is nearly parallel to the strike of the axes of regional recumbent folding of the Nappes and their recumbent synclines are folded into broad arcs symmetrical about its axis. The axis plunges from east and west towards Arnarpa Homestead.

Another fold, probably an isoclinal synform, trends due east-west about four miles north of The Garden Homestead (Plate 5). The fold is in Arunta Complex rocks which had previously been folded about north-south axes and the area still has the north-south lineation preserved. This fold parallels the Atnarpa Antiform but may possibly be an older fold of the Arunta Orogeny (A-F2).

<u>North-South Folds</u>: Culminations and depressions of the axis of the Atnarpa Antiform are associated with regional north-south folds (see Plates 2, 3 & 5) which have also folded the rocks of the Arunta Complex.

One of these can be traced for over 45 miles on the western side of the Illogwa Creek Sheet area. The fold has domed the rocks of the Arunta Complex about Inkamulla and has domed the infolded Heavitree Quartzite farther south. The Inkamulla Granodiorite and the Huckitta Granodiorite occur in the core of domes within this area and may have been intruded at the same time as the doming.

The depression of the Atnarpa Antiform axis near Atnarpa Homestead shows the position of a regional downwarp which can also be clearly demonstrated in the arcuate curve of the strike of Arunta Complex rocks farther north in the Mount Riddock-Harts Range area.

Harts Range Anticline: Joklik (1955) used the concept of the Harts Range Anticline to explain the core structure of the area of crystalline rocks between the Georgina and Amadeus Basins. He described the area as an anticlinorium, the axis of which is parallel to that of the Harts Range Anticline and suggested that the faulting and folding of the Amadeus Basin sediments generally occurred in sympathy with pre-existing structures in the Precambrian basement complex. We believe that Joklik mistook the north-south trend of the domed structure which passes through Inkamulla and ascribed an east-west trend to it instead and joined it to a structure south of Mount Brassey thereby creating his "Harts Range Anticline".

The Alice Springs Orogeny superimposed on the Arunta Orogeny in the Harts Range - Strangways Range area: It has been shown that the effects of the Arunta Orogeny in the Chewings Range area have been to fold the rocks about isoclinal north-south axes and tightly refold them about near vertical east-west axes. The Alice Springs Orogeny has caused east-west isoclinal and recumbent folding on a large scale and the associated minor structures are a north-south isoclinal folding and li tion and a tight east-west cross folding with a weak linea n, (with later east-west and north-south folds). In terms of their minor structures at least there does not appear to be any basis on which to separate the two orogenies. McCarthy's work (in Part II) was specifically carried out to attempt to resolve this problem on a basis of metamorphism during orogeny; the Arunta Orogeny apparently producing moderate to high grade mineral assemblages and the Alice Springs Orogeny apparently causing retrograde metamorphism of them to the greenschist facies within the Ormiston and Arltunga Nappe Complexes. However it cannot be assumed that the Alice Springs Orogeny had no metamorphic effects in the Harts Range-Strangways Range area farther north. It has already been suggested that the Huckitta and Inkamulla Granodiorites have been emplaced during the Alice Springs Orogeny and as these granodiorites are in close association with high grade metamorphic gneisses, the minerals in the gneisses may also have formed at this time. This hypothesis is supported by the Palaeozoic age of several pegmatites and of a specimen of gneiss from this area.

Joklik (1955) reports that the grade of metamorphism decreases southwards from his great thrust-fault system in the Harts Range area. The most southerly specimen he describes came from half a mile north of White Range and consists of augen of quartz, biotite and feldspar in a matrix of sericite, chlorite and quartz. Joklik considers this rock to have suffered retrograde dynamic metamorphism to the chlorite zone of the greenschist facies. Farther away from the Nappe Complex the rocks progress to the albite-epidote-ampbibolite facies and the amphibolite facies. Joklik also reports cataclastic structure in the area of the headwaters of Cadney Creek and in the area of his great thrust-fault system. Biotite, garnet and silimanite are common in the catac stic rocks.

Faulting: The age of many of the faults in the Arunta Complex is unknown but many others intersect the Heavitree Quartzite and the Bitter Springs Formation and displace them in the area of the Arltunga Nappe Complex. These probably developed during the Alice Springs Orogeny.

Thrust faults occur at Trephina Gorge and Mount Benstead, south of Alice Springs, between the Hale River and Illogwa Creek on the western side of the Illogwa Creek Sheet area, and others occur within the Nappe Complex. The thrust faults in the Mount Benstead-Trephina Gorge area and four miles north-north-west of Bullhole Dam have been folded into an anticlinal shape and show clearly that displacement along them has been from north to south. This movement is in the same direction as the movement in the Arltunga Nappe Complex. It is assumed that movement on the other thrusts in the Illogwa Creek sheet area and south of Alice Springs has also been from north to south. Wells et. al., 1965d describe the structure south of Alice Springs and call it the "Blatherskite Nappe".

The faults which displace the Heavitree Quartzite-Arunta Complex boundary to the east of Ruby Gap Gorge are high angle reverse faults along which the northern block has ridden over the southern block. The dip of the remaining faults and their direction of movement is unknown except in the following cases: The fault on the southern side of the Georgina Range has a south block up movement and the fault near the Arltunga gold mining field appears to have a south block down movement.

Joklik (1955 p.105-108) describes the faulting of the Arunta Complex in the Harts Range area. The authors are not in total agreement with Joklik, regarding some of these fault structures and suggest that many of the thrust faults in the area may have originated by shearing of incompetent layers against competent layers during folding.

<u>Structure of the Amadeus Basin sediments</u>: During the Alice Springs Orogeny the Heavitree Quartzite and Bitter Springs Formation were infolded with the Arunta Complex in the nappe structures. At this time the Bitter Springs Formation was overlain by 10,000 to 14,000 feet of mostly conformable Upper Proterozoic, Cambrian and Ordovician sediments in the Macdonnell Ranges and some distance southwards. The

Orogeny commenced with upwarping late in the Ordovician and reached a climax in the Devonian and possibly carried on into the Carboniferous. The Mereenie Sandstone was deposited in the earlier stages of the orogeny during the period of upwarping and the Pertnjara Formation was deposited in the Devonian during the main orogenic period when the nappe complexes were formed.

None of the sediments overlying the Bitter Springs Formation are known within the nappe complexes. The Bitter Springs Formation was highly plastic during the deformation and was largely squeezed southwards out of the recumbent synclines of the Nappe Complex and pushed the younger sediments before it. The younger sediments slid southwards over a decollement surface in the Bitter Springs Formation and folded into a series of anticlines and synclines independently of the basement. The decollement within the Bitter Springs Formation was probably largely taken up in the evaporite sequence which was penetrated in Ooraminna No.1. (Planalp and Pemberton, 1963).

Another salt horizon in the Chandler Limestone (Wells et. al., 1965d) was proved by the drilling of the Alice No.1 well (Pemberton, Chambers, Planalp and Webb, 1964) and has played a prominent part in the development of the structures in the sedimentary pile. This upper salt horizon, near the base of the Cambrian sediments, caused the development of a second decollement surface and the mapping by Wells et. al., (1965d) demonstrates clearly that sediments have been stripped off the first or lower decollement surface and thrust upwards in the section and over the second or upper decollement surface.

The base of the decollement in the Bitter Springs Formation is best exposed in the north-west corner of the Hale River Sheet area (Plate 5). In this area the movement in the Bitter Springs Formation has been transmitted in some places to the Heavitree Quartzite and has stripped it off the Arunta Complex and doubled it up farther along the strike. The contact between the Bitter Springs Formation and the Arunta Complex has been mapped as a fault. The Bitter Springs Formation and the overlying Upper Proterozoic and Palaeozoic sediments are thrust faulted and tightly folded about east-north-east trending axes which are clearly independent of the Heavitree Quartzite-Arunta Complex structures which trends west-north-west.

The folds and many of the faults, thrusts and folded thrusts in the sedimentary succession above the Bitter Springs Formation will not be reflected in the Heavitree Quartzite-Arunta Complex structure at depth. The Heavitree Quartzite and the Arunta Complex have been deformed into nappe structures in the Arltunga Nappe Complex and the Ormiston Nappe Complex along the northern margin of the Amadeus Basin. There is therefore a large scale disharmonic relationship between the structures developed above and below the Bitter Springs Formation during the Alice Springs Orogeny.

<u>The age of the Alice Springs Orogeny</u>:

Prichard and Quinlan (1962) give the thickness of the Pertnjara Formation as 21,000 feet comprising 16,000 feet of conglomerate and 5000 feet of arenite. They also point out that although 21,000 feet of sediment has been measured the actual vertical thickness of the formation in the trough of the Missionary Plain syncline probably does not exceed 10,000 feet. Their facies studies prove a provenance from the north and east. They also state (p.28) - 'The marked angular conformity in both dip and strike of formations one to another proves the absence of any widespread orogeny between the times of deposition of the Heavitree Quartzite and the Pertnjara Formation'. They report (p.31) - 'that all faulting and folding in the area probably occurred during and shortly after the deposition of the Pertnjara Formation'. Wells (1964) recognizes two periods of diastrophism from the north-east of the Amadeus Basin. 'The first period of folding resulted in the uplift of the Bitter Springs Limestone and older rocks. An angular unconformity is present between the Bitter Springs Limestone and the overlying Areyonga Formation'.

'The second period of uplift and folding was in part synchronous with the deposition of the Pertnjara Formation; large thicknesses of synorogenic conglomerate make up a large part of the formation'.

The first period of diastrophism recognized by Wells cannot be classed as major because no angular unconformity is recognized between the Bitter Springs Formation and the Areyonga Formation on the northern part of the Rodinga Sheet area (Ranford & Cook, pers. comm.) or from our own observations on the northern part of the Alice Springs Sheet area.

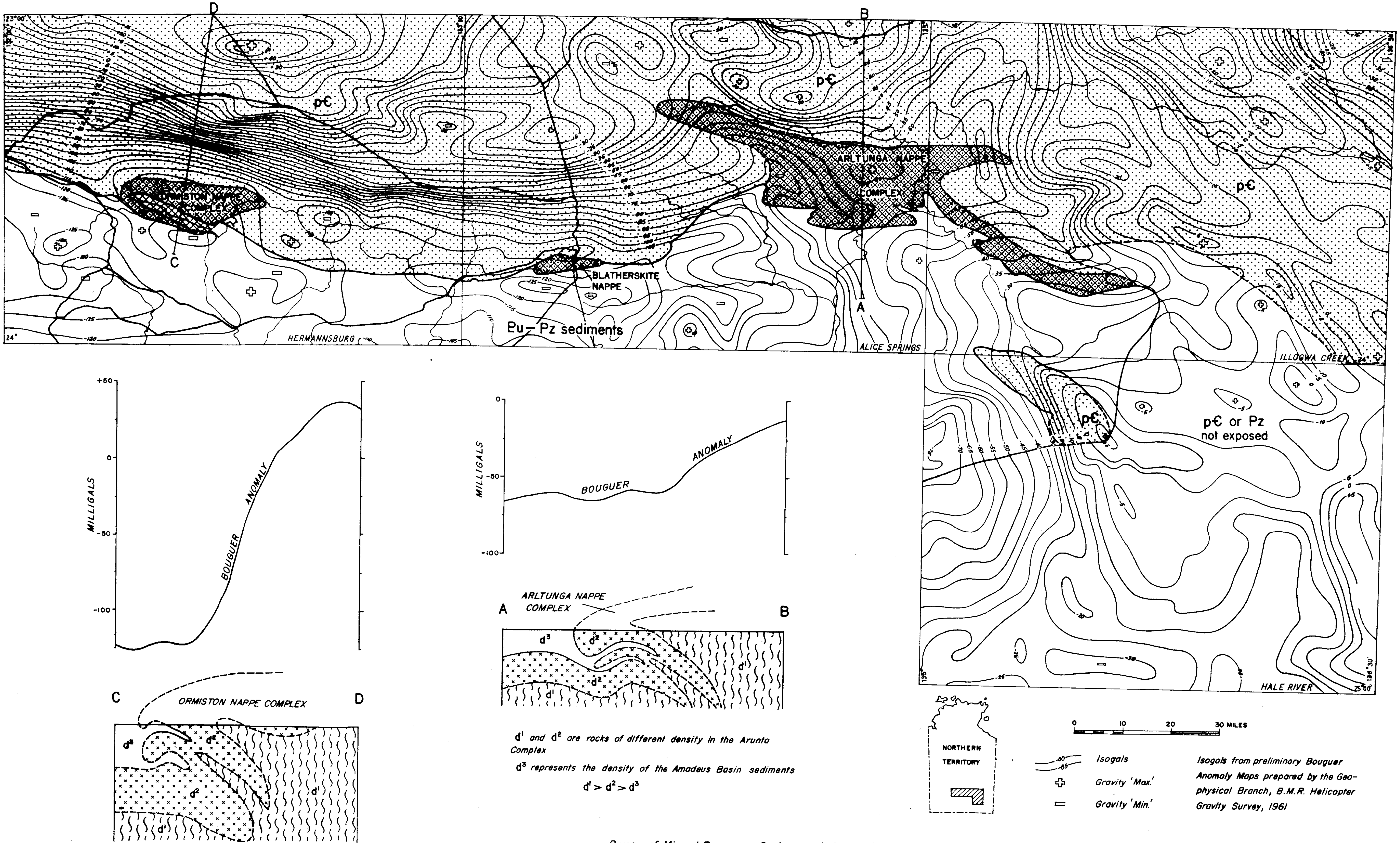
Therefore the Pertnjara Formation was deposited during the Alice Springs Orogeny. Fossils from the base of the Pertnjara indicate a middle or upper Devonian age (Forman 1965, Ranford et. al., 1965, Wells et. al., 1965c).

Some preliminary age determination work has been carried out on specimens of pegmatite and gneiss. Apparent ages are set out below.

Locality	Rock	Mineral	Method	Age (in millions of years)	Calculated by (or reference)
Rex pegmatite 4 m.S.E. of Harts Range Police Station	Pegmatite	Muscovite Apatite Plagioclase	Rb/Sr	400 ± 20	G.H.Riley
Harts Range	Pegmatite	Samarskite	Lead	700 ± 600	Wilson, Compston, Jeffery & Riley (1960)
		Muscovite	Rb/Sr	410	
2 m.S.W. of Harts Range Police Station	Irindina Gneiss	Biotite	K/Ar	367	Walpole & Smith (1961)
?Delma Mine	Pegmatite	Samarskite	Lead	420	J.T.Wilson
4 m.N.N.W. of Alice Springs	Arunta Complex	Muscovite & Biotite	Rb/Sr	1280	G.H.Riley
	(?Granite)	Feldspar & total rock	Rb/Sr	2900	
Ooraminna No.1	Pertatataka Formation (Shale)	Illite	Rb/Sr	750	V.M. Bofinger

BOUGUER ANOMALY MAP WITH GEOLOGICAL AND GRAVITY SECTIONS

Figure 20



Bureau of Mineral Resources, Geology and Geophysics, March 1965

To accompany Record 1965/44

NT/A/99

The oldest age is the total rock age (2900 m.y.) from 4 miles north-north-west of Alice Springs and may represent the age of formation of the Arunta Complex. The apparent age of 1280 m.y. for muscovite and biotite may be the age of pegmatite injection in this area (a number of pegmatites are known to be older than the Upper Proterozoic Heavitree Quartzite). The ages of 420 to 367 m.y. correspond to the age of formation of the Harts Range pegmatites and to the age of the Alice Springs Orogeny which has affected that area (the ages are equivalent to Silurian to Upper Devonian).

The age of the Pertatataka Formation (750 m.y.) confirms the Upper Proterozoic age of this formation and suggests the Heavitree Quartzite and Bitter Springs Formation are also of Upper Proterozoic age (600 m.y. - 1400 m.y. Walpole, Roberts & Forman, 1965).

The fossil ages and the apparent mineral ages both suggest the Orogeny took place mostly in the Devonian. At this time the Arunta Complex was probably covered by 14,000 to 18,000 feet of sediment (including Upper Proterozoic, Cambrian and Ordovician, but not the Mereenie Sandstone and Pertnjara Formation of post Ordovician age).

Explanation of the gravity gradient: During 1961 the geophysical section of the Bureau of Mineral Resources carried out a gravity survey of the area. A minimum density of one gravity station per 50 square miles was established. Bouguer anomaly maps prepared from the results of this survey and detailed surveys by Magellan Petroleum Corporation (also in 1961) are shown in Figure 20. Langron (1962) discusses the results of the survey and states that the most prominent feature is the zone of steep gravity gradient which trends in a westerly direction across the Hermannsburg Sheet area and most of the Alice Springs Sheet area. The zone has a maximum gradient of about 3 m.gal. per mile, near its centre on the Hermannsburg Sheet. Towards its eastern portion on the Alice Springs Sheet area the gradient weakens and intersects a strong north-north-west feature which continues on the Illogwa Creek and Hale River Sheet areas. Langron noted that the gradient occurred over Arunta Complex outcrop and that the margin of the Amadeus Basin lay to the south of it. To explain the feature, overthrusting or overfolding of the Arunta Complex over the Amadeus Basin sediments was invoked. In addition Langron (1962) and Marshall & Narain (1954) point out that there is good reason to expect crustal warping within the area. Langron concluded that the gradient was due to a combination of the density contrast between basement and sediments, the very great thickness of sediments, overthrusting and crustal warping.

The overthrust or nappe hypothesis was proved by the results of the geological mapping described in this report. However, the only sediments which are actually infolded with the Arunta Complex are the Heavitree Quartzite and the Bitter Springs Formation. The density contrast between these and the Arunta Complex is probably not as great as the density contrast between the other sediments in the Amadeus Basin and the Arunta Complex (particularly when it is considered that the salt bearing section of the Bitter Springs Formation was probably squeezed out of the nappes) and the maximum known thickness of infolded sediment is probably no more than 5,000 feet in the Arltunga Nappe Complex. In any case Figure 20 shows that the main gradient occurs directly to the north of the Nappe Complexes and not over them. For these reasons overthrusting must be discarded as the direct cause of the observed gravity gradient. The geological cross-sections in Figure 20 show the way in which the known geological facts can be used to explain the gradient by crustal warping. This

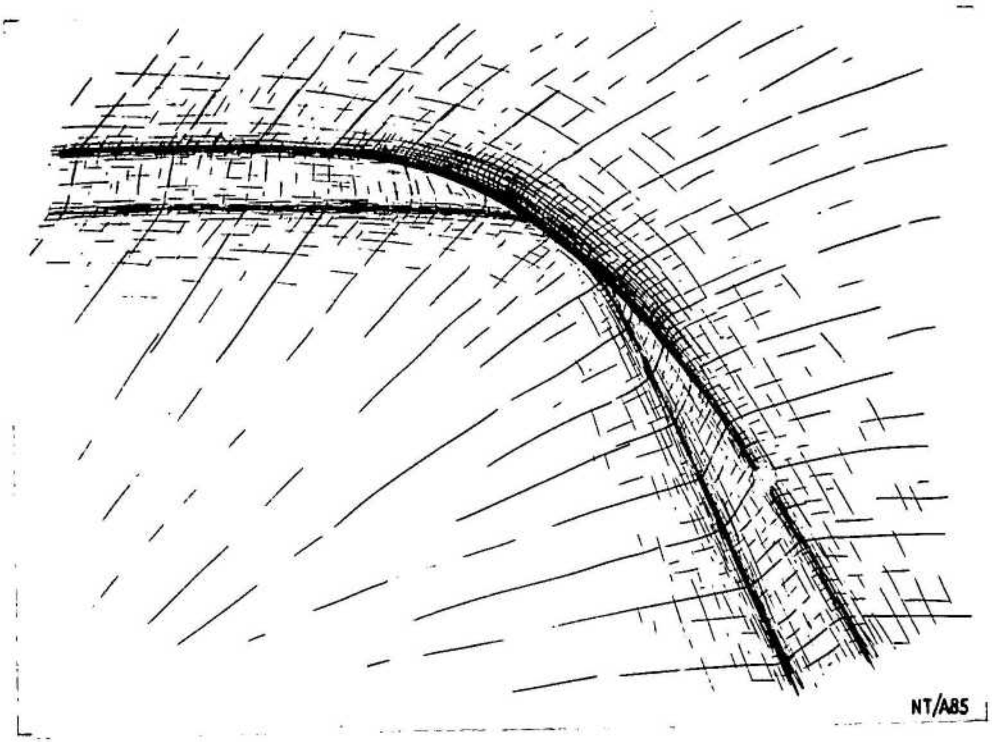


Figure 21. Recumbent folding as the result of a bent crustal upwarp.

hypothesis assumes crustal upwarp to the north of the present margin of the Amadeus Basin which would bring upward rocks of a higher density from below. During this upwarp the overlying less dense rocks slumped southwards and formed nappes in the area of gravity low and built up an increased thickness of lower density rocks within it. Later erosion from the upwarped area and deposition in the gravity low to the south helped to accentuate the observed gravity differences between the two areas.

The north-west trends on the eastern side of the area correspond to the trend of the margin of the Amadeus Basin in that area and also to the trend of the margin of the Georgina Basin to the north-east. These trends may also be explained by a process of crustal upwarp and they appear to be continuous with those discussed above. This suggests the possibility that the Arltunga Nappe Complex at least is situated on the concave side of a bend in a zone of major crustal upwarp. Similarly the Ormiston Nappe Complex and the nappes in the Mount Liebig Sheet area (Wells, Forman & Ranford, 1965b) are situated on the concave side of a bend in the gravity gradient which is situated near Haasts Bluff. Figure 21 illustrates the concept.

GEOLOGICAL HISTORY

The following is a resume of the order of geological events which occurred along the north-eastern margin of the Amadeus Basin.

1. Folding and high grade metamorphism of the Arunta Complex during the Arunta Orogeny. Intrusion of granite.
2. Intrusion of pegmatite and dolerite.
3. Deposition of Heavitree Quartzite and Bitter Springs Formation during the Upper Proterozoic in a shallow epicontinental sea. Formation of salt deposits. Period of tectonic stability. Some minor volcanic activity in east of area.

4. Slight tectonic instability in neighbouring areas, possibly to the north and east, produced some local warping of the Bitter Springs Formation and local weathering before deposition of the Areyonga Formation.
5. Deposition of the Upper Proterozoic Areyonga Formation and Pertatataka Formation during a period of slight to moderate tectonic instability in neighbouring areas. Possible period of glaciation (see Wells et. al. 1965d). Stability appears greater in the eastern area where limestones are more abundant.
6. Marine deposition continued into the Cambrian. Deposit of salt near the base of the Pertaoorrta Group and a thick succession of calcareous sediments suggest deposition in a fairly shallow sea during a period of relative tectonic stability. Evidence of instability to the south at the beginning of this period (see Forman, 1965 and Wells et. al. 1965c).
7. Marine deposition during the Ordovician in shallow seas during a period of tectonic stability.
8. Pre-orogenic phase of the Alice Springs Orogeny. The sea receded from the area and weathering and erosion took place in the east before deposition of the Mereenie Sandstone in a predominantly continental environment. In the west, deposition of the Mereenie Sandstone appears continuous after deposition of the Larapinta Group. Period from late Ordovician to about middle Devonian.
9. Orogenic phase of the Alice Springs Orogeny in the middle to upper Devonian. Uplift of the northern and north-eastern area to provide a source for the Pertnjara Formation. Development of nappes along the northern margin of the basin and folding, decollement sliding, and thrusting of the sediments within the Amadeus Basin. Refolding of Arunta Complex,

retrograde metamorphism and intrusion of mica bearing pegmatites in Harts Range area. Possible development of some granite.

10. Weathering and erosion.
11. Probable marine transgression and regression over the south-eastern corner of the Illogwa Creek Sheet area in the Mesozoic.
12. Weathering and erosion.
13. Tertiary pluvial period commences with infilling of topographic lows by clastic fluviatile and lacustrine sediments.
14. Period of weathering, duricrusting and lateritization.
15. Return to pluvial conditions, deposition of lacustrine deposits in low lying areas.
16. Erosion and deposition of Quaternary alluvium.
17. Period of aridity in Pleistocene or Recent. Formation of aeolian sand plain and sand dunes.
18. Dunes reach stability under present day conditions.

ECONOMIC GEOLOGY (E.N.M.)

Mica has provided the bulk of the revenue from mining in the area. Over the years 1892 to 1952, the value of mica from the Harts Range and the neighbouring Plenty River Mica Field (on the Huckitta 1:250,000 Sheet area) exceeded £600,000. Gold has been mined at a few localities and had realized over £30,000 by 1925. Shows of the other metalliferous ores have not yet proved to be economically important. The pastural industry depends largely upon underground water for watering stock.

Metalliferous Ores

Gold: Alluvial gold was discovered at Arltunga in April 1887. The government geologist H.Y.L. Brown visited the district in 1888 (Brown 1889) and reported that about 18 to 20 claims (including alluvial diggings) were in existence, although the lack of water was seriously hampering their development. By 1890, over 20 auriferous reefs were being worked along with some fifteen alluvial claims.

Gold was discovered and worked in the Heavitree Quartzite at White Range in 1897 and south of Winnecke's Depot, some 25 miles north-west of Arltunga in 1902.

Returns from all three fields showed averages of about one ounce per ton on treatment at the batterys and cyanide plants, but Playford (1920) estimated that the average of ore raised, to ore treated, was about three to one, so that the average return for ore mined would be nearer 9 dwts. Most of the reefs were small and discontinuous and in all cases the gold was finely disseminated on pyrite in vughs and in 'cellular quartz', which appeared to be the loci of pyrite accumulations which had been oxidised to limonite and weathered out of the enclosing quartz.

Very little prospecting was done at Arltunga from 1920 to 1932 and the battery was sold soon after this. In 1934 new discoveries in veins near Claraville encouraged further prospecting, but by the end of 1936 work had ceased on the field. The gold in the oxidised zone occurs in quartz with vughs and joints with limonite, calcite and siderite. The country rock is dark coloured basic gneiss. The majority of the veins are about a foot in length and three to four inches across although some reach 50 feet or more in length and up to a foot across.

Soon after its discovery, the White Range Field became the major producer in the district; the average return for stone treated was about 1½ oz. per ton. However, by 1905 activity had slackened off, and continued to decline until 1920 when all work ceased. The field was confined wholly to the metamorphosed Heavitree Quartzite in the White Range. Hossfeld (1937b) attributed the formation of the reefs to tensional faulting during arching of the competent quartzite beds during a period of regional folding and metamorphism.

Eighteen claims were pegged in the Winnecke's Gold Field district in the period 1901-1905, but activity declined rapidly after this date. Sporadic attempts were made to prove further deposits in the period 1933-1937, but only about 300 oz. of gold was won at this time and the poor returns discouraged further work. The gold occurs in ferruginous material in vughs and fractures in highly irregular quartz bodies in a gneissic group of rocks including micaceous and quartzose schists, dolomitic marble and rarely metaquartzites.

Copper: Minor amounts of copper have been recorded from a number of localities, principally in the gold field areas and in a north western extension of the gold mineralization belt. The copper occurs in stockworks of red copper oxide in quartz on the edges of intrusive quartz reefs, or as veins of the carbonates, malachite, azurite, atacamite. Chalcanthite has also been recorded. Arsenic is associated with the copper in the Excelsior Mine, White Range. Copper shows also occur within a five mile radius east and north of Southern Cross Bore; three miles south-south west and seven miles south of Mount Riddock Homestead, and two miles north of Ruby Gap Gorge.

Lead, silver, bismuth: Small lead shows, with associated silver, and in one case, bismuth have been prospected at the Glankroil Mine, (Winnecke's Gold Field) at Kenny's Prospects (a few miles north of the field) and at a locality 1½ miles north of the old Arltunga Police Station. An analysis of two samples from Kenny's Prospect (unpublished A.M.D.L. report AN339-63) indicated silver contents of 30 oz. and 14 oz. per long ton.

Tin: Minor deposits of tin have been reported from two of the copper prospects in the Strangways Range.

Radioactive minerals: Betafite, samarskite, columbite and monazite are associated with some of the mica-bearing pegmatites in the Harts and Strangways Ranges, but none of these occurrences have been exploited.

Non-metalliferous ores.

Mica: Tate (1880) first recorded the presence of mica in the district. In November 1888 (Brown, 1899) commented on a mica mine (Lindsay's) in the headwaters of Illogwa Creek. A year later, (Brown, 1890) he visited a mica claim in what is now the Harts Range Mica Field. Numerous claims had been tested, mined and abandoned by 1905 when Mathews (1905b) reported that only one claim (the Spotted Dog) was being worked. Mathews attributed this situation to a lack of local buyers for the product. There was little activity on the field until 1926 when two miners, representing an Adelaide company, opened up four mines in the White Quartz Hill Field, and two in the Mount Riddock area.

In 1929, a company, directed by a mine manager with experience in the Indian mica fields, introduced Italian labour and began deep sinking and systematic mining.

Scarcity of overseas supplies during World War II stimulated further development of a large number of prospects. During this period a phlogopite mine was opened near Mount Johnstone in the Strangways Range, but owing to the sporadic occurrence of the mica the mine was abandoned within a year. This peak of activity continued (highest return - £71,067 in 1948) until a decline in 1950. A rise in the price of mica in 1952 caused a revival of work in the field but this was short lived. In the last period of operations, activity was confined to recovering mica from the dumps. In 1961 less than a ton of mica was recovered in this fashion, and all activity on the fields finished in that year.

<u>Asbestos</u>: Jensen, in an unpublished report dated 20th October, 1943, (on B.M.R. files) described an asbestos deposit in Disputed Creek, $\frac{3}{4}$ mile north-east of the Rex Mica Mine. The remoteness of the area and the varying quality and shortness of the fibre make this deposit an unlikely commercial prospect.

<u>Gemstones</u>: Beryl occurs in many of the mica-bearing pegmatites, but in all instances the stone is extensively fractured.

Garnet was gathered in large quantities towards the end of the 19th century in the belief that it was oriental ruby. More than 20 leases were taken up, but Rennie (1889) identified the stone as garnet and all activity in the field ceased.

<u>Phosphate</u>: A sample of magnetite-apatite-metaquartzite from the upper reaches of Illogwa Creek has been examined and the apatite content was estimated at 15% (see description 443A, McCarthy, Part II). The extent and composition variation of the apatite rock is unknown.

<u>Underground water</u>

<u>Stock</u>: The area includes a number of 'groundwater provinces' outlined by Jones and Quinlan (1962) - Macdonnell, Hermannsburg, Plenty and Simpson.

The characteristics of the groundwater provinces (with reference to suitability for stockwater) were summarized (pp.157-158) under the following headings:-

	Aquifers	Depth to Peizo-metric Surface	Drilling Depth	Quality	Avail-ability
Macdonnell	Fractured weathered metamor-phics. Alluvial sands	Shallow (less than 100 feet)	generally shallow	variable	generally poor
Hermannsburg	Upper Proterozoic limestone, sandstone. Tertiary and Quaternary sand pockets	variable	variable	very variable	variable
Plenty	minor basins piedmonts;	variable	variable	good (less than 1500 p.p.m. * t.d.s. to moderate	variable
	weathered metamor-phics	shallow to moderate (100-250 feet)		variable	generally poor
Simpson	Tertiary sand	deep (over 250 feet) to west	deep to very deep	good to moderate, some poor	good except north and west

* p.p.m.t.d.s. = parts per million, total dissolved solids

Woolley (1963) has assessed the groundwater prospects of the lower Plenty River basin which is situated in the central and north-east sectors of the Illogwa Creek Sheet area. The potential water supply for stock and domestic purposes from aquifers of four ages were discussed:

Precambrian rocks: Aquifers in schists have produced low to moderately saline water (suitable for stock) in the north-west and highly saline water in the south-east of the sector.

Lower Cretaceous and Tertiary rocks: Aquifers have supplied over 1,000 gals. per hour from shallow to moderate depths.

Quaternary alluvium: Quaternary alluvium was generally thin in the sector and the base is mostly above the piezometric surface.

Irrigation: Jones and Quinlan (1962) and Perry et. al. (1963) have made a hydrological study of seven catchments and groundwater basins (covering over 10,000 square miles in the area and have made a preliminary assessment of groundwater suitable for irrigation in three of these. In these three basins, which occupy the plains extending up to 20 miles north from the Macdonnell Ranges, the aquifers were poorly consolidated sand and gravel and partly cemented kunkar.

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PRELIMINARY EDITION, 1965

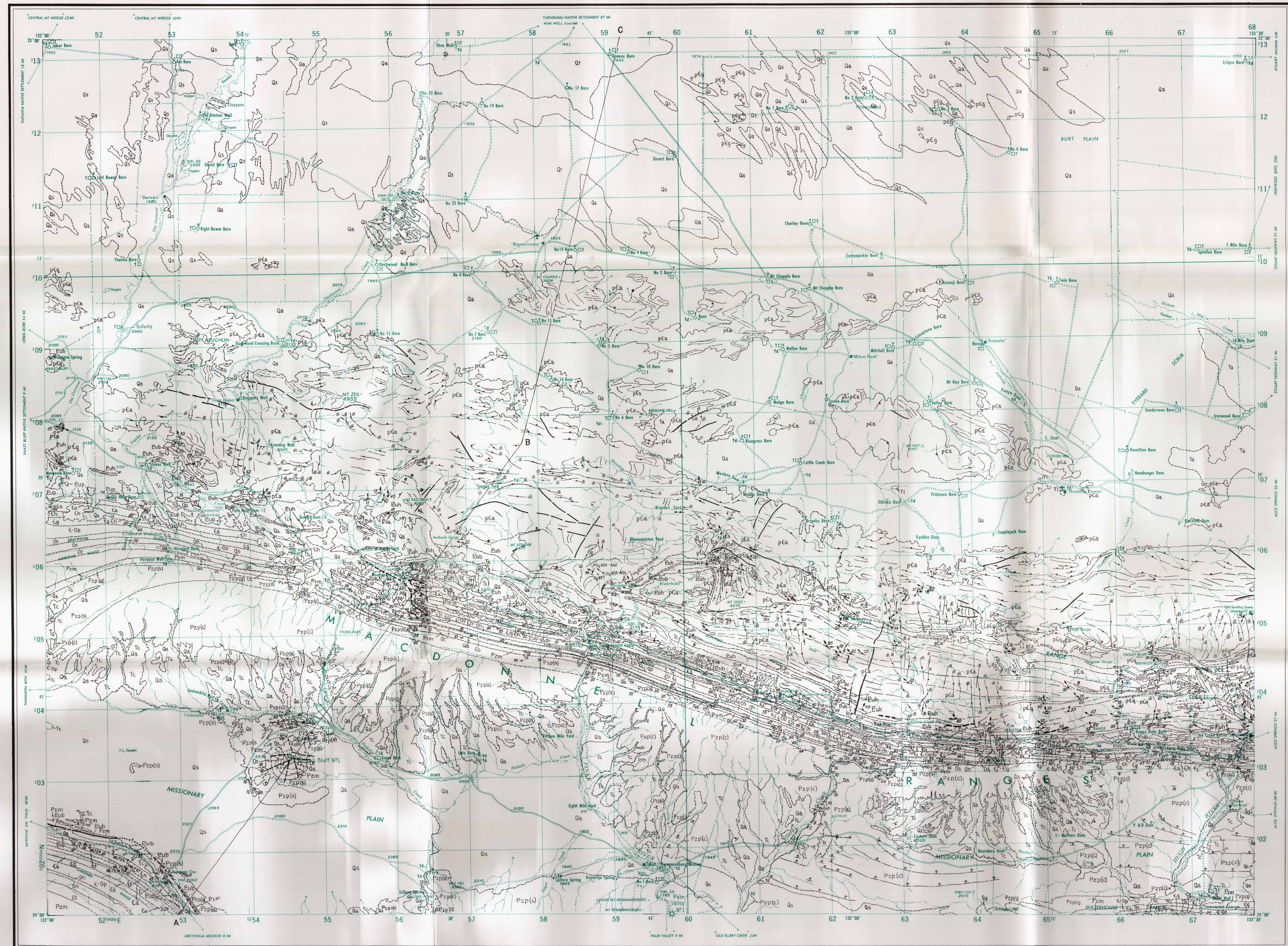
SUBJECT TO AMENDMENT

AUSTRALIA 1:250,000

HERMANNSBURG

NORTHERN TERRITORY

1:250,000 GEOLOGICAL SERIES SHEET SF 53-13

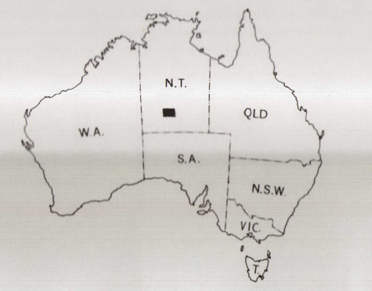


Reference

CAINOZOIC	QUATERNARY	Undifferentiated	Q	Alluvium, sand, travertine, conglomerate (section only)
			Qa	Alluvium
			Qs	Aeolian sand
			Qt	Travertine, kunkar
	TERTIARY		Tc	Conglomerate
			Tl	Chalcedonic limestone
			Ta	Laterite, ferricrete
			Ts	Sandstone, conglomeratic sandstone, sandy siltstone, lignite
PALAEOZOIC	DEVONIAN TO CARBONIFEROUS	Pertnjara Formation	Pzp(c)	Calcareous conglomerate
			Pzp(s)	Calcareous sandstone, pebbly sandstone
			Pzp(a)	Siltstone, shale
	ORDOVICIAN TO DEVONIAN	Mereenie Sandstone	Pzm	Sandstone
	CAMBRIAN TO ORDOVICIAN	Larapinta Group: Undifferentiated	Є-Ol	Fossiliferous sandstone, siltstone, shale, limestone
		Stokes Formation	Ot	Siltstone, shale, fossiliferous limestone
		Stairway Sandstone	Os	Fossiliferous sandstone, silty sandstone
		Horn Valley Siltstone	Oh	Siltstone, fossiliferous limestone
		Pacoota Sandstone	Є-Op	Fossiliferous sandstone, silty sandstone
	CAMBRIAN	Pertaoorrta Group: Undifferentiated	Єp	Sandstone, siltstone, shale, dolomite, limestone
		Goyder Formation	Єg	Sandstone, calcareous sandstone
		Jay Creek Limestone	Єj	Limestone, shale, dolomite
		Hugh River Shale	Єh	Shale, limestone, siltstone
		Arumbera Sandstone	Єa	Silty sandstone, siltstone
		Petermann Sandstone	Єe	Red-brown sandstone, silty sandstone
		Deception Formation	Єd	Red-brown siltstone, shale
		Illara Sandstone	Єi	Red-brown sandstone, silty sandstone
		Tempe Formation	Єt	Siltstone, calcareous sandstone, fossiliferous glauconitic limestone
		Eninta Sandstone	Єn	Red-brown sandstone, silty sandstone, siltstone
PRECAMBRIAN	UPPER PROTEROZOIC	Pertatataka Formation	Ꝑup	Siltstone, sandstone, limestone
		Areyonga Formation	Ꝑua	Calcareous sandstone, tillitic siltstone, conglomerate
		Bitter Springs Formation	Ꝑub	Dolomitic limestone, shale, siltstone
		Heavitree Quartzite	Ꝑuh	Quartzite, sandstone
		Arunta Complex	pЄa	Gneiss, schistose gneiss, granite, gneissic granite, schist, amphibolite, sericite-quartz schist, meta-quartzite, pegmatite
			pЄg	Granite
			pЄq	Meta-quartzite, quartz-sericite schist

- Geological boundary
- Anticline, showing plunge
- Syncline, showing plunge
- Overturned anticline
- Fault
- Where location of boundaries, folds and faults is approximate, line is broken; where inferred, queried; where concealed, boundaries and folds are dotted, faults are shown by short dashes
- 35 Strike and dip of strata
- Vertical strata
- 20 Overturned strata
- Dip < 15° (air-photo interpretation)
- Dip 15°-45° (air-photo interpretation)
- Dip > 45° (air-photo interpretation)
- Trend lines (air-photo interpretation)
- Joint pattern (air-photo interpretation)
- Unmeasured joint
- Vertical joint
- Strike and dip of foliation
- Vertical foliation
- 75 Foliation with trend of lineation
- 60 Trend of lineation
- Macrofossil locality
- × Hg 450 Specimen locality. Text reference prefixed by H
- HLFX7 Measured section
- Dyke; dl—dolerite, p—pegmatite
- Bore
- Windpump
- Well
- T Tank
- E Earth tank
- Dam on stream
- WH Waterhole
- Gas well
- Abandoned well with show of gas
- Road
- Vehicle track
- Fence
- "Anburla" Homestead
- Yd Yard
- Landing ground
- N.M.H157 Astronomical station
- . 2045 Height in feet, barometric; datum: mean sea level

Compiled and issued by the Bureau of Mineral Resources, Geology and Geophysics, Department of National Development. Base map compiled by the Division of National Mapping, Department of National Development. Aerial photography by the Royal Australian Air Force; complete vertical coverage at 1:46,000 scale
Transverse Mercator Projection



INDEX TO ADJOINING SHEETS

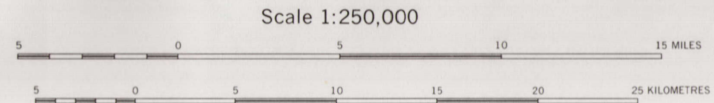
Showing Magnetic Declination

HIGHLAND ROCKS SF 52-7	MOUNT THEO SF 52-8	MOUNT PEAKE SF 53-5	BARROW CREEK SF 53-6	ELKEDRA SF 53-7
LAKE MACKAY SF 52-11	MOUNT DOREEN SF 52-12	NAPPERBY SF 53-9	ALCOOTA SF 53-10	HUCKITTA SF 53-11
MOUNT RENNIE SF 52-15	MOUNT LIEBIG SF 52-16	HERMANNS-BURG SF 53-13	ALICE SPRINGS SF 53-14	ILLOGWA CREEK SF 53-15
BLOODS RANGE SG 52-3	LAKE AMADEUS SG 52-4	HENBURY SG 53-1	RODINGA SG 53-2	HALE RIVER SG 53-3
PETERMANN RANGES SG 52-7	AYERS ROCK SG 52-8	KULGERA SG 53-5	FINKE SG 53-6	McDILLS SG 53-7

4°30'E 5°E

ANNUAL CHANGE 1'30"E

Scale 1:250,000



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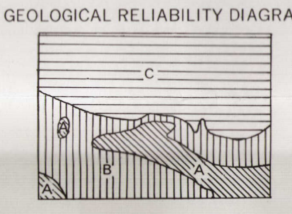
1962, by : T. Quinlan, D. Woolley, L.C. Ranford.
1964, by : D.J. Forman, E.N. Milligan,
Compiled, 1964, by : D.J. Forman, E.N. Milligan, T. Quinlan, N.L. Kruger.
Drawn by : N.L. Kruger.

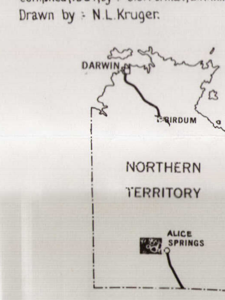
GEOLOGICAL RELIABILITY DIAGRAM



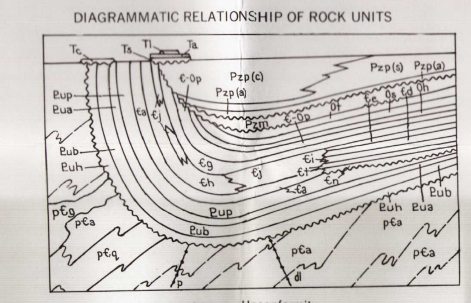
A Detailed Mapping

B Detailed reconnaissance, general reconnaissance, reconnaissance and air-photo interpretation.

C Air-photo interpretation



DIAGRAMMATIC RELATIONSHIP OF ROCK UNITS



Section

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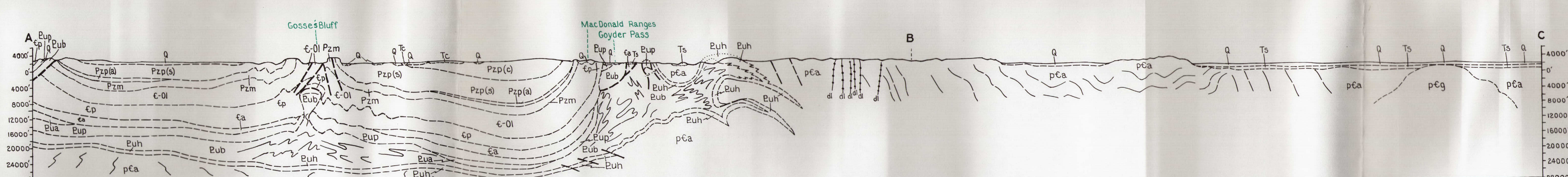


HERMANNSBURG

SHEET SF 53-13

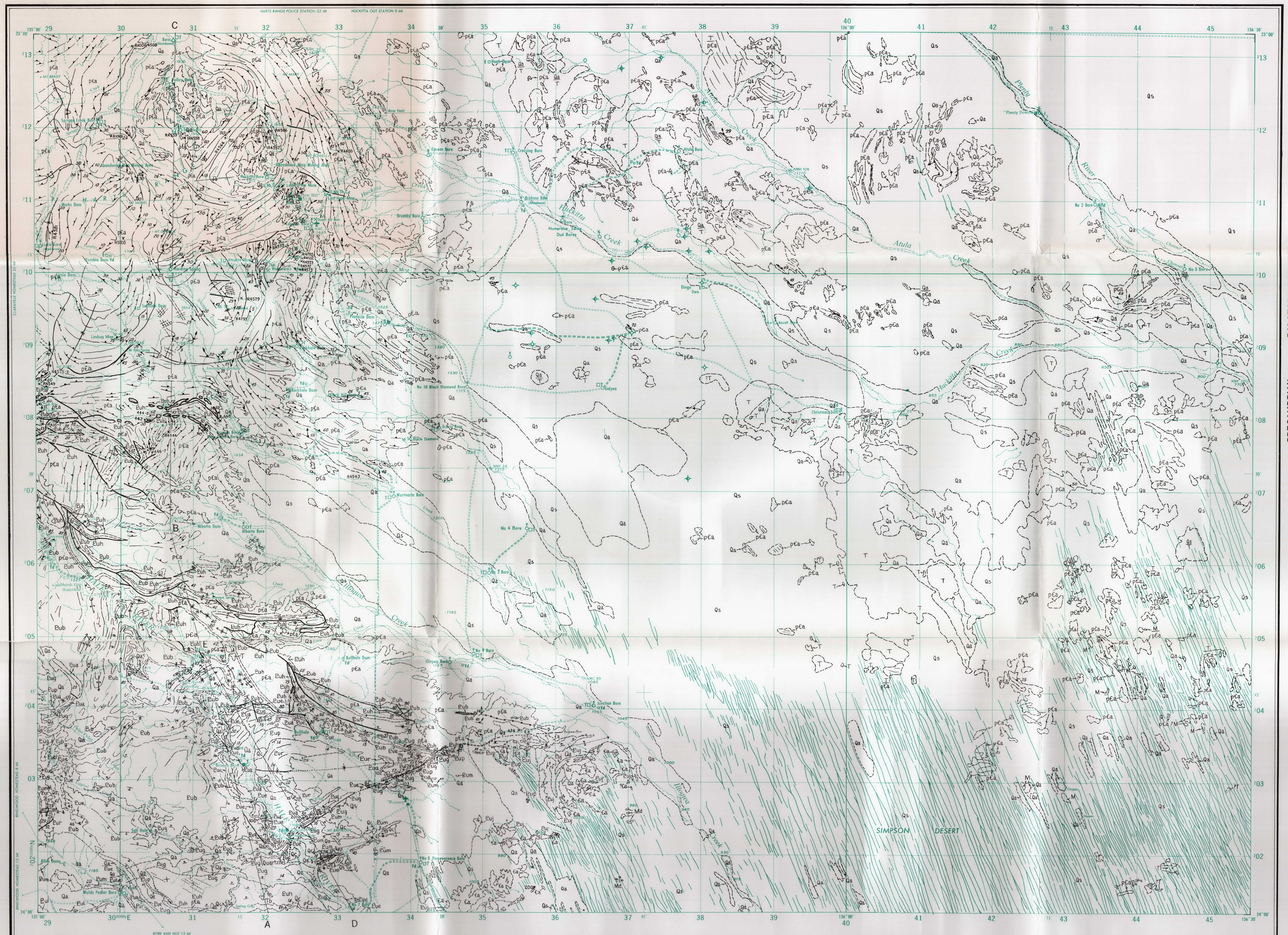
Plate 1
Alice Springs-Geology

AUSTRALIA 1:250,000

ILLOGWA CREEK

NORTHERN TERRITORY

1:250,000 GEOLOGICAL SERIES SHEET SF 53-15



PRELIMINARY EDITION, 1965

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Reference

CAINOZOIC	QUATERNARY	Undifferentiated	Q	Alluvium, sand, conglomerate. (Section only)
			Qa	Alluvium, river gravel
			Qs	Aeolian sand
			Qc	Conglomerate, scree
	TERTIARY		Tb	Silcrete (greybilly)
		Undifferentiated	T	Sandstone, conglomeratic sandstone, calcareous silty sandstone, chalcedony, conglomerate, siltstone, laterite
MESOZOIC	? JURASSIC	De Souza Sandstone	Md	Coarse ferruginous sandstone, siltstone, conglomeratic sandstone
		Undifferentiated	M	Ferruginous sandstone, siltstone, conglomerate
PALAEOZOIC	CAMBRIAN	Pertaoorrta Group Arumbera Sandstone	€a	Red-brown sandstone, silty sandstone, siltstone
PRECAMBRIAN	UPPER PROTEROZOIC	Pertatataka Formation	Pup	Siltstone, shale
		Julie Member	Puj	Dolomite, limestone, lenses of sandstone and calcareous sandstone
		Waldo Pedlar Member	Pul	Siltstone, fine-grained platy sandstone
		Limbla Member	Pum	Cross-laminated sandstone, sandy calcarenite
		Ringwood Member	Pur	Algal dolomite, calcarenite
		Areyonga Formation	Pua	Sandstone, arkose, boulder clay, conglomerate, dolomite
		Bitter Springs Formation	Pub	Dolomite, limestone, siltstone, sandstone, basic volcanics
		Loves Creek Member	Pue	Massive algal dolomite, red siltstone, quartzite
			Pue₁	Basic volcanics
		Gillen Member	Pug	Dolomite, green siltstone, sandstone
		Heavitree Quartzite	Puh	Quartzite, conglomeratic sandstone
		Huckitta Granodiorite Inkamulla Granodiorite	p€g	Massive hornblende granodiorite Biotite granodiorite
		Arunta Complex	p€a	Gneiss, amphibolite, meta-quartzite; metamorphosed limestone, basalt, dolerite, porphyrite, gabbro

Geological boundary

Anticline, showing plunge

Syncline, showing plunge

Fault

Where location of boundaries, folds and faults is approximate, line is broken; where inferred, queried; where concealed, boundaries and folds are dotted

Strike and dip of strata

Horizontal strata

Overturned strata

Dip < 15° — air-photo interpretation

Dip 15-45° — air-photo interpretation

Dip > 45° — air-photo interpretation

Trend lines — air-photo interpretation

Joint pattern — air-photo interpretation

Strike and dip of foliation

Strike and dip of foliation—unmeasured

Foliation with trend of lineation

Vertical foliation

Fossil locality—general

× I Specimen locality. Text reference prefixed by IC

×R4573 Registered B.M.R. collection number

Measured section

Vein; p—pegmatite, q—quartz

Mine

Minor mineral occurrence

Ce Cerium

Cu Copper

Au Gold

Gp Gypsum

Mi Mica

Nb Niobium

Ta Tantalum

Th Thorium

U Uranium

Bore

Abandoned bore

Abandoned saline bore

Windpump

T Tank

E Earth tank

Dam on stream

Spring

WH Waterhole

Sand dunes

Road

Vehicle track

Fence

Homestead

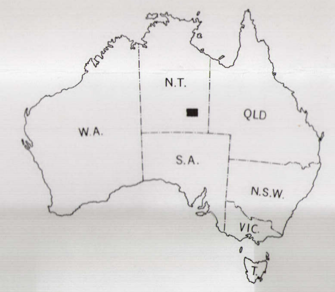
Yd Yard

Landing ground

MNF1 Astronomical station

920′ Height in feet, barometric; datum: mean sea-level

Compiled and issued by the Bureau of Mineral Resources, Geology and Geophysics, Department of National Development. Topographic base compiled by the Division of National Mapping, Department of National Development. Aerial photography by the Royal Australian Air Force; complete vertical coverage at 1:46,000 scale. Transverse Mercator Projection.



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Showing Magnetic Declination

MOUNT PEAKE SF 53-5	BARROW CREEK SF 53-6	ELKEDRA SF 53-7	SANDOVER RIVER SF 53-8	URANDANGI SF 54-5
NAPPERBY SF 53-9	ALCOOTA SF 53-10	HUCKITTA SF 53-11	TOBERMORY SF 53-12	GLENORMISTON SF 54-9
HERMANNSBURG SF 53-13	ALICE SPRINGS SF 53-14	ILLOGWA CREEK SF 53-15	HAY RIVER SF 53-16	MOUNT WHELAN SF 54-13
HENBURY SG 53-1	RODINGA SG 53-2	HALE RIVER SG 53-3	SIMPSON DESERT NORTH SG 53-4	BEDOURIE SG 54-1
KULGERA SG 53-5	FINKE SG 53-6	McDILLS SG 53-7	SIMPSON DESERT SOUTH SG 53-8	BIRDSVILLE SG 54-5

ANNUAL CHANGE 1′30″E

Scale 1:250,000

5 0 5 10 15 MILES

5 0 5 10 15 20 25 KILOMETRES

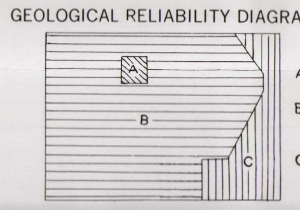
Sections

A-B-C D-E

Scale $\frac{V}{H} = 1$

Cainozoic sediments omitted from section

GEOLOGICAL RELIABILITY DIAGRAM

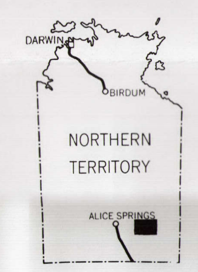


A Detailed mapping

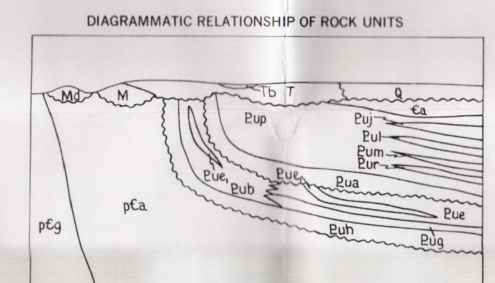
B Detailed reconnaissance, general reconnaissance, reconnaissance and air-photo interpretation

C Air-photo interpretation

Geology, 1949 to 1951, by: G.F. Joklik et. al.
1964, by: D.J. Forman, A.T. Wells, E.N. Milligan, A.J. Stewart, R.D. Shaw, D.R.G. Woolley
Compiled, 1964-1965, by: D.J. Forman, A.T. Wells, E.N. Milligan, A.J. Stewart, R.D. Shaw, N.L. Kruger
Drawn by: N.L. Kruger



DIAGRAMMATIC RELATIONSHIP OF ROCK UNITS



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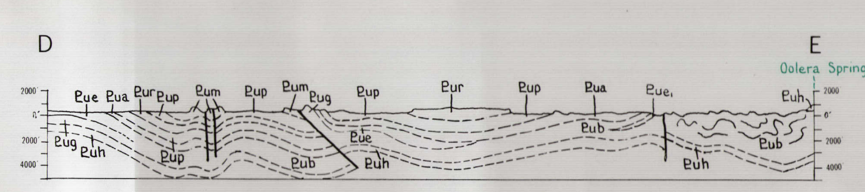

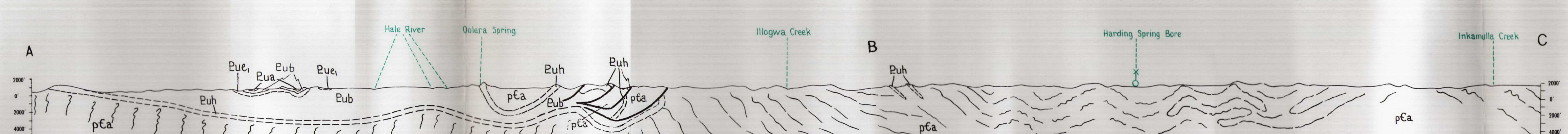

ILLOGWA CREEK

SHEET SF 53-15

PRELIMINARY EDITION, 1965

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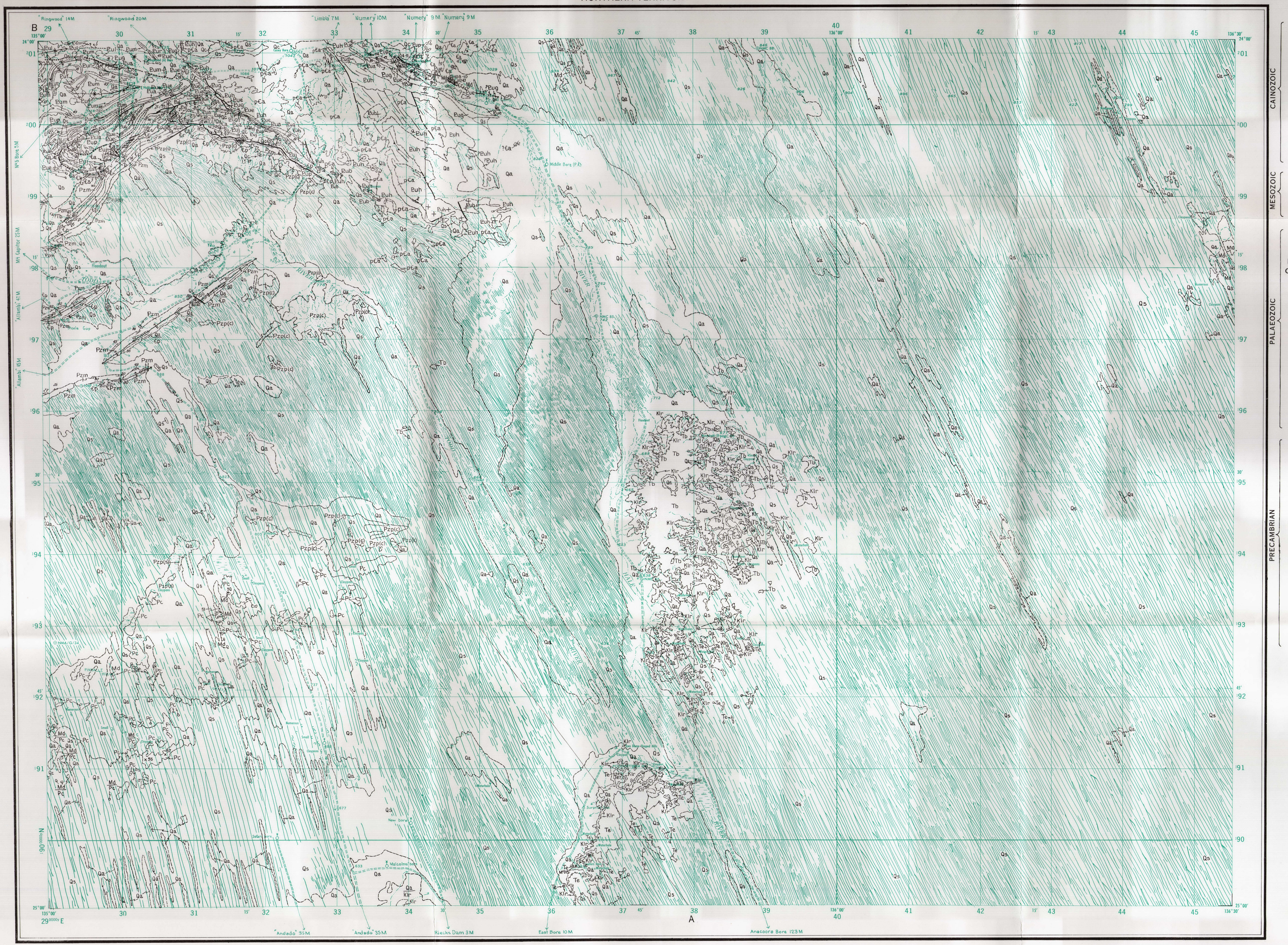
AUSTRALIA 1:250,000

HALE RIVER

NORTHERN TERRITORY

1:250,000 GEOLOGICAL SERIES SHEET SG 53-3



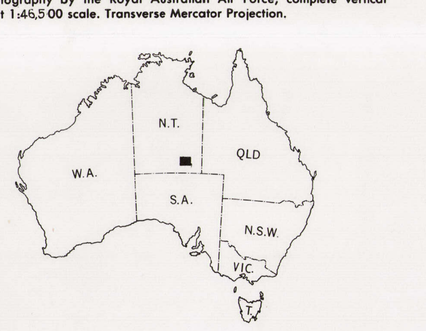
Reference

CAINOZOIC	QUATERNARY		Q	Undifferentiated (section only)
			Qa	Alluvium, river gravel
			Qs	Aeolian sand
			Qc	Conglomerate, gravel, scree
	TERTIARY		Tb	Silcrete (grey billy)
			Ts	Sandstone, silty sandstone, siltstone, conglomerate, claystone, chalcedony
		Etingambra Formation	Te	Coarse sandstone, granule conglomerate
MESOZOIC	LOWER CRETACEOUS	Rumbalara Shale	Klr	Shale, claystone, kaolinitic sandstone, sandstone
	? JURASSIC	De Souza Sandstone	Md	Cross-bedded, ferruginous sandstone, pebbly sandstone, conglomerate, siltstone
PALAEOZOIC	PERMIAN	Crown Point Formation	Pc	Sandstone, pebbly sandstone, siltstone, boulder conglomerate tilloid
	DEVONIAN T CARBONIFEROUS	Pertnjara Formation	Pzp(c)	Pebble and cobble conglomerate
			Pzp(s)	Sandstone
	ORDOVICIAN TO DEVONIAN	Mereenie Sandstone	Pzm	White, cross-bedded sandstone
	CAMBRIAN	Pertaoorrta Group: Shannon Formation	Ꞓs	Siltstone, dolomite, limestone
		Giles Creek Dolomite	Ꞓk	Dolomite, limestone, shale
		Todd River Dolomite	Ꞓr	Dolomite, shale
		Arumbera Sandstone	Ꞓa	Red-brown sandstone, siltstone, chert-pebble conglomerate
		Undifferentiated	Ꞓp	Dolomite, limestone, siltstone
		Undifferentiated	Pz	Sandstone, limestone, dolomite, siltstone, shale (Section only)
PRECAMBRIAN	UPPER PROTEROZOIC	Pertatataka Formation	Ꝑup	Siltstone and shale with lenses of sandstone, limestone and conglomerate
		Julie Member	Ꝑuj	Oolitic dolomite, limestone, lenses of sandstone, and calcareous sandstone
		Waldo Pedlar Member	Ꝑul	Siliceous, platy, fine sandstone, siltstone
		Olympic Member	Ꝑuf	Sandstone, siltstone, conglomerate, dolomite
		Limbla Member	Ꝑum	Cross-laminated sandstone, oolitic and sandy limestone and dolomite
		Ringwood Member	Ꝑur	Limestone, algal dolomite, siltstone
		Areyonga Formation	Ꝑua	Boulder clay, arkosic sandstone, siltstone, sandstone, conglomerate
		Bitter Springs Formation	Ꝑub	Dolomite, limestone, siltstone, sandstone and basic volcanics
		Loves Creek Member	Ꝑue	Algal dolomite, limestone, red siltstone and dolomitic siltstone
			Ꝑue₁	Basic volcanics
		Gillen Member	Ꝑug	Green siltstone, sandstone, dolomite, gypsum
		Heavitree Quartzite	Ꝑuh	Silicified sandstone, pebbly sandstone
		Arunta Complex	pꞒa	Gneiss, schistose gneiss, schist, quartzite

Geological boundary
Anticline, showing plunge
Syncline, showing plunge
Fault
Where location of boundaries, folds and faults is approximate, line is broken; where inferred, queried; where concealed, boundaries and folds are dotted, faults shown by short dashes
55 Strike and dip of strata
Horizontal strata
50 Overturned strata
Dip < 15°
Dip 15-45°
Dip > 45°
Trend lines
(Dip < 15° to Trend lines: air-photo interpretation)
Strike and dip of foliation, unmeasured
55 Strike and dip of foliation
Macrofossil locality
× 51 Specimen locality.
R-1 Measured section

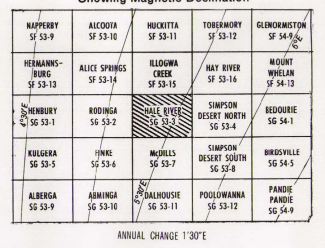
Bore
Abandoned bore
Windpump
T Tank
E Earth tank
Dam on stream
WH Waterhole
Sand dunes
Road
Vehicle track
Fence
Building
Yd Yard
Astronomical station
.677 Height in feet, instrument levelled;
·1124 Height in feet, barometric;
datum: mean sea level

Compiled and issued by the Bureau of Mineral Resources, Geology and Geophysics, Department of National Development. Topographic base compiled by the Division of National Mapping, Department of National Development. Aerial photography by the Royal Australian Air Force; complete vertical coverage at 1:46,500 scale. Transverse Mercator Projection.



INDEX TO ADJOINING SHEETS

Showing Magnetic Declination



Scale 1:250,000

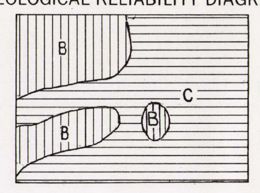
5 0 5 10 15 MILES

5 0 5 10 15 20 25 KILOMETRES

Section

Scale: $\frac{V}{H} = 1$

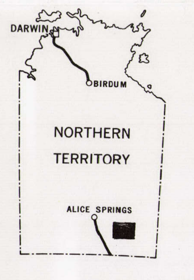
GEOLOGICAL RELIABILITY DIAGRAM

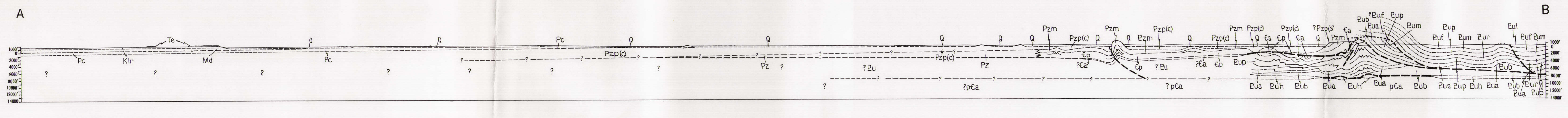


B Detailed reconnaissance, general reconnaissance, reconnaissance and air-photo interpretation.

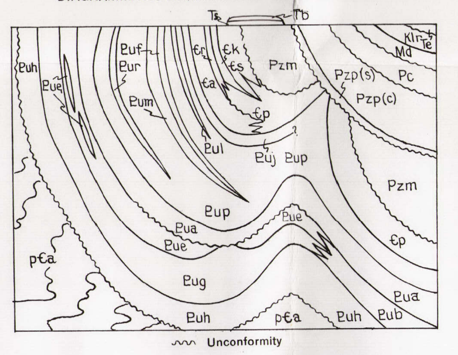
C Air-photo interpretation.

Geology, 1964, by: A.T. Wells, A.J. Stewart, R.D. Shaw, D.J. Forman, E.N. Milligan.
Compiled, 1964, by: A.T. Wells, A.J. Stewart, R.D. Shaw, L. Kerec
Drawn by: N.L. Kruger





DIAGRAMMATIC RELATIONSHIP OF ROCK UNITS



HALE RIVER

SHEET SG 53-3

TECTONIC INTERPRETATION 1: 500,000
(NORTH-EASTERN AMADEUS BASIN)

Bureau of Mineral Resources, Geology & Geophysics. May 1965.

To accompany Record No. 1965/44/108

NT/A/111

REGIONAL GEOLOGY AND STRUCTURE OF THE NORTH-EAST MARGIN, AMADEUS BASIN, NORTHERN TERRITORY

PART II (PETROLOGY)

by

W.R. McCARTHY

RECORDS 1965/44

CONTENTS

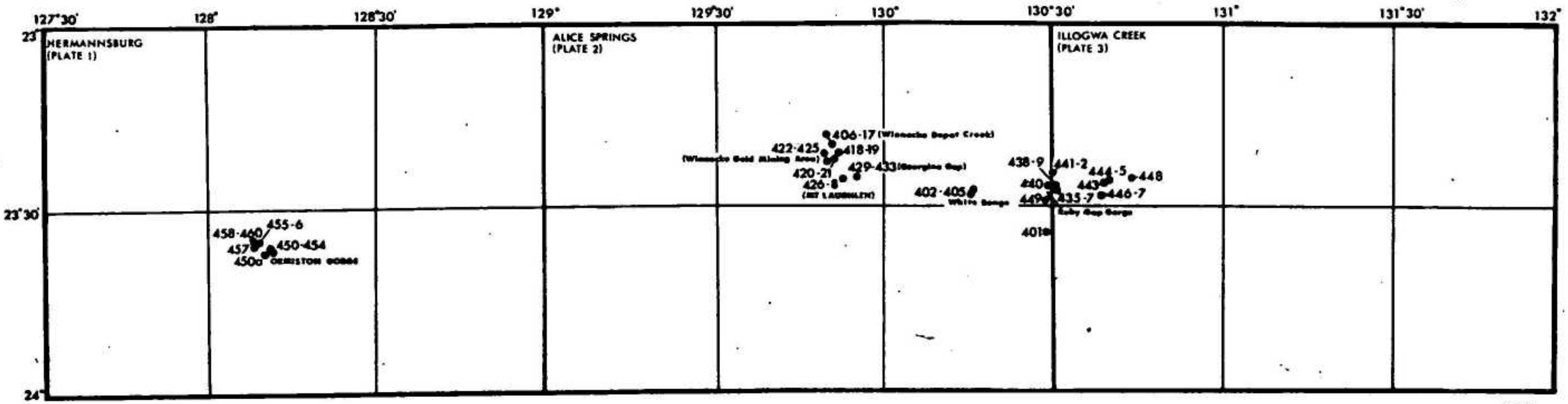
CONTENTS

SUMMARY

An investigation of the relationships of Proterozic sediments and the Archean basement metamorphics and granitic rocks of the Arunta Block along the northern margin of the Amadeus Basin, NT, was undertaken by The Australian Mineral Development Laboratories. Mineralogical study of 70 samples of the units indicated that the Arunta rocks are regionally metamorphosed sediments, under greenschist and almandine-amphibolite facies conditions, which have undergone a period of retrogressive metamorphism and intense deformation where adjacent to a highly structured Proterozoic quartzite. The quartzite is thought to be a portion of the Heavitree Quartzite which has been deformed and recrystallized synchronously with the Arunta rocks. The folded Proterozoic sediments, the Heavitree Quartzite and the Bitter Springs Limestone have undergone a period of low grade regional metamorphism during their deformation that does not appear to be restricted to the northern margin of the Amadeus Basin. Further study of certain aspects of the petrogenesis of these rocks is recommended.

LOCATION OF ROCK SPECIMENS

(SEE ALSO PLATES 1,2 & 3 OF PART I)



Bureau of Mineral Resources, Geology and Geophysics, May 1965

To accompany Record 1965/44

D.R.W.

F53/A15/7

1. INTRODUCTION

Early in 1964 an agreement was reached whereby The Australian Mineral Development Laboratories would provide a petrologist to assist a field party of the Bureau of Mineral Resources in the Northern Territory. The objective of the mapping programme was to determine the relations of the Proterozoic sediments of the northern margin of the Amadeus Basin with the metasediments and granitic rocks of the Archean basement rocks. In addition to providing complete mineralogical data of representative samples of the mapped units, it was hoped that detailed study of selected rock samples might provide a more complete understanding of the Pressure/ Temperature conditions of the rocks during their deformation. It was intended that the petrologist accompany the field party and collect the material for the laboratory examination The results of the investigation would then be submitted to the Bureau of Mineral Resources as a project report in January, 1965.

A preliminary meeting was held in Adelaide in May, 1964, between members of the field party and the petrologist, W.R. McCarthy, who joined the group at Alice Springs, NT, on the 10th August. The sampling traverses were carried out at selected localities along about 165 miles (latitude 132° 39' - 135° 08' E) of the northern flanks of the MacDonnell Ranges. Approximately 14 days were spent in the field and 65 rock specimens were collected.

Additionally two drill core specimens of one of the mapped units from a bore within the Amadeus Basin have been described.

2. TECHNIQUES, EQUIPMENT AND MINERALOGICAL NOTES

Most of the mineralogical examinations were carried out using a polarizing microscope on thin sections prepared from the rock specimens. Several specimens were nearly monomineralic and their mineralogy was determined using immersion oils instead of rock sections. Some special optical and x-ray diffraction techniques were also used for mineral determinations.

During field discussions, the petrologist learned that there was some doubt as to the type(s) of carbonate comprising one of the mapped units – the Bitter Springs Limestone. Three of the carbonate samples were identified by x-ray diffraction methods, since quantitative optical identification of carbonate is rather lengthy and staining methods are sometimes unreliable and not particularly quantitative. The method of carbonate identification of these specimens is noted in the petrography. Differentiation of calcite and dolomite by optical techniques employed in this study is not considered to be conclusive.

For metamorphic interpretative purposes it was considered desirable to have reliable and accurate plagioclase compositions. Therefore, unless otherwise stated, the anorthite content of the plagioclase has been determined by extinction methods on a universal stage. A 4-axis Leitz universal stage was applied with the method described by Turner (1947) and the curves compiled by Slemmons (1962). Approximately 65 anorthite determinations were made by this method. The species of feldspar present in some of the samples is not considered to be completely known. Some untwinned feldspar grains in certain specimens would have to be separated before they could be reliably identified. Techniques other than optical examination, would be necessary to define exactly the variety of alkali feldspar present in a number of samples.

In the petrography, the minerals forming a part of a rock name are listed in order of increasing abundance.

3. PETROGRAPHY AND PETROLOGY

3.1 Heavitree Quartzite Specimen (7 miles south of Ruby Gap Gorge)

AS-401: HS-8-5052: TS15203: Heavitree Quartzite. The rock is a sericite metaquartzite. It has formed by low grade metamorphism of a rather pure quartz arenite. Sericite has crystallized during metamorphism and a considerable portion of the quartz has recrystallized. Shearing, and important mechanism during metamorphism, and recrystallization have destroyed the sedimentary form of many of the quartz grains.

In the thin section a number of mutually parallel elements – quartz with crystallization foliation, quartz elongated by shearing, and foliated sericite – impart a moderate structure to the rock. The sericite is confined to intergranular areas, to newly crystallized fine-grained aggregates of quartz, and to shears. Accessories observed were tourmaline (rare), zircon (rare) and opaques (rare).

3.2 North-west of the White Range Traverse

Summary. During the sampling the rock was collected as an example of the White Range Quartzite (Joklik, 1955). Mineralogically this specimen differs from those described by Joklik as both alkali feldspar and plagioclase are present.

AS-402: AS-7-5222: TS15204: Arunta Complex. The rock is a fine- to medium-grained sericite-feldspar-quartz schist. Sheared and broken feldspar porphyroblasts and foliated, laminar bodies of sericite are the most significant petrogenetic elements of the rock's fabric. The rock has undergone a period of intense shearing during which earlier formed feldspar porphyroblasts have been broken and sheared out into elongated grains. Muscovite (sericite) appears to have crystallized during the deformation. Part of the quartz is segregated into coarser grained, laminar bodies. The quartz of these laminae is generally foliated. Both quartz and sericite fill fractures in porphyroblasts (Plate 1, A). The porphyroblasts show a random form and lattice orientation to the schistosity.

Most plagioclase grains are small and broken and many have strained extinction. The anorthite content of a suitable plagioclase grain was determined to be An_{24}. The optical indicatrix and crystallography of several alkali feldspar grains was plotted. The results indicated that the grains did not have monoclinic symmetry. A number of grains show microcline "grid" twinning – others are untwinned. From this data, the alkali feldspar is thought to be microcline. Some grains are microcline-microperthite.

Visual estimation of the mineral proportions is particularly hazardous in this rock, but it is suggested that feldspar forms a third of the specimen. Accessory minerals observed were apatite, opaques, and sphene.

3.3 White Range Traverse (AS403-405, north to south)

Summary. The most striking aspect of these rocks is that the final phase of their petrogenesis is similar – a period of rather intense deformation and recrystallization.

There are indications that an earlier structure (S_1) was present in at least one of the samples which was folded and sheared to form the final observable micro-structure (S_2). The "S" structure parallels the rock cleavage observed in the field. The intensity of the micro-structure (S_2) and the amount of rock cleavage, decrease in the northerly direction.

The metamorphic recrystallization of the rocks of the Arunta complex at this locality is evident by the new generation of minerals – epidote, biotite, muscovite and quartz – now comprising them. The data are not sufficient to classify the rock to metamorphic facies but the mineral assemblage is of a low grade nature. The earlier rock types of the Arunta complex cannot be determined with any certainty as the data are too few. However there is an indication that the "White Range Quartzite" sample and AS405 of this traverse were metamorphosed sediments and that the others were granitic rocks.

AS-403: AS-7-5222: TS15205: Arunta Complex. This is a medium- to coarse-grained, epidote-mica-alkali-feldspar-quartz-plagioclase rock. Although the rock shows only moderate structure, it is probably best termed a gneiss. Preferred orientation of minerals is slight, but they are often preferentially concentrated. Quartz tends to be restricted to irregularly shaped, elongate bodies; microcline is commonly associated with it. The quartz bodies separate irregular aggregates of poikiloblastic plagioclase that form a matrix for intermatted aggregates of mica and epidote.

The petrogenesis of the rock is less evident than others of the traverse, because recrystallization appears to have been more intense. The microcline probably crystallized during the segregation of quartz and crystallization of muscovite, biotite and epidote. The aggregates of plagioclase with associated minerals are interpreted as being part of an earlier rock which has been cataclastically deformed and recrystallized to form the present mineralogy.

Some alkali feldspar crystals (probably microcline) have "grid" twinning, others are untwinned and a few are perthitic. The plagioclase is too poorly twinned, deformed or intergrown with other minerals to determine its anorthite content. Mica is primarily muscovite; it often has rectilinear distribution within the plagioclase aggregates. There are moulds of ?allanite within epidote crystals in a number of places in the thin sections (Plate 1, B). The allanite appears to have been a stable constituent of the mineral assemblage; most has now been removed by weathering or other processes. Providing unweathered rock is available, this might be a likely rock for age dating.

<u>AS-404: AS-7-5222: TS15206: Arunta Complex.</u> This is a sheared and partially recrystallized, medium- to coarse-grained <u>mica-epidote-quartz-plagioclase gneiss</u>. The rock has a moderate to strong structure in thin section which parallels the cleavage observed in the hand specimen. Mutually parallel elements of the fabric form the rock's structure. These are lenticular concentrations and crystallization foliation of much of the quartz, and foliated lenses of mica.

A tentative petrogenesis for the gneiss is proposed:

1. The crystallization of an earlier probably plagioclase bearing rock.
2. A period of shearing and metamorphic crystallization resulting in:
    a. concentration of quartz in areas of low stress (incipient shears)
    b. crystallization of a new, foliated generation of mica
    c. crystallization of epidote during shearing (some crystals were "rolled" during these movements)
    d. deformation of earlier formed minerals (especially noticeable in the case of plagioclase).

Biotite is generally restricted to the borders of relict lenses from the earlier rock and is in contrast to the foliated lenses of sericite which transgress the relict lenses. Plagioclase is extremely deformed and a host of new mineral grains are included within it. Part of the biotite has weathered to chlorite. Some of the opaques have weathered to ?goethite. Accessory minerals observed were apatite, opaques, and sphene (very conspicuous).

AS-405: AS-7-5222: TS15207: Arunta Complex. This is a fine- to medium-grained epidote-feldspar-mica-quartz schist. The fine-grained nature of much of the quartz in the relatively mildly recrystallized portion of the rock suggests that the original sediment was an impure siltstone.

Two structures (S_1 and S_2) are visible. The earliest structure (perhaps relict sedimentary bedding) has been folded and then sheared along the axial planes of the folds to form S_2.

Mineral phases seem to be of two periods of crystallization and are presumed to have crystallized synchronously with the development of the structures. The earliest assemblage was comprised of quartz, sericite and perhaps also feldspar. Minerals which crystallized during the development of S_2 were quartz, biotite, sericite, epidote and perhaps also feldspar. The data on feldspar are not sufficient to indicate its petrogenesis completely. A number of broken and rotated grains indicate that it was present during movements associated with S_2. However part of it may have crystallized synchronously with latest mineral phases. The anorthite content of the plagioclase was determined to be An_{31}. Much of the feldspar is untwinned or poorly twinned. Alkali feldspar may be present but, because of the deformed or fine-grained nature of the feldspar, it is difficult to be confident of its identification.

Accessory minerals observed were opaques, zircon, and sphene (conspicuous). Some of the biotite has weathered to chlorite.

3.4 Winnecke Depot Creek Traverse 1

Summary. The rocks of the traverse are the regionally metamorphosed equivalents of a sequence of interbedded carbonates and impure siliceous and pelitic sediments. The type of metamorphism and mineral zoning observed in this terrane has been termed Dalradian or Barrovian after early work carried out in the Grampian Highlands of Scotland. More recently Miyashiro (1961) has termed this the kyanite-sillimanite type. Other major examples of this type of metamorphism occur in the Caledonian metamorphic belt of Norway and the Appalachian metamorphic belt of North America.

The limited data indicate that there is a possible decrease in metamorphic grade both north and south from the highest subfacies of the almandine-amphibolite facies to the greenschist facies. Additional data are needed to verify the facies distribution and delineate the structures or faults which appear to have exposed the metamorphic zoning.

No indications of retrogressive metamorphism were observed in any of the described samples.

AS-406: AS5-5020: TS15208: Arunta Complex. This is a rather pure marble. The carbonate crystals (calcite) are generally coarse-grained and form about 97 per cent of the rock.

Fine- or medium-grained crystals of sphene, apatite, muscovite, quartz, tremolite and epidote comprise the remainder of the rock. No preferred orientation of any minerals is apparent. Some of the calcite crystals have vermicular-like bodies of a mineral too fine-grained for optical determination, but this was the only unusual aspect of the fabric observed.

The mineral assemblage compares with those recorded in the literature for the quartz-albite-epidote-biotite subfacies of the greenschist facies.

AS-407: AS-5-5020: TS15209: Arunta Complex. This is a porphyroblastic, amphibole-quartz-epidote hornfels. In general the rock is medium-grained and has a hornfelsic texture. Mutually parallel, linear concentrations of quartz and ?actinolite give the rock a moderate structure. The origin of the structure was not determinable from the available data (i. e., sedimentary layering or metamorphic differentiation).

Minor mineral constituents present are biotite, calcite, sphene and muscovite. Accessory minerals observed were tourmaline, apatite, and opaques.

The mineralogy of the specimen compares with those recorded for calcareous schists of the quartz-albite-epidote-biotite subfacies of the greenschist facies.

AS-408: AS-5-5020: TS15210: Arunta Complex. This is a fine- to coarse-grained muscovite-quartz-alkali feldspar rock. The rock shows a moderate structure in thin section which is imparted by mutually parallel, linear bodies of fine-grained, alkali feldspar and lenticular quartz aggregates; sometimes the quartz shows a conformable crystallization foliation. Medium- and coarse-grained porphyroblasts of alkali feldspar modify the structure of the rock's fabric. The conformable nature of the rock body with the metasediments, its lateral extent, and the described textural features, suggest a metasedimentary origin. The original sediment was probably an argillaceous siltstone.

By visual estimation, it is suggested that the mineral constituents are present in the following proportions: accessories plus plagioclase (2%), muscovite (8%), quartz (30%), and alkali feldspar (60%). Only a few crystals of each of the accessories — tourmaline, apatite, sphene and zircon — were observed.

The alkali feldspars are microcline and microcline-microperthite. Two thin sections of the rock were examined and only a single grain of plagioclase was observed in each section.

The mineral assemblage alone does not allow assignment of the rock to a single facies of regional metamorphism (i. e., the assemblage is recorded in both the greenschist and almandine-amphibolite facies).

AS-409: AS-5-5020: TS15211: Arunta Complex. This is a sillimanite-quartz-mica- ?orthoclase rock. The rock has a moderate structure in thin section which is formed by mutually parallel, linear aggregates of quartz, biotite, and sillimanite. In other respects the rock has hornfelsic texture. Some of the orthoclase crystals and biotite "books" are coarse-grained, but most of the constituent minerals are medium- or fine-grained. The mica is dominantly biotite with muscovite present also as an important constituent. Sillimanite crystals are scattered through most of the biotite and concentrations of mottled sillimanite transgress biotite aggregates. There is some indication that the sillimanite has been the last mineral of the assemblage to crystallize.

A few crystals of plagioclase were observed; the anorthite content of one of them was determined as An_{37}. Opaques form about 5 per cent of the rock. Accessories observed were zircon and apatite.

The rock has a mineral assemblage in accord with the highest subfacies of the almandine-amphibolite facies – the sillimanite-almandine-orthoclase subfacies. It compares in mineralogy, with the exception of the absence of cordierite, and texture to specimen AS-417.

<u>AS-410: AS-5-5020: TS15212: Arunta Complex</u>. This is a medium- to coarse-grained <u>staurolite-kyanite-quartz-mica-schist</u> and is assigned to the staurolite-almandine subfacies of the almandine-amphibolite facies of metamorphism. The kyanite association in this subfacies is indicative of original rocks very rich in Al_2O_3 and low in alkalis. Compositionally this is a rare situation in pelitic rocks (Turner and Verhoogen, 1960, p 545). The absence of any alkali-rich minerals (e. g. , feldspar, epidote) substantiates the low alkali content of the original sediments.

The rock shows a moderate structure in thin section which is imparted by foliated mica and by linear aggregates of quartz that are mutually parallel. Some kyanite and staurolite crystals are aligned with the structure; many crystals show a random orientation Biotite and muscovite are present in about equal proportions; muscovite shows a greater tendency to be foliated. Staurolite and kyanite are both important constituents; kyanite appears to be the more abundant. Opaques are common (5-7%). No feldspar was observed. Some of the biotite has weathered to chlorite.

<u>AS-411: AS-5-5020: TS15213: Arunta Complex</u>. This is a medium- to fine-grained <u>plagioclase-epidote-mica-quartz-alkali feldspar gneiss</u>. Several mutually oriented elements of the fabric impart a moderate structure to the rock in thin section and are probably responsible for its rock cleavage. Biotite tends to be foliated, many quartz and alkali feldspar crystals show a crystallization foliation, and occasionally linear aggregates of fine-grained quartz and feldspar were observed. Muscovite tends to occur as coarse poikiloblasts which have a random orientation. Epidote occurs as scattered, fine-grained, anhedral to euhedral crystals.

By visual estimation, it is suggested that the minerals are present in the following proportions: epidote (8%), mica (15%), quartz (20%) and feldspar (55%). Accessory minerals observed were zircon, apatite (common) and sphene (conspicuous).

Feldspar appears to be almost entirely alkali feldspar with the exception of three plagioclase grains observed. However much of it is untwinned, therefore a part of this portion may be plagioclase. Much of the alkali feldspar shows grid twinning and is therefore microcline; a portion of it is microcline-microperthite. One crystal of plagioclase was determined to have an anorthite content of An_{33}.

The mineral assemblage of the rock is in accord with the staurolite-almandine subfacies of the almandine-amphibolite facies.

AS-412: AS-5-5020: TS15214: Arunta Complex. This is a metamorphosed impure carbonate rock and now termed a calc-silicate. It is composed of tremolite, diopside, plagioclase, microcline, quartz, calcite and clinozoisite. A number of mutually parallel, linear elements give the rock a moderate to strong structure in thin section. Quartz and calcite often occur in linear concentrations and frequently show a crystallization foliation.

Quartz, calcite and clinozoisite are the most abundant minerals of the rock. Microcline is more abundant than plagioclase (An_{28}). Plagioclase is generally cloudy in appearance, probably as a result of very fine, included mineral phases, and is generally untwinned. Tremolite is slightly green coloured and therefore probably not an end member of the tremolite-ferro-actinolite series. Accessories observed were sphene (conspicuous), apatite (common), tourmaline (rare), and opaques (rare).

The calcareous assemblage is in accord with those recorded for the staurolite-almandine subfacies.

AS-413: AS-5-5020: TS15215: Arunta Complex. This is a medium- to coarse-grained phlogopite-tremolite-epidote marble. Silicate minerals form about 15 per cent of the rock and calcite the remainder. The silicate minerals occur in concentrations which may have been original silty laminations in the carbonate sediment before metamorphism. No other oriented elements of the fabric were observed.

Accessory minerals are not common; tourmaline is the most important; apatite, spehene and zircon were also observed.

The absence of diopside in the mineral assemblage suggests a greenschist facies assignment for the rock rather than almandine-amphibolite. However more material would have to be examined before the lower facies assignment would be considered valid.

3.5 Winnecke Depot Creek Traverse 2

Summary. The rocks of the traverse compare in mineralogy to examples considered to have been regionally metamorphosed under almandine-amphibolite facies conditions. Two of the subfacies, the staurolite-almandine and sillimanite-almandine-orthoclase, are represented in the rocks of the traverse. If, by more sampling, garnet were found in the pelitic rocks represented by specimen AS-416, the kyanite-almandine-muscovite subfacies could also be recognized. The limited data indicate that a progressive metamorphic zonal arrangement may be present from north to south (i.e., AS-414-AS-417).

Co-existence of cordierite and sillimanite is inconsistent with the mineralogy of other localities of the kyanite-sillimanite type of regional metamorphism (Miyashiro, p 278, 1961). Two reported occurrences of cordierite seem to provide the most logical explanation for its presence in this situation:

1. Cordierite is found as a major constituent in a number of localities, from regionally metamorphosed terranes, where rocks of the charnockitic type are found (Deer, Howie and Zussman, 1962).
2. In a lower pressure situation as a representative of a metamorphic area transitional between the almandine-amphibolite facies and the hornblende-hornfels facies (Turner and Verhoogen, p 552, 1960).

More data are required before either of these working hypotheses can be favoured or excluded.

In the Harts Range, where metasediments have also been evolved under similar facies conditions, cordierite is reported as being absent (Joklik, p 76). Metamorphic conditions and/or original compositional differences appear to have existed within the two regions during their metamorphic evolution.

Mineralogically the staurolite-kyanite bearing rock of the traverse compares to the one of the first Winnecke Depot Creek traverse. The assemblage may thus prove to be a logical marker zone for future mapping.

<u>AS-414: AS-5-5020: TS15216: Arunta Complex</u>. This is a medium- to coarse grained <u>staurolite-kyanite-quartz-mica schist</u>. It compares in all mineralogic regards to AS-410 collected from the Winnecke Depot Creek Traverse 1. The only noticeable difference between these two samples is that this one has a slightly stronger structure. Some of the quartz shows a crystallization foliation and the mica is in general more strongly foliated.

<u>AS-415: AS-5-5020: TS15217: Arunta Complex</u>. This is a medium-grained, porphyroblastic <u>epidote-mica-alkali feldspar-quartz-plagioclase gneiss</u>. In thin section, the strong structure of the rock is seen to be imparted by foliated mica, crystallization foliation of quartz and, to a lesser degree, feldspar. Porphyroblasts of feldspar have displaced the mica foliation during growth.

By visual estimation, it is suggested that the minerals occur in the following proportions: epidote (5%), biotite (7%), muscovite (7%), alkali feldspar (20%), quartz (20%), and plagioclase (40%). Accessory minerals observed were zircon (rare), sphene (common) and apatite (conspicuous). The alkali feldspars present are microcline and microcline-microperthite. Most of the alkali feldspar occurs as porphyroblasts. The coarsest plagioclase grains are generally poikiloblastic with inclusions of mica and epidote. The anorthite content of two coarse plagioclase grains was determined to be An_{34}, An_{35}, and three matrix grains all as An_{27}. Some of the matrix grains were zoned.

The displacement of the mica foliation by the porphyroblastic growth of alkali feldspar indicates that the crystallization continued after the development of the foliation; also that differential stress may have been less intense during the concluding stages of crystallization. The significance of differing anorthite content of coarse and finer plagioclase is not clear. It may be an indication of polymetamorphism, but detailed sampling would be necessary before the petrogenesis could be deduced with any degree of certainty.

AS-416: AS-5-5020: TS15218: Arunta Complex. This is a medium- to coarse-grained quartz-kyanite-mica schist. Structure is moderate and imparted by alignment of linear opaque bodies and a moderate foliation of mica.

The rock differs from other kyanite bearing rocks described by the absence of staurolite, the smaller quantity of quartz present, and that it has the least developed structure. These features indicate original compositional differences, and possibly differing P/T and stress conditions during metamorphism from the preceding kyanite bearing rocks described.

By visual estimation, it is suggested that the minerals occur in the following proportions: opaques (5%), quartz (10%), kyanite (35%), and mica (50%). Muscovite appears slightly more abundant than biotite. The opaques and zircon were the only accessory minerals observed.

AS-416A: AS-5-5020: TS15219: Arunta Complex. This is a medium- to fine-grained biotite-quartz-plagioclase-epidote schist. In thin section the rock is seen to possess a moderate structure which is imparted by several mutually parallel, linear elements of the fabric. Part of the biotite is foliated, some of the quartz and plagioclase show a crystallization foliation, and several linear bodies of quartz and plagioclase are present. The structure is displaced where segregations of quartz and feldspar and epidote are found. Quartz and to a lesser degree plagioclase are notable in that they are often subhedral in form.

Epidote is the most abundant mineral although all the constituents appear to be relatively equal in importance. Accessory minerals observed were opaques (3-5%), and apatite (common). No muscovite or alkali feldspar was observed.

The anorthite content of a matrix plagioclase grain was determined as An_{38} and a coarse grain in a plagioclase-quartz segregation as An_{39}.

AS-417: AS-5-5020: TS15220: Arunta Complex. This is a coarse- to medium-grained biotite-sillimanite-quartz-cordierite-alkali feldspar gneiss. Originally it was probably a quartzo-feldspathic sediment. The rock appears foliated in the field. Mutually parallel, linear elements – aggregates of sillimanite, aggregates of opaques, and crystallization foliation of part of the quartz – give it a moderate micro-structure. Only the coarser sillimanite crystals show a preferred orientation.

By visual estimation, it is suggested that the minerals occur in the following proportions: biotite (10%), sillimanite (10%), opaques (10%), quartz (20%), cordierite (25%), and alkali feldspar (25%). Several small plagioclase crystals were observed. Zircon, in addition to opaques, was the only accessory mineral seen.

Alkali feldspar is generally microperthitic; no twinned alkali feldspar was observed. It appears to be either orthoclase, microcline, or a transitional type. Exact identification of the alkali feldspar is beyond the scope and time limits of this investigation. The plagioclase crystals observed occur included within alkali feldspar or in association with it and opaques, or with sillimanite and biotite. The anorthite content of two of these crystals was determined as An_{44} and An_{46}. The structural type of the plagioclase appears to be transitional (between the plutonic and volcanic types); the anorthite content for the intermediate type is reported. Textural data indicate that part of the plagioclase, at least, has crystallized with the other mineral phases of the rock. Plagioclase within the alkali feldspar could be relict from an earlier, lower P/T mineral assemblage.

3.6 Winnecke Gold Mine Area Traverse 1

Summary. Both samples indicate that the earliest mineral assemblage still determinable was a metamorphic one. Tremolite, epidote, feldspar and quartz appear to have been the mineral phases of the probable low grade assemblage. The final stage in the petrogenesis of the metasediments has been plastic deformation and folding. A period of low grade recrystallization accompanied the defromation.

AS-418: AS-6-5096: TS15221: Arunta Complex. The rock is a partially recrystallized feldspar-quartz-tremolite-epidote calc-silicate. It has a strong structure which will be discussed in detail below.

By visual estimation, it is suggested that epidote and tremolite form 55 per cent of the rock and quartz and feldspar about 40 per cent. Most of the feldspar appears to be alkali variety (microcline). Only a few crystals of plagioclase were confidently identified. Both sphene and tourmaline are present and are estimated to form several per cent of the rock.

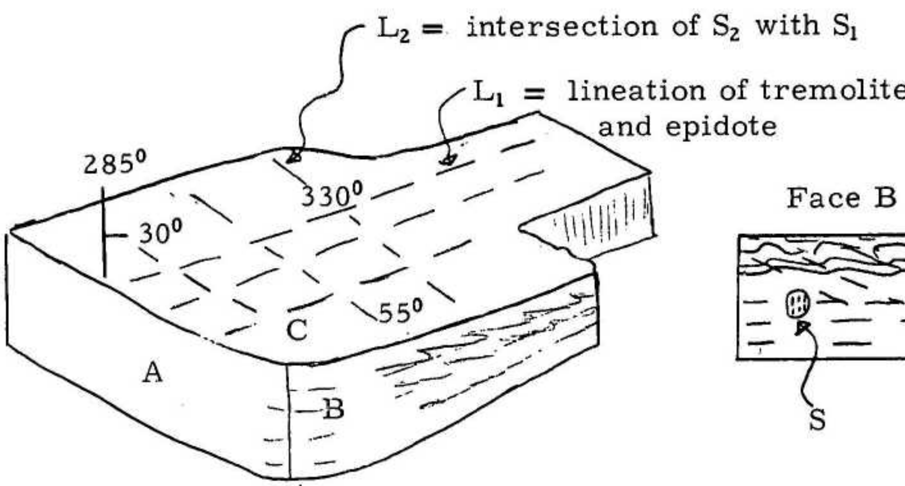
The specimen is an oriented one which was collected from a minor fold (Plate 2, A) and is illustrated on page 12.

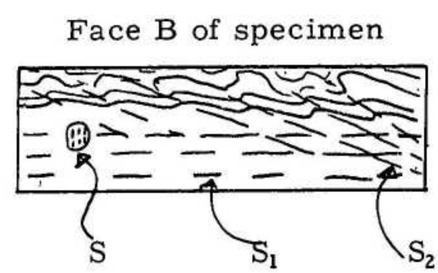
The microscopic data of this sample suggest the following petrogenesis:

1. The formation of S by metamorphism of a pre-existing sediment. Minerals identified as having crystallized during this period are feldspar, quartz, epidote and tremolite. A proterogenic relict (Plate 1, D) which has been rotated during plastic

deformation of the rock gives evidence to the earlier structure (S) of the rock. It contains undeformed feldspar and has been only mildly deformed (i. e., strained extinction).

2. The plastic deformation of the rock (Plate 1, C) was accompanied by partial recrystallization. Rock flowage occurred along a set of parallel shear planes (S_1), and a second set of parallel shears (S_2) appears to have developed synchronously. The second set of shears has folded S_1 (slip folds). Lineated tremolite and less oriented epidote, forming L_1, and quartz appear to have crystallized during this period. The earlier feldspar was cataclastically deformed. The strike measured appears to have been on S_1. The angularity between S_1 and L_2 (intersection of S_1 and S_2) is noted here, but a unique explanation is not evident to the petrologist.





Thin sections from faces A, B, and C were cut and examined in order to determine the lineated fabric elements and to attempt to unravel the petrogenesis.

Naturally the detailed structure study of a single rock sample cannot be applied to a large area. Therefore confirmatory data are needed before the regional significance of the specimen can be ascertained. In particular the earlier S structure and the deduction that S_1 and S_2 formed during the same period of synkinematic metamorphism need to be verified. Disregarding any perhaps premature regional application of the structural information, it is quite apparent from numerous and available field data and microscopic study that the latest low grade dynamic metamorphism of the Arunta complex may be applicable to detailed study in this general locality.

AS-419: AS-6-5096: TS15222: Arunta Complex. This is a coarse- to medium-grained alkali feldspar-quartz-tremolite-plagioclase-epidote-calcite calc-silicate. Much of the calcite shows a crystallization foliation; some of the silicate aggregates show a crystal orientation; several very elongate, coarse epidote crystals were observed. The rock has formed by low grade metamorphism of an impure carbonate rock. It is likely that the original rock contained siliceous laminations. The disordered nature of oriented elements of the fabric suggests that the rock has been deformed during the latter stages of its petrogenesis. Cores of many tremolite and epidote crystals are of a different composition (the pleochroism and optical orientation of the cores are different from the rims). Both minerals appear to have iron rich cores. Consequently it seems that chemical conditions have varied during the crystallization of these mineral phases.

Calcite is the dominant mineral of the rock. Accessory minerals observed were tourmaline (rare), and sphene (conspicuous).

Alkali feldspar occurs as twinned and untwinned crystals; the twinned crystals are microcline.

3.7 Winnecke Gold Mine Area Traverse 2

Summary. The traverse was started in the Heavitree Quartzite and carried about 850 yards in a northerly direction into the Arunta complex. The Proterozoic quartzite appears to dip steeply to the north under the Archean which crops out as a low ridge. Talus covers any possible contacts with the underlying quartzite. Both rock bodies are strongly cleaved in this vicinity. Five samples were collected along the traverse – two of the quartzite, and the remainder from the Arunta complex. The latter, in the first 350 yards, was comprised of a cataclasite, marble (not sampled), amphibolite and metaquartzite, while the remainder consisted of deformed (folded and cleaved) gneisses. Of the data obtained from the traverse, the micro- and macro-deformation of all the rocks and the recrystallization of those of the Arunta complex are undoubtably important in regional interpretation.

All the rocks examined indicate that plastic deformation or shearing stresses have been important mechanisms during the final petrogenic episode. In the Heavitree Quartzite, shearing stresses resulted in the orientation of minerals during its metamorphism. Microscopic deformation (i. e., cataclasis) of the Arunta complex is greatest near its contact with the Heavitree Quartzite and diminishes in a northerly direction; the rock cleavage also becomes less intense in this direction.

AS-420: AS-6-5096: TS15223: Heavitree Quartzite. This is a medium- to fine-grained sericite metaquartzite. In thin-section the rock has a strong structure imparted by the crystallization foliation of quartz and foliated sericite; the oriented fabric elements are mutually parallel. Augen-like aggregates of quartz, free of sericite, were occasionally observed. Generally the crystals forming the aggregates are coarser than other quartz crystals of the rock. The bodies may represent recrystallized, originally coarser sedimentary grains. The crystal faces and foliation of considerable portions of the quartz indicate that quartz of the original sediment has recrystallized during the metamorphism (no sedimentary structures were observed).

Other than sericite and quartz, only accessory minerals were observed. They were zircon (rare), tourmaline (rare), sphene (common), and apatite (common).

The rock is strongly cleaved in the field.

AS-421: AS-6-5096: TS15224: Arunta Complex. This is recrystallized cataclasite (Plate 2, B). Before deformation the rock was composed of alkali feldspar, and quartz. Now clasts of the alkali feldspar, quartz and green coloured biotite comprise the rock. The quartz and biotite have crystallized during the period of cataclastic deformation.

The mineral clasts vary considerably both in size and shape, and a number of linear bodies of mylonite transgress the cataclastic matrix. The rock has strong macro- and micro-structure formed by mutually parallel, linear elements of its fabric. The linear elements are foliated biotite, lenticular bodies of granulated feldspar, and elongated mineral clasts or grains.

The only accessory minerals observed were opaques. Many of these grains have weathered to form goethite.

Feldspar occurs as twinned and untwinned crystal fragments; the untwinned ones are less abundant. The twinning observed was generally albite although some of the microcline "tartan" type were also seen. It is not possible to identify the feldspar precisely without resorting to techniques beyond the scope and requirements of this investigation. However, from the associated mineralogy, the feldspar is thought to be dominantly or entirely microcline.

Some of the biotite has been altered to a fine-grained mineral phase (vermiculite perhaps) presumably by weathering.

AS-422: AS-6-5096: TS15225: Heavitree Quartzite. This is a medium- to fine-grained sericite metaquartzite. It compares in mineralogy and all other aspects, except for a feature of the fabric, to the first specimen of the Heavitree Quartzite described from the traverse. The structure of the fabric differs in that linear aggregates of strongly foliated quartz occur. The foliated quartz is mutually parallel to the other linear elements of the fabric. Shearing has apparently been more intense in these portions of the rock.

AS-423: AS-6-5096: TS15226: Arunta Complex. This is a partially recrystallized cataclasite. Clasts of ?hornblende and plagioclase are enclosed in a finer matrix of minerals. The very intense micro-structure of the rocks is imparted by mutually parallel, linear elements of the fabric. Oriented elements of the fabric are elongated porphyroclasts, linear aggregates of fine crystals, linear aggregates of quartz and a crystallization foliation of part of the quartz. The linear aggregates of the fine crystals (epidote, actinolite, etc.) appear to have formed in areas of granulated rock.

The original rock type, before cataclasis, cannot be indisputably deduced from the present brecciated mineral relics but it was probably a coarse-grained amphibolite. A number of minerals – muscovite, biotite, actinolite, calcite, quartz and epidote – appear to have crystallized during the cataclastic deformation of the rock. The earlier minerals have either been partially recrystallized into or replaced by the latest minerals (Plate 2, C).

Chlorite is present but appears to be a weathering product of the amphibole or biotite. Some opaque bodies occur and are generally associated with the amphibole.

AS-424: AS-6-5096: TS15227: Arunta Complex. This is a medium- to fine-grained epidote-biotite-sericite metaquartzite. It has a well developed structure both in hand specimen and thin section. The mica is generally foliated and part of the quartz has an excellent crystallization foliation. Alternating quartz and mica concentrations are also one of the oriented elements of the rock's fabric. The oriented elements have been intensely deformed by folding and, in a number of places, by shearing parallel to the axial planes of the folds. Most of the sericite and epidote appear to have crystallized before deformation but recrystallization of quartz and, to a lesser degree, sericite seems to have accompanied the deformation.

Quartz is the major mineral of the rock; sericite is estimated to form about 30 per cent and minor amounts of epidote, biotite and chlorite, and accessories complete the mineral assemblage. Accessories observed were sphene, zircon, apatite, and opaques.

Chlorite was observed in a number of scattered localities and biotite only in a few aggregates. The biotite of the aggregates appeared to be partly altered to chlorite. Thus it is deduced that the chlorite of the rock is a weathering product of biotite rather than a primary metamorphic mineral. Some of the opaque grains have weathered to ?goethite.

AS-425: AS-6-5096: TS15228: Arunta Complex. This is a medium- to fine-grained epidote-mica-feldspar-quartz gneiss of granitic composition. In hand specimen fine, light and dark laminations, which are gently and isoclinally folded, give the rock a distinctive structure. In the rock section the structure is moderate and formed by mutually parallel oriented elements of the fabric. The elements are: foliated mica; fine crystal aggregates of epidote and feldspar; crystallization foliation of part of the quartz; and linear concentrations of opaques.

The texture of the rock is unusual. Commonly the feldspar grains are surrounded by finer feldspar grains, epidote and mica. Often these fine-grained aggregates coalesce to form laminae. This feature of the texture is thought to have resulted from stresses that have caused recrystallization and/or granulation at the borders of crystals. A number of deformed feldspar crystals were also observed. The epidote and mica appear to have crystallized during the rock's period of deformation. The specimen is not as intensely deformed as the first rocks of the traverse, but is still thought to have been synchronously altered. Further sampling, between localities would probably be required to substantiate the interpretation fully.

Most of the feldspar of the rock is untwinned; Carlsbad twinning was the only type observed. No plagioclase was observed either in thin section or in oil mounts, consequently the feldspar of the rock appears to be an alkali variety (microcline and/or orthoclase). Myrmekitic intergrowths and perthite are notably absent.

By visual estimation, it is suggested that the minerals occur in the following proportions: opaques (4%), mica plus epidote (11%), quartz (30%) and alkali feldspar (55%). Accessory zircon is also present.

Weathering has produced some secondary minerals – chlorite, and sericite.

3.8 Mt Laughlen Traverse

Summary. The specimen of the Heavitree Quartzite here is notable for the sedimentary grain form of the quartz and also that the arenite probably had a feldspar fraction. It is the least recrystallized specimen of the Heavitree Quartzite described by the petrologist.

The unconformity with the Arunta complex and the attitude of the Heavitree are important field data. The two metamorphosed quartzose sediments interbedded with the amphibolite and gneissic units observed in the Arunta complex have important stratigraphic implications as it is evident that quartzites similar to the Heavitree Quartzite occur within the Arunta complex. Not only mineralogically but in fabric as well, the Arunta quartzite (AS427) could not be differentiated from the more intensely recrystallized specimens of the Heavitree Quartzite. It will be demonstrated in later descriptions that intensity of recrystallization is not a sufficient criterion alone to differentiate Arunta complex quartzites from the Heavitree Quartzite. Specimen AS-428 also, except for the amount and coarseness of muscovite, has a fabric no stronger than that developed in certain specimens of the Proterozoic quartzite.

AS-426: AS-6-5096: TS15229: Heavitree Quartzite. The sedimentary rock, a quartz arenite, has been partially recrystallized; the rock is now termed a quartzite. Individual grains are cemented by fine-grained quartz and sericite. Often the fine quartz and sericite are oriented. Some intergranular, secondary quartz of coarser grain size is also oriented. While many of the quartz grains still have rounded sedimentary outlines, others appear to be broken and sheared off. Many grains show a marked strained extinction. There is a moderate, mutual parallelism of the oriented elements when they are observed on the scale of an entire thin section. The oriented secondary minerals, strained and broken sedimentary quartz grains, all indicate that shearing stresses have been operative during the recrystallization of the rock.

Aggregates of sericite, quartz, and ?kaolinite, which sometimes still have a preserved grain form, are thought to have formerly been sedimentary grains of feldspar.

The average grain size of the sedimentary quartz grains is 0.72 mm.

Accessories observed were opaques (rare) and tourmaline (rare).

The Heavitree Quartzite is cross-bedded at this locality (Plate 8, A). The cross-bedding indicated that the succession was normal at Mt Laughlen.

AS-427: AS-6-5096: TS15230: Arunta Complex. This is a medium- to fine-grained muscovite-metaquartzite or muscovite-quartz schist. In thin section as well as in hand specimen the rock has a strong structure. Parallelly oriented elements of the fabric are laminae of quartz and sericite, foliated muscovite and sericite, and crystallization foliation of part of the quartz. Sericite crystals are often seen to be intergrown with adjacent quartz crystals normal to the grain boundaries. Fine, dust-like grains of opaques are present in muscovite aggregates. Most of the quartz grains of the rock are foliated or tend to have crystal faces. Therefore it is doubtful that the present grain size of quartz is inherited from the siliceous sediment.

Accessories observed were sphene (rare), zircon (common), and opaques (abundant).

AS-428: AS-6-5096: TS15231: Arunta Complex. This is a medium- to coarse-grained mica-quartz schist. The rock has a strong structure which is formed by the following, mutually parallel elements of its fabric: laminae of quartz and muscovite, foliated muscovite, and crystallization foliation of the quartz. Mineralogically the rock is similar to the preceding rock (AS-427) described. However the minerals of this specimen are notably coarser grained – even the muscovite is much coarser. There is no indication of sedimentary textures remaining after metamorphism. Quartz crystals have interlocking, crenulated boundaries. Fine, disseminated opaques are present in some muscovite aggregates. The only accessory mineral observed, in addition to the opaques, was zircon.

3.9 Georgina Gap Traverse

Summary. The petrographic data of the traverse substantiates the field observations that the rocks of the locality are generally deformed and in several instances rather intensely altered. It is also confirmed that

Specimen AS-433 is a carbonate unit of the Arunta complex and that Specimen AS-431 is a sample of the Bitter Springs Limestone.

The metaquartzite, assigned to the Heavitree Quartzite by field interpretation, cannot be differentiated mineralogically from quartzites within the Arunta complex. The foliated nature of the rock does however indicate that it was subjected to intense shearing stresses during its crystallization. The intensity of the structure of this rock is matched only by the structure of the Heavitree Quartzite sample (Hg 450) which was undoubtably recrystallized during low angle faulting.

AS-429: AS-6-5094: TS15232: ?Arunta Complex. This is a coarse-grained, altered chlorite-muscovite-quartz-alkali feldspar rock. The rock has an unusual texture. The data do not allow a unique petrogenetic solution. Quartz has irregular outline and often aggregates of chlorite occur between grains. Aggregates of alkali feldspar and altered feldspar crystals form the remainder of the rock. The alkali feldspar is also altered along fractures and in border areas of grains. Pre-existing feldspar grains have been altered to reticulate and irregular aggregates of sericite.

From a visual estimate, it is suggested that the minerals are present in the following proportions: chlorite (10%), alkali feldspar (15%), quartz (30%), and altered plagioclase and alkali feldspar (45%). Accessories generally occur in the chlorite aggregates and are zircon (common) and apatite (abundant). ?Goethite also occurs and is associated with chlorite.

AS-430: AS-6-5094: TS15233: ?Arunta Complex. This is a breccia. It seems unlikely that the origin of the rock can be deduced from its present mineral assemblage or texture. One factor of the rock's history is evident though; it appears to have been recrystallized during or after brecciation. The large "fragments" are composed of a matrix of medium- to fine-grained quartz in which muscovite crystals, varying in size and orientation, are enclosed. These larger fragments are enclosed by an aggregate of very fine sericite and quartz with patchy bodies of ?iron hydroxide scattered through them. Coarser quartz aggregates are also present. Vein-like bodies of quartz and calcite transgress both the fragments and their enclosing matrix. Accessory apatite, zircon and opaques were observed.

AS-431: AS-6-5094: TS15234: Bitter Springs "Limestone". This is a sheared dolomite. Since deposition the rock has been rather intensely sheared. Large portions of the matrix are composed of medium- to fine-grained dolomite crystals which are shaped like extremely flattened rhombs. The flattening of these crystals is interpreted to have occurred during plastic deformation (i.e., shearing on two planes) of the rock. Muscovite is distributed through the rock as scattered "sheets" with random orientation (possibly primary) as crystals parallel to the oriented dolomite, and in transgressive bodies. At least a part of the muscovite has formed during the deformation of the dolomite. Vein-like or lamellar bodies of quartz are oriented parallel to the general rock structure; others transgress the structure. Quartz in places appears to have replaced earlier calcite adjacent to or at the margins of quartz bodies. Some of the dolomite in these areas is coarser and appears stained by ?iron hydroxide. A few opaques were observed. The dolomite was identified by x-ray diffraction and is the only carbonate present.

AS-432: AS-6-5094: TS15235: Heavitree Quartzite. This is a medium-grained sericite metaquartzite. The rock is in the stratigraphic position of the Heavitree Quartzite but it is one of the most highly recrystallized examples of this unit the writer has examined. The structure of the rock in thin section (Plate 3, A) is quite unusual. It consists of interlocking crystals of highly foliated quartz (with a length-to-width ratio of 9:1) and small amounts of sericite which is evenly distributed through the rock and is parallelly foliated. Accessory minerals are very fine-grained generally and are rare. They are opaques, tourmaline, sphene and zircon.

It is very evident that the quartz arenite has been metamorphosed under intense shearing conditions.

AS-433: AS-6-5094: TS15236: Arunta Complex. This is a medium- to fine-grained, impure marble. There is some evidence (fractured silicates and a nebulous linear structure) that the rock has been sheared after recrystallization.

Silicate minerals form 10 to 15 per cent of the specimen and are plagioclase, quartz, tremolite and muscovite. They occur as scattered grains and as aggregates of large crystals. Accessory minerals observed were apatite and sphene.

3.10 Illogwa Creek Sample

IC-434: AS-12-5018: ?Arunta Complex. The rock is composed entirely of one of the members of the tremolite-actinolite-ferroactinolite series. Moderately accurate oil immersion data indicate that it has a composition more in agreement with tremolite than actinolite.

3.11 Hale River Traverse 1, North of Ruby Gap Gorge

Summary. The specimens were collected in the Arunta complex north of the Heavitree Quartzite. It is notable that the Arunta complex is again highly structured near the contact with the Proterozoic quartzite where it appears to overlie the younger unit stratigraphically.

The three samples collected indicate that differential shearing (perhaps plastic and intense cataclastic deformation of earlier rock) has been important during at least the final phase of their petrogenesis. The shearing and crystallization can have occurred during an initial synkinematic metamorphism or during a period of retrogressive metamorphism. There is some indication in one specimen and perhaps a second that diapthoresis has occurred, though the evidence is not conclusive.

IC-435: HS-7-5042: TS15238: Arunta Complex. This is a medium- to fine-grained calc-silicate. The rock has a moderate structure which is imparted by the crystallization foliation of part of its mineral assemblage and linear quartz concentrations. Quartz, actinolite and, to a lesser degree epidote, are foliated.

Actinolite and epidote form about 75 per cent of the rock and are present in about equal quantities; quartz forms the remainder of the specimen. Accessories are not abundant and only sphene and some weathered opaques were observed.

The very fine-grained nature of the rock and strong structure observed in actinolite and epidote (two minerals not noted for their form orientation during metamorphic recrystallization) are two features of the rock which warrant attention in the petrogenesis.

IC-436: HS-7-5042: TS15239: Arunta Complex. This is a porphyroblastic, medium- to fine-grained epidote-sericite-quartz-plagioclase gneiss. The rock is very finely laminated in hand specimen. In thin section darker coloured, sericite-epidote laminae alternate with quartz laminae. Lenticular bodies of quartz grains, parallel to the other oriented elements of the fabric, also contribute to the rock's structure.

No alkali feldspar was observed in the rock either in thin section or by oil immersion examination. The anorthite content of three plagioclase porphyroblasts was found to be An_{25}, An_{26}, and An_{31}. The variety of epidote present could not be determined because of the small size of the crystals; it appears to be epidote rather than clinozoisite. A minor amount of biotite is present and associated with epidote. Plagioclase and slightly less abundant quartz are the major constituents of the rock. Sericite and epidote, by a visual estimate, comprise about 15 per cent of the total. Sphene and a few opaques were the only accessory minerals observed; others may be present but, because of their small size, cannot be differentiated from the epidote. A single crystal of garnet was observed.

Some features of the texture are worth recording for general petrologic interpretative purposes. In several places the sericite laminae transgress plagioclase grains. Most of the feldspar grains are deformed and all have at least several inclusions of epidote and sericite. It is of interest also that the sericite of the laminations is not foliated; quartz is only occasionally foliated and then only moderately oriented.

The petrology cannot be deciphered with certainty from the single sample. However, two general hypotheses are proposed for future investigation:

1. An earlier feldspar-quartz rock which has been deformed and recrystallized (i.e., a second generation of minerals — sericite, epidote and quartz — crystallized).

2. A feldspar-quartz rock in which differential movement was not important in the initial stages of crystallization but became intense during the final stages of its petrogenesis.

The anorthite content of the plagioclase and the general mineral assemblage indicates that the rock is a quartzo-feldspathic rock which has been metamorphosed under almandine-amphibolite facies conditions (Turner and Verhoogen, 1960). The first hypothesis (i. e., diapthoresis under conditions of differentiational movement) would provide a suitable explanation, in the writer's opinion, for the features and mineralogy of the rock.

IC-437: IC-7-5042: TS15240: Arunta Complex. This is a porphyroblastic, medium- to fine-grained sphene-quartz-epidote-actinolite amphibolite. The rock has a very strong micro-structure. Oriented elements of the fabric are: crystallization foliation of quartz, actinolite and, to a lesser degree, epidote; linear concentrations of minerals – particularly quartz and sphene – and rhomb shaped coarse-grained crystals of actinolite.

Epidote and actinolite comprise about 55 per cent of the rock, quartz about 40 per cent and sphene about 5 per cent. Several opaque grains and one of probable plagioclase were observed; plagioclase if present is only a very minor constituent.

There is some indication that the large grains of amphibole are porphyroclasts. Providing this suggestion could be verified, it would seem that the amphibolite had been cataclastically deformed and recrystallized.

3.12 Hale River Traverse 2, North of Ruby Gap Gorge

Summary. There are possible structural complications (faulting or folding) in the traverse as the metaquartzite (IC-439) is found between several gneisses of the Arunta complex. As stated previously neither by composition nor fabric can the Arunta quartzites be distinguished from the Heavitree Quartzite. Thus at the reconnaissance stage of mapping it will be necessary to make an arbitrary assignment of the quartzite to either of the units.

The gneisses, intervening quartzite, and the Proterozoic quartzite have a conformable rock cleavage. The quartz concentrations forming the micro-structure of the gneisses are also conformable. It is thus deduced that these structures formed during the same period of deformation and recrystallization of the Archean and Proterozoic rocks – the time when the reversal of stratigraphy was achieved at so many places along the northern margin of the Amadeus Basin.

The uniformity of the anorthite content – An_{30} to An_{35} – tends to support a general conclusion that the recrystallization of the Arunta has taken place under the same general P/T conditions. The available data limit this conclusion to a working hypothesis for future testing.

The gneisses are remarkably similar in mineralogy and fabric to several from the White Range Traverse.

IC-438: IC-7-5042: TS15241: Arunta Complex. This is a finely laminated, porphyroblastic, medium- to fine-grained biotite-epidote-sericite-quartz-plagioclase gneiss. Linear fabric elements showing mutual parallelism are: laminae of quartz and of sericite; composite laminae of plagioclase, quartz, sericite, and epidote; and foliation of part of the mica. These oriented fabric elements give the rock a moderate to strong structure both in thin section and hand specimen. Poikiloblastic plagioclase with inclusions of sericite and epidote are characteristic; they are sometimes deformed. Metamorphic differentiation appears to be the process by which the quartz laminae have formed.

The anorthite content of two plagioclase porphyroblasts was determined as An_{30}, and An_{32}. No alkali feldspar was observed by either thin section or oil immersion examination. Accessory minerals observed were sphene and apatite.

IC-439: IC-7-5042: TS15242: Arunta Complex. This is a sericite-quartzite. The rock in thin section has a moderate to strong structure which is formed by fine, foliated sericite and moderate crystallization of the quartz. No sedimentary grain form of the quartz remains — crystals are subhedral or xenomorphic in form. Sericite is present as inclusions in the quartz crystals as well as at grain margins. It is thus evident that the present mineral assemblage of the rock, excluding accessories, has crystallized after diagenesis. Several transgressive quartz laminae cut the general structure and displace the foliation in some examples.

Quartz has an average grain size of 0.063 mm contrasted to the accessory minerals zircon and tourmaline which are coarser — 0.09 mm and 0.10 mm, respectively. This indicates that the original grain size of the quartz, before metamorphism, was coarser than the present crystalline quartz.

IC-440: IC-7-5043: TS15243: Arunta Complex. This is a medium- to fine-grained biotite-epidote-sericite-quartz-plagioclase gneiss. The rock shows a moderate structure in thin section. Oriented elements of the fabric are lenticular bodies of quartz and linear concentrations of epidote and biotite. The fabric is rather unusual as the quartz lenticules separate aggregates of epidote, sericite and biotite in a framework of plagioclase. The plagioclase is generally untwinned and shows a range of grain size from fine to coarse. The mica within the plagioclase is generally unfoliated. The linear epidote aggregates transgress the plagioclase bodies and often border them; biotite associated with this epidote is generally foliated. The fabric of the rock is thought to be formed by the metamorphism; accompanied by differential shearing, of an earlier probable coarse-grained granitoid rock.

Alkali feldspar was not observed either in thin section or by oil immersion examination. The anorthite content of two plagioclase grains was determined as An_{35} and An_{34}. Accessory minerals observed were apatite, sphene and zircon.

IC-440A: IC-7-5042: TS15244: Arunta Complex. This is medium-grained, porphyroblastic epidote-sericite-microcline-quartz-plagioclase gneiss. Medium- to coarse-grained, irregularly shaped grains of feldspar are enclosed by medium-grained quartz. Plagioclase is notably poikiloblastic with inclusions of sericite and ?epidote.

By a visual estimate, it is suggested that the minerals occur in the following proportions; epidote plus sericite (10%), microcline (20%), quartz (30%) and plagioclase (40%). Accessory minerals are rare — only a few scattered sphene and opaque grains were observed.

The anorthite content of two plagioclase grains was determined as An_{31} and An_{33}. Plagioclase is often notably deformed; microcline has also been deformed during its crystallization but the evidence is not as clear. A few of the plagioclase grains have a relatively clear marginal zone — generally cryptocrystalline material is scattered through these grains. It is thus evident that deformation of the feldspar during its crystallization has been an important feature of the petrogenesis of the rock.

3.13 Hale River Traverse 3, North of Ruby Gap Gorge

Summary. This is an important locality because examination of the transitional beds provides conclusive evidence that they have been metamorphosed under moderate P/T conditions. In all probability, the beds are involved in large scale overfolds at this locality. Therefore it is not known to what degree the local intense deformation has affected the P/T conditions during metamorphism here, as compared to less deformed sediments in the central portions of the Amadeus Basin. However, the anorthite content of the plagioclase and the development of biotite suggest that the metamorphism is a regional one.

AS-441: IC-7-5042: TS15245: Bitter Springs Limestone (Transitional Beds). This is medium- to fine-grained biotite-andesine- calcite-muscovite-quartz schist. Oriented elements of the fabric are foliated mica, laminae in which one mineral dominates (quartz, mica and carbonate), and crystallization foliation of part of the calcite and quartz fraction. Shortening of the rock body is indicated by folding and shearing (causing repetition) of mica laminae (Plate 3, B).

By visual estimation, it is suggested that the minerals occur in the following proportions: biotite (7%), andesine (10%), ?calcite (15%), muscovite (18%), and quartz (50%). Accessories observed were zircon and apatite.

The anorthite content of two plagioclase crystals was determined as An_{33} and An_{35}. No alkali feldspar was observed.

AS-442: IC-7-5042: Bitter Springs Limestone (Transitional Beds). The specimen was collected to determine the type of carbonate present. The carbonate was found to be siderite. The remainder of the rock is comprised of mica and quartz.

3.14 Illogwa Creek Traverse 1

Summary. The banded iron facies rock may prove to be a suitable marker quartzite among those of the Arunta complex. The phosphate may have some, perhaps only remote, potential as an economic deposit.

The negative evidence that the Arunta complex cannot be shown to have been retrograded may be used only to support the stratographic evidence that the sequence is normal at this locality. The rocks are not ideally chemically suitable for detecting diapthoresis, thus lack of evidence for such an alteration is not considered to be conclusive.

AS-443: IC-7-5040: TS15246: Arunta Complex. This is a medium- to fine-grained calcite-actinolite-epidote-quartz rock. The rock shows a moderate structure in thin section which is imparted by mutually parallel elements of the fabric. The oriented elements are linear concentrations of quartz and epidote, and occasionally quartz shows a crystallization foliation. Quartz, epidote and, less frequently, actinolite show subhedral crystal form.

Quartz and epidote are the major constituents; actinolite is an important constituent of the rock also, whilst calcite is a less abundant constituent. Sphene forms about 4 per cent of the rock. Less important accessories observed were zircon (rare), apatite (common) and opaques (common). No feldspar was observed in the specimens.

There is no indication of earlier mineral phases (i. e., no evidence of retrogressive metamorphism). All the minerals present in the specimen are comparable to those found in retrogressive assemblages of the Arunta complex.

AS-443A: IC-7-5040: TS15247: Arunta Complex. This is a magnetite-apatite metaquartzite. Sedimentary bedding is shown by linear concentrations of apatite and opaques. Presumably during metamorphism the rock was folded, and now isoclinal micro-folds are evident.

By visual estimation it is suggested that the minerals are present in the following proportions: apatite (15%), opaques (10%), and quartz (64%). Epidote and less abundant chlorite are minor constituents. The rock is slightly weathered and some of the quartz grains are coated by ?goethite.

The most significant aspect of this rock is the mineral association which is typical of banded iron formations. Phosphate is more important than normally reported and magnetite less abundant. Still, the rock is representative of a facies of the banded iron deposits which are so notable in the Pre-Cambrian of the world.

3.15 Illogwa Creek Traverse 2

AS-444: IC-7-5040: TS15248: Heavitree Quartzite. This is a sericite metaquartzite. Oriented elements of the fabric – foliated sericite, linear concentrations of quartz and sericite, and crystallization foliation of the quartz – give the rock a moderate micro-structure.

The most interesting feature of the fabric is that two planes of mineral orientation were observed in places (Plate 4, A). The orientations are interpreted as resulting from two movement components during plastic deformation of the arenite associated with its metamorphism. Some quartz grains have a form orientation affected by both directions of movement.

Sericite forms an estimated 15 per cent of the rock, and quartz, excluding accessories, the remainder. Accessories observed were sphene, opaques and tourmaline.

AS-444A: IC-7-5040: TS15249: Heavitree Quartzite. This quartzite is more highly weathered than the preceding one. It was collected in an attempt to determine the cause of the contrasting weathering seen in outcrop. The outcrop was highly cleaved and the cleavage parallels a micro-structure termed S_1. In this specimen S_1 has been folded and S_2 has developed parallel to the axial planes of the folds (Plate 3, D). Crystallization of very fine sericite and probably quartz has accompanied the deformation.

AS-445: IC-7-5040: TS15250: Arunta Complex. This is an impure, medium- to fine-grained marble. Calcite forms about 70 per cent of the rock and sphene, quartz, actinolite-tremolite, feldspar and epidote form the remainder. The mineral assemblage appears to be a stable one (i. e., no proterogenic relicts were observed). Epidote was the only mineral that was observed to be deformed.

The feldspar is microcline and oligoclase. The calcite was determined by x-ray diffraction; no dolomite is present.

3.16 Illogwa Creek Traverse 3

AS-446: 7A-5116: TS15251: Heavitree Quartzite. Mineralogically the rock is similar to specimens of this formation which have been described from other localities. The fabric of the rock differs from other examples described in that the grain size is less regular and all the sericite is not preferentially oriented. Crystallization foliation of part of the quartz and wisp-like aggregates of sericite impart the micro-structure to the rock and also are responsible for the second structure (S_1) observable in the field.

At this locality it is evident that deformation of the rock body during metamorphism was not conformable with its sedimentary attitude.

AS-447: 7A-5116: TS15252: Arunta Complex. This is a fine- to medium-grained biotite-epidote-quartz-plagioclase gneiss. Mutually oriented elements of the fabric — linear concentrations of minerals (quartz, biotite and epidote), foliation of part of the biotite, and crystallization foliation of part of the quartz — give the rock a moderate micro-structure. Coarse plagioclase crystals and mosaics from a general framework in which epidote and biotite are enclosed. The minerals within it are not preferentially oriented. The plagioclase is generally untwinned. Its anorthite content was found to be $An_{30} \pm _5$ by oil immersion determination.

Plagioclase is the major constituent of the rock; quartz and epidote are important constituents and biotite forms approximately 10 per cent of the total. Sphene forms perhaps 2 per cent of the specimen and a few grains of zircon were observed.

Chlorite is present and often associated with biotite. It is thought to be a weathering product of biotite.

The rock appears to have formed under amphibolite facies conditions. Petrologically interesting features are the intense structure and the multiplicity of inclusions in plagioclase which is generally untwinned.

3.17 Arema Creek Specimen

AS-448: IC-7-5038: TS15253: ?Arunta Complex. This is a coarse- to fine-grained biotite-epidote-andesine-amphibole hornfels. Variably sized crystals of amphibole, biotite and most abundant epidote are included in plagioclase. The crystallites do not displace plagioclase twin lamellae when they transgress them, are more abundnat in the cores of plagioclase, and some epidote crystallites extend from plagioclase into adjacent crystals of amphibole or biotite. Plagioclase appears fresh and unaltered. These features suggest that the minerals crystallized simultaneously. The mineral assemblage appears to be characteristically metamorphic rather than igneous and deuteric.

It is estimated that amphibole, the major constituent, forms 50 per cent of the rock. Plagioclase is an important constituent, and biotite and epidote less important; quartz is a minor constituent. Accessories observed were apatite (common), opaques (rare) and zircon (rare).

The anorthite content of two plagioclase crystals was determined as An_{49} and An_{48}.

3.18 Specimen Locality South of Ruby Gap Gorge

Summary. Three petrologic conclusions of note are indicated from study of the samples:

1. The "shaly" interbeds within the Proterozoic carbonate have been metamorphosed (i. e., metamorphic sericite and stilpnomelane have crystallized).
2. The slaty cleavage (i. e., foliation of mica) has developed at a high angle to bedding but in some places the bedding has been mechanically rotated parallel to the foliation of the mica.
3. The example of the carbonate unit is a dolomite rather than a limestone.

AS-449A: AS-7-5228: TS15254: Bitter Springs Limestone ("Shale"). This is a slate. The rock shows a cleavage in hand specimen and has an excellent micro-structure. Oriented elements of the fabric are foliated mica and elongated quartz grains. These elements form S_1. Sedimentary bedding (S_O) is visible and consists of concentrations of angular quartz with feldspar and some muscovite flakes. S_1 and S_O intersect at an angle (Plate 4, B). S_O in some cases has been folded during the development of S_1, by affine deformation.

The rock is dominantly composed of sericite, with some stilpnomelane. Feldspar, mostly untwinned though some grains show microcline twinning, occur in the S_O laminae with quartz and muscovite. Accessories observed were opaques, sphene, and zircon.

AS-449B: AS-7-5228: TS15255: Bitter Springs Limestone. This is a medium- to fine-grained, recrystallized dolomite. Recrystallization of the carbonate has occurred during shearing of the rock. In a large portion of the rock, the carbonate shows a crystallization foliation. In some fractures which transgress the foliation chalcedony was observed. A few quartz aggregates and scattered flakes of muscovite are present. Iron hydroxide (?goethite) is present as irregular aggregates and as linear concentrations which parallel the rock's structure.

An x-ray determination of carbonate minerals and their relative proportions was made. The ratio of calcite to dolomite was found to be 3 to 67 hence the rock is a dolomite.

3.19 Ormiston Gorge Sample

Hg-450A: H-10-5109: TS15257: Heavitree Quartzite. This is a highly sheared and partially recrystallized specimen of the Heavitree Quartzite (Plate 4, C). A number of fractured and partially recrystallized granules are present and sericite is particularly abundant. It appears then that the original arenite was more argillaceous and had a sedimentary fraction coarser than sand size (i. e., granules and small pebbles).

The locality was sampled in order to determine why it was preferentially weathered and showed a pronounced rock cleavage. Size of the quartz grains and the compositional difference (i. e., the greater amount of mica) probably affect the weathering process. However the intense differential shearing seen in the quartzite here is thought to be the major cause of the increased weathering as well as of the rock cleavage.

3.20 Traverse North of Ormiston Gorge 1.

Summary. This is one of the most important traverses sampled during the field survey where the Arunta complex stratigraphically overlies the younger Heavitree Quartzite. The Proterozoic quartzite and the Arunta show a conformable rock cleavage near their contact. The rocks of the Archean complex become progressively less cleaved in the northerly direction until at the final sample locality only a few small epidote-quartz filled fractures disrupt the adamellitic gneiss. It is evident from microscopic examination that cataclasis of the rocks of the Arunta is responsible for their cleavage. Cataclasis and recrystallization of the Archean rocks also decrease in a northerly direction. The sample of the Heavitree Quartzite at the contact with the Archean rocks is one of the most foliated examples of the quartzite the writer has examined. Unfortunately the Proterozoic quartzite was not sampled any farther south on the traverse, but it would be expected that its foliation decreases in that direction.

In conclusion, it is quite evident from field observation of the cleavage and the petrography that the reversal of stratigraphy has been accompanied by considerable deformation of both the Heavitree and Arunta units. Recrystallization of both units has occurred during the deformation.

Hg-450: H-10-5109: TS15256: Heavitree Quartzite. This is a fine- to medium-grained sericite metaquartzite. There is a dominant structure (S_1') and a secondary one (S_1'). S_1' appears to have developed in incipient, oblique shears by recrystallization of the quartz into very fine unoriented grains (Plate 4, D). The dominant structure (S_1) is formed by foliated quartz and augens and lenses of quartz. Sericite is only a minor constituent but is also oriented. Accessories observed were tourmaline, zircon and sphene.

This is one of the most highly structured examples of the Proterozoic quartzite the writer has described.

Hg-451A: H-10-5109: TS15259: Arunta Complex. This is an intensely structured, partially recrystallized mylonite. Porphyroclasts of quartz and feldspar are medium sized and not as abundant as those in the following specimen. Lenticule-like bodies of quartz are common. Newly crystallized minerals are quartz, epidote, biotite and sericite. Sericite is more abundant in this specimen and epidote and biotite less abundant than in the less intensely structured mylonite (Hg-451). The specimen was taken from within a foot of the underlying highly foliated Proterozoic quartzite.

Hg-451: H-10-5109: TS15258: Arunta Complex. This is a partially recrystallized mylonite. The rock has a very strong micro-structure (Plate 5, A) along which the prominent rock cleavage seen in the field has developed. Linear aggregates of foliated, fine-grained quartz are interlaminated with linear aggregates of epidote, sericite and, less frequently, biotite. Porphyroclasts of feldspar and less abundant quartz are scattered through the oriented matrix. The porphyroclasts are augen-shaped or elongate and are the only remaining relicts of the original rock before its mechanical deformation and recrystallization.

Hg-452, 3: H-10-5109: TS15260, 1: Arunta Complex. These two specimens are described together as they are mineralogically and structurally similar.

Both rocks are now partially recrystallized cataclasites (Plate 5, B). The cataclasites have been formed by deformation of earlier rocks composed of plagioclase and alkali feldspar but cataclasis has not been as intense as observed in the mylonites of the traverse. Feldspar porphyroclasts are included in matrix of quartz. Quartz is often present in linear bodies or lenticular aggregates. Linear or lenticular bodies of biotite and epidote were observed, especially in Specimen Hg-453 (Plate 5, C). The plagioclase of both rocks has generally been partially recrystallized to epidote and sericite. Minerals formed during the partial recrystallization of the rocks were biotite, sericite, epidote and quartz. Alkali feldspar generally is perthitic. The perthite may have formed by exsolution during the shearing and/or recrystallization.

Most of the plagioclase of the cataclasites was too badly deformed for determination of the anorthite content by extinction methods. However, two determinations were made on plagioclase crystals of Specimen Hg-453. The first, on a fine, relatively undeformed crystal, which appeared unaltered as well, was found to have an anorthite content of $An_{32.5}$. The second, on a coarse deformed crystal, was found to have an anorthite content of An_{27}.

Hg-454: H-10-5109: TS15262: Arunta Complex. This is a partially recrystallized, coarse- to medium-grained plagioclase-quartz-microcline gneiss of adamellitic composition. The structure of the rock is moderate and appears to have been entirely formed during its cataclasis and partial recrystallization. Transgressive shears, broken crystals and deformed crystals (Plate 6, B) attest to the period of deformation. Recrystallization appears to have accompanied cataclasis, as epidote and quartz fill fractures (Plate 5, D). Secondary minerals – sericite, biotite and epidote – also occur in intergranular areas and replacing plagioclase (Plate 6, A). Shearing, as contrasted to the earlier rocks of the traverse, is confined to a few planes.

The anorthite content of two plagioclase crystals was determined as $An_{28.5}$ and $An_{29.5}$. The alkali feldspar often shows "tartan" twinning and is thus identified as microcline. Accessories observed were apatite and zircon.

3.21 Sample Locality North of Ormiston Gorge 1

Summary. The specimens described were taken from a single sample as examples of the massive and gneissic felsic rocks seen intermingled during the field traverse. These granitic rocks were seen to be transgressed in several places by dolerite dykes. The writer gained the field impression that the gneissic adamellite was older than the tonalite. However detailed mapping and petrography would probably be required to substantiate the impression. Certainly the petrography indicates that the last phase of crystallization was recorded within both types and that it appears to have been a phase of granitization. It is also interesting to note the accordance in the composition of the plagioclases of the two rock types. This suggests the hypothesis, for future testing perhaps, that the massive tonalite has formed by recrystallization of the gneiss.

Hg-455: H-10-5109: TS15263: Arunta Complex. The rock is a porphyroblastic epidote-biotite-quartz-plagioclase-microcline adamellite. Mildly foliated biotite and porphyroblasts of microcline are the most notable features of the rock's fabric.

By a visual estimate, it is suggested that the mineral constituents are present in the following proportions: mica plus epidote (15%), quartz (15%), plagioclase (15%), and microcline (45%). Accessory minerals observed were sphene, apatite and zircon.

The alkali feldspar may be entirely microcline as most grains show the "tartan" twinning. The anorthite content of a number of plagioclase grains was determined. The results indicated that $An_{25.5}$ was the average of the older plagioclase. The latest plagioclase, from initial data, does not appear to have reached conditions of equilibrium within the rock as anorthite contents both higher (An_{32} and An_{33}) and lower (An_{23}) than the primary plagioclase were determined.

A number of mineralogical features indicate that the rock has undergone a period of recrystallization: sericitization and epidotization of plagioclase; a second generation of plagioclase "replacing" the earlier plagioclase (Plate 7, A and Plate 6, D); plagioclase crystals embayed by quartz; and plagioclase partially replaced by microcline. The earlier mineral assemblage is now represented by relict plagioclase. The epidote, sericite, biotite, part of the microcline (Plate 6, C) and a small portion of the plagioclase appear to have crystallized during the final crystallization of the rock.

Hg-456: H-10-5109: TS15264: Arunta Complex. This is a equigranular, partially recrystallized tonalite. By a visual estimate, it is suggested that the minerals occur in the following proportions: mica and epidote (8%), microcline (2%), quartz (35%), and plagioclase (55%).

The anorthite content of the plagioclase was determined as: older – $An_{26.5}$, An_{28} and An_{27}, and younger – An_{22} and An_{23}.

The rock has undergone a mild period of recrystallization, compared to the preceding sample described. Biotite and epidote have replaced earlier plagioclase generally in intergranular areas but these minerals and sericite are also included within the plagioclase. As a consequence, the older plagioclase contrasts markedly to the later formed clear plagioclase which is present along the margins of the earlier plagioclase (Plate 7, B). Microcline, which appears also to have formed during the recrystallization, is found as small patches within plagioclase or in the intergranular spaces.

3.22 Sample Locality North of Ormiston Gorge 2

Summary. In the field the rock was seen to be interlayered with gneisses of varied felsic content, amphibolites, and granitoid rocks that were dipping moderately to the west. The sequence was cut by several dolerite dykes.

The cataclastic deformation and partial recrystallization of granitic gneiss indicate that the rock has undergone a final phase of the petrogenesis similar to the other rocks of the Arunta described in the Ormiston area.

Hg-457: H-10-5109: TS15265: Arunta Complex. This is a porphyroblastic sericite-epidote-biotite-plagioclase-quartz-microcline gneiss of granitic composition. Structure is moderately developed and imparted by foliated biotite and by linear concentrations of biotite and quartz.

By a visual estimate, it is suggested that the minerals are present in the following proportions: mica plus epidote (10%), plagioclase (20%), quartz (25%), and alkali feldspar (45%). Accessories observed were zircon, apatite and opaques.

The anorthite content of a plagioclase crystal was determined as $An_{26.5}$. The alkali feldspar appears to be microcline.

The paragenesis of the rock has been complex and thus, logically, cannot be unravelled with any certainty from the limited material available. Nevertheless two periods of deformation, an earlier one during which recrystallization occurred and a later one, can be recognized. The structure of the rock was probably evolved during the earlier deformation. Most of the biotite, epidote and sericite were probably crystallized during the initial deformation. Plagioclase and alkali feldspar were cataclastically deformed during this period. Some of the fractures transgressing alkali feldspar contain biotite (Plate 7, C).

During the latest deformation the feldspar was again deformed, but no recrystallization is apparent. This period of cataclasis has been of a minor degree and accomplished at low temperature – probably by minor faulting.

3.23 Traverse North of Ormiston Gorge 2

Summary. A number of rock types, defined by the ratio of light to dark minerals, were observed a long the traverse. Three of them were sampled for description. The first described is an example of the more massive type which became, without perceptible contacts, more gneissic in a westerly direction. In places these more massive granitic rocks had conformably oriented porphyroblasts. The second sample described is an example of the gneisses observed and the final sample is one of the less abundant, interlayered amphibolites.

All three of the rocks of the traverse have been cataclastically deformed and partially recrystallized. The late mineral assemblage of epidote, sericite, biotite and quartz present in them has crystallized after or during their deformation.

Hg-458: H-10-5109: TS15266: Arunta Complex. This is a coarse- to medium-grained, cataclastically altered and partially recrystallized granite. The feldspar appears to have been present before the deformation and crystallization of epidote, biotite and sericite. Shears through the feldspar contain mica and epidote.

The plagioclase is now very poikiloblastic with inclusions of epidote, biotite, and sericite. The rock is almost a cataclasite in degree of brecciation, but its composition is emphasized in the classification rather than the deformation. Mica, especially biotite, is found along the fractures which traverse the specimen. Much or perhaps all of the quartz has crystallized and/or recrystallized during the final crystallization.

By a visual estimate, it is suggested that the minerals are present in the following proportions: mica plus epidote (15%), quartz (15%), plagioclase (20%), and alkali feldspar (50%). Accessory minerals observed were zircon, apatite and opaques.

Much of the alkali feldspar shows microcline tartan twinning and is identified by that criterion. Plagioclase was found to have an anorthite content of An_{26} (a single grain determination) but because of mild strained extinction the result is thought to be less exact than normally obtained.

Hg-459: H-10-5109: TS15267: Arunta Complex. This is a coarse- to medium-grained sericite-epidote-biotite-quartz-plagioclase gneiss of tonalitic composition. The structure of the rock is imparted by linear concentrations of moderately foliated biotite. While recrystallization and deformation are not as intense as observed in other specimens from the Ormistion Gorge traverses, the processes are evident from a number of features observed in the rock section. Epidote, sericite and perhaps also a second generation of biotite have crystallized during the deformation. The paragenesis of these minerals is indicated by: epidote and biotite in deformed areas of plagioclase; fine, linear bodies of sericite transgressing plagioclase crystals; zones of fine grains bordering some of the larger quartz grains; and some fine, plagioclase grains which have been formed by recrystallization at the margins of the earlier coarser crystals.

By a visual estimate, it is suggested that the minerals occur in the following proportions: mica plus epidote (20%), quartz (25%) and plagioclase (55%). Accessories observed were spinel, apatite and opaques.

No alkali feldspar was observed. Plagioclase (a single grain) was found to have an anorthite content of An_{27}.

Hg-460: H-10-5109: TS15268: Arunta Complex. This is a medium- to coarse-grained, deformed and partially recrystallized amphibolite. Because of the moderate to intense deformation of minerals, the rock could be termed a cataclasite if one wished to emphasize this aspect of its history. Minerals indisputedly present before deformation and recrystallization were apatite, plagioclase and hornblende (quartz and sphene probably were part of the pre-deformation assemblage). Biotite, epidote, sericite and some of the sphene and quartz crystallized during or after deformation. Biotite is preferentially found in fractures (Plate 7, D), whereas epidote and sericite more commonly replace portions of earlier minerals (e.g., plagioclase – Plate 2, D and Plate 3, C).

By a visual estimate, it is suggested that the minerals are present in the following proportions: mica plus epidote (9%), quartz (10%), plagioclase (30%), and amphibole (50%). Accessories observed were apatite, opaques and sphene.

No alkali feldspar was observed. Plagioclase (a single grain) was determined to have an anorthite content of An_{35}.

3.24 Ooraminna Bore Sample Locality

Summary. During the examination of samples from the Bitter Springs Limestone, it became evident that siliceous intercalations within it had been metamorphosed at the northern margin of the Amadeus Basin. In an effort to compare the rocks to examples of supposedly unmetamorphosed carbonate, samples from a more central basin locality were examined. These were taken from the Ooraminna No. 1 Core at a depth of 5881 feet.

recrystallized The two samples examined were found to have been ~~metamorphosed~~. The orientation of the minerals in one sample and the complete recrystallization of both rocks lead the writer to conclude that the recrystallization of the Ooraminna carbonate occurred during a period of regional metamorphism. ~~The assemblage appears to be a stable one and is assigned to the greenschist facies (Fyfe, et al, 1958), and the quartz-albite-muscovite-chlorite subfacies~~. Additional samples from other localities and several confirmatory mineral identifications are needed before the regional metamorphism and facies assignment can be considered as sufficiently verified.

transgressing plagioclase crystals; zones of fine grains bordering some of the larger quartz grains; and some fine, plagioclase grains which have been formed by recrystallization at the margins of the earlier coarser crystals.

By a visual estimate, it is suggested that the minerals occur in the following proportions: mica plus epidote (20%), quartz (25%) and plagioclase (55%). Accessories observed were spinel, apatite and opaques.

No alkali feldspar was observed. Plagioclase (a single grain) was found to have an anorthite content of An_{27}.

Hg-460: H-10-5109: TS15268: Arunta Complex. This is a medium- to coarse-grained, deformed and partially recrystallized amphibolite. Because of the moderate to intense deformation of minerals, the rock could be termed a cataclasite if one wished to emphasize this aspect of its history. Minerals indisputedly present before deformation and recrystallization were apatite, plagioclase and hornblende (quartz and sphene probably were part of the pre-deformation assemblage). Biotite, epidote, sericite and some of the sphene and quartz crystallized during or after deformation. Biotite is preferentially found in fractures (Plate 7, D), whereas epidote and sericite more commonly replace portions of earlier minerals (e.g., plagioclase – Plate 2, D and Plate 3, C).

By a visual estimate, it is suggested that the minerals are present in the following proportions: mica plus epidote (9%), quartz (10%), plagioclase (30%), and amphibole (50%). Accessories observed were apatite, opaques and sphene.

No alkali feldspar was observed. Plagioclase (a single grain) was determined to have an anorthite content of An_{35}.

3.24 Ooraminna Bore Sample Locality

Summary. During the examination of samples from the Bitter Springs Limestone, it became evident that siliceous intercalations within it had
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Note: Additional core samples of the Bitter Springs Formation higher in the Ooraminna No.1 section were examined. Metamorphism is not required to explain any of their post-sedimentation features. Forman considers the recrystallization of core 20 to be the result of shearing movements associated with décollement as salt occurs about 70 feet below it.

Ooraminna No. 1, Core 20: TS15323: Bitter Springs Limestone. This is a fine- to medium-grained muscovite-?stilpnomelane-microcline-quartz ~~prehnite~~ anhydrite-?calcite ~~calc-silicate~~ marble. The rock has a general hornfelsic texture but some of the ~~prehnite~~ anhydrite and muscovite show a preferred orientation.

A visual estimate of the minerals suggests they are present in the following proportions: accessories (3%), microcline (7%), muscovite plus stilpnomelane (10%), ~~prehnite~~ anhydrite (15%), quartz (15%), and ?calcite (50%). Accessories are rutile, zircon, opaques, and sphene (conspicuous). Feldspar grains with fourling and tartan twinning indicate that microcline is present. A number of untwinned feldspar grains are present and these have not been identified. The optical identification of ~~prehnite~~ anhydrite is rather conclusive. The identification of stilpnomelane, carbonate and the untwinned feldspar needs confirmation by more detailed study.

Ooraminna No. 1, Core 20: TS15324: Bitter Springs Limestone. This rock is termed a schist. It is similar in mineralogy to the other core specimen but differs in structure and the relative proportions of the minerals present. ~~Prehnite~~ Anhydrite is more abundant and calcite less important in this sample. The rock has a moderate structure imparted by a general, mutual orientation of the muscovite, stilpnomelane and ~~prehnite~~ anhydrite and crystallization foliation of part of the quartz. There is ample, textural evidence to indicate that the mineral phases crystallized during the same period of metamorphism.

The accessory minerals of the two rocks are similar except that in this specimen tourmaline and apatite were also observed. Much of the feldspar present is untwinned; other twinned grains show tartan or albite twinning and both types appear to be microcline. The untwinned grains are too small to identify without separation.

4. CONCLUSIONS

4.1 Stratigraphy

4.1.1 The Arunta Complex

About 50 specimens from the metasediments, gneisses, amphibolites, and granitic rocks comprising the unit have been described. Details of these specimens are given in the petrography, but attention is drawn here to the occurrence of several quartzites interbedded with the metasediments. These quartzites cannot be clearly differentiated from certain examples of the Heavitree Quartzite except by their stratigraphic position (e.g., Mt Laughlen Traverse). Should the Archean and Heavitree Quartzite be adjacent in a structually complex area, their differentiation might prove difficult at best.

4.1.2 The White Range Quartzite

The more highly structured quartzites of this report adjacent to the Arunta complex were previously considered to be a separate stratigraphic unit, the White Range Quartzite (Joklik), but have now been mapped as the Heavitree Quartzite (D. Forman personal communication).

The results of this investigation indicate that mineralogy and "lineation" are not sufficient criteria to distinguish a separate lower Proterozoic quartzite, the White Range Quartzite, from the Heavitree Quartzite. It is concluded that the highly structured or lineated quartzite has formed during intensive recrystallization of the Heavitree Quartzite. Discussion of the data upon which these conclusions are based is included in Section 4. 3 – Reversal of Stratigraphy.

4.1.3 Heavitree Quartzite

Ten samples of the slightly argillaceous, quartz arenite were examined. The sedimentary quartz has been recrystallized in all of the rocks and all contain a new generation of mica. The newly crystallized minerals are preferentially oriented. The degree of orientation and recrystallization appears to be dependent on the intensity of deformation during metamorphism. In several samples a second S plane has developed synchronously with the primary mineral orientation. The recrystallization of the Heavitree Quartzite is thought to have occurred under metamorphic conditions.

In one specimen where sedimentary grain form is still visible, some of the grains are of granule or small pebble size. Accessory minerals are neither conspicuous nor unusual.

4.1.4 Bitter Springs Limestone

Two rocks dominantly composed of carbonate and five others of siliceous and pelitic intercalations found occurring within the unit have been described. The carbonate of the first two specimens is mainly dolomite. Both rocks have been plastically deformed by differential shearing after diagenesis. Some accessory mica, of an undetermined origin, is the only other mineral of any importance found associated with the dolomite.

The siliceous and pelitic intercalations contain a low grade metamorphic mineral assemblage. Metamorphism of the unit is thus only evident when sufficient silica and other components are available for the crystallization of a definitive metamorphic assemblage.

4.2 Metamorphism

4.2.1 Progressive Metamorphism of the Arunta Complex

The detailed stratigraphy of the Arunta complex over much of the sampled area has not been defined. The data obtained indicate that granitoid rocks and gneisses are overlain by sediments which have been metamorphosed under almandine-amphibolite facies conditions. Rocks metamorphosed under greenschist facies conditions appear to overlie the medium grade metamorphics conformably in the Winnecke Depot Creek area.

In the Harts Range, Joklik (p 59) has reported that the grade of metamorphism is everywhere equivalent to the sillimanite isograd; some lower grade metamorphic rocks present were related to a period of retrogressive hydrothermal metamorphism rather than progressive regional metamorphism. Some of the latter metasediments may compare with certain rocks of the Winnecke group. However, the time limits imposed by this investigation do not allow study of the correlation. The greenschist facies mineral assemblage of some of the carbonate rocks at Winnecke may result from conditions other than P/T (e.g., water pressure). Nevertheless, the occurrence of rocks of the greenschist facies does not appear anomalous, as lower grade subfacies of the almandine-amphibolite facies are present in the Winnecke area than have been reported in the Arunta metamorphics of the region.

The absence of the metasediments of the almandine-amphibolite facies at one locality (Ormiston Gorge) along the northern margin of the basin and of the lower facies rocks at perhaps all but one locality (Winnecke Gold Mine Area Traverse 1) is of regional significance. Angular unconformity between the Arunta complex and the Heavitree Quartzite may not provide a complete explanation for these relationships (i.e., structural omissions may be necessitated).

4.2.2 Progressive Metamorphism of the Proterozoic Sediments

The synkinematic recrystallization of the Proterozoic quartzite is evident in all samples examined. Along the northern margin, in one sample only of the carbonate – a siliceous-pelitic intercalation – is a metamorphic assemblage evident. The assemblage is in accord with the greenschist facies. Samples of the carbonate from a less deformed area within the basin have been recrystallized ~~metamorphosed under conditions of the quartz-albite-muscovite-chlorite subfacies of the greenschist facie~~s. In the highly folded, deformed portions of the Bitter Springs unit, the recrystallization may have been more complete as a result of the higher temperatures and more intense differential shearing. Consequently it is concluded that the Proterozoic arenite and carbonate have been regionally metamorphosed under greenschist facies conditions.

4.2.3 Retrogressive Metamorphism of the Arunta Complex

The Illogwa Creek Traverse. At these localities the Heavitree Quartzite appears to be in normal stratigraphic position over the Arunta complex. The Proterozoic quartzite has been moderately recrystallized but there is no positive evidence that the Arunta rocks have undergone diapthoresis. The carbonate and quartzite rocks types accessible here within the Arunta are not particularly suitable for determining retrogression. Therefore while retrogression has not been proved, the data do not preclude it.

The Hale River Traverses. The gneisses show the most conclusive evidence for low grade metamorphism with associated shearing stresses. The petrographic data of the amphibolite and calc-silicate rocks do not give a clear indication of diapthoresis but neither do they conflict with that interpretation.

The White Range Area. A low grade mineral assemblage has developed in the probable earlier metasediments and granitoid rocks of the Arunta.

Georgina Gap Traverse. Except for the marble, the rocks of the Arunta have undergone a period of deformation and recrystallization. The nature of the recrystallization is not clear here, but some aspects of the rocks suggest it was hydrothermal.

Winnecke Gold Mine Area Traverse 1. The siliceous metacarbonate rocks sampled indicate a polymetamorphic history. The final crystallization has been of a low grade, and differential movements within the rock body and deformation of it are indicated. The latest period of metamorphism evident in the metasediments here may have been the same event which altered and deformed the rocks of the Arunta adjacent to the Heavitree Quartzite.

Winnecke Gold Mine Area Traverse 2. The rocks of the Arunta, especially near their contact with the Heavitree Quartzite, have been cataclastically deformed and have undergone a low grade metamorphic recrystallization. The recrystallization is evident in all the rock types examined, although naturally enough the retrogressive mineral assemblage is dependent on the composition of the particular Arunta rock recrystallized. It is evident that the cataclasis and recrystallization occurred during the same event.

Winnecke Depot Creek Traverses. Here the metasediments appear to have been unaffected by the period of retrogressive recrystallization recorded in the Arunta rocks at so many of the other sampled areas.

Traverse North of Ormiston Gorge 1. The Archean rocks have undergone a period of retrogressive recrystallization accompanied by cataclasis which was particularly intense near its contact with the "underlying" Proterozoic quartzite.

Ormiston Gorge Samples (excluding those of the first traverse). The Arunta rocks of these localities consist of granitic rocks of varied composition and amphibolite. In all of them a low grade mineral assemblage has developed. It is evident in all of the described rocks, excluding one, that cataclasis has accompanied the recrystallization.

It is thus apparent from the results of this investigation that the rocks of the Arunta have undergone a period of retrogressive metamorphism in localities where they appear to overlie the Heavitree Quartzite stratigraphically. The diapthoresis is restricted to the immediate vicinity (within a horizontal distance of four miles) of the contact with the Heavitree; deformation of the Arunta has occurred in co-ordination with the recrystallization. The data are not sufficient to delineate any possible diapthoresis of the Arunta when it normally underlies the Heavitree Quartzite (e.g., the Mt Laughlen Traverse).

4.3 Reversal of Stratigraphy

During this investigation four general localities, and possibly a fifth, were visited where an intensely structured quartzite appears to dip under the Arunta complex or to be interbedded with the Archean rocks. This relationship has most recently been explained by postulating the occurrence of a lower Proterozoic quartzite, the White Range Quartzite, which was conformably folded with the Archean basement during the development of a regional anticlinorium (Joklik, pp 22, 23, 1955). The field and microscopic observations of the rocks of the four traverses are remarkably similar. The quartzite and Archean rocks show a conformable rock cleavage which diminishes northerly into the Arunta Block, and in all of the areas the Archean rocks have been retrogressively recrystallized. Where the Proterozoic quartzite is adjacent to gneisses of the Arunta, they have been intensely granulated in the immediate vicinity, cataclastically altered farther from the contact, and moderately fractured still farther into the Archean basement. Where metasediments of the Arunta are adjacent to the Proterozoic quartzite, cataclastic or plastic deformation is evident which also diminishes in a northerly direction away from the quartzite. At all of the localities the quartzite is highly structured.

It is therefore concluded that the highly structured quartzite, formerly termed the White Range Quartzite, has formed by intensive recrystallization of the Heavitree Quartzite. The recrystallization of the Proterozoic quartzite and the deformation and retrogressive metamorphism of the Arunta rocks are thought to have occurred synchronously. Any mechanism evoked to explain these events must thus incorporate both cataclasis and recrystallization of the Heavitree and Arunta which is most intense at their contact and diminishes in intensity with increasing distance from it. The gold mineralization appears to be related to the same event which has affected these rocks.

At Houghton, in South Australia, a somewhat analogous situation of deformation of the Archean and overlying Proterozoic sediments has been described by Spry (1951). Here the Archean core and overlying Proterozoic sediments were folded during a Paleozoic orogeny. Along the western margin of the anticline formed by the deformation of the Archean, the sediments were overturned, sheared and metamorphosed. The Archean in these positions was retrogressively metamorphosed and along this zone mineralization has occurred (calcite, quartz, pyrite, and gold).

5. RECOMMENDATIONS

5.1 Age Dating

It may be possible to date successfully some of the events which have affected the rocks of the area by radioactive age dating methods. The period of recumbent folding of the Bitter Springs Limestone, so spectacularly displayed along the gorge of the Hale River near Ruby Gap, may be determinable by age dating some of the mica-plagioclase bearing rocks which have formed during its deformation. The writer would consider that the folding of the Proterozoic has occurred during the same period of deformation and retrogressive recrystallization of the Archean in the areas studied during this investigation. However, this deduction can possibly be confirmed by dating minerals formed during the retrogression as well as those crystallized during the folding. Suitable material for the age dating of the diapthoresis is not as available as that for dating the folding because, in most of the altered Archean rocks, minerals of both periods of crystallization are present. Potential solutions to the problem may be available including dating of any possible lead sulphides associated with the mineralization and dating the biotite-microcline rock (AS-421) of which the present mineral assemblage may have formed entirely during diapthoresis.

In the Winnecke Depot Creek area, the metasediments do not appear to have been affected by the retrogressive event. Some of the micaceous metasediments here may be suitable for age dating of the crystallization of this portion of the basement.

5.2 Stratigraphy of the Arunta Complex

In order to determine the effects within the Arunta Block of the period of low grade metamorphism of the Proterozoic sediments, it is recommended that some detailed mapping of the Archean be undertaken. In the proposed programme, it would be necessary to map isograds or facies within the metasediments adjacent to areas where the Heavitree Quartzite appears to overlie the Archean basement normally. In these areas the Heavitree would also need to be sampled and structures formed by mineral orientations, etc., measured and recorded. The study in addition, would provide a more complete knowledge of the stratigraphy of the Arunta for application to structurally complex areas along the margin of the Amadeus Basin.

5.3 Metamorphism of the Proterozoic Sediments

The metamorphism of these units within the central portions of the Amadeus Basin needs further confirmation. Therefore study of any available core samples of the siliceous and pelitic intercalations of the carbonate unit is recommended.

5.4 Synchronous Recrystallization and Deformation of the Proterozoic Sediments and Archean Rocks

It would seem under the premises of the hypothesis that, where the highly recrystallized Proterozoic quartzite is found, the rocks of the Arunta should be cataclastically altered or recrystallized adjacent to it. From the results of this investigation, cataclasis will be most evident when the gneisses or granitic rocks are in this situation. Where carbonate and perhaps other metasediments are adjacent to the Proterozoic quartzite, the cataclasis may not be as evident. While perhaps unnecessary, it is noted that the quartzite used to test the hypothesis must not be one of Archean age (e.g., those at Mt Laughlen, or AS-443A).

6. ACKNOWLEDGEMENTS

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PLATE 1

A. AS-402: TS15204: x 25: XN

Arunta Complex

Late sericite transgressing earlier feldspar.

B. AS-403: TS15205: x 100 PPL

Arunta Complex

Epidote rim around ?allanite cast.

C. AS-418: TS15221: x 40: XN

Arunta Complex

Deformed feldspar.

D. AS-418: TS15221, L_2: x 25

Arunta Complex

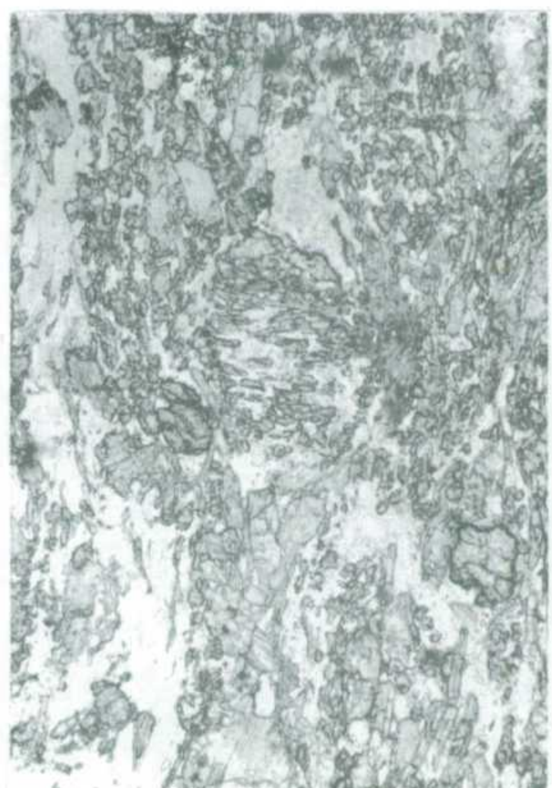
"Snowball" clast of S_o.

PLATE 1

A

B

C



D

PLATE 2

A. AS-418: Winnecke Gold Mining Area Traverse No. 2

Arunta Complex

Fold from which AS-418 collected.

B. AS-421: TS15224: x 25: XN

Arunta Complex

Structured feldspar-quartz cataclasite.

C. AS-423: TS15226: x 25: PPL

Arunta Complex

Hornblende cataclasite with late biotite within fractures in the amphibole.

D. Hg-460: TS15268: x 100: XN

Arunta Complex

Sericite and epidote which have crystallized along fractures in plagioclase.

A

B

C

D

PLATE 3

A. AS-432: TS15235: x 100: XN

Heavitree Quartzite

Completely recrystallized, foliated quartzite.

B. AS-441: TS15245: x 25: PPL

Bitter Springs Limestone transition beds

Shortening by micro-shear overfolds.

C. Hg-460: TS15268: 100: XN

Arunta Complex

Sericite and epidote crystallized within an incipient shear in plagioclase.

D. AS-444A: TS15249: x 25: PPL

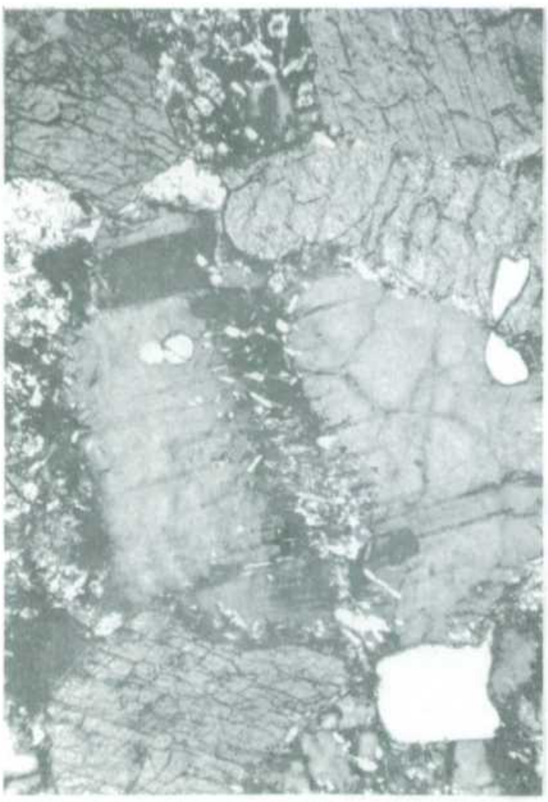
Heavitree Quartzite

S_1 folded and S_2 developed parallel to the axial plane of the S_1 fold.

PLATE 3

A

B



C

D

PLATE 4

A. AS-444: TS15248: x 40: XN

Heavitree Quartzite

Concurrent development of oriented minerals:

S_1 = sericite and quartz often oriented.

S_1^1 = quartz occasionally oriented, sericite rarely.

B. AS-449A: TS15254: x 25: PPL

Bitter Springs Limestone

Affine deformation of S_o by movement on one set of parallel shear planes. Note the folding of S_o by the same mechanism; elsewhere S_o has been sheared into a parallel position with S_1.

C. Hg-450A: TS15257: x25: XN

Heavitree Quartzite

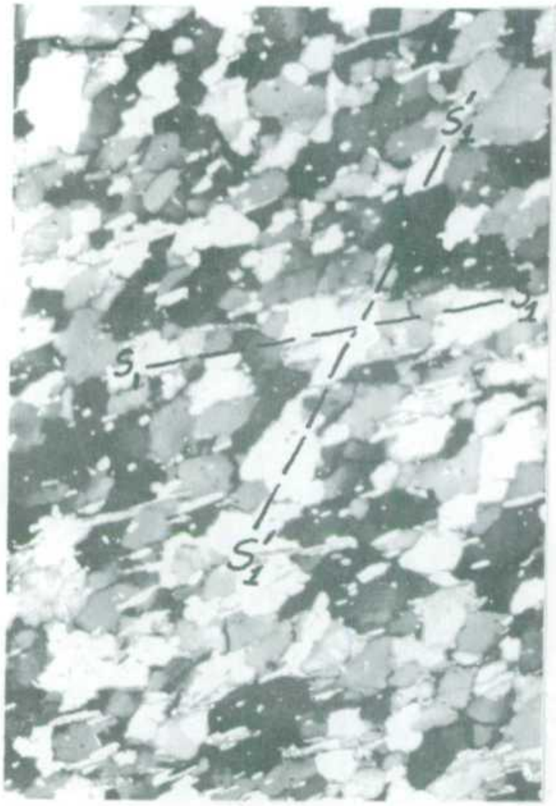
Sheared and partially recrystallized quartzite.

D. Hg-450: TS15256: x 25: XN

Heavitree Quartzite

Completely recrystallized quartzite. Occasionally an S_1^1 structure has developed.

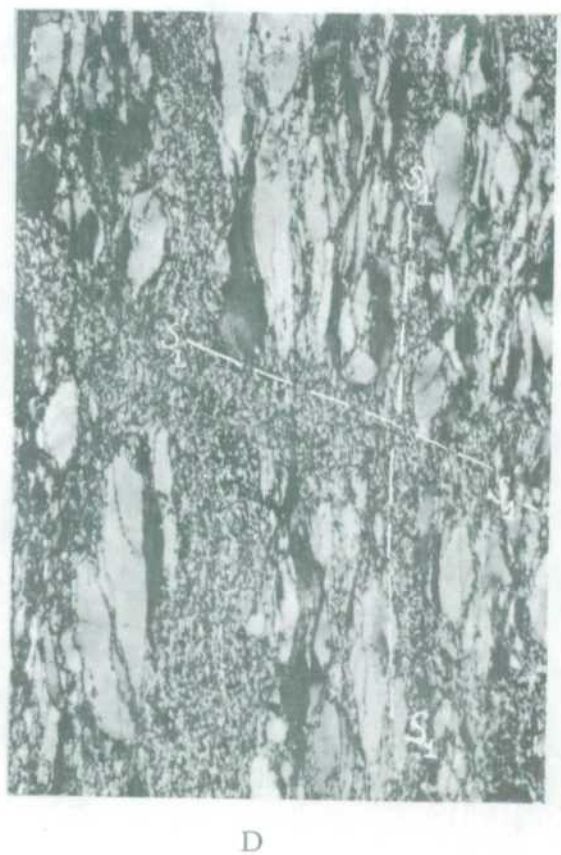
PLATE 4



A

B

C



D

PLATE 5

A. Hg-451: TS15258: x 25: XN

Arunta Complex

Recrystallized mylonite

B. Hg-451: TS15260: x 25: XN

Arunta Complex

Partially recrystallized cataclasite.

C. Hg-453: TS15261: x 25: XN

Arunta Complex

Cataclasite with mylonitic lenses.

D. Hg-454: TS15262: x 25: XN

Arunta Complex

Shear transgressing gneiss filled with quartz and along its margins epidote, sericite and biotite have crystallized.

PLATE 5

A

B

C

D

PLATE 6

A. Hg-454: TS15262: x 40: XN

Arunta Complex

Plagioclase replaced by and/or recrystallized into sericite.

B. Hg-454: TS15262: x 25: XN

Arunta Complex

Cataclastically and plastically deformed plagioclase.

C. Hg-456: TS15264: x 40: XN

Arunta Complex

Late microcline (2) and plagioclase (1) partially replaced by sericite.

D. Hg-456: TS15264: x 100: XN

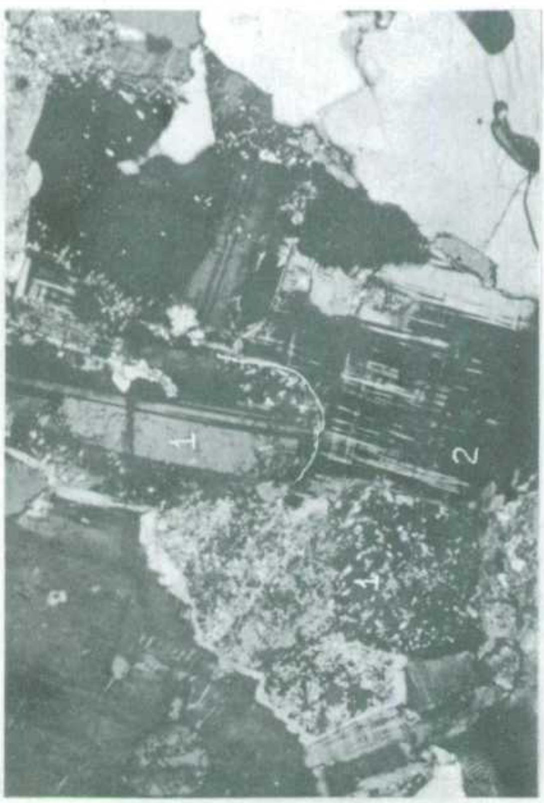
Arunta Complex

Late zone of plagioclase rimming older plagioclase and in serrated contact with microcline.

PLATE 6

A

B



C

PLATE 7

A. Hg-456: TS15264: x 40: XN

Arunta Complex

Late pseudomorphic zone of plagioclase (An_{22}) which has "replaced" earlier plagioclase (An_{28}).

B. Hg-455: TS15263: x 40: XN

Arunta Complex

Late pseudomorphic margin of plagioclase (An_{23}) which has "replaced" earlier plagioclase ($An_{26.5}$).

C. Hg-457: TS15265: x 40: XN

Arunta Complex

Biotite in fracture transgressing earlier microcline.

D. Hg-460: TS15268: x 40: PPL

Arunta Complex

Biotite in fractures transgressing earlier hornblende.

PLATE 7

A

B

C

D

PLATE 8

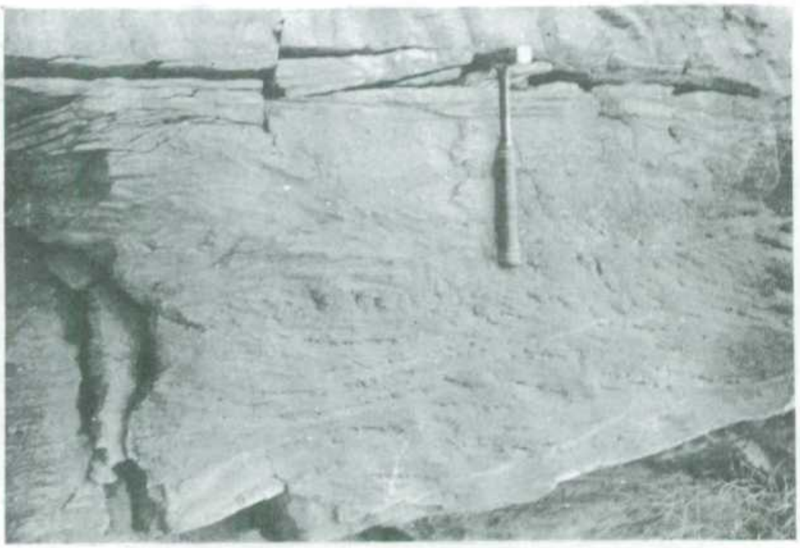
A. AS-426: Mt Laughlen Traverse

Cross-bedded Heavitree Quartzite.

B. Illogwa Creek Traverse

Quartz lenses of the Arunta Complex sheared off and "rolled-up" as it moved over the Heavitree Quartzite.

PLATE 8



A

B