COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

REPORT No. 103

Regional Geology and Structure of the North-Eastern Margin of the Amadeus Basin, Northern Territory

BY

D. J. FORMAN and E. N. MILLIGAN
(Bureau of Mineral Resources)

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MINISTER: THE HON. DAVID FAIRBAIRN, D.F.C., M.P.

SECRETARY: R. W. BOSWELL, O.B.E.

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PART I

by D.J. FORMAN and E.N. MILLIGAN

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 and low-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 evaporites within the sedimentary succession. At the start of the orogeny late in the Ordovician the sea receded from the area and the Mereenie Sandstone was deposited during the interval Ordovician to Devonian under predominantly continental conditions. The main climax of the orogeny occurred in the Devonian and possibly Carboniferous, 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 been moved up to 15 miles to the south over the incompetent Bitter Springs Formation. The Arunta Complex has been subjected to a period of deformation and retrograde metamorphism (see Part II).

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

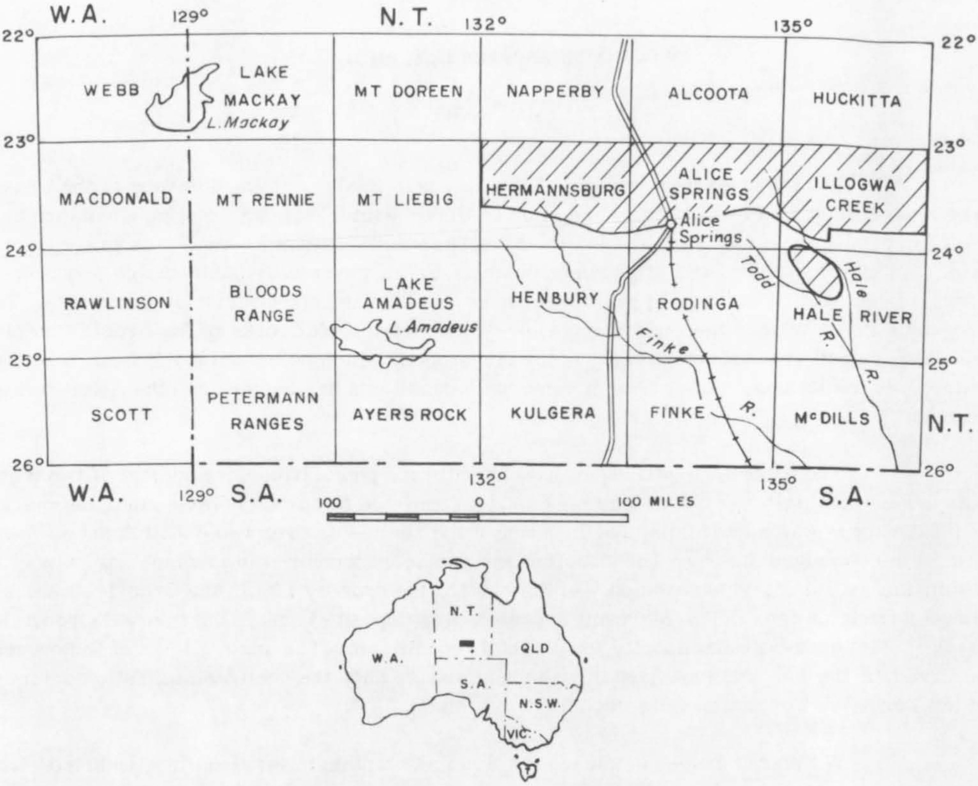
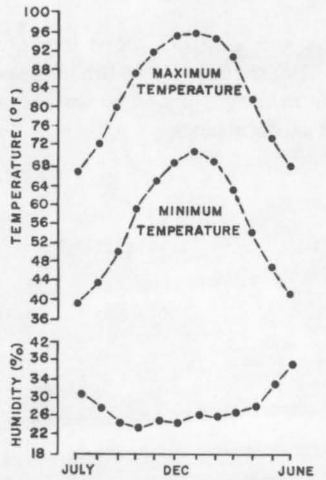
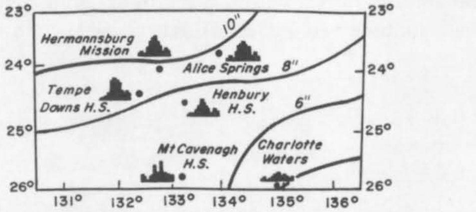


Fig. 1. 1:250,000 Sheet index and locality map



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



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

Fig. 2. Temperature, relative humidity, and rainfall

INTRODUCTION

The area described in this Report (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 (Fig. 3) and by numerous graded roads and vehicle tracks, usually in poor condition. Parts of the rugged terrain are inaccessible even with four-wheel-drive vehicles. The Simpson Desert was reached 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 homesteads.

Climate

Figure 2 gives the monthly mean 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 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 homestead these is a network of tracks to the cattle watering points, which include bores, dams, wells, and waterholes.

The aborigines are no longer truly nomadic, and most of them live on the settlements, or at Alice Springs, or on the cattle stations. There is a considerable local industry in aboriginal paintings and artifacts.

Alice Springs, in the centre of the area, has a population of about 3500; it is a popular tourist centre during the winter months. Alice Springs is the terminus of the railway from Adelaide and is connected to Darwin by the Stuart Highway. Regular air services are available to Adelaide and Darwin, and Connellan Airways flies a regular run to most of the stations and provides transport for tourists. Alice Springs is a centre for the Royal Flying Doctor Service.

The Northern Territory Administration has established Branches of Animal Industries, Water Resources, Mines, Agriculture, Lands and Survey, and Social Services at Alice Springs. The Bureau of Mineral Resources provides geologists to the Northern Territory Administration for assistance in the development of the mineral and water resources. The Division of Land Research and Regional Survey of the CSIRO has until recently maintained an office in Alice Springs to examine methods of pasture improvement and to conduct experimental work on small catchments. The Department of Works is the main Commonwealth 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 the production of 1:250,000 Sheets. Surveyors from the Department of the Interior have provided levels for geophysical surveys by the Bureau of Mineral Resources.

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 homestead.

The geology was plotted on air-photographs on a scale of about 1:46,000 and transferred to slotted templet assemblies which were reduced photographically to a scale of 1:250,000.

Previous Investigations

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 conspicuous zigzag contortions in the Bitter Springs Formation near Bitter Springs.

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

Fossils were found by Brown and Thornton in 1890, probably near Tempe Downs (Brown, 1892; Etheridge, 1892). Etheridge reported on additional fossils in 1893. In 1894, Tate & Watt (1896), geologists of the Horn Expedition, 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 grouping, but 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 Cambrian and Ordovician ages for the sedimentary rocks and suggested that the basal members such as the Arltunga/White Range and Chewings Range quartzites were infolded and partly assimilated in the basement.

Investigations by Mawson & Madison (1930) in 1927 and Madigan (1932a,b, 1933) from 1929 to 1931, showed that the sedimentary succession could be divided into several units ranging from Upper Proterozoic to Permian. Madigan (1932a) proposed a subdivision of the rocks into Árchaean (Arunta Complex), Upper Proterozoic (Pertaknurra and Pertatataka Series), Cambrian (Pertaoorrta Series), and Ordovician (Larapintine Series). Hodge-Smith (1932), who visited the area in 1929, proposed a division of the Arunta Complex into six units and postulated at least one unconformity within the complex.

Ellis (1937) correlated the quartzite in the Petermann Ranges and the quartzite in the Rawlinson Range with the Pertaknurra quartzite at Heavitree Gap, near Alice Springs. He also noted the concordance of strike of the Heavitree Gap quartzite with the foliation in the Arunta Complex and concluded that the Heavitree Gap quartzite, and the Winnecke and 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 (AGGSNA), principally Voisey (1939) and Hossfeld (1936, 1937a,b,c, 1940, 1954), investigated mineral occurrences in the area. 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 (1949), Browne (1950), Noakes (1953, 1956), Opik (1957), and Walpole et al. (1965), but the first comprehensive regional map was prepared 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 difference between the Heavitree Quartzite and the White Range Quartzite. He assigned the White Range Quartzite to the Lower Proterozoic and considered that it lies unconformably between the Arunta Complex and the Heavitree Quartzite.

Some of the findings of the officers of the Bureau of Mineral Resources engaged in a search for radioactive minerals are recorded in Daly (1951) and Ryan (1957). Wilson, Compston, Jeffery, & Riley (1960) and Walpole & Smith (1961) reported on the results of isotopic age determinations.

In 1956, Prichard & Quinlan (1962) initiated a programme of regional mapping of the Amadeus Basin on a scale of 1:250,000 by mapping the southern half of the Hermannsburg Sheet area. Wells, Forman, & Ranford (1965a,b), Forman (1965), Ranford, Cook, & Wells (1965), and Wells, Stewart, & Skwarko (1966) continued this programme to the west and south during the years 1960 to 1963. A detailed photo-interpretation of the region was carried out in 1960 by the Institut Francais du Pétrole (Scanvic, 1961).

Quinlan (1962) and Ryan (1962) reported on the geology, Mabbutt (1962) on the geomorphology, and Jones & Quinlan (1962) on the groundwater 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, & Basinski (1963) made an assessment of the groundwater potential for agricultural purposes. Other observations on groundwater, particularly in the Alice Springs Town Basin, have been made by Owen (1952, 1954), Jones (1957), and Quinlan & Woolley (1962, 1963).

A regional gravity traverse into the Amadeus Basin was made by Marshall & Narain (1954), and in 1961 and 1962, the Geophysical Branch of the Bureau of Mineral Resources completed a regional gravity survey of the basin (Langron, 1962; Lonsdale & Flavelle, 1963).

The aeromagnetic surveys include total magnetic intensity maps on a scale of 1:250,000 of the Hale River and the southern half of the Illogwa Creek Sheet areas. Both were compiled from an aeromagnetic survey of part of the Simpson Desert in 1962 by Aero Service Ltd (Quilty & Milsom, 1964) under contract to the Bureau of Mineral Resources. A 1:250,000 map of the northern half of the Illogwa Creek Sheet area showing total magnetic intensity profiles and geology was prepared by the Bureau of Mineral Resources. Some reconnaissance aeromagnetic profiles to the west of Alice Springs have been reported by Goodeve (1962).

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

From 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.

McNaughton (1962) of the Magellan Petroleum Corporation made an assessment of the petroleum prospects of Oil Permits 43 and 46, and Hopkins (1962) 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, Ranford, Cook, Stewart, & Shaw (1965) have reported on the geology of the country to the south of the area described in this Report: it is now (1966) being prepared for publication.

PHYSIOGRAPHY

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

The ranges and hills comprise extensive ranges with intermontane basins and minor alluvial pockets. The sharpest topography is formed by quartzite ridges which reach heights of over 4000 feet above sea level, with a relief of over 2000 feet. Most of the crystalline and metamorphic rocks have subdued relief; an exception is Mount Zeil (4955 ft), in the west, which is the highest mountain in the area.

The low ranges and hills with intervening sand plain comprise low but sharp ridges, rarely over 500 feet high, and long narrow valleys.

The sand plain with some dunes and low outcrops comprise extensive plains of low relief, 1800 to 2300 feet above sea level in the north, and below 1000 feet in the south-east. The plains are composed of alluvial outwash and some wind-blown sand.

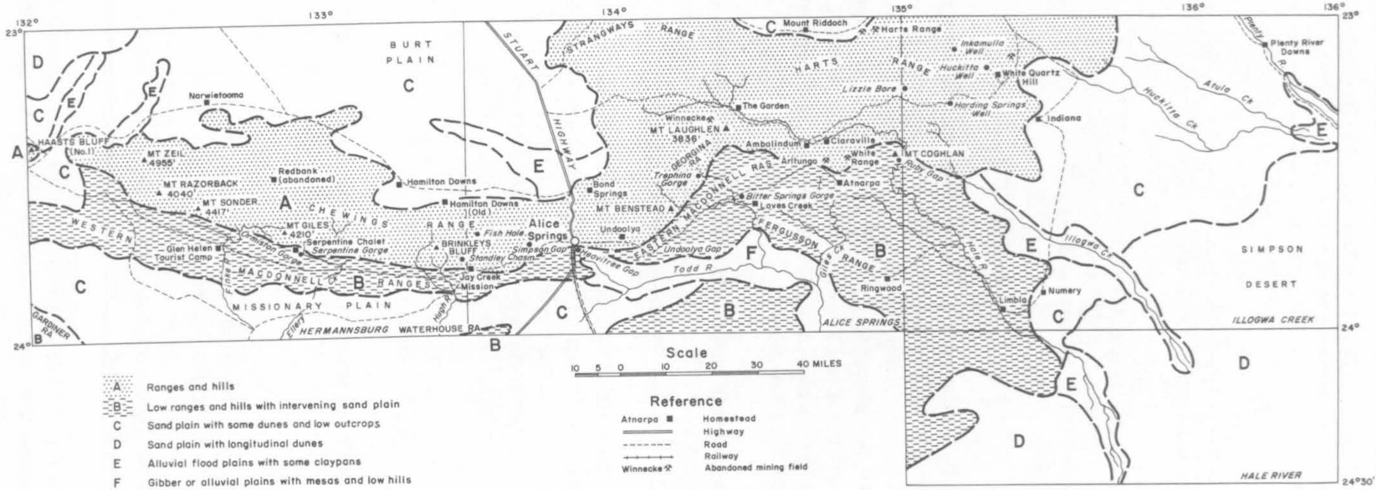


Fig. 3. Physiographic divisions and access

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

The alluvial flood plains with some claypans border the rivers and are active flood plains encroaching on the sand plain and dunes.

The gibber or alluvial plains with mesas and low hills occur west and south of Ringwood homestead in the alluvial plain of the Todd River. They comprise wide plains 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 Upper Proterozoic Heavitree Quartzite. The Heavitree Quartzite is the basal formation of the Amadeus Basin succession and is overlain by a generally conformable sequence of Upper Proterozoic, Cambrian, and Ordovician sediments. The Cambrian and Ordovician rocks are overlain with regional unconformity by Ordovician-Devonian sediments, which are separated by another regional unconformity from Devonian sediments.

Mesozoic sediments occur in the south-east of the Illogwa Creek Sheet area in the Great Artesian Basin. Continental Tertiary and Quaternary sediments rest unconformably on 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, Ranford, Cook, Stewart, & Shaw, 1965).

PRECAMBRIAN

Arunta Complex

Mawson & 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 the following order of succession, from north to south, on the southern side of the MacDonnell Ranges: '....chlorite schist; granite, micaceous schists and metamorphic granite with occasional outcrops of coarse eruptive granite and other eruptive rocks; quartzite; metamorphosed clays and shales inter-stratified with yellow and blue crystalline limestone'. Chewings included the Upper Proterozoic rocks in his 'older rocks'.

Moulden (1895) described 'altered amphibolite, altered diorite, augen gneiss and garnetiferous gneiss' from the Arunta Complex on the upper reaches of the Hale River.

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

Later workers recognized that correlation of the structurally deformed and metamorphosed quartzite outliers in the Arunta Complex with the Upper Proterozoic Heavitree Quartzite introduced further problems with regard to the age, tectonic history, and mineralization 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 Precambrian; more than one would be expected if the quartzite was an integral part of the tightly folded Arunta Complex.

Madigan (1932, p. 33) 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, and divided the Arunta Complex into:

(v) Oolgarna Acid Intrusives (upper unit); (iv) the Everard Range Granite; (iii) the Ambalindum Series (altered limestone and schist); (ii) the Augen Schist; (i) 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 following characteristics that distinguish the two quartzites:

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 the strike
Continuity of outcrop; underlying limestone and overlying the Arunta Complex 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 included conglomerate, arkose, grit, sandstone, mudstone, limestone, volcanics, and intrusives which have been regionally metamorphosed, granitized, and intruded by basic dykes. He considered them to be Lower Archaean, and named them the 'Arunta Series'. The rocks of the Harts Range, in which granite gneiss is absent, he named the 'Riddock Series' and referred them to the Upper Archaean. He considered the White Range Quartzite and associated rocks to be probably Middle Proterozoic.

Joklik (1955) mapped the rocks of Hossfeld's Riddock Series. He called these the 'Harts Range Group' and proposed a subdivision into five units:

(v) Cadney Gneiss: most commonly fine-grained quartzo-feldspathic gneiss

(iv) Brady Gneiss: garnet-mica-feldspar gneiss with bands and lenses of quartzite, metamorphosed calcareous sediments, and amphibolite

(iii) Irindina Gneiss: garnet-mica-feldspar gneiss; some sillimanite-garnet-mica-feldspar gneiss; and the Riddock Amphibolite

(ii) Bruna Gneiss: with conspicuous porphyroblasts of potash feldspar

(i) Entia Gneiss: acid mica-quartz-feldspar gneiss, in places rich in kyanite and including narrow bands of amphibolite

All the formations of the Harts Range Group contain bands, lenses, plugs, dykes, and sills of metamorphosed basic igneous rocks. Some are contemporaneous with the Riddock Amphibolite, others are younger than the Cadney Gneiss, but none of them are younger than the acid and intermediate plutonic rocks and associated pegmatites and aplites. Four of the largest 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 eastern Harts Ranges. It is intruded by the Huckitta and Inkamulla Granodiorites, and is overlain by the Bruna Gneiss. A typical specimen (R4559) is composed of quartz and microcline in about equal proportions with subordinate andesine and 1.7 percent mica. The fabric is granoblastic and all the minerals are fresh and completely recrystallized. Joklik suggests that the unusual association of abundant free quartz and microperthitic microcline with subordinate andesine indicates that the rock is a hybrid, and that the andesine is a relic of the original rock before the potash and soda were introduced. The chemical composition is characteristic of palingenetic granites formed by the soaking of granitic material into more basic rocks.

The Entia Gneiss is the most intensely metamorphosed formation in the Harts Range Group, but kyanite and sillimanite are generally absent owing to the high potash content. The potash was introduced during a later metamorphism and the kyanite has been retrogressively metamorphosed to sericite. The kyanite-bearing Entia Gneiss is believed to have been formed by metasomatic replacement of the country rock by solutions rich in alumina 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, and (c) even-grained acid gneiss.

(a) The large porphyroblasts of potash feldspar contain numerous remnants of plagioclase and mafic minerals, but the porphyroblasts of andesine and hornblende are not poikiloblastic. The older constituents are aligned along the borders of the porphyroblasts and have probably been forced aside during their growth.

Joklik gives chemical analyses which indicate that the formation of the porphyroblasts of potash feldspar involved the introduction of potash, alumina, and possibly 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 rapakivi granite in chemical composition and appearance, but the mineralogical composition and texture indicate that it has been formed by the metamorphism of a sedimentary rock.

(b) The large porphyroblasts of bluish grey orthoclase are weakly perthitic and poorly twinned, and contain flakes and grains of altered feldspar, quartz, and hornblende. The matrix contains oligoclase-andesine and is generally intensely crushed.

(c) The third variety of the Bruna Gneiss (R4563) occurs in narrow bands. It contains equal amounts of quartz, microcline, and oligoclase; the oligoclase is partly porphyroblastic.

The Irindina Gneiss is characterized by the absence of potash feldspar. Specimen R4577, collected 2 yards from a large thrust fault, is composed of quartz, andesine, and biotite in about equal proportions, and 9 percent of almandine forming porphyroblasts 3 mm in diameter, commonly felted with sillimanite fibres. In certain bands, where pegmatite injection and migmatization are particularly intense, small porphyroblasts of microcline microperthite are present. Where the feldspathization is most intense, large porphyroblasts of microcline have been formed. Specimen R4267 contains porphyroblasts of microcline set in a dark biotite-rich matrix; the borders of the porphyroblasts are rimmed with myrmekite. Joklik regards the garnets as unassimilated relics derived from the original sediments.

Sillimanite is locally common in the Irindina Gneiss and averages 16 percent. The rock generally contains abundant concordant veins of quartz and plagioclase, and small ellipsoidal segregations of feldspar, both indicative of migmatization.

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 granitized Irindina Gneiss is a quartzo-feldspathic gneiss generally found in association with granitic veins. The granitized gneiss (R4616) is coarsely granular, practically structureless, and contains 53 percent microcline microperthite, 29 percent quartz, and 15 percent oligoclase. According to Joklik the original rock was probably a psammopelitic sediment, metamorphosed, and then crushed and granitized by the introduction of potash and silica and the expulsion of ferrous oxide, magnesia, some alumina and soda. Most of the albite of the original feldspar was either replaced by microcline or taken into solution later to form microperthite. Finally, myrmekite developed along the boundaries between oligoclase and microcline, and microcline was replaced in part by albite veins. Joklik's observations on specimens R4788 and R4616 indicate that the granitization was associated with intense crushing. The quartz, microcline microperthite, and to a lesser extent albite-oligoclase, form fresh irregular porphyroblasts; the remainder of the rock is fine-grained, severely crushed, and strained.

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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.

In the Brady Gneiss, the mica occurs as large flakes that emphasize the schistosity. The gneiss has unusually high silica and low alumina, and Joklik suggests that quartz and plagioclase were introduced metasomatically. It also contains less garnet and less sillimanite than the Irindina Gneiss. The garnet forms large porphyroblasts and the sillimanite occurs in felted aggregates 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 gneiss has a low potash content and the excess alumina has been incorporated in the almandine. The sillimanite-bearing Brady Gneiss is generally restricted to narrow zones which are more intensely metamorphosed than the neighbouring rocks.

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 metamorphosed tuffaceous sediments which represent the greenschist, albite-epidote-amphibolite, and amphibolite facies. Another specimen of the Cadney Gneiss was identified by Joklik as a schist in the biotite zone which has been retrogressively metamorphosed to the chlorite-zone grade. The rock is 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 acid to intermediate plutonic rock. In colour, texture, and general appearance the rock is difficult to distinguish from the surrounding Entia Gneiss. The mafic component of the granodiorite ranges from hornblende in the centre of the intrusion to biotite at the margins; this change is accompanied by an increase in the size of the quartz and feldspar crystals. The principal feldspar is oligoclase, with subordinate non-perthitic microcline. Hornblende, epidote, and iron-rich biotite are the principal mafic constituents. The marginal phase of the granodiorite consists of quartz, oligoclase, and biotite.

The Huckitta Granodiorite is similar to the Inkamulla Granodiorite, but biotite is the main mafic constituent, and the lime content is lower.

The Bungitina Granodiorite is a small boss of diorite, but the mineralogical composition varies considerably between the centre and the margin. According to Joklik, the centre of the intrusion is composed of large crystals and porphyroblasts of oligoclase and unstrained quartz in an almost mylonitic mesostasis of feldspar, severly strained quartz, and biotite. The margin of the intrusion consists mainly of a fine-grained partly mylonitic aggregate of quartz and alkali feldspar, with a few large remnants or original crystals; the intergranular boundaries are sutured and feldspar intergrowths are common.

The variation in the composition of the Bungitina Granodiorite is attributed by Joklik to the effects of the granitization of the surrounding Irindina Gneiss. A residual fraction rich in alkalis and silica was probably responsible for the 'granitization' of the margin of the intrusion and the surrounding gneiss.

The Schaber Hornblende Granite crops out over an area of about 1 square mile at Mount Schaber and is surrounded by granitized Cadney Gneiss. The granite is cut by prominent regular joints, and is markedly lineated. The presence of porphyroblastic feldspars, the introduction of quartz, the granulation of the edges of the porphyroblasts, and the development of myrmekite suggest that the original granite has been attacked by residual fluids rich in alkalis and silica.

A few smaller granitic intrusions and some aplite dykes also occur. Pegmatites are common, and occur in all the subdivisions of the Harts Range Group, but are less common in the amphibolites and metamorphosed calcareous sediments, which are more resistant to pegmatization, feldspathization, and migmatization.

Joklik considers that the pegmatites were emplaced towards the end of the diastrophism during 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 accessory minerals. In the Harts Range structure associated with the Inkamulla and Huckitta Granodiorites, the composition generally ranges from potassic at the core to calc-alkaline at the margin. The pegmatites in the Entia and Bruna Gneiss consist mainly of potash feldspar and quartz, with subordinate mica, but most of the pegmatites in the Irindina and Brady Gneiss contain plagioclase, quartz, subordinate potash feldspar, and abundant mica.

There are two main groups of pegmatites, the younger predominantly potassic and the older predominantly calc-alkaline.

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, in which the main constituents are hornblende, diopsidic augite, and plagioclase. Garnet is common, with lesser amounts of epidote, biotite, scapolite, hedenbergite, magnetite, apatite, and sphene. The relative amounts of the constituents vary considerably near contacts, and the rock may consist entirely of plagioclase or hornblende. Pegmatitic amphibolite occurs where there are acid pegmatites in the adjacent country rock, and in extreme cases is converted into hornblende pegmatite.

Prichard & Quinlan (1962) outlined the distribution of the Arunta Complex in the Hermannsburg Sheet area and made special mention of the 'metamorphic recrystallized quartzite' cropping out 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 the metaquartzites in the Ormiston Gorge/Mount Sonder region. They also admitted the possibility of other Arunta metaquartzites occurring in the area.

In the present study, some of the quartzite referred to by Prichard & 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, p. 10) had deduced by photogeological interpretation a strong structural discordance. At this locality, the Heavitree Quartzite (with basal conglomerate) dips at 25° to the north and overlies quartzites interbedded in gneisses which dip at 45° to the west.

Other unconformities between quartzite and the Arunta Complex were deduced in the Chewings Range 4 miles east of Mount Giles, and at Brinkleys Bluff. These can also be interpreted as due to structural causes, but it is possible that a post-Arunta (and perhaps pre-Heavitree) quartzite is present in the Chewings Range. Some of the Chewings Range quartzites are associated with slate, quartz-sericite phyllite, and schist similar to those at the base of the Bitter Springs Formation at Ormiston Gorge, which 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 appear to antedate the Heavitree Quartzite. Also, the folds in the quartzite are identical with the structures in the gneiss which is unconformable beneath the Heavitree Quartzite.

Similar problems of stratigraphy arose in connexion with the metamorphosed quartzites (White Range Quartzite of Joklik) in the east of the Alice Springs Sheet area. The present survey has demonstrated that the White Range Quartzite is equivalent to the Heavitree Quartzite.

We attempted no detailed stratigraphical interpretation of the Arunta Complex, but in the Illogwa Creek Sheet area 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 crop out and underlie most of the sand cover. For the most part, they appear to be of a lower grade of metamorphism than most of the previously mapped Arunta rocks, but they have been included in it.

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 north-south, except to the north-west of Ormiston Gorge, where the trend swings to the west. 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, 2 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 1 inch across.

The dykes intrude the Arunta Complex and the quartzite of the Chewings Range, but are not known to intrude the Heavitree Quartzite. At one locality, 2 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 a medium-grained silicified quartz sandstone which rests unconformably on the Arunta Complex and is overlain conformably by the Bitter Springs Formation. It contains subordinate amounts of coarse quartz sandstone, pebbly sandstone, and siltstone. It extends almost continuously along the north-eastern margin of the Amadeus Basin across the Hermannsburg and Alice Springs Sheet areas and into 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. It crops out as a prominent ridge or range, usually with a gentle dip-slope and a steep escarpment.

The unit is about 1440 feet thick at Ellery Creek Big Hole (Madigan, 1932a, 1944; Prichard & Quinlan, 1962) and 600 feet thick at Heavitree Gap (Joklik, 1955; Madigan, 1932a). The Heavitree Quartzite appears to thicken tx 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).

In some areas it is difficult to interpret the nature of the original contact owing to the complicated structure and the metamorphism of the Heavitree Quartzite and older Precambrian rocks. During this survey it has been established that the Heavitree Quartzite overlies metamorphic rocks of the Arunta Complex unconformably throughout most of the area (Pl. 1, fig. 1). Where the Heavitree Quartzite is infolded with the Arunta Complex, it is apparently conformable with the adjacent schists on the overturned limb, but it is believed that the conformable schists were derived from the older unconformable high-grade Precambrian rocks by retrograde metamorphism during the infolding (p.49).

The basal beds are the most variable. At most localities they are strongly 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 and Ellery Creek Big Hole.

Prichard & 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 a 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 in the Heavitree Quartzite in the Illogwa Creek Sheet area. The quartzite is commonly silicified and cross-bedded and contains some thick gritty beds. Ripple marks and synaeresis cracks were noted at several localities.

In the Hale River Sheet area the Heavitree 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 marks 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 the Hale River Sheet area the Heavitree Quartzite has been tectonically stripped off the Arunta Complex and doubled up farther along the strike as the result of a décollement. In these areas the Bitter Springs Formation rests directly on the Arunta Complex.

The Heavitree Quartzite has been metamorphosed in the Arltunga and Ormiston Nappe Complexes, and it has been most highly deformed where it is overturned (see p.23).

Near the front of the structures the quartzite is shattered, brecciated, and silicified, but deeper in the structures the quartzite has a faint to strong schistosity and may be partly or completely recrystallized to sericite-bearing quartzite and schistose quartzite (p.57).

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

Four miles east of Serpentine Gorge on the Hermannsburg Sheet area a clastic 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 carbonate rocks at Bitter Springs Gorge the 'Bitter Springs Limestone'. He gave no section or thickness. Prichard & Quinlan (1962) mapped the same unit in the Hermannsburg Sheet area and measured a sequence of about 2500 feet of dolomitic limestone and siltstone at Ellery Creek. Banks (1964) suggested an informal subdivision of the Bitter Springs Limestone into the Ellery Formation, Bitter Springs Formation, and Gillen Formation. Ranford, Cook, & Wells (1965) revised the name to 'Bitter Springs Formation' and Wells, Ranford, et al. (1965) subdivided it into two members: the Loves Creek Member above and the Gillen Member below.

The Gillen Member rests conformably on the Heavitree Quartzite, and consists mainly of dolomite, with subordinate siltstone, sandstone, and shale. The name is derived from Mount Gillen, 4 miles west of Alice Springs. The dolomite is generally dark bluish grey 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 and 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 Loves Creek Member lies conformably on the Gillen Member, and consists mainly of dolomite with subordinate limestone, calcareous siltstone, chert, and basic volcanics. The name is derived from Loves Creek, which joins the Ross River 5 miles west of the Ross River tourist chalet in the Alice Springs Sheet area. The type locality is at Ellery Creek. The dolomite is pink, or 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 was probably formed by silicification of siltstone. The basic volcanics occur in the east of the area and are known at a number of horizons.

Bitter Springs Formation in the Arltunga Nappe Complex. The Gillen Member and the Loves Creek Member have not been 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 in the nappe complex to phyllite and slate. Beneath the Giles Creek synform the formation is tightly folded (Pl. 4, fig. 2), but the main metamorphic effect is brecciation and a weakly developed fracture cleavage. The degree of metamorphism increases northwards from the synform, and the phyllite and schist occur in the Winnecke 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 part of the

Ormiston Nappe Complex. The Ormiston Nappe contains a core of phyllite derived from siltstone of the Bitter Springs Formation. The slate and phyllite in the Razorback Nappe, south of Mount Razorback, and at Redband Gorge are derived from the basal siltstone of the Bitter Springs Formation and from the siltstone interbeds in the Heavitree Quartzite. The carbonate rocks of the Bitter Springs Formation near the nappe complex have been brecciated and crushed, and show fracture cleavage.

MESOZOIC

The flat-lying sandstone and lutite which crop out in the south-eastern sector of the Illogwa Creek Sheet area are tentatively referred to the Mesozoic. They overlie unlateritized schists of the Arunta Complex and have a ferruginous capping. No diagnostic fossils have been found.

One section measured is as follows (commencing at the top):

Thickness (ft)	
20	Red-brown poorly sorted muddy sandstone, with occasional laminae of mottled white and purple claystone, and scattered pebbles of Arunta Complex rocks
15	White gypsiferous(?) shale and variegated pink and white claystone
6	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 in neighbouring areas: Opik (in Sullivan & Opik, 1952) and Wells, Stewart, & Skwarko (1966) have described the Lower Cretaceous Rumbalara Shale which crops out in the Finke Sheet area. It includes a white kaolinitic rock, porcellanite, yellow ochre, red and grey sandstone, and fragmental pelecypods. Crespin & 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 (BMR, pers. comm.) has recognized a lithological similarity between the outcrop of the Mesozoic De Souza Sandstone in the Hale River Sheet area, and the sandstone with worm trails in the south-eastern part of the Illogwa Creek Sheet area. The De Souza Sandstone underlies the Rumbalara Shale at Colsons Point in the Finke Sheet area.

The lithological similarity to Mesozoic sediments and the flat attitude of the beds suggest that the outcrops in the south-eastern part of the Illogwa Creek Sheet area are Mesozoic.

TERTIARY(?)

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

In the Illogwa Creek Sheet area the Tertiary sediments may be subdivided into three units. At the base, about 6 feet of brown pisolitic laterite rests on the highly weathered and ironstained 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 10 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 were probably developed on a mature but uneven surface: Woolley (1963) states that about 100 feet of section is exposed about 4 miles farther north. Woolley describes a sequence with white and cream clay at the base of the section overlain by poorly bedded cream argillaceous limestone with some well-bedded brown limestone and a hard chalcedonic cap. He has suggested that the Tertiary sediments were deposited in valleys trending north-west.

Tertiary sediments crop out in the valley containing the Arltunga airstrip and Arltunga Bore and in the valley containing the Garden, Ambalindum, and Claraville homesteads. The deposits have been described by Madigan (1932a), Joklik (1955), and Lloyd (1966).

Madigan included all the Tertiary rocks to the east of Alice Springs in the Arltungan Beds. Smith, Vine, & Woolley (1960) and Smith (1964) revised the name to 'Arltunga Beds'. As the deposits at the type locality at Arltunga are lacustrine and fluviatile, and are not continuous with other Tertiary deposits, the name 'Arltunga Beds' should be restricted to the Arltunga sequence.

Lloyd reported 12 feet of arenaceous limestone containing gastropods, ostracods, and charophytes, 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 resting on the Arunta Complex. Madigan (1932a) reported osmundaceous plant stems from these deposits.

Lloyd described the deposits between Claraville and Ambalindum homesteads 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 (1932) 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 a well at a depth of 26 feet on the south bank of the Hale River, 5 miles west of Ambalindum homestead.

Extensive Tertiary(?) sediments are known north of the Harts Ranges on the Alcoota and Alice Springs Sheet areas. A bore has been sunk near Mount Riddock homestead to a depth of 600 feet through fine alluvium without reaching bedrock. 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. Outcrops include a white sandstone dipping off Precambrian basement 4 miles north-east of Bond Springs homestead, and Perry et al. (1963) recorded 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 reliable 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 beds by an ancient weathered land-surface. Some of the sediments are older and some younger than the laterite and grey 'billy'. The older sediments contain lignite and pollen, and the younger sediments contain freshwater gastropods. At Alcoota to the north, and Phillipson Pound to the south, there is an assemblage of vertebrate remains, including crocodiles, turtles, other reptiles, birds, and marsupials including diprotodonts. The sediments were deposited in a lacustrine and fluviatile environment while the rainfall was higher than in the present arid phase.*

* See also Woodburne, M.O., 1966 - The Alcoota Fauna. Bur.Min.Resour.Aust. Bull. 87.

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

The age of the younger sediments is probably Miocene (Lloyd, BMR, pers. comm.).

QUATERNARY

The Burt Plain in the west and the northern margin of the Simpson Desert in the east are covered by extensive tracts of superficial red-brown aeolian sand, alluvium, and red-earth soil. Intermontane valleys filled with alluvial gravel, sand, silt, and clay occur in 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-formed sand plains are stable in the present climate and are fixed by a cover of spinifex and small shrubs. The alluvium and red earth are commonly covered with a light to dense growth of mulga or gidyea. Alluvium is now being deposited in the intermontane valleys and in and near the channels and floodout areas of the streams. Perry et al. (1963) consider that much of the area covered by sand and soil is probably underlain by Pleistocene wash and alluvium, and that deposition of the Pleistocene beds has been continuous since the Tertiary, although deposition at any one place may have been intermittent.

T. Quinlan (BMR, pers. comm.) states that the boundary between the Quaternary and Tertiary(?) sediments is known only from boreholes. The Quaternary sediments are of alluvial origin and comprise red-brown silty sand and gravel, whereas the Tertiary(?) sediments of lacustrine origin comprise 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

There is evidence of at least two orogenies in the area. The older, the Arunta Orogeny, took place before the deposition of the Amadeus Basin sediments and caused the deformation and low and medium-grade metamorphism of the Arunta Complex. The younger, the Alice Springs Orogeny, probably commenced late in the Ordovician and reached a climax in the Devonian. It 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 décollement surfaces. The general structure of the area is illustrated in Figure 4.

ARUNTA OROGENY

Joklik (1955) referred to the Arunta Orogeny informally as the epi-Archaeozoic orogeny, but there is no proof of the age either of the orogeny or of the rocks 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. The Arunta Complex was isoclinally folded about north-south axes. The present attitude varies between steep and

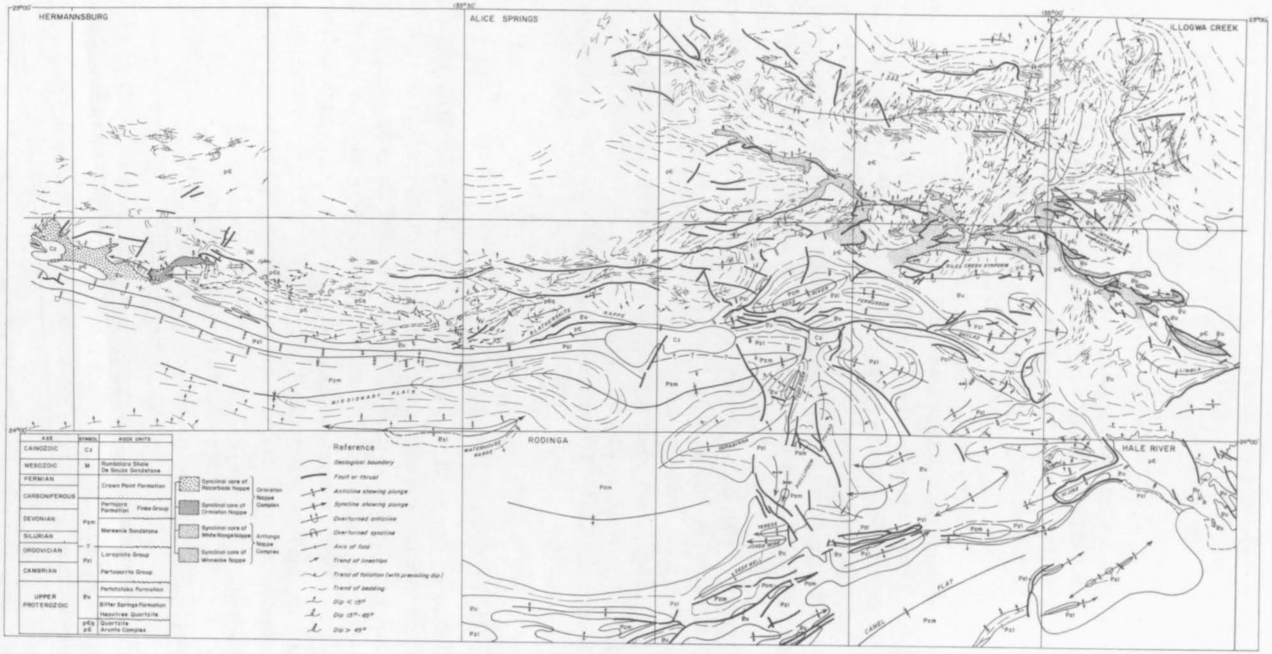

Fig. 4. Structural map of the north-eastern margin of the Amadeus Basin.

recumbent (see Pl. 1, fig. 2) and was tightly refolded about steeply dipping east-west axes (see Pl. 2, fig. 1). 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 was not everywhere destroyed by the development of the east-west folds (see Pl. 2, fig. 2) and lineation. The structures are well developed in the metaquartzite and gneiss at Fish Hole at the eastern end of the Chewings Range on the Alice Springs Sheet area.

The metamorphic rocks developed during the orogeny include metaquartzite, marble, calc-silicate rock, schist, schistose gneiss, porphyroblastic augen gneiss, and amphibolite. North of Ormiston Gorge the metamorphic rocks are intruded by pegmatite, and dykes, irregular masses, and veinlets of leucocratic medium-grained biotite granite. The granite may have been derived from the adjacent gneisses as it contains coarse feldspars similar to those in the adjacent porphyroblastic augen gneiss.

It is not clear whether the banding in the isoclinally folded* metaquartzite, marble, and calc-silicate rocks represents the original bedding or a pre-existing metamorphic foliation or schistosity. In the schistose gneiss and gneiss, however, it is clear that an older foliation has been folded, and it is possible that the Arunta Orogeny was preceded by an earlier period of folding and metamorphism, or that the earlier foliation developed mimetically to the bedding planes 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 Arunta Orogeny has also been a major factor in the development of the crystalline rocks in the Harts Range area, north of the Winnecke and White Range goldfields, and north of Atnarpa Homestead, Ruby Gap Gorge, and Aremra Bore. The rocks in this area have also been subjected to the most intense deformation during the Alice Springs Orogeny, and it is difficult to distinguish between the structures formed by the two 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 mainly 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 axes of the recumbent folds and of minor folds on the margin of the Amadeus Basin trend east-west. These structures parallel the general trend of the north-eastern margin of the Amadeus Basin. However, there is a remarkable parallelism between these structures of the Alice Springs Orogeny and the second set of folds (AF_2) produced during the Arunta Orogeny. The parallelism is evident from inspection of the Alice Springs and Hermannsburg 1:250,000 geological Sheets (Pls 11, 10), and the structural interpretation (Fig. 4). This conformity in structural trends is probably more than coincidental and it suggests that the structures produced during the Alice Springs Orogeny either followed a pre-existing direction of weakness in the basement (A-F_2) or else were caused or assisted by rejuvenation of the A-F_2

* A-F^1 folds

folds in the Arunta Complex. This explanation provides a logical reason for the apparent similarity in fold style and pattern in the two orogenies and explains the difficulty of separating the effects of each orogeny where they are directly superimposed.

The orogeny caused the development of 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 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 Proterozoic Bitter Springs Formation were squeezed out of the nappes by the highly plastic Bitter Springs Formation and were forced southwards over a décollement surface within it (D1). Another décollement surface or plane of weakness (D2) developed in the Cambrian sediments during this movement, and in places the sediments ripped off the décollement surface D1 were thrust higher up the section and came to rest on the upper décollement surface D2.

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

<u>Ormiston Nappe Complex</u>

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 (Fig. 5). Another nappe or series of nappes may be present farther west.

<u>Ormiston Nappe</u>: The synclinal core of the Ormiston Nappe, which dips to the north, is exposed at Ormiston Gorge and for about 10 miles to the east-north-east along part of the Chewings Range (Figs 4, 5 and Pl. 3, fig. 1).

In the core of the nappe the Heavitree Quartzite rests unconformably on the Arunta Complex and is overlain by slate and phyllite, probably of the Bitter Springs Formation. The Bitter Springs Formation is overlain by schistose quartzite and quartzite of the Heavitree Quartzite dipping north apparently conformably beneath schist derived from the Arunta Complex (Pl. 3, fig. 2). The repetition of the Heavitree Quartzite appears to be due to folding rather than thrusting (Fig. 6), and the metamorphism and shearing has taken place largely on the inverted middle limb (see Part II). Two miles west of Ormiston Gorge, the Heavitree quartzite has been replaced by a thrust and the Arunta Complex rests directly on the Bitter Springs Formation. Two miles 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 to the north and west. North of Ormiston Gorge the Heavitree Quartzite apparently dips conformably beneath schist derived from the Arunta Complex (Pl. 3, fig. 2 and specimens 450-454, p. 66). The quartzite and schist have a prominent northerly lineation and at least one isoclinal fold plunging to the north is preserved in the schist.

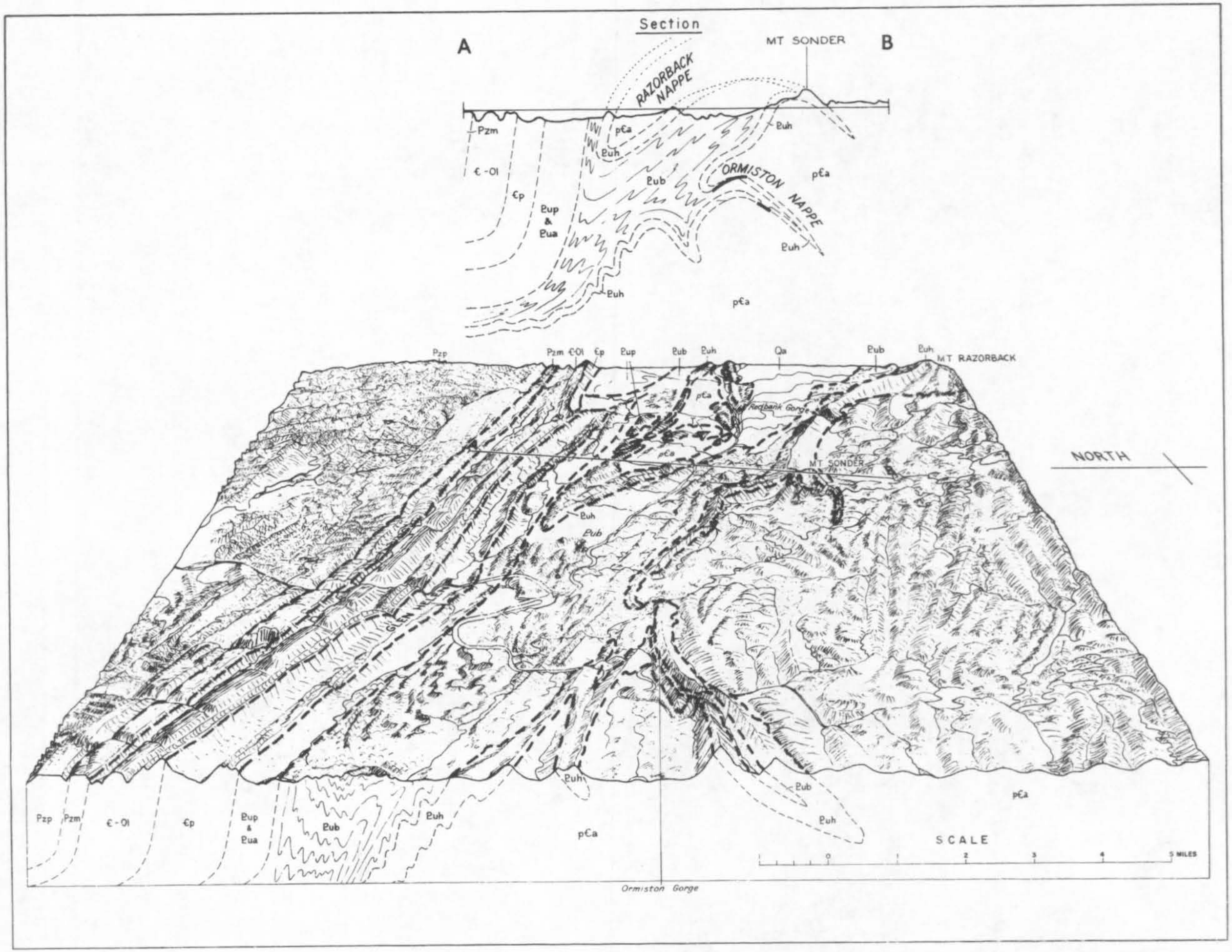

Fig. 5. Ormiston Nappe Complex

Mount Razorback Nappe: The overturned limb of the Mount Razorback Nappe crops out between Mount Razorback and Mount Sonder (Fig. 5). The Heavitree Quartzite is schistose and strongly folded (Pl. 4, fig. 1), 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 Pl. 4, fig. 2) 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 4 miles farther south in the Boomerang Bore area. The nappe is overturned or overthrust for a distance of 8 miles across the strike.

All the sediments cropping out to the south of the nappe complex are nearly vertical and in some areas they are slightly overturned. The sediments form a simple homocline except in the Goyder Pass area, where the lower beds appear to have been thrust upwards to form a trapdoor type of diapiric structure (McNaughton et al., 1965). The structure could also be a listric thrust.

Arltunga Nappe Complex

The Arltunga Nappe Complex contains the two largest nappes on the northern margin of the Amadeus Basin - the Winnecke Nappe and the White Range Nappe. The complex crops out for 80 miles along the strike and 20 miles across it. The nappes have a core of metamorphic Arunta Complex rocks 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 7.

The metamorphism of the Heavitree Quartzite, Bitter Springs Formation, and Arunta Complex in 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 goldfield to Bitter Springs Gorge (see Pl. 11 and Fig. 4). The core plunges to the east beneath the Arunta Complex, but parts of it reappear in the Arltunga goldfield owing to a reversal of plunge. From the Arltunga area, the synclinal core plunges to the east, and reappears from beneath the Arunta Complex in the Mount Coghlan/ Ruby Gap Gorge area (Pls 11, 12). In the normal limb at the base of the synclinal core the Heavitree Quartzite is little altered (see specimen descriptions 426 and 446, p. 59, 64), and rests unconformably on gneiss, amphibolite, schist, and thin quartzite (specimens 427, 428, 429, 430, p. 59).). Four miles east of Mount Laughlen the Heavitree Quartzite has been thrust out and the Bitter Springs Formation rests directly on brecciated Arunta Complex (see specimen descriptions 429-431, p. 59-60). The Heavitree Quartzite is overlain by carbonate rocks, shale, and siltstone of the Bitter Springs Formation, which have been little altered in some areas and converted to slate, phyllite, or schist in others (see specimen descriptions 431, 441, 449, p. 59, 63, 65).). The Bitter Springs Formation is overlain in most places by highly contorted, brecciated, and schistose Heavitree Quartzite (see specimen descriptions 420, 422, 432, 444, p. 57, 60, 63), which is overlain directly by conformable schists derived from the Arunta Complex (see specimen descriptions 420-425, p. 57). As the normal stratigraphical sequence is reversed it is assumed that the uppermost Heavitree Quartzite is overturned and that it has been repeated by isoclinal folding (Fig. 6). The unconformity at the base of the quartzite has not been preserved, and the cross-bedding and other sedimentary structures which might indicate facing have been obliterated.

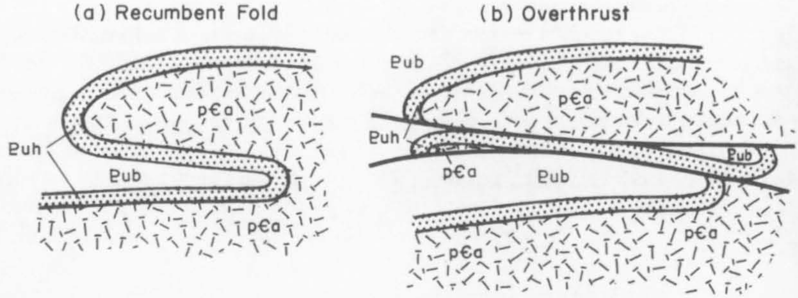

Fig. 6. Alternative interpretations of the repetition of the Heavitree Quartzite in the Arltunga Nappe Complex

Figure 6 illustrates how the repetition could be explained by overthrusting, but the large size of the structure and the distribution of the rock units suggests that this interpretation is unlikely. Carbonate-bearing schists crop out above the Heavitree Quartzite 2 miles west of Ruby Gap Gorge (Ƀub(?) on map), but the exposure is probably a carbonate bed in 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 3 miles east of Bitter Springs and 6 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 plunges below the Atnarpa area and reappears in the Heavitree Quartzite ridge which crosses the Hale River at Amarata Waterhole. Plate 5, figure 1 shows the repetition of the Heavitree Quartzite in the synclinal core of the nappe 2 miles south-south-west of Ruby Gap Gorge, and Plate 5, figure 2 shows the recumbent folds in the Bitter Springs Formation 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 east of Atnarpa homestead. The core crops out again south of Atnarpa in the quartzite ridges containing the Chabbana Waterholes and is buried farther south beneath the Giles Creek synform (Fig. 7 and Pl. 11). 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.

It has been assumed that the repetition of the Heavitree Quartzite in the synclinal core of the nappe is due to recumbent folding and that the rocks overlying the core are overturned (Fig. 6a). This overturning has been proved at only one locality, 2 miles north-east of Atnarpa homestead, where the conglomerate at the base of the Heavitree Quartzite is preserved beneath the overlying Arunta Complex. Figure 6 compares the recumbent fold interpretation with a complex overthrust interpretation. The distribution of the rock units suggests that the recumbent fold interpretation is more likely. Some thrusting has occurred on the overturned middle limb of the nappe, where the Heavitree Quartzite is considerably thinner or absent.

The Heavitree Quartzite and the Bitter Springs Formation are only slightly altered near the front of the White Range Nappe, but become progressively more highly metamorphosed deeper in the structure. The Arunta Complex has suffered retrograde metamorphism, particularly near the overturned limb (see specimen descriptions 403, 404, p).

Giles Creek Area: Forman and Milligan have different views on the structure of the Giles Creek area and related structures.

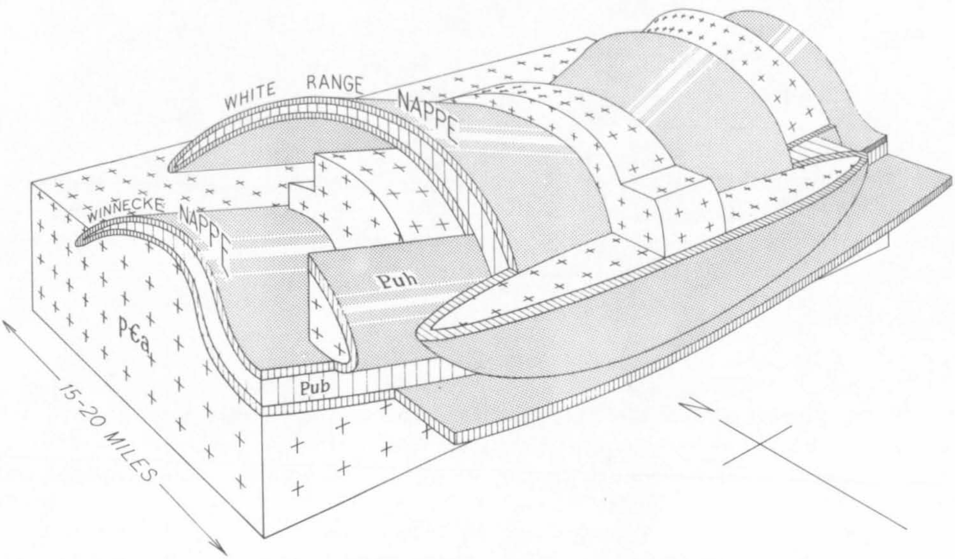

Fig. 7. Arltunga Nappe Complex

Forman considers that the structure is a synform (Figs 4, 7) which 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. The plunges at the western end of the structure and overturning along the southern margin suggest that the structure is synformal and that the Arunta Complex is underlain by the Heavitree Quartzite and 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, north of Oolera Spring, but this is probably a continuation of the Winnecke Nappe (see cross-section A-B-C, Pl. 12).

Milligan, however, considers that the tectonic elements at the margin of the Amadeus Basin, from south of Bitter Springs Gorge to north of Numery station, are controlled by near-vertical strike faults (south side up), which persistently repeat the Arunta Complex, and the steeply inclined south-facing Heavitree Quartzite/Bitter Springs Formation succession. The Giles Creek 'Synform' and similar structures have probably been formed by movements on comparable strike faults which have arcuate oblique-strike extensions. Transcurrent movement on these oblique-strike sections has probably had an important effect on the outcrop pattern (Fig. 8).

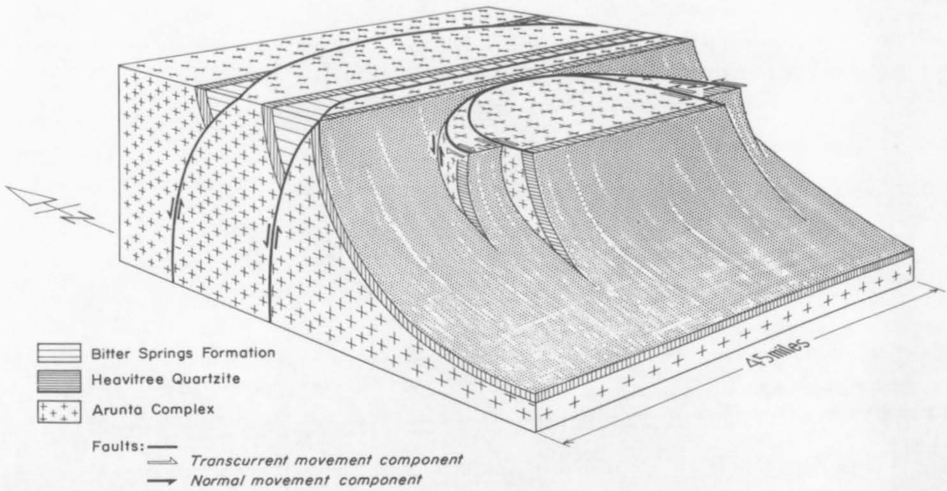

Fig. 8. Structure of the Giles Creek area

Similar tectonic elements have been described by Harlton (1964) and Wise (1963). The Amadeus examples could have resulted from east-west horizontal compressive stresses acting on rigid basement blocks in an area where the Heavitree Quartzite cover was nearly vertical as shown in Figure 8.

Atnarpa Antiform: The Atnarpa antiform is a structure over 80 miles long which trends east-west through the centre of the Arltunga Nappe Complex (Pls 11, 12 and Figs 4, 7). The strike is nearly parallel to the axes of regional recumbent folds in the nappes, and the recumbent folds are folded symmetrically about its axis. The axis plunges from east and west towards Atnarpa homestead.

Another fold, probably an isoclinal synform, trends east-west about 4 miles north of The Garden homestead (Fig. 4). The fold is in Arunta Complex rocks which had previously been folded about north-south axes, and the north-south lineation is still preserved. This fold is parallel to the Atnarpa antiform, but may possibly be an older fold of the Arunta Orogeny (A-F2).

North-South Folds: Culminations and depressions of the axis of the Atnarpa antiform are associated with regional north-south folds (see Pls 11, 12 and Fig. 4) 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 Arunta Complex about Inkamulla and the infolded Heavitree Quartzite farther south have been domed by the fold. The Inkamulla and Huckitta Granodiorites crop out in the cores of domes and may have been intruded at the same time as the doming.

The depression of the Atnarpa antiform axis near Atnarpa homestead corresponds to a regional downwarp which is also indicated by the arcuate strike of the Arunta Complex farther north in the Mount Riddock/Harts Range area.

Harts Range Anticline: Joklik (1955) postulated the Harts Range anticline to explain the presence of crystalline rocks between the Georgina and Amadeus Basins. He described the entire structure as an anticlinorium parallel to the Harts Range anticline, and suggested that the faults and folds in the Amadeus Basin sediments were generally controlled by pre-existing structures in the Precambrian basement complex. We believe that Joklik ascribed an east-west trend instead of a north-south trend to the domed structure which passes through Inkamulla, and it appears that he joined it to a structure south of Mount Brassey to form his 'Harts Range Anticline'.

Alice Springs and Arunta Orogenies in the Harts Range/Strangways Range Area: During the Arunta Orogeny the rocks in the Chewings Range area were folded about isoclinal north-south axes and tightly refolded about near-vertical east-west axes. During the Alice Springs Orogeny east-west isoclinal folds and large-scale recumbent folds were formed. Associated minor structures include north-south isoclinal folds and lineation and tight east-west cross-folds with a weak lineation (with a later set of east-west and north-south folds). The minor structures in each of the orogenies are similar. McCarthy has attempted to resolve the problem on the basis of the characteristics of the metamorphism during each orogeny. The Arunta Orogeny produced low to moderate-grade mineral assemblages, but during the Alice Springs Orogeny there was a period of retrograde metamorphism to the greenschist facies in 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 may have been emplaced during the Alice Springs Orogeny, and as they are closely associated with the high-grade metamorphic gneisses, the gneisses may also have been formed at this time. This hypothesis is supported by the Palaeozoic age of several pegmatites and of a specimen of gneiss from this area (Table 1).

Joklik (1955) reported that the grade of metamorphism decreases to the south from his great thrust-fault system in the Harts Range area. The most southerly specimen he describes was collected 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 that this rock has been subjected to retrograde dynamic metamorphism to the chlorite zone of the greenschist facies. Farther away from the nappe complex the rocks progress to the albite-epidote-amphibolite and amphibolite facies. Joklik also reported cataclastic structures in the headwaters of Cadney Creek and in the area of his great thrust-fault system. Biotite, garnet, and sillimanite are common in the cataclastic rocks.

Faulting: The age of many of the faults in the Arunta Complex is unknown, but some of them displace the Heavitree Quartzite and the Bitter Springs Formation in the Arltunga Nappe Complex, and were 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 within the nappe complex. The thrust faults in the Mount Benstead/Trephina Gorge area and 4 miles north-north-west of Bullhole dam have been folded into an arch and show clearly that the displacement has been from north to south, as in the Arltunga Nappe Complex. It has been 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, Ranford, Cook, Stewart, & Shaw (1965) have described the structure south of Alice Springs as the 'Blatherskite Nappe'.

To the east of Ruby Gap Gorge the boundary between the Heavitree Quartzite and the Arunta Complex has been displaced by high-angle reverse faults along which the northern block has ridden over the southern block. The hade and direction of movement on the remaining faults is unknown, except for the fault on the southern side of the Georgina Range, which has a south-block-up movement, and the fault near the Arltunga goldfield, which appears to have a south-block-down movement.

Joklik (1955, pp. 105-108) has described the faulting of the Arunta Complex in the Harts Range area. We are not in complete agreement with Joklik, and suggest that some of the thrust faults may have originated by the shearing out 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 for some distance to the south. The orogeny began with upwarping late in the Ordovician and reached a climax in the Devonian and possibly continued 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 found in 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, pushing the younger sediments before it. The younger sediments slid southwards over a décollement surface in the Bitter Springs Formation and were folded into a series of anticlines and synclines independently of the basement. The décollement within the Bitter Springs Formation was probably largely taken up in the evaporite sequence which was penetrated in Ooraminna No. 1 (Planalp & Pemberton, 1963).

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

The base of the décollement in the Bitter Springs Formation is best exposed in the north-western corner of the Hale River Sheet area (Fig. 4). In this area, the movement in the Bitter Springs Formation has been transmitted in places to the Heavitree Quartzite, which has been stripped off the Arunta Complex and doubled 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-easterly axes which are independent of the Heavitree Quartzite/Arunta Complex structures which trend west-north-west.

The folds and many of the faults, thrusts, and folded thrusts in the sedimentary succession above the Bitter Springs Formation are not continued in the Heavitree Quartzite and Arunta Complex at depth. The Heavitree Quartzite and the Arunta Complex have been deformed into nappes in the Arltunga and Ormiston Nappe Complexes, and there is therefore a large-scale disharmonic relationship between the structures developed above and below the Bitter Springs Formation during the Alice Springs Orogeny.

Age of the Alice Springs Orogeny: Prichard & Quinlan (1962) give the thickness of the Pertnjara Formation as 21,000 feet. It comprises 16,000 feet of conglomerate and 5000 feet of arenite; but although the measured thickness of sediment is 21,000 feet the vertical thickness of the formation in the trough of the Missionary Plain syncline probably does not exceed 10,000 feet. Their facies studies indicate 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'; and (p. 31) 'all faulting and folding in the area probably occurred during and shortly after the deposition of the Pertnjara Formation'. Wells (1964) has recognized two periods of diastrophism in the north-eastern part of the Amadeus Basin. 'The first period of folding resulted in the uplift of 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 can be seen between the Bitter Springs Formation and the Areyonga Formation in the northern part of the Rodinga Sheet area (Ranford & Cook, pers. comm.) or from our own observations in 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 Formation indicate a Middle or Upper Devonian age (Forman, 1965; Ranford et al., 1965; Wells, Stewart, & Skwarko, 1965).

Some preliminary age determinations have been made on specimens of pegmatite and gneiss from the Arunta Complex. Apparent ages are set out in Table 1.

The ages of 420 to 367 m.y. correspond to the age of formation of the Harts Range pegmatites and the Alice Springs Orogeny (the ages are equivalent to Silurian to Upper Devonian).

The age of 750 m.y. for the sample from the Pertatataka Formation indicates that the formation is Upper Proterozoic, and suggests that the Heavitree Quartzite and Bitter Springs Formation are also of Upper Proterozoic age (600 to 1400 m.y., Walpole, Roberts, & Forman, 1965).

The age of the fossils and the apparent mineral ages suggest that the Alice Springs Orogeny took place mostly in the Devonian. During the orogeny, the Arunta Complex was probably covered by 14,000 to 18,000 feet of Upper Proterozoic, Cambrian, and Ordovician sediments.

Explanation of the Gravity Gradient: In 1961 the geophysical section of the Bureau of Mineral Resources carried out a gravity survey of the area, with a minimum density of one gravity station per 50 square miles. The regional Bouguer anomalies shown in Figure 9 are

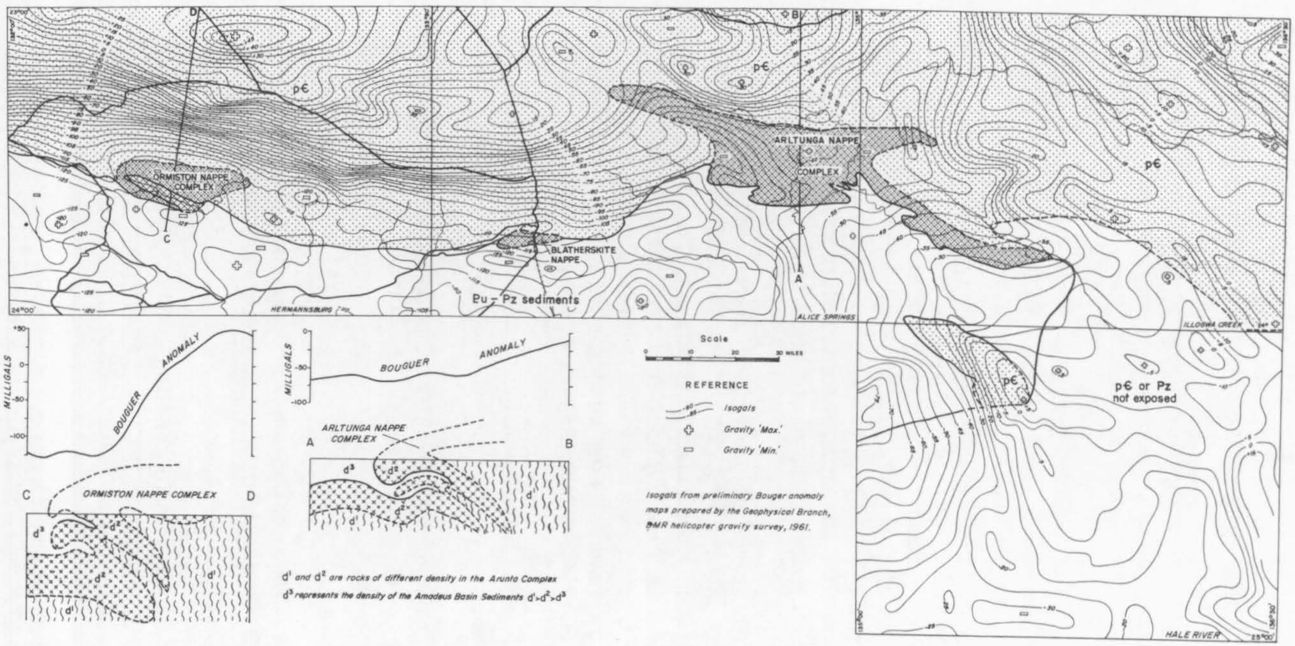

Fig. 9. Regional Bouger anomalies and gravity cross-sections

based on the results of this survey and detailed surveys by the Magellan Petroleum Corporation in 1961. Langron (1962) has noted 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 milligals per mile, near its centre on the Hermannsburg Sheet area. Towards the east 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 occurs over the Arunta Complex, with the margin of the Amadeus Basin to the south, and suggested that the Arunta Complex has been overthrust or overfolded over the Amadeus Basin sediments. Langron (1962) and Marshall & Narain (1954) also 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 the basement and sediments, the great thickness of sediments, overthrusting, and crustal warping.

The overthrust or nappe hypothesis has been confirmed by the regional geological mapping, but only the Heavitree Quartzite and the Bitter Springs Formation are infolded with the Arunta Complex. The density contrast between the Heavitree Quartzite and Bitter Springs Formation and the Arunta Complex is probably not as great as the density contrast between the other sediments, and the maximum thickness of infolded sediment is probably about 5000 feet in the Arltunga Nappe Complex. In any case Figure 9 shows that the main gradient occurs directly to the north of the nappe complexes and not over them. For these reasons, it seems unlikely that the observed gravity gradient is due to overthrusting. The geological cross-sections in Figure 9 show how the gradient can be explained by crustal warping. This hypothesis assumes crustal upwarping to the north of the present margin of the Amadeus Basin which would bring rocks of higher density from below. During the upwarping the overlying less dense rocks may have slumped southwards and formed nappes in the area of gravity minima and built up an increased thickness of lower density rocks within it. Later erosion from the upwarped area and deposition in the basin to the south helped to accentuate the gravity differences between the two areas.

TABLE 1: ISOTOPIC AGE DETERMINATIONS

Locality	Rock	Mineral	Method	Age (in millions of years)	Calculated by (or reference)
Rex pegmatite 4 mi.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 mi.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 mi.N.N.W. of Alice Springs	Arunta Complex (?Granite)	Muscovite & Biotite	Rb/Sr	1280	G.H. Riley
		Feldspar & total rock	Rb/Sr	2900	
Ooraminna No. 1	Pertatataka Formation (Shale)	Illite	Rb/Sr	750	V.M. Bofinger

The north-west trends on the eastern side of the area correspond to the trend of the margin of the Amadeus Basin and the trend of the margin of the Georgina Basin to the north-east. These trends may also be explained by crustal upwarping and appear to be continuous with those discussed above.

Assuming that the two trends or crustal warps are not continuous with each other, they may be likened to the fronts of ocean waves which have travelled southwards into the Amadeus Basin. Intersection of the crustal warps in the area of the Arltunga Nappe Complex would produce an interference pattern compatible with the gravity pattern (see Fig. 9). The Arltunga Nappe Complex has developed south of the area of intersection. At the point of intersection of the two crustal upwarps the effect of the upwarp would be cumulative and the upwarp would become unstable and slump to the south as it grew, in the same way that a wave 'breaks' when it becomes too high or too steep. Further movement of the two crustal upwarps southwards into the Amadeus Basin would cause the nappe to grow. The size of the nappe would depend on the distance travelled by the wave-like crustal warps, their speed of travel, and the strength of the rocks pushed into the core of the nappe in the area of intersection. Thus strong crystalline rocks would be expected to produce the largest nappes. Once the nappe reached maximum size, further movement of the crustal warps could result in the formation of another nappe beneath it and arching of the nappe complex at right angles to the direction of movement. The concept is illustrated in Figure 10.

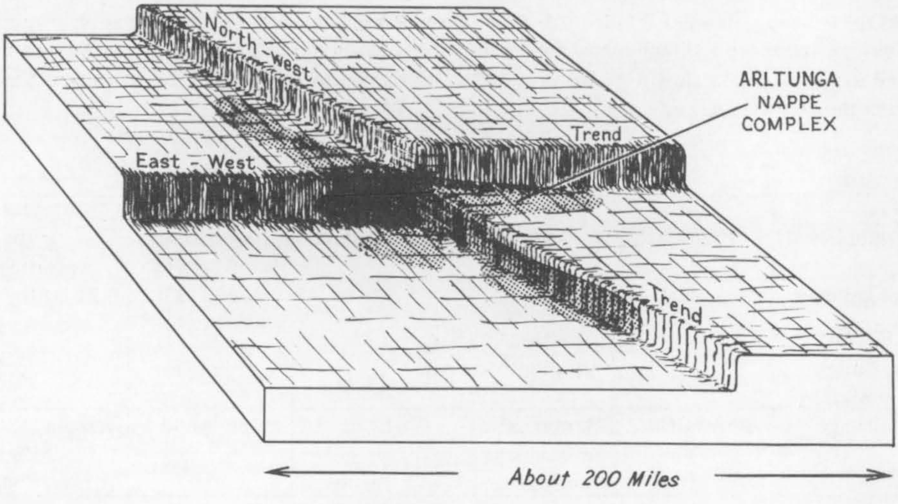

Fig. 10. Recumbent folding as the result of a bent crustal upwarp

GEOLOGICAL HISTORY

The following is a resumé 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 the eastern part of the area.

(4) Slight tectonic instability in neighbouring areas, possibly to the north and east, producing some local warping of the Bitter Springs Formation and local weathering before deposition of the Areyonga Formation.

(5) Deposition of the Upper Proterozoic Areyonga and Pertatataka Formations during a period of slight to moderate tectonic instability in neighbouring areas. Possible period of glaciation (see Wells, Ranford, Cook, Stewart, & Shaw, 1965). The eastern area, where limestones are more abundant, appears to have been more stable.

(6) Marine deposition continued into the Cambrian. The presence of salt near the base of the Pertaoorrta Group and the 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; Wells, Stewart, & Skwarko, 1966).

(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 land in the east was weathered and eroded before the Mereenie Sandstone was laid down in a predominantly continental environment. In the west, the Mereenie Sandstone appears to have followed directly after deposition of the Larapinta Group. This period extends 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 which provided 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 the Arunta Complex, retrograde metamorphism, and intrusion of mica-bearing pegmatites in the Harts Range. Possible development of some granite.

(10) Weathering and erosion.

(11) Probable marine transgression and regression over the south-eastern corner in the Mesozoic.

(12) Weathering and erosion.

(13) The Tertiary pluvial period; infilling of topographic depressions by clastic, fluviatile, and lacustrine sediments.

(14) Period of weathering, and formation of duricrust and laterite.

(15) Return to pluvial conditions, and 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

During the period 1892 to 1952, the value of mica from the Harts Range and its easterly neighbour the Plenty River mica field on the Huckitta 1:250,000 Sheet area exceeded £600,000. Gold has been mined at a few localities; production to 1925 was valued at £30,000. Traces of other metalliferous ores have also been recorded. The pastoral 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 being worked, although the lack of water seriously hampered development. By 1890, over 20 auriferous reefs and 15 alluvial claims were being worked. Gold was discovered and worked in the Heavitree Quartzite at White Range in 1897 and south of Winneckes Depot, some 25 miles north-west of Arltunga, in 1902.

Returns from all three fields showed averages of about 1 oz per ton for ore treated at the batteries and cyanide plants, but Playford (1920) estimated that the average grade of ore mined was about 9 dwt. Most of the reefs were small and discontinuous, and the gold was finely disseminated on pyrite in vugs and in 'cellular quartz' in which the pyrite had been oxidized and weathered out.

Very little prospecting was done at Arltunga from 1920 to 1932 and the battery was sold soon afterwards. In 1934 new veins were discovered near Claraville, but by the end of 1936 work had ceased on the field. In the oxidized zone the gold occurs in quartz containing vugs and in joints filled with limonite, calcite, and siderite. The country rock is a dark-coloured basic gneiss. Most of the veins are about a foot long and 3 to 4 inches across, but some reach 50 feet or more in length and up to a foot across.

Soon after its discovery, the White Range field became the main producer in the district; the average return was about 1½ oz per ton. By 1905, activity had slackened off, and continued to decline until 1920, when all work ceased. The field was confined 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 goldfield in the period 1901-05, but activity declined rapidly after 1905. Sporadic attempts were made to prove further deposits in 1933-37, but only about 300 oz of gold were produced. The gold occurs in ferruginous material in vugs and fractures in highly irregular quartz bodies in a gneissic group of rocks including micaceous and quartzose schists, dolomitic marble, and rarely metaquartzites.

Copper: A little copper has been recorded from several localities, principally in the goldfields and in a north-western extension of the belt of gold mineralization. The copper occurs in stockworks of red copper oxide on the edges of intrusive quartz reefs, or as veins of malachite, azurite, and atacamite. Chalcanthite has also been recorded. Arsenic is associated with the copper in the Excelsior mine, White Range. Copper shows also occur within a 5 mile radius east and north of the Southern Cross Bore; 3 miles south-south-west and 7 miles south of Mount Riddock homestead; and 2 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 goldfield), at Kennys prospect (a few miles north of the field), and at a locality $1\frac{1}{2}$ miles north of the old Arltunga Police Station Two samples from Kennys prospect (unpublished AMDL Report AN339-63) assayed 30 oz and 14 oz of silver per long ton.

Tin: A little tin has been reported from two of the copper prospects in the Strangways Range.

Radioactive Minerals: Betafite, samarskite, and monazite have been recorded in some of the mica-bearing pegmatites in the Harts and Strangways Ranges.

Non-metalliferous Ores

Mica: Tate (1880) first recorded the presence of mica in the district. In November 1888 Brown (1889) commented on Lindsays mica mine in the headwaters of Illogwa Creek, and a year later he visited a mica claim in the Harts Range mica field (Brown, 1890). Numerous claims had been marked and abandoned by 1905, when Mathews (1905b) reported that only one claim (the Spotted Dog) was being worked. In 1926 two mines were opened up 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.* 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 short-lived revival of work in the field. In the last period of operations, activity was confined to the recovery of mica from dumps. In 1961 less than a ton of mica was recovered, and all activity on the fields ceased.

Asbestos: H.I. Jensen (unpublished report, 20th October 1943, BMR files) described an asbestos deposit in Disputed Creek, three-quarters of a mile north-east of the Rex mica mine. The deposits are unlikely to be of commercial value because of the remoteness of the area and the variable quality and shortness of the fibre.

Gemstones: Beryl occurs in many of the mica-bearing pegmatites, but the mineral 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 ceased.

Phosphate: A single specimen of the magnetite-apatite metaquartzite from the upper reaches of Illogwa Creek was found to contain about 15 percent apatite, but the extent of the apatite-bearing rock is unknown.

Groundwater

Jones & Quinlan (1962) have divided the area into the Macdonnell, Hermannsburg, Plenty, and Simpson groundwater provinces. The main characteristics of the groundwater provinces are summarized in Table 2.

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* A phlogopite mine was opened near Mount Johnstone in the Strangways Range, but owing to the sporadic distribution of the mica the mine was abandoned within a year.

TABLE 2: GROUNDWATER PROVINCES

Province	Aquifers	Depth to Piezo metric Surface	Drilling depth	Quality	Availability
MacDONNELL	Fractured weathered metamorphics. 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 metamorphics	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 in the central and north-east sectors of the Illogwa Creek Sheet area.

Precambrian: 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.

Lower Cretaceous and Tertiary: The Lower Cretaceous and Tertiary aquifers have yielded over 1000 gph from shallow to moderate depths.

Quaternary Alluvium: The Quaternary alluvium is generally too thin to provide useful aquifers.

Jones & Quinlan (1962) and Perry et al. (1963) have made a hydrological study of seven catchments and groundwater basins, covering over 10,000 square miles, 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 are poorly consolidated sand and gravel and partly cemented kunkar.

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PART II

PETROLOGY

by W.R. McCARTHY

SUMMARY

An investigation of the relationships of the Upper Proterozoic sediments and the Precambrian basement metamorphics and granitic rocks of the Arunta block along the north-eastern margin of the Amadeus Basin was undertaken by the Australian Mineral Development Laboratories. Petrological study of 67 specimens indicates that the rocks of the Arunta Complex are sediments regionally metamorphosed to the greenschist and almandine-amphibolite facies, which have undergone a period of retrogressive metamorphism and intense deformation where adjacent to a highly deformed Upper Proterozoic quartzite. The quartzite is thought to be part of the Heavitree Quartzite which has been deformed and dynamically metamorphosed together with the Arunta Complex along the margins of faults. The folded upper Proterozoic sediments, Heavitree Quartzite, and Bitter Springs Formation have undergone a period of low-grade metamorphism during their deformation.

INTRODUCTION

Early in 1964 it was arranged that the Australian Mineral Development Laboratories should provide a petrologist to assist a field party of the Bureau of Mineral Resources to determine the relationships of the Upper Proterozoic sediments on the north-eastern margin of the Amadeus Basin to the metasediments and granitic rocks of the Precambrian basement. In addition to the petrographic descriptions of the main stratigraphic units, it was hoped that detailed study of selected specimens might provide a more complete understanding of the pressure/temperature conditions during the deformation of the rocks.

I joined the Bureau of Mineral Resources field party at Alice Springs on 10th August 1964. The sampling traverses were carried out at selected localities between longitudes 132°39'E. and 135°03'E. on the northern flank of the MacDonnell Ranges (see Fig. 11). Fourteen days were spent in the field and 65 rock specimens were collected.

Special optical and X-ray diffraction techniques were used for some of the mineral determinations. As there was some doubt about the type of carbonate contained in the Bitter Springs Formation, three carbonate samples were identified by X-ray diffraction. About 65 determinations of the anorthite content of the plagioclase have been made with the universal stage. The method described by Turner (1947) and the curves compiled by Slemmons (1962) were used.

The minerals in the rock names are listed in order of increasing abundance. The mineralogical composition of the rocks has been estimated visually.

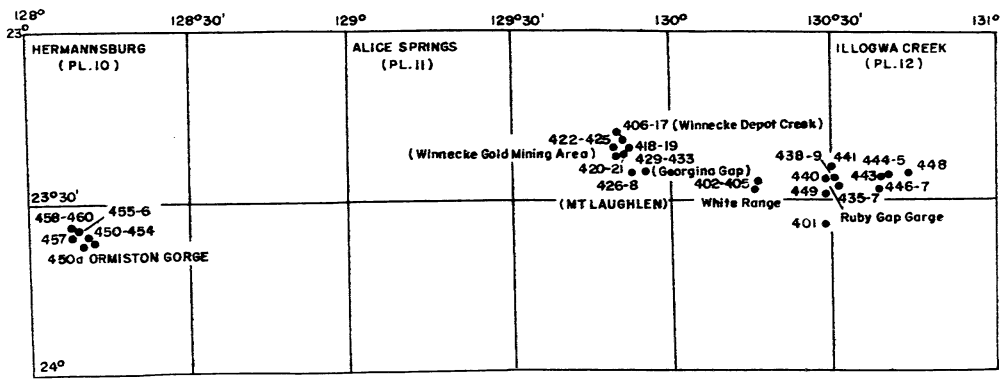

Fig. 11. Location of specimens

DISCUSSION OF RESULTS, AND CONCLUSIONS

Arunta Complex

About 50 specimens of the metasediments, gneisses, amphibolites, and granitic rocks comprising the Arunta Complex are described. Several quartzites are interbedded with the metasediments. The older Precambrian quartzites cannot be clearly differentiated from the Heavitree Quartzite except by their stratigraphical position (e.g., the Mount Laughlen Traverse).

White Range Quartzite

The more highly structured quartzites adjacent to the Arunta Complex were previously considered to be a separate stratigraphic unit, the 'White Range Quartzite' (Joklik, 1955), but have been mapped by Forman (Pls 11, 12) as Heavitree Quartzite.

The results of this investigation indicate that mineralogical composition and lineation are not sufficient criteria to distinguish the White Range Quartzite from the Heavitree Quartzite. Except at the White Range localities (AS402-5), the highly structured or lineated quartzite adjacent to the Arunta Complex seems clearly to be intensely deformed and recrystallized Heavitree Quartzite. The quartzite at the White Range localities could be one of those of the Arunta Complex, instead of the Heavitree Quartzite; however, it is correlated with the Upper Proterozoic quartzite for the purposes of this study.

Heavitree Quartzite

Ten specimens of the slightly argillaceous quartz arenite were examined. The sedimentary quartz has been recrystallized in all the rocks and all contain a new generation of mica. The newly crystallized minerals have a preferred dimensional orientation. The degree of orientation and recrystallization probably depends on the intensity of deformation. In several specimens 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, in which the form of the sedimentary grains is still visible, some of the grains are as large as granules or small pebbles. The accessories are not conspicuous.

Bitter Springs Formation

Two specimens composed mainly of carbonate and two specimens of siliceous and pelitic intercalations have been described. The carbonate is mainly dolomite, and both specimens have been plastically deformed by differential shearing after diagenesis. Some accessory mica of unknown origin is also present.

The siliceous and pelitic intercalations contain low-grade metamorphic mineral assemblages.

Progressive Metamorphism of the Arunta Complex

The detailed stratigraphy of the Arunta Complex is unknown. The granitoid rocks and gneisses are associated with metasediments of the almandine-amphibolite facies. Rocks of the greenschist facies appear to overlie the medium-grade metamorphics conformably in the Winnecke Depot Creek area.

Joklik (1955, p. 59) considers that the grade of metamorphism in the Harts Range is equivalent to the sillimanite isograd, and he related the lower-grade metamorphic rocks to a period of retrogressive hydrothermal metamorphism rather than progressive regional metamorphism. Some of these metasediments may compare with certain rocks of the Winnecke area. The greenschist mineral assemblages of the rocks of the Winnecke traverses may be due to factors such as water pressure. Nevertheless, the occurrence of rocks of the greenschist facies is not anomalous, as the subfacies of the almandine-amphibolite facies in the Winnecke area are of lower grade than those reported in the Arunta metamorphics of the Harts Range.

Progressive Metamorphism of the Proterozoic Sediments

The synkinematic recrystallization of the Proterozoic quartzite is evident in all specimens examined. Only two specimens of the Bitter Springs Formation were found to contain metamorphic minerals. These are siliceous pelitic intercalations of the carbonate from within recumbent overfolds. Thus it appears that the Proterozoic arenite and carbonate along this part of the northern margin have undergone low-grade metamorphism during deformation.

Retrogressive Metamorphism of the Arunta Complex

During this investigation four general localities, and possibly a fifth, were visited where an intensely structured quartzite dips under, or is interbedded with, the Arunta Complex rocks. Joklik (1955, pp. 22-23) has explained this relationship by postulating the occurrence of a lower Proterozoic quartzite, the 'White Range Quartzite', which was conformably folded with the Precambrian basement during the development of a regional anticlinorium.

The field relationships and microscopic characteristics of the rocks from the four traverses are remarkably similar. The quartzite and Arunta Complex rocks show a conformable rock cleavage which diminishes to the north into the Arunta block, and in all four areas the basement rocks have been retrogressively recrystallized. Where the Proterozoic quartzite is adjacent to gneisses of the Arunta Complex, they have been intensely granulated in the immediate vicinity, cataclastically altered farther from the contact, and moderately fractured still farther into the Precambrian basement. Metasediments of the Arunta Complex adjacent to the Proterozoic quartzite have been subjected to cataclastic or plastic deformation, which also diminishes to the north away from the quartzite. At all four localities the quartzite has a highly developed microstructure.

These features are probably due to large-scale faulting which resulted in dynamic metamorphism of the Arunta Complex and of the Upper Proterozoic quartzite, and it is concluded that the 'White Range Quartzite' was formed by intense recrystallization of the Heavitree Quartzite during dynamic metamorphism. If this is so, wherever the Heavitree Quartzite dips under the Arunta Complex, the older Precambrian rocks should be retrogressively metamorphosed. Before this test can be applied, the Proterozoic quartzite must be clearly differentiated from the quartzites within the Arunta metamorphics such as those at Mount Laughlen.

The data are not sufficient to delineate possible diapthoresis of the Arunta Complex where it unconformably underlies the Heavitree Quartzite (e.g., the Mount Laughlen traverse).

The evidence for retrogression of the rocks of the Arunta Complex is summarized below:

In the Illogwa Creek traverse the Heavitree Quartzite overlies the Arunta Complex. The quartzite has been moderately recrystallized, but there is no positive evidence that the Arunta Complex has undergone diapthoresis. The carbonate and quartzite of the Arunta Complex are not suitable for determining retrogression.

In the Hale River traverse there is conclusive evidence that the gneisses have been subjected to low-grade metamorphism and associated shear stresses. In the amphibolite and calc-silicate rocks there is no clear evidence of diapthoresis, but the data do not preclude this interpretation.

In the White Range area a low-grade mineral assemblage has been developed in the probable metasediments and granitoid rocks of the Arunta Complex.

In the Georgina Gap traverse the rocks of the Arunta Complex (except for the marble) have undergone a later period of deformation and recrystallization. The cause of the recrystallization is not clear, but some aspects of the rocks suggest that it was due to hydrothermal metamorphism.

In the Winnecke gold mine area traverse 1 the Arunta Complex siliceous metacarbonates appear to have had a polymetamorphic history. The final crystallization has been of a low grade, and accompanied by differential deformation of the rock. The latest period of metamorphism may have been the same event which altered and deformed the Arunta Complex adjacent to the Heavitree Quartzite.

In the Winnecke gold mine area traverse 2 the rocks of the Arunta Complex, especially near the contact with the Heavitree Quartzite, have been cataclastically deformed and recrystallized under low-grade metamorphic conditions. The recrystallization is evident in all the rock types examined, although the retrogressive mineral assemblages are dependent on the composition of the original rocks. It is evident that cataclasis and recrystallization occurred during the same event.

In the Winnecke Depot Creek traverses the rocks of the Arunta Complex do not appear to have been affected by the retrogressive recrystallization recorded in other areas.

In the Ormiston Gorge traverse 1 the older Precambrian rocks have undergone a period of retrogressive recrystallization and cataclasis which was particularly intense near the contact with the underlying Upper Proterozoic quartzite.

The Ormiston Gorge specimens (excluding those of the first traverse) consist of granitic rocks of varied composition, and amphibolite. A later low-grade mineral assemblage has developed in all and, with one exception, cataclasis has accompanied the recrystallization.

PETROGRAPHY

Seven miles south of Ruby Gap Gorge

Heavitree Quartzite: AS401: Sericite metaquartzite

The rock has been formed by low-grade metamorphism of a rather pure quartz arenite. Sericite has crystallized during metamorphism and a considerable proportion of the quartz has been recrystallized. Shearing, an important mechanism during metamorphism, and recrystallization have destroyed the sedimentary form of many of the quartz grains.

Quartz has a dimensional orientation and the sericite is foliated. Sericite is confined to intergranular areas, to newly crystallized aggregates of quartz, and to shears. Accessories include tourmaline, zircon, and opaques.

North-west of the White Range Traverse

'White Range Quartzite': AS402: Sericite-feldspar-quartz schist

The rock was collected as an example of the White Range Quartzite of Joklik (1955). It differs from those described by Joklik as both alkali feldspar and plagioclase are present.

The rock is fine-grained to medium-grained, contains sheared and broken feldspar porphyroclasts, and laminar bodies of foliated sericite. Feldspar appears to be relict whereas sericite crystallized during the deformation. Part of the quartz is segregated into coarser-grained laminar bodies in which it is dimensionally oriented. Quartz and sericite fill fractures in the feldspar porphyroclasts (Pl. 6, fig. 1).

Most of the plagioclase grains are small and broken and many have strained extinction. The anorthite content of the plagioclase is An_{24}. The alkali feldspar is microcline and microcline microperthite. Feldspar probably forms about a third of the specimen. The accessories are apatite, opaques, and sphene.

White Range Traverse

The most striking feature of specimens AS403-405 is the final phase of intense deformation and recrystallization.

In at least one of the specimens there are indications of an earlier structure, S_1, which was folded and sheared to form the microstructure S_2. The S_2 structure is parallel to the rock cleavage. The intensity of S_2 and the amount of rock cleavage decrease to the north.

The metamorphic recrystallization of the Arunta Complex resulted in the formation of a low-grade assemblage of epidote, biotite, muscovite, and quartz. The nature of the original rocks is uncertain, but it is likely that specimen AS405 is a metamorphosed sediment and that the others are altered granites.

Arunta Complex: AS403: Epidote-mica-alkali feldspar-quartz-plagioclase gneiss

The rock is medium-grained to coarse-grained. Dimensional orientation of minerals is slight, but in places they are concentrated. Quartz tends to be restricted to irregularly shaped elongate bodies and is commonly associated with microcline. The quartz bodies separate irregular aggregates of poikiloblastic plagioclase that form a matrix for intermatted aggregates of mica and epidote.

Some of the alkali feldspar crystals are probably microcline, but others are untwinned, and a few are perthitic. The mica is mainly muscovite; it often has a rectilinear distribution in the plagioclase.

Arunta Complex: AS404: Mica-epidote-quartz-plagioclase gneiss

The medium-grained to coarse-grained rock is sheared and partly recrystallized. It has a moderate to conspicuous microstructure parallel to the cleavage. The main fabric features are lenses of quartz, dimensional orientation of quartz, and foliated lenses of mica. The gneiss appears to have been formed by deformation and recrystallization of an earlier rock composed in part of plagioclase.

Biotite is generally restricted to the borders of relict lenses of the earlier rock, whereas the foliated lenses of sericite transgress the lenses. The plagioclase is extremely deformed and contains numerous inclusions. Part of the biotite has weathered to chlorite, and some of the opaques to goethite(?). The accessories include apatite, opaques, and abundant sphene.

Arunta Complex: AS405: Epidote-feldspar-mica-quartz schist

The rock is fine-grained to medium-grained. The fine grainsize of much of the quartz in a mildly recrystallized zone 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 parallel to the axial planes to form S_2.

The mineral phases seem to belong to 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 feldspar, and the minerals which crystallized during the development of S_2 were quartz, biotite, sericite, epidote, and perhaps feldspar. The presence of a number of broken and rotated grains of feldspar indicate that it was present during movements associated with S_2, but part of it may have crystallized synchronously with the latest mineral phases. The anorthite content of the plagioclase was found to be An_{31}, but much of it is untwinned or poorly twinned. Alkali feldspar may also be present.

The accessories include opaques, zircon, and abundant sphene.

Winnecke Depot Creek Traverse 1

The rocks of the Winnecke Depot Creek traverse 1 are the regionally metamorphosed equivalents of a sequence of interbedded carbonate rocks and impure siliceous and pelitic sediments. The type of metamorphism and mineral zoning in this terrain has been termed 'Dalradian' or 'Barrovian', and recently Miyashiro (1961) has termed this the 'kyanite-sillimanite type'. The available 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.

No indications of retrogressive metamorphism were observed in any of the specimens.

Arunta Complex: AS406: Marble

The carbonate crystals are generally coarse-grained and form about 97 percent of the rock. The minor constituents include fine-grained or medium-grained crystals of sphene, apatite, muscovite, quartz, tremolite, and epidote. No preferred orientation of the minerals is apparent. The mineral assemblage is comparable with the quartz-albite-epidote-biotite subfacies of the greenschist facies.

Arunta Complex: AS407: Amphibole-quartz-epidote hornfels

The rock is porphyroblastic, medium-grained, and hornfelsic. Other fabric features are parallel linear concentrations of quartz and actinolite(?). Minor constituents include biotite, calcite, sphene, and muscovite, with accessory tourmaline, apatite, and opaques. The mineralogical composition is comparable with the calcareous schists of the quartz-albite-epidote-biotite subfacies of the greenschist facies.

Arunta Complex: AS408: Muscovite-quartz-alkali feldspar rock

The rock is interbedded with the metasediments and is considered to be a metamorphosed argillaceous siltstone.

It has a conspicuous microstructure formed by linear aggregates of fine-grained feldspar and by others of quartz which is sometimes dimensionally oriented. Coarse porphyroblasts of alkali feldspar are also present.

The mineralogical composition is estimated to be: plagioclase, 1 percent; muscovite, 8 percent; quartz, 30 percent; and alkali feldspar, 60 percent. Accessories include tourmaline, apatite, sphene, and zircon. The alkali feldspar is microcline and microcline microperthite. Plagioclase is rare.

Arunta Complex: AS409: Sillimanite-quartz-mica-orthoclase(?) rock

Linear aggregates of quartz, biotite, and sillimanite occur, but in general the rock has a hornfelsic texture. The rock is medium-grained to fine-grained. Biotite is the predominant mica, but muscovite is also an important constituent. A few crystals of plagioclase(An_{37}) were observed. Opaques form about 5 percent of the rock; other accessories include zircon and apatite.

The rock is assigned to the highest subfacies of the almandine-amphibolite facies in the sillimanite-almandine-orthoclase subfacies. It is similar to specimen AS417, except for the absence of cordierite.

Arunta Complex: AS410: Staurolite-kyanite-quartz-mica-schist

The rock is medium-grained to coarse-grained and is assigned to the staurolite-almandine subfacies of the almandine-amphibolite facies. It has been formed by metamorphism of a sediment rich in alumina and deficient in potash, lime, and soda.

The fabric of the rock is formed by parallel linear aggregates of quartz. Some of the kyanite and staurolite crystals are aligned with the foliation, but many show a random orientation. Biotite and muscovite are present in about equal proportions. Staurolite and kyanite are both important constituents, but kyanite is more abundant. Opaques are common (5 to 7 percent). No feldspar was observed.

Arunta Complex: AS411: Plagioclase-epidote-mica-quartz-alkali feldspar gneiss

The rock is medium-grained to fine-grained. Biotite tends to be foliated, many quartz and alkali feldspar crystals are dimensionally oriented, and a few linear aggregates of fine-grained quartz and feldspar were observed. Some of the muscovite occurs as coarse poikiloblasts with a random orientation. Epidote occurs as scattered small anhedral to euhedral crystals.

The mineralogical composition is estimated to be: epidote, 8 percent; mica, 15 percent; quartz, 30 percent; and feldspar, 55 percent. The accessories include zircon, and abundant apatite and sphene.

The feldspar appears to be entirely alkali feldspar; most of it is microcline, and some is microcline microperthite.

The mineral assemblage may be compared to the staurolite-almandine subfacies of the almandine-amphibolite facies.

Arunta Complex: AS412: Calc-silicate rock

Specimen AS412 is a metamorphosed impure carbonate rock composed of tremolite, diopside, plagioclase, microcline, quartz, calcite, and clinozoisite. Quartz and calcite often occur in linear concentrations and frequently are dimensionally oriented.

Quartz, calcite, and clinozoisite are the most abundant constituents, and microcline is more abundant than plagioclase(An_{28}). Accessories include sphene, apatite, tourmaline, and opaques.

The assemblage may be compared to the staurolite-almandine subfacies.

Arunta Complex: AS413: Phlogopite-tremolite-epidote marble

The marble is medium-grained to coarse-grained. Silicate minerals occur in linear concentrations which may represent silty laminations in the original carbonate. Calcite forms 85 percent of the rock and silicate minerals about 15 percent. The accessories include tourmaline, apatite, sphene, and zircon.

Winnecke Depot Creek Traverse 2

The mineralogical composition of the specimens from the Winnecke Depot Creek traverse is similar to rocks formed by regional metamorphism of the almandine-amphibolite grade. The staurolite-almandine subfacies and the sillimanite-almandine-orthoclase subfacies are represented. The facies series is considered to represent the kyanite-sillimanite type of Miyashiro (1961) and the available data indicate that the grade of metamorphism may increase from north to south.

According to Miyashiro, cordierite is not generally developed under the conditions of the kyanite-sillimanite type of regional metamorphism. Thus its occurrence here appears to require further explanation. From the literature, it appears that this cordierite may represent part of a transformation zone into rocks of a higher facies (i.e., granulite facies), or that it may occur along the margin of an intrusive body in a superimposed hornfels zone (i.e., hornblende-hornfels facies). In the Harts Range, where the metasediments have evolved under similar facies conditions, cordierite is absent (Joklik, 1955, p. 76).

The staurolite-kyanite-bearing rock is similar to one of those of the first Winnecke Depot Creek traverse, and the assemblage may be a useful marker zone.

Arunta Complex: AS414: Staurolite-kyanite-quartz-mica schist

The rock is medium-grained to coarse-grained, and is similar in mineralogical composition to specimen AS410 from the Winnecke Depot Creek traverse 1. Specimen AS414 has a slightly better developed microstructure (i.e., part of the quartz shows a crystallization foliation and the foliation of mica is more complete).

Arunta Complex: AS415: Epidote-mica-alkali feldspar-quartz-plagioclase gneiss

The rock is medium-grained with porphyroblasts of feldspar. The well developed fabric is imparted by foliated mica, the dimensional orientation of quartz and, to a lesser degree, feldspar. The mineralogical composition is estimated to be: epidote, 5 percent; biotite, 7 percent; muscovite, 7 percent; alkali feldspar, 20 percent; quartz, 20 percent; and plagioclase, 40 percent. Sphene and apatite are common, and zircon is rare. The alkali feldspars are microcline and microcline microperthite. The anorthite content of two coarse grains of plagioclase was An_{34} and An_{35}, and of three grains in the matrix An_{27}.

Arunta Complex: AS416: Quartz-kyanite-mica schist

The rock is medium-grained to coarse-grained with a moderate fabric imparted by the alignment of linear opaque bodies and foliated mica. It differs from the other kyanite-bearing rocks described here in the absence of staurolite, the smaller quantity of quartz present, and the less well developed foliation. These features indicate original compositional differences, and possibly differing pressure-temperature and stress conditions during metamorphism.

The mineralogical composition is estimated to be: opaques, 5 percent; quartz, 10 percent; kyanite, 35 percent; and mica, 50 percent. Muscovite is slightly more abundant than biotite. Opaques and zircon are the only accessories.

Arunta Complex: AS416A: Biotite-quartz-plagioclase-epidote schist

The rock is medium-grained to fine-grained with a moderate microstructure. Part of the biotite is foliated, some of the quartz and plagioclase is dimensionally oriented, and several linear bodies of quartz and plagioclase are present. The oriented fabric is displaced by segregations of quartz, feldspar, and epidote. Much of the quartz, and some of the plagioclase, is subhedral.

Epidote, biotite, quartz, and plagioclase are present in about equal proportions. The accessories include 3 to 5 percent opaques, and abundant apatite. No muscovite or alkali feldspar was observed.

The anorthite content of two plagioclase grains was found to be An_{38}.

Arunta Complex: AS417: Biotite-sillimanite-quartz-cordierite-alkali feldspar gneiss

The rock is coarse-grained to medium-grained and was probably derived from a quartzo-feldspathic sediment. The rock's microstructure is formed by parallel aggregates of sillimanite, and of opaques, and the dimensional orientation of part of the quartz.

The mineralogical composition is estimated to be: biotite, 10 percent; sillimanite, 10 percent; opaques, 10 percent; quartz, 20 percent; cordierite, 25 percent; and alkali feldspar, 25 percent. Several small plagioclase crystals were observed. Zircon and opaques were the only accessories noted. The untwinned alkali feldspar is generally microperthitic and is either orthoclase or microcline. The plagioclase crystals occur as inclusions in the alkali feldspar or in association with it and opaques, or with sillimanite and biotite. The anorthite content of two crystals was found to be An_{44} and An_{46}.

Winnecke Gold Mine Area Traverse 1

A polymetamorphic history is suggested for these specimens. During the earliest low-grade metamorphism tremolite, epidote, feldspar, and quartz crystallized. The latest crystallization was accompanied by plastic deformation and folding of the metasediments.

Arunta Complex: AS418: Feldspar-quartz-tremolite-epidote calc-silicate

Epidote and tremolite form about 55 percent of the rock and quartz about 40 percent. Most of the feldspar is microcline, and only a few crystals of plagioclase were identified. Sphene and tourmaline are abundant.

The oriented specimen was collected from a minor fold and is illustrated in Figure 12.

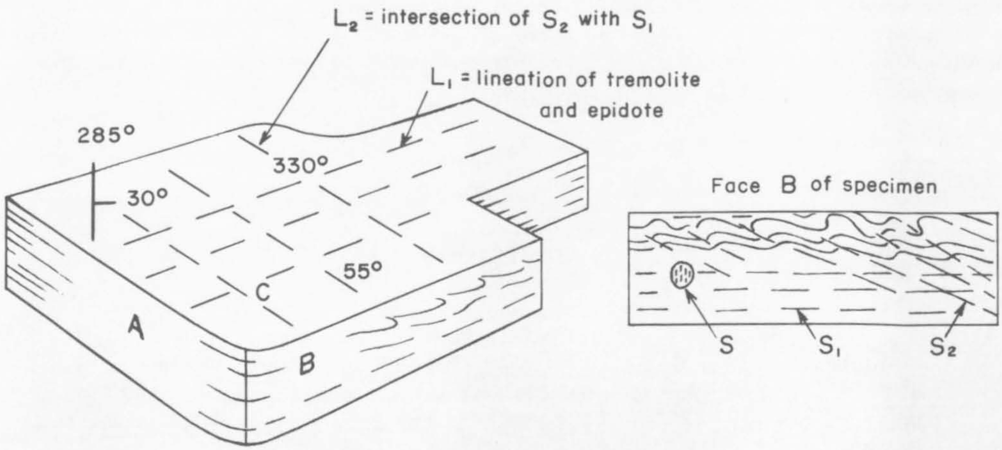

Fig. 12. Oriented specimen, Arunta Complex

The microscopic data suggest that the history of the rock may have been as follows:

(i) the formation of S by metamorphism of a sediment. The minerals which crystallized during this period include feldspar, quartz, epidote, and tremolite. A proterogenic relict, which has been rotated during plastic deformation of the rock, indicates the earlier structure (S) of the rock. It contains undeformed feldspar and has been only mildly deformed (i.e., strained extinction);

(ii) the plastic deformation of the rock (Pl. 6, figs 2, 3) 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 the S_1 (slip folds). Lineated tremolite, 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 no unique explanation can be offered.

Arunta Complex: AS419: Calc-silicate marble

The rock is coarse-grained to medium-grained and has been formed by low-grade metamorphism of an impure carbonate rock, probably with siliceous laminations. Deformation of the rock occurred during the concluding stages of crystallization or during recrystallization. The optical properties of the cores of some of the tremolite and epidote crystals suggest they are rich in iron.

Calcite is the major constituent. Alkali feldspar (microcline?), quartz, tremolite, plagioclase, and epidote also occur. Accessories observed were sphene and tourmaline.

Winnecke Gold Mine Area Traverse 2

The Winnecke gold mine area traverse 2 was started in the Heavitree Quartzite and continued for about 850 yards in a northerly direction into the Arunta Complex. The Upper Proterozoic quartzite appears to dip steeply to the north under the older Precambrian, which crops out as a low ridge. The contacts with the underlying quartzite are covered by scree. Both the Upper Proterozoic quartzite and older Precambrian rocks are strongly cleaved. Five specimens were collected along the traverse - two of the Heavitree Quartzite, and three from the Arunta Complex. For the first 350 yards, the Arunta Complex consists of a cataclasite, marble (not sampled), amphibolite, and metaquartzite, followed by folded and cleaved gneiss.

In all the rocks, plastic deformation or shearing stresses have been important in the final stage of their development. The Heavitree Quartzite has been recrystallized during shearing and the quartz shows an intense dimensional orientation. The cataclasis, recrystallization, and cleavage of the Arunta Complex are greatest near its contact with the Heavitree Quartzite and diminish to the north.

Heavitree Quartzite: AS420: Sericite metaquartzite

The rock is medium-grained to fine-grained with a well-developed fabric imparted by the dimensional orientation of quartz and foliated sericite. Accessory minerals include common sphene and apatite, and zircon and tourmaline.

The rock is strongly cleaved.

Arunta Complex: AS421: Cataclasite

This is a recrystallized and cataclastically altered rock originally composed of alkali feldspar and quartz. It is now composed of clasts of alkali feldspar, quartz, and green biotite. The quartz and biotite have crystallized during the cataclastic deformation. The clasts vary considerably in size and shape, and a number of linear bodies of mylonite transgress the cataclastic matrix. The macrostructures and microstructure are due to the presence of foliated biotite, lenticular bodies of granulated feldspar, and elongated mineral clasts or grains.

Feldspar occurs as twinned and untwinned crystal fragments. It is thought to be predominantly microcline. The only accessory minerals are opaques.

Heavitree Quartzite: AS422: Sericite metaquartzite

The rock is medium-grained to fine-grained, and before alteration was probably an amphibolite. It is similar in mineralogical composition to specimen AS420, but the fabric differs in that linear aggregates of strongly foliated quartz occur.

Arunta Complex: AS423: Cataclasite

The rock is partly recrystallized with clasts of hornblende(?) and plagioclase enclosed in a finer-grained matrix. The intense microstructure is due to the presence of fine epidote and actinolite, linear aggregates of quartz, and the dimensional orientation of part of the quartz.

Muscovite, biotite, actinolite, calcite, quartz, and epidote have crystallized during the cataclastic deformation of the rock. The earlier minerals have been partly recrystallized or replaced by the later minerals. The opaques are generally associated with the amphibole.

Arunta Complex: AS424: Epidote-biotite-sericite metaquartzite

The rock is medium-grained to fine-grained, with a well-developed microstructure. The mica is generally foliated and part of the quartz has a pronounced dimensional orientation. The alternating concentrations of quartz and mica 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 main constituent, but sericite forms about 30 percent of the rock. Minor amounts of epidote, biotite, and chlorite are also present. The accessories include sphene, zircon, apatite, and opaques. Chlorite was observed in a number of places and biotite only in a few aggregates. The chlorite appears to be a weathering product of biotite. Some of the opaque grains are weathered to goethite(?).

Arunta Complex: AS425: Epidote-mica-feldspar-quartz gneiss

The rock is medium-grained to fine-grained and of granitic composition. In hand specimen, fine light and dark laminations, which are gently and isoclinally folded, give the rock a distinctive structure. The moderate microstructure is imported by foliated mica, fine crystal aggregates of epidote and feldspar, the dimensional orientation of part of the quartz, and linear concentrations of opaques.

The texture of the rock is unusual, and the feldspar grains are commonly surrounded by smaller feldspar grains, epidote, and mica which often coalesce to form laminae. The structure is thought to be due to stresses which caused recrystallization or granulation, or both, at crystal margins. A number of deformed feldspar crystals are also present. The epidote and mica have crystallized during the deformation of the rock. The rock is not as intensely deformed as others of the traverse, but is still thought to have been synchronously altered.

The mineralogical composition is estimated to be: opaques, 4 percent; mica plus epidote, 11 percent; quartz, 30 percent; and alkali feldspar, 55 percent. A little zircon is also present. The feldspar appears to be microcline and/or orthoclase. Weathering has produced some secondary chlorite and sericite.

Mount Laughlen Traverse

In specimen AS426 of the Heavitree Quartzite the form of the sedimentary quartz grains has been preserved, and some feldspar was probably present. In specimen AS426 the degree of recrystallization is less than in other specimens of the Heavitree Quartzite examined.

The unconformity with the Arunta Complex and the attitude of the Heavitree Quartzite are important field data. Two metamorphic quartzites, lithologically similar to the Heavitree Quartzite, are interbedded with the amphibolitic and gneissic units in the Arunta Complex. The mineralogical composition and fabric of the Arunta quartzite (AS427) are almost identical with those of the more intensely recrystallized specimens of the Heavitree Quartzite. It will be shown later that the quartzite in the Arunta Complex cannot be differentiated from the Heavitree Quartzite. Specimen AS428, except for the amount and coarseness of muscovite, is also similar to certain specimens of the Upper Proterozoic quartzite.

Heavitree Quartzite: AS426: Quartzite

The original quartz arenite has been partly recrystallized and individual grains are cemented by fine-grained quartz and sericite. Much of the fine quartz and sericite are dimensionally oriented, and some intergranular secondary quartz of coarser grainsize is also oriented. The oriented elements are roughly parallel. While many of the quartz grains still retain their rounded sedimentary outlines, others are broken and sheared. The shearing took place during the recrystallization of the rock.

Aggregates of sericite, quartz, and kaolinite(?), which sometimes retain the form of the original grains, are believed to represent sedimentary grains of feldspar. Accessories observed were opaques and tourmaline.

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

Arunta Complex: AS427: Muscovite-quartz schist

The rock is medium-grained to fine-grained and has a well-developed microstructure. The microstructure is formed by laminae of quartz and sericite, foliated muscovite and sericite, and the dimensional orientation of part of the quartz. The sericite is often intergrown with quartz crystals normal to the grain boundaries. Fine dust-like grains of opaques are present in the muscovite aggregates. The original quartz has been completely recrystallized.

Accessories are abundant opaques and zircon, and rare sphene.

Arunta Complex: AS428: Mica-quartz schist

The rock is medium-grained to coarse-grained and has a well-developed microstructure formed by laminae of quartz and muscovite, foliated muscovite, and dimensional orientation of the quartz. The mineralogical composition is similar to specimen AS427 but the rock is coarser in grain. Fine disseminated opaques are present in some muscovite aggregates, and a little zircon also occurs.

Georgina Gap Traverse

The petrographic data substantiate the field observations that the rocks are generally deformed and in several instances rather intensely altered. They also indicate that specimen AS433 is a carbonate unit of the Arunta Complex and that specimen AS431 is from the Bitter Springs Formation.

The foliated nature of the Heavitree Quartzite indicates that it was subject to intense shearing stresses during its crystallization. The intensity of the foliation is similar to that in specimen Hg450, which was recrystallized during low-angle faulting.

Arunta Complex(?): AS429: Chlorite-muscovite-quartz-alkali feldspar rock

The rock is coarse-grained, and appears to have been recrystallized or deformed. It is formed of aggregates of alkali feldspar and altered feldspar crystals separated by aggregates of quartz in association with chlorite. The alkali feldspar is altered along fractures and the borders of the grains. Some feldspar grains have been altered to reticulate and irregular aggregates of sericite.

The estimated mineralogical composition is: chlorite, 10 percent; alkali feldspar, 15 percent; quartz, 30 percent; and altered plagioclase and alkali feldspar, 45 percent. The accessories generally occur in the chlorite aggregates and include abundant zircon and apatite. Goethite(?) also occurs in association with chlorite.

Arunta Complex: AS430: Breccia

The rock appears to have been recrystallized during or after brecciation. The large 'fragments' are composed of a matrix of medium-grained 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 scattered patchy bodies of iron hydroxide(?). Coarser aggregates of quartz are also present. Veins of quartz and calcite transgress both the fragments and matrix. The accessories include apatite, zircon, and opaques.

Bitter Springs Formation: AS431: Dolomite

Most of the matrix is composed of medium-grained to fine-grained dolomite crystals in the form of extremely flattened rhombs. The crystals were probably elongated during plastic deformation of the rock. Muscovite occurs as scattered 'sheets' with random orientation, as crystals parallel to the oriented dolomite, and in transgressive bodies. At least part of the muscovite has been formed during the deformation of the dolomite. Lamellar bodies of quartz are oriented parallel to the general structure of the rock; others transgress the structure. In places, the quartz appears to have replaced earlier calcite near or at the margins of quartz bodies. Some of the dolomite is coarser and is stained by iron hydroxide(?). A few opaques were observed. The dolomite was identified by X-ray diffraction and is the only carbonate present.

Heavitree Quartzite: AS432: Sericite metaquartzite

The rock is medium-grained. It lies in the stratigraphic position of the Heavitree Quartzite, but is one of the most highly recrystallized quartzites examined. The rock is highly foliated (Pl. 6, fig. 4), and consists of interlocking crystals of quartz (with a length-to-width ratio of 9:1) and small amounts of sericite arranged parallel to the foliation. The accessory minerals consist of very small crystals of opaques, tourmaline, sphene, and zircon.

Arunta Complex: AS433: Marble

The rock is a medium-grained to fine-grained impure marble. The presence of fractured silicates and a nebulous linear structure suggest that the rock has been sheared after recrystallization. Plagioclase, quartz, tremolite, and muscovite form 10 to 15 percent of the specimen. The accessories include apatite and sphene.

Hale River Traverse 1, North of Ruby Gap Gorge

The specimens were collected from the Arunta Complex north of the Heavitree Quartzite. The Arunta Complex is highly cleaved near the contact with the Upper Proterozoic quartzite, where it overlies the younger unit.

The three specimens indicate that differential shearing (perhaps plastic and intense cataclastic deformation of earlier rock) has been important during the final phase of their development. The shearing and crystallization may 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, of diapthoresis, though the evidence is not conclusive.

Arunta Complex: IC435: Calc-silicate

The rock is medium-grained to fine-grained, and has a moderate microstructure imparted by crystallization foliation of part of the quartz, actinolite, and to a lesser degree epidote, and linear concentrations of quartz. Actinolite and epidote in equal quantities form about 75 percent of the rock and quartz forms 25 percent. A little sphene and opaques are also present.

Arunta Complex: IC436: Epidote-sericite-quartz-plagioclase gneiss

The rock is medium-grained to fine-grained and porphyroblastic. It is finely laminated, with dark sericite-epidote laminae alternating with quartz. Lenticular bodies of quartz are also present.

No alkali feldspar was observed. The composition of three plagioclase porphyroblasts was found to be An_{25}, An_{26}, and An_{31}. A little biotite is associated with the epidote. Plagioclase is slightly more abundant than quartz, and sericite and epidote comprise about 15 percent of the rock. The accessories include sphene and a few opaques. A single crystal of garnet was also noted.

The composition of the plagioclase and the general mineral assemblage indicate that the quartzo-feldspathic rock has been metamorphosed to the almandine-amphibolite facies (Turner & Verhoogen, 1960).

Arunta Complex: IC437: Sphene-quartz-epidote-actinolite amphibolite

The rock is medium-grained to fine-grained and porphyroblastic. It has a well-developed microstructure imparted by the dimensional orientation of the quartz, actinolite, and, to a lesser degree, epidote, and linear concentrations of quartz, sphene, and actinolite. Epidote and actinolite constitute about 55 percent of the rock, quartz about 40 percent, and sphene about 5 percent. Several opaque grains and one crystal of plagioclase(?) were observed. The large grains of amphibole appear to be porphyroclasts, and it appears that the amphibolite has been cataclastically deformed and recrystallized.

Hale River Traverse 2, North of Ruby Gap Gorge

The metaquartzite (IC439) is considered to be one of those of the Arunta Complex; however, it can conceivably be the Heavitree Quartzite faulted into position within the gneisses of the Arunta Complex.

The gneisses, intervening quartzite, and the Upper Proterozoic quartzite have a conformable rock cleavage. The bands and lenses of quartz in the gneisses are also conformable. It is therefore proposed that they were formed during the same period of deformation and recrystallization of the older Precambrian and Upper Proterozoic rocks.

The gneisses are remarkably similar in mineralogical composition and fabric to several specimens from the White Range traverse.

12487/66—6

Arunta Complex: IC438: Biotite-epidote-sericite-quartz-plagioclase gneiss

The rock is finely laminated, porphyroblastic, and medium-grained to fine-grained. It has a moderate to conspicuous microstructure imparted by laminae of quartz and of sericite; composite laminae of plagioclase, quartz, sericite, and epidote; and the foliation of part of the mica. The poikiloblastic plagioclase contains numerous inclusions of sericite and epidote, and is sometimes deformed.

The composition of two plagioclase porphyroblasts was found to be An_{30} and An_{32}. No alkali feldspar was observed. Accessories are sphene and apatite.

Arunta Complex: IC439: Sericite quartzite

The rock has a moderate to conspicuous microstructure imparted by fine foliated sericite and a dimensional orientation of the quartz. The quartz crystals are subhedral or xenomorphic. Sericite is present as inclusions in the quartz and at the margins of the grains. Accessories include tourmaline and zircon. Quartz has an average grainsize of 0.063 mm, but some of the accessories range up to about 0.10 mm, which suggests that the original quartz was coarser in grain.

Arunta Complex: AS440: Biotite-epidote-sericite-quartz-plagioclase gneiss

The rock is medium-grained to fine-grained and has a moderate microstructure imparted by lenticular bodies of quartz and linear concentrations of epidote and biotite. The quartz lenticles separate aggregates of epidote, sericite, and biotite in a framework of plagioclase. The linear epidote aggregates transgress the plagioclase bodies and often border them, and the biotite associated with the epidote is generally foliated. The fabric of the rock was probably formed by the metamorphism and differential shearing of an older coarse-grained granitoid rock.

Alkali feldspar was not observed. The anorthite content of two plagioclase grains was determined as An_{35} and An_{34}. Accessories include apatite, sphene, and zircon.

Arunta Complex: IC440A: Epidote-sericite-microcline-quartz-plagioclase gneiss

The rock is medium-grained and porphyroblastic. Plagioclase is poikiloblastic with inclusions of sericite and epidote(?). The estimated mineral content is: epidote plus sericite, 10 percent; microcline, 20 percent; quartz, 30 percent; and plagioclase, 40 percent. A few scattered grains of sphene and opaques were noted.

The anorthite content of two plagioclase grains was determined as An_{31} and An_{33}. Much of the plagioclase is deformed, and the microcline has also been deformed. A few of the plagioclase grains have a relatively clear marginal zone, which is considered to be a second generation of plagioclase.

Hale River Traverse 3, North of Ruby Gap Gorge

Examination of the transitional beds between the Heavitree Quartzite and Bitter Springs Formation(?) provides evidence that they have been metamorphosed under low-grade conditions. The beds are involved in large-scale recumbent overfolds (D. Forman, pers. comm.) and thus the deformation has probably caused the metamorphic crystallization.

Bitter Springs Formation(?) (Transitional Beds): IC441: Biotite-andesine-calcite-muscovite-quartz schist

The rock is medium-grained to fine-grained. Oriented elements of the fabric are foliated mica, laminae in which quartz, mica, or carbonate predominates, and the dimensional orientation of part of the calcite and quartz fraction. Shortening of the rock body is indicated by folding and shearing of the mica laminae (Pl. 7, fig. 1).

The estimated mineral content of the rock is: biotite, 7 percent; andesine(?), 10 percent; calcite(?), 15 percent; muscovite, 18 percent; and quartz, 50 percent. Accessories are zircon and apatite.

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

Illogwa Creek Traverse 1

The Heavitree Quartzite is underlain by a carbonate rock and quartzite of the Arunta Complex here. The Arunta Complex cannot be shown to have been retrogressively altered because the metasediments are not suitable for detecting the degree of diapthoresis which has probably affected the sequence.

The banded iron facies rock may prove to be a useful marker in the Arunta Complex.

Arunta Complex: IC443: Calcite-actinolite-epidote-quartz rock

The rock is medium-grained to fine-grained and has a moderate microstructure imparted by linear concentrations of quartz and epidote, and occasional dimensional orientation of quartz. Quartz and epidote are the major constituents, with subordinate actinolite and minor calcite. Sphene forms about 4 percent of the rock; opaques are common, and zircon is rare.

There is no evidence of retrogressive metamorphism.

Arunta Complex: IC443A: Magnetite-apatite metaquartzite

Sedimentary bedding is shown by linear concentrations of apatite and opaques. The presence of isoclinal microfolds indicates that the rock was folded during metamorphism.

It is estimated that the minerals are present in the following proportions: opaques, 10 percent; apatite, 15 percent; and quartz, 64 percent. Minor constituents include epidote and little chlorite.

The mineral association is typical of a banded iron formation, but the phosphate content is higher than normal and magnetite less abundant.

Illogwa Creek Traverse 2

Heavitree Quartzite: IC444: Sericite metaquartzite

Foliated sericite, linear concentrations of quartz and sericite, and the crystallization foliation of the quartz give the rock a moderate microstructure. Two planes of mineral orientation were observed in places, and the orientations probably resulted from two components of movement during plastic deformation and metamorphism of the arenite.

Some of the quartz grains have a dimensional orientation affected by both components of movement. Sericite forms about 15 percent of the rock, and quartz about 85 percent. Accessories include sphene, opaques, and tourmaline.

Arunta Complex: IC445: Marble

The impure marble is medium-grained to fine-grained; calcite forms about 70 percent of the rock. Other minerals include sphene, quartz, actinolite-tremolite, feldspar, and epidote. The mineral assemblage appears to be stable, and epidote is the only mineral which has been deformed.

The feldspars are microcline and oligoclase. The calcite was identified by X-ray diffraction and no dolomite is present.

Illogwa Creek Traverse 3

Heavitree Quartzite: IC446: Quartzite

The rock is similar to specimens from other localities, but the grainsize is less regular and not all the sericite is oriented. The microstructure is imparted by crystallization foliation of part of the quartz and wisp-like aggregates of sericite, which are also responsible for the S_1 structure observable in the field.

Arunta Complex: IC447: Biotite-epidote-quartz-plagioclase gneiss

The rock is fine-grained to medium-grained. The linear concentrations of quartz, biotite, and epidote; foliation of part of the biotite; and the crystallization foliation of part of the quartz give the rock a moderate microstructure. Coarse plagioclase crystals and mosaics form a general framework in which epidote and biotite are enclosed. The minerals are not preferentially oriented. Plagioclase ($An_{30 \pm 5}$), generally untwinned, is the main constituent, with subordinate quartz and epidote. Biotite forms about 10 percent of the rock. Sphene forms about 2 percent of the specimen and a few grains of zircon were observed.

Chlorite is associated with much of the biotite, and was probably formed by weathering.

The rock appears to have formed under amphibolite facies conditions.

Aremra Creek

Arunta Complex: IC448: Biotite-epidote-andesine-amphibole hornfels

The rock is coarse-grained to fine-grained. Crystals of various sizes of amphibole, biotite, and abundant epidote are included in the plagioclase. The plagioclase is fresh and unaltered. The mineral assemblage is metamorphic and the minerals appear to have crystallized simultaneously. Amphibole forms about 50 percent of the rock; of the other constituents, plagioclase is abundant, biotite and epidote less so, and there is a little quartz. The accessories include abundant apatite, and rare opaques and zircon.

The composition of two plagioclase crystals was found to be An_{49} and An_{48}.

Specimen Locality South of Ruby Gap Gorge

It is concluded that : (i) the 'shaly' interbeds in the Upper Proterozoic carbonate have been metamorphosed as they contain metamorphic sericite and stilpnomelane; (ii) the slaty cleavage has developed at a high angle to the bedding, but in some places the bedding has been mechanically rotated parallel to the foliation of the mica; and (iii) the predominant carbonate is dolomite rather than limestone.

Bitter Springs Formation: AS449A: Slate

The rock has a cleavage and excellent microstructure imparted by foliated mica and elongated quartz grains that form S_1. The sedimentary bedding (S_o) consists of concentrations of angular quartz with feldspar and some muscovite flakes. S_1 and S_o intersect at an angle (Pl. 8, fig. 1). S_o in some cases has been folded during the development of S_1, by affine deformation.

The rock is mainly composed of sericite, with some stilpnomelane(?). The feldspar appears to be microcline and is found in the S_o laminae with quartz and muscovite. Accessories are opaques, sphene, and zircon.

Bitter Springs Formation: AS449B: Dolomite

The recrystallized dolomite is medium-grained to fine-grained. The recrystallization of the carbonate occurred during shearing of the rock and most of the carbonate has a dimensional orientation. Chalcedony occurs in some fractures which transgress the foliation. A few aggregates of quartz and scattered flakes of muscovite are present. Goethite(?) occurs as irregular aggregates and linear concentrations parallel to the foliation.

The carbonate is primarily dolomite and was identified by X-ray diffraction.

Ormiston Gorge

Heavitree Quartzite: Hg450A: Quartzite

The quartzite is highly sheared and partly recrystallized (Pl. 8, fig. 2). A number of fractured and partly recrystallized granules are present, and sericite is particularly abundant. It appears that the original arenite was argillaceous and that it contained granules and small pebbles.

The rock probably weathers more readily because of the size of the quartz grains, and the greater proportion of mica, but the deep weathering is probably mainly due to the intense shearing.

Traverse 1 North of Ormiston Gorge

The Arunta Complex overlies the younger Heavitree Quartzite, and they have a conformable rock cleavage near their contact. The rocks of the Arunta Complex become progressively less cleaved to the north, and at the northern end of the traverse only a few small fractures in the gneiss, filled with epidote and quartz, are evident. Cataclasis and recrystallization also decrease to the north. The deformation and recrystallization are thought to have occurred during low-angle faulting that resulted in the dynamic metamorphism of the Upper Proterozoic rocks and the rocks of the Arunta Complex.

12487/66—7

Heavitree Quartzite: Hg450: Sericite metaquartzite

The rock is fine-grained to medium-grained with a dominant structure, S_1, and a secondary structure, S_1'. S_1' appears to have developed in incipient oblique shears by recrystallization of the quartz into fine unoriented grains (Pl. 8, fig. 3). The dominant structure S_1 is formed by foliated quartz and augen and lenses of quartz. Sericite is only a minor constituent but is also dimensionally oriented. Accessories include tourmaline, zircon, and sphene.

This is one of the most highly foliated examples of the Upper Proterozoic quartzite described.

Arunta Complex: Hg451A: Mylonite

Specimen Hg451A was taken from within a foot of the underlying highly foliated Proterozoic quartzite. The mylonite is partly recrystallized. The porphyroclasts of quartz and feldspar are medium-sized and not as abundant as those in specimen Hg451. Lenticular bodies of quartz are common. Newly crystallized minerals are quartz, epidote, biotite, and sericite. Sericite is more abundant and epidote and biotite less abundant than in the less intensely foliated mylonite Hg451.

Arunta Complex: Hg451: Mylonite

The mylonite is partly recrystallized and has a conspicuous microstructure (Pl. 8, fig. 4) parallel to the rock cleavage. 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 relicts of the original rock preserved.

Arunta Complex: Hg452 and Hg453: Cataclasites

Both the cataclasites have been partly recrystallized (Pl. 9, figs 1, 2). They have been formed by deformation of earlier rocks composed of plagioclase and alkali feldspar, but cataclasis has not been as intense as in the mylonites. The feldspar porphyroclasts are enclosed in a matrix of quartz, and quartz is also present in linear bodies or lenticular aggregates. Linear or lenticular bodies of biotite and epidote are present, especially in specimen Hg453 (Pl. 9, fig. 2). The plagioclase of both rocks has been partly recrystallized to epidote and sericite. The minerals formed during recrystallization were biotite, sericite, epidote, and quartz. The alkali feldspar is generally perthitic and the perthite may have been formed by exsolution during the shearing and recrystallization.

A relatively undeformed crystal of plagioclase in specimen Hg453 was found to have an anorthite content of An_{33}, and a coarse deformed crystal was found to have an anorthite content of An_{27}.

Arunta Complex: Hg454: Plagioclase-quartz-microcline gneiss

The gneiss is partly recrystallized, coarse-grained to medium-grained, and adamellitic in composition. The microstructure was formed during the cataclasis and partial recrystallization. The cataclasis appears to have been accompanied by recrystallization with epidote and quartz filling the fractures. Sericite, biotite, and epidote occur in intergranular areas, and replacing plagioclase. Shearing, in contrast with the other gneisses, is confined to a few places.

The anorthite content of two plagioclase crystals was found to be An_{29} and An_{30}. The alkali feldspar is microcline. Accessories include apatite and zircon.

Sample Locality 1 North of Ormiston Gorge

The specimens were collected from a single locality as examples of the intermingled massive and gneissic felsic rocks. The granitic rocks are cut by dolerite dykes. The gneiss is probably older than the tonalite, and the petrography indicates that the last phase of crystallization in both types was granitization. The composition of the plagioclase is similar in both rock types.

Arunta Complex: Hg455: Epidote-biotite-quartz-plagioclase-microcline gneiss

Mildly foliated biotite and porphyroblasts of microcline are the main features of the rock's fabric. The mineralogical composition is estimated to be: mica plus epidote, 15 percent; quartz, 15 percent; plagioclase, 15 percent; and microcline, 45 percent. The accessories include sphene, apatite, and zircon. Most of the alkali feldspar is twinned microcline. The average composition of the older plagioclase is An_{26}. The latest plagioclase does not appear to have reached equilibrium as the anorthite content ranges from An_{23} to An_{33}.

The following 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 (Pl. 9, fig. 3); plagioclase crystals embayed by quartz; and plagioclase partly replaced by microcline. The earlier mineral assemblage is represented by relicts of plagioclase. The epidote, sericite, biotite, part of the microcline, and a small portion of the plagioclase appear to have formed during the final crystallization of the rock.

Arunta Complex: Hg456: Tonalite

The tonalite is equigranular and partly recrystallized. The estimated mineralogical composition is : mica and epidote, 8 percent; microcline, 2 percent; quartz, 35 percent; and plagioclase, 55 percent. The anorthite content of the two generations of plagioclase was determined as: older - An_{27}, An_{28}, and younger - An_{22} and An_{23}.

The rock has undergone a mild period of recrystallization, compared to specimen Hg455. The earlier plagioclase has been partly replaced by granular aggregates of biotite and epidote along the interstices, and sericite occurs as inclusions in the plagioclase. The older plagioclase crystals are rimmed by a later generation of clear plagioclase. Microcline also appears to have formed during the recrystallization.

Sample Locality 2 North of Ormiston Gorge

This granitic gneiss is interlayered with gneisses of varied felsic content, amphibolites, and granitoid rock dipping at a moderate angle to the west. The sequence is cut by dolerite dykes.

The gneiss has been cataclastically deformed and partly recrystallized similarly to the Arunta rocks in the Ormiston Gorge area.

Arunta Complex: Hg457: Sericite-epidote-biotite-plagioclase-quartz-microcline gneiss

The gneiss is porphyroblastic and granitic in composition. The moderate microstructure is imparted by foliated biotite and linear concentrations of biotite and quartz. The estimated mineralogical composition is: mica plus epidote, 10 percent; plagioclase, 20 percent; quartz, 25 percent; and alkali feldspar, 45 percent. The accessories include zircon, apatite, and opaques. The composition of one plagioclase crystal was found to be An_{27}. The alkali feldspar appears to be microcline.

Two periods of deformation can be recognized. The recrystallization occurred during the earlier deformation and the structure of the rock was probably evolved at the same time. Most of the biotite, epidote, and sericite were probably formed during this period and the feldspar cataclastically deformed.

During the later deformation the feldspar was again deformed, but no recrystallization is apparent. This period of mild cataclasis was probably accomplished by minor faulting.

Traverse 2 North of Ormiston Gorge

Specimen Hg458 is a massive granite which becomes more gneissic to the west. In places the massive granitic rocks contain conformably oriented porphyroblasts. Specimen Hg459 is one of the less abundant interlayered amphibolites.

All three rocks have been cataclastically deformed and partly recrystallized. The epidote, sericite, biotite, and quartz crystallized after or during the deformation of the rocks.

Arunta Complex: Hg458: Granite

The granite is coarse-grained to medium-grained, cataclastically altered, and partly recrystallized. The rock is almost a cataclasite in the degree of brecciation. The deformation of the rock was accompanied by the crystallization of epidote, biotite, and sericite. Shears in the feldspar contain mica and epidote. The plagioclase is poikiloblastic with inclusions of epidote, biotite, and sericite. Mica, especially biotite, is found along the fractures. Most of the quartz has been recrystallized during the final stage.

The estimated mineralogical composition is: mica plus epidote, 15 percent; quartz, 15 percent; plagioclase, 20 percent; and alkali feldspar, 50 percent. The accessory minerals are zircon, apatite, and opaques. Much of the alkali feldspar is twinned microcline. One less deformed plagioclase grain was found to have an anorthite content of An_{26}.

Arunta Complex: Hg459: Sericite-epidote-biotite-quartz-plagioclase gneiss

The gneiss is coarse-grained to medium-grained and tonalitic in composition. The microstructure is imparted by planar concentrations of moderately foliated biotite. Recrystallization and deformation are not as intense as in specimens from the Ormiston Gorge traverses. Epidote, sericite, and perhaps a second generation of biotite have crystallized during the deformation.

The estimated mineralogical composition is: mica plus epidote, 20 percent; quartz, 25 percent; and plagioclase, 55 percent. The accessories are spinel, apatite, and opaques. A single grain of plagioclase was found to have an anorthite content of An_{27}.

Arunta Complex: Hg460: Amphibolite

The amphibolite is medium-grained to coarse-grained, deformed, and partly recrystallized. Minerals present before deformation and recrystallization were apatite, plagioclase, and hornblende; and probably quartz and sphene also. Biotite, epidote, sericite, and some of the sphene and quartz have crystallized during or after deformation. Biotite is mainly found in fractures (Pl. 9, fig. 4), but the epidote and sericite commonly replace the earlier minerals such as plagioclase.

The estimated mineralogical composition is: mica plus epidote, 9 percent; quartz, 10 percent; plagioclase, 30 percent; and amphibole, 50 percent. The accessories observed are apatite, opaques, and sphene. No alkali feldspar is present. A single grain of plagioclase was found to have an anorthite content of An_{35}.

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PLATE 1

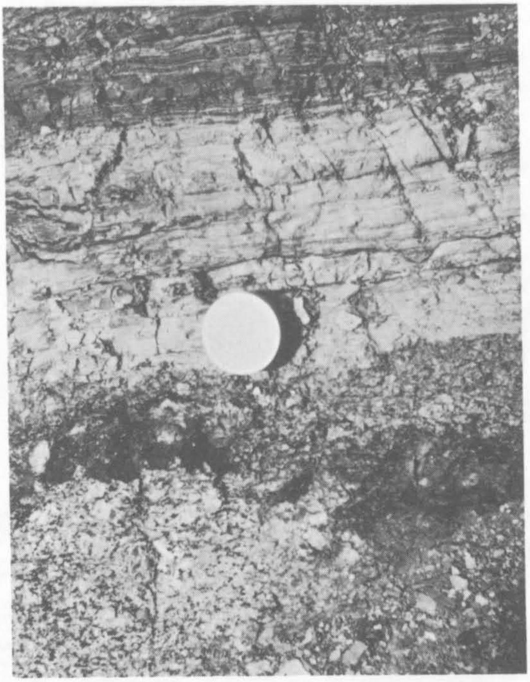


Fig. 1. Unconformity between basal siltstone of the Heavitree Quartzite and gneiss of the Arunta Complex at Heavitree Gap

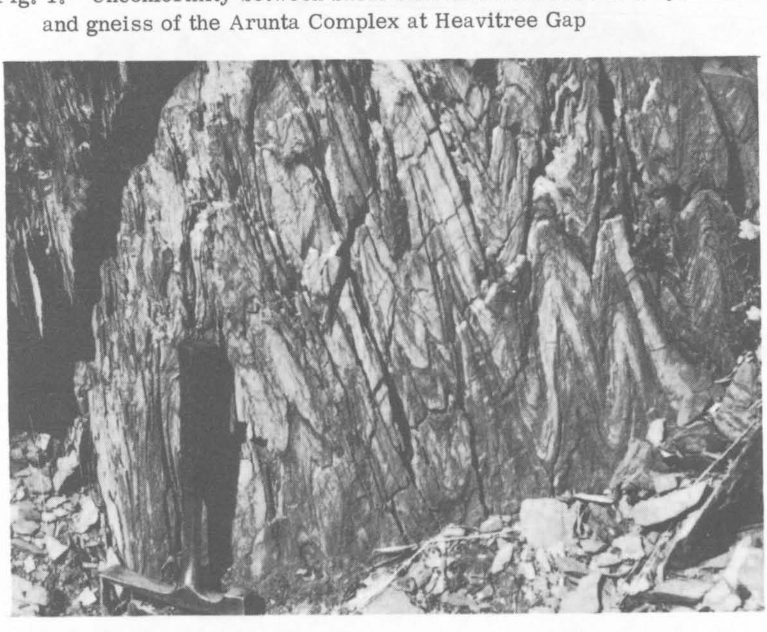


Fig. 2. Isoclinal folds (A-F_1) in Precambrian quartzite of the Chewings Range at Ellery Creek

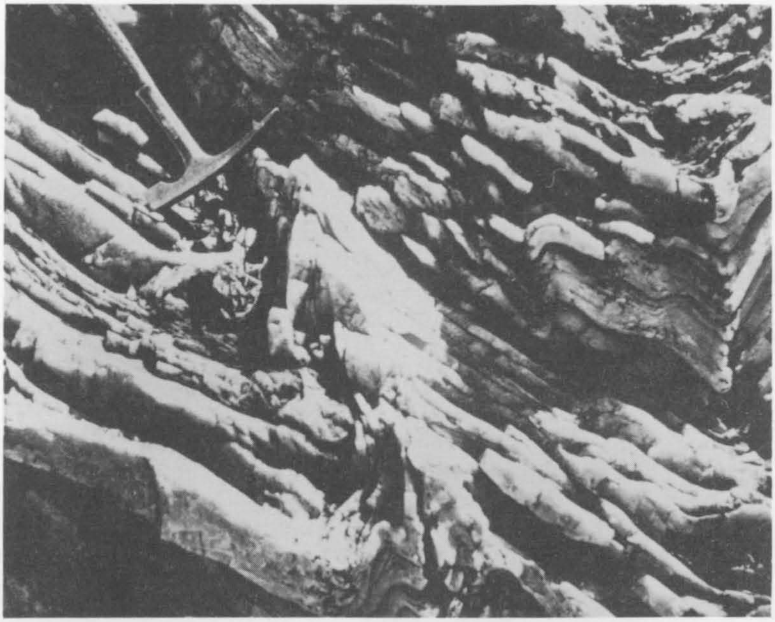


Fig. 1. Chevron folds with steeply dipping east-west-trending axes ($A-F_2$) in Precambrian quartzite of the Chewings Range at Ellery Creek

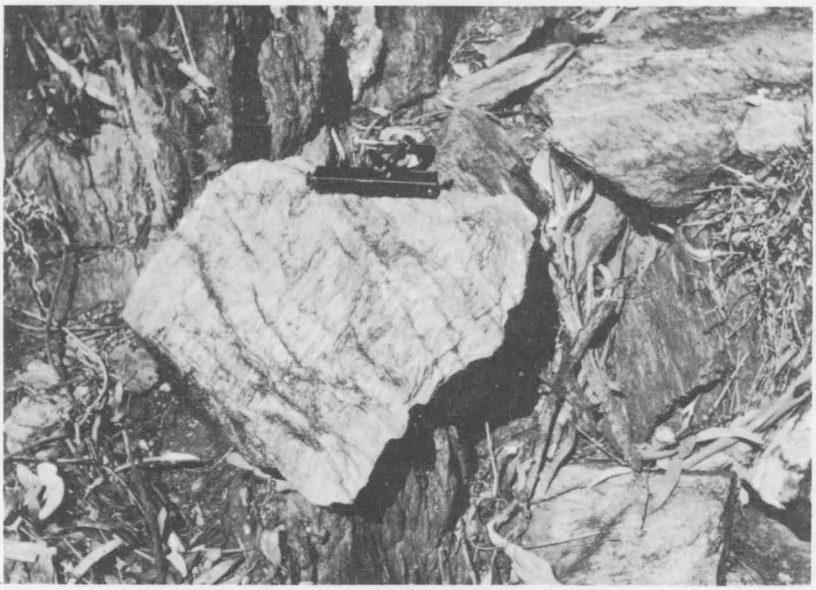


Fig. 2. Chevron folds ($A-F_2$) in mica-quartz schist of the Chewings Range, 1 mile east of Ellery Creek

PLATE 3

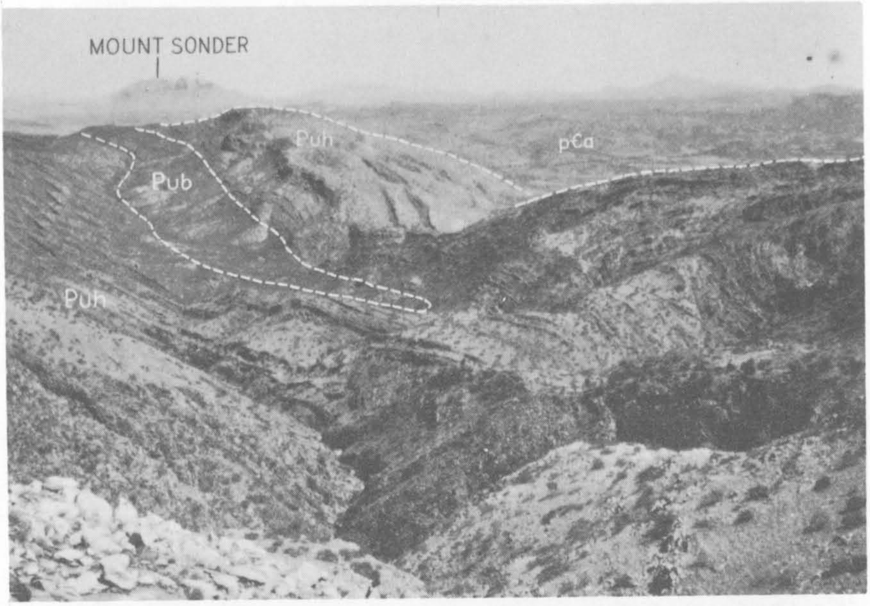


Fig. 1. Synclinal core of the Ormiston Nappe, looking west along the Chewings Range from 8 miles east-north-east of Ormiston Gorge

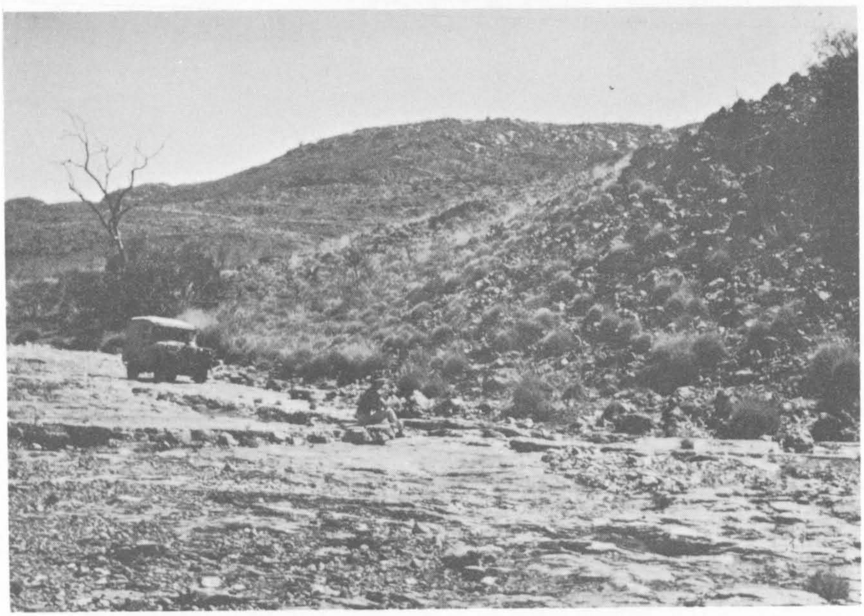


Fig. 2. Heavitree Quartzite in the Ormiston Nappe, dipping under hills composed of schist and gneiss of the Arunta Complex

PLATE 4

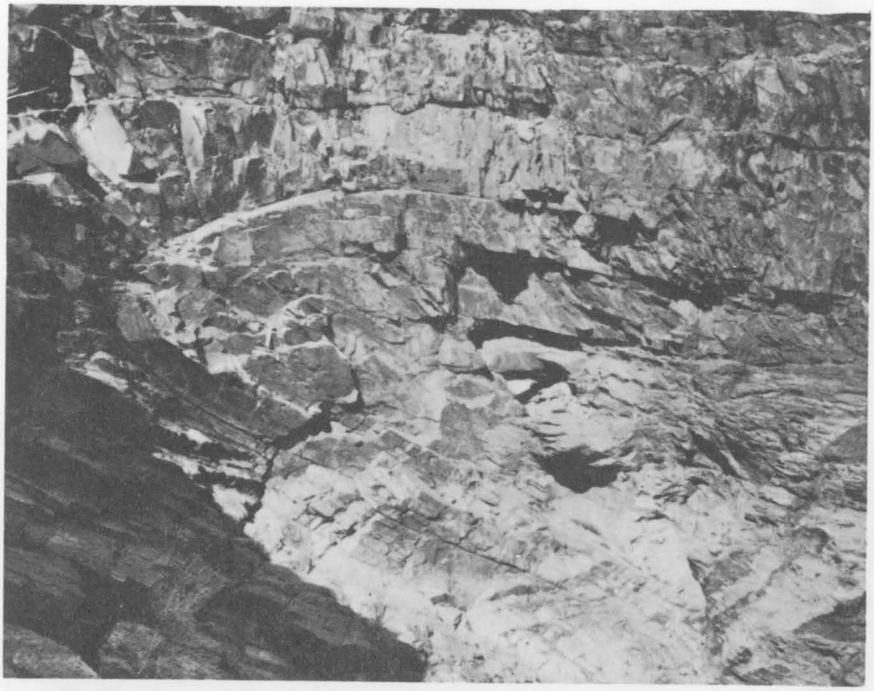


Fig. 1. Recumbent fold in the Heavitree Quartzite, 8 miles south of Haast Bluff No. 1

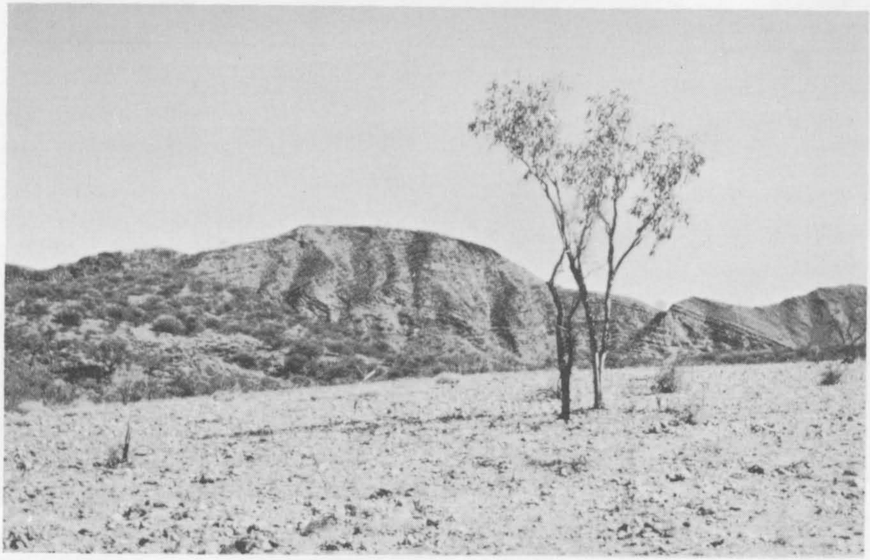


Fig. 2. Recumbent fold in the Bitter Springs Formation near Bitter Springs Gorge

PLATE 5

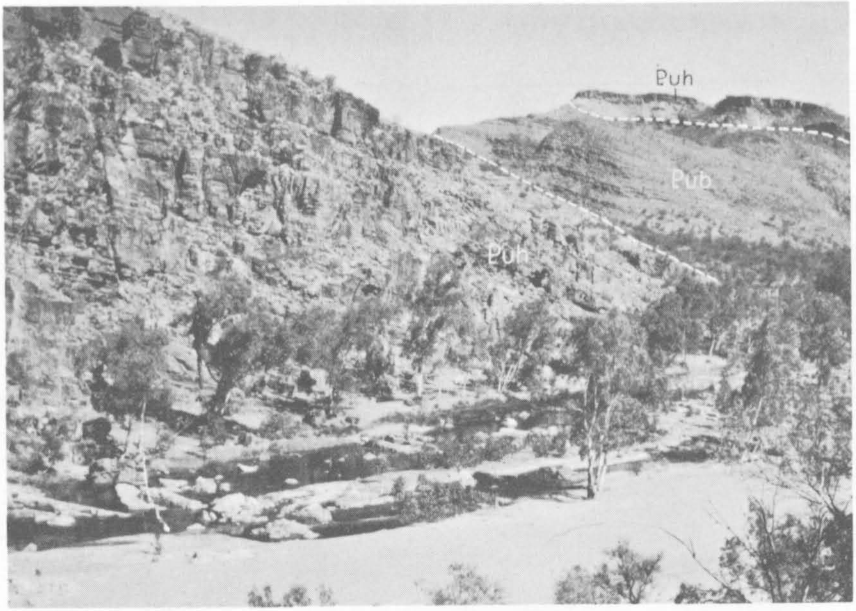


Fig. 1. Repetition of the Heavitree Quartzite in the Winnecke Nappe, 2 miles south-south-west of Ruby Gap Gorge

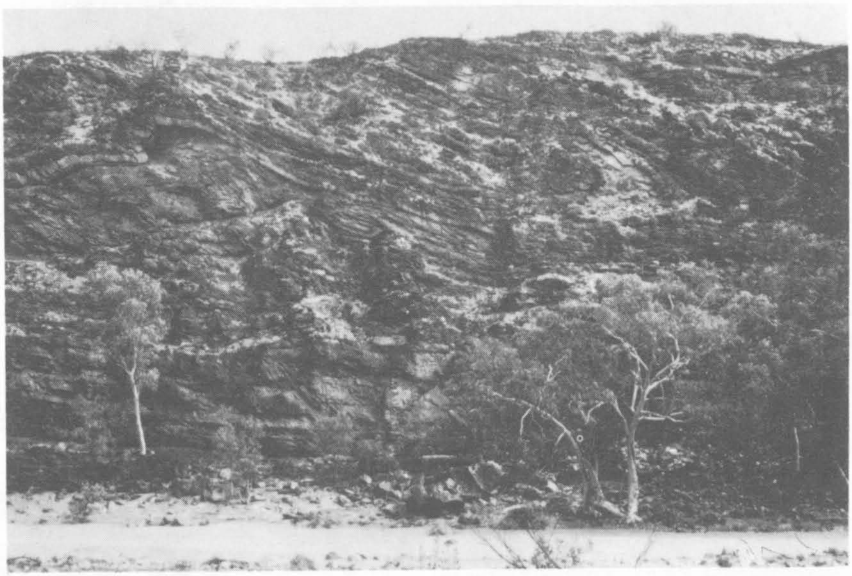


Fig. 2. Recumbent folds in carbonate rocks of the Bitter Springs Formation, Hale River, 2 miles south-south-west of Ruby Gap Gorge

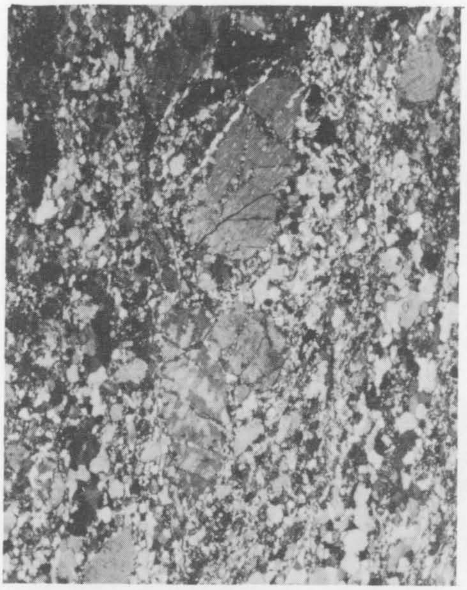


Fig. 1 Late sericite transgressing earlier feldspar, Arunta Complex. Photomicrograph

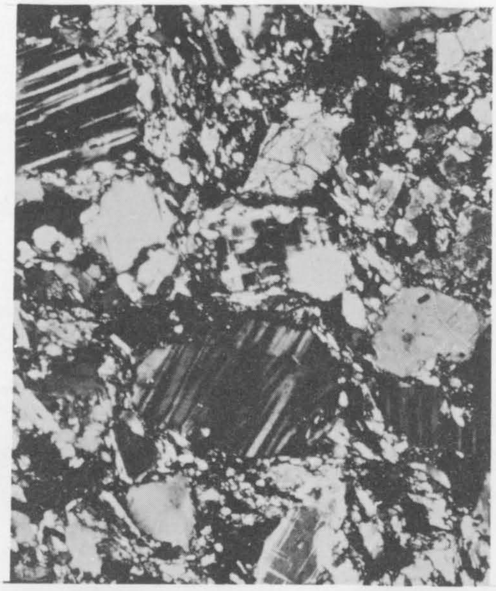


Fig. 2. Deformed feldspar, Arunta Complex. Photomicrograph

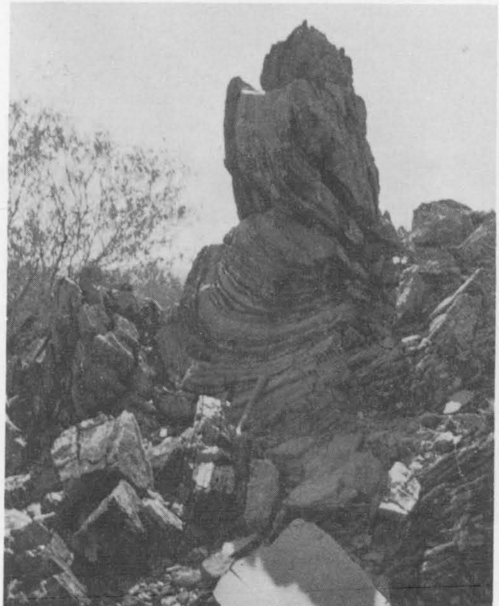


Fig. 3. Fold in the Arunta Complex from which Specimen Plate 6, fig. 2 was taken

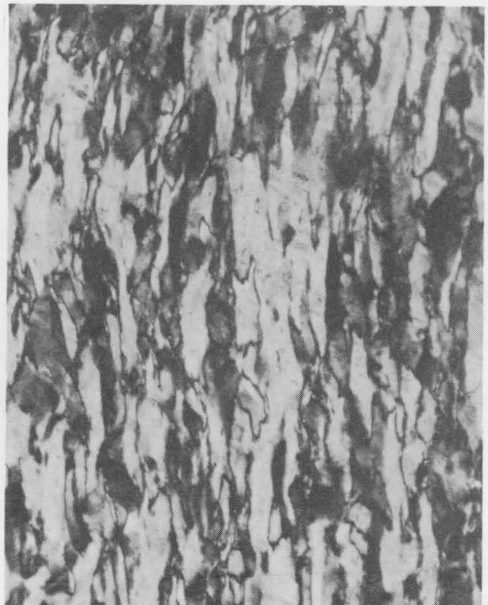


Fig. 4. Completely recrystallized, foliated Heavitree Quartzite. Photomicrograph

Fig. 1. Shortening by micro-shear overfolds, Bitter Springs Formation transition beds. Photomicrograph

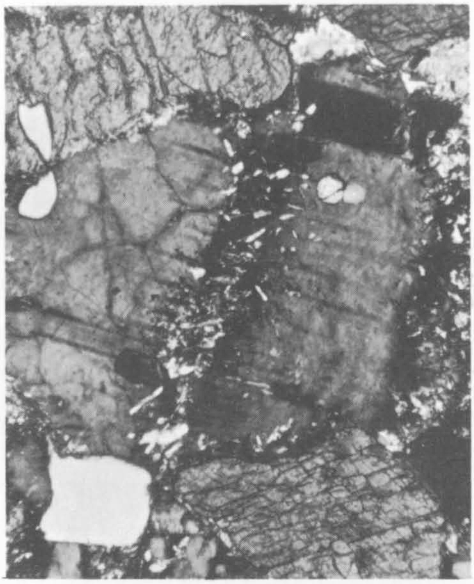


Fig. 2. Sericite and epidote crystallized in an incipient shear in plagioclase, Arunta Complex. Photomicrograph

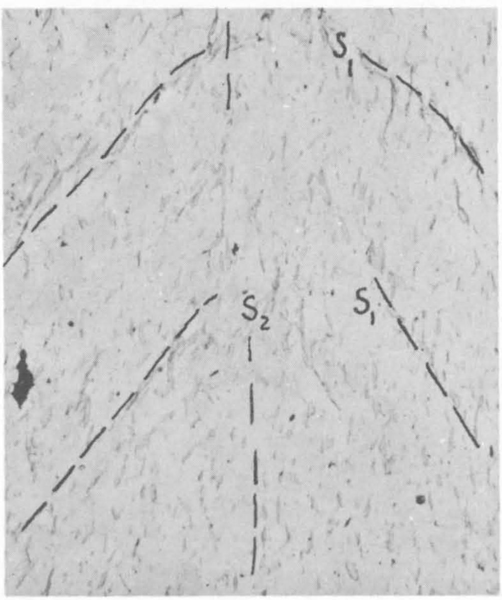


Fig. 3. S_1 folded and S_2 developed parallel to the axial plane of the S_1 fold, Heavitree Quartzite, Photomicrograph

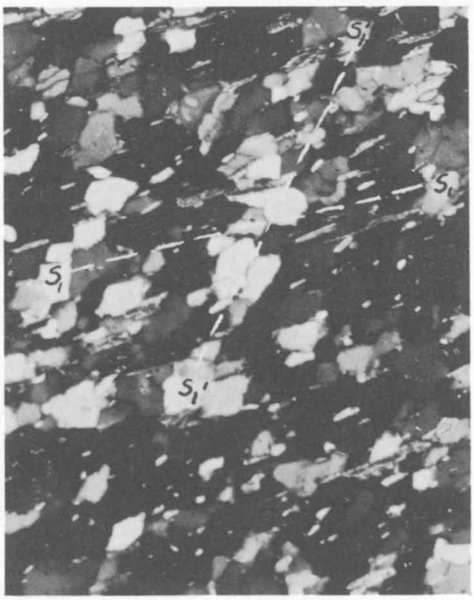


Fig. 4. Concurrent development of oriented minerals in Heavitree Quartzite. Photomicrograph

PLATE 8

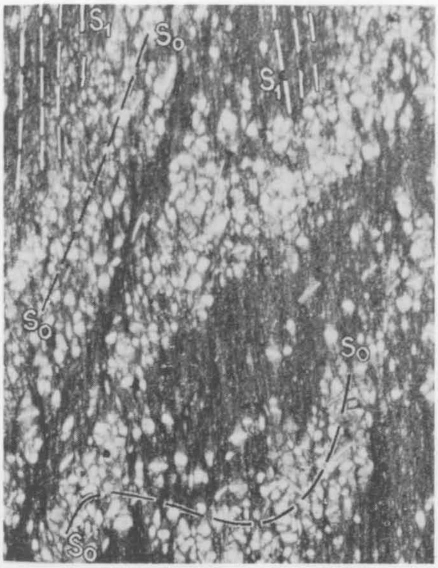


Fig. 1. Affine deformation of S_0 by movement on one set of parallel shear planes, Bitter Springs Formation. Photomicrograph

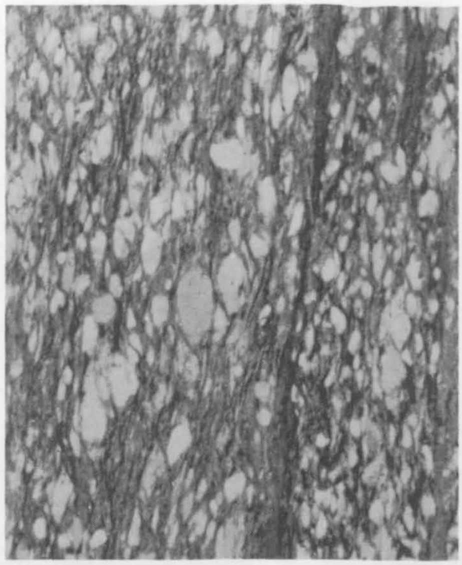


Fig. 2. Sheared and partially recrystallized Heavitree Quartzite. Photomicrograph

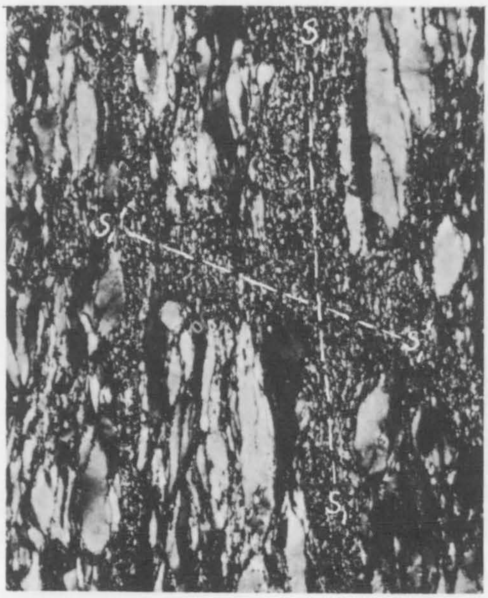


Fig. 3. Completely recrystallized Heavitree Quartzite, with occasional S_1 structure. Photomicrograph

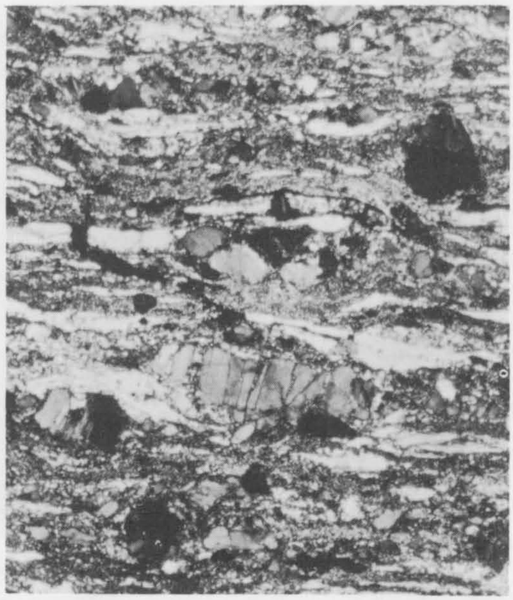


Fig. 4. Recrystallized mylonite, Arunta Complex. Photomicrograph

PLATE 9

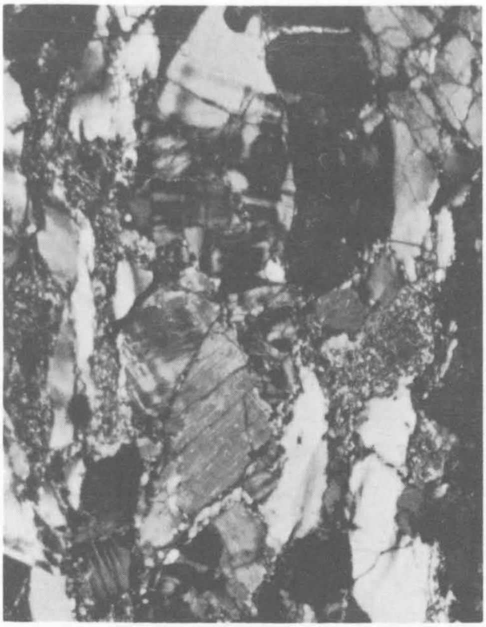


Fig. 1. Partially recrystallized cataclasite, Arunta Complex. Photomicrograph

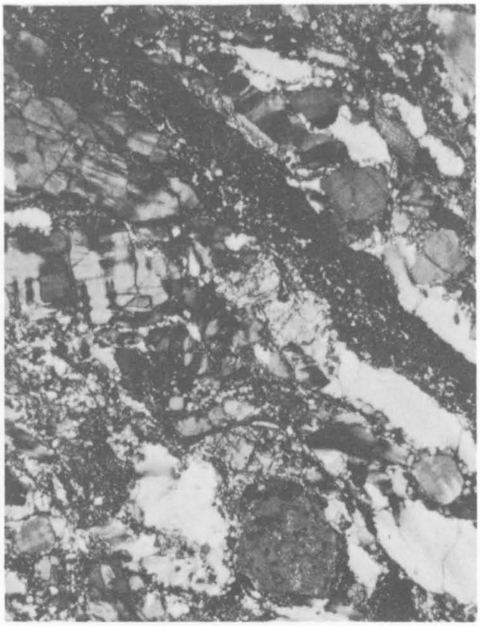


Fig. 2. Cataclasite with mylomitic lenses, Arunta Complex. Photomicrograph

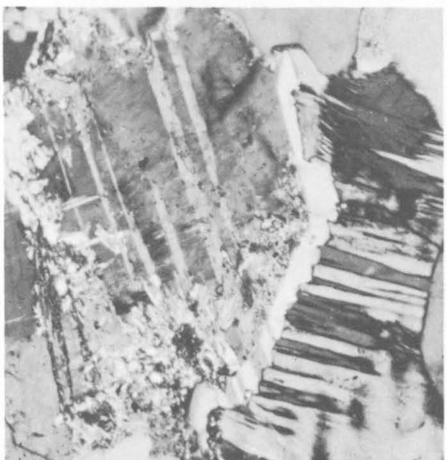


Fig. 3. Late pseudomorphic zone of plagioclase (An22) which has 'replaced' earlier plagioclase (An28), Arunta Complex. Photomicrograph

Fig. 4. Biotite in fractures transgressing earlier hornblende, Arunta Complex. Photomicrograph

PRELIMINARY EDITION, 1966

PLATE 10

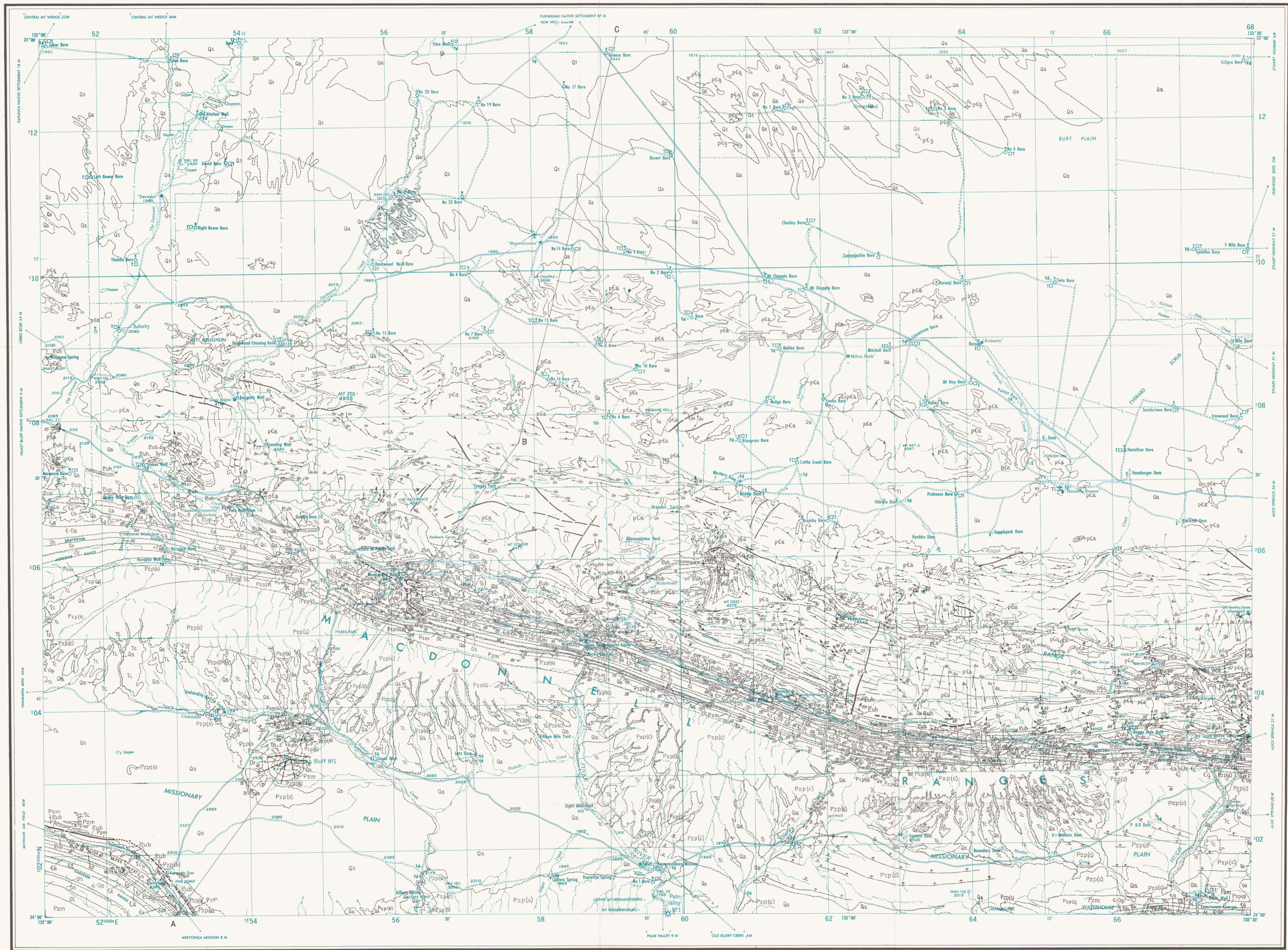
SUBJECT TO AMENDMENT

AUSTRALIA 1:250,000

HERMANNSBURG

NORTHERN TERRITORY

SHEET SF 53-13



Reference

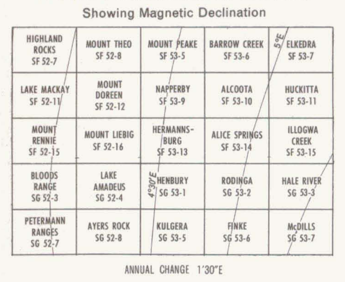
Era	Period	Unit	Symbol	Lithology
CAINOZOIC	QUATERNARY	Undifferentiated	Q	Alluvium, sand, travertine, conglomerate (section only)
			Qa	Alluvium
			Qs	Aeolian sand
			Qt	Travertine, kunkar
	TERTIARY		Tc	Conglomerate
			Tl	Chalcedonic limestone
			Ta	Laterite, ferricrete
			Ts	Sandstone, conglomeratic 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	€-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	€-Op	Fossiliferous sandstone, silty sandstone
	CAMBRIAN	Pertaoorrta Group: Undifferentiated	€p	Sandstone, siltstone, shale, dolomite, limestone
		Goyder Formation	€g	Sandstone, calcareous sandstone
		Jay Creek Limestone	€j	Limestone, shale, dolomite
		Hugh River Shale	€h	Shale, limestone, siltstone
		Arumbera Sandstone	€a	Silty sandstone, siltstone
		Petermann Sandstone	€e	Red-brown sandstone, silty sandstone
		Deception Formation	€d	Red-brown siltstone, shale
		Illara Sandstone	€i	Red-brown sandstone, silty sandstone
		Tempe Formation	€t	Siltstone, calcareous sandstone, fossiliferous glauconitic limestone
		Eninta Sandstone	€n	Red-brown sandstone, silty sandstone, siltstone
PRECAMBRIAN	UPPER PROTEROZOIC	Pertatataka Formation	Pup	Siltstone, sandstone, limestone
		Areyonga Formation	Pua	Calcareous sandstone, tillitic siltstone, conglomerate
		Bitter Springs Formation	Pub	Dolomitic limestone, shale, siltstone
		Heavitree Quartzite	Puh	Quartzite, sandstone
		Arunta Complex	p€a	Gneiss, schistose gneiss, granite, gneissic granite, schist, amphibolite, sericite-quartz schist, meta-quartzite, pegmatite
			p€g	Granite
			p€q	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; do—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 published by the Bureau of Mineral Resources, Geology and Geophysics, Department of National Development, Issued under the authority of the Hon. David Fairbairn, Minister for 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



Scale 1:250,000

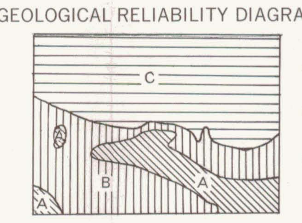
5 0 5 10 15 MILES

5 0 5 10 15 20 25 KILOMETRES

Section

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

GEOLOGICAL RELIABILITY DIAGRAM



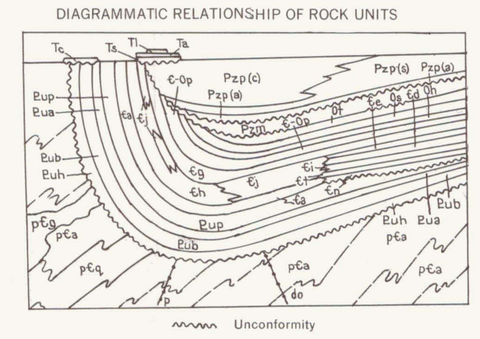
A Detailed Mapping

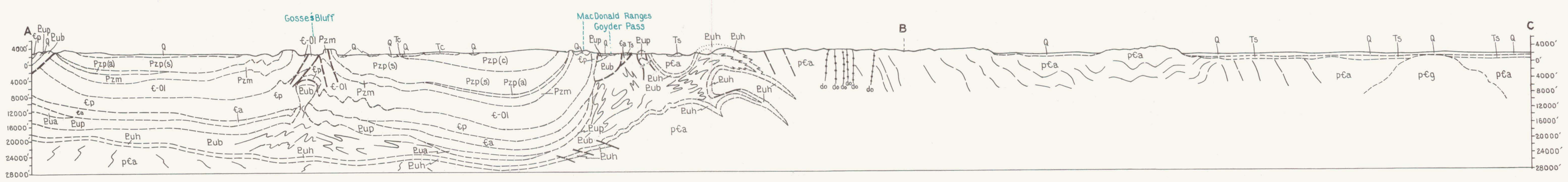
B Detailed reconnaissance, general reconnaissance, reconnaissance and air-photo interpretation.

C Air-photo interpretation

Geology, 1956, by : C.E. Pritchard, T. Quinlan, W.M. Burnett
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.

DIAGRAMMATIC RELATIONSHIP OF ROCK UNITS





HERMANNSBURG

SHEET SF 53-13

AUSTRALIA 1:250,000

ALICE SPRINGS

NORTHERN TERRITORY

1:250,000 GEOLOGICAL SERIES SHEET SF53-14

PRELIMINARY EDITION, 1966 — PLATE 11

SUBJECT TO AMENDMENT

Reference

- Geological boundary
- Anticline, showing plunge
- Syncline, showing plunge
- Overturned anticline showing general direction of plunge
- Overturned syncline showing general direction of plunge
- Overturned (downward facing) antiform
- Fault
- Low-angle thrust fault
- High-angle reverse 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.

- Strike and dip of strata
- Vertical 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
- Vertical joint
- 30 Strike and dip of foliation
- Vertical foliation
- Foliation with trend of lineation
- Trend of lineation
- Vertical lineation
- Plunge of lineation on vertical foliation
- Macrofossil locality
- x157 Specimen locality. Specimens are marked with prefix AS.
- x R4753 Registered B.M.R. collection number
- R-4 Measured section
- Dyke; dl-dolerite, p-pegmatite
- Sand dunes
- Bore
- Bore with windpump
- Abandoned bore
- Well
- T Tank
- E Earth tank
- Dam
- WH Waterhole
- Spring
- Mine
- Minor mineral occurrence
- Ag Silver
- Au Gold
- Sn Tin
- Nb Niobium
- Ck Kaolin
- Cu Copper
- Gp Gypsum
- Mi Mica
- Pb Lead
- Ph Phosphate
- Ta Tantalum
- Th Thorium
- U Uranium
- Abandoned well with show of oil
- Road
- Vehicle track
- Railway with siding
- Telegraph line
- Fence
- "Atnarpa" Homestead or hut
- Aerodrome
- Landing ground
- Yd Yard
- Astronomical station
- ·1958 Trignometric station
- ·1976 Height in feet, barometric; datum: mean sea level
- (P.A.) Position approximate

Reference

Era	Period	Unit	Symbol	Lithology
CAINOZOIC	QUATERNARY		Qa	Alluvium, river gravel
			Qs	Aeolian sand
			Qc	Conglomerate, scree
	TERTIARY	Undifferentiated	T	Sandstone, conglomeratic sandstone, calcareous silty sandstone, limestone, travertine, conglomerate, chalcedony
			Tl	Chalcedonic limestone and calcareous sandstone
			Tb	Silcrete (grey billy)
			Ta	Laterite, ferricrete
			Ts	Sandstone, siltstone, some lignite
PALAEOZOIC	DEVONIAN TO CARBONIFEROUS	Pertnjara Formation	Pzp(c)	Conglomerate
			Pzp(s)	Sandstone, pebbly sandstone
	? SILURIAN TO DEVONIAN	Mereenie Sandstone	Pzm	White, cross-bedded sandstone
	CAMBRIAN TO ORDOVICIAN	Larapinta Group: Pacoota Sandstone	€-Op	Fossiliferous sandstone and silty sandstone
		Larapinta Group: N'Dahla Member	On	Purplish-brown sandstone and siltstone
	CAMBRIAN	Pertaoorrta Group: Undifferentiated	€p	Sandstone, siltstone, shale, dolomite, limestone
		Goyder Formation	€g	Silty sandstone, siltstone, limestone, dolomite
		Jay Creek Limestone	€j	Limestone, shale, dolomite
		Hugh River Shale	€h	Siltstone, shale, limestone
		Shannon Formation	€s	Siltstone, shale, limestone, dolomite
		Giles Creek Dolomite	€k	Dolomite, limestone, siltstone, shale
		Chandler Limestone	€l	Limestone and dolomite with chert laminae
		Todd River Dolomite	€r	Pink fossiliferous dolomite
		Arumbera Sandstone	€a	Red-brown sandstone, silty sandstone, siltstone
			$€a_3$	Sandstone
			$€a_2$	Siltstone, sandstone, some dolomite
			$€a_1$	Sandstone, siltstone, some pebbly sandstone
PRECAMBRIAN	UPPER PROTEROZOIC	Pertatataka Formation	Pup	Siltstone and shale with lenses of sandstone, limestone, conglomerate
		Julie Member	Puj	Dolomite, limestone, lenses of sandstone and calcareous sandstone
		Waldo Pedlar Member	Pul	Siltstone, fine-grained platy sandstone
		Olympic Member	Puf	Conglomerate, siltstone, sandstone, dolomite
		Limbla Member	Pum	Cross-laminated sandstone, sandy calcarenite
		Ringwood Member	Pur	Algal dolomite and calcarenite
		Cyclops Member	Puy	Platy, even-bedded, fine-grained sandstone
		Areyonga Formation	Pua	Sandstone, arkose, siltstone, conglomerate, dolomite
		Bitter Springs Formation	Pub	Dolomite, limestone, siltstone, sandstone, and some basic volcanics
		Loves Creek Member	Pue	Massive, algal dolomite, red siltstone, and sandstone
			Pue_1	Basic volcanics
		Gillen Member	Pug	Dolomite, green siltstone, sandstone, gypsum
		Heavitree Quartzite	Puh	Quartzite
		Schaber Hornblende Granite	p€c	Porphyroblastic hornblende oligoclase-microcline granite
		Bungitina Granodiorite	p€t	Biotite-microcline-oligoclase granodiorite
			p€g	Granite
			p€q	Meta-quartzite, quartz-sericite schist
		Arunta Complex	p€a	Mica-quartz-feldspar schist and gneiss, garnet-mica-feldspar gneiss, quartzo-feldspathic gneiss, amphibolite, meta-basic rocks, meta-limestone, quartzite, pegmatite

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 1:46,500 scale. Transverse Mercator Projection.

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Showing Magnetic Declination

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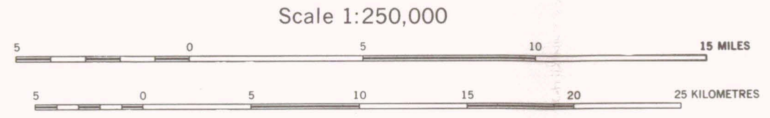
MOUNT DOREEN SF 52-12	NAPPERBY SF 53-9	ALCOOTA SF 53-10	HUCKITTA SF 53-11	TOBERMORY SF 53-12
MOUNT LIEBIG SF 52-16	HERMANNSBURG SF 53-13	ALICE SPRINGS SF 53-14	ILLOGWA CREEK SF 53-15	HAY RIVER SF 53-16
LAKE AMADEUS SG 52-4	HENBURY SG 53-1	RODINGA SG 53-2	HALE RIVER SG 53-3	SIMPSON DESERT NORTH SG 53-4
AYERS ROCK SG 52-8	KULGERA SG 53-5	FINKE SG 53-6	McDILLS SG 53-7	SIMPSON DESERT SOUTH SG 53-8

ANNUAL CHANGE 1'30"E

Scale 1:250,000

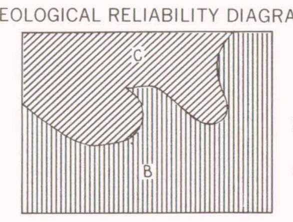


Sections

Cainozoic sediments omitted from section

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

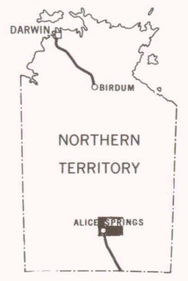
GEOLOGICAL RELIABILITY DIAGRAM



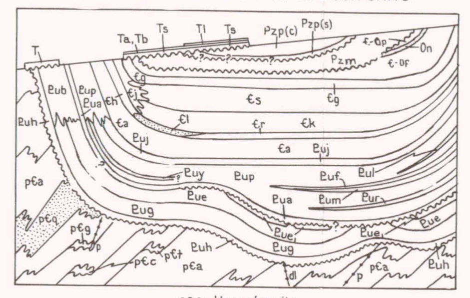
B Detailed reconnaissance, general reconnaissance, reconnaissance, and air-photo interpretation.

C Air-photo interpretation with helicopter reconnaissance.

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

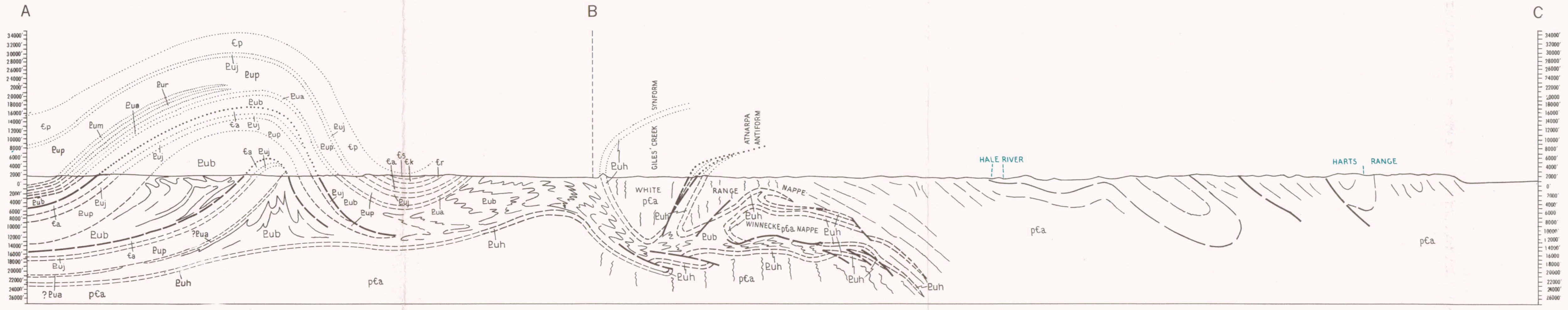


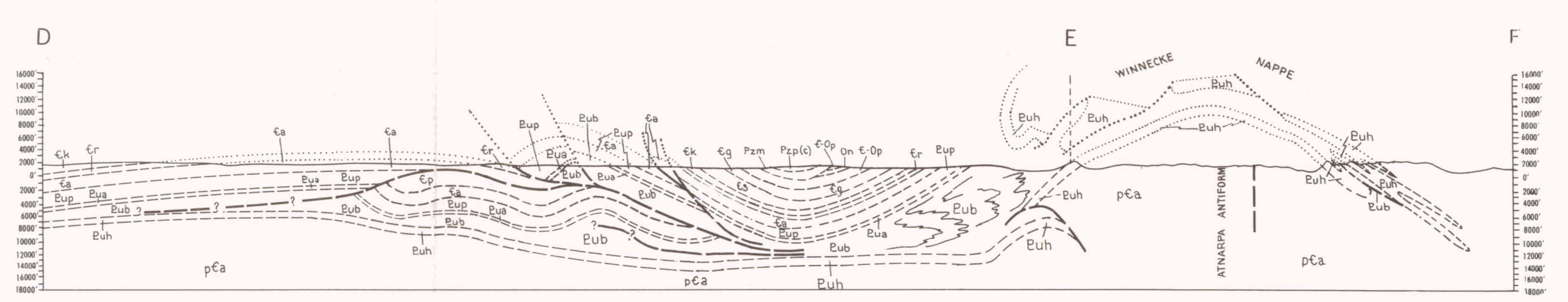
DIAGRAMMATIC RELATIONSHIP OF ROCK UNITS



ALICE SPRINGS

SHEET SF 53-14





Copies of this map may be obtained from the Bureau of Mineral Resources, Geology and Geophysics, Canberra, A.C.T., or Darwin, N.T.

AUSTRALIA 1:250,000

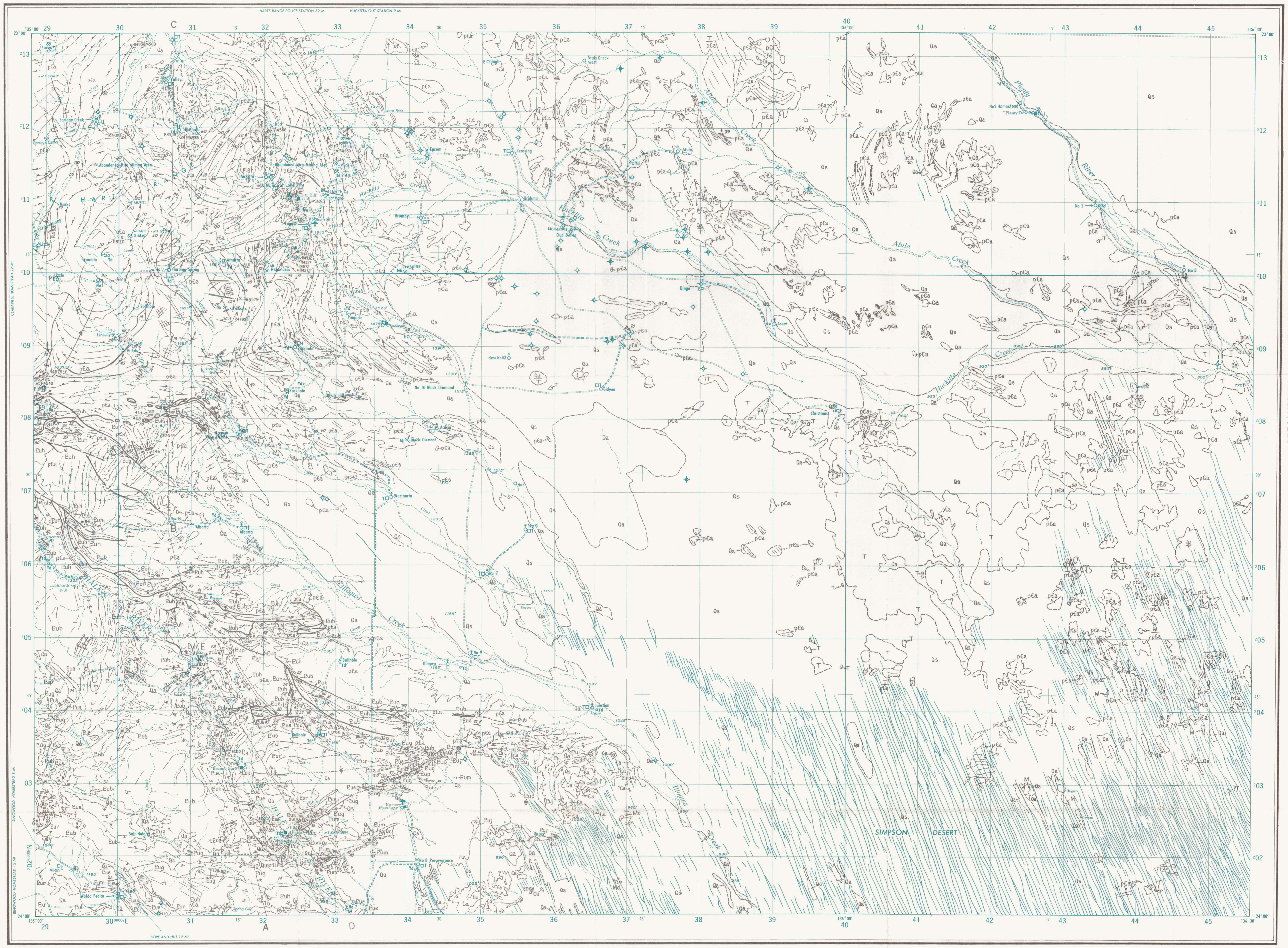
ILLOGWA CREEK

NORTHERN TERRITORY

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

PRELIMINARY EDITION, 1966 PLATE 12

SUBJECT TO AMENDMENT



Reference

Era	Period	Unit	Symbol	Description
CAINOZOIC	QUATERNARY		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	Єa	Red-brown sandstone, silty sandstone, siltstone
PRECAMBRIAN	UPPER PROTEROZOIC	Pertatataka Formation	Ꝑup	Siltstone, shale
		Julie Member	Ꝑuj	Dolomite, limestone, lenses of sandstone and calcareous sandstone
		Waldo Pedlar Member	Ꝑul	Siltstone, fine-grained platy sandstone
		Limbla Member	Ꝑum	Cross-laminated sandstone, sandy calcarenite
		Ringwood Member	Ꝑur	Algal dolomite, calcarenite
		Areyonga Formation	Ꝑua	Sandstone, arkose, boulder clay, conglomerate, dolomite
		Bitter Springs Formation	Ꝑub	Dolomite, limestone, siltstone, sandstone, basic volcanics
		Loves Creek Member	Ꝑue	Massive algal dolomite, red siltstone
			Ꝑue₁	Basic volcanics
		Gillen Member	Ꝑug	Dolomite, green siltstone, sandstone
		Heavitree Quartzite	Ꝑuh	Quartzite, conglomeratic sandstone, quartzite
		Huckitta Granodiorite Inkamulla Granodiorite	pЄg	Massive hornblende granodiorite Biotite granodiorite
		Arunta Complex	pЄa	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
- Strike and dip of foliation
- Strike and dip of foliation—unmeasured
- Foliation with trend of lineation
- Vertical foliation
- Fossil locality—general
- Specimen locality. Text reference prefixed by IC
- 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
- Tank
- Earth tank
- Dam on stream
- Spring
- Waterhole
- Sand dunes
- Road
- Vehicle track
- Fence
- Homestead
- Yard
- Landing ground
- Astronomical station, with height in feet
- 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.

INDEX TO ADJOINING SHEETS

Showing Magnetic Declination

ANNUAL CHANGE 1'30"E

Scale 1:250,000

5 0 5 10 15 MILES

5 0 5 10 15 20 25 KILOMETRES

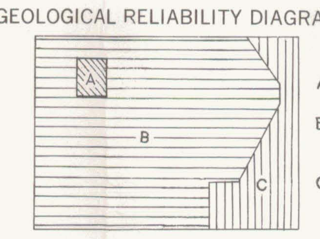
Sections

A-B-C D-E

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

Cainozoic sediments omitted from section

GEOLOGICAL RELIABILITY DIAGRAM

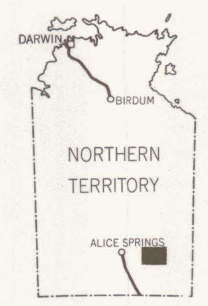


A Detailed mapping

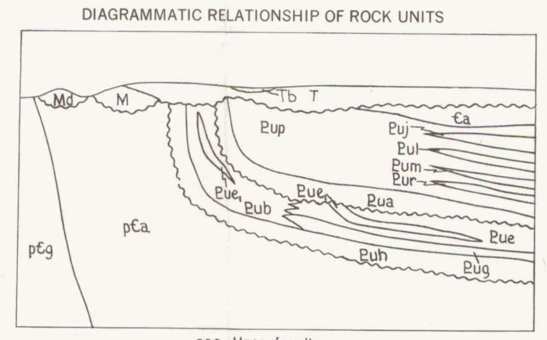
B Detailed reconnaissance, general reconnaissance, reconnaissance and air-photo interpretation

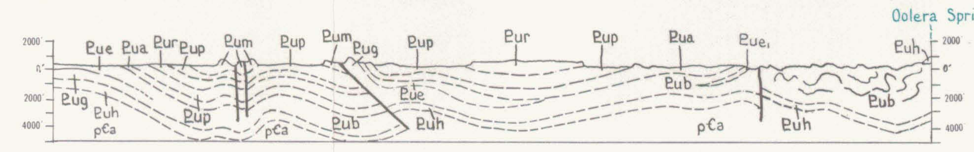
C Air-photo interpretation

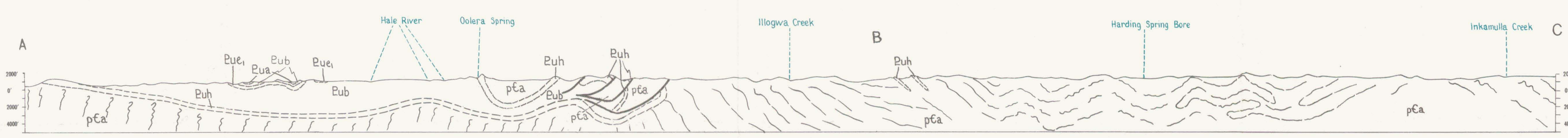
Geology, 1949 to 1951, by: G.F. Joklik et al
1964, by: A.T. Wells, D.J. Forman, E.N. Milligan, A.J. Stewart, R.D. Shaw, D.R.G. Woolley
Compiled, 1964-1965, by: A.T. Wells, D.J. Forman, E.N. Milligan, A.J. Stewart, R.D. Shaw, N.L. Kruger
Drawn by: N.L. Kruger



DIAGRAMMATIC RELATIONSHIP OF ROCK UNITS







ILLOGWA CREEK

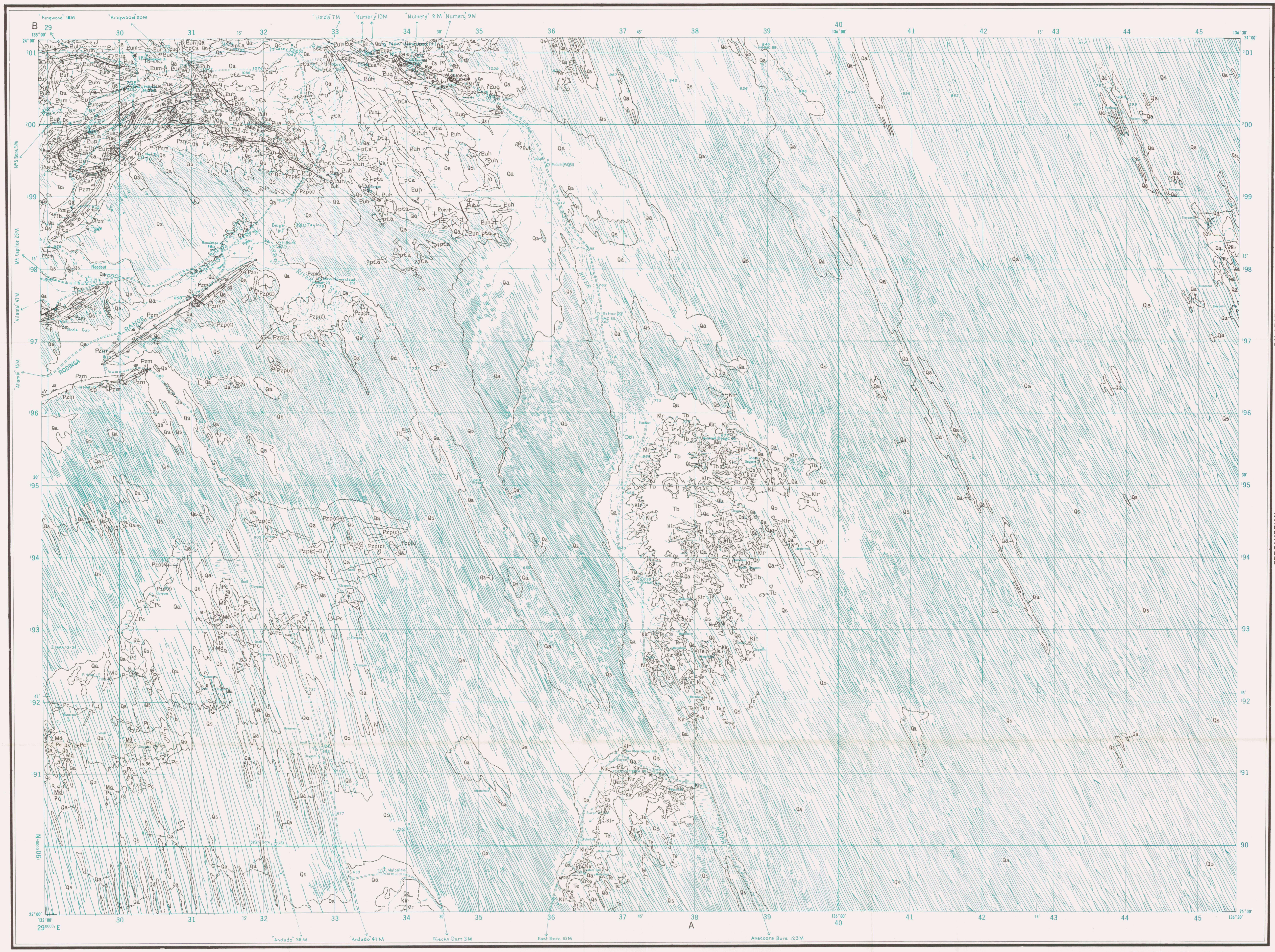
SHEET SF 53-15

AUSTRALIA 1:250,000 GEOLOGICAL SERIES

HALE RIVER
NORTHERN TERRITORY

SHEET SG 53-3

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS
FIRST EDITION 1966
PLATE 13



Reference

Era	Period	Unit	Symbol	Description
CAINOZOIC	QUATERNARY		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 TO CARBONIFEROUS	Pertnjara Formation	Pzp(c)	Pebble and cobble conglomerate
			Pzp(s)	Sandstone
	? SILURIAN TO DEVONIAN	Mereenie Sandstone	Pzm	White, cross-laminated sandstone
	CAMBRIAN	Pertaoorrta Group: Shannon Formation	€s	Siltstone, dolomite, limestone
		Giles Creek Dolomite	€k	Dolomite, limestone, shale
		Todd River Dolomite	€r	Dolomite, shale, sandstone
		Arumbera Sandstone	€a	Red-brown sandstone, siltstone, chert-pebble conglomerate
		Undifferentiated	€p	Dolomite, limestone, siltstone
PRECAMBRIAN	UPPER PROTEROZOIC	Undifferentiated	Pu	Sandstone, limestone, dolomite, siltstone, shale (Section only)
		Pertatataka Formation	Pup	Siltstone and shale with lenses of sandstone, dolomite limestone and conglomerate
		Julie Member	Puj	Oolitic dolomite, limestone, lenses of sandstone, and calcareous sandstone
		Waldo Pedlar Member	Pul	Siliceous, platy, fine sandstone, siltstone
		Olympic Member	Puf	Sandstone, siltstone, conglomerate, dolomite
		Limbla Member	Pum	Cross-laminated sandstone, oolitic and sandy limestone and dolomite interformational conglomerate, siltstone
		Ringwood Member	Pur	Limestone, algal dolomite, siltstone
		Areyonga Formation	Pua	Tilloid, arkosic sandstone, siltstone, sandstone, conglomerate
		Bitter Springs Formation	Pub	Dolomite, limestone, siltstone, sandstone and basic volcanics
		Loves Creek Member	Pue	Algal dolomite, limestone, red siltstone and dolomitic siltstone
			Pue₁	Basic volcanics
		Gillen Member	Pug	Green siltstone, sandstone, dolomite, gypsum
		Heavitree Quartzite	Puh	Silicified sandstone, pebbly sandstone
		Arunta Complex	p€a	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
Strike and dip of strata
Horizontal strata
Overturned strata
Dip < 15°
Dip 15-45°
Dip > 45°
Trend lines
(Dip and trend lines: air-photo interpretation)
Strike and dip of foliation, unmeasured
Strike and dip of foliation
Macrofossil locality
Specimen locality.
Measured section

Bore
Abandoned bore
(numbers refer to records of Resident Geologist, Alice Springs.)
Windpump
Tank
Earth tank
Dam on stream
Waterhole
Swamp
Sand dunes
Road
Vehicle track
Building
Yard
Astronomical station
Height in feet, instrument levelled;
Height in feet, barometric;
(datum: mean sea level)

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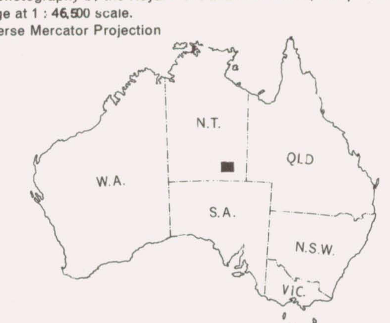
Transverse Mercator Projection



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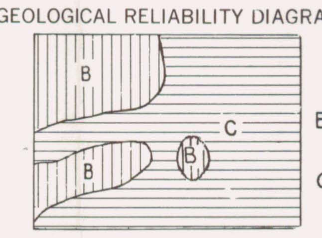
ALBERGA SG 53-9	ABMINGA SG 53-10	DALHOUSIE SG 53-11	POOLOWANNA SG 53-12	PANDIE PANDIE SG 54-9

ANNUAL CHANGE 1°30'E

Scale 1:250,000
5 0 5 10 15 MILES
5 0 5 10 15 20 25 KILOMETRES

Section
Cainozoic sediments omitted from section
Scale $\frac{V}{H} = 1$

GEOLOGICAL RELIABILITY DIAGRAM



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Compiled, 1964, by: A.T. Wells, A.J. Stewart, R.D. Shaw, L. Kerec
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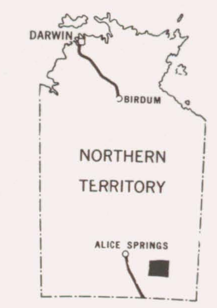
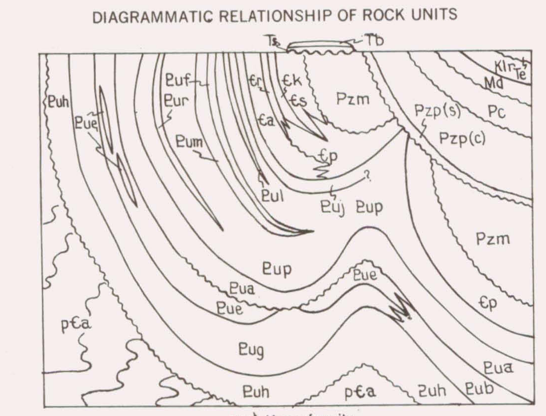
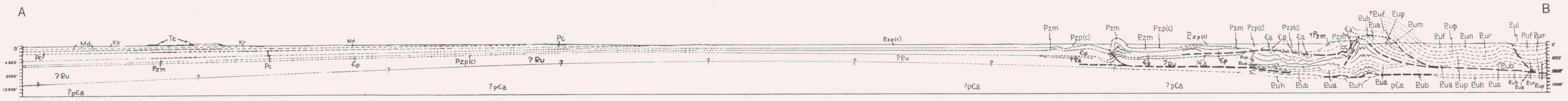


DIAGRAMMATIC RELATIONSHIP OF ROCK UNITS





HALE RIVER
SHEET SG 53-3

Copies of this map may be obtained from the Bureau of Mineral Resources, Geology and Geophysics, Canberra, A.C.T., or Darwin, N.T.

DATE DUE

~~24.5.8~~5			