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GEOLOGY OF THE ALCOOTA 1:250 000 SHEET AREA, N.T.

by

R.D. Shaw, R.G. Warren, B.R. Senior, & A.N. Yeates.

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SUMMARY

The Alcoota Sheet area is situated in central Australia, northeast of Alice Springs, between latitudes 22°S and 23°S and longitudes 133°30'E and 135°E. The area has a subdued relief, ranging from over 760 m above sea level at Mount Bleechmore to less than 460 m in the northeastern corner.

A reconnaissance of the Georgina Basin and underlying Adelaidean sediments in the northern part of the Sheet area was carried out by the Bureau of Mineral Resources (BMR) in 1963, and the eastern tip of the Ngalia Basin in the southwest corner was visited in 1968. The remainder of the area, chiefly Precambrian basement rocks, was not mapped until 1970 and 1971.

The Precambrian stratigraphic sequence as set out in this report assumes that the youngest rocks are the least deformed (and in the Alcoota Sheet area, the least metamorphosed). Under this scheme the oldest rocks are a sequence of interlayered mafic granulite, felsic gneiss, and pelitic gneiss (Mount Bleechmore Granulite, Kanandra Granulite) with associated small bodies of anatectic granite. These rocks are exposed as a discontinuous belt trending eastward from the southwestern part of the Sheet area to beyond Mount Swan. A second belt of similar granulites (p€y) crosses the northern part of the Alice Springs Sheet area and encroaches on to the southwestern corner of the Sheet area. In the southwestern part of the Sheet area near Bushy Park homestead, the granulite belts are cut by the Wallaby Knob Schist Zone, which in places contains kyanite and staurolite and is considered to have been formed by retrogression of the granulite rocks. To the east, in the Undippa Dam area, a sequence of interlayered meta-pelite and amphibolite (Harts Range Group) separates the northern and southern granulite belts and probably overlies them.

The rock units immediately north of the granulite belts, Chiripee and Mapata Gneisses, are predominantly felsic gneisses similar to those in the granulite units, but have been metamorphosed only to the amphibolite facies and contain considerably less mafic rock. North of these, and apparently overlying them, are two metamorphic sequences (Delny Gneiss and Delmore Metamorphics) whose rock types are sufficiently different from those of the underlying Chiripee and Mapata Gneisses to suggest a major stratigraphic break. The Delny Gneiss consists mainly of felsic gneiss (characteristically containing muscovite clots), subordinate biotite schist, and amphibolite.

The Delmore Metamorphics possibly overlie the Delny Gneiss, and consist mainly of calc-silicate rock, microcline-rich meta-pelites, and a lens of chlorite-quartz-anthophyllite-cordierite gneiss. The Delmore Metamorphics are lithologically similar to, and are tentatively correlated with the Mount Stafford Beds and the Wickstead Creek Beds of the Napperby Sheet area.

The Delmore Metamorphics are unconformably overlain by the Ledan Schist, which consists mainly of tourmaline-bearing muscovite-biotite-quartz schists, and tourmaline-bearing and magnetite-bearing quartzite. The Ledan Schist is, in turn, overlain by the Utopia Quartzite. The Mendip Metamorphics in the south-central part of the Sheet area are in part lithologically similar to the Ledan Schist and the units are therefore considered to be laterally equivalent. The Mendip Metamorphics, Ledan Schist and Utopia Quartzite are tentatively correlated on lithological grounds with the Hatches Creek Group of the Davenport Ranges, and with the Reynolds Range Group in the Napperby 1:250 000 Sheet area. The rocks below the unconformity at the base of the Ledan Schist have been metamorphosed only to the greenschist facies, or, at the most, the lower amphibolite facies. Large masses of calc-alkaline granite intruding the sequences below the unconformity (Kanandra Granulite, Chiripee Gneiss, Mapata Gneiss, Delny Gneiss and Delmore Metamorphics) are considered to have been intruded during the final stages of the metamorphism which affected the overlying schist and quartzite.

The overlying Adelaidean and Cambrian sequences in the northeast, north, and northwest of the Sheet area (the sequences of the Ngalia and Georgina Basins), are not intruded by granite, contain no volcanic rocks, and are unmetamorphosed.

One formation of the Ngalia Basin sequence, the Vaughan Springs Quartzite (including the Treuer Member), is exposed in the southwest. It is part of the north-dipping southern margin of the Ngalia Basin and overlies the Arunta Complex. Rb-Sr isotopic dating of migmatites from the Complex in the Hermannsburg 1:250 000 Sheet area indicates that the Vaughan Springs Quartzite must be younger than 1070 m.y. and may be about 950 m.y. old.

During the late Adelaidean and Lower Cambrian, sediments were laid down between the Ngalia and Georgina Basins in the north and northwest of the Sheet area. The red beds of the Central Mount Stuart Beds occupy most of this area. Near their base the red beds contain a glacial unit, correlated with the upper (Marinoan) tillite unit of the Adelaide Geosyncline and the Egan glaciation of the Kimberley region. The Beds possibly interfinger with, and are substantially underlain by, the marine Grant Bluff Formation, which extends eastwards beyond the Sheet area.

The early Middle Cambrian base of the Georgina Basin sequence is not exposed in the Sheet area. The only units of the sequence cropping out are the late Cambrian to early Ordovician Tomahawk Beds and the overlying Lower Devonian part of the Dulcie Sandstone. The Tomahawk Beds were probably deposited under near-shore marine conditions; the Dulcie Sandstone under terrestrial conditions.

During the Alice Springs Orogeny, in the Early to Middle Carboniferous, the Arunta Block was uplifted, and shortly afterwards sedimentation ended in the Georgina and Ngalia Basins. The lack of preserved sediments of Permian and Mesozoic age suggest that the elevated block underwent continuous erosion until the end of the Mesozoic.

In early Tertiary or late Cretaceous time the metamorphic and igneous rocks were deeply weathered and partly eroded before widespread sedimentation began in rivers, channels, and lakes. In the western part of the Sheet area, where deposition has continued until recent times, up to 310 m have accumulated. On the other hand, in the eastern part, sedimentation ceased after deposition of the fossiliferous late Miocene to early Pliocene Waite Formation. Termination of sedimentation perhaps corresponded with the tilting of the eastern part of the region, possibly in the Pliocene, from a southerly to a northerly direction. Sheet and dune sands were formed during arid phases in the Pleistocene. The main period of dissection by the Plenty, Sandover, and Bundey Rivers followed in the Holocene.

Several small tantalite, tungsten, and copper prospects are regarded as similar in age to the Hatches Creek and Wauchope mineralisation. At least 17 tonnes of mica were mined near Yam Creek Bore in 1945-6 from pegmatites thought to be derived by ultrametamorphism of the Harts Range Group. Chalcopyrite is disseminated in grey lithic sandstone interbedded with grey siltstone in the Central Mount Stuart Beds. Copper values up to 6500 ppm were detected during drilling by the Northern Territory Administration over a 30 cm interval. Zinc values up to 950 ppm and lead values up to 6700 ppm were also found over 30 cm intervals at separate levels, distinct from the copper-bearing horizons. Airborne radiometric results, including data from the uranium channel, and gamma-ray logs from bores suggest that a few areas of both granite and Tertiary rocks warrant further investigation to assess their uranium potential.

INTRODUCTION

The Alcoota 1:250 000 Sheet area is in the south of the Northern Territory between latitudes 22^{o} and 23^{o}S and longitudes $133^{o}30'$ and 135^{o}E. Alice Springs is about 100 km to the south by the Stuart Highway. The Plenty River Beef Road runs east from the Stuart Highway across the southern part of the Sheet area to the Harts Range Police Station and the Jervois Range mineral area, and from there to Urandangi in Queensland. The Sandover Beef Road, which leaves the Stuart Highway at Connors Well, serves Woodgreen and Utopia Cattle Stations and from there continues to Camooweal in Queensland. There are graded tracks to the other stations (Mount Skinner, Delmore Downs, Waite River, Alcoota, and Bushy Park) and well marked tracks to water bores, the water from which is mostly suitable for drinking. Most parts of the area can be reached using four-wheel-drive vehicles.

The region is semi-arid. The annual rainfall is very variable, but averages about 300 mm; most falls in the summer months (December to March). An evaporation level of 250 cm a year has been recorded at Alice Springs. Summer temperatures commonly exceed 38^{o}C, and frosts occur during the winter. Further information on climate, soil, vegetation, and land use is given in Perry & others (1962).

The Alcoota Sheet area was mapped by BMR in three stages:

(1) In 1961 Milligan and Smith (Milligan 1964) made a reconnaissance of the northern half of the Sheet area during a study of the Georgina Basin and related unmetamorphosed rocks.

(2) In 1967-68 a small region around the Hann Range was mapped during the Ngalia Basin Survey (Evans & Glikson, 1969).

(3) In 1970-71 Shaw and Warren mapped the metamorphic and igneous rocks of the Sheet area, as part of a regional study of the Arunta Block, and made a reconnaissance of the cover rocks; Senior studied the Cainozoic sedimentary rocks (Senior, 1972; also this report); and Yeates spent three weeks studying the Grant Bluff Formation and its relation to the Central Mount Stuart Beds. Yeates and Senior were the well-site geologists for BMR scout holes Alcoota SH2 and SH3, which were drilled in 1971 to give stratigraphic information on the Tertiary sediments. In 1972 eight more holes (SH4-11) were drilled through Tertiary sediments between the Strangways and Reynolds Ranges to determine the metamorphic grade of the basement rocks.

The area was mapped by reconnaissance traverses using four-wheel-drive vehicles. Geological information was initially plotted on aerial photographs taken by the Royal Australian Air Force in 1950, and was later transferred to controlled photo-scale overlays. The scale of the aerial photography was 1:50 000 in the northern part of the Sheet area, and 1:46 500 in the southern part. The photo-scale compilations were reduced photographically to 1:250 000 scale and redrafted to fit the topographic base map compiled by National Mapping. In 1971, photographs taken for National Mapping, at 1:80 000 scale, became available and were used for a reinterpretation of Quaternary units. Colour aerial photographs at 1:26 000 scale, covering the southern part of the Alcoota 1:100 000 Sheet area, were used for a reinterpretation of this region, particularly in regard to the distribution of mafic granulites. The results have been incorporated into the 1:250 000 map. Grid references given are metric units referred to the Australian Map Grid.

Petrographic study has been restricted in most cases to determination of mineral assemblages. Percentages of minerals given are visual estimates only.

BMR registered specimen numbers referred to in the text are located on the Preliminary Map in a coded form: a cross reference to which is stored in BMR technical files.

Previous geological investigations

The earliest geological observations were made in 1895 by H.Y.L. Brown who traversed the route of the overland telegraph line, through the southwestern corner of the Sheet area, (Brown, 1895).

Virtually no geological interest was shown in the Sheet area until World War II, when the small tungsten-tantalum deposits were visited by Nye and Sullivan (1942). During the search for uranium in the late 1940s, several of the tantalite deposits were again examined (Daly & Dyson, 1963). Prospecting for mica was carried out, but the only geological reports were a reconnaissance sketch map of parts of the Sheet area by Jensen (1945) and a very brief comment by Joklik (1955) on the area surrounding Undippa Mica Mine (Yam Creek Bore area). Hossfeld (1954) regarded the Palaeozoic sediments of the Alcoota Sheet area as Ordovician, because of their similarity in lithology and stratigraphic position to rocks which contain Ordovician fossils in the Toko, Tarlton, and Dulcie Ranges. During CSIRO land research studies of the southern part of the Northern Territory, a reconnaissance geological map at a scale of 1:1 000 000 was prepared by Quinlan (Perry & others, 1962).

Copper prospects in the Central Mount Stuart Beds at Mount Skinner have been investigated by both government and company geologists. The copper minerals were discovered by a prospector, S. Griffiths, in March 1965, and were first reported on by Youles (1965), of the Resident Geologist's staff at Alice Springs, who considered them indicators of possible economic mineralization. Kennecott Exploration (Aust.) Pty Ltd mapped the area, attempted an orientation geochemical survey of stream sediments, and bull-dozed trenches across selected outcrops of mineralized sediments. Three percussion holes were drilled near Mount Skinner to a maximum depth of 230 m (Halliday, 1966). The prospect was later drilled by the Northern Territory Administration and the results described in detail by Grainger (1969). As a result of semi-detailed mapping in 1970, Utah Development Co. subdivided the Central Mount Stuart Beds into an upper quartzose unit, a middle red lithic unit, and a thin basal quartzose unit. Also in 1970, Centamin N.L. began investigating the main mineral leases near Mount Skinner. Their investigations included a seismic and resistivity survey by Companie Générale de Géophysique in an attempt to find places where grey beds onlap basement, such places being thought favourable to the concentration of ore. Later, stratigraphic diamond drilling was undertaken in the Mount Skinner area. Results of the first two holes in the drilling program (DDC 1 and DDC 2) are referred to in the section on the Grant Bluff Formation, but no assays are available.

A radiometric survey was conducted over the district around Mount Swan by Kratos Uranium N.L. and associated companies (Mannoni, Lehmann & Stree, 1971), but the only anomalies detected were found to be due to thorium minerals.

Geologists of Central Pacific Minerals N.L. conducted an airborne survey and ground reconnaissance over the central and eastern sections of the sheet area (Clarke, 1971), and carried out on evaluation of the Perenti Copper Prospect, just east of the Sheet area boundary.

Kostlin and Hughes, of CRA Exploration Pty Ltd., made a brief study of two nearly circular mafic meta-igneous bodies in the Mount Byrne area (Kostlin & Hughes, 1971).

Studies have been made of the underground water resources of the Alcoota Sheet area by staff of the former BMR Resident Geologist's Office and Water Resources Branch, Northern Territory Administration. In particular, groundwater studies have been made of the Tea Tree Basin in the Napperby Sheet area (N.O. Jones, unpubl.; Jones & Quinlan, 1962; K. Edworthy, in prep), Cainozoic sediments near Utopia homestead (Woolley, 1965a), and the Dulcie Sandstone (Woolley, 1965b).

The adjoining 1:250 000 Sheet areas were mapped between 1956 and 1961: Barrow Creek by Smith & Milligan (1964), Huckitta by Smith (1963, 1964), Napperby and a small part of Alcoota by Evans & Glikson (1969). In 1970, C.J. Simpson (BMR photogeology group) interpreted the geology of the southern part of the Sheet area.

Shaw & Stewart (1975) have summarized the regional geology of the Arunta Block as it is known to date (Fig. 1), by Webb (1972).

The results of age determinations made on rocks from the Alcoota Sheet area are summarized in Table 1.

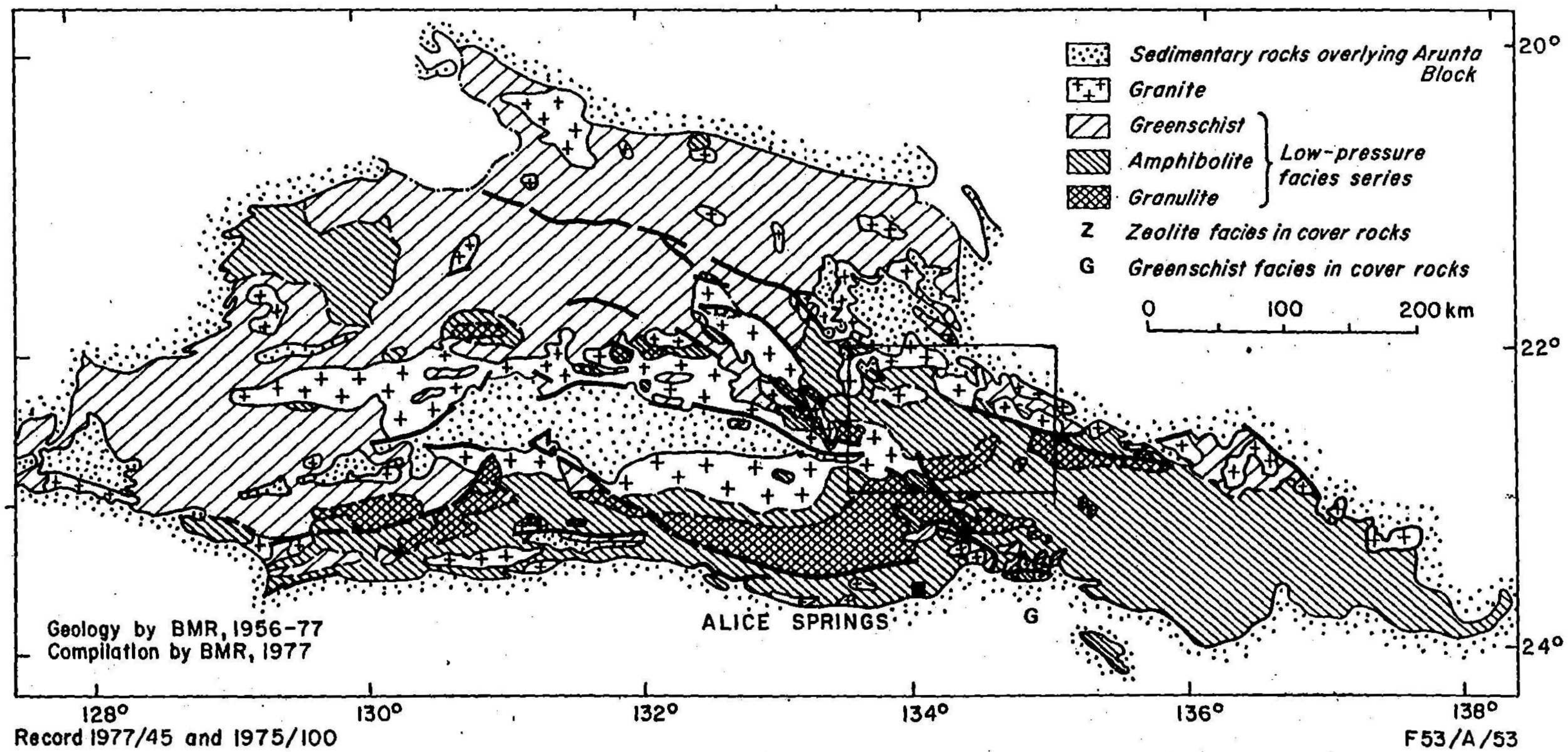


Fig 1 Regional geology of Arunta Block
(Alcoota Sheet area outlined)

TABLE 1: Age determinations - Alcoota 1:250 000 Sheet area

Date (m.y.)	Rock Unit	Location	Method
306	Small boss of granite	Near Mallee Bore, spec. 719000-50, pt. 227	K-Ar date on Biotite
1532 (±35)	Ledan Schist	Spec. 71900034, 5 km W. Western Watering Point; 0.5 km NE map pt. 44	K-Ar date on muscovite
1537 (± 35)	Pegmatite	Spec. 71900036, 3.5 km NW Western Watering Point; map pt. 53	K-Ar date on muscovite

PHYSIOGRAPHY

Four topographic units can be recognized in the area: areas of high relief; plains; dissected areas; and alluvial river tracts.

Areas of high relief

In the southwest of the Sheet area the eastern end of the Hann Range rises 150 m above the nearby plain. It has a steep south-facing scarp and a gentle northern dip slope. In the south, the foothills of the Harts and Strangways Ranges, which rise sharply up to 300 m above the level of the plains, just extend into the Sheet area. Two dissected land surfaces are recognizable within the Harts and Strangways Ranges. The highest peaks retain remnants of an older surface, and a younger surface forms broad intermontane valleys. The present cycle of erosion has dissected the younger surface to the level of the Plenty River Plain, producing deeply incised meanders.

Plains

Two sets of plains, an older and younger, can be recognized. The older Burt and Hanson-Lander Plains occupy most of the western half of the Sheet area. They have no clearly defined drainage system, but there are traces of relict northward-flowing drainage system, once active in more pluvial conditions. Three soil and vegetation units can be recognized on the older plains: (i) a white sandy soil, which supports spinifex-dominated vegetation and which has a light photo tone; (ii) a red sandy soil, readily recognized by the arcuate photo-pattern of the mulga it supports, and (iii) kunkar with grass and herbs, which is seen as a mottled white and light grey photo-tone.

The younger plains extend to the northeast of the Sheet area along the outwash plains of the Sandover and Bundey Rivers systems, and to the east of the Sheet area as the Plenty River Plain. Both areas merge headward into the valleys of the dissected areas. The plains flanking the Sandover River in the north-east of the Sheet area contain sand rises (Mabbutt, 1967), and the Plenty River Plain contains sand dunes covered with vegetation.

Dissected areas

The remainder of the Sheet area is drained by either the headwaters of the Sandover and Bundey Rivers or by minor tributaries of the Plenty River. Both rivers begin in the Harts and Strangways Ranges, and most of the water in their ephemeral flows comes from rain on high ground south of the Sheet area. The rivers have incised the older plains to about 30 m deep, creating a topography of sharp escarpments, low rounded residual hills and tors, and broad alluvial tracts. The steepest slopes occur where chalcedonic Tertiary limestone is being dissected. Steep slopes also form in the lateritic weathered profile, partly because of vertical joints, which control the shape of the blocks removed by erosion. Where the deeply weathered profile joins less altered rocks there is generally a distinct change in slope, marked by a line of small caverns. The lower slopes of the steep hills are covered by large blocks and finer scree; chalcedony from the Tertiary limestone almost entirely masks the lower slopes of measa developed in it. Hills of fresh rock, from which all the deeply weathered material has been removed, are more rounded in profile, but rock-type, structure, and joints control scarp retreat. Granite, orthogneiss, and felsic gneiss form tors and rounded hills; layered rock sequences form elongate strike ridges and poorly developed hog backs. The sharpest cuestas form on the Upper Proterozoic-Lower Palaeozoic quartzites in the north of the Sheet area.

The broad valleys are carpeted by alluvium which is generally less than 4 m thick, and nowhere exceeds 15 m.

Alluvial river flats

The main courses of the Sandover, Bundey, and Plenty Rivers, are incised up to 5 m deep and filled with coarse sand. The width of the incised areas ranges from about 10 m to a kilometre or more. The incised areas are bordered by overflow channels, abandoned channels partly filled by unconsolidated alluvium, and levee banks of various generations.

Evolution of landforms

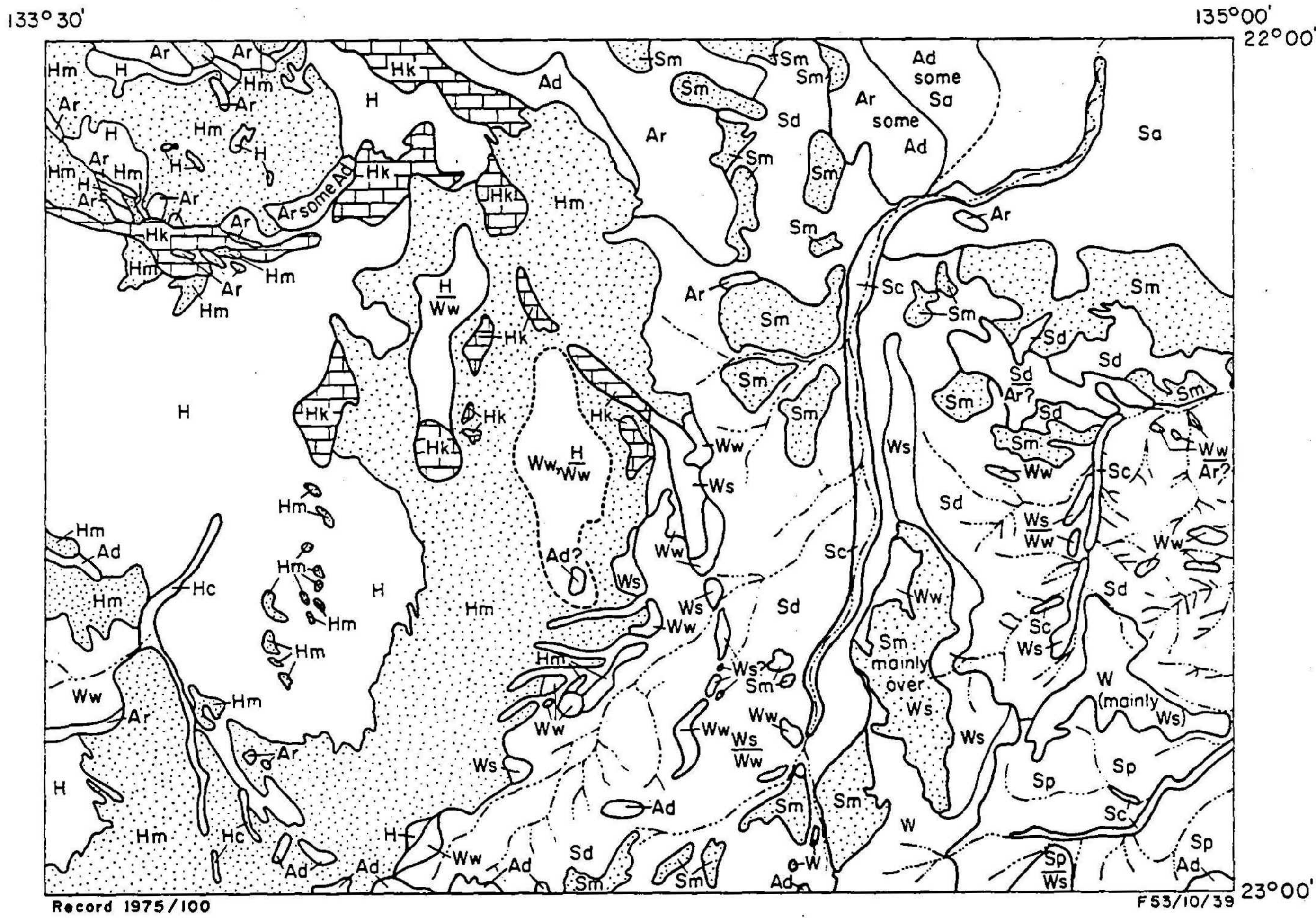
The distribution of the main physiographic units and their time-relations are shown in Figure 2. The evolution of the present land surfaces can be traced back to at least the Cretaceous. Correlatives of the Ashburton Surface (Ad) (Hays, 1967), include the levelled tops of the Hann, Harts, and Strangways Ranges, which stand up to 300 m above the deep-weathering profile. Hays considered the Ashburton Surface to have been peneplained sometime before the Cretaceous.

The Ashburton Surface was dissected and deeply weathered during the Cretaceous, a time of Australia-wide epirogenesis. The deeply weathered surfaces in the Sheet area (WW) are continuous with the Tennant Creek Surface, which Hays considered to have formed in the Late Cretaceous and Early Tertiary. Litchfield (1969), working in the Burt Plain in the Alice Springs Sheet area, proposed McGrath Surface for the same deeply weathered surface.

The period of deep weathering was followed by one of local down-warping, accompanied by erosion and sedimentation, which produced broad plains. In the west of the Sheet area these plains have continued to evolve virtually to the present (the Hanson Plain); in the ease only residuals (Waite Surface) remain, as the area has been strongly dissected and filled to form the Plenty River Plains in a new erosion cycle.

A complex surface and groundwater drainage system is preserved on the Hanson Plain as lines of calcrete deposits (Hk). During the Pleistocene and Holocene the Hanson Plain has been covered by red soils (Hm) and aeolian sand deposits (H).

The Waite Basin is thought to have been filled, at least in part, by sediments from streams draining south from the northern part of the Alcoota Sheet area. Uplift in the MacDonnell Ranges (Mabbutt, 1967) and apparent subsidence beyond the Sheet area during the late Tertiary produced the Plenty and Sandover River systems. The Sandover River appears to be a consequent stream incised on the new northward dipping surface. The Plenty River and the Sandover River (with its major tributary, the Bundey River) are still actively eroding headwards along their tributaries, to form new land surfaces (Sd & Sp in Fig. 2). The present arid climate has resulted in pedimentation, characterised by broad valleys, low rounded hills, and retreating scarps (Sd, Sp). Alluvial outwash from the Sandover has been deposited in the northeast of the Sheet area.



—— Physiographic boundary

-------- Approximate physiographic boundary

River or stream, intermittent

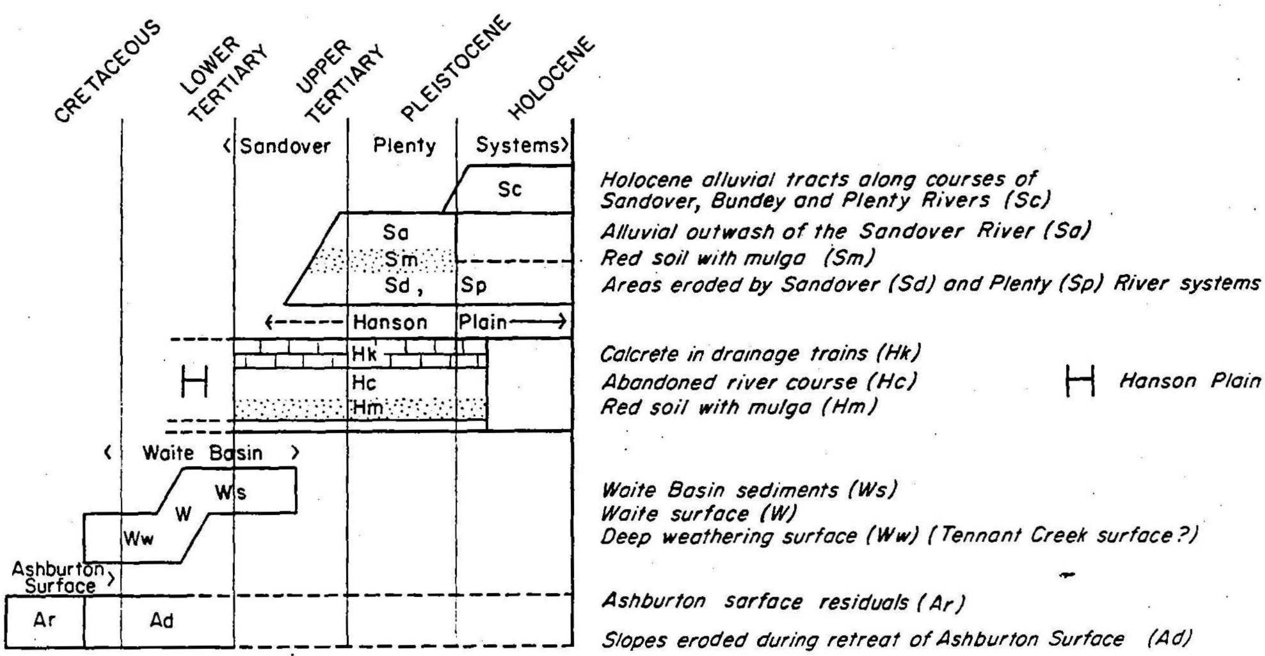


Fig 2 Evolution of Landforms

Renewed incision of the main courses of the Sandover, Bundey and Plenty Rivers to depths of 5 m has taken place during the Holocene, producing the narrow alluvial tracts (Sc) which contain abandoned river channels, levee banks, and flood-out plains as well as the present river channels.

PRECAMBRIAN METAMORPHIC UNITS

The rocks of the Arunta Complex, as defined by Mawson & Madigan (1930), have been put into three informal divisions, two of which were recognised by Hossfeld (1954) in the Harts Range, during a revision of work by Hodge-Smith (1932).

The divisions are thought to be separated by major regional unconformities. The relations between the units in each division are less certain, as the units were mapped on lithology.

DIVISION 1

Units of this division, the Strangways Range Metamorphic Complex, (the oldest division of the Arunta Complex) are predominantly felsic and mafic gneisses and granulites. The metamorphosed sediments are generally immature, corresponding to original arkosic or greywacke composition. A large part of Division 1 is probably volcanogenic. The reference area for the Complex is the Strangways Range south of Bushy Park homestead in the Alice Springs 1:250 000 Sheet area. The Strangways Range Metamorphic Complex is considered to be the basement on which rocks of Division 2 were deposited, and it may have been metamorphosed before this happened.

Division 1 is also recognised in the Napperby Sheet area to the west.

p€y

Unit p€y consists of a variety of felsic gneisses and granulites with small amounts of mafic granulite. These crop out extensively south and southeast of the old Bushy Park homestead in the Strangways Ranges, mainly in the Alice Springs Sheet area. Here they form steep-sided hills and north-trending ridges with up to 300 m relief. In the Alcoota Sheet area they have a subdued topography of less than 50 m relief. Two sub-units are recognised.

pЄya. Outcrops southeast of Muller Bore are predominantly of pelitic gneiss, which is commonly garnetiferous, but rarely sillimanite-bearing. This gneiss is normally massive and coarse-grained, and closely resembles pelitic gneiss of the Mount Bleechmore Granulite. Granitic gneiss is subordinate and mafic granulite almost insignificant, thereby distinguishing these outcrops from those of the Mount Bleechmore Granulite.

Southwest of Muller Bore outcrops are mainly biotite gneiss containing both microcline and plagioclase. The gneiss is distinguished in the field by its fine grain size and faint gneissic layering, although folded leucosome layers are prominent. Towards the southeast, outcrops become granitic. Amphibolite and mafic granulite, forming a few small pods, are the only other rock types in this area.

Southeast of Old Bushy Bore, outcrops are transitional in composition between those southeast of Muller Bore and pЄyb. The most extensive rock type, a massively jointed coarse to medium-grained felsic granulite, increases in abundance towards the west. Like the felsic granulite southwest of West End Bore, it is typified by a closely spaced wavy schistosity. The mafic granulite is identical to the mafic granulite that occurs throughout pЄy.

Southwest of West End Bore, the outcrops are principally felsic gneissic granulite, with minor muscovite-microcline-granitic gneiss and mafic granulite at several places. The felsic granulite is hypersthene-bearing, and contains only very small amounts of biotite and accessory zircon. Its foliation is marked by closely-spaced biotite folia, separated locally by thin quartz-rich and biotite-rich layers.

pЄyb. The rocks to the southeast of West End Bore have a much higher colour index (15 to 35) than those in pЄya, and, as well as hypersthene-bearing felsic to intermediate granulite, include quartz-biotite-feldspar gneiss, garnet-biotite-feldspar gneiss, and lesser amounts of schistose biotite gneiss and mafic granulite. These rock types commonly have a well-developed wavy gneissic structure, and are mostly medium to coarse-grained. The felsic and pelitic rocks contain both potassium feldspar and plagioclase. The mafic granulite contains green-brown hornblende, hypersthene, and scant biotite.

Mount Bleechmore Granulite

The Mount Bleechmore Granulite forms rugged terrain with a relief of up to 200 m in the centre of its outcrop area, but merges with the surrounding peneplain along its margins. The reference area (GR 42704710) is in a creek bed east of Mount Bleechmore.

(Where interlayered mafic granulite can be mapped as a separate unit, it has been designated p€ea, but otherwise it is included in the main unit. Rocks of granitic appearance have been mapped as p€eg.).

The most abundant rock type in the unit is migmatitic gneiss, typically composed of alternating coarse to medium-grained biotite-rich and felsic layers. In places the biotite-rich layers contain sillimanite; garnet is abundant in the felsic gneiss (up to 20 percent) and also in the pelitic gneiss, where it accounts for up to 10 percent (e.g. 70090944). The layering is generally 1-4 cm thick and lenticular. Intrafolial folds are present in places. A few garnet porphyroblasts are idiomorphic, and cut across the foliation. Perthite locally forms porphyroblasts, but, together with microcline, is more commonly interstitial. Specimen 71900043, a more felsic variety, contains sillimanite and is about 40 percent plagioclase; some specimens contain as much as 60 percent quartz.

The leucosome, though generally conformable with the foliation, is in places cross-cutting. In a few places where felsic rock completely encloses mafic, their respective foliations are discordant, suggesting extreme boudinage or, more probably, partial absorption of the mafic rock by the enclosing felsic gneiss in a mobile state before the final foliation was formed.

The unit is cut in places by zones of retrograde metamorphism, indicated by biotite clots that have pseudomorphed garnet and the presence of narrow biotite schist zones.

The numerous pelitic and quartzose layers and the rare calcareous layers suggest a sedimentary origin, and the high feldspar content typical of the main rock type suggests immature sediments. The more felsic gneiss may have been derived from acid to intermediate tuffs, volcanics, or sheets of granitic material intruded before metamorphism, although felsic enrichment in individual layers has probably also been produced by metamorphic differentiation and migmatization. A few small dykes appear to cut across the dominant mafic rock (e.g. 70090925B, 70090944B), although they also have been metamorphosed to the granulite facies.

The Mount Bleechmore Granulite is generally similar to the Chiripee Granulite, though the latter is at a lower metamorphic grade and has a lower proportion of mafic rocks.

pЄeg

Massive, homogeneous granitoids crop out 10 km northwest, west and southwest of Alcoota homestead. Many of these rocks can be classified as plutonic migmatites, a term used by Mehnert (1968, pp. 67-72) for migmatites in which there is no definite distinction between leucosomes and melanosomes. Such rocks contain both plutonic and blastic fabric features. Features of the microfabric indicating classification as plutonic migmatite include unoriented or weakly aligned biotite and equant, subidiomorphic to idiomorphic plagioclase (e.g. 70090624, 70090935). Features indicating the transitional to high-grade metamorphic facies include a granoblastic and seriate texture (i.e. having an abundance of xenoblastic minerals with wide range of grainsize; Moore, 1970) and the presence in some rocks of large plagioclase and quartz inclusions in potassium feldspar (70090975).

The migmatites typically contain garnet, rarely contain sillimanite, and generally have a much lower mafic content than the surrounding rocks. A rough visual estimate of the mineral content of a typical example (70090624) is 40 percent quartz, 30 percent plagioclase, 15 percent microcline, 12 percent biotite, 3 percent garnet, and accessory iron oxide.

The rocks do not contain mineral assemblages diagnostic of granulite metamorphism, but they are contiguous with mafic gneisses of the Mount Bleechmore Granulite, which have been metamorphosed to the hornblende granulite facies. The plutonic migmatites may represent the most mobilised part of the granulite-migmatite complex of the Mount Bleechmore Granulite.

pЄea

Mappable mafic rocks constitute 40 percent of the outcrop area in the eastern part of the Mount Bleechmore Granulite, but elsewhere account for only a small part of the unit. The mafic rocks are massive, finely foliated, and commonly cut by thin anastomosing felsic stringers. Hornblende varieties (70090963 70090926) are typically composed of 10 percent quartz, 20-30 percent pyroxene (both clinopyroxene and hypersthene), 20-30 percent plagioclase, and 55-30 percent hornblende. Varieties without hornblende contain up to 60 percent plagioclase, 10-15 percent quartz, and 15-25 percent pyroxene. Both varieties contain very small amounts of biotite and opaque minerals.

Kanandra Granulite

Felsic gneiss and migmatite, mafic granulite, and minor intercalations of calc-silicate rock crop out from Kanandra Gap, north of Kanandra Yard (4899 7478), north and northwestwards to near the Bundey River, and eastwards into the Huckitta 1:250 000 Sheet area. The rocks have been metamorphosed to upper amphibolite or granulite facies, and have been intruded by the Mount Swan Granite. The best exposures of the unit are near Mount Swan, where gneiss and migmatite form a small area of rugged terrain with up to 100 m relief, and in a small group of outcrops about 5 km northwest of Mount Swan. Here the outcrops consist mainly of felsic migmatite with folded and disrupted layers of mafic rock, and calc-silicate intercalations containing actinolite, diopside, and epidote. The felsic gneiss and migmatite generally consist of biotite, garnet, potassium feldspar, and quartz, but locally contain sillimanite and rarely cordierite.

The mafic rocks are composed of plagioclase, clinopyroxene, hypersthene and accessory biotite. Hornblende is found in rocks from low-lying outcrops, but is generally absent in the more resistant higher-grade metamorphic rocks forming the hills.

Microcline porphyroblasts in the felsic gneiss are more abundant near the Mount Swan Granite. The proportion of mobilizate in the migmatite also increases towards the Mount Swan Granite. Pegmatite and gneissic granite veins commonly cut the gneisses.

The Kanandra Granulite is distinguished from the Mount Bleechmore Granulite by its lower proportion of semipelitic units and the more disrupted nature of its mafic granulite.

Mapata Gneiss

The Mapata Gneiss is poorly exposed; it is deeply weathered and crops out southeast of Delny homestead (G.R. 4813 5060), south of the track from Delny to the Sandover Stock Route, and in two small areas west of Waite River homestead. The type area east of Netting Bore is centred on 47555024.

The dominant rock-type is biotite-quartz-feldspar migmatitic gneiss which is characterized by conspicuous, ptygmatically folded quartz-feldspar layers. Biotite schist, amphibolite, and muscovite schist account for only a small part of the known outcrop.

The Mapata Gneiss is interpreted as the low-grade equivalent of the Kanandra Granulite, lacking hypersthene in the mafic rocks, and garnet in the felsic gneisses. It differs also from the Kanandra Granulite in containing a smaller proportion of mafic rock. The difference in grade may be due to local introduction of water during prograde metamorphism of the Delny Gneiss to the north. Another interpretation is that the Mapata Gneiss is equivalent to the lower Cadney Gneiss in the Alice Springs 1:250 000 Sheet area. The Mapata Gneiss is intruded by the Crooked-Hole Creek, Copia, and Ida Granites and probably by the Mount Swan Granite.

Chiripee Gneiss

The Chiripee Gneiss is exposed as low hills and deeply-weathered rises scattered over a wide plain between Plew Bore and Arno Peak to the north. The type area extends from near Arno Peak (at 43652045) south for about 4 km to the Alcoota Station boundary fence.

The most widespread rock type is fine to medium-grained, migmatitic gneiss, containing up to 15 percent garnet and 30 percent biotite. The migmatites are irregularly layered, and contain felsic layers (1-5 cms) alternating with schistose mafic layers rich in biotite and garnet. Calc-silicate rock crops out 5 kms west of Lignum Dam, and a very fine-grained quartzite crops out farther north. Small lenses of para-amphibolite still farther north (7190 0044, 7190 0045) carry up to 10 percent quartz. Pods of calc-silicate rocks, including actinolite, diopside, and calcite-bearing types, are interlayered with felsic migmatite in a small area about a kilometre west of Arno Peak. The unit also contains small amounts of muscovite-biotite-feldspar gneiss (p€r_1), calc-silicate rock, quartzite, biotite-feldspar gneiss, and amphibolite. Garnetiferous orthogneiss (p€g) intrudes the Chiripee Gneiss between Arno Peak and the Alcoota Station boundary and possibly also at Red Cliff.

In sub-unit p€r_1, muscovite is generally more abundant than biotite. The gneiss is medium to coarse-grained, schistose, and migmatitic, containing small amounts of leucosome, which are generally parallel to the foliation. Narrow lenses of amphibolite which cut across the foliation, but are metamorphosed, are believed to be of igneous origin and to have been intruded near the close of the metamorphism. The largest outcrop is 5 km northwest of '720' Bore.

The Mount Bleechmore Granulite and Chiripee Gneiss are similar in composition, but different in metamorphic grade. Sillimanite and hypersthene, typical of the Mount Bleechmore Granulite, are absent in the Chiripee Gneiss. The felsic gneiss in the Chiripee Gneiss, though garnetiferous, does not contain the higher proportions (up to 20 percent) of garnet present in the felsic gneisses of the Mount Bleechmore Granulite. Mafic rocks are much less abundant in the Chiripee Gneiss than in the Mount Bleechmore Granulite.

DIVISION 2

Division 2 comprises the Harts Range Group (Joklik, 1955), Woolla Gneiss, Delny Gneiss, Delmore Metamorphics, and the unnamed unit p€i.

The units, which include felsic, pelitic, and calcareous gneisses and amphibolite, have a higher proportion of metasedimentary rocks, which were originally more mature than those of the Strangways Range Metamorphic Complex. They are also generally less deformed and of a lower metamorphic grade than those of the Division 1.

Division 2 is tentatively correlated with the Warramunga Group of the Tennant Creek area. Therefore it is at least as old as Early Proterozoic, as granites intruding the Davenport Geosyncline, including the Warramunga Group and the lower part of the Hatches Creek Group have been isotopically dated at 1760 m.y. (Riley, 1968). Rocks of Division 2 are also tentatively correlated on lithological grounds with the Lander Rock, Wickstead Creek, and Mount Stafford Beds of the Napperby 1:250 000 Sheet area, which are in turn correlated with the Killi Killi and Mount Charles Beds of the Tanami Complex (Blake & others, 1973; Blake & others, 1975; Shaw & Stewart, 1976).

Harts Range Group

Joklik (1955, p. 36) described the Harts Range Group as "that portion of the Archaeozoic Complex of Central Australia that outcrops in the Harts Range area, south of the plain of the Plenty River, and north of the Proterozoic Heavitree and White Range Quartzites which overlie it". He divided the Harts Range Group in the Alice Springs and Illogwa Creek Sheet areas into five named units. Three of these, the Bruna Gneiss, the Irindina Gneiss, and the Entia Gneiss, probably extend into the Alcoota 1:250 000 Sheet area, and the Brady Gneiss crops out in the extreme southeast of the Sheet area.

Geological trends and the few measured dips, as well as several dips interpreted from magnetic data (Wyatt, 1974), suggest that the Harts Range Group in the southeast of the Alcoota Sheet area lies on the northern limb of a broad regional syncline and probably overlies the Mount Bleechmore and Kanandra Granulites of the Strangways Range Metamorphic Complex, although the actual contacts are covered by Cainozoic deposits.

Harts Range Group, Undippa Dam area

Joklik identified the rocks of the Undippa area as Irindina Gneiss of the Harts Range Group. Subsequent mapping has confirmed that these rocks belong to the Harts Range Group, and geophysical evidence (Wyatt, 1974) supports the view that the Harts Range Group extends from Low Rock to Queenie Flat Dam and from there to Pinnacle Well. Similar rock types are present in both the Alcoota Sheet area and in the type area of the Harts Range Group (M.J. Rickard, A.N.U., pers. comm.). However, it has not been possible to identify conclusively Joklik's units that make up the Harts Range Group; and in the light of revisions being made in the Riddoch 1:100 000 Sheet area containing the original units as set out by Joklik, it does not seem wise to apply his nomenclature to the Undippa area. Moreover, it appears that some units in the Alcoota Sheet area have no equivalents in the Riddoch Sheet area, though they are certainly part of the Harts Range Group. Lithological units distinguished in the Undippa Dam area are described below.

The most common rock type which is tentatively correlated with the Irindina Gneiss of the Harts Range Group is migmatitic pelitic gneiss containing pods of amphibolite. Sillimanite and garnet are common. The amphibolite pods are probably boudinaged sills. Copper carbonate staining was found on a freshly broken surface in one amphibolite pod, 5 km south of Yam Creek Bore.

A lense of leucocratic felsic gneiss that crops out between Yam Creek Bore and Pinnacle Well consists of medium to coarse-grained potassium feldspar, quartz, biotite and, locally, almandine. The gneiss is believed to be a metamorphosed acid igneous rock. This unit has not been recognized in the Harts Range.

The Brady Gneiss exposed in the foot-hills of the Harts Range southeast of the Harts Range Police station was mapped by Joklik (1955) as a quartz-plagioclase-biotite-muscovite-almandine gneiss, which locally includes sillimanite and garnet porphyroblasts. Metamorphic differentiation into mica-rich and quartz-feldspar layers is prominent. Joklik (1955, p. 75) considered that the chemical analysis of a single sample was low in magnesia and normative corundum for a normal psammo-pelitic sediment, but postulated that quartz and plagioclase might have entered the system. The analysis of the Brady Gneiss quoted by Joklik is lower in K_2O and Al_2O_3 and higher in CaO and MgO than analyses of sediments of similar age from the Tennant Creek district, but this may merely reflect a difference in depositional facies. (These outcrops were regretably not delineated on the 1st edition geological map, but they are considered to be different from the main mass of the Harts Range Group present in the Alcoota 1:250 000 Sheet area.).

$\underline{p\text{Є}h_3}$ is a fine-grained and finely-layered leucocratic biotite-quartz-feldspar gneiss, which characteristically shows mesoscopic folding. It is confined to the area north of Yam Creek, and is correlated with the Entia Gneiss of the Harts Range Group. It probably represents a metamorphosed sub-arkosic sediment.

$\underline{p\text{Є}h_4}$ consists of calc-silicate rock and flaggy quartzite. Part of it crops out adjacent to $p\text{Є}h_3$, a similar relation of rock types is seen in the Harts Range. Locally the calc-silicate rocks are scapolite-bearing. In hills east and west of Undippa Dam, the unit includes diopsidic quartzite. (It may be the equivalent of the Naringa calcareous member of the Irindina Gneiss).

$\underline{p\text{Є}h_5}$ is thought to be partly an orthoamphibolite. Para-amphibolite, containing a high proportion of plagioclase, forms a persistent thin layer alongside quartzite and diopside quartzite in hills east of Undippa Dam. It may be a thin equivalent to the Riddock Amphibolite.

Woolla Gneiss

The Woolla Gneiss crops out as low hills and deeply weathered rises north of Mount Solitary (G.R. 3605 5460), and is elsewhere covered by soil or sand. The characteristic rock types are quartz-biotite-feldspar gneiss, muscovite-biotite-quartz schist and garnet-biotite-quartz-feldspar gneiss which are moderately well exposed along the Woolla Downs outstation/Tea Tree road.

Seven kilometres west of Woolla Downs outstation (3826 5448) the gneiss is intruded by unmetamorphosed melanocratic tonalite. Mafic dykes cut the gneiss in the northwestern corner of the Sheet area. At Mount Solitary the gneiss is overlain, probably unconformably, by quartzite and slate tentatively correlated with the Ledan Schist. Elsewhere, the gneiss and schist are unconformably overlain by the Central Mount Stuart Beds, but the contact is covered by soil and alluvium.

Delny Gneiss

The Delny Gneiss is composed mainly of massive quartzofeldspathic gneiss characterized by clots of muscovite and two-mica schist. It crops out as small hills in the headwaters of Crooked Hole Creek, northeast of Milton Waterhole, and in the southern headwaters of Dingo Creek. The type area is centred on G.R. 4665 5060, northwest of Delny homestead.

The quartzofeldspathic gneiss contains microcline and up to 15 percent biotite. The muscovite clots are very fine-grained in eastern outcrops and coarse-grained in the west, and in places have andalusite-like cross-sections. Interlayered with the gneiss and muscovite-biotite schist are lesser amounts of meta-psammite, amphibolite, and very small amounts of calc-silicate rock. Some of the amphibolite bodies, such as those northeast of Copia Bore, are metamorphosed intrusive plugs, showing cross-cutting relations.

Zones of dynamic metamorphism have resulted in the sericitization of potassium feldspar and the brittle deformation of quartz.

The Delny Gneiss is considered to be younger than the Kanandra Granulite and Mapata Gneiss at it has undergone fewer deformations. It lacks intrafolial folds, and has not formed a leucosome phase, features common to the Kanandra Granulite and Mapata Gneiss. The junction between the Delny Gneiss and Mapata Gneiss is poorly exposed, but at least in the west is isoclinally overfolded.

Delmore Metamorphics

The Delmore Metamorphics consist of calcareous metasediments, metapelites, a lens of anthophyllite-chlorite-cordierite rock, and amphibolite. They are exposed north of Mount Ida as low-lying scattered outcrops, the best exposed of which are centred on 47357518, about 8 km west of Delmore Downs homestead.

Typically the metasediments consist of chlorite, biotite, microcline, albite, epidote or diopside, and quartz. In some specimens strongly saussuritized andesine-oligoclase is present instead of albite. These pelitic gneisses grade into hornblende-bearing varieties which lack quartz in places, but, like the pelitic gneisses, are microcline-bearing. Less common are epidote quartzite and rare epidosite.

Amphibolite occurs in small amounts as lenses. In places the amphibolite shows amygdale-like structures, which are probably tectonic in origin. The amphibolites grade into more leucocratic rocks that are probably intermediate in composition.

A small outcrop of cordierite-anthophyllite-quartz-biotite-chlorite gneiss (7190 0014) occurs immediately beneath the Ledan Schist, 6 km southwest of Western Watering Point. The cordierite is extensively altered to pinite.

The Copia and Ida Granites and numerous pegmatites intrude the Delmore Metamorphics. The relation between the Delny Gneiss and the Delmore Metamorphics is difficult to interpret. They may be facies equivalents; but as the Ledan Schists overlie the Delmore Metamorphics with angular unconformity, whereas the Delny Gneiss is nowhere in contact with the Ledan Schists, the Delny Gneiss is probably stratigraphically below at least the upper part of the Delmore Metamorphics.

Calcareous metasediments within the Delmore Metamorphics are similar to the host rocks for scheelite mineralization in the Bonya District, Huckitta 1:250 000 Sheet area. They are also similarly intruded by numerous pegmatites, and thus should be considered prospective for scheelite.

p-Ꞓi

p-Ꞓi is composed mainly of metasediments and mafic rocks; it extends east from near Aileron (in the Napperby 1:250 000 Sheet area) to the southwestern part of the Alcoota Sheet area, where it crops out as a series of low scattered hills up to 100 m high. The reference area for the unit is in the Napperby Sheet area. The lithology of p-Ꞓi places it in Division 2.

The unit is composed of calc-silicate rock, semi-pelitic and pelitic rocks, quartzite, quartz-feldspar gneiss, and rare lenses of diopside and fosterite marble. Small mafic pods are believed to be metamorphosed basic plugs.

DIVISION 3

Division 3, characterized by quartz and mica-rich metasediments, includes the Mendip Metamorphics, Ledan Schist, and Utopia Quartzite. It unconformably overlies units of Division 2 and is tentatively correlated with the Hatches Creek Group in the Barrow Creek Sheet area and the Reynolds Range Group in the Napperby Sheet area.

On regional geological evidence, Division 3 is, like Division 2, at least as old as Early Proterozoic.

Mendip Metamorphics

The Mendip Metamorphics are a sequence of metamorphosed shelf-facies sediments composed of quartzite and biotite gneiss with small amounts of granule conglomerate, para-amphibolite, calc-silicate rock, and schist. The unit crops out around Mendip Hill, and forms comparatively rugged terrain with up to 100 m relief. The type area is Mendip Hill (G.R. 4386 4827) and adjoining ridges northwest of Alcoota homestead.

The quartzite (70090946) is crossbedded, medium to coarse-grained, grading into granule conglomerate. A few beds contain flakes of muscovite and biotite. Small iron-stained voids are common. The quartzite is typically deeply weathered, and in places is heavily stained with manganese and iron.

The biotite-gneiss (70090955) is fine to coarse-grained, generally quartz-rich and schistose, and commonly contains a pegmatitic leucosome phase. Feldspar-rich and muscovite-bearing biotite gneisses are less common variants of this rock type.

Calc-silicate rock and amphibolite are locally interlayered. The calc-silicate rock grades into impure quartzite that typically contains about 60 percent quartz, 20 percent plagioclase, 12 percent biotite, and 8 percent epidote. A typical para-amphibolite (7190 0041) contains 50 percent blue-green hornblende, 20 percent quartz, 15 percent epidote, and 15 percent biotite.

Poorly exposed outcrops of quartz-rich mica schist and quartzite, uncovered by partial dissection of the deep-weathering profile in the headwaters of Mapata Creek and farther southwards, have been equated with the Mendip Metamorphics. Biotite-muscovite-quartz schist exposed in a creek bed at G.R. 4718 4768 contains minor tourmaline and an opaque mineral (probably hematite). Iron-stained cubic voids in the rock may have contained euhedral pyrite. Although metamorphosed, these rocks are less deformed than the Harts Range Group to the south, and are therefore considered to be younger.

The Mendip Metamorphics may unconformably overlie the Mount Bleechmore Granulite, but the contact is poorly exposed. They are of considerably lower metamorphic grade; the hornblende in the Mendip Metamorphics is blue-green, and garnet, sillimanite, and hypersthene, which are common in the Mount Bleechmore Granulite, are not present. The quartzite and calc-silicate rock of the Mendip Metamorphics suggest a much shallower-water environment for the original sediments than is indicated by the pelitic and felsic gneisses for the Mount Bleechmore Granulite. Mafic meta-igneous rocks (p€ea) and cross-cutting dykes in the Mount Bleechmore Granulite are absent from the Mendip Metamorphics. The change in rock types between the units is abrupt, and supports the interpretation of an unconformable relation.

The poorly exposed quartz-rich mica schists and quartzites in the headwaters of Mapata Creek are separated from the Kanandra Granulite and Mapata Gneiss by a wide shear zone and the boundary with the Harts Range Group is not exposed. The Mount Swan Granite intrudes the rocks and has produced a narrow rim of alteration.

The Mendip Metamorphics are similar to the Ledan Schist, but the latter is less mafic, contain little calcareous material, and is characterized by the predominance of muscovite over biotite.

Ledan Schist

The Ledan Schist is named from Ledan Peak, in the northern part of the outcrop area. The type section is in the range forming the limbs of a syncline, 12 km west of Delmore Downs homestead. The unit forms strike ridges which extend southeastwards from Ledan Peak in the Alcoota Sheet area to the Huckitta Sheet area. The rocks forming Mount Solitary and an adjacent hill are tentatively correlated with the Ledan Schist. From descriptions by Smith & Milligan (1964), the Ledan Schist resembles the Hatches Creek Group in the Osborne Range, Barrow Creek 1:250 000 Sheet area.

The Ledan Schist unconformably overlies the Delmore Metamorphics and is probably disconformably overlain by the Utopia Quartzite.

The dominant rock type in the unit is mica-quartz schist, consisting mainly of muscovite, quartz, and biotite. Minor rock types in the unit are grey medium-bedded quartzite; black, thin-bedded, tourmaline-rich, quartzite; conglomerate, and amphibolite. Amphibolite (probably para-amphibolite) crops out in the floor of a small pound enclosed by ridges of schist, but has not been observed in contact with other rock types of the units; on structural grounds it appears to be part of the unit. The basal conglomerate is overlain by conglomerate of cobbles, mainly of vein quartz and grey quartzite in a matrix of fine-grained muscovite-quartz schist. Deep blue tourmaline is thinly disseminated through some of the mica schists of the unit. (Similar tourmaline in some of the pegmatites of the district suggests these may be derived from the schists.). Minor black quartzite contains disseminated needles of blue-green tourmaline, and at some localities, magnetite.

A potassium-argon age of 1532 m.y. was obtained from muscovite from the Ledan Schist, and 1537 m.y. was obtained from muscovite from a pegmatite intruding the schist (Table 1; Webb, 1972). These are regarded as minimum ages, and are significantly older than K-Ar ages from the Ida and Mount Swan Granites; but all are considered to have been slightly reset, possibly during the Alice Springs Orogeny. On stratigraphic, lithological, and structural grounds the Ledan Schist is tentatively correlated with the Hatches Creek Group in the Davenport Ranges and hence is probably Early Proterozoic (age of sediments, but not necessarily age of deformation).

Utopia Quartzite

The Utopia Quartzite is named from Utopia Station, which occupies the north central part of the area. Strike ridges of the Utopia Quartzite extend from here south-eastwards into the Huckitta Sheet area. The type section is the range which lies in the axis of a syncline 10 km southeast of Ledan Peak.

The Utopia Quartzite consists mainly of massive to flaggy clean quartzite cemented by quartz. The unit includes several grit horizons, including one near the base. Colour ranges through white, pale pink, light grey or blue; the blue colour is caused by the presence of tourmaline. The unit also includes a band of highly weathered ironstone. Analyses of the ironstone are given in Appendix 1. Similar ironstones are found in the Hatches Creek Group.

The Central Mount Stuart Beds and Grant Bluff Formation are believed to overlie the Utopia Quartzite unconformably, but no contacts are exposed. It is tentatively correlated with the quartzose part of the Hatches Creek Group and the Mount Thomas Quartzite of the Reynolds Range Group (Stewart & others, in prep.), and is therefore probably Early Proterozoic.

UNASSIGNED METAMORPHIC ROCKS

Ɛlq

Pods of flaggy, schistose, or massive but well foliated mylonitized quartzite occur along many of the faults in the east of the Sheet area. Their development postdates the granites, and the faults where they are found do not cut the Adelaidean. They are thought to have resulted from renewed movement along faults already filled by quartz.

Similar faults are found in the east of the Napperby 1:250 000 Sheet area and also in the Huckitta 1:250 000 Sheet area.

The unit is tentatively correlated with the Wallaby Knob Schist Zone and the Redbank Zone (Marjoribanks & Black, 1974).

pЄ

On the geological map, pЄ has been used for deeply weathered rock believed to be gneiss or schist and for outcrops photo-interpreted as gneiss or schist, but not visited during the survey.

pЄd

pЄd consists of small outcrops of mafic granulite and amphibolite. They are common in the southern part of the Sheet area, but as they are mostly very small dykes, sills and discordant plugs up to 3 m across, most cannot be shown separately on the map.

An amphibolite and a metagabbro plug, both of which crop out as circular features near Mount Byrne, were described by Kostlin & Hughes, (1971). The composition of the metagabbro was estimated as 45 percent hornblende, 45 percent plagioclase (An_{70}), 3 percent quartz, 3 percent augite, and rare opaque grains. These exposures are too small to show on the map.

Several mafic igneous plugs have been interpreted by Wyatt (1974) from magnetic data north of Coppock Bore in the southwestern corner of the Sheet area.

Small bodies of mafic granulite and amphibolite have intruded unit p€y southeast of Old Bushy Bore.

Relations seen in the Aileron 1:100 000 Sheet area indicate that mafic rocks were intruded after folding and before the final granulite metamorphism which affected the region.

p€g

At Red Cliff garnet-biotite-gneiss is found in the western part of the outcrop area of the Chiripee Gneiss, but its relations with contiguous rock are obscured by superficial sediments. The granitic appearance of the gneiss suggests it may be an orthogneiss.

Five kilometres south of Old Bushy Bore a similar, though very small, plug-like body of garnet-bearing granitoid intrudes granulite of unit p€y.

Orthogneiss intrudes the Chiripee Gneiss between Arno Peak and the southern boundary of Waite River Station. Specimen 7009 0656 consists of microcline, sodic plagioclase, quartz, biotite, garnet, and accessory zircon. The orthogneiss may be a local melanocratic and garnetiferous variant of the Crooked Hole Granite, which crops out to the north. It is unlike the Copia Granite in that it has sharper margins and contains a high proportion of pegmatitic leucosome.

Wallaby Knob Schist Zone

The Wallaby Knob Schist Zone forms low hills near Muller Bore in the southern-central part of the Sheet area. The unit is readily recognizable on black and white aerial photographs because of its pale colour. The main rock types are gneissic to schistose biotite-bearing gneiss and muscovite biotite felsic gneiss, both of which, very locally, contain garnet. In other places the gneisses are quartz-rich and contain potassium feldspar porphyroblasts. The unit includes a few lenses of amphibolite, hornblende gneiss, and calc-silicate rock, mainly in the south. Five kilometres southeast of Muller Bore a muscovite schist layer contains attractive crystals of green kyanite, up to 7 cm long. Kyanite is also known at 70090615B. Staurolite is contained in chlorite-biotite quartz schist (70090620) 6 km southwest of old Bushy Bore.

The rocks are characterized by a penetrative, planar schistosity which parallels the axial-plane of steeply plunging second generation folds. Quartz veins are sparsely scattered throughout the unit, and are commonly parallel to the schistosity.

The metamorphic grade of the Wallaby Knob Schist Zone decreases northwards. Both kyanite and staurolite are confined to the more schistose rocks in the central part of the outcrop area, whereas in the southern part, sillimanite, andalusite, and cordierite (69090286) as well as hornblende-bearing assemblages (70090965), are widely distributed.

The unit, particularly the southern part, is thought to be a deformed and metamorphically retrogressed equivalent of the more potassic part of unit p€y. The penetrative schistosity cuts the granulite trend at right angles, and the change from typical felsic granulite assemblages to mineral assemblages including muscovite, staurolite, and kyanite, indicates that the unit is a wide zone produced by retrograde metamorphism, possibly associated with faulting. The southern part of the Wallaby Knob Schist Zone has the same magnetic character as unit p€y (Wyatt, 1974). The presence of staurolite, kyanite, cordierite, andalusite, and sillimanite indicate that at least part of the unit has a metasedimentary composition. The northern part of the unit is magnetically "quiet" which would indicate a granite origin for this part.

IGNEOUS ROCKS

Pegmatite (Ep)

Pegmatite is abundant in three areas: (1) the Undippa Dam area north of the Plenty River, (2) north and west of Delmore Downs homestead, and (3) west of Waite River homestead between Boomerang Bore and Muller Bore.

(1) In the Undippa Dam district, numerous pegmatites intrude the Harts Range Group. Most are confined to three east-west lines, one immediately north of the Plenty River and the other two between Yam Creek and Queenie Flat Dam. At least 17 tons of mica were mined from the pegmatites during and immediately after World War II. Only in the largest bodies was the muscovite of a suitable size for mining, and consequently only about twenty pegmatites were productive.

(2) In the Delmore Downs area quartz-muscovite-orthoclase-tourmaline pegmatites are abundant around the Ida Granite and in the Ledan Schist. Only one is reputed to have been mined for mica. Tantalite has been found in two other pegmatites, and one of these contains traces of the amorphous phosphate mineral, griphite (Jaffe, 1946) and bismuth minerals (Daly & Dyson, 1963).

(3) West of Waite River homestead many small pegmatites surround intrusions of the Crooked Hole Granite, but do not contain mica flakes large enough for them to be prospective.

A K/Ar age of 1537 m.y. for muscovite from a pegmatite 6 km northwest of Delmore Downs homestead (Webb, 1972) gives only a minimum age for emplacement, because widespread resetting of K/Ar ages is evident throughout the Arunta Block (Shaw & Stewart, 1976). The coarse-grained pegmatites of the Undippa area are correlated with those in the Plenty River district, which were considered by Smith (1964) to be unconformably overlain by the Grant Bluff Formation, and hence early Adelaidean or older in age. The pegmatites of both areas were probably emplaced during the late stages of a major regional metamorphic event at about 1700 m.y. (Shaw & Stewart, 1976).

Langford Gneiss

The Langford Gneiss is believed to be a deformed granite, consisting of porphyroblastic biotite-feldspar gneiss interlayered with schistose biotite-muscovite gneiss. The gneiss forms low hills between Langford Creek (from which it is named) and Plew Bore, and is best exposed at 42754835 in low ridges 11 km west of Mendip Hill. Its composition is uniform throughout the outcrop area.

The biotite-feldspar gneiss has a colour index of 30-40, and is characterized by microcline porphyroblasts 0.5 to 8 mm long and up to 3 cm wide. The porphyroblasts are generally aligned with the foliation though in places they cut across it and in other places are wrapped around by it. Reaction rims around some zoned porphyroblasts are unfoliated. A few porphyroblasts are twinned and some contain biotite inclusions.

The mineralogical composition of a typical specimen of porphyroblastic gneiss (70090928A) was estimated as 10 percent plagioclase (approx. An_{50}), 10 percent quartz, 5 percent muscovite, 10 percent biotite, and 60-65 percent microcline. The mineralogy of the schistose gneiss is variable, but it is consistently rich in muscovite or biotite.

The Langford Gneiss has a conformable contact with the Mendip Metamorphics. The origin of the large-scale layering is problematical; possibly it is due to later selective deformation. The Langford Gneiss is considered to be anatectic, possibly a metamorphosed and partly remobilized felsic volcanic unit.

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Tonalite crops out 7 km west of Woolla Downs outstation. The tonalite contains 20 percent quartz and a little perthite as well as biotite, plagioclase, and hornblende (70091300).

PROTEROZOIC GRANITES

The granites in the Alcoota Sheet are typically of calc-alkaline composition and contain relatively few xenoliths. All except the Woodgreen Granite are strongly gneissic, and most contain abundant microcline phenocrysts. Descriptions of the granites and their relations are summarized in Table 3.

Copia Granite

The Copia Granite can be mapped from 5 km northeast of Copia Bore (G.R. 46157504) northwards to about 19 kms west-southwest of Western Watering Point. At the type locality (G.R. 46605040) about 7 km northeast of Copia Bore, from which it takes its name, the granite is exposed in a low circular scarp.

Characteristically the granite is strongly gneissic, coarse to medium-grained, has a high colour index (15) and fairly uniform composition. A paler coloured phase forms a small proportion of southern outcrops. It intrudes the Delny Gneiss with contacts typically transitional across one to several metres and with numerous pegmatite bodies in the adjacent Gneiss. We infer from the map pattern that the granite also intrudes the Delmore Metamorphics though no intrusive contact has been found. The granite is intruded by the Ida Granite.

The Copia Granite consists of strained quartz, microcline, oligoclase, biotite, possibly magnetite, and accessory apatite, zircon, and sphene. The biotite content is about 15 percent, but drops to less than 5 percent in the leucocratic phase (71900009). Specimen 70090608 from the northernmost outcrop also contains accessory blue-green hornblende.

The Copia Granite is considered to be an early or syntectonic intrusion because of its commonly folded, strong gneissic fabric, and its lack of sharp margins.

The analysis given in Appendix 2 is of 72902003, taken from the age determination site shown as 2003 about 6 kms northeast of Copia Bore. The sample contains primary muscovite, and is therefore probably more potassic and aluminous than the "type" granite. It is nevertheless an I-type granite, on the main criteria applied in southeastern Australia. (Trace elements show the source region is distinctly different from that in southeast Australia however.). The U/Th (0.66) is high, but the low absolute uranium content (8 ppm) indicates that the granite is not a likely source area for later uranium deposits.

In common with the Delny Gneiss, the Granite has been intruded by mafic rocks, which have been subsequently thermally metamorphosed on a regional scale.

Crooked Hole Granite

The Crooked Hole Granite crops out in the headwaters of Crooked Hole Creek (after which it is named) between Boomerang Bore (GR 430 514) and Muller Bore (GR 44805080). The most typical exposures are in low hills at GR 4350 5120, 4 km north-northwest of Arno Peak where the granite intrudes the Delny Gneiss with sharp, slightly discordant margin. It possibly also intrudes the Mapata Gneiss. Many small pegmatites are scattered through the area marginal to the granite.

The granite has an unusually high colour index of 30 to 40, which distinguishes it from the Ida Granite. A typical specimen (70090665) contains microcline, zoned plagioclase, quartz, biotite, and secondary muscovite. As the specimen was collected 1 km north of a major fault zone, the secondary muscovite and straining of the quartz may be ascribed to dynamic metamorphism. A small area of hornblende granite west of Muller Bore is included in the unit.

Mount Swan Granite
(Smith, 1964)

The Mount Swan Granite was defined by Smith (1964) from the Huckitta Sheet area, where it was mapped between Mount Swan and New Macdonald Downs homesteads, and traced westward into the Alcoota Sheet area. It has now been followed as far west as the Bundey River, and to the southwest, south of the Delny Fault Zone, where numerous small bosses intrude the Kanandra Granulite. A small body of granite in the headwaters of Mapata Creek is also mapped as Mount Swan Granite. North of the Delny Fault Zone, one large body of Kanandra Granulite and several rafts of unassigned gneiss form elongate inliers in the granite. Margins of the granite against country rock are generally sharp (Smith, 1964, p. 14). However, 2 km southeast of little Dam (G.R. 486493) basic granulite of the Kanandra Granulite has been retrogressively metamorphosed and partly absorbed adjacent to a granite boss. West of the Bundey River deep weathering masks intrusive contacts between probable Mount Swan Granite and Delny Gneiss. Here, the granite is more even-grained than is t-pical of the Mount Swan Granite and may be a melanocratic phase of the Ida Granite. About 0.5 km southeast of Delny homestead, granite mapped as Mount Swan Granite intrudes a gneissic granite comparable with the Ida type. Contacts with the Ledan Schist are covered by soil, but airphotograph-lineaments suggest they are faulted.

Smith observed that the main phase of the granite is characterized by large feldspar phenocrysts oriented sub-parallel to the foliation in the gneissic groundmass. The granite consists of phenocrysts of microcline (up to 35 mm long) set in a ground mass of quartz, microcline, biotite, and sodic plagioclase, with accessory sphene and zircon. At some localities the granite grades into an adamellite. Secondary muscovite present in one specimen may be a product of dynamic metamorphism concurrent with the development of the Delny Fault Zone; epidote also occurs in the granite close to this fault zone.

Smith (1964) considered that the Mount Swan could be the product of metasomatism of a unit like the Brady Gneiss of the Harts Range Group. The analysis of the Mount Swan Granite (Appendix 2) shows it is a distinct I-type, and makes this theory untenable. The probability of anatectic melting of the Kanandra Granulite is only moderate. The S-I criteria do not discriminate between the products of melting of a primary igneous source and remelting of an I-type igneous unit such as the Kanandra Granulite may be.

Near the Delmore Downs/MacDonald Downs boundary fence, wolframite has been mined in a raft of sillimanite-quartz-garnet-biotite gneiss close to the granite margin. Samples containing scheelite and fluorite have also been obtained from these workings, and small quantities of copper carbonate stain a quartz reef close by (Nye & Sullivan 1942) described wolframite deposits east of Delny in a raft of metasediments within the Mount Swan Granite.

The Mount Swan Granite has a K/Ar age of 1460 m.y. (Hurley & others, 1961) but this may have been partly reset. The true age may be comparable with that of the Jinka Granite to the east in the Huckitta Sheet area, which is dated at 1840 m.y.* using muscovite (Wilson & others., 1960), 1690 m.y. on the basis of Rb/Sr total rock and mineral isochrons (Riley, 1961; pers. comm. in Compston & Arriens, 1968), but which gave a K/Ar age of 1440 m.y. (Hurley & others., 1961).

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(Unnamed granite north of Allungra Creek)

Granite is exposed as hills up to 50 m high near Allungra Waterhole on the western boundary of the Sheet area. The granite extends into the adjacent Napperby Sheet area where a type locality has been nominated imme-

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* Recalculated on revised decay constants at 1803 m.y.

diately north of Mount Boothsby (Napperby 1:250 000 Sheet area).

There are two distinct mineralogical types: the dominant one, a porphyritic variety, contains large microcline phenocrysts in a matrix of biotite, quartz, plagioclase, and potassium feldspar; and the subordinate, more gneissic, one is of similar composition, but not porphyritic.

The granite intrudes unit p€i, and (in the Napperby Sheet area) intrudes mafic granulite of the Strangways Range Metamorphic Complex. Northwest of Harrys Dam (Napperby 1:250 000 Sheet area) a gradation from felsic migmatite into the granite can be traced. Warren therefore considers the granite to be a product of anatectic melting of felsic units within the Strangways Range Metamorphic Complex.

Queenie Flat Granite

The Queenie Flat Granite, named from Queenie Flat Dam in the southeastern part of the Sheet area, extends in a zone about 5 km wide, from the type exposures, half a kilometre southwest of the dam, west-southwestwards to near Table Hill Dam.

The Queenie Flat Granite is porphyritic, strongly gneissic, and ranges in composition from adamellite to granite. A younger biotite foliation locally overprints the gneissic fabric marked by the quartzofeldspathic layers. The granite typically contains microcline phenocrysts up to 2 cms across in a matrix of biotite, microcline, plagioclase, and quartz, with accessory zircon and an opaque mineral, possible ilmenite. The microcline occurs as augen irregular aggregates in the matrix and euhedral laths which cross the main foliation.

The Queenie Flat Granite has an intrusive contact with p€h_3 of the Harts Range Group. The contact is folded about approximately west-trending axes.

The Queenie Flat Granite superficially resembles the Mount Swan Granite, but has a higher colour index and is chemically distinctive. This granite also resembles the Bruna Gneiss of the Harts Range Group (M.J. Rickard, ANU, pers. comm.) in that it occupies a similar stratigraphic position and has a similar appearance in outcrop. However, Joklik (1955, p. 66) considered that, although the chemical composition of the Bruna Gneiss was similar to that of certain granites, the gneiss was of sedimentary origin; the Queenie Flat Granite is clearly intrusive.

The analysis of the Queenie Flat Granite (72902011, Appendix 2) shows the unit to be distinctive from the Bruna Gneiss (Joklik, 1955, p 67) (though perhaps one should not place great dependance on single analyses of each unit). The Bruna Gneiss is closer to an S-type whereas the Queenie Flat is an I-type granite with low normative corundum.

An intrusive unit, similar to the Queenie Flat Granite, crops out in the Harts Range Group a kilometre north of Marshall Bore in the Huckitta 1:250 000 Sheet area. This granitoid was intruded at the same stratigraphic horizon, but the units are at granulite grade. Compositionally this granitoid has a higher biotite content, and texturally it is coarser grained.

Ida Granite

Outcrops of a grey or greyish-pink fine to coarse-grained gneissic granite extend from 7 km south of Mount Ida (after which the granite is named) to about 14 kms north of the peak. The type locality is a tor-like hill at G.R. 4465 5150, 3 km north-northwest of Mount Ida, where the granite is gneissic, grey, and even-grained.

Granite similar to the Ida Granite crops out in a zone along the Bundey River from 1 km north of Delmore Downs homestead to about 1 km south of Delny homestead. It is shown on the 1st Edition Map as Mount Swan Granite; however, it is non-porphyritic gneissic granite, generally somewhat darker than the main mass of Ida Granite and has been intruded porphyritic granite typical of the main phase of the Mount Swan Granite.

The Ida Granite generally consists of microcline, quartz, biotite, minor plagioclase and opaques (?magnetite); orthoclase is present in some parts of the granite, as are primary muscovite, hornblende, and garnet. As the granite crops out in an area affected by major faults, some specimens show the results of dynamic metamorphism: quartz is strained, secondary muscovite replaces microcline, and in one specimen biotite has chloritized margins.

Pegmatites associated with the granite are generally confined to its margins and to a broad contact zone in the country rock.

The Ida Granite is known to intrude the Copia Granite and Delmore Metamorphics, and pegmatites similar to those associated with the Ida Granite intrude the Ledan Schist. Equally significant, the granite shows no sign of having been affected by the regional metamorphism that affects the Ledan

Schist. Potassium-argon age determinations on biotite separates from samples of the Ida Granite gave 1391 ± 30 m.y. and 1387 ± 30 m.y. (Webb, 1972). These results reflect partial resetting either during the undated major faulting or during the Alice Springs Orogeny. From stratigraphic relations, it is considered that the Ida Granite is early Carpentarian or late Early Proterozoic in age.

Woodgreen Granite Complex

The Woodgreen Granite Complex crops out from 1 km north of Boomerang Bore northwards to the foothills of Mount Skinner, west of Waite River Station and east of Woodgreen Station (from which the Complex is named). It contains a number of granite types, most of which are coarse-grained. It is not known whether the types are phases within a single mass, or several separate granite intrusions, as outcrops consist of tors and small hills separated by soil. South of West Bore at G.R. 4330 5190 the main granite type is adamellite, containing phenocrysts of large subhedral feldspars set in a medium-grained matrix. Non-porphyritic granite is also present. Tors about a kilometre northwest of the northwest corner of Waite River station consists of coarse-grained granite with large aggregates of garnet, and tors a kilometre east of the corner are composed of fine-grained leucogranite containing garnet. The Complex is cut by numerous faults and zones of shearing and dynamic metamorphism.

The granites show considerable compositional range: 70090652 south of West Bore is composed of about 50 percent microcline and 20 percent plagioclase (probably oligoclase), whereas 70090666, an adamellite, contains 36 percent sodic labradorite. J.K. Lovering described three typical specimens of Woodgreen Granite Complex (B4933-35) submitted by T. Quinlan (Perry & others, 1962). This typical granite consists mainly of microcline-perthite and quartz with up to 5 percent biotite and 10 percent andesine. Accessory minerals include zircon, apatite, and in places iron oxide and sphene.

All the specimens collected during the BMR survey show some degree of dynamic metamorphism, possibly a result of the Alice Springs Orogeny. Chlorite and epidote replace biotite; sericite and clinozoisite have formed from plagioclase; quartz is strained or polygonized.

The Woodgreen Granite Complex is thought to be a late intrusion because of the weakly developed foliation. The generally coarse grainsize and the presence of garnet suggest deep-seated emplacement. The Complex is unconformably overlain by the Central Mount Stuart Beds and is probably also overlain by the Grant Bluff Formation, although the contact is not exposed.

Pg

Several granites mapped have not been assigned to any of the named units.

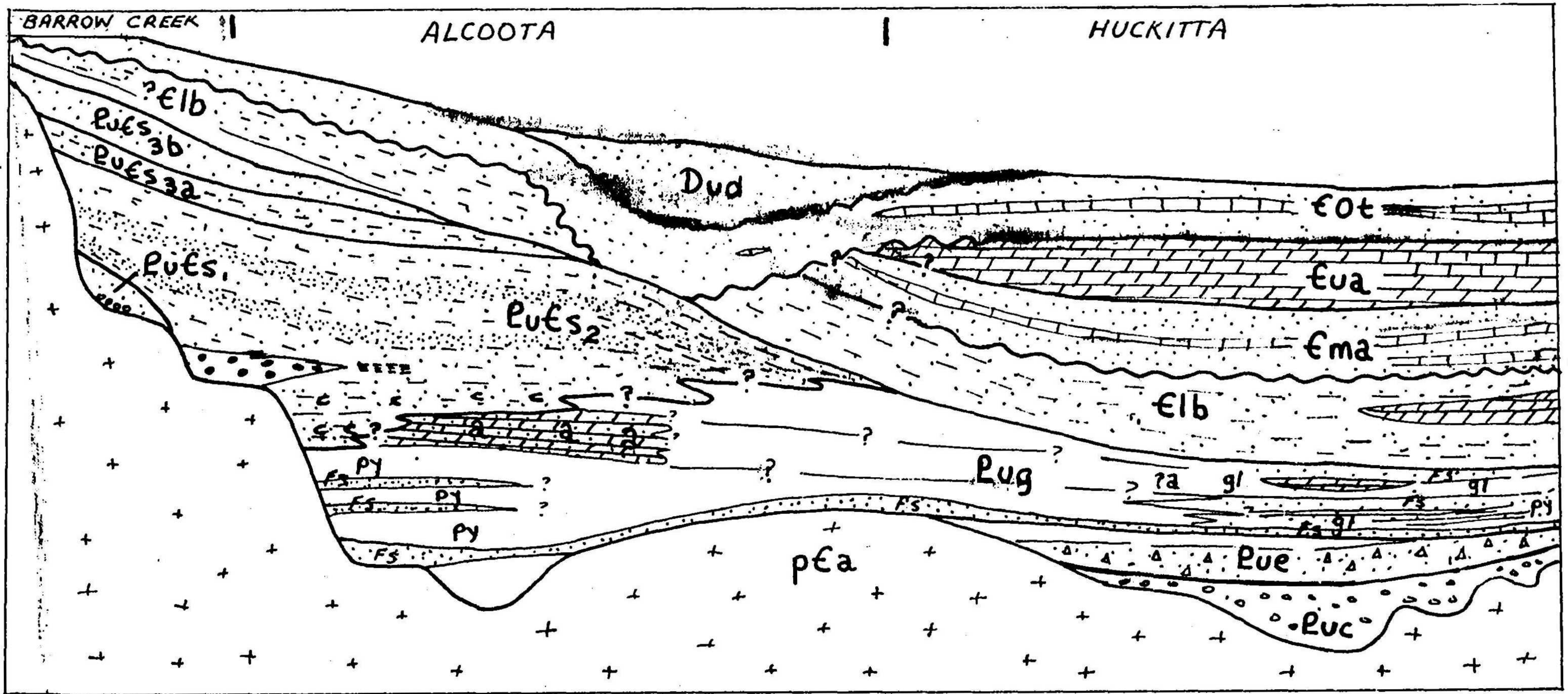
1. Near Lily Bore a weakly gneissic, fine to medium-grained biotite granite, containing feldspar porphyroblasts, crops out. This granite is probably syntectonic, as its foliation parallels the axial plane schistosity of a fold in the Ledan Schist. It is considered to intrude the Ledan Schist (C.J. Simpson, BMR, pers. comm.).

The foliated nature of this granite resembles that of the Ida and Mount Swan Granites, suggesting that all three granites were intruded after or during metamorphism of the Ledan Schist.

2. Medium-grained, pink, gneissic granite near Mount Michael is unlike either the Mount Swan or Ida Granites but somewhat resembles the Dneiper Granite (Huckitta Sheet area). It is cut by numerous quartz and jasper reefs. The granite 71900016 consists of microcline, small amounts of intergrown perthite and quartz-feldspar, sodic plagioclase which has been deuterically altered, quartz, biotite, and accessory zircon, apatite and opaque minerals rimmed by rutile. Some outcrops of this granite contain small phenocrysts of microcline, 4-10 mm long.

Two inliers of paragneiss in the granite are unlike any metamorphic units mapped to the south of the Ledan Schist. The Grant Bluff Formation rests unconformably on the granite.

3. Northeast of Mallee Bore, mafic and felsic gneiss of the Harts Range Group are intruded by two plug-like granite bodies. These granites are pale grey and weakly gneissic, and show an exceptional range in grainsize. One granite (71900050) consists of microcline, plagioclase, biotite and small amounts of garnet and strained quartz. Biotite from this gave a K-Ar



Record 1975/100

Dominant Lithology

- Red sandstone, and siltstone
- Pale grey and brown sandstone, conglomerate
- Siltstone, shale
- Dolomite, sandy dolomite
- Limestone
- Arkose
- Boulder beds, tilloid, varves

gl - Glauconite
a - Anhydrite, gypsum
py - Pyrite
c - Calcareous
Fs - Feldspathic

Dud	Dulcie Sandstone
ƐOt	Tomahawk Beds
Ɛua	Arrinthrunga Fm.
Ɛma	Arthur Creek Bds.
Ɛlb	Mt. Baldwin Fm.
PuƐs	Central Mt. Stuart Bds.
Pug	Grant Bluff Fm.
Pue	Elyuah Fm.
Puc	Mt. Cornish Congl.
pƐa	Arunta Complex

F53/A10/41

Figure 3 Relationship of Adelaidean and Palaeozoic units isotopic age of 306 $\pm$ 8 m.y. (Spec. 71900058, Webb, 1972), but this is regarded as an age reset during warming associated with the Alice Springs Orogeny (Shaw & Stewart, 1976).

4. Pale grey, fine-grained granite about 1 km north of Boomerang Bore is unlike the Woodgreen Granite Complex to the north and has therefore been mapped separately. It intrudes the Delmore Metamorphics with a slightly discordant contact.

5. Biotite granite and medium-grained muscovite granite crop out in the basement inlier west and northwest of Mollie Bluff. This granite may be responsible for the response of roughly twice background observed on the uranium channel during the BMR airborne radiometric survey in this area in 1972 (Wyatt, 1974).

SEDIMENTARY PLATFORM COVER

Platform cover in the Alcoota 1:250 000 Sheet area falls into two major units: (a) the Adelaidean - Lower Palaeozoic sequences of the Ngalia and Georgina Basins, together with the Central Mount Stuart Beds occupying a high between the Basins and (b) the Tertiary and Quaternary units.

Adelaidean - Lower Palaeozoic

Adelaidean to lower Palaeozoic sedimentary rocks are preserved in two structural basins; the Ngalia Basin, of which only the extreme east portion is within the Alcoota 1:250 000 Sheet area; and the Georgina Basin which impinges on the northeast corner of the Sheet area. The Central Mount Stuart Beds occur in fault bounded blocks across the north west of the Sheet area. The relationship between the Adelaidean - Lower Palaeozoic units is shown in Figure 3.

NGALIA BASIN

Only one formation of the Ngalia Basin sequence crops out on the Alcoota 1:250 000 Sheet area. This is the Vaughan Springs Quartzite containing the Treuer Member, which is exposed along the north dipping southern margin of the Basin in the Hann Range (southwestern margin of the Alcoota 1:250 000 Sheet area)

Vaughan Springs Quartzite (Adelaidean)

The Vaughan Springs Quartzite at the eastern end of the Hann Range consists of tough, pink, grey, and white massive to thick-bedded ortho-quartzite, white friable sandstone, a local basal conglomerate, and pebbly hematitic conglomerate. The formation was named from Vaughan Springs on the Mount Doreen Sheet area by Wells & others., (1968), and its type section is in the same Sheet area (Wells, 1972). It unconformably overlies crystalline basement which is mostly granite in the eastern Hann Range.

Treuer Member of the Vaughan Springs Quartzite

The Treuer Member occurs in the lower half of the Vaughan Springs Quartzite. It consists of laminated to thin-bedded white to grey sandstone with white, yellow and red siltstone. The sandstone is cross-bedded in places, micaceous in part, contains a few clay pellets and includes glauconitic sandstone. The Treuer Member may contain evaporites, as gypsum was found in the Hann Range associated with the siltstone.

The member is named from the Treuer Range in the Mount Doreen Sheet area, and its type section is in the same Sheet area (Evans & Glikson, 1969; Wells, 1972).

Rb-Sr and K-Ar measurements on glauconite from the Treuer Member indicate a minimum age of deposition of 1280 m.y. (Cooper & others, 1971). However, the Vaughan Springs Quartzite can be correlated with the Heavitree Quartzite which is younger than the 1076 m.y. determined for a migmatite event in basement beneath Heavitree Quartzite in the Hermannsburg 1:250 000 Sheet area (Marjoribanks & Black, 1974).

GEORGINA BASIN

The Georgina Basin, as defined by Smith (1972), is an widespread sheet of middle Cambrian to Carboniferous sediments extending northeast from the Alcoota Sheet area into the western part of Queensland. The Myponga Group, of late Adelaidean to Cambrian age, crops out along the southwest margin of the Georgina Basin, but it was not included in the sequence of the Georgina Basin despite the parallelism between it and the remaining sequence.

Only the Grant Bluff Formation of the Myponga Group and the Tomahawk Beds and Dulcie Sandstone of the sequence of the Georgina Basin crop out in the Alcoota 1:250 000 Sheet area.

Grant Bluff Formation (Adelaidean)

The Grant Bluff Formation, part of the Myponga Group, consists mainly of thin-bedded glauconitic quartz sandstones, siltstone, and shale, with, in places, thin beds of dolomite, crops out in the northeastern part of the Sheet area (Smith, 1964, 1972).

The type section of the Grant Bluff Formation is in the Elyuah Range (lat. 22°44'S, long. 135°04'E) in the adjoining Huckitta Sheet area, where Smith (1964, 1972) recorded 63 m of quartz sandstone overlain by 71 m of siltstone, quartz greywacke?, and dolomite, followed by 25 m of quartz sandstone. Secondary gypsum is present in the siltstone. Yeates (this survey) considers that in the area surrounding the type section the main rock types are shale and siltstone together with subordinate fine-grained, well-bedded sandstone and lesser amounts of coarse-grained quartz-feldspar sandstone. The sandstones are even-grained and well sorted, and dolomite is rare.

In the northeastern part of the Alcoota Sheet area, the Grant Bluff Formation consists mainly of medium-bedded hard white to grey quartz sandstone. Oscillation ripple marks and sandstone. Oscillation ripple marks and distinctive large mudflake casts up to 15 cm across are common. About 60 m of this sandstone is present at Mount Michael, but at a locality 8 km northwest, 6 m of white quartz-feldspar conglomerate rests on basement and is overlain by a unit of quartz-feldspar sandstone, which is overlain by quartz sandstone, followed by dark-red-shaly siltstone. Water bore data and the presence of purple chert gravel immediately north indicate that the siltstone probably forms the thickest unit.

South of Prince Henry Gap the basal part of the sequence consists of white, slightly micaceous siltstones and sandstone showing manganese and iron-staining on exposed surfaces. The middle part of the sequence consists of pale-grey medium to coarse-grained sandstone which in places contains mud pellet casts, as well as cross-bedded units and long wavelength ripple marks. Quartz pebble and granule conglomerate and white and red quartz-feldspar sandstone are minor components. The upper part of the sequence consists of very well-sorted, fine to medium-grained quartz sandstone and minor quartz siltstone; both rock types are characterised by very even, parallel bedding. Some bedding-planes show longitudinal, bifurcating and interference ripple marks.

The Grant Bluff Formation was intersected below the red-bed sequence of the Central Mount Stuart Beds in two holes drilled and logged by Centamin N.L. in the Mount Skinner area (DD-C1 and C2, Cotton, 1971, pers. comm.). In both holes a 200 m thick dolomitic unit which underlies the red-beds is underlain by 180 m of dark pyritic scale and minor quartz-feldspar sandstone. The dolomitic unit is dominantly pale grey sandy dolomite which grades into grey-green dolomitic sandstone and into siltstone and green and while dolomite in some parts of the core. Some sediments are calcareous rather than dolomitic. Small amounts of anhydrite are present throughout core from DD-C1 where they invade and extensively replace the dolomite; in core DD-C2 the anhydrite has been leached and only vugs remain. Minor rock types include greenish-grey and red shale, siltstone, and less common sandstone. The shale unit consists dominantly of black and green-grey pyritic shale with layers of fine-grained pale-grey quartz sandstone and quartz-feldspar sandstone. The shale unit directly overlies basement in one hole where it is green sandy siltstone containing quartz and feldspar fragments.

Thickness

The Grant Bluff Formation is about 420 m thick at Allen Creek Yard (DD-C2) and exceeds 400 m at Mount Skinner (DD-C1). The upper part of the formation is concealed in the eastern part of the Sheet area, but the unit is only 162 m at the type section in the Huckitta Sheet area (Smith, 1972, Table 8).

Environment of Deposition

The formation is considered to be mainly marine; it contains widespread, very evenly bedded and well-sorted shale, siltstone, and sandstone, and algae are present in the type section. Glauconite is absent from the rocks in the Alcoota Sheet area. The red-beds and drab green rock-types indicate terrestrial or near-shore marine conditions. Small amounts of anyhydrite in the dolomitic unit near Mount Skinner (DD-C1) and rare secondary gypsum in the type section (Smith, 1964) indicate that deposition in the upper part of the formation took place in restricted, saline and possibly relatively shallow waters, particularly in the central part of the Sheet area. The lack of conglomerate and the predominance of fine-grained sediments and occurrence of glauconite (in the Huckitta Sheet area) suggest slow sedimentation that kept pace with gentle subsidence. The ripple cross bedding and mudflakes point to shallow water conditions during deposition.

Between Poomingi Hill and Prince Henry Gap, the overlying Central Mount Stuart Beds rest directly on basement; this may indicate a depositional limit near the western limits of outcrop of the Grant Bluff Formation.

Relationships

In the type area, the Grant Bluff Formation is conformable with both the underlying Elyuah Formation and the overlying Mount Baldwin Formation (Smith, 1964). The basal beds are conglomerate or pebbly in places, and rest on basement throughout much of the Alcoota and western part of the Huckitta Sheet areas. The southern, very linear, limit of the outcrop area is probably controlled by late faulting rather than being a shoreline.

The relationship of the Grant Bluff Formation to the Central Mount Stuart Beds is problematical, and will be discussed following the description of the Central Mount Stuart Beds (see also Figs. 3 & 5).

The Grant Bluff Formation, particularly the lower part, is correlated with part of the Pertatataka Formation of the Amadeus Basin sequence, especially the Cyclops Member (Wells & others, 1964) or the Limbla Member (A.J. Stewart, BMR, pers. comm.). On the other hand, Daily (1974) prefers to correlate the Grant Bluff Formation with the unit on the Barrow Creek Sheet mapped as Grant Bluff Formation by Milligan (1964) and Smith (1972) (but considered by us to be younger). This unit contains a fauna common to the Allua and Parachilna Formations with ages near the base of the Cambrian. This correlation by Daily is in accord with the conformable contact between the Grant Bluff Formation and the overlying Mount Baldwin Formation containing the lower Cambrian Faunal Assemblage No. 2 of Daily (1956), 300 m from its base. (In the correlation we propose this conformable contact is considered equivalent to the conformable contact between the Pertatataka Formation and Arumbera Sandstone in the Amadeus Basin as shown by Wells & others in Fig. 15 of their 1970 report).

Tomahawk Beds (€Ot) upper Cambrian to Lower Ordovician)

The Tomahawk Beds was the name given by Smith (1965) to a sequence of grey and brown sandstone, dolomite, grey limestone, and green siltstone that crops out at the southeastern end of the Dulcie Range, in the Huckitta 1:250 000 Sheet area (reference section at lat. 22°37'30"S, long. 135°50'E).

Distribution

The Beds crop out as low hills and ranges, in the western part of the Huckitta Sheet area; in the Tomahawk Range in the Alcoota Sheet area; and in the northeastern Barrow Creek Sheet area. Exposures are distributed round the rim of the Dulcie Syncline as shallowly dipping outcrops, mainly of the quartz sandstones.

Lithology

The sequence in the Alcoota Sheet area contains more sandstone and less carbonate rock than in the reference section. (See Milligan, 1964, for details of Section KS3, measured 10 km north of Utopia homestead).

Contacts and stratigraphic relationships

The Beds are conformable with the underlying Arrinthrunga Formation in the central part of the Huckitta Sheet area, but in the west of the Huckitta Sheet area and continuing onto the Alcoota Sheet area, the lower contact is obscured by alluvium. Core hole BMR Grg. 1, located 3 km east of the eastern boundary of the Alcoota Sheet area, penetrated 31 m of Upper Cambrian interbedded sandstone, siltstone, and fossiliferous oolitic limestone (Milligan, 1963). This sequence resembles the Arrinthrunga Formation. West of Tomahawk Range, the Tomahawk Beds may unconformably overlie the Central Mount Stuart Beds and, farther south, possibly rest on crystalline basement (see Fig. 5 and section on Central Mount Stuart Beds). The boundary west of Tomahawk Range has been interpreted by Smith (1972) and American Overseas Petroleum (1966) as a major fault of uncertain displacement, although the evidence could be interpreted otherwise (see section on magnetic survey). Possible Tomahawk Beds have been mapped directly overlying Hatches Creek Group in the northeastern quarter of the Barrow Creek Sheet area.

The Tomahawk Beds are unconformably overlain by the Dulcie Sandstone over most of the Alcoota, Huckitta, and Barrow Creek Sheet area, and are conformably overlain by the Nora Formation in part of the Dulcie Range in the Huckitta Sheet area (Smith, 1972).

Fossils and age

The Tomahawk Beds range in age from middle Late Cambrian (Franconian) to Early Ordovician. Rocks in the Alcoota Sheet area probably represent the upper part of the time-rock sequence. Fossils AL7 and AL8 (section KS3) are tentatively assigned to the Upper Cambrian on the basis of a very poor trilobite fauna. AL9-15 (higher in Section KS3) contain a Lower Ordovician fauna of asaphid and richardsonelloid trilobites, and ribeirioids. AL6, (collected 2.5 km south of Buggy Camp Bore) contains saukiid trilobites indicating an Upper Cambrian age. (J.G. Tomlinson and J.H. Shergold, BMR pers. comm.). Saukiid trilobite faunas in the Barrow Creek Sheet area (BC2, 4, 5, 6, 9, 10 and 11) belong to the uppermost Cambrian. The lowest part of the sequence which crops out in the Huckitta-Marqua region contains abundant trilobites, pelecypods, brachiopods, and ribeirioids which Tomlinson regarded as middle Upper Cambrian (Franconian) (*in* Casey & Tomlinson, 1956; Smith, 1972).

Environment of Deposition

In section KS3 (Milligan, 1964) the presence of glauconite together with ripple marks, ribeiroids, cruziana ichnofossils, worm trails, and pipe rock in grey and brown sandstones suggest near-shore marine conditions, particularly in the upper part above AL9. The section below AL9 includes more dolomite and red, yellow, cream, pink and brown rock types, suggesting an environment even closer to the shoreline.

Dulcie Sandstone (Dud) (Devonian)

The Dulcie Sandstone occupies the core of the assymmetrical Dulcie Syncline, and extends about 210 km from the type locality (lat. 22°35'S, long. 135°41'E) in the Dulcie Range in the Huckitta Sheet area to about 50 km east of Neutral Junction homestead in the Barrow Creek Sheet area (Smith, 1964).

Lithology

The formation consists predominantly of medium to coarse-grained, clean to silty quartz sandstone with beds of pebble conglomerate, calcareous silty sandstone, and white siltstone (Smith, 1972). Very large-scale cross-bedding is characteristic.

Thickness

The thickness of the Dulcie Sandstone exceeds 450 m at the eastern margin of the Alcoota Sheet area and in the southern part of the Barrow Creek Sheet area (Smith, 1972). The unit thins eastwards, and is less than 40 m thick along the northeastern limb of the Dulcie Syncline. In the type section it is 622 m thick.

Contacts

In the Alcoota Sheet area, the Sandstone rests unconformably on the Tomahawk Beds, and is overlain unconformably by Cainozoic sediments.

Fossils

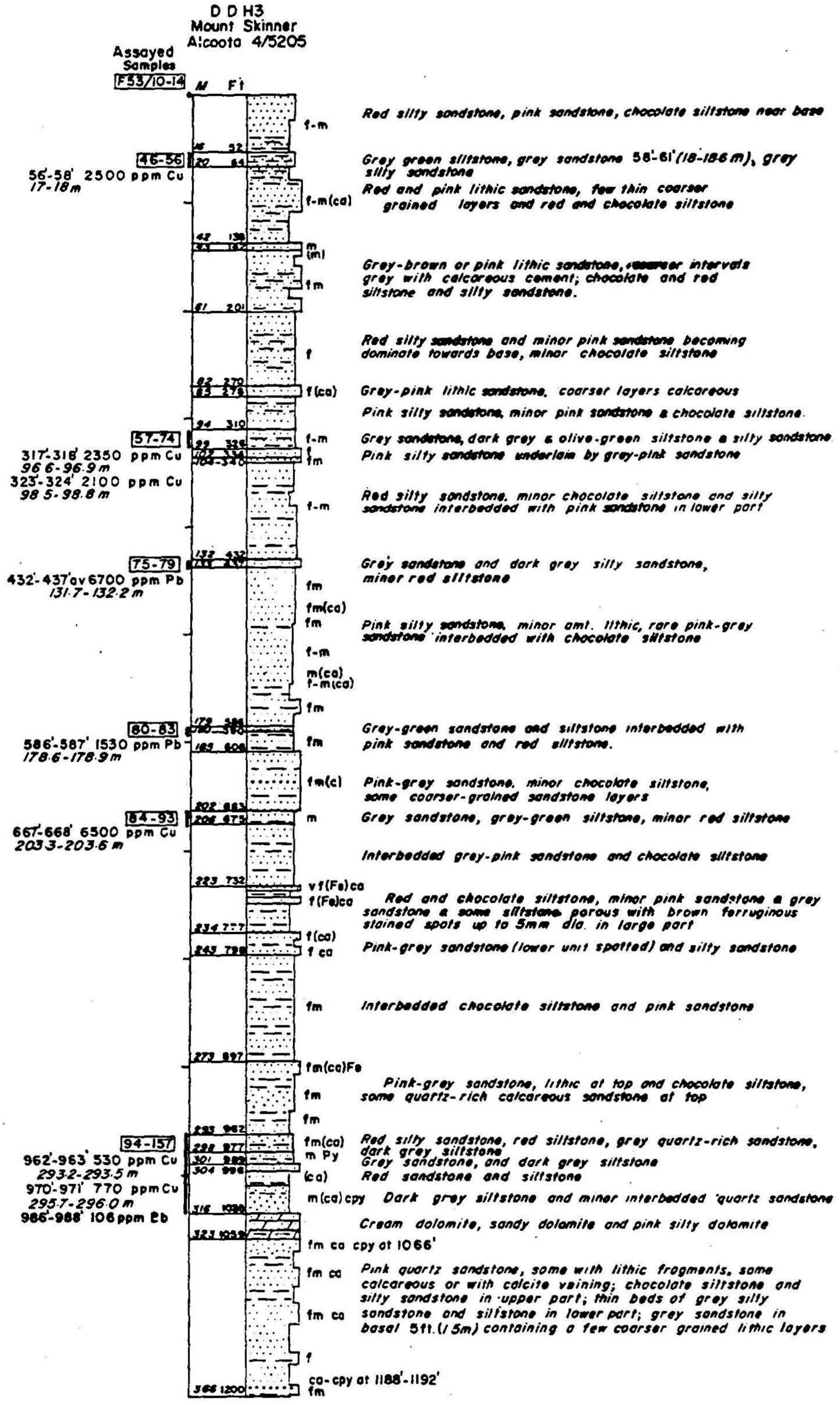
Two assemblages of placoderm plates recovered from the Dulcie Sandstone in the Huckitta Sheet area were identified and dated as Upper Devonian (Hills, 1959). *Bothriolepis* occurs 501 m above the base and *Phyllolepis* 122 m higher. Tomlinson (1968) considers the *Phyllolepis* is probable Famennian. A second placoderm assemblage collected from three localities at the northwestern end of the Dulcie Syncline may be older than the *Bothriolepis* Fauna (Hills pers. comm. in Tomlinson, 1968).

Age, correlation and environment of deposition

The upper part of the Dulcie Sandstone, which is possibly confined to the Huckitta Sheet area contains *Bothriolepis* and *Phyllolepis* of Upper Devonian age. The lower part of the Dulcie Sandstone, thought to be the unit present in the Alcoota Sheet area, is correlated with the lower part of the Cravens Peak Beds, which contain scales of primitive jawless vertebrates of the family *Coelolopididae* of Siegenian age (early Lower Devonian). The

FIGURE 4

LITHOLOGICAL LOG OF DIAMOND DRILL HOLE CORE, CENTRAL PART OF CENTRAL MOUNT STUART BEDS, MOUNT SKINNER AREA



REFERENCE

f	Fine - grained	Py	Disseminated pyrite
m	Medium - grained	cpy	Disseminated chalcopyrite
c	Coarse - grained	Cu	Copper bearing
vc	Very coarse	Pb	Lead bearing
Fe	Ferruginous		
Mi	Micaceous		
ca	Calcareous		

Logged by D.J. Grainger, summarised by R.D. Shaw

Lower Dulcie Sandstone is lithologically similar to the Mereenie Sandstone of the Amadeus Basin, and both may be of Lower Devonian age, although direct evidence is not yet available. Tomlinson (1968, Fig. 6) and Smith (1972) have suggested that the Upper Dulcie Sandstone may be separated from the Lower Dulcie Sandstone by a disconformity marking a change from rapid oscillation between marine and non-marine conditions with local erosion to lacustrine and fluviatile conditions.

CENTRAL MOUNT STUART BEDS (upper Adelaidean to Lower Cambrian Structural High)

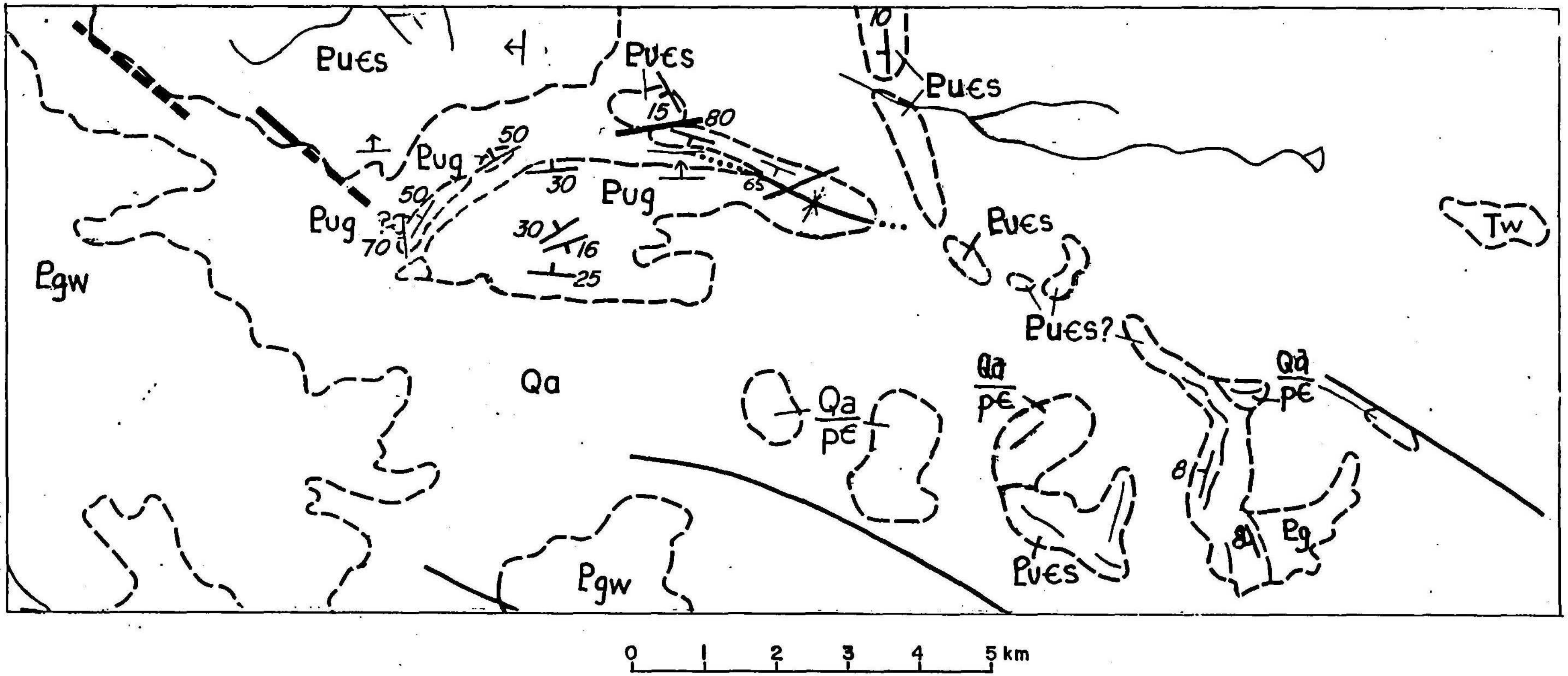
The Central Mount Stuart Beds (Milligan, 1964; Smith, 1972) of late Adelaidean to early Cambrian age occur outside the two major structural basins. They appear to have been deposited on a structural high between two major depositional basins; the western Amadeus - Ngalia region to the west and the Wiso - Georgina - east Amadeus region to the north and east. The Central Mount Stuart Beds are a red-bed sequence that crops out in a belt extending northwards from the Sandover River almost to Barrow Creek in the Barrow Creek Sheet area. The unit also crops out discontinuously to the west on the Mount Peake 1:250 000 Sheet area, and equivalent rocks occur farther west at Crown Hill in the Napperby 1:250 000 Sheet area. The sediments are mainly red lithic sandstone and siltstone with small amounts of grey sandstone and siltstone Figs. 4 & 6. The relative position of DDH3 (Fig. 4) to the lower part of the section shown in Figure 3 is uncertain. Boulder beds and tillite are present in small amounts near the base. Probable varves have been reported by Smith (1972 near the base of Central Mount Stuart southwest of lat. 22°S, long. 133°30'E. Both features indicate a glacial origin for a section of the lower part of the unit.

Thickness

A maximum thickness of 760 m has been estimated in the Mount Skinner area (Fig. 6). An incomplete section of 370 m was intersected in DD-H3 (see fig 4 Grainger, 1968); and 445 m has been estimated west of Mount Dixon from magnetic data (Wyatt, 1973). Northwards the beds thin rapidly and range from 73 to 137 m thick south of Barrow Creek settlement (Smith, 1972).

FIGURE 5

GEOLOGY OF PRINCE HENRY GAP AREA



QUATERNARY	Qa	*Alluvium*
ADELAIDEAN TO LOWER CAMBRIAN	Pu€s	*Central Mount Stuart Beds*
	Pug	*Grant Bluff Formation*
PROTEROZOIC	Pg	*Granite*
	Pgw	*Woodgreen Granite*
PRECAMBRIAN	p€	*Gneiss, Schist*

Age and Fossils

The Central Mount Stuart Beds are believed to straddle the Precambrian-Cambrian boundary. Two Medusae, *Hallidaya brueri gen. et. sp. nov.* and *Skinnera brooksi gen. st. sp. nov.*, have been found in and above a unit of pale-green flaggy sandstone in what is thought to be the upper part of the middle member (Ꝑu€s_2; described later) of the Central Mount Stuart Beds (Wade, 1969). The time-range of the species is unknown. *Hallidaya brueri* is also found in the lower part of the Arumbera Sandstone west-southwest of Alice Springs (Wade, 1969). A thin glauconite quartzite interbed which succeeds the red sandstones and conglomerates contains trace fossils and bilobate trails (Daily, 1974) of the type found in the Box Hole Formation (Middle Arumbera Sandstone) of the Amadeus Sequence where abundant trace fossils represent the oldest Cambrian assemblage (Glaessner, 1969; Daily, 1974). This unit presumably overlies the level containing *Hallidaya brueri*, although their relationship is not known to us.

The tillitic bed in the Central Mount Stuart Beds is correlated with the Mount Doreen Formation in the Ngalia Basin, which is in turn correlated by Wells & others, (1972) with the Olympic Member of the Pertatataka Formation, which is the younger of two tillitic horizons in the Amadeus Basin sequence. The tillitic portion of the Central Mount Stuart Beds is thus considered correlatable with the upper tillitic unit of Adelaidean age (i.e. the Marinoan of the Adelaide Geosyncline and the Egan glaciation of the Kimberley region (cf. Roberts & others, 1972). Smith (1972) incorrectly correlated the tillitic horizon of the Central Mount Stuart Beds with the Mount Cornish Formation, which in turn he correlated with the Areyonga Formation, the lower of the two tillite units in the Amadeus Basin. As the Grant Bluff Formation underlies the Central Mount Stuart Beds or is a facies equivalent of the lower part, the tillitic horizon in the Central Mount Stuart Beds is stratigraphically above the Mount Cornish Formation since the latter underlies the Grant Bluff Formation.

Relationships (Fig. 3)

The Central Mount Stuart Beds appear to have been deposited in a group of northwest-trending shallow basins separated by basement highs. Beds high in the sequence rest on basement, indicating that considerable basement relief existed before deposition.

The relationship between the Grant Bluff Formation and the Central Mount Stuart Beds is suggested by the section in DD-C1 at Allen Creek Yard. Elsewhere the boundary may be time-transgressive but there is no evidence to support this. The units may interfinger along the boundary, as grey beds in the Central Mount Stuart Beds are not unlike those of the Grant Bluff Formation. The Central Mount Stuart Beds consist mainly of red-beds which were possibly deposited under transitional marine and terrestrial or deltaic conditions possibly close to a source on a structural high that separated the Ngalia and Georgina depositional basins. The Grant Bluff Formation was, for the most part, deposited basinwards mainly under reducing conditions.

At Prince Henry Gap (Fig. 5) moderately folded grant Bluff Formation is in fault contact with flat-lying Central Mount Stuart Beds. Folding of this magnitude is not seen elsewhere, and may have been caused by sliding of the sediments on basement and the development of a decollement at the upper boundary of the Grant Bluff Formation and the Central Mount Stuart Beds facilitated by evaporites in the upper part of the Grant Bluff Formation. In drillhole DD-C1 (Centamin N.L., 1971) personal ommmunication) immediately north of Prince Henry Gap, the Grant Bluff Formation (380 m thick) rests directly on basement and underlies the Central Mount Stuart Beds.

The Grant Bluff Formation has been traced by A.N. Yeates (this survey) from Prince Henry Gap eastwards, with little change in lithology, to its type section in the Huckitta Sheet area where it is overlain with apparent conformity (Smith, 1964) by the Lower Cambrian Mount Baldwin Formation (Fig. 3). In the Barrow Creek Sheet area, the Central Mount Stuart Beds are overlain by a unit containing Helcionella of probable Lower Cambrian age (J.G. Tomlinson, BMR, pers. comm.). This unit also contains Bemella and the trace-fossils plagioginus arcuatus and Laevicykes Quenstedt in addition to the oldest shelly fauna in the Northern Territory (Daily, 1974, BMR collection B.C.3). These fossils indicate correlation with the Parachilna Formation of South Australia and Allua (Upper Arumbera) Formation of the Amadeus Basin. The lithology suggests assignment to the Mount Baldwin Formation and not to the Grant Bluff Formation as indicated by Milligan (1964) and Smith (1972). These rocks consist of red-brown, coarse-grained glauconitic quartz sandstone and brown, white and grey-green siltstone containing worm trails. Rocks considered to be equivalent to the middle and upper units of the Arumbera Sandstone of the Amadeus Basin (renamed the Box Hole and Allua Formations by Daily, 1974) crop out southeast and east of Neutral Junction homestead. Similar rocks on the Alcoota Sheet area near Mount Octy also contain a fauna like that of the Allua and Parachilna Formations (Daily, 1974). The fauna includes brush marks attributed to trilobites, and the trace fossils Cochlichnus serpens, Phycodes pedum, Phycodes palmatum, Plagiogmus arcuatus, various kinds of shafted-burrows, and various trails attributed to molluscs. Daily prefers to correlate rocks of both these localities with the Grant Bluff Formation.

The Central Mount Stuart Beds are thus possibly equivalent to the upper part of the Grant Bluff Formation (Fig. 3), although the relationships would be more neatly explained if a considerable time-gap existed between the Mount Baldwin Formation and the underlying Grant Bluff Formation in the Huckitta Sheet - an interpretation in conflict with the conformable boundary described by Smith (1964). If an unconformity existed most of the Grant Bluff Formation would be older than the Central Mount Stuart Beds (cf. Milligan, 1964, Fig. 4). Daily (1974), on the other hand, prefers to correlate the upper part of the Central Mount Stuart Beds with the upper part of the Elyuah Formation and the lower part with the Oorabra Arkose Member of the Elyuah Formation.

The contact with the younger Tomahawk Beds is obscured by alluvium. As pointed out by Smith (1972) the Central Mount Stuart Beds generally dip at low angles to the southwest away from the Georgina Basin. He suggested the Beds may be on the upthrownside of a major northwest-trending fault, but this would require a considerable displacement, as the Central Mount Stuart and Tomahawk Beds are separated by a strip of alluvium only 3.5 km wide in a region of very shallow dips across which the Mount Baldwin Formation, the Arthur Creek Beds and the Arrinthrunga Formation, representing probably 1500 m of section, are missing in outcrop. It is considered more likely that the Upper Cambrian to Lower Ordovician Tomahawk Beds unconformably overlie the Central Mount Stuart Beds as a result of a pre-existing basement high (see Fig. 3). A large part of the Arrinthrunga Formation and probably the Arthur Creek Beds may have been on-lapped by the Tomahawk Beds in the Huckitta Sheet area east of the Alcoota Sheet area.

Detailed lithological description

Regional mapping by Utah Development Co. in 1970 resulted in a threefold division of the beds:

1. Upper quartzose unit (ꝐuЄS$_3$)
2. Red lithic unit (ꝐnЄS$_2$)
3. Thin basal quartzose unit (ꝐuЄS$_1$)

Basal quartzose unit (ꝐuЄS$_1$)

This unit generally consists of thin-bedded ripple-marked fine to medium-grained feldspathic sandstone, which is tough and generally grey or white (Utah Development, 1970). The feldspars have been replaced by kaolin. Silicification has occurred near the base of the unit. A lenticular basal quartz-pebble conglomerate with a poorly sorted sandstone matrix occurs in a few places; the best exposed outcrop is located 16 km east of No. 3 Bore, Stirling Station, Barrow Creek Sheet area.

Utah Development state that "the upper surface of this unit is very even and it may have been a blanket sand" filling hollows in the peneplained surface of basement rocks.

The unit is exposed in the Adnera Creek area, Barrow Creek Sheet area, northeast of Mount Octy.

The thickness of the unit ranges from 6 m to 30 m.

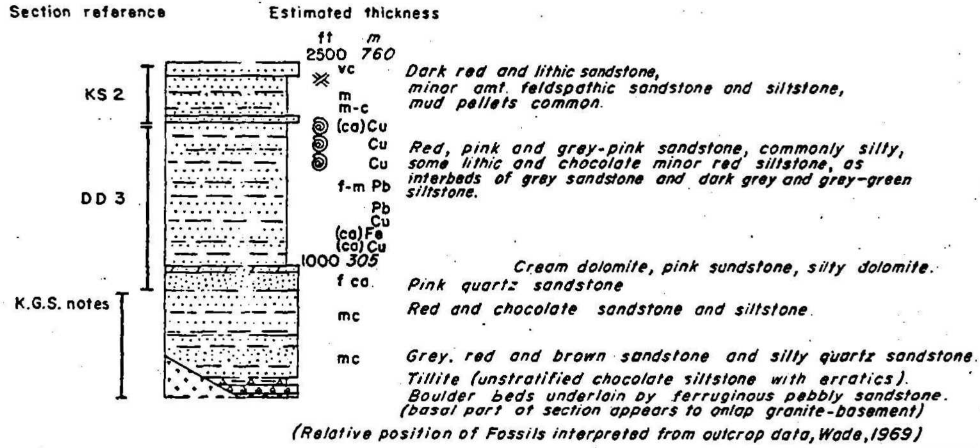
Red lithic unit (ꝐuЄS$_2$) - includes tillite horizon near base

This unit consists mainly of a red-bed sequence with minor interbeds of grey siltstone and sandstone. A tillite and a unit containing varves occur at a few widely separated places near the base. A summary section is presented in Figure 6. The sequence is calcareous near the base. The red sediments are probably at least 350 m thick and may be up to 760 m thick as shown in Fig. 3. The thickness may be less than shown in Figure 6 as the dolomite may underlie the tillite.

Fig. 6

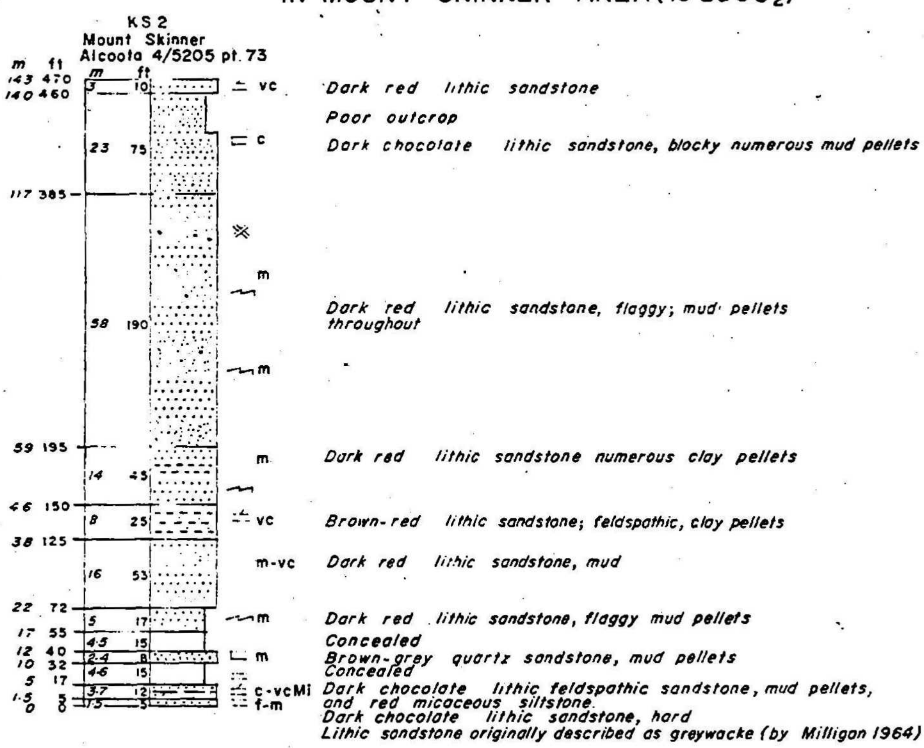
INTERPRETATIVE SUMMARY OF SECTION, CENTRAL MOUNT STUART BEDS, MIDDLE MEMBER (ꝒuЄS₂)

Alcoota 1:250 000 Sheet area



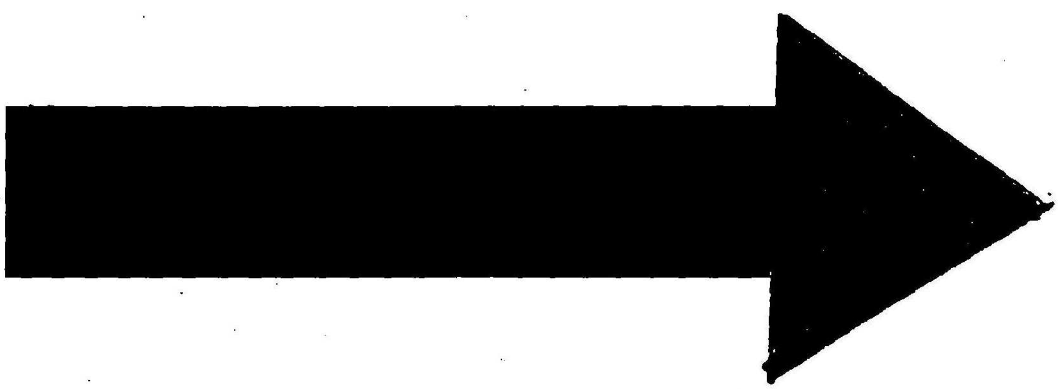
(Relative position of Fossils interpreted from outcrop data, Wade, 1969)

MEASURED SECTION-TOP PART OF CENTRAL MOUNT STUART BEDS; IN MOUNT SKINNER AREA (ie ꝒuЄS₂)



REFERENCE

f	Fine – grained		Medium – bedded
m	Medium – grained		Thin – bedded
c	Coarse – grained		Cross-bedding
vc	Very coarse – grained		Ripple marks, current
Fe	Ferruginous		Tracks and trails
Mi	Micaceous		Macrofossil
ca	Calcareous		
Cu	Copper bearing		Alcoota 4/5205, run and photo number
Pb	Lead bearing		



Glacigene rocks

Probable varves occur near the base of Central Mount Stuart, in the Mount Peake Sheet area (a few kilometres northwest of lat. 22^{o}S, long. $133^{o}30'$E; Smith, 1972).

Boulder beds and tillite with a chocolate-coloured siltstone matrix are interbedded with a grey-purple silty quartz sandstone 5 km northwest of New Bore, Alcoota Sheet area. Three kilometres northwest of New Bore, 12 m of tillite containing numerous boulders, cobbles, and pebbles up to 1 m across which occur in a matrix of chocolate-coloured siltstone (K. G. Smith, BMR, pers. comm., and Smith, 1972). Most of the boulders are polished but only poorly faceted. The tillite overlies a boulder sequence containing clasts of probable Hatches Creek Group rocks, sheared quartz sandstone, red coarse-grained pebbly quartz mudstone, basic volcanic rock, sheared volcanic rock, blue quartzite, gneiss, granite, and pegmatite. Yeates (this survey) considers some of the clasts to be similar to sandstones of the Grant Bluff Formation. The tillite is included in the Central Mount Stuart Beds primarily because it has a chocolate-coloured matrix and is interbedded with red-beds.

Deeply weathered tilloid and boulder beds at AL 451 (lat. $134^{o}40'$, long. $22^{o}20'$) contain boulders of blue-grey quartzite, feldspathic sandstone schist, minor arkose, and dolomite. The rocks are cleaved and coarsely spotted, and look like metamorphic rocks.

Arkose west of Ledan Peak and at Poomingi Hill contains boulders and pebbles, and is probably correlatable with the tillite. Pebbles of sandstone and white sandy siltstone at Poomingi Hill are lithologically similar to the sandstone of the Grant Bluff Formation.

Dominant rock types

The bulk of the middle unit ($\text{P}\!\text{u}\mathrm{\epsilon}S_2$) consists predominantly of chocolate-brown or reddish purple flaggy lithic quartz sandstone and considerably lesser amounts of shale and siltstone (Fig. 6). In places the sandstone, particularly the coarser-grained sandstone, is feldspathic and poorly sorted; in places, especially near the top of the unit, it is arkosic. Minor lenses of very poorly sorted pebbly sandstone are also present (Utah, 1970). Quartz accounts for about 75 percent of the sandstone (J.S. Cotton, Centamin N.L., pers. comm.). Lithic grains, more common in the lower part of the unit, are commonly fine-grained, sericite-bearing schist. The sandstone is generally well-sorted and in places micaceous. Some of the coarse-grained sandstones have siltstone pellets. The red colouration is caused by iron oxide coating on detrital grains.

A few of the coarser-grained sediments, particularly those in the upper part of the section, are cemented by authigenic quartz. Calcareous sandstone is present near the base of the sequence north of Mount Skinner (Grainger, 1969). The calcareous material mainly occurs as calcite cement, but some fragments of limestone are present in the coarser sandstones.

Copper-bearing grey-beds

Copper-bearing units, usually less than 5 m thick, consist of fine to medium-grained grey sandstone and grey-green and grey siltstone. The sandstones are well-sorted and contain rounded quartz grains and clay pellets. A few grey beds show a surface staining of copper carbonates. In drill core, chalcopyrite is either disseminated or forms small lenses in grey sandstone (Grainger, 1969). Cotton (pers. comm., 1971) reports that the sandstones elsewhere consist of 70 percent quartz, 20 percent feldspar, 5-10 percent interstitial carbonate and very minor lithic grains.

Sedimentary structures and depositional environment of the middle unit PuЄS$_2$

The arenaceous rocks are generally cross-bedded, and bedding surfaces are commonly extensively scoured. Grainger (1969) observed flute casts, mud cracks, and other sole marks which testify to deposition in shallow marine or coastal plain conditions. Terrestrial, nearshore, or deltaic conditions are in accord with the abundance of red-beds. Many siltstone laminae are contorted and broken, and indicate contemporaneous brecciation of underlying laminae by turbulent shallow water. Breccia consisting of laths of siltstone incorporated in the lower part of sandstone intervals indicate erosion of underlying beds and probable terrestial conditions. The iron oxide coating on grains indicates oxidizing conditions for the red-beds. The mineralised grey and green-grey beds were presumably deposited under reducing conditions, in a marine environment.

Upper Quartzose Unit $P\!u\!ЄS_3$

This unit consists of white and red, fine to coarse-grained, well-sorted quartz sandstone and feldspathic sandstone interbedded with minor red siltstone and red-brown lithic sandstone. The unit is mainly preserved in the Barrow Creek Sheet area.

At Mount Octy (southern Barrow Creek Sheet area), the unit conformably overlies the middle unit ($P\!u\!ЄS_2$). On a broad scale the middle unit thins northwards and the upper unit thickens northwards. The upper and middle units may be facies equivalents in part.

The upper unit can be further subdivided in the Barrow Creek Sheet area. The lower subdivision (3a) is about 120 m thick, and, like $P\!u\!ЄS_2$, consists of fine to coarse-grained, well sorted quartz sandstone and minor feldspathic sandstone. The unit lacks the partly mineralized grey-beds of the middle unit. Unit 3a directly overlies the Barrow Creek Granite in places. The upper subdivision (3b) is a massive, white to grey feldspathic and quartzose sandstone, and is about 30 m thick.

CAINOZOIC

Introduction

Cainozoic rocks are widely distributed in the Sheet area and their generalized distribution is given in Figure 7. The larger part of the following account, particularly that of the laterite and Tertiary sediments is taken from Senior (1972). Cainozoic rocks of the Sheet area, include laterite developed on igneous and metamorphic rocks of the Arunta Complex, and younger lacustrine and fluviatile Tertiary and Quaternary sediments. The relationships between Cainozoic sediments are shown beside the map sheet. In situ deep chemical weathering formed the typical tri-zonal laterite profile, and preceded deposition of the Tertiary sediments. The exposed section accounts for about 15% of the total thickness. Most of the exposures are in a dissected area in the southeastern quadrant where an east-west depression bounded to the south by the Harts Range contains up to 180 m of Tertiary sediments which have been slightly folded. Woodburne (1967) applied the term "Waite Basin" to the northwest part of this depression, and Waite Formation to the upper exposed section. Mabbutt (1965, 1967) used "Alcoota

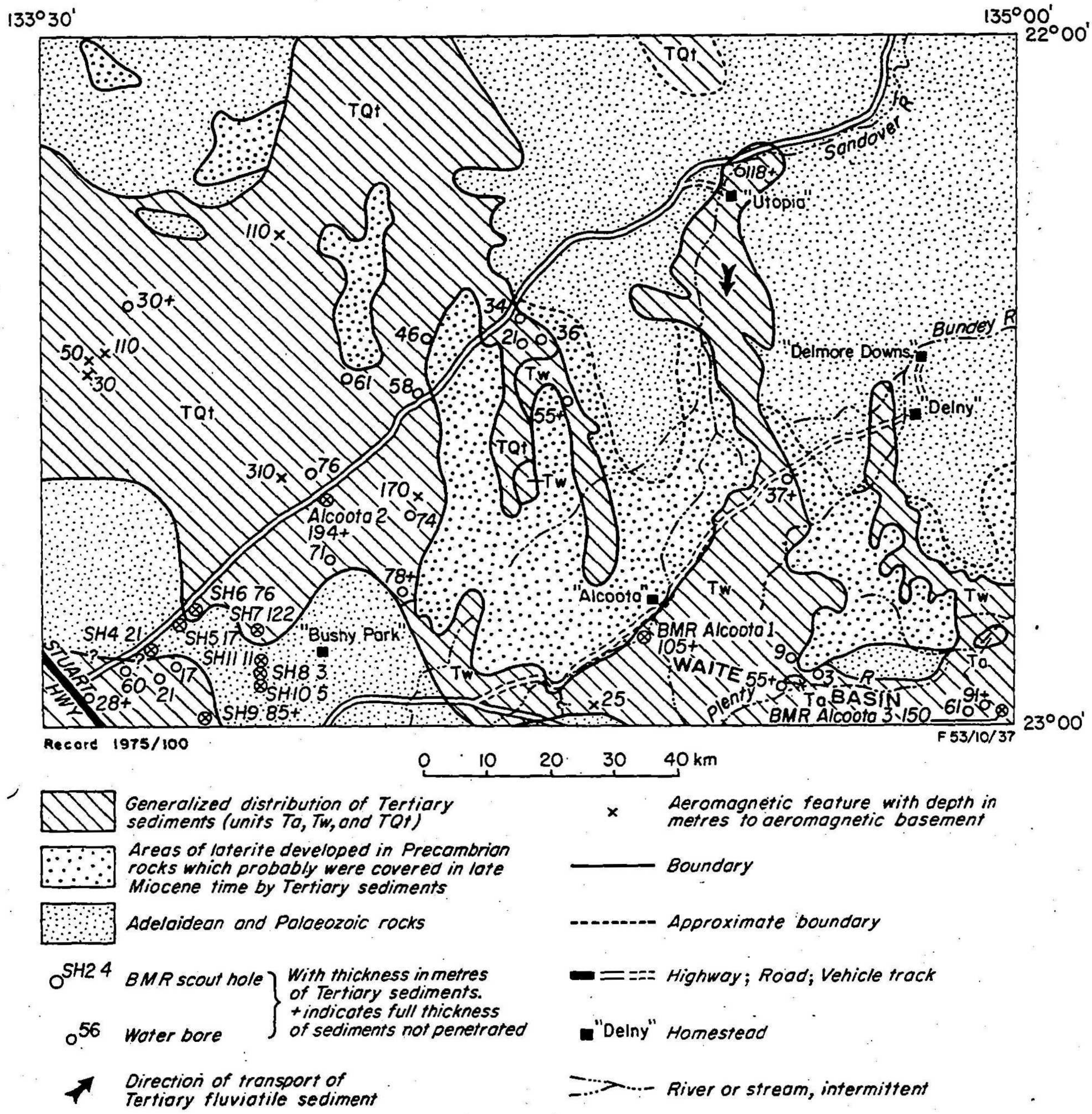


Fig 7 Distribution of Laterite and Cainozoic sediments

Beds"* to describe the entire sequence of Tertiary to Quaternary sediments exposed on Alcoota and the western part of the Huckitta 1:250 000 sheet area.

Similar sediments to those in the Waite Basin extend at least from the Tea Tree Basin in the northeast of the Napperby Sheet (Edworthy, in prep.) area eastwards into the central-western part of the Alcoota Sheet area.

Outcrop in this area is limited to low, sandy, soil-mantled rises, and most of the sediments are known only from BMR drill holes (SH2, SH4-11) and from driller's lithological logs of water bores. Sediment thicknesses up to 310 m are suggested by estimates of the depth to magnetic basement near SH2 (Wyatt, 1963). The sediments of the Tea Tree Basin have not been warped and dissected like those in the Waite Basin, and include a younger unit overlying the Waite Formation. The boundary between the Waite Basin and the Tea Tree Basin is arbitrarily taken as the watershed of the Sandover River system.

The lithology and possible correlation between Tertiary units is shown in Figs. 8-10. The coarse sediments in BMR Alcoota 3 are thought to be a facies equivalent of the Waite Formation, the clastics having been locally derived from the nearby Harts Range, which forms the southern boundary of the Waite Basin.

TERTIARY

Laterite (Cz)

Deep chemical weathering, which is inferred to have taken place in early Tertiary or possibly late Cretaceous time (Woolnough, 1927; Hays, 1967), altered the upper 40 m of exposed metamorphic and igneous rocks to laterite. The laterite has the typical three zones of different mineralogical and chemical composition, with a lowermost leached zone, an intermediate mottled zone, and a ferruginous top. In the Alcoota Sheet area laterite was widespread by the beginning of the Miocene.

*" Alcoota Beds" as used on the face of the Preliminary Map in the sense of Mabbutt, 1965 was disallowed by the Northern Territory Stratigraphic Nomenclature Committee.

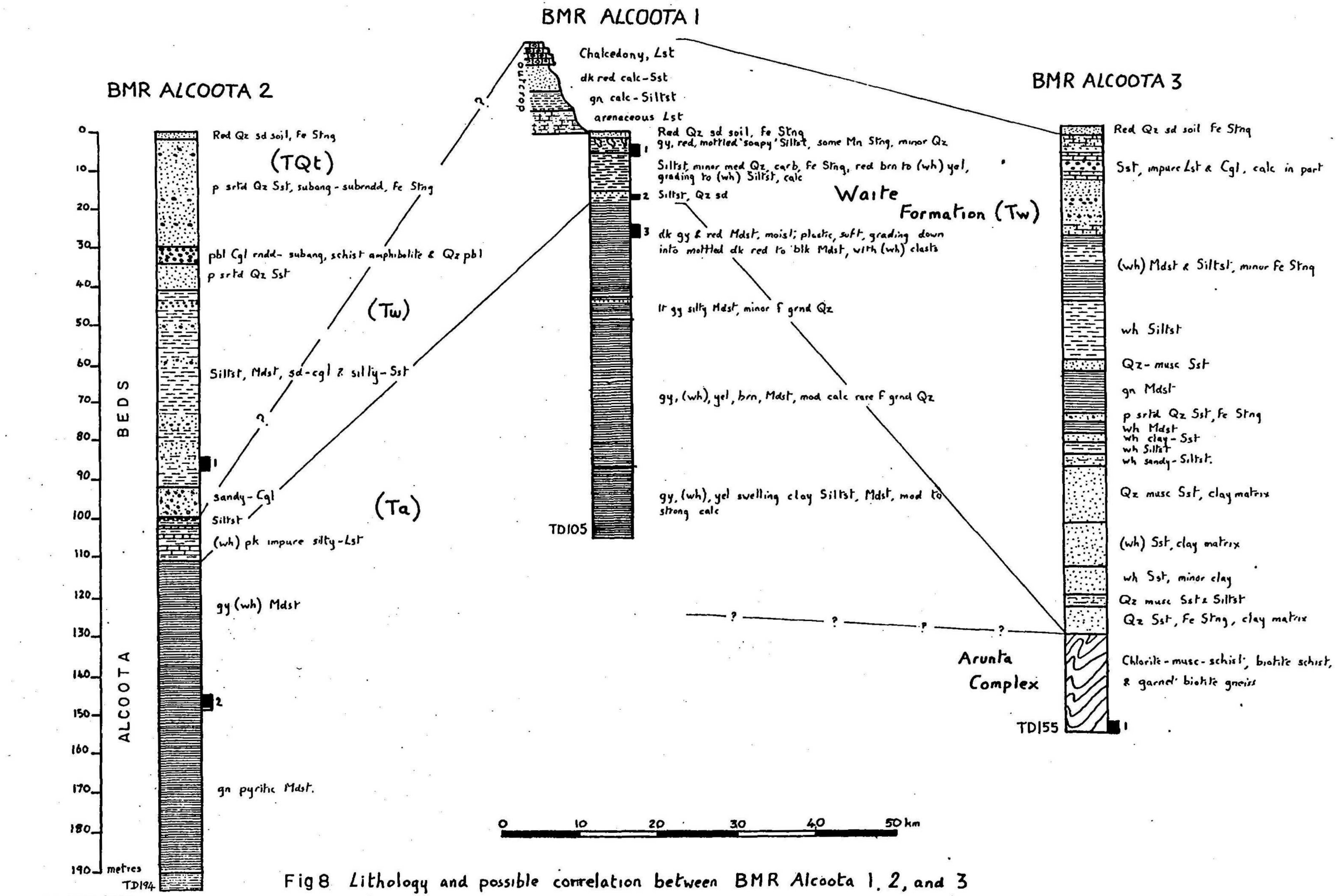


Fig 8 Lithology and possible correlation between BMR Alcoota 1, 2, and 3

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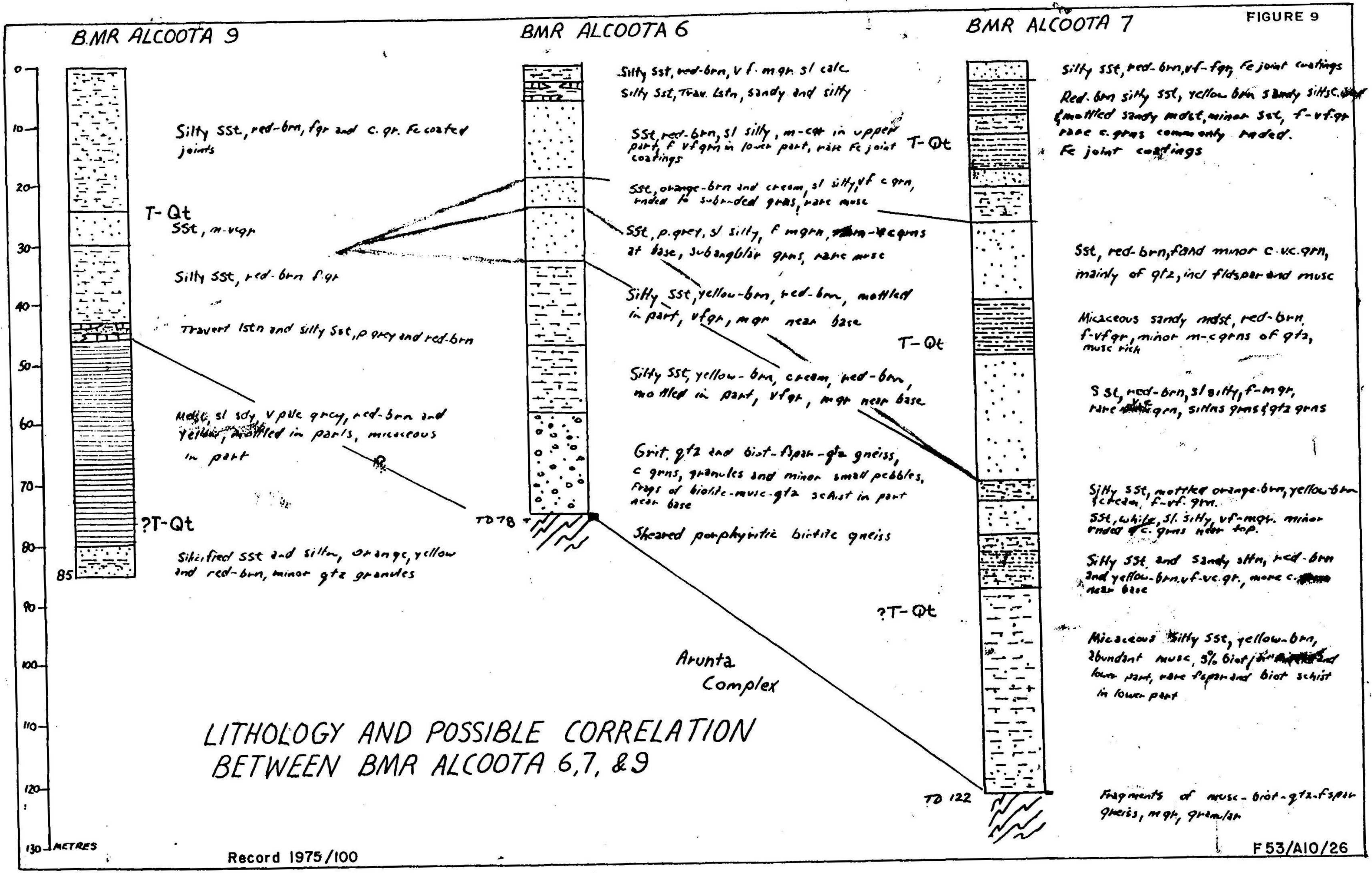
FIGURE 9



LITHOLOGY AND POSSIBLE CORRELATION BETWEEN BMR ALCOOTA 6, 7, & 9

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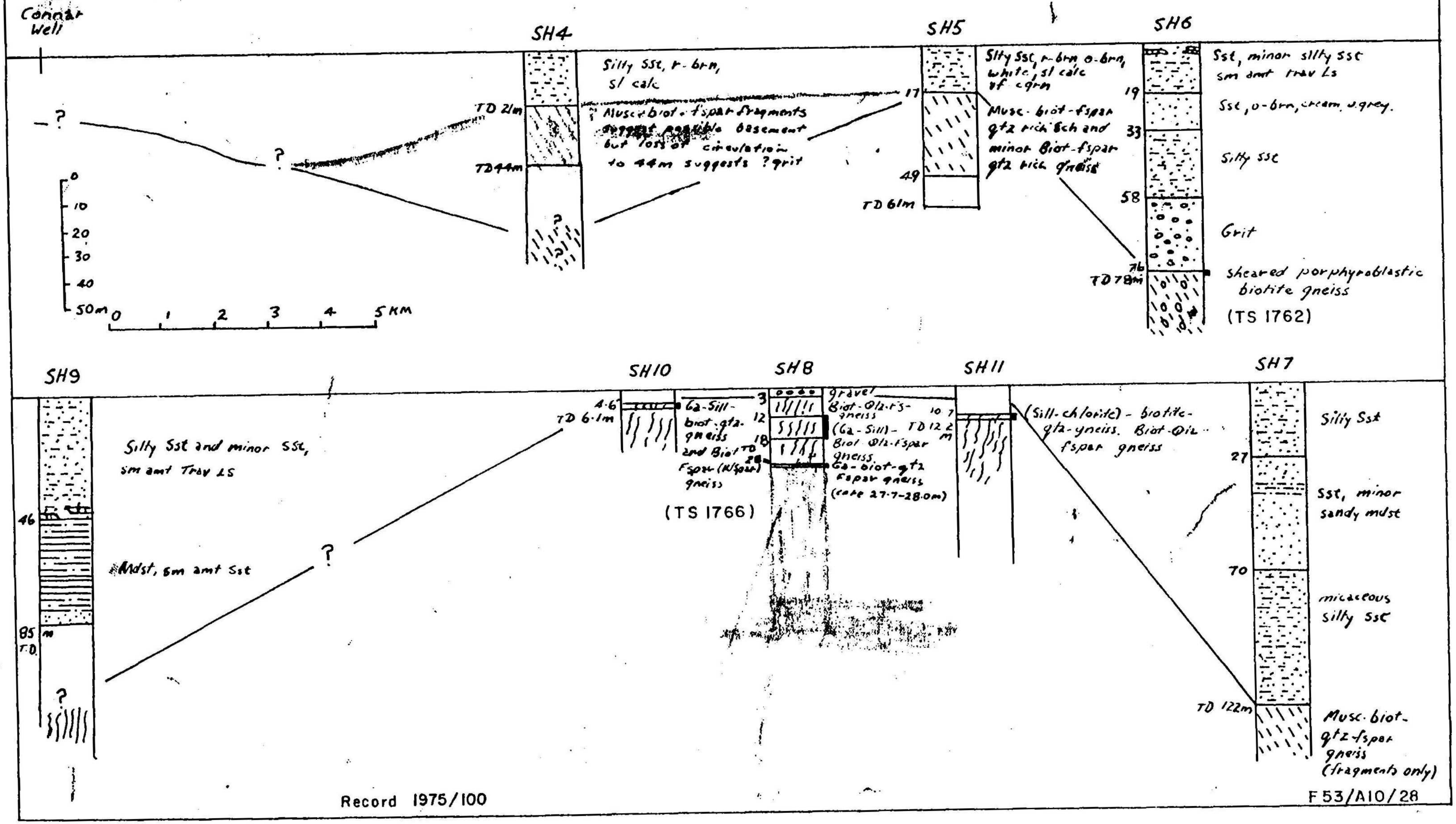
FIGURE 10

DRILLING RESULTS, BMR ALCOOTA SCOUT HOLES 4-11



A subsequent period of erosion stripped the laterite from most of the area, and some of the detritus was incorporated into the Waite Formation, which now covers the wholly or partly eroded surface. In the south-eastern part of the Sheet area an almost complete profile is preserved below the Waite Formation.

The leached or clay-rich zone of the laterite grades from relatively unweathered parent rock at the base into a zone dominated by white kaolinitic clay minerals. It is generally possible to identify the gross lithology of the parent rock in the basal to middle part of this zone where textural features of the host rock, together with quartz veins and remnants of large phenocrysts such as quartz and muscovite, are preserved.

The leached zone grades up into a variegated or mottled zone. This zone, which is up to 10 m thick, contains patches, stained pink, purple, brown or yellow by iron oxides, which conrast markedly with the white clay-rich matrix. Individual stained patches or mottles vary in size, and range from small nodular shapes to structureless masses. Iron oxide staining, and enrichment of iron oxide increases upwards through the mottled zone. Kaolinite and quartz are dominant, with subordinate amounts of hematite and goethite (Table 2). The texture of the parent rock cannot be recognized at the top of the mottled zone.

Overlying the mottled zone is a ferruginous zone up to 8 m thick. This is the most strongly indurated part of the laterite profile and forms prominent vertical escarpments generally with a columnar structure. Goethite and hematite are the dominant iron minerals. The rock is generally fine-grained, rather massive and structureless, although it is cut by an irregular mosaic of fine fractures. Numerous vertical and subhorizontal joints give the zone a pronounced columnar structure, similar to that developed in some soil profiles as a result of volume changes. In places the upper 3 or 4 m of the ferruginous zone is reworked by pedogenic processes and consists of a re-cemented fragmentary layer, with a nodular structure in part, containing numerous iron pisolites. The pisolites range up to 1 cm in diameter and have a simple layer structure of concentric shells of contrastingly coloured iron oxides. This material has slumped by solifluxion into the underlying ferruginous zone down vertical fractures, commonly forming 'pipe-like' infillings.

TABLE 2

Minerals identified by X-ray diffraction in order of relative intensities (1-3) and grouped according to their position in the laterite profile

G.E. Berryman analyst, BMR laboratories.

Sample No.	Muscovite	Kaolinite	Quartz	Goethite	Hematite	Grid Ref.
		Ferruginous	Zone			
70091101	-	2	1	-	3	253158
" 1106	-	2	1	-	-	268173
" 1111	-	2	1	-	3	249145
		Mottled	Zone			
" 1102	-	1	2	3	-	253158
" 1112	-	2	1	-	3	249145
" 1115	-	2	1	3	-	212157
" 1120	-	2	1	-	-	264186
		Leached	Zone			
" 1103	-	1	2	-	-	253158
" 1105	-	2	1	-	-	268173
" 1119	1	3	2	-	-	255184

TABLE 3

X-Ray fluorescence analyses of laterites, grouped according to their position in the laterite profile

J.W. Sheraton analyst, BMR Laboratories
(For data retrieval at the BMR each sample number is prefixed 7009)

Ferruginous zone

Sample No.	1101	1106	1111	1110
SiO_2	34.74	47.05	73.78	65.93
TiO_2	1.31	0.12	1.54	2.60
Al_2O_3	19.65	11.53	15.51	0.64
*Fe_2O_3	42.74	41.42	8.24	30.86
MnO	0.04	0.04	0.01	0.03
MgO	0.48	0.29	0.16	0.22
CaO	0.38	0.16	0.05	0.01
Na_2O	0.00	0.02	0.04	0.06
K_2O	0.07	0.02	0.06	0.00
P_2O_5	0.05	0.05	0.07	0.06
Total	99.46	100.69	99.45	100.41
Loss on Ignition	9.60	7.34	7.10	3.67

Mottled zone

Sample No.	1102	1112	1115	1120
SiO_2	68.94	84.41	79.92	75.77
TiO_2	0.67	0.90	1.55	1.04
Al_2O_3	19.27	11.51	12.74	21.41
*Fe_2O_3	9.84	5.72	4.18	1.68
MnO	0.00	0.00	0.00	0.00
MgO	0.65	0.19	0.21	0.13
CaO	0.31	0.06	0.04	0.08
Na_2O	0.00	0.03	0.25	0.04
K_2O	0.09	0.02	0.02	0.08
P_2O_5	0.04	0.03	0.05	0.06
Total	99.82	99.87	98.95	100.29
Loss on Ignition	8.37	5.16	6.24	9.07

Leached zone

Sample No.	1103	1105	1119
SiO_2	69.61	76.12	89.15
TiO_2	1.23	0.02	0.48
Al_2O_3	22.81	21.09	8.19
$*Fe_2O_3$	1.10	1.54	0.66
MnO	0.00	0.00	0.00
MgO	0.64	0.27	0.48
CaO	2.70	0.20	0.08
Na_2O	0.05	0.06	0.05
K_2O	0.13	0.18	2.16
P_2O_5	0.02	0.03	0.02
Total	98.29	99.52	101.27
Loss on Ignition	11.17	8.89	1.72

Biotite-quartz-feldspar-gneiss (parent rock)

Sample No.	1104
SiO_2	75.30
TiO_2	0.11
Al_2O_3	13.45
$*Fe_2O_3$	0.97
MnO	0.00
MgO	0.22
CaO	0.99
Na_2O	2.90
K_2O	5.91
P_2O_5	0.05
Total	99.90
Loss on Ignition	0.52

* Total iron is expressed as FeO.

Geochemistry of the laterite

Twelve samples of laterite collected from the leached, mottled, and ferruginous zones, and one sample of unaltered parent rock for comparison, were analysed by x-ray diffraction and x-ray fluorescence. The results are given in Table 3 and the average analyses for each part of the profiles are illustrated by histograms in Figure 11.

The results show that the formation of laterite involves rock decomposition, liberation of alkai and alkaline earth metals (K, Na, Ca, Mg) and of silica, and the concentration of iron and aluminium oxides and hydroxides. In general, iron oxide concentrations increase upward in the laterite profile, reaching 40 percent or more in the ferruginous zone. The abundance of SiO_2 is similar in both the leached and mottled zones, but in the ferruginous zone, where Fe_2O_3 concentrations are high, the SiO_2 content is markedly reduced.

Lukashev (1958) gives examples of laterites developed over mafic and ultramafic rocks which have concentrations of between 60 and 80 percent iron oxide, and points out that they may contain significant amounts of Ni, Co, Mn, Ag, Au, and Cr. Only one sample, No. 70091110 (Grid. ref. 253143) was collected from a laterite developed on mafic igneous rock.

Unit Ta

BMR Alcoota 1 and 2 scout holes penetrated a massive mudstone and siltstone sequence conformable below the Waite Formation to total depth (Fig. 8). The upper part of these argillaceous sediments is weathered and mottled and stained by red oxide. The red coloration is especially evident in BMR Alcoota 1. However, in the sequence in both holes there is a zone of slightly leached white mudstone and siltstone; in BMR Alcoota 2 it grades into a basal sequence of green and grey, unweathered, pyritic mudstone. The sediments are almost devoid of bedding except for a few indistinct laminations. Apparently, they were deposited in a lacustrine environment, in very quiet water under reducing conditions.

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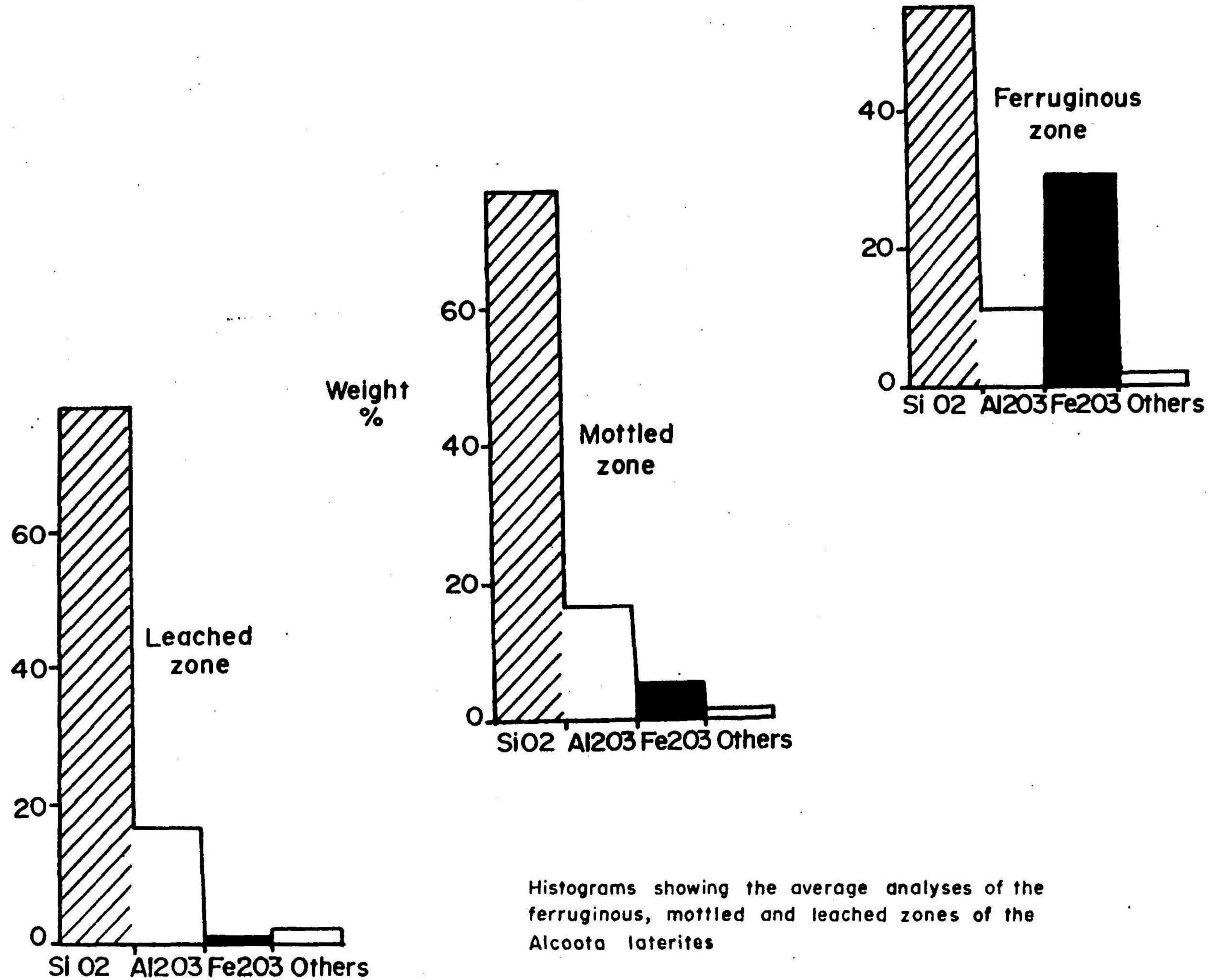


Histograms showing the average analyses of the ferruginous, mottled and leached zones of the Alcoota laterites

FIGURE 11

Waite Formation (Tw)

About 40 m of the upper part of the Tertiary Waite Formation crops out in the Alcoota Sheet area; the full thickness is nowhere exposed. BMR Alcoota 3 (SH3), located 500 m east of Harts Range police station, intersected 130 m of sandstone, siltstone, and mudstone (Yeates, 1971), which is considered to be a facies equivalent to the Waite Formation (Fig. 10). Mudstones underlying a unit of limestone and silty sandstone in BMR Alcoota 2 and possibly 9 (Figs. 8 & 9) are considered to be correlates of the Waite Formation.

In outcrop the Waite Formation consists of interbedded chalcedonic limestone, sandstone, siltstone, and minor sandy conglomerate. Beds of cream or white chalcedony form hard resistant summit caps to many low plateaux and mesas. The multiplicity and lack of clastic detritus in the chalcedonic beds indicate that the silica was deposited between periods of active clastic deposition of the Waite Formation and was not deposited by groundwater. Some beds have the appearance of limestone, and secondary replacement of $CaCO_3$ by SiO_2 may have played a part in altering the composition of the original chemical sediments. A sample of chalcedonic material (70091113) analyzed by x-ray fluorescence consisted dominantly of SiO_2 (96 percent) with minor FeO (0.77 percent), CaO (0.35 percent), and P_2O_5 (0.25 percent.).

In most outcrops the sediments increase in grainsize upwards, and in the Alcoota Sheet area Woodburne (1967) attributed this to a change from a lacustrine to a fluviatile environment of deposition. BMR Alcoota No. 1 tends to confirm this, because the subsurface sediments are dominantly argillaceous, and include abundant mudstone, siltstone, and claystone.

Vertebrate fossils in the outcropping lacustrine part of the sequence are late Miocene or early Pliocene (Woodburne, 1967). The bulk of the animal remains belong to the extinct family Diplotocontidae. The fauna also includes a crocodile (possibly related to Crocodylus porosus of New Guinea), large emu-like birds, and a wallaby-sized macropodid apparently related to Doncopsis and Dorcopsulus currently found in New Guinea. The fine grainsize of the sediments, and prolific iron-staining (the result of contemporaneous weathering), observed in the underlying section recovered in BMR Alcoota No. 1, suggest that an early Tertiary age might be appropriate for this part of the sequence. Sediments from cuttings in the interval 102 to 105 m in BMR Alcoota No. 1 (unit Ta) proved to be palynologically barren.

The distribution of Tertiary sediments (Fig. 7) shows two north-trending extensions of the Waite Basin. At a point 10 km south of Utopia homestead, in the westernmost extension, coarse-grained sediments occur with pebble to small boulder-sized clasts. The linearity and coarseness of these deposits, and the probable decrease in grainsize southwards, indicate a northerly source of detritus with drainage flowing southward into the Waite Basin. This is a reversal of the present-day drainage direction. As late Miocene to early Pliocene vertebrate fossils are present in the upper part of the Waite Formation, the Waite Basin was warped and dissected after the early Pliocene. The geological and palaeontological evidence indicates that the middle Tertiary climate in the Alcoota region was subtropical.

Undifferentiated Tertiary-Quaternary sediments (TQt)

Figure 8 shows a broad area of Tertiary sediments in the centre and central-west part of Alcoota Sheet area, which extends into the neighbouring Napperby Sheet (Edworthy, in prep.). Little is known of them as they are poorly exposed and mantled by Quaternary red sandy soils. (Only 11 of approximately 50 drillers' logs of water bores in this area record lithological information.). Over 100 m of sediment assigned to this unit were intersected in BMR Alcoota SH2. BMR drill holes SH4-11 intersected thicknesses of Unit T-Qc up to 122 m in the southwestern corner of the sheet area (see Figs. 9 and 10). Surface outcrops consist of silty sandstone overlying beds of travertinous limestone and, rarely, chalcedony (cf. its characteristic occurrence in the Waite Formation).

In subcrop the sediments consist of poorly sorted quartzose silty sandstone, minor granule and pebble conglomerate, and mudstone; some siltstone and mudstone beds are considered to overlie Units Tw and Ta in SH2 (Fig. 8) and SH9 (Fig. 9). A summary of the geological sections intersected in SH4-11 is given in Figure 10. In places, the section can be divided into three units: (e.g., Scout Hole No. 7, Fig. 9).

1. Upper unit of silty sandstone, commonly red-brown and slightly calcareous in places. Limonite commonly coats joint surfaces.

2. Middle unit of slightly silty vari-coloured sandstone, probably thinner than upper unit. Muscovite is present particularly in minor silty interbeds. (This unit appears to be missing in SH2).
3. Lower unit of multi-coloured and commonly mottled silty sandstone which is micaceous in places. In a few places (e.g. SH6 and SH2) pebble or granule conglomerate is present near the base.

Gamma Ray (G), self-potential (S.P.) and resistivity (R) logs for SH2 are shown in Figure ; and a gamma-ray log for water bore Woodgreen No. 1 (Reg. No. 56) is given in Figure 12. Both show slight gamma-ray anomalies not detected in two abandoned water bores on Woodgreen Station. Gamma-ray logs are not available for Scout holes 4-11.

No fossils have been recorded from the sequence and the age of the sediments is unknown. Unlike the Waite Formation in the Waite Basin, the sediments are not dissected and so are probably younger, the upper part being possibly younger than early Pliocene. Kunkar deposition, particularly in regions where there has been a shallow water-table with groundwater drainage has probably continued from the mid-Tertiary to the Holocene.

QUATERNARY

The Quaternary geological history is complex and has been influenced by climatic fluctuations and by a changing drainage pattern. Some of the units may have begun their development in the Tertiary, and a number of units are multi-phase or diachronous in their formation.

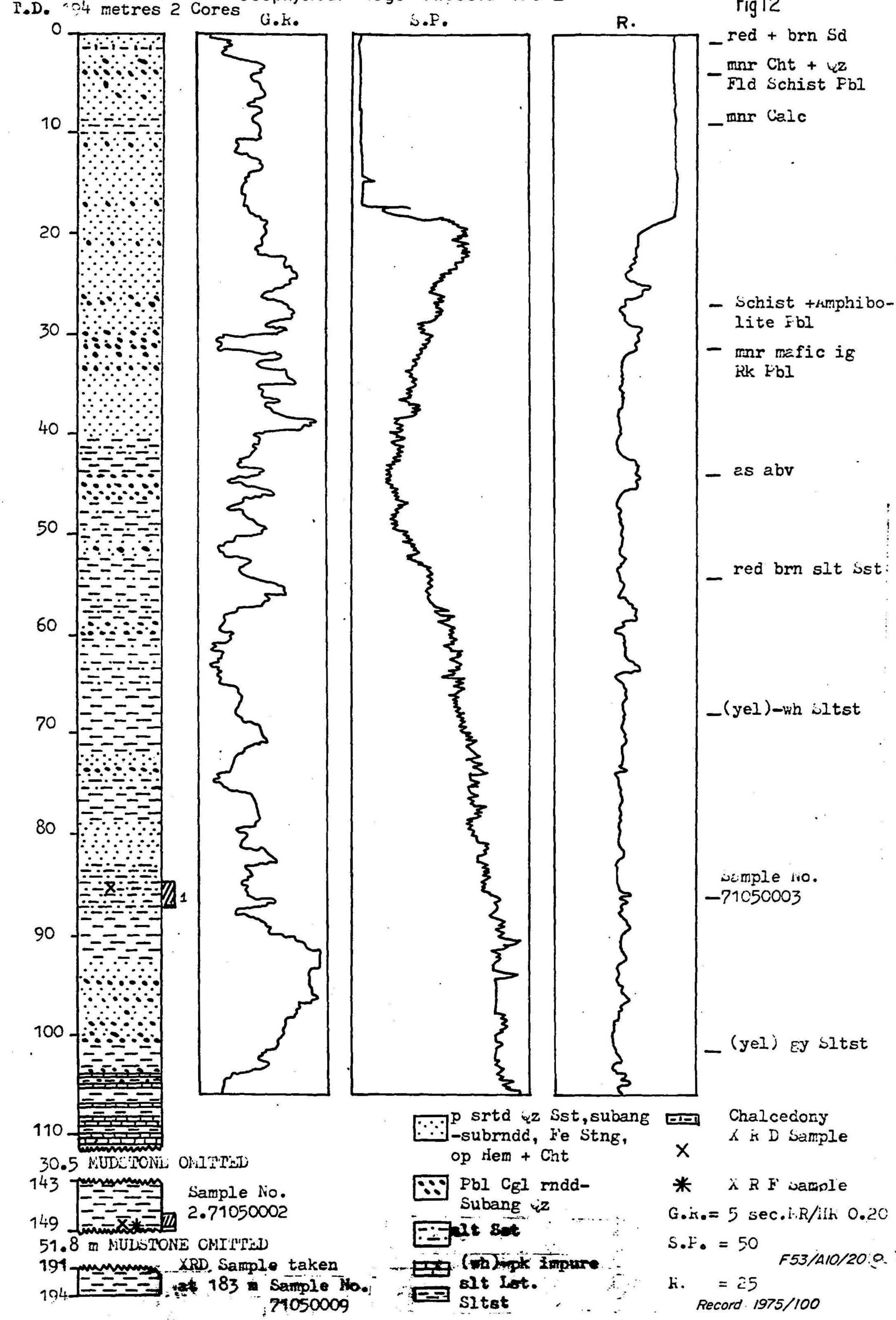
Sand units (Qps_1, Qps_2, Qs)

These mainly developed during the more arid interludes in the Pleistocene. The sands are subdivided into dune sands of Pleistocene age, sheet sands of Pleistocene age, and sheet sands in the west of the Sheet area, which may still be active.

Dune sands (Qps_1) in the south eastern part of the Sheet area, recognized by Quinlan (in Perry & others, 1962), cover about 100 sq km. The sands have been partly dissected and levelled by present day erosion. The sand is now fixed by vegetation (mulga and bloodwood in the south, and

Geophysical logs Alcoota No 2

Fig 12



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by spinifex and grasses adjacent to the Plenty River). The dunes trap streams from the Harts Range, thereby increasing recharge to the underlying Tertiary aquifers.

Sheet sand (Qps_2) forms extensive blanket sands in the northeast of the Sheet area and continue north and east beyond the Sheet boundary. Because these sands are now dissected, by both the present and abandoned channels of the Sandover River system, a Pleistocene age is suggested.

Two sources for the sand are probable. Sheet sand overlying the Dulcie Sandstone probably resulted from weathering of the underlying rock. Trend-lines of Dulcie Sandstone outcrops continue into loose sand areas. Dissected sheet sand in the valley of the Sandover River has probably largely originated from reworking during arid times of alluvial sands brought down by the river.

Sheet sand (Qs) covers much of the western half of the Sheet area. The sand supports both mulga with low shrubs and spinifex floras. These sands are partly dissected by stream channels, but also in places sand has covered stream channels originating from the Hann Range. Although the main large-scale development of the sheet-sand may have halted in the Pleistocene, continued Recent mobility of the sand is probable in local areas.

Sheet sand (Qs) in the central north of the Sheet area has been dissected by present day drainage and is considered to be Pleistocene.

Red-earth soil (Qr) has formed on very low-angle slopes common in the land surfaces of the Hanson and the Sandover-Plenty River Systems. The soils are generally a clayey sand and have slightly developed profiles commonly superimposed on repeated phases of alluviation and burial. Buried soils equivalent to Qr may occur beneath Qa and the sand units to depths of 100 m. The unit has been mainly interpreted photographically on the basis of the distinct pattern of arcuate groves of mulga it supports. (Between 1950 and 1970 when the two sets of aerial photographs for the sheet area were flown, the mulga has died back from the tops of ridges and from the bases of hills of outcropping basement. Moreover, Bateman (pp. 237-8 in Perry & others., 1962) quotes local reports dating back for several decades that indicate long term retreat of mulga stands). The extent of the unit as gauged from air-photo interpretation is therefore only approximate. The development of the red-earth soil is possibly related, in some areas, to the trapping of sheet runoff by mulga groves. In other areas the unit grades downwards into the underlying basement in about three metres like a normal soil profile as for example the exposure in a pit on the Waite River-Woodgreen track. On the Hanson Land Surface the unit is thicker and is overlain by sheet sands of probable Pleistocene age implying the unit began forming in the late Pliocene. It may interdigitate with sand units in a manner dictated by climatic change.

Scree, fanglomerate, sheet wash, soil, alluvium and flood-out plain deposits (Qa)

The other Quaternary units labelled Qa on the map include units of various ages and many origins as discussed below.

Scree and Fanglomerate deposits rim the bases of the higher hills. The unit consists of unconsolidated, coarse, and unsorted sediments produced by mass wasting of the steep slopes or by flash floods.

Sheet wash and fine alluvium cover broad pedimented areas. The sheet wash shows well defined layering where it is cut by gullies.

The soil cover is typical of an arid climate and lacks a marked profile (except possibly in the Qr unit), because the sparse vegetation seldom prevents the continual reworking of surface material with high winds and rapid stream run off.

Alluvium and flood-out plain deposits have formed at grade in the lower courses of streams. Material transported from the hills is deposited on the pediment slopes.

HOLOCENE

River channel deposits (Qha)

The present channels of the Sandover, Bundey, and Plenty Rivers are outlined by levee banks, and the present and recently abandoned channels are filled with poorly-sorted, coarse-grained sand. The channels date from the latest pluvial period, so these sands are either Holocene or, at the oldest, latest Pleistocene.

METAMORPHISM

Most of the rocks of the area have been metamorphosed to lower amphibolite facies. Figure 13 shows the distribution of index minerals and the associated assemblages. Rocks of the Harts Range Group in the southeast belong to the upper amphibolite facies; having assemblages containing sillimanite in association with potassium feldspar. A discontinuous east-west belt of granulite occupies the southern part of the Sheet area from south of Bushy Park homestead to east of Mount Swan; granulite is also present near Mount Lucy. A schist zone containing rare kyanite and staurolite cuts the granulite belt in the southwest. Greenschist retrograde metamorphism is most common in regions of faulting in the northern part of the Sheet area. Greenschist minerals are mainly confined to granites, the predominant rock type, and are distinguished from deuteric minerals by the presence of fracture cleavage. Some contact metamorphism may have been produced by the granites, but is difficult to distinguish from the regional metamorphism.

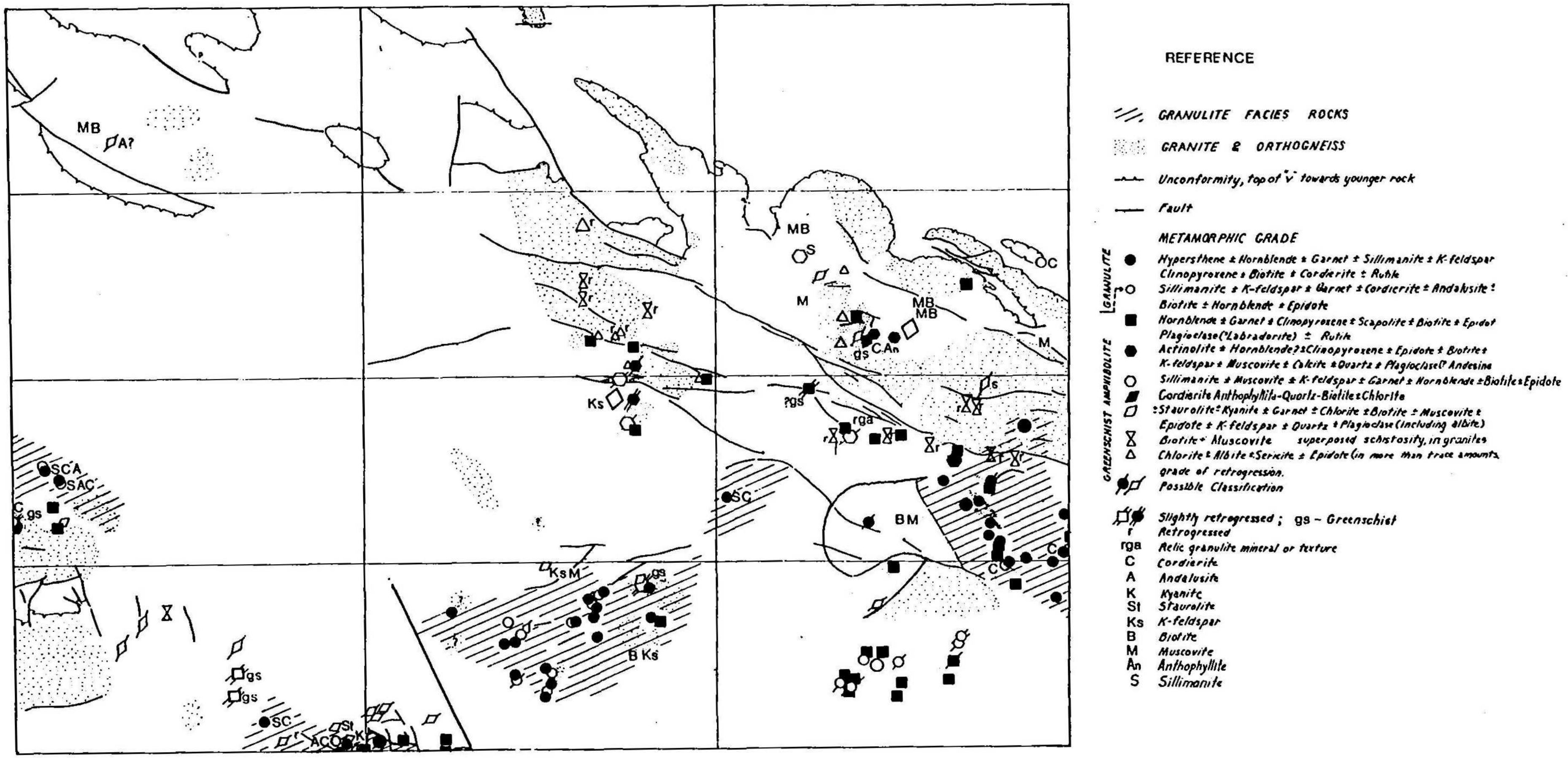
Granulite Facies

The typical granulite facies assemblage in mafic rocks is plagioclase-clinopyroxene-hypersthene, with or without hornblende, quartz and small amounts of biotite. Associated pelitic rocks are characterized by the assemblage quartz-potassium feldspar-sillimanite-garnet-biotite and, less commonly, cordierite (70090655A, 70090618; 70090625) and andalusite (69090286). The presence of cordierite and andalusite suggests a moderately high temperature, low pressure origin. Andalusite in granulite near Mount Lucy (68660052D) may be of later contact metamorphic origin. A less common assemblages is biotite-plagioclase-hypersthene-quartz-iron oxide. Hornblende and biotite-bearing rocks are abundant suggesting the rocks are transitional to the amphibolite facies. Biotite commonly accounts for up to 3 percent of the content of mafic hypersthene-bearing rocks and rarely rises to 10 percent. Mostly, the biotite is a secondary alteration product of hypersthene, but in those rocks where it accounts for more than 3 percent of the mineral content it appears to be in equilibrium with both hornblende and hypersthene. In associated felsic and pelitic gneisses, biotite constitutes up to 25 percent of the rocks. Hornblende-clinopyroxene-plagioclase assemblages are common in hypersthene-bearing rocks in the eastern part of the granulite belt near Mount Swan, where the hornblendic rocks may have retained a greater proportion of water than the hypersthene-bearing rocks.

FIGURE 13

METAMORPHIC FACIES

ALCOOTA SHEET AREA



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Amphibolite facies

Upper amphibolite facies

Rocks of the Harts Range Group in the southeast of the Sheet area contain assemblages compatible with granulite facies rocks, but mafic rocks lack hypersthene. Pelitic rocks are characterized by the mineral pair potassium feldspar-sillimanite. A typical assemblage is: quartz-perthitic potassium feldspar-sillimanite-garnet-biotite-epidote. Submafic rocks contain, in addition, hornblende, plagioclase and clinopyroxene. Common assemblages in mafic rocks are:

biotite-hornblende-plagioclase and
plagioclase-clinopyroxene-hornblende.

Quartz and sphene are possible additional minerals in these two assemblages. The calc-silicate rocks have the assemblage:

diopside-scapolite-quartz

as well as the less dignostic assemblages;

clinopyroxene-scapolite-amphibole (70090663B)
clinopyroxene-calcite-biotite-plagioclase (70090664).

Lower amphibolite facies

The lower part of the amphibolite facies contains too few index minerals to allow subdivision. Mafic rocks containing hornblende and plagioclase, with or without biotite and quartz, persist at the lower grade. Assemblages of retrogressed minerals including actinolite, and relict minerals such as clinopyroxene and potassium feldspar characteristic of the amphibolite facies, have been grouped separately from those containing hornblende (e.g. 70090650).

Pelitic assemblages containing sillimanite have been distinguished from less diagnostic assemblages, possibly of lower grade assemblages, containing garnet or potassium feldspar. Typical assemblages in the garnet-bearing group are:

garnet-biotite-quartz-perthitic microcline
garnet-biotite-muscovite-plagioclase-quartz.

Garnet-bearing gneisses are distinctive of the Chiripee Gneiss and are also present in the western part of the Walla Gneiss.

Potassium feldspar-bearing assemblages include:

microcline-muscovite-biotite-quartz-plagioclase-sphene

microcline-epidote-muscovite-biotite-quartz.

Lower pressure amphibolite facies

The assemblage (garnet)-cordierite-anthophyllite-chlorite-phlogopite-quartz found in the Delmore Metamorphics close to the unconformity with the Ledan Schist is considered to be a regional metamorphic assemblage produced under low pressure conditions similar to the conditions of the Abukuma facies series (cf. Winkler, 1967).

Retrogressive amphibolite facies

The easterly trending Wallaby Know Schist Zone in the Bushy Park-Muller Bore area cross cuts a granulite terrain of similar composition and is interpreted as the result of later dynamic metamorphism.

A typical assemblage is:

muscovite-biotite-potassium feldspar-plagioclase-quartz.

Kyanite and staurolite are found at a few localities within the Schist Zone suggesting it may be correlated with the Kyanite-staurolite facies of the lower amphibolite facies (Turner, 1968). Little garnet has been found in this zone by comparison with the Barrovian sequence in Scotland (cf. Winkler, 1967; Chinner, 1966).

Greenschist Facies

The grade of the Ledan Schist and the Mendip Metamorphics is problematical. Both have probably been metamorphosed to at least the upper greenschist and possibly to the lower amphibolite facies. The Ledan Schist is characterized by the assemblages:

magnetite-tourmaline-biotite-muscovite-quartz, and

muscovite-biotite-quartz.

The micas are well-formed and coarse. Microcline occurs at one locality. Upper greenschist facies or lower amphibolite facies are also indicated by

one small mafic body near the base of the schist which contains the assemblage-
epidote-?actinolite-quartz-plagioclase-sericite-iron oxide.

The Mendip Metamorphics commonly consist of biotite-muscovite-quartz; other more diagnostic assemblages include:

blue-green amphibole-epidote-quartz (71900041)

biotite-quartz-plagioclase-microcline-sphene-epidote-tourmaline (70090628D)

muscovite-biotite-quartz-plagioclase-microcline-sphene-iron oxide (70090628D).

Retrograde Greenschist Metamorphism

Greenschist facies minerals, found in granite or as pockets in amphibolite facies rocks, in the northern part of the region of crystalline basement, are interpreted as having formed by retrograde metamorphism. In granite, muscovite or chlorite are commonly associated with biotite in zones of incipient fracture cleavage (e.g. 70090916, 70090917A), or in recrystallized rocks (e.g. 70090958, 70090911, 70090613, 70090617). Much less common is retrogressed amphibolite containing chlorite (70090917A or chlorite and epidote (70090977) as alteration products of hornblende. Pelite and calcareous pelite at the northern margin of the Ida Granite west of Western Watering Point commonly contain the assemblages:

chlorite-biotite-muscovite-plagioclase-microcline-quartz (e.g. 70090902B, 71900015)

chlorite-epidote-quartz-microcline-calcite-hornblende (e.g. 70090902A).

In these rocks, which are characterized by recrystallised quartz grains, the chlorite, epidote, and sericite are considered to have formed by retrograde metamorphism, either as a result of contact metamorphism by the Ida Granite or a later dynamic event.

Polymetamorphism

The mafic rocks in the Mount Bleechmore Granulite have hornblende assemblages, yet are overlain directly by the Mendip Metamorphics which is lower amphibolite facies or greenschist in grade. It is considered probable that the abrupt change in metamorphic grade is an unconformity, and that a second metamorphism, after the deposition of the Mendip Metamorphics, produced retrogressive amphibolite facies assemblages in the granulite and thus account for the presence of biotite in both mafic and felsic rocks of the Mount Bleechmore Granulite.

GEOPHYSICS

Magnetic and radiometric surveys

A regional aeromagnetic survey east of the Alcoota 1:250 000 Sheet area was flown by BMR in 1963-64 (Wells & others, 1966). An aeromagnetic survey by Adastra Hunting Geophysics Pty Ltd for American Overseas Petroleum in 1966 covered a small northeast-trending zone through basement rocks in the centre of the Alcoota Sheet area, but was mainly concerned with the region of the Georgina Basin exposed in the northeastern corner of the Sheet area. Both aeromagnetic surveys showed that the metamorphic rocks form a well defined magnetic basement, and that its depth in the Dulcie Syncline northeast of the Alcoota Sheet area is about 1500 m. Young & Shelly (1966) produced a combined total magnetic intensity and radiometric map of Alice Springs 1:250 000 Sheet area during a study of the depth to magnetic basement in the Amadeus Basin. An aerial radiometric survey of a small part of the central eastern part of the Sheet area which was covered by Authority to Prospect 1726 (1969) was flown for Central Pacific Minerals N.L. (Clarke, 1969). The survey did not reveal any radiometric anomalies. A low-level scintollometer survey was flown in the Mount Swan area by Kratos Uranium N.L. during the tenure of Authority to Prospect 2587 (Mannoni & others, 1971), but only small anomalies caused by thorium minerals were detected. The BMR flew an airborne magnetic and radiometric survey of the Alcoota Sheet area in 1972 (Wyatt, 1974).

Aeromagnetic Features

Generalized magnetic basement zones and magnetic lineaments described and interpreted by Wyatt (1974) have been liberally used to produce the interpretation of solid geology shown in the Tectonic sketch on the 1:250 000 geological map.

Magnetically "quiet" regions correspond to exposures of granite or to thick (greater than 400 m) deposits of Adelaidean to Devonian age. Magnetically "quiet" regions covered by Tertiary or Quaternary sediments have been generally interpreted as granite. Several mafic igneous plugs have been interpreted by Wyatt (1974) north of Coppock Bore on the basis of a strong, localized magnetic response.

Some magnetically disturbed regions correspond to granulites within the Strangways Range Metamorphic Complex (the stratigraphically oldest unit at granulite facies). The magnetic disturbances are primarily due to the mafic rocks within the granulite sequences which have been traced out beneath superficial cover where possible. On the south west of the Sheet area recent drilling along the Stuart Highway and along the south western Bushy Park boundary fence has penetrated only amphibolite facies rocks as basement in a region interpreted as granulite from its magnetic response. Very disturbed magnetic zones are also present north of the Delny Fault Zone and parallelling the Mount Ida Fault Zone - these are attributed by Shaw and Wyatt to the faults cutting magnetic rocks beneath sheet-like granites.

Major magnetic lineaments correspond to the Arno Fault (which contains magnetite in the dynamic metamorphic zone) and the Maparta Fault Zone. Magnetic lineaments with similar trends are also interpreted as faults (e.g. Queenie Flat Lineament).

Areas of moderate magnetic disturbance are interpreted to correspond to gneisses of amphibolite grade. (Those magnetic lineaments believed to represent stratigraphic beds have been distinguished from interpreted faults in the Tectonic sketch. The Harts Range Group is characterized by very long and marked magnetic lineaments parallelling some units in an area which is otherwise magnetically "quiet".

The Mount Dixon Lineament corresponds to a definite change in magnetic character at the margin of the Georgina Basin with an increase in magnetic intensity to the northeast. The edge of the Georgina Basin, as a whole, was interpreted by American Overseas Petroleum (1966) as a suspected fault margin. Although faults are common near the margin of the Georgina Basin in the eastern part of the Sheet area, the zone boundary corresponding to the Dixon Lineament is not sufficiently sharp to indicate a definite fault; the lineament would, equally well, represent a marked lithological boundary.

Estimated depths to magnetic basement (Wyatt, 1974; American Overseas Petroleum, 1966) are shown in the Tectonic sketch for both the Georgina Basin and parts of the Central Mount Stuart Beds. Depths to magnetic basement under the Tertiary basins reach a maximum of 310 m, and are discussed in the account of Tertiary sedimentation and shown in Figure 8.

The magnetic evidence for the Woolanga Fault which has been extrapolated northwards from the Alice Springs Sheet area, along the western limit of outcrop of Mount Bleechmore Granulite is reasonably good. Other similar magnetically defined structures occur in the east of the Sheet area and north of Mount Lucy.

Radiometric interpretation

Radiometric data for the Alcoota 1:250 000 Sheet area was described and interpreted by Wyatt (1974). High radioactivity corresponds to regions of outcropping metamorphic and igneous basement. Interpreted thorium anomalies are the most abundant type. The most marked anomalies are located within the Woodgreen and Mount Swan Granites and in possible granite (pЄeg) within the Mount Bleechmore Granulite. Small increases in radioactivity over the northern part of the Sandover River and in the Spinifex Bore area possibly correspond to regions of recent deposition from igneous and metamorphic source rocks. The great majority of potassium anomalies are confined to areas of granite outcrop. A few very small uranium anomalies occur in the Ida Granite and in granite exposed west of Mollie Bluff. These two granites have only moderate anomalies (total count) with a high proportion of radiation from potassium compared to Woodgreen and Mount Swan Granites. A small group of potassium and uranium anomalies correspond to outcrops of granite at Red Cliff. Similar uranium and potassium anomalies to the north, just southeast of Lily Bore, may correspond to a similar granite outcrop.

A few small uranium and potassium anomalies similar to those in adjacent granite occur locally in the basal parts of the Central Mount Stuart Beds and in the surrounding unconsolidated Cainozoic sediments. The radioactive material probably came from a nearby granitic source. A uranium and potassium anomaly in the Mollie Bluff area is about 2-3 times the level of radioactivity in similar rocks in the immediate area and warrants ground investigation.

Gravity surveys

The regional gravity surveys of Lonsdale & Flavelle (1963) and Barlow (1966) outlined the main gravity features which have been named by Vale (1965) and others.

The relationship in central Australia between tectonics, particularly as portrayed by the distribution of metamorphic rocks, and regional Bouguer anomalies has been discussed by Forman & Shaw (1973). In the Alcoota Sheet area Bouger-anomaly highs (about -15 milligals) are associated with granulite facies rocks, partly because of their high density and partly because of their content of mafic igneous rocks. Granulite facies rocks correspond to parts of the Papunya Gravity Ridge, the Lake Caroline Gravity Ridge, and the Hale River Gravity Platform. The positive gravity anomaly near Woodgreen (-35 milligals) at the northwestern end of the Lake Caroline Gravity Ridge corresponds to rocks of the amphibolite facies, though granulite facies rocks may occur at relatively shallow depths beneath. A small positive gravity anomaly within the Yuendumu Gravity Low also corresponds to granulite faceis mafic rocks.

Granites probably contribute substantially to the low Bouguer anomaly values within the Hay River Gravity Low. Unmetamorphosed sediments of the Georgina Basin sequence and the underlying Central Mount Stuart Beds and Grant Bluff Formation also contribute to the Hay River Gravity Low and, where they are thicker, to the margin of the Georgina Regional Gravity Shelf.

A major gravity boundary separates the Papunya Gravity Ridge from the Hale River Gravity Platform, and corresponds to the Woolanga Fault in Alice Springs 1:250 000 Sheet area and an abrupt termination of a positive gravity anomaly in the southern part of the Alcoota 1:250 000 Sheet area. The lineament also shows particularly well on ERTS Satellite imagery.

GEOLOGICAL HISTORY

The geological history is summarized in Tables 9 and 10. The oldest rock units, comprising the Strangways Range Metamorphics Complex (Division 1), were probably mainly flows and dykes of acid and basic rocks before metamorphism, but also included minor amounts of argillite and calcareous sediments.

The next group of rocks (Division 2), interpreted as overlying the Strangways Range Metamorphic Complex, differ from it in containing a substantially greater amount of pelite and, except for the Riddock Amphibolite in the Harts Range Group, lack the metamorphosed equivalents of basic lavas. An unconformity, suggesting deformation followed by erosion and a change in the tectonic regime, is postulated between Divisions 1 and 2 to explain their marked difference in composition and the change in fold trend and style.

The third sequence to be deposited, represented by the Ledan Schist, Utopia Quartzite and Mendip Metamorphics, consisted of potassium-rich pelites and psammites, suggesting they were originally mature sediments laid down in a shallow sea. Like the Hatches Creek Group with which they are correlated they were probably deposited in the Early Proterozoic. An unconformity at the base of the sequence indicates a time break, which may also be a major break following granulite metamorphism. There is a metamorphic discordance between the Mendip Metamorphics of lower amphibolite facies and the Mount Bleechmore Granulite which cannot be explained by faulting.

Widespread regional metamorphism to at least lower amphibolite facies, affecting the Ledan Schist and older rocks, probably occurred immediately before the main plutonic episode at about 1700 m.y. (Shaw & Stewart, 1976). A minimum age of metamorphism is established by K-Ar muscovite ages of 1532 m.y. for the Ledan Schist and 1537 m.y. for a pegmatite intruding the Ledan Schist. The rocks have been isoclinally folded and refolded.

The Wallaby Knob Schist Zone transgresses a granulite belt and is considered to have formed at the same time as, or earlier than, a migmatite event in the Southern Arunta dated (in the Hermannsburg 1:100 000 Sheet area) at 1076 $\pm$ 50 m.y. on the basis of concordant Rb-Sr mineral and total rock ages (Marjoribanks & Black, 1973, cf. Thomson, 1970; Compston & Arriens 1968).

A period of uplift and erosion succeeded the last major metamorphic event.

The Vaughan Springs Quartzite was deposited in a marine environment as sandstone, about 1000 m.y. ago (see Table 5) in the southwestern part of the Sheet area.

The Areyonga Movement (Forman in Wells & others, 1970) is an epeirogenic event evidenced by a slight unconformity beneath the Adelaidean Areyonga Formation in the Alice Springs Sheet area. Subsidence of the eastern part of the Mount Skinner Block during deposition of the Mopunga Group mainly in the Huckitta Sheet area, (Smith, 1964) is also believed to be due to the Areyonga Movement. Sedimentation probably became continuous over the eastern end of the Ambalindum Block between the Georgina and Amadeus Basin during deposition of the Mopunga Group and its correlate, the Pertatataka Formation. Continuing subsidence is suggested by the onlap fo the Grant Bluff Formation onto crystalline basement in the Alcoota Sheet area. The Grant Bluff Formation was deposited under shallow marine conditions.

Subsidence over a widening area continued into the Early Cambrian, resulting in the onlap of the Central Mount Stuart Beds over crystalline basement ridges and the Grant Bluff Formation in the northern part of the Sheet area.

The Central Mount Stuart Beds are mainly red-beds deposited on land or in deltas. They include a tillite member near the base.

In the early Middle Cambrian a major extension of the subsidence resulted in the incursion of a shallow sea as a northerly belt across the continent. The incursion marks the base of the Georgina Basin Sequence (Smith, 1972), but there is no evidence of the incursion reaching the Alcoota Sheet area. Mild regional uplift, in the northern part of the Georgina Basin, occurred in the late Middle Cambrian, so that the Georgina Basin contracted to south of latitude 22°S (Smith, 1972). Evidence of the movement in the Alcoota Sheet area includes the probable unconformity at the base of the Tomahawk Beds where the nearshore marine deposits of the Tomahawk Beds probably onlap the Central Mount Stuart Beds and possibly the crystalline basement of the Poomingie High.

Mild regional uplift, probably corresponding to the Rodingan Movement in the Amadeus Basin (Wells & others, 1970) resulted in a regression of the sea preceding deposition of terrestrial Dulcie Sandsotne in the Devonian. The uplift must have been later than Middle Ordovician, when marine sedimentation ceased in the Georgina Basin (Smith, 1972).

In the Georgina Basin, the Dulcie Sandstone was folded and faulted before Mesozoic sediments were deposited. This event is correlated with the Alice Springs Orogeny, which is dated from the northern margin of the Amadeus Basin, where the only major folding and thrusting of the sedimentary sequence followed the deposition of the Upper Devonian to Carboniferous Pertnjara Group, and preceded that of the Crown Point Formation in the Late Carboniferous (Wells & others, 1970). The Alice Springs Orogeny culminated in the Early to Middle Carboniferous, as indicated by the K-Ar dates from the metamorphically retrogressed root-zone of the Arltunga Nappe Complex (Armstrong & Stewart, 1975).

During the orogeny the Ambalindum Block was uplifted, and widespread west-northwest normal faulting was reactivated in the Mount Skinner Block with down-throws commonly to the northeast. Only slight folding occurred during the orogeny, and no igneous activity is known in the Sheet area.

No sediments are known to be preserved in the Sheet area from shortly after the Alice Springs Orogeny until terrestrial sedimentation spread over much of the Sheet area in the early Tertiary. The Late Carboniferous to Cretaceous period was therefore probably one of continued erosion together with mild epeirogenic uplifts.

Development of the basins in which Tertiary sediments have been deposited was probably coincident with more marked movements in the Lake Eyre Basin southeast of the area. The beginning of sedimentation corresponds with a poorly documented change in climate (cf. Woodburne, 1967, p. 16). During a later period, possibly in the late Pliocene or early Pleistocene, uplift may have occurred along the site of the present Strangways and Harts Ranges, producing a reversal of drainage in the eastern part of the Sheet area from a southerly to a northerly direction (cf. Mabbutt, 1967). Woodburne (1967) has mapped a short north-trending fault having a 2 m vertical displacement cutting late Miocene or early Pliocene sediments south of Alcoota homestead, and the Mapata Fault displaces the Tertiary units east of Mapata Creek. The drainage reversal and vigorous stream incursion could also be partly due to continued subsidence in the Lake Eyre Basin affecting the grade of the local drainage.

ECONOMIC GEOLOGY

Mineral Deposits

Abandoned mica mines of the Undippa field (Joklik, 1955) lie in a east-trending narrow belt, 3 km north of Yam Creek Bore. These mines were operated from about 1945 to 1948 for a recorded production of about 17 tonnes of muscovite, then valued at 18,940. The country rock is leucocratic biotite-quartz-feldspar gneiss which is garnetiferous in part, and the muscovite is contained in quartz-feldspar pegmatites considered to be anatectic. The pegmatites are localised in faults or joints. Pegmatites have also been mined for mica 3 km south of Undippa Dam. Micaceous pegmatites also occur on Waite River and Delmore Downs stations, but probably less than one tonne of mica has been won from this area. (cf. Daly & Dyson, 1963).

Copper occurs in subcrop near Mount Skinner in grey sandstone beds within the Central Mount Stuart Beds as disseminated chalcopyrite and less commonly, as lenses of chalcopyrite. At the surface malachite forms films on cleavages of grey siltstone. The deposits were discovered near Mount Skinnerin March 1965, and briefly investigated by Youles (1965). In 1955 Kennecott Explorations (Aust.) Pty Ltd, in partnership with the holders, made a brief survey of the prospect and put down three percussion drill-holes (Halliday, 1966). The prospect was later drilled by the Northern Territory Administration and the results reported in detail by Grainger (1969). In 1969-70 Utah Development Co. mapped the Central Mount Stuart Beds in the surrounding area; and Centamin N.L. mapped the more prospective area and completed two diamond drill holes, but no assay results are available. Compagnie Generale de Geophysique undertook a geophysical survey using electrical methods on behalf of Centamin N.L.

The highest copper value found during drilling by the Northern Territory Mines Branch was 6500 ppm for a 0.3 m interval in DD-3 (at about 203 m, see Table 1). In DD-1 and DD-2 the highest values were 2570 and 1880 ppm copper over 1 m intervals. Zinc values up to 950 opm, over 0.3 m and lead values up to 6700 ppm over 1.5 m found in DD-3 at other levels distinct from the copper-bearing intervals (lead at 132 m, zinc at 313 m).

The Perenti copper prospect, located just in the Huckitta Sheet area about 23 km east-southeast of Delmore Downs homestead (Central Pacific Minerals, 1970), consists of disseminated copper minerals in one of a series of quartz-breccia reefs in a large northwesterly shear zone, which cuts across the contact of the Mount Swan Granite. The Perenti reef is 850 m long and about 450 m wide. Drilling has shown copper values to be very low.

Radiometric anomalies, possibly due to uranium, have been detected from gamma-ray logs both in Tertiary sediments, consisting mainly of silty sandstone and calcrete; and in two areas of granite during an airborne survey.

A gamma-ray log of Alcoota BMR Scout Hole No 2, drilled into Tertiary sediments 26 km north of Bushy Park homestead, shows an anomaly at of twice background at 90-100 m for a sandy conglomerate bed (Fig. 13). The anomaly is believed to be due to very low concentration of soluble compounds in groundwater. A second gamma-ray anomaly of twice geological background was detected in an abandoned waterbore (Woodgreen No 1, Reg No 56; Fig. 14) over the interval 24-34 m, which, according to the drillers log, consisted of medium-grained sandstone extending through the zone of oxidation. The interface between the oxidised and reduced zones is considered favourable for the concentration of uranium in a sedimentary environment (Adler, 1970). Scout holes 4 to 7 in the southwest corner of the Sheet area were logged but no gamma-ray anomalies found.

Airborne radiometric results (Wyatt, 1973) showed anomalous radioactivity over two areas of granite. These were interpreted as being due to potassium and uranium. One anomaly was over the Ida Granite; the larger was over granite and its erosional debris near Mollie Bluff.

Tantalite was mined during 1944-6 from the Bundey River prospect, 5 km northwest of Delmore Downs homestead. The prospect was briefly described by Jaffe (1946), who reported the discovery of the amorphous phosphate mineral, griphite. Daly & Dyson (1963) visited the tantalite prospect and recorded the discovery of bismuth minerals which contained slight traces of uranium. The Utopia tantalite prospect, 10 km west of Utopia homestead, also contains bismuth minerals, and is weakly radioactive (Daly & Dyson, 1963). Shaw (1968) described it as a tourmaline-muscovite-feldspar-quartz pegmatite intruded parallel to the foliation of the muscovite-biotite gneiss country rock. Although there is no record of production, the presence of pits and costeans suggests that small-scale mining of eluvial deposits may have been attempted.

Small quantities of wolframite have been won east of Delmore Downs homestead (Anon, 1941), mainly from eluvium, but also from pegmatite veins cutting a garnet-bearing gneiss close to its contact with the Mount Swan Granite. Specimens from these lodes also contained fluorite and scheelite.

Eluvial garnet, some of semi-precious quality, is derived from metamorphic rocks, particularly north of the Plenty River, south of Yam Creek Bore, and south of Muller Bore (Bushy Park station). Colourless clear quartz, smoky quartz, and rose quartz are contained in pegmatites throughout the Sheet area (eg. north of Pinnacle Well). Tourmaline, normally black, but in rare cases brown and translucent, is common in pegmatites in the northern part of outcropping crystalline basement.

Some of the granites and gneisses should be suitable for building stone should ever a market develop. Flaggy sandstones of the Grant Bluff Formation and Central Mount Stuart Beds would make good paving stone. Local sand supplies are obtained from the beds of the larger streams. Road gravel has been obtained from pits in hilly areas.

Groundwater Resources

Jones & Quinlan (1962) included the Alcoota Sheet area in their preliminary assessment of the groundwater resources in the Alice Springs area. They divided the area into a number of groundwater provinces related to the various drainage systems. Their results suggest that three provinces may contain water suitable for irrigated agriculture. The most recent assessments of areas with groundwater suitable for irrigation agriculture are:

(1) The Waite River Province (Sandover River) in the region of Utopia homestead (Woolley, 1965a), (2) the Dulcie Sandstone (Woolley, 1965b), and (3) Tertiary sediments in the Woolla Downs area (Jones & Quinlan, 1962).

TABLE 4. GROUNDWATER POTENTIAL OF GEOLOGICAL UNITS

Geological Formation (see Fig. 21)	Age	Main Rock Types	Range of Standing Water Levels (metres)	Yield Range (litres/sec) of successful bores (gph in brackets)	Estimated Percentage of successful bores*	Salinity Range (mg/l)	Range of Total depth (in metres) of successf bores
1. Dulcie Sandstone	Devonian	Porous sandstone	21-110	0.65-2.50 (500-2000 or more)	95%	400-450 Bore No. 84 800	30-320
2. Tomahawk Beds	Upper Cambrian to Lower Ordovician	Sandstone, minor siltstone and dolomite	12-50	0.65-1.25 (500-1000)	90%	1200 (one bore)	32-82
3. Tertiary Sediments (sandstone-rich facies) (1) Western area	Tertiary to Quaternary	Silty sandstone, siltstone, sandstone and minor travertinous limestone	3-18	0.375-3.75 (300-3000)	85%	500-1750	6-78
(2) Central and Southern area		As above	7-27	0.65-2.50 (500-2000)		1600-2400 Av. 1800	19-101
(3) South eastern area		As above	5-53	0.25-1.25 (200-1000)	70%	700-1400 Av. 900	12-94
4. Tertiary Sediments (shale-rich facies)	Tertiary to Quaternary	Shale, silty sandstone, minor travertinous limestone	18-20	0.25-1.25 (200-1000)	30%	750,1350 1550 (3 bores)	24-60

TABLE 4 (continued)

Geological Formation (see Fig. 21)	Age	Main Rock Types	Range of Standing Water Levels (metres)	Yield Range (litres/sec) of successful bores (gph in brackets)	Estimated Percentage of successful bores*	Salinity Range (mg/l)	Range of Total depths (in metres) of successfu bores
5. Alluvium of Sandover River and Muller Creek	Quaternary	Alluvium	7-9	0.25-2.50 (200-2000)	60%	300-1500	10-102
6. Grant Bluff Formation - Granite	Adelaidian	Siltstone, sandstone, granite	21-30	0.25-1.25 (200-1000)	50%	No. 8 1200 No. 176 10,000?	32-85
7. Central Mount Stuart Beds	Adelaidean to Cambrian	Sandstone, siltstone	?20	0.25-1.25 (200-1000)	40%	1500-15000	61-62
8. Crystalline Basement	Precambrian	Granite, gneiss, minor schist	9-30	0.25-1.25 (200-1000)	10% or less	1900-4600	15-61
9. Ledan Schist Ida Granite, Delmore Metamorphics	Precambrian	Schist, granite	15-27	0.25-0.65 (200-500)	10% or less	5 bores Av. 1300	18-57

* Estimates based on filed and word of mouth information and adjacent sheet areas.

The Alcoota Sheet area has been subdivided into geological units (Fig. 14) having similar groundwater potential (Table 4), defined by the success-rate of finding groundwater, and by the previous yields and salinity of water in each unit. Data have been mainly obtained from the files of the Northern Territory Geological Survey, Alice Springs but additional data have been obtained from Water Resources Branch (NTA) and local pastoralists. The salinities of groundwater from about 40 additional bores were estimated from conductive measurements of sampled groundwater. An attempt has been made to contour salinities (see Fig. 15). Detailed chemical analysis by the Animal Industry Branch, NTA, is available for many of the bores, but no attempt has been made to subdivide the groundwater on chemical grounds. The ratios of bicarbonate to chlorite (as mg/1) have been contoured in Fig. 20. to give a rough idea of regions of fresh water and possibly recharge areas (cf. Quinlan & Woolley, 1968, pp 32-33).

Groundwater potential

1. Dulcie Sandstone

The Dulcie Sandstone is the most important aquifer in the Sheet area. Like the Mereenie Sandstone with which it is correlated, it is an excellent source of water suitable for irrigated agriculture or a possible town supply (Woolley, 1965b). Supplies of up to 2.5 l/sec (200 gph), obtained in Water Resources Branch investigation bores during pumping tests, could probably be increased with more efficient bore completion and higher capacity pumps. Supplies are less than might be expected from such a porous rock. Permeability may be partly dependent on micro-fractures and joints. The water table surface level falls rapidly to the northeast. The Dulcie Sandstone is considered to be a semi-confined aquifer as water levels rise 3 to 4 metres once the water is struck. In investigation hole D2 the water level rose 12 m to a level similar to that in adjacent holes suggesting more than one aquifer may be present within the Dulcie Sandstone.

2. The Tomahawk Beds

Only a small amount of drilling has been done in the Tomahawk Beds, but drilling results recorded by Smith (1964) from the adjacent Sheet area suggest that the Beds contain moderately good aquifers. Recorded supplies are in the range 0.65 - 1.25 l/sec (500-100 gph). The bicarbonate content

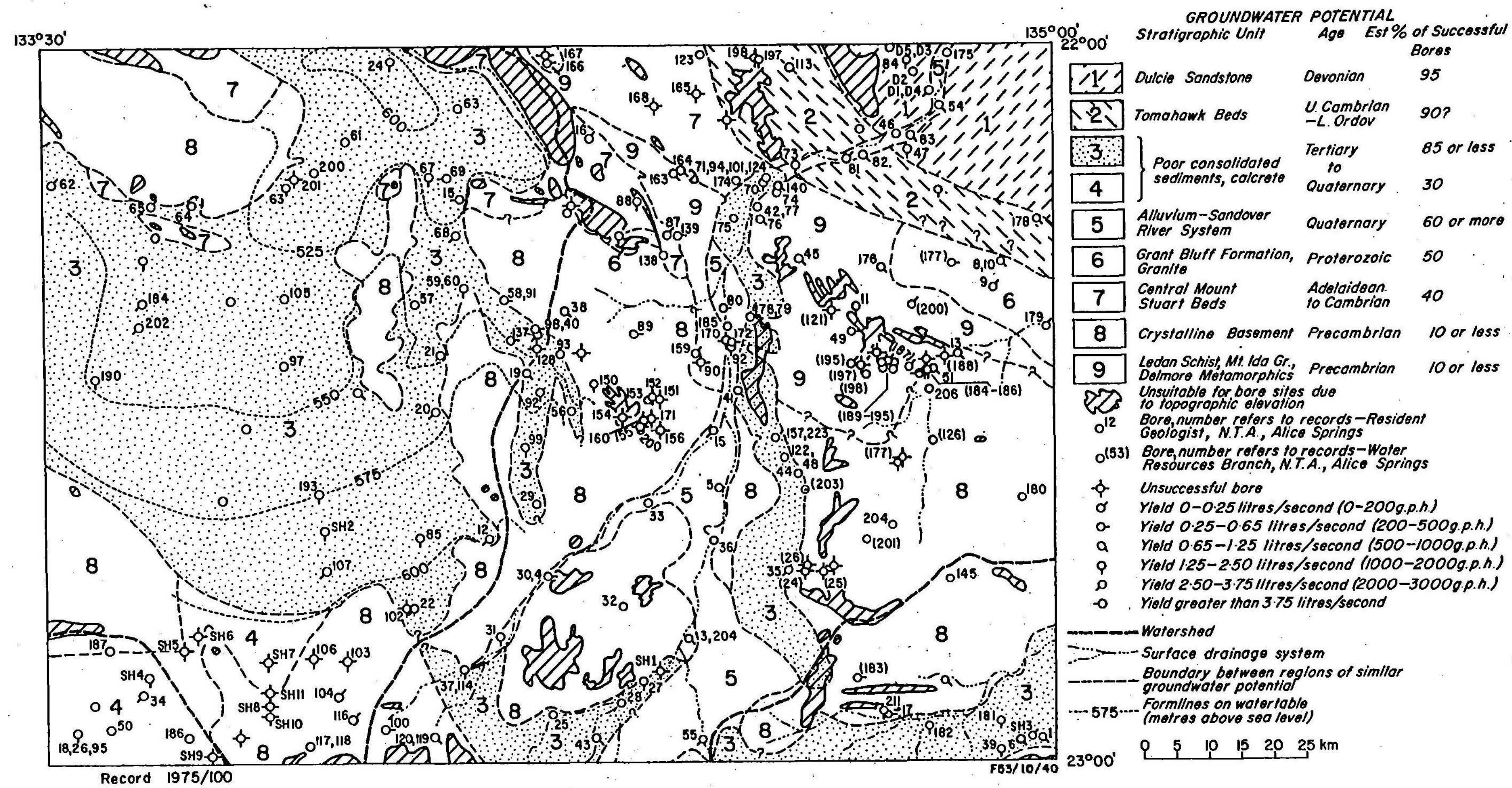


Fig 14 Ground Potential-Alcoota Sheet area

is high (Fig. 20), suggesting moderately rapid recharge similar to that in the Tertiary units.

3. The Tertiary sediments (sandstone-rich facies)

In the Tertiary sediments of the sandstone-rich facies a few bores have had poor supplies of water (0.25 - 0.65 l/sec or 200-500 gph); but the greater number of bores have good supplies (0.65 - 3.75 l/sec or 500-3000 gph) (see Fig. 18 for distribution) and some of these are suitable for irrigation. For convenience the groundwater potential is described for the three geographically separated areas of outcrop.

(1) In the Western Area form-lines on the water-table show groundwater flows northeasterly towards the Stirling Swamp near Stirling homestead in the Barrow Creek 1:250 000 Sheet area northwest of Mount Skinner. Groundwater from the Tertiary Tea Tree Basin in the adjacent Napperby 1:250 000 Sheet area flows eastwards into the Alcoota Sheet area south of Mount Solitary. The water-table shows decrease in depth below ground-level from about 30-40 m in the south to about 3-5 metres in the north. The groundwater has groundwater has a relatively high bicarbonate content (Fig. 16) suggesting moderately efficient recharge when compared to the recharge rate of other geological units. The highest bicarbonate contents are in the northern part of the sandstone of the western area indicating that considerable recharge is probably taking place in the low rise regions of weathered crystalline basement and red-earth plains with their characteristic mulga groves. The relatively efficient recharge is the result of both the permeable nature of the surficial sediments and the slow movement of the surface water due to the slight relief and internal drainage within the region. Good recharge may also occur in those regions where limestone crops out. Groundwater in the southern part of the region has a lower bicarbonate content, indicating more limited recharge or slower groundwater movements in that region.

The region has relatively high nitrate levels of up to 190 mg/l in the central and northern parts and bores 20, 21, 57, 96 and 97 (average 120 mg/l) have shown a progressive increase in levels with time. Such levels are considered to have accumulated as a result of nitrogen fixation by the abundant mulga, common on red-earth plains and low rises.

SALINITY INTERPRETATIVE CONTOURS, TOTAL DISSOLVED SALTS mg/l

FIGURE 15

Interpretative distribution of Tertiary groundwater basins.

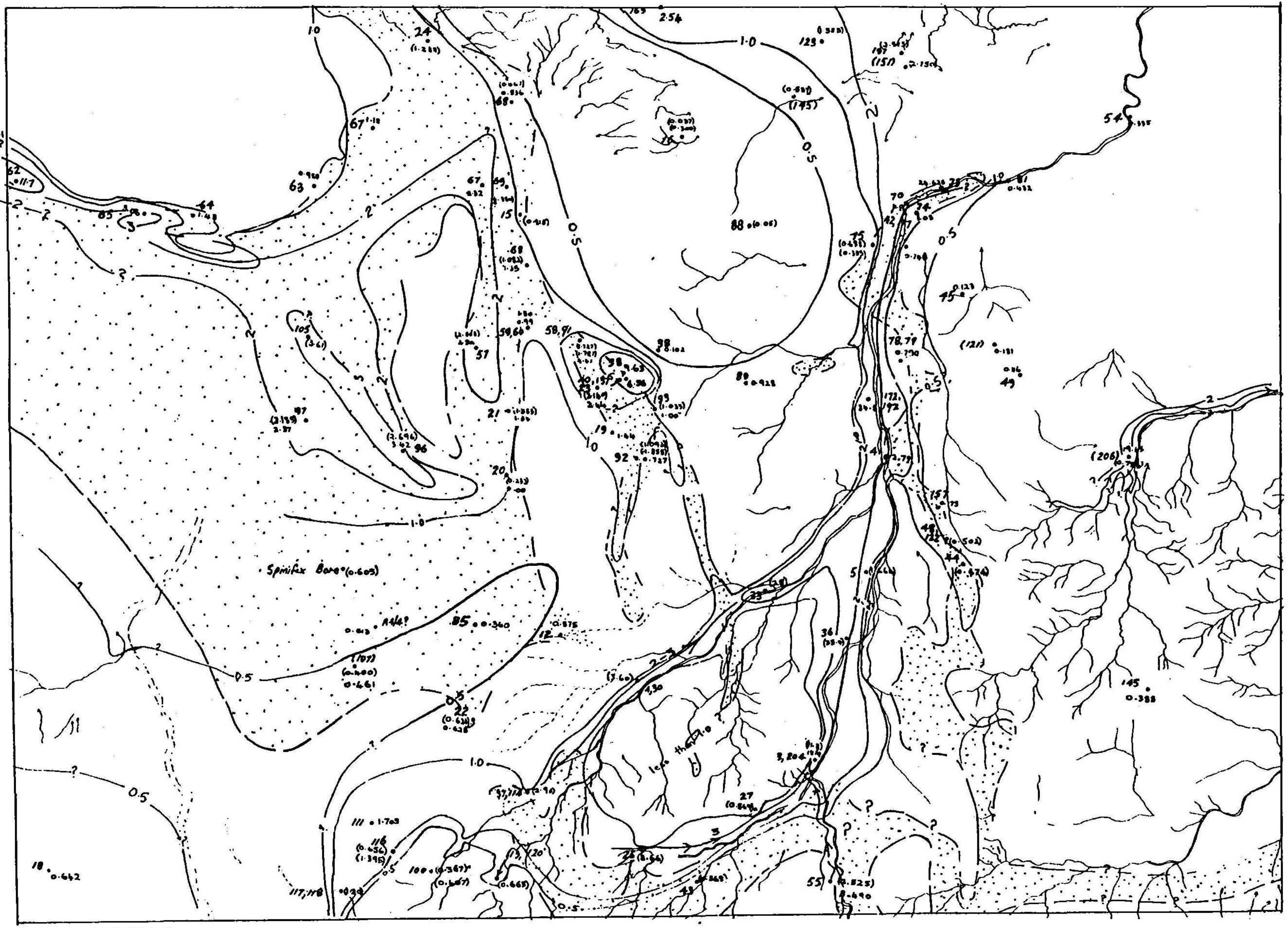
705 Analysis by A.I.B, N.T.A.
(2300) Analysis by W.R.B, N.T.A.
1200 Estimate from Conductivity measurement
17 Registered Number Res. Geol. N.T.A.
(206) Registered Number W.R.B, N.T.A.

Record 1975/100

F53/A10/34

GROUNDWATER COMPOSITION
BICARBONATE TO CHLORIDE RATIO mg/l

FIGURE 16



Record 1975/100

Interpretative distribution of Tertiary groundwater basins.

(2·521) - Analysis by W.R.B., N.T.A.
3·490 - Analysis by A.I.B., N.T.A.
54 Registered Nos. Res. Geol., N.T.A.
(121) Registered Nos. W.R.B.

(2) The Central and Southern area is very similar to the Western Area. In the bores put down so far yields are generally good (1/25-2.50 l/sec or 100-2000 gph). However, the predominantly shale section intersected in BMR Scout Hole No. 1 is considered to have poor groundwater potential. Comparatively less efficient recharge is suggested by the slightly higher salinity of 1600-2500 mg/l T.D.S. (cf. 500-1750 for western province) and the lower bicarbonate content (Fig. 16). A higher proportion of water is possibly taken off by the present drainage system, which in general does not overlie the Tertiary sediments. Near Utopia homestead the subarea is overlain by Quaternary alluvial deposits of the Sandover River. The efficient recharge of the Sandover drainage system combines with the good storage features of the Tertiary sediments to produce an excellent source of water suitable for irrigated agriculture. A preliminary report on the groundwater potential in the region of Utopia homestead has been made by Woolley (1965a). He estimated that at least 9.8×10^6 cu.m (8000 acre-feet) of water were stored upstream of pumps as placed in 1964, and considered supplies of at least 12.5 l/sec (10 000 gph) should be obtainable from individual bores.

(3) The Southeastern Area is also very similar to the Western Area. Bore yields seldom exceed 1.25 l/sec (1000 gph), insufficient to produce water suitable for irrigation purposes. Recharge probably takes place along the talus slopes of the Harts Ranges and along the Plenty River. Good recharge is indicated by the low salt content of bores, averaging 900 mg/l.

4. Tertiary sediments (shale-rich facies)

Where the Tertiary sediments have a high content of shale, silt, and silty sandstone, as is the case near Connor Well, drilling for groundwater has been considerably less successful than elsewhere.

5. Alluvium of the Sandover River

This area includes soaks along the Sandover River and Muller Creek and bores sited in the River banks. It receives efficient recharge which is reflected by the high bicarbonate content of groundwater (cf. Fig. 16) and the low salinities (200-1500 mg/l). Supplies are very variable but may be as high as 2.50 litres/sec (2000 gph).

6. Other miscellaneous areas

Supplies of up to 1.25 l/sec (1000 gph) are obtained from both the sandstones of the Grant Bluff Formation and from probable fault or fracture zone aquifers in granite. The upper part of the Grant Bluff Formation is unexposed, but meagre subcrop information suggests the upper part consists of siltstone and shale and is likely to be a poor aquifer. As parts of the Grant Bluff Formation include pyrite and pyritic sandstone in the Huckitta Sheet area, groundwater from these could have a high SO_4 content. Dolomites of the Formation in subcrop near Mount Skinner contain anhydrite and would produce very saline water. However, dolomites in the Huckitta Sheet area are generally good aquifers.

7. The Central Mount Stuart Beds

The groundwater porential of this unit is generally poor. Although supplies up to 1.25 l/ sec (1000 gph) have been obtained in two bores, much of the drilling in the Beds has yielded poor supplies of water, commonly with a saline content in excess of 3000 mg/l. The low average yield of these bores is probably due to the high content of siltstone (about 50 percent) typical of the Beds. The Central Mount Stuart Beds may underlie the Tertiary and Quaternary units north of Woolla Downs outstation and Mount Skinner homestead.

8. Crystalline Basement

The crystalline rokks are not inherently porous and the success rate for bores is less than ten percent. The difficulty of obtaining good supplies is reflected by the large number of dams within the region of crystalline basement. Aquifers occur in very limited Quaternary alluvial deposits overlying the crystalline basement, within zones of fracturing and jointing, or where the Tertiary deep weathering has extended below the water table. A few supplies up to 1.25 l/sec (1000 gph) have been obtained. Salinities average 2700 mg/l.

9. High basement areas

Groundwater in the area occupied by the Ledan Schist, Delmore Metamorphics, the Ida Granite and the schistose parts of the Delny Gneiss, as well as regions further down the watertable surface from these units, is highly saline, the salt content averaging 1300 g/l (Figs. 15 and 16).

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APPENDICES

Appendix 1

"Gossan" Samples.

A number of ironstone outcrops on the Alcoota 1:250 000 Sheet area were sampled for chemical analysis. Most were massive limonite bodies rising only centimetres above the peneplain.

Sample location Description

7009 0668

A, B, and D were taken from three small bodies of massive limonite which occur in an area 100 m squart covered with quartz scree about 1½ km southeast of Mount Ida. C was a quartz-limonite sample from the same area.

7190 0001 B

The sample was taken from a quartzose vein about 150 m southwest of Low Rock. The vein now contains quartz and hematite, but is presumed to have been originally a quartz-pyrite vein.

7190 0006

The sample was taken from a small cross-cutting biotite-iron oxide vein on the west slopes of Mount Swan.

7190 0012 A, B, C.

The three samples were taken from a large limonitic body at the junction between the Ledan Schist and the Utopia Quartzite over a vertical interval of about 10 m. It appears to have been an iron-rich sediment. Similar sediments occur elsewhere in the Utopia Quartzite.

7190 0018

The sample was taken from a dark coloured cross-cutting ironstone at the Ledan Schist - Utopia Quartzite junction. The outcrop had a marked bluish surficial bloom.

7190 0030

The sample was taken from a narrow, low-lying ironstone about 6 km northwest of Alcoota homestead.

Results of Spectrographic Analysis

All figures are in parts per million.

Specimen	Cu	Pb	Zn	Ni	Co	Ag	Ba	Sr	Comments
7009 0668 A	20	90					P	P	P indicates that the element was present in trace amount. Gold, Zinc and silver were not detected in any sample. Analysis by J. Weekes - BMR.
B	20	30					P	P	
C	2	20					P	P	
D	20	a					P	P	
7190 0001 B	360	40	110			2			Gold was detected in 7190 0006, but was less than 3 gn/tonne Analysis by AMDL. Rep. AN1354/72
7190 0006	100	40	105			2			
7190 0012 A	60	19	30	85	35				Silver and bismuth were tested for, but not detected. Analysis by C.W. Claxton - BMR.
7190 0012 B	20	23	15	65	16				
7190 0012 C	16	23	33	80	38				
7100 0018	170	23	70	19	230				
7100 0030	340	40	275	120	70				

Appendix 2. Analyses of granites
(ex AMDEL Report AN2/1/0 - 3805/77)

	72902003 (Copia) Percent	72902008 (Moun- Swan) Percent	72902011 (Queenie Flat) Percent
SiO_2	72.46	71.49	69.48
TiO_2	.21	.34	.45
Al_2O_3	13.85	13.62	14.09
Fe_2O_3	.31	.88	.89
FeO	1.53	1.50	2.80
MnO	.03	.03	.04
MgO	.33	.60	.71
CaO	1.27	1.46	2.29
Na_2O	2.40	2.80	2.82
K_2O	6.54	5.71	4.85
P_2O_5	.08	.14	.16
H_2O^+	.72	.61	.58
H_2O^-	.02	.05	.04
CO_2	.10	.05	.15
SO_3	.01	.01	.02
	p.p.m.	p.p.m.	p.p.m.
Li	13	11	9
B	5	5	5
Be	2	2	2
Ba	880	900	980
F	500	700	780
CO	4	5	5
Ni	5	4	8
Zn	36	41	46
Rb	250	280	220
Sn	10	6	6
Sr	130	160	130
Th	12	36	24
U	8	4	4
W	10	10	10
Y	20	16	16

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