COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

REPORT No. 88

Geology of the South-Eastern Part of the Amadeus Basin, Northern Territory

BY

A. T. WELLS, A. J. STEWART, and S. K. SKWARKO

Issued under the Authority of the Hon. David Fairbairn
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MINISTER: THE HON. DAVID FAIRBAIRN, D.F.C., M.P.

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* The maps accompanying this Report were printed before the text was complete. Certain amendments are necessary to the legends:

Bitter Springs Limestone should be Bitter Springs Formation;
Pertaoorrta Formation should be Pertaoorrta Group;
Age of Mereenie Sandstone should be Ordovician - Devonian;
Age of Finke Group and Pertnjara Formation should be Devonian - Carboniferous;
Age of de Souza Sandstone should be ?Jurassic.

SUMMARY

The area mapped includes the south-eastern part of the Amadeus Basin and a small area of sediments on the western edge of the Great Artesian Basin.

The Precambrian basement in the southern part of the area consists of granite, gneiss, and dolerite. In the Upper Proterozoic about 12,000 feet of dolomite, siltstone, sandstone, and glacial sediments were deposited in the northern parts of the Kulgera and Ayers Rock Sheet areas. The sediments were derived principally from large uplifted masses of Precambrian rocks to the south and south-west. A major period of faulting, folding, and extensive erosion followed the deposition of the Upper Proterozoic rocks.

The Cambrian shoreline lay along the northern part of the area mapped and coarse clastics were deposited. The Ordovician sea transgressed the Cambrian shoreline and the younger formations of the Larapinta Group unconformably overlie the Upper Proterozoic rocks. Some of the more resistant ridges of Upper Proterozoic rocks formed islands or peninsulas in the Ordovician sea.

The deposition of the Mereenie Sandstone on the Larapinta Group probably began in the Upper Ordovician. The formation appears to be formed of aeolian erosion products, laid down in a shallow marine environment. The Pertnjara Formation was laid down mainly in the Upper Devonian and probably extended into the Carboniferous. The major folding of the Amadeus Basin succession was in part synchronous with the deposition of the Pertnjara Formation. The thickness of Palaeozoic sediments in the south-eastern part of the Basin does not exceed 2000 feet.

The lateral equivalents of the Pertnjara Formation extend south-eastwards into the Finke Sheet area, where they have been mapped as part of the Finke Group. To the south, the sediments transgressed over older Palaeozoic and Upper Proterozoic rocks on to the Precambrian basement. Thin Permian glacial sediments unconformably overlie the Finke Group and are followed unconformably by Mesozoic sediments. The Finke Group, and the Permian and Mesozoic sediments, whose total thickness is about 3000 feet, are considered to be part of the Great Artesian Basin succession.

The major structures are indicated by the geophysical surveys. The structures include a large depression with low density rocks trending east-west in the southern half of the Kulgera Sheet area. The depression is situated in an area blanketed by flat-lying Mesozoic sediments between the southern exposures of Precambrian igneous rocks and the northern outcrops of Upper Proterozoic rocks. The granitic rocks in the south may be thrust over the less dense rocks. The depression is bounded to the north by a ridge probably composed of near-surface basement rocks, which divides the thick Palaeozoic and Proterozoic sediments to the north from a thick Precambrian sequence to the south.

Much of the Finke Sheet area is a shelf with thin sediments.

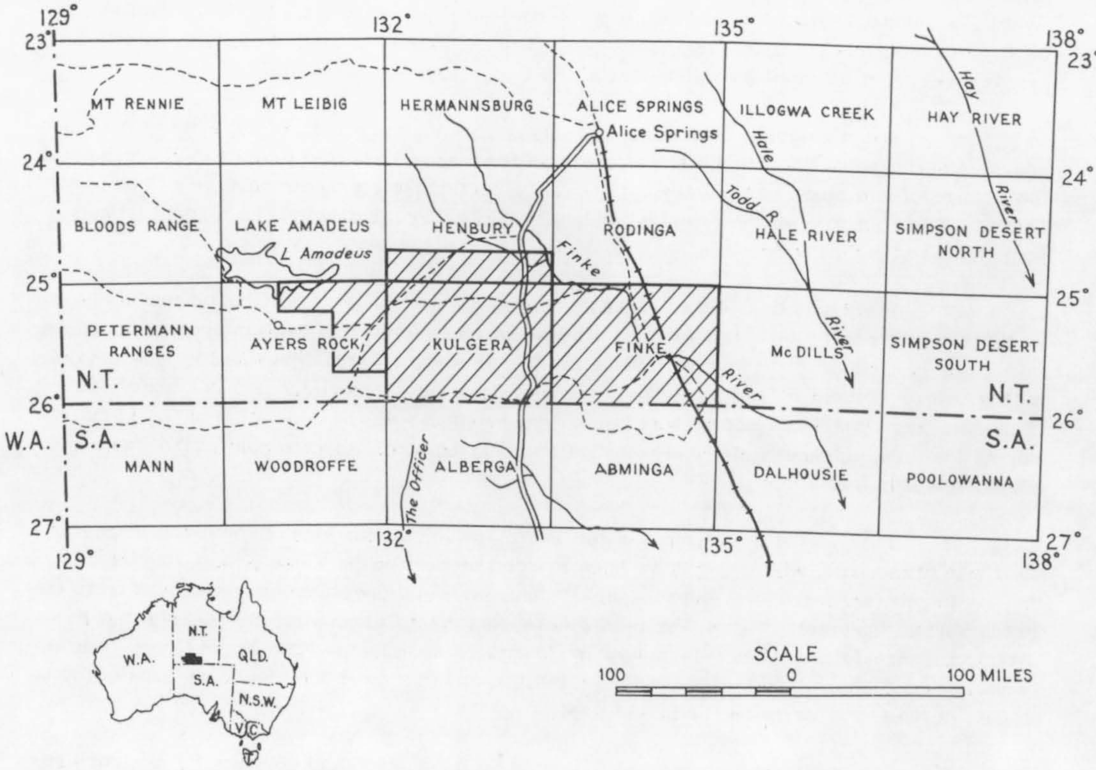

Fig. 1. 1:250,000 Sheet index and locality map.

INTRODUCTION

The south-eastern part of the Amadeus Basin and a small part of the western edge of the Great Artesian Basin, comprising the Kulgera, Finke, and parts of the Ayers Rock and Henbury Sheet areas, were mapped by the authors in 1963. Other parts of the Amadeus Basin have been described by Wells, Forman, & Ranford (1964, 1965), Ranford, Cook, & Wells (1966), and Forman (1966).

The area mapped lies in the southern part of the Northern Territory between latitudes 24°45'S. and 26°00'S. and longitudes 131°30'E. and 135°00'E. (Fig. 1). The main north-south road passes through the centre of the area, and the homesteads are connected to it by graded roads.

The area lies almost entirely between the 8" and 5" isohyets, and most of the rain falls during the summer. Summer temperatures are high, with a daily maximum in January between 95°F and 100°F, and a minimum between 70°F and 75°F. In July the daily maximum is between 65°F and 70°F, and the minimum around 40°F. The prevailing wind is from the south-east.

Beef cattle are raised in the area, and about 330 bores and wells have been sunk, though many of these have been unsuccessful.

Most of the mapping was done by Landrover reconnaissance traverses, but helicopter traverses occupied 30 hours' flying time, mainly in the Finke Sheet area. Stratigraphic sections (Fig. 3) were measured with tape and Abney level.

PREVIOUS INVESTIGATIONS

On all three of his northern journeys, John McDouall Stuart passed through the area, along the same route, discovering and naming the Finke River, Mount Daniel, and Mount Beddome (Stuart, 1865). Giles, during his second expedition (Giles, 1889), passed through Ayers Range, and on his fifth visited Mount Conner, which Gosse (1874) had discovered and named, along with Ayers Rock.

The first geological observations were recorded by East (1889): at Cunningham's Gap, near Crown Point in the Finke Sheet area, he noted 'large boulders of red granite' in the bed of the stream, and at Polly Spring he noted a 'ridge of argillaceous and hornblendic schists, having a central core of red granite'. This was the Black Hill Range, now mapped as Winnall Beds, but his 'core of red granite' must be a mistaken interpretation of the granite boulders derived from the Polly Conglomerate. Flanking the ridge he also observed the flat-lying clays and sand grits which are now mapped as part of the Finke Group.

The Horn Expedition (Tate & Watt, 1896, 1897; Winnecke, 1897) started and finished at Charlotte Waters Telegraph Station, and most of the major landmarks in the Finke Sheet area were named, including the Newland Ranges, Mount Magarey, Mount Hopetoun, Jenkins Bluff, Mount Kingston, and Mount Watt, where 'Lower Silurian' fossils were collected. Physiographic notes on the whole area were also published. On the same expedition, Tate (1897) noted striated boulders at Yellow Cliff on the Finke River, and at first ascribed the striations to bedding, but after discussion with T.W.E. David he believed them to be of glacial origin. David himself (1898) described striated and grooved boulders from the same locality, and considered them to be of Permo-Carboniferous age. However, the Committee of the Australian Association for the Advancement of Science (of which David was Secretary) would only allow a late Palaeozoic or Mesozoic age, because of insufficient stratigraphic evidence. They were actually mapped as Tertiary by Tate & Watt (1896). Years later, David & Howchin (1924) visited Yellow Cliff and Crown Point and described the stratigraphy. David & Howchin had no hesitation in assigning a Carboniferous or Permo-Carboniferous age to the glacials of Yellow Cliff and Crown Point.

Basedow (1905) published brief notes on Ayers Range, Mount Conner, and Mount Kingston, and in 1926 he travelled with the MacKay Exploring Expedition (Basedow, 1929a,b), and again visited the Ayers Range on the way to the Petermann Ranges.

The 'Finke River sandstones' (now part of the Finke Group) between Mount Daniel and Idracowra homestead were described by Chewings (1914). He noted the shales underlying the sandstone between Horseshoe Bend and Idracowra, and considered the Crown Point glacials to be a river conglomerate of non-glacial origin. He included the conglomerate in the Finke River sandstone, and assigned both the sandstone and the underlying shale to the Jurassic (?). Later (1928) he still considered them to be Jurassic. He discussed (1935) the 'Pertatataka Series' of the older part of the Amadeus Basin sequence, and regarded Mount Olga, Ayers Rock, and Mount Conner as 'Newer Proterozoic'. He also thought that the Erldunda, Basedow, and Kernot Ranges were 'Larapinta residues', and outliers of the 'Marena' red sandstone (Mereenie Sandstone) of the Levi and George Gill Range. These ranges are now mapped as Winnall Beds.

The 'Finke Series of Sediments' were also described by Ward (1925). At Polly Spring he noted the 'coarse pebbly grits [now Polly Conglomerate and Langra Formation].... resting unconformably upon the old Palaeozoic sandstone and quartzite [now Winnall Beds].... probably above this came white and red shales.... [and] greenish-grey shales [now Horseshoe Bend Shale], overlain by 100 feet of cross-bedded variegated sandstone and grit' (now De Souza Sandstone). He considered the tillite of Yellow Cliff to be related to the cross-bedded sandstone, and regarded them both as Permo-Carboniferous. He regarded the 800 feet of Jurassic sands (now De Souza Sandstone) in the old Charlotte Waters Bore as resting directly on the sandstones of the 'Finke Series'; and the 494 feet of his Lower Cretaceous 'Rolling Downs Formation' resting on the Jurassic in this bore is now mapped as Rumbalara Shale. Madigan (1932) correlated the 'Finke River Sandstone' with the Pertnjara Formation (as is done in this Report), and considered them both as Permo-Carboniferous.

In 1930, Terry (1931) conducted a purely exploratory trip from Horseshoe Bend, and travelled west to Erdunda, Mount Conner, Ayers Rock, and on to the Schwerin Mural Crescent in Western Australia. He returned by way of the Kernot, Basedow, and Erdunda Ranges, and concluded that 'no evidence of any mineral of commercial value exists in this area'. Ellis (1937) accompanied a private expedition to the Robert Range (in Western Australia), and considered Mount Olga, Ayers Rock, and Mount Conner as Upper Proterozoic in age.

Wilson (1947, 1950, 1952a, 1960) has made a detailed petrological study of the pyroxene-bearing granites of the Musgrave Ranges, including some from the Ayers Range, and has also discussed other aspects of the geology of this area (Wilson, 1948, 1952b, 1953, 1954, 1959). Robinson (1950) described two thin sections from specimens collected by Basedow in 1903 from the Ayers Range.

Sullivan & Õpik (1951) named Rumbalara Shale and De Souza Sandstone during an investigation of the Rumbalara ochre deposit.

Hossfeld (1954) included a discussion of the 'Finke Series' and the Musgrave block in a general description of the stratigraphy of the Northern Territory.

Thomas (1956) of Frome-Broken Hill reviewed the literature and discussed the physiography and general geology of the Amadeus Basin, and Weegar (1959) produced a photogeological map of the basin. Gillespie (1959) investigated the south-western parts of the basin and regarded Mount Conner as Upper Proterozoic to Lower Palaeozoic. Leslie (1960) worked in the southern part of the basin, named the Pioneer Formation (now mapped as Inindia Beds and Areyonga Formation) and recognized glacial beds in it. He noted the angular unconformity at the base of the Stairway Sandstone, and recognized several unconformities in the succession. He also considered that, on a regional scale, time horizons were crossed by the sedimentary units. Wulff (1960) regarded the whole of the 'Finke River Beds' in the south-east as glacial, though he only noted the horseshoe Bend Shale ('varved micaceous siltstones') and Idracowra Sandstone of the present Finke Group. He considered the De Souza Sandstone to be closely associated with the glacials and regarded them all as Permian. Taylor (1959) examined the fossils collected by the field parties, and concluded that the rock units as named were diachronous.

In 1960-61 the Institut Français du Pétrole prepared photogeological maps of the Amadeus Basin on a scale of 1:250,000 (Scanvic, 1961). Prichard & Quinlan (1962) mapped the southern half of the Hermannsburg Sheet area, measured the section at Ellery Creek, established the sedimentary succession in the Amadeus Basin, and defined the main rock-units.

The Bureau of Mineral Resources extended its geological work to the rest of the basin, and accounts of various areas have been published by Wells, Forman, & Ranford (1964, 1965), Ranford, Cook, & Wells (1965), and Forman (1966). A gravity survey of the basin has also been completed (Langron, 1962a, b; Lonsdale & Flavelle, 1963).

Company geologists have been active in the area since 1960 (Hopkins, 1962; Stelck & Hopkins, 1962; Hartman, 1963; Grasso, 1963), and Sprigg (1963) has discussed the geology of the Simpson Desert and its surroundings directly east and south-east of the Amadeus Basin.

Cook (1963) recorded the discovery of phosphorites in the Amadeus Basin by the Bureau of Mineral Resources. He considers that the phosphate deposits were formed by the mixing of oxygenated and detrital-laden water with phosphate-rich marine bottom waters.

Rochow (1965) made a rapid reconnaissance of the Finke Sheet area, and recognized and described (but did not name) the four units of the 'Finke Series' (now formally named the Finke Group). He included the overlying Crown Point glacials and the De Souza Sandstone in the 'Finke Series'. He correlated the fossiliferous sandstone which caps Mount Watt with the Stairway Sandstone, and regarded the Crown Point glacials as unconformable with the underlying formations.

PHYSIOGRAPHY

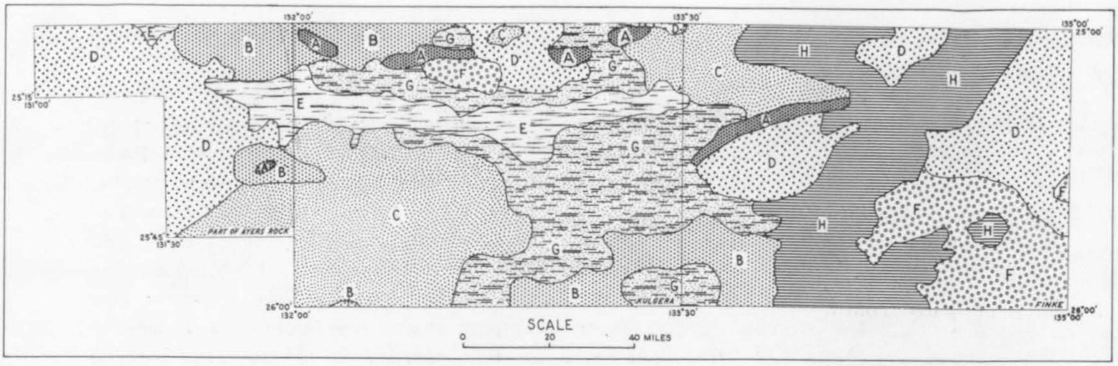

Fig. 2 Physiographic divisions. A: Mountain ranges and hills; B: Low ranges and hills with intervening dunes and sand plain; C: Sand plain with many dunes and some low outcrops; D: Sand plain with dunes; E: Salt lakes; F: Gibber or alluvial plains; G: Alluvial plains; H: Mesas and buttes.

Mountain ranges and hills of sandstone are found at Mount Conner in the Ayers Rock Sheet area, in the Kernot, Basedow, Erldunda, and Mount Sunday Ranges, in the northern part of the Kulgera Sheet area, and in the Mount Kingston/Black Hill Range on the Finke Sheet area. Mount Conner, a large flat-topped mesa with a sheer vertical wall on the north-west side, rises about 1000 feet above the plain. Ollier & Tuddenham (1961) found that weathering took place mainly by blocky disintegration of the quartzite as a result of thermal expansion and contraction. The 300-foot cliff around the top of the mountain is a joint-controlled vertical free-face of quartzite, and below this is a rock-cut waning slope of 35° in the softer siltstones, passing down imperceptibly into a pediment. Slope retreat is parallel.

The other ranges rise only 300 to 500 feet above the plain, and all have prominent escarpments to the north (except for the Mount Sunday Range), owing to the southerly dip and vertical jointing in the sandstones. All the ranges are composed of Winnall Beds, except for the Mount Sunday Range, which is an eroded anticline of Palaeozoic sediments with steeply dipping parallel strike ridges on its northern flank. Mount Sunday itself is a flat-topped mesa situated at the turnover of the anticline.

Low ranges and hills, with intervening dunes and sand plain: From Curtin Springs homestead to Angas Downs homestead, and around Mount Conner, strike ridges of gently dipping Lower Palaeozoic rocks or sandstone of the Inindia Beds rise above the level of the plain; the ridges are generally less than 100 feet high, but in places they rise to 200 feet. Dunes are poorly developed between them. In the area between Victory Downs and Umbeara homesteads, which is underlain by granite, rounded inselbergs rise sharply from the alluvial plain; south-east of Umbeara homestead, on the local divide between south-flowing and east-flowing creeks, the alluvium is thinner and the bedrock between the inselbergs is better exposed.

Sand plain with many dunes and some low outcrops: In the south-western part of the Kulgera Sheet area and on the Ayers Rock Sheet area, rock exposures are small and sparse. Dunes are long and straight and covered with mulga scrub. In the other areas dunes are short and curved, and mulga is absent.

No solid rock is exposed in the five areas delineated as sand plain with dunes. Dunes are short and curved in the Ayers Rock Sheet area and between the Basedow and Erldunda Ranges; and long and braided in other areas. The interdune areas in the eastern part of the Ayers Rock Sheet are covered with alluvium.

Salt lakes continue from Lake Amadeus, north-west of the mapped area, in an east-west belt across the Kulgera Sheet area, becoming smaller towards the east. Water is only occasionally present, but the beds are always damp. The lakes are covered with a layer of powdery salt less than an inch thick.

Gibber or alluvial plains with mesas or low hills occupy the south-east corner of the Finke Sheet area. Some patches of sand dunes occur, and some larger watercourses are present, heading east to the Finke River.

Alluvial flood plains with some clay pans are present in the Kulgera Sheet area on each side of the salt lakes. Large parts of the area are underlain by Quaternary and Tertiary limestone. The country is flat and monotonous, with only occasional small creeks.

Mesas and buttes, with intervening sand or alluvium, are associated with the flat-lying Upper Palaeozoic and Mesozoic sediments in the Finke River Sheet area. The mesas range up to 200 feet high. They are steep-sided, and in places have a compound stepped structure owing to differential weathering of the flat-lying beds. They have a close dendritic drainage pattern with steep-sided gullies. The major watercourses only flow for a short time after heavy rain, although the pools in the Finke River, which are commonly salty, may persist for several weeks.

The last period of erosion may have started in the upper Tertiary, after the deposition of the non-marine Tertiary sediments in the central part of the Kulgera Sheet area. The topmost beds of the Tertiary sediments were silicified, probably at the same time as the formation of the 'billy' on the Mesozoic rocks to the east. The siliceous capping of the hills has since been considerably eroded.

The present period of aridity probably began a considerable time ago. Surface run-off is slight; slopes are long, gentle, and unbroken for miles; hills and ranges are few, low, and isolated. Dust storms are common around the cattle stations where the plant cover has been eaten out, and during them a good deal of sand is moved near the ground. Some deflation is therefore taking place. Large parts of the area are covered by sand dunes, but most of them are now fixed. Other features include the gibber plains and the inselbergs in the southern part of the area. All these phenomena suggest a senile arid landscape.

STRATIGRAPHY

The stratigraphy of the south-eastern part of the Amadeus Basin is summarized in Tables 1, 3, and 4, and the correlation of the main rock units with these in adjacent areas is shown diagrammatically in Figure 4. The locations of the measured sections and phosphorites are shown in Figure 3. Specimen localities and reference points on the geological maps are prefixed by the letters AR for Ayers Rock, K for Kulgera, and CW for Finke.

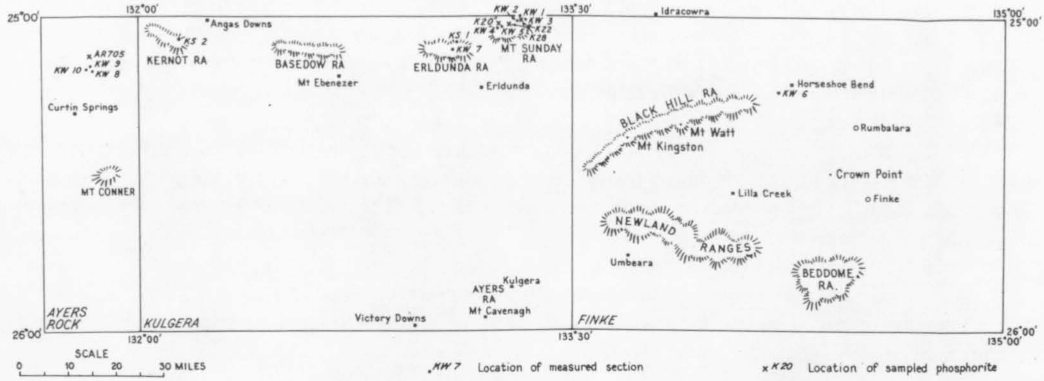

Fig. 3 Location of measured sections and samples of phosphorites.

PRECAMBRIAN (See Table 1)

Precambrian rocks of the Musgrave block crop out along the southern margin of the Kulgera Sheet area; and in the south-eastern corner of the Finke Sheet area. Most of the exposures are inselbergs, rising about 400 feet above the surrounding alluvium. Surface run-off on the inselbergs follows the joints, and has incised steep-sided gullies up to 100 feet deep. Near Umbeara homestead in the Finke Sheet area, the cover of alluvium is more sparse, and large areas of rock are exposed between the inselbergs.

The Precambrian igneous and metamorphic rocks have been divided into four rock units: schist (Kulgera Sheet only), gneiss, granite, and dolerite.

Schist

Precambrian schists are exposed in the south-west corner of the Kulgera Sheet area. They are greenish grey and micaceous, and the schistosity strikes east-west and dips steeply south. The existence of a lineation in the plane of the schistosity, parallel to the dip, and also a horizontal lineation, formed by the intersection of an earlier S-surface with the schistosity, indicates that there were at least two phases of deformation.

Gneiss

Precambrian gneiss was mapped in the following three areas:

(i) East and north-east of Mount Cavenagh homestead, where the rock is granitic in composition, and was probably a primary igneous gneiss.

(ii) North-east of Kulgera homestead, where the rock-types include gneissic hornblende-biotite trondhjemite, gabbro, norite, sillimanite-cordierite-biotite gneiss, and cordierite gneiss; the gabbro and norite have undergone metasomatic replacement by quartz. The gneissic foliation is strong, and appears to form a synform, which plunges gently to the north-west.

TABLE 1 : PRECAMBRIAN STRATIGRAPHY.

AGE	FORMATION & SYMBOL	THICKNESS (FEET)	CORRELATION	LITHOLOGY	REMARKS
UPPER PROTEROZOIC	Winnall Beds (Ᵽuw)	2000	Pertatataka Formation	Silicified white and purple-brown thin to thick-bedded sandstone; dark brown siltstone and glauconitic siltstone. Abundant flow casts, cut-and-fill structures, silt pellets, and ripple marks.	
	Inindia Beds (Ᵽun)	About 7000	In part equivalent to the Areyonga Formation.	Coarse cross-bedded sandstone; medium silicified sandstone; siltstone; fine pink and yellow dolomite; conglomerate with chert pebbles and siltstone and tillitic texture in upper part. Bedded chert; chert breccia; red-brown and grey siltstone; hematitic and manganiferous breccia in lower part.	Siltstone in upper part contains striated and faceted erratics.
	Bitter Springs Formation (Ᵽub)			Dark grey and pink fine to medium dolomite, recrystallized in part; interbedded siltstone and minor sandstone. Secondary chert abundant. Numerous stromatolites in places.	Thin sandstone at top of formation at Ippia Hill contains halite pseudomorphs.
	(do)			Dolerite	Complex sequence of granite intrusions with dykes of microgranite, pegmatite, and aplite; confined to south-eastern part of Kulgera Sheet area and south-western part of Finke Sheet area.
	(p€g)			Granite	
	(p€e)			Geniss and minor amphibolite.	
	(p€)			Schist and minor quartzite.	

(iii) South-east and east of Umbeara homestead, where the gneiss is coarsely foliated and granitic, and includes some augen gneiss, 'lenticle gneiss' which in a few places grades into 'pencil gneiss', and bodies of gneissic amphibolite. The gneissic foliation forms several antiforms and synforms with east-west axes and limbs dipping at about 45° north and south. (Sprigg, 1963, states that the folds are isoclinal, and have north-east axes).

Granite

At least 13 types of granitic rock, including the hypabyssal rocks, are present in the Victory Downs/Umbeara area. The largest body of granite, which extends for at least 20 miles west from Mount Cavenagh homestead, is a grey coarse-grained clinopyroxene-hornblende granite, with a weak to well-developed planar orientation of mafic clots. Near Mount Cavenagh homestead, hornblende-biotite granite and hornblende-clinopyroxene-biotite granodiorite are also present. Microcline has replaced a good deal of the oligoclase metasomatically. Most of the other bodies of granite are only a mile or so across, and are situated near Kulgera. Microgranite dykes are common south-east of Umbeara; they form a network controlled by two major sets of fractures in the gneiss, one trending north-east, the other north-west.

Dolerite

Large numbers of olivine dolerite dykes have been injected into the granite and gneiss. They are composed of labradorite, clinopyroxene, olivine, and magnetite. Granite has been metamorphosed by dolerite at several places. The dykes dip south at between 20° and 40°, and a few undulatory sheets are present near Umbeara homestead.

Five miles west-south-west of Mount Cavenagh homestead, veinlets of tachylite have been injected into fractures in the granite. Numerous small isotropic euhedral crystals of leucite are present in the tachylite, and in xenocrysts of feldspar derived from the granite, and may have been formed by reaction between the granite and tachylite.

UPPER PROTEROZOIC

Bitter Springs Formation

The name 'Bitter Springs Limestone' of Joklik (1955) was revised to Bitter Springs Formation by Ranford, Cook, & Wells (1966). The formation crops out in a few places; identification is based on its lithology and stratigraphical position. The base of the formation is not exposed, and it is overlain disconformably by the Inindia Beds or unconformably by the Ordovician Stairway Sandstone, the Cambrian Pertaoorrta Group, and the Palaeozoic Langra Formation. The formation is poorly exposed and generally forms low hills or moulds.

The Bitter Springs Formation crops out in the core of an overturned anticline, 23 miles north-north-east of Curtin Springs homestead, where it is unconformably overlain by the Stairway Sandstone. Several isolated outcrops are exposed on the alluvial plain north of the Kernot Range.

In the east-west ridge 3 miles south of Angas Downs homestead there are several small outcrops of Bitter Springs Formation which are intricately folded with the Inindia Beds. These outcrops are unconformably overlain by the Stairway Sandstone dipping to the south.

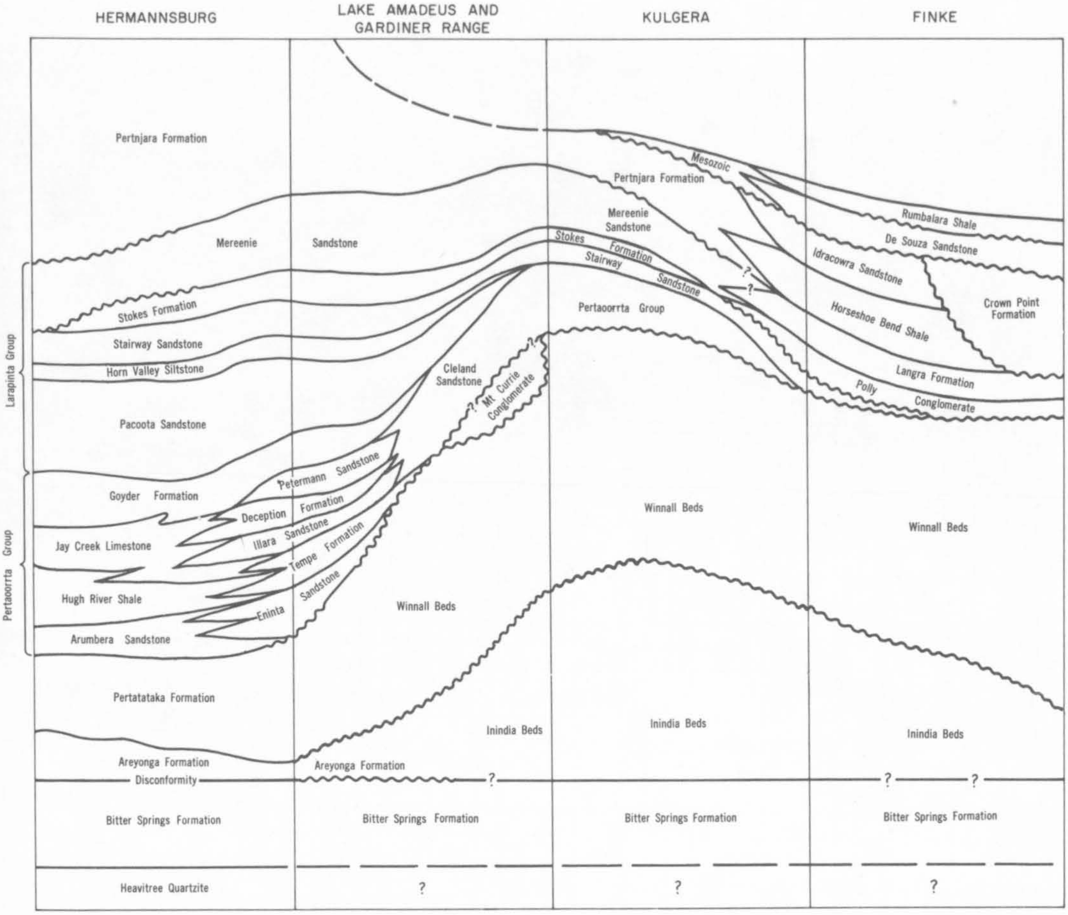

Fig. 4. Correlation of rock units.

The best exposures of the formation are the two outcrops in the core of the Erldunda Range, where it is overlain disconformably by the Inindia Beds, and unconformably by conglomerate and greywacke of the Pertaoorrta Group.

In the Black Hill Range there is one small poorly exposed outcrop of the Bitter Springs Formation near the Inindia Beds. The formation is unconformably overlain by the Langra Formation.

Exposures of the Bitter Springs Formation consist predominantly of dolomite with a few interbeds of calcareous dolomite and limestone. The dolomite is commonly dark blue-grey, with red, pink, maroon, and purple-brown varieties. Most of it is fine-grained, but some is medium and coarse-grained. Oolitic dolomite is found at some localities. Some of the dolomite contains abundant coarse sand grains, and most specimens contain blebs or thin laminae of fine sand. The beds are laminated or thin, and in the Erldunda Range there are interbeds of grey thin-bedded siltstone and medium friable sandstone. In the western exposure in the Erldunda Range a small thickness of thin-bedded silty fine silicified dark purple-brown sandstone with pseudomorphs after halite occurs above the dolomite; the beds have been tentatively placed in the Bitter Springs Formation, but in nearby areas the dolomite is overlain by chert and sandstone of the Inindia Beds, which suggests that the top of the formation has been removed by erosion. Irregular bands, laminae, and lenses of chert are common in most outcrops. Possible stromatolites are present in the Erldunda Range, and well-preserved stromatolites in the Black Hill Range.

In thin section, the dolomite from north of the Kernot Range is a fine-grained rock which has been partly recrystallized and partly replaced by chert. Fine subangular grains of quartz up to 1 mm across are present. The rock is partly oolitic, with the oolites set in a recrystallized dolomitic matrix. The dolomite near Ippia Hill consists of small masses of fine carbonate surrounded by coarser crystalline dolomite. The rock contains scattered irregular pods of fine sand and silt. The coarser carbonate and quartz may be secondary materials filling the voids. Ironstaining is common and is probably responsible for the red colour of the rock.

As the Bitter Springs Formation is poorly exposed its total thickness in the south-eastern part of the Amadeus Basin is unknown: the maximum exposed thickness is only 200 to 300 feet. The formation is a shallow marine deposit on a stable epicontinental shelf. It was deposited over the whole of the Amadeus Basin, and originally it probably extended well beyond the present limits of the basin. Its age is probably Upper Proterozoic. It is overlain by several thousand feet of other probable Upper Proterozoic sediments, and by Cambrian rocks with a pronounced angular unconformity. The only fossils found are stromatolites.

Inindia Beds (Ranford, Cook, & Wells, 1966).

The Inindia Beds are exposed discontinuously from about 20 miles north-west of Curtin Springs homestead in the Ayers Rock Sheet area, across the northern part of the Kulgera Sheet area, to Black Hill, 4 miles north-east of Mount Watt in the Finke Sheet area. The most southerly exposures are around Mount Conner and at Mount Kingston. Most of the outcrops are covered by mounds of fragments of chert and jasper with some low ridges of sandstone or pale silicified siltstone. Better exposures occur on the prominent ridge 12 miles north-east of Curtin Springs homestead, in the circular strike ridges around Mount

Conner, and on the isolated ridges 17 miles south of Mount Ebenezer, near the middle of the Kulgera Sheet area.

The contact with the Bitter Springs Formation is only exposed in the Erldunda Range and 12 miles south-east of Angas Downs homestead, where it appears to be conformable; but since the tillite exposed in several localities in the Inindia Beds contains numerous small erratics of dolomite, chert, and siltstone derived from the Bitter Springs Formation, the contact is probably disconformable. In the core of an anticline 7 miles west of Angas Downs homestead a sandstone in the Inindia Beds dips south at 30^{o} under the Bitter Springs Formation, but the beds have almost certainly been locally overturned.

Only at the eastern end of the Basedow Range do the Inindia Beds crop out close to the Winnall Beds. The Inindia Beds comprise coarse white kaolinitic sandstone and siltstone which are overlain by the closely jointed dark brown blocky siltstone at the base of the Winnall Beds. The strike of the two formations is parallel, but the dip of the Winnall Beds is uncertain. On the northern side of the Basedow Range and the northern side of the Kernot Range the strike and dip of the Inindia Beds and the overlying Winnall Beds are the same or nearly so. In the Henbury Sheet area (Ranford, Cook, & Wells, 1966), however, the formations are unconformable in places.

In a small area 16 miles north-east of Mount Ebenezer homestead, and in the Erldunda Range, the Inindia Beds are unconformably overlain by the conglomerate of the Pertaoorrta Group. At many localities in the Ayers Rock Sheet area, and as far east as the Basedow Range, the Stairway Sandstone rests unconformably on the Inindia Beds. The unconformity is seldom exposed, but the boundary can generally be located within a few feet.

The Inindia Beds comprise mainly sandstone and siltstone, with small amounts of chert, dolomite, and tillite. The formation contains at least eight sandstone intervals, most of which are less than 100 feet thick (see Table 2). The sandstone is white to yellow-brown, slightly kaolinitic, generally medium to coarse-grained but with some fine-grained beds, medium-bedded and blocky, moderately tough to friable. One of the thicker friable sandstones near the middle of the sequence contains well-developed spheroidal siliceous concretions up to an inch across. The upper two sandstone units form the outer and inner concentric strike ridges around Mount Conner. The inner ridge is coarse-grained, friable, strongly cross-bedded, and contains some angular granules of chert. Thin-section examination shows that the sandstone is an orthoquartzite composed of grains of quartz and chert, with a little siliceous cement. Some quartz greywacke also occurs.

In places, the sandstone near the base of the Inindia Beds is conglomeratic, with granules and pebbles of chert, reef quartz, and jasper, both well rounded and poorly rounded in the one bed. In some exposures the conglomeratic sandstone grades into chert breccia. In many cases the sandstone has a blue-black manganiferous matrix, and in other localities it contains oolitic hematite.

The siltstone is mostly white and pale cream, yellow, pink, and yellow-brown, laminated to thin-bedded, kaolinitic, in places micaceous, and moderately tough, and often has a subconchoidal fracture. Claystone occurs commonly with the siltstone, and in thin section laminae of siltstone can be seen grading into claystone. Other siltstones are poorly sorted and sandy. Occasional interbeds of shale also occur in the siltstone.

Most of the chert in the Inindia Beds is in the middle of the sequence, but some thin alternating beds of chert and sandstone occur near the base. The chert is varicoloured; the commonest varieties are red, green, and yellow, irregularly laminated, and splintery; massive, cloudy, blue-white, and fractured; white and oolitic; black, oolitic, and with quartz geodes; or pale grey and white, and thin-bedded.

Dolomite was found in situ in the Inindia Beds at only two localities. In the prominent ridge 12 miles north-east of Curtin Springs homestead, dolomite occurs at the top of the exposed sequence. It is a pale pinkish brown tough laminated rock, interbedded with yellow-brown siltstone. In the prominent strike ridge 17 miles south of Mount Ebenezer, dolomite is overlain by white sandstone followed by tillite. This sandstone is correlated with the outer arcuate ridge around Mount Conner.

Tillite is well exposed 4 miles west of Pulcura Well and beneath the scarp of the inner sandstone ridge on the north-eastern side of Mount Conner. It consists of non-bedded poorly sorted yellow-brown tough siltstone, with angular quartz grains up to half an inch across in the matrix. It contains erratics of quartzite, black oolitic chert, red jasper, siltstone with striations, and banded chert. Many of the rounded erratics are broken. Beneath the same scarp on the north-western side of Mount Conner the erratics include pieces of yellow-brown silicified dolomite which are partly replaced by black chert. In the Erldunda Range the tillite is similar, but in places erratics are absent and the rock is very clayey.

In section KW9 (Fig. 5), 12 miles north-east of Curtin Springs homestead, the Inindia Beds are about 1700 feet thick, but beds above the dolomite have been removed by erosion. From the air-photographs the thickness of the sandstone and siltstone sequence around Mount Conner is estimated as about 4500 feet, and the estimated thickness of the red-brown siltstone below the measured section is 500 feet. The total aggregate thickness of the Inindia Beds is therefore about 7000 feet. The known sequence is shown in Table 2.

The considerable thickness of the sandstone and siltstone units without cross-bedding, and the presence of chert and dolomite, indicate that the Inindia Beds are probably mostly marine. The environment of deposition is unknown, but the beds were probably deposited on a shelf in water of intermediate depth. The presence of tillite indicates glacial conditions while the upper part of the sequence was deposited. The overlying thick cross-bedded coarse-grained sandstone may indicate deposition under continental conditions. The beds directly below the tillite are exposed at only one locality, 17 miles south of Mount Ebenezer, and consist of about 200 feet of white medium-grained kaolinitic sandstone which towards the top becomes coarser and more poorly sorted, and contains some angular chert fragments. The coarser sandstone is similar, except for the absence of cross-bedding, to the inner sandstone ring above the tillite at Mount Conner, but whether it is continental is not certain.

No fossils have been found in the Inindia Beds. As they lie unconformably between the Winnall Beds and the Bitter Springs Formation they are assigned to the Upper Proterozoic. They are correlated with the Areyonga Formation of Prichard & Quinlan (1962).

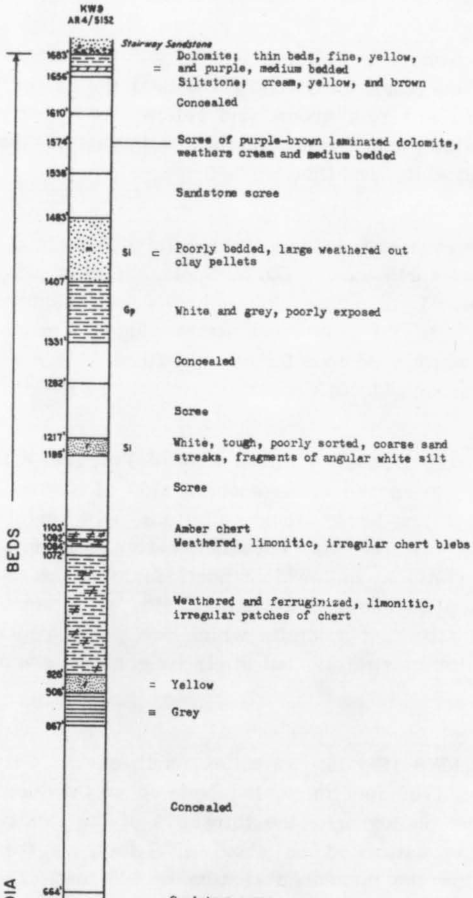

Fig. 5. Section KW9, Inindia Beds, 12 miles north-east of Curtin Springs homestead

TABLE 2

Sequence in the Inindia Beds

Thickness (feet)	Lithology	Remarks
Top of sequence		
1000	Sandstone, white, red-brown, and orange; laminated to thin-bedded, cross-bedded; coarse to medium-grained, poorly sorted, well rounded to poorly rounded, friable, kaolinitic, porous, with lenticles of quartz and chert granules	Forms inner strike ridge around Mount Conner
75	Tillite, yellow to off-white; non-bedded; coarse to fine-grained, poorly sorted to un-sorted, poorly rounded, tough, irregularly jointed, clayey, with erratics, some striated	Exposed directly below inner sandstone ridge around Mount Conner; in Erldunda Range; and 17 miles south of Mount Ebenezer
3000	Not exposed	
650	Sandstone, white, laminated, fine-grained platy, clean, silicified. Higher in section, thin-bedded, poorly rounded, kaolinitic. Near top of ridge, medium-grained, poorly sorted, clean, blocky, and friable	Forms outer partial strike ridge around Mount Conner
25	Siltstone, cream, yellow, and brown, with thin beds of yellow and purple fine-grained medium-bedded dolomite near top	At top of section KW9, (Fig. 5) and below sandstone ridge, 17 miles south of Mount Ebenezer
160	Not exposed	
75	Sandstone, medium-grained, poorly medium-bedded, with large clay pellets.	
75	Siltstone, white and grey, gypsiferous	
115	Not exposed	
20	Sandstone, white, fine-grained, poorly sorted, with coarse sand streaks and siltstone fragments	
90	Not exposed	
10	Chert, golden-brown	
180	Siltstone, weathered, limonitic, with irregular patches of chert	

TABLE 2 (Cont'd)

Thickness (feet)	Lithology	Remarks
20	Sandstone, yellow, fine-grained, medium-bedded	
40	Shale, grey, laminated	
225	Not exposed	
90	Sandstone, pale brown to white, medium-grained, with siliceous concretions	
50	Sandstone, pale brown, thin-bedded, medium-grained, platy in middle section; medium-bedded and kaolinitic near top	
70	Siltstone, yellow and white, thin-bedded, with a few beds of ferruginous sandstone, and fawn poorly sorted medium-grained sandstone	
310	Chert and sandstone, interbedded, and some siltstone. Mostly covered	Interpolated into section KW9
25	Sandstone, grey and purple-brown, in places manganiferous	In places contains many chert pebbles, angular or rounded
500	Siltstone, red-brown	Below base of section KW9

Base of sequence.

Winnall Beds (Ranford, Cook, & Wells, 1966)

Most of the prominent topographic features in the area, such as Mount Conner, the Erldunda (Fig. 6), Basedow, and Kernot (Fig. 7) Ranges, Mount Kingston, and the Black Hill Range, are composed of the Winnall Beds; they also occur in a ridge in the north-east corner of the Ayers Rock Sheet area, and in a small downfaulted block in the unnamed hills 17 miles south of Mount Ebenezer. They rest unconformably on the Inindia Beds, and unconformably below a variety of Palaeozoic rocks.

The sandstone units in the Winnall Beds are relatively resistant and form high strike ridges. The siltstone units are easily weathered and crop out on hill slopes beneath the sandstone ridges or as rubble on low rises.

Ranford, Cook, & Wells (1966) have subdivided the Winnall Beds into three units: upper and lower siltstone units, and a middle sandstone unit. Only the lower siltstone and middle sandstone crop out in the south-eastern part of the Amadeus Basin. A younger sand-

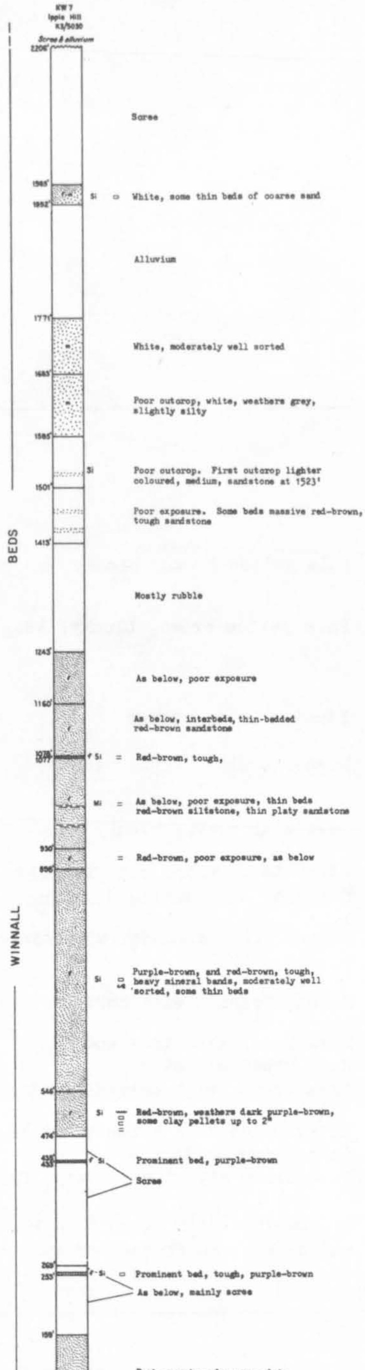

Fig. 6. Section KW7, Winnall Beds, Ippia Hill.

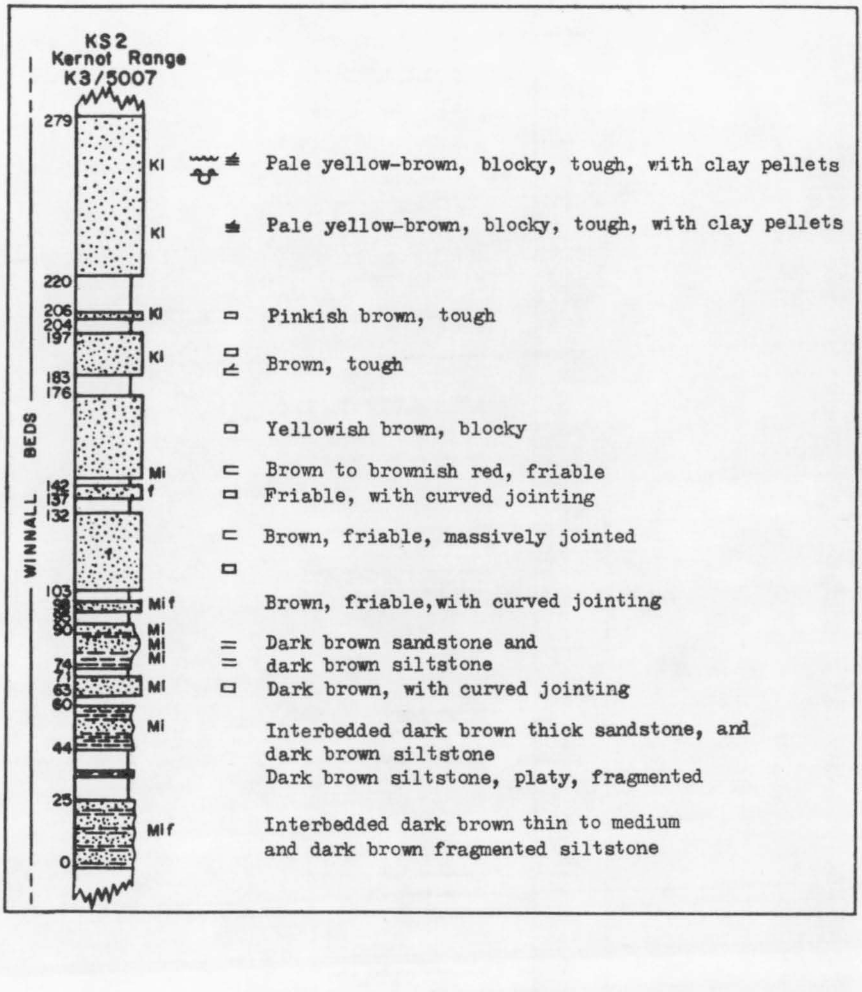

Fig. 7. Section KS2, Winnall Beds, Kernot Range.

stone unit has been mapped in the Liddle Hills in the south-western part of the Henbury Sheet area.

The lower siltstone unit is well exposed on the flanks of Mount Conner. It comprises dark purple-brown thin-bedded friable siltstone and fine silty sandstone followed by slightly calcareous dark purple-brown or black fine sandy siltstone which is poorly thin and medium-bedded and contains some clay and rock fragments.

The basal siltstone also occurs in a small downfaulted block between Inindia Beds 17 miles south of Mount Ebenezer. The sediments consist of thin-bedded dark brown silty sandstone which is in part calcareous, and interbedded dark brown silty thin-bedded sandstone and siltstone. Some fine white and yellow-brown tough sandstone is interbedded with the dark brown variety. The dark brown sandstone splits into rhomboidal joint blocks about 3 inches across.

The middle sandstone unit forms the prominent cliffs of Mount Conner. It is separated from the siltstone by 15 to 20 feet of conglomerate, which consists of rounded and subrounded pebbles of silicified sandstone and black and white chert set in a poorly sorted matrix of sand. The conglomerate occurs in beds 4 to 5 feet thick with interbeds of sandstone. The overlying sandstone is pink, silicified, poorly thick-bedded, and in places cross-bedded. It is medium-grained, and contains a few slump structures, and some subrounded pebbles and thin beds with weathered-out pellets. The sandstone capping Mount Conner is white, silicified, and poorly sorted. It contains some flat ellipsoidal clay pellets.

The sandstone unit is well exposed in the other large ranges, and can be subdivided into two parts. The lower part is a thick-bedded cross-bedded pink medium sandstone with convolute laminations, a few laminae of heavy minerals, and current lineations. The upper part consists of a thinner section of finer-grained thin-bedded to laminated white sandstone with abundant ripple marks and numerous bedding-plane markings.

In many places, particularly near the top of the sandstone, the bedding planes are covered with tabular casts of sand, which are usually flattened and gently tapering at either end (Pl. 1, fig. 1). The casts have irregular branches and one cast may cut across the path of another. A few show traces of a small meridional groove or depression. They range from 2 to 4 mm across and are gently curved or sinuous. There is a clear-cut boundary with the underlying sediment, and the casts do not appear to penetrate into the underlying bed. Similar markings occur in the Winnall Beds in the Lake Amadeus Sheet area and have been compared with synaeresis cracks, which are defined by White (1961) as fissures that develop in a suspension where waters are expelled from a clay-water system by internal forces; they resemble mud cracks in the sediments. Frarey & McClaren (1963) describe fossil relics, as internal casts with tubes, which occur on a ripple-marked surface of a fine arkose of Huronian age (Lower Proterozoic) from the Canadian Shield. Frarey & McClaren do not believe that they originated by desiccation because of the absence of clay or argillaceous material in the beds, the clear separation of cast and substratum, the flattened form with a longitudinal groove, the consistent dimensions of the rods, and the overlap of one cast by another without mutual deformation. The markings in the Winnall Beds are similar, and although they cannot be definitely identified as worm casts or feeding burrows they appear to be fossil remains rather than mud cracks.

The upper part of the lower sandstone unit contains many types of depositional structures, such as cut-and-fill structures, flow clasts, current lineation, ripple marks, and convolute lamination. In places the lower siltstone unit is absent and the middle sandstone unit rests unconformably on the Inindia Beds.

In the Black Hill Range the Winnall Beds form a line of strike ridges nearly 50 miles long, and the lithology changes considerably along the strike. In the west near Mount Kingston, the sandstone is light-coloured, medium to thin-bedded, with silt pellets and minor interbeds of siltstone, but at the eastern end of the Black Hill Range and at Horseshoe Bend, shale is predominant. The shale and interbedded siltstone are grey, grey-brown, purple-brown, and green, and contain some interbeds of fine dark sandstone. The sediments are over 1500 feet thick at this locality. All the beds contain abundant grains of bright green glauconite, which are arranged in thin laminae or rarely in small clots. Flow casts and clay pellets are abundant. The sediments in this area bear a close resemblance to the siltstone of the Pertatataka Formation.

On the basis of their stratigraphical position the Winnall Beds are correlated with the Pertatataka Formation and are probably Upper Proterozoic. The decrease in grain-size to the north and east suggests that the sediments were derived from the south and west, probably mainly from the southern parts of the Kulgera and Ayers Rock Sheet areas. The sedimentary structures in the Winnall Beds indicate rapid deposition and strong current action.

A thickness of over 2000 feet was measured at Ippia Hill (section KW7, Fig.6), mainly in the middle sandstone unit. The estimated thickness is only approximate because of the large variation in dip, particularly in the lower part of the unit where siltstone is interbedded with sandstone.

PALAEOZOIC (Table 3)

CAMBRIAN

Pertaoorrta Group

(Plates 7 and 8)

In the south-eastern part of the Amadeus Basin the lithology of the Pertaoorrta Group (Prichard & Quinlan, 1962, p.14) is considerably different from that farther north, and the main rock types present are conglomerate, coarse sandstone, greywacke, siltstone, and dolomite. The beds are unfossiliferous and the identification of the group is based on its stratigraphical position.

In the Kulgera Sheet area the Pertaoorrta Group rests on the Bitter Springs Formation, Inindia Beds, and Winnall Beds with an angular unconformity and is overlain with a regional unconformity by the Ordovician Stairway Sandstone. Although in several sections the Pertaoorrta Group and the overlying Larapinta Group have the same dip, it is apparent that they are separated by an erosional interval, and in most places there is a conglomerate at the base of the Stairway Sandstone.

The Pertaoorrta Group is poorly exposed in small mounds and hills north and east of Basedow Range, and in the Erldunda and Mount Sunday Ranges. One small outcrop of

TABLE 3. PALAEOZOIC STRATIGRAPHY

AGE		FORMATION & SYMBOL	THICKNESS (FEET)	CORRELATION	LITHOLOGY	REMARKS
PERMIAN		Crown Point Formation (Pc)	150-200		Poorly sorted sandstone, boulder beds, tillite, thick interbeds of siltstone and claystone. Striated and faceted inaties. Large slump structures.	Lower Permian Spores from several water bores (Evans, 1964). Artinskian spores in Malcoluns Bore, Hale River Sheet area, from similar sediments beneath Cretaceous rocks.
DEVONIAN-CARBONIFEROUS?	Finke Group	Idracowra Sandstone (Pzi)	500	Possibly equivalent wholly or in part to Pertnjara Formation	Fine and medium white kaolinitic sandstone, conglomeratic and cross-bedded near base.	
		Horseshoe Bend Shale (Pzh)	300		Red-brown and green biotitic calcareous and gypsiferous shale, and some interbeds of fine to medium sandstone.	
		Langra Formation (Pzn)	400-500		Fine and coarse yellow sandstone, beds of conglomerate with pebbles and cobbles of granitic and metamorphic rocks and large fragments of fossiliferous Stairway Sandstone. Interbeds of red-brown siltstone.	
		Polly Conglomerate (Pzo)	200		Pebbles, cobbles, and boulders mainly of granitic and metamorphic rocks and large fragments of Winnall Beds. Matrix of coarse poorly sorted sand.	
		Pertnjara Formation (Pzp)	700	?Finke Group	Fine and medium silty red-brown and fawn sandstone, overlying red-brown micaceous siltstone with minor sandstone.	Late Middle or Upper Devonian fossils (placoderm fish plates, cf. Bothriolepis or Remigolepsis, and spores) in northern flank of Mereenie Anticline, Mount Liebig Sheet area.
ORDOVICIAN-DEVONIAN		Mereenie Sandstone (Pzm)	340		White and red-brown medium kaolinitic sandstone interbedded with red and yellow gypsiferous siltstone near base.	Formation is noticeably coarser-grained in south-east of Henbury Sheet area.
ORDOVICIAN	Larapinta Group	Stokes Formation (Ot)	50-400+		Variegated siltstone and shale with halite pseudomorphs. Grey-green medium-bedded dolomite and sandy dolomite with abundant worm trails	Poorly preserved fossils chiefly pelecypods.
		Stairway Sandstone (Os)	150-350		White thin-bedded coarse medium and fine sandstone, minor conglomerate and siltstone. Thin lensing beds with phosphatic pellets. Base coarse sandstone.	Only upper part of formation deposited. Richly fossiliferous.
CAMBRIAN		Pertaoorrta Group (€p)	370		Silty sandstone, siltstone, boulder conglomerate, arkose, greywacke, and thin beds of fine grey dolomite.	Fragmentary brachiopods in dolomite in Henbury Sheet area.

pebble conglomerate, referred to the Pertaoorrta Group, is present in the north-eastern corner of the Ayers Rock Sheet area.

The outcrops of the Pertaoorrta Group, near Angas Downs homestead and as far east as the Erldunda Range, consist predominantly of conglomerate, quartz greywacke, silty sandstone, and some clayey siltstone. The sediments are mostly poorly sorted, and contain abundant rock fragments, and pellets and lenses of clay. Most of the pebbles, cobbles, and boulders in the conglomerate consist of silicified sandstone, and some of the boulders are 5 feet across. The phenoclasts are well rounded, poorly sorted, and enclosed in a matrix of extremely poorly sorted coarse kaolinitic purple-brown greywacke. The phenocrysts of silicified white and red-brown sandstone are derived from the Winnall Beds. Many chert fragments, similar to the chert in the Inindia Beds, are also present.

The greywacke is purple-brown, poorly sorted, coarse and medium, with small angular fragments of rock and minerals, an abundant matrix of silt and clay, and subrounded to rounded pebbles. Interbeds of friable red-brown and purple-brown siltstone are present in the sequence. In places the sandstone is thin-bedded, finely kaolinitic, purple-brown or white, silicified or friable, and with clay pellets. The sandstone is mostly moderately well to poorly sorted, medium to coarse-grained, with small cross-beds, and small angular fragments of clay and rock. In many of the outcrops visited the sandstone has a sharp contact with the overlying conglomerate.

The conglomerate, greywacke, sandstone, and siltstone are exposed in small outcrops extending from the north-eastern part of the Ayers Rock Sheet area to the Erldunda Range. In the Mount Sunday Range the sediments are predominantly variously coloured siltstone, with thin interbeds of grey and white fine-grained slightly calcitic dolomite. The siltstone shows some bedding-plane markings. The dolomite contains some secondary chert, and is mostly laminated to thin-bedded, but weathers medium-bedded. In the eastern part of the Mount Sunday Range a thin sequence of poorly sorted silty orange and brown sandstone, arkose, and pebble beds overlies the siltstone and interbedded dolomite sequence. The phenoclasts in the pebble conglomerate range up to 6 inches across and include granite, mica schist, pegmatite, quartzite, quartz, and some purplish dolomite. The arkose contains abundant angular pink feldspar and clear quartz grains (Pl. 7).

An incomplete section measured in the sandstone, siltstone, and dolomite at Mount Sunday gave a thickness of about 260 feet. A section measured in the conglomerate, sandstone, and siltstone in the Erldunda Range gave a thickness of 370 feet between the Bitter Springs Formation below and the Stairway Sandstone above.

The types of sediment and their lateral variations (Pl. 7) suggest that the area was close to the margin of the Cambrian sea, where the deposits consisted predominantly of coarse clastic sediments. The transition from shallow-water to deeper-water sediments probably corresponds to the change from coarse clastics in the Erldunda Range to dolomite and fine clastics in the Mount Sunday Range.

The Pertaoorrta Group is assigned to the Cambrian on the basis of its stratigraphical position. The beds are unfossiliferous and cannot be correlated directly with formations of the Pertaoorrta Group from neighbouring areas. Conglomerate is present at the base of the Cambrian sequence in the Henbury Sheet area, but there is no evidence to suggest that it is the same age as the conglomerate on the southern margin of the basin: the marginal conglomerate may represent a late transgressive stage and could be Upper

Cambrian. Similarly, the siltstone and dolomite in the Mount Sunday Range can be correlated lithologically with the basal part of the Jay Creek Limestone in the Henbury Sheet area, but they are not necessarily the same age.

ORDOVICIAN

Larapinta Group

The Larapinta Group has been defined by Prichard & Quinlan (1962) and consists of four formations which are, in ascending order, the Pacoota Sandstone, Horn Valley Formation, Stairway Greywacke, and Stokes Formation. The name Stairway Greywacke was revised to Stairway Sandstone by Wells, Forman, & Ranford (1965), and the Horn Valley Formation was revised to Horn Valley Siltstone by Ranford, Cook, & Wells (1966). Only the Stairway Sandstone and Stokes Formation are present in the south-eastern part of the Amadeus Basin (Pl. 8).

Stairway Sandstone

The Stairway Sandstone rests unconformably on the Bitter Springs Formation, Inindia Beds, and Winnall Beds, and lies disconformably on the Pertaoorrta Group. It is overlain conformably by the Stokes Formation or unconformably by Mesozoic sediments. The unconformity at the base of the sandstone is a well-defined feature which can be traced for several miles on the air-photographs.

The formation crops out between Curtin Springs homestead in the west and Mount Watt in the east. The most southerly outcrops are 17 miles south of Mount Ebenezer and to the south of Mount Kingston. The formation generally crops out as low strike ridges and small hills, but in the north-eastern part of the Kulgera Sheet area the Stairway Sandstone forms the high ridges and hills of the Mount Sunday Range.

The Stairway Sandstone comprises medium and fine white thin and medium-bedded sandstone; coarse cross-bedded orange, yellow, and white sandstone; and minor interbeds of kaolinitic fine sandstone, siltstone, and conglomerate. In parts of the formation pelletal phosphate occurs in lenticular beds, and large phosphate pellets occur in the basal conglomerate in the Mount Sunday Range.

At most localities, the lower part of the formation consists of yellow, orange, and white sandstone, and is coarse-grained; in places it is bimodal, poorly sorted and bedded, with large cross-beds and thin beds of coarse angular sand. Where the formation unconformably overlies Upper Proterozoic rocks there is a thin basal conglomerate, 2 to 3 feet thick, with angular fragments of the underlying beds. The fragments are mostly 3 to 4 inches across, with some up to 6 inches. They consist commonly of chert, silicified sandstone, and some siltstone. The matrix is a siliceous poorly sorted coarse sand. In many places the Stairway Sandstone, near the unconformity with Upper Proterozoic formations, is slickensided and veined with quartz. The disconformable contact with the Pertaoorrta Group is marked by a thin basal conglomerate, 1 to 2 feet thick. The conglomerate is composed mainly of angular white quartz and quartzite averaging half an inch across and a few fragments of pink feldspar and flakes of biotite set in a matrix of coarse angular sand. The conglomerate is well exposed in the Mount Sunday Range and in several places contains dark grey, and some smaller brown, phosphate pellets up to 3 inches across. The pellets are flattened ovoids or irregular in shape. Some of the beds in the basal sandstone contain abundant worm burrows (pipe-rock), and some bedding planes are covered with a multitude of invertebrate tracks including Cruziana (Pl. 1, fig. 2). Some of the vertical U-shaped burrows can be referred to Diplocraterion. A similar coarse basal part of the Stairway Sandstone on the south-east part of the Lake Amadeus Sheet area was doubtfully referred to the Pacoota Sandstone (Map, preliminary edition) but it is now apparent that the Pacoota Sandstone is absent in these sections and that the Stairway Sandstone rests unconformably on older Precambrian units. At many localities the basal few feet of the Stairway Sandstone have been silicified. The rock breaks with a conchoidal fractures and has been used by the aborigines for the manufacture of tools.

The medium and fine sandstone overlying the coarser basal sandstone is very fossiliferous, and also has abundant markings on the bedding planes including 'dingo paws' (Pl. 2, fig. 1) and Cruziana. The sandstone, which is silicified to varying degrees, contains interbeds of kaolinitic or ferruginous fine sandstone, coarse sandstone (in places phosphatic), and siltstone. Some thin beds with clay pellets are present in the sandstone. The marine fossils include pelecypods, brachiopods, nautiloids, and trilobites.

Pseudomorphs of fine sand after halite were found in a fine poorly thin-bedded silicified white sandstone 4 miles south-west of Mount Ebenezer. The sandstone contains abundant tracks and trails on the bedding planes.

At Mount Watt a small outlier of Stairway Sandstone, about 80 feet thick, overlies the Winnall Beds unconformably. The topmost beds consist of fossiliferous silicified tough sandstone, overlying friable white and orange-brown fine sandstone. The basal beds consist of coarse rounded sandstone, with a thin conglomerate containing subrounded to subangular pebbles of white quartz, up to about 2 inches across, at the unconformity. To the east of Mount Kingston the silicified and fractured beds of the Stairway Sandstone crop out in a small strike ridge in which the beds are overturned to the north.

The Stairway Sandstone is 350 feet thick in section KW1 in the Mount Sunday Range, and 220 feet thick in section KS1 in the Erldunda Range. Two sections were measured 12 miles north-east of Curtin Springs homestead. In section KW10, where there is a good upper contact with a sandy dolomite of the Stokes Formation, the Stairway Sandstone is 150 feet thick and at section KW8 the upper limit of the formation is poorly defined, but about 170 feet of sediments are exposed. Measured sections KW1, KW8, KW10, and KS1 are shown in Plate 8.

The abundant fossils in the Stairway Sandstone indicate an Ordovician age, but only the upper part of the formation was deposited in the south-eastern part of the Amadeus Basin. The fossil assemblage from Mount Watt is considered to be anomalous, and the earliest possible age of this fauna is early middle Ordovician (Joyce Gilbert-Tomlinson, BMR, pers. comm.).

The abundance of fossils and the presence of pseudomorphs after halite indicate deposition in a shallow-marine stable-shelf environment. The increased coarseness of the sediments and the presence of only the upper part of the formation indicate that the formation is a transgressive deposit which was probably derived from an Upper Proterozoic and Precambrian terrain to the south. Parts of the conglomerate at the base of the formation indicate that it was derived from a nearby granitic terrain.

Stokes Formation (Prichard & Quinlan, 1962, p.21)

The upper and lower boundaries of the Stokes Formation are not well exposed. Twelve miles north-east of Curtin Springs homestead there is a sharp contact between the sandy dolomite at the base of the Stokes Formation and the fine silicified sandstone of the Stairway Sandstone. In most areas the contact with the Mereenie Sandstone is apparently conformable and gradational. The top of the Stokes Formation has been arbitrarily placed at the base of the first prominent bed of sandstone, which generally forms a small scarp or ridge. It may be succeeded by thin beds of siltstone and then by the main body of sandstone of the Mereenie Sandstone.

The Stokes Formation is easily weathered and is usually covered by alluvium in small strike valleys. In places it is exposed on the slopes beneath the Mereenie Sandstone ridges, or rarely as rubbly outcrops in the alluvial flats. The thin dolomite beds in the Stokes Formation are more resistant and may form low strike ridges. Poor exposures are present in the northern part of the Kulgera Sheet area, north of Curtin Springs homestead, and in an outcrop 17 miles south of Mount Ebenezer.

The Stokes Formation consists of variegated thin-bedded and laminated siltstone, interbedded minor fine sandstone and calcareous sandstone, and thin beds of silty and sandy dolomite. The calcareous beds usually occur towards the base of the formation. Most outcrops of the siltstone contain pseudomorphs after halite.

Marine fossils, mainly pelecypods, were collected from a sandy dolomite at the base of the formation north-east of Curtin Springs homestead and from a green siltstone in the Mount Sunday Range.

In the most complete section measured (KW8, Pl. 8), 12 miles north-east of Curtin Springs homestead, the formation is 400 feet thick. The base of the formation is not exposed, and the total thickness may be 490 feet if the basal part of the section is the same as in the nearby section KW10 (Pl. 8). In section KW10 a thin bed of fossiliferous sandy dolomite marks the base of the formation. In the outcrop 17 miles south of Mount Ebenezer the sediments comprise interbedded pale blue-grey and pale red laminated siltstone, and thin and medium beds of pink and purple-brown silty dolomite. The dolomite contains abundant worm markings, but no other fossils were found. In this locality the Stairway Sandstone is overlain by a siltstone of the Stokes Formation, which contains abundant pseudomorphs after halite. The thin sequence of Stokes Formation in the Mount Sunday Range consists of variegated siltstone with interbeds of thin-bedded light grey silty dolomite, both of which contain halite pseudomorphs. Numerous small pelecypods are present in the dolomite. The chocolate-coloured poorly bedded hematitic siltstone at the top of the formation is conformably overlain by the Mereenie Sandstone.

The thickness of Stokes Formation in section KW1 (Pl. 8) is about 50 feet. In other exposures in the Mount Sunday Range the formation is much thinner and comprises a few thin beds of silty red brown and grey fine-grained medium-bedded sandstone, and some interbeds of siltstone.

The Stokes Formation is a shallow-marine deposit of Upper Ordovician age. The variation in thickness in different localities indicates that the southern limit of deposition probably lies just south of the Mount Sunday Range, but the formation probably extended much farther south in the central part of the Kulgera Sheet area.

ORDOVICIAN DEVONIAN

Mereenie Sandstone (Prichard & Quinlan, 1962, p.22)

The Mereenie Sandstone is well exposed in the north-eastern corner of the Ayers Rock Sheet area, and continues intermittently across the northern part of the Kulgera Sheet area as far as the Mount Sunday Range. The formation also crops out 17 miles south of Mount Ebenezer, but is probably not present in the Finke Sheet area. The Mereenie Sandstone generally crops out as strike ridges up to 50 feet high, but where the dip flattens steep escarpments up to 150 feet high are formed. On the north side of the Mount Sunday Range the steep strike ridges range up to 200 feet high.

The Mereenie Sandstone rests conformably on the Stokes Formation. The contact with the overlying Pertnjara Formation is not exposed, but they are unconformable in the Henbury Sheet area (Ranford, Cook, & Wells, 1966).

The lithology of the Mereenie Sandstone is generally uniform over the area. In the Ayers Rock Sheet area the basal beds consist of 20 to 30 feet of red-brown to purple-brown poorly bedded gypsiferous micaceous fragmented siltstone with a small proportion of poorly rounded quartz grains, and in places the rock grades into a sandy siltstone. In several places a 5 to 10-foot bed of sandstone occurs near the middle of the siltstone. The siltstone is succeeded by about 70 feet of white to cream or slightly greenish sandstone, which is medium-grained, laminated to thin-bedded, cross-bedded, poorly sorted, poorly rounded, porous, flaggy to blocky, friable, and kaolinitic. The white sandstone is overlain by about 100 feet of orange-brown to red-brown fine to medium-grained sandstone which is laminated and cross-laminated, moderately well sorted, poorly rounded, porous, moderately friable, platy to flaggy, ripple marked, slightly kaolinitic, and ferruginous. The lower part of the sandstone contains interbeds of dark brown slightly sandy gypsiferous and in places slightly micaceous siltstone. The total thickness of Mereenie Sandstone in the Ayers Rock Sheet area is estimated at around 200 feet.

In the Kulgera Sheet area the Mereenie Sandstone is thinner and rarely forms prominent scarps. The lithology is similar to that in the Ayers Rock Sheet area, and the sandstone is generally pinkish brown, cross-bedded, and kaolinitic, with some red-brown slightly micaceous sandy siltstone at the base. At the Mount Sunday Range about 340 feet of Mereenie Sandstone is well exposed along the northern side (section KW1, Pl. 8). The lithology is similar to that described above except that some of the sandstone interbeds are coarse-grained.

The 340 feet of Mereenie Sandstone measured in the Mount Sunday Range is the greatest thickness recorded. The formation cannot be subdivided into the two units found farther north (Ranford, Cook, & Wells, 1966), but almost certainly corresponds to the lower of the two units described by Ranford et al.

The origin and environment of deposition of the Mereenie Sandstone is not fully understood. The existence of probable pseudomorphs after halite in two localities (Ranford et al., 1966), the presence of worm tubes, the occurrence of Cruziana in the south-eastern corner of the Lake Amadeus Sheet area, the large-scale cross-bedding, the thinness of the unit compared to its development farther north, and the general (but not exclusively) conformable relationship with the underlying marine Stokes Formation, indicate that the Mereenie Sandstone was probably deposited in a shallow-marine environment at the edge of the basin, during an arid cycle. The lower part of the formation may consist of erosion products derived from an aeolian sand and laid down in tidal flats; and the upper part, which is not exposed in the area mapped, is possibly an aeolian sand.*

The age of the Mereenie Sandstone is thought to be Upper Ordovician, as it rests conformably on the Stokes Formation, and contains Cruziana and a few worm tubes.

DEVONIAN-CARBONIFEROUS

Pertnjara Formation (Prichard & Quinlan, 1962, p.24)

The Pertnjara Formation is not exposed in the Finke Sheet area, and few exposures are present in the Kulgera and Ayers Rock Sheet areas. Small patches of siltstone and sandstone are found on the northern side of the Erldunda Range, and a larger area of very poorly exposed siltstone occurs to the north-west of the Mount Sunday Range. A low strike ridge of sandstone crops out on the north side of the eastern end of the same range.

In the north-eastern corner of the Ayers Rock Sheet area, the flat-lying Tertiary limestone rests on very poorly exposed red-brown siltstone which is regarded as Pertnjara Formation. The exposures occur in the axial regions of synclines in the Mereenie Sandstone and Larapinta Group.

In the Kulgera Sheet area the relationship of the Pertnjara Formation to the underlying Mereenie Sandstone is uncertain. At the top of section KW1 the siltstone overlying the Mereenie Sandstone to the north of the Mount Sunday Range trends and dips parallel to the Mereenie Sandstone, but the exposure is too small to be of great significance. The small sandstone ridge on the north side of the Erldunda Range dips at 10° to the north-west in contrast to the steep northerly or overturned southerly dip of the Larapinta Group half a mile to the south. The Pertnjara Formation is unconformably overlain by flat-lying Mesozoic deposits in the Erldunda Range and at the western end of the Mount Sunday Range, but the contacts are obscured.

In the extreme south-eastern corner of the Henbury Sheet area, the nearby flat-lying red-brown sandstone of the Pertnjara Formation is interbedded with two intervals of white kaolinitic sandstone, each about 30 feet thick and about 30 feet apart. This white sandstone is very similar to some of the sandstones in the Finke Group. The red-brown biotite-bearing shale and siltstone of the Pertnjara Formation underlying the sandstone sequence are similar to the Horseshoe Bend Shale, and the Pertnjara Formation and the Finke Group probably interfinger.

The Pertnjara Formation can be subdivided into lower and upper units. The lower unit is exposed on the north side of the Mount Sunday Range, and consists of red-brown to pink and rarely green laminated to thin-bedded well-sorted biotite-bearing siltstone, with a few interbeds of thin-bedded micaceous sandstone. The thickness is estimated from the air-photographs to be about 650 feet. The siltstone beneath the Tertiary limestone in the Ayers Rock Sheet is red-brown to pinkish brown, well sorted and finely fragmented, and contains patches of biotite flakes on the bedding planes. The thickness is unknown.

The upper unit of the Pertnjara Formation consists of orange-brown to red-brown sandstone. It is medium to coarse-grained (though in a few places fine-grained), thin

* More recent work elsewhere in the Basin shows that this "lower unit" should be considered as the youngest formation in the Ordovician Larapinta Group. The name "Mereenie" will be restricted to the upper unit, which is separated by a regional unconformity.

to thick-bedded, cross-bedded, poorly sorted to moderately well sorted, poorly rounded to well rounded, porous, kaolinitic, and ferruginous. In places bands of clay pellets from 2 to 3 inches thick are present. The thickness is estimated at 50 to 60 feet.

In the northern part of the Amadeus Basin the Pertnjara Formation consists of a thick series of continental conglomerate and interbedded sandstone about 10,000 feet thick. Conglomerate is absent in the south, but isolated pebbles and cobbles are present near the top of the sandstone unit in the north-eastern part of the Henbury Sheet area (L.C. Ranford, BMR, pers. comm.).

No sections were measured, but the thickness of the Pertnjara Formation in the Kulgera and Ayers Rock Sheet areas is estimated at about 700 to 800 feet.

The Pertnjara Formation has some of the characteristics of the post-orogenic or molasse facies. The great thickness of conglomerate in the northern part of the Amadeus Basin, the change from conglomerate to sandstone and siltstone from north to south, and the marked thinning of the formation to the south indicate that the sediments were derived from the north. The presence of phenoclasts derived from the underlying formations, including the basement Arunta Complex (Prichard & Quinlan, 1962, p.24), the considerable thickness of the formation, and its unconformable relationship with the underlying units, suggest that the Pertnjara Formation was deposited during and after a particularly strong phase of the tectonism affecting the margin and northern part of the Amadeus Basin. However, the steep dips in the Pertnjara Formation on the northern side of the basin indicate that major movement took place after it was laid down.

A placoderm fish plate has recently been found by R.M. Hopkins of Magellan Petroleum in a sandstone bed in the lowest siltstone unit on the northern flank of the Mereenie anticline in the Mount Liebig Sheet area. The plate is probably referable to Bothriolepis or Remigolepis (Gilbert-Tomlinson, 1966) of late Middle or Upper Devonian age. More recently spores of Middle or Upper Devonian age have been found in the basal siltstone of the Pertnjara Formation from a water-bore sample obtained near the Mereenie anticline on the Lake Amadeus Sheet area (Hodgson, 1966). By inference the upper sandstone unit of the Pertnjara Formation may be Carboniferous.

On the basis of the similarity of the Pertnjara siltstone unit to the Horseshoe Bend Shale, and the intertonguing of the sandstones of the Pertnjara with sandstones similar to those in the Finke Group, the formation is correlated with the Finke Group in the Finke Sheet area.

Finke Group (new name)

The term 'Finke River sandstone formation or series' was used by Chewings (1914) for the beds extending from the Goyder River to near Idracowra homestead. He regarded the beds as Jurassic(?). The 'Finke River sandstone' as used by Chewings included the Mesozoic De Souza Sandstone (Sullivan & Öpik, 1951), the Permian Crown Point Formation, defined in this Report, and the Finke Group.

The Finke Group lies unconformably below the De Souza Sandstone and Crown Point Formation, and rests unconformably on Precambrian rocks and older Palaeozoic formations. The Group consists of four conformable formations; they are (in order of decreasing age) the Polly Conglomerate, Langra Formation, Horseshoe Bend Shale, and

Idracowra Sandstone. The distribution of the units in the type area at Horseshoe Bend is shown in Figure 10. The greatest exposed thickness of the Group is 1500 feet. The Finke Group intertongues at least in part with the Pertnjara Formation.

Polly Conglomerate (new name)

The Polly Conglomerate is here defined as the conglomerate with rounded pebbles, cobbles, and boulders of granite, metamorphic, and sedimentary rocks which rests unconformably on much older strata and which is overlain apparently conformably by the Langra Formation. The type section is KW6 at Polly Corner (Fig. 8).

The Polly Conglomerate is confined almost entirely to the Finke Sheet area. It crops out at Polly Corner, Horseshoe Bend, on both flanks of the Black Hill Range, and probably underlies the Langra Formation and Horseshoe Bend Shale just north of Lilla Creek. The granite pebble and cobble conglomerate to the north-west and west of Umbeara homestead extends into the Kulgera Sheet area, and has been tentatively mapped as Polly Conglomerate.

In the Umbeara area, where it overlies igneous rocks, the Polly Conglomerate is composed entirely of well-rounded pebbles, cobbles, and boulders of granite, gneiss, amphibolite, porphyry, and vein quartz. Away from the granite the proportion of quartz, quartzite, and metamorphic rocks increases and towards the Winnall Beds in the Black Hill Range angular fragments of siltstone and sandstone become more common (Pl. 2, fig. 2).

On the south side of the Black Hill Ranges, at locality CW17, the Polly Conglomerate is vertical where it has been faulted against the Winnall Beds. About 20 yards to the south, the Langra Formation dips at about 15^{o} to the south. The Polly Conglomerate contains phenoclasts, up to about 8 inches across, of pink granite, pegmatite, some quartz, and a few boulders of dolomite. The dolomite is pink to reddish and medium-grained, and is similar to the Bitter Springs Formation.

The Polly Conglomerate does not usually form prominent features, and crops out at the base of the scarp formed by the overlying sandstone of the Langra Formation. On the northern flank of the Black Hill Range, where the formation overlies the Winnall Beds, Rochow (1963) estimated that the maximum thickness of the Polly Conglomerate is about 200 feet. In section KW6 (Fig. 8) at Horseshoe Bend a thickness of about 80 feet was measured.

The Polly Conglomerate is probably a coarse facies developed locally at the base of the Finke Group, where the sediments were deposited next to or on hills of Precambrian rocks. In the Mount Charlotte No. 1 Bore just north of the Finke Sheet area, the Polly Conglomerate is represented by a shale facies below the Langra Formation.

Langra Formation (new name)

The Langra Formation is here defined as the sequence of fine to medium-grained coarsely cross-bedded sandstone with isolated pebbles and cobbles, and interbeds of conglomerate and siltstone (Pl. 3), overlain by red-brown siltstone and medium to fine-grained sandstone (Pl. 4, fig. 1). The formation conformably overlies the Polly Conglomerate and conformably underlies the Horseshoe Bend Shale (Pl. 5, fig. 2) between Polly Corner and Horseshoe Bend homestead in the Finke Sheet area. The type section, which is shown on page 31, is between Polly Corner and Horseshoe Bend homestead.

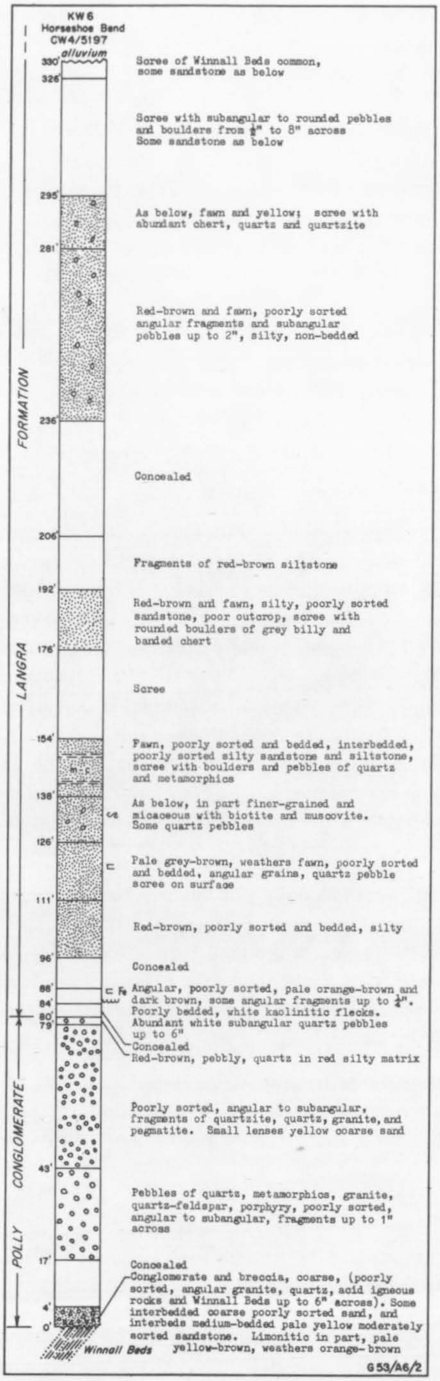

Fig. 8. Section KW6, Polly Conglomerate and Langra Formation, Horseshoe Bend

The Langra Formation is much more extensive than the Polly Conglomerate. In addition to the type area, it is found near Langra Well, in a few small outcrops north of the Black Hill Range, near Mount Watt, south-west of Mount Kingston, south of the type area to Cloughs bore, eastward to Mount Musgrave and Mount Squire, and around Mount Hakea and Point Eremophila; small scattered outcrops also occur between Mount Watt and Lilla Creek homestead. A few small outcrops have been identified tentatively as Langra Formation in the area between and near Outside and Corella Creeks. I.P. Youles (BMR, pers. comm.) has subsequently investigated part of this region and suggests that a large proportion of the outcrops and the sediments covered by alluvium north of the Newland Range are Crown Point Formation. At the time of the survey insufficient evidence was obtained to support this view, and the tentative identification as Langra Formation is retained in this Report. Information from bores indicates that the formation has an even wider distribution (Rochow, 1963). All the localities cited above are in the Finke Sheet area, but according to Rochow the formation extends westwards as far as the salt lakes in the Kulgera Sheet area, and finally lenses out on the Lower Palaeozoic rocks south of Maryvale.

The Langra Formation comprises sandstone, siltstone, and beds of conglomerate. The sandstone is yellow and white, poorly-sorted, with some rare clay pellets, friable, with some limonitic laminae, coarsely cross-bedded, medium and coarse-grained, with scattered pebbles mostly of granitic and metamorphic rocks. Interbeds of cobble conglomerate from 5 to 10 feet thick and thin interbeds of red-brown siltstone are also present. The sandstone shows slump structures and cut-and-fill structures with large eroded channels filled with conglomeratic sandstone (Pl. 3, fig. 2). Many of the sandstone outcrops are overlain by scree composed of rounded pebbles and cobbles of granite, porphyry, quartzite, white quartz, several varieties of metamorphic rocks, and large subangular pieces of fossiliferous Stairway Sandstone.

The penecontemporaneous brecciation of the red-brown siltstone (Pl. 4, fig. 2) is due to the rapid deposition of the overlying coarse cobble beds, and in places angular silt fragments have been incorporated in the sandstone above. The red-brown siltstone occurs both in the upper and lower part of the Langra Formation (Pl. 4, fig. 1; Pl. 5, fig. 1). It contains both biotite and muscovite, and is thin-bedded, laminated, and partly calcareous.

The thickness of the Langra Formation at Horseshoe Bend was estimated by Rochow (1965) to be 400 to 450 feet. Section KW6 (Fig. 8) is an incomplete section through about 250 feet of the formation exposed at Horseshoe Bend.

The type section at Horseshoe Bend, with approximate thicknesses, is:

Thickness (feet)	Lithology
	Shale and siltstone, red-brown, of the Horseshoe Bend Shale.
50	Sandstone, yellow and white; thin to medium-bedded, weathers thick-bedded; poorly sorted; subrounded quartz grains up to 2 mm; with conglomerate at top, and scree with white quartz pebbles. Large mica flakes in upper part. Few thin interbeds of red-brown siltstone and silty sandstone. Sandstone, cross-bedded; near base kaolinitic, few white clay and kaolin pellets; friable. Grades into siltstone below. A few pebbles.

Thickness (feet)	Lithology
50	Siltstone, red-brown; micaceous in part with muscovite and biotite; poorly thin-bedded to laminated. Some dark red limonitic parts.
175	Sandstone, yellow-grey and white; medium and coarse and very coarse; poorly sorted; cross-bedded, medium to thick-bedded; friable; interbeds of red-brown sandstone and siltstone, scattered pebbles, and pebble and boulder beds 5 to 10 feet thick with rounded and well rounded phenoclasts of granite, porphyry, and metamorphic rocks and large fragments (up to about 15 inches across) of Stairway Sandstone in scree from the conglomerate. Slump structures and cut-and-fill structures common.
225	Sandstone and interbeds of siltstone: Sandstone, yellow, red-brown, fawn; poorly sorted and bedded; angular grains; micaceous in part; few white subangular quartz pebbles; white kaolinitic flecks in places; friable; cross-bedded; thin pebble interbeds with phenoclasts of quartz; metamorphics, and banded chert. Siltstone, red-brown; thin-bedded; with some interbeds of fine sandstone from 5 to 10 feet thick.

Conglomerate, polymictic, of the Polly Conglomerate.

This section shows that the Langra Formation can be divided into three units, an upper sandstone (unit 3) and a lower sandstone (unit 1) separated by a red-brown siltstone (unit 2). The three units can be identified in bores and outcrops in several places away from the type section. The means of identification is based partly on the sequences penetrated in water-bores and the salinity of water in the sandstone units. The sandstone of unit 3 is almost indistinguishable from the Idracowra Sandstone and the red-brown micaceous shale of unit 2 is difficult to distinguish from the Horseshoe Bend Shale.

At Cloughs Bore the siltstone of the Langra Formation is about 175 feet thick and the underlying sandstone was penetrated in the bottom 25 feet of the bore. The water is very salty and is characteristic of the arenaceous beds in the Langra Formation.

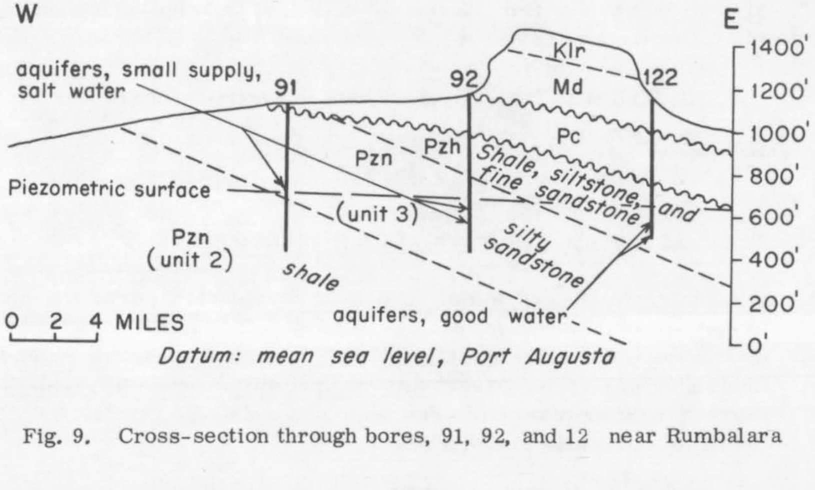

Fig. 9. Cross-section through bores, 91, 92, and 12 near Rumbalara

In the Mount Hakea/Point Eremophila Area, the sandstone identified as unit 3 is unconformably overlain by the De Souza Sandstone. The identification is based on the sequences penetrated in bores in the area. A cross-section is shown in Figure 9. Very salty water was obtained in the unit 3 sandstone, whereas the Horseshoe Bend Shale in the easternmost bore provided good-quality water. Bore 91 is about 5 miles west-south-west of Mount Hakea, and bore 122 is about 9 miles south of Mount De Souza.

The three units are much thinner in the type area at Horseshoe Bend than in sections penetrated in water bores outside this area: they have thinned over the Precambrian basement ridge of the Black Hill Range. Their relationship to other formations in the Finke Group and a cross-section of the structure in the type area at Horseshoe Bend are shown in Figure 10.

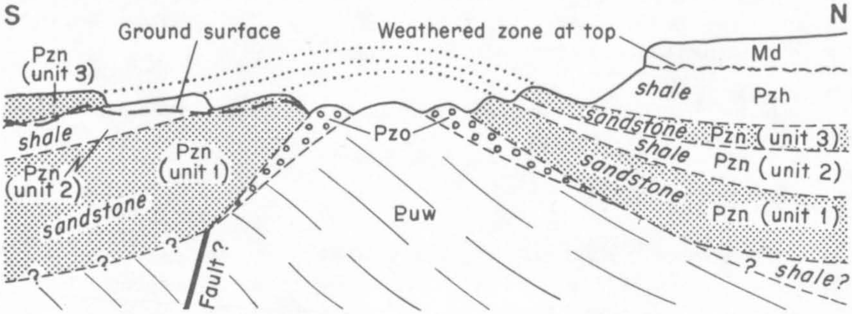

Fig. 10. Cross-section, Horseshoe Bend, Finke River. Puw: Winnall Beds; Pzo: Polly Conglomerate; Pzn: Langra Formation; Pzh: Horseshoe Bend Shale; Md: De Souza Sandstone.

Horseshoe Bend Shale (new name)

David & Howchin (1924) referred to the red shale and siltstone at Horseshoe Bend as the 'Horseshoe Bend Series' and 'Horseshoe Bend Beds', but were not certain of their stratigraphical position. The Horseshoe Bend Shale is here defined as the sequence of red and green biotite shale with thin interbeds of fine sandstone which rests apparently conformably on the Langra Formation. The formation is overlain apparently conformably, or with local disconformities, by the Idracowra Sandstone, and is unconformably overlain by the Crown Point Formation, the De Souza Sandstone, and Tertiary sediments. The shale is distributed widely over the central parts of the Finke and Kulgera Sheet areas. The type section of the Horseshoe Bend Shale is at Mount Engoordina, north of Horseshoe Bend homestead on the Finke River.

The lithology of the Horseshoe Bend Shale varies little over its area of outcrop. It is red and green in outcrop but grey in bores (Rochow, 1965). It is usually very biotitic and gypsiferous, and contains pseudomorphs after halite, ripple marks, mud cracks, and thin lenses of gypsum and calcite. The shale is uniformly fine, but small lenses and bands of fine sand are not uncommon. Just north of the north-western corner of Finke Sheet area the Horseshoe Bend Shale becomes progressively coarser and appears to grade into the medium-grained red siltstone of the Pertnjara Formation. Several water-bores, which intersect the Horseshoe Bend Shale beneath the Crown Point Formation east of Rumbalara Siding, also show a coarse-grained facies, and coarse siltstone and fine sandstone beds are common.

The Horseshoe Bend Shale rests apparently conformably on the Langra Formation (Pl. 5, fig. 2) with a sharp contact between sandstone and shale. The Horseshoe Bend Shale and the overlying Idracowra Sandstone are probably conformable, with local disconformities. In several places the top of the Finke Group was removed by erosion before the Permian, and the Crown Point Formation rests unconformably on the Horseshoe Bend Shale. In some areas the shale is unconformably overlain by the De Souza Sandstone. The greatest thickness of Horseshoe Bend Shale measured is about 300 feet at Horseshoe Bend on the Finke River and the thickness is about the same in a bore 20 miles to the west (Rochow, 1965).

In the Finke Sheet area the formation crops out in mesas or in low rolling hills capped with billy from near Impadna Dam eastwards to Horseshoe Bend homestead. To the south, the formation is found near Echidna Retreat, along Lilla Creek, and west-south-west to the Newland Ranges almost as far as Mount Falconer.

In the Kulgera Sheet area the Horseshoe Bend Shale is widely distributed, but it is generally concealed by travertine.

Idracowra Sandstone (new name)

The Idracowra Sandstone is here defined as the sequence of medium-grained kaolinitic quartz sandstone which crops out in the north-western part of the Finke Sheet area, where it overlies the Horseshoe Bend Shale apparently conformably or with local disconformities. The type section of the Idracowra Sandstone is 4 miles on a bearing of 155^{o} from the Idracowra homestead. The section is made up of about 180 feet of sediments and the sequence from top to bottom is:

Thickness (feet)	Lithology
10	Grey billy, pale yellow, mottled in places
70	Sandstone, white, medium-grained, kaolinitic, friable, poorly sorted, poorly medium to thick-bedded, white kaolin flecks, clay pellets in places
100	Sandstone, yellow and brown, weathers orange-brown, cross-bedded, poorly thick-bedded, poorly sorted, medium-grained, friable, silty, thin beds of brown ferruginous sandstone

In all outcrops the top of the formation is an erosion surface, and the silicified sandstone forms the capping on mesas.

The Idracowra Sandstone crops out in mesas from near the north-western corner of the Finke Sheet area as far east as Ryko Lookout, and near Horseshoe Bend. It is not exposed in the southern half of the Finke Sheet area and has probably been removed by erosion.

The unit consists of white and yellow thin-bedded, or in places massive, medium-grained to fine-grained kaolinitic quartz sandstone with pebbles of clay and rare pebbles of quartz and quartzite. In several sections a basal conglomerate was observed. In outcrop the sandstone is seldom more than 200 feet thick.

In the northernmost mesas between the Finke River and Nine Mile Creek, the sandstone rests apparently conformably on the Horseshoe Bend Shale. The top of the formation has been removed by erosion and the surface silicified. The section is as follows:

Thickness (feet)	Lithology
8	Grey billy with solution tubing and mottled staining in grey and brick red;
50	Idracowra Sandstone: white, with pinkish outer layer, near the top of the section, yellowish towards the base; kaolinitic towards the base, porous near the top; mostly medium-grained but somewhat variable in grainsize; laminated and poorly cross-bedded;
40	Horseshoe Bend Shale

At Mount Casuarina in the north-central part of the Sheet area over 250 feet of Idracowra Sandstone is exposed. It is harder than in the outcrops to the south and south-west, and cross-bedding is better developed. The contact with the underlying Horseshoe Bend Shale seems to be conformable. Near Mount Kingston, the upper 50 feet of the Idracowra Sandstone has a capping of billy 1 foot thick, and is very hard and laminated, and has a shattered appearance. The lithology of the lower 70 feet is similar to that in the type area, but contains pebbles of quartz and thin bands of red-brown fine micaceous sandstone and siltstone near the base.

Just north of the north-western corner of Finke Sheet area the Idracowra Sand-Stone appears to interfinger with the sandstone of the Pertnjara Formation.

The Mount Charlotte No. 1 well drilled for Transoil (N.T.) Pty Ltd in 1964-65 penetrated an almost complete section of the Finke Group. The well is situated just north of the northern margin of the Finke Sheet area at latitude 20° 52'03"S., longitude 133° 59'11"E. The general sequence in the well, and correlation with the Finke Group, are as follows:

Thickness (feet)	Lithology
0 - 60	Surface sand and sandstone - Idracowra Sandstone
60 - 523	Shale - Horseshoe Bend Shale,
523 - 630	Sandstone - Langra Formation, unit 3,
630 - 720	Shale - Langra Formation, Unit 2.
720 - 1050	Sandstone - Langra Formation, unit 1
1050 - 1160	Shale - equivalent of Polly Conglomerate(?)

PERMIAN

Crown Point Formation (new Name)

Tate (1897) recognized the glacial origin of the beds now known as the Crown Point Formation. David (1898) suggested that the beds were Permo-Carboniferous in age. Chewings (1914) included them in his 'Finke River Sandstone' (Jurassic), which comprised the present Finke Group, Crown Point Formation, and De Souza Sandstone. David & Howchin (1924) and Ward (1925) gave details of the 'Crown Point Series'; we have amended the name to 'Crown Point Formation', which refers to the sequence of sandstone, siltstone, tillite, and conglomerate. The formation rests unconformably on the Langra Formation or Horseshoe Bend Shale of the Finke Group and is overlain unconformably by the De Souza Sandstone. The type section at One Tree Point, near Crown Point, is as follows:

Thickness (feet)	Lithology
50	De Souza Sandstone
150	Sandstone, poorly sorted, with angular rock fragments in a matrix of white rock flour, and rounded pebbles of quartzite up to 6 inches across Sandstone, silty, medium-grained, with pebbles, at base.

The Crown Point Formation is found in the central, north-eastern, and south-western parts of the Finke Sheet area. The formation crops out to the north of Lilla Creek homestead, along the track to the Rumbalara ochre mine, and in the type area at Crown Point. It is also exposed between Mount Humphries, Echidna Retreat, and the Rumbalara Railway Siding between Echidna Retreat and Mount Squire, and at Mount Gordon North. It has been identified in water-bores near Mount Peterswald and east of Rumbalara Railway Siding. In bores the fresh siltstone and sandstone are pyritic, and the order of abundance of the sediments is sandy clay, siltstone, and sandstone.

At Colsons Pinnacle the upper part of the Crown Point Formation consists of about 100 feet of medium and fine-grained very kaolinitic sandstone which is predominantly white, but is stained yellow and pink near the top. The upper part of the sequence has been removed by erosion and the formation is unconformably overlain by the De Souza Sandstone. The sandstone is underlain by slumped tillite with pebbles and cobbles of quartz and quartzite.

In the mesas about 3 miles west-north-west of Rumbalara Railway Siding about 100 feet of tillite crops out. The tillite consists of well-sorted yellow-brown medium-grained sandstone with scattered pebbles, cobbles, and boulders.

Heaps of round boulders, mainly quartz and quartzite, were noted at Cunninghams Gap and near Echidna Retreat, but very few of the boulders are striated (Pl. 6, fig. 1).

The lower contact of the Crown Point Formation was observed at only a few points. Between Crown Point and Mount Humphries the glacial conglomerate rests unconformably on the Horseshoe Bend Shale and is indurated with lime derived from the underlying formation. At Mount Squire the Langra Formation dips gently to the south beneath the glacial conglomerate of the Crown Point Formation. The boundary between the pebble and cobble beds of the Crown Point Formation and the sandstone of unit 3 of the Langra Formation is well exposed 3 miles north-west and 4 miles north of the Rumbalara Siding.

At One Tree Point and in the Veros Hills the formation is overlain unconformably by the De Souza Sandstone. The contact between the two formations can also be seen north and south of the track to the Rumbalara ochre mine, and at Colsons Pinnacle.

Spores of Lower Permian age (Evans, 1964) have been found in samples of the formation from water-bores about 2 miles east of Mount Peterswald, about 10 miles east-south-east of Rumbalara Siding, and 14 miles east-south-east of the Rumbalara ochre mine. At Malcolms bore on Andado Station, about 40 miles east of the Rumbalara ochre mine, Artinskian spores were identified by Balme (in Sprigg et al., 1960) from a depth of 1350 feet in a sandy grey shale from the Crown Point Formation. According to Rochow (1963) the thickness of Permian sediments in the bore may be up to 1200 feet.

MESOZOIC (Table 4)

Outliers of thin flat-lying sediments comprising poorly bedded and poorly sorted siltstone and fine to coarse kaolinitic sandstone occur, mostly in the Kulgera Sheet area. In places they can be seen to rest unconformably on Palaeozoic or Precambrian rocks. They have been mapped as undifferentiated Mesozoic as they resemble the Mesozoic sediments in the Finke Sheet area, but they cannot be assigned to a particular formation.

JURASSIC(?)

De Souza Sandstone (Sullivan & Öpik, 1951)

The type locality of the De Souza Sandstone is at Mount De Souza, near the Yellow King or Rumbalara ochre mine in the Finke Sheet area. The Sandstone crops out over a wide area in the south-eastern part of the Northern Territory and probably extends across the border into South Australia. Quinlan (1962) showed its possible lateral extent, and Rochow (1965) mapped and described it in detail. Sprigg (1963) discussed the formation briefly and outlined its distribution.

The De Souza Sandstone is a friable white, reddish, or brown medium to coarse-grained steeply cross-bedded sandstone. At Colsons Pinnacle the generalized section is as follows:

Thickness (feet)	
15	Strongly silicified sandy shale with some grey billy near the top;
110	Rumbalara Shale: soft white, yellow, or purplish shale with rare fragmental pelecypods;
110	De Souza Sandstone: separated from the Rumbalara Shale by a strongly ferruginized layer 2 to 3 feet thick; strongly and steeply cross-bedded near the top and bottom but tends to be massive in the middle. Free of kaolin; coarse to medium-grained. Separated from the underlying strata by another iron-rich band.
130	Crown Point Formation

TABLE 4. MESOZOIC AND CAINOZOIC STRATIGRAPHY

AGE	FORMATION & SYMBOL	THICKNESS (FEET)	LITHOLOGY	REMARKS
QUATERNARY	Qa		Alluvial gravel, sand, clay and red earth plains	
	Qa		Aeolian sand	
	Qt		Salt lake evaporites	
	Ql		Travertine	
	Qg		Earthy gypsum	
TERTIARY	Tb		Grey 'billy'	
	Tc		Conglomerate and breccia	
	Tl		Lacustrine limestone, calcareous siltstone, siltstone and sandstone.	One outcrop of fossiliferous siltstone in Kulgera Sheet area.
LOWER CRETACEOUS	Rumbalara Shale Klr	900+	Shale, siltstone, and some porcellanite. Lenses of glauconitic sandstone.	Contains marine Aptian fossils. Base of formation is ochreous at Rumbalara
JURASSIC(?)	De Souza Sandstone Md	300+ (possibly 850+)	Sandstone and pebbly sandstone, medium to coarsely cross-bedded with bands and lenses of claystone and siltstone Some pipe-rock.	Contains poorly-preserved fossil plants. Fossil plants from similar sequence at Anna Mount in South Australia are Upper Jurassic/ Lower Cretaceous.
MESOZOIC (Undifferentiated)	M		Kaolinitic sandstone and siltstone.	

The lithology of the De Souza Sandstone outside the type area is extremely variable. It may be very rich in kaolin, or it may contain lenses and layers of siltstone, shale, and conglomerate. The conglomerate is composed predominantly of pebbles and cobbles of quartz and quartzite, particularly in the south-western part of the Finke Sheet area, where it wedges out on granite. The thickness of the De Souza Sandstone recorded in various bores ranged from 50 to 300 feet, and possibly 800 feet in the Charlotte Waters bore (Rochow, 1965).

The contact with the Rumbalara Shale in unconformable, though in places it appears to be conformable. The formation rests unconformably on the Crown Point Formation, Langra Formation, and Horseshoe Bend Shale. The only fossils are a few indeterminate plant remains; a similar sandstone at Mount Anna in the Peake and Denison Range, South Australia, contains well-preserved Upper Jurassic to Lower Cretaceous plants (Wopfner & Heath, 1963).

LOWER CRETACEOUS

Rumbalara Shale (Sullivan & Öpik, 1951, p.13)

The type sequence (Pl. 6, fig. 2) described by Sullivan & Öpik is as follows:

Thickness (feet)		
10	Siliceous laterite (Tertiary)	
14	Ferruginous sandstone	
76	Soft white kaolinitic rock with hard bands of porcellanite: most of the pelecypods came from this horizon	
8	Relatively hard sandy bed. Sponge horizon	
28	Soft white kaolinitic rock with hard bands of porcellanite. The fossils include radiolaria and fragmental pelecypods	
1.5-4	Yellow ochre, probably of bacterial origin	
1.5-4	Hard limonite with quartz bounders	
140+	Red and grey cross-bedded sandstone with some conglomerate	) De Souza) Sandstone

The boundary between Rumbalara Shale and De Souza Sandstone is unconformable. According to Rochow (1965) the Rumbalara Shale is 900 feet thick to the south of Charlotte Waters bore in the south-eastern part of the Finke Sheet area, but the thickness decreases towards the old shoreline in the west. Since the Rumbalara Shale is nowhere followed unconformably by another formation in outcrop, its original thickness is unknown.

In the Finke Sheet area the best outcrops of Rumbalara Shale are south-west of the Rumbalara ochre mine. The formation also crops out extensively in the southern and south-eastern parts of the Sheet area, but exposures are poor and in most places the outcrops are obscured by cobbles and boulders of grey billy. The Rumbalara Shale has been mapped in the eastern and north-eastern parts of the Kulgera Sheet area, but the exposures are small. The lithology of the Rumbalara Shale is remarkably persistent over large areas. Samples from water-bores show that the unweathered shale is grey and grey-green, and in part glauconitic. In places the shale contains scattered coarse to very coarse sand grains.

Several large outcrops of flat-lying fine-grained Rumbalara Shale, near the centre of the Hale River Sheet area, were visited by helicopter, and a few poorly preserved fossils were collected.

Öpik (in Sullivan & Öpik, 1951) identified 11 fossils from the Rumbalara Shale which indicate a Lower Cretaceous age. Later the formation was dated as Aptian and correlated with the Lower Wilgunya Formation of the Great Artesian Basin in Queensland (Skwarko, 1965). Terpstra & Evans (1963) reached the same conclusion from the study of the microfossils from Birthday bore 10 miles north of Andado (new homestead), about 45 miles east-south-east of the Rumbalara ochre mine.

TERTIARY (Table 4)

Grey billy, conglomerate, and limestone of Tertiary age are found in all three Sheet areas.

Grey billy occurs as a continuous layer of siliceous duricrust capping mesas and cuestas, or as a layer of rubble formed by the disintegration of the duricrust. It has been formed on the Finke Group and the Mesozoic sediments, particularly on the sandy siltstone or silty sandstone. The billy on the De Souza Sandstone ranges up to 12 feet thick, and at one locality the Idracowra Sandstone is capped by a layer of billy 20 feet thick.

The rock shows different shades of grey from place to place, and varies considerably in texture and grainsize. The billy found on the Idracowra Sandstone has a mottled brick-red and grey colour.

At one locality in the Kulgera Sheet area, a Tertiary limestone has been silicified, but the billy does not occur on the Quaternary sediments. The main period of silicification is believed to have been the Middle Tertiary.

Beds of gravel and poorly consolidated conglomerate are found around Mount Conner in the Ayers Rock Sheet area, around the Kernot and Erldunda Ranges in the Kulgera Sheet area, and around the Black Hill Range in the Finke Sheet area. They generally consist of angular to poorly rounded pebbles, cobbles, and boulders of sandstone from the Winnall Beds set in a dark brown matrix of silt or sand. No bedding is visible, but the deposits slope gently away from the ranges and on the plains are covered by alluvium or sand.

On the northern flanks of the Kernot and Basedow Ranges the conglomerate has been deeply dissected by erosion. The large circular gully around Mount Conner is bounded by scarps 70 to 100 feet high, and radial gullies have also cut through the conglomerate.

The Tertiary conglomerate is consolidated, but the scree and rubble at the top of the section may include some Quaternary deposits.

Some outcrops of silicified limestone (or chalcedony) were mapped in the central and eastern parts of the Kulgera Sheet area and north of the Black Hill Range in the Finke Sheet area. Some of the Tertiary sediments at locality K4 near the central part of the Kulgera Sheet area show concentrations of black manganese oxides and common opal. The silicified limestone is younger than the Rumbalara Shale and is probably Tertiary. One small outcrop of silicified limestone in the Kulgera Sheet area overlies a thin sequence of sandstone and siltstone with non-marine Tertiary gastropods. Oogonia of the alga Chara and poorly preserved ostracods, all of Tertiary age, were found in a sample from 95 feet in a shot hole (SP170) located 5 miles north of Erldunda homestead (A. Lloyd, BMR, pers. comm.).

QUATERNARY

The Quaternary sediments include alluvium, aeolian sand, evaporites, travertine, and gypsum.

Quaternary alluvium was laid down along the watercourses and on the flood plains bordering the rivers. Extensive sheets of alluvium occur in the plains and between the sand dunes. Large areas in the Kulgera Sheet area are covered by alluvium, but it is less widely distributed in the Finke Sheet area.

Aeolian sand has been formed into two main types of dunes (seifs and dendritic or braided dunes) in the Finke and Kulgera Sheet areas. The seifs are linear dunes several miles long, and have a parallel or subparallel alignment. They cover large areas in the eastern part of the Finke Sheet area on the western margin of the Simpson Desert, and have a northerly or north-north-westerly trend. In the east, the dunes are shorter and less regular in shape, and their orientation is less uniform. The south-western quarter of the Kulgera Sheet area is covered by dunes with a north-easterly trend. The dendritic or braided dunes are best developed in the northern part of the Kulgera Sheet area and in the Ayers Rock Sheet area.

Evaporites occur in a chain of salt lakes along the continuation of the Lake Amadeus depression. They stretch east-west across the northern part of the Kulgera Sheet area into the north-western part of the Finke Sheet area. Water is only present in the lakes after rain, and for most of the time the beds of the lakes are dry. They are covered by successive layers of gypsum and salt, intermixed with fine sediment brought in by surface run off during the brief periods of rain. Where the floors of lakes are clayey and hard, they have been mapped as claypans with alluvium.

Two types of Quaternary travertine can be distinguished - a yellow-brown sandy and layered hard limestone, which is by far the more common, and a soft bluish limestone which gives off a characteristic foetid odour when struck with a hammer. On the air-photographs the travertine can be readily distinguished by its hummocky surface relief, the low scarps around the outcrops, and the dendritic drainage pattern.

Extensive areas of travertine crop out in the central part of the Kulgera Sheet area, where its distribution is probably related to the salt lakes. Travertine is also found on outcrops of the Horseshoe Bend Shale. The travertine has been formed by the upward migration of lime, probably as a result of the seasonal fluctuation of the water-table following the heavy rain which falls every few years. Travertine occurs on the Horseshoe Bend Shale on the Finke Sheet area, and the conglomerate of the Crown Point Formation is cemented with travertine.

The travertine is younger than the silicification which occurred in the Tertiary. In many places it is difficult to distinguish the travertine from Tertiary limestone, especially where the silicified surface of the limestone has been stripped off by erosion.

Gypsum is present mainly in the Ayers Rock Sheet area. In the salt lakes near Curtin Springs homestead, it occurs in the silts beneath the thin crust of evaporites, and has been crystallized from groundwater draining into the lakes. The dissolved calcium sulphate has probably been derived from gypsiferous horizons in the Pertaoorrta Group, Stokes Formation, Mereenie Sandstone, and Pertnjara Formation, which crop out in the ranges to the north.

About 30 miles north-west of Curtin Springs homestead lumps and masses of white powdery gypsum are intimately associated with the sand dunes which fringe the numerous small salt lakes at the eastern end of Lake Amadeus. The gypsum has also probably been formed by the evaporation of groundwater.

Gypsum is rare on the margins of the salt lakes in the Kulgera Sheet area, and the lakes are generally surrounded by Tertiary and Quaternary limestone, which suggests that the groundwater contains calcium carbonate rather than calcium sulphate.

STRUCTURE

Gravity Survey

The area mapped was included in the regional reconnaissance gravity survey of the Amadeus Basin carried out by the Bureau of Mineral Resources in 1962 (Lonsdale & Flavelle, 1963). The regional Bouguer anomalies and gravity features are shown in Figure 11. The main features are the Angas Downs gravity ridge, the Ayers Rock gravity depression, the McDills gravity platform, and the Amadeus gravity depression.

The part of the Ayers Rock gravity depression that extends across the southern part of the Ayers Rock Sheet areas into the Kulgera Sheet area is known as the Musgrave gravity trough. The Amadeus gravity depression represents the thick pile of sediments in the Amadeus Basin (Langron, 1962a); it includes the thick sequence of sediments in the north-west corner of the Finke Sheet area.

The Angas Downs gravity ridge, which separates the Amadeus gravity depression from the Ayers Rock gravity depression, probably represents a ridge of Precambrian basement extending westwards to the Bloods Range gravity high. Upper Proterozoic sediments with a thin veneer of Palaeozoic sediments crop out along the Angas Downs gravity ridge. Positive culminations are associated with the Bitter Springs Formation in the Ayers Rock Sheet area and in the core of the Erldunda Range. The gentle gradient on the northern side of the ridge indicates a gradual thinning of the Amadeus Basin sediments towards the ridge. The geology of the area underlain by the Ayers Rock gravity depression is obscured by superficial deposits. The magnitude of the Musgrave gravity trough suggests a large thickness of sediments or a thickening of the acid-igneous rocks. A narrow north-westerly branch of the depression continues into the Petermann Range Sheet area, where it is underlain mainly by granitized sediments and granites; and similar rocks may underlie the Ayers Rock gravity depression. In the south-eastern corner of the Kulgera Sheet area and the south-western part of the Finke

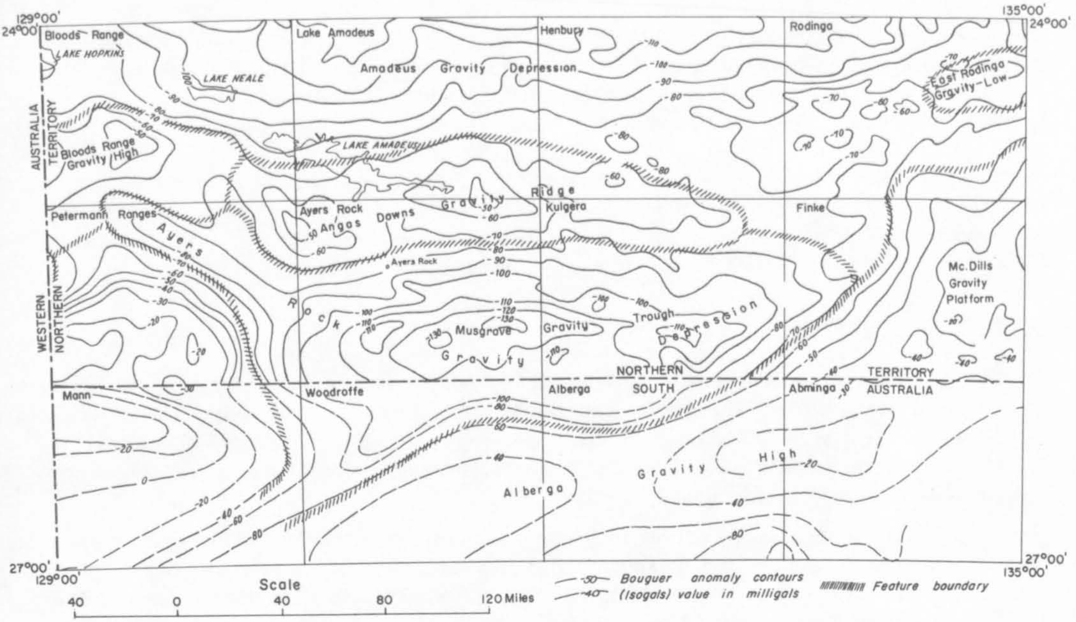

Fig. 11. Regional Bouguer anomalies and gravity features.

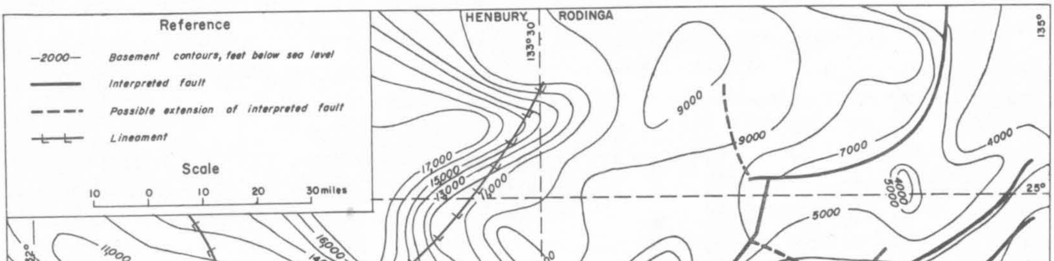

Fig. 12. Basement contours interpreted from aeromagnetic survey.

Sheet area the steep gravity gradients coincide with outcrops of granite, gneiss, and dolerite dykes. Similar rocks crop out on the southern margin of the Musgrave gravity trough, and the structures may be analogous to that on the northern side of the Amadeus Basin, where the basement rocks are infolded with and partly thrust over the sedimentary pile.

The McDills gravity platform on the Finke Sheet area is a shelf area with a moderate thickness of sediments of the Great Artesian Basin. A positive gravity lobe, trending south-south-west from the more positive gravity features of the McDills gravity platform to the east, coincides with Upper Proterozoic rocks of the Black Hill Range.

Aeromagnetic Survey

Part of the area was surveyed in 1963 by Aero Service Limited for Exoil (N.S.W.) Pty Ltd (Hartman, 1963). The survey covered the northern part of the Kulgera Sheet area, all the Finke Sheet area, and a small strip along the north-eastern margin of the Ayers Rock Sheet area. Interpretations of depths to magnetic basement were made, and contours and structural interpretations compiled (Fig. 12).

The aeromagnetic survey indicates that the sediment's greatest thickness occurs between the Mount Sunday and Basedow Ranges, where the depth to magnetic basement is estimated to be as much as 17,000 feet. A large embayment with magnetic basement below 13,000 feet extends from north of Mount Conner on the Ayers Rock Sheet area to Murrathurra well in the Kulgera Sheet area. In the eastern part of the Kulgera Sheet area the magnetic basement rises to the south until it is truncated by an interpreted fault, that trends east-north-east roughly parallel to the Finke River east-west fault about 15 miles north of Kulgera; the fault farther east roughly parallels the east-north-east course of the Finke River. Several smaller faults have been interpreted in the Finke Sheet area. The displacement at the western end of the main fault is estimated to be several thousand feet.

To the south of the main fault the estimated depths to basement are generally between 1000 and 3000 feet, except in the south-east corner of the Finke Sheet area, where the depth to basement increases to over 7000 feet near Charlotte Waters bore.

In the eastern part of the area the gravity values and aeromagnetic interpretation are in general agreement except in the area south of Mount Kingston. Here there is an area of low gravity values which corresponds to the eastern end of the Ayers Rock gravity depression. This depression is taken to indicate moderately thick sediments as shown in the cross-section on the Finke 1:250,000 geological sheet. The large fault interpreted in the Finke Sheet area corresponds closely to the trend of the gravity high over the Black Hill Range. The fault is roughly parallel to the trend of the Upper Proterozoic rocks in the Black Hill Range and may be related to the uplift of the Black Hill Range block. In the Kulgera Sheet area there is little correspondence between the aeromagnetic anomalies and the gravity gradients around the Angas Downs gravity ridge, and the rocks under the ridge may be comparatively dense but only weakly magnetic. The decrease in the depth to magnetic basement to the south, on the eastern side of the Kulgera Sheet area, is probably due to the presence of granitic and basic rocks near the surface.

Seismic Surveys

Four short seismic traverses were made by the Bureau of Mineral Resources in the Finke Sheet area. They are designated the Horseshoe Bend, Black Hills, Lilla Creek, and Lilla Creek South traverses (Moss, 1962).

The Horseshoe Bend seismic traverse crosses the large fault interpreted from the aeromagnetic data. The seismic reflectors to depths of 6000 feet are flat, and the poor reflections down to 15,000 feet show a strong north dip. The interpreted depths to magnetic basement are 4000 to 5000 feet on the south side of the fault. A velocity of 21,000 fps was recorded from a depth of 3500 feet and has been correlated by Moss (1962) with a similar refractor thought to be in the Cambrian Jay Creek Limestone at Mount Charlotte, north of the Finke Sheet area. The reflections in the Black Hill traverse are in an area where aeromagnetic basement was interpreted at 3000 to 4000 feet, which corresponds closely with the reflector depths. The reflectors down to about 4000 feet generally show a northerly dip, but at about 5000 feet are flat. There is no apparent satisfactory explanation of this abrupt change in dip. An apparent reflection of poor quality with a crest at about 4500 feet shown in cross-section (Langron, 1962b) is most probably associated with the uplifted block of Proterozoic Winnall Beds in the Black Hill Range area.

At Lilla Creek, refraction results indicated a refractor with a velocity of 18,900 fps at a depth of about 580 feet. This velocity is similar to that recorded for granite at Lilla Creek South (19,400 fps at a depth of 500 feet) and presumably indicates shallow basement in the area.

Part of a seismic reflection traverse carried out in 1964 by Geophysical Associates (1964a) for the Finke Oil Co. extends from Nine Mile Creek to near Mount Watt in the Finke Sheet area. A velocity analysis at Nine Mile Creek indicated four different horizons in the sedimentary section. The recorded velocities indicate changes in the sediments at about 1900 feet, 2800 feet, and 4700 feet, with basement at about 7400 feet. The seismic cross-section can be interpreted, using thickness of formations in outcrop as indicating 2000 feet of Upper Palaeozoic (Finke and Larapinta Groups), 900 feet of Cambrian (Pertaoorrta Group), and 4600 feet of Upper Proterozoic rocks (Winnall Beds, Inindia Beds, and Bitter Springs Formation). Just to the north of the Finke Sheet area the Mount Charlotte No. 1 well penetrated 1100 feet of Finke Beds, 350 feet of Stairway Sandstone, 1000 feet of Jay Creek Limestone, 600 feet of Chandler Limestone, and 1600 feet of Pertatataka Formation, and bottomed at 6943 feet in Bitter Springs Formation.

Several faults are interpreted in the section in a zone about 2 miles wide, 6 miles north of Mount Watt. The faults are confined to Upper Proterozoic rocks and the undisturbed section above the faulted zone indicates an unconformity between the Upper Proterozoic and younger sediments.

The interpreted basement profile rises uniformly and abruptly southwards from a point about 5 miles north of Mount Watt.

A seismic reflection survey was made near Erldunda homestead on the Kulgera Sheet area by Geophysical Associates (1964b) for Exoil (N.S.W.) Four intervals in the sedimentary rocks with different velocities have been traced throughout the area. The stratigraphic information available from outcrops in the Erldunda Range and Mount Sunday Range indicates that these intervals could be made up of 1500 to 2000 feet of Cambrian, Ordovician, and Upper Palaeozoic sediments, resting unconformably on 3000 to 7000 feet of Upper Proterozoic rocks (Winnall Beds(?) and Inindia Beds) underlain nonconformably by 1500 to 400 feet of other Upper Proterozoic rocks (Bitter Springs Formation?). Basement is interpreted at depths ranging from 8000 to 12000 feet. The cross-sections generally indicate a regional thickening of the sediments to the west.

Three major anticlines occur; from Erldunda homestead they lie 6 miles south, 3 miles east-north-east, and 8 miles east-north-east. The complex reflections in the lower part of the Upper Proterozoic section (Bitter Springs Formation?), the unconformity of this horizon with younger sediments, and the thinning of the younger sediments over the anticlines suggest structural growth possibly by salt intrusion from the Bitter Springs Formation. Four miles north of Erldunda homestead several vertical faults are interpreted in the section with only a small thickness of Upper Proterozoic rocks beneath the Palaeozoic sediments.

Another structural dome, possibly due to salt intrusion, is present about 18 miles north-east of Erldunda homestead towards the south-eastern end of the Mount Sunday Range.

Structural History

A structural interpretation of part of the area mapped is shown in Figure 13. The Upper Proterozoic and older rocks were deformed in the Upper Proterozoic or early Cambrian, mostly into chevron folds with sharp axial crests and troughs, or rarely into broad basin structures such as Mount Conner. This period of folding falls within the Petermann Ranges Orogeny of Forman (1966), which probably affected the whole of the southern margin of the Amadeus Basin. The intensity of folding in the Upper Proterozoic rocks gradually decreases to the north. The orogeny produced large recumbent folds in the Petermann Ranges, Bloods Range, and Ayers Rock Sheet areas (Forman, op.cit.), and the major structures in the south-eastern part of the Amadeus Basin.

After the orogeny, the Upper Proterozoic rocks were eroded and Palaeozoic sediments deposited unconformably on them. In places, in the northern part of the area mapped, the unconformity forms a prominent linear feature which can be traced for several miles. The striking linearity of the contact suggests that the Palaeozoic sediments have been deposited against the uplifted blocks caused by major faults in the Upper Proterozoic succession.

The Palaeozoic rocks were folded during the Alice Springs Orogeny. The Alice Springs Orogeny was centred along the northern margin of the basin and its effects were similar to those produced by the Petermann Ranges Orogeny. Recumbent folds and nappes were formed and the basement rocks are possibly folded over part of the Amadeus Basin succession (Langron, 1962a). The axes of the broad folds in the south-eastern part of the Amadeus Basin trend east west, roughly parallel to the folds in the Proterozoic rocks. There are some minor cross-folds, particularly in the north-eastern corner of the Ayers Rocks Sheet Area, where the sediments are locally overturned. Some of the dips in the Palaeozoic sediments were probably initial depositional dips, particularly near the higher ranges of Upper Proterozoic rocks. The contact of the Upper Proterozoic rocks with the Ordovician Larapinta Group sediments is very irregular and in several places the Stairway Sandstone is infolded on a small scale with the Inindia Beds.

The Pertnjara Formation is a synorogenic deposit which had its greatest development next to the uplifted Alice Springs orogenic zone along the northern margin of the basin. To the south of the orogenic zone in the south-eastern part of the Amadeus basin, only a thin sequence of finer-grained sediments were deposited.

Faulting during the Upper Palaeozoic Alice Springs Orogeny was probably responsible for the uplift of the Black Hill Range block. The major fault inferred from the aeromagnetic survey is roughly parallel to the uplifted block, and the depths to magnetic base-

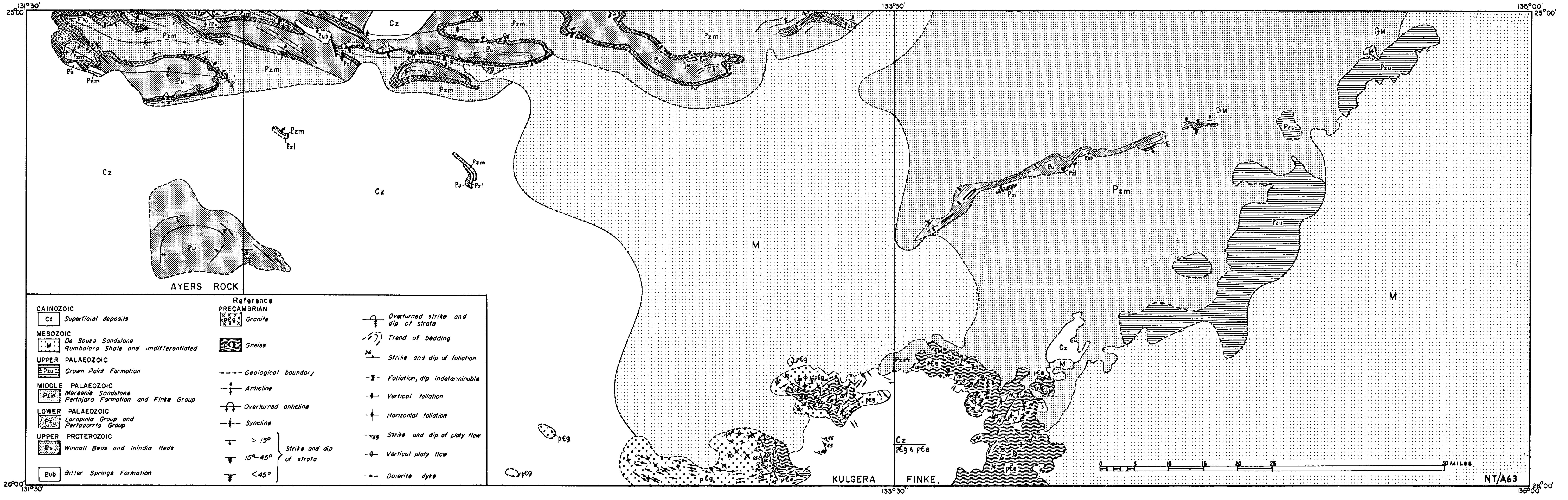

Fig. 13. Structural Interpretation

ment suggests that the block to the south of the range has been upthrown several thousand feet. In places, the dip of the Finke Group sediments adjacent to the uplifted block is vertical.

The Permian and Mesozoic rocks of the Great Artesian Basin have been subject to only minor tilting and faulting.

GEOLOGICAL HISTORY

The sequence of geological events in the south-eastern part of the Amadeus Basin may be summarized as follows:

1. The inferred deposition of a thick sequence of Precambrian sediments in an east-west depression in the southern part of the area on an unknown basement. The gneissic and granitic rocks of the Kulgera and Finke Sheet areas may be an integral part of the basement.

2. The deposition of the marine dolomite of the Bitter Springs Formation on a stable epicontinental shelf, after an unknown interval.

3. Deposition of thick water laid and in part glacial sandstone, siltstone, chert, and tillitic siltstone (the Inindia Beds) disconformably on the Bitter Springs Formation. Some exposed areas of Bitter Springs Formation were probably eroded at this time, perhaps as a consequence of local upwarps.

4. Slight tilting and folding of the Inindia Beds.

5. Uplift of the Precambrian sediments.

6. Deposition of a thick sequence of sandstone and siltstone (the Winnall Beds) derived from Precambrian rocks to the south.

7. Major folding and uplift of the Upper Proterozoic and older rocks followed by a long period of erosion. The possible thrusting of the basement over the earlier Precambrian rocks was probably initiated during this orogenic episode. A dècollement may have developed at the top of the Bitter Springs Formation during this orogeny.

8. Erosion of the recently uplifted Cambrian land-surface and deposition of coarse clastics (the Pertaoorrta Group) along the shoreline in the northern part of the area. Some carbonates were deposited on the seaward side of the shoreline.

9. Period of erosion.

10. Marine transgression in the Upper Ordovician and deposition of the Stairway Sandstone and Stokes Formation (part of the Larapinta Group) disconformably on the Pertaoorrta Group in a shallow-water stable-shelf environment. The sea transgressed the Cambrian shoreline and the Ordovician sediments were deposited unconformably on the Upper Proterozoic sediments. Some of the resistant Upper Proterozoic rocks probably formed islands or peninsulas in the Ordovician sea.

11. Deposition of the Mereenie Sandstone in a shallow sea. In the Kernot Range area the formation transgressed the Larapinta Group to rest unconformably on the Upper Proterozoic rocks.

12. Slight tilting of the Lower Palaeozoic sediments before the deposition of the Pertnjara Formation in a shallow marine and transitional environment. Only the finer-grained facies was deposited on the tectonically stable southern side of the basin. Initial minor folding of the Amadeus Basin sediments was probably partly contemporaneous with the deposition of the Pertnjara Formation.

13. Completion of folding after the deposition of the Pertnjara Formation. Locally the Palaeozoic sediments were overturned to the south. The incompetent folding in the Bitter Springs Formation and the possible décollement at the top of the formation may have been further accentuated during this period.

14. Deposition of the Finke Group mainly contemporaneously with the Pertnjara Formation. The sediments transgressed on to the basement in the south-western part of the Finke Sheet area. Local basal conglomerates were developed where the Finke Group sediments were deposited next to and on Precambrian highs in the Black Hill Range and Umbeara areas.

15. Uplift of the Black Hill Range block and tilting and faulting of the Finke Group sediments near the range.

16. Period of erosion and removal of a large part of the Finke Group before the deposition of the Crown Point Formation during a period of continental glaciation in the Permian.

17. Further erosion followed by deposition of the Mesozoic rocks. The De Souza Sandstone was deposited in a marginal facies, possibly deltaic with some of the material derived from the Crown Point Formation. This was followed by a marine incursion during which the Rumbalara Shale was deposited. The Mesozoic rocks overlapped the Finke Group and Crown Point Formation and transgressed to the west where they were deposited unconformably on the Amadeus Basin succession.

18. Deposition of Tertiary limestone, siltstone, and sandstone, probably in freshwater lakes, and deposition of conglomerate on the flanks of the ranges.

19. Period of deep weathering and formation of billy on the kaolinitic sediments of the Finke Group and Mesozoic rocks. Silicification of the Amadeus Basin sediments.

20. Initiation of the present cycle of erosion with the deposition of evaporites and gypsiferous silt in the salt lakes, and the formation of travertine. Dunes were formed in an arid period, and in the period which followed, were fixed by sparse vegetation, and alluvium was deposited.

ECONOMIC GEOLOGY

Petroleum Prospects

The only likely source rocks for petroleum are the Cambrian and Ordovician sediments and possibly the Upper Proterozoic Bitter Springs Formation. Potential cap-rocks and reservoirs are also present. In the Finke Sheet area the older Palaeozoic source rocks may be concealed beneath the Upper Palaeozoic and Mesozoic.

In the Ayers Rock, Kulgera, and Finke Sheet areas the marine Ordovician rocks include only the Stokes Formation and the upper part of the Stairway Sandstone. The sediments are thin and there are no known closed structures. The Cambrian sequence consists of thin deposits of coarse continental conglomerate, silty sandstone, and siltstone, and some thin beds of marine dolomite and siltstone. The sandy facies of the Cambrian Pertaoorrta Group could serve as a reservoir for petroleum migrating up dip from possible concealed thick sections of marine sediments. The Upper Proterozoic Bitter Springs Formation is present over large parts of the area, but its potential is unknown. The Erldunda seismic survey has delineated several anticlines that would be suitable drilling sites to test this formation.

The flat-lying Mesozoic and Palaeozoic rocks crop out over a large part of the Finke Sheet area. The succession includes about 3000 feet of sandstone, conglomerate, and siltstone deposited in a transitional environment, with Mesozoic marine shale above. The Finke Group, Permian, and Mesozoic rocks include suitable reservoirs and cap-rocks for petroleum migrating from concealed Lower Palaeozoic source beds. Concealed marine Permian sediments may also be present.

The anticlines exposed in the northern part of the Kulgera Sheet area and the north-eastern part of the Ayers Rock Sheet area are breached into the Upper Proterozoic rocks, except in the Mount Sunday Range, where thin sequences of Cambrian dolomite, siltstone, and sandstone are exposed in the core of the anticline. A small reversal of plunge on the axis of the anticline produces a small area of closure at the western end, but there is apparently no surface closure to the east.

The geophysical surveys of the south-eastern Amadeus Basin have indicated areas where thick accumulations of sediments may be preserved. The large gravity depression in the southern part of the Kulgera Sheet area is probably due to the presence of thick Upper Proterozoic and older Precambrian rocks which are covered by a thin veneer of Mesozoic and Palaeozoic sediments.

In the northern part of the Kulgera Sheet area and the north-eastern part of the Ayers Rock sheet area the aeromagnetic survey indicates a depth to magnetic basement of over 10,000 feet, with depths possibly up to 17,000 feet in places. The outcrops of Palaeozoic rocks account for only a fraction of this inferred thickness and the bulk of the succession probably consists of Precambrian sediments. The thickness of the Winnall Beds, Inindia Beds, and Bitter Springs Formation could easily account for this thickness of sediments, and the petroleum prospects depend on the potential of the Bitter Springs Formation.

The areas of possible thick sediments north of the Black Hill Range and in the south-eastern corner of the Finke Sheet area may warrant further investigation. To the north of the Black Hill Range the geophysical surveys indicate a thickness of sediments possibly exceeding 10,000 feet. The area is covered by flat-lying sediments of the Finke Group. The Upper Proterozoic Winnall Beds dip to the north and may form a broad synclinal structure, but the age and thickness of the overlying Lower Palaeozoic sediments, if present, are not known. Ordovician sediments were deposited as far south as Mount Watt, where a thin remnant of the Stairway Sandstone overlies the Winnall Beds. Thick Ordovician and possible Cambrian sediments could be preserved below the veneer of the Finke Group sediments to the north.

In the south-eastern corner of the Finke Sheet area there are outcrops of flat-lying Cretaceous and Mesozoic rocks and the aeromagnetic survey indicates that the depth to magnetic basement is about 7000 feet. The nature of the sediments below the Mesozoic rocks and underlying possible Permian and Finke Group sediments is unknown, but they could consist of older Palaeozoic sediments or perhaps a thick marine facies of the Permian. The Great Artesian Basin farther east may contain thick marine sediments, but only the marginal deltaic and fluviatile facies are exposed in the Finke Sheet area.

Phosphate Deposits

Pelletal phosphatic beds have been found in the Larapinta Group in many parts of the Amadeus Basin, including the area under discussion. The richest beds occur in the Stairway Sandstone, which crops out in many places, and pelletal phosphate beds were found 12 miles north-east of Curtin Springs homestead, and at several localities in the Mount Sunday Range. The phosphate pellets are usually present in coarse poorly sorted sandstone, but in the Mount Sunday Range large pellets are also present in a conglomerate 2 to 3 feet thick at the base of the Stairway Sandstone.

In the Stairway Sandstone, 12 miles north-east of Curtin Springs homestead, the phosphate occurs as grey pellets up to 1 inch across in a coarse bed of sandstone. The pellets occur in lenses and can only be traced laterally for a short distance. The phosphatic bed lies 135 feet above the base of the formation, which has a total thickness of 152 feet. A bed rich in phosphatic brachiopods and some white phosphatic pellets occurs 90 feet above the base of the formation.

In the Mount Sunday Range the phosphate occurs similarly as grey and brown pellets in lenses up to 1 foot thick in a coarse sandstone. The phosphate bed is about 230 feet above the base of the formation, which is 350 feet thick in section KW1 at the eastern end of the range. No phosphate was recorded in the measured section, although the coarse sandstone in which the phosphate pellets occur can be identified. In addition, large grey phosphate pellets of flattened ovoid or irregular form and up to 4 inches across occur in the poorly sorted subangular conglomerate at the base of the Stairway Sandstone in the Mount Sunday Range. The pellets were found in the basal conglomerate only at the western end of the range. This is the only recorded occurrence of phosphate in the basal conglomerate of the Stairway Sandstone, and pellets are amongst the largest found in the Amadeus Basin.

Analyses of samples of the Stairway Sandstone for phosphate gave the following results:

Sample No.	Locality	P_2O_5 (percent)
K28A	Mount Sunday Range	4.9 (equiv. 11.6 percent apatite)
K28B	"	4.6
K28C	"	4.4
K20A	"	0.8
K22	"	0.5
AR750	N.E. Ayers Rock Sheet area	0.5

The origin of the phosphate deposits is discussed by Ranford, Cook, & Wells (1966) and Barrie (1965).

Water Supply

Underground Water. In the north-eastern part of the Ayers Rock Sheet area and the northern part of the Kulgera Sheet area the best aquifer is the clean porous sand of the Mereenie Sandstone, and most of the bores in this formation yield good supplies of potable water. Good supplies are also obtained from sand in the Winnall Beds. Some of the sandstone beds in the Stairway Sandstone and Inindia Beds may also be good aquifers, but they have not been tested.

Several bores have been sunk along the chain of salt lakes extending across the south-eastern part of the Amadeus Basin, but many of the bores are extremely saline and unsuitable even for cattle. Many of the bores were sunk in the Horseshoe Bend Shale or in sands interbedded with the alluvium near the salt lakes. In the Kulgera Sheet area good-quality water has been obtained from several shallow bores in alluvial deposits and beds of travertine some distance from the salt lakes.

Rochow (1965) has appraised the groundwater potential in the Finke Sheet area. The main aquifers are the De Souza Sandstone and the Langra and Crown Point Formations. Rochow has divided the area into five zones as shown in Figure 14. The main features of these zones are as follows:

Zone 1. The aquifer is the De Souza Sandstone and the piezometric surface is 470 feet above the sea level. Groundwater occurs a few feet below the base of the Rumbalara Shale.

Zone 2. The aquifers are the De Souza Sandstone and the Crown Point Formation; the two formations probably form a single large aquifer. The piezometric surface is about 470 to 500 above sea level, and the salinity of the water rarely exceeds 1000 ppm. The depth at which water is struck is about 500 feet below surface.

Zone 3. The aquifer is the Langra Formation, mainly the sandstone in the upper part of the formation. The piezometric surface is 700 to 800 feet above sea level and the depth at which water is struck is variable.

Zone 4. The Langra Sandstone is the main aquifer, but the water is highly saline. The only likely freshwater areas are those with local recharge. Some successful bores have been sunk on or near hills and rises. The aquifers in the Upper Proterozoic rocks are saline. The depth at which water is struck is variable.

Zone 5. Local aquifers are present in granite, sediments of the Finke Group, and alluvium along the large watercourses. The piezometric surface is usually shallow, from about 50 to 30 feet.

The Rumbalara Shale yields salty water from local aquifers. No extensive aquifers are present in the Horseshoe Bend Shale and bores in this formation yield salt water. Salt water is known in the Finke River in areas outside the outcrop of the Langra Formation, so there may be a combination of recharge into and outflow from outcrops of the Langra Formation, depending on the position of the piezometric surface. The Polly Conglomerate probably also contains salt water unless there is sufficient recharge, but no water-bores have penetrated this formation.

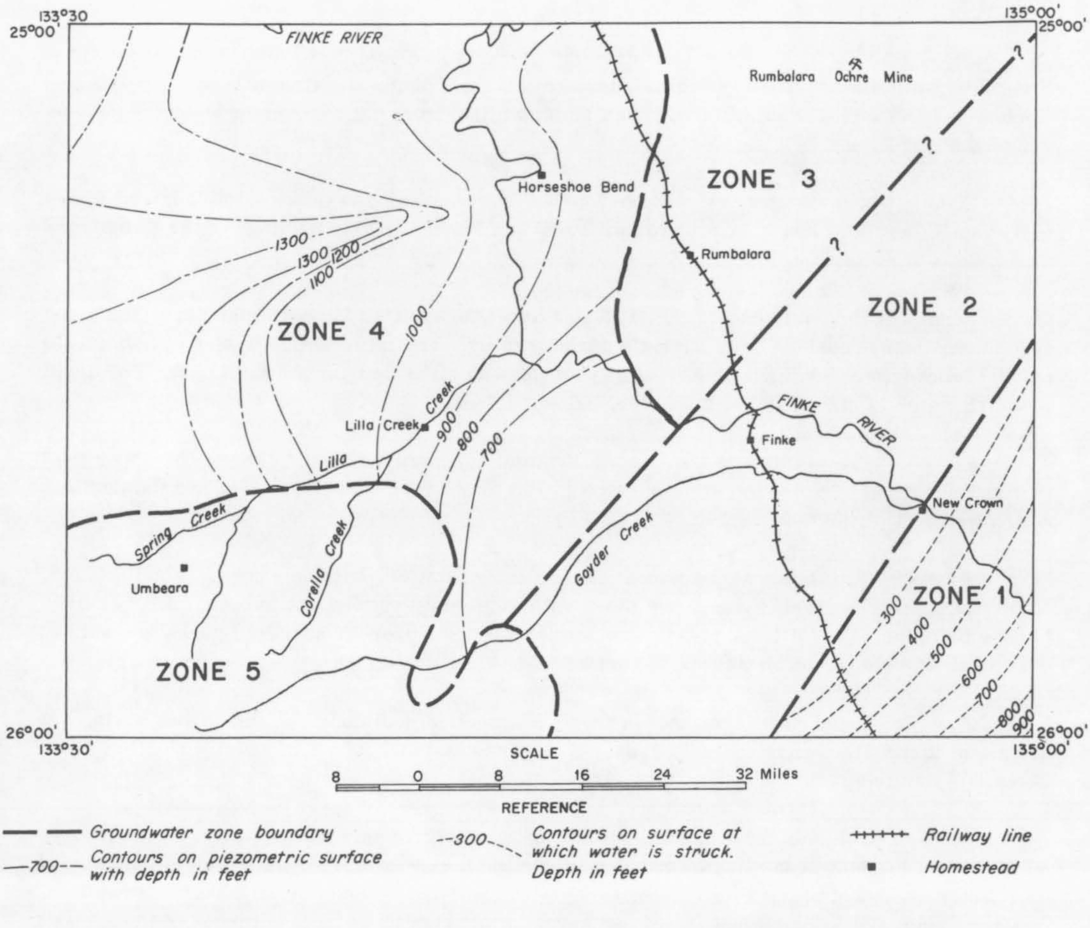

Fig. 14. Groundwater zones in the Finke Sheet area (after Rochow, 1965).

Woolley (1964) gives a regional appraisal of the water resources in the south-eastern part of the Northern Territory. He states that the aquifers occur in Upper Palaeozoic, Permian, and Mesozoic rocks. The average depth of bores is about 550 feet and the piezometric surface about 300 feet. The aquifers in the Finke Group, particularly the lower sandstone unit, have water with a salinity ranging up to 130,000 ppm, whilst the Permian rocks yield groundwater with a salinity generally less than 3000 ppm. The De Souza Sandstone always yields good water and is utilized in the south-eastern part of the Finke Sheet area. The Rumbalara Shale yields water unfit for the use of stock.

Surface Water. Natural surface waters include pools in the larger watercourses, small springs, and a few rockholes.

The salt water obtained from the alluvium in the Finke River and in waterholes in the stream bed is generally derived from the outflow of groundwater from the Langra Formation. In a creek cutting through the Black Hill Range west of Horseshoe Bend homestead a salt spring issues from the Langra Formation. A sample of the salts from the stream bed was found to contain:

		Percent
Chloride	-	30.1
Sulphate	-	13.7
Nitrate	-	Nil
Sodium	-	19.5
Potassium	-	0.40
Calcium	-	0.75
Magnesium	-	0.90
Water insolubles	-	18.9
Carbon dioxide	-	0.04

Analyst: I. Francis, A.M.D.L.

Rockholes with fresh water occur in the Polly Conglomerate at Horseshoe Bend, and several rockholes are present in the granitic rocks in the southern and south-eastern part of the Kulgera Sheet area. Springs are known in the same parts of the Kulgera sheet area, and there are also a few in the area of the salt-lake chain in the central part of the Sheet area. Several wells and bores have been sunk near the springs.

Earth dams have been constructed on several of the cattle stations, particularly in the Finke Sheet area. In 1963, most of the dams were dry, because of the prolonged period of low rainfall. Erosion of the walls of the dams and intake channelways leads to siltation of the dams, particularly newly made dams built of fine uncompacted sand. Nevertheless, earth dams are probably the most economical method of conserving water, particularly in areas where the aquifers yield poor supplies, or the water is salty.

Yellow Ochre

Yellow ochre deposits occur near the base of the Rumbalara Shale north-east of the Rumbalara Railway Siding. The deposits have been mined at the Rumbalara ochre mines (Yellow Queen and Yellow King) near Mount De Souza. The following description of the deposit is summarized from Sullivan & Öpik (1951).

The ochre occurs in a band $1\frac{1}{2}$ to 4 feet thick and averages $2\frac{1}{2}$ feet thick. The golden-yellow ochre contains 45 to 55 percent Fe_2O_3, and the other main constituent is kaolin with a few fine grains of quartz and flakes of muscovite. It has a specific gravity of

3.33. The ochre is underlain by a bed of limonite 1 to 1½ feet thick which contains 60 to 70 percent Fe_2O_3.

The deposit was under a mining lease to the Australian United Paint Co. Ltd, who took the entire output. The total production was 7875 tons up to the time of the closing of the mine in 1951. It is estimated that the possible reserves are 25,000 to 30,000 tons of ochre if the band maintains its thickness through the mesa. Other deposits of unknown extent occur 12 miles south-west of the Rumbalara ochre mines.

Öpik (in Sullivan & Öpik, 1951) says the ochre has the features of a sediment. It is the basal bed of the marine Cretaceous sequence and is probably a sedimentary iron ore formed by Cretaceous micro-organisms comparable to the Recent Leptotrix ochracea.

Evaporites

Thin deposits of evaporites are present in the long chain of salt lakes which extends from the north-east corner of the Ayers Rock Sheet area to near the eastern edge of the Kulgera Sheet area. The lakes are a continuation of the Lake Amadeus chain.

The evaporites consist mainly of halite. Odd lots of salt are mined near Curtin Springs homestead and sold in Alice Springs. The proportion of salts in the lakes is highest in the west. The lakes near Erldunda homestead are filled mainly with silt and clay with only minor amounts of evaporites.

Two samples of the evaporites (K8A and K30) from the crust of the salt lakes in the Kulgera Sheet area were analysed. Sample K8A was collected near Pulcura Well, and sample K30 is from near Migura Well about 5 miles to the east. The metals detected by flame photometer include sodium, potassium, calcium, magnesium, and strontium. The acid radicals detected in sample K8A were abundant sulphate, minor chloride, and less than 1 ppm of borate, and sample K30 was found to contain abundant chloride, minor sulphate, and less than 1 ppm borate.

Analyses of the component fractions of the samples gave the following results:

Component fractions	Weight percent	Minerals found by X-ray and petrological examination
K8A		
Soluble in H_2O	48.12	Thenardite Na_2SO_4 (90%)
		Halite NaCl (10%)
Soluble in HCl	1.46	Anhydrite $CaSO_4$
Insoluble	50.41	Quartz sand, clay, and limonite
K30		
Soluble in H_2O	70.45	Halite NaCl
Soluble in HCl	4.11	Anhydrite $CaSO_4$
Insoluble	25.50	Sand, clay, and limonite

Analyst: I.R. Pontifex, S. Baker, and N. Le Roux, BMR laboratory.

Evaporites also occur in some of the salt pools in the Finke River and some of its small tributaries. Most of the salts in the rivers and creeks are derived from springs issuing from the Langra Formation. A small stream flowing south through the Black Hill Range is encrusted with white salts which consist mainly of sodium chloride and sodium sulphate.

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PLATE 1

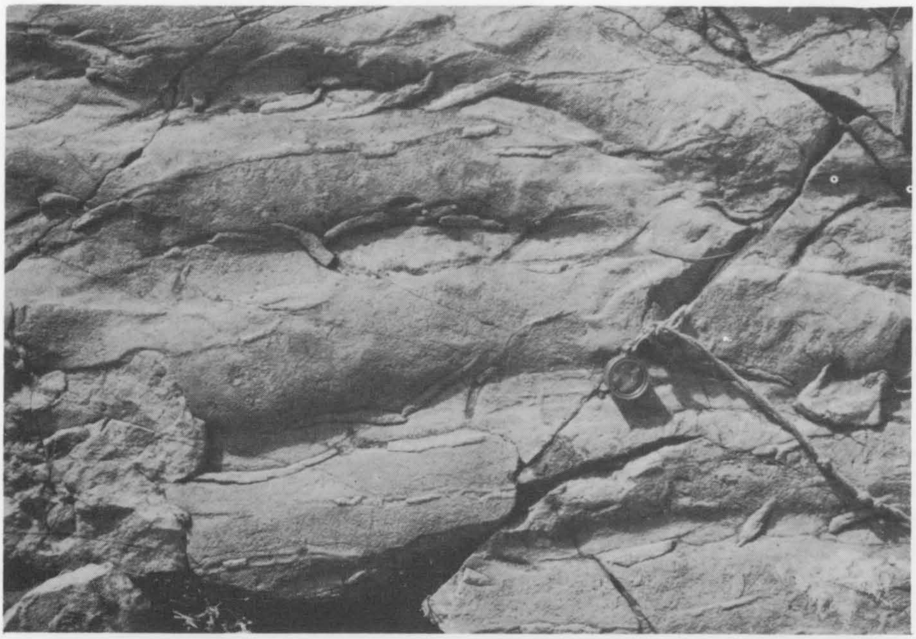


Fig. 1. Possible organic trails in ripple-marked silicified sandstone of the Winnall Beds, Basedow Range.

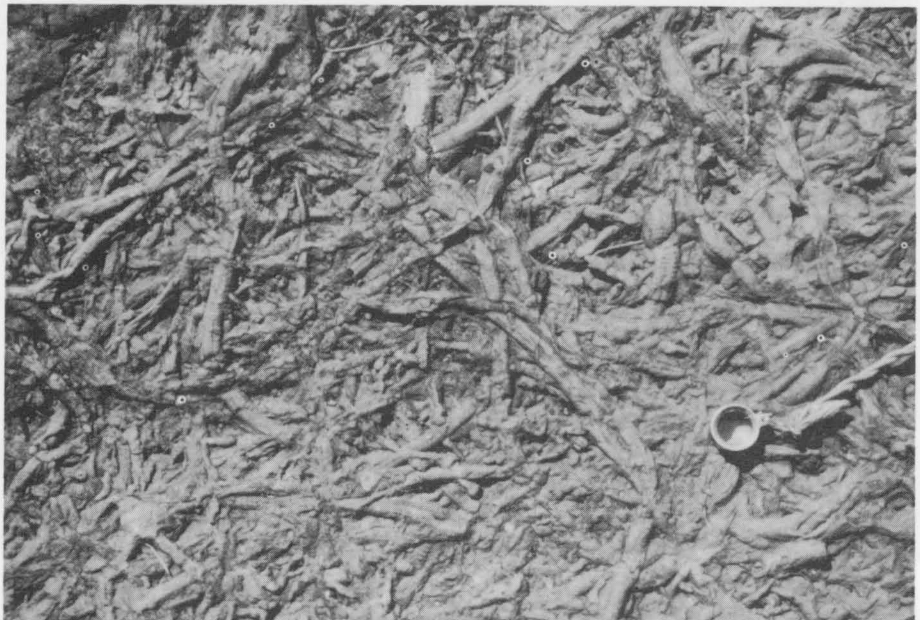


Fig. 2. Cruziana and other tracks and trails in the basal part of the Stairway Sandstone, western end of the Basedow Range.

PLATE 2

Fig. 1. 'Dingo-paws' in the Stairway Sandstone, north of Curtin Springs homestead.

Fig. 2. Polly Conglomerate at Horseshoe Bend, Finke River. Pebbles and cobbles of sandstone from the Winnall Beds, quartzite, and many varieties of igneous and metamorphic rocks set in a poorly sorted matrix.

PLATE 3

Fig. 1. Conglomerate of granite pebbles in cross-bedded sandstone of the Langra Formation. Horseshoe Bend, Finke River.

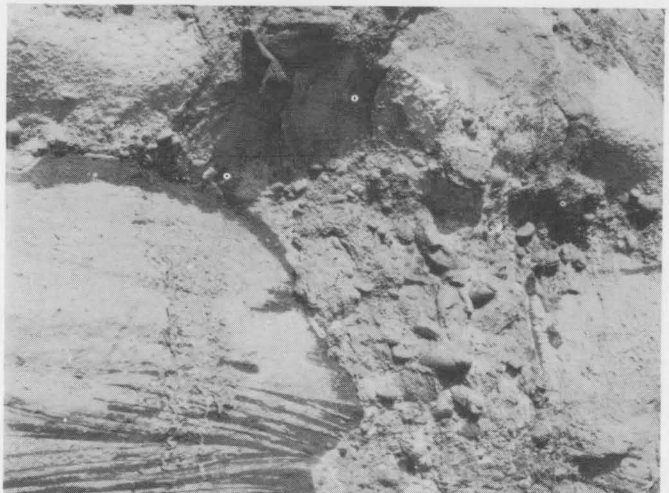


Fig. 2. Cut-and-fill structure in the Langra Formation. Conglomerate and coarse sand filling depression eroded in banded sandstone. Horseshoe Bend, Finke River.

PLATE 4

Fig. 1. Red-brown siltstone and overlying kaolinitic sandstone, Langra Formation, near Horseshoe Bend homestead.

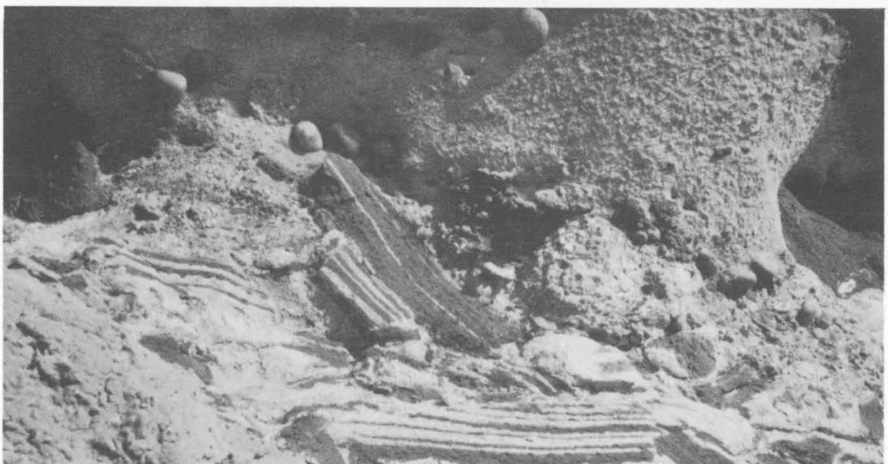


Fig. 2. Langra Formation showing penecontemporaneous brecciation of banded sandstone by overlying mass of coarse sandstone and conglomerate. Horseshoe Bend, Finke River.

PLATE 5

Fig. 1. Shale of the Langra Formation exposed in gully in foreground and low benches near base of mesas, Mount Musgrave.

Fig. 2. Contact (top of hammer handle) of Horseshoe Bend Shale with underlying conglomerate and sandstone of the Langra Formation, near Polly Spring, Finke River.

PLATE 6

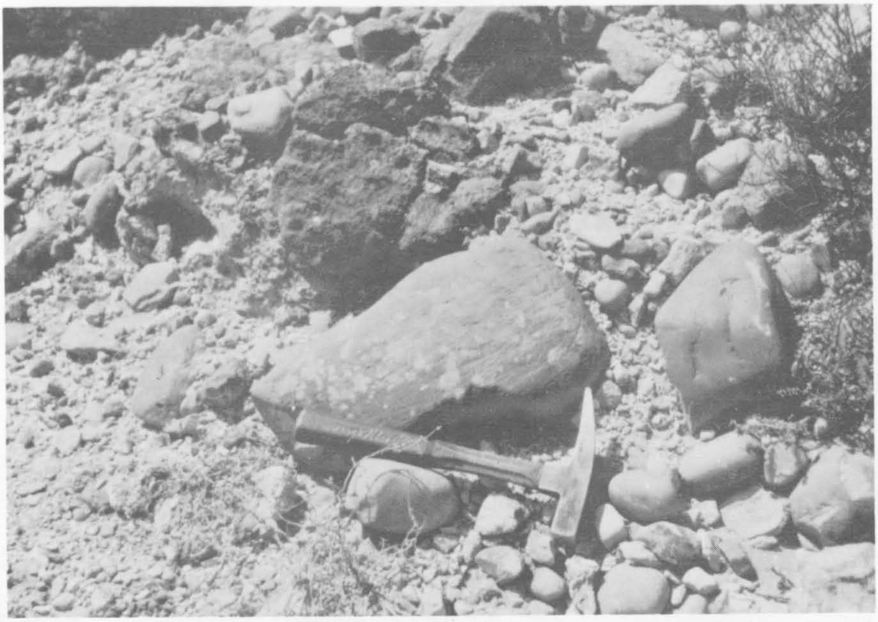


Fig. 1. Glacial striae on quartzite boulder from the Crown Point Formation, 3 miles west of Crown Point.

Fig. 2. Light-coloured Rumbalara Shale, with some thin interbeds of sandstone (forming benches), overlying the De Souza Sandstone at the Rumbalara ochre mine.

PLATE 7

SECTIONS, PERTAOORRTA GROUP

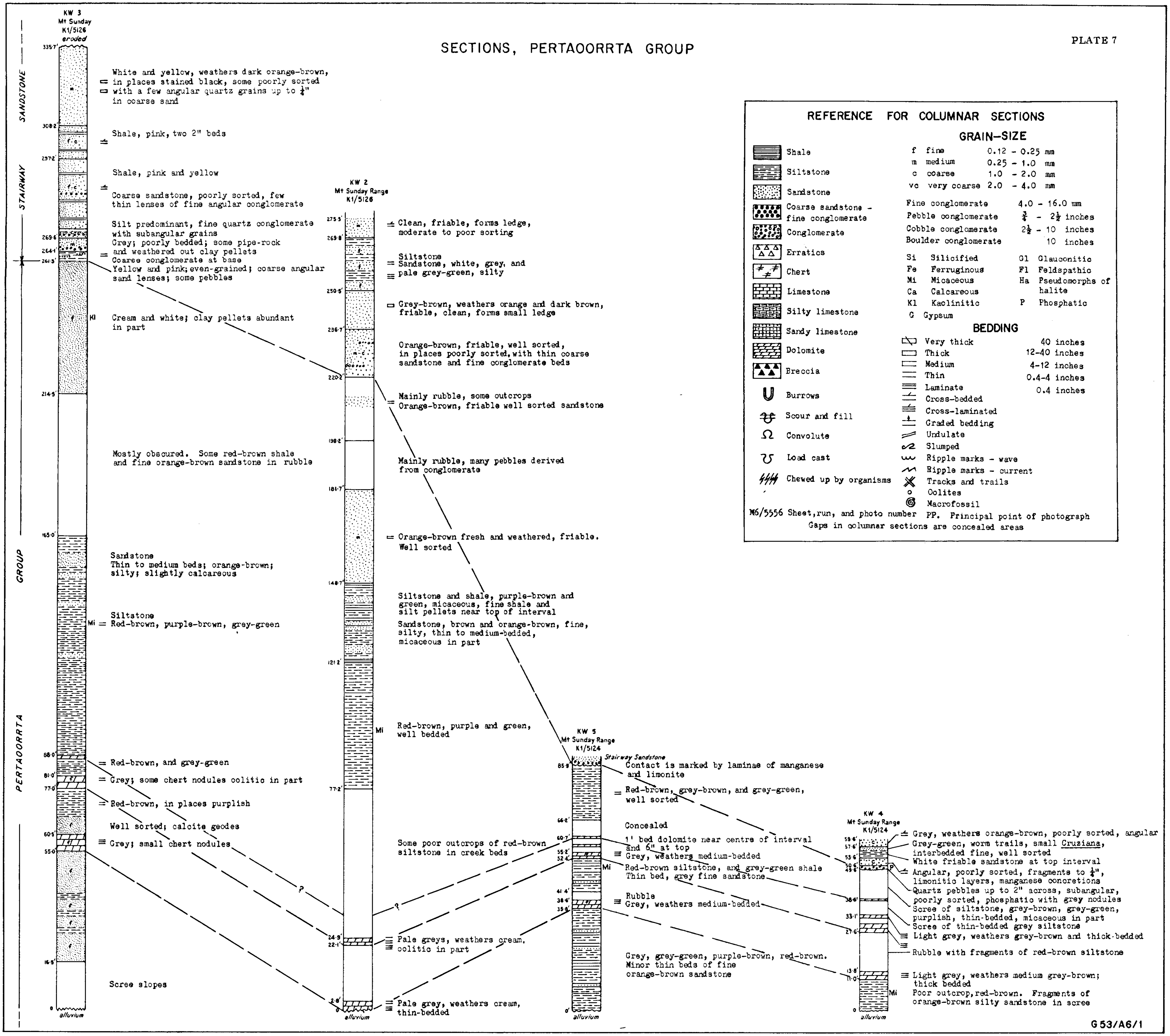
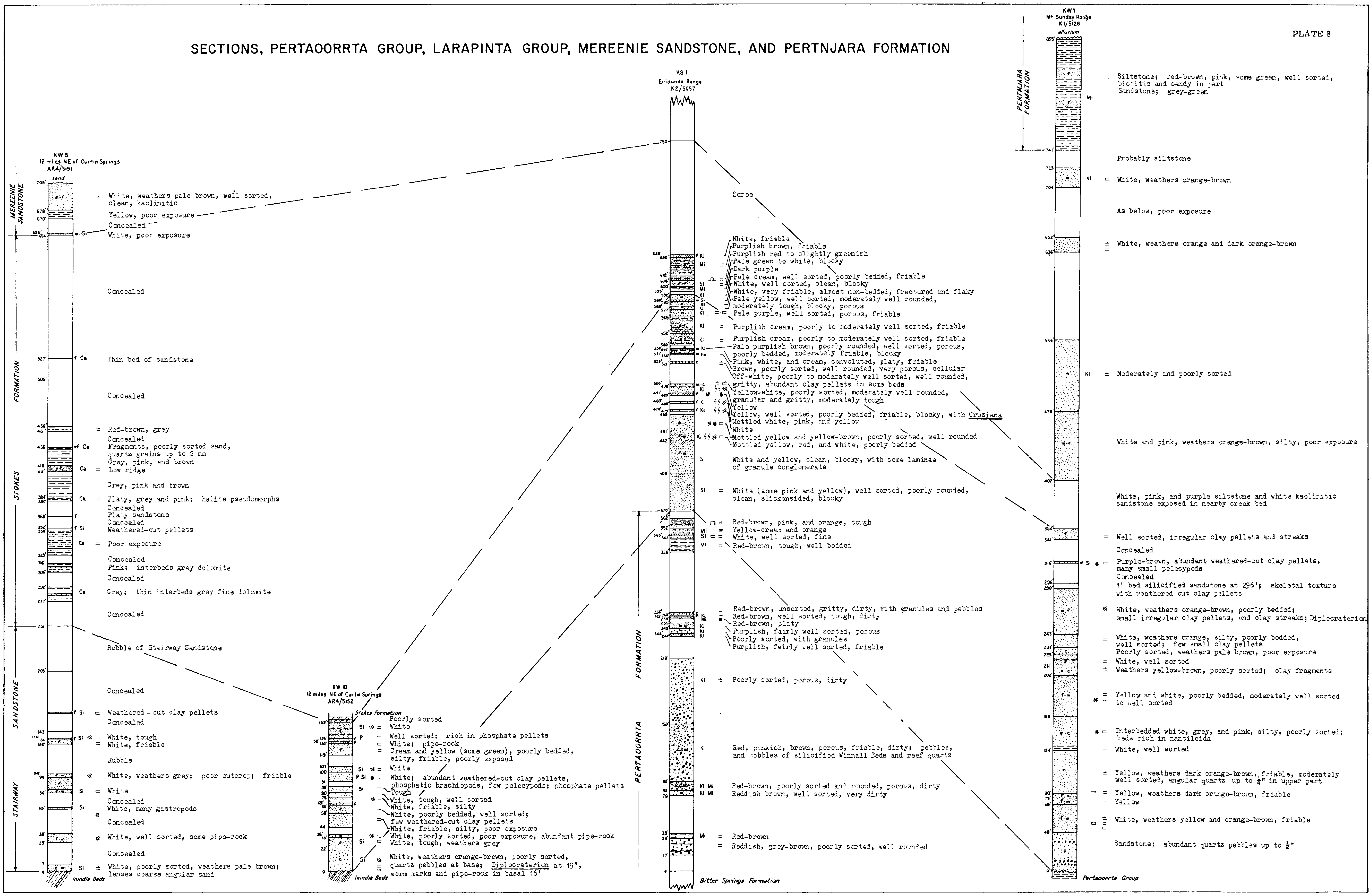


PLATE 8

SECTIONS, PERTAOORRTA GROUP, LARAPINTA GROUP, MEREENIE SANDSTONE, AND PERTNJARA FORMATION

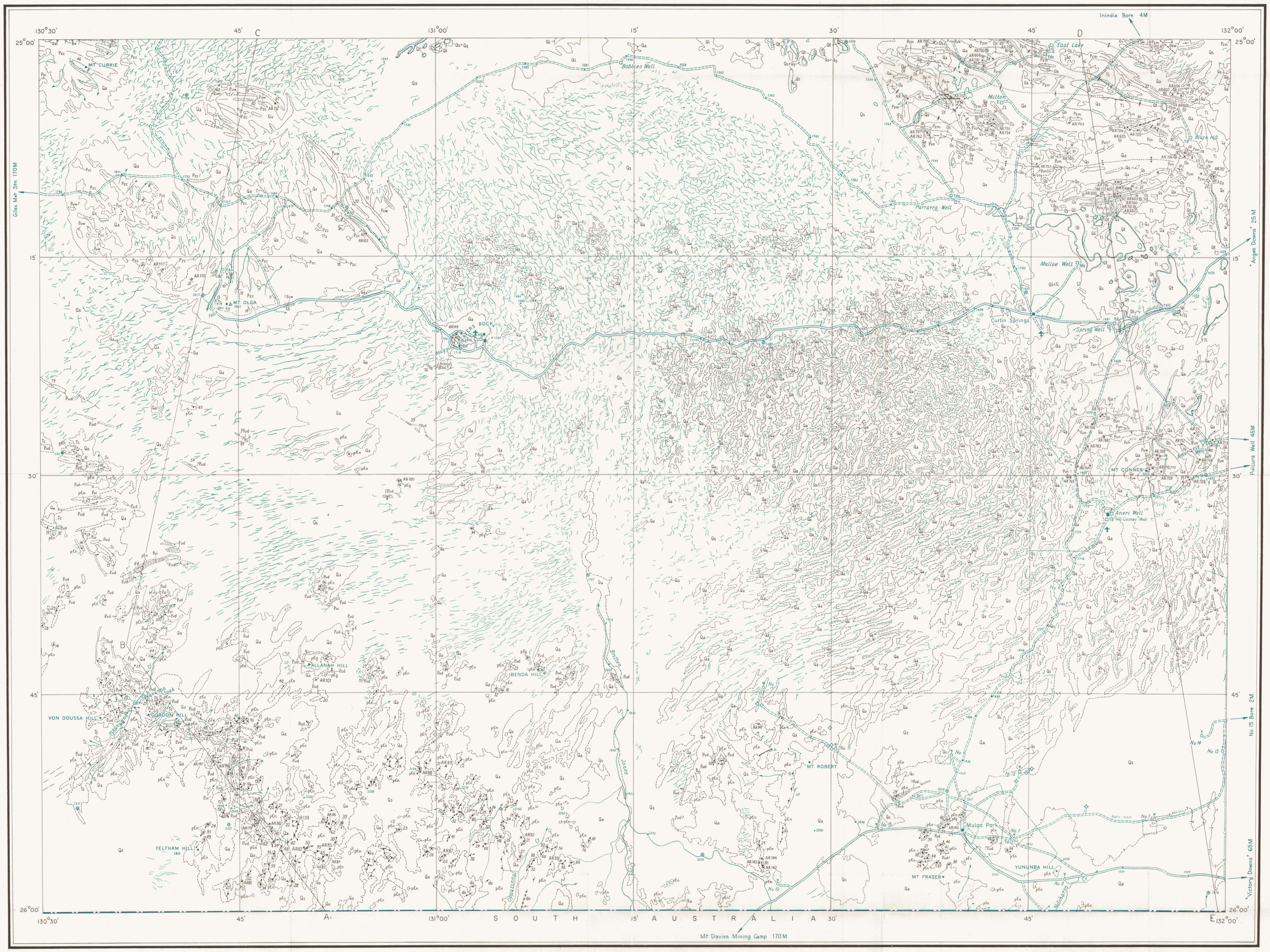


AUSTRALIA 1:250,000

AYERS ROCK

NORTHERN TERRITORY

1:250,000 GEOLOGICAL SERIES SHEET SG 52-8



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

Geology, 1963, by : D.J.Forman, P.M.Hancock, A.J.Stewart, A.T.Wells
Compilation by : D.J.Forman, A.T.Wells, A.S.Mikolajczak
Drawn, 1964, by : A.S.Mikolajczak

PRELIMINARY EDITION, 1964
SUBJECT TO AMENDMENT

Reference

CAINOZOIC	QUATERNARY		Qa	Alluvium
			Qs	Sand
			Qt	Evaporites
			Ql	Travertine
			Qg	Gypsum
	TERTIARY		Tc	Conglomerate
			Tl	Limestone
PALAEOZOIC	UNDIFFERENTIATED	Mereenie Sandstone	Pzm	Red-brown silty sandstone and white cross-bedded sandstone
	ORDOVICIAN	Stokes Formation	Ot	Shale and siltstone, some fossiliferous dolomite at base
		Stairway Sandstone	Os	White fine sandstone and kaolinitic sandstone, minor siltstone
	CAMBRIAN	Pertaoorrta Formation	Ꞓp	Pebble conglomerate
	UNDIFFERENTIATED		Pzc	Conglomerate; arkose at Ayers Rock possible lithological variant
PRECAMBRIAN	UPPER PROTEROZOIC	Winnall Beds	Puw	Fine siliceous sandstone and dark brown siltstone, minor conglomerate
		Inindia Beds	Pun	Red-brown and white siltstone, chert, sandstone, pebbly siltstone, thin beds of dolomite
		Bitter Springs Limestone	Pub	Dark grey dolomite
		Pinyinna Beds	Pui	Grey phyllite and quartz-sericite schist
		Dean Quartzite	Pud	Schistose quartzite
	UNDIFFERENTIATED		pꞒn	Gneiss with schist and amphibolite
			pꞒg	Granite

- Geological boundary
- Anticline, showing plunge
- Syncline, showing plunge
- Overturned anticline
- Fault
  Where location of boundaries, folds and faults is approximate, line is broken; where inferred, queried; where concealed, boundaries and folds are dotted, faults are shown by short dashes
- Strike and dip of strata
- Horizontal strata
- Overturned strata
- Dip < 15° (air-photo interpretation)
- Dip 15° — 45° (air-photo interpretation)
- Dip > 45° (air-photo interpretation)
- Trend lines (air-photo interpretation)
- Joint pattern (air-photo interpretation)
- Strike and dip of foliation
- Strike and dip of foliation, unmeasured
- Vertical foliation
- Horizontal foliation
- Strike and dip of bedding with trend of lineation
- Strike and dip of foliation with trend of lineation
- Trend of lineation
- Macrofossil locality
- ×AR705 Specimen locality
- KW-8 Measured section
- Dyke: do - dolerite

- Bore
- Abandoned bore
- Well
- T Tank
- E Earth tank
- Windpump
- Spring
- RH Rockhole
- Sand dunes
- Road
- Vehicle track
- State boundary
- Fence
- "Mt.Conner" Homestead
- Landing ground
- Yd Yard
- Astronomical station
- Trigonometrical station
- • 1725 Height in feet, instrument levelled } datum: mean sea level
- • 1725 Height in feet, barometric } ~~Port Augusta~~

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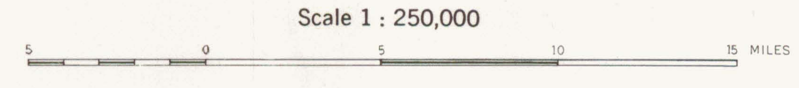
Showing Magnetic Declination

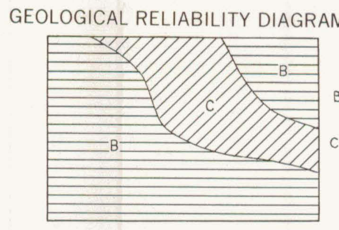
MACDONALD SF 52-14	MT RENNIE SF 52-15	MT LIEBIG SF 52-16	HERMANNSBURG SF 53-13	ALICE SPRINGS SF 53-14
RAWLINSON SG 52-2	BLOODS RANGE SG 52-3	LAKE AMADEUS SG 52-4	HENBURY SG 53-1	RODINGA SG 53-2
SCOTT SG 52-6	PETERMANN RANGES SG 52-7	AYERS ROCK SG 52-8	KULGERA SG 53-5	FINKE SG 53-6
COOPER SG 52-10	MANN SG 52-11	WOODROFFE SG 52-12	ALBERGA SG 53-9	ABMINGA SG 53-10
WAIGEN SG 52-14	BIRKSGATE SG 52-15	LINDSAY SG 52-16	EVERARD SG 53-13	WINTINNA SG 53-14

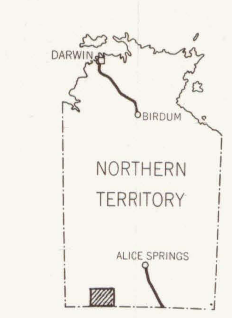
ANNUAL CHANGE 1'30"E

Scale 1 : 250,000



GEOLOGICAL RELIABILITY DIAGRAM



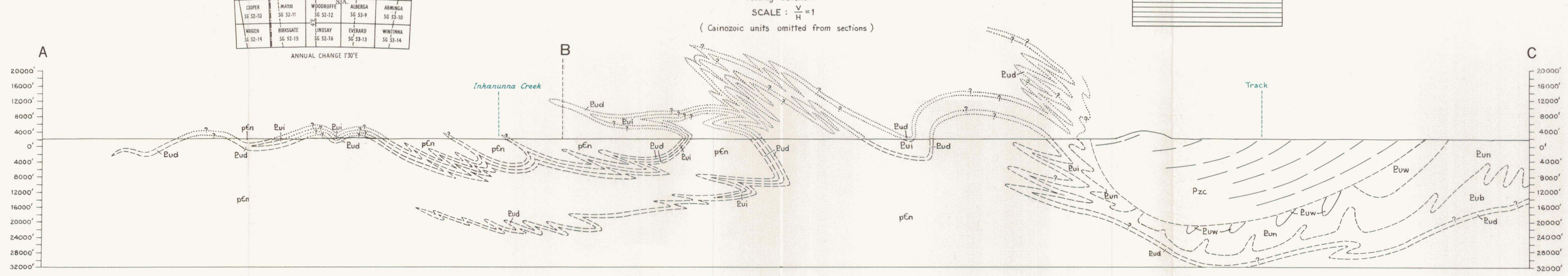


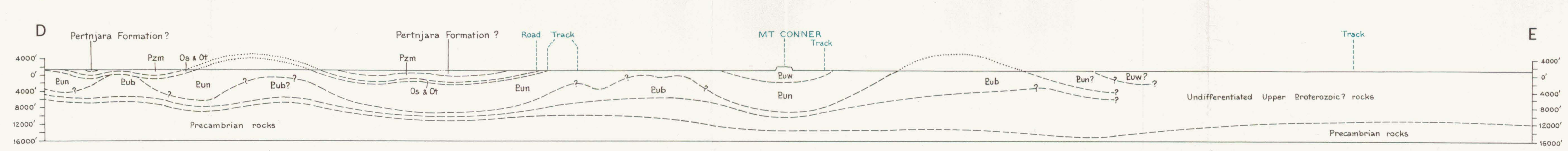
Sections

Folding schematic

SCALE : V/H = 1

(Cainozoic units omitted from sections)

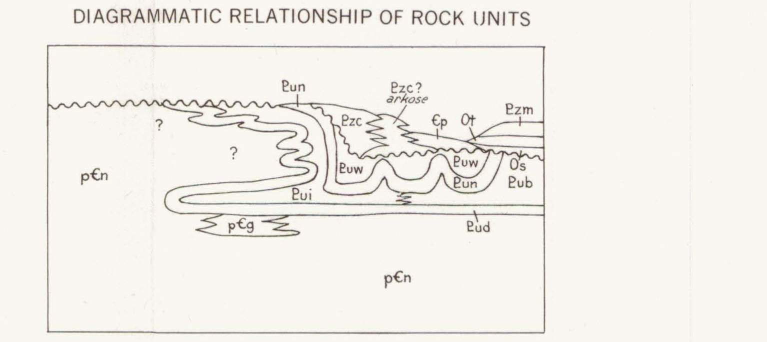




AYERS ROCK

SHEET SG 52-8

DIAGRAMMATIC RELATIONSHIP OF ROCK UNITS



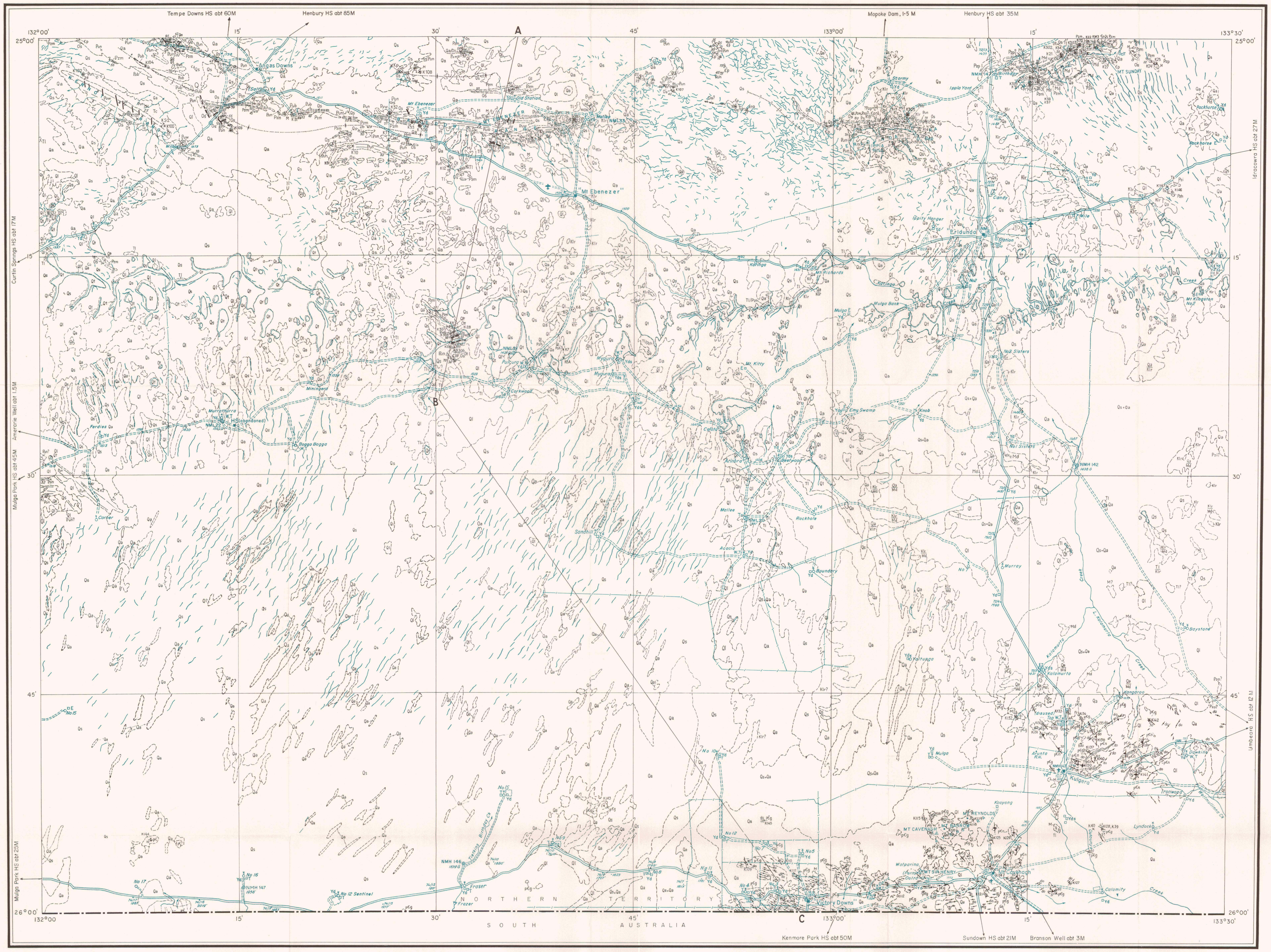
Unconformity

AUSTRALIA 1:250,000

KULGERA

NORTHERN TERRITORY

1:250,000 GEOLOGICAL SERIES SHEET SG 53-5

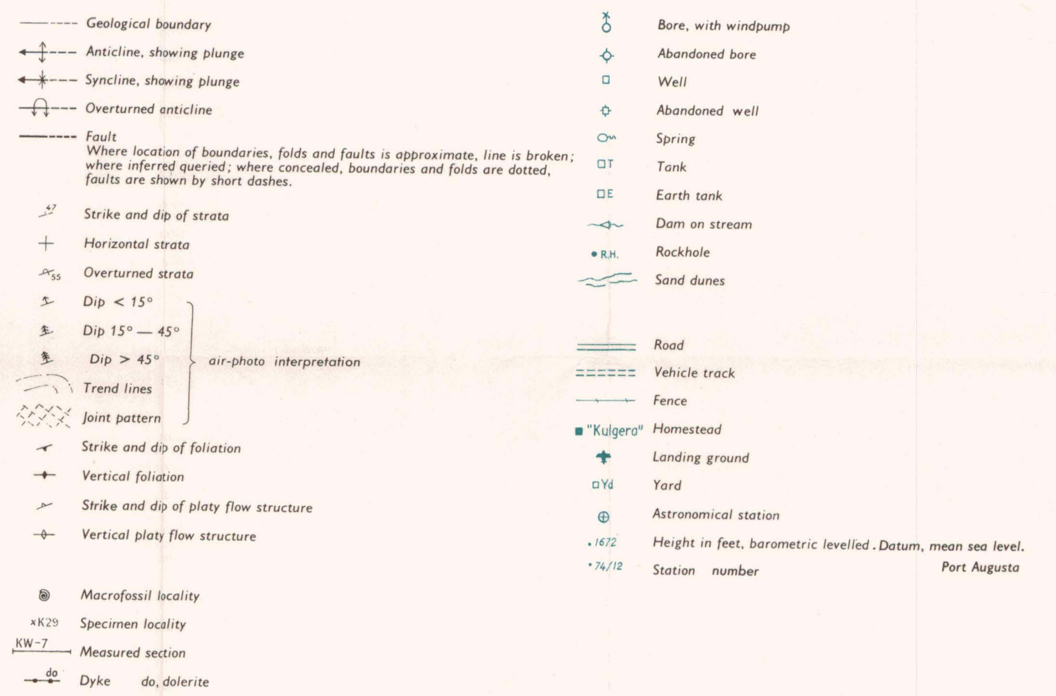


PRELIMINARY EDITION, 1965

SUBJECT TO AMENDMENT

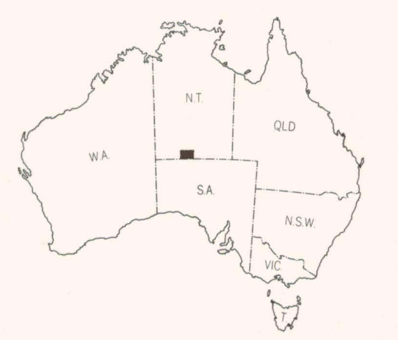
Reference

CAINOZOIC	QUATERNARY		Q	Undifferentiated (Section only)
			Qa	Alluvium, conglomerate
			Qs	Sand
			Ql	Travertine
			Qt	Evaporites
	TERTIARY		Tc	Conglomerate
			Tl	Limestone, calcareous siltstone, siltstone, sandstone
			Tb	"Grey billy", silicified sediments
MESOZOIC			M	Sandstone, siltstone
	LOWER CRETACEOUS	Rumbalara Shale	Klr	Fossiliferous shale and siltstone
	UNDIFFERENTIATED	De Souza Sandstone	Md	Sandstone, pebbly sandstone
PALAEOZOIC	UNDIFFERENTIATED	Finke Group: Idracowra Sandstone	Pzi	White kaolinitic sandstone
		Finke Group: Horseshoe Bend Shale	Pzh	Red-brown biotite shale, some fine sandstone
		Finke Group: Polly Conglomerate	Pzo	Conglomerate
		Pertnjara Formation	Pzp	Red-brown sandstone, siltstone
		Mereenie Sandstone	Pzm	Red-brown kaolinitic sandstone, siltstone
	ORDOVICIAN	Stokes Formation	Ot	Siltstone, silty dolomite
		Stairway Sandstone	Os	Fossiliferous sandstone, phosphorite, conglomerate
	CAMBRIAN	Pertaoorrta Formation	Єp	Sandstone, siltstone, conglomerate
PRECAMBRIAN	UPPER PROTEROZOIC	Winnall Beds	Puw	White and purple-brown sandstone, dark brown siltstone
		Inindia Beds	Pun	Bedded chert, chert breccia, siltstone, dolomite, sandstone, tillite
		Bitter Springs Limestone	Pub	Dolomite, sandstone, chert
			do	Dolerite
			pЄg	Granite, gneiss
			pЄn	Gneiss
			pЄ	Schist

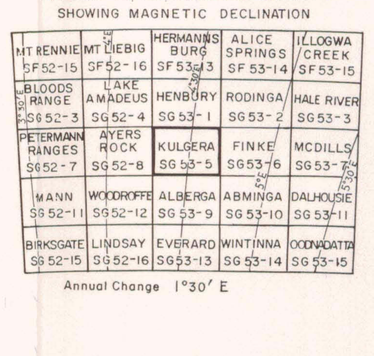


Compiled and issued by the Bureau of Mineral Resources, Geology and Geophysics, Department of National Development. Photo scale compilation supplied by the Division of National Mapping, Department of National Development.
Aerial photography by R.A.A.F.; complete vertical coverage at 1:46,500 scale
Transverse Mercator Projection.

Geology and compilation, 1963, by: A. T. Wells, A.J. Stewart, S.K. Skwarko and A. Mikolajczak
Drawn, 1964, by: R.J. Molloy, J Pasman and G.Matveev



INDEX TO ADJOINING SHEETS
SHOWING MAGNETIC DECLINATION



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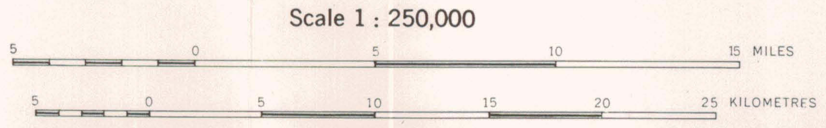
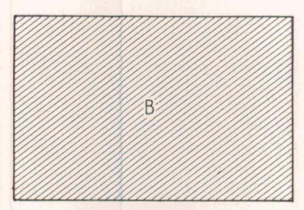
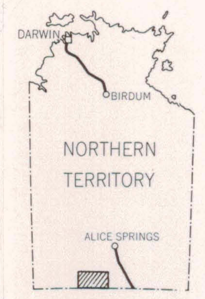
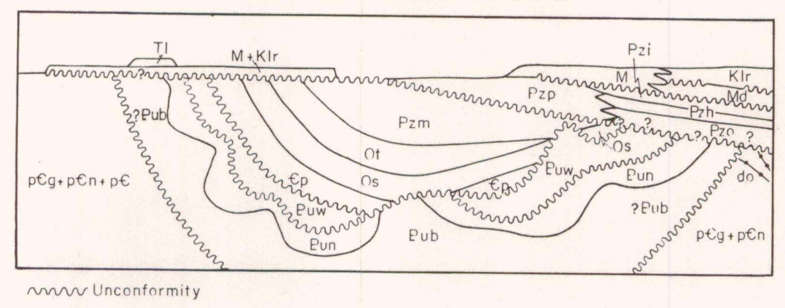


GEOLOGICAL RELIABILITY DIAGRAM



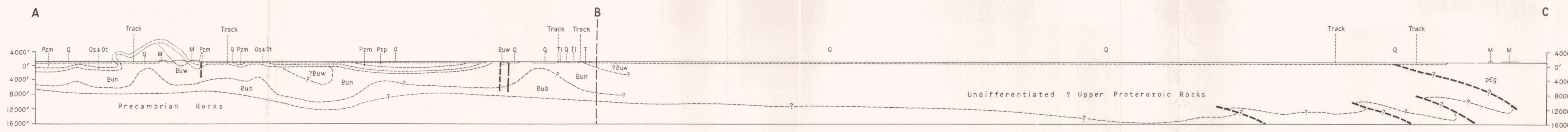


ROCK RELATIONSHIP DIAGRAM



Section

Scale $V=H$



KULGERA

SHEET SG 53-5

AUSTRALIA 1:250,000

FINKE

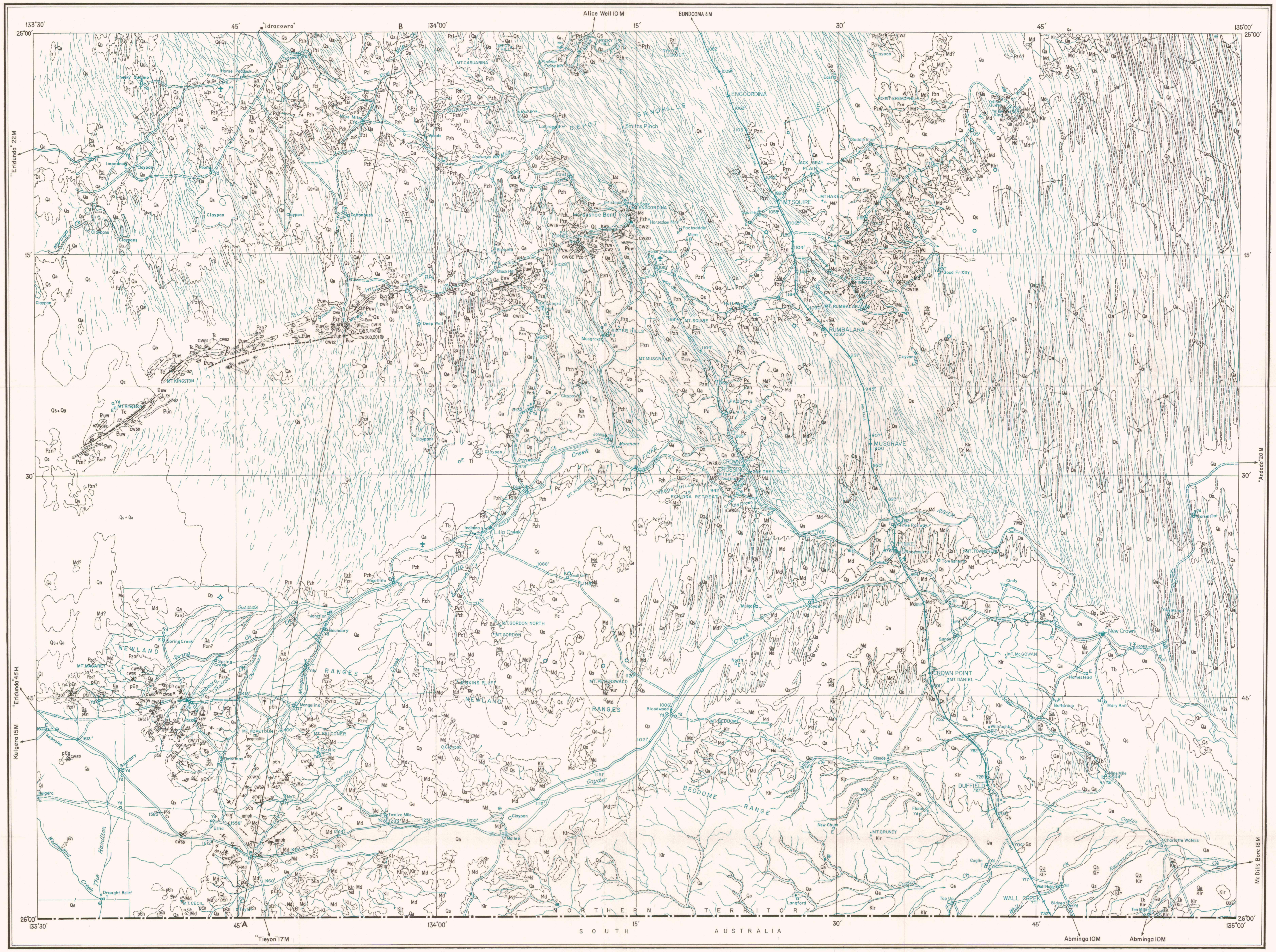
NORTHERN TERRITORY

1:250,000 GEOLOGICAL SERIES SHEET SG 53-6

PRELIMINARY EDITION, 1964

SUBJECT TO AMENDMENT

PLATE 11



Reference

CAINOZOIC	QUATERNARY		Q	Undifferentiated (section only)
			Qa	Alluvium
			Qs	Sand
			Ql	Travertine, caliche
	TERTIARY		Tc	Conglomerate
			Tl	Limestone
			Tb	"Grey Billy"
MESOZOIC	LOWER CRETACEOUS	Rumbalara Shale	Klr	Fossiliferous shale and siltstone
	? JURASSIC	De Souza Sandstone	Md	Sandstone, pebbly sandstone
PALAEOZOIC	PERMIAN	Crown Point Formation	Pc	Sandstone, conglomerate, siltstone
	DEVONIAN - CARBONIFEROUS	Finke Group: Idracowra Sandstone	Pzi	White kaolinitic sandstone
		Finke Group: Horseshoe Bend Shale	Pzh	Red-brown biotite shale, some fine sandstone
		Finke Group: Langra Formation	Pzn	Yellow sandstone, conglomerate, red-brown siltstone
		Finke Group: Polly Conglomerate	Pzo	Conglomerate
	ORDOVICIAN	Stairway Sandstone	Os	Fossiliferous sandstone, conglomerate
PRECAMBRIAN	UPPER PROTEROZOIC	Winnall Beds	Puw	White and purple-brown sandstone, glauconitic siltstone
		Inindia Beds	Pun	Bedded chert, chert breccia, red-brown siltstone, sandstone, tillitic siltstone
		Bitter Springs Formation	Pub	Grey-brown dolomite with stromatolites
	UNDIFFERENTIATED		do	Dolerite
			p€g	Granite
			p€n	Gneiss
			amph	Amphibolite

Geological boundary

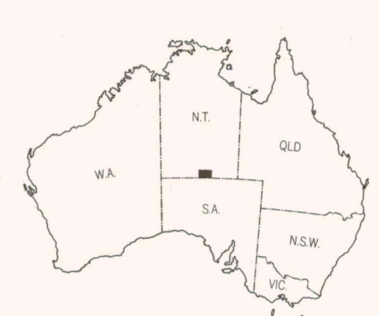
Fault

Where location of boundaries, folds and faults is approximate, line is broken; where inferred, queried; where concealed, boundaries and folds are dotted, faults are shown by short dashes.

- Strike and dip of strata
- Vertical strata
- Horizontal strata
- Overturned strata
- Dip < 15° (air-photo interpretation)
- Dip 15° - 45° (air-photo interpretation)
- Dip > 45° (air-photo interpretation)
- Trend lines (air-photo interpretation)
- Joint pattern (air-photo interpretation)
- Strike and dip of foliation
- Vertical foliation
- Horizontal foliation
- Foliation, dip indeterminable
- Direction and plunge of lineation
- Horizontal lineation
- Inclined platy flow
- Vertical platy flow
- Macrofossil locality
- ×CW20 Specimen locality
- KW-6 Measured section
- Dyke; do - dolerite

- Mine, not being worked
- •Oc Minor mineral occurrence; Oc - ochre
- Bore
- Abandoned bore
- Well
- Abandoned well
- Windpump
- T Tank
- E Earth tank
- Dam on stream
- Spring
- RH Rockhole
- Sand dunes
- Road
- Vehicle track
- Railway with siding
- State boundary
- Fence
- Telegraph line
- "Umbeara" Homestead
- Landing ground
- Yd Yard
- Astronomical station
- ·717' Height in feet, barometric; datum: mean sea level
- Trigonometrical station

Compiled and issued by the Bureau of Mineral Resources, Geology and Geophysics, Department of National Development. Photoscale compilation supplied by the Division of National Mapping, Department of National Development.
Aerial photography by R.A.A.F., complete vertical coverage at 1:46,500
Transverse Mercator Projection.



INDEX TO ADJOINING SHEETS

SHOWING MAGNETIC DECLINATION

MT.LIEBIG SF 52-16	HERMANNSBURG SF 53-13	ALICE SPRINGS SF 53-14	ILLOGWA CREEK SF 53-15	HAY RIVER SF 53-16
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AYERS ROCK SG 52-8	KULGERA SG53-5	FINKE SG53-6	MCDILLS SG53-7	SIMPSON DESERT S. SG53-8
WOODROFFE SG52-12	ALBERGA SG 53-9	ABMINGA SG53-10	DALHOUSIE SG53-11	POOLOWANNA SG53-12
LINDSAY SG 52-16	EVERARD SG53-13	WINTINNA SG53-14	OODNADATTA SG53-15	NOOLYEANA SG53-16

Annual change 1'30"E

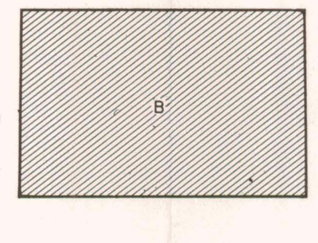
Scale 1 : 250,000

5 0 5 10 15 MILES

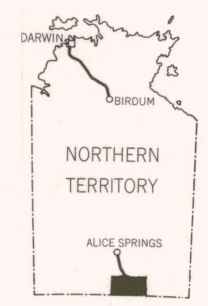
5 0 5 10 15 20 25 KILOMETRES

Geology and compilation, 1963 by: A.T. Wells, A.J. Stewart, S.K. Skwarko and A.S. Mikolajczak
Drawn by: R.J. Molloy and J. Pasman, 1964.

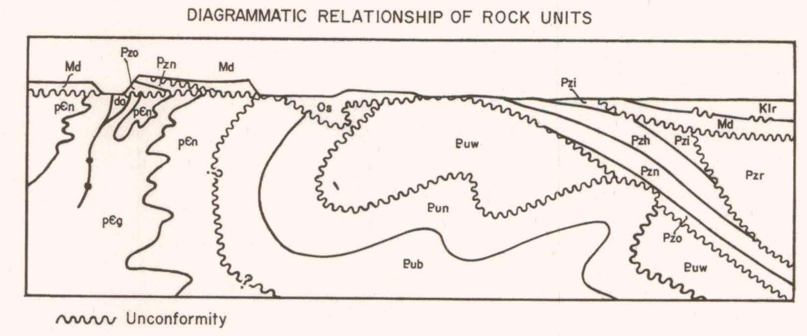
GEOLOGICAL RELIABILITY DIAGRAM



B *Detailed reconnaissance - numerous traverses, with air-photo interpretation*

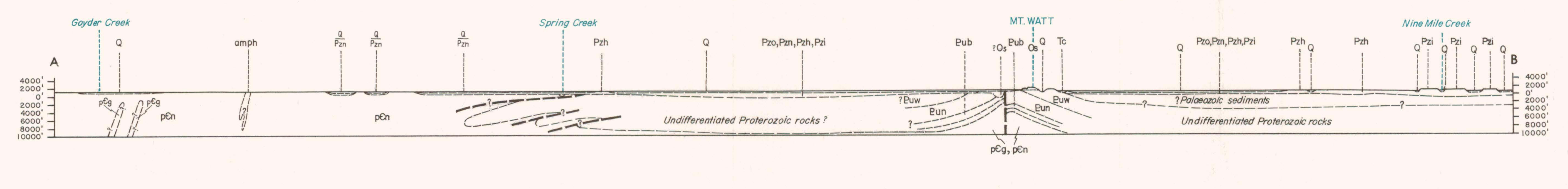


DIAGRAMMATIC RELATIONSHIP OF ROCK UNITS



Section

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



FINKE
SHEET SG 53-6

Date	B 1/4/86	D 15/4/86	B	D	B	D	B	D	B	D	B	D	B	D

DATE DUE

15/4/86			