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THE GEOLOGY OF THE GLENORMISTON 1:250,000 SHEET AREA

by

M.A. Reynolds and P.W. Pritchard

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SUMMARY

Rocks and sedimentary deposits in the Glenormiston Sheet area range in age from Proterozoic to Cainozoic, but those units younger than Ordovician are generally less than 100 feet thick. The younger rocks comprise Quaternary alluvium and aeolian sand, thin Tertiary limestone and sandstone, marine to non-marine Mesozoic deposits, and small patches of ?Permian glacigenes. The Lower Palaeozoic rocks are also (fairly) thin in the northern to eastern parts of the area but thicken to the south-west where they form the north-eastern limb of the Toko Syncline. Here, sediments composed of sandstone and siltstone with limestone bands, and which may be up to 1,200 feet thick, overlie a carbonate sequence whose thickness is more than 1,200 feet. Precambrian rocks are confined to the north-east corner where folded and faulted Lower Proterozoic metasediments and metavolcanics have been intruded by granite which is also Precambrian.

Many outcrops in the higher parts of the area appear to have been lateritised and subsequently indurated by silicification. Lateritisation predates deposition of the Tertiary lacustrine limestone, but silcrete development appears to have been later.

The strong faulting and folding in the north-eastern corner is mainly Precambrian with predominant meridional and north-east to south-west trends. These have been reflected in the overlying Palaeozoic to Mesozoic rocks during subsequent minor movements. A major thrust from the south-west is thought to have brought sedimentation in the Georgina Basin, which includes most of the Glenormiston area, to a close and formed the Toko Syncline; the age of the movement is post-Upper Devonian, ?Kanimblan. Minor folding and faulting, some transverse, occurred throughout the Glenormiston area as a result of this thrust movement against the more stable Cloncurry -Mount Isa Precambrian block.

Water supplies, either from bores or from surface supplies, are generally unreliable both in quantity and quality.

Palaeozoic rocks in the Glenormiston area include potential source rocks and good reservoirs for oil accumulation, but suitable traps may be difficult to locate. The most likely area for oil is in the Toko Range area in the south-western part.

Copper, manganese and magnesite occur as small uneconomic deposits in and around the Glenormiston area, and some phosphate has been found in pellet beds in the Toko Group of sediments.

INTRODUCTION

The Glenormiston Sheet area is in central-western Queensland adjoining the Northern Territory boundary between Latitudes 22° and 23° South. (See Figure 1). The Georgina River runs almost meridionally through the centre of the area, but just below the south edge, turns east towards Boulia. Graded roads from Boulia to Glenormiston, and Glenormiston to Dajarra afford the main access to the area in Queensland, and it may also be reached from Alice Springs via Tobermory in the Northern Territory. Channel country air services do not extend into this area but airstrips at Glenormiston and Roxburgh Downs are suitable for small planes of the type used by the Flying Doctor Service. Nearest airports are at Boulia and Dajarra, and Dajarra is also a rail terminal.

Most of the southern and western parts are occupied by large cattle stations: Glenormiston, Roxburgh Downs, and Linda Downs, whose homesteads are within the area, and parts of Walgra, Carandotta, Mungerebar (which is owned by Ardmore), Buckingham Downs, Alderley, and Herbert Downs. Glenormiston Station also extends into the Mount Whelan Sheet area to the south and altogether occupies 2,900 square miles; under good seasonal conditions it supports 13,000cattle. Two smaller sheep properties, Stockport and Badalia, extend into the south-east corner of the Glenormiston Sheet area, with Badalia Homestead just near the east edge.

The north-east corner is largely unstocked except for wild cattle and some camels; the country is rough and dry but some small springs drain into Spring Creek at the head of Smoky Creek. Here, and in other parts of the Glenormiston area, cattle may be poisoned at certain times of the year by eating pods of some types of gidyea trees which are very common in the limestone - dolomite terrain.

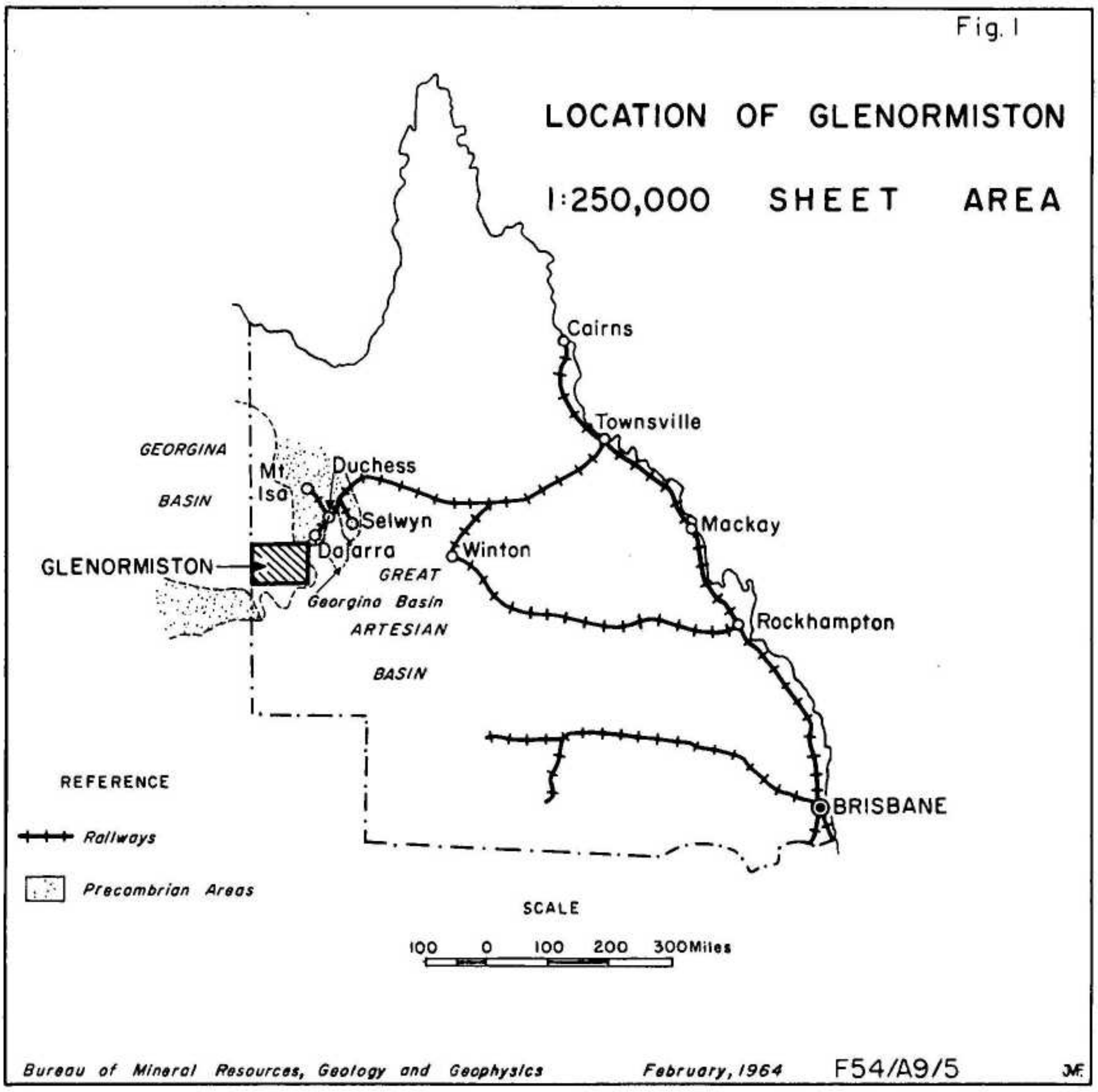


Fig. I
LOCATION OF GLENORMISTON
1:250,000 SHEET AREA
Cairns
Townsville
GEORGINA
BASIN
Mt
Isa
Duchess
Selwyn
Dajarra
Mackay
Winton
GLENORMISTON
GREAT
Georgina Basin
ARTESIAN
BASIN
Rockhampton
BRISBANE
REFERENCE
Railways
Precambrian Areas
SCALE
100 0 100 200 300Miles
Bureau of Mineral Resources, Geology and Geophysics
February, 1964
F54/A9/5
JMF

Water supply from bores and dams varies throughout the area and is generally unreliable. Large waterholes occur in the channels of the Georgina River and along Pituri Creek, but the only one which is known to be permanent is that opposite Roxburgh Downs Homestead. Annual rainfall is spasmodic but averages between 7 and 10 inches. Rain develops mainly during the time of monsoonal influence in northern Australia between November and March; access to the area by vehicle at such times may be difficult either because the roads are impassable or the streams may be flowing and cannot be crossed. The climate is mainly dry and days are mostly hot (and the roads dusty) with cold nights; drought conditions generally prevail.

Mapping by the Bureau of Mineral Resources in the Georgina River area began in 1947-48 when Noakes and Traves (1954) representing the Bureau in the Northern Australia Regional Survey, carried out a survey of the resources of the Barkly region in north-western Queensland and the Northern Territory. Mapping was continued in the Georgina River area in the early 1950's but it was not until 1957 that any work was done south of latitude 22^{o} South. In 1957 a joint Bureau of Mineral Resources (B.M.R.) - Queensland Geological Survey (Q.G.S.) party under J.N. Casey (B.M.R.) mapped the Boulia area, and in 1958 continued to the west in the Glenormiston area. During this period some reconnaissance traverses were also run into the Tobermory and Hay River areas of the Northern Territory, and to the south in the Springvale, Mount Whelan and Bedourie areas.

The 1958 field party consisted of J.N. Casey, M.A. Reynolds, P.W. Pritchard, K.G. Lucas of the B.M.R., and R.J. Paten of the Q.G.S. The field work extended from 14th May to 8 th October and was undertaken from a base camp on the Georgina River, near Roxburgh Downs Homestead, 120 miles from Dajarra and an equal distance from Boulia. The report on the Glenormiston area has been prepared mainly by P.W. Pritchard and M.A. Reynolds; the individual contributions of others have been acknowledged in the text.

An extensive collection of rock samples and fossils was made and has been studied as follows: early Palaeozoic fossils by Dr. A.A. Opik and Miss J. Gilbert-Tomlinson, plant fossils by Mrs. M.E. White, fossil wood by Mr. C.E. Carter (Carter, 1959), and microfossils by Dr. I. Crespin; lithological descriptions by W.B. Dallwitz and K.G. Lucas are given as Appendices I and II of this report.

OTHER INVESTIGATIONS AND REPORTS

Prior to the mapping in 1958, most geological reports involving the Glenormiston area were based on reconnaissance surveys. These included the work of Daintree (1872), Hodgkinson (1877) who named the Cairns (Toko) Range, Jack (1885-1897) who first reported Ordovician fossils from the Cairns Range, Dunstan (1920), and Jensen (1925). Whitehouse (1927-1955) did more detailed work in north-western Queensland than any previous worker and his reports were the main source of information for the 1957-58 surveys. Other general summaries of the geology of Queensland were published by Andrews (1937), Bryan and Jones (1944, 1946), David (1950), and Hill (1951), but these were based largely on Whitehouse's papers on the Lower Palaeozoic rocks of north-west Queensland, and on the younger sediments of the Great Artesian Basin.

Öpik (1956-1961) worked mainly in areas north of parallel 22° South but has extended his studies into the Glenormiston area. Contributions to the Geology of Queensland (Hill and Denmead, 1960) on the Cambrian and Ordovician of the north-west region were given by Öpik and Pritchard; Reynolds (Cretaceous) and Paten (Tertiary) also covered the Glenormiston area in this volume. The results of some of the 1958 mapping programme were included in these contributions. Other B.M.R. -G.S.Q. work relevant to the Glenormiston area is by Carter, Brooks and Walker (1961) who mapped and described Precambrian rocks which extend into the north-east corner.

Gravity work was done in the area by Mr. van Son of the B.M.R. Geophysical Branch in 1957, and further reconnaissance and some more detailed traverses were run in the Black Mountain (Boulia) area to the east in 1958. (See Neumann, 1959 a, b). Levelling for the geophysical work was done by the Department of Interior surveyors under Mr. W. Kennedy. The B.M.R. airborne magnetic party made some reconnaissance flights across the area in 1958. (Jewell, 1960). Mines Administration conducted a semi-detailed gravity survey over part of the Georgina Basin in this area for Papuan Apinaipi Petroleum Co.Ltd., (Starkey, 1960), and Austral Geoprospectors also carried out seismic reflection surveys in the Glenormiston-Boulia areas for Papuan Apinaipi and Phillips Petroleum Company during 1960-61, (Phillips Petroleum Company, 1961). Seismic work is being continued in 1963 to the south-east of Glenormiston by the B.M.R.

PLATE I

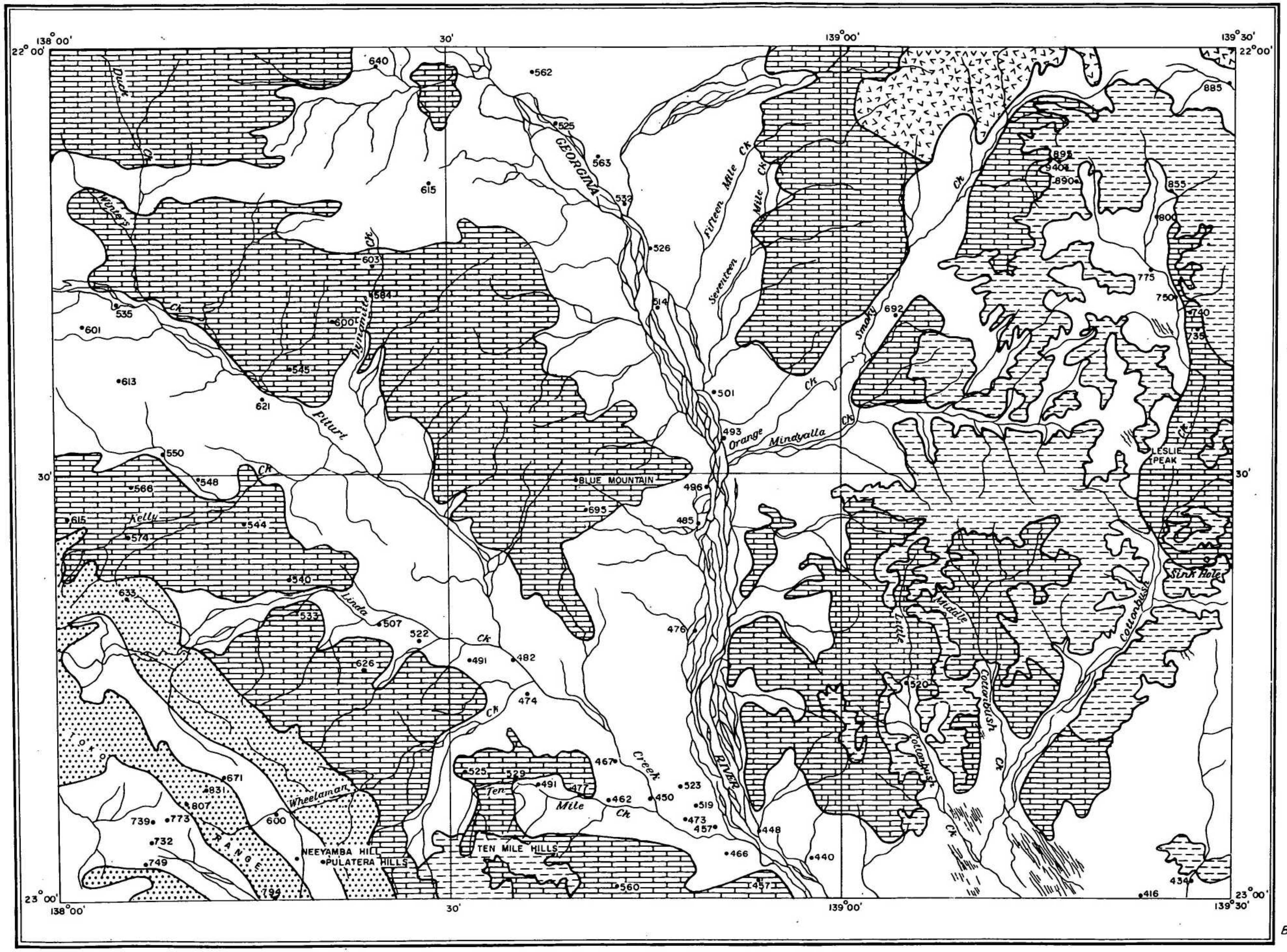
GLENORMISTON

TOPOGRAPHIC DIVISIONS

SCALE 1:500,000

5 0 5 10 15 MILES

5 0 5 10 15 20 25 KILOMETRES



Precambrian rock area

Plateau and cuesta topography of Toko Range country

Dissected Mesozoic plateau

Old limestone-dolomite country

Alluvial and sandy valleys and flats

Sand dunes

•501 Height in feet

Bureau of Mineral Resources, Geology and Geophysics. Nov. 1963. F54/A9/1 and a preview report of this project by Robertson and Allen (1963) contains a useful summary of previous geophysical work in the southern part of the Georgina Basin.

Oil companies showed interest in the area during 1956, and two brief summary reports by Thomas (1957) for Frome - Broken Hill Pty Ltd, and Rowe and Swindon (1957; later included in Sprigg, Rowe and Swindon 1957) for Santos were prepared. Reports were also prepared by Leslie (1959) and Taylor (1959) on field mapping in the Boulia - Toko Range - Glenormiston area for Frome-Broken Hill in 1958. A report on the Georgina Basin was prepared for Shell by Mulder, (1961), and also referred to the Glenormiston area.

PHYSIOGRAPHY

The Glenormiston area may be divided into five broad physiographical regions (Plate 1).

1. The belt of Precambrian rocks which extends south-west from the Urandangi - Duchess Sheet areas into the north-east part of Glenormiston, and continues towards the junction of Smoky Creek and the Georgina River, is one of the two highest divisions. This is an old land surface with sharp ridge-like features and strong lineations, and the attitude of Lower Palaeozoic rocks over and around this surface appears to be mainly depositional. There has, however, been some post depositional faulting . Drainage is mainly controlled by the topographic expression of the deformed Precambrian rocks, but may also be influenced by the late-Tertiary uplift to the north-east in the Selwyn Range area, (Duchess Sheet; see Öpik, 1961). Ridges are up to 120 feet high in relation to surrounding flats, and their tops may be just over 1,000 feet above sea-level.

2. The Toko Range plateau and associated cuesta topography in the south-west corner is the other relatively high area. It is controlled partly by structure and partly by lithology. The Range is due to the formation of the Toko Syncline in post-Ordovician time, and is associated with cuestas within and peripheral to it. The rim of the steep outer scarp of the main range, and its plateau surface (actually part of a shallow dip slope), are formed by the Carlo Sandstone, a formation which is 200-300 feet thick, composed mainly of sandstone and indurated in the upper part. (The induration occurred possibly post Tertiary lateritisation). Elevations determined along the track from Wheelaman Hut to Cravens Peak

Bore (abandoned) vary from 924 feet near the outer, north-eastern edge to 800 feet at the inner edge of the plateau. A younger sandstone unit forms a lower cuesta to the south-west; the peak near Cravens Peak Bore is an erosional remnant of this cuesta. Some of the more resistent carbonate and sandstone beds of formations older than the Carlo Sandstone form the rounded hills and cuestas surrounding the Toko Range. The preservation of these subsidiary topographic forms also appears to be controlled by a combination of silicification and lithology.

Drainage is governed mainly by the structural forms in the area, but the unusual east-north-east trend of Kelly Creek and parts of Linda, and Wheelaman Creeks is possibly a reflection of Precambrian lineations.

3. The dissected eastern plateau of ?lateritised Cretaceous sediments is the remnant of a widespread peneplain which apparently covered much of the Great Artesian Basin area in Tertiary time, and in which lateritisation and subsequent surface induration have occurred. The surface of the plateau remnant has a slight gradient from between 900 and 1,000 feet above sea level in the north to between 700 and 800 feet in the south. The gradient is attributed to the Selwyn Range uplift which has also brought about the dissection of the plateau, and formation of mesas and buttes up to 150 feet high.

The steep, concave sides of mesas, etc., are due to the effect of the indurated cap and erosion by scarp retreat but are not necessarily due to rapid erosion. Wherever the silicified cap is missing, slopes are convex, and rounded residual hills have been formed. This suggests that although rainfall is probably the main erosive agent, the process is slow and intermittent.

Removal of Mesozoic sediments has exhumed an old Palaeozoic carbonate land surface, similar to that described hereunder in 4(a) but it is not as weathered and rounded. Evidence of karst topography remains in the old surface and accounts for some quite abrupt changes in the thickness of Cretaceous sediments in the area.

Structural lineaments of Precambrian rocks are reflected by the Palaeozoic rocks underlying the plateau area, and appear to influence the main southerly drainage system of Cottonbush Creek and its branches. Another old lineation

Plate 4: Limestone-dolomite hill country showing terrace development, Bannockburn Hills.

in an east-west to N.E.-S.W. direction is shown by the Mindyalla Creek drainage; this is in the same general direction as the lineation of the creeks south-west of Pituri Creek and referred to above. These lineations show up also in the trends of plateau dissection.

4. The division of limestone-dolomite hills extending diagonally across the area from north-west to south-east may be considered in two parts:

(a) The larger, which is on the north-east side of Pituri Creek, is composed mainly of Ordovician dolomite and forms low rolling hills. These are terraced because of the alternate hard and soft layering within the rocks, (see Plate 4), and due to jointing effects exhibit the bastion appearance described by Öpik (1961). West of the Georgina River the sediments are mostly undisturbed and sub-horizontal; east of the river, however, some minor buckling has been observed particularly in those beds extending south from the south-west tip of Precambrian rocks.

(b) A smaller area of low limestone-dolomite hills with rocks of Cambrian to Ordovician age is developed in the south-central part of the Glenormiston Sheet area, between the Toko Range foothills and Pituri Creek. These have been folded by the same movements which formed the Toko Syncline and form small terraced rises in irregular attitudes, particularly around the Ten Mile Hills.

The general elevation of this division as a whole is between 500 and 600 feet above sea level. The effects of the post-Ordovician orogeny, and possibly some older Precambrian trends influence the drainage. Pituri Creek in particular follows the direction of the main axis of post-Ordovician folding and is continuous with a lineation formed by the Sun Hill Fault to the south-east in the Mount Whelan area.

5. More than a third of the Glenormiston area is occupied by the alluvial flats with low Tertiary limestone plateaus of the Georgina River and Pituri Creek plains. A system of braided channels has developed in the Georgina River because of its low gradient. The other main streams do not generally become braided and lose their form until they reach the Georgina flats; these streams are mainly structurally controlled.

Aeolian sand deposits occur on parts of the plains, and on Herbert Downs in the south-east, well-developed sand ridges trending N.W. - S.E. have formed.

The vegetation pattern of the area is governed by the soil and moisture availability, and therefore reflects to some extent the various physiographic divisions. Densest vegetation and largest trees such as the Paper Bark Titree, Bauhenia, Eucalypts (mainly Coolabahs and Bloodwoods), etc., follow the alluvial plains and main channels of the Georgina River. The calcareous soils formed in the carbonate belt support mainly Gidyea trees and Mitchell Grass on which the cattle thrive. The higher areas, because of their lithologies, develop sandy soils and scrubby growths of Minnaritchie and Mulga. Where sandy areas develop in the valleys of dissected plateaus and on the plains, the vegetation is mainly Spinifex Grass.

The annual rainfall is small and the Georgina River and other streams only flow intermittently. Gradients are generally low and the fall of the Georgina River from north to south across the area is only about 100 feet. Higher gradients occur in the north-east corner and reflect the late-Tertiary uplift in the Selwyn Range. Apart from the late Tertiary uplift effect on the physiography, the Glenormiston area may also be divided on a structural basis into

(a) the region north-east of Pituri Creek where topography mainly reflects Precambrian structural elements, and

(b) the south-western area whose present form is the result of a post-Ordovician orogeny. The drainage pattern of both areas is largely controlled by these structural influences.

STRATIGRAPHY

General

Precambrian, Lower Palaeozoic, ?Permian, Mesozoic and Tertiary rocks are exposed in the Glenormiston area. The Precambrian crystalline basement of metamorphic rocks intruded by granite is overlain with major unconformity by slightly folded and faulted Lower Cambrian to Ordovician arenaceous and carbonate sequences containing several stratigraphic discontinuities. This Lower Palaeozoic sequence is separated by a major unconformity from Mesozoic sandy and silty sediments of the Great Artesian Basin and small deposits

TABLE 1: STRATIGRAPHY OF THE GLENORMISTON 1:250,000 SHEET AREA

AGE	FORMATION	THICKNESS	AREA OF OUTCROP	TOPOGRAPHY	LITHOLOGY	STRUCTURAL RELATIONS	FOSSILS
QUATERNARY	Alluvium and soil (Cza); sand (Czs)	Up to 30'; up to 50'	Major streams and alluvial flats; valley floor of dissected plateau in north-east and flats.	Plain or valley; sand ridges.	Grey soils and red-brown sands		
TERTIARY	Austral Downs Limestone Ta	30'	Along Georgina River and Pituri Creek	Low scarps formed by stream dissection, low plateaux and benches	Chalcedony, limestone, red pisolitic and sandy beds at base (lacustrine).	Unconformably overlies Ninmaroo Formation and other older formations	Rare; charophyte and other algal remains, plant tissue ostracods and rare foraminifera.
	Marion Formation Tm	Not known here, but up to 25' elsewhere	Very small area north of Winberg Bore at eastern edge of area.	Gravel patches - residuals of small outcrops	Silicified pebbly sandstone	Overlies Cretaceous and Ordovician rocks; covered in past by aeolian sand.	None in this area; wood in Boulia area.
MESOZOIC	Wilgunya Formation Klw	up to 100'	Scattered outcrops in eastern half of area.	Forms upper parts of dissected plateau country.	Mudstone, sandy to pebbly; leached, ?lateritised, and silicified in top part.	Conformable over Longsight Sandstone, or with erosional unconformity over Lower Palaeozoic and Precambrian rocks.	Foraminifera and radiolaria.
	Longsight Sandstone Kll	0 - 110'	Scattered outcrops in eastern half of area.	Forms lower parts of dissected plateau country; occupies valleys; etc., in old land surface and missing from high parts.	Sandstone and conglomerate with minor shaly "wormy" siltstone; mainly leached, ?lateritised.	Deposited on erosion surface of Lower Palaeozoic and Precambrian rocks; conformably overlain by Wilgunya Formation or top eroded.	Plants, pelecypods, rare gastropods and belemnite moulds, Rhizocorallium (?) and worm burrows.
	Undifferentiated M	up to 70'	Scattered residuals west of Glenormiston Homestead and in the Toko Range and possibly over ?Permian fluvioglacials at Blue Mountain.	Flat thin caps on old land surface.	Siltstone, poorly sorted sandstone and conglomerate.	Rest with angular unconformity on older rocks of various ages.	Fossil wood and plant remains
?PERMIAN	Undifferentiated P	?	Blue Mountain, 11 miles west of Roxburgh Downs Homestead.	Residual gravels weathered out on slopes of low rounded hills	?Fluvioglacial boulders and pebbles of silicified sandstone with some blocks of fossiliferous Ordovician sandstone probably associated with pocket of brownish green siliceous, laminated shale.	Overlies Ordovician and occurs below leached ?Mesozoic sediments; type of relationship not seen.	(Silicified fossil wood fragments in vicinity may be Mesozoic or Permian).
ORDOVICIAN/ DEVONIAN	Undifferentiated O/D	5' (300' + in Mount Whelan area)	South-west corner surrounded by Toko Range plateau	Forms the resistant top to cuestas	Brown, ferruginised fine to medium-grained quartz sandstone with clay pellets.	Apparently conformable on Mithaka Formation; top eroded	Fish scales
ORDOVICIAN	Mithaka Formation Omm	200' - 400'	Arcuate area around Cravens Peak Bore in south-west corner surrounded by Toko Range plateau.	Lower parts of south-dipping cuestas, strike ridges in valley.	Brown gypsiferous siltstone and sandstone; some pellet beds.	Conformable with underlying Carlo Sandstone and also appears to be conformable with formation above.	Pelecypods, brachiopods, trilobites, sponges, nautiloids, Receptaculites, conodonts, tracks and trails.
	TOKO GROUP: Carlo Sandstone Omc	200' to 300'	Toko Range	Forms top of scarp and plateau	Red and brown thick-bedded sandstone with clay pellets and some siltstone.	Conformable with Nora Formation; top eroded on plateau but to south is apparently conformable with Mithaka Formation.	Nautiloids, brachiopods, pelecypods, trilobite casts and tracks. Some U-tubes, thought to be organic.
	TOKO GROUP: Nora Formation	190'	In eastern scarp of Toko Range and the plains adjacent to the range.	Base and slope of range, on plains and in low hills.	Olive, yellow and green siltstone, fine-grained sandstone and coquinite with lenses up to 50 ft. thick some pellet beds.	Conformable with the Coolibah Formation below and Carlo Sandstone above.	Pelecypods, brachiopods, nautiloids, trilobites, bryozoa, gastropods, tracks and trails, tubular structures
	TOKO GROUP: Coolibah Formation Olc	100'	Follows north-east edge of Toko Range, and valley of headwater branches of Linda and Wheelaman Creeks	Low hills and strike ridges around the range.	Grey, calcilutite and green-white marl; with chert lenses ("buck quartz"), and minor calcarenite, dolarenite.	Conformable on and transitional with underlying Kelly Creek Formation; upper part conformable.	Nautiloids, gastropods, ?corals, sponges, ribeirioids.
	TOKO GROUP: Kelly Creek Formation Olk	250'	Parallel to scarp of Toko Range, and forms a belt around north-east side of foothills.	Buttes and strike ridges	Lower part - mainly sandstone, overlain by laminated to thin-bedded hard and soft dolomite with marl and chert interbeds.	In some parts gradational with the upper Ninmaroo Formation, in other parts disconformable; conformably below the Coolibah Formation.	Nautiloids, brachiopods, trilobites, ribeirioids,
CAMBRIAN-ORDOVICIAN	Ninmaroo Formation Є - On	1200' + -	From Toko Range to Georgina River and Urandangi; to Glenormiston and Herbert Downs.	Plains, low rises and terraced hills; bastion and karst topography in parts.	Limestone and dolomite, some places sandy with sandstone interbeds and algal beds, intraformational breccia and oolites. Basal thin-bedded leached sandstone and siltstone beds near McCabe Knob.	Disconformable on the Georgina Limestone and Mungerebar Limestone.	Algae (stromatoliths), nautiloids, brachiopods, ribeirioids ("keyhole") and "mandibles".
CAMBRIAN Upper	Georgina Limestone Єug	100' + -	South-west of Glenormiston Homestead extending south into Mount Whelan area.	Plains with low irregular strike ridges	Flaggy blue and grey calcarenite, calcilutite, with sandy beds, some intraformational breccia and chert "biscuits".	Overlain disconformably by Ninmaroo Formation; lower contact not seen.	Trilobites (agnostid , etc.), brachiopods, hyolithids.
CAMBRIAN Middle-Upper	Mungerebar Limestone Єm- u	At least 80'	From east of Fifteen Mile Creek through the McCabe Knob area and along the east side of Smoky Creek and in the Cottonbush Creek area north of Tripod Waterhole.	Low rises with strike ridges and shallow dip slopes interrupted by strong joints and minor faulting.	Platy grey calcilutite and calcarenite with soft marly interbeds, sandy, oolitic bands, and some intraformational breccia; and with thin chert layers and nodules.	Overlain disconformably by leached silty to sandy Ninmaroo Formation. Lowest beds intertongue with the upper part of the Steamboat Sandstone.	Trilobites, brachiopods gastropods, (?)pelecypods, (?) sponges.
CAMBRIAN Middle	Steamboat Sandstone Єms	270' +	In a belt up to 7 miles wide around the Precambrian rocks in the north-east corner of the area, and a small inlier crops out at the head of Cottonbush Creek.	Low rises with terraces to relatively high flat-topped hills north and east of Andy's Bore on Mungerebar; bastion topography in parts.	Grey salt-and-pepper sandy limestone, calcareous sandstone and siltstone and leached brown sandstone; laminated to thin bedded and platy.	Base not seen in Glenormiston area but to north rests disconformably on Quita Formation; top part interfingers with lower beds of Mungerebar Limestone.	Trilobites (agnostids), brachiopods.
CAMBRIAN Middle	Thorntonia Limestone equivalent Єmt	10'	Western and southern parts of Precambrian area.	Form tops of some mesas and buttes in Precambrian outcrop area, and a narrow rim around its margin.	Banded light and dark grey chert and chert breccia	Rests on eroded surface of Riversdale Formation; upper contact not seen	Trilobites (Redlichia), algae.
CAMBRIAN Lower	Riversdale Formation Єlr	0 - 25'	Western and southern parts of Precambrian area.	Easily eroded and preserved only below Thorntonia Limestone in mesas, buttes and rim of Precambrian outcrop area.	Brown and white leached sandstone and "chalky" siltstone, conglomerate; brown coarse sandy claystone.	Unconformable on Precambrian rocks or missing; disconformably overlain by Thorntonia Limestone equivalent.	None found
PRECAMBRIAN GRANITE INTRUSION	Sybella Granite Egs		Small area at the south-west tip of Precambrian rocks, around Yarrie Rock Hole.	Low undulating plain dominated by quartz reefs.	Granite and gneiss, quartz reefs.	Rarely covered other than by rubble.	
LOWER PROTEROZOIC	Eastern Creek Volcanics Ele	Not known here but elsewhere 20,000'	Outcrops occur along the northern margin from Quita Creek to the eastern edge.	Mesas, buttes and strike ridges up to 120 feet high above rubble covered valleys.	Strongly folded and faulted metasediments and metabasalts, in places schist and amphibolite.	Intruded by Sybella Granite; Unconformably overlain by Palaeozoic and Mesozoic sediments.	

of Tertiary freshwater limestone rest unconformably on the earlier rocks along present day stream courses. ?Permian sediments crop out below Mesozoic leached rocks in a small area west of Roxburgh Downs.

The Precambrian rocks are part of the Mount Isa - Cloncurry mineral belt which is discussed by Carter, Brooks and Walker (1961).

The Lower Palaeozoic sediments were deposited in the Georgina Basin. This term has several meanings throughout the literature and is used here as it is defined by Casey, et al (1960), but with slight amendment - that area of Middle Cambrian to Ordovician sediments in north-west Queensland and central-eastern Northern Territory which is bounded in the south-west, west, to north by Precambrian to Lower Cambrian rocks, north-east and east by Precambrian of the Isa-Cloncurry massif and in the south-east and south it is covered by Mesozoic sediments of the Great Artesian Basin; it contains several thousand feet of marine calcareous and sandy Cambrian and Ordovician sediments.

Precambrian

The following notes on the Precambrian rocks have been prepared by K.G. Lucas.

Metamorphic and igneous rocks, probably all Lower Proterozoic in age, crop out in the north-east part of the Glenormiston Sheet area. They form part of the south end of the Precambrian mineral belt of north-west Queensland, (Carter, et al., 1961). Only the Eastern Creek Volcanics and Sybella Granite are represented in the Glenormiston area.

Eastern Creek Volcanics. The Eastern Creek Volcanics which crop out over a total of 1,500 square miles consist of strongly folded and faulted metasediments and metabasalts, in most places schist and amphibolite. The formation trends north-south and is intruded by granite.

The name "Eastern Creek Volcanics" was first published in the Urandangi 4-mile map and explanatory notes (Noakes, Carter, and Öpik, 1959). The type section occurs from 1½ to 5 miles along the Cloncurry road from Mount Isa.

In the Glenormiston area, the formation crops out between Quita Creek and Valley Tank extending about 8 miles south from the north edge of the Sheet area , and in another small area in the north-east corner. Metasediments include quartzite, quartz-sericite schist, and quartz-chlorite-sericite schist; minor phyllite was also noted. Resistant quartzose metasediments occur in steep narrow strike-ridges which rise to 120 feet above the general level, and in mesas and buttes capped by Lower Palaeozoic and Mesozoic sediments. Less resistant rocks underlie fairly smooth, broad, rubble-covered valleys dissected by sharp gullies. Quartzite is a minor though prominent rock type. The thick-bedded to thin-bedded milky to translucent grey quartzite is interbedded with fine quartz-sericite schist or phyllite with cleavage generally parallel to the bedding. The plicated finely crystalline spotted quartz-chlorite-sericite schists contain cigar-shaped aggregates , up to 1.5 centimetres long, of even-grained chlorite and muscovite laths; the host rock consists of lepidoblastic muscovite, clear quartz, and accessory chlorite and elongated grains of black oxide. Some of the schists and phyllites have been deeply weathered, and appear as contorted, laminated maroon "siltstone".

Medium crystalline gneiss occurs with schist at some localities, and in concordant lenticular bodies with fine amphibolite in soft impure schist elsewhere. The gneiss may have been associated with granite intrusion during regional metamorphism rather than formed as a relatively coarse metamorphic rock in situ. Similar gneiss is common in the area mapped as Sybella Granite.

Basic rocks include metadolerite (cf. amphibolite in the hand specimen), and epidosite; they are in part interbedded with quartzose metasediments. In outcrop, they form slightly elevated undulating tracts with distinct boundaries and a regular fine drainage pattern. The greatest variety of rock type crops out between Smoky Creek and Duncan's Creek. Rocks which have been examined in thin section include:

Dark green "amphibolite" - an equigranular quartz-bearing hornblende dolerite whose texture shows little effect of metamorphism; it is cut by veinlets of epidote and untwinned alkali feldspar. Composition is essentially hornblende and plagioclase (An_{50}), with accessory epidote, intergranular quartz, ragged aggregates of sphene, and black ore with minor apatite and calcite. The pleochroism of the hornblende is identical with that described by Joplin (1955, p.49) from the ortho-amphibolites to the north of the Glenormiston area.

Bright green epidote - shows a fine interlocking granular quartz-epidote mosaic in which the only indication of the texture of the original rock is the presence of an octahedral epidote aggregate whose size and outline suggest that it was a euhedral pyroxene phenocryst.

The petrography of rock types in the Eastern Creek Volcanics from localities G 402, G 403 and G 405 is given in Appendix 1.

With the exception of the gneiss of problematical origin and phyllite, the metamorphics are of the same grade and belong to the biotite and green schist facies.

The Eastern Creek Volcanics constitute most of the material in the lower part of the western basin of an extensive Lower Proterozoic orogenic belt. Thickness in the southern part of the Glenormiston Sheet area is not known but elsewhere the formation attains at least 20,000 feet. Quartzose metasediments are more common than basic rocks in the Glenormiston area, but are subordinate farther north.

Sybella Granite. The Sybella Granite forms a composite batholith, elongated north-south and cropping out mainly on the eastern side of the Urandangi 4-mile Sheet area (Noakes, et al., 1959). The main components are a coarse, porphyritic, foliated biotite - microcline granite with plagioclase and hornblende, and a later finer, more even-grained, massive granite. The type area is the upper part of Sybella Creek, 12 to 15 miles south-south-west of Mount Isa.

The Sybella Granite extends into the Precambrian part of Glenormiston Sheet area in a roughly circular area of about five square miles, centred about Yarrie Rock Hole and forming the headwaters of Seventeen Mile Creek. It occupies a low, undulating, treeless, rubble-covered plain cut by small sharp gullies, and dominated by the quartz blows which cross it.

Exposure is poor in this area. Granite and gneiss are the chief rock types; "amphibolite" and biotite schist or hornfels are to be found on some ridges formed by the quartz blows. These non-granitic rocks are probably roof pendants or minor inclusions of the batholith: the granite appears to be barely unroofed.

The main granitic rock type is a medium-grained pink microcline granite, poor in mafic minerals, and with ill-defined porphyritic masses characterised by euhedral microcline crystals up to four inches across. Thinly banded biotite and muscovite gneiss is common in the south part of the outcrop. Adamellite also occurs and a sample from G 441, 10 miles east-north-east of Yarrie Rock Hole, is described in Appendix 1.

To the east, the Eastern Creek Volcanics are intruded by small bodies of foliated and massive granites which commonly crop out side by side. The foliated rocks are generally more intermediate in composition and are intruded by the massive acidic rocks. Five miles east-north-east of Yarrie Rock Hole, at Locality G 442, a porphyroblastic foliated biotite granodiorite containing aligned inclusions of fine-grained metavolcanics is apparently intruded by an adjacent massive ?granodiorite. The foliated granodiorite may be a hybridised granite which has partly assimilated metavolcanic rock, and finally undergone potash metasomatism; the rock is described in more detail in Appendix I. Apart from this effect, contact metamorphism is not very marked.

Lower Cambrian

Riversdale Formation. The thin sedimentary deposit found in small outcrops between Precambrian and lower Middle Cambrian rocks in the north-eastern part of the Glenormiston Sheet area is considered to be a southerly extension of the Riversdale Formation; this formation is referred to by Noakes, et al., (1959) in the explanatory notes of the Urandangi 4-mile Sheet which adjoins the Glenormiston Sheet to the north.

Outcrops occur below chert beds on top of small mesas and buttes in the main outcrop area of Precambrian rocks or beneath the cherts around the margin of the Precambrian outcrops. The formation is not conspicuous on the geological map because:

Thorntonia Limestone equivalent

sandstone, siltstone) Riversdale Formation
basal conglomerate)

Precambrian phyllite.

Plate 5: The section at locality G 122a, 4 miles north-east of Yarrie Rock Hole

(a) it is only a few feet thick at the most;

(b) it is easily eroded and rarely preserved except under the overlying chert bed;

(c) around the margin of the Precambrian rocks it is concealed by younger Palaeozoic and, in some places, Mesozoic sediments.

A typical section of the Riversdale Formation in the Glenormiston area crops out between the upper limits of the northern tributaries of Yarrie Creek, (4 miles north-east of Yarrie Rock Hole, see Plate 5):

Top of butte (G 122a locality):

Brecciated dark and light grey laminated chert bed with matrix of partly silicified lutitic material; algae and rare fragments of trilobites occur in the chert; age probably lower Middle Cambrian; (Thorntonia Limestone equivalent); thickness 10 feet.

Erosional break

Riversdale Formation:

Sandstone at base overlain by siltstone, red-brown to light grey and white "chalky"; well-bedded; friable; partly silicified; caverns formed in upper parts below the cherts; thickness 15 feet.

Conglomerate with pebbles of red medium-grained siliceous sandstone and rare chert; sandy matrix; partly silicified; thickness 10 feet.

Unconformity

Phyllite?, light grey to chocolate, with vertical cleavage; (Pre-cambrian).

A brown, coarse-grained sandy claystone, 1 foot thick, occurs above the conglomerate in some localities (including G 139) south-west of G 122a.

Noakes, et al., (1959) state that the Riversdale Formation "consists of conglomerate, red sandstone and a sandy dolomite, not more than 100 feet thick"; in the gully north of the main outcrop at the Ardmore Outlier where the formation was named, 30 feet of sediments above the red sandstone were seen to consist of siltstone and sandstone beds, pink and white, dolomitic to highly calcareous and chalky. The sediments in the Glenormiston area have obviously been leached of carbonate, but are of similar type.

Plate 6: Unusual structure in sandstone of Riversdale Formation at G 139 locality, 1 mile north of Yarrie Rock Hole.

The thickness of the Riversdale Formation in the Glenormiston area varies from a few feet to 25 feet; in some places the formation is missing and the Thorntonia Limestone equivalent (as chert) rests directly on Precambrian rocks.

No fossils have been found in these sediments. The nature of the structures in sandstone at G 139 locality, (see Plate 6), is unknown. They are circular corrugations in the surface of thin beds of sandstone and are preserved by layers of limonite between the beds; minor concentric lines formed by smaller undulations follow the corrugations.

The Riversdale Formation appears to have been laid down in shallow water over an eroded land surface of Precambrian rocks. The nature of the material, particularly in the basal conglomerate, suggests that sediment supply was from Upper Proterozoic and/or older Lower Cambrian rocks to the north. The formation has been correlated with part of the Camooweal Dolomite, (Öpik, 1956a) and is thought to be of Lower Cambrian age.

Middle Cambrian

Thorntonia Limestone equivalent.

The banded cherts of the Thorntonia Limestone equivalent form caps over the Riversdale Formation on mesas and buttes in the Precambrian outcrop area; they also overlie the Riversdale Formation in a narrow belt around the southern limits of the Precambrian outcrops. The formation is also developed to the north in the Urandangi 4-mile Sheet area where it is called Thorntonia Limestone: at Ardmore Outlier as dolomite mainly, with some chert; and as dolomite and chert in the upper Quita Creek area. Because of the discontinuous nature of the outcrops of this formation and the fact that the type area of the"Thorntonia Limestone is in the Camooweal Sheet area, over 150 miles to the north, it is referred to as "Thorntonia Limestone equivalent" in this report.

The banded light and dark grey cherts in the Glenormiston area are generally brecciated. Thin grey fossiliferous chert bands have been found at the base in some places. The cherts are thought to be, at least in part, secondary and derived from the silicification of carbonate rocks. Cherts which are similar in every respect including fossil content occur in the dolomite at Ardmore Outlier and change of lithology from dolomite into chert was seen along beds in some outcrops. The fact that dolomite does not occur in the

Glenormiston area suggests that the formation was never very thick here and has been completely silicified.

The thickness of the cherts is never more than about 10 feet in the Precambrian outcrop area. The upper contact, however, was not seen and maximum thickness is not known. The thickness of the formation at the Ardmore Outlier is 70 feet (Öpik, 1956a), and a thickness of about 200 feet is given by Öpik (in Hill and Denmead, 1960, p.102), although he notes that far less than this amount is usually preserved.

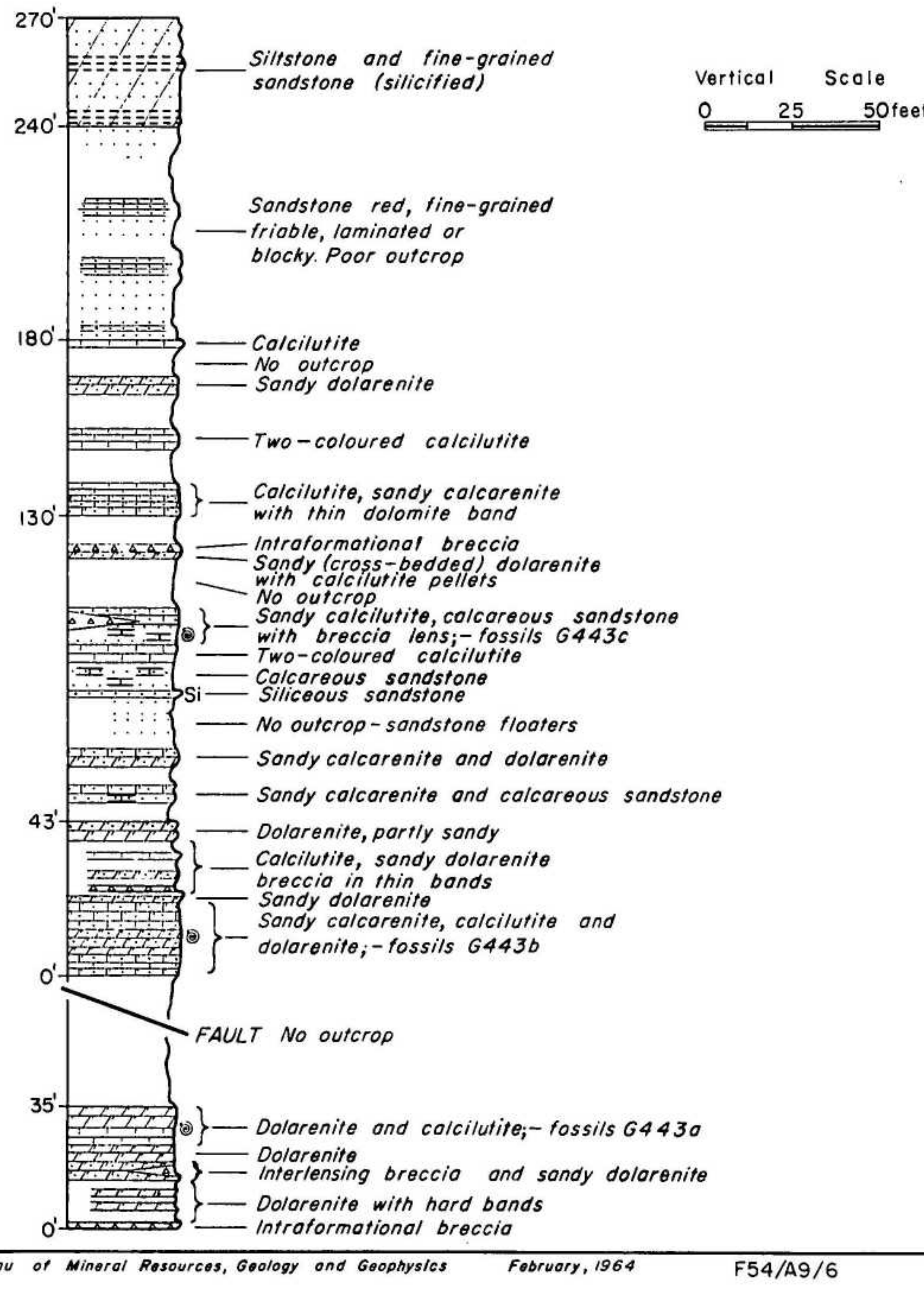
The formation rests on the eroded surface of the Riversdale Formation; the contact between the Thorntonia Limestone equivalent and Steamboat Sandstone was not seen in the north-east part of the Glenormiston area. The Thorntonia Limestone forms an irregular erosion surface on which the Blazan Shale was deposited to the north in the upper Quita Creek area, (Öpik, in Noakes, et al. 1959); the dolomites with fossiliferous cherts at Ardmore Outlier are replaced in the upper part and overlain by shales and chert of the Beetle Creek Formation and "Yelvertoft Bed", (Hill and Denmead, 1960, p.102).

Fossils include trilobites (Redlichia and others) and algae. They are common to the formation in the three outcrop areas at Ardmore Outlier, upper Quita Creek area, and north-east part of Glenormiston Sheet area.

Outcrops of the formation are not continuous and become thinner from Ardmore Outlier in the north to the Glenormiston area in the south. Thickness of sediment probably varied considerably over the irregularly eroded surface which formed the sea-floor at that time. The only remnants of the formation preserved after subsequent periods of erosion are those which were silicified or were protected in hollows in the floor.

The age of the banded cherts in the north-east of the Glenormiston area is thought to be lower Middle Cambrian. The sequence of dolomitic limestone with Redlichia (Thorntonia Limestone) followed by shale and chert (Beetle Creek Formation) in the Ardmore Outlier is lower Middle Cambrian (Öpik, op.cit.) and the banded cherts in the Glenormiston area are considered to be the equivalent of part of that sequence. The Thorntonia Limestone equivalent chert beds in the Glenormiston area are either capped by Mesozoic sediments or not covered in the narrow belt around the Precambrian area in which they occur. The basal parts of the next, younger outcropping Cambrian formations are generally at a lower topographic level and separated from the Thorntonia Limestone equivalent by a

Fig.2 SECTION OF STEAMBOAT SANDSTONE, G443-G444, MUNGEREBAR, WITH DIP 4° TO EAST-SOUTH-EAST



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gully(in which Mesozoic depositions occurred).

Steamboat Sandstone

The Steamboat Sandstone (defined by Noakes, et al, 1959) swings in a belt from the eastern part of Carandotta to the south and east around (but a short distance from) the margin of the Precambrian rocks in the north-east corner of the Glenormiston Sheet area. The belt is up to 7 miles wide. Near the eastern margin the sandstone dips under the basal Mesozoic sandstone and the two are hard to separate.

Lithology varies from calcarenite in the lower part to sandstone with some siltstone bands. Figure 2 shows the lithology in a section about 4 miles north-east of Andy's bore on Mungerebar between G 443 and G 444, (about ½ mile east of G 443). Some of the basal beds in the section are probably dolomitised calcarenite rather than "dolarenite" and result from dolomitisation at the time of the faulting in this area; dolomite was rare in basal beds elsewhere. Sandstone without carbonate rock predominates in the upper 90 feet. This is also the upper weathered and leached zone of the section.

The predominance of sandstone, therefore, may be a weathering effect. Lateral changes along beds from comparatively fresh sandy carbonate rock to weathered red, slightly ferruginous and kaolinitic? porous sandstone (with internal moulds of fossils preserved) have been seen in one or two places; step pyramids in sandstone in some places also suggest that the sandstone was at one time calcareous with hard and soft bands, and weathered to form bastion-type topography typical of banded limestone. However, changes from sandy limestone to sandstone, either laterally or in vertical section, can be explained as well by transgressions and regressions of shore-lines. Limestone which crops out at a few places around the northern edge of the Steamboat Sandstone is generally reddish, very sandy "salt and pepper" calcarenite (or calcareous sandstone in some places). At G 438 locality near the easternmost margin of the Steamboat Sandstone, the "salt and pepper" calcarenite is above flaggy grey calcarenite with brachiopods and thin bands of white calcareous shale. At G 136 locality between Duncan's and Smoky Creeks, thin bands of grey, fine-grained calcarenite with small red calcite crystals, small ?dolomite lenticles and flat slickensides, oolitic limestone, intra-formational limestone breccia and very sandy "salt and pepper" calcarenite occur below the predominantly sandstone part of the section. Similar beds occur farther west and south in the Steamboat Sandstone, and contained other sedimentary structures such as ripple marks and flowage laminations.

The main features of the upper sandstones are their fine-grained, laminated or thin-bedded, blocky properties. In many places surfaces of beds show well defined rip-wash marks. Laminated siltstone bands occur in some places with fossiliferous chert nodules and lenses. A thin section of a sample from G 121 locality (1½ miles south-east of Top Yarrie bore near the barrier netting fence between Carandotta and Mungerebar) shows a well-sorted, very-fine-grained sandstone with silica, iron oxide and rare kaolinitic? cement. It is a slightly porous rock. The quartz sand was fairly well rounded. Muscovite, green-brown tourmaline, and green biotite are minor constituents and some weathered feldspar was observed. Chert fragments and zircon? are accessories. A sample from G 133 locality (just north of the section G 443-G 444) was not as well sorted as above but otherwise very similar in thin section. (The samples from G 121 and G 133 are described in Appendix 1 together with a siltstone sample from G 427a). The upper part of the sandstone is silicified in this area and the resultant flat-topped hills of Steamboat Sandstone form the dominant high topography east and north of Andy's bore on Mungerebar.

The section between G 443 and G 444 has a thickness of 340 feet but faulting effects were seen at about 70 feet above the base just east of an area of no outcrop; Dr. Öpik (pers. comm.) has since pointed out that fossils from the basal (western) part of the section appear to be younger than those found at 75 feet above the base. Section west of the faulting therefore is probably younger, or a repetition of the upper parts of the topographically higher section to the east. The main faulting is thought to have been right lateral movement * with some minor reverse faults at right angles to it. Maximum measured thickness is therefore reduced to 270 feet + - (bottom and top not seen). The thickness given for the Steamboat Sandstone in the Urandangi area is 200 feet, 'top not seen', (Noakes, et al, 1959).

The Steamboat Sandstone probably represents in part at least a near-shore sandy facies of limestone beds which occur to the south and deeper in the marine environment. Some of the outcropping sandstone was probably originally calcareous and, as described above, it interfingers with or changes laterally into calcarenite. Apart from leaching

* This term is after Hill (1947) "Right lateral (in horizontal section side opposite observer is relatively and apparently to the right)".

effects, the uppermost beds appear to be more sandy than the lower beds; this suggests that the shoreline may have been receding during deposition of the Steamboat Sandstone.

The age of the Steamboat Sandstone is upper Middle Cambrian.

Middle to Upper Cambrian

Mungerebar Limestone

The Mungerebar Limestone has been briefly described and defined by Casey (1959); the type area extends from Chummy Tank, north-west for six miles towards Andy and Chummy Bores on Mungerebar. The limestone crops out in a belt around the south end of the Steamboat Sandstone outcrops. The belt is up to 8 miles wide in the Smoky Creek area and extends from McCabe Knob in the west to G 12 locality on Cottonbush Creek in the east. Outcrops in the eastern half are scarce as there is a cover of Mesozoic sediments, and Cainozoic sand and alluvium.

The lithology of the Mungerebar Limestone is distinctive; it is unlike the older Middle Cambrian Quita Formation limestone in the Urandangi area, but is similar in part to carbonate beds in the lower part of the Steamboat Sandstone. The greatest thickness seen in one section occurred between G 153 and G 155 localities, south east of Smoky Creek. At G 153 grey and dark grey, laminated to thin bedded, fine-grained calcarenite forms a small rounded hill about 10 feet above general level in this area. The top bed has a low dip to south-east. The calcarenite has coarse-grained patches which are richly fossiliferous. Fossils also occur in silicified laminae and chert biscuits in the calcarenite. The calcarenite is light brown to pink in part. Manganese dendrites are common; some limonite pseudomorphs (after pyrites) were noted. This bed underlies a small section 2 miles to the south-east at locality G 155, but by how much is not known. The lithology of the section is as follows:

Top - Fine-grained calcarenite to calcilutite, thin-bedded with soft interbeds; worm? burrows and fine irregular calcite "threads" through the rock; 12 feet thick;

As above but more soft material - outcrop rare; a thin calcarenite band with sandy lenses and fossils occurs near the top; it overlies a thin sandy oolite band; fossils: trilobite, gastropod, brachiopod fragments and worm? burrows; 13 feet thick.

calcilutite, grey, thin bedded to laminated hard and soft bands; very poor exposure; a 6 inch band forms a small bench at 10 feet from base and a 4 inch band forms a bench at top; the bench bands are very sandy oolite and are ripple marked; 20 feet thick.

Total thickness - 45 feet.

The only other section worth recording is that which outcrops just west of McCabe Knob. Its stratigraphic position with respect to the section described above is not clear. However, the lithology at G 153 is thought to be the same as that which occurs north-east of Chummy Tank (G 147) and just south of Chummy Tank (G 128); and fossil evidence suggests that these localities are below the McCabe Knob beds, (Öpik, pers. comm.).

The McCabe Knob section is as follows :

Top - 10 feet - Two-coloured grey, blue-grey calcilutite, thin to medium bedded; outcrop, generally poor;

4 feet - Intraformational limestone breccia altering to two coloured calcilutite; outcrop poor; G 409, G 161b, fossil horizon near base; partly dolomitic;

1 foot - Calcilutite, grey; with irregular burrows? filled with crystalline calcite;

6 feet - Calcarenite, coarse-grained oolitic, and intraformational limestone breccia; very sandy and shows cross-bedding; with lenses of calcareous oolitic fine-grained sandstone; G 161a horizon;

12 feet - Calcilutite, grey laminated, mostly soft, friable; sandy in part; very little outcrop; G 161 fossil horizon 6 feet above base.

Total thickness - 33 feet.

In the spur west of McCabe Knob there are three repetitions of the sequence described above, or parts thereof. These may be due to repetition by small faults, by small folds or by lithologies repeating. Exactly the same sequence can be found at a lower level to the south. The evidence favours repetition by faulting: small faults do occur in the McCabe Knob outcrops, and some dolomitisation has occurred. Therefore the thickness in the McCabe Knob area could only be given as 33 feet minimum.

If repetition by small faults, perhaps accompanying minor folding, is common to the whole Mungerebar area, the correlation of lithologies at G 153, G 147 and G 128 and the stratigraphic position assigned to them , should be regarded as approximate only.

All that can be said of thickness therefore is that the maximum seen in section is 45 feet and that fossil evidence suggests a minimum thickness of 78 feet.

The relation of the Mungerebar Limestone to the Steamboat Sandstone is not clear in outcrop but interfingering of the lowest beds of the Mungerebar Limestone with upper beds of the Steamboat Sandstone is suggested. The red and white sandstone and siltstone beds up to 30 feet thick which crop out in a narrow strip around the southern edge of the Mungerebar Limestone from McCabe Knob to Chummy Tank are regarded in this report as the leached basal beds of the Ninmaroo Formation; they appear to sit on an erosional surface of the Mungerebar Limestone, and younger rocks to the south are mainly dolomites of the Ninmaroo type. (Samples of these beds from 'localities' near McCabe Knob (G 408), and at Chummy Tank (G 129a,b) are described in Appendix 1). They could also belong to a separate formation between the Mungerebar Limestone and Ninmaroo Formation. This has been suggested from the evidence of fossils found in a pink siltstone near McCabe Knob by Frome-Broken Hill geologists, (Leslie, 1959; Taylor, 1959), and which could belong to the leached sandstone-siltstone sequence.
During the hiatus between deposition of the Mungerebar Limestone and the Ninmaroo Formation, another limestone deposit, the Georgina Limestone, was laid down but crops out only in the south part of the Glenormiston area. Fossils suggest that deposition of the Georgina Limestone closely followed the Mungerebar Limestone, but no contact has been observed and outcrops are separated by a 40 mile strip of Ninmaroo Formation.

The Mungerebar Limestone is rich in fossils in some thin beds with trilobites, brachiopods, gastropods, ?pelecypods, and small ?sponges. Öpik (in Hill and Denmead, 1960, p. 101) gives the age as late Middle Cambrian to early Upper Cambrian. Jones (1961) has also found ostracods in samples from G 8 locality 3 miles north-east of the junction of Smoky and Duncans Creeks.

The environment of deposition of the Mungerebar Limestone was one of shallow water which sometimes receded long enough to allow drying and cracking of the surface layer of sediment and formation of intraformational breccias. The presence of dark smelly shaly beds and pyrites suggests that anaerobic conditions existed.

Upper Cambrian

Georgina Limestone

The name Georgina Limestone was first published by Whitehouse (1931). As Öpik (1956a, p.3) points out, the name was proposed by Ogilvie who intended it for the Upper Cambrian Limestone on Glenormiston Station, but Whitehouse subsequently (1936) used it for the limestone in and around the basin of the Georgina River.

This usage was continued by David and Browne (1950, vol.1, pp. 115-118) and by the compilers of the Geological Map of Queensland (1953) and of the Geological Map of Australia (1953).

Subsequently Öpik (1956a, p.6 and p.22) restricted the use of the name to a fossiliferous Upper Cambrian Limestone on and near Glenormiston Station. In this paper, Georgina Limestone is used for this rock body which consists of sets* up to five feet thick of hard laminated and thin-bedded blue-grey and brown calcilutite and sandy calcilutite, and soft white marl. The calcilutite is current-bedded and ripple-marked and shows small scouring. Oolitic limestone, intraformational breccia, two-tone (grey-blue and grey-brown) limestone, sandy limestone and calcareous sandstone are interbedded with the main rock types. These minor constituents increase towards the top of the unit.

The thickness is about 100 feet,(Öpik, in Hill and Denmead, 1960); however, Tyson's No.1 Bore, nine miles south of Glenormiston Homestead, spudded in a horizon below the top of the Georgina Limestone and penetrated a thickness of 1,810 feet of carbonate rock before it was abandoned.

The Georgina Limestone occurs above the Mungerebar Limestone but the contact has not been seen. A disconformity exists between the Georgina Limestone and Ninmaroo Formation, (Öpik, 1963, p.16).

Topographically the unit is characterised by low rounded rises with poor outcrop. Its presence is usually indicated solely by plates of limestone scattered along the strikes of the harder beds.

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* The term 'set' is used, as defined by McKee and Weir (1952), for a group of conformable strata.

Where the formation is exposed near the remnants of the erosion surface on which Mesozoic sediments were deposited, both the limestone and marl beds tend to be brecciated and altered to chert, and in some places they are stained with iron and manganese oxides.

Upper Cambrian to Lower Ordovician

Ninmaroo Formation

The most widespread of Lower Palaeozoic formations in the southern part of the Georgina Basin is the Ninmaroo Formation it occurs in the adjoining Urandangi, Tobermory and Boulia Sheet areas and occupies a wide north-west to south-east belt in the Glenormiston area.

The name 'Ninmaroo Limestone' was originally used by Whitehouse (1936) for the Lower Palaeozoic carbonate rocks exposed on Black Mountain, Mount Ninmaroo and Mount Datson, east of Boulia. Casey (1959) restricted the use of the name to the upper part only of the carbonate sequence, and because of the large amount of dolomite in the sequence, altered the nameto 'Ninmaroo Formation'.

Because of its lithology, mainly of hard and soft bands of dolomite and limestone, its general sub-horizontal attitude, and the effects of minor faulting and strong jointing, the Ninmaroo Formation has a distinct topography of low stepped hills with a pronounced bastion appearance. The form has been modified in areas of long erosion, but where the old surface has been protected by younger sediments and later exhumed, the form is still preserved and is in part karst topography.

The geology of the Ninmaroo Formation was mapped during field work in two parts, east and west of the Georgina River. To the east, the rim of leached and weathered sandy and silty beds which is up to 30 feet thick around the southern margin of the Mungerebar Limestone, is regarded as the base of the Ninmaroo Formation; the lowest beds are sandy and were deposited on an erosion surface of the Mungerebar Limestone. The beds are shaly to thin-bedded and platy. Oolitic texture is visible in thin sections of the sandy material which is a silicified fine to medium-grained quartz sandstone with accessory chert and tourmaline (G 408, Appendix 1). Thick continuous sequences of Ninmaroo Formation do not exist in the area and the lithology can only be studied in random sections, The overlying beds are generally not as weathered and are composed of fine to coarse dolarenite with sandy or siliceous laminae showing current and cross-bedding, with some interbeds of sandy intraformational breccia and oolitic dolomite. The following section at G 142 locality (9 miles south of Roxburgh -Glenormiston Station boundary near the Georgina River stock route) occurs higher in the formation:

Top - Dolarenite, brown or two coloured light brown and brown; very-fine - to coarse-grained; sandy over top 4 feet; Fossiliferous ("mandibles") 4 feet from top; cherts at 10 feet from top; vughy in parts; thickness 26 feet (about 50% outcrop).

No outcrop - 10 feet.

Dolarenite, brown lutitic to coarse-grained; laminated to thick-bedded; mostly sandy showing cross -and current-bedding; some soft interbeds with travertine in surface outcrop; thickness 16 feet (80% outcrop).

No outcrop - 7½ feet.

Base- Dolarenite, brown to light brown; fine-grained; with sandy laminae; some beds with spherical silica blebs (1 - 2 mms.) common; stylolites common; some soft friable interbeds; 13½ feet thick.

Half a mile to the north, basal beds of the section overlie 10 feet of sandy dolarenite with oolites and intraformational breccia, and sandy calcarenite with limestone breccia. Beds possibly higher in the formation are exposed at G 410 locality, about 6 miles south of G 142. They include about 80 feet of hard and soft beds of dolarenite, as above, sandy in places, with chert plates and rolls (with concentric laminae) common in the bottom 30 feet; a few fossiliferous bands and a silicified coquinite in the top 10 feet; fossils: ribeirioids and "mandibles". On Herbert Downs in the south of the area, sandy dolarenite, intraformational breccia, algal limestone (G414) oolitic limestone with green calcite fragments are included in the lithology. Laminated and blocky sandstone lenses with moulds of trilobites and other fossil fragments occur in some surface outcrops. Laminated white to buff siltstone lenses which show microstructures crop out in the western part of Alderley, just west of Seven Mile Waterhole on Cottonbush Creek. Various lithologies from outcrops east of the Georgina River are described in detail in Appendix 1.

The nature of the soft interbeds which are so common in the Ninmaroo Formation is shown in the chemical analyses of two samples; G 53 from 10 miles north-west of Roxburgh Downs, and G 142a from the basal 13½ feet of the section (above). These are given in Table II -

Table II - Results of some chemical analyses by A. McClure, B.M.R. Laboratory.

	G53	G142a
Moisture at 108°	0.17%	0.08%
Loss on ignition (1000°)	40.50	31.28
SiO_2	9.72	26.34
Al_2O_3	2.94	4.81
Fe_2O_3	0.96	0.84
TiO_2	trace	trace
CaO	25.20	20.20
MgO	17.90	13.02
Na_2O	2.20	1.43
K_2O	1.17	2.74
Total	100.59	100.66

The analyses show that the deposits from which the samples were taken are composed mainly of carbonates with very little clayey material, and these deposits therefore appear to be more in the nature of evaporitic clastic facies. These two samples are thought to be typical of the soft interbeds in the Ninmaroo Formation in the Glenormiston Sheet area north of Pituri Creek and east of the Georgina River.

The Ninmaroo Formation has been divided and mapped as four separate members between the Toko Range and Pituri Creek in the south-west of the Glenormiston area, and as an undivided unit elsewhere west of the Georgina River. Members 1 to 4 correspond to the Units Є-2 to O1-5 of Pritchard, (in Hill and Denmead, 1960).

Member 1 - This forms the lowest part of the Ninmaroo Formation and is exposed only around the core of Georgina Limestone in the anticlinal structure opposite No.16 (Unjiliguna) Bore, eight miles west of Glenormiston Homestead, and in scarps below Mesozoic sediments at the eastern end of the Ten Mile Hills.

Plate 7: Algal colonies in the Ninmaroo Formation

It consists of thick to massive sets of white and brown laminated thin and medium-bedded fine and medium-grained dolarenite with minor amounts of fine and medium-grained dolomitic quartz sandstone. At the top and bottom of the formation there are medium interbeds of blue thin-bedded calcilutite. It is estimated to be 200 feet thick. A detailed description of the upper 27 feet is given in Section G 511 in Appendix 2.

Member 1 appears conformable on the Georgina Limestone but a disconformity exists between them.

No fossils other than possible algal structures have been found in Member 1.

Member 2 - This member is formed mainly of calcilutite and is more resistant to weathering than adjacent dolomite formations. It therefore crops out as moderate rises and hills along the north side of Member 1 and north of the Ten Mile Hills.

It consists of sets of up to ten feet thick of two-tone grey-brown and grey-blue crudely thin-bedded calcilutite, grey-brown and grey-blue thin-bedded calcilutite, and minor amounts of white thin-bedded marl, grey-brown thin-bedded oolitic limestone, white thin-bedded medium-grained calcarenite, grey-blue and grey-brown intraformational calcilutite conglomerate and algal colonies, (see Plate 7). It is estimated to be 350 feet thick. Member 2 is described in part in detailed sections from localities G 511 and 514 in Appendix 2.

No fossils other than algae have been seen in the formation.

Member 3 - Member 3 forms a belt around Member 4 and south of Pituri Creek, extending from west and north of the Ten Mile Hills to just south of Linda Downs. It forms low rounded rises with poor outcrop.

Outcrops actually follow in a belt from the east around to the west side of the Toko Range and consist mainly of alternating thick and massive hard and soft sets of sediment. Only hard bands occur in outcrop. On the eastern side there are laminated, thin and medium-bedded brown and white fine to coarse-grained dolarenite and fine-grained well sorted and rounded dolomitic quartz sandstone. On the western side both the sets and the bedding within the sets tend to be thicker, and the dolarenite is generally medium-grained. It is estimated to be 200 feet thick. A section of 91 feet measured at locality G 518 is shown in Appendix 2, and a sample of dolomitic sandstone from that section is described in Appendix 1.

Large nautiloids have been found at Lake Wonditti in the Glenormiston area and trilobites found thirteen miles south-east of Lake Wonditti are listed by Öpik (1959), and are thought by him to be of upper Upper Cambrian age.

Member 4 - This member also flanks both sides of the Toko Range in a belt within the upper limits of Member 3. On the eastern side of the range in the Glenormiston area it forms a low ridge, but to the west where it is less resistant to erosion, it occurs as low rises and hills.

The unit consists of sets of mottled brown and brown-grey laminated and thin-bedded calcilutite with lesser amounts of brown and grey oolitic limestone, brown laminated and thin-bedded calcilutite and sandy calcilutite, brown very-fine and fine-grained calcarenite and sandy calcarenite, and of algal colonies. It is estimated to be 400 feet thick. A section of 235 feet, measured at locality G 519 is shown in Appendix 2, and mottled "two-tone limestone" is described in Appendix 1,

The member is conformable in the Glenormiston area with the overlying Kelly Creek Formation.

Nautiloids,ribeirioids and gastropods, similar to those found in the Lower Ordovician (Tremadocian) part of the Ninmaroo Formation which crops out in the Boulia area, are found in the unit.

Apart from the areas of alluvial and sand deposits, the area north of Pituri Creek and west of the Georgina River is mainly occupied by the Ninmaroo Formation. Outcrops are similar to those east of the GeorginaRiver and correspond mainly with Member 3 which crops out south of Pituri Creek. Apart from strong jointing, the beds show little structure and are mainly sub-horizontal.

In Upper Cambrian-Ordovician times, the sea covered a belt from Cambridge Gulf in the north-west across the Northern Territory and into the Glenormiston area,(Öpik,1956b). The large volume of dolomite suggests that at the time of the Ninmaroo Formation deposition, this area was covered by shallow seas, possibly in periodically barred basins or embayments (not unlike conditions applying in shallow lagoons and in the Coorong in south-east South Australia at present, but on a larger scale, see Alderman, 1959). Such conditions would allow accumulation of dolomite in the water and subsequent precipitation. Also, much carbonate was undoubtedly introduced into the sea from pre-existing lower Palaeozoic dolomites and limestones (both in solution and as detritus). Although both clastic and syngenetic dolomite may have been originally deposited, further dolomitisation probably occurred during diagenesis and by later metasomatism.

Lower to Middle Ordovician

Toko Group

A sequence of five units, which occurs above the Ninmaroo Formation in the Toko Range area, was called 'Toko Beds' by Casey (1959). This name was to be used until such time as the formations had been named and defined. They have now all been named - three have been defined by Casey (in Appendix A of Smith, 1963), and the other two are defined and described hereunder. The sequence was renamed 'Toko Group' by Casey (in Smith). The formations are the Kelly Creek Formation (at the base), Coolibah Formation, Nora Formation, Carlo Sandstone, and Mithaka Formation. The thickness of sediments in the group is just over 1,000 feet.

Kelly Creek Formation

This formation was first described in an unpublished report by Smith and Vine (1960). It is composed of a lower quartz sandstone unit up to 390 feet thick and an upper dolomite, 160 feet thick. The name is derived from Kelly Creek at latitude 22°30' South, longitude 138°24' East, in the Glenormiston area. It is exposed in a belt east of, and parallel to the scarp of the Toko Range . In general, the formation has been eroded into rubble-covered hills, buttes and cuestas.

Best exposures of the formation were seen in the Tobermory Sheet area to the west. The lower sandstone unit consists of white and brown laminated, thin and medium-bedded, very fine to fine grained quartz sandstone, in part glauconitic, with some interbeds of green laminated siltstone in lower to middle parts and a calcarenite lens near the top; some cross-bedding is present. Some beds, particularly thin coquinite bands have been silicified. The thickness of 390 feet given for the lower sandstone unit was measured at Gaphole Creek. (T68 locality), just west of the south-west corner of the Glenormiston area. The top part consists of alternating soft and hard beds of dolarenite, interbedded with some marl and chert; the thickness at Gaphole Creek is 160 feet. Details of the T68 section, together with details of the upper dolomitic part at T221 and T215, and lower sandstone unit at T212 and T246 localities are given in Appendix 3. The thickness of the formation in the Glenormiston area is not known, but just south, in the Mount Whelan Sheet area, it is estimated to be 250 feet thick along the Mulligan River.

In the Glenormiston and Tobermory areas, the base of the Kelly Creek Formation appears to be gradational with the upper parts of the Ninmaroo Formation. Casey (in Smith, 1963), however, states that the base of the Toko Group (viz. base of Kelly Creek) overlies the Ninmaroo Formation with an "unconformity" - essentially an erosional break, (Casey, pers. comm.), and therefore referred to herein as a disconformity. The Kelly Creek Formation is overlain conformably by the Coolibah Formation.

Brachiopods, nautiloids, ribeirioids and trilobites have been found in the Kelly Creek Formation, as well as some tubular structures attributed to organisms. The fossils are best preserved in the chert and silicified beds. The age of the formation is upper Lower Ordovician.

Coolibah Formation

The name Coolibah Formation was used in the unpublished report by Smith and Vine (1960); it derived from Coolibah Dam at 22°49' South, 137°44' East in the Tobermory area. The formation consists mainly of medium and thick sets of blue-grey and brown-grey thin-bedded calcilutite and green-white marl. Some of the calcilutite beds are oolitic and some have mottlings of brown coarse-grained carbonate which has been susceptible to silicification. Minor amounts of yellow and white chert and brown, thin to medium-bedded, medium to coarse-grained calcarenite and dolarenite which is sandy in part occur in the unit. Limestone from the Coolibah Formation at G 236 is described in Appendix 1. The formation is gradational with the overlying and underlying formations.

The Coolibah Formation is only 27 feet thick in the type section at Gaphole Creek, but up to 47 feet thick at T 238, T 239 localities elsewhere in the Tobermory Sheet area (see Appendix 3); in the Tarlton Range area of Tobermory, however, this formation is missing entirely and the Nora Formation rests directly on the Kelly Creek Formation. In the

Glenormiston area the Coolibah Formation extends in a belt $\frac{1}{2}$ to 2 miles east of the Toko Range scarp. It forms a drainage divide of low hills and cuestas. No sections could be measured here, but the thickness is estimated to be 100 feet. The thickest known section of 520 feet occurs at W271 on the western limb of the Toko Syncline in the Mount Whelan Sheet area.

The formation is richly fossiliferous, containing coiled and straight nautiloids, gastropods, ribeirioids, tubular structures and horn-shaped fossils ?corals. Its age is uppermost Lower Ordovician.

Nora Formation

Overlying the Coolibah Formation is a predominantly silty and sandy sequence which has coquinite beds near its base. This sequence has been called the Nora Formation (Smith and Vine, 1960; and defined by Casey, in Smith, 1963). It is exposed in the valley bordering the Toko Range and in the basal part of the Toko Range scarp.

In the Glenormiston area, the formation consists of grey-brown and tan sandstone with interbeds of calcarenite and coquinite overlain by green, brown, purple gypsiferous siltstone and sandstone. The lower sandstone is laminated to thin-bedded, fine-grained, well-sorted and composed mainly of well-rounded quartz grains. The thickness of the interbedded sandstone, calcarenite sequence is about 120 feet; one coquinite band near the base is up to 50 feet thick in parts. The overlying sequence of green to purple siltstone and sandy siltstone with interbeds of thin-bedded to laminated, very fine to fine-grained, well-rounded, and well-sorted quartz sandstone is about 70 feet thick. Sandstones in this upper sequence contain clay and phosphatic pellet beds. A measured section of the Nora Formation at G 261 is given in Appendix 2. The section is thicker, up to 400 feet, at W 272 locality in the western limb of the Toko Syncline.

The Nora Formation is richly fossiliferous with nautiloids, brachiopods, pelecypods, trilobites, sponges, and bryozoa. Its age is Middle Ordovician.

In the Glenormiston area, the Nora Formation is conformable with the underlying Coolibah Formation and overlying Carlo Sandstone.

Carlo Sandstone

The Carlo Sandstone is defined by Casey (in Smith, 1963). The name is used for a sequence of 200 to 300 feet of Middle Ordovician red and brown thick-bedded, current-bedded sandstone with a prominent clay pellet bed at the base. The sandstone forms the upper part of the scarp of the Toko Range and the plateau surface. The name is taken from Carlo Station in the Mount Whelan Sheet area; the station homestead is at latitude 23°30' south, longitude 138°40' east.

The Carlo Sandstone is estimated to be from 200 to 300 feet thick and consists of red, brown and white thin to thick-bedded, fine to medium-grained quartz and feldspathic quartz sandstone with a few thin beds of siltstone; an abundance of clay pellets occurs near the base. Current bedding is common. A measured section of 65 feet above the Nora Formation at G 261 locality is given in Appendix 2.

Most fossils were found in the upper part of the formation. They include nautiloids, brachiopods, pelecypods and some U-tubes thought to be organic in origin. Casey also records worm trails and tracks and trilobite (?Asaphid) casts. The age of the Carlo Sandstone is Middle Ordovician. It grades upwards into the Mithaka Formation.

The nature of the sediments suggest that the energy level of sediment deposition during Carlo Sandstone time was higher than for underlying sediments in the Toko Group.

Mithaka Formation

The topmost unit of the Toko Group exposed in the Glenormiston area is the Mithaka Formation. The name was first used by Smith and Vine (1960) and defined by Casey (in Smith, 1963); it is taken from Mithaka Waterhole on Gaphole Creek on the central western side of the Toko Range. The unit is exposed in the scarps of small buttes and mesas on the top of and within the scarp line of the Toko Range.

The formation represents a return to quieter conditions of sedimentation similar to those in which the Nora Formation was deposited. The main rock type is a soft, brown fossiliferous, gypsiferous siltstone which is interbedded with flaggy, brown laminated and thin-bedded fossiliferous quartz sandstone. Some calcareous siltstone beds were also noted. The thickness ranges from 200 to 400 feet. The proportion of sandstone in the unit increases towards the top where there is also a small amount of impure calcareous coquinite. Sedimentary structures and tracks and trails are abundant on the surfaces of the sandstone beds. A section of 50 feet of

Mithaka Formation measured between localities G 29 and G 30 is given in Appendix 2.

Fossils are not as abundant in this unit as in the Nora but they are of similar types: nautiloids, trilobites and sponges including Receptaculites, and with rarer pelecypods and brachiopods. Jones (1963) also records conodonts from the Mithaka Formation, (see Appendix 4). The formation is Middle Ordovician in age.

The distribution in the Glenormiston Sheet area is confined to a small area west of the Toko Range in the south-western corner. Here it is overlain unconformably by undifferentiated pelletoid sandstone of possible Ordovician or Devonian age.

Undifferentiated Ordovician or Devonian

Five feet of red and brown medium-bedded, fine grained quartz sandstone caps the Mithaka Formation in the south-west corner of the Glenormiston Sheet area. Clay pellets are common. This forms Unit Om 11 of Pritchard, (in Hill and Denmead, 1960), and may reach 450 feet in thickness in outcrops which cross the area of the junction of the Hay River and Mount Whelan Sheets, (see Undifferentiated Ordovician in Smith, 1963).

This formation has been mapped as Undifferentiated Ordovician or Devonian because of its position above the Mithaka Formation and of its deformation in the Toko Syncline which may have been coincident with the Kanimblan orogeny. The evidence on the age of deformation was based on the Dulcie Sandstone, (Smith, 1963a), which is concordant with folded older Palaeozoic rocks of the region, and which is Devonian in age.

Since the mapping has been completed, Jones (1963, Appendix 4) has found fish-scales of Upper Silurian - Lower Devonian age in the shot-hole samples from this formation.

?PERMIAN

At Blue Mountain 11 miles west of Roxburgh Downs homestead, boulder to pebble-size gravel was found weathering out from the slopes of small rounded hills. It appeared to be associated with green-brown laminated siliceous shale in a small creek bank outcrop, and was overlain by white leached and weathered silty beds.

The gravel was mainly of silicified sandstone of the type which crops out in the Ordovician formations in and around the Toko Range, and some blocks were fossiliferous. Tomlinson (1959) identified boulders of the Kelly Creek Formation and Nora Formation in samples from G 300. The cobbles and pebbles have various shapes, some like flat-irons, and some showed "chatter" or impact marks; rare pebbles are striated. These features do not specifically indicate a glacial origin for the sediments, but when considered together with the associated laminated shale, a glacial origin can be considered probable. Because of their probable glacial origin and the age of some of the erratics, the sediments are thought to be Permian, and similar to the scattered pebble patches elsewhere in the west part of the Glenormiston area (but too small to be mapped), and to the south-west in the trough of the Toko Syncline. The thickness of the ?Permian sediments is not known but would not be more than a few feet at Blue Mountain. They are much thicker in the Toko Syncline area.

The pebble beds therefore thin to the north and north-east from the Toko Range area, and are obviously derived from there. Such pebble beds, particularly those involving long distances of transport, are rare in the basal Mesozoic beds of the region around the western to north-western side of the Great Artesian Basin, and furthermore, the direction of transport of the pebbles from the Toko Range to Blue Mountain is away from the Basin. This evidence does not favour a Mesozoic age for the beds.

Outcrops are basically small outliers in the belt of Ninmaroo Formation which extends across the Glenormiston area. Their base was not seen and the relationship to the Ninmaroo Formation is not known; elsewhere these deposits appear to be unconformable on deformed lower Palaeozoic rocks. The overlying beds at Blue Mountain are typical of the weathered Mesozoic sediments elsewhere in the Glenormiston area, and show relict gypsum structures. They may be deeply weathered shaly beds of ?Permian age but because of their general appearance they have been mapped as ?Mesozoic.

Fragments of silicified fossil wood were formed among the rubble weathered out from the low hills at Blue Mountain, but their age was indeterminate.

MESOZOIC

Outliers of Mesozoic strata occur in the dissected plateau area in the eastern half of the Glenormiston area and in scattered small outcrops elsewhere. Two formations are recognisable in the eastern half: the Longsight Sandstone and the Wilgunya Formation. Undifferentiated Mesozoic sediments referable to both or one of these formations occur at Blue Mountain in the centre of the Glenormiston area and in the Ten Mile Hills on its south edge. A sample of Mesozoic Sandstone from the Ten Mile Hills (G 211) has been described in Appendix 1.

Longsight Sandstone

A sequence of conglomerate and sandstone resting unconformably on Precambrian and Lower Palaeozoic rocks is exposed in buttes and mesas in various parts of the Glenormiston area. In the eastern part of the area it is distinguished from an overlying leached siltstone unit and called the Longsight Sandstone, first described by Casey et al, (1960) from the Boulia area to the east, and defined by Casey (1959).

Sandstones and conglomerate , generally micaceous, form the dominant lithology; they are commonly red ferruginous in outcrop. White and mottled red, purple and yellow shaly siltstone and claystone occur in thin bands in some outcrops. Silty beds in which irregular networks of small burrows occur are common in lower beds of the formation. Basal conglomerates, with locally derived material including fragments of Ordovician rocks, are found in some localities. A prominent glauconitic to limonitic, pebbly coarse-grained sandstone which is generally fossiliferous is commonly found near the top of the Longsight Sandstone; it may be up to ten feet thick and form a strong bench.

The thickness of the Longsight Sandstone in the Glenormiston Sheet area is generally less than 100 feet. The lower contact is unconformable on Lower Palaeozoic or Precambrian rocks. Outliers of the formation which occur in a belt just east of the Georgina River and south-east of Roxburgh Downs Homestead have been slickensided and contorted by apparent slippage on the steep scarps on the old Ninmaroo Formation erosion surface. A dark brown limonite and a black manganese-rich layer at the base of the Longsight Sandstone is common above Lower Palaeozoic rocks in outcrop. The formation changes conformably upwards into the Wilgunya Formation.

Fossils can be divided into two groups: those found in basal beds which are plant remains, and those which occur in the prominent limonitic bed near the top which are marine. Plant remains include Taeniopteris spatulata, Cladophlebis australis, Elatocladus cf. planus, Pterophyllum fissum, Ptilophyllum pecten (?) and Ptilophyllum acutifolium. A lower Jurassic age was suggested by White (1959) for beds in which Pterophyllum fissum is abundant, on the basis of its occurrence in the Rajmahal Group in India. The Rajmahal Group, however, is no longer regarded as Liassic but as Neocomian (Arkell, 1956). Fossils from the limonitic sandstone bed include Cyrenopsis sp., Fissilunula clarkei?, Mytilus inflatus, Thracia?, Natica, and belemnite moulds. The age, therefore, is Lower Cretaceous, and fossils of Roma Formation aspect appear near the top.

The Longsight Sandstone is mostly continuous south of the Boulia and Glenormiston areas and forms the basal sandstone and main aquifer of the Great Artesian Basin in Western Queensland.

Wilgunya Formation

The Wilgunya Formation may be divided into two parts: a lower part which contains fossils of Roma Formation aspect, and an upper part, (with a fossiliferous limestone bed, the Toolebuc Member, at the base), equivalent to the Tambo Formation of Whitehouse, (1955). It is the lower part which extends from the Great Artesian Basin area into the Glenormiston Sheet area and caps the Longsight Sandstone in most of the eastern half.

The lithology of the lower part of the Wilgunya Formation is mainly grey mudstone where found fresh in bores in the Great Artesian Basin. Outcrops in the Glenormiston area have been deeply weathered and leached, and appear as white or mottled purple, red and yellow silty rocks, in parts silicified to a porcellanite. The rocks are sandy in parts, and contain relict gypsum structures; thin bands of limonite (altered limestone?) are common. The thickness of the formation in the eastern part of the Glenormiston Sheet area is generally less than 40 feet but may be up to 100 feet. The lower parts are conformable on the Longsight Sandstone or unconformable on older rocks not covered by the Longsight Sandstone; the formation caps buttes and mesas and is not covered, except in part by sand.

Crespin (1960) identified arenaceous foraminifera and indeterminate radiolaria from the Wilgunya Formation in the Glenormiston area; the age of the formation is Lower Cretaceous.

Tertiary

The main events during the Tertiary geological history of the region were:

(1) the deposition of the sandy Marion Formation
(2) deposition of lacustrine limestone, the Austral Downs Limestone
(3) a period of widespread silicification.

A period of deep weathering(lateritisation?), which formed a lateritic-type profile, preceded deposition of the lacustrine limestone, but it is not certain whether it occurred before or after the deposition of the Marion Formation.

Marion Formation

About 25 feet of silicified sandy rock forms a capping over Lower Cretaceous sediments in the Boulia and Mount Whelan areas adjoining the Glenormiston Sheet area to east and south. This is a tough rock with angular sand fragments in an opaline silica matrix; on weathering it breaks down and forms pebbles with a brown shiny coating, locally called "gibbers". The only outcrops of Marion Formation known from the Glenormiston area are two patches at the eastern edge in which only the pebbles occur.

The formation is named and defined by Casey, (1959), and further described by Paten, (in Hill and Denmead, 1960; and Paten, in press).

Austral Downs Limestone

The Austral Downs Limestone, named by Noakes and Traves (1954) in the Urandangi and Sandover River map areas, extends into the Glenormiston Sheet area where it crops out within the valleys of the Georgina River and Pituri Creek. This section has been written mainly by R.J. Paten.

Except for the area on the western side of the Georgina River at Roxburgh Downs where there are scattered small plateaux, ridges and hills, the outcrop of the Austral Downs Limestone is an extensive elongated low plateau up to twelve miles wide. It was deposited in stream channels cut in the Ninmaroo Formation and is flat lying and up to 30 feet thick.

The formation is predominantly calcareous consisting of cream and grey limestone, impure limestone, limestone conglomerate and chalcedony; the limestone is in part recrystallised and calcite-veined. In places the bottom ten feet of the formation contains material redistributed from an underlying ferruginous soil and varies from a sandy pisolitic ferruginous soil with calcite veins to an impure limestone with disseminated rounded ferruginous fragments and iron oxide-coated quartz grains. White and blue tinted translucent chalcedony occurs throughout the sequence although it is usually restricted to the top fifteen feet.

The formation contains algae (charophytes), ostracods, and foraminifera; gastropods are known from other areas. The foraminifera which were globigerine and rotaline forms (Crespin, pers. comm.) were obtained from a small plateau near the junction of Manner Creek and the Georgina River. Ludbrook(1953) reports rotaline foraminifera in association with ostracods and charophytes from sediments in Lake Eyre which is a periodic brackish water lake in South Australia. This suggests a similar environment - continental brackish lacustrine conditions - for the Austral Downs Limestone.

Silicification

A period of silicification followed deposition of Tertiary lacustrine limestones and is responsible for the chalcedony capping and infiltration into these rocks, and to the siliceous cappings of rocks of various ages throughout the Glenormiston area. The siliceous caps to plateaus and mesas in this area are part of the 'duricrust' (Woolnough,1927) which is widespread in western Queensland and central Australia generally.

Lateritisation(?)

Much outcrop in the southern and eastern parts of Glenormiston and in adjoining Sheet areas appears to have been lateritised, and was later silicified. The time of lateritisation in relation to the time of deposition of the Marion Formation, has not been finally established - Paten (in press) considers that the Marion Formation was deposited after lateritisation, whereas Reynolds, (in Reynolds, Olgers and Jauncey, 1961), regards the Marion Formation as lateritised.

Paten's evidence may be summarised as follows:

(i) the Marion Formation has been observed unconformably overlying the uneven eroded surface (mottled zone) of the lateritised Wilgunya Formation at a number of localities in adjacent areas;

(ii) valley fill occurs on a small scale, and fragments of lateritised sandy siltstone (presumed to be from the underlying lateritised Wilgunya Formation) occur near the base of the Marion Formation.

Reynolds independently noted in the Springvale Sheet area that a transition occurs upwards from leached Wilgunya Formation mudstones into leached and mottled sandy siltstone which contained lenses of coarse gritty and cherty sandstone of the Marion Formation in the upper part. This suggested that the mudstones of the Wilgunya Formation were reworked and mixed with sand at the time of deposition of the Marion Formation and that lateritisation occurred later. Unconformable relationships between the two formations, such as Paten reports, occur elsewhere, but Reynolds considers that in some, if not all of these exposures, the following sequence of events took place:

(a) lateritisation occurred after deposition of the Marion Formation;

(b) it affected the whole unconformable section;

and

(c) silicification has subsequently masked the effects of lateritisation in the top of the section.

The valley-fill effect described by Paten is thought by Reynolds to be due to a sub-soil breccia development occurring below a ferruginous zone at the time of lateritisation; this effect was also seen in the "paper-weight breccias" formed in lateritised Upper Proterozoic rocks in the northern part of the Boulia Sheet area. Also, the breccia fragments noted by Paten are characterised by scattered sand grains and are unlike the typical sediments of the Wilgunya Formation in this respect; some mixing of sediments of the Wilgunya and Marion Formations is therefore suggested for these occurrences also.

PLATE 3

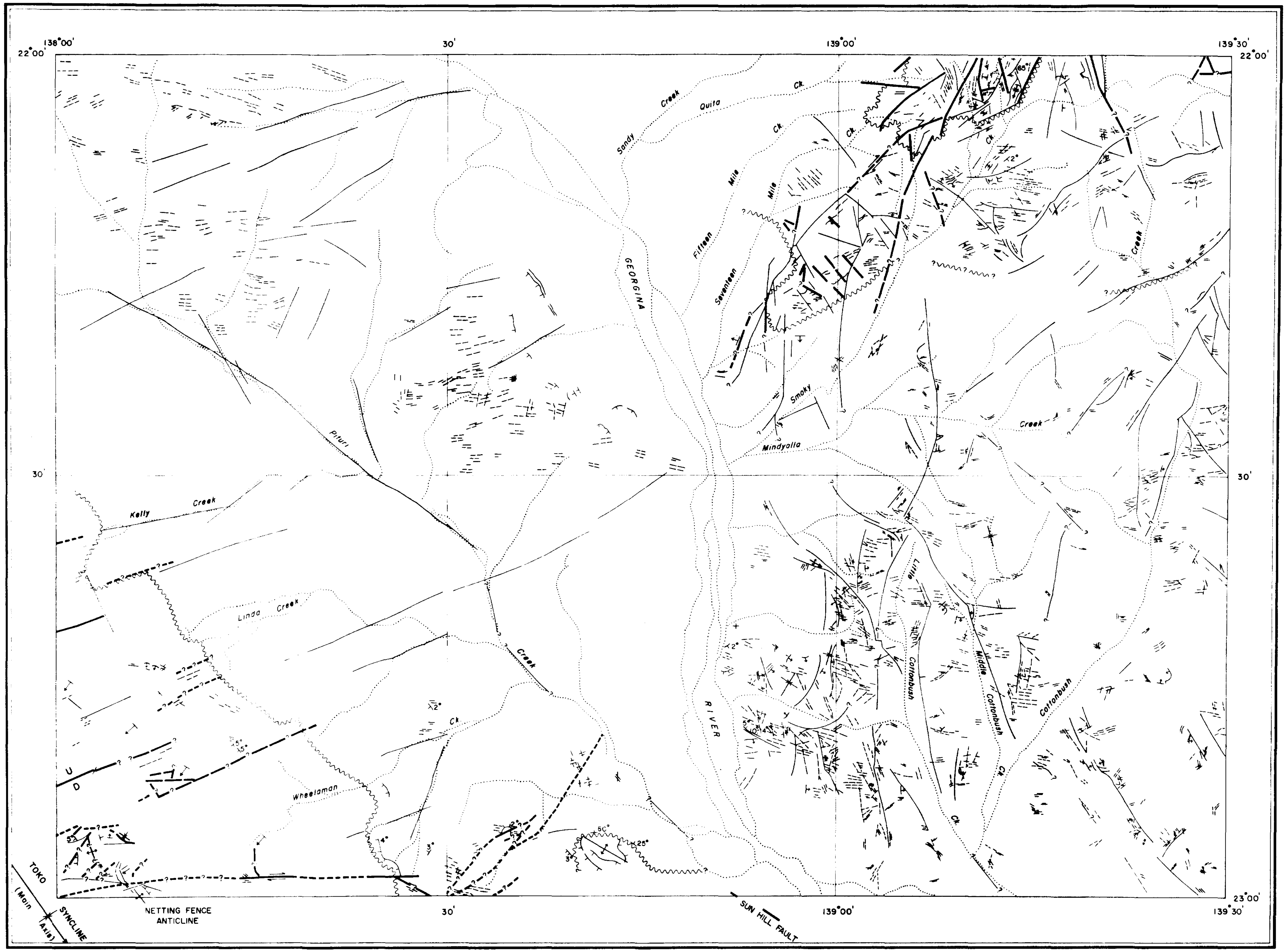
GLENORMISTON

STRUCTURAL MAP

SCALE 1:500,000

5 0 5 10 15 MILES

5 0 5 10 15 20 25 KILOMETRES



Rivers and creeks

Unconformity

Strike and dip of strata

Horizontal strata

Dip slope

Trend of bedding showing direction of dip

Strike and dip by air-photo interpretation, dip < 15°

Anticline

Syncline

Fault

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

Lineament

Joints

Bureau of Mineral Recources, Geology and Geophysics. Nov. 1963

F54/A9/2

A C B

Reduce AB (60 cms) to AC (30cms)

Cainozoic Undifferentiated

The Cainozoic cover in the Glenormiston area is brown loamy soil, black soil, sandy soil and sand.

In general the black and brown soils are found in the valley of the Georgina River and lower reaches of main streams. They are therefore mostly alluvial deposits. These soils tend to crack badly in dry conditions, and travel over black soil plains can be very rough.

The Longsight Sandstone in the east, and Ordovician sandy formations in the west give rise to sandy soil areas. Portions of the Marion Formation which were not fixed by induration in the laterite profile or by silicification probably also contributed to sandy areas. The only dunes are of the sand ridge type and occur ten miles west of Badalia; they have a north-west to south-east orientation. The sands are generally orange-brown to red in colour.

Lime deposits cement the banks of the Georgina River up to 10 feet above water level at the waterhole near Roxburgh Downs Homestead; the following notes on the deposits are by R.J. Paten. Cementation occurs in bands which may dip towards the river at angles of up to 30 degrees cutting the normal fluviatile structures. The hard bands contain irregularly branched, hard, rod-like structures which range up to 1½ inches in diameter and 2 feet long; they are not lime filled channels left by root decay. These bands are formed by water seepage from the banks, the water having seeped through alluvium or from the unconformity between the Ordovician and Tertiary carbonate formations. Fragments of fresh water mussel shells similar to those of forms living in the river have been cemented into the bands. Bands composed of gypsum crystals up to 1 inch long are also common in the alluvium.

STRUCTURE

The Glenormiston Sheet area is in the southern part of the Georgina Basin, a basin bounded by Lower Cambrian to Precambrian rocks to the east, north and west, and plunging south below sediments of the Great Artesian Basin. A segment of the Precambrian mineral belt of north-western Queensland extends into the north-eastern corner of the Glenormiston area.

Major structural deformation occurs in two areas: the north-eastern Precambrian area, and the Toko Range area in the south-west corner.

The Precambrian rocks are strongly folded and faulted low-grade metamorphics intruded by massive granite. The metamorphosed Eastern Creek Volcanics are folded on roughly north-south axes but few folds can be traced because of the extensive faulting, some of which is believed to be strike-faulting. Dips are mostly 60° or greater. Cleavage is generally strong. Lineations (striations, small plications, and quartz rods) are common and pitch mainly at 50° North, or steeper, on cleavage planes. On the other hand, shallow south-plunging lineation exists in the gneisses of the Sybella Granite outcrop. In the sheared, irregularly-plunging, drag-folded syncline east of Spring Creek, feldspathic mica schist dips under quartzite on the eastern rim; amphibolite, epidote and pink granite occupy the trough.

Faulting in the Precambrian area varies from mainly meridional in the east part to south-south-west and south-west in the western part. The largest fault is probably the one which crosses the upper reaches of Duncan Creek. The fault continues to the north-north-east for nearly twenty miles on the Urandangi Sheet area and is reflected in Lower Palaeozoic rocks for ten miles to the south of the Precambrian rocks. Structure in the Precambrian rocks is mainly Lower Proterozoic in age. However the unusual east-west fault trend at the north edge of the Sybella Granite is thought to result from later Palaeozoic movement.

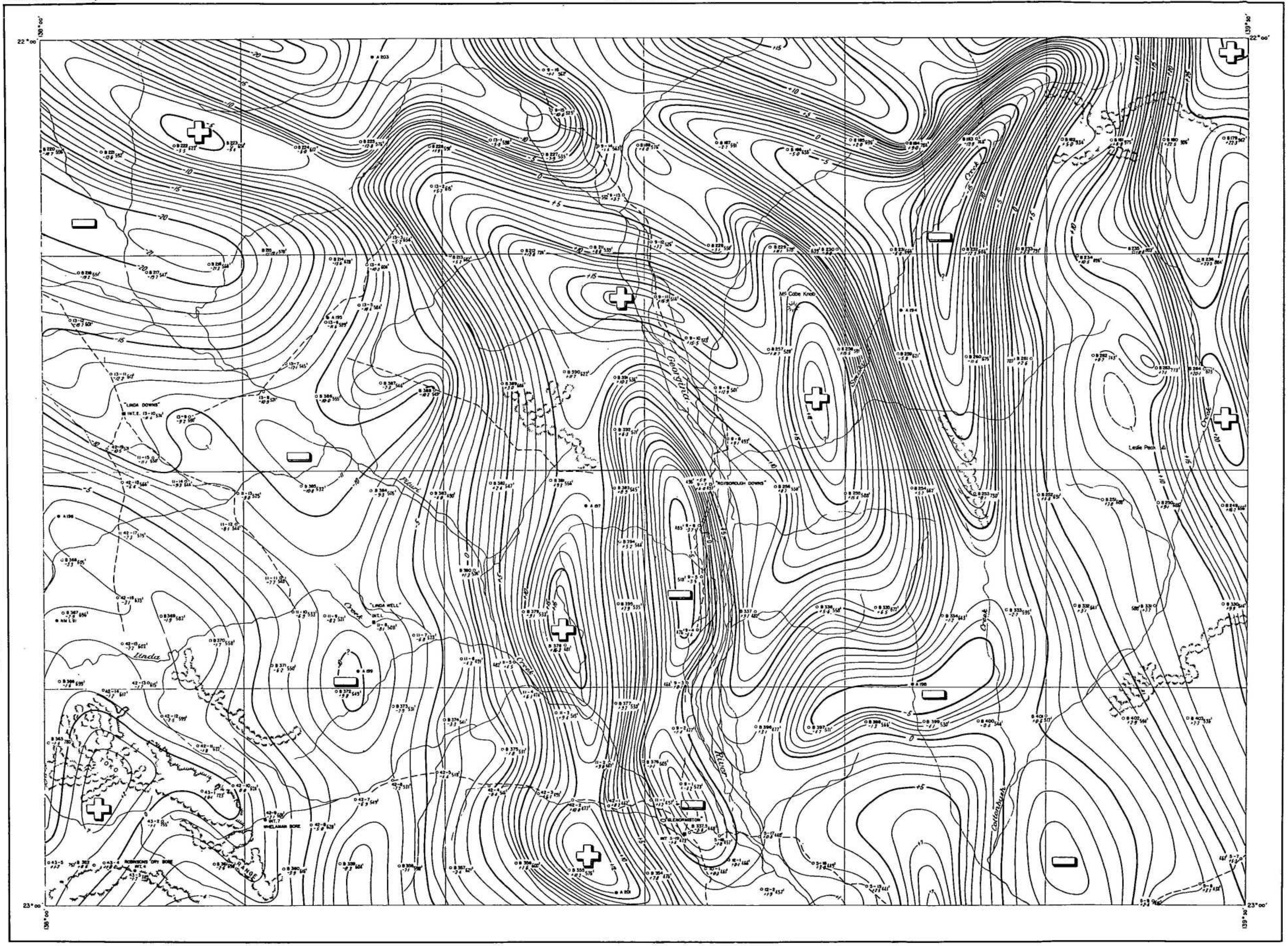
The Toko Syncline in the south-west part of Glenormiston resulted from the later, Palaeozoic orogeny. The axis of folding is north-west to south-east, with plunge to the south-east. Upper Cambrian to Middle Ordovician, and the undifferentiated Ordovician or Devonian sediments, have been affected by this folding, and, in the Glenormiston area, their outcrops occur in cuestas and dip-slopes with generally low dips. Exceptional steep dips, up to 60° to the North , have been measured along the north side of the small anticline east of Ten Mile Hills. This anticline, and other small folds such as the Netting Fence Anticline at the north edge of the Toko Syncline, are associated with the Toko folding and generally show a north-west to south-east lineament. This direction is reflected very strongly also in the course of Pituri Creek, and can be extended south-east to link with the Sun Hill Fault on the Mount Whelan Sheet area. Minor faulting associated with the Toko Syncline is mainly transverse in an east-north-east direction with right lateral displacement.

AUSTRALIA 1:500,000

GLENORMISTON

QUEENSLAND

F54-9 ZONES 5 AND 6



LOCATION

SANDOVER RIVER	URANDANGI	DUCHESS
TOBERMORY	GLENORMISTON	BOULIA
HAY RIVER	MT. WHELAN	SPRINGVALE

REFERENCE TO AUSTRALIAN NATIONAL 4 MILE MAP SERIES

NOVEMBER 1959

MAP DATA

PROJECTION: TRANSVERSE MERCATOR, AUSTRALIAN SERIES.

CONTROL: R.A. SVY. CPS. PLANIMETRIC MAP AND DEPT. OF THE INTERIOR GRAVITY SURFACE CONTROL MAP WITH THE SAME NAME.

DETAIL: B.M.R. LAND TRAVERSES PLOTTED FROM FIELD NOTES AND DEPT. OF THE INTERIOR GRAVITY SURFACE CONTROL MAP. B.M.R. HELICOPTER TRAVERSES IDENTIFIED FROM AIR PHOTOGRAPHS, PLOTTED ON NATIONAL MAPPING 4 MILES TO 1 INCH PHOTOMAP AND SUBSEQUENTLY ADJUSTED TO THE BASE MAP.

RELIABILITY: PLANIMETRIC - GOOD (FROM CONTROLLED PLANIMETRIC MAP) GEOPHYSICAL - GRAVITY RECONNAISSANCE.

RECONNAISSANCE GRAVITY SURVEY (1957-1959)

GEORGINA BASIN, Q.L.D.

BOUGUER ANOMALIES

SCALE IN MILES

4 0 4 8 12 16 20

CONTOUR INTERVAL 1 MILLIGAL

LEGEND

TOPOGRAPHY

——	ROAD		WATERCOURSE (NON-PERENNIAL)
— — —	TRACK	■	HOMESTEAD
△	TRIG. STATION	●	ASTR. STATION

GRAVITY

o	B.M.R. STATION		ISOGALS
+10·2	RELATIVE BOUGUER ANOMALY	✚	HIGH ANOMALY
135'	ELEVATION	▭	LOW ANOMALY

EXPLANATION

RELATIVE BOUGUER ANOMALIES ARE BASED ON THE OBSERVED GRAVITY VALUES OF FOLLOWING B.M.R. PENDULUM STATIONS:

Nº 55 CLONCURRY ...... 978,650·7 MILLIGALS

Nº 56 BOULIA ...... 978,793·2 MILLIGALS

FOR THE CALCULATION OF BOUGUER ANOMALIES 1·9 GR./CCM HAS BEEN ADOPTED AS AN AVERAGE ROCK DENSITY

GRAVITY FIELD SURVEYS BY B.M.R.

NOTE: THIS GRAVITY MAP SUPERSEDES ALL PREVIOUS ISSUES. TOPOGRAPHY AND CULTURAL FEATURES SHOWN ONLY TO LOCATE GEOPHYSICAL DATA.

GEOPHYSICAL BRANCH, BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS. G69-44

Apart from the major structural elements, other minor structures occur in the Glenormiston Sheet area, but are either associated with or reflect the major structures. They include:

(a) strong east-north-east lineaments shown by Lower Palaeozoic sediments west of the Georgina River, and to the east cutting across the more prominent near meridional trends, and these appear to reflect Precambrian structures;

(b) minor gentle folding and faulting in Lower Palaeozoic rocks south of Precambrian rocks and east of the Georgina River, and these are attributed to the Toko Syncline orogeny; movements also occurred at this time along Precambrian trends, and the strong fault across the upper reaches of Duncans Creek shows buckling of adjacent Middle Cambrian beds and evidence of right lateral movement; some vertical displacement was also noted in subsidiary faults at right angles to the Duncans Creek fault.

(c) strong jointing.

The "Smoky Anticline", referred to by Öpik (in Hill and Denmead 1960, p.97), is a structure extending south-west from the Precambrian rocks, west of Smoky Creek; it is mainly an old Precambrian structural high over which Lower Cambrian and younger sediments have been deposited. It has been affected in a small way by later movements.

The Bouguer Anomaly Map Plate 2, (B.M.R., 1959) shows Precambrian structural trends in the eastern one-third of the Glenormiston Sheet area, and another irregular but well-defined trend which the Georgina River appears to follow. This trend is to the south-east in the north-west part of Glenormiston and swings to the south in the central part; near the south edge, a north-west to south-east trend is resumed. Anomalies and trends elsewhere appear to be irregular.

GEOLOGICAL HISTORY

In Precambrian times the area formed part of the Mount Isa - Cloncurry mineral belt to the north, and was probably linked with the Arunta Complex - Warramunga geosynclinal belt to the west. This link became obscured in Lower Palaeozoic times by the deposition of sediments in the broad depression of the Georgina Basin formed as a result of the major orogeny at the end of the Lower Proterozoic. The next major event was a major thrust movement from the south-west to form the Toko Syncline; the movement may have been associated with the compressional Amadeus Basin folding. After a long period of stability, and after possible deposition of Permian glacial or fluvioglacial sediments, the Glenormiston area appears to have been mildly affected during the formation of the Great Artesian Basin - Lower Cretaceous and possibly older Mesozoic lacustrine to marine sediments were deposited in what appear to be small structural embayments in its eastern and south-western parts. The last event of any consequence was regional warping which occurred during the Tertiary, and led to the formation of large lakes, and later to the development of the present drainage system.

These events are discussed in more detail below :-

(1) The Proterozoic history of the north-eastern part of the Glenormiston area is described by Carter and Brooks, (in Hill and Denmead, 1960), and by Carter, et al, (1961). Their work shows that the Eastern Creek Volcanics were deposited in a subsiding meridional trough controlled by tension faults; the eastern margin was formed by the Kalkadoon Granite, and the western side by stable Proterozoic land and unstable shelf area. The trough was shown as far south as the north edge of the Glenormiston and Boulia Sheet areas. Geophysical work by the B.M.R., (B.M.R., 1959; Jewell, 1960) shows a probable extension to the south of the Kalkadoon Granite as a negative Bouguer anomaly, through the west side of the Boulia Sheet area, (and granite was penetrated along this extension at 1,740 feet in Phillips - Sunray Beantree No.1 Well - Green, Hamling, and Kyranis, 1963). Flanking the west side of the negative anomaly is a belt of positive Bouguer anomalies (which also shows strong positive profile in the aeromagnetic traverses); this extends south-south-east along and across the margin area of the Glenormiston and Boulia Sheets. The belt is thought to be a narrow buried graben of Eastern Creek Volcanics. The fault along the west edge of the graben shows in the north-east corner of the Glenormiston Sheet (see Plate 2) at the head of Smoky Creek, and its surface reflection in younger sediments to the south presumably controls the upper part of Cottonbush Creek.

The western part of the main trough of Eastern Creek Volcanics probably dies out along the southern part of the fault through Duncans Creek in the northern part of the Glenormiston Sheet area. The trend of this fault is south-south-west, but a subsidiary south-west trend has been noted to the west. The south-west trend may have developed with the intrusion of the Sybella Granite along the western edge of the Eastern Creek Volcanics trough during the first major Lower

Proterozoic orogeny, (see Carter, et al), or at the time of the second orogeny at the close of the Lower Proterozoic. The fact that the south-westerly trend is shown by lineaments across the main meridional trough lineation to the south of the Precambrian rocks suggests that it belongs to the later orogeny. The east-north-east to west-south-west trends shown west of the Georgina River are thought to be continuations on to the Proterozoic land of the transverse south-west trend.

The epeirogeny at the end of the Lower Proterozoic formed land masses in the north-western Queensland region and farther west in the Northern Territory, and a broad depression between. During Upper Proterozoic to Lower Cambrian times, sediments were deposited in the depression under lacustrine to marine conditions. The land masses then rose slightly and Middle Cambrian to Ordovician sediments were deposited in what is now called the Georgina Basin.

(2) The Georgina Basin is considered to have formed as such before, or in early Middle Cambrian times, and extended from Daly Waters in the north, through Glenormiston, to the south-east where it is now covered by sediments of the Great Artesian Basin. Middle Cambrian sediments appear to have been deposited as a blanket over the whole Georgina Basin area, but Upper Cambrian to Ordovician beds are concentrated mainly in a southern belt between Huckitta in the west and Black Mountain in the east. Sedimentation was not continuous in any one area, and according to palaeontological evidence, some time-breaks occur; deposition continued until the Middle Ordovician and possibly also during the Devonian.

A major thrust from the south-west is thought to have brought sedimentation in the Georgina Basin to a close. Evidence for thrust movement is as follows :

(a) The beds in the south-west limb of the Toko Syncline are very steeply dipping and overturned in part, whereas those on the north-east have gentle dips;

(b) minor faulting in the Toko Syncline area was of the transverse type with right lateral movement along old west-south-west to east-north-east lineaments and along the extensive fault near the south edge of the area;

(c) the strong lineaments formed along the Pituri Creek parallel to the Toko Syncline axis was also slightly displaced by a right lateral movement.

The Precambrian rocks in the north-east of Glenormiston and their continuation below the Lower Palaeozoic rocks east of the Georgina River acted as a stable block and a buttress against the force of the thrusting. However the following effects seem to have been produced:

(i) folding and buckling south of the Precambrian outcrops and minor faulting in the McCabe Knob area;

(ii) apparent distortion of Precambrian lineaments as reflected by younger sediments;

(iii) buckled Lower Palaeozoic beds along the fault across Duncans Creek which suggest that secondary right lateral movement has occurred along this line of weakness;

(iv) east-west faulting at the north side of the Sybella Granite outcrop affecting both the older rocks and overlying Middle Cambrian sediments.

The age of thrusting is not known. Smith (1963a) refers to a major post-Upper Devonian, pre-Triassic orogeny which affected Upper Devonian sediments in the Dulcie Range, (Huckitta 1:250,000 Sheet area), and the thrust movements in the Glenormiston area are thought to belong to this orogeny. It may be possible to relate the orogeny to the Kanimblan (Lower Carboniferous) orogeny of eastern Australia. After this period of deformation, movements in the Glenormiston area have been comparatively minor, and little sedimentation has occurred.

(3) Glaciation occurred in Australia in Permian times, and scattered remnants of fluvioglacial and ?glacial deposits have been found in the western part of the Glenormiston area. Some winnowing of the sediments may have occurred during Mesozoic times.

(4) The main areas of Mesozoic sedimentation are in the eastern half of the Glenormiston Sheet area east of the Georgina River, and in the south-western part within the trough of the Toko Syncline and in the Ten Mile Hills area. They probably formed as shallow troughs during the development of the Great Artesian Basin. The eastern area reflects a southerly extension of the old Eastern Creek Voclanics trough of Proterozoic age, possibly modified by the post-Upper Devonian orogeny, and was subsequently uplifted to form the land around which the Georgina River valley formed. Mesozoic deposition in the

western part was obviously in low areas, structurally controlled and formed as a result of the post-Upper Devonian orogeny.

At first sedimentation was under fresh to brackish water conditions and may have been Upper Jurassic to Lower Cretaceous in age. Marine conditions developed later during the Lower Cretaceous but only in the eastern area.

Mesozoic sediments occur in another small area west of Roxburgh Downs, but they are so leached that their exact age is uncertain,

(5) No further deposition occurred in the Glenormiston area during the Cretaceous and it was not until Tertiary, Marion Formation, time that sedimentation recurred. Silicified sandy beds of the Marion Formation extend from the Boulia Sheet area on to the eastern edge of Glenormiston. The formation was deposited in shallow valleys in an old surface that had undergone or was undergoing peneplanation.

At about this time deep weathering and leaching of the sediments began. Exposed profiles in parts of western Queensland suggest that the sediments were actually lateritised, but subsequent silicification has altered their composition to such an extent that no laterite is left. The relative age of events in western Queensland during the Tertiary is uncertain and the relation has been confused even more by periods of warping.

It is suggested that in the Glenormiston area, the eastern part was uplifted slightly after Marion Formation deposition, and the ?laterisation process. After a short period of erosion which denuded most younger deposits from above the Ninmaroo Formation in the western part, and probably initiated the courses of present drainage systems, a large lake formed. The lake occupied the areas through which the Georgina River and Pituri Creek now run, and was apparently very similar to Lake Eyre in South Australia (Paten, 1961). The lake area was eventually in filled with limestone deposits and the whole region was probably again fairly flat. Conditions then favoured periodic sheet flooding in a region of practically no drainage, and formation of silica gel which replaced siliceous clastics in part and also the top parts of the carbonate beds.

(6) The Selwyn Range uplift of late-Tertiary time (Öpik, 1961) revived drainage and erosion in the area. Drainage followed older trends formed after Marion Formation time, and structural trend lines reflected by the Palaeozoic and Mesozoic sediments. Unconsolidated sediments, such as Marion Formation sands, left above the level of silicification were quickly eroded and, in the arid conditions which have followed, formed the aeolian sand deposits which occur in parts. The red colour of these sands suggest that they are derived from lateritised or ferruginised sediments. The silica deposits were widespread and now form the duricrust cap over the eroded plateau country, mesas and cuestas of the present topography.

ECONOMIC GEOLOGY

Hydrology

Water supplies either from bores or from surface sources are unreliable in the Glenormiston area. No widespread supplies of good potable water have been found by boring, and with one exception, most surface accumulations may be depleted by evaporation. The exception is the water hole opposite Roxburgh Downs in the Georgina River channels which is considered permanent.

No underground water supplies are known from alluvium and recent sediments; these are generally concentrated near the main streams, and no boring has probably been attempted because of the possibility of bore-head equipment being ruined by flooding.

Small supplies of good water have been obtained in some parts from below the Tertiary limestones but the limestones may also yield salty water and boring results are not predictable. The same remarks apply also to the lower Palaeozoic carbonate rocks over which the Tertiary sediments were deposited. Nevertheless the best supplies known from the Glenormiston Sheet area are from dolomites and porous sandstones of lower Palaeozoic age. Some bores which yielded good water from these sediments have had to be abandoned because they are in areas with vegetation composed mainly of gidyea trees of the type that poison stock.

Localised subartesian water supplies have been obtained in the eastern half of the Glenormiston area from the basal Lower Cretaceous sandstone where it is confined and capped by the Wilgunya Formation shale in steep-sided valleys in the old Ninmaroo Formation surface.

Springs occur in Precambrian folded rocks in the east part of Kallala Station, just north of the Glenormiston area; the water is potable and trickles into Spring Creek, a tributary of Smoky Creek. It is this supply which probably supports the wild stock, mainly cattle and camels, which roam this uninhabited area.

After good rains, surface water is available for a few months from water-holes, dams, and combination earth dams and tanks.

Petroleum Prospects

Traces of oil have been reported from the Georgina Basin sediments in and about the Glenormiston area. Small quantities of oil were extracted from Cambrian limestones from the Mungerebar area and other nearby areas by the B.M.R. Petroleum Technology Laboratory. Residual asphaltum was found in vuggy dolomites whose age is lower Palaeozoic (Cambrian or Ordovician) in B.M.R. Grg 14 Hole in the Sandover River Sheet area north-west of Glenormiston, (Milligan, 1963), and a strong smell of kerosene was reported by the driller of Tysons No.2 Bore in the Mount Whelan Sheet area. In Phillips-Sunray Black Mountain No.1 Well, however, which drilled through 5,500 feet of Upper Cambrian to Upper Proterozoic sediments including a thick section of Cambrian carbonate rocks, no oil or gas shows were noted but some fracture and intergranular porosity was encountered (Green, et al, 1963). This well is situated in the south-east part of the Georgina Basin in the Boulia Sheet area, east of Glenormiston.

Most of the Glenormiston area appears unfavourable for oil accumulation. The most likely source rocks crop out at the surface or are overlain by porous dolomites which have been slightly faulted and strongly jointed. Best prospects lie in the south-western corner where a thick section of Cambrian to Ordovician sediments with interbedded source, reservoir and cap rocks has been thrust-folded into the Toko Syncline and subsidiary anticlines. Associated faulting and shearing, however, has not enhanced these prospects.

The samples of dark grey limestone from G 147 (Mungerebar Limestone) and G 35d (Ninmaroo Formation), which were reported to contain small amounts of oil, had low porosities, (2½%), and permeability less than 0.3 Millidarcys; their average densities were each 2.7.

Minerals

Some copper was seen as malachite in Precambrian rocks north of the Glenormiston area in the upper reaches of Quita Creek; the deposits are referred to in Noakes, et al, (1959), as uneconomic. They also refer to low-grade manganese deposits in the Steamboat Sandstone; similar concentrations were noted in the area between Smoky Creek and Cottonbush Creek and occur at the unconformity between dolomite of the Ninmaroo Formation and Longsight Sandstone. Scattered pockets of manganese, and manganese and iron oxide occur over the dolomite hills between Roxburgh Downs and Blue Mountain; small magnesite concretions were found in the same area.

Pellet beds in the Nora Formation and Mithaka Formation have been shown by analysis to be phosphatic (J.N. Casey, pers. comm.), but further sampling would be necessary to establish whether economic deposits occur.

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APPENDIX I

Petrography

by

W.B. Dallwitz and K.G. Lucas

(Each author's descriptions indicated by his initials.)

PRECAMBRIAN ROCKS (All by K.G.L.)

Eastern Creek Volcanics

G.403 Microslide 4029. Glenormiston run 1, photo 5133.

A plicated fine-grained spotted chlorite - sericite schist crops out three and three quarter miles east of Yarrie Rock Hole. The spots are cigar-shaped aggregates, up to 1.5 cms. long, of even-grained chlorite and muscovite flakes. The host rock, which also contains scattered irregular grains (up to 2.5 mm. long) and rare veinlets of black oxide, consists of lepidoblastic muscovite, clear quartz, accessory chlorite and elongated grains of black oxide, and rare dark blue tourmaline.

G.402 Microslide 4028. Glenormiston run 1, photo 5133.

The least altered basic rocks are represented by specimen G.402 from three and a half miles east of Yarrie Rock Hole. This specimen is a blocky, fine-grained, dark green "amphibolite". In thin section it is seen to be an equigranular quartz-bearing "uralitized" dolerite whose texture shows little effect of regional metamorphism; it is cut by two monomineralic veinlets, one of pleochroic epidote and one of untwinned alkali feldspar. The dolerite consists essentially of poikiloblastic, hornblende and partly sericitized plagioclase (An_{50}), minor epidote, intergranular quartz, ragged aggregates of sphene (probably after ilmenite), and black oxide, and accessory pyrite, apatite, and calcite. The pleochroism of the hornblende is identical with that described by Joplin (1955, p.49) in the ortho-amphibolites to the north.

G.405 Microslide 4030.

Glenormiston run 1, photo 5135.

In some of the areas of metavolcanics, such as at locality G405 four miles east of Yarrie Rock Hole, fine-grained bright green epidosite is common. This specimen exhibits a fine interlocking granular quartz-epidote mosaic in which the only indication of the texture of the original rock is the presence of an octahedral epidote aggregate whose size and outline suggest that it pseudomorphs a euhedral pyroxene phenocryst or phenoclast.

Sybella Granite

G.441 Microslide 4032. Glenormiston run 1, photo 5137.

This specimen from ten miles east-north-east of Yarrie Rock Hole is dark, medium-grained, foliated biotite-hornblende adamellite intersected by a vein of massive pink quartz.

The rock consists of partly sericitised and very rarely twinned oligoclase-andesine, fresh microcline-perthite, aligned grains of stressed quartz, hornblende, and biotite, with accessory granulated or recrystallized sphene, iron oxide, epidote and apatite. The mafic minerals are mutually intergrown. The quartz vein encloses elongate fragments of the adamellite, and was emplaced before or possibly during the times when the directional structure was impressed on the rock.

G442 Microslide 4034. Glenormiston run 1, photo 5135.

At locality G442 five miles east-north-east of Yarrie Rock Hole there is a porphyroblastic foliated biotite granodiorite containing aligned inclusions of fine-grained (?) metavolcanic, and adjacent to it is a massive (?) granodiorite. The foliated granodiorite consists of abundant twinned and partly saussuritized plagioclase laths (composition approximately oligoclase) and scattered porphyroblasts of microcline, set in a groundmass of quartz and biotite, with accessory sphene, epidote, apatite, muscovite, altered allanite, black iron oxide. A little of the biotite has been partly or completely chloritized. The microcline porphyroblasts have granulated margins and include grains and clots of saussuritized plagioclase, biotite, quartz, epidote, and chlorite, Biotite encloses some of the apatite as well as minute grains or zircon or monazite surrounded by pleochroic haloes. The rock may be a hybridised granite which has partly assimilated metavolcanic rock, and finally undergone potash metasomatism to give rise to the microcline porphyroblasts.

PALAEOZOIC

Steamboat Sandstone

G.121 Microslide 4013, (K.G.L.)

Glenormiston run 1, photo 5131. Four miles south of new QT Bore.

A porous, silicified orange-red quartz sandstone.

In thin section it is seen to be a fine-grained, well-sorted, sub-rounded, quartz sandstone with silica, iron oxide and clay cement. The quartz grains are usually unstrained and clear, though some are strained, and some are clouded with dark, irregular inclusions. They are commonly mantled by secondary outgrowths. The siliceous cement is probably chalcedony, and the formless translucent iron oxide cement is probably haematite. Accessory minerals are muscovite, well rounded green-brown tourmaline, green biotite, feldspar (? potash), chert, zircon, and brown rock fragments.

Specimen G133 (slide 4548), (W.B.D.) Glenormiston run 3, photo 5115. 4¾ miles NE of Andy's bore, Mungerebar.

A porous, fossiliferous, yellow-brown, massive, sandy rock. Porosity appears to be 20-25 percent.

This rock, when examined microscopically, is found to consist of quartz which is cemented by iron-stained argillaceous material, hydrated iron oxide, and thin layers of the possible montmorillonitic material described in specimen G129a. Fragments of chalcedony, tourmaline, and very rare zircon and muscovite are the only accessories.

The grainsize of the quartz ranges from about 0.03 to 0.3 mm., the average being about 0.1 mm.. The quartz grains are angular to subangular, but it is clear that their angularity has been at least partly determined by secondary silica which has been added. It is not possible to estimate the percentage of grains so affected, but it is probably very much greater than that suggested by the few grains which show unmistakable signs of addition.

The rock is a <u>very fine, porous, ferruginous, and argillaceous sandstone</u>.

<u>G427a Microslide 4025</u>, (K.G.L.)

Glenormiston run 3, photo 5115. Four miles east of Andy's Bore.

A yellow and white laminated siltstone with small faults.

In thin section the rock is seen to be a micaceous, limonite-stained siltstone. The resolvable detritus is quartz sand and shredded flakes of muscovite. The intergranular material (?halloysite) which is isotropic and transparent in the white laminae, is limonitic in the yellow laminae.

Leached sediments occurring between Mungerebar Limestone and Ninmaroo Formation.

<u>G408 Microslide 4019</u> (K.G.L.)

Glenormiston run 6, photo 5077. One mile west-south-west of McCabes Knob.

This is a cream, fine-grained, impure (?)silicified quartz sandstone with thin laminae of brown and pale green clay and occasional buff coloured clay pellets.

In thin section it is seen to be a well sorted, fine to medium-grained, oolitic, silicified, impure quartz sandstone containing second cycle quartz. The quartz grains which make up 40% of the rock show mosaic and undulose extinction, and commonly contain entrained globular, prismatic, and acicular inclusions. The grain boundaries show little relation to the earlier rounded edges on which there has been secondary growth of silica. The intergranular material is commonly sub-isotropic, finely granular siliceous material which is probably chalcedony. Semi-transparent spherical bodies (?oolites) with marginal concentric structures are common. They appear to consist of chalcedonic interiors with outer concentric isotropic bands which are commonly limonitic. Accessory minerals are tourmaline and chert.

Specimen G129a slide 4547, (W.B.D.) Glenormiston run 5, photo 5017 Chummy Tank, Mungerebar, Glenormiston 4-mile sheet.

This is a somewhat friable, browhish buff, porous, fine-grained, massive, sandy rock containing irregularly-shaped, cream-coloured, clayey pellets measuring up to 0.75cm. Porosity seems to be about 15 percent.

Apart from cementing material, and clay pellets the rock consists almost entirely of quartz. Tourmaline is the only accessory mineral.

The quartz grains range in size from 0.05 to 0.25mm.; some are well-rounded, but most are sub-rounded, Addition of silica has taken place in some, at least.

The clay pellets consist of a pale buff clay mineral with very low double-refraction and refractive index less than that of quartz but greater than that of balsam. They contain a few quartz grains of sand size and numerous minute specks of indeterminable minerals, two of which may be tourmaline and anatase.

Somewhat darker and much smaller pockets of clayey material, which can be described more appropriately as unusually abundant cement between the quartz grains, are also present. This material has a somewhat higher double refraction than that in the normal pellets, and its refractive index is consistently higher than that of quartz. In places this clayey material forms a normal cementing shell, about 0.3 mm. thick, around the quartz grains.

The commonest cementing material, also forming layers 0.03$\pm$mm. thick around the quartz grains, is a medium red-brown, frequently layered, chloritic or, more probably, montmorillonitic material which has a strong tendency, within the limitations imposed by its interstitial mode of occurrence, to develop an irregular, distorted spherulitic structure. On account of the strong colour of the mineral, it is rather difficult to tell whether its double refraction is high or low, but the general impression is that it is moderate to fairly high. Its sign is negative, and 2V is 0° to very small. Its R.I. is greater than that of quartz. All this suggests a mineral of the montmorillonite type. The main feature which argues against this suggestion is that pleochroism is absent. (It should be mentioned in passing that a mineral closely resembling the (?)montmorillonite is rather common in some soils, and has also been noted by us in outcropping late Palaeozoic and Mesozoic rocks from W.A.) Frequently the (?)montmorillonite is locally replaced as a cement by the second (?)clay mineral referred to above; it is possible that this also is a type of montmorillonite.

The rock is a porous fine quartz sandstone containing clay pellets and having a possible montmorillonitic cement.

Specimen G129b slide 4550, (W.B.D.) Locality as above.

This is a yellow-brown, thinly bedded, silty rock with minute flakes of muscovite along the bedding planes.

In thin section the rock is seen to consist essentially of angular quartz grains embedded in a matrix of ferruginous, argillaceous material. The percentage of quartz is probably about 50, and the quantity of it varies in the different layers, which tend to be lenticular, and are generally poorly defined. The thickness of the layers ranges between about 0.1mm and 1.5mm. The size of the quartz grains ranges from 0.008 mm. to 0.16 mm., and there is a fairly good gradation between these sizes. A few odd grains are larger than 0.16 mm.. The average grainsize of the quartz is about 0.05 to 0.06 mm..

Accessory constituents are muscovite, colourless chlorite, and rare tourmaline.

The rock is a ferruginous, argillaceous quartz siltstone.

Ninmaroo Formation

G39a Microslide 4009, (K.G.L.) Glenormiston Run 5, photo 5052. On the Georgina River; Four and a half miles east of Bullock Paddock No.3 Bore.

HAND SPECIMEN Thin-bedded pale green fine dolomite and sandy dolarenite microbreccia.

THIN SECTION The fine dolomite beds consist entirely of finely crystalline, subhedral, granular dolomite crystals. The coarser bed consists mainly of moderately clear, subhedral dolomite crystals. (60%) and sand-sized grains of quartz and rock fragments, as well as fine dolomite grains.

The quartz grains are fine to medium subangular sand. Some of it has secondary outgrowth which may however, predate part of its clastic history. Some has undulose extinction and a few grains are granulated or composite. Much of the quartz contains inclusions which are commonly aligned in trains; most of the inclusions are irregular or globular, though a few are prismatic. Siliceous rock fragments include chalcedonic blocky chert and laminar silty chert. Medium and coarse ovate sand grains and small discoidal pebbles of fine dolomite or marly dolomite lie parallel to the bedding plane.

Accessory clastic minerals include chloritised biotite flakes and very minor tourmaline and muscovite. Some of the chlorite is stained by limonite.

G39b Microslide 4010, (K.G.L.) Glenormiston run 5, photo 5025. On the Georgina River four and a half miles east of Bullock Paddock No.3 Bore.

HAND SPECIMEN Laminated green and grey (?)clayey dolomite in which cross-lamination is apparent in one thick lamina.

THIN SECTION Similar to G39a.

The thick, cross-laminated, grey lamina is sandy, and consists of about 35 percent of fine, sub-angular quartz sand and subordinate muscovite, set in a moderately crystalline carbonate matrix. The intervening laminae are of fine subhedral, interlocking carbonate crystals.

G44a Microslide 4012, (K.G.L.) Glenormiston run 2, photo 5067. From measured section four miles north-west of Johnstone Dam.

HAND SPECIMEN A buff-surfaced, sandy limestone in which varying richness in resistant sand grains from lamina to lamina has resulted in regular differential weathering of the laminae.

THIN SECTION A sandy limestone in which fine quartz sand grains and other non-carbonate detritus make up 15 to 40 percent of representative fields of view. The sand consists mainly of fairly clear sub-angular quartz which has suffered some intergrowth with (including penetration by) the carbonate, but there is a significant minor proportion of feldspar, mostly plagioclase, some of which exhibits zoning, and possibly some microcline. Accessory constituents are detrital muscovite, cherty rock fragments, tourmaline, and chloritised biotite.

Specimen G433b slide 4542, (W.B.D.) Run 7, photo 5099. Two miles west of 7-mile Water Hole, Alderley Station,

This is a buff-coloured, somewhat friable, flaggy, bedded, fine-grained rock which effervesces slightly with cold, dilute HCl.

In thin section the rock is seen to consist of about 85 to 90 percent carbonate minerals; the remainder is made up of quartz, accessory hydrated iron oxide, microcline, and albite, rare muscovite, and very rare (?)glauconite and tourmaline. The quartz grains show little sign of rounding.

Most of the carbonate has the form of generally imperfect rhombs; judging by those shapes, the minimum refractive index of the rhombs, and the reaction of the rock to acid, it seems that the bulk of the carbonate is dolomite. The slight effervescence noted in handspecimen is due to the presence of a small amount of calcite. The average grainsize of the carbonate is about 0.07 mm., and the range of grainsize is from about 0.02 mm. to 0.15 mm..

The bedded and flaggy structure of the handspecimen suggests that this rock is of the calcarenite type. However, the presence of subhedral to (rarely) euhedral dolomite suggests that at least some recrystallisation has taken place.

The rock is a very fine sandy dolarenite.

Specimen G433c slide 4551, (W.B.D.) Locality as above.

This is a very pale buff, finely laminated, compact, fairly soft, silty to argillaceous rock.

In thin section the rock is seen to be very fine-grained. It appears to consist principally of quartz, a probable clay mineral, and subordinate sericite. The average grainsize seems to be about 0.015 mm., and the largest quartz grain measures about 0.05 mm.

Accessories are leucoxene, black iron-ore, and rare tourmaline.

The rock is a sericitic argillaceous quartz siltstone or silty argillite.

Specimen G112 slide 4544, (W.B.D.) Glenormiston run 8, photo 5133.
Three miles south-west of 7-mile Water Hole, Alderley Station.

This is a medium-grained, purplish brown, ferruginous limestone containing irregular (and irregularly distributed) cavities up to about 0.5 cm. across. Weathering, both external and internal (where solutions have penetrated along cracks), has locally changed the colour of the rock to light rust-brown.

In thin section the main constituent is seen to be medium-grained carbonate. Judging from the strong effervescence when the rock is treated with dilute HCl it appears that most of the carbonate is calcite. However, more or less perfect rhombic shapes are developed in most parts of the slide, and it could be that dolomite makes up a substantial part of the rock. Most of the grains of carbonate are enclosed in a thin ($0.05^{\pm}$ mm.) shell of hematite; in many places the hematite has altered the enclosed carbonate as veinlets and aggregates of small grains. In some places the hematite has been converted to hydrated iron oxide.

The rock is a <u>ferruginous dolomitic limestone</u>.

Specimen G123 slide 4549, (W.B.D.) Glenormiston run 13, photo 5105.
Four miles north of Gumhole Bore, Herbert Downs.

This is a porous, somewhat friable, fine-grained, buff-coloured, thinly bedded, flaggy, sandy rock on whose freshly-broken bedding planes flakes of fine-grained muscovite are conspicuous. From examination of the thin section and the handspecimen it seems that the pore-space is between 10 and 15 percent.

The thin section shows that the rock is even-grained, and that its average grainsize is about 0.06 mm. or slightly less. Feldspar makes up about 60 percent of the specimen; it occurs as subhedral to angular grains, most of which are probably cleavage pieces. By far the most abundant variety is orthoclase; a little microcline, plagioclase, and perthite are present, and a number of grains appear to consist of a core of albite surrounded by an ((?) authigenic) shell of orthoclase.

Quartz (20%) occurs as rather angular grains, but they may owe their angularity to secondary outgrowths of silica ; some grains show original perfectly rounded detrital grains within the added shell.

Muscovite flakes are conspicuous, but make up only a few percent of the rock. Flecks and intergranular films of hydrated iron oxide are present throughout, but this mineral is less plentiful than is muscovite. Other accessories are tourmaline, films of extremely fine-grained chloritic or argillaceous material, leucoxene, and rare zircon, chlorite, (?)anatase, (?)chert, and epidote.

The rock is a porous <u>arkose siltstone</u>.

The cementing material is probably made up of three or four components already mentioned, viz. chloritic and argillaceous material, hydrated iron oxide, secondary silica, and possibly authigenic orthoclase.

G421 Microslide 4020, (K.G.L.) Glenormiston run 13 photo 5109. Four miles west-north-west of New Bore.

HAND SPECIMEN A creamy-pale brown moderately crystalline dolomite with discontinuous (?)graded fine sandstone laminae.

THIN SECTION Very thin laminae, thicker laminae, and patches of sandy dolomite are present. The thicker sandy laminae are graded in proportion of non-carbonate detritus: grading in the grain-size of the detrital material, where present, is very slight. At the base of a lamina, non-carbonate detritus amounts to about 50 percent of the horizon, whereas at the top it falls to about half this value. These proportions indicate that at least some of the dolomite must be detrital.

The non-carbonate detritus is fairly angular, fine sand and silt, consisting of quartz and accessory microcline, plagioclase (some composite quartz-feldspar fragments), muscovite, and tourmaline.

Ninmaroo Formation, Member 3, (K.G.L.)

G518, Microslide 4038. Glenormiston run 15, photo 5155. Six miles south of Pybbagene Waterhole.

HAND SPECIMEN A cross-laminated, dolomitic, fine quartz sandstone.

THIN SECTION A fine-grained, well sorted, dolomitic sandstone in which the non-carbonate detritus (mainly quartz) constitutes about 50 - 60 percent of the rock. Some intergrowth between the carbonate and the quartz has taken place. Scattered fairly large areas (approx. equal to that of two or three detrital grains) are occupied by pure carbonate, and these must represent sites either of former detrital carbonate or of completely replaced non-carbonate detritus.

Quartz is commonly fairly clear. It contains some intrained globular and prismatic inclusions, and shows mild undulose and mosaic extinction. Some grains are composite, and others show secondary outgrowths. Boundaries between detrital grains and outgrowth are seldom visible; there is a tendency for crystal faces to be developed on the outgrowth.

Detrital feldspar is a minor constituent and the grains have cleavage-controlled outlines. They comprise twinned and untwinned orthoclase zoned, plagioclase, and microcline. Limonite and chlorite are accessory.

Member 4, (K.G.L.)

G519-(14) Microslide 4936 and 4937. Glenormiston run 15, photo 5155. Seven miles south-west of Pybbagene Waterhole.

HAND SPECIMEN "Two-tone limestone". Laminated buff and creamy grey, fine grained limestone. In a surface etched with acid the buff strata, which are thinner and exhibit small-scale contemporaneous deformation (contortion, injection into adjoining strata, and pull-apart), are less corroded.

THIN SECTION A sandy, recrystallized limestone with variable proportion of non-carbonate detritus from lamina to lamina, and variable states of crystallinity of the carbonate.

There are fine almost pure carbonate strata, fine carbonate layers containing variable and usually minor quantities of non-carbonate sand, layers of sandy calcarenite consisting of dark, sand-sized, finely crystalline fragments, and the darker (buff) laminae. These last laminae are among the richest in non-carbonate sand, but sand-size mineral grains of subhedral rhombic outline (possibly dolomite) are more common than non-carbonate grain in some layers; these are set in finely crystalline, relatively dark, carbonate matrix.

Non-carbonate detritus comprises quartz and relatively common feldspar - microcline, plagioclase, and untwinned types - commonly as cleavage fragments with rhombic outline. Accessory tourmaline is also present.

Coolibah Member (K.G.L.)

G236, Microslide 4016. Glenormiston run 14, photo 5181. One and a half miles east of Wheelaman Bore.

HAND SPECIMEN A dense, blocky, creamy-grey, fine limestone with crystalline maroon plates, probably carbonate, lying parallel to the bedding (rock parting).

THIN SECTION A finely crystalline (?)calcite mosaic containing laminae, which carry "lenses" of euhedral (?)dolomite up to 5mm. across and 1mm. thick. Many of these lenses have a dark brown core which is responsible for their maroon colour in hand specimen. The core consists of a carbonate crystal or crystals rich in small, irregular, semi-opaque limonite shreds, and it is bounded by a sheath of clear (?)dolomite.

Mesozoic (K.G.L.)

G211. Microslide 4015. Glenormiston run 14, photo 5187. In Ten Mile Hills, four miles south-south-west of the Ten Mile Bore.

HAND SPECIMEN A blocky, dark, buff, slightly porous and friable, fine-grained, bedded quartz sandstone.

THIN SECTION A fairly well sorted fine to medium quartz sandstone with a variety of mineral cements.

The only essential clastic component is quartz. Many of the grains have a significant elongation, and the original clastic grains were sub-rounded to sub-angular. The quartz is commonly unstrained and fairly clear, but it contains some fairly crowded sheets of globular inclusions and some prismatic inclusions which may lie in planes parallel to crystal faces of outgrowths.

Accessory detritus includes chert, rock fragments, brown semi-opaque rock fragments, minor cloudy (?)potash feldspar, and tourmaline.

Cement makes up about 30 percent of the rock, and consists in probable order of formation, of quartz outgrowth, minor chlorite, hematite, minor chalcedony, and a colourless, isotropic mineral (opal). The quartz outgrowth is in optical continuity with detrital quartz, and commonly shows crystal faces. Pale chlorite occurs as small flakes adhering to secondary quartz crystals. The hematite occurs as formless aggregates of irregular granules, and in places forms a coating on the borders of original clastic quartz grains; however, it is most common in the more or less central parts of (?)original pore spaces. Most of the remaining pore space is filled with colourless (?)opal. Minor brown colloform chalcedony post-dates quartz outgrowth, but its age relation with hematite is uncertain.

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APPENDIX 2

Sections measured in various formations in and around the Toko Range, in the south-west corner of the Glenormiston Sheet area.

Compiled by
P.W. Pritchard

NINMAROO FORMATION

Members 1 and 2

Section G511 : Glenormiston Run 15, Photo 5152; eastern edge of the Ten Mile Hills. In outcrop, a small inlier of Member 1 is capped by Member 2.

Lower part of Member 2:

	Thickness (in feet)	
Top of Section	2	Sandy calcilutite. Blue laminated calcilutite containing algal patches.
	2	Calcilutite, grading into dolomite. Blue-grey thick-bedded calcilutite containing algal patches which are replaced by coarsely crystalline calcite. The bed grades into dolomite along the strike.
	6	Two-tone calcilutite. Two-tone blue and brown laminated and thin-bedded calcilutite.
	2	Sandy calcilutite. Dark blue-grey sandy thin-bedded sandy calcilutite.
	1	Calcilutite. Mottled blue-grey thin-bedded calcilutite grading into dolomite.
	Upper part of Member 1	
	2	Dolarenite. Soft white laminated, thin-bedded and medium-bedded medium-grained dolarenite.
	4	No outcrop
	2	Dolarenite. Medium sets of white laminated and thin-bedded medium-grained dolarenite.
	2	No outcrop. Cellular travertine covers the ground.
	1	Calcilutite. Light blue-grey thin-bedded calcilutite with tubes filled with medium to coarsely crystalline brown carbonate.
	4	Dolomitic quartz sandstone. Red-brown thin-bedded fine-grained dolomitic quartz sandstone.
	6	Calcilutite and dolarenite. Blue-grey laminated and thin-bedded calcilutite. Red-brown laminated and thin-bedded fine-grained dolarenite.
Base	6	Dolarenite and calcilutite. White laminated medium-grained dolarenite. Blue thin-bedded calcilutite.
	40 feet.	

Member 2

Section G514: Glenormiston Run 15, Photo 5152; northern side of the Ten Mile Hills.

Top of Section	Thickness (in feet)	
	10	Calcilutite. Thin beds of brown laminated patchy calcilutite containing thick lenses of mottled brown and brown-grey calcilutite. Forms top of rise and almost top of section; a few feet of poorly exposed dolomite with algae occurs above, in rise to north, conformably below Member 3.
	2	No outcrop
	1	Calcilutite. Mottled blue-grey thin-bedded and laminated calcilutite.
	3	No outcrop
	2	Calcilutite. Mottled blue-grey thin-bedded and laminated calcilutite.
	4	Calcilutite. Brown thin-bedded and laminated calcilutite.
	2	No outcrop
	1	Calcilutite. Brown thin-bedded and laminated calcilutite.
	10	Calcilutite. Mottled grey-brown thin-bedded calcilutite with thin stringers of calcilutite. Red-brown thin-bedded cross-bedded calcilutite.
	1	Sandy calcilutite. Light blue-grey laminated calcilutite with sandy laminae.
	8	Marl and calcilutite. Thick sets of white laminated and thin-bedded marl with thick interbeds of brown-grey laminated and thin-bedded calcilutite some of which is mottled.
	2	Mottled calcilutite. Mottled brown-grey thin-bedded calcilutite.
	2	No outcrop
	3	Sandy calcilutite. Brown laminated and thin-bedded calcilutite with sandy laminae.
	3	No outcrop
	2	Algae
	6	Calcilutite. Medium sets of olive-grey laminated and thin-bedded calcilutite and of mottled olive-grey thin-bedded calcilutite.
	1	Calcilutite. Red-brown, thin-bedded calcilutite
	4	No outcrop
	2	Algae
	2	No outcrop
	3	Calcilutite. Grey thin-bedded calcilutite with fine mottling.

Top of Section	Thickness (in feet)	
	1	No outcrop
	2	Calcilutite. Grey thin-bedded calcilutite with fine mottling.
	3	No outcrop
	10	Calcilutite and marl. Thick sets of blue medium-bedded calcilutite and of white thin-bedded marl.
	2	No outcrop
	4	Calcilutite. Medium sets of brown thin-bedded calcilutite and of mottled brown calcilutite. The sets are slumped.
	2	Sandy calcilutite. Red-brown laminated calcilutite with sandy laminae.
	4inches	Calcilutite breccia. Brown-grey calcilutite breccia.
	3	No outcrop
	5inches	Oolitic limestone. Brown-grey oolitic limestone with calcilutite patches.
	3	Mottled calcilutite. Mottled brown-grey thin-bedded calcilutite.
	1	Calcilutite. White laminated and thin-bedded calcilutite.
	2	No outcrop
	1	Mottled calcilutite. Mottled brown-grey thin-bedded calcilutite.
	2	Calcilutite and calcarenite. Medium sets of white laminated calcilutite, of mottled grey calcilutite, and of white laminated medium-grained calcarenite.
	1	No outcrop
	3	Mottled Calcilutite. Mottled brown and blue-grey laminated and thin-bedded calcilutite.
	1	Calcarenite. Friable white thin-bedded medium-grained calcarenite.
	3	No outcrop
	2	Two-tone calcilutite and calcilutite. Medium sets of two-tone brown and blue-grey thin-bedded calcilutite and of brown laminated calcilutite.
	4	No outcrop
	2	Calcilutite. Faintly mottled brown-grey thin-bedded calcilutite.
	1	No outcrop
	1	Two-tone calcilutite. Blue and brown thin-bedded calcilutite.
	4	No outcrop
	4inches	Calcilutite. Blue oalcilutite with wavy laminae.
	7	No outcrop
	3	Calcilutite breccia. Breccia of pieces up to 6 inches long of blue calcilutite and of blue-grey-calcilutite with sandy laminae set in a grey calcilutite matrix.

	2	Calcilutite and sandy calcilutite. Mottled blue thin-bedded calcilutite and blue thin-bedded calcilutite with sandy laminae.
	1	Sandy calcilutite. Grey and brown laminated and thin-bedded calcilutite with sandy laminae.
	4	Algae and intraformational calcilutite conglomerate. Two feet thick lens of algae in blue-grey thin-bedded intraformational calcilutite conglomerate.
	3 inches	Two-tone calcilutite. Two-tone brown and blue calcilutite.
	1	Calcarenite. White, thin-bedded medium-grained calcarenite.
	5	Sandy calcilutite, calcareous quartz sandstone. Blue thin-bedded calcilutite with sandy laminae. Half inch bed of white fine-grained calcareous quartz sandstone at the base.
	8 inches	Two-tone calcilutite. Two-tone light blue-grey and brown calcilutite.
	10	No outcrop
	1	Calcilutite breccia. Breccia of brown-grey laminated calcilutite and brown-grey laminated calcilutite with sandy laminae set in a grey calcilutite matrix.
	1	Sandy calcilutite. Brown-grey laminated and thin-bedded calcilutite with sandy laminae.
	4	No outcrop
	3	Sandy calcilutite, two-tone calcilutite. Thin to medium sets of blue-grey thin-bedded calcilutite with brown medium-grained carbonate crystals and sandy laminae. Two-tone blue-grey and brown thin-bedded calcilutite with wavy laminae.
	2	No outcrop
Base	1	Sandy calcilutite. Red-brown laminated and thin-bedded calcilutite with sandy laminae. Lowest bed exposed above creek in this locality.
Total	179 feet	

Member 3:

Section G 518: Glenormiston Run 15, Photo 5155; north-western edge of the Ten Mile Hills.

Top of Section	Thickness (in feet)	
	4	Dolarenite. Brown vughy coarse-grained dolarenite. Dips below creek alluvium and sand.
	2	No outcrop.
	2	Dolarenite. Brown vughy coarse-grained dolarenite.
	1	No outcrop.
	1	Dolarenite. Brown vughy coarse-grained dolarenite.
	2	Dolomitic quartz sandstone. Brown laminated fine-grained dolomitic quartz sandstone.
	1	Dolarenite, sandy dolarenite. Soft white thin-bedded coarse-grained dolarenite becoming sandier towards top.
	2	Dolarenite. Brown thin-bedded medium-grained dolarenite with stylolites.
	1	No outcrop.
	1	Dolarenite. Brown fine-grained dolarenite.
	2	No outcrop.
	6	Dolarenite. Brown vughy laminated and thin-bedded fine to medium-grained dolarenite.
	7	Dolomitic quartz sandstone rubble. Thin plates of brown laminated fine-grained dolomitic quartz sandstone.
	1	Dolarenite. Brown, vughy coarse-grained dolarenite.
	1	Dolilutite, dolarenite. Brown thin-bedded dolilutite with interbeds of brown thin-bedded medium-grained dolarenite.
	15	Dolomitic quartz sandstone rubble. Thin plates of brown laminated fine-grained dolomitic quartz sandstone rubble showing ripple marks.
	2	Dolarenite. Thin beds of faintly-mottled brown medium-grained dolarenite and dark-brown fine-grained dolarenite with scattered coarse grains.
	1	No outcrop.
	1	Dolarenite and dolilutite. Faintly mottled vughy brown thin-bedded fine to medium-grained dolarenite with thin beds of brown dolilutite.
	1	No outcrop.
	6	Dolarenite. Faintly mottled brown fine to medium-grained dolarenite.

	2	No outcrop.
	3	Dolarenite. Brown coarse-grained dolarenite with scattered very-coarse-grained dolomite crystals.
	3	Sandy dolarenite. Brown cross-laminated medium grained sandy dolarenite.
	2	No outcrop. Travertine on the surface of the ground.
	2	Dolarenite. Light brown vughy thin-bedded cross-laminated medium-grained dolarenite containing chalcedony and coated by travertine.
	2	No outcrop.
	1	Dolarenite. Light brown and white vughy thin-bedded cross-laminated medium-grained dolarenite with a travertine crust.
	3	No outcrop.
	1	Dolarenite. White and brown medium-bedded coarse-grained dolarenite.
	3	No outcrop.
	1	Dolarenite. Light brown thin to medium-bedded medium-grained dolarenite.
	2	No outcrop.
	3	Dolarenite. Light brown thin to medium-bedded medium-grained dolarenite.
	1	No outcrop.
Base	2	Dolomitic quartz sandstone. Brown thin-bedded fine-grained dolomitic quartz sandstone.
		Lower beds covered to east by Mesozoic sediments.
	91 feet.	

Member 4

Section @519: Glenormiston Run 15, Photo 5155; four miles west of the north-west tip of the Ten Mile Hills.

Top of Section	Thickness (in feet)	
	4	Calcarenite. Brown, thin-bedded and medium-bedded coarse-grained calcarenite. Top of section covered by alluvium, but only few feet missing.
	18	Calcilutite and calcarenite. Thick sets of brown thin and medium-bedded calcilutite and thick sets of brown thin and medium-bedded medium to coarse-grained calcarenite.
	2	Mottled calcilutite and calcarenite. Mottled brown-grey thin-bedded calcilutite with medium sets of thin-bedded medium to coarse-grained calcarenite.
	2	Calcilutite. Brown thin-bedded calcilutite.
	1	Mottled calcilutite. Mottled brown-grey thin-bedded calcilutite.
	10	No outcrop.

6 inches	Calcilutite. Brown laminated and thin-bedded calcilutite
3	No outcrop.
1	Mottled calcilutite. Mottled brown-grey laminated and thin-bedded calcilutite.
1	No outcrop
4	Mottled calcilutite. Mottled brown-grey roughly laminated and thin-bedded calcilutite.
10	Marl. White laminated and thin-bedded marl.
5	No outcrop
6	Calcilutite. Brown laminated and thin-bedded calcilutite with sandy laminae towards the top.
15	No outcrop.
6	Marl and calcilutite. Friable white marl with thin to medium sets of mottled brown-grey laminated and thin-bedded calcilutite and of brown-grey calcilutite.
1	No outcrop.
2	Oolitic limestone. White roughly thin-bedded oolitic limestone containing ribeirioids and gastropods.
2	Marl. Friable white marl.
7	Mottled calcilutite. Rubbly mottled brown-grey laminated and thin-bedded calcilutite.
1	No outcrop.
1	Calcarenite. Brown-grey thin-bedded coarse-grained calcarenite.
1	No outcrop.
1	Calcareous quartz sandstone. Brown laminated fine-grained calcareous quartz sandstone.
1	No outcrop.
2	Sandy calcilutite. Brown-grey laminated and thin-bedded calcilutite with sandy laminae.
10	Calcilutite rubble. Scattered medium plates of mottled brown-grey calcilutite.
1	Two-tone calcilutite. Two-tone brown and brown-grey calcilutite containing circular structures from 6 inches to 4 feet in diameter.
4	No outcrop.
3	Calcilutite and calcarenite. Thin beds of brown-grey laminated calcilutite with wavy and cross-bedded laminae, and of brown fine to medium-grained calcarenite.
12	No outcrop.
1	Two-tone calcilutite. Two-tone grey thin-bedded calcilutite containing gastropods.
1	Calcarenite. Brown-grey thin-bedded medium-grained calcarenite containing brown-grey pelletoids up to 1/3 inch by 3 inches of brown-grey calcilutite.
7	Two-tone calcilutite. Two-tone brown and brown-grey thin-bedded calcilutite with ribeirioids and gastropods.
4	No outcrop.

6 inches	Calcarenite. Brown bed of fine-grained calcarenite with tubes on the top bedding plane.
6	Two-tone calcilutite. Two-tone brown and brown-grey thin-bedded calcilutite.
5	No outcrop.
5	Two-tone calcilutite. Two-tone brown and brown-grey roughly thin-bedded calcilutite.
2	Marl. White laminated marl.
6	No outcrop.
1	Two-tone calcilutite, sandy calcilutite. Thin sets of two-tone brown and brown grey roughly laminated and thin-bedded calcilutite and brown-grey laminated calcilutite with sandy laminae.
4	No outcrop.
1	Algae. Light brown bed of algae.
3	Calcilutite, mottled calcilutite, Thick sets of light brown laminated calcilutite and mottled brown and brown-grey laminated and thin-bedded calcilutite.
6	Calcareous quartz sandstone. Flags of brown laminated very-fine-grained calcareous quartz sandstone.
2	Calcilutite. Brown roughly thin-bedded calcilutite with cherty stringers. Gastropods.
5	No outcrop.
2	Two-tone calcarenite. Two-tone brown and light-brown roughly thin-bedded very-fine to fine-grained calcarenite.
2	Calcareous quartz sandstone. Thin plates of brown laminated and thin-bedded fine-grained calcareous quartz sandstone.
6	Two-tone calcilutite with sandy laminae, oolitic limestone. Two-tone grey and grey-brown thin-bedded calcilutite with sandy laminae and small calcilutite pellets. Grey thin-bedded oolitic limestone.
2	Calcarenite. Brown-grey thin-bedded medium to coarse-grained calcarenite.
2	No outcrop.
6 inches	Mottled calcilutite and oolitic limestone. Faintly mottled brown-grey thin-bedded calcilutite with thin beds of oolitic limestone.
4	No outcrop.
o	
6 inches	Two-tone oolitic limestone. Two-tone brown-grey and brown thin-bedded oolitic limestone.
6 inches	No outcrop.
1	Calcarenite. Brown very-fine-grained fontainbleau calcarenite with white and dark brown patches.
6 inches	Oolitic limestone. Brown-grey thin-bedded oolitic limestone.

	1 foot 6"	No outcrop.
	6 inches	Calcilutite. Brown-grey laminated and thin-bedded calcilutite.
	3 inches	Calcarenite. Brown very-fine-grained calcarenite.
	1	No outcrop.
	9 inches	Calcarenite. Brown fine-grained calcarenite with grey calcilutite pellets.
	1foot 6"	No Outcrop.
	6 inches	Oolitic limestone. Brown-grey oolitic limestone.
	5	Calcarenite, oolitic limestone. Brown laminated and thin-bedded fine to medium-grained calcarenite containing lenses of oolitic limestone.
	1	No outcrop.
	6 inches	Calcarenite. Brown very-fine-grained pelletoid calcarenite.
	1 foot 6"	Two-tone oolitic calcarenite. Two-tone brown and grey thin-bedded very-fine-grained calcarenite containing pellets of brown laminated sandy calcilutite.
	1	No outcrop.
	6 inches	Sandy calcarenite. Brown laminated fine-grained sandy calcarenite.
Base	2	Two-tone oolitic calcarenite. Two-tone brown and grey thin-bedded very-fine-grained oolitic calcarenite with pellets of brown laminated sandy calcilutite. Lower section with different dips hard to correlate with above.
	235 feet	

TOKO GROUP

The Toko Group is made up of the Kelly Creek Formation at the base, Coolibah Formation, Nora Formation, Carlo Sandstone, and Mithaka Formation.

Best exposures of the Kelly Creek Formation occur in the Tobermory Sheet area west of Glenormiston, and are only poorly exposed in the north-eastern part of the Toko Syncline. Sections from this formation in the Tobermory area are therefore described separately in Appendix 3. The Coolibah Formation also gives poor outcrop in the Glenormiston and two thin sections from the Tobermory area are given in Appendix 3.

NORA FORMATION

Section G261: Glenormiston Run 11, Photo 5221;
North-eastern side of Toko Range scarp, 2 miles north of Linda Creek.

Top of Section	Thickness (in feet)	
	30	Sandy siltstone. Yellow-brown and purple laminated and thin-bedded quartz siltstone with blebs and stringers of siltstone containing very-fine sand grains. Overlain conformably by Carlo Sandstone.
	20	No Outcrop.
	6	Micaceous quartz sandstone and siltstone. Purple laminated and thin-bedded fine-grained micaceous quartz sandstone with a few clay pellets and interbeds of siltstone and sandy siltstone.
	20	Sandy siltstone and siltstone. Yellow-brown, white and purple sandy siltstone and siltstone with tracks and trails.
	85	No outcrop. A few plates of brown coquinite 40 feet from the top of the interval.
	35	Quartz sandstone and coquinite. Friable brown, grey-brown and tan laminated and thin-bedded fine-grained well-sorted well-rounded quartz sandstone with thin interbeds of grey-brown and tan coquinite.
	196	Base of scarp

CARLO SANDSTONE

Section G261 Continued:

The top of the section is in a laterite profile.

	Thickness (in feet)	
	20	Quartz sandstone and siltstone. Friable brown laminated and thin and medium-bedded medium-grained well-sorted well-rounded quartz sandstone with irregularly distributed clay pellets and medium interbeds of quartz siltstone. There are tracks and trails on the bedding planes.
	10	Quartz sandstone and siltstone. Brown laminated and thin-bedded fine and very-fine-grained well-sorted well-rounded quartz sandstone and thin laminated interbeds of siltstone. There are tracks and trails on the bedding planes.
	5	Quartz sandstone. Brown thick-bedded cross-bedded medium-grained well-sorted well-rounded quartz sandstone with clay pellets and clay breccia.
Base	30	Quartz sandstone and siltstone. Mottled white, yellow-brown and purple thin and medium-bedded in places current bedded medium-grained well-sorted well-rounded quartz sandstone with clay pellets and thin-bedded and laminated siltstone. Tracks and trails on the bedding planes. Rests conformably on Nora Formation.
	65 feet.	

MITHAKA FORMATION

Section G 29, G 30: Glenormiston Run 15, Photo 5163; section measured in the upper part of the Mithaka Formation, in small hills two miles north of Craven's Peak Bore.

G 29

Top of Section Thickness (in feet)	
20	Quartz sandstone and shale. Medium sets of light brown and white laminated and thin-bedded cross-bedded fine-grained quartz sandstone with a few lenses of clay pellets. Brown shale.
10	Coquinite. Dark brown thin-bedded phosphatic coquinite containing *Lingula* and gastropods.
10	No outcrop.
G 30	
10	Quartz sandstone. Brown thin-bedded fine-grained quartz sandstone containing nautiloids, brachiopods and asaphid trilobites.
50 feet	

APPENDIX 3

Sections measured in the Kelly Creek Formation and Coolibah Formation, Tobermory 1:250,000 Sheet area.

Compiled by
P.W. Pritchard

KELLY CREEK FORMATION

Type section of Kelly Creek Formation.

Section T 68: Tobermory Run 13, Photo 5051; western side of Toko Range at Gaphole Creek.

	Thickness (in feet)	
Top of Section	10	Dolarenite. Grey-brown thin and medium-bedded fine-grained dolarenite. Overlain conformably by Coolibah Formation.
	2	Chert. White thin-bedded chert.
	2	Dolarenite. Grey-brown bed of fine to medium-grained dolarenite.
	17	No outcrop.
	7	Chert and dolarenite. White fossiliferous thin and medium-bedded chert containing one medium bed of thin-bedded and laminated fine-grained dolarenite.
	60	No outcrop.
	10	Dolarenite. Alternating thick soft and hard grey-brown beds of thin-bedded and laminated fine-grained dolarenite.
	13	No outcrop.
	20	Dolarenite. Alternating soft and hard thick beds of thin-bedded and laminated fine-grained dolarenite.
	7	No outcrop.
	10	Dolarenite and calcarenite. Fawn thin-bedded and laminated fine-grained dolarenite and calcarenite.
	12	No outcrop.
	3	Calcarenite. Fawn thin-bedded fine-grained calcarenite with sandy lenses.
	11	No outcrop.
	11	Calcarenite. Fawn thin-bedded fine-grained calcarenite with sandy lenses.
	16	No outcrop.
	5	Calcarenite. Fawn thin-bedded fine-grained calcarenite with sandy lenses.
	150	No outcrop.
	26	Quartz sandstone. White laminated thin and medium-bedded very-fine and fine-grained, rounded and sorted quartz sandstone with worm trails on the bedding planes and brachiopod coquina towards the top of the unit.
	14	No outcrop.

	18	Quartz sandstone. White thin to medium-bedded very-fine and fine-grained, rounded and sorted quartz sandstone with worm trails on the bedding planes.
	9	No outcrop.
	7	Quartz sandstone. White thin-bedded very-fine-grained, rounded and sorted quartz sandstone.
	11	No outcrop.
	4	Quartz sandstone. White thin-bedded very-fine-grained, rounded and sorted quartz sandstone.
	6	No outcrop.
	7	Quartz sandstone. White laminated very-fine-grained rounded and sorted quartz sandstone.
	31	No outcrop.
	10	Quartz sandstone. White thick to medium sets of laminated and cross-laminated very-fine-grained rounded and sorted quartz sandstone.
	6	No outcrop.
	3	Quartz sandstone. White silicified thin and medium-bedded very-fine-grained, rounded and sorted quartz sandstone.
	8	No outcrop.
Base	24	Rubble. White silicified quartz sandstone rubble. Contact with Ninmaroo Formation obscured below rubbly area of no outcrop.
	550	

Other sections in the upper, dolomitic part of the Kelly Creek Formation : -

Section T 221: Tobermory Run 9, Photo 5039; 2½ miles south of the dud bore on Bloodwood Creek.

	Thickness (in feet)	
Top of Section	6	Chert and sandy dolarenite. Thin to medium beds of white laminated chert containing fossils and thin interbeds of brown medium-grained sandy dolarenite. Conformably overlain by about 20 feet of Coolibah Formation.
	2	Dolarenite. Brown thin-bedded and laminated fine to medium-grained dolarenite.
	30	Dolarenite, sandy dolarenite and dolomitic sandstone. Alternating hard and soft, thick and massive beds of thin-bedded and laminated medium-grained dolarenite with sandy laminae, medium-grained sandy dolarenite and medium-grained dolomitic sandstone. Tubes on the bedding planes.
	12	Dolarenite and marl. Hard brown thin and medium-bedded fine to medium-grained dolarenite with soft thin and medium beds of marl.

	6	No outcrop. Rubble of silicified sandstone, sandy dolarenite and dolarenite.
	18	Dolarenite and marl. Thick beds of hard and soft brown medium-bedded very-fine-to fine-grained dolarenite with softer interbeds of marl.
Base	6	Dolarenite. Hard light-brown medium-bedded very-fine to fine-grained dolarenite.
	80	

Section T 215: Tobermory Run 12, Photo 5125; 3 miles west of Halfway Dam.

Top of Section	Thickness (in feet)	
	10	Chert rubble. White and yellow chert rubble.
	1	Dolarenite. Light grey fine-grained dolarenite.
	15	Chert rubble. White and yellow chert rubble.
	25	Dolomite marl and sandy dolarenite. White dolomite marl with thin to medium beds of grey fine-grained sandy dolarenite.
	5	Dolarenite. Grey thin-bedded and laminated fine-grained dolarenite.
	15	Dolarenite and chert. Grey thin-bedded fine-grained dolarenite with thin to medium lenses of chert.
	20	Sandy dolarenite. White laminated and thin-bedded fine to medium-grained dolarenite with sandy laminae.
Base	25	Dolarenite. Brown-grey laminated and thin-bedded fine to medium-grained dolarenite with cross-laminated lenses up to 4 inches thick.
	116 feet	

Other sections in the lower, sandy part of the Kelly Creek Formation:

Section T 212: Tobermory Run 12, Photo 5125; 4½ miles west of Halfway Dam.

Top of Section	Thickness (in feet)	
	20	Quartz sandstone. Brown laminated and thin-bedded fine-grained quartz sandstone; weathered top.
	6	Quartz sandstone. Yellow fine-grained quartz sandstone with manganese staining and ferruginous leisengang rings.
	20	Quartz sandstone. Red-brown thin and medium beds of laminated and cross-bedded fine-grained quartz sandstone with vertical tubes; forms bench.
	10	No outcrop.
	20	Quartz sandstone. Rubbly outcrop of white fine-grained quartz sandstone.
	15	No outcrop.

	15	Quartz sandstone. Brown and white thin-bedded cross-bedded fine-grained quartz sandstone with vertical tubes and with ripple marks and tubular trails on the bedding planes; forms bench.
	30	Quartz sandstone. Brown thin-bedded cross-bedded fine-grained quartz sandstone with U-tubes.
	5	Quartz sandstone. Friable red laminated fine to medium -grained quartz sandstone; forms bench.
	30	Quartz sandstone. Friable brown and white laminated and thin-bedded cross-bedded fine-grained quartz sandstone.
Base	25	No outcrop. Brown siltstone rubble. Apparently conformable over Member 4 of Ninmaroo Formation although actual contact not seen.
	196 feet	

Section T 246: Tobermory Run 13, Photo 5053; 4 miles south-east of Halfway Dam.

	Thickness (in feet)	
Top of Section	1	Pelletoid calcarenite. Brown-grey medium-bedded medium-grained pelletoid calcarenite with grains and clusters of grains of brown coarse-grained carbonate and with calcite veins in the joints.
	2	Calcareous quartz sandstone. Light brown thin-bedded fine-grained calcareous quartz sandstone.
	6 inches	Pelletoid calcarenite. Brown-grey medium-bedded coarse -grained pelletoid calcarenite.
	3	Mottled calcarenite. Faintly mottled brown laminated thin-bedded and cross-laminated medium-grained calcarenite.
	6	No outcrop.
	6	Calcarenite, pelletoid calcarenite. Brown-grey thick-bedded coarse-grained pelletoid calcarenite, with thin interbeds of brown fine-grained calcarenite.
	23	No outcrop. Some rubble of brown fine-grained quartz sandstone 8 feet from the top of the interval.
	2	Calcareous quartz sandstone. Yellow-brown laminated and thin-bedded very-fine-grained well-sorted well-rounded calcareous quartz sandstone with tubes and oscillation ripple marks on the bedding planes.
	2	No outcrop.
	2	Oolitic calcarenite. Brown bed of medium-grained oolitic calcarenite which is partly silicified.
	2	No outcrop.
Base	1 foot 6"	Two-tone oolitic calcarenite Faintly two-tone brown crudely thin-bedded medium-grained oolitic calcarenite with ribeirioids.
	51 feet	

COOLIBAH FORMATION

Section T 238: Tobermory Run 9, Photo 5141; The section is measured in the top of the Coolibah Formation, six miles west-south-west of the dud bore on Bloodwood Creek.

	Thickness (in feet)	
Top of Section	6inches	Oolitic and brecciated limestone. Brown-grey thin-bedded fine-grained oolitic limestone containing fragments of the same composition up to 1 cm. across.
	6	No outcrop.
	1	Oolitic and brecciated limestone. Brown-grey thin-bedded fine-grained oolitic limestone containing fragments of the same composition up to 1 cm. across.
	3	No outcrop.
	6 inches	Oolitic and brecciated limestone. Brown-grey thin-bedded fine-grained oolitic limestone containing fragments of white calcilutite and gastropods, The bed is silicified.
	3	No outcrop.
	6inches	Oolitic and brecciated limestone. Brown-grey thin-bedded fine-grained oolitic limestone containing fragments of the same material up to 1 cm. across.
	11	No outcrop.
	6inches	Dolomite. Brown medium-grained dolomite.
	3	Calcilutite. Brown-grey medium-bedded calcilutite with stringers (thin) and blebs of brown medium-grained carbonates.
Base	18	No Outcrop.
	47 feet	

Section T 239: Tobermory, Run 9, Photo 5141; the section is measured seven miles west-south-west of the dud bore on Bloodwood Creek.

	Thickness (in feet)	
Top of Section	3	No outcrop.
	1	Mottled calcilutite. Mottled brown-grey thin-bedded calcilutite with stringers and pellets of brown coarse to very-coarse-grained carbonate. Weathers to honeycomb structure.
	3	No outcrop.
	6 inches	Calcilutite. Brown-grey thin-bedded calcilutite with stringers and pellets of brown coarse to very-coarse-grained carbonate.
	4	No outcrop.
	10inches	Calcilutite. Brown-grey thin-bedded calcilutite with stringers and pellets of brown coarse to very-coarse-grained carbonate.
	5	No outcrop.

Top of Section	Thickness (in feet)	
Section	1	Calcilutite. Brown-grey crudely thin-bedded calcilutite containing a few pellets of brown calcilutite and numerous fossils including nautiloids and gastropods.
	4	No outcrop.
	2	Calcilutite. Blue-grey roughly thin-bedded calcilutite containing pellets of calcilutite, and gastropods and trails up to 3/8 of an inch across on the bedding planes.
	2	Calcilutite. Brown crudely laminated calcilutite.
	3	Calcilutite. Brown-grey roughly thin-bedded pelletoid calcilutite.
	1	Calcareous sandstone. Brown laminated fine to medium-grained calcareous sandstone.
Base	17	Marl. Green thin to medium-bedded marl containing hard nodules and beds of very-fine-grained calcilutite.
	47 feet	

APPENDIX 4

THE UPPER SILURIAN-LOWER DEVONIAN AGE OF THE SANDSTONE OVERLYING THE MIDDLE ORDOVICIAN TOKO GROUP, GEORGINA BASIN.

(Interim Report)

by

P.J. Jones

SUMMARY:

In five shot-hole samples taken from the Toko Range, Western Queensland, at approximately latitude 23°00'E, longitude 138°07'E, coelolepid fish-scales are abundant, indicating an Upper Silurian-Lower Devonian age. The fish-scales occur in a quartz sandstone, overlying the late Middle Ordovician Mithaka Formation which contains conodonts.

In 1960, Austral Geoprospectors Pty Ltd conducted on behalf of Phillips Petroleum Co. & Sunray Mid-Continent Oil Co., a seismic reflection survey of the eastern part of the Toko Range, on the central western boundary of Queensland. The area of the survey covered about 250 square miles at the south-west and north-west corners of the Glenormiston and Mount Whelan 1:250,000 sheets, respectively. The shot-hole samples (166, in number), were submitted to the Bureau of Mineral Resources for palaeontological examination, and the main results are briefly outlined below.

1. Upper Silurian-Lower Devonian fish scales.

(a) In shot-hole samples (S.P. 798, 799, 801, 813, and 839) taken from beds which cap the Middle Ordovician Mithaka Formation (Smith, 1963; equivalent to unit Om-10 of Pritchard, 1960, p.113), Coelolepid fish-scales are abundant, indicating an Upper Silurian-Lower Devonian age.

(b) The Coelolepid scales occur in "unit Om-11" of Pritchard (1960, p.113), described as "five feet of medium-bedded fine-grained quartz sandstone carrying clay pellets --".

2. Middle Ordovician conodonts

A conodont fauna has been found in more than 80 shot-hole samples taken from the Mithaka Formation. This fauna has yet to be sorted, but the Mithaka Formation contains shelly fossils, for which a late Middle Ordovician age is provisionally proposed by Miss Joyce Gilbert-Tomlinson (verbal communication).

REFERENCES

PRITCHARD, P.W., 1960 - The Ordovician section in the Toko Range *in* "The Geology of Queensland". *J.Geol.Soc.Aust.*, 7, 110-114

SMITH, K.G., 1963 - Hay River, N.T. - 1:250,000 Geological Series. *Bur.Min.Resour.Aust.*SF/53-16. *Explan. Notes*.

PRELIMINARY EDITION, 1964

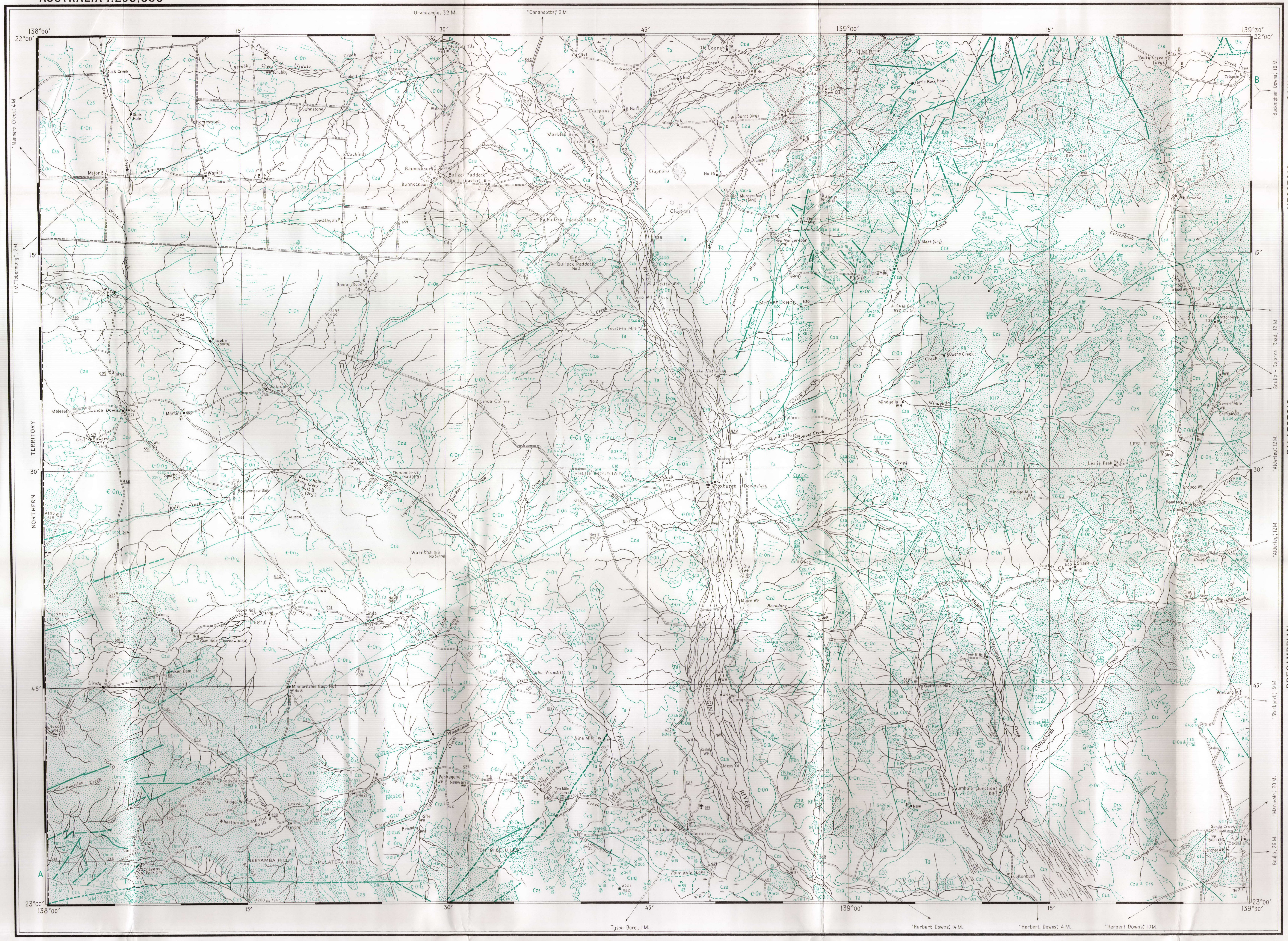
SUBJECT TO AMENDMENT

AUSTRALIA 1:250,000

GLENORMISTON

QUEENSLAND

1:250,000 GEOLOGICAL SERIES SHEET SF 54-9



Reference

CAINOZOIC	UNDIFFERENTIATED		Cza	Alluvium and soil
			Czs	Sand
				Leached and ferruginised (?lateritised) rock
	TERTIARY	Austral Downs Limestone	Ta	Limestone, chalcedony
		Marion Formation	Tm	Silicified pebbly sandstone
MESOZOIC	LOWER CRETACEOUS	Wilgunya Formation	Klw	Siltstone, fine sandstone, pebbly
		Longsight Sandstone	Kll	Sandstone, conglomerate, plant bearing, some marine fossils
	UNDIFFERENTIATED		M	Sandstone, siltstone, conglomerate
PALAEOZOIC	? PERMIAN		P	Pebble bed, shale
	ORDOVICIAN OR DEVONIAN		O/D	Sandstone with clay pellets
	MIDDLE ORDOVICIAN TO LOWER ORDOVICIAN	TOKO GROUP: Mithaka Formation	Omm	Siltstone, sandstone, gypsiferous, pellet beds
		Carlo Sandstone	Omc	Sandstone, massive
		Nora Formation	Omn	Siltstone, sandstone, coquinite, pellet beds
		Coolibah Formation	Olc	Limestone, marl, dolomite, some chert
		Kelly Creek Formation	Olk	Siltstone, sandstone with chert, dolomite
	CAMBRIAN TO ORDOVICIAN	Ninmaroo Formation	Є-On	Limestone, dolomite, sandstone interbeds
		Member 4	$Є\text{-}On_4$	Calcilutite with oolitic beds, sandy, algae (South-west Glenormiston area)
		Member 3	$Є\text{-}On_3$	Dolarenite, sandstone, hard and soft bands (South-west Glenormiston area)
		Member 2	$Є\text{-}On_2$	Calcilutite with algae (South-west Glenormiston area)
		Member 1	$Є\text{-}On_1$	Dolarenite, sandstone, calcilutite (South-west Glenormiston area)
	UPPER CAMBRIAN	Georgina Limestone	Єug	Limestone, some sandy interbeds
	MIDDLE CAMBRIAN TO UPPER CAMBRIAN	Mungerebar Limestone	Єm-u	Limestone, soft marly interbeds
	MIDDLE CAMBRIAN	Steamboat Sandstone	Єms	Sandstone, calcareous, sandy limestone
		Thorntonia Limestone	Єmt	Banded chert
	LOWER CAMBRIAN	Riversdale Formation	Єlr	Conglomerate, sandstone, siltstone
PRECAMBRIAN	LOWER PROTEROZOIC	Sybella Granite	Egs	Granite, gneiss with quartz reefs
		Eastern Creek Volcanics	Ele	Interbedded metasediments and metavolcanics

Geological boundary

Anticlinal axis

Synclinal axis

Fault

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

Lineament

Strike and dip of strata

Horizontal strata

Trend of bedding showing direction of dip

Strike and dip by air-photo interpretation, dip < 15°

Joints

Macrofossil locality

Microfossil locality

Plant fossil locality

Fossil wood locality

× G326 Text reference to specimen locality

G23 Section locality

B Bore

W Well

Abandoned bore or well

(dry) Dry, bore or well

T Tank

E Earth tank

Dam

Sink hole

WH Waterhole

Windpump

Swampy area

Sand ridges

Main road

Vehicle track

Fence

"Badalia" Homestead

Building or hut

Yd Yard

Landing groud

A194 Astro station

485 Height in feet, instrument levelled (Datum: mean sea level, Brisbane)

610 Height in feet, barometric (Datum: mean sea level, Brisbane)

(PD) Position doubtful

Compiled and issued by the Bureau of Mineral Resources, Geology and Geophysics, Department of National Development, in conjunction with the Geological Survey of Queensland. Topographic base compiled by the Division of National Mapping, Department of National Development. Transverse Mercator Projection.

INDEX TO ADJOINING SHEETS

Showing Magnetic Declination

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ANNUAL CHANGE 1′45″ E

Scale 1 : 250,000

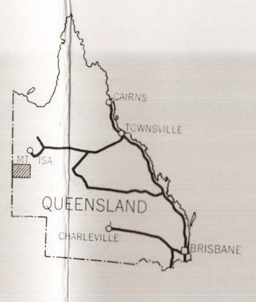
5 0 5 10 15 MILES

5 0 5 10 15 20 25 KILOMETRES

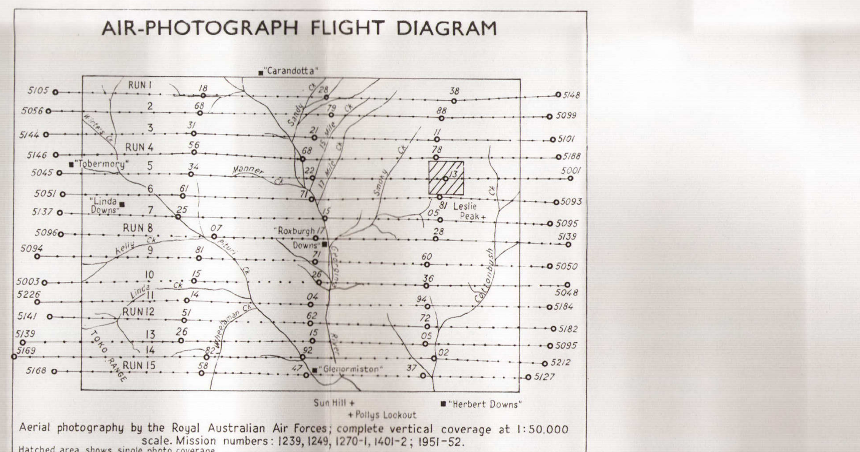
GEOLOGICAL RELIABILITY DIAGRAM

B. General reconnaissance, - traverses and air-photo interpretation

Geology 1958, and Compilation 1958-1963, by: J.N. Casey, M.A. Reynolds, P.W. Pritchard, K.G. Lucas, (B.M.R.) and R.J. Paten (Q.G.S.)
Drawn by: G. Matveev (B.M.R.)



AIR-PHOTOGRAPH FLIGHT DIAGRAM



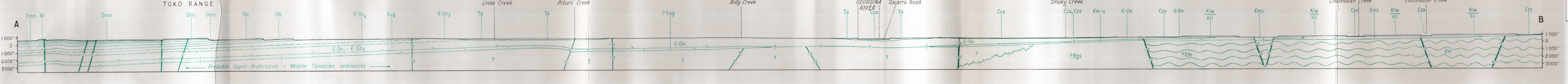
Aerial photography by the Royal Australian Air Forces; complete vertical coverage at 1:50.000 scale. Mission numbers: 1239, 1249, 1270-1, 1401-2; 1951-52.

Hatched area shows single photo coverage

Section

Scale: V/H = 3

(Some Cainozoic omitted from Section)



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SHEET SF 54-9