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RECORDS.

1960/71

SUMMARY OF THE GEOLOGY OF THE TOBERMORY 4-MILE GEOLOGICAL SHEET.

by

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INTRODUCTION

The area covered by the Tobermory Four-Mile Sheet is bounded by the meridians of 136 degrees 30 minutes and 138 degrees of East Longitude, and the 21st and 22nd parallels of South Latitude. The area is sparsely inhabited with a total white population of about 30. Nearly all of these are engaged in some section of the pastoral industry, producing cattle for beef. The area has four cattle stations (Tarlton Downs, Marqua, Tobermory and Manners Creek), one small Quarantine Reserve and a few Grazing Licences. Some of the area is not used for pastoral purposes.

Access is provided by the southerly one of the two main routes from Alice Springs to Mt Isa; this road has a formed, earth surface and it is usually impassable for several days after heavy rainfalls. From this road a network of station tracks leads to bores and other watering places for stock. Large parts of the area have no access roads or tracks.

All of the station homesteads have transceivers which are linked, according to proximity, with either the Cloncurry or the Alice Springs Base Stations of the Royal Flying Doctor Service. This Service provides prompt medical attention and transmits and receives telegrams. Tarlton Downs, Marqua and Tobermory Stations have aerodromes suitable for light aircraft.

Water for stock and for domestic purposes is obtained mainly from bores; there are also several dams, earth tanks and waterholes. The largest of the waterholes is Cockroach Waterhole which lasts for about eight months after being filled.

The courses of the larger streams are lined with tall eucalypts; elsewhere, vegetation is generally sparse and consists mainly of low gidyea, bloodwood and mulga trees and many varieties of stunted shrubs. Large areas are covered by spinifex.

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The climate is one of short, mild winters and long, hot summers. The summer temperatures frequently exceed 100 degrees Fahrenheit for periods of weeks and because of such conditions it is advisable to do field work between the months of May and September. The average annual rainfall is about ten inches and although most of this falls in summer months it is not uncommon to get rain in June. The reliability of rainfall is generally low, and droughts are frequent. The prevailing wind is from the south-east and in times of drought this wind is heavily charged with sand and dust.

The two most prominent topographic units are the flat-topped, heavily dissected Tarlton and Toko Ranges; these rise 180-250 feet and 200-400 feet respectively above the level of the surrounding land. The remainder of the area consists of gently-undulating country dotted with small peaks and mesas. In 1959, Surveyors from the Department of the Interior obtained levels along the main road which crosses the area, along Arthur Creek and the Hay River, and along the road from Goatyard Bore to Yardida Bore (which is on the adjoining Hay River Four-Mile Sheet). These levels show -

(a) On the main road, the highest elevation is at Survey Peg 60-18 which is located north of Mt Guide. At this peg the elevation is 961 feet above mean sea-level and the land slopes from here to Tobermory homestead whose altitude is 551 feet. From peg 60-18 the land slopes also to the road crossing of Arthur Creek where the elevation is 870 feet above mean sea-level.

(b) Survey Peg 61-8, located 1 mile north of No. 8 Dam, is near the divide between the north-flowing Bloodwood Creek and the south-flowing Dinner Creek. The land falls from 803 feet at this peg to an altitude of 561 feet at Goatyard Bore.

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No levels are available for that part of the area which lies north of the main road, and there are too few clearly-defined streams to give a reasonable indication of a topographic basin which may occur in that area.

GEOLOGICAL INVESTIGATIONS

In the late 19th century the explorers Barclay, David, Hodgkinson, Lindsay and Winnecke journeyed through various parts of the area. Before 1958, geological investigations were of a reconnaissance nature only; Whitehouse (1936) published a sketch map of part of the area, and Madigan (1937,a) and Hossfeld (1954) referred to the general geology of the area. Noakes (1956) and Casey & Tomlinson (1956) published accounts of the geology of separate parts of the Tobermory Four-Mile Sheet.

In 1958, Casey and Pritchard mapped the Toko Range area of the Sheet, and Condon and Smith reconnoitred the southern part of the sheet.

In 1959 a field party consisting of K.G. Smith, P.W. Pritchard, D.R. Woolley, R.R. Vine, D.J. Forman and A.R. Jensen mapped the remainder of the Tobermory Four-Mile Sheet. The 4-mile map and these notes are based mainly on the work of that party.

Since 1954, Miss Tomlinson and Dr A.A. Opik have examined fossil material collected in the area and have determined the age of the Lower Palaeozoic formations.

GEOLOGY

On the Tobermory Four-Mile Sheet there are outcrops of Archaean metamorphic rocks, Lower Proterozoic granite, and sediments of Upper Proterozoic, Cambrian, Ordovician, Permian, Cretaceous and Tertiary ages. The sediments have not been metamorphosed.

(1) Precambrian Metamorphic and Igneous Rocks

(a) Archaean. Outcrops of Archaean rocks are confined to the south-western quadrant of the Sheet, either

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in small peaks surrounded by sand plain or in low mesas. There are a few sharp ridges which are the expression of fault traces.

The rocks are regionally-metamorphosed psammitic and pelitic sediments. The lithologies include muscovite schist, biotite-quartz schist, biotite-quartz-chlorite schist, quartz-hornblende schist, quartz-feldspar biotite gneiss, quartz-feldspar-muscovite gneiss and a quartz-feldspar-chlorite rock which is roughly foliated.

Outcrops are too sparse to enable a reliable prediction of regional structure. Observations on available outcrops suggest that the regional strike is 320 degrees; observed dips are generally steep.

The age of the metamorphic rocks is assumed to be Archaean. The rock types and the degree of metamorphism are very similar to those found in metamorphic rocks mapped on the adjoining Huckitta Four-Mile Sheet (Joklik, 1955; Smith et al., 1960, unpubl.). On the Huckitta Sheet metamorphic rocks are regarded as belonging to the Archaean Arunta Complex; granites which intrude them have been dated, by Potassium-Argon ratio methods, at 1400-1500 million years (Hurley, Walpole and Smith, in press). This age, on current practice of the Bureau of Mineral Resources, Geology and Geophysics, is Lower Proterozoic. Therefore, the Arunta Complex, and its correlates on the Tobermory Four-Mile Sheet, are regarded as being Archaean in age. No age determinations have been made for granites which intrude metamorphic rocks on the Tobermory Sheet.

(b) Lower Proterozoic. Rocks which are assumed to be of this age consist of granite, with a few pegmatites. Outcrop generally is poor, low and sparse, but a few small peaks occur. Several types of granite have been mapped; the dominant one is a leucocratic, coarse-

grained, muscovite granite which is poorly foliated. Other types include very coarse-grained porphyritic granite and medium-grained, even-textured, leucocratic granite. Numerous fine-grained granitic dykes cut the granite bodies and there are a few discordant pegmatites. No workable mica-bearing pegmatite was mapped in the south-western quadrant of the Sheet, where most of the granite crops out. In the south-eastern quadrant, one pegmatite has been worked for muscovite; the workings are not extensive. This pegmatite is located about 6 miles west-north-west of Craigie Dam.

The age of the granite is incompletely known; it intrudes rocks believed to be of Archaean age and is overlain unconformably by unmetamorphosed sediments of Upper Proterozoic age. Therefore the age of the granite on the Tobermory Sheet is believed to be Lower Proterozoic.

(2) Sedimentary Rocks

(a) Upper Proterozoic. In rocks of this age one Formation and one set of Beds have been mapped. These are the Grant Bluff Formation and the Field River Beds. The Field River Beds (new name) are the oldest of the Upper Proterozoic sedimentary rocks exposed. They have been named and defined from the Field River area on the adjoining Hay River Four-Mile Sheet which the field party also mapped during 1959. On the Tobermory Sheet the distribution of the Field River Beds is confined to the following -

(i) South-eastern area. Extensive, low outcrops in the area between Red Heart Bore and Craigie Dam. In the type area the thickness of the Field River Beds is 3650 feet; the basal unit consists of boulder beds and green siltstone and this is succeeded by a sequence of arkose, dolomite, shale, siltstone and quartz greywacke. On the Tobermory Sheet the top part only of the boulder beds

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crops out and the full sequence of younger units of the Field River Beds is not present because it has been eroded prior to the deposition of unconformably overlying sediments of lower Middle Cambrian age.

(ii) South-western area. Small outcrops in the base of the Keepera Ridges and small but strong outcrops in a fault block on the eastern bank of Limestone Creek.

(i) South-eastern area. Two part-sequences of the Field River Beds have been measured near a prominent mesa located ¼ mile east of the junction of station tracks leading to Craigie Dam and to Noakes Bore. The sequences are separated by a horizontal distance of about 900 feet; this is underlain by green siltstone which has been faulted and folded to such a degree that reliable estimates of the thickness represented there are impossible. A summary of the sequences, in descending order, is -

Blue chert of lower Middle Cambrian age unconformably overlying Sequence 2 :

50 feet of	red, thin-bedded, fine-grained quartz sandstone;
80 feet of	brown, coarse, dolomitic arkose with pebbles, cobbles and boulders; this lenses along strike into pink and purple dolomite with thin interbeds of hard, laminated medium-grained purple quartz sandstone;
110 feet of	grey, very coarse-grained, cross-bedded pebbly arkose;
75 feet of	red and yellow dolomitic siltstone;
100 feet of	hard, dense, medium-bedded, yellow and purple dolomite;
220 feet	concealed;

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210 feet of medium-coarse grained, cross-bedded, pink and brown, micaceous pebbly arkose;

720 feet of poorly-outcropping, green, micaceous siltstone with thin interbeds of fine-grained, pink arkose;

Total: 1565 feet thickness of part-section

Gap of 900 feet (horizontal distance) underlain by Sequence I :

165 feet of green and grey, medium-grained, micaceous arkose with thin interbeds of green siltstone;

185 feet of red and yellow, laminated, dolomitic silstone with some beds of buff dolomite lensing along strike into dolomitic arkose;

340 feet of Boulder beds with interbeds of green siltstone with "tillitic" texture;

Total: 690 feet thickness of part-section

The top part of sequence 2 can be identified easily with beds in the Type Section of the Field River Beds; the lower part of 2 and most of sequence 1 cannot be so readily identified with beds of the Type Section but that may be because exposure is poor in this part of the Type Section.

(ii) South-Western Area. The following sequence has been measured on the eastern bank of Limestone Creek; in descending order the sequence consists of - Blue chert of lower Middle Cambrian age unconformably overlying :

1 foot of red siltstone;

7 feet of brown, laminated, micaceous greywacke;

9 feet of grey, medium-bedded, cross-bedded

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silty quartz sandstone with ripple marks and mud pellets;

190 feet of red, micaceous, laminated, dolomitic silstone with thin interbeds and lenses of red and purple, brecciated dolomite;

4 feet of dark-brown, medium-bedded, medium-grained, sandy dolomite;

105 feet of yellow, tan and buff fine-grained limestone with some sandy lenses and some thin interbeds of medium-grained arkose;

94 feet of laminated, flaggy, fine-grained blue limestone, highly micaceous and containing fragments of reworked red garnets;

Total: 410 feet thickness of part-section. (Base not exposed).

In the same area there are some arkose beds containing boulders, and some dolomitic arkose. These beds have been strongly disrupted by fault movements.

In the Keepera Ridges, a thickness of 960 feet of the Field River Beds has been measured. This section, in descending order, consists of - Grant Bluff Formation conformably overlying :

635 feet of poorly-outcropping, leached siltstone, gypsiferous in part, with lenses of coarse-grained arkose;

325 feet of poorly outcropping, coarse-grained grey arkose with some interbeds of green siltstone and some interbeds of dolomitic arkose;

Total: 960 feet thickness of part-section. Base not exposed.

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This sequence in the Keepera Ridges is very similar to that of the Elyuah Formation (Smith et. al. 1960 unpubl.) which conformably underlies the Grant Bluff Formation in the Jervois Range to the west, on the Huckitta Four-Mile Sheet.

The Grant Bluff Formation:

This Formation has been named and defined (Smith et. al., 1960 unpubl.) on the adjoining Huckitta Four-Mile Sheet. The Type Section of the Formation is located in the Elyuah Range, where the thickness is 530 feet. The thickness of the Formation increases to the east and on the Tobermory and Hay River Four-Mile Sheets it is about 1500 feet thick.

On the Tobermory Four-Mile Sheet, outcrops of the Grant Bluff Formation are restricted to the Keepera Ridges, in the western part of the area. The Formation has a distinctive lithology of alternating sequences of grey, fine to medium-grained quartz sandstone, and leached siltstone with, in some places, thin dolomite bands containing the algal form Collenia. In some localities, the quartz sandstone beds contain up to 10% of glauconite.

In the Keepera Ridges a thickness of 1500 feet has been measured in the Formation. The age of the Grant Bluff Formation is regarded as Upper Proterozoic, but it is considered that part, or all, of it may be of Lower Cambrian age. No determinations of age have been made on the glauconite content. On the adjoining Huckitta Four-Mile Sheet the Grant Bluff Formation is conformably overlain by the Mt Baldwin Formation (Smith et. al., 1960 loc. cit.) which contains Lower Cambrian archaeocyathids in its upper part. The position of these fossils in Lower Cambrian stratigraphy has not yet been determined.

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(b) Cambrian. There are no known outcrops of Lower Cambrian sediments on the Tobermory Four-Mile Sheet; the Mt Baldwin Formation does not crop out and no other beds which may be equivalent to it have been recognised. The oldest Cambrian sediments are fossiliferous, blue cherts of lower Middle Cambrian age (A.A. Opik, pers. comm.). These are succeeded by richly fossiliferous shale and limestone with lenses of sandstone, ranging in age from lower Middle Cambrian to uppermost Middle Cambrian. A complete study of the fossils from this sequence has not yet been made; a preliminary study indicates that there may be breaks in the sequence which are not discernable on the ground and accordingly the sequence is not divided into formations but is named the Marqua Beds (new name).

The Marqua Beds crop out in the southern part of the Tobermory Four-Mile Sheet, in isolated localities between Limestone Creek, in the west, and roughly the longitude of Craigie Dam in the east. Usually, lower units of the Beds do not crop out strongly, but the upper (limestone) units often form prominent ridges. These upper units, when not cropping out strongly, usually support a dense vegetation of gidyea trees and these are readily identifiable on air photographs. (Gidyea grows also on Upper Proterozoic and Ordovician dolomite in the area, and care must be exercised in interpretation).

The Marqua Beds, and their equivalents to the west and the east, form the basal units of sedimentary rocks deposited in the Georgina Basin. The name 'Marqua' is taken from Marqua Station homestead and the Type Section of the Beds is located about ½ mile north of the junction of station tracks leading to Noakes Bore and to Craigie Dam. The Type Section was measured about 50 yards west of an old track which leads north from this junction. At this locality the sequence, in descending order, consists of -

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30 feet of buff, medium-grained, flaggy, ? calcareous sandstone with fragments of trilobites;

530 feet of poorly-outcropping, fine-grained, flaggy blue limestone with fragments of trilobites; some strongly-outcropping, thin interbeds of grey, medium-grained sandy limestone;

105 feet of buff, silicified shale with a rich fauna of trilobites;

10 feet of blue chert with fragments of trilobites

Total: 675 feet thickness of part-section, unconformably overlying dolomite of the Field River Beds.

In the western part of the Sheet the following part-sections have been measured in a small area on the east of Limestone Creek; contacts between the sequences are not exposed. In descending order the sequences consist of :

3. 65 feet of creamy, fine-to medium-grained, thin-bedded, cross-bedded silty sandstone with worm trails;

515 feet of blue and blue-black flaggy limestone containing a rich brachiopod fauna, fragments of trilobites and numerous echinoderms.

Total: 580 feet thickness of part-section

2. 250 feet of hard, dense, laminated, blue and blue-black limestone; some beds have a rich trilobite fauna and have a petroliferous odour when struck. Upper beds are faulted against dolomitic arkose of the Field River Beds.

Total: 250 feet thickness of part section.

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1. Tarlton Formation, of ? Permian age, unconformably overlying

80 feet of strongly-outcropping buff shale;

15 feet of blue chert;

95 feet of thickness of part-section, unconformably overlying the Field River Beds.

The sequence in this western area has four units whose lithology is very similar to units of the Type Section; the 250 feet of limestone in sequence 2 has not been observed in the eastern area, although its time equivalents could be represented. The Type Section was located in the east because of ease of access.

The Marqua Beds are correlated, in part, with the Arthur Creek Beds (Smith, Wooley and Vine, 1960, unpubl.) exposed on the Huckitta Four-Mile Sheet. The buff shale and the flaggy, blue limestone with lenses of sandstone are present on both the Huckitta and Tobermory Sheets; the buff shale and its faunal content are very similar in lithology and fauna to the Sandover Beds (Opik, 1956) which dip south and east off the margins of the Lower Proterozoic sediments of the Davenport Range (Smith, Stewart and Smith, 1960, in preparation) on the Elkedra Four-Mile Sheet. On the Elkedra Sheet wet gas was obtained from a water bore drilled, in 1956, into a limestone-shale sequence which would correspond approximately to the top unit of the Marqua Beds and the Arthur Creek Beds.

<u>The Arrinthrunga Formation</u>.

This Formation was named and defined (Smith, Woolley and Vine, 1960, unpubl.) on the Huckitta Four-Mile Sheet, where it overlies the Middle Cambrian Arthur Creek Beds and is overlain by fossiliferous sandstone of Upper Cambrian age. On the Tobermory Sheet the Arrinthrunga Formation crops out strongly in a belt extending from the vicinity of Marqua Station homestead east-south-east to

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to the southern margin of the Sheet. To the west of this homestead the Formation crops out poorly and usually only the top part of it is exposed; evidence from water bores proves that it underlies a large area between Marqua Station homstead and Limestone Creek.

A complete section of the Arrithrunga Formation was measured at a locality some three miles north of Craigie Dam. Here, the sequence in descending order consists of -

Cambro-Ordovician sandstone conformably overlying

5 feet	of	buff limestone;
10 feet	of	medium-grained calcarenite;
15 feet	of	limestone with dolomitic mottling;
5 feet	of	medium-grained, dolomitic sandstone;
35 feet		concealed;
35 feet	of	limestone with dolomitic mottling and thin interbeds of dolomite and intra-formational breccia;
65 feet		concealed;
25 feet	of	limestone with interlaminated dolomite;
10 feet	of	fine-grained, dolomitic sandstone;
40 feet	of	limestone with dolomitic mottling in part; some silty interbeds and inter-laminated dolomite and algal limestone;
30 feet		concealed
125 feet	of	limestone with dolomitic mottling; some algal limestone
100 feet		concealed;
15 feet	of	sandy dolomite;
15 feet		concealed
10 feet	of	limestone with dolomitic mottling;
15 feet		concealed;
20 feet	of	dolarenite;
55 feet		concealed;
40 feet	of	limestone with dolomitic mottling; some thin beds of calcarenite;

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20 feet of	limestone, limestone conglomerate and coarse-grained calcarenite;
5 feet of	sandy dolomite;
15 feet	concealed;
130 feet of	poorly-outcropping limestone with dolomitic mottling; some inter-laminated dolomite;
200 feet of	limestone with dolomitic mottling;
125 feet of	limestone with interlaminated dolomite; some concealed softer interbeds;
185 feet of	coarse-grained dolarenite, overlying the Marqua Beds.
1350 feet	thickness of Arrinthrunga Formation.

In small fault blocks on the eastern side of Limestone Creek the lower beds of the Arrinthrunga Formation are exposed. In this area a thickness of 410 feet was measured; the sequence consists of dolomite in the lower parts, succeeded by limestone and oolitic limestone.

The contact between the Arrinthrunga Formation and the Marqua Beds is not exposed in sufficient detail to prove conformity or otherwise of the two stratigraphic units. The Arrinthrunga Formation is unfossiliferous; it is overlain by fossiliferous sandstone of Upper Cambrian age but its actual position in the Upper Cambrian is in doubt.

(c) CAMBRO-ORDOVICIAN AND LOWER ORDOVICIAN. Around the margin of the outcrop of the Ninmaroo Formation (named by Casey 1959) and scattered within it are numerous outcrops of sandstone. Many of these outcrops are poor and discontinuous. The lithology is usually fine to medium-grained, micaceous, well-sorted sandstone, glauconitic in part; the sandstone is usually thin-bedded, laminated and strongly slumped. In part it is richly fossiliferous. Interbedded with the sandstone are dolomite, sandy dolomite which grades laterally into sandstone, and minor beds of micaceous silt-

stone.

Because of the discontinuity of outcrop and because of sharp slump folds in the beds the relationships between the sandstone and the Ninmaroo and Kelly Creek Formations are incompletely known. The significant facts are:

(1) A sandstone unit of the order of 200 feet thick is present below the Ninmaroo Formation and above the Arrinthrunga Formation, throughout the southern part of the Tobermory Sheet. In the vicinity of Southern Cross Bore this sandstone contains lenticular dolomite, and from the sandstone Upper Cambrian fossils have been collected (Casey & Tomlinson, 1956). Some 4 miles south-east of Lucky Bore the sandstone contains numerous fossils, of Upper Cambrian age (A.A. Opik, pers. comm.)

(2) In the south-eastern part of the Tobermory Sheet the sandstone sequence is well-exposed; here the sequence becomes richer in carbonate rocks.

(3) Through the central part of the Sheet there are many small sandstone hills; in some of these it is clear that the sandstone overlies dolomite of the Ninmaroo Formation.

(4) 15 miles north of Tarlton Downs Station homestead, and also 6 miles east of the southern tip of the Tarlton Range, sandstone units change laterally into the carbonate-siltstone sequence of the Ninmaroo Formation.

(5) East of the central part of the Tarlton Range the Kelly Creek Formation overlies sandstone beds, without apparent unconformity; here it appears that the equivalent of the whole of the Ninmaroo Formation has a sandstone lithology.

(6) In the north-western part of the sheet a sequence of sandstone with interbedded dolomite contains fossils

of Upper Cambrian age.

It is believed probable that there is a sandstone unit generally present between the Arrinthrunga and Ninmaroo Formations, but without detailed palaeontological study of the faunas contained in the sandstone outcrops on the Tobermory Sheet, it is not possible to separate sandstone within the Ninmaroo Formation from sandstone immediately below that Formation. Accordingly, most of the sandstone is shown on the map as an un-named unit of Cambro-Ordovician age.

The Ninmaroo Formation:

Whitehouse (1936) named the Ninmaroo Limestone from the Lower Palaeozoic limestone and dolomite sequence exposed at Mt. Ninmaroo, Mt. Datson and Black Mountain, north-east of Boulia in western Queensland. Subsequent work by field parties from the Bureau of Mineral Resources showed that the lower third of the sequence at Black Mountain contained a rich fauna of Upper Cambrian age and could be separated as another Formation. The Ninmaroo Limestone was accordingly subdivided, and the names Chatsworth Limestone and Ninmaroo Formation applied to the lower and upper units respectively (Casey, 1959). The age of the Ninmaroo Formation is uppermost Upper Cambrian and Lower Ordovician.

The Ninmaroo Formation crops out in a belt extending through the centre of the Tobermory Four-Mile Sheet and spreading over most of the northern half of the Sheet. The outcrops normally form extensive plains dotted with rocky rises, but where erosion has been more active a marked bench topography is developed. On the western side of the Toko Range the Formation has been strongly folded and forms a strong ridge.

A section in the Ninmaroo Formation has been measured at a locality 5½ miles south-west of Coolibah Dam.

At this locality the sequence, in descending order, consists of:

Kelly Creek Formation overlying

111 feet of very coarse-grained, blue-grey calcarenite with interbedded quartz sandstone;

115 feet of poorly-outcropping, fine-grained quartz sandstone; siltstone; thick interbeds of calcarenite, intraformational breccia and grey dolarenite;

131 feet of thick and thin-bedded blue-grey limestone, dolomite and oolitic limestone;

83 feet of poorly-outcropping, fine-grained quartz sandstone.

172 feet of grey, coarse-grained, thick-bedded dolarenite, the interval contains concealed interbeds of soft rock;

612 feet thickness of Ninmaroo Formation, conformably overlying 229 feet of quartz sandstone with thin interbeds of dolarenite, dolomite and limestone; this 229 feet is placed in the un-named Cambro-Ordovician beds.

In the western part of the Sheet a section has been measured in outcrops between Limestone Creek and Camel Creek. Here the upper part of the Ninmaroo Formation is well exposed; the base is not exposed but it is estimated that not more than 150 feet of the Formation is concealed. The sequence, in descending order, consists of: Kelly Creek Formation conformably overlying

73 feet of grey, oolitic limestone, intraformational limestone conglomerate and glauconitic calcarenite; some interbedded buff sandstone;

85 feet of interbedded white, porous sandstone (fossiliferous) and green siltstone, with some thin beds of very coarse-grained, grey calcarenite;

170 feet of blue-grey, coarse-grained calcarenite with some

oolitic limestone; thin interbeds of white, porous sandstone (fossiliferous) and green siltstone; short, straight nautiloids are present in the interval, 80-95 feet above the base;

328 feet — thickness of part-section.

Base not exposed.

The Kelly Creek Formation (unpublished name). The name is taken from Kelly Creek, which rises in the Toko Range and flows east across the Northern Territory-Queensland border at 138 00' E, 22 35'S. The Formation crops out around the margins of both the Toko and Tarlton Ranges.

In the Toko Range the lower part of the Kelly Creek Formation is sandy, sometimes containing glauconite; the upper part is dolomitic and cherty. The Formation is transitional and apparently conformable with both the underlying Ninmaroo Formation and the overlying Coolibah Limestone. The type section of the Kelly Creek Formation has been measured at Gaphole Creek, on the western side of the Toko Range. A summary of this section, in descending order, is: Coolibah Limestone conformably overlying:

38 feet of — grey-brown, thin and medium-bedded, fine-grained dolarenite with white, thin-bedded fossiliferous chert;

60 feet — concealed;

60 feet of — alternating hard and soft thick sets of thin-bedded and laminated, fine-grained dolarenite, with calcarenite at base of the interval;

208 feet of — poorly-outcropping, thin-bedded, fine-grained calcarenite, with sandy lenses in the upper 50 feet of the interval;

102 feet of — white, thin-bedded, very fine-grained quartz sandstone;

31 feet — concealed;

51 feet of — white, thick to medium sets of thin and medium-

bedded, cross-laminated in part, fine-grained quartz sandstone;

550 feet — thickness of Kelly Creek Formation, conformably overlying the Ninmaroo Formation.

In the Tarlton Range area, the best exposures of the Kelly Creek Formation are on the east side of the Range; numerous sections have been measured here and the Formation is about 250 feet thick. It is dominantly a sandstone unit but much of the sandstone is micaceous and glauconitic and in the lower and middle parts of the Formation there are numerous interbeds of laminated green siltstone. Several of the sandstone beds grade laterally into dolomite and sandy dolomite beds which feature cross-lamination.

In the Tarlton Range area the Kelly Creek Formation is transitional and conformable with the underlying Ninmaroo Formation. The relationship with the overlying Nora Formation is not clear; there is a sharp lithological break between the two Formations and the lithology of the Coolibah Limestone is not represented. No other evidence of non-conformity was found.

In the Tarlton Range area shelly fossils are not very common in the beds of the Kelly Creek Formation; brachiopods, trilobites and cephalopods have been collected from a few thin bands. Worm tubes and trails are very common, and some beds seem to have been almost completely "digested" by burrowing organisms. A preliminary determination of shelly fossils indicates a Lower Ordovician age for the Kelly Creek Formation (Joyce Gilbert-Tomlinson, pers. comm.)

(d) MIDDLE ORDOVICIAN.

The TOKO GROUP. (New name). The name 'Toko' was first used by Whitehouse in 1936, when he proposed Toko Series to replace Glenormiston Series which he had used in 1930. The name has been used by David and Browne (1950) and by the

compilers of the Geological Map of Queensland (1953 edition). Casey (1959) used "Toko Beds" for all the rocks above the Ninmaroo Formation. Subsequent mapping has shown that the Kelly Creek Formation is intimately related to the Ninmaroo Formation and it appears likely that there is a faunal break between the Kelly Creek and Coolibah Formations. Accordingly, Toko Group is now used for the Middle Ordovician sediments (Coolibah to Mithaka Formations)

In the Toko Range the Toko Groups consists of four gradational and conformable Formations, namely the Coolibah, Nora, Carlo and Mithaka Formations. In the Tarlton Range the lithology of the Coolibah Formation is not present but an apparently conformable sequence similar to the other three units has been mapped and these are tentatively correlated with the corresponding units in the Toko Range. The outcrop of the Toko Group is restricted to the two Ranges. Preliminary fossil determinations indicate a Middle Ordovician age for the whole Toko Group (Joyce Gilbert-Tomlinson, pers. comm.).

The Coolibah Formation (unpublished name)

The name is taken from Coolibah Dam on Gravehole Creek, at 137 44' E, 22 49' S. Outcrops of the Coolibah Formation form well-developed cuestas around the Toko Range.

The Coolibah Formation consists mainly of medium and thick sets of blue-grey and brown-grey, crudely thin-bedded calcilutite and green-white marl. Some of the calcilutite beds are oolitic and some have mottlings of brown, coarse-grained carbonate lithology which is susceptible to silicification. There are minor amounts of yellow and white chert and of brown, thin to medium-bedded, medium-grained to coarse-grained calcerenite and dolarenite which is sometimes sandy.

Several complete sections of the Coolibah Formation have been measured on the Tobermory Four-Mile Sheet. These range in thickness from 27 feet (Type Section at Gaphole

Creek) to 47 feet; farther east, in Queensland, the Formation is much thicker.

The Coolibah Formation is richly fossiliferous and contains nautiloids, gastropods, ribeirioids and horn-shaped coral-like organisms up to 2 inches long.

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The Nora Formation (Unpublished name)

The name is taken from Nora Gap, on the north-eastern edge of the Toko Range, at 137 56' E, 22 43' S. The Formation crops out around the edge of the Toko Range, where it is about 400 feet thick; it crops out also in the Tarlton Range but there the thickness is about 200 feet.

The Type Section of the formation is in the southern part of the Toomba Range, Mt. Wheelan 4-mile sheet).

In the Toko Range area a part-section has been measured 1½ miles north-west of Half-way Dam. There the sequence, in descending order consists of:

Top not exposed

25 feet of brown and yellow micaceous shale;

15 feet of impure calcarenite and fine-grained quartz sandstone, thin-bedded and laminated;

35 feet of micaceous shale and fine-grained quartz sandstone;

30 feet concealed;

45 feet of calcarenite and sandy calcarenite, with thin beds of coquinite and brown, thin-bedded, laminated fine-grained quartz sandstone;

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150 feet thickness of part-section of Nora Formation, conformably overlying Coolibah Formation.

In the Tarlton Range the scarp is formed of a dominantly siltstone-claystone lithology which grades upwards into fine-grained sandstone. Coquinites are common in the basal part of the Formation and they persist as thin inter-beds throughout most of the unit. A complete section has been measured in the southern part of the Range, where the sequence, in descending order, consists of:

Carlo Sandstone conformably overlying

49 feet	concealed;
28 feet of	porous, friable, fine-grained quartz sandstone, highly gypsiferous in part;
25 feet	concealed;
56 feet of	brown and green claystone and siltstone, gypsiferous in part, with numerous thin interbeds of brown, pellety coquinite, and indurated pale brown fine-grained sandstone;
27 feet of	green, micaceous siltstone, with thin interbeds of ferruginous, pellety coquinite, indurated quartz sandstone and glauconitic sandstone;
17 feet of	poorly-outcropping, ferruginous, pellety coquinite, and shelly dolomite;
202 feet	thickness of Nora Formation, overlying the Kelly Creek Formation.

The Nora Formation is richly fossiliferous in the lower part, where nautiloids, brachiopods, pelecypods, trilobites, sponges and bryozoa are common. In the upper part there are abundant tracks and trails on bedding planes, but few shelly fossils have been found.

The Carlo Sandstone (New name)

This dominantly sandstone unit forms the resistant rim of the scarp of the Toko Range and the rubble-covered rises above. The name is taken from Carlo Station in the Mt. Whelan area of Queensland.

The Carlo Sandstone consists of white and brown, thin, medium and thick-bedded, fine to medium-grained quartz sandstone with some felspathic quartz sandstone in the lower part. Towards the bottom of the formation there are a few beds of quartz siltstone and an abundance of clay pellets. A few nautiloids, brachiopods, pelecypods and worm tubes have been found in the formation, particularly in the upper part of it.

In the Toko Range the maximum thickness measured is 263 feet but this does not represent a complete section.

In the Tarlton Range a sandstone unit forms the main rim and this sandstone is tentatively assigned to the Carlo Sandstone. It consists mainly of a fine to medium-grained, well-sorted quartz sandstone, dominantly chocolate and pale brown to grey in colour, with a few interbeds of kaolinitic sandstone, and laminae of ferruginised siltstone. The characteristic features of the unit are the presence of current features -- flute casts, current ripple marks, mud pellets (some arranged in channels) and incipient and small-scale slumps develped from ripple marks. The maximum thickness measured was 65 feet; the full thickness of the Carlo Sandstone in the Tarlton Range is estimated to be 100 feet.

The Mithaka Formation (New Name)

This name is taken from Mithaka Waterhole in the Toko Range, at 138 00' E, 25 53' S. In that area the Formation usually forms low, rubble-covered rises and good sections are rare. The best-exposed sections of the upper part of the Mithaka Formation are to the north of Cravens Peak Bore (Type Section) on the adjoining Glenormiston Four-Mile Sheet in Queensland (Casey et al., pers. comm.) There the lithologies consist of thin-bedded and laminated, fine-grained quartz sandstone with some coquinite and brown shale towards the top. Asaphid trilobites, nautiloids, brachiopods and gastropods have been found in these beds, which are capped by about 5 feet of medium-bedded, fine to medium grained quartz sandstone with clay pellets.

On the Tobermory Four-Mile Sheet thin sections of the lower part of the Mithaka Formation are exposed on the western edge of the Toko Range near Gaphole Creek. In this locality the dominant rock type is a brown, soft, fossiliferous gypsiferous siltstone with interbedded brown, laminated,

thin-bedded, fossiliferous, ripple-marked quartz sandstone. The thickness of the Formation is estimated to be 200 feet.

On the Tarlton Range there are several strongly-lateritised residuals of massive siltstone, with a micaceous, fine-grained sandstone at the base. They contain fossil bands with asaphid trilobites and linguloid brachiopods. This sequence is tentatively assigned to the Mithaka Formation. The maximum thickness measured was 41 feet.

(e) ? PERMIAN

Tarlton Formation

Thin sequences of sedimentary rocks, believed to be of terrestrial glacial origin and of Permian age, crop out in many localities between the Tarlton Range and the Georgina River in Queensland (Condon and Smith, 1959, unpubl.) On the Tobermory Four-Mile Sheet the Formation crops out in numerous mesas between the Tarlton and Toko Ranges, and in low rises to the north and west of McCrae's Bore, near the northern Margin of the Sheet, the Tarlton Formation unconformably overlies Ordovician, Cambrian and Proterozoic sediments on the Tobermory Sheet, and in Queensland is overlain by Cretaceous sandstone and shale. The Formation is strongly lateritised.

The Type Section of the Tarlton Formation is located 11 miles south of Tarlton Downs homestead. The exact location is shown on the map by Condon & Smith, (loc. cit.). There the sequence, in descending order, consists of:

3 feet of "billy," at top surface of mesa;

17 feet of silty, coarse and medium-grained sandstone, and siltstone;

30 feet of white, silty, thin-bedded, medium-grained sandstone, and siltstone;

20 feet of white, silty, very coarse, coarse and medium-grained, cross-laminated sandstone with scour and fill structures; silty, pebble conglomerate,

thin, laminated siltstone;

3 feet of pale grey, pebbly claystone with a few boulders (ground moraine);

73 feet thickness of Type Section, unconformably overlying Ordovician sediments.

The thickest section measured in the Tarlton Formation, on the Tobermory Sheet, is at Mt. Ewing; here the thickness if 140 feet, but the base of the Formation is not exposed. The base is not exposed in most localities where the Formation has been examined, but usually the lowest exposure is a pebble or cobble conglomerate and therefore the base is probably not far below the surface. The Formation effectively masks the underlying rocks in large areas between the Tarlton and Toko Ranges.

There is no definite evidence of Permian age for the Tarlton Formation. Coniferous wood has been found in it at a locality 5 miles south-east of Burnt Well; fragments of unidentified fossil wood were located in numerous localities during 1959, and some specimens from the Tarlton Range, some 4 miles north of the Type Section, have been examined by Mary E. White. This collection contained Equisetales and one possible Vertebraria, but the preservation of the latter made positive identification impossible.

(f) MESOZOIC

In the south-eastern part of the Sheet there are several small mesas of sediments which unconformably overlie various units in the Ordovician sequence. They are thought to be of Mesozoic (probably Cretaceous) age. The sediments consist of a basal conglomerate, succeeded by medium and fine-grained sandstone, and siltstone containing Rhizocorallium and fossil wood. The wood has not been identified. The thickness of the sediments ranges from 50 to 100 feet.

(g) TERTIARY

Austral Downs Limestone

In the north-eastern part of the Tobermory Sheet there are numerous outcrops of sediments which are believed to be of Tertiary age. These sediments crop out in small mesas which show on air photographs as a distinctive white pattern. The sediments consist of chalcedony and silicified limestone; the thickness ranges from 20 to 50 feet. From the Tobermory Sheet the sediments extend eastwards into Queensland where they have been traced (Casey et. al. pers. comm.) along the valley of the Georgina River to outcrops of the Austral Downs Limestone on the Urandangi Four-Mile Sheet.

(h) STRUCTURE

The regional structure of the Archean rocks is unknown because of paucity of outcrop. Sediments of Upper Proterozoic and lower Palaeozoic ages have been strongly affected, in the southern part of the sheet, by post-Middle Ordovician movements which have resulted in faulting and sharp monoclinal folding. A second series of faults, probably of the same age, has a north-easterly trend but affects rocks of the Toko Range only.

Along the Tarlton Fault, on the western side of the Tarlton Range, Archaean and Upper Proterozoic rocks have been faulted against the Ninmaroo Formation, which is steeply dipping and tightly folded. On the west side of the Keepera Ridges the Grant Bluff Formation apparently dips into Archaean rocks and a faulted contact is postulated. Associated with this probable fault is a parallel fold, the Keepera Syncline.

On the western side of the Toko Range there are three parallel, strong, structural lines which are faults, at least in part. The most easterly one, the Toomba structure, is represented on the Tobermory sheet as a line of

sharp folding south-east of Burnt Well. It trends south-eastwards onto the Hay River sheet and continues along the Toomba Range, where it is a double fault, onto the Mt. Wheelan Sheet of Queensland.

Along the middle line, the Craigie Fault, Field River Beds are faulted against the complete sequence from the base of the Middle Cambrian to the Ninmaroo Formation. Faulting is evident to only a short distance west of the meridian of Craigie's Dam, thereafter the line continues north-westwards as a zone of steep dips which gradually swings westwards.

The westerly line, the Marqua Structure, is monoclinal for most of its length, but in the south-east, where the surface rocks are Upper Proterozoic, it changes into a fault.

The Toko Syncline is the most prominent of the broad fold structures; its axis trends north-west. On the western edge of this fold, the oldest beds are steeply-dipping because of the effect of faulting along the north-west trending structural lines.

The dips and distribution of the Arrinthrunga Formation indicate a regional anticline with a shallow pitch to the north-west. The axis of this fold would lie roughly midway between Southern Cross Bore and the eastern edge of the Tarlton Range. Field River Beds in the Red Heart Bore area form the core of this anticline.

To the north of the main road, the regional structure is incompletely known. In the western part of the Sheet the interpretation of structure depends upon the solution of the problem of stratigraphic position of many of the sandstone units which are designated ?Cambro-Ordovician on the map. In the north-west and west, the distribution of fossiliferous Upper Cambrian sandstone could indicate the edge of a basin structure. For the remainder of the area north of the main road, the lack of regional

dips in the Ninmaroo Formation and inadequate knowledge of its thickness (some deep bores have been drilled, e.g, Dummy Bore - 600 feet, but they could have penetrated the Arrinthrunga Formation) do not permit an interpretation of regional structure based on dips, sub-surface information and topography. The mapping of the lower part of the Sandover River Four-Mile Sheet (schedule for the 1960 field season) is expected to assist in the interpretation of this regional structure.

The regional distribution of formations between Marqua and Elkedra suggests that the regional dip in the northern part of the Tobermory sheet is northward towards the Sandover River syncline but the available information does not permit confirmation or denial of this

ECONOMIC GEOLOGY

(i) Mica. On the whole of the Tobermory Four-Mile Sheet there is only one known locality where a mineral has been mined. This locality is about three miles west-north west of the junction of tracks leading to Noakes Bore and to Craigie Dam. A pit and a few small costeans have been sunk on an outcropping pegmatite but records of production are not available.

(ii) Lead. Samples of galena have been obtained, according to local information, from the area east of the southern tip of the Tarlton Range. These almost certainly were obtained from small pockets of galena contained in the Ninmaroo Formation.

(iii) Under-ground Water. In the area covered by the Tobermory Four-Mile Sheet, there are about 45 bores which produce useful supplies of water and there are at least 20 dud bores.

There is no bore which produces a reliable supply of water from the Upper Proterozoic Field River Beds (but there are some on the adjoining

Hay River Sheet). The only bore drilled into these Beds is Red Heart, on Marqua Station; about 1000 gallons per hour were obtained from a sandstone interbed in a sequence of green siltstone, but the aquifer was soon exhausted and the bore is no longer in use.

There are no producing bores in the Marqua Beds and these sediments are not known to include any aquifers; one unsuccessful bore was drilled, on Marqua Station, to a depth of 600 feet in steeply-dipping blue limestone of the Middle Cambrian sequence.

The Arrinthrunga Formation contains a few good aquifers on the Huckitta Four-Mile Sheet; it is known that one of the aquifers is in the basal dolarenite but the stratigraphic positions of at least two other aquifers is uncertain. On the Tobermory Sheet, five bores have been drilled in the Formation and three of these have been unsuccessful. One successful one on Marqua Station drilled into the basal dolomite of the Formation and produced about 1400 gallons per hour. The other successful bore was drilled on Tarlton Downs Station and produced about 700 gallons per hour after penetrating the topmost 170 feet of the Formation. It is possible that some deep bores in the north-eastern quadrant of the Sheet have passed through the Ninmaroo Formation into the Arrinthrunga Formation but the thickness of the Ninmaroo Formation in those parts is not known and such logs as are available do not indicate the presence of a thick sandstone unit in any of the bores.

Numerous bores have been drilled into the Ninmaroo Formation, with mixed success. On Tarlton Downs Station, three dud bores have been drilled and another yielded, for a short time, 3000 gallons per hour from a depth of 40 feet. This water was contained either in fractures or in solution cavities.

Manners Creek, Marqua, and Tobermory Stations each have several bores producing from the Ninmaroo Formation. In some cases the yields are very good, e.g., 2000 gallons per hour from Southern Cross Bore, 1800 from West End Bore and 1600 from No. 2 Bore on Tobermory Station. Yields such as these are probably obtained from solution cavities in carbonate rocks of the Formation, but some of the bore logs show thin interbeds of sandstone. Although some dud bores have been drilled into the Ninmaroo Formation in the eastern part of the Tobermory Sheet, it is believed that the general success in drilling this Formation has been achieved because the Formation contains less siltstone than it does in the west and because of the topographic basin in the north-eastern quadrant.

Tarlton Downs Station has three successful bores in the Kelly Creek Formation and one has been drilled on Tobermory Station. There are no successful bores in Middle Ordovician sediments, partly because topography precludes the use of the land for pastoral purposes.

(iv) Petroleum prospects;

The richly-fossiliferous Marqua Beds are possible source beds for petroleum and they may contain some cap rocks. The Marqua Beds form the basal unit of the sedimentary sequence in the Georgina Basin; on the Tobermory Four-Mile Sheet their outcrop is always near the margins of Precambrian outcrop but the Marqua Beds probably underlie much of the area of the Sheet and structures worthy of examination are believed to exist.

Both the Arrinthrunga and Ninmaroo Formations may contain suitable reservoir rocks; the Arrinthrunga Formation in particular contains water reservoirs and evidence from water bores indicates that the water in such reservoirs is under fairly strong pressure. The lutites of the Middle Ordovician Nora Formation may be a good cap rock, but the value of other Middle Ordovician formations as source,

reservoir and cap rocks is unknown.

Structures which may be favourable for oil accumulation on the Tobermory Sheet are:

(i) The Toko Syncline.

(ii) The Toomba Structure.

(iii) the probable regional syncline to the north of the main road on the Tobermory Four-Mile Sheet.

Apart from incomplete information from water bores, there is no available subsurface information for any of these structures and no geophysical surveys have been done on them.

It is worthy of note that wet gas was obtained, in 1956, from a water bore which penetrated Middle Cambrian sediments on the Elkedra Four-Mile Sheet. As explained earlier in this report, the Middle Cambrian sediments on the Elkedra Sheet are correlated in part with the Marqua Beds.

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