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RECORDS:

THE GEOLOGY OF THE HELEN SPRINGS AND BEETALOO 1:250,000 SHEET AREAS, N.T.

by

M.A. Randal, M.C. Brown, and H.F. Doutch

Records 1966/110

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SUMMARY

The Helen Springs and Beetaloo 1:250,000 Sheet areas contain rocks of Precambrian, Cambrian, Mesozoic, and Tertiary ages, but much of the area is covered by superficial Cainozoic deposits.

The Precambrian Tomkinson Creek Beds crop out in the Ashburton and Whittington Ranges from near Banka Banka in the south to Elliott in the north. The rocks consist of alternating sandstone and siltstone with interbeds of carbonate, leached carbonate rocks and conglomerate. Algae and stromatolites occur in the carbonates. Glauconitic sandstone has been found at only one locality. The rocks are complexly folded and faulted, and occur in four structural blocks; the estimated thickness of the sediments is 50-55,000 feet. The age of the Beds is tentatively regarded as Lower Proterozoic. They are intruded by dolerite sills and dykes.

The Tomkinson Creek Beds are unconformably overlain by the Lower Cambrian Helen Springs Volcanics (Noakes and Traves, 1954) and the lower Middle Cambrian Gum Ridge Formation (Opik in Ivanac, 1954). The Helen Springs Volcanics consist of heavily lateritized and kaolinized basalt with a basal sandstone. The Volcanics occur in valleys eroded into the older Precambrian rocks, both within the Ashburton and Whittington Ranges and on the eastern and western flanks. The Gum Ridge Formation occurs as scattered outliers mainly within the ranges and on the eastern flanks. However, some outcrops have been mapped west of Powell Creek and Muckety Homestead on the edge of the Wiso Tableland. The unit extends in discontinuous outcrops southwards into the Tennant Creek Sheet area where it was originally mapped and named (Opik in Ivanac, 1954). The unit contains the Banka Banka fossil localities referred to by Opik (1956).

In the eastern part of the Helen Springs Sheet area outcrops of sandstone and dolomitic limestone appear to be continuous with the Middle Cambrian Anthony Lagoon Beds, which occur extensively in the adjoining Brunette Downs Sheet area (Randal, 1966a). Their exact relationship with the Gum Ridge Formation has not been established, and the thickness is unknown.

Mesozoic plant bearing sandstone and siltstone unconformably overlie the Tomkinson Creek Beds and Helen Springs Volcanics in the western part of the Helen Springs Sheet area. The relationships with freshwater and marine fossiliferous Lower Cretaceous sandstone and siltstone on the Beetaloo Sheet area is unknown.

Outcrops of limestone and chalcedonic limestone in the eastern part of the Helen Springs Sheet area are considered to be the western extension of the Brunette Limestone which crops out further to the east (Randal, 1966a).

The area is covered by extensive superficial deposits of sand, gravel, black soil, and laterite.

During the 1965 survey, ground mapping was supplemented by shallow scout-hole drilling. One hole was drilled at the approximate centre of the Beetaloo Sheet area, and six holes between Eva Downs and the flood-out of Tomkinson Creek in the Helen Springs Sheet area. Twelve hundred and thirty-six (1236) feet, including coring, was drilled, and the results confirmed the presence of Cambrian rocks beneath the Mesozoic and superficial cover over much of the two Sheet areas.

INTRODUCTION

Location and Access

The Helen Springs and Beetaloo 1:250,000 Sheet areas are in the western part of the Barkly Tableland in the Northern Territory of Australia. The Helen Springs Sheet area lies between longitudes 133°30'E and 135°E, and between latitudes 18°S and 19°S; the Beetaloo Sheet area adjoins it to the north between the same longitudes and between latitudes 17°S and 18°S (Fig. 1).

The bitumen-sealed Stuart Highway from Alice Springs (365 miles south) to Darwin (480 miles north) traverses the western part of the region*, and the graded Barkly Stock Route crosses the central part (from Elliott to Camooweal in Queensland). These roads provide access to an extensive network of station tracks, most of which are impassable for several days after heavy rain. Twelve cattle stations occupy the region: Brunchilly, Banka Banka, Muckety, Helen Springs, Eva Downs, Ucharonidge, Mungabroom, and portions of Beetaloo, Rockhampton Downs, Anthony Lagoon (Shandon Downs outstation), Newcastle Waters, and Dunmarra. The homesteads of the last four stations occur outside the region (Fig. 1). Other settlements are the township of Renner Springs Roadhouse, and the Maryville road train base, all on the Stuart Highway. Powell Creek Telegraph Station, west of the highway, is now abandoned. Renner Springs, Helen Springs, Maryville, Banka Banka, and Elliott are served by telephone, all other homesteads are incorporated in the Alice Springs radio network of the Royal Flying Doctor Service of Australia. The mining township of Tennant Creek is 50 miles south of the region. The township of Newcastle Waters is about 5 miles west of the region and 16 miles north-north-west of Elliott.

Climate

The climate of the region is arid. The rainfall, which is seasonal, ranges from about 14 inches per annum at Tennant Creek to 17 inches per annum at Newcastle Waters; at Powell Creek it is 16.5 inches per annum. The mean maximum temperature at Tennant Creek is 89.4°F and the mean minimum 65.3°F. The mean relative humidity is 36 percent.

The time and duration of the wet season is controlled by the north-west monsoon, which in this region usually lasts from about November or December to January or early February. The weather for the remainder of the year is typically a period of very low and infrequent rainfall and mainly south-east

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*Unless otherwise qualified the word 'region' in this record refers to the combined area of the Helen Springs and Beetaloo 1:250,000 Sheet areas.

winds with transitional periods between the two main seasons when the wind and rainfall are variable.

Previous Investigations

No systematic and detailed geological mapping (other than at the Muckety manganese deposit) had been attempted before the 1965 survey. This region and adjoining parts of the Northern Territory have been traversed in the past by explorers and by geologists engaged in regional reconnaissance geological mapping.

Brown (1895) passed through the region en route to Alexandria Homestead from Powell Creek, and made brief notes on rock types and the arduous travelling conditions. He found the first Cambrian trilobite on the Barkly Tableland near Alexandria Homestead in the Ranken Sheet area to the south-east of the region (Randal, 1966b). Woolnough (1912) and Jensen (1914) passed through the region and its environs and commented on the Cambrian units and the sub-artesian water resources of the Barkly Tableland. L. Keith Ward (1926) travelled through the region during 1925 collecting bore data and selecting bore-sites on stock routes and elsewhere. Chewings (1931) described the geology to the south of the region together with brief notes on the rocks of the Ashburton Range between Tennant Creek and Newcastle Waters, and the overlying Cambrian rocks of the Barkly Tableland.

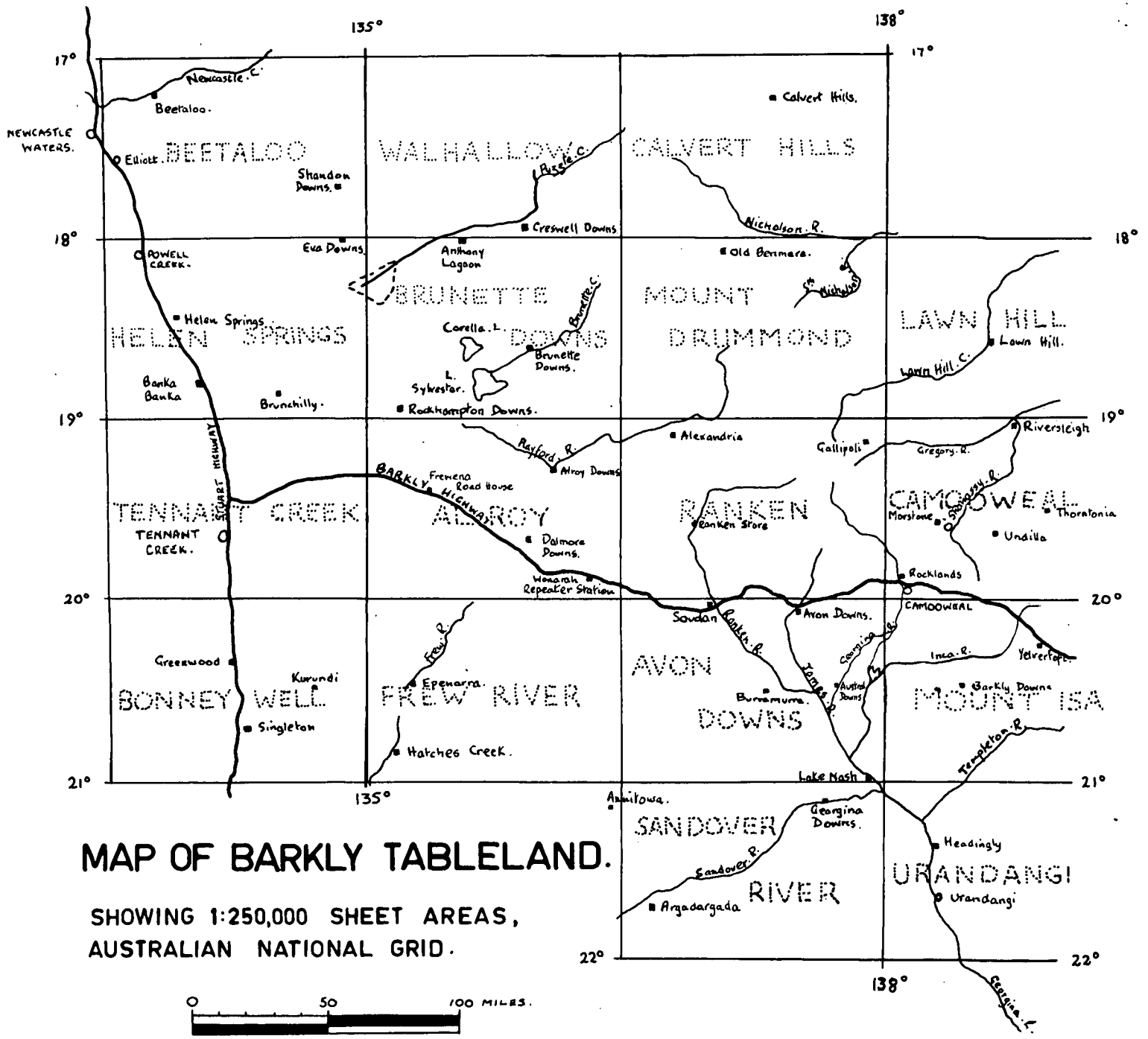
In 1947 and 1948 Noakes and Traves (1954) visited the Barkly Tableland and its environs during the C.S.I.R.O. (1954) investigation of the Barkly Region. They referred to the Cambrian rocks of the Tableland as the Barkly Group, and the rocks of the Ashburton Range as the Ashburton Sandstone of Upper Proterozoic age. Hossfeld (1954) also has published comments on the geology of the region.

Since 1948 A.A. Opik (1956a) has visited the Tableland on many occasions and made many fossil collections. The results of this work were presented to the 20th International Geological Congress at Mexico.

The manganese deposits near Bootu Creek on Muckety Station were examined in detail by geologists of the Northern Territory Mines Branch in association with Rio Tinto Finance and Exploration Co. (Jones, 1955; MacKay, 1956). Mines Branch geologists have also reported on groundwater investigations, and on the feasibility of constructing dams on some creeks.

The region was included in a large airborne gravity survey in 1965 by Wongela Geophysics for the Bureau of Mineral Resources (Flavelle, 1965).

FIG. 1.



MAP OF BARKLY TABLELAND.

SHOWING 1:250,000 SHEET AREAS,
AUSTRALIAN NATIONAL GRID.

0 50 100 MILES.

Bureau of Mineral Resources, Geology & Geophysics. April, 1962

To accompany Records 1962/49, 55, 56, 61, 110

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Previous gravity surveys in the region are described by Neumann (1964). An aeromagnetic survey over Brunette Downs by Adastra Hunting extended into the eastern part of the Helen Springs Sheet area (Howe and Faessler, 1963).

The geology of the surrounding areas is relevant to this region and the most important are: Tennant Creek (Ivanac, 1954; Crohn and Oldershaw, 1966; Dunnet and Harding, 1965); Tanumbirini (Paine, 1964); Wallhallow (Plumb and Rhodes, 1963, 1964); Brunette Downs and Alroy (Randal and Nichols, 1963); and the Wiso Basin (Milligan, Smith, Nichols and Doutch, 1966).

Aerial photographs and maps

Both sheet areas are covered by vertical aerial photographs at a nominal scale of 1:50,000 flown by the R.A.A.F. in 1947, and also at a nominal scale of 1:85,000 flown by Adastra Airways Pty Ltd in 1963.

The Helen Springs sheet was published in 1961 in the 4-mile planimetric series by the Division of National Mapping, who also prepared a preliminary unpublished map of Beetaloo at the same scale. The Division are at present preparing both sheets for publication at 1:250,000 scale.

Photo-scale compilations of Helen Springs at 1:46,500 are available from the Division of National Mapping; they are based on the 1947 photography, but have been amended by information from the 1963 photography. The Division have prepared 1:100,000 scale compilations of Beetaloo based on the 1963 photography.

The Department of the Interior have run traverses of 3rd order levels along some of the roads and tracks in the region.

PHYSIOGRAPHY

Four main physiographic units are recognized in the region and are delineated in fig. 2. They are: (1) the Ashburton and Whittington Ranges in the west (referred to henceforth as "the Ranges"), (2) a lateritic tableland covering about half of the Beetaloo Sheet area, (3) the downs country of the north-east half of the Helen Springs Sheet area and parts of the Beetaloo Sheet area, and (4) sand plains, each side of the Ranges and in smaller areas surrounded by downs country. The country east of the Ranges is part of the Barkly-Birdum Tableland (Plumb and Rhodes, 1964), and that west of the Ranges is part of the Wiso Tableland (Hossfeld, 1954).

The highest measured elevation in the Ranges is 1230 ft., near the headwaters of Morphett Creek, and the general elevation decreases to the north. The maximum relief within the Ranges is about 200 ft..

The Ranges are composed mainly of the resistant silica-cemented sandstones of the folded Precambrian Tomkinson Creek Beds, which form strike ridges and plateaux. The highest plateaux appear to be remnants of a former more extensive plain (the "Ashburton Surface" of Hays, 1966). Less-resistant intervals in the Tomkinson Creek Beds are eroded preferentially into broad valleys. Some of these valleys contain Cambrian rocks (Fig. 2), and most contain Mesozoic (probably Lower Cretaceous) sediments, indicating that the resistant sandstones had positive topographic expression in the Cambrian and Lower Cretaceous, as well as the present day.

Extensive areas of the lateritized upper depositional surface of the (?)Lower Cretaceous sediments occur at considerably lower elevations (up to about 100 ft.) than adjacent plateau remnants of the Ashburton Surface, confirming the pre-Lower Cretaceous age assigned by Hays (op. cit.) to the Surface.

Post-Lower Cretaceous erosion has been relatively unimportant in shaping the present topography of the Ranges. The present non-perennial streams are incised mainly into the softer rock types in the Ranges. They terminate either in "flood-outs" in sand plains bordering the Ranges, or in swamps and lakes in the downs.

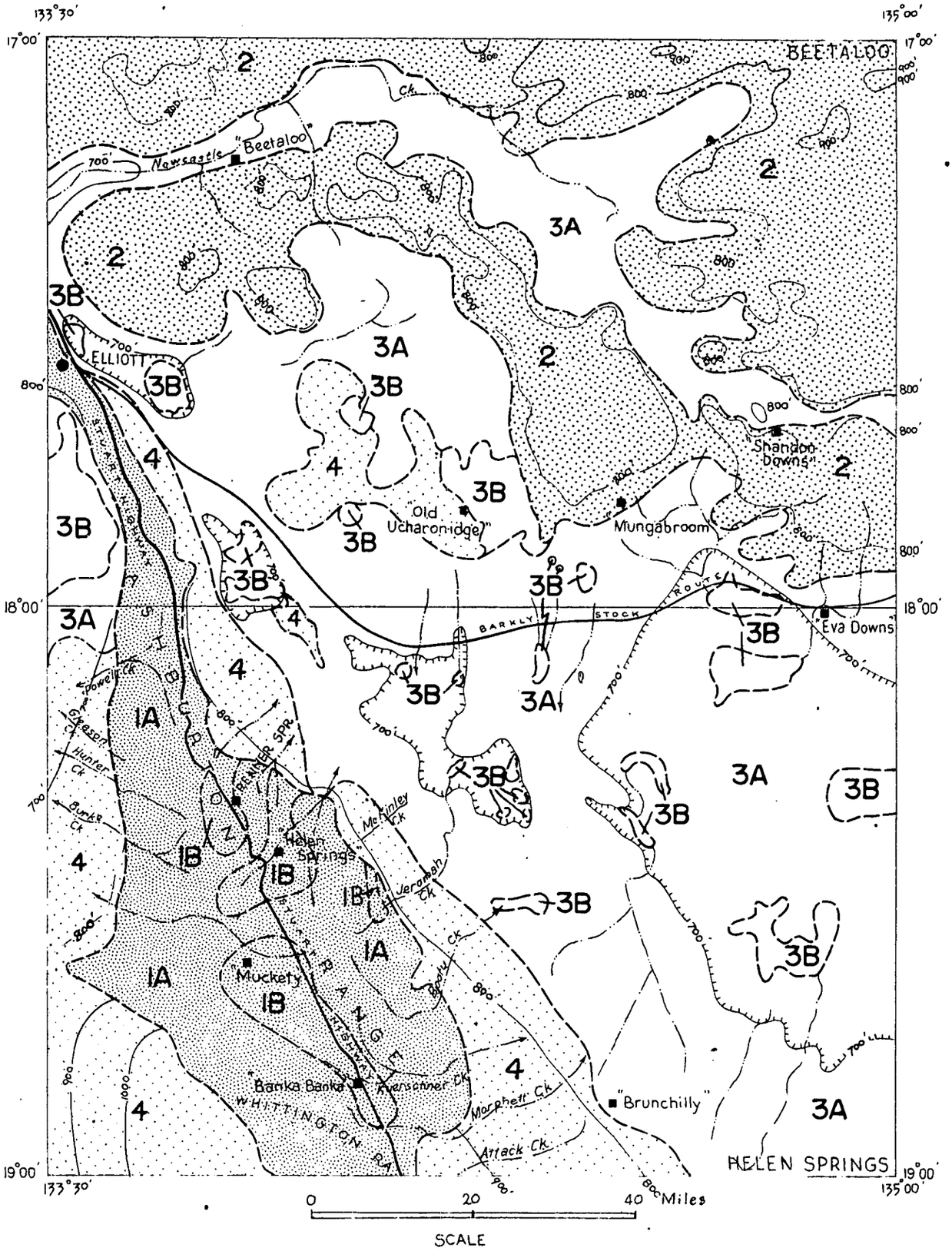
The Lateritic Tableland of the Beetaloo Sheet area is gently undulating, with a maximum elevation of about 900 ft. in the east, descending to about 750 ft. in the west. It is developed on argillaceous sediments of the Lower Cretaceous Mullaman Beds and constitutes part of Hays' "Tennant Creek Surface". It can be correlated with laterite surfaces overlying Mesozoic sediments within the Ranges. The laterite surface is dissected by Newcastle Creek and tributary valleys and by drainage systems falling towards downs country to the south and west. The surface is predominantly of ironstone rubble on the higher areas and reddish sandy and loamy soils in the valleys.

The downs country is largely covered by black soil. It has low relief, with very broad low rises, closed topographic depressions, and a few non-perennial water courses. The main closed depressions have rims about 700 ft. above sea level. They contain stream distributary systems and most of the blue bush swamps and lakes. On the higher ground there are low rises with rubble of Cambrian and Mesozoic rocks, often lateritized. Rubbly outcrops of Tertiary siliceous limestone occur mainly within and marginal to the closed depressions.

Plains covered with red sand, supporting a cover of spinifex, low acacias and eucalypts, and locally termed "desert" country, form a major physiographic unit. The sand plain to the west of the Ranges is the eastern extremity of

Fig 2.

SKETCH MAP SHOWING PHYSIOGRAPHIC UNITS
BEETALOO AND HELEN SPRINGS AREA



1 ASHBURTON RANGE
- 1A Precambrian rocks
- 1B Valleys with Cambrian rocks

2 LATERITIC TABLELAND

3 DOWNS AND LAKE WOODS PLAINS
- 3A Black soil plains and gravelly rises.
- 3B Lakes and swamps.

4 SAND PLAINS

Physiographic Unit boundary
Topographic contours
Depression contours
"Muckety" Homestead
ELLIOTT Settlement
Highway
Stock Route
Creek

E 53/A/4

Bureau of Mineral Resources, Geology and Geophysics, June 1966. To accompany Record No 1966/110

the extensive Tanami "Desert". Another extensive sand area occurs between the Ranges and the downs to the east. It slopes gently away from the Ranges and has an abrupt boundary with the downs. Another major area occurs west of Old Ucharonidge and there are other smaller patches surrounded by downs country. Most of the valleys in the Ranges have a sand cover, not shown in Fig. 2.

The topography of the sand plains has minor irregular undulations, and longitudinal dunes are developed in the south-west corner of the Helen Springs Sheet area.

STRATIGRAPHY

The region contains rocks of Precambrian, Cambrian, Mesozoic, and Tertiary ages, but there is an extensive cover of Cainozoic superficial deposits.

In the central and eastern part of the region scattered outcrops of the Middle Cambrian Anthony Lagoon Beds occur in the black soil downs together with outcrops of Tertiary Brunette Limestone. In the north, lateritized and sand-covered freshwater and marine Mesozoic sandstone and siltstone cover most of the Beetaloo Sheet area. The western part of the region contains the ridges of the Ashburton Range, which is composed mainly of the Precambrian Tomkinson Creek Beds. Outliers of the Middle Cambrian Gum Ridge Formation and the Lower Cambrian Helen Springs Volcanics occur within the Range and on its eastern and western flanks.

Scout-hole drilling, totalling 1236 feet spread over seven holes, provided some help in the stratigraphic mapping: the details of lithology and core-recovery are given in Appendix 1. Scout-hole B1 was drilled in the approximate centre of the Beetaloo Sheet area, and holes HS1 to HS6 are located between Eva Downs Homestead in the east and Muckety Homestead in the west in the Helen Springs Sheet area.

A summary of the stratigraphy is given in Table 1.

PRECAMBRIAN

Tomkinson Creek Beds

The name Tomkinson Creek Beds is applied to a sequence of quartz sandstone, siltstone, dolomite, dolomitic limestone, chert, and leached and silicified carbonate rocks, which forms the Ashburton Range in the western part of the region. The Beds crop out in three discrete structural blocks and tentative correlations between them suggest a total thickness of about 50,000 feet. The sequence is tentatively correlated with the Hatches Creek Group of Lower Proterozoic age.

Previous workers in the Tennant Creek area and authors writing on the regional geology of the Northern Territory have referred to the Precambrian rocks of the Ashburton Range as the Ashburton Sandstone following the usage of Noakes and Traves (1954). However, the name is invalid because of priority usage of the term Ashburton Beds for a Proterozoic sequence in the Ashburton River district in Western Australia. Dunnet and Harding (1965) recognized this and used the informal term Hayward Creek Beds, but did not map the unit in detail. Work during the 1965 survey has shown that there is a wider variety of rock types in the sequence and also the probability of a higher rank than is implied in Noakes and Traves' (op. cit.) term Ashburton Sandstone. As the term Hayward Creek Beds is not well defined, because of the limited area mapped by Dunnet and Harding (op. cit.) who were mainly concerned with the mineralized Warramunga Group, and as the term is not particularly suited as a name for the unit away from the Hayward Creek area, we have formally proposed the name Tomkinson Creek Beds. This name is derived from Tomkinson Creek, the main (southern) branch of which crosses the Stuart Highway about 14 miles north of Banka Banka Homestead at longitude 133°15'44"E and latitude 18°36'20"S.

There is no single reference section for the Tomkinson Creek Beds. The unit is complexly folded and faulted, and the stratigraphy is not well established. The Beds occur in four apparently discrete structural blocks, between which correlation is difficult. Tentative correlations and composite sections indicate the sequence consists of 14,000 feet of quartz sandstone overlain by 10,000 feet of alternating sandstone and siltstone with minor interbeds of carbonate rocks. This is overlain by 15 - 20,000 feet of sandstone and siltstone, in turn overlain by 2000 feet of carbonate-bearing rocks and chert, and 8000 feet of alternating sandstone and siltstone. The drainage area of Tomkinson Creek covers all four blocks, but although traversing good exposures, does not occur in the most suitable place for measuring sections. Sections have been measured in the headwaters of Morphett Creek in the southern part of the Ashburton Range, Bootu Creek in the central part, and west of Renner Springs Roadhouse in the northern part: they are illustrated in Figure 3.

The Tomkinson Creek Beds crop out in the western part of the region in a 20-30 mile wide belt trending north-north-west from near Attack Creek in the south to Elliott Township in the north. The rocks form the Ashburton and Whittington Ranges, and extend southwards in to the Tennant Creek and Green Swamp Well Sheet areas, and westwards into the South Lake Woods and Newcastle Waters Sheet areas.

The medium and coarse-grained rocks occur as rugged strike ridges and dip slopes, or dissected elevated tablelands. The finer-grained sandstones

TABLE 1: STRATIGRAPHIC TABLE; HELEN SPRINGS AND BEETALOO 1:250,000 SHEET AREAS

ERA	PERIOD	STRATIGRAPHIC UNIT	DISTRIBUTION	LITHOLOGY	APPROXIMATE MAXIMUM THICKNESS (ft.)	TOPOGRAPHY	REMARKS
CAINOZOIC	Undifferentiated	Cza	Stream valleys and floodouts; swamps and distributaries of downs country.	Sands and gravels in hill country stream valleys, sandy and silty alluvium of floodouts, clayey sediments of swamps; may include some residual soils.	68 ft.	Flat valley floors, plains with distributary stream channels, closed depressions of downs country swamps.	Thickness of 68 ft. of sandy alluvium in Scout Hole HS5 on Tomkinson Creek floodout.
		Czb	North-eastern half of *Helen Springs, parts of *Beetaloo including Newcastle Creek valley.	Black soil, clayey with variable sand and pebble content; in part residual, may also include some alluvium.	8 ft.	Downs country. Flat grassy plains with low rises. Gilgai micro-topography in some areas.	Thickness from borehole data. Support Mitchell and Flinders grasses.
		Czs	Along eastern margin and west of Ashburton Range, west of Ucharonidge Homestead, northern and eastern parts of Beetaloo sheet, smaller patches elsewhere.	Sand, generally red; also includes some reddish loamy soils with ferruginous rubble on Beetaloo. Sands are in part colluvial, in part reworked by wind.	?	Gently sloping plains with minor undulations; rise above adjacent "downs" country. Some longitudinal dunes south-west of Whittington Range.	Support spinifex, low eucalypts and acacias; locally termed "desert". Czs/Kl is timbered and grassy country with some Kl outcrops and rubble.
	Tertiary	Brunette Limestone (Tb)	Mainly on downs country of Helen Springs. Smaller patches in Ashburton Range.	White limestone, mainly calcilutite, with chalcedonic silica; some massive chalcedony; minor sandstone.	15 ft.	Low rises in downs country; near valley floors in Ashburton Range.	Thickness from borehole data. Greater thickness recorded east of region.
		Tl	Extensive on northern and eastern halves of Beetaloo. Smaller patches on Helen Springs.	Laterite, massive or pisolitic ironstone and ferruginous rubble; some sand.	20 ft.	On Tableland; country with low relief generally rising above adjacent "downs" country. In ranges; generally as residual mesas in major valleys.	Best developed on basic igneous rocks and argillaceous sedimentary rocks (especially Mesozoic).
				UNCONFORMITY			
MESOZOIC	Undifferentiated	M	Ashburton and Whittington Ranges.	Sandstones, pebbly sandstones with plant impressions, local pebble to boulder conglomerates, sandy and clayey siltstones, micaceous sandstones and siltstones.	80 ft.	Laterite-capped plains and residual mesas in major valleys in the ranges. Some terraced topography.	Leaf impression from Whittington Range area indicates Jurassic or Lower Cretaceous age.
	Lower Cretaceous	Mullaman Beds (Kl)	Beetaloo, east of Ashburton Range; small areas in northern part of Helen Springs.	Sandstones, pebbly and cobbly sandstones, siltstones, white claystones and silty claystones with radiolaria. Silicification at outcrop is usual.	285 ft. +	Low relief; laterites common on argillaceous rocks, "desert" sand on sandstones; grassy downs country on all lithologies.	Thickness from borehole data. Age is (?)Neocomian-Aptian to Albian.
				UNCONFORMITY			
		Anthony Lagoon Beds (Smy)	North-eastern half of Helen Springs, and south of Barkly Stock Route on Beetaloo.	Fine-grained feldspathic sandstone and chocolate to red siltstone, often calcareous and dolomitic; limestone, dolomitic limestone, and dolomite with chert nodules.	285 ft. + ?	Low rubbly rises in "downs" country.	Thickness from borehole data.

ERA	PERIOD	STRATIGRAPHIC UNIT	DISTRIBUTION	LITHOLOGY	APPROXIMATE MAXIMUM THICKNESS (ft.)	TOPOGRAPHY	REMARKS
PALAEOZOIC	Middle Cambrian	Gum Ridge Formation (Cmg)	Within and marginal to Ashburton and Whittington Ranges.	Fossiliferous siliceous siltstone and chert, some sandstone and silicified limestone. Outcrop often brecciated and recemented.	170 + ?	Low rubbly rises.	Thickness from borehole data. Fossils indicate Lower Middle Cambrian age.
				UNCONFORMITY			
	Lower Cambrian	Helen Springs Volcanics (Clh)	Valleys in Ashburton and Whittington Ranges, also 8 miles south-west of Ladabah bore.	Basalt, usually with coarse doleritic texture, but fine-grained and vesicular at base; basal sandstone with large-scale cross beds, sandy breccia, and minor silt-stone.	120 +	Grassy "downs" country with some gilgai patterns, and mesas with cappings of laterite or Mesozoic sediments.	Thickness from borehole data.
				UNCONFORMITY			
PROTEROZOIC	Lower Proterozoic	Tomkinson Creek Beds (Plt)	Ashburton and Whittington Ranges.	Quartz sandstone often with mud clasts and some-times pebbly, siltstone, calcareous siltstone, dolomite, limestone, leached carbonate rocks, chert, minor conglomerate and dolomite breccia. Sandstones sometimes glauconitic. Sedimentary structures include cross-bedding, ripple marks, mudcracks, halite casts. Cherts contain stromatolites. Dolerite sill intrudes sedimentary rocks.	50,000 ?	Sandstones stand up as strike ridges and plateaux. Siltstones and carbonate rocks and eroded into valleys, but locally protected by siliceous or lateritic cappings.	Fine to medium grained cross-bedded quartz sandstone is dominant rock type. Beds formerly termed "Ashburton Sandstone".

* In this table, "Beetaloo" and "Helen Springs" refer to the corresponding 1:250,000 Sheet areas.

and siltstone usually occur in the intervening valleys. The cherts and carbonate rocks form lines of gently rounded rubble-covered hills, with an occasional small escarpment.

The Tomkinson Creek Beds consist of arenaceous sediments ranging from fine-grained sandstone to grit and pebbly sandstone; the arenites apparently form the bulk of the unit but interbeds of siltstone, dolomite, chert, and leached and silicified carbonate rocks total several thousand feet. The sequence occurs in four structurally and, in part, lithologically discrete areas: (i) the Tomkinson Creek - Powell Creek block; (ii) the Muckety - Renner Springs block; (iii) the Bootu Creek block, and (iv) the Whittington Range block. The stratigraphic relationships between the rocks of the four blocks are obscured by the complexity of the folding and faulting.

The Whittington Range block occurs in the south-western part of the region and contains the Whittington Range and the southern part of the Ashburton Range; it is separated from the other three blocks by a marked discontinuity which trends south-eastwards from the lower reaches of Tomkinson Creek past Muckety Homestead to near Banka Banka Homestead whence it flexes in a southerly direction and presumably joins a north-trending fault zone through Churchills Head near Morphett Creek on the Stuart Highway.

Probably the oldest rocks of the Tomkinson Creek Beds occur in this block in a section between Churchill's Head and a syncline around the head-waters of Morphett Creek. There, 2700 feet of medium to coarse-grained quartz sandstone is overlain by 12,000 feet of thin-bedded fine to medium-grained quartz sandstone overlain by about 7000 feet of interbedded siltstone and fine-grained sandstone with minor interbeds of carbonate rocks (Fig. 3). This sequence appears to be continuous with the rocks mapped in the Gibson Creek area by Dunnet and Harding (op. cit.).

The rocks in the western part of this block overlie the sequence between Churchills Head and Morphett Creek, and may represent part of the sequence in the Bootu Creek and Muckety/Renner Springs block, but this latter relationship cannot be proved at present.

Five miles south-west of Banka Banka Homestead about 5000 feet of sandstone, siltstone, chert, and conglomerate appear to overlie the main bulk of the sequence in this block with a marked angular unconformity. The bottom part of this section is marked by ridges of algal chert striking generally east-west in contrast to the north-south strike of the underlying rocks. The sequence is clearly younger than the remainder of the rocks in the block, but its relationship to the rocks of the Tomkinson Creek Beds elsewhere is unknown. The section has not been adequately measured and is not illustrated.

The rocks of the Whittington Range block are tentatively correlated with rocks of the Bootu Creek block by means of coarse sandstone lenses occurring in both blocks in similar positions in sequences of fine to medium-grained sandstone, siltstone, and carbonates.

The Bootu Creek block occurs between Morphett Creek and McKinlay Creek in the eastern part of the Ashburton Range. It derives its name from Bootu Creek, which drains the area occupied by a prominent anticline and a syncline in the centre of the block.

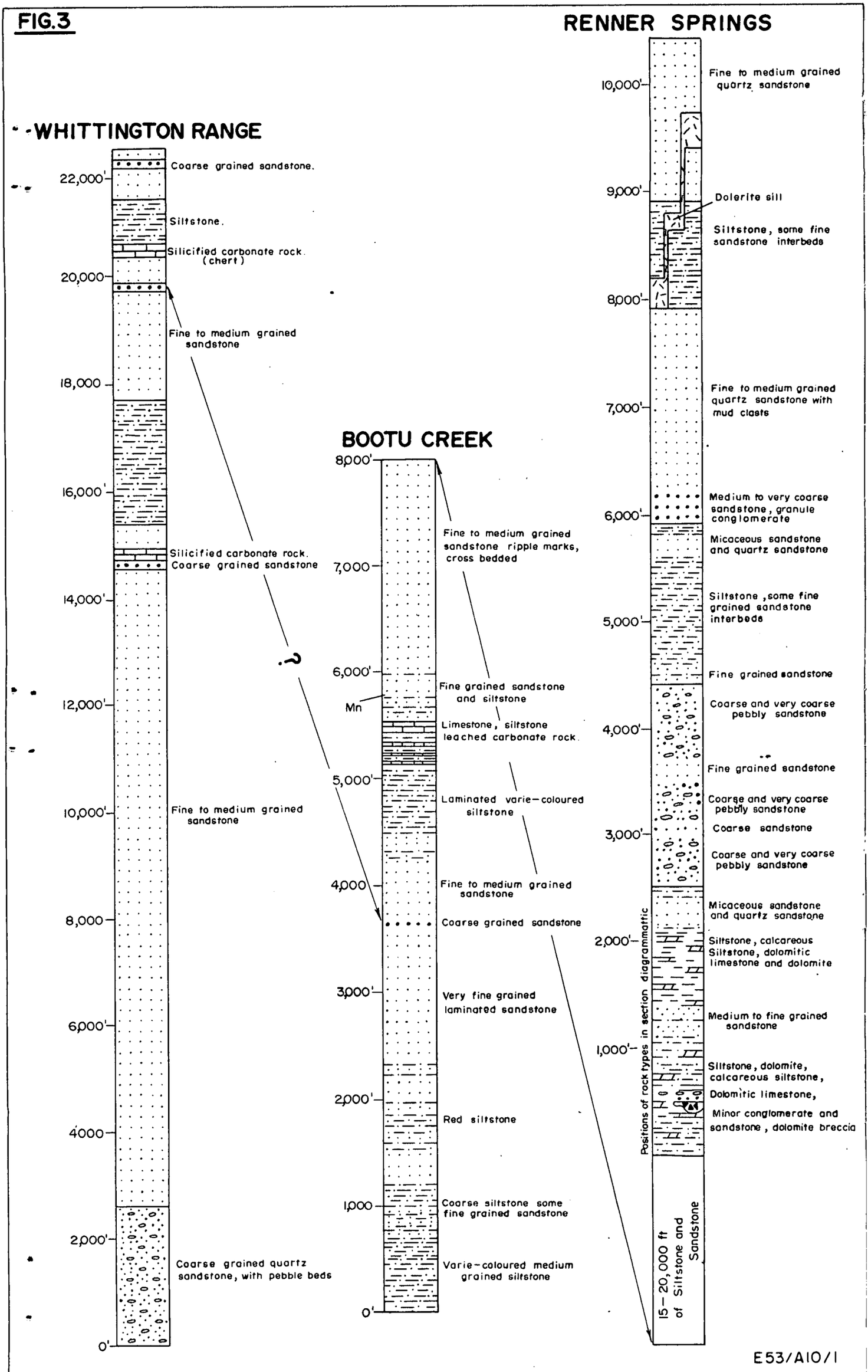
A measured section was obtained during 1965 across the eastern limb of the anticline, and it was tied to a section measured by Jones (1955) across the western limb of the adjoining syncline. These two sections indicate a total of about 8400 feet of siltstone, flaggy fine-grained sandstone, massive medium-grained sandstone, and minor carbonate and leached carbonate interbeds (Fig. 3). The upper part of the section is manganiferous and contains the Muckety manganese deposits which are discussed under Economic Geology.

The section about Bootu Creek appears to be overlain by 15-20,000 feet of sandstone and siltstone in turn overlain by correlates of the Muckety/Renner Springs block. This estimate is based on air-photo measurements down the plunge of the syncline bounded by Bootu Creek, and although measured dips along the limbs of the syncline indicate consistent plunge, the estimate has not been checked in the field, nor has the detailed rock sequence.

The rocks of the Bootu Creek block are overlain by a sequence of carbonate and leached carbonate rocks overlain by coarse pebbly sandstone which have been correlated with a coarse pebbly sandstone east of Helen Springs Homestead in the Muckety/Renner Springs block. The sequences in the Muckety/Renner Springs block and in the Tomkinson Creek/Powell Creek block can be traced continuously across the structure; consequently a composite section for the two blocks is possible and is illustrated in Figure 3 under Renner Springs. The sequence consists essentially of carbonate and leached and silicified carbonate rocks overlain by alternating sandstone and siltstone. Near the top it is intruded by a dolerite sill which has been traced for about 30 miles from near Burke Creek northwards to near Fergusson Creek. The carbonate rocks consist of dolomite breccia, dolomite, dolomitic limestone, and calcareous siltstone. The sandstone units range from fine-grained sandstone with siltstone interbeds to very coarse-grained sandstone with pebble beds and granule conglomerate interbeds.

The upper beds of the sequence can be traced into the Beetaloo Sheet area where the sequence and the structure have not been mapped in detail.

FIG.3



E53/A10/1

To accompany Record No 1966/110.

The structure of the Tomkinson Creek Beds is complex; the unit is divided into four blocks by two major north-trending fault zones, and by a marked north and north-west trending discontinuity. A major north trending fault zone also occurs on the western part of the Tomkinson Creek/ Powell Creek block, and a major fault zone in the Bootu Creek block trends north-north-west. Strike, near strike, and cross-strike faults of varying magnitude occur throughout the region, and together with complex folding make impossible on accurate assessment of the thickness and stratigraphy. The largest fold is a faulted north-pitching anticline between Powell Creek and Carruthers Creek. It is adjoined on both the east and the west by subsidiary anticlines and synclines. A major syncline pitches north about Helen Springs Homestead. Siltstones in the trough of the structure are eroded and the valley so caused is occupied by the Helen Springs Volcanics. It is truncated on the east by a major fault and bounded to the west by a north-south trending zone of faulting and folding. Small anticlines and synclines occur in the Bootu Creek block; the most important are those near the Muckety Manganese Deposit.

No relationship between the Tomkinson Creek Beds and the underlying rocks can be established in the Helen Springs Sheet area. In the Tennant Creek Sheet area the Beds overlie the Lower Proterozoic Warramunga Group, but the nature of the contact is not yet clear: the problem cannot be resolved until the Tomkinson Creek Beds are mapped in detail in this Sheet area.

In the Helen Springs Sheet area the Tomkinson Creek Beds are unconformably overlain by the Lower Cambrian Helen Springs Volcanics, the Middle Cambrian Gum Ridge Formation, unnamed Mesozoic rocks, and chalcedonic material referred to the Tertiary Brunette Limestone.

Ivanac (1954) considered the unit (then called Ashburton Sandstone) consisted of epicontinental sediments deposited on the edge of a continental shelf. This is supported by the cross-bedding and ripple-marks and the clean nature of the sandstone. However, the possible thickness of the sequence, the occurrence of halite pseudomorphs, mud cracks, and primary current lineation, and the presence of significant quantities of siltstone and carbonates with algae (all noted in the 1965 survey) suggest that the environment was continually changing. Intertidal conditions appear to have been important.

The thickness of the Tomkinson Creek Beds has been discussed earlier with the stratigraphy of the four blocks and the tentative correlation between them. It appears to be of the order of 50-55,000 feet.

The age of the Tomkinson Creek Beds is shown on the map as ?Lower Proterozoic. Dunnet and Harding (op. cit.) referred to it as Carpentarian following the general reclassification of the Middle and Upper Proterozoic in Northern Australia into Carpentarian and Adelaidean respectively. Both Dunnet and Harding (op. cit.) and K.G. Smith (B.M.R., pers. comm.) regard the unit as probably equivalent to the Hatches Creek Group, which Smith, Stewart, and Smith (1961) regarded as Lower Proterozoic. The Group has been regarded as Carpentarian (Dunn, Smith and Roberts, in prep.) in age on the basis of K/Ar radioactive age determinations on granites which intrude it (Hurley, et. al., 1961). However, K.G. Smith (B.M.R. pers. comm.) points out that Wilson et al. (1960) redetermined by Rb/Sr methods one of Hurley's granites (which does not intrude Hatches Creek Group) at 1840 m.y., and all of Hurley's ages may be too young. Therefore Smith tentatively regards the Hatches Creek Group to be Lower Proterozoic. Until all the results can be rechecked by more reliable techniques it seems best to retain a Lower Proterozoic age for the Group, and hence for the Tomkinson Creek Beds also.

No information is forthcoming from this region concerning the age of the Beds other than the unconformity with overlying Cambrian rocks. Glauconitic sandstone was found at one locality in the Whittington Range (H.S. 914), and is being processed for radioactive age determination, but the result is not yet available. In any case the result from a single sample will be of little real value in placing a definite age on the sequence and will be useful as a guide only.

1700 m.y.

CAMBRIAN

Helen Springs Volcanics

The Helen Springs Volcanics (Noakes and Traves, 1954) crop out in broad topographic depressions in the Ashburton Range. They consist of coarse-grained tholeiitic basalt, fine-grained and vesicular or amygdaloidal at the base. They conformably overlie a basal sandstone and breccia. The basalt and basal sedimentary rocks rest with a strong unconformity on the Tomkinson Creek Beds, occupying erosional valleys, and are in turn overlain, probably disconformably, by the Gum Ridge Formation.

Noakes and Traves (1954) applied the name Helen Springs Volcanics to basaltic rocks which crop out around Helen Springs Homestead, and further south near Tennant Creek. They correlated the Volcanics with Lower Cambrian volcanics of the Ord-Victoria Region. [illegible] Ivanac (1954) used the name Helen Springs for basic volcanic rocks in the Tennant Creek area which are overlain disconformably by the Lower Middle Cambrian Gum Ridge Formation.

Mapping in the Helen Springs Sheet area during 1965 has delineated several areas of basalt, other than the main area around Helen Springs

Homestead, which are correlated with the Helen Springs Volcanics. Sedimentary rocks conformably underlying the basalts are included in the formation. Basic dyke rocks in the Whittington Range, which may represent feeders for the flows, are also mapped as Helen Springs Volcanics.

Noakes and Traves regarded the area around Helen Springs Homestead (latitude 18°26.00'S, longitude 133°52.28'E) as the type area for the formation. There are no type sections.

The outcrop areas mapped during 1965 are all in the Helen Springs 1:250,000 Sheet area: around Helen Springs Homestead, around Muckety Homestead, near Banka Banka Homestead, near Renner Springs Roadhouse, about 8 miles south-west of Ladabah Bore, near Loveday Creek, and the Whittington Range. In the latter area there are both extrusive and intrusive basic igneous rocks. At locality HS565, about 13 miles south-west of Banka Banka Homestead, an outcrop of tuffaceous sediments is referred to the Helen Springs Volcanics although its age and relationships are not definitely established.

The Helen Springs Volcanics occur in broad valleys in the Ashburton Ranges. They form mesas capped by thick laterite or lateritized sediments, and black soil plains in the surrounding lower country. The basal sedimentary rocks sometimes form well-developed strike ridges.

In most exposures the volcanic rocks are massive and have a coarse doleritic texture. At and near the base the volcanics are aphanitic, but usually have abundant amygdales and vesicles. Unweathered dark basalt occurs extensively only in the black soil areas, below the laterite cappings and the pallid zone, but occasional small core-stones of fresh basalt occur in surface rubble at localities where the basalt is otherwise completely ferruginised (HS149, HS708). In the pallid zone of the laterite profile the basalt is kaolinized, but the original igneous textures usually remain. Thick sections of kaolinized basalt occur in the slopes below the Mesozoic outcrops south of Muckety Homestead. Original igneous textures are again usually visible in the transitional mottled zone of laterite profiles, but are usually completely obliterated in the ferruginous zone.

Silicification is common, and is most frequent in the fine-grained and vesicular rock types. Glassy vesicular or amygdaloidal basalt at the base is often now represented by a pale yellow opaline material with the original vesicles filled with white opal (HS144 and exposures east of HS771). Silicified amygdaloidal basalt occurs as surface rubble about 2 miles west of Cox Knob near Banka Banka Homestead (HS72). The original basaltic nature of this material is not easily demonstrable in hand specimen, but is obvious in thin section.

Chemical analyses and petrographic examination of almost unaltered rocks show the chemical and mineralogical composition to be that of a normal basalt. Well-crystallized specimens are ophitic, with plagioclase more abundant than ferro-magnesian minerals. Specimens from near the base consist of plagioclase laths in a matrix of devitrified glass. Olivine and its pseudomorphs are apparently absent. In the coarser specimens small amounts of interstitial quartz are often present between the feldspar laths. Quartz is often present in amygdales.

Some alteration of the original igneous minerals is present in the freshest specimens. Augite is partially altered to chlorite and/or pale green fibrous amphibole, and plagioclase is often partially albitized and sericitized. In the most lateritized specimens still showing basalt textures, the feldspars are altered to clay minerals and the ferro-magnesian minerals to iron oxides. In silicified basalts the rock is fairly uniformly replaced by silica. Feldspars are generally replaced by clearer silica than original glass or ferro-magnesian minerals, and consequently the igneous textures can be identified. The replacing silica is opaline material, cryptocrystalline chalcedony, or fine-grained quartz.

Open joints and larger vesicles in the basalt frequently contain well-crystallized quartz, occasionally in the form of doubly-terminated prisms. The quartz is smoky, white, red, or pale greenish. This quartz becomes concentrated at the surface on weathering and erosion of the basalt, especially where the basalt is kaolinized, as at Locality HS167 near the Helen Springs - Muckety boundary fence beside the Stuart Highway. It also occurs in the pebble fraction of Mesozoic and Recent sediments.

The basic dyke rocks of the Whittington Range are badly weathered and ferruginized, but show a similar range of textures to those of the known extrusive volcanics.

The tuffaceous rocks which crop out around locality HS565 are brown to reddish ferruginized bedded rocks. They contain a variety of grains set in a near-isotropic brownish matrix. The grains include quartz and chert sand grains, kaolinized and ferruginised opaque particles possibly representing altered ferro-magnesian minerals, devitrified volcanic glass, and pellets of a brown isotropic to cryptocrystalline material and a microcrystalline green mineral.

Sedimentary rocks underlie the basalts in the outcrop areas near Helen Springs Homestead, Muckety Homestead, Renner Springs Roadhouse, and Loveday Creek. The predominant rock type is a laminated semi-friable buff sandstone with very large scale cross-bedding in sets up to 20 feet thick. The grain

size varies from very fine sand to medium sand, but sorting is good within individual laminae. The grains are of quartz, quartzite, chert, and siltstone, with very minor amounts of tourmaline and muscovite. The lithification of the sediment is due to some overgrowth on quartz grains accompanied by some interpenetration and contact solution, and squashing of clayey siltstone clasts. The rock contains no clay or silt matrix, or pebbles. It has yielded no fossils or trace fossils, despite the good exposures.

A sedimentary breccia with a sandy matrix underlies the basalt at some localities, either alone or interbedded with the cross-bedded sandstone. The pebbles in the breccia consist of quartzite and siltstone, derived from the Tomkinson Creek Beds. The sandy matrix has the same appearance and contains the same types of grains as the cross-bedded sandstone. The breccia frequently occurs as sedimentary dykes, filling fissures in underlying siltstones of the Tomkinson Creek Beds.

Five feet of laminated siltstone occurs interbedded with the more usual buff sandstone underlying the basalt at locality HS194, south-west of Wiggenty Well near Muckety.

At the base of the basalt, the underlying sandstones are strongly indurated for about 1 inch to 2 inches below the contact, and the contact surface has shallow ridges and furrows apparently caused by viscous drag of the lava moving over the surface. In a specimen from locality HS149, north of Loveday Creek, the indurated sandstone near the contact contains patches in which the quartz sand grains are embedded in a matrix of coarsely crystalline quartz containing abundant (?)sillimanite or (?)mullite needles. This coarsely crystalline quartz is apparently a product of partial melting of the sandstone and later crystallization of the interstitial melt.

Partially melted sedimentary material has also been found as inclusions in the basalt. One specimen from locality HS72, west of Cox Knob near Banka Banka, consists of basalt (now silicified) with abundant botryoidal aggregates of partially melted sandstone superficially resembling amygdales. They consist of cryptocrystalline material enclosing varying amounts of fine sand size quartz grains. A specimen from about a half mile south of Banka Banka Homestead consists of abundant spheroids of quartz-(?)sillimanite rock in a matrix of highly ferruginous material, probably ferruginized basalt. The quartz-(?)sillimanite rock contains some carbonate rhombs but is otherwise similar to material interpreted above as interstitial melt in sandstones heated by the basalt.

The Helen Springs Volcanics have not suffered obvious tectonic deformation and for the most part are probably in their original structural attitude, filling valleys eroded into siltstone units of the Tomkinson Creek Beds. However in the outcrop areas around Helen Springs Homestead, Muckety Homestead, and Loveday Creek, the underlying siltstones have heaved upwards at many separated localities producing a number of domes in the volcanics and basal sediments. The domes vary from near-circular to elliptical in plan, with dimensions from about one third of a mile to one and a half miles across. In detail the contact has abrupt changes of strike so that the outline of the domes has many small promontories and embayments. The base of the basalt dips outward from the domes at angles varying from 9° to 30°. The basal sandstone often forms a strike ridge.

Towards the centre of many of the domes are circular to elliptical outcrops of fossiliferous Lower Middle Cambrian Gum Ridge Formation, overlying the basal sandstones of the Helen Springs Volcanics. Where dips can be measured, the sandstone around the margins of these outcrops dips towards the centre of the domes at angles up to 30°, and the margins of the Gum Ridge outcrops form circular or elliptical strike ridges paralleling the margins of the domes. The Gum Ridge Formation was probably deposited after development of the domes and after erosional truncation had exposed the basal sandstones of the Helen Springs Volcanics. The exposed cores of the domes and underlying Gum Ridge sediments have then collapsed downward to form a central basin. Later erosional planation has removed the Gum Ridge Formation except from the collapsed areas, to give the present distribution of outcrops.

The domes do not appear to be associated with evaporites. The sediments producing the domes crop out poorly and consequently the detailed lithology is not known, but no evaporite indications have been found in outcrops or in borehole cuttings. A bore drilled 350 feet into the sediments (Muckety Homestead Bore) produces groundwater with only 175.8 ppm of Cl^{-} ion.

The original upward heaving to produce the domes was apparently due to the specific gravity difference between the massive volcanics and underlying argillaceous sediments. The later collapse after erosional truncation and deposition of the Gum Ridge Formation is more difficult to explain. Possibilities include shrinking of clays or solution of carbonates.

The volcanic rocks are massive lava flows. No pillow lavas or palagonite breccias, as might be expected from extrusion into a water body, have been found, and it is assumed that they were extruded on a land surface.

In many localities where the base of the basalt is well exposed, there are no signs of an erosional unconformity with the basal sedimentary rocks; the basalt always rests on a bedding plane. The lack of an unconformity implies a terrestrial environment for the sediments if the basalt was extruded subaerially. The very large scale of the cross-bedding, lack of pebbles or clay matrix, the lack of fossils, and the rapid variations in thickness of the basal sandstone suggests that it is an aeolian dune sandstone. The alternative interpretation of a marine or fluviatile sandstone would require a water depth several times greater than the thickness of the cross bedding sets (Allen, 1963) for which there is no evidence in the overlying basalt. The basal sandy breccias can be interpreted as deposits of intermittent streams containing locally-derived pebbles from surrounding hills of Tomkinson Creek Beds.

The maximum thickness of the volcanic rocks is not known. At Muckety Homestead a bore penetrated 120 feet of basalt without encountering the underlying rocks. In dissected country near Helen Springs Homestead a minimum thickness of 60 feet can be measured. Bore No.19, Helen Springs Station, and Helen Springs Government Bore were drilled into basalt, but no logs or cuttings are available. Ivanac (1954) gives no figure for the thickness of the Helen Springs Volcanics in the Tennant Creek area.

The basal sediments vary considerably in thickness from 6 inches to around 40 feet. The thicker sections are composed dominantly or completely of the buff cross-bedded sandstone. Sections less than about 10 feet thick are often largely or entirely of sandy breccia.

Noakes and Traves (1954) correlated the Helen Springs Volcanics with Lower Cambrian volcanics of the Katherine-Darwin and Ord-Victoria regions, based on lithological similarity. Ivanac (1954) demonstrated that in the Tennant Creek area the Helen Springs Volcanics rest on the Lower Proterozoic Warramunga Group and younger granitic rocks with a marked angular unconformity and are overlain disconformably by the fossiliferous Lower Middle Cambrian Gum Ridge Formation.

During the 1965 survey the relationships of the Helen Springs Volcanics with older and younger rocks have been established for the type area. The volcanics and basal sedimentary rocks rest with strong angular unconformity on a differentially-eroded surface of the Tomkinson Creek Beds. The younger Lower Middle Cambrian sediments were deposited following local gravity folding and erosion of the volcanics.

The basalts and basal sediments occupy valleys eroded into soft siltstone units of the Precambrian Tomkinson Creek Beds. For most of the

outcrop areas it is difficult to demonstrate conclusively that the basalts have this relationship and are not in sequence with the Precambrian rocks. However the outcrops south of Renner Springs Roadhouse demonstrably overlie siltstones some 2000 feet lower in the Tomkinson Creek Beds than those around Helen Springs and Muckety Homesteads. The similarity between the basalts and basal sediments of the Renner Springs outcrops and those of the latter two areas precludes the volcanics being on two stratigraphic horizons in the Tomkinson Creek Beds sequence.

The stratigraphic relationships of the Helen Springs Volcanics on the Helen Springs and Tennant Creek 1:250,000 Sheet areas, and their lithological similarity with Lower Cambrian volcanics to the north and west are consistent with the Lower Cambrian age originally assigned by Noakes and Traves (op. cit.)

Gum Ridge Formation

The Gum Ridge Formation (Opik, 1951, 1956b, in Ivanac, 1954) crops out on the western and eastern flanks of the Ashburton and Whittington Ranges, and in an isolated area near Brunchilly Homestead. It is fossiliferous, and Opik (op. cit.) regards it as lower Middle Cambrian in age. The unit forms rubble covered rises of chert, siliceous shale, altered carbonate rocks, and thin sandstone. Its thickness in the region is unknown, but it is at least 170 feet.

Opik (op. cit.) used the name Gum Ridge Formation for fossiliferous impure sandy limestones, cherts, siliceous shales, and sandstones which crop out in isolated areas east of Tennant Creek and along the western part of the Barkly Highway. The type locality is Gum Ridge, a trigonometrical station 14 miles east-north-east of Tennant Creek township; there it is 45 feet thick. Identical rocks to those shown on Ivanac's map (Ivanac, 1954) can be traced in discontinuous outcrops northwards from the Barkly Highway to near Brunchilly Homestead in the southern part of the Helen Springs Sheet area, and thence westward to the eastern flanks of the Ashburton Range.

In the region occupied by the Helen Springs and Beetaloo Sheet areas, the Gum Ridge Formation crops out on the western flank of the Ashburton and Whittington Ranges near Tomkinson Creek and between Burke and Fergusson Creeks; on the eastern flank it crops out between Keurschner and Loveday Creeks. The unit presumably extends beneath the sand cover eastward to near Brunchilly Homestead, and southward on to the Tennant Creek Sheet area. The Gum Ridge Formation also occurs as discontinuous outcrops within the Ashburton Range in the vicinity of Banka Banka Homestead, near Muckety Homestead, and in the valley of Helen Creek.

The Gum Ridge Formation usually occurs as low rubble covered mounds and rises on which dip measurements are impossible. Scrapings in old quarries along the Stuart Highway near Banka Banka Homestead have revealed the rocks in situ, but the attitudes recorded are unreliable and of local significance only.

As with other Cambrian units to the east, the rocks of the Gum Ridge Formation have been extensively altered and lateritized (Randal, 1966a, b). Most of the surface exposures now consist of fossiliferous chert, silicified shale and sandstone, and altered carbonate rocks. Some are liberally coated with red iron oxides or hydroxides presumably precipitated during lateritization. Not all rocks are iron-stained: at locality HS541 the rocks consist of fine to medium-grained micaceous white sandstone and yellow siltstone. White leached siltstone containing Biconulites was found in scout-hole HS6 (appendix). The surfaces of the outcrops are frequently covered by a brecciated and recemented mixture of chert and silicified sandstone or shale, identical to that formed on the Wonarah Beds to the east (Randal and Brown, 1962a and b).

No unaltered limestone has been found in outcrop. However, at No.12 bore on the South Barkly Stock Route, south of the region, chips of fossiliferous blue-grey limestone and dolomitic limestone occur in the bore drain. Two holes were drilled at the site and the following logs were prepared by the Mines Branch of the Northern Territory Administration.

NO.12 BORE 1ST TRY (UNSUCCESSFUL)

0-5	feet	Soil
5-12	feet	Red-brown fine silty and sandy clay
12-23	feet	Red-brown fine to coarse silty and sandy clay
23-48	feet	Yellowish-brown as above
48-75	feet	Brown, fine to medium silty and clayey sand
75-107	feet	Red-brown fine sandy and clayey silt
107-120	feet	Yellow clay, weathered dolomite and limestone
120-127	feet	Very fine-grained fawn limestone
127-144	feet	Yellow brown claystone
144-176	feet	Pale creamy grey limestone
176-188	feet	Pale grey and creamy grey dolomitic limestone

NO.12 BORE 2ND TRY

0-23	feet	Red-brown silty sand
23-155	feet	White medium-grained sandy clay
155-187	feet	Fine-grained grey and cream dolomitic limestone
187-309	feet	No samples
309-320	feet	Pale grey chert, fragmentary shelly fossils
320-325	feet	White, hard, fine-grained crystalline dolomitic limestone

The rocks below 107 feet in the first hole and below 155 feet in the second presumably represent unaltered material of the Gum Ridge Formation, but do not include the full sequence.

Because of the absence of coherent outcrops it is difficult to assess the structure of the Gum Ridge Formation although some information can be gleaned from its relationship with other units in the area. With the exception of the domes in the Helen Creek Valley, the unit is generally flat-lying or has very low dips. In the Tennant Creek Sheet area it rests unconformably on both the Helen Springs Volcanics and the Lower Proterozoic Warramunga Group (Ivanac, 1954) - in places the unconformity with both older units is angular. In this region the contacts with the underlying rocks are not well-defined, but there is a strong angular discordance between the Gum Ridge Formation and the Lower Proterozoic Tomkinson Creek Beds, and a disconformity between it and the Helen Springs Volcanics, which it appears to overlap near Banka Banka Homestead. Its relationship with the Anthony Lagoon Beds to the east is unknown, but the two may be lateral equivalents. The Gum Ridge Formation is overlain by Mesozoic rocks south of Muckety Bore. It is not overlain directly by Tertiary rocks but has been extensively altered during the Tertiary lateritization.

Ivanac (1954) considers the Formation was laid down during an epicontinental marine transgression. The occurrence of coquinites suggests a near-shore environment.

The thickness of the unit is unknown. In the Tennant Creek area 45 feet of rocks are exposed at Gum Ridge with the upper part eroded. If all the rocks penetrated in No.12 South Barkly Stock Route are referable to the Formation then its thickness exceeds 170 feet.

The age of the Gum Ridge Formation is early Middle Cambrian. Opik (1956b) reports Xystridura ff. browni, Peronopsis cf. elkedraensis, Pagetia cf. significans, Chancelloria, Eiffelia, Biconulites, Billingsella cf. humboldti and Redlichia in the Tennant Creek area. He also reports that a new species of Xystridura is associated with Biconulites and brachiopods similar to the Gum Ridge types at Banka Banka (in the Helen Springs Sheet area). C.G. Gatehouse (Appendix A, this record), reports the following fossils from the Formation in the Helen Springs area, including localities near Banka Banka: Billingsella cf. humboldti, Xystridura sp. nov. (Opik, MS), Xystridura, Biconulites, Wimanella, Redlichia forresti, Redlichia, ptychopariidae, and inarticulate brachiopods.

Anthony Lagoon Beds

The Anthony Lagoon Beds (Plumb and Rhodes, 1963, 1964; Randal and Nichols, 1963) crop out in the south-eastern, central, and northern part of the Helen Springs Sheet area, and in the southern part of the Beetaloo Sheet area. The rocks, which are more or less continuous with similar outcrops in the Brunette Downs area to the east, are mainly carbonates with sandstone and siltstone interbeds. They are part of the widespread Middle Cambrian sequence of the Barkly Tableland. The thickness is unknown but is probably several hundred feet.

The name Anthony Lagoon Beds was used by Plumb and Rhodes (1963, 1964) to describe carbonates, sandstone, chert, and silicified limestone cropping out in the vicinity of Anthony Lagoon and Creswell Downs Homestead in the Wallhallow Sheet area. Randal and Nichols (1963) extended the name to identical outcrops in the Brunette Downs Sheet area. It includes rocks previously referred to as the Barkly Group (Noakes and Traves, 1954), but as this name is invalid it has been discontinued.

In the Helen Springs Sheet area the Anthony Lagoon Beds crop out as isolated boulders and rubbly rises in the black soil downs which cover the eastern, central and northern part of the area. Water-bore logs and scout-hole drilling indicate the unit underlies thin Lower Cretaceous and Tertiary rocks in the northern and north-eastern part of the Helen Springs Sheet area. Scattered outcrops occur in the southern part of the Beetaloo Sheet area, and it has been recognized below Lower Cretaceous rocks in B.M.R. scout-hole B1 in the centre of this area. Bore logs suggest the unit is continuous beneath the black soil which appears in part to be a weathering product. The downs are covered by chert and rubble derived from silicified coquinites and oolites and from chert nodules within the carbonates.

The topography of the areas underlain by the Beds is essentially controlled by the rock types at or near the surface. Grassy downs with occasional light timber are developed over the carbonates and siltstone, but the sandstone outcrops and lateritic material form low rises which support a light cover of eucalypt shrubs and small trees and various species of acacias.

Surface exposures comprise limestone, dolomitic limestone, dolomite, sandstone, chert, siltstone and silicified and leached carbonate rocks. Scout-hole drilling and rock-chips from water-bores indicate considerable amounts of calcareous and dolomitic siltstone and sandstone, dolomitic limestone, limestone, and dolomite. These are described in detail in Appendix A. Surface exposures of unaltered carbonate rocks are less numerous than in the adjoining Brunette Downs Sheet area: they occur along Brunchilly

Creek and between Tarrabool Lake and the lowermost reaches of Attack Creek. Both the altered and unaltered carbonate rocks are in part fragmental and oolitic. The colours of the limestone and dolomite are dark grey, grey, buff, cream, and brown. Chert nodules are rare. The fragmental rocks are similar to the Ranken Limestone in the Ranken Sheet area (Randal, 1966b). No identifiable fossils or even fossil fragments have been found in this region, but Randal and Nichols (op. cit.) report algae and fragments of trilobites and echinoderms in the Brunette Downs Sheet area, and a brachiopod was found between 1009 and 1019 feet in Brunette Downs No.1 Well (Randal, 1966a).

Quartz sandstone is associated with carbonate rocks of the Anthony Lagoon Beds both in outcrop and in the subsurface. The sandstone is flaggy, and occasionally ripple-marked. Quartz grains are variable in size, but generally the rocks are fine to medium-grained. Surface silicification is common, but some of the sandstone chips from bores and scout-holes are friable. Some of the sandstones may be the end product of the leaching of carbonate rocks which contained a very high percentage of quartz: calcareous and dolomitic sandstones from the B.M.R. scout-holes are discussed in Appendix A.

The lack of good exposures and the widespread superficial cover restricts the assessment of the structure of the Anthony Lagoon Beds. Minor structural trends and the regional structure of the Cambrian sequence is discussed elsewhere in this report (p. 32).

The maximum known thickness of the Anthony Lagoon Beds in this region is about 258 feet recorded in the driller's log of No.6 Bore on the Barkly Stock Route, in which 84 feet of soil, "volcanic rock"* and clay overlie 258 feet of limestone which may be related to the Anthony Lagoon Beds.

Because of the lack of diagnostic fossils the exact stratigraphic relationship of the Anthony Lagoon Beds with other Cambrian rocks is indefinite. Some information is available from the Brunette Downs Sheet area immediately to the east (Randal, 1966a; Randal and Nichols, 1963), and there it appears the Beds are equivalent in part to the lower Middle Cambrian Burton Beds in the Ranken Sheet area, and the Wonarah Beds in the Alroy Sheet area. The Anthony Lagoon Beds in this region may be a lateral equivalent of the Gum Ridge Formation. The Beds are unconformably overlain by Lower

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* Probably ferricrete

Cretaceous and Tertiary rocks.

The sediments appear to have been laid down on an irregular basement surface in a shallow water environment with medium current activity (Nichols, 1963).

MESOZOIC

Mullaman Beds

Flat-lying sediments referable to the Mullaman Beds of Lower Cretaceous age crop out over most of the Beetaloo and parts of the Helen Springs 1:250,000 Sheet areas. They were deposited on an irregular erosion surface and consist of non-marine, generally arenaceous, sediments of variable thickness overlain by argillaceous sediments with Lower Cretaceous microfossils. A total thickness greater than 285 feet has been proved in a water bore.

The name "Mullaman Group" was first used by Noakes (1949) for marine Lower Cretaceous sediments around Darwin, and plant-bearing sandstones occurring further inland. Since then geologists of the Bureau of Mineral Resources have modified the term to "Mullaman Beds", to conform with the Australian Code of Stratigraphic Nomenclature, and extended the use of the term to include all Cretaceous sediments in the northern part of the Northern Territory. The name Mullaman Beds is used in the above sense by Skwarko (1966). Field work during 1965 has shown that the southern limit of Lower Cretaceous sediments in the region is about 40 miles further south than previously known. The name Mullaman Beds is retained because of the similarity of the sediments in lithology, palaeontology, and age to sediments mapped previously as Mullaman Beds.

The type area for the Mullaman Beds is the Katherine-Darwin region (Noakes, 1949).

Sediments mapped as Mullaman Beds crop out over most of the Beetaloo 1:250,000 Sheet area, east of the Stuart Highway. They extend south into the Helen Springs 1:250,000 Sheet area for about 4 miles near Monmoona Creek and about 15 miles near Eva Downs. All of the above area of outcrop is in country with low relief (either "downs" country with Flinders and Mitchell grass, sandy "desert" country, or lateritic country with thick lancewood scrub). Exposures occur in valleys within the lateritic country, around the junction of lateritic and sandy country with downs country, and as blocks and rubble on low rises in the downs country. Laterites are best developed on argillaceous rock types. The red sand desert country west of Ucharonidge Homestead overlies arenaceous sediments. The downs country occurs on areas of both argillaceous and arenaceous sediments.

The Mullaman Beds comprise sandstone, often with pebbles or cobbles, and white, yellow, and pinkish argillaceous sediments varying from sandy and clayey siltstone to silty claystone. The sediments are unconsolidated or poorly consolidated below the surface as shown by drilling but outcrops are frequently silicified. In sections from bores the arenaceous sediments occur at the base and pass upward, sometimes with a transition zone of mixed lithologies, into dominant argillaceous sediments. This corresponds to the general sequence established by Skwarko (op.cit.) for his "inland belt" of Mullaman Beds comprising a basal sandstone (Unit A), a transition zone (Unit B) and an upper marine shale (Unit C).

The basal sandstone ranges in grain size from fine to very coarse and occasionally contains pebbles or cobbles. Plant stem impressions occur in fine-grained sandstone at localities BTL112 and BTL113. The detrital grains are of quartz and other stable materials such as quartzite, chert, and tourmaline. Pebbles and cobbles are of chert, quartz,and quartzite. The chert pebbles and cobbles are often of ribbonstone and derived from earlier Cambrian sedimentary rocks. The quartz pebbles are often a smoky variety of quartz with little-abraded crystal faces and are almost certainly derived from Lower Cambrian basic volcanics. The quartzite pebbles are similar to silicified sandstones of the Precambrian Tomkinson Creek Beds. In silicified surface outcrops, the detrital grains are cemented by yellow to brown silica, which varies from isotropic opaline material to fibrous chalcedony.

Sediments from the "transition zone" (see description of core No.1, scout hole B1, in Appendix A) contain sand, silt, and clay detritus, in thin interbeds and irregular lenses and patches of material of differing grain size.

Specimens from the upper argillaceous unit consist of claystone with thin laminae of silt-size quartz, and quartz siltstone with a clayey matrix or laminae. The opaline tests of Radiolaria are generally a notable constituent of the sediment and are in sufficient abundance to supply the silica necessary for the widespread surface silicification of the sediments.

The rubbly nature of surface exposures prohibits reliable dip measurements. The available bore data and exposed sections in the dissected areas north east of the region (Paine, 1964) show that the Mullaman Beds form a widespread, near-horizontal, thin sheet of sedimentary rocks. The broad undulations of the surface topography in the outcrop area of the Mullaman Beds are probably due to warping of the Mullaman Beds.

The various rock types in the Mullaman Beds reflect variations in environment of deposition. Skwarko (1966) suggests a non-marine, lacustrine environment for the sediments of Units A and B of the "inland belt" on the evidence of occasional plant fossils and the lack of marine fauna. The sediments could be fluviatile, rather than lacustrine, with the sands and pebbly sands deposited by migrating river channels and the argillaceous sediments in Unit B being flood plain deposits. The white and pinkish argillaceous sediments of Unit C contain a marine microfauna and were deposited during a very widespread marine transgression.

There are no naturally-exposed sections of the Mullaman Beds in this region, but the material from four boreholes which penetrated Mullaman Beds has been examined by geologists (Appendix A, and Crespin, 1949). The thicknesses of Mullaman Beds penetrated in these bores are 285 feet (Beetaloo No.1 water bore), 230 feet (Eva Downs Government Bore), 151½ feet (Eva Downs O Bore), and 60 feet (Scout hole B1). These are all minimum thicknesses since the upper limit is an erosion surface in each case and for Beetaloo No.1 water bore the bottom of the hole is in Mullaman Beds. The drilling results indicate that the basal arenaceous beds are variable in thickness. At Beetaloo No.1 water bore they are greater than 120 feet thick; at Scout Hole B1 they are 25 feet thick and at Eva Downs "O" bore they appear to be local pocket deposits on a karst topography developed on older Cambrian carbonate rocks.

Radiolaria in white claystones and siltstones from surface outcrops on the Beetaloo 1:250,000 Sheet area (BTL35 and BTL18) and from Beetaloo No. 1 water bore indicate a Lower Cretaceous age according to A. Lloyd (pers.comm.). Crespin (1949) regards radiolarian siltstones and silty claystones from the intervals 145-150 feet, 170-180 feet, 205-220 feet and 220-230 feet in Eva Downs Government Bore, as Lower Cretaceous in age. Skwarko (op.cit.) regards the Mullaman Beds of the inland belt to be of (?)Neocomian-Aptian to Albian age, by correlation with Mullaman Beds of the "coastal belt" further north, which contain dateable shelly faunas.

Undifferentiated Mesozoic

Flaty-lying sediments of several outcrop areas within the Ashburton Ranges pre-date the main lateritization and at one locality have yielded a Jurassic or Lower Cretaceous plant fossil. These Mesozoic sediments were deposited in valleys eroded into older rocks and consist of arenaceous and rudaceous sediments, sometimes passing up into predominantly argillaceous sediments.

The Mesozoic sediments occur within broad valleys which have been eroded below a well-defined summit plain (the "Ashburton Surface" of Hays, 1966). Within these broad valleys the sediments (and overlying laterites) have been partly removed by erosion so that they occur sometimes as cappings of low mesas. The main outcrop areas are as follows: 4 miles north, 8 miles west, and 5 miles south-west of Renner Springs Roadhouse; Mount Willieray; north, east, and south of Helen Springs Homestead; between Muckety and Banka Banka Homesteads; and about 10 miles south-west of Banka Banka. In the area east and north of Helen Springs Homestead the Mesozoic sediments occur as mesa cappings on the basalt and are overlain by laterite. Most of these latter occurrences, and some south of Helen Springs Homestead, are either shown as Tertiary laterite or are too small in area to be shown on 1:250,000 scale maps.

The sediments include boulder conglomerate, sandstone, pebbly sandstone, and siltstone. Boulder conglomerates, with rounded to angular boulders up to 2 feet of Tomkinson Creek Beds sandstone and chert, occur at the south-west end of the outcrop area 10 miles west of Renner Springs at the base of the section, and in the outcrop area around Mount Willieray. Pebble conglomerates, containing quartzite, chert, and quartz pebbles, also occur locally at the base of the section. At most localities sandstones, pebbly sandstones, and sandy siltstones are the dominant rock types. The sandstones and siltstones are sometimes micaceous and frequently show plant root or stem impressions. The sandstones may be either friable or strongly silicified. Some of the well-exposed sections show a general decrease in grain size upwards. At locality HS727, south-south-west of Renner Springs Roadhouse, the following section is exposed in a cliff:

(top)	15';	ferruginous sandstone passing up into pisolitic laterite.
	23';	purplish to white micaceous siltstone, ferruginous near the top.
	0" - 6";	pebble band resting on irregular surface (quartzite pebbles about 4" across).
(base)	15'+;	massive friable sandstone with vertical and inclined tree trunk or root cavities.

A further thickness of up to 40 feet underlying the cliff section can be seen in outcrops of pebbly sandstone, sometimes cross-bedded, which occur east of the cliffs. It is not known whether the above section is representative.

The beds are near-horizontal. Some low dips may be depositional or compactional. Compactional "draping" over an irregular basement can be

seen in micaceous sandstones exposed around the margins of the outcrop area 10 miles south-west of Banka Banka Homestead. The lateritized upper surface and bedding surfaces, within the outcrop area about 5 miles south-west of Renner Springs, have a gentle regional tilt south-west towards higher country.

The plant impressions and the lack of marine fossils in these sediments suggest a non-marine origin. The boulder conglomerates are probably alluvial fan deposits and the cross-bedded pebbly sandstones stream channel deposits. The finer sediments (fine-grained micaceous sandstone and siltstone) may have been deposited in lakes produced by minor faulting or tilting, or could be flood plain sediments. Some of the conglomerates could be lake shoreline deposits.

The preserved thickness of these sediments is less than 100 feet. The section around HS727 (approximately 80 feet) is the thickest known. Exposures in the outcrop area 10 miles south-west of Banka Banka are up to 40 feet thick.

The age of the sediments cannot be established precisely from fossil evidence. A fossil leaf from locality HS915, about 10 miles south-west of Banka Banka Homestead, has been identified as a leaf of Hausmannia sp., of Jurassic or Lower Cretaceous age (White, in prep.). The sediments are tentatively correlated with the lower non-marine part of the Lower Cretaceous Mullaman Beds exposed to the north-east, because of similarities in lithology, thickness, structure, and stratigraphic relationships.

CAINOZOIC

Tertiary Laterite

Laterite occurs over much of the region and is developed preferentially on basic igneous rocks and argillaceous sedimentary rocks.

The largest areas of outcrop are on the north-eastern half of the Beetaloo Sheet area. Smaller patches occur on the Helen Springs Sheet area, east of the Ashburton and Whittington Ranges and within the ranges, where they occur mainly in broad valleys as gently sloping surfaces or isolated mesa cappings. The laterites on the Beetaloo Sheet area support dense acacia (Lancewood) scrub. Elsewhere they support a sparse cover of spinifex and eucalypts. Away from the ranges the laterite areas are topographically higher than areas of black soil plain.

The laterite profile usually shows a well-developed massive upper ferruginous zone passing downwards through a transitional mottled zone into strongly kaolinized rocks. In the ferruginous zone, original rock textures

are usually not preserved, and a pisolitic texture is often developed. Laterites developed on sediments usually contain relic sedimentary quartz grains. Samples from the ferruginous zones of laterites at several localities and from laterites developed on several rock types have been analyzed by Australian Mineral Development Laboratories. The highest iron percentages (up to 51.2 percent) were recorded for laterites on basic igneous rocks. High percentages of iron (44.2 percent) were also recorded for laterites on marine argillaceous sediments of the Mullaman Beds and Gum Ridge Formation respectively. Most of the laterites in the Ashburton Range area were developed on non-marine (probably Mesozoic) sandstone and sandy siltstone. These have relatively low iron contents, (around 30 percent) and high silicon contents (around 14 percent) due to the high content of sedimentary quartz grains. Aluminium contents were low for all analyses (around 4 percent and none greater than 10 percent). Some analyses are listed below, and are followed by details of the specimens listed.

Specimen No.	Si%	Fe%	Al%	Cu(p.p.m.)	Mn(p.p.m.)	Ni (p.p.m.)
6567H42	6.50	49.2	3.40	6	89	5
6567H906	4.10	51.2	3.00	69	320	42
6567H911A	7.95	49.4	1.68	34	192	7
6567B117	9.30	42.5	4.80	20	37	7
6567H622A	9.85	44.2	2.90	10	265	34
6567H909	15.6	30.0	7.05	27	237	10
6567H907A	14.2	28.3	9.10	21	79	8

6567H42. Developed on dolerite sill, about 8 miles SSE of Powell Telegraph Station (near HS370)

6567H906. On basalt of the Helen Springs Volcanics, east side of Stuart Highway, 5 miles south of Helen Springs Homestead (average of several specimens collected across outcrop)

6567H911A. On basalt of Helen Springs Volcanics, top of mesa, Lubra's Lookout, near Renner Springs Roadhouse

6567B117. Small patch of pisolitic laterite on marine claystones and siltstones of Mullaman Beds, locality BTL117 near Reg Williams Bore

6567H622A On fossiliferous marine mudstones of Gum Ridge Formation, top of quarry face at locality HS622, 5½ miles SSE of Banka Banka Homestead

6567H909. On flat-lying Mesozoic sediments overlying Helen Springs Volcanics; composite sample taken along crest of east-west trending ridge, east of Stuart Highway and about 4½ miles SSE of Helen Springs Homestead

6567H907A. On Mesozoic sediments overlying Tomkinson Creek Beds; composite sample along N-S trending laterite outcrop about 1½ miles ESE of Mount Willieray

The massive ferruginous zones of laterites in the region are of variable thickness up to 20 feet. Bleached and kaolinized rocks extend, in some cases, up to another 100 feet below this as shown by natural exposures and drilling results in the area around Muckety Homestead (c.f. Scout Hole HS6, Appendix A, this record).

The bulk of the laterite post-dates fossiliferous Lower Cretaceous sediments. It is at present being dissected and younger laterite is not developed on areas from which the main laterite sheet has been removed. In the Brunette Downs area to the east (Randal and Nichols, 1963) the Miocene Brunette Limestone locally overlies material derived from an earlier laterite, showing that some laterite pre-dates the Brunette Limestone. No more definite evidence of the age of the laterite is available from the region or adjoining areas. Hays (1966) argues that lateritization requires a humid climate, and suggests that lateritization of the Tennant Creek Surface occurred during the regression of the Cretaceous sea when the coastline was further inland than at present.

Highly ferruginous material has been recovered from bore holes, underlying the Mullaman Beds and possibly representing an earlier period of lateritization. Some of the surface material mapped as Tertiary Laterite could be this older ferruginous material (e.g. outcrops around the Cambrian-Mesozoic boundary west of Monmoona waterhole, and some of the pockets of laterite on the higher parts of the Ashburton Range). Ironstone-cemented stream gravels have formed more recently than the main areas of laterite and are mentioned later under "Superficial Deposits".

Brunette Limestone

The Tertiary Brunette Limestone (Noakes and Traves, 1954) crops out in the south-eastern and central part of the region. The rocks consist mainly of chalcedonic limestone, chalcedony, and sandstone. The thickness is unknown, but is at least 15 feet. The rocks are fossiliferous; they contain forams and freshwater shelly fossils.

Noakes and Traves (1954) used the name Brunette Limestone to describe white nodular limestone which crops out near Brunette Downs, Alroy Downs and Rockhampton Downs Homesteads east of this region. They describe no type sections, but list the outcrops at Crow's Nest Bore (Brunette Downs Sheet area) and Alroy Downs No.9 Bore (Alroy Sheet area) as the best exposures. The rocks extend westward into the Helen Springs Sheet area.

In this region the Brunette Limestone crops out in the south-eastern, central, and north-eastern parts of the Helen Springs Sheet area. Isolated outcrops of chalcedonic and travertinous material near Muckety and Banka Banka Homesteads have been mapped as this unit. The Brunette Limestone crops out as isolated boulders in the grass-covered downs country or as low rocky rises. The best exposures are south-west and north-west of Tarrabool Lake, and around the margins of an unnamed lake south-west of Eva Downs Homestead.

The Brunette Limestone consists of white to brown fine-grained to coarsely crystalline limestone, dolomitic limestone, and dolomite. The rocks are siliceous, containing chert and opaline nodules and smears; they are frequently nodular or skeletal in appearance. Sandstone boulders found on the surface with limestone boulders are probably part of the sequence, but they have not been found in situ. The silica in the unit occurs as micro and cryptocrystalline silica, amorphous silica, fibrous chalcedony, and drusy quartz. Some contain original carbonate textures and Nichols (1963) believes that some of the silica may be replacing organic remains. Near Eva Downs "L" Bore, south-west of Tarrabool Lake, the unit contains sub-angular fragments of brown and white dolomite and dolomitic limestone apparently derived from the underlying Cambrian rocks. Randal and Nichols (1963) report similar occurrences in the Brunette Downs Sheet area.

Bedding is poorly developed in the unit; the few solid outcrops are rounded and irregularly jointed.

The Brunette Limestone appears to be a thin deposit unconformably laid down on the Lower Palaeozoic and Mesozoic rocks. Near Banka Banka Homestead it rests directly on the (?)Lower Proterozoic Tomkinson Creek Beds and near Muckety Homestead on the Helen Springs Volcanics. It is similar to the Austral Downs Limestone (Noakes, 1951). Noakes and Traves (1954) considered both these units were laid down contemporaneously with the lateritization of the older rocks, and that the leaching of lime and silica from the older rocks provided the sources for the younger siliceous limestones.

The limestone has been previously regarded as a lacustrine deposit, but fossils found in the Brunette Downs Sheet area (Randal and Nichols; 1963) and in BMR Scout-hole HS1 south-west of Eva Downs Homestead has caused some modification of the ideas on its environment. Lloyd (in prep., b) lists the foram Ammonia beccarii, freshwater ostracods, the freshwater pelecypod Corbiculina sp., and the freshwater gastropods Plotiopsis sp. and Syrioplanorbis hardmani from the Brunette Downs Sheet area. He lists (in prep., a) Ammonia beccarii and Plotiobsis sp. from Helen Springs (BMR) Scout-hole No. 1.

A probable explanation of the environment is that a brief marine transgression occurred during the deposition of siliceous carbonates under essentially lacustrine conditions, with the consequent development of local lagoonal or estuarine conditions. Paten (1964) has inferred brackish water conditions for the Austral Downs Limestone south of Urandangi.

The maximum known thickness of the unit in this region is 15 feet in Helen Springs (B.M.R.) Scout hole No.1; in the Brunette Downs Sheet area it is at least 60 feet (Randal and Nichols, 1963).

Noakes and Traves (1954) regarded the age of the Brunette Limestone as Miocene. Lloyd (op.cit.) agreed with this and suggests the possibility of it being Lower Miocene.

Superficial Deposits

There are three main categories of unconsolidated superficial deposits in the region: sands and sandy or loamy soils (Czs), black soils (Czb), and alluvia (Cza).

Red sand, supporting spinifex, scattered acacias and eucalypts, occurs on the eastern and western sides of the Ashburton Range. To the east it covers a piedmont desert which slopes down gradually from the Range to terminate abruptly against the black soils and alluvia of the downs country. To the west it marks the edge of the desert country of the Wiso Tableland (Hossfeld, 1954). Within the Range, red sand covers valley plains formed when the drainage systems were more active than they are now: e.g., the drainage basin of Tomkinson Creek. Sand covers a large area of Lower Cretaceous rocks west of Ucharonidge Homestead; it supports a mixed eucalypt and acacia scrub.

The sand is mainly colluvial, but probably contains some wind and stream transported material. West of Ucharonidge Homestead a large area of coarse sand has been derived from the Lower Cretaceous sandstone which it overlies. Smaller patches of sand are common on Cambrian outcrops in the downs country. Wind action has probably winnowed fine materials from the piedmont red sand, which is partly derived from sandstone and siltstone of the Tomkinson Creek Beds.

Three low ridges near No.16 Bore, Rockhampton Downs, have been interpreted as sand dunes, although their west-south-westerly trend conflicts with the general north-westerly trend of dunes and travertine near Dalmore Downs in the Alroy Sheet area further to the south-east (Randal and Nichols, 1963).

Sand areas and sandy soil south-west of Eva Downs Homestead and south of Tarrabool Lake include soils which probably incorporate much wind-transported sand and dust. Occasional dust storms probably contribute some material to deposits in the downs; a veneer of red sand is left on tracks in the downs country after windy periods.

On the lateritic tableland of the Beetaloo Sheet area, superficial deposits mapped as Czs consist of sandy and loamy residual soils.

The black soils of the Mitchell grass downs country and Newcastle Creek are termed by Stewart (1954) Heavy Grey Pedocals. They have developed from clay, silt, and sand deposited under water during Tertiary times, and from colluvial and alluvial material derived from Cambrian, Lower Cretaceous and Tertiary outcrops within the same depositional area, together with wind-blown sand and dust. The character of this soil may have changed little since soil formation in the downs country first became possible, particularly as the climate seems to have fluctuated little, and no buried soils have been recognized during water-boring and scout-drilling.

Thicknesses of black soil recorded during drilling are 2'6" in Eva Downs 'O' Bore, 5' in Beetaloo No.1 and Banka Banka No.17, and 7' in Banka Banka No.18 and Scout Holes B1, HS4 and HS5.

At present the black soils are being slowly dissected by small non-perennial watercourses, and contribute sediment to swamp and floodout areas.

In the downs country alluvium occurs in bluebush swamps and areas of distributaries, both being localities for Stewart's (op.cit.) Distributary Heavy Grey Pedocals, and also as flood plain strips along major creeks. Boundaries on the map between black soils and downs country alluvia are arbitrary, depending on air-photo interpretation.

In the Ashburton Range alluvia consist in part of river sands and gravels and minor flood plain deposits. Bright red clayey soils of old flood plains are being slowly eroded. Where Attack, Morphett and Burke Creeks leave the Range they are cutting down into 'river laterites' - iron-cemented cobbles, gravel and sand which sometimes rest on a mottled clayey horizon. Floodout sediments, the soils of Stewart's Sandy Distributary Complex, are deposited downstream when streams reduce grade in the desert or downs country. Grey or brown soils have developed within the Range in favourable locations, in particular in valleys occupied by the Helen Springs Volcanics (igneous, calcareous desert soils), siltstones, and carbonate rocks. They commonly support Mitchell grass. Occurrences large enough to show on the map have been called alluvium because of their floodplain relationships.

Some of the superficial deposits in the old valley systems in the Lower Cretaceous outcrops of the Beetaloo Sheet area also appear on the map as alluvium, although it is probable that no deposition has taken place for a long time.

STRUCTURE

The region comprises parts of the Wiso and Barkly Tablelands in which the structure is only poorly known, and the Ashburton and Whittington Ranges in which the structure is known in some detail.

An outline of the structure of the Tomkinson Creek Beds, which form the Ashburton and Whittington Ranges, has already been given under "Stratigraphy". The major faults and the axes of folds both have a predominant north-south trend, approximately paralleling the general trend of the ranges. The main exceptions to this are the area of west-north-west trends to the south-west of Muckety Homestead and the major north-north-east trending fault south-east of Helen Springs Homestead. The faulting and folding appear to be genetically related. The Tomkinson Creek Beds show no signs of metamorphism, so that the thick sandstone beds could not have yielded significantly by plastic flow during folding. Under these circumstances fracturing (faulting) of the sandstones would necessarily accompany fold movements.

The faults appear to be all high angle structures, but the local topographic relief is normally too low to allow adequate observation. The major faults with throws of several thousands of feet are accompanied by a zone about $\frac{1}{4}$ mile wide of strong jointing and slickensiding, with the strata "dragged" up into steep and locally overturned attitudes. Low angle slickensides are common but their azimuth is generally near-perpendicular to the fault trend.

Thick intervals of sandstone, as expected, have a larger-scale fold pattern than intervals of siltstones with thin sandstone interbeds, which often have folds too small to plot at 1:250,000 scale.

The general intensity of folding (and accompanying faulting) decreases from south to north, and from lower to higher stratigraphic positions. In the Whittington Range and Bootu Creek areas dips are variable but average around 40°. The two thick sandstone intervals with interbedded siltstone, the uppermost 4,500 feet of the succession in the Helen Springs and Renner Springs areas, usually have dips between 5° and 10°, with local upturning and occasional folding close to major faults.

On the Barkly and Wiso tablelands in the region, the outcrops are such that no reliable dip measurements have been made. Interpretation of the

structure thus depends on recognition of outcrop trend lines, subsurface information, geophysical measurements, and possible reflections of structure in topography.

The structure of the Cambrian rocks underlying the tableland areas is least well known. Some outcrop trends are shown on fig. 4 but the topographic relief is too low to enable estimation of the direction and angle of dip of the outcropping beds. Many bores penetrate Cambrian rocks on the tableland areas but none are known to have reached underlying rocks and the Cambrian sections are usually too thin or too poorly logged to enable detailed correlation between holes. The available bore cores, however, show near-horizontal bedding. The contours of provisional Bouguer anomalies (Flavelle, 1965) indicate a gravity minimum centred near Beetaloo Homestead and trending roughly north-south. A.J. Flavelle (pers.comm.) suggests that this may be due to a southerly extension into the region of Upper Proterozoic Roper Group sedimentary rocks rather than being due to a thickening of the Phanerozoic section. Mapping in more dissected areas to the north-east of the region (Plumb and Rhodes, 1963), and borehole information from elsewhere on the Barkly Tableland, suggest that the Cambrian sedimentary rocks of the Barkly Tableland are near horizontal.

The Mesozoic Mullaman Beds are better known than the Cambrian rocks and again they appear to form a widespread, thin, near-horizontal sheet.

Broad warping movements post-dating the Lower Cretaceous sediments have probably produced the major elements of the topography and drainage pattern of the tableland area and were responsible for the development of closed topographic depressions, mostly between the Ashburton Range and higher country in the north-east of the region, but also including Lake Woods to the west of the ranges. These topographic depressions close at about 700 feet. Their outlines show some linear trends which may reflect basement fractures. Some other linear features occur on the tableland area and are shown on fig. 4. They are mostly boundaries between superficial deposits or straight stream trends and are of uncertain significance, but could again reflect basement fractures.

GEOLOGICAL HISTORY

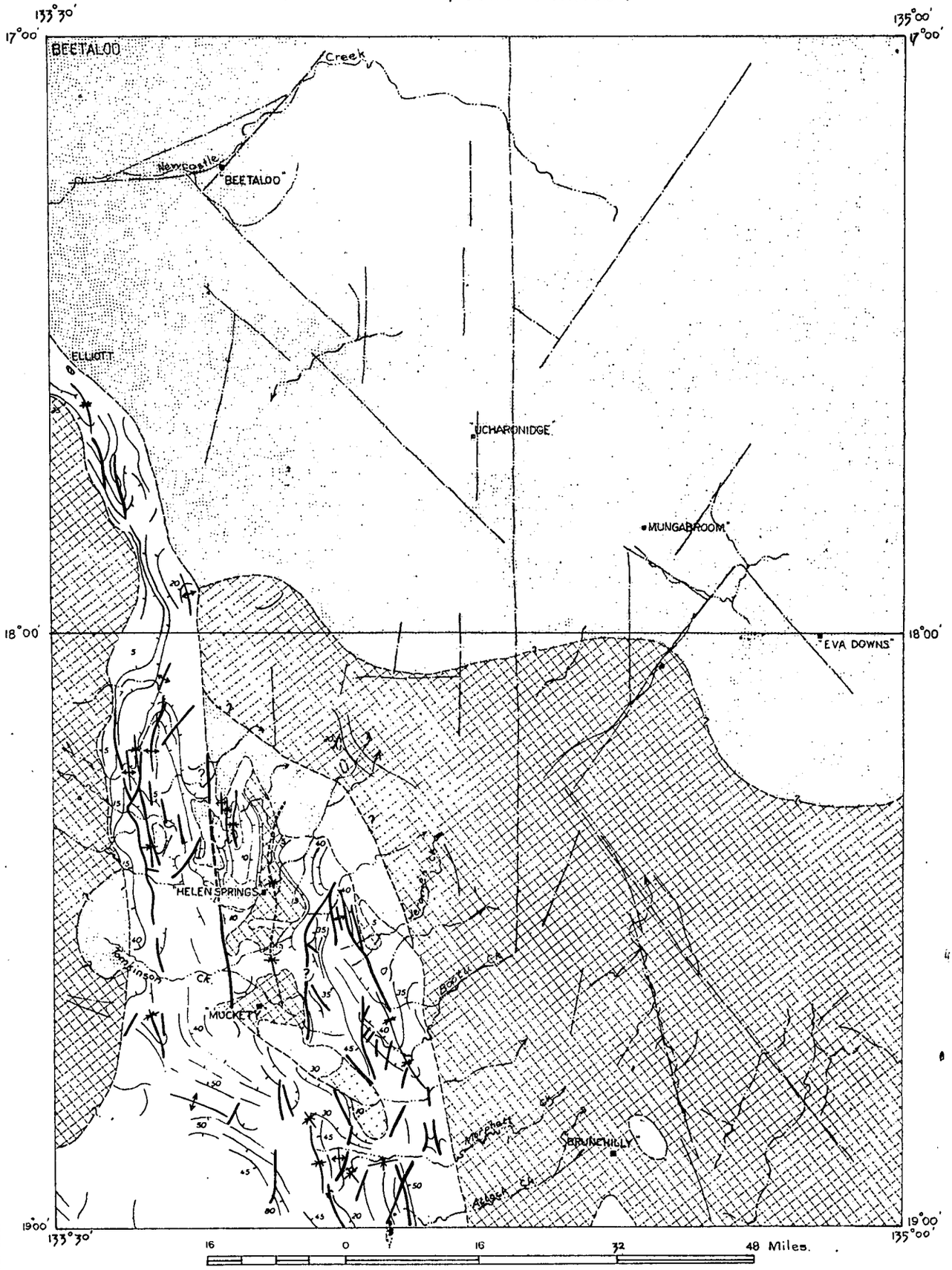
The sediments of the Tomkinson Creek Beds were laid down in Lower Proterozoic times. They appear to post-date the Warramunga Group in the Tennant Creek area (Ivanac, 1954) and may be correlates of the Hatches Creek Group in the Davenport Ranges further south (K.G. Smith, B.M.R., pers.comm.). Their time relationship with the Carpentarian sediments to the north is obscure (Dunn, Smith, and Roberts, in prep.).

Figure 6

STRUCTURAL SKETCH MAP

BEETALOO AND HELEN SPRINGS AREA

(Cainozoic deposits omitted)



Mesozoic

Cambrian

Lower Proterozoic

Geological boundary

Fault (dashed where concealed)

Anticline (dashed where concealed)

Syncline (dashed where concealed)

Trend of bedding with angle of dip shown.

Trends of uncertain significance (tableland areas)

Streams

"MUCKETY" Homestead.

E 53/A/8

Bureau of Mineral Resources, Geology and Geophysics June 1966.

To accompany Record No 1966/110

A dolerite sill near Powell Creek may represent later Proterozoic igneous activity; it occurs within the Tomkinson Creek Beds, which were later folded and faulted.

By Lower Cambrian times erosion of the Proterozoic rocks had produced structurally controlled valleys in which the Helen Springs Volcanics were deposited and are now preserved in approximately their original attitude. Early Middle Cambrian seas flooded the same area and the Gum Ridge Formation was laid down disconformably on the Helen Springs Volcanics, and also peripheral to the present Ashburton Range, both to the east and west. At the same time the Anthony Lagoon Beds were deposited to the east on an irregular surface of Proterozoic rocks (Randal and Nichols, 1963).

Between the times of deposition of the Cambrian and the Mesozoic sediments, the only event which can be postulated is the maturation of the Ashburton Surface (Hays, 1966), which developed across the Tomkinson Creek Beds and the surrounding Cambrian rocks. Hays suggests that the dissection of this surface may have produced most of the sediments of the Lower Cretaceous Mullaman Beds, which were laid down unconformably on the Anthony Lagoon Beds. This implies some mild tectonics, for which no other evidence is forthcoming.

The Mullaman Beds in this region provide evidence for deposition of fresh-water sediments followed by a Lower Cretaceous marine transgression. In valleys which are cut into the Ashburton Surface within the Ashburton Range, unnamed fluviatile and lacustrine sediments contain plant remains of Jurassic or Lower Cretaceous age, and lie unconformably on the Tomkinson Creek Beds and the Helen Springs Volcanics.

In the Lower Cretaceous an erosion surface may have existed between the Ashburton Range and the depositional area of the Mullaman Beds. Gentle folding or warping along a northwest/south-east axis or hinge line during late Mesozoic or Tertiary times elevated the Mullaman Beds above sea-level; this movement could have blocked off valleys in the erosion surface, initiating the depressions characteristic of the downs country today. Uplift probably continued, perhaps intermittently throughout most of the Tertiary.

There was some erosion of the Mullaman Beds prior to lateritization. The lateritized surfaces of the Mullaman Beds and of Cambrian and Proterozoic rocks further south comprise Hays' Tennant Creek Surface, a culminating erosional climatic event. Hays contends that laterite in this region is younger than laterite in the Alice Springs region, for which Mabbutt (1966) argues a minimal mid-Tertiary age. Penecontemporaneously with, or perhaps slightly after, lateritization, of the Brunette Limestone was deposited in water covering the downs country and along some river courses. There is fossil evidence for a

possible marine incursion at this stage (Randal and Nichols, 1963).

Mabbutt (1966) suggests that silcrete is produced in a more arid climate than laterite. Silcreted laterite, soil and rubble, rock silicification, and general dessication of minor drainage systems dissecting the Tennant Creek Surface probably represent increasing aridity following soon after lateritization.

The youngest tectonic event was the uplift of the area to its present altitude. Regional slopes and drainage of the Tennant Creek Surface including the northern end of the Ashburton Range, and Lake Woods, suggest a minor tilt to the west. Slight rejuvenation of drainage can be explained by a slightly wetter climate.

ECONOMIC GEOLOGY

Petroleum

Until the surface mapping of this region is supplemented by adequate subsurface investigations no reliable assessment of the petroleum prospects can be made.

Fossiliferous marine Cambrian and Mesozoic rocks are known in the region and may provide source rocks for petroleum. The Cambrian carbonate rocks and perhaps the Mesozoic sandstones could form reservoirs for oil or gas; the large quantities of subartesian groundwater produced from them is proof of their permeability. None of the water-bores or scout-holes in the region have encountered hydrocarbons, but few have penetrated even half of the probable section of Cambrian and Mesozoic rocks and none have penetrated the full section. Fine-grained and compact carbonates are known in outcrop and have been reported in the bore-logs; these, and Mesozoic siltstones could act as cap rocks for potential reservoir rocks. However, the structure and lithological sequence of the potential source, reservoir, and cap rocks are not well known. The regional geology suggests the sequence is thin and lacking in well developed structures. The prospects are not considered attractive.

Manganese

Manganese mineralization occurs in the Tomkinson Creek Beds about Bootu Creek and west of Renner Springs. The occurrence at Bootu Creek is the most important and has been sporadically worked for several years. It was mapped by Jones (1955) who recommended diamond drilling to prove the extent of the deposit; this was done in 1956, and the results reported by Mackay (1956). The main mine workings are known as the Muckety Manganese Deposit, and are operated by the Renner Springs Manganese Company.

The deposit along Bootu Creek occurs as a replacement of a favourable siltstone bed and can be traced as discontinuous dark ridges along both limbs of a syncline pitching north-north-west. The greatest concentration and the main workings occur on the western limb at the top of a limestone-siltstone sequence which separates two sandstone units. The valley of Bootu Creek is controlled by the strike and position of the softer materials and generally follows the swing in strike around the syncline, but the limestone has not been traced around to the eastern limb.

Although some sandstone and limestone are replaced, Jones (op.cit.) and Mackay (op.cit.) believe the siltstone is the most favourable rock for replacement. This was substantiated in 1965 by examination of the working face and some adits, which are now situated at least 10 feet further down dip than in 1956. The ore in sandstone is patchy and contains a great deal of residual quartz grains. Both Jones (op.cit.) and Mackay (op.cit.) recognized three types of ore: good grade massive ore ($>$ 60 percent MnO_2), medium grade sandy ore (35 to 60 percent MnO_2), and low grade ore ($<$ 35 percent MnO_2). The good grade ore occurs only in the siltstone, and the sharp cut-out between good and medium grades of ore frequently reflects the contact between siltstone and sandstone.

Cross-faulting and near strike faulting has complicated the geometry of the favourable siltstone, which also is lenticular, and causes consequent difficulty in the assessment of reserves. However, Mackay (1956) assessed the reserves after the diamond drilling, and considers there was about 11,000 tons of good grade ore at that time. Several thousand tons have since been removed. Jones (1955) considered there were about 500 tons of good grade ore at a similar deposit on the eastern limb 5 miles to the south-east.

Diamond drilling indicated that the mineralization does not persist for any great depth and that good ore rapidly diminishes down dip. The mineralization appears to be a secondary enrichment at the surface of beds which contained small amounts of manganese. It is related to the present ground surface and its connection with the laterite profile is probably of minor importance. Jones (1955) notes pebbles and grits in the sandstone above the ore and suggests the manganese may have originally been concentrated at the surface of a disconformity.

Building materials

Flaggy carbonate rocks and flaggy sandstones have been used for minor building purposes - pathways around homesteads, mounting bore equipment, and as foundations for cattle troughs. The silicified sandstones of the Tomkinson Creek Beds are useful for quarrying and crushing for road metals and suitable sites occur at several places along the Stuart Highway. The sandstone is at

present being quarried for this purpose near Attack Creek, a few miles south of the region.

Gravel supplies are scattered over wide areas, but are thin and sparse. In the downs they are mainly chert with minor silicified ironstone, but in the timbered areas ironstone forms the greater part. There are numerous occurrences of detrital laterite but these are recemented and would be difficult to scrape.

There are no large occurrences of good quartz sand: the ferruginous and often silty sand of the desert areas is of doubtful value for building purposes, but it has been used mixed with a high proportion of cement for paved floors. Some of the streams in the Ashburton Range contain small pockets of good sand. Most streams contain a great deal of reworked gravels and soil.

The heavy clayey soils of the downs country make excellent earth tanks for the storage of bore-water. The soils become plastic and impervious when wet and if maintained in moist and vegetated conditions make a virtually water-proof container ("turkey nest"). They are considerably weakened by admixed sand.

Water

This region is occupied by several large cattle stations, and there is a heavy demand on its water resources.

There are few permanent waterholes because of the arid climate, and these are generally restricted to the incised watercourses on the flanks of the Ashburton Range in the western part of the region. The more important are in Attack Creek, Morphett Creek, Tomkinson Creek, and Burke Creek. Small permanent waterholes are fed by springs in Gleeson Creek and Powell Creek, and small semi-permanent rock-holes occur in tributaries of Bootu Creek. Three small springs at Renner Springs flow into small artificial catchments and provide sufficient water for domestic purposes and a few head of stock. Most of the water-holes adjacent to the ranges occur in country which is not the most suitable for cattle grazing, most of which is carried out in the grass-covered black soil plains and along the alluviated valley of Newcastle Creek.

The most important permanent waterholes in Newcastle Creek are Mundah, Hollomo Noon, and a very large waterhole alongside Beetaloo Homestead. In the downs country Coolunjie Waterhole on Brunchilly Creek, and Munkaderry Waterhole on the northern extension of Attack Creek are the largest permanent surface waters. Indamilly Waterhole on McKinlay Creek, though large, is regarded by local pastoralists as not normally permanent. Numerous depressions in the watercourses in the downs country form waterholes of varying importance, but

most are dry by the middle of the dry season. Brunchilly Dam on Brunchilly Creek, is the only man-made permanent waterhole in the downs country; small dams on Carmilly and Attack Creeks do not have sufficient depth or catchment and are semi-permanent.

In the dissected country north of Eva Downs permanent water is available at Surveyors Waterhole Broad Creek, 6-mile Dam, and 10-mile Dam on Cherub Creek.

The quality of the surface waters is good, although most are milky because of suspended clay and silt. All contain less than 200 parts per million of total dissolved solids, and there appears to be little major variation in composition. In the downs country the surface waters contain mainly calcium and magnesium ions associated with bicarbonate ions; calcium is dominant over magnesium. In the waterholes north of Eva Downs, which are in areas of lateritized and silicified Lower Cretaceous rocks, the waters, although dominant in calcium, magnesium, and bicarbonate, contain much higher amounts of iron and silica than waters elsewhere. The surface waters and springs in the areas of the Precambrian Tomkinson Creek Beds also contain calcium, magnesium, and bicarbonate ions as the dominant ones.

The springs in the Ashburton Ranges have not been investigated in detail. They occur in deep alluviated valleys bordered by large elevated areas of jointed sandstone, or issue from joints and fissures on the slopes of sandstone ridges. Some may be controlled by faulting, but this has not been clearly established. No high temperatures have been recorded; the three springs at Renner Springs were 80°F, 85°F, and 82°F, with an air temperature of 90°F. Many springs are not permanent and the flow of the permanent springs rapidly diminishes towards the end of the dry season.

Because of inadequate surface water the pastoral industry is largely dependent on groundwater. There are over 120 private and government stock route bores in the region, including two bores at Elliott township. Most bores were working during the 1965 survey, although some were temporarily disconnected because of mechanical failure, or lack of suitable feed nearby.

Most bores are situated in the grassy downs where they are obtaining supplies from the mainly carbonate sequence of the Middle Cambrian Anthony Lagoon Beds. On the flanks of and within the Ashburton Range, the bores may be obtaining water from the Gum Ridge Formation; others are clearly obtaining supplies from the Tomkinson Creek Beds. In the Beetaloo Sheet area some bores are obtaining groundwater in the Cambrian carbonates beneath the Lower Cretaceous rocks, but others, particularly about Beetaloo Homestead,

are producing from Mesozoic aquifers. Bores near Helen Springs Homestead may be obtaining groundwater from within the Helen Springs Volcanics or at its contact with the underlying Tomkinson Creek Beds. In Scout Hole HS6, basal sandstones of the Helen Springs Volcanics produced a good supply. The majority of bores are less than 300 feet deep, but few logs have recorded the depth of the aquifers.

Supplies are generally regarded as adequate, although the pumping tests are usually not reported in detail, and some tests commonly under-estimate, and occasionally over-estimate, the safe yield (Randal, 1966d). However, the supplies are variable, ranging from 1000 gallons/hour to 3000 gallons/hour with most within the range of 1500-1800 gallons/hour. It has not been possible to assess in detail the relative abundance of groundwater in the units of different ages, but it appears that the Cambrian carbonate aquifers have the better yields, particularly towards the centre of the basin. The Mesozoic rocks in the north give reasonable yields but there are insufficient data to provide clear-cut trends. Bores in the Tomkinson Creek Beds tend to yield less than 1200 gallons per hour, and a few abandoned bores are known both in the Precambrian and Mesozoic rocks. Generally the recorded supplies from the Cambrian aquifers in this region are lower than those to the east, but this may not be a reliable assessment owing to incomplete testing or early tests with old equipment (Randal, op.cit.). Supplies from the Cambrian carbonates are expected to be superior to those from the Tomkinson Creek Beds: the former contain joints and solution cavities whereas the jointing in the Tomkinson Creek Beds is not widespread.

Figure 5 shows the contours on the piezometric surface i.e. the standing water levels, where available, have been reduced to heights above sea level and contoured. The highest elevations of thepiezometric surface (greater than 900 feet) occur between Muckety and Banka Banka Homestead; the lowest (less than 530 feet) values occur in a belt which trends south-easterly from Barkly Stock Route No.6 Bore to the south-eastern part of the Helen Springs Sheet area where it joins a similar area of low values near Rockhampton Downs Homestead (Randal, op.cit.). Low values also occur to the north of a sinuous line from near Elliott township to north of Ucharonidge Homestead, and, by extrapolation of the 530 foot contour to the east, they occur in the north-eastern part of the Beetaloo Sheet area. The 600 foot contour parallels the eastern flank of the Ashburton Range, and in the south swings eastwards on to the Alroy Sheet area (Randal, op.cit.). On the western flank of the Range the 750 foot contour strikes from near Powell Creek to somewhat west of Ladabah bore on Muckety Station.

Groundwater movement appears to be directed to the east and to the west, away from the Ashburton Range, and northwards from the desert country south of

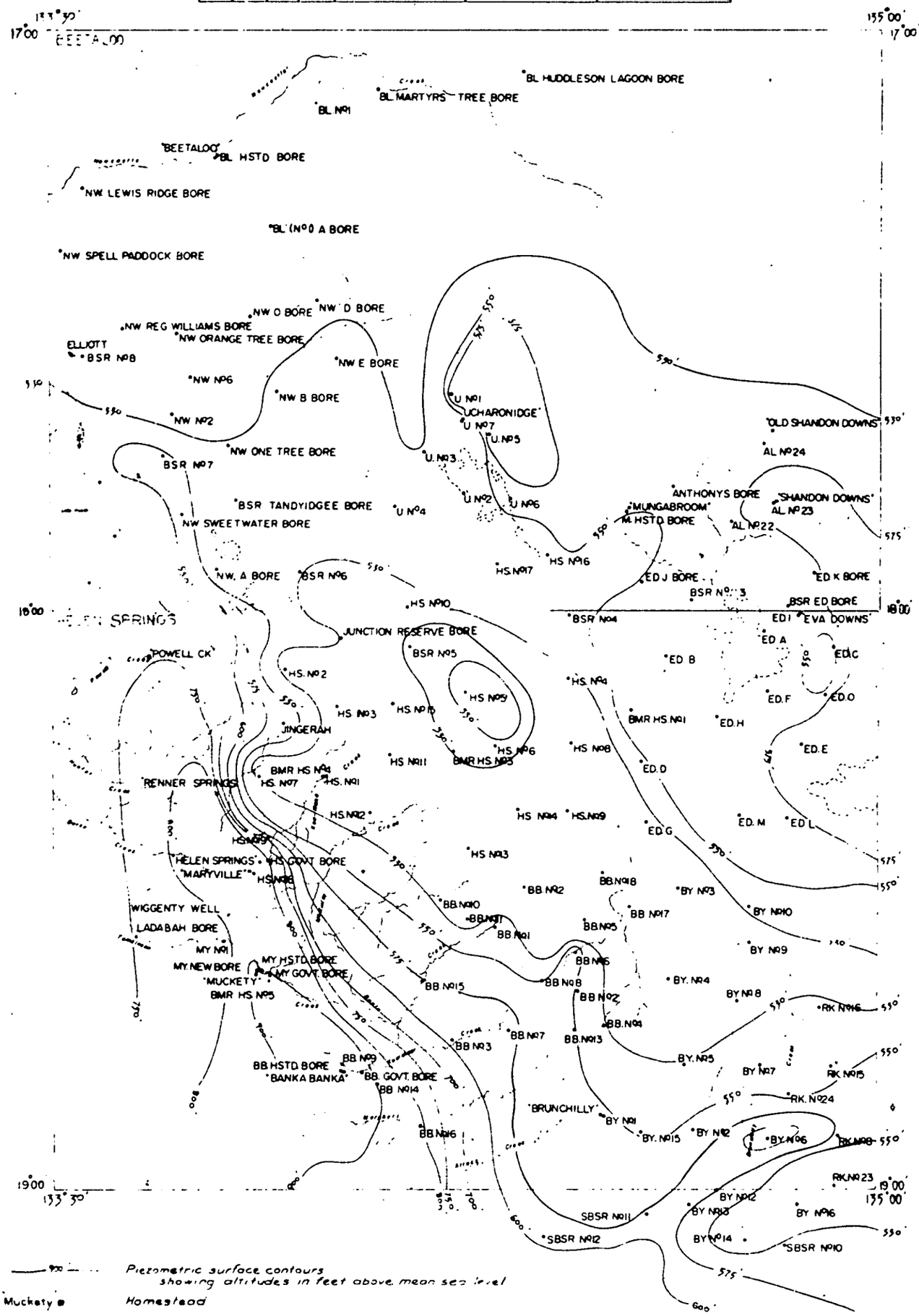
Fig 5

PIEZOMETRIC SURFACE CONTOURS

BEETALOO AND HELEN SPRINGS AREA

SCALE

16 0 16 32 48 MILES



— 900 — Piezometric surface contours showing altitudes in feet above mean sea level

Muckety ● Homestead

U No5 ● Bore

AL	Anthony Lagoon	MY	Muckety
BB	Banka Banka	M	Mungabroom
BMR	Bureau of Mineral Resources	NW	Newcastle Waters
BL	Beetaloo	RK	Rockhampton Downs
BSR	Barkly Stock Route	SBSR	South Barkly Stock Route
BY	Brunchilly	U	Ucharonidge
ED	Eva Downs		
HS	Helen Springs		

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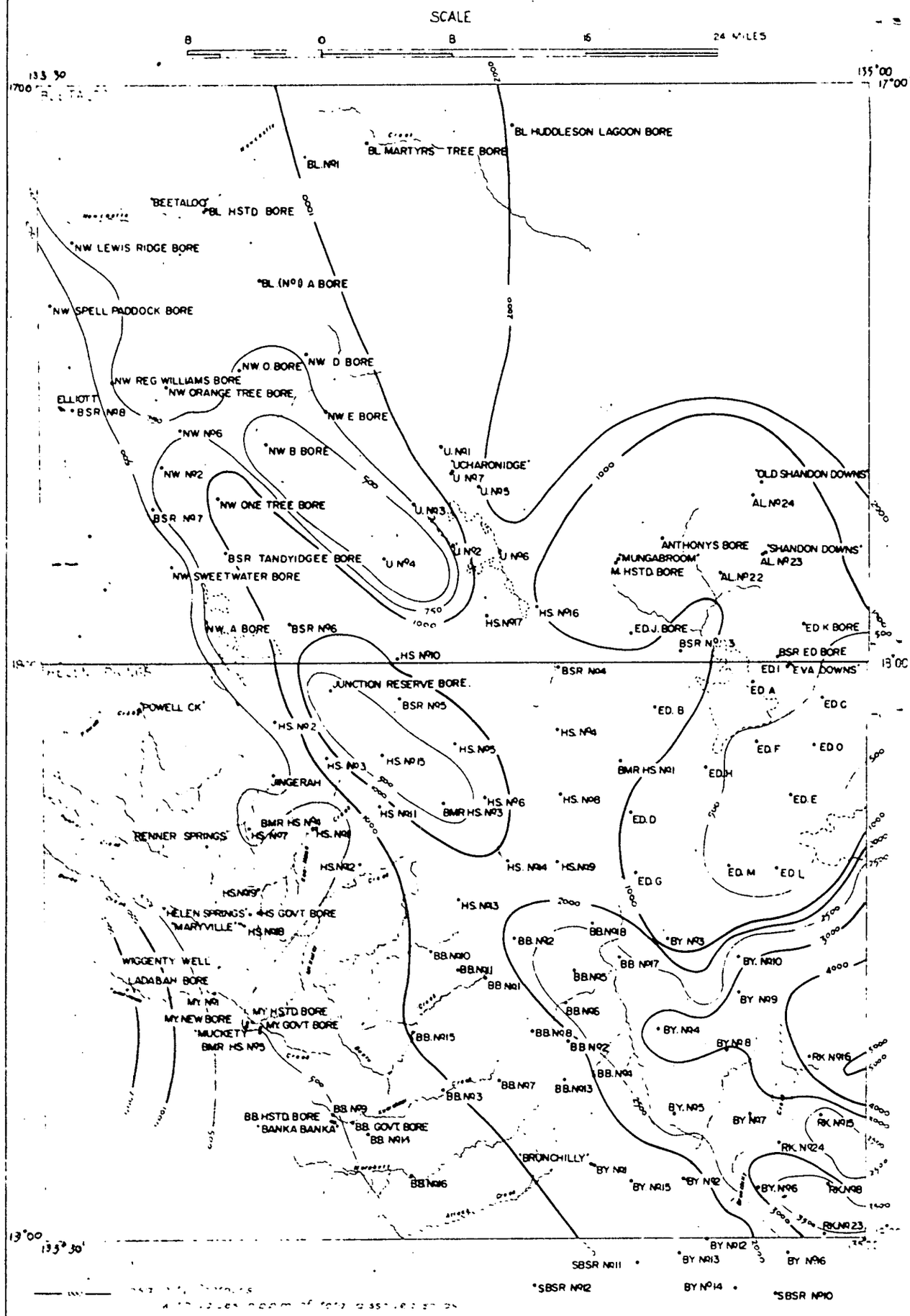
To accompany Record No 1966/140

FIG 6

GROUNDWATER ISOSALINITY CONTOURS

BEETALOO AND HELEN SPRINGS AREA



Homesteads

Bore • AL Anthony Lagoon
BB Banka Banka
BMR Bureau of Mineral Resources
BL Beetaloo
BSR Barkly Stock Route
BY Brunchilly
ED Eva Downs
HS Helen Springs
MY Muckety
M Mungabroom
NW Newcastle Waters
RK Rockhampton Downs
SBSR South Barkly Stock Route
U Ucharonidge

E53/A/7

Bureau of Mineral Resources Geology & Geophysics June 1966

To accompany Record No 1966/110

Brunchilly Homestead. Movement is also away from closed high value contours near Eva Downs and Ucharonidge Homesteads. The general trends conform to the pattern established by Randal (op.cit.) for groundwater movement in the adjoining areas of the central Barkly Tableland.

This pattern is also supported by the salinity variations indicated by the total dissolved solids. Figure 6 illustrates contours on the concentration in parts per million of total dissolved solids. The salinity of the groundwater from the Tomkinson Creek Beds is generally lower than 1000 ppm. In the southern part of the region there is a marked salinity increase to the east of Brunchilly Homestead and the high values (greater than 3000 ppm.) fit the pattern established in the adjoining Brunette Downs Sheet area. Low salinity values near Eva Downs Homestead reflect the high piezometric surface and also fit the pattern in the adjoining areas to the east. About Mungabroom Homestead there is an ill-defined salinity increase to the north. A salinity increase to the west of the Ashburton Range is indicated by the high salinity of groundwater from Ladabah bore, but the trend cannot be determined because of insufficient data. All the groundwater is suitable for stock, and most for humans. Most bores produce water with less than 2 ppm. of fluoride but some exceptions occur about Brunchilly Creek, and about Helen Springs Nos. 8 and 13 bores. The highest fluoride content so far reported is 5.6 ppm. from Brunchilly No.10 Bore. The sulphate concentration is above the recommended limit for human consumption in the highly saline areas in the south-eastern part of the Helen Springs Sheet area.

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APPENDIX A

RESULTS OF SCOUT DRILLING PROGRAMME, HELEN SPRINGS PARTY

SUMMARY

Seven scout-holes were drilled during the 1965 survey, one on the Beetaloo and the remainder on the Helen Springs 1:250,000 Sheet areas. The well-sites and the main outcrop areas are shown on Figure 1. A Failing "Holemaster" rig equipped for air-drilling was used. The depths of the holes ranged from 100 feet to 251 feet; and a total of 1236 feet was drilled.

Nine cores, over intervals totalling 49 feet 9 inches were cut, including bottom hole cores where lithology permitted. Core recovery ranged from nil to 100 percent. Cuttings were collected at 10 foot intervals (at 5 foot intervals to 35 feet in HS1).

Water was encountered during drilling in four of the holes, at depths varying from 66 feet to 205 feet.

Cuttings and cores were initially examined by hand lens and described at the well-site, and tested for carbonate with 10 percent hydrochloric acid. Most of the material was re-examined in the laboratory using a binocular microscope at magnifications up to 40 diameters. Thin sections from cuttings and cores were examined with a petrological microscope. Calcimetry determinations were made on cuttings and representative core specimens known or suspected to be carbonate-bearing.

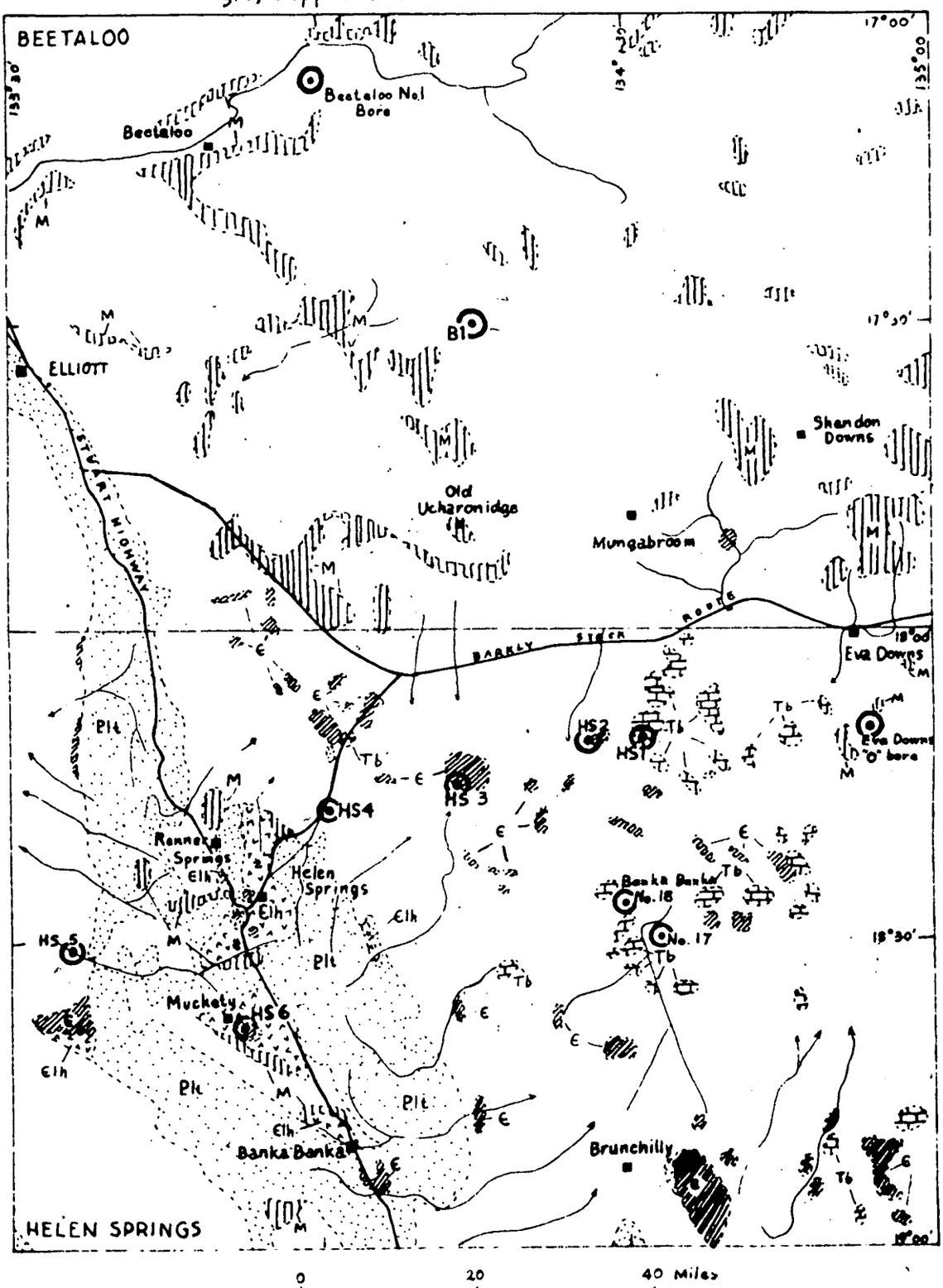
Three samples of clay-bearing sediments (clay from core No.2, scout-hole HS1; and clayey siltstones from core No.1, scout-hole B1, and core No.2, scout-hole B1) were submitted to the Australian Mineral Development Laboratories for semi-quantitative determination of their clay mineralogy.

Samples of clay from cuttings between 25 feet and 110 feet and from core No.2 of scout-hole HS1, were submitted to P. Duff (Petroleum Technology Section, B.M.R.) for examination of thixotropic properties.

Logs of the seven scout-holes, plotted at a scale of 100 feet to an inch, are presented in figs. 2 to 8 of this Appendix.

Location of Bores Described in Appendix A

Fig. 1, Appendix A



Bureau of Mineral Resources, Geology and Geophysics, June 1966

To accompany Record 1966/110 Appendix A

ES3/A/9

BEETALOO (B.M.R.) SCOUT NO. B1

Location. Latitude 17°30'S. Longitude 134°15'E on Beetaloo 1:250,000 Sheet area, approximately 8 miles at a bearing of 10° true from No.1 bore, Ucharonidge Station.

Surface Geology. Near the eastern margin of a large black soil plain. Timbered country with a surface of rubbly lateritic material occurs 100 yards to the east.

Objective. The hole was drilled to obtain a section in the Mesozoic sediments inferred to underlie the black soil plain, and to determine the nature of underlying rocks, in particular whether the Mesozoic is underlain by an extension of the Cambrian sedimentary rocks which occur further south on the Barkly Tableland.

Total Depth. 251 feet.

Cores. Core No.1, 52 feet to 57 feet, recovered 28 ins. Core No.2, 201 feet to 206 feet, recovered 5 feet. Core No.3, 241 feet to 251 feet, recovered 7 feet 6 inches.

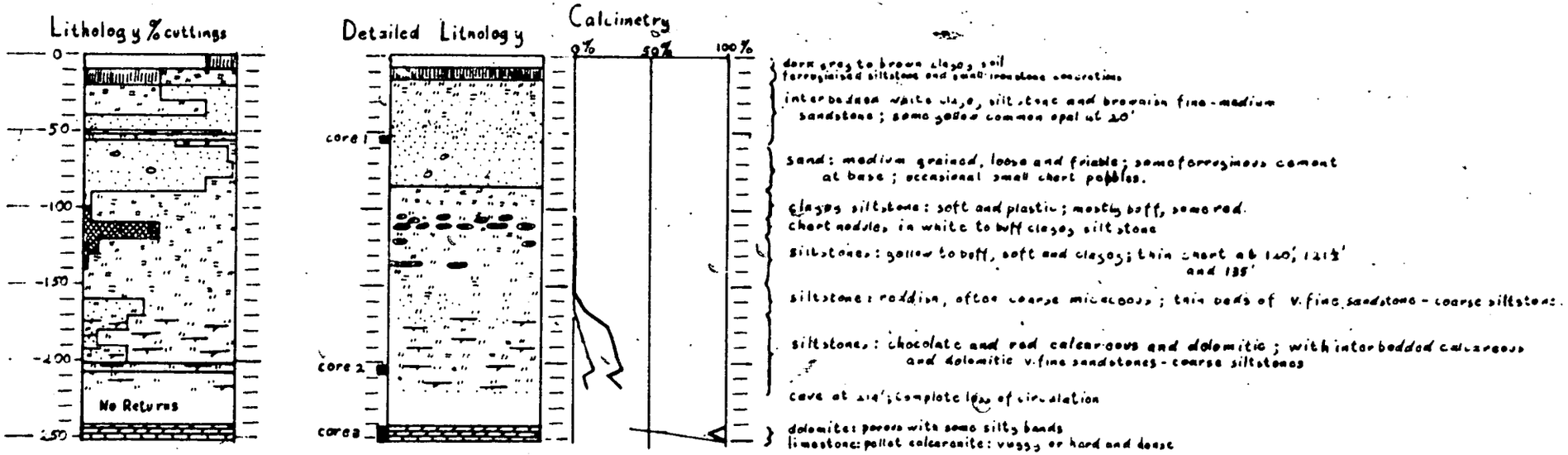
Fossils. No macrofossils were found. Samples of red calcareous and dolomitic siltstone from core 2, and limestone from core 3 were submitted to Dr. E. Druce for digestion for conodonts. The residues contained some fragments of organic origin, none of which could be identified.

Superficial deposits. The surface black soil continued to a depth of 8 feet. From 8 feet to 15½ feet the drill penetrated ferruginous material similar to the surface rubble east of the hole.

Cretaceous (Mullaman Beds). The section from 15½ feet down to 85 feet is in sediments referable to the Mullaman Beds of Mesozoic (Lower Cretaceous) age. The white clayey siltstone with fine to medium-grained sandstone interbeds above 60 feet corresponds to unit B of Skwarko (1966) and the loose sands with occasional chert pebbles below this to Skwarko's unit A. A sample of clayey siltstone from core 1 contained 7 percent of material less than 2 microns which consisted of dominant kaolin ($>$ 50 percent) and accessory illite ($<$ 20 percent).

B.M.R. Scout Hole B1 (Ucharonidge Station)

Fig 2, Appendix A, with Legend to Figs. 2-12



- black soil
- clay, claystone
- silt, siltstone
- sand, sandstone
- pebbles
- limestone
- dolomite
- chert
- ferruginous material
- calcareous lithologies
- dolomitic lithologies
- chalcedony-cemented sandstone
- travertine
- silicified claystone
- silica veinlets
- gypsum crystals
- Aq aquifer
- SWL standing water level
- microfossil
- macrofossil

Bureau of Mineral Resources Geology and Geophysics June 1966

To accompany Record 1966/110 Appendix A

E53/A/10

Cambrian (Anthony Lagoon Beds). The section from 85 feet to the total depth of 251 feet is similar lithologically to the Anthony Lagoon Beds both cropping out and encountered in holes south of the Barkly Stock Route (see later descriptions of scout-holes HS1, HS2, HS3). The section down to 219 feet consists dominantly of micaceous and clayey siltstones. Below 160 feet these are interbedded with well-sorted coarse siltstone and very fine-grained sandstone. Below 160 feet the rocks are dolomitic and calcareous. The micaceous and clayey siltstones are dominantly red to buff, contrasting with the white clayey siltstone of the overlying Mesozoic section.

A sample of red calcareous and dolomitic clayey siltstone from core No.2 contained 16 percent of less than 2 micron clay, with the following composition: smectite sub-dominant (20 percent to 50 percent), illite sub-dominant (20 percent to 50 percent), kaolin accessory (less than 20 percent), chlorite trace (less than 10 percent),kaolin accessory (less than 20 percent), chlorite trace (less than 10 percent).

The detrital minerals in the siltstone and very fine-grained sandstone consist of quartz, muscovite, chert, microcline, orthoclase, biotite, tourmaline, and zircon. This mineral assemblage occurs also in the Anthony Lagoon Beds penetrated by other scout-holes. Biotite and feldspars have not been seen in the detrital mineral assemblage of the clayey siltstone from core 1 or from outcrop specimens of Mesozoic in the area.

In the calcareous and dolomitic rocks the dolomite usually occurs as small grains similar in size to the terrigenous grains in the same rock. Some of the dolomite grains are euhedral rhombs but others have rounded shapes, indicating the possibility of transportation. The calcite occurs as poikilitic patches enclosing terrigenous grains and perhaps partly replacing clay, and as a vug filling.

Chert, mainly brownish, occurs abundantly between 105 feet and 113 feet, and less abundantly down to 135 feet. Observations during drilling suggested that the chert occurs as large nodules.

At 219 feet, circulation was completely lost, but drilling without returns continued to 241 feet. In core No.3 (241 feet to 251 feet) the rocks are clean carbonates: dolomite in the upper two thirds of the core and limestone in the lower one third. The dolomite generally has a fine pelletal texture with incompletely filled pore spaces between pellets, but thin bands of compact microcrystalline dolomite also occur. The limestone also shows a pelletal texture, with spaces between pellets completely filled with calcite cement. Both the dolomite and the limestone contain zones with abundant large solution vugs.

B1, Cuttings descriptions

0 - 10'
60% grey sandy and silty plastic clay soil
30% buff and reddish sandy and silty clay
10% ferruginous pellets $\frac{1}{8}$" to $\frac{5}{8}$" diameter (appear to be mainly ferruginised claystones or clays)

10'- 20'
50% ironstone pellets and fragments
30% iron-stained soft or hard clayey siltstone (grades into ironstone)
20% clayey and micaceous siltstone, buff to white. Trace, loose sand grains

20'- 30'
50% white clayey siltstone
30% coarse siltstone and/or fine sandstone, reddish
20% sandstone, with opaline silica cement

30'- 40'
80% white micaceous silty claystone or clayey siltstone
20% fine sandstone, silica-cemented, reddish, yellowish to white

40'- 50'
100% (almost) sandstone, fine silty to medium-grained, in part friable and in part opaline silica cement. Traces common opal fragments

50'- 52'
90% siltstone, pale pinkish with mica flakes
10% sandstone, fine-medium grained, red-brown, silty

57'- 60'
40% siltstone and clayey siltstone, white, pinkish and grey
40% sandstone, very fine to fine, laminated micaceous, red, buff and white
5% sandstone, medium grained friable, dark purplish
5% loose sand grains, medium-coarse

60'- 70'
90% loose sand, medium to coarse grained
5% sandstone, medium to coarse, strong to weak ferruginous cement
2% white clayey siltstone
traces sandstone cemented by opaline silica
traces chert fragments with some rounded surfaces (pebbles)

70'- 80'
95% loose sand, medium to coarse grained
5% sandstone, strong to weak ferruginous cement
traces white clayey siltstone

80'- 90'
80% loose sand (as above), with poorly to well-cemented sandstone
20% white to pinkish claystone and some buff siltstone

90'- 100' 75% pale silty claystone and clayey siltstone (some fragments coated with red dust
10% deep red to chocolate silty claystone
10% pale very fine to fine silty sandstone
5% loose sand

100'-110' 80% clayey siltstone, white to yellow-brown, soft (possibly decalcified)
10% clayey siltstone, red and chocolate, soft
5% chert
5% loose sand

110'-120' 50% chert, some sedimentary lamination, some colloform bandings
50% siltstone, clayey siltstone, white to yellow-brown (?decalcified)

120'-130' 90% clayey siltstone, yellow-brown to white, soft
10% chert

130'-140' 98% clayey siltstone, dark red to buff to near-white
2% chert

140'-150' (near) 100% micaceous and clayey siltstone, soft and sometimes plastic, chocolate, reddish and purple.
traces white claystone
traces chert

150'-160' 100% micaceous and clayey siltstone, soft, chocolate and reddish

160'-170' 60% as above
40% very fine quartzose sandstone, some fragments with silica cement

170'-180' 70% siltstone, micaceous and/or clayey and calcareous and dolomitic in part, chocolate colour
30% coarse siltstone and very fine sandstone, some red-brown micaceous calcareous and dolomitic, mostly white or pale brown well-sorted quartzose, calcareous and dolomitic
trace: crystals of clear calcite

180'-190' 90% siltstone, as above
10% coarse siltstone and very fine sandstone, as above

190'-200' 70% siltstone, as above
20% coarse siltstone and very fine sandstone, well sorted quartzose and pale
10% coarse siltstone, chocolate, micaceous
trace crystals of clear calcite

206'-210' (near) 100% siltstone, as above
trace: crystals of clear calcite

210'-219' 90% siltstone, mainly coarse and micaceous, chocolate, calcareous and dolomitic
10% very fine sandstone and coarse siltstone, pale brownish, calcareous

N.B. No returns after 219'

Cores

Core No.1. About 28" of broken pieces. Large fragments and collections of small fragments numbered 1 to 15 from top down.

Down to portion 12, lithology is of white to pink laminated claystone and micaceous clayey siltstone with disturbed laminae common. Some thin hematite coatings on joints. The silt-size grains are dominantly very angular quartz, chert, muscovite, and tourmaline. Feldspars were not seen in thin section.

Portions 13 to 15 (about bottom 6" of recovered material) consist mainly of pink to buff laminated very fine-grained micaceous sandstone, with a few white clay laminae.

Core No.2. 201' to 206' recovered 5' (100%) in 20 cylindrical pieces between 1" and 4" long numbered 1 to 20 from top down.

Lithology predominantly chocolate-red calcareous and dolomitic micaceous siltstone with small patches or irregular layers of paler material with coarser terrigenous detritus (very fine sand and coarse silt-size material). No regular bedding lamination. Some paler patches may be burrows. Vugs, filled or part filled with clear calcite, are common.

Core No.3. 241' to 251', recovered 7'6" in pieces up to 3½" long. Pieces and collections of pieces numbered 1 to 38 from top to base.

Down to portion 20 (about upper 4' of core). Finely granular clean dolomite with intergranular porosity and some vugs. In places shows traces of dome-shaped stromatolites. Thin sections show a fine pelletal texture with some thin bands of uniform microcrystalline texture. Insolubles are rare (< 1%).

Portions 31 to 38. Limestone, pale buff to brownish, in part vuggy, in part massive and hard. Shows well-preserved pellet calcarenite textures.

HELEN SPRINGS (B.M.R.) SCOUT-HOLE HS1

Locality. Latitude 18°10.30'S. Longitude 134°33.98'E on Helen Springs 1:250,000 Sheet area, N.T., on eastern side of track about half way between "B" and "D" bores, Eva Downs Station, at south end of a low rise with rock outcrops.

Surface Geology. Outcrops and surface rubble of white sandy calcilutite with large irregular masses of white translucent chalcedonic chert, mapped as Tertiary Brunette Limestone. Outcrop is surrounded by black soil.

Objective. The hole was drilled to determine the thickness of the Tertiary sediments and to obtain a section in underlying Cambrian rocks.

Total Depth. 176 feet 9 inches.

Cores. Core No.1, 35'-40', nil recovery.
Core No.2, 40'-45', recovered about 2'7" of broken fragments.
Core No.3, 175'-176'9", recovered 1'6".

Fossils. The gastropod Polotiopsis sp.was found in cuttings from the interval 0'-5', and the foram Ammonia beccarii was identified in a thin section of cuttings from the same interval.

Water. Groundwater was obtained at 155'6". Standing water level was 138' (measured about 30 minutes after cessation of drilling). The estimated yield by air-lifting was 800 g.p.h.

Tertiary (Brunette Limestone). The drill penetrated white calcilutite and white chalcedonic chert down to 15'. The lithology is similar to that of the surface exposures and can be correlated with the Brunette Limestone.

Tertiary(?). The section penetrated between 15 feet and 130 feet is difficult to correlate with surface exposures. The material penetrated down to 120 feet is mainly clay with some clayey silt and very fine sand between 85 feet and 100 feet. Between 120 feet and 130 feet the sediment is dominantly yellow to brown clayey silt. The clay has a soapy appearance and texture. Colours are mainly pale greenish yellow to buff. It shrinks and cracks into small fragments on exposure. A sample from core No.2 contained 73 percent of less than 2 micron clay with the following composition: smectite dominant (> 50 percent), random mixed-layer chlorite-smectite sub-dominant (20 - 50 percent), chlorite sub-dominant (20 - 50 percent), illite trace (<10 percent), kaolin trace (< 10 percent). The composition and appearance of the clay suggested that it may be a useable bentonite and the thixotropic

properties of cuttings and core samples were examined with this in mind. None of the samples gave results as good as Wyoming Bentonite. A composite cuttings sample from the 60' to 70' interval gave the best results.

Above 35 feet the clay contains thin clear silica (hyalite) veins and much of it is silicified and hardened.

The age of the clays and silts is not known at present. According to a driller, Mr. A. Gorey, about 200 feet of similar clays underlie about 40' of lateritic material in No.4 (Barkly Stock Route) bore to the north. In HS1 the clays and silts overlie dolomitic siltstone and dolomite regarded as Cambrian in age. This gives a wide range of possible ages for the clays and silts. They could be Tertiary sediments pre-dating laterite and Brunette Limestone. Another possibility is that they represent a lateral equivalent of the finer-grained upper parts of the Lower Cretaceous Mullaman Beds, and that the usual basal sands and pebbly sands of the Mullaman Beds are absent at this locality. The section could, in the latter respect, be compared with that in Eva Downs "O" bore, about 23 miles east of HS1, where the cuttings suggest only small pockets of the basal sands at the base of fossiliferous Mullaman Beds claystone and siltstone (see later description).

Cambrian (Anthony Lagoon Beds). From 130 feet to total depth of 176'9" the section consists of carbonate-rich rocks which are correlated with the Anthony Lagoon Beds. Calcimetry indicates that dolomite is the predominant carbonate mineral. Down to 150 feet, dolomitic siltstone and silty dolomite predominate. Below that, clean dolomite and silty dolomite occur with minor dolomitic very fine-grained sandstone. The silt to fine sand size terrigenous grains consist of quartz, microcline, muscovite, chert, biotite, tourmaline, and zircon. The clean dolomite is mostly uniformly microcrystalline to finely crystalline.

The dolomite from core 3 has abundant small vugs. Some vugs are irregular or curved and are partially filled with clear dolomite. The remainder of the vugs have sharp boundaries with the enclosing dolomite and show lath shapes and twinned lath shapes, probably representing moulds of gypsum crystals.

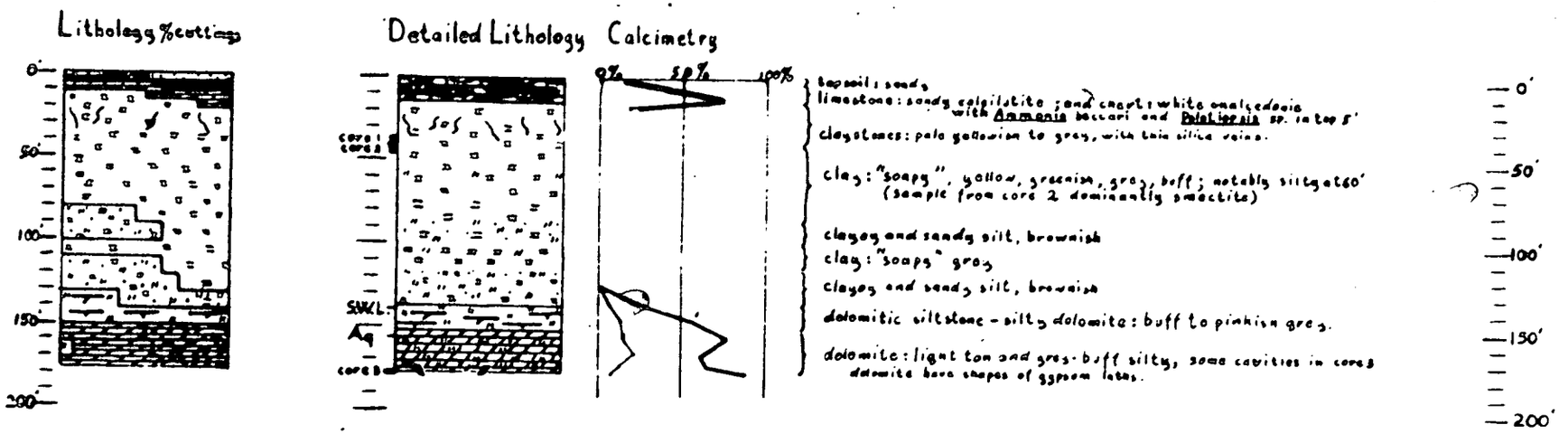
Cuttings Description HS1

N.B. In order to obtain a detailed record in the first 50', cuttings were taken at 5' intervals instead of the usual 10' intervals.

0' - 5' 50% loose sand
25% chert
25% limestone, sandy, composed of calcilutite fragments in sandy limestone matrix. Small gastropod occur in limestone
Thin sections show presence of foraminifera

B.M.R. Scout Hole HS1 (Eva Downs Station)

Fig 3, Appendix A



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E53/A/11

5' - 10' 60% limestone, pale, in part sandy and pelletal
40% chert, white translucent

10' - 15' 50% limestone (calcilutite)
50% clay, pale greenish-yellow, plastic when moist
(traces) chert

15' - 20' 80% clay, pale yellowish, plastic when moist
20% limestone (pale calcilutite)
(traces) chert, ferruginous and calcareous claystone, ?opaline silica

20' - 25' 60% clay, pale yellowish, plastic
25% ferruginous claystone
15% claystone, yellowish, siliceous, with clear silica veinlets

25' - 30' 70% clay, soft, plastic or "soapy" textured and crumbly
30% claystone, yellowish green siliceous, with clear silica veinlets
(traces) claystone, buff to red limonitic and hard

30' - 35' 50% clay, pale, "soapy" textured
30% claystone, greenish, with veinlets of clear silica
20% clay, reddish ferruginous, mainly soft and crumbly

45' - 50' 90% clay, white to very pale yellow-green, and soft
5% clay, limonite-stained
5% claystone, siliceous and hard

50' - 60' (near) 100% clay, very pale grey to buff with "soapy" feel, with some very small mica flakes and coarse silt size quartz grains
(trace) claystone, strongly iron-stained and hard

60' - 70' 99% clay, grey, brittle, some iron staining
(traces) quartz, ?siltstone, calcite fragments

70' - 80' 100% clay, (?silty), white, powdery

80' - 90' 55% clay, grey, brittle
45% clay, brownish-grey plastic, with some sub-rounded quartz grains, "dirty" appearance

90' - 100' 60% "dirty" clay as in 80' - 90' interval
40% clay, grey, partly brittle, partly plastic, with silty appearance on fractured face

100' - 110' clay, grey brittle (slightly plastic), some iron staining, silty appearance as before

110' - 120' 60% "dirty clay" - fine-grained sub-rounded quartz grains bound by ?limonitic plastic clay
40% clay, grey, brittle, with silty appearance

120' - 130' 70% clayey silt, khaki, with quartz grains and mica falkes
30% clay, grey to white, with 20% quartz grains

130' - 140' 65% fine sandy silt with clayey matrix, khaki
35% very fine buff silt, dolomitic and calcareous

140' - 150' 90% clayey calcareous dust, pinkish-grey
9% silt, very fine, buff, calcareous
1% silty ?limonitic plastic clay, calcareous

150' - 160' 50% grey-buff silty dolomite
50% light tan dolomite with low silt content
(traces) grey brittle clay

160' - 170' 46% grey-buff silty and fine sandy calcareous dolomite
46% light tan calcareous dolomite, very little silt
8% grey brittle clay. A little quartz

170' - 175' 59% light tan calcareous dolomite
39% grey buff silty calcareous dolomite
2% grey brittle clay, a little quartz

Core Descriptions, HS1

Core No.1. 35' - 40' Nil recovery

Core No.2. 40' - 45' Recovered about 2'7" of broken fragments, longest piece about 4".

Core is entirely of pale greyish to buff clay. Mechanical properties strongly influenced by water content. As taken from hole it has "soapy" character. When moistened further it becomes plastic. Exposed to dry air it shrinks and cracks into small angular fragments.

Some polished and hardened slickensided surfaces present, also some thin veins of harder material.

Core No.3. 175' - 176'9" Recovered 1'6".

6" of silty dolomite, overlying vuggy dolomite with little silt. Some vugs in latter lithology have shapes like moulds of gypsum crystals.

HELEN SPRINGS (B.M.R.) SCOUT-HOLE HS2

Locality. Latitude 18°10.93'S. Longitude 134°25.78'E, Helen Springs 1:250,000 Sheet area, on pebbly rise, 4.3 miles south along road from Helen Springs No.4 bore to Helen Springs No.8 bore, about 400 yards to west of road on south-eastern side of rise.

Surface Geology. Surface scree and pebbles of fine-grained silicified sandstone (occasionally medium to coarse-grained), some travertine, and ribbonstone. The low rise is part of a series of prominent discontinuous low ridges trending in a generally north-easterly direction for about 25 miles. The fine-grained sandstone and ribbonstone are included in the Middle Cambrian Anthony Lagoon Beds.

Objective. To determine the lithology of the rocks associated with the low rise and to obtain a section in the rocks below.

Total Depth. 132 feet. (A first attempt was abandoned at 105 feet owing to breaking of bit on chert. Second attempt was drilled 5 feet away from first hole. Results are recorded as for one hole).

Cores. Core No.1, 122 feet to 132 feet, recovered 9'2".

Fossils. No macrofossils were found. A sample of sandy calcarenite from core 1 was submitted to E. Druce for digestion for conodonts. Some fragments of organic origin were found but none could be identified.

Water. None was encountered.

Superficial Deposits. Black soil and travertine were penetrated down to 9 feet.

Cambrian (Anthony Lagoon Beds). The section down to the total depth of 132 feet has been included in the Anthony Lagoon Beds. Silty clays and claystones and clayey siltstones, with some buff chert nodules or bands, were penetrated down to 50 feet. Abundant thin silica veinlets are present in the claystones and siltstones between 30 feet and 50 feet. Below 50 feet the rocks contained abundant carbonate, with calcite dominant over dolomite. Rocks below 50 feet include calcareous and dolomitic clayey siltstone, silty and sometimes dolomitic limestone, and minor sandy limestone. The buff cherts contain some silt-size terrigenous grains in a chalcedonic matrix. The chalcedony contains abundant

ghosts of euhedral dolomite rhombs, indicating that the chert is probably a replacement of a silty calcareous dolomite or dolomitic limestone.

The sandy limestone from core No.1 has unusual textures. It consists of closely packed terrigenous sand grains, ooliths, and limestone fragments in a calcilutite matrix. The limestone fragments are largely composed of previously-consolidated oolitic limestone. The mineralogy of the terrigenous sand in this rock is also of interest. The terrigenous grains are of quartz, orthoclase, microcline, muscovite, tourmaline, chert, and biotite, similar to that of other Cambrian rocks from the scout holes, and also include one well rounded rock fragment of granophyre or micropegmatite. The latter suggests at least some contribution by acid igneous material to the detrital minerals of the Anthony Lagoon Beds. An igneous source was postulated for the detritals of Cambrian carbonate rocks from the Georgina Basin to the south-east (Nichols and Fehr, 1964; Fehr and Nichols, 1963).

HS2 - Cuttings details

0' - 10' 95% travertinous limestone, remainder grey soil with siliceous and hematitic pebbles.

10' - 20' 90% grey silty calcareous plastic clay
10% calcareous clayey siltstone, white
trace chert, 'ironstone' and red siltstone

20' - 30' 50% red clayey siltstone
45% grey plastic silty clay
5% chert
trace grey calcareous clay

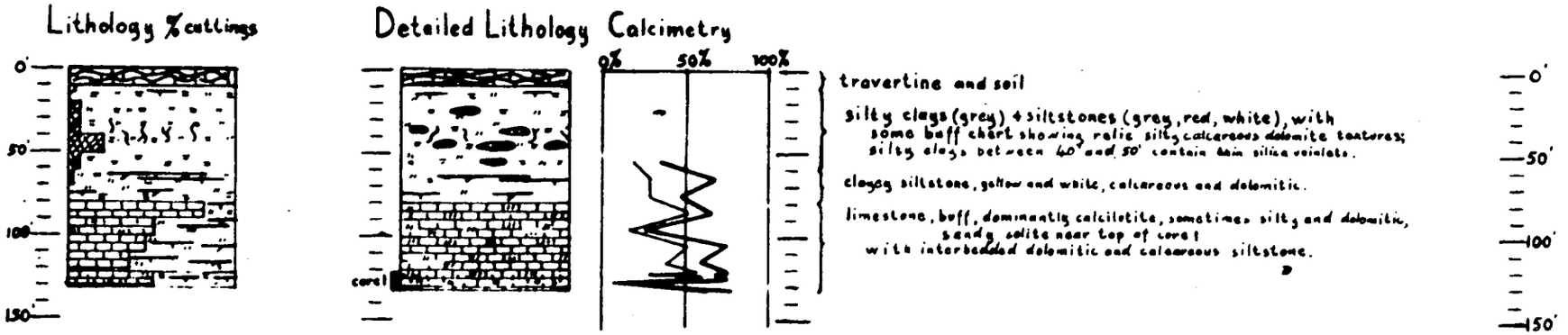
30' - 40' 95% clayey siltstones, grey to white, often with clear silica veinlets and vug fillings
5% chert, tan, showing relic silty and calcareous dolomite textures in thin section

40' - 50' 80% clayey siltstones, grey-white, with some very fine sand grains; some clear silica veins
20% chert, usually with relict texture of an original silty calcareous dolomite

50' - 60' 80% grey clay
5% yellow clay, slightly calcareous
10% white siltstone, some yellow-coated
5% grey chert

B.M.R. Scout Hole HS2 (Helen Springs Station)

Fig 4, Appendix A



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To accompany Record 1966/110 Appendix A

E53/A/12

60' - 70' 60% yellow
50% white
trace chert
} clayey siltstone: calcareous and dolomitic

70' - 80' 70% white
30% yellow
} clayey siltstone: calcareous and dolomitic
trace red calcareous clayey siltstone

80' - 90' 25% white calcareous and dolomitic clayey siltstone
80% grey-buff limestone, a little silty

90' - 100' 50% buff ?Calcilutites, usually silty and/or dolomitic
50% red and yellow clayey dolomitic and calcareous siltstone
remainder from second hole.

100' - 110' 10% red siltstone, calcareous
45% grey-buff siltstone, calcareous
45% hard buff limestone, in part dolomitic, generally showing pellet calcarenite textures.
trace tan chert

110'-120' 10% red coated ?calcilutite
25% red clayey calcareous siltstone
25% buff ?calcilutite
40% creamy and buff clayey calcareous siltstone
trace fine-grained sandstone

120' - 122' 15% fine-grained crystalline limestone
85% creamy, yellow and buff clayey calcareous siltstone

Core 1.

top 8" silty and sandy calcareous dolomite, some ripple lamination
27" sandy limestone, yellow (calcarenite with intraclasts and ooliths)
11" calcareous siltstone, red and yellow bands
23" clayey limestone, dominantly yellow (some red)
36" dolomitic siltstone, dominantly red (little yellow)
bottom 5" grey silty calcilutite

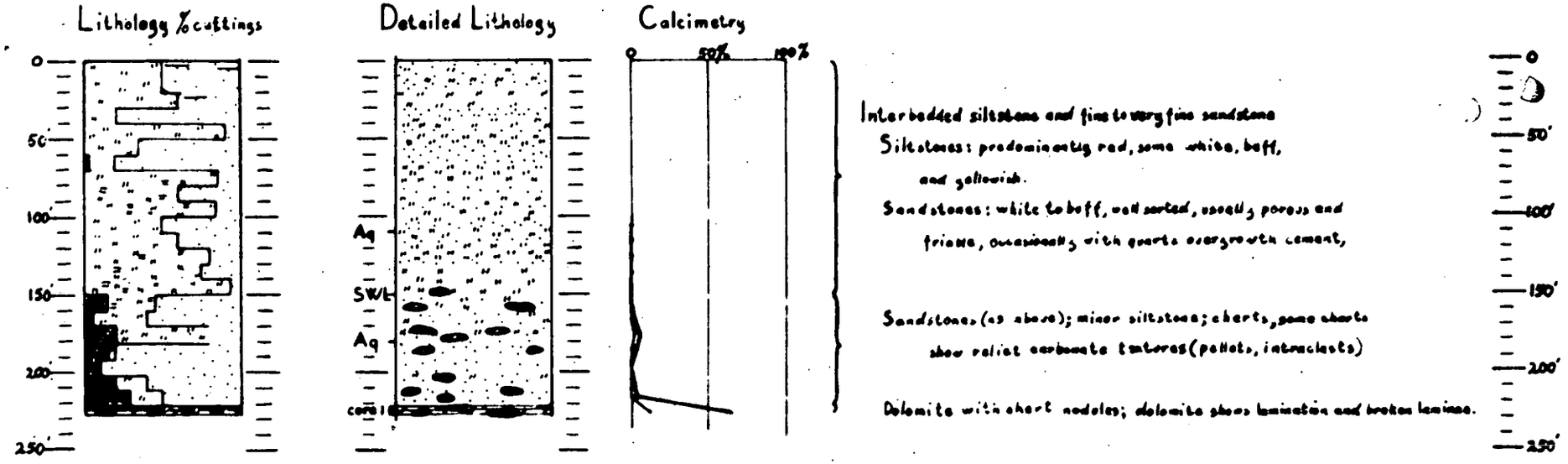
HELEN SPRINGS (B.M.R.) SCOUT-HOLE HS3

Locality: Latitude 18°15.00'S. Longitude 134°14.00'E beside old road, 9 miles east of Bore 11 (Helen Springs Station) towards Bore 6 (Helen Springs Station).

Surface Geology: Western side of rubbly siltstone and sandstone outcrop. At site - brown soil with lateritic pebbles, occasional cobbles and slabs of fine-grained sandstone and siltstone, with some ribbonstone. Surface outcrop mapped as Cambrian Anthony Lagoon Beds.

BMR. Scout Hole HS3 (Helen Springs station)

Fig 5. Appendix A



Bureau of Mineral Resources Geology and Geophysics June 1966

To accompany Record 1966/110 Appendix A

E 53/A/13

Objective. To obtain a section in the Cambrian Anthony Lagoon Beds presumed to underlie the surface rubble.

Total Depth. 225 feet.

Cores. Core No.1, 222 to 225 feet; recovered 1 ft.

Fossils. No fossils were found.

Water. Minor aquifer at 110 feet; an aquifer at 180 feet gave a supply (estimated by air-lifting) of 700-1000 g.p.h. Standing water level 150 feet (measured 15 hours after cessation of drilling).

Cambrian (Anthony Lagoon Beds). The total section penetrated down to the total depth of 225 feet has been referred to the Cambrian Anthony Lagoon Beds: it consists of interbedded siltstone and fine to very fine-grained sandstone to 150 feet. From 150-222 feet, similar sandstone and siltstone occur with abundant chert nodules. Core No.1 (222'-225') consisted of cream-dolomite with some chert, but recovery was poor and may not be representative.

The siltstones are predominantly red, but some are white, buff, and yellow. They are lithologically very similar to siltstones from scout-hole B1. The sandstones are white to buff and well sorted. They are usually porous and partly friable, but occasionally strongly cemented by overgrowth quartz. The grains in the sandstones consist of quartz, chert, orthoclase, microcline, muscovite, biotite and tourmaline. The chert from the cuttings has few relict textures. Some chips have traces of sedimentary lamination and one chip has well-defined pellet calcarenite textures.

The dolomite from core No.1 has a well-laminated texture with laminae of microcrystalline dolomite and finely pelletal dolomite, and some bands of fragmented microcrystalline laminae.

HS3 - cuttings details

0' - 10' 50% ferruginous siltstone, dark red brown
50% calcareous fine sandstone, white; fine soil; rounded quartz grains up to 1.4mm. diameter.

10' - 20' 50% mottled white fine sandstone, often porous with grains joined by overgrowths
50% dark red-brown siltstone, micaceous and ferruginous

20' - 30' 20% red siltstone (ferruginous cement)
80% speckled white siltstone

30' - 40' 80% white fine sandstone
20% reddish siltstone, ferruginous cement

40' - 50' 15% yellow clayey siltstone } break up when wet
5% white siltstone }
70% speckled white siltstone (hematitic?)
10% yellowish fine - very fine sandstone

50' - 60' 55% white very fine to fine sandstone
20% red very fine-grained siltstone } break up when wet
15% white siltstone }
5% yellow very fine to fine sandstone
5% red speckled very fine to fine sandstone

60' - 70' 80% very fine - fine sandstone and some loose sand. (Max. grain size 0.6mm. medium sand grain)
20% red and yellow micaceous siltstone, trace white translucent chert

70' - 80' 15% speckled white, and yellow, very fine sandstone
85% red siltstone with mica flakes

80' - 90' 40% white very fine to fine sandstone, friable in part
60% red siltstone
trace yellow siltstone
(white siltstone more coherent than red siltstone when wet; all types clayey)

90' -100' 15% white fine sandstone (mostly ?hematite speckled)
75% red siltstone with mica flakes
10% yellow siltstone
(See final remark, cuttings 80' - 90' - ditto here)

100'-110' 50% fine red siltstone with mica flakes
5% white fine sandstone in part speckled (?hematite)
45% yellow fine sandstone (?limonitic cement)
(disintegrate when wet)

110'-122' 40% red-coated white, and red-and-black speckled fine and very fine sandstone
60% fine red siltstone with mica flakes

122'-132' 20% speckled white fine sandstone with some medium sand grains up to 0.6mm
70% fine red siltstone with white mica flakes and some very fine sand size quartz grains
10% yellow clayey siltstone

132' - 142' 25% speckled, white fine sandstone
65% fine red clayey siltstone, with mica flakes
10% yellow red clayey siltstone, with mica flakes

142' - 152' 5% speckled, white clayey fine sandstone
90% fine red clayey siltstone with mica (fine to coarse siltstone)
5% yellow clayey siltstone

152' - 162' 55% fine, some very fine sandstone; white and porous
15% fine red clayey siltstone with mica
15% green silty and yellow soapy clay
15% chert and silicified fine sandstone

162' - 172' 70% mostly fine, (some very fine) sandstone, (10% of this has very small white layered clay flakes)
5% chert = silicified siltstone and ?carbonate
5% greenish and yellowish silty clays
20% fine red clayey siltstone with mica - some very hard

172' - 182' 10% yellow fine and very fine sandstone
10% white fine to very fine sandstone
50% red siltstone
20% chert - grey, red, white - ? some carbonate textures
10% clay, yellowish and grey, silty

182' - 192' 80% fine sandstone
5% white siltstone
15% chert - ? some carbonate textures, including pellet calcarenites
trace red siltstone

192' - 202' 90% very fine sandstone
10% chert - red, green, grey - ? some carbonate textures present, including pellet calcarenites

202' - 212' 15% red siltstone
5% yellow fine sandstone
60% white fine sandstone
20% chert

212' - 222' 30% chert - yellow, with black spotty dendrites (?Mn); also grey and red, some show pellet calcarenite textures
50% white fine sandstone
15% red siltstone
5% yellow siltstone

HS3 - Core No.1

22' - 225' One foot recovered

Pieces 1 and 2: 1½" yellow, black dendrite-spotted chert

Pieces 3: fragment, to ¾" deep; possibly dolomite, creamy; and chert

Pieces 4: egg-sized lump yellow chert, very spotted

Pieces 5: 2" depth of creamy dendrite spotted dolomite, fairly porous; interlaminated microcrystalline and finely pelleted dolomite, some layers of broken-up laminae cemented by clear dolomite

Piece 6: 4 fragments spotted yellow chert and ?dolomite

Piece 7: 2" depth creamy, dendrite spotted, dolomite

Piece 8: large fragment white and blue-grey chert, banded, with ?carbonate textures

HELEN SPRINGS (B.M.R.) SCOUT-HOLE HS4

Locality. Latitude 18°17.12'S. Longitude 133°59.71'E, about 50 yards west of Koo-Nana Creek and about ½ mile downstream from Helen Springs No.1 bore

Surface Geology. On floodout plain of Koo-Nana Creek. At site, cracked dark grey-brown sandy soil with occasional cobbles of red silicified fine, medium, and coarse-grained sandstone.

Objective. To determine the thickness of the floodout deposits and the nature of underlying sediments, and to obtain a section in Cambrian rocks expected to occur at depth.

Total Depth. 224 feet

Cores. None taken.

Fossils. None found.

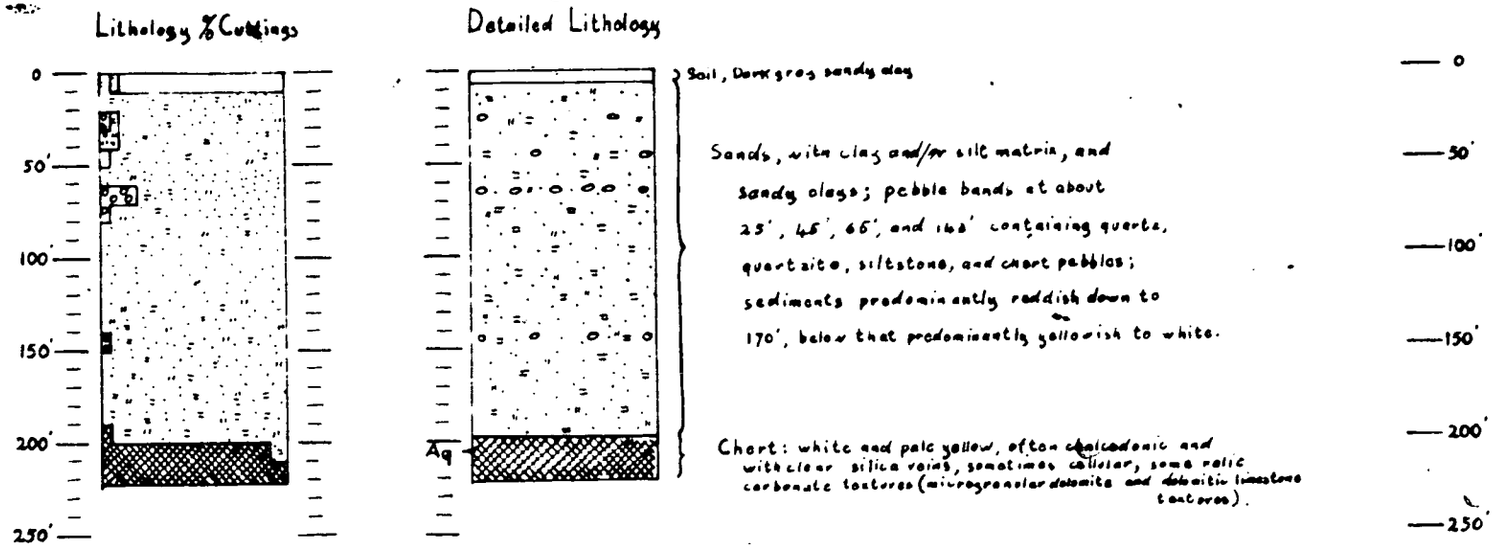
Water. Good supply struck at 205' (standing water level not measured).

Superficial soil. Grey soil was encountered down to 7 feet from surface.

Cainozoic, (?)Mesozoic. The section from 7 feet to 191 feet consists dominantly of sand with some clay or silt matrix, some sandy clays, and occasional pebble bands. Colours are dominantly red down to 170', and below that are predominantly yellow to white. No definite evidence of the age of any of this material is available as no fossils were found. The sediment is similar to that in the bed of Koo-Nana Creek, and the higher parts of the section probably represent Cainozoic sediments of the present-day floodout

BMR Scout Hole HS4 (Helen Springs station)

Fig 6, Appendix A



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plain. It is difficult, however, to explain the complete thickness of sediments down to 191' as being part of the present-day floodout material since this would imply either a deep ancestral valley for which there is no known present-day outlet or a geologically recent relatively severe local downwarp marginal to the Ashburton Range. Some of the section may be of Mesozoic sediments. Outcrops of sandstone and sandy claystones and siltstones 3½ miles to the west of the hole have been mapped as Mesozoic. These beds dip gently north-east below the superficial cover and thus may occur in depth in the scout hole.

Cambrian (Anthony Lagoon Beds). Below 191 feet the drill penetrated chert, with some clayey and sandy material. The cherts are generally yellowish to white, sometimes greyish. Thin section were made of chert from the 190 feet to 200 feet and 200 feet to 210 feet intervals. Textures are somewhat variable but several of the chips showed well-defined "ghosts" of carbonate (probably dolomite) rhombs and textures suggesting the chert to have replaced a dolomitic limestone. The presence of dolomite "ghosts" suggests that the cherts are best correlated with the Cambrian rocks, rather than with the chalcedonic cherts of the Brunette Limestone or the silicified claystones of the Mullaman Beds.

HS4 - cuttings details

0' - 10'	90% dark grey, crumbly, slightly plastic clayey soil
	5% brown sand
	5% sandy clay, dark brownish grey
	trace: quartz pebbles, claystone, chert, brown siltstone
10' - 20'	40% yellow clayey sand
	60% grey-brown sandy clay
	trace siltstone, red and black
20' - 30'	10% red sandstone (lateritised?)
	5% quartz pebbles and gravel
	5% grey sandy clay
	80% yellow-brown clayey sand
30' - 40'	60% light and dark red clayey sand
	10% grey brittle clay
	30% yellow-brown clayey sand
40' - 50'	50% yellow clayey sand
	45% dark red clayey sand
	5% quartz gravel

50' - 60' 100% sandstone - colourless and red coated quartz grains, poorly sorted
trace: yellowish clay

60' - 70' 5% red siltstone pebbles
20% gravel - quartz and siltstone
25% clayey sandstone, mottled
50% sand.

70' - 80' 40% red and white mottled clayey sand
5% rounded chert pebbles
5% white clayey sand
50% red clayey sand

80' - 90' 95% dark red clayey sand
5% white and mottled clayey sand

90' -100' 15% red sandstone
85% red-and-white sandstone
trace: white sandstone

100' -110' 20% white and mottled sandstone
80% red sandstone

110' -120' 95% red, and mottled reddish, clayey sand
5% white clayey sand

120' -130' 100% red clayey sand

130' -140' 70% red clayey sand
30% white sandstone

140' -150' 5% chert with rounded and weathered surfaces (probably pebbles)
50% red clayey sand (rounded sand grains up to 2.8mm)
45% white clayey sand

150' -160' 5% yellow clayey sand
50% white clayey sand
45% red clayey sand

160' -170' 90% red clayey sand
10% white clayey siltstone, some red coated

170' -180' 90% yellow-grey sandy clay, plastic
5% red clayey sand
5% white sandy clay

180' -190' 5% dark grey silty clay
90% grey-white clay
5% red, yellowish, clay

190' -200' 95% greyish, yellowish, sandy clay (quartz grains up to 3mm)
5% chert, yellow and blue black, black spotted; a little red, some relic microgranular dolomite textures

200' -210' 90% chert, blue, and yellowish-white, often chalcedonic, with black spotty dendrites, relic dolomite and dolomitic limestone textures
10% sandy grey clay (some lost during washing)

210' -220' 100% chert (as interval 200'-210')

220' -222' 90% chert (as interval 200'-210')
10% grey clay, sandy

HELEN SPRINGS (B.M.R.) SCOUT-HOLE HS5

Locality. Latitude 18°32.00°S. Longitude 133°36.40'E, on floodout area of Tomkinson Creek, approximately 4 miles at a bearing of 300° true from Ladabah bore.

Surface Geology. The site is on dark yellowish-brown soil with some coarse sand grains. The alluvium passes into sandy "desert" country about a half mile to the south. The nearest outcrops are sandstones of the Tomkinson Creek Beds, about 3½ miles east of the hole.

Objective. To penetrate superficial cover and obtain information on the rocks, presumed to be Cambrian, below this cover.

Total Depth. 129 feet (abandoned owing to caving of loose sand).

Cores. No cores were taken.

Fossils. None found.

Water. None encountered.

Superficial. The surface dark soil continued to a depth of 7 feet. From 7-68 feet the drill penetrated sandy sediments with generally some reddish clay or silt binding material. Some pebbly bands with chert and sedimentary quartzite pebbles occur. These

sediments are thought to be the alluvial deposits of Tomkinson Creek.

(?)Mesozoic, Lower Cretaceous. From 68 feet to 71 feet the drill penetrated hard chalcedony-cemented pebbly quartz sandstone ("billy"). Below that, down to 118 feet, clayey sandstone and sandy clays, predominantly white, with some loose sand and pebbles, were penetrated. From 118-129 T.D. the drill penetrated well-washed loose medium to coarse-grained quartz sand with some pebbles.

The section from 68 feet to total depth shows strong lithological similarities to known Mesozoic sediments such as those penetrated in Scout Hole B1 and the lower part of the section in Beetaloo No.1 water bore. The "billy" sandstone from 68 feet to 71 feet is similar to that of surface outcrops of Mesozoic sandstones in the Beetaloo Sheet area and probably represents silicification on an old land surface subsequently buried by the sediments of Tomkinson Creek. The presence of suspected Mesozoic sedi[illegible] of Tomkinson Creek. The presence of suspected Mesozoic sediments at this locality is of interest since they are well south of previously-known occurrences of Mesozoic sediments west of the Ashburton Ranges, and they are not known from outcrop. Cambrian rocks suspected below the alluvium were not encountered, but may occur below the ?Mesozoic.

HS5 - Cuttings Details

0' - 10' 90% dark yellow-brown silty and clayey sand soil, with some quartz grains up to coarse sand size
10% medium sand, buff, with some silt or clay binding

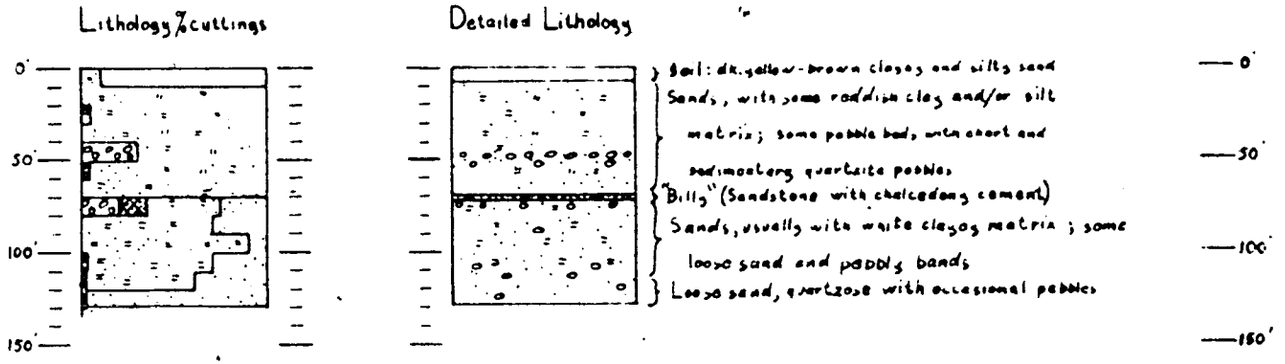
10' - 20' 100% buff and red friable sandstone, with some silt or clay binding, and sand grains up to coarse sand size mainly quartz with some chert.
traces: granule-size ironstone pellets, chert (fragment of pebble)

20' - 30' 95% sandstone, friable, similar to above but generally finer with more silt or clay matrix.
5% clay, pale, with "soapy" feel

30' - 40' 100% loose sand grains, and chips of friable white, buff, and reddish sandstones with clayey binding. Some quartz up to very coarse sand size.
traces: polished ironstone pellets up to $\frac{1}{8}$" diam.

BMR Scout Hole HS5

Fig. 7, Appendix A



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40' - 50' 40% fragments of white, buff and reddish friable sandstone with some clay binding
30% loose medium to coarse sand grains
30% pebbles of chert(up to ½") and polished ironstone (probably represents about 50% sandy gravel and 50% clayey sand)

50' - 60' 50% pale yellow to buff friable sandstone fragments with clay binding, some ferruginous cement
45% loose sand (medium-coarse)
5% pebbles and fragments of pebbles (include "billy" type quartzite, dark chert, reddish sedimentary quartzite)

60' - 70' 50% loose sand, medium to coarse well-rounded
45% yellow to pale buff sandstone, bound by clayey material
4% fragments to "billy" type quartzite (silica-cemented sandstone)
1% granule-size pebbles of chert

70' - 80' 40% white claystone with sand grains and clayey white sandstone
25% loose sand grains, medium-coarse
20% pebbles of dark chert, quartzites, up to ½" across
15% small chips of "billy" type quartzite (poorly sorted sandstone cemented by amorphous silica)

80' - 90' 70% white clay-rich sandstones with poorly sorted sand grains
30% loose sand grains, medium to coarse

90' -100' Lithologies as above, but less loose sand (10%)

100' -110' As at 80' - 90', plus a few chips of chert and some granule size quartz

110' -120' 60% loose sand, grains medium to very coarse, mostly quartz
37% sandstone fragments, poorly sorted with clayey binding, some angular quartz grains. Sometimes partly limonite-cemented
3% "billy" type quartzite
traces: broken chips and very small pebbles of chert

120' -129' (near) 100% loose sand, mainly well-sorted medium sand with a few very coarse grains. About 50% of grains angular or poorly rounded
traces: pebbles, up to ½" longest dimension, of sandstone and quartz

HELEN SPRINGS (B.M.R.) SCOUT-HOLE HS6

Locality. Latitude 18°38.75'S. Longitude 133°53.44'E, about 1 mile at 190°T from Muckety (Government) bore.

Surface Geology. The hole was spudded among outcrops of poorly sorted sandstone with pebbles of quartz crystals (mapped as Mesozoic) dipping gently north off a low gravelly rise of chert gravel and recemented chert breccia with Biconulites sp., gastropods, and trilobites (Gum Ridge Formation). The contact is about 15 yards north-west of the hole. A further 25 yards north-west are outcrops (partly collapsed) of well-sorted medium-grained sandstone, partly silicified (basal sandstone of the Helen Springs Volcanics). Outliers of Mesozoic and underlying Cambrian rocks occur in a small basin resting on the core of a dome involving the Helen Springs Volcanics and incompetent strata of the Tomkinson Creek Beds.

Objective. To verify the structural setting of the small patch of Cambrian and Mesozoic, as inferred from surface mapping, to determine the nature of the Gum Ridge Formation below the rubbly surface outcrops, and to obtain fresh material from the poorly exposed beds forming the core of the dome.

Total Depth. 100 feet.

Cores. Core No.1, 35' to 40', recovered 1'5".

Fossils. Biconulites sp. (silicified) was found in core 1.

Water. Good quality water was struck at 66 feet. Standing water level was 47 feet, measured about 1 hour after cessation of drilling (estimated 1200 gallons per hour by air lifting).

Mesozoic. The Mesozoic sediments continued down-hole to about 4 feet. A white to pink silty shale overlies coarse sandstone with pebbles.

Lower Middle Cambrian (Gum Ridge Formation). From 4 feet-66 feet the drill penetrated rocks correlated with the Gum Ridge Formation. The rocks are white claystone and clayey siltstone, sometimes with fine sand size quartz grains. The siliceous lithologies of surface exposures do not persist in depth, except for some minor veining of the rocks by clear silica (and the replacement of Biconulites sp. by silica in core No.1). In general the rocks are softer with increasing depth. The whiteness of the material seems to be due to deep weathering. Similar whitening is common in various rock types in the Muckety area.

HELEN SPRINGS (B.M.R.) SCOUT HOLE HS6

Locality: Latitude 18°38.75'S. Longitude 133°53.44'E about 1 mile at 190°T from Muckety (Government)bore.

Surface Geology. The hole was spudded among outcrops of poorly sorted sandstone with pebbles of quartz crystals (mapped as Mesozoic) dipping gently north off a low gravelly rise of chert gravel and recemented chert breccia with *Biconulites* sp., gastropods, and trilobites (Gum Ridge Formation). The contact is about 15 yards north-west of the hole. A further 25 yards north-west are outcrops (partly collapsed) of well-sorted medium-grained sandstone, partly silicified (basal sandstone of the Helen Springs Volcanics). Outliers of Mesozoic and underlying Cambrian rocks occur in a small basin resting on the core of a dome involving the Helen Springs Volcanics and incompetent strata of the Tomkinson Creek Beds.

Objective: To verify the structural setting of the small patch of Cambrian and Mesozoic, as inferred from surface mapping, to determine the nature of the Gum Ridge Formation below the rubbly surface outcrops, and to obtain fresh material from the poorly exposed beds forming the core of the dome.

Total Depth: 100 feet

Cores: Core No.1, 35' to 40', recovered 1'5".

Fossils. *Biconulites* sp.(silicified) was found in core 1.

Water. Good quality water was struck at 66 feet. Standing water level was 47 feet, measured about 1 hour after cessation of drilling (estinated 1200 gallons per hour by air lifting).

Mesozoic. The Mesozoic sediments continued down-hole to about 4 feet. A white to pink silty shale overlies coarse sandstone with pebbles.

Lower Middle Cambrian (Gum Ridge Formation). From 4 feet-66 feet the drill penetrated rocks correlated with the Gum Ridge Formation. The rocks are white claystone and clayey siltstone, sometimes with fine sand size quartz grains. The siliceous lithologies of surface exposures do not persist in depth, except for some minor veining of the rocks by clear silica(and the replacement of *Biconulties* sp. by silica in core No.1). In general the rocks are softer with increasing depth. The whiteness of the material seems to be due to deep weathering. Similar whitening is common in various rock types in the Muckety area.

Lower Cambrian. From 66 feet to total depth of 100 feet the drill penetrated well-sorted medium sand. Fairly abundant white clay was returned with the sand over this interval, but it is uncertain whether the clay is present as a matrix in the sand or was washed from higher in the hole by the strong water flow yielded by the sand. The sand is correlated with the surface outcrops of sandstone north-west of the well-site.

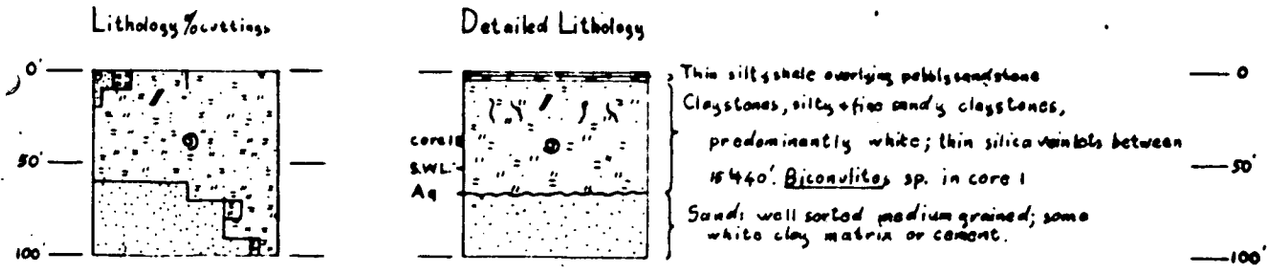
Structural Inferences. The depth of 66 feet to the base of the Gum Ridge Formation in the scout hole implies that the contact with the underlying sandstones dips at an average of about 29° away from the margin of the outcrop at this locality.

HS6 Cuttings Details

0' - 10'	50% white claystone, hard 30% white sandy claystone 10% white to buff fissile ?silty shale 10% medium-coarse sandstone with small quartz pebbles, and some white clayey grains or matrix
10' - 20'	85% siltstones, pale, with fine sand and clay 10% white structureless claystone 5% sandstone, buff and white, fairly well sorted traces: Gypsum crystals, fragments of thin silica veins (about ½ to 1mm thick)
20' - 30'	100% white claystone, in part with mica silt and some fine or very fine quartz sand grains traces: thin silica flakes (?veins or replaced shells) ½ - 1mm thick, chips of white chert
30' - 35'	100% white claystone, with quartz and mica silt or very fine sand grains traces: chert (grey translucent)
40' - 50'	100% silty clay or claystone, or clayey siltstone, sometimes showing traces of lamination, small quartz grains (coarse silt or very fine sand) abundant
50' - 60'	Similar to above. Material is plastic when wet
60' - 70'	50% claystone and silty claystone as above 50% well-sorted medium sand, quartz-rich with well-rounded grains abundant
70' - 80'	70% sand, as above 20% white claystone and silty claystone 10% buff fissile shale } ? cavings due to strong water flow

BMR Scout Hole HS6

Fig 8, Appendix A



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80' - 90' 70% sand, as above (with some remnants of white clay matrix)
30% white claystone and silty claystone
traces: silicified sandstone, buff shales

90' -100' 85% sand (as above)
10% white claystone, silty claystone
5% buff shale

Core Description

Core No.1 35' - 40' recovered 1'5", consisting of 11 pieces, numbered from top down, and one bag of small fragments from bottom.
Core consists of white to very pale grey clay and silty clay, in part soft and powdery (plastic when wet) in part hard. Thin veinlets of silica occur and are especially abundant below portion 7. Pieces 8 and 9 contain silicified Biconulites sp. Portion 1 shows bedding (not very regular) dipping at about 40°.

NOTES ON CUTTINGS FROM FOUR WATER BORES

Introduction

Cuttings samples from four water bores were available, one from the Beetaloo 1:250,000 Sheet area and three from the Helen Springs 1:250,000 Sheet area. These were examined under a binocular microscope and some of the more interesting rock types were thin-sectioned and examined with a petrological microscope. Dolomites and limestones in carbonate-bearing intervals were distinguished with the aid of Alizarin red S staining solution.

The results have been plotted (figs. 9 to 12, this Appendix) as percentage cuttings logs only. Detailed lithological logs could not be drawn in the absence of detailed observations during drilling.

BEETALOO NO.1 WATER BORE

Locality. About 10 miles east-north-east of Beetaloo Homestead. Latitude 17°7.2'S, longitude 133°59'0'E.

Surface Geology. Black soil at surface. Nearest outcrops are of siliceous claystone of Mullaman Beds (often lateritized).

Total Depth. 285 feet

Water. Standing water level is 258 feet.

Cuttings Intervals. Irregular, from 5 feet to 95 feet.

Fossils. Thin sections of claystone and silicified claystone from the 10 to 20 feet and 20 to 50 feet intervals showed well-preserved radiolaria. A. Lloyd (B.M.R. pers. comm.) regards these as lower Cretaceous age and the same fauna as found in surface outcrops north-east of Beetaloo.

Superficial. Black soil was penetrated from 0 to 5 feet. This overlay 5 feet of pale yellow sandy clay with limonitic nodules.

Lower Cretaceous (Mullaman Beds). The cuttings indicate that the entire section down to 285 feet is in Lower Cetaceous Mullaman Beds, and includes units A, B, and C of Skwarko (1966). The marine claystones, silty claystone and silicified claystone of unit A are present from below the thin superficial cover to 50 feet. Below that, the section is predominantly of sand and sandstone, with fairly abundant white sandy siltstone in the 75 to 165 feet interval, which presumably includes the transitional unit B. The sands become generally coarser and less consolidated in depth. Pebbles occur in the sand below 210 feet, and in the 260 to 270 feet and 270 to 275 feet intervals the sediment is dominantly coarse to very coarse sand with up to 50% granules and pebbles up to 7mm. The pebbles are mainly of chert, but some are of fine sandstone and quartzite. The chert pebbles include silicified mudstones and silicified limestone (including pellet and intraclast limestones) and are probably derived from Cambrian rocks.

EVA DOWNS O BORE

Locality. Latitude $18^{\circ}14.22'$S. Longitude $134^{\circ}53.73'$E, about 10 miles, bearing 170° true, from Eva Downs Homestead.

Surface Geology. Black soil at site, nearest outcrops are of white siliceous claystone of the Mullaman Beds.

Total Depth. 191 feet.

Cuttings Intervals. Variable, from 6 ins. to 27 feet.

Water. Aquifers at 137 feet, 151 feet, 182 feet. Supply 1800 g.p.h. Standing water level 157 feet.

Fossils. Thin sections were made of claystones and siliceous claystones from the $2\frac{1}{2}$ to $4\frac{1}{2}$ feet and $4\frac{1}{2}$ to 18 feet intervals and of soft white silty claystone from the 57 to 73 feet interval. The claystone from the 57 to 73 feet interval contains well-preserved radiolaria similar to those of Mullaman Beds claystones from surface outcrops and from Beetaloo No.1 water bore. The

Beetaloo No. 1 water bore

Fig. 9, Appendix A

Lithology/cuttings

Black soil
Sandy clay, pale yellow with limonitic nodules
Claystones, white, yellow, buff, and purplish with radiolaria
Claystones, silicified white to reddish silty with abundant microcavities;
some softer claystone, buff, also with small cavities;
both lithologies with radiolaria
Sand: grains dominantly quartz around 0.5 mm., poorly rounded;
some friable porous white sandstone.

Sandstone (and some loose sand grains); variable grain sizes, include medium to v.fine well-sorted types sometimes with quartz overgrowth cement, and some poorly sorted coarse sandstone; all types generally white

also siltstone: white, with some fine sand grains

Sand: mainly coarse to v.coarse, with some granules up to 3 mm.
also siltstone: soft micaceous, reddish buff and white

Sand: mainly coarse to v. coarse; some rounded small pebbles up to 5 mm.
also siltstone or silty claystone: white to pale pink or buff and chert (siliceous claystone) white to pale pink translucent.
Sand: mainly coarse, with some granules up to 3 mm.
Sand, with pebbles of chert and quartzite.
Sand, with pebbles up to 7 mm. mainly of chert, some quartzite.

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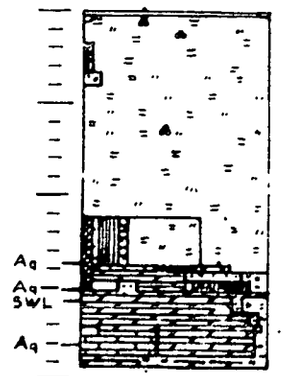
Eva Downs "O" Bore

Fig. 10, Appendix A

Lithology & cuttings



black soil
claystone, white to buff with some silt-size quartz and muscovite and poorly preserved radiolaria.

claystone, white with little silt; also about 5% bigely foraminiferous claystone

white claystone; buff to pink silty claystone; 10% med-coarse sandstone, chalcedony cemented

claystones; white, yellow, buff, and pink, soft, with some quartz and muscovite silt;

radiolaria abundant in fragments from 57'-75' interval

claystones, silty, white, pink, and yellowish; "ironstone", fine sandstone; calcareous siltstone; chert.

vfine sandstone; claystones; ironstone; chert; small pebbles; calcareous or dolomitic siltstone.

dolomite (buff); vfine sandstone; claystone; chert; quartz grains.

dolomite; limestone; ironstone; quartz sand; vfine sandstone; buff clayey siltstone, chert.

dolomite, buff microcrystalline, in part silty; siltstone; vfine sandstone

dolomite, buff to greyish, in part silty; limestone (pale calcilutite) minor vfine sandstone & siltstone.

dolomitic siltstone & silty dolomite, dark purple, grey-green, glauconitic; also dolomite, pale buff to brownish, cryptograined.

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claystones from the higher intervals showed poorly preserved radiolaria.

Superficial Deposits. Black soil was penetrated from surface to 2½ feet.

Lower Cretaceous (Mullaman Beds). Rock types corresponding to the Lower Cretaceous Mullaman Beds occur at least down to 112 feet. From 112-151½ feet the cuttings contain a mixture of Mullaman Beds rock types and rock types corresponding to the Anthony's Lagoon Beds, together with fairly abundant highly ferruginized material. This intermixing suggests karstic topography on the pre-Mullaman unconformity surface, with the early Mullaman sediments and ferruginous weathered material from the underlying carbonate rocks deposited as "pocket" deposits in solution cavities or under collapsed blocks. The Mullaman Beds section differs from the usual in that the basal sands and pebbly sands of Skwarko's unit A are much reduced in thickness and occur only in the pocket deposits in the cuttings from 137 to 151½ feet. The transitional unit B is also difficult to recognize or is absent, the bulk of the section being white, yellow, buff, and pinkish radiolarian claystones and silty claystones referable to the marine unit C at least as far down as the 57 to 73 foot interval. About 10 percent of poorly sorted sandstone with chalcedony cement occurs with the claystones in the 33 to 40 foot interval.

Cambrian (Anthony Lagoon Beds). From 112-191 feet (T.D.) rock types corresponding to the Middle Cambrian Anthony Lagoon Beds occur in the cuttings. Dolomite is dominant and is usually microcrystalline, buff to grey, with a variable terrigenous silt content and grades into dolomitic siltstone. Limestone also occurs in small quantities as oolite in the 145 to 151½ feet interval, about 40% of pale calcilutite in the 172 to 186 feet interval and 10% of similar calcilutite in the 169 to 172 feet interval. Chert occurs in the intervals from 112 to 151½ feet. Porous, friable, very fine sandstone occurs in intervals from 112 to 169 feet. Buff siltstone is also present, and in places is interlaminated with very fine sandstone.

BANKA BANKA NO.17 WATER BORE

Locality. Latitude 18°30.30'S. Longitude 134°32.90'E, about 25 miles north of Brunchilly Homestead.

Surface Geology. In black soil "downs" country. Nearest outcrops are of Tertiary Brunette Limestone.

Total Depth. 199 feet.

Cuttings Intervals. Variable, from 5 feet to 70 feet.

Water. Equipped as a water bore. Standing water level and depths of aquifers not recorded.

Superficial. Cuttings from surface to 5 feet consist of black soil.

(?)Cainozoic, (?)Mesozoic. From 5 to 84 feet the cuttings consist dominantly of white to buff clay, in part containing quartz sand grains. The cuttings also contain about 10 percent of ferruginized clay between 14 and 84 feet, and some rounded quartz grains up to 3mm diameter. The age of this material is doubtful. It resembles clay encountered below Brunette Limestone in Scout-Hole HS1. The cuttings intervals are too wide to allow comparison in detail with the section in HS1, and the sample available from the 14 to 84 foot interval was small and not necessarily representative of the entire interval.

Cambrian (Anthony Lagoon Beds). From 84 feet to total depth of 199 feet the cuttings consist of rock types typically occurring in the Anthony Lagoon Beds. The dominant lithology in the cuttings is a reddish to white fine to medium grained well sorted sandstone, sometimes porous and friable and resembling sandstones from Scout-Hole HS3. Chert becomes abundant near the bottom of the hole (about 10 percent in the 160 to 185 foot interval and 50 percent in the 185 to 199 foot interval). Some reddish micaceous silty clay occurs between 120 and 185 feet, and may represent the comminuted remains of a more abundant micaceous siltstone. A few chips of white limestone occur in the cuttings from 120 to 160 feet. The chert cuttings usually show the textures of replaced pellet limestones.

BANKA BANKA NO.18 WATER BORE

Locality. Latitude 18°27.00'S. Longitude 134°29.79'E, about 29 miles north of Brunchilly Homestead.

Surface Geology. In black soil "dunes" country. Nearest outcrops are of Tertiary Brunette Limestone.

Total Depth. Not available, but is greater than 130 feet.

Cuttings Intervals. Variable, from 8 to 38 feet.

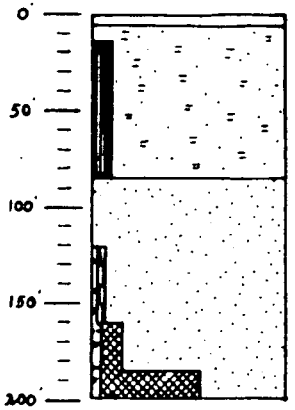
Superficial Deposits. Cuttings from surface to 8 feet consist of black soil, fairly sandy with rounded quartz grains up to 2mm diameter.

Tertiary (Brunette Limestone). Cuttings from the 8 to 22 feet interval contain about 15 percent limestone and about 5 percent calcite crystals. The limestone

Banka Banka No17 water borg.

Fig. 11, Appendix A

Lithology % cuttings



black soil
white clay with sand grains — 0'

white to buff clay, in part with fine-medium sand grains; some loose quartz grains up to 3 mm; also 10% highly ferruginised clay. — 50'

sandstone, reddish to white fine to medium, quartzose; traces of chert; claystone; quartz sand grains up to 2½ mm. — 100'

sandstone, as above, in part porous and friable; some white limestone, in part sandy; some red micaceous silty clay. — 150'

sandstone, as above; chert with pellet calcarenite texture; red silty micaceous clay.

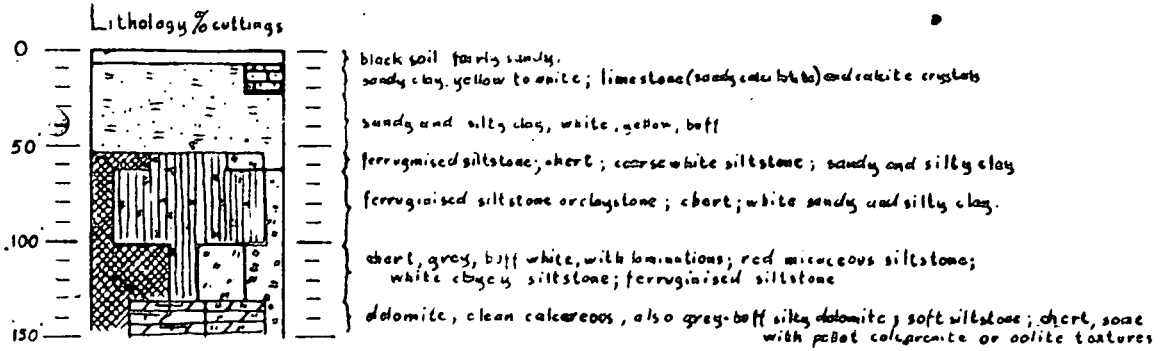
sandstone, as above; chert; buff to white silty and fine sandy clay — 200'

Bureau of Mineral Resources, Geology and Geophysics, June 1966 To accompany Record 1966/110 Appendix A

E53/A/19

Banka Banka No 18 water bore

Fig. 12, Appendix A



Bureau of Mineral Resources, Geology and Geophysics, June 1966 To accompany Record 1966/110 Appendix A
E53/A/20

is a white calcilutite containing sand-size quartz grains and is lithologically correlated with surface exposures in the area mapped as Brunette Limestone.

(?)Tertiary, (?)Mesozoic. Cuttings from 22 to 54 feet consist of white to buff silty and sandy clay. Similar clay forms the bulk of the cuttings from 8 to 22 feet. In the latter interval the relationship between the Tertiary Limestone and the clay is not known. The bulk of the clay down to 54 feet and perhaps all of it, is overlain by Brunette Limestone. It also overlies Cambrian rocks and hence its stratigraphic relationships are in these respects the same as that of the clays in Scout-Hole HS1. The precise age is again not known.

Cambrian (Anthony Lagoon Beds). Below 54 feet the cuttings contain rock types corresponding to the Anthony Lagoon Beds. The 54 to 62 foot and 62 to 100 foot intervals and, less importantly, the 100 to 130 foot intervals contain also abundant highly ferruginised material which may represent ferruginous weathered material formed on an old land surface prior to deposition of the clays above 54 feet. It is similar to the ferruginous material on the pre-Mullaman Beds surface in Eva Downs O bore. The Anthony Lagoon Beds rock types comprise chert, red clayey and micaceous siltstone, and some coarse white siltstone down to 130 feet. From 130 feet to total depth (not recorded) the cuttings consist of calcareous clean dolomite, some grey to buff silty dolomite, chert and some soft siltstone. The chert cuttings from below 130 feet show well-defined relic carbonate textures, including pelletal and oolitic textures.

In the interval between 54 and 130 feet the chert and ferruginous material are much harder than the siltstone. Consequently the relative proportions of each as indicated by the cuttings may be misleading and the siltstone may actually be dominant.

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APPENDIX B

PALAEONTOLOGICAL REPORT ON SAMPLES FROM HELEN SPRINGS 1:250,000 SHEET AREA, N.T.

by

C.G. Gatehouse

Fourteen samples collected by the Helen Springs geological party (M.A. Randal party-leader) were submitted for palaeontological examination.

Four samples contain Redlichia; Redlichia forresti (Etheridge Jr.) has been identified in two of them. Xystridura sp. nov. (Opik MS), distinguished by finger-print ornament, occurs in seven samples and is the only identifiable Xystridura present. Three samples, which do not contain either of the above genera, are of early Middle Cambrian age.

The following is a list of the locality numbers and the fossils identified from the samples:

Samples with Xystridura

HS69	Gum Ridge Formn.	Billingsella cf. humboldti Walcott (Opik ident.) Xystridura sp. nov. Biconulites
HS70		Xystridura sp. nov. Biconulites hardmani (Eth. Jr.)
HS160		Xystridura sp. nov. Biconulites
HS161		Xystridura sp. nov. Biconulites
HS177		Xystridura Wimanella (Opik ident.) Biconulites
HS514		Xystridura "Helcionella" Biconulites hardmani (Eth. Jr.) ?Billingsella cf. humboldti Walc. Inarticulate brachiopods
HS622		Xystridura Biconulites hardmani (Eth. Jr.) ?Wimanella

Samples with Redlichia

HS23		Biconulites
		Redlichia fragments
HS330		Redlichia forresti (Eth. Jr.)
		Inarticulate brachiopods
HS361		Redlichia
HS374		Redlichia forresti (Eth. Jr.)

Samples without either Redlichia or Xystridura

HS19	Gum Ridge Formation	Biconulites
HS175		Ptychopariidae
HS541		Ptychopariidae
		Biconulites

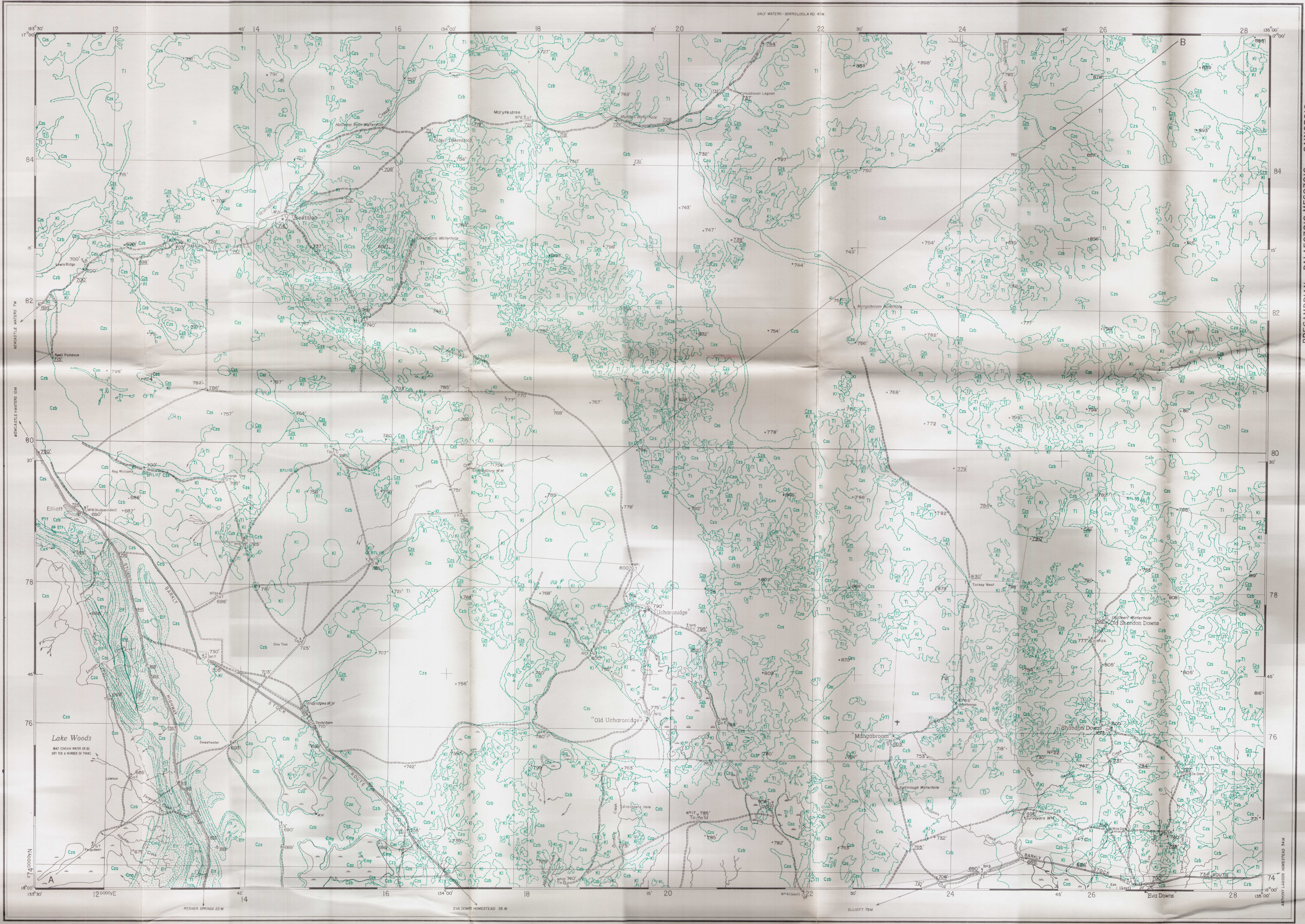
AUSTRALIA 1:250,000 GEOLOGICAL SERIES

BEETALOO
NORTHERN TERRITORY

SHEET SE 53-6

PRELIMINARY EDITION, 1966

SUBJECT TO AMENDMENT



Reference

Era	Period	Unit	Symbol	Description
CAINOZOIC	QUATERNARY		Cza	*Alluvium, some black soil*
			Czb	*Black and grey clayey soils, some sand and gravel.*
			Czs	*Sand, sandy and loamy soils, some lateritic material.*
	TERTIARY		Tl	*Laterite, ferruginous rubble, some sand*
MESOZOIC	CRETACEOUS	Mullaman Beds	Kl	*Quartz sandstone, some pebbles and cobbles, siltstone, siliceous siltstone and claystone with radiolaria.*
PALAEOZOIC	CAMBRIAN	Anthony Lagoon Beds	€my	*Fine-grained sandstone and siltstone in part calcareous and dolomitic, limestone, dolomite and dolomitic limestone with chert nodules.*
		Gum Ridge Formation	€mg	*Silicified siltstone and chert, brecciated at surface, some sandstone and leached calcareous sandstone, silicified limestone.*
		Top Springs Limestone	€t	*Massive grey to buff fossiliferous limestone. (Section only)*
PRECAMBRIAN	PROTEROZOIC	Tomkinson Creek Beds	Ēlt	*Dolerite sill.*
			Ēlt	*Medium to very fine-grained quartz sandstone with mud clasts*
			Ēlt	*Medium to very course-grained sandstone, minor conglomerate*
			Ēlt	*Siltstone, some thin interbeds of fine-grained sandstone.*

Not in stratigraphic sequence

Geological boundary (position approximate)
Fault

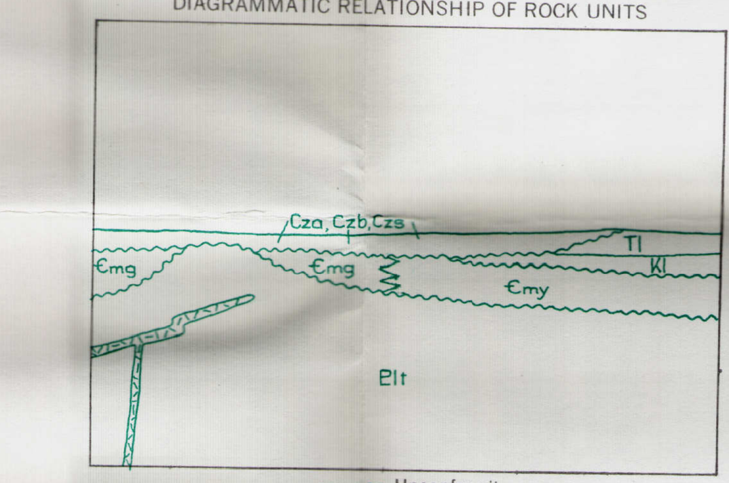
Strike and dip of strata
Trend lines air-photo interpretation

BTL 35 — *Microfossil locality*
BTL 113 — *Plant fossil locality*
BTL 117 × — *Text reference to specimen locality*
St ⊙ B1 — *Scout hole (B.M.R.)*

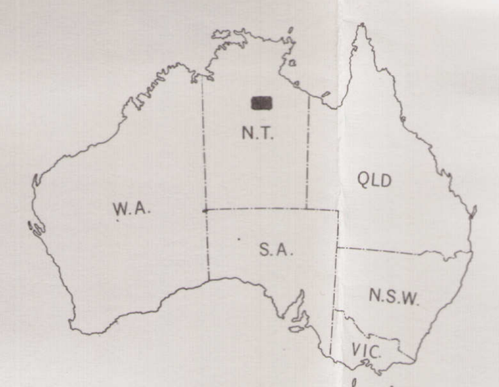
Nº 24 ○ — *Bore*
W.H. — *Waterhole*
Dam
T □ — *Tank*
Windpump

Highway
Road
Track
Fence
Elliott — *Township*
Telephone line
"Ucharonidge" ■ — *Homestead*
Landing ground
Yd □ — *Yard*
⊕ — *Astronomical station*
899 △ — *Trigonometrical station*
·790' — *Height in feet, instrument levelled; datum: mean sea level.*
·724' — *Height in feet, barometric; datum: mean sea level.*

DIAGRAMMATIC RELATIONSHIP OF ROCK UNITS



Compiled and issued by the Bureau of Mineral Resources, Geology and Geophysics, Department of National Development. Topographic base compiled by the Division of National Mapping, Department of National Development. Aerial photography by Adastra Airways Pty. Ltd. Complete vertical coverage at 1:85,000 scale.
Transverse Mercator Projection.



INDEX TO ADJOINING SHEETS
Showing Magnetic Declination

DELAMERE SD 52-16	LARRIMAH SD 53-13	HODGSON DOWNS SD 53-14	MOUNT YOUNG SD 53-15	PELLEW SD 53-16
VICTORIA RIVER DOWNS SE 52-4	DALY WATERS SE 53-1	TANUMBIRINI SE 53-2	BAUHINIA DOWNS SE 53-3	ROBINSON RIVER SE 53-4
WAVE HILL SE 52-8	NEWCASTLE WATERS SE 53-5	BEETALOO SE 53-6	WALLHALLOW SE 53-7	CALVERT HILLS SE 53-8
WINNECKE CREEK SE 52-12	SOUTH LAKE WOODS SE 53-9	HELEN SPRINGS SE 53-10	BRUNETTE DOWNS SE 53-11	MOUNT DRUMMOND SE 53-12
TANAMI EAST SE 52-16	GREEN SWAMP WELL SE 53-13	TENNANT CREEK SE 53-14	ALROY SE 53-15	RANKEN SE 53-16

ANNUAL CHANGE 0°30'E

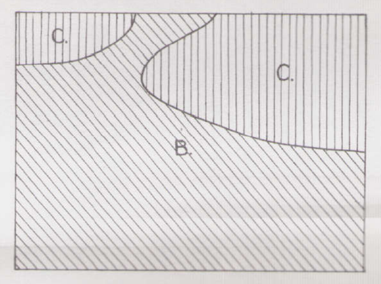
Scale 1:250,000

5 0 5 10 15 MILES

5 0 5 10 15 20 25 KILOMETRES

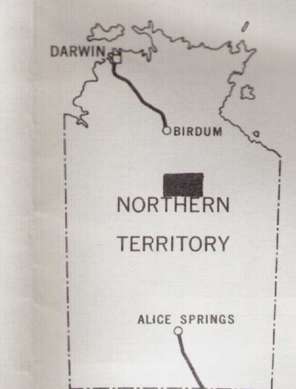
Section
Tl, Cza Czb and Czs omitted from section
Folding schematic
Scale: $\frac{V}{H} = 4$

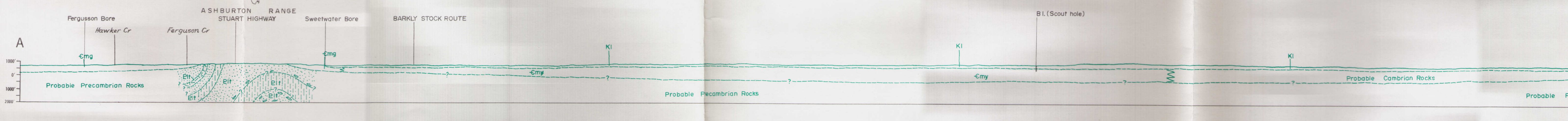
GEOLOGICAL RELIABILITY DIAGRAM



B. General reconnaissance and air-photo interpretation.
C. Helicopter traverses and air-photo interpretation.

Geology 1965 by; M.A. Randal and M.C. Brown
Compilation, 1966 by; H.F. Doutch, M.C. Brown and G.J. Squire.
Drawn by; G.J. Squire.





BEETALOO
SE 53-6

PRELIMINARY EDITION, 1966

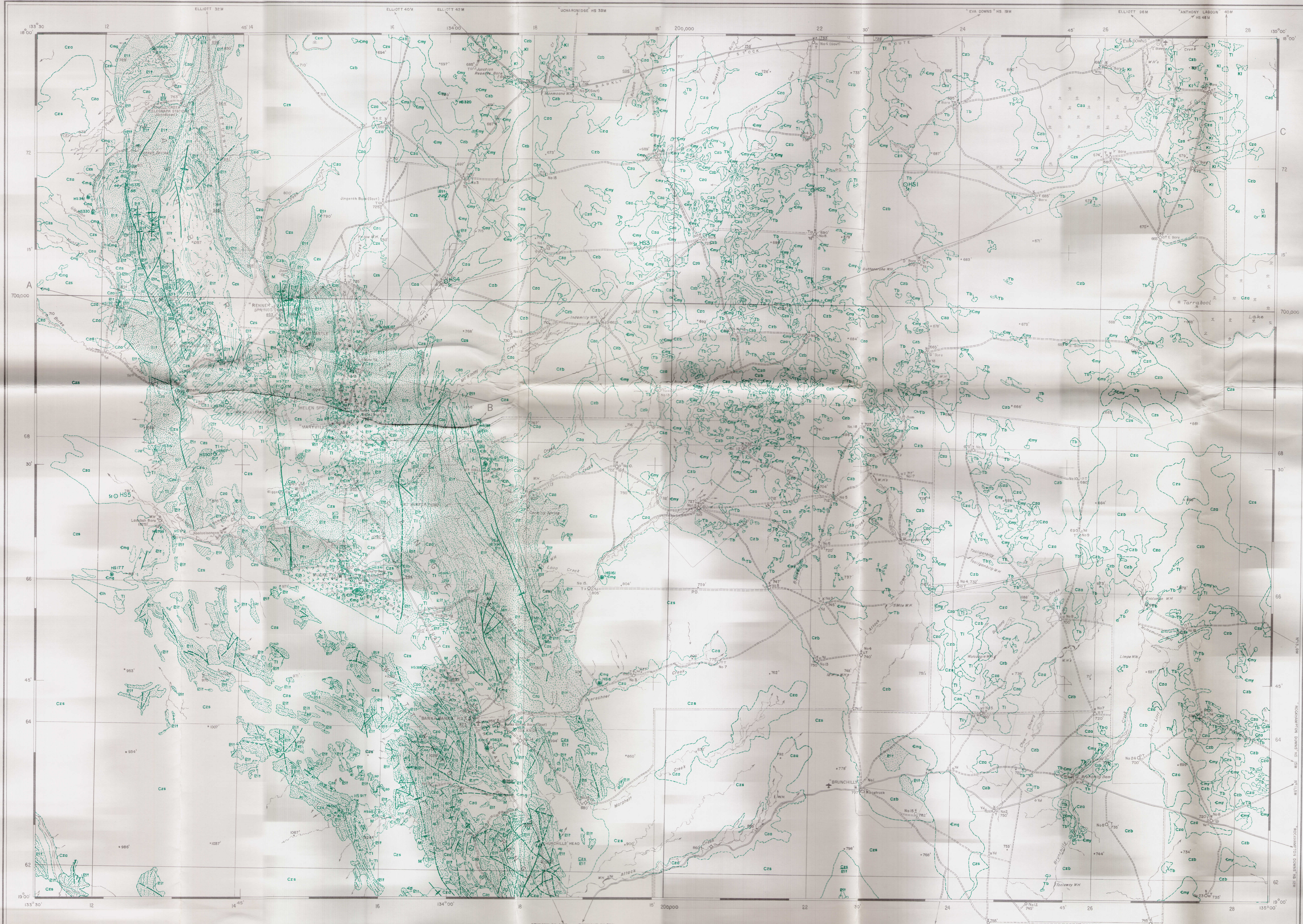
SUBJECT TO AMENDMENT

AUSTRALIA 1:250,000 GEOLOGICAL SERIES

HELEN SPRINGS

NORTHERN TERRITORY

SHEET SE 53-10



Reference

CAINOZOIC	QUATERNARY		Cza	Alluvium, some black soil
			Czb	Black and grey clayey soils, some sand and gravel
			Czs	Sand, sandy soils, some lateritic material
	TERTIARY	Brunette Limestone	Tb	White chalcedonic limestone with chert nodules, chalcedony, some sandstone
			Tl	Laterite, ferruginous rubble, some sand
MESOZOIC	UNDIFFERENTIATED		M	Sandstone, pebbly sandstone, siltstone, some cobbles and boulder conglomerate plant impressions
	CRETACEOUS	Mullaman Beds	Kl	Quartz sandstone with plant impressions, some pebbles and cobble, siltstone siliceous claystone and siltstone with radiolaria
PALAEOZOIC	CAMBRIAN	Anthony Lagoon Beds	Ꞓmy	Fine sandstone and siltstone in part calcareous and dolomitic, limestone dolomite and dolomitic limestone with chert nodules
		Gum Ridge Formation	Ꞓmg	Fossiliferous silicified siltstone and chert, brecciated at surface, some sandstone and leached calcareous sandstone, silicified limestone
		Helen Springs Volcanics	Ꞓlh	Basalt, basal sandstone with minor breccia and siltstone
PRECAMBRIAN	PROTEROZOIC	Tomkinson Creek Beds	Ꞓlt	Dolerite sill
			Ꞓlt	Medium to very fine-grained quartz sandstone with mud clasts
			Ꞓlt	Medium to very coarse-grained sandstone, pebbly sandstone, minor conglomerate, dolomite breccia
			Ꞓlt	Siltstone, some thin interbeds of fine-grained sandstone
			Ꞓlt	Calcareous siltstone, limestone, dolomite, some leached carbonate rocks
			Ꞓlt	Chert, siliceous siltstone

Not in stratigraphic sequence

Geological boundary

Anticline

Syncline

Fault

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

Strike and dip of strata

Prevailing strike and dip of strata

Horizontal strata

Prevailing strike and dip of joints

Trend lines
Joint pattern
} Air-photo interpretation

General fossil locality

Macrofossil locality

Plant fossil locality

HS 156 × Text reference to specimen locality

Specimen locality, sampled for age determination

Dyke, do dolerite.

HS6⊙St Scout hole (B.M.R)

Mine

Abandoned mine

·Mn Minor mineral occurrence

Mn Manganese

Bore

Abandoned bore

W Well

Spring

WH Waterhole

T Tank

Dam on stream

Swamp

Windpump

Highway

Road

Track

Telephone line

Fence

"HELEN SPRINGS" ■ Homestead

Landing ground

Yd Yard

Astronomical station

1210' Trigonometrical station

·989' Height in feet, instrument levelled, datum; mean sea level

·958' Height in feet, barometric, datum; mean sea level

PD Position doubtful

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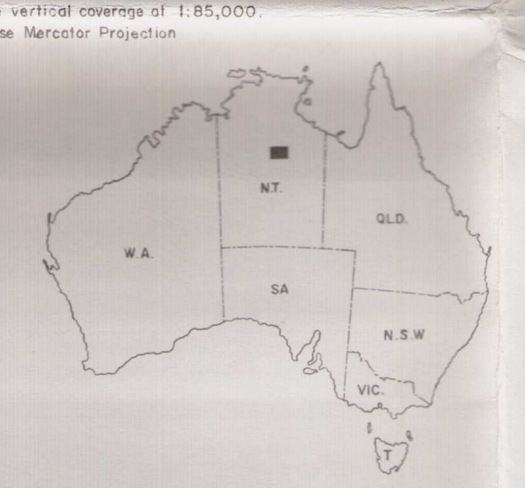
Transverse Mercator Projection



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MOUNT SOLITAIRE SF 52-4	LANDER RIVER SF 53-1	BONNEY WELL SF 53-2	FREW RIVER SF 53-3	AVON DOWNS SF 53-4

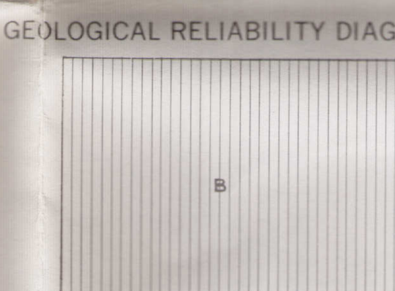
ANNUAL CHANGE 0°30'E

Scale 1:250,000

5 0 5 10 15 MILES

5 0 5 10 15 20 25 KILOMETRES

GEOLOGICAL RELIABILITY DIAGRAM



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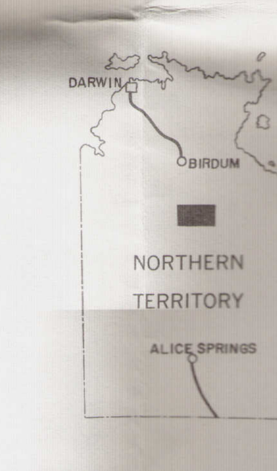
Cartography by: Geological Branch, B.M.R.
Drawn by: G.J. Squire.



Section

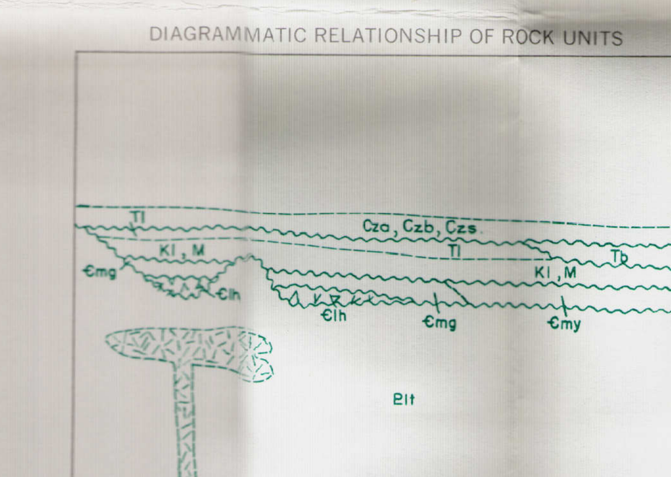
Folding schematic

Tl, Cza, Czb, Czs, omitted from section

Attitude of faults not known

Scale: $\frac{V}{H} = 4$

DIAGRAMMATIC RELATIONSHIP OF ROCK UNITS



Unconformity

HELEN SPRINGS

SHEET SE 53-10