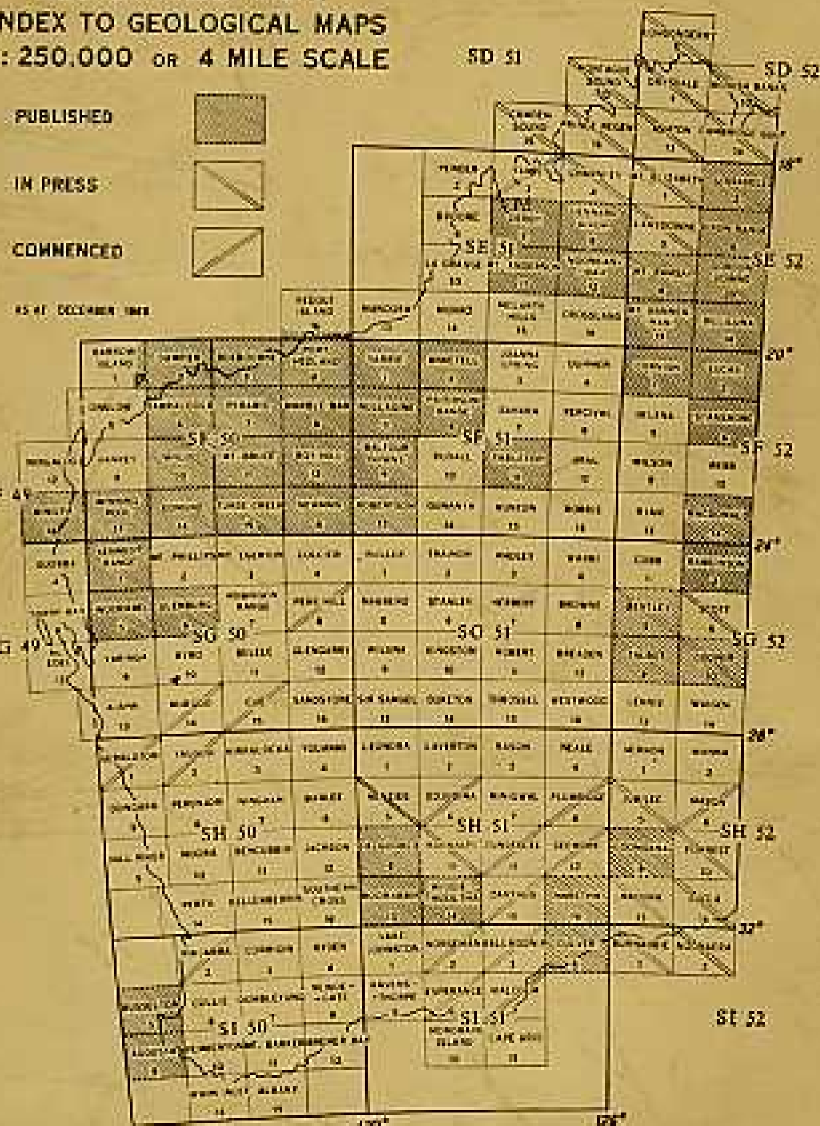
1:250,000 GEOLOGICAL SERIES—EXPLANATORY NOTES

BENTLEY

WESTERN AUSTRALIA

SHEET SG/52-5 INTERNATIONAL INDEX

WESTERN AUSTRALIA
INDEX TO GEOLOGICAL MAPS
1:250,000 OR 4 MILE SCALE



GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

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BENTLEY

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SHEET SG/52-5 INTERNATIONAL INDEX

Compiled by J. L. Daniels

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Explanatory Notes on the Bentley Geological Sheet

INTRODUCTION

The Bentley 1 : 250,000 Sheet SG/52-5 is bounded by latitude 25° S and 26° S and by longitude 126° E and 127° 30′ E. It is located on the western end of the Proterozoic Musgrave Block in Western Australia.

Some nomadic Aborigines frequent the area, but otherwise the region is devoid of settlements.

The Sheet area is crossed from south to north by a badly kept road which connects Warburton Mission, 9 miles south of the southern boundary of the Sheet area, with Giles Meteorological Station in the Rawlinson Ranges. From this road a branch road proceeds 235 miles west to Carnegie Homestead. The only other track in the region is an old disused one, which runs approximately northeast from near Scamp Hill to low hills 20 miles southeast of Bedford Range. This track is part of the old route from Warburton Mission to Giles Meteorological Station. It was used before the other road, which is part of Gunbarrel Highway, was made to improve access within the Woomera rocket range.

No records of annual rainfall have been kept in the Sheet area. At nearby Warburton Mission the annual rainfall, which is unreliable and shows no consistent seasonal bias, has averaged 8.53 inches since 1941, with a range of from 27.19 inches to 1.37 inches. Since the Bentley Sheet area is much less hilly than it is around Warburton Mission, it probably receives less rainfall.

Surface water is almost non-existent and consists of occasional small rock holes, which only contain water for short periods after rain and rapidly become polluted. The capacity of most of the rock holes is only a few gallons but larger ones may contain up to several hundred gallons.

No systematic regional mapping has been carried out in the area before the present survey was undertaken by the Geological Survey of Western Australia. This formed part of a programme undertaken to map the western part of the Musgrave Block and included the Bentley, Scott, Talbot and Cooper 1 : 250,000 Sheet areas. Work has been concentrated on the Proterozoic rocks and only a few traverses have been made across Phanerozoic deposits.

Nearly a half of the Sheet area to the southeast is included in a Native Reserve. Permission to enter the Reserve must be obtained from the Native Welfare Department of Western Australia.

Visitors to the Sheet area must be completely self-sufficient.

PREVIOUS INVESTIGATIONS

Giles, in 1873, made several traverses in the region and in 1874 the southern part of the Bentley Sheet area near Scamp Hill was visited by Forrest, but it was not until 1916 when Talbot and Clarke studied the area that any detailed

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geological information became available (Talbot and Clarke, 1917). Their studies were also confined entirely to the very southern edge of the Sheet area.

Later work to touch on this southern area includes a petrographic study of some of the rocks near Scamp Hill by Fletcher (1932), studies of the stratigraphy and regional correlations by Forman (1932, 1933), Sofoulis (1962a), and Horwitz and Sofoulis (1963), and investigations of the water supplies by Sofoulis (1962b) and Farbridge (1968).

Other studies include a regional geological and geophysical survey of the Phanerozoic sediments in the western half of the Sheet area by Hunt Oil Company and a regional reconnaissance gravity survey by Lonsdale and Flavelle (1963).

The systematic geological investigation by the Geological Survey of Western Australia described in this report was undertaken in 1967.

PHYSIOGRAPHY

The physiographic subdivisions of the Bentley Sheet area are controlled largely by the distribution of Proterozoic and Phanerozoic rocks which allow a very broad subdivision of the area into two major zones:

Western half of the Sheet area: This consists of low-lying, undulating laterite country with superimposed alluvium and eolian deposits both of which are controlled by the pattern of broad valleys in the laterite.

Eastern half of the Sheet area: This consists largely of eolian sands with widely scattered isolated monadnocks or small groups of hills.

The junction of the two major zones is well defined along most of its length by a low escarpment which faces east.

A more detailed subdivision is possible into seven units (Figure 1). These are:

A. Mountain ranges, prominent hills and ridges.

B. Widely separated hills and low ridges with intervening plains. The plains may have a variable sand cover.

C. Alluvial flats. Not well developed in the area and confined to small creeks draining hills.

D. Plains with few sand dunes and an occasional low outcrop. Dense mulga growth is common.

E. Sand dune country.

F. Undulating laterite country.

G. Salt lake country.

Unit C is poorly developed and has been included and shown together with unit B on the figure as a single unit.

STRATIGRAPHY

The Bentley Sheet area contains representatives of the Middle Proterozoic and the Phanerozoic. A stratigraphic column is given in Table 1.

PROTEROZOIC

Proterozoic rocks occur in two adjacent but geologically different areas. They occupy the northern and southern parts of the eastern half of the Sheet area and are referred to as the Northern and Southern Zones respectively. Because there are very few outcrops the mutual relationships of the two zones are not

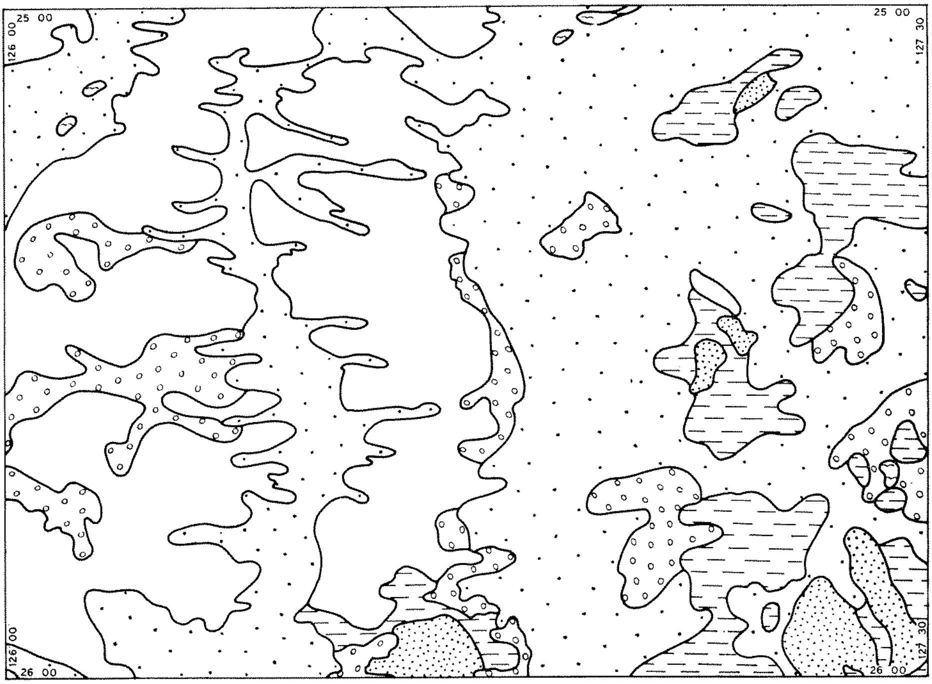

FIGURE 1

PHYSIOGRAPHIC UNITS

BENTLEY SHEET SG 52 - 5

SCALE OF MILES

10 0 10 20 30

REFERENCE

- A: ranges, hills and ridges
- B(&C): widely separated hills and low ridges, with alluvial flats (C) not shown on map
- D: plains with few dunes
- E: sand dune country
- F: undulating laterite country
- G: salt lake country

positively determined. The contact between the two is thought to consist of parts of two large 'ring' faults which define two cauldron subsidence areas (Daniels, in prep. a). Therefore the relationship of the Northern Zone to the layered sequence, which is well developed in the Talbot Sheet area to the South (Daniels, in prep. b), is obscured. The Northern Zone is deduced from regional considerations to be older than the Southern Zone.

TABLE 1. BENTLEY 1:250,000 GEOLOGICAL SERIES STRATIGRAPHIC COLUMN

Age		*Group*	*Map Symbol*	*Formation*	*Lithology*	*Thickness (feet)*	*Remarks*
CAINOZOIC	QUATERNARY		Qrl		Lake deposits. Clay and gypsum		
			Qqs		Eolian sands	up to 60	Occurs as sheets or dune fields
			Qqc		Partly consolidated silty sand		Sheet-form deposits
	TERTIARY		Czk		Calcrete, calcareous gravel and opaline silica	?50–100	Probably very good aquifer
			Czl		Laterite and lateritic gravel	?25–50	Mostly residual on Phanerozoic
			Czx		Deeply weathered rock		Largely affects Phanerozoic

				UNCONFORMITY			
?PALAEOZOIC	?PERMIAN		P		Sandstone, porcellaneous siltstone, and pebble beds		Fluvioglacial and glacial deposits
				UNCONFORMITY			
MIDDLE PROTEROZOIC	BENTLEY SUPERGROUP		Ᵽws	Townsend Quartzite	Quartzite and sandstone	?400	*Unconformable on Scamp volcanic association and Ᵽcg*
			Ᵽpp Ᵽpo Ᵽpa Ᵽpt Ᵽps		Porphyritic acid volcanic rocks Some 'white' pyritic rhyolite Devitrified obsidian with abundant perlitic cracks Agglomerate of acid volcanic fragments Grey-green epidotic tuff Quartzite and minor acid lava and tuff		Collectively termed the Palgrave volcanic association and preserved in a probable cauldron subsidence area
			Ᵽsa Ᵽsr Ᵽsf		Porphyritic rhyolite. Some 'white' pyritic rhyolite. Abundant flow-banding Siliceous breccia, possibly associated with faulting in Ᵽsa Felsite, pink to brown, finely crystalline, altered Ᵽsa		Collectively termed the Scamp volcanic association and preserved in a probable cauldron subsidence area
		Pussy Cat Group	Ᵽcg	Glyde *Formation*	Amphibolite, mica schist and *marble.* Originally basic amygdaloidal lava, tuff, shale, siltstone and dolomite		
			Ᵽlb		Amphibolite and garnet amphibolite Originally amygdaloidal basic lavas		Occurs as small plugs and ?flows in northeast of Sheet area, and as lava flows in southeast
			Ᵽq		Quartzite and quartz-muscovite schist Well-bedded. Relict cross-bedding		Unconformable on Pbg
					IGNEOUS ROCKS		
			d p Ᵽpg Ᵽpc Po Pom Ᵽog Ᵽsn Ᵽbg		Dolerite sheets and dykes Pegmatite veins Granophyre and granite Porphyritic microgranite Usually marginal to Ᵽpg or as dykes Gabbro, troctolite, anorthositic gabbro Contaminated gabbroic rocks Granophyre closely related to Po Granitic gneiss Complex of adamellite gneiss, adamellite and relict masses of granulite. Much migmatization		Several ages Related to Palgrave volcanic association (Ᵽpg, Ᵽpc) Part of Giles Complex (Po, Pom, Ᵽog) *Closely related to Scamp volcanic association* (Ᵽsn)

Northern Zone

A large portion of the northeast of the Bentley Sheet area is occupied by adamellite gneisses and migmatites in which sit isoclinally and recumbently folded remnants of quartzite and quartz-muscovite schist.

Adamellite gneiss and migmatite

The gneisses and migmatites form the basement to the quartzites and quartz-muscovite schists and have undergone a complex series of changes. These are not fully understood because of the lack of good exposures.

A small mass of unsheared adamellite occurs in the region of Gungungmura Waterhole in the northeast of the Bentley Sheet area. It consists of small mafic clots in a medium-grained groundmass of poorly twinned oligoclase, orthoclase perthite, and quartz. The mafic clots carry hornblende, biotite, ilmenite, and minor garnet, sphene, apatite, zircon, hematite and ?monazite.

Approximately 500 yards to the west of the above locality there is a moderately well lineated and foliated biotite-hornblende adamellite gneiss, which mineralogically closely resembles the hornblende-biotite adamellite. Small differences between the two rocks can be attributed to minor mineralogical changes consequent to shearing.

Similar adamellitic gneisses occur further south at Mitika Waterhole. These gneisses are extremely well lineated, the lineation being defined by elongated biotite aggregates. They are poorly foliated and cut by thin, irregular biotite-bearing pegmatites which are roughly parallel to the poor foliation. Thin quartz veins cross-cut the mass.

The adamellite and adamellite gneisses have apparently intruded high-grade metamorphic rocks. Most of the resultant complex was subsequently structurally and mineralogically modified. Remnants of the older metamorphic rocks are found as rare xenoliths of banded granulite in the unsheared adamellite near Gungungmura Waterhole. Larger masses of migmatitic gneisses occur further east in the Yulun-Kudara and Gungarungal areas. These gneisses are well foliated dominantly acidic, and show abundant evidence in the form of folded lineations of having been folded at least twice. The youngest folding took place along northeast to north-northeast axes similar to that which affected the quartzites and quartz-muscovite schists (see below).

Quartzite and quartz-muscovite schist

The prominent ridges of the Bedford Range, the unnamed range 2 miles east of Mitika Waterhole, and several minor ridges and outcrops of this Northern Zone consist of quartzite and quartz-muscovite schist which represent a metamorphosed sequence of sandstone and argillaceous sandstone. The rocks are well bedded and often display relict cross-bedding.

At several localities (e.g. near Neena Magura Waterhole) abundant stretched pebbles are present in a quartz muscovite matrix. Their frequency and size increases towards the contact with the stratigraphically lower adjacent adamellite gneiss, and the deposit is regarded as a basal conglomerate. The unconformity is rarely exposed, but may be seen in the low hills approximately 8 miles southeast of Mitika Waterhole.

Mineralogically the rocks are simple and generally consist of varying proportions of quartz and muscovite with minor accessory opaques. In the most southerly exposure of the rock type, 20 miles southwest of Mitika Waterhole, garnet and kyanite are present in one small band.

The deposits have been recumbently and isoclinally folded along northeast to north-northeast axes. Probably during this folding they were also regionally metamorphosed.

Summary of the origin of the Northern Zone

It is considered that the migmatitic gneisses of the Northern Zone are modified granulites which were originally the westerly continuation of the extensive high grade metamorphic belt that forms much of the Musgrave Block. It is also thought that the original granulites were intruded in the northeast of the Bentley Sheet area by copious adamellite, subsequently unconformably overlain by arenaceous sediments and subjected to a period of isoclinal and recumbent folding with associated metamorphism. This downgraded the granulites, converted most of the adamellite to gneiss, and produced quartzite and quartz-muscovite schist from the sediments.

This sequence of events is thought to have taken place before the formation of the Bentley Supergroup.

SOUTHERN ZONE

The Southern Zone is occupied by representatives of the Bentley Supergroup (Daniels, in prep. b) which is thought to be of Middle Proterozoic age. Subdivisions of the supergroup present include the Pussy Cat Group, Townsend Quartzite, and the Palgrave and Scamp volcanic associations. Some unnamed metamorphosed basic lavas are also included, but their age relations to the other representatives of the Supergroup are not certain.

Pussy Cat Group

Glyde Formation. Eight miles west-southwest of Scamp Hill poorly exposed rocks of the Glyde Formation are present. The rocks consist of a thick sequence of thin bands and lenses of basic, epidotic, amygdaloidal lava, tuff, shale, siltstone, dolomite, thin quartzite, and dirty sandstone.

Basic lava is the most prominent rock type and coarse clastics are generally rare.

Regional metamorphism has altered the original rocks to chlorite schist, sericite schist, marble, and biotite-hornblende rock. Folding is well developed with dips generally around 45°. Some recumbent folding is present and a strong axial plane cleavage has been developed.

These rocks are unconformably overlain by the Cassidy Group in the Talbot Sheet area to the south (Daniels, in prep. b). No rocks of this Group are exposed on the Bentley Sheet area, but their subsurface extension is thought to exist in the area 4 to 5 miles south of Mount Harvest.

Acid volcanics of the Scamp volcanic association lie to the northeast and north of the Glyde Formation. Their contact is partly faulted, and partly a probable unconformity with the acid volcanics being the younger unit.

Within the acid volcanic exposures to the southwest of Scamp Hill, an elongated, northwest-trending, oval-shaped inlier of similar rocks to the Glyde Formation occurs some 3 miles east of Mullangarri Well. These are correlated with the Glyde Formation, and are apparently unconformably overlain by the acid volcanics.

Unnamed metamorphosed basaltic rocks

Two small areas of metamorphosed basic volcanic rocks occur near the eastern margin of the sheet area. One is near Yulun-Kadura Waterhole and the other lies approximately one mile to the north of Domeyer Hill.

In the vicinity of the Yulun-Kadura Waterhole there are four irregularly shaped masses of the basic volcanic rock. These are thought to be small volcanic plugs. The largest is approximately a quarter of a mile across.

The rock is a metamorphosed amygdaloidal basalt, which carries xenoliths of the acid gneisses which form the country rocks. It is cut by veins of epidosite and pegmatites composed of quartz, feldspar, epidote, hematite and magnetite.

The groundmass of the basic rock consists of a fine to medium-grained mosaic of pale green clinopyroxene, brownish green hornblende, plagioclase, euhedral garnet, epidote, and opaques. Relict phenocrysts of plagioclase are easily recognisable. Amygdales in the rock contain mosaic quartz with small amounts of plagioclase, garnet (partially pseudomorphed by epidote), opaques, and sphene.

Near Domeyer Hill slightly metamorphosed bedded amygdaloidal basic lavas are present and underlie the northwesterly extension of the Jameson Range Gabbro (Daniels, 1967a). They possibly unconformably overlie the granulites in the Scott Sheet area to the east, and have been tentatively correlated with the Glyde Formation.

Townsend Quartzite

Two miles west of Mount Harvest there is a small ridge of silicified and partly silicified bedded sandstone and quartzite. It apparently unconformably overlies rhyolites of the Scamp volcanic association. The sandstone and quartzite is lithologically comparable to the Townsend Quartzite in the Talbot Sheet area to the south (Daniels, in prep. b) and has been tentatively correlated with this formation.

The ridge is overlain on the southwest by laterite, colluvium, and eolian sands.

Volcanic associations of the Bentley Supergroup

Two important volcanic associations, the Scamp volcanic association and the Palgrave volcanic association are included in the Bentley Supergroup. These are not part of the regional layering, but are preserved in probable cauldron subsidence areas (Daniels, in prep. a).

The Bentley Sheet area includes only part of each cauldron. One occurs along the central southern margin of the Sheet area between Mount Harvest and an area a few miles to the east of Bentley Hill. The other occupies the southeast corner of the Sheet area and forms the northern continuation of the Barrow Range in the Talbot Sheet area to the south. This latter cauldron, containing the Palgrave volcanic association is apparently the younger. The cauldron is oval-shaped, measures approximately 40 miles long by 22 miles broad and trends roughly north-northwest. The overall shape of the cauldron associated with the Scamp volcanic association is not known in detail, but it is thought to be roughly oval with an east-west elongation.

The names are derived from postulated source areas for the volcanic material (Scamp Hill on the Bentley Sheet area and Mount Palgrave on the Talbot Sheet area). The location of the source areas having been determined principally by a study of the flow-lineations in the rhyolites (Daniels, in prep. a).

Scamp volcanic association

In the Mount Harvest area the Scamp volcanic association consists of well flow-banded and flow-lineated extremely fine-grained acid volcanic rocks. They are slightly porphyritic, carry frequent specks of blue fluorite, and weather to a medium reddish brown. Often, abundant small oval-shaped darker rock fragments are present and suggest that the rock may be referred to as a tuff lava.

Towards Scamp Hill the rock gradually becomes slightly coarser grained until in the Scamp Hill area and northwards the rock can be identified as a felsite. The change in grain size has not destroyed some of its original primary features such as spherulitic texture and banding. However, north of Scamp Hill the rocks have been more strongly folded and tectonic features have been impressed on igneous ones with consequent difficulties in interpretation.

The felsitization of the acid volcanic rock may be related to the intrusion of granite north and east of Scamp Hill together with subsequent folding. This was possibly accompanied by some metamorphism.

The southern margin of the Scamp volcanic association is a curved fault line, of which only a small portion appears in the Bentley Sheet area five miles south-west of Scamp Hill. It is marked by thin quartz reefs and a moderate development of a white, pyritic, altered rhyolite, which weathers showing patchy brown and yellow stains.

The eastern margin of the Scamp volcanics association is probably marked by the western fault of the Palgrave cauldron subsidence area which brings unaltered rhyolite of the Palgrave volcanic association against felsite of the Scamp volcanic association.

The nature of the northern margin can only be speculative because there are no good rock exposures. The presence of a faulted margin seems to be the most likely possibility and this has been indicated in the structural sketch map (Figure 3). The approximate positions of the faults were determined from vague linear features in the superficial deposits.

Palgrave volcanic association

The Palgrave volcanic association is more complex than the Scamp volcanic association. Rock types include a large variety of porphyritic rhyolites, devitrified obsidians, agglomerates, and minor tuffs. It has been intruded by granite, porphyritic microgranite, gabbro and dolerite.

The margins of the cauldron have been deduced from regional considerations. The probable marginal fault shows up well on the air-photographs of the southwest corner of the Scott Sheet area. This continues northwestward into the Bentley Sheet area approximately 9 miles north of Mount Rawlinson. The northwest margin of the assumed cauldron is also probably faulted with the fault bringing unaltered rhyolites into close proximity to the adamellite gneisses of the Northern Zone.

PHANEROZOIC

PERMIAN

The oldest Phanerozoic rocks exposed in the Bentley Sheet area are possibly of Permian age and rest with pronounced unconformity on the Proterozoic. They are confined mainly to the western half of the Sheet area, but also occur as small outliers, sometimes as mesas, on the Northern Zone of the Proterozoic.

The deposits are generally horizontal, but dips of up to 40° have been observed near faults. Rock types include a cross-bedded sandstone which is often variegated, pebble and boulder beds, siltstone, and mudstone. Desiccation cracks are not infrequent, and surface ferruginization of the sandstones is a common feature. The rocks are probably of glacial and fluvio-glacial origin.

Lithological variations in four measured sections are given in the Appendix.

In the northeast corner of the Sheet area there is part of the northwest continuation of the Cobb Depression, found by Lonsdale and Flavelle (1963) during a gravity survey of the region. It contains sediments which are probably Permian, and is an important potential aquifer (Farbridge, 1967).

TERTIARY

Laterite and lateritic gravel

Laterite and lateritic gravel are very extensively developed in the western half of the Bentley Sheet area and mostly overlie Permian deposits.

The rocks consist of pisolitic limonite or ironstone gravel which overlies a deeply weathered mottled zone. The deposit generally mantles a mature topography and forms gently undulating country. The crusts of the low-relief undulations are being actively eroded by small non-perennial streams which have exposed numerous small areas of weathered Permian.

Calcrete

The rock type referred to as calcrete consists of a white-weathering, fawn, calcareous deposit, formed by the evaporation of water. The deposit usually partly fills old drainage channels and has become an aquifer because of the presence in it of abundant small cavities and occasional larger potholes. Calcareous loams are frequently to be found on the sides of the calcrete bodies. Associated with the calcrete is a variable development of opaline silica. The maximum thickness of the calcrete is unknown, but a range of from 50 feet to 100 feet is suggested.

The surface and subsurface extent of the calcrete bodies in the Bentley Sheet area is indicated on the drainage province map (Figure 2) which records parts of two ancient drainage systems. Most of the area drains southward into the Eucla Basin. The northeast corner of the Sheet area drains to the north, partly into the Cobb Depression and partly into the Canning Basin. These drainage channels are now largely covered by eolian sands.

Superficial linear features can often be seen on the calcrete by an examination of relevant air-photographs. These features often consist of a series of parallel lines or less commonly appear as meandering, sometimes coalescing lines. They seem to be the remains of old drainage lines and have been indicated as such on the geological map.

The calcrete bodies are important potential aquifers and should be considered in any future development of the region.

QUATERNARY

Eolian sands

Much of the Bentley Sheet area is covered by an extensive development of eolian sands in the form of sheets and longitudinal sand ridges, which, apart from the crests of some dunes, are fixed by a thin vegetation cover. The ridges range in height from 10 feet to 60 feet and extend for several miles. The most northerly of the dunes are the largest.

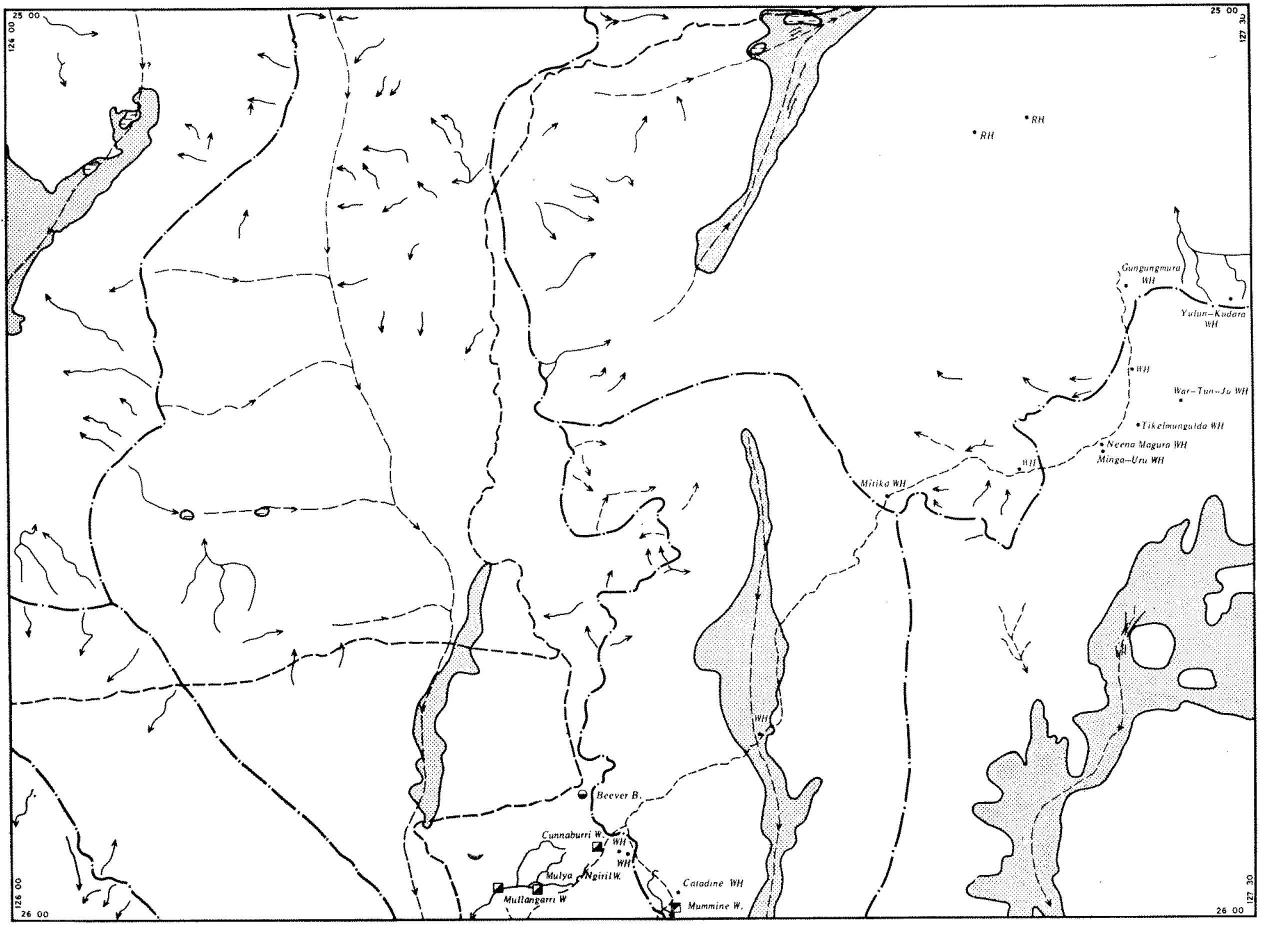

FIGURE 2
DRAINAGE PROVINCES AND WATER SUPPLIES
BENTLEY SHEET SG 52 - 5

SCALE OF MILES

5 0 5 10 15

REFERENCE

Main road
Track
Stream (non - perennial)
Suggested sub-surface drainage channels
Waterhole • WH
Drainage province boundary
Major calcrete bodies with superimposed drainage pattern indicated
Salt lakes
Well quality- potable
quality–good stock
Bore quality–brackish

The dune fields of the Bentley Sheet area lie on the southern side of the Gibson Desert and have been formed under the influence of a generally prevailing easterly air stream (King, 1960). In the most southerly part of the Sheet area the dune patterns are more complex, and this can be explained by a number of factors. These include the effects of interference by the two opposing causal wind directions of the Gibson Desert and the Great Victoria Desert to the south, the proximity of the dunes to hills, and the seasonal shift of wind regimes (Daniels, 1969).

Lake deposits

Lakes are poorly developed on the Sheet area and they are confined to small low areas on old drainage channels. The deposits in the Van Der Linden Lakes on the northern margin of the Sheet area are gypsiferous.

INTRUSIVE ROCKS

Acid intrusives

Intrusive granitic rocks occur in both Northern and Southern Zones and are of Proterozoic age.

In the Northern Zone large quantities of adamellite have intruded migmatites and granulites, and subsequently have been converted to various gneisses by younger folding and metamorphism.

The granitic rocks of the Southern Zone are confined to one or the other of the two cauldron subsidence areas and are genetically related to the volcanic associations.

Two modes of occurrence within these cauldron subsidence areas have been noted:

1. As massive granite with lesser granophyre and porphyritic microgranite which are intrusive into various acid volcanics of the Palgrave and Scamp volcanic associations. The intrusive granite of the Palgrave volcanic association in the Bentley Sheet area forms part of the Winburn Granite.
2. As partial ring dykes of porphyritic microgranite which are intrusive into the Palgrave volcanic association. The dykes are probably apophyses from the Winburn Granite.

The Winburn Granite is a complex of porphyritic and non-porphyritic varieties of granite and granophyre with a sporadic marginal development of porphyritic microgranite which grades into normal granite over a distance of approximately 50 feet.

A typical granite consists of microcline, albite-oligoclase, and quartz, with accessory biotite, opaques, fluorite, zircon, sphene, apatite, and epidote. Hornblende is also present in some varieties. Phenocrysts in the porphyritic variety consist of microcline perthite and occasional plagioclase.

The porphyritic microgranite of the marginal facies and the ring dykes carry plagioclase, perthite and corroded quartz phenocrysts in a fine-grained quartz-feldspar groundmass. Accessories may include green biotite, zircon, opaques, sphene and tourmaline.

In detail the porphyritic microgranite contacts are transgressive and show numerous minor apophyses extending into the country rocks. The coarse porphyritic character and the intrusive nature of these rocks distinguishes them from most of the porphyritic acid volcanics. These relationships are well displayed *6 miles southwest of Mount Rawlinson.*

The granitic rock intrusive into the Scamp volcanic association has been subjected to folding and shearing and much has been converted to granitic gneiss.

Basic Intrusives

Thin dolerite dykes cut the rhyolites of the Palgrave and Scamp volcanic associations. They also intrude granitic rocks related to these associations. In the Scamp Hill area the dykes have been folded along with their host rocks. Dolerite dykes cutting the Palgrave volcanic association are not known to be deformed.

Three occurrences of gabbroic rocks have been located in the Bentley Sheet area. The main one is a northwesterly continuation of the Jameson Range Gabbro (Daniels, 1967a) in the Domeyer Hill area, and this forms part of the Giles Complex. The gabbro is fresh, layered, and carries bands of titaniferous magnetite several feet thick which dip southwest. The bands can be correlated with the uppermost titaniferous magnetite bands of zone 4 of the Jameson Range Gabbro in the Scott Sheet area. Northeast of Domeyer Hill exposures are poor, but the gabbro apparently rests on metamorphosed basic lavas. To the west the gabbro is faulted against the Winburn Granite.

Gabbro which intrudes the Palgrave volcanic association is also found in a small domal structure 11 miles almost due west of Mount Rawlinson. The gabbro carries hornblende and is capped by a thin granophyric differentiate. It is not impossible that this occurrence is a continuation of the Jameson Range Gabbro. The third occurrence of gabbroic rocks lies approximately 4 miles to the west of Bedford Range where it forms Diorite Hill. Another small exposure of similar rock lies 2 miles southwest of Diorite Hill. Apparently the gabbro has concordantly intruded a sequence of thin-bedded quartzites. The resultant mass consists of thin, basic and ultramafic bands with a minor development of pegmatitic gabbro and cross-cutting veins. Most of the rock types have been uralitized, but the original igneous banding is preserved, except along some narrow shear zones. The occurrence appears to be older than the rocks of the Jameson Range Gabbro.

STRUCTURE

The oldest known rocks of the Bentley Sheet area are the migmatites and acid gneisses of the Yulun-Kadura Waterhole area. These are suspected of originally being granulites whose structure has been modified by younger isoclinal and recumbent folding along north-northeast to northeast axes. Unconformably overlying these modified granulites is a series of quartzites and quartz-muscovite schists which have also been involved in this younger folding.

Near Mitika Waterhole the folds have a north-northeast trend which gradually swings to northeast in the Bedford Range region. A younger minor modification of these fold axes is suspected and this probably took place along west-northwest axes.

Two large cauldron subsidences dominate the structure of the Southern Zone.

Some of the rocks in the northern part of the older cauldron subsidence area which contains the Scamp volcanic association, have been modified by a younger folding and metamorphism. The fold axis trends appear to have formed a broad arc which is concave to the north, with west-northwest trends in the Scamp Hill area, and east-northeast trends near Bentley Hill. As these trends appear to cut across those of the recumbent and isoclinal folding, they are assumed to be younger.

Apart from some local doming, no regularity of folding and no regional metamorphism is noted in the cauldron subsidence area containing the Palgrave

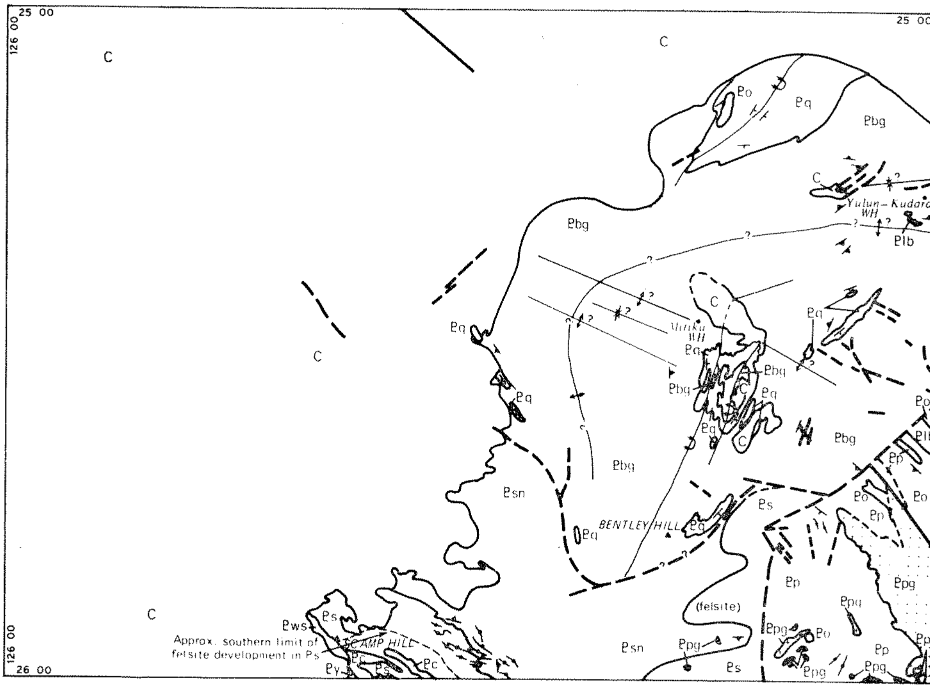

FIGURE 3

STRUCTURAL SKETCH MAP

BENTLEY SHEET SG 52-5

SCALE OF MILES

10 0 10 20 30

REFERENCE

PROTEROZOIC

C	Upper Palaeozoic and Cainozoic
	Unconformity
Ɛws	Townsend Quartzite
	Unconformity
Ɛy	Cassidy Group
Ɛp	Palgrave volcanic association
Ɛs	Scamp volcanic association
Ɛc	Pussy Cat Group
Ɛlb	Basic volcanic rocks
Ɛq	Quartzite and quartz-muscovite schist

IGNEOUS ROCKS

PROTEROZOIC

d	Dolerite dykes
Ɛpg	Granophyre, granite and associated rocks
Ɛo	Gabbroic rocks of Giles Complex
Ɛsn	Granitic gneiss closely associated with Scamp volcanic association
Ɛbg	Adamellite and adamellite gneiss

Geological boundary
Fault
Probable fault
Inferred fault
Regional dip of bedding
Igneous banding dip
Metamorphic foliation, inclined
Anticline
Anticline, inferred
Syncline
Syncline, inferred
Overturned syncline

volcanic association. The irregular pattern of dips is probably the result of a combination of original dips and adjustments made by the suspected sinking which caused the formation of the cauldron.

The Phanerozoic rocks display dips of only a few degrees, except near rare faults, where dips of up to 40° have been seen.

GEOLOGICAL HISTORY

The oldest rocks in the area are probably granulites which are related to the extensive high-grade metamorphic belt which forms much of the Musgrave Block. These were intruded by large quantities of adamellite, uplifted and eroded, and subsequently unconformably overlain by arenaceous sediments. The assemblage was then subjected to a period of isoclinal and recumbent folding associated with regional metamorphism. This downgraded the granulites and converted most of the adamellite to gneiss, while the sediments were changed to quartzite and quartz-muscovite schist.

After a period of uplift and erosion, the lower part of the Bentley Supergroup, i.e. the Glyde Formation, was deposited. This consisted mainly of basic volcanics and clastic sediments, which were subjected to moderate folding and low-grade regional metamorphism.

The next event recorded in the Bentley Sheet area was an outpouring of a very large quantity of acid volcanic material which has been called the Scamp volcanic association, and the formation of a probable cauldron subsidence area. Granite intruded these acid volcanics in the cauldron and possibly caused the felsitization of a portion of them. Folding and probably some regional metamorphism affected the northern part of the cauldron after a minor phase of basic dyke injection.

The formation of the cauldron which preserved the Palgrave volcanic association followed. After copious outpourings of acid volcanic rocks, and the formation of agglomerates and tuffs, gabbro was emplaced. This was followed by the intrusion of a granite mass with associated apophyses, and the sinking of the cauldron.

The youngest Proterozoic event recorded in the area was a period of dolerite dyke injection. This was almost entirely confined to the southeast part of the Sheet area. The Phanerozoic history of the area is not well recorded. In Permian times the area was subjected to a glaciation. In the Tertiary extensive lateritization took place and this was possibly accompanied by the development of large calcrete sheets which filled broad valleys. Later an extensive dune field developed over most of the area.

At the present time the dunes are fixed by sparse vegetation and only minor erosion is in progress in the more hilly regions.

ECONOMIC GEOLOGY

No mining has been undertaken, nor are there any companies actively engaged in prospecting in the Bentley Sheet area.

Vanadium

Vanadium is probably present in the titaniferous magnetite bands which occur near the top of the gabbro near Domeyer Hill. These bands can be correlated with, and are probably physically continuous with the titaniferous magnetite bands at the top of the Jameson Range Gabbro sequence to the southeast (Daniels, 1967a). On this basis the bands probably contain approximately 0.75 per cent V_2O_5 (Daniels, 1967b).

Copper

Traces of copper staining together with a trace of silver were found by H. Domeyer in 1930 in quartzite and tuffaceous sediments at Domeyer Hill. The mass is probably a large xenolith in gabbro. Freshly broken surfaces of the quartzite give off a strong smell of hydrogen sulphide.

Both of the cauldron subsidence areas should be considered as possible hosts for copper mineralization.

Water

No permanent surface water exists in the Sheet area. The few rock holes present contain only a few gallons of water for short periods after rain and they are not reliable sources of supply.

TABLE 2. BENTLEY 1 : 250,000 SHEET—WELLS AND BORES

Name	*Total Depth ft*	*Water Level ft*	*Quality (ppm)*	*Yield (gph)*	*Aquifer*
Mulya Ngiril	30	—	<1,000	—	alluvium
Beever Bore	80–90	50–60	brackish	350	
Cunnaburri W					
Mullangarri W					
Mummine W					

Very little is known about underground water, but from general considerations there are two probable sources of moderate to good supplies. It seems possible that high yields may be obtained from the calcrete bodies depicted in Figure 2, and from Permian sediments in the Cobb Depression in the northeast corner of the Sheet area.

All the wells sunk in the Sheet area are confined to the hilly region around Scamp Hill. The known details of the wells are given in Table 2.

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APPENDIX

PHANEROZOIC SECTIONS

LOCALITY: Bentley 1 : 250,000 Sheet. Lat. 25° 29′ S, Long. 127° 10′ E. Isolated mesa; horizontal strata.

Thickness (feet)	Lithology
6 Top	Purple-brown, ferruginous, coarse-grained sandstone. Cross-bedded. Gradational into lithology below.
32	Coarse-grained, cross-bedded, feldspathic or kaolinitic sandstone with minor muscovite. Interstratified with fine-grained, kaolinitic sandstone, siltstone and pebble beds. Pebbles are poorly sorted angular and rounded quartzite and quartz-mica schist.
17	Fine to medium-grained, cream, kaolinitic sandstone. Somewhat porcellanous with minor convolutions or whorls in bedding. Sits on kaolinized quartz-feldspar-mica gneiss.
55	Base not seen.

LOCALITY: Bentley 1 : 250,000 Sheet. Lat. 25° 08′ S, Long. 127° 07′ E. West Hill. Mesa of horizontal strata.

Thickness (feet)	Lithology
15 Top	Cream to white, medium to coarse-grained massive to blocky sandstone. Poorly sorted with isolated well-rounded quartz clasts; matrix subrounded to subangular. Interbedded with white quartzose claystone, with isolated quartz clasts up to 5 cm diameter. Gradational into well-cemented quartz claystone and sandstone with kaolin matrix and scattered cobbles up to 10 cm diameter.
32	Coarse-grained, grey, poorly cemented porous sandstone, with angular kaolin fragments. Interbedded with 1 to 3-foot thick bands of white, very fine-grained sand, silt or porcellanous claystone with subconchoidal fracture. Bands may be discordant with coarse sandstone bedding and have acted thixotropically. Minor current-bedding with some overturned cross-sets suggesting syn-depositional deformation.
54	Medium sandstone, fine sandstone, siltstone and white claystone. Highly folded or convoluted bedding alternates with finely laminated thin-bedded flaggy layers. Probably syn-depositional slumping.
13	Pale yellow, very fine-grained sandstone and siltstone. Conchoidal fracture, blocky and ochreous.
3	Purple siltstone flecked with hematite and manganese.
6	Ochreous, yellow, limonitic siltstone. Blocky with minor tough purple siltstone with botryoidal manganese coating.
123	End of observed section.

LOCALITY: Bentley 1 : 250,000 Sheet. Lat. 25° 45′ S, Long. 126° 11′ E. Todd Ranges.

Thickness (feet)	Lithology
5½ Top	Cream to white or pale yellow siltstone and porcellanous claystone. Well banded with blocky fracture. Minor convolutions.
6	Grey to mauve, fine to medium-grained, well sorted, well cemented, blocky sandstone.
2	Purple to brown, fine to medium-grained fissile sandstone with fine-grained cream to white sandstone.
10	Brown to buff, variegated, medium to fine-grained silicified sandstone.
12	Green to buff, banded, fine to medium-grained sandstone. Tabular cross-sets Contains lamellibranch.

1½	Buff to yellow, coarse granule sandstone. Limonitic. Moderate to well rounded matrix. Erosional contact on to:
3	Siltstone and mudstone. Bioturbated worm burrows and possible feeding traces on top of bedding plane.
9	Buff to yellow medium grained sandstone with shale and mudstone flakes.
10	Buff to white mudstone with medium to coarse-grained micaceous sandstone lenses.
3	Purple to grey mudstone with blocky fracture.
6	Mauve to buff sandstone with shale flakes, interbedded with medium-grained sandstone and buff to purple siltstone. Bioturbated.
68	Base not seen.

LOCALITY: Bentley 1 : 250,000. Lat. 25° 16′ S, Long. 127° 21′ E.

Thickness (feet)	Lithology
3 Top	Dark brown ferruginous sandstone with pebbles, worm burrows and fossil fragments of wood.
12	Fine-grained yellow sandstone. Poorly cemented, poorly bedded. Many desiccation cracks.
1½	Finely laminated, fine-grained sandstone with desiccation cracks. Thin gypsum veins.
15	Fine-grained, white to cream sandstone. Poorly developed banding. Some worm burrows.
6	Variegated, very fine-grained sandstone with convolutions. Colours include maroon, white and ochre.
10	White, compact, very fine-grained sandstone. Bioturbated.
40	Variegated sandstone with liesegang banding. Some clay pellet bands.
87½	Base not seen.

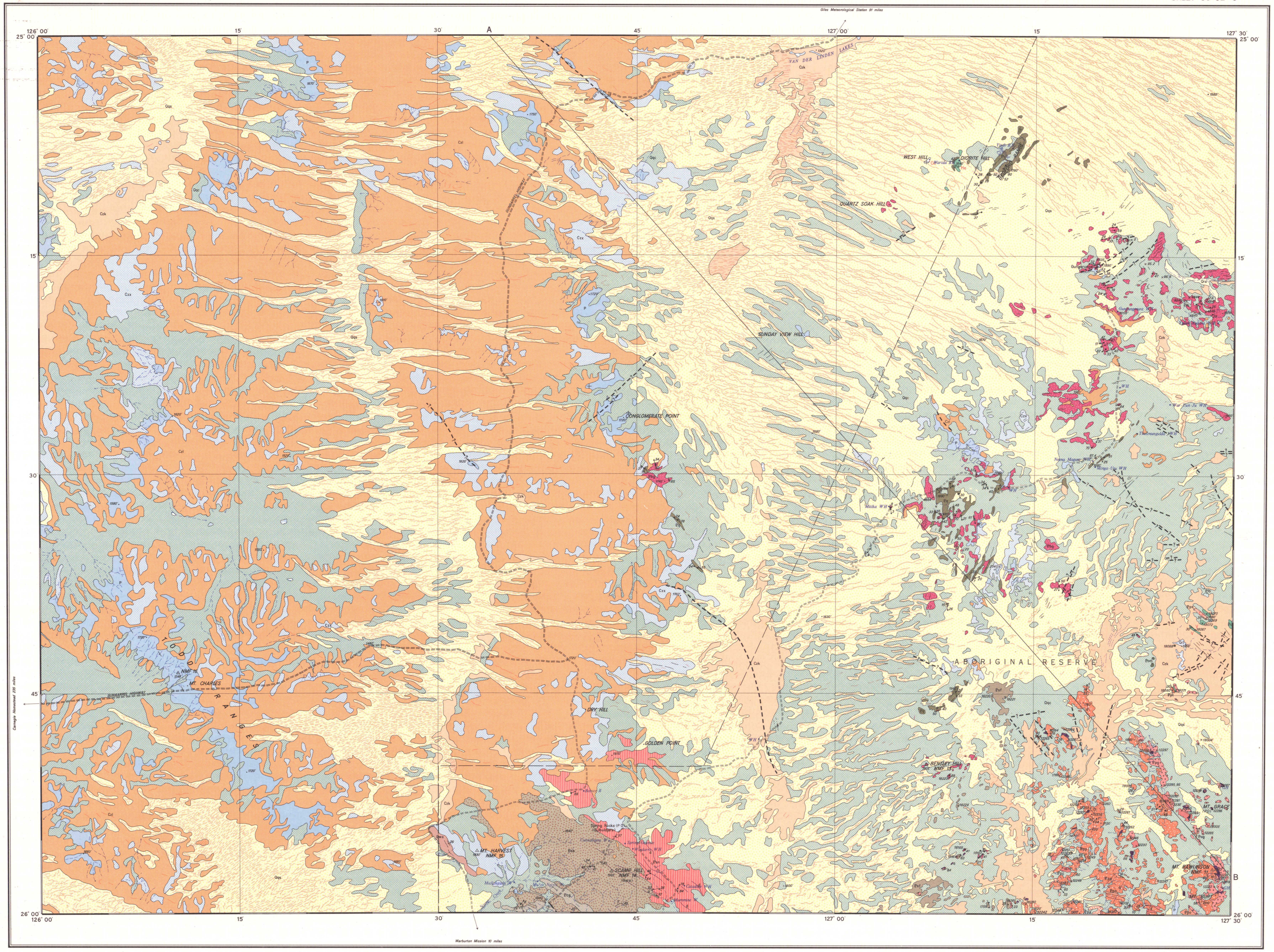
22243/70

BENTLEY

AUSTRALIA 1 : 250,000 GEOLOGICAL SERIES

GEOLOGICAL SURVEY OF WESTERN AUSTRALIA

SHEET SG 52 - 5



SYMBOLS

Geological boundary
Fault
- Approximate
- Concealed
- Inferred and concealed

Bedding
- Strike and dip measured
- Strike and dip unmeasured
- Horizontal
- Vertical
- Overturned
- Trend of bedding or foliation

Plunge of minor fold axis
Lineation with plunge
Elongation of stretched pebbles
Igneous banding
- Inclined

Metamorphic foliation
- Inclined
- Vertical

Cleavage
- Inclined
- Vertical

Current direction (cross-bedding)
Flow lineation in acid volcanics
Specimen locality — × 18333

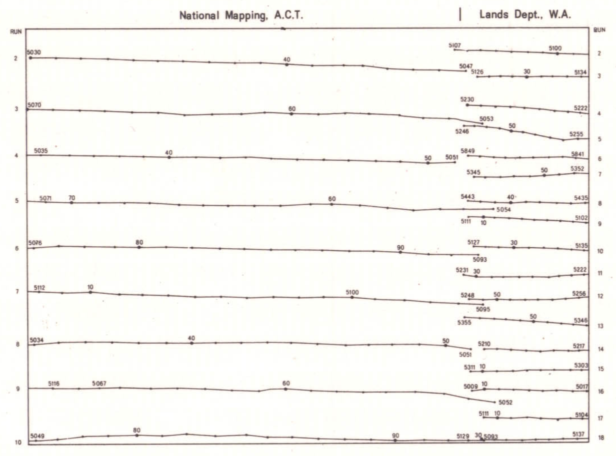
Aboriginal reserve boundary (approximate)
Highway, formed only
Track
Horizontal control, major
Spot height, approximate — • 1650'
Locality — Spring Rocks
Position doubtful — (P D)
Sand dunes

Watercourse, intermittent
Ancient drainage line, mainly in calcrete
Waterhole — • WH
Rockhole — • RH
Gnamma hole — • GH
Well — • W
Bore — • B

Mineral occurrence
- Copper — Cu
- Fluorite — Fl
- Hematite — He
- Ochre — Oc
- Titaniferous magnetite with vanadium — V

FLIGHT DIAGRAM

Air Photography by: Department of National Mapping, Canberra, May 1960 (scale 1: 87,500)
Lands and Surveys Department of Western Australia, February 1959 (scale 1: 40,000)



REFERENCE

CAINOZOIC — QUATERNARY
- Qra — Alluvium and river gravel
- Qrl — Lake deposits—clay and gypsum
- Qqs — Eolian sands
- Qqc — Colluvium—partly consolidated

CAINOZOIC — TERTIARY
- Czk — Calcrete, calcareous gravel and opaline silica
- Czl — Laterite and lateritic gravel
- Czx — Deeply weathered rock—weathering mainly affects Phanerozoic rocks

? UPPER PALAEOZOIC — ? PERMIAN
- P — Sandstone, porcelanous siltstone, and pebble beds—fluvioglacial and glacial deposits

MIDDLE PROTEROZOIC — Bentley Supergroup
- Ꝑws — **TOWNSEND QUARTZITE:** quartzite and sandstone

Palgrave volcanic association
- Ꝑpp — Porphyritic acid volcanic rocks. Some white pyritic rhyolite
- Ꝑpo — Devitrified obsidian—abundant perlitic cracks
- Ꝑpa — Agglomerate—acid volcanic fragments
- Ꝑpt — Tuff—epidotic, grey-green
- Ꝑps — Quartzite with minor acid lava and tuff

Scamp volcanic association
- Ꝑsr — Siliceous breccia—possibly associated with faulting in Ꝑsa
- Ꝑsf — Felsite—pink to brown, finely crystalline, altered Ꝑsa
- Ꝑsa — Porphyritic acid volcanic rock—abundant flow-banding, much white pyritic rhyolite

Not part of the regional layering. Confined to cauldron subsidence areas

Pussy Cat Group
- Ꝑcg — **GLYDE FORMATION:** amphibolite, mica schist and marble. Originally basic amygdaloidal lavas, tuff, shale, siltstone and dolomite
- Ꝑlb — Amphibolite and garnet amphibolite—originally amygdaloidal basic lavas
- Ꝑq — Quartzite and quartz-muscovite schist—well-bedded, relict cross-bedding

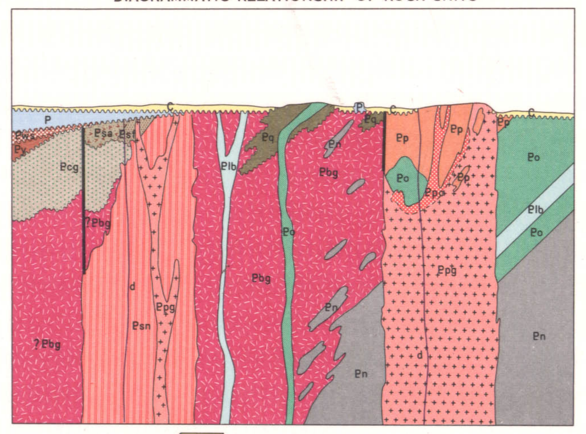
IGNEOUS ROCKS

MIDDLE PROTEROZOIC
- d — Dolerite sheets and dykes—several ages
- p — Pegmatite
- Ꝑpg — Granophyre and minor granite—genetically related to the Palgrave volcanic association
- Ꝑpc — Porphyritic microgranite—related to Ꝑpg

Giles Complex
- Ꝑo — Gabbro, troctolite, anorthositic gabbro —generally well banded
- Ꝑom — Contaminated gabbroic rocks
- Ꝑog — Granophyre—closely related to Ꝑo

- Ꝑsn — Granitic gneiss—closely related to Ꝑsa and Ꝑsf
- Ꝑbg — Complex of adamellite gneiss, adamellite and relict masses of granulite, much migmatisation

DIAGRAMMATIC RELATIONSHIP OF ROCK UNITS



- C — Undifferentiated Cainozoic
- Ꝑp — Palgrave volcanic association
- Ꝑy — Cassidy Group (not exposed)
- Ꝑn — Granulite and downgraded granulite
- Unconformity

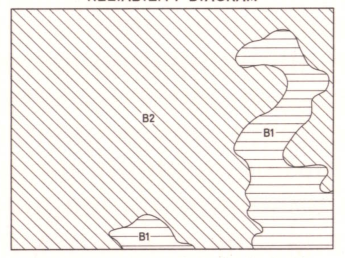
Compiled by Geological Survey of Western Australia. Cartography by Geological Drafting Section, Mines Department. Topographic base from compilations by Lands and Surveys Department, W.A. and Royal Australian Survey Corps, Department of Army.

Published by Bureau of Mineral Resources, Geology and Geophysics, Department of National Development, Canberra, A.C.T.

Copies of this map may be obtained from the Geological Survey of Western Australia in Perth; or the Bureau of Mineral Resources, Geology and Geophysics in Canberra, A.C.T.

Geology by J. L. Daniels, J. J. G. Doepel and R. A. Farbridge, 1967

RELIABILITY DIAGRAM



B1 Numerous traverses with air photo interpretation
B2 Air photo interpretation with a few traverses

HON. A. F. GRIFFITH, M.L.C.
MINISTER FOR MINES
J. H. LORD, DIRECTOR, GEOLOGICAL SURVEY

SCALE 1 : 250,000

5 0 5 10 15 20 Miles
10,000 0 10,000 20,000 30,000 Yards
5 0 5 10 15 20 25 30 Kilometres

UNIVERSAL TRANSVERSE MERCATOR PROJECTION
ZONE 52 AUSTRALIAN NATIONAL SPHEROID

INDEX TO ADJOINING SHEETS

WARRI SG 51-4	COBB SG 52-1	RAWLINSON SG 52-2
BROWNE SG 51-8	BENTLEY SG 52-5	SCOTT SG 52-6
YOWALGA SG 51-12	TALBOT SG 52-9	COOPER SG 52-10

DECLINATION DIAGRAM

The lines indicate magnetic declination, 1965.
+ means declination is east and correction must be added to compass bearing to give true bearing.
− means declination is west and correction must be subtracted from compass bearing to give true bearing.
Annual change is +1' easterly

DIAGRAMMATIC SECTION

NATURAL SCALE

SECTION A - B

Ꝑp Palgrave volcanic association

BENTLEY
SHEET SG 52 - 5

FIRST EDITION 1971