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THE GEOLOGY OF THE CONNEMARA, JUNDAH, CANTERBURY, WINDORAH, AND ADAVALE 1:250,000 SHEET AREAS, QUEENSLAND

by

C.M. GREGORY, B.R. SENIOR and M.C. GALLOWAY

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SUMMARY

This report describes the geology of portion of the south-west Eromanga Basin, a sub-basin in the Great Artesian Basin.

Geographically the area covered is in the arid zone of western Queensland and extends from near Adavale, west to near Betoota.

The stratigraphic succession as revealed by surface outcrop, ranges from the Lower Cretaceous Mackunda Formation to the Quaternary. Oil exploration wells throughout the area have revealed a subsurface sedimentary sequence ranging down to the lower Palaeozoic, with all periods younger than Silurian being represented.

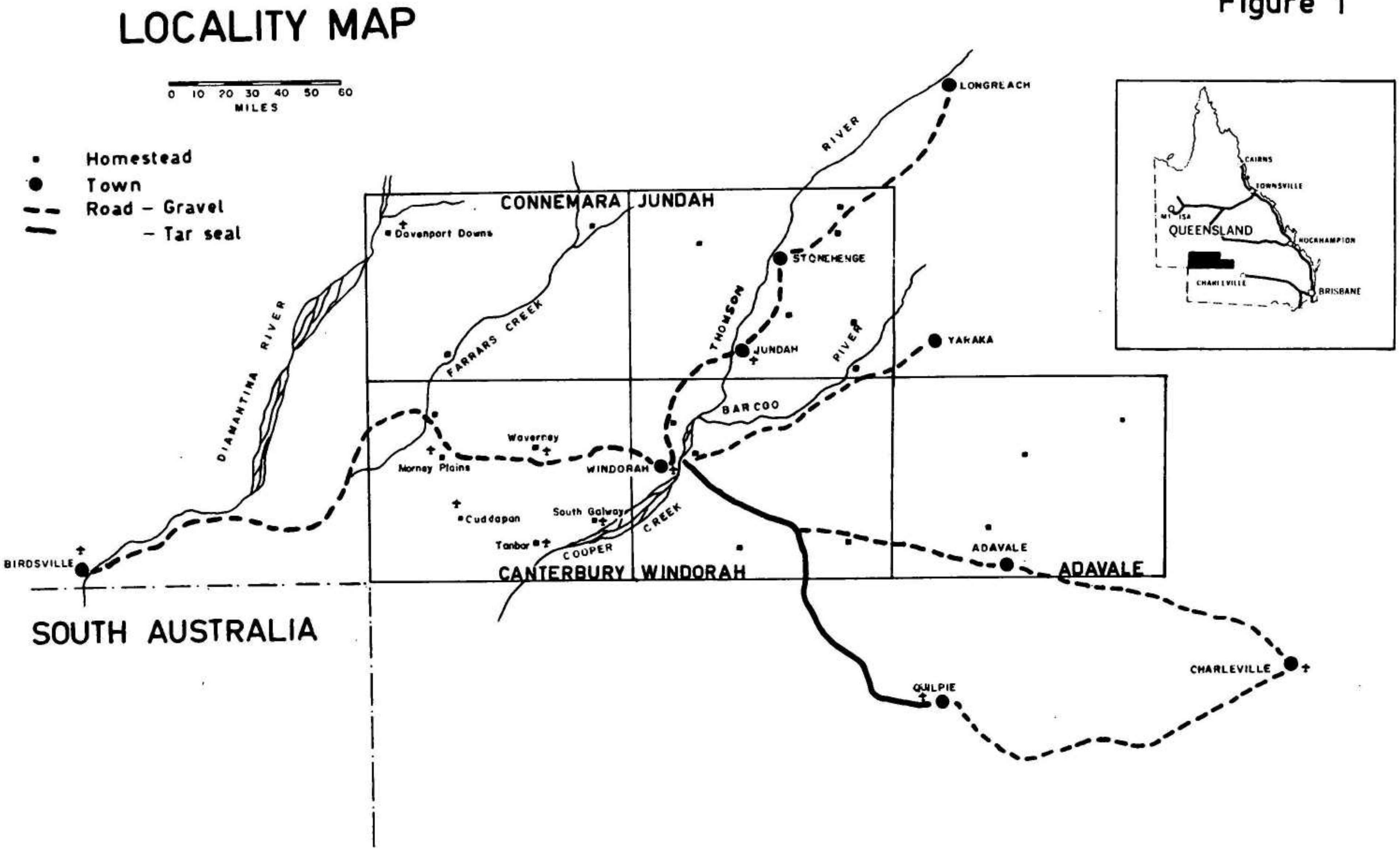
Periods of chemical alteration have profoundly effected Winton Formation sediments and Glendower Formation sediments beneath Tertiary peneplain surfaces.

There has been continuing tectonic activity throughout geological time extending into the Quaternary. This activity has produced numerous gentle folds and a few large faults. The Glendower Formation and particularly its upper beds, can be used throughout the area as a structural marker.

Geophysical surveys have covered large portions of the area. Gravity results are available for the whole area, seismic results are available for much of the eastern part, and aeromagnetic results for most of the western part.

The area is considered to have considerable petroleum potential. The Gilmore area has produced commercial quantities of petroleum gas from the Devonian, and Chandos No. 1 had significant oil shows in the Lower Triassic. So far oil wells in other areas have produced no significant traces of hydrocarbons. Artesian water is available throughout the area, but depths to the main aquifer ranges from about 1,000 to 5,000 feet. Subartesian water is available from shallow depths in most areas. Opal mineralization has been exploited in a number of places, but distribution of this mineral is restricted to a few small areas.

Figure 1



Bureau of Mineral Resources, Geology and Geophysics.

To accompany Record 1967/16

INTRODUCTION

The area mapped for this report lies between 24° and 26° south and 141° and 145°30 east, in the arid zone of Western Queensland. (Fig. 1)

Within this area the population is less than 0.25 persons per square mile, much of which is concentrated in the four townships, Windorah (population approximately 100) (Photo 1), Jundah (approximately 150), Stonehenge (approximately 100) and Adavale (approximately 80). These centres are linked with each other by gravel roads and Windorah is linked with Quilpie by a tar-sealed road. The nearest rail heads are at Quilpie (160 miles from Windorah), and Yaraka (about 130 miles from Windorah). There is one commercial airline operating a once a week flight from Brisbane to Windorah, and a once a fortnight flight to Jundah. The aircraft lands at five homesteads on the Canterbury Sheet area en route to Birdsville and Adelaide. There is also a fortnightly flight from Longreach to Davenport Downs Homestead.

Photo 1. Township of Windorah on edge of Cooper Creek flood plain.

The four towns are all linked by telephone and to centres outside the area as well as to some of the homesteads. Homesteads not linked by telephone rely on two-way radio contact with the Royal Flying Doctor network at either Charleville or Cloncurry for urgent communications.

There are small hospitals at Jundah and Adavale which are visited regularly by a doctor attached to the Royal Flying Doctor Service (based at Charleville), who also visits other selected centres of population as well as the numerous homesteads when required.

The area receives between five and twenty inches of rain a year; the western and south-western sections receive the least. The wettest months are December to March when more than three quarters of the annual rainfall occurs. The dryest month is August.

The average daily temperature ranges from 85° to 90° in summer to 55° to 60° in winter. The average maximum temperature in summer is 90° to 100° and in winter 65° to 70°.

The major land use is beef cattle and wool production. Sheep for wool, are grazed on Jundah, Adavale, and most of the Windorah Sheet areas. Cattle are bred and fattened on Canterbury and Connemara, and parts of Windorah Sheet areas. To the Cooper Creek channel country, south-west of Windorah, cattle are imported from north Queensland and fattened before being sent east for sale.

Water courses within the area drain into the major streams, the Diamantina River, Farrars Creek, Cooper Creek, Thomson River and Barcoo River, which in turn all flow south-west into internal drainage basins.

The field work for this report was carried out between mid-May and October, 1966, from a base camp on Cooper Creek, near Windorah, by C.M. Gregory and B.R. Senior (full time) and M.C. Galloway (for six weeks). At the start of the field season the area was introduced to Gregory and Senior by R.R. Vine. In August, Professor J. Mabbutt, University of N.S.W., visited the party for two weeks and contributed much to the geomorphological thinking on the area. Field traversing was done by 4-wheel drive vehicles, and observations from these traverses were supplemented by shallow drilling (B.M.R. drilling party, A. Zoska, driller), in a number of areas during August and the first two weeks of September. A light aircraft was chartered from Bush Pilots Airways (Pilot A. Ashton), and used for geological and geomorphological reconnaissance, and to position accurately many of the large number of bores shown on the maps.

Access within the area is good to all areas adjacent to the roads, but access by vehicle is very difficult in the areas of hills and the flood plain of Cooper Creek, away from roads. In the areas where sheep are grazed access is often impeded by high netting fences and this is especially so where the fences separate cattle country from sheep country. Seismic traverse lines afford some access to otherwise inaccessible country but these lines tend to become untrafficable and washed out after rain.

The area is covered by air photographs at 1:50,000 scale taken by Adastra in 1958 (Windorah, Canterbury and Connemara), and by the R.A.A.F. in 1951 (Adavale and Jundah); photo mosaics at 1 mile to 1 inch scale have been made from these air photos for the Windorah, Canterbury and Connemara Sheet areas, and at 4 miles to one inch for the Jundah and Adavale Sheet areas. Topographic base maps compiled from the air photos by the Division of National Mapping were used as the base for the geological maps, but numerous corrections and additions have been made.

PREVIOUS INVESTIGATIONS

Within the area mapped there has been little systematic geological investigation prior to this present survey. Woolnough (1927) and Whitehouse (1948, 1954), had both travelled through parts of the area and made brief notes on some aspects of the geology. More recently geologists with the B.M.R. and Geological Survey of Queensland have been engaged in systematic mapping in areas to the west, north and east in adjacent parts of the Artesian Basin, (see B.M.R. Records and Explanatory Notes by Vine, Reynolds, Jauncey, et al.).

In the mapped area where opal mineralization has been exploited there has been some local detailed geological investigation, but little of this work has been published. Generalised papers on opal mineralization have been compiled by a number of authors (Connah, 1966; Hiern, 1965; Noakes, 1949), and in these papers there are references to places within the mapped area.

A systematic reconnaissance gravity survey has been completed of the whole area on behalf of the B.M.R., (Lonsdale, 1965). Also, systematic aeromagnetic and seismic surveys by the B.M.R. and private companies have covered portions of the area. Detailed seismic surveys have been carried out over much of the Adavale Sheet area and the eastern part of the Windorah Sheet area. Details are discussed later under "Geophysical Surveys".

Other workers (Mabbutt, Jessup, Wopfner, Dury, Langford-Smith), have worked in adjacent areas of Queensland, South Australia, New South Wales and the Northern Territory, and have made observations on aspects of the Cainozoic geology in those areas that are applicable in this area.

Drilling by oil-search companies and by individuals seeking artesian and subartesian water have contributed much to the knowledge of the deep sub-surface geology. This knowledge was not added to by this survey, but is being added to by a gamma-ray logging program of deep artesian and sub-artesian bores, initiated by the B.M.R..

GENERAL PHYSIOGRAPHY

(by J.A. Mabbutt)*

The survey area of approximately 30,000 square miles forms part of the inland plains of south-west Queensland. Part of the Channel Country, it contains the floodplains of the Diamantina River in the west, Cooper Creek, with its tributaries the Barcoo and Thomson, and in the east the Bulloo River. It is drained south-westwards towards Lake Eyre by these rivers, which are subject to seasonal flooding. The altitude of the main river plains descends from 900 feet above sea level in the north-east to 400 feet in the south-west. The divides between the river flats consist of stony plains and flat-topped hills and plateaux with up to 400 feet of relief; the highest point of the area, 1174 feet above sea level, is in the Grey Range on Adavale Sheet.

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The mean annual rainfall at Windorah is 10.05 inches, and the amount increases north-eastwards across the area to about 15 inches. Cooper Creek, the largest river, drains an area of 60,000 square miles above Windorah with an average annual rainfall of 17 inches, and substantial floods occur about one year in four. The Diamantina drains about 20,000 square miles with somewhat lower annual rainfall, but is subject to more frequent smaller floods.

The six following types of landscape dominate the area, as shown in Fig. 2:

1. Plateaux These have gently sloping summits and prominent bounding escarpments formed by resistant siliceous duricrust (photo 14). Entrenched valleys and their dissected margins constitute only a minor part of the area. On the plateaux, outcrops of silcrete alternate with stony, soil-covered tracts and locally with sandplain. Plateau surfaces are particularly extensive on the divide between the Barcoo and the Bulloo (Powell Plateau).

2. Mesas and Plains (photos 6, 8, 10, 12). These landscapes, which represent a more advanced stage of dissection of the plateaux, consist of groups of flat-topped hills, small plateaux, and cuestas (photo 26), with silcrete cappings, above broadly undulating stony lowlands (photo 27) with alluvial flats. Relief locally attains 400 feet.

3. Rolling Downs (photo 11). These are broadly rolling lowlands with less than 20 feet of relief, often stony and with gilgaid surfaces. They have closely branching drainage systems with alluvial floodplains along the larger river channels. Within the survey area such plains are principally localized along axes of uplift, in areas of advanced stripping; however, they broaden and link up to the north.

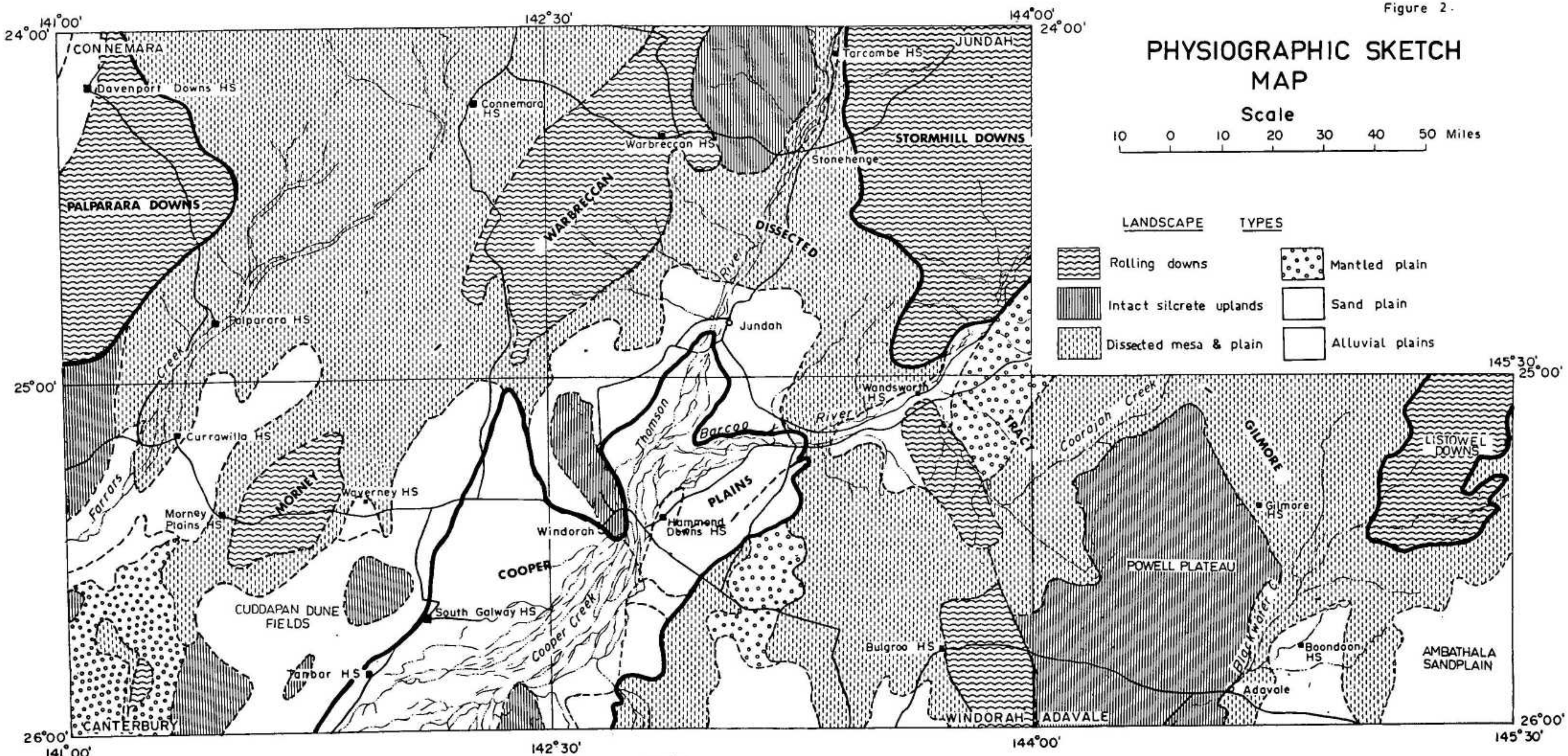
4. Stony Plains (photo 25, 28). These are strongly undulating surfaces characterized by abundant silcrete gravel derived from a former duricrust.

5. River Floodplains These are alluvial clay and silt plains of the larger rivers (Diamantina and Cooper), falling south-westwards with gradients of less than 1 foot per mile. They broaden downstream, particularly that of the Cooper, which attains 40 miles below Windorah. They are characterized by anastomosing systems of channels and flood depressions, with many billabongs, and by featureless backplains with marginal swamp depressions. They are subject to extensive flooding in the larger season "freshes".

6. Aeolian Sand Surfaces These comprise sandplain (Ambathala Sandplain) and dune ridges (Cuddapan Dune Fields, photo 20) generally about 30 feet high and up to a few miles long. They are particularly extensive in the south of the area, as on the borders of the Cooper floodplain. The sand surfaces are mainly vegetated and stable, but there is living sand on ridge crests and in areas of disturbance. Drainage entering such areas gives rise to numerous claypans (photo 19) and to complex dune networks. In the south there has been considerable encroachment of aeolian sands across the river plains (photo 18), and consequent disruption of drainage systems.

In Fig. 2 these types have been grouped into the following regional systems (constituent landscape types are given in parenthesis).

Figure 2.



Bureau of Mineral Resources, Geology & Geophysics. To accompany Record 1967/16.

Morney-Warbreccan-Gilmore Dissected Tract	an area which coincides with domal deformation and differential dissection of the duricrust; locally invaded by aeolian sand (2, 3, 4, 6)
Palparara Downs Stormhill Downs Listowel Downs	an extension southwards of broader plains to the north (3; minor 5 and 6)
Cooper Plains	river floodplains and adjacent and included sandy tracts (5; minor 6)

STRATIGRAPHY

INTRODUCTION

A general summary of the stratigraphy of the area is given in Tables 1 and 2. Table 2 allows a direct comparison of lithologies intersected in oil exploration wells, which are the only source of knowledge of all units older than the Cretaceous Mackunda Formation in the area mapped. This information has been extracted from well completion reports, on open file at the Bureau of Mineral Resources, Canberra, and from publications covering work done in adjacent areas of Queensland. Because of this, the descriptions and most of the discussions on all units older than the Mackunda Formation are in the form of a summary only.

"BASEMENT"

The term basement is used to denote igneous, metamorphic, or steeply dipping sediments, generally of Lower Palaeozoic age that underlie the potentially economic petroleum-bearing sedimentary sequence. The nature of the basement is different from area to area. In the eastern part of the area granite underlies Etonvale No. 1 and forms a basement high. To the south-west of here beneath Gumbardo No. 1 and Cothalow No. 1 and Yongala No. 1 the basement consists of altered basaltic and andesitic volcanics with minor metamorphosed sediments. Beneath Canaway No. 1, a basement high consists of quartz-mica phyllite and associated metamorphic rocks. Beneath Chandos No. 1, Galway No. 1 and the Warbreccan Nos. 2 and 3 wells the basement consists of steeply dipping indurated and low grade metamorphosed sediments. Granite is reported from Warbreccan No. 1.

The age of these various rocks is only approximately known. The sediments, altered volcanics and low grade metamorphics are thought of as Silurian to Ordovician. The granite at Etonvale No. 1 has been radiometrically dated at 429 m.y. (Upper Silurian) (Etonvale No. 1 Completion report).

DEVONIAN

Rocks of Devonian age have been identified in most of the petroleum exploration wells in the eastern part of the area and from lithological evidence are correlated with sediments as far west as Chandos No. 1 and Yongala No. 1.

Three formations have been recognised;

(a) Gumbardo Formation

(b) Gilmore Formation, and

(c) Etonvale Formation

The extent and thickness of these formations is shown in Figure 3.

(a) Gumbardo Formation

This unit was named from Gumbardo No. 1 where the unit consisted of reddish-brown acid welded tuff, altered lithic tuff and recrystallised crystal tuff with minor interbedded greywacke. Tuffaceous sandstone and shale are dispersed throughout but are more common in the upper part of the sequence (Gumbardo No. 1 Completion report). To the east in Cothalow No. 1 and presumably in Leopardwood No. 1 the sequence contains a much higher proportion of sediments in its upper portion. In Etonvale No. 1 the unit is predominantly arkosic sediments. To the west in Yongala No. 1 the unit is quite thin and is composed largely of volcanics in its upper portion which grade down into sediments.

In the predominantly arkosic sandstone sequence at Etonvale No. 1, there are also interbeds of siltstone, shale, and tuff. This sequence yielded a few marine fossils including the brachiopods Orbiculoidea sp. and Coelospira sp., as well as the pelecypod Orthonota sp. and some crinoid ossicles. These fossils indicate an uppermost Silurian or Lower Devonian age (Day and McKellar, Appendix 2, in Etonvale No. 1 Completion report).

The only other positive age determination of the unit is a radiometric (K-Ar) age of 384 - 40 m.y. (Middle ~~Lower~~ Devonian) from a welded tuff obtained between 10756 and 10776 feet in Gumbardo No. 1 (see Completion report).

The unit, which is quite limited in its extent compared with the overlying Mesozoic sedimentary sequence, forms the basal member of the Adavale Group (Tanner, 1966a).

(b) Etonvale and Gilmore Formations

The Etonvale Formation was first recognised and named in Etonvale No. 1, and has subsequently been recognised in many other oil exploration wells in the area mapped (see Figure 3), as well as in adjacent areas. Subsequently it was subdivided into two units, the name Etonvale Formation being retained for the upper part and the lower unit being called the Gilmore Formation (Tanner, 1966a). These two formations have been subdivided into a number of members denoted by D1 to D4 and a lower shale member. D1 to D3 are included in the Etonvale Formation.

TABLE 1: SUMMARY OF STRATIGRAPHIC UNITS

AGE	FORMATION (LETTER SYMBOL)	LITHOLOGY	STRATIGRAPHIC THICKNESS	RELATIONSHIPS	ENVIRONMENT OF DEPOSITION	PREVIOUS NOMENCLATURE	REMARKS
Quaternary	Q, Qa, Qs, Qg, Qc, Qf	Sand, silt, silcrete gravel, ferruginous gravel, gravel, rubble, breccia.	Superficial generally, may be in the order of 500 feet in axis of Cooper Creek, and other large streams.	Superficial deposit overlying all older units. Deposits are significant in the synclinal area.	Continental alluvial, colluvial and eolian.		
Cainozoic (Undifferentiated)	Czp	Limestone, chalcedony	6 feet.	Unconformable on older units.	Evaporite deposits in shallow lakes, pans and streams.		Correlates with similar deposits throughout western Queensland.
Tertiary (lower)	Glendower Formation Tg	Quartz sandstone, siltstone, breccia, minor quartz-pebble conglomerate.	Ranges up to 200 feet. Very variable.	Unconformably overlies the Winton Formation. Not in contact with Moses Sandstone, but presumed to be younger than Moses Sandstone.	Major river and continental lake system, with a few major axes of sedimentation, and many minor short-lived interconnecting channels.		Locally is a source of sub-artesian water.
	Moses Sandstone Ts	Quartz sandstone, siltstone.	In outcrop 60 feet, may be as high as 90 feet.	Disconformable on Winton Formation.	Restricted continental basin with periods of shallow water.		Sequence appears to have been effected by a period of mild chemical alteration, similar to that of the Winton Formation.
Lower-Upper to Lower Cretaceous	Winton Formation Kw	Calcareous labile sandstone, siltstone, mudstone, minor coal and carbonaceous siltstone and mudstone	Up to 2,800 feet in F.P.C. Galway No. 1.	Conformable on Mackunda Formation.	Continental freshwater.	Whitehouse (1954) included part of the now Mackunda Formation in the lower part of this unit.	The unit was peneplaned in the Tertiary, and beneath this peneplane a leached and altered profile up to 300 feet deep developed. This zone is locally mineralised with precious opal. Artesian and sub-artesian water have been obtained from the unit in many areas.
Lower Cretaceous	Mackunda Formation Klm	Calcareous labile sandstone, siltstone and mudstone, minor limestone. Numerous marine fossils locally.	200 to 800 feet	Conformably overlies Allaru Mudstone.	Paralic.	Whitehouse (1954) included the unit in his Winton and Tambo Formations.	
(Albian)	Allaru Mudstone Kla	Predominantly siltstone and mudstone, minor sandstone. Some calcareous and glauconitic beds.	Between 550 and 1250 feet.	Conformably overlies Toolebuc Limestone.	Shallow marine.	Included in Whitehouse (1954) Tambo Formation, and in Vine and Day (1965), is a Member in the Wilgunya Formation.	
(Albian)	Toolebuc Limestone Klo	Calcareous mudstone and limestone.	Up to 80 feet.	Conformable on Wallumbilla Formation.	Shallow marine.	Tambo Formation, (Whitehouse, 1954), and Toolebuc Member, (Vine and Day, 1965).	Is readily identifiable in subsurface sections where gamma-ray logs are available, hence is an excellent marker bed.

AGE	FORMATION (LETTER SYMBOL)	LITHOLOGY	STRATIGRAPHIC THICKNESS	RELATIONSHIPS	ENVIRONMENT OF DEPOSITION	PREVIOUS NOMENCLATURE	REMARKS
(Aptian to Lower Albian)	Wallumbilla Formation Kla	Blue-grey mudstone, siltstone, minor sandstone. Some glauconitic, calcareous and carbonaceous beds.	Between 700 and 1000 feet.	Conformable on "Hooray Sandstone".	Shallow marine to paralic.	Roma and Tambo Formations (Whitehouse, 1954), includes Doncaster, Jones Valley and Ranmoor, members of Wilgunya Formation (Vine and Day, 1965).	
Upper Jurassic to Lower Cretaceous	"Hooray Sandstone" J-Kh	Predominantly sublabile sandstone in the east to a sandstone and shale sequence in the west.	Up to 900 feet.	This "unit" is thought to contain an unconformity (Exon, 1966). The lower section is conformable on the Westbourne Formation.	Fluviatile, lacustrine in places, minor marine incursions.	Blythesdale 'Group' (Whitehouse, 1954)	An important aquifer, supplying water to most of the artesian bores in the area.
Upper Jurassic	Westbourne Formation Juw	Siltstone, shale, quartz sandstone, minor coal.	Between 100 and 400 feet.	Conformable on the Adori Sandstone.	Fresh water, lacustrine.		
Middle to Upper Jurassic	Adori Sandstone Ja	Quartz sandstone with minor siltstone and shale, in places carbonaceous.	Between 50 and 150 feet.	Appears to be conformable on Birkhead Formation.	?Fluviatile or lacustrine.	Walloon Coal Measures (Whitehouse, 1954)	Potential aquifer.
Middle Jurassic	Birkhead Formation Jmb	Carbonaceous shale and siltstone, coal, minor sandstone.	Between 200 and 400 feet.	Conformably overlies Hutton Sandstone.	Lacustrine.		
Lower to Middle Jurassic	Hutton Sandstone	Predominantly quartz sandstone, minor siltstone and shale.	Between 600 and 1200 feet.	Unconformable on older units.	Continental, minor marine incursions.		Potential aquifer.
Lower Triassic	R	Quartz sandstone, siltstone, shale, minor coal.	Up to 800 feet.	Unconformable on older units.	Continental, shallow to deep water.		
Upper Permian	P	Coal-bearing sandstone and shale sequence in the west, becoming less coaly with carbonaceous shale interbedded with shale and sandstone in the east.	Up to 300 feet.	Unconformable on older units.	Paludal		At A.O.D. Chandos No. 1 correlated with Gidgealpa Formation.
Lower Permian	P (Included with Upper Permian in map sections)	Sandstone, siltstone, shale, carbonaceous shale, minor coal.	Up to 700 feet.	Unconformable on older units.	Fresh water lucustrine.		
Carboniferous - Devonian	Buckabie Formation C	Red-bed sequence of sandstone, siltstone and shale.	Up to 5500 feet, but absent in some areas.	Conformable on Etonvale Formation.	Thought of as continental because of complete lack of marine fossils.		
Middle Devonian	Etonvale Formation De	Siltstone, sandstone and shale, dolomite in lower part of section.	Up to 2000 feet.	Unconformable on Gilmore Formation and older units.	Marine.		

AGE	FORMATION (LETTER SYMBOL)	LITHOLOGY	STRATIGRAPHIC THICKNESS	RELATIONSHIPS	ENVIRONMENT OF DEPOSITION	PREVIOUS NOMENCLATURE	REMARKS
Middle to Lower Devonian	Gilmore Formation Di	Sandstone, becoming more shaley towards the base. Minor dolomite.	Up to 2000 feet.	Unconformable on Gumbardo Formation and older units.	Marine.	Previously included in Etonvale Formation.	Contains petroleum gas at P-S Gilmore.
Lower Devonian	Gumbardo Formation Dg	Acid and intermediate volcanics and pyro-clastics with minor sediments. Includes more arkosic sedi-ments in the east.	Up to 2500 feet.	Unconformable on older units and on granite at P-S Etonvale No. 1.	Probably marine.		
Lower Palaeo-zoic	Pz	Includes meta-sediments, altered basalt and granite.					

TABLE 2

LITHOLOGICAL SUMMARY OF OIL EXPLORATION WELLS (INFORMATION OBTAINED FROM COMPANY REPORTS)

Formation or its equivalent	Warbreccan	Galway	Chandos	Yongala	Canaway	Gumbardo	Cothalow	Leopardwood	Gilmore No. 1	Log Creek	Etonvale	Bonnie
Cainozoic (Tertiary)		Quartz, sandstone, breccia, siltstone.	Quartz sandstone, sandy breccia, siltstone.			Mottled red and white breccia, and poorly sorted material.	Siliceous and ferruginous clay; grey, white red-brown and yellow.	Red-brown hard dense breccia, light grey quartz sandstone.	Quartz, sandstone, fine to coarse, angular to rounded grains.	Quartz sandstone, mottled sandy breccia.		
Winton Formation	Light blue-grey shales, labile and argillaceous sandstones; few porous beds.	Labile sandstone, siltstone, abundant carbonaceous remains; some calcareous cement. Some thin coal seams.	Carbonaceous shale with plant fragments, fine grained labile sandstone and coal.	Carbonaceous shale with plant fragments; fine grained, labile, poorly porous sandstone and coal.	Shale: grey sometimes carbonaceous; siltstone: grey and argillaceous moderately calcareous, Sandstone: light grey, fine to medium grained, labile, some calcareous cement.	Clay and shale, brown to grey, in part silty and carbonaceous; fine to medium argillaceous sandstones interbedded, some are calcareous. Minor coal towards base.	Grey carbonaceous shale, interbedded with grey argillaceous siltstone and fine to medium grained sandstone, sometimes calcareous. Thin coal seams in lower part.	Grey-green-blue shale, some carbonaceous; siltstone grey, in part carbonaceous, some pyrite; sandstone light grey, medium to coarse; some thin coal.	Grey-brown silty shale in part carbonaceous; grey to grey-green sandstones interbedded. Numerous thin coal seams.	Interbedded sandstone and shale, with thin coal seams becoming more abundant towards the base.	Light grey, mainly fine grained, normally argillaceous and carbonaceous sandstone; light grey to green siltstone and mudstone. Numerous coal seams towards base.	Sandstone and minor siltstone, numerous thin coal seams. (No details in report).
Mackunda Formation	Light grey shale dominates. Minor sandstone.	Carbonaceous grey siltstone and mudstone.	Sandstone, siltstone and shale, grey-brown, calcareous in part; some carbonaceous beds.	Carbonaceous shale with plant fragments, fine grained labile, poorly porous sandstone and coal.	Light grey sandstone, moderately calcareous, moderately to strongly carbonaceous, with interbeds of argillaceous siltstone and shale. Some quartzose beds. Abundant calcareous beds towards base.	Grey and brown shale, siltstone and sandstone. Some calcareous cement. Minor coal towards base.	Grey carbonaceous shale, laminated and interbedded with white to grey argillaceous siltstone and sandstone, occasionally hard and calcareous. Thin coal seams.	Sandstone and shale (no details in report).	Light to medium grey, very fine to fine, argillaceous sandstone with minor interbedded shales.	Sandstone, minor siltstone and shale. (No details in report).	Alternating grey to grey-brown carbonaceous shale and grey to white sandstone; thin coal throughout.	Sandstone, minor siltstone and shale. (No further details in report).

Formation or its equivalent	Warbreccan	Galway	Chandos	Yongala	Canaway	Gumbardo	Cothalow	Leopardwood	Gilmore No. 1	Log Creek	Etonvale	Bonnie
Allaru Mudstone	Light grey shale and sandstone.	Calcareous grey siltstone and mudstone.	Sandstone, siltstone, and shale; calcareous in part(?).	Calcareous dark grey shale with marine fossils.	Dark grey to black shale interbedded with minor siltstone. Beds slightly calcareous with carbonaceous flecks and minor pyrite.	Grey soft silty shale with shell fragments and interbedded sandstone. Beds are slightly calcareous and carbonaceous, with traces of glauconite and mica.	Medium to dark grey fossiliferous shale with thinly laminated grey friable siltstone and fine grained sandstone.	Shale: grey to dark green, silty in part slightly calcareous, interbedded with grey carbonaceous siltstone. Numerous shell fragments.	Shale, light grey to brown, carbonaceous with interbedded sandstone, greenish-grey, fine grained, silty, slightly calcareous; grading down into glauconitic silty shale. Numerous shell fragments.	Shale (no details in report).	Light and dark grey shale with minor interbedded grey siltstone and sandstone; abundant fossil shell fragments.	Shale (no further details in report).
Toolebuc Limestone	(No details)	Brown limestone and marl.	Dark grey shale. Marl, dark brown, soft, laminated, very fossiliferous and carbonaceous.	Dark grey shale. Dark brown fissile marl. Carbonaceous shaly limestone.	Dark brown calcareous shale with abundant white calcareous specks.	(Not mentioned in report)	Dark brown white-speckled calcareous shale.	(Not mentioned in report)	(Not mentioned in report)	(No details in report)	Dark brown shale with buff specks and laminations.	(No details in report).
Wallumbilla Formation	Blue-grey shale and sandstone. Some porous beds.	Grey-black fissile micaceous shale, slightly calcareous, with fine streaks of fine grained argillaceous sandstone, glauconitic in part.	Light grey to brown shale and sandstone. Calcareous and often contain glauconite. Thin beds of limestone. Some carbonaceous material.	Dark grey to black calcareous, silty, carbonaceous, fossiliferous and glauconitic shale grading to fine grained glauconitic sandstone. Occasional thin limestone beds.	Dark grey to black, calcareous, shale with minor glauconite and a trace of pyrite, becoming moderately glauconitic towards base, thinly interbedded with siltstone. Fragmentary fossils.	Grey silty carbonaceous shale with minor interbedded siltstone. Several thin coal seams. Shell fragments and glauconite-rich beds are present throughout.	Grey, fossiliferous shale with thin interbeds of siltstone and dark brown limestone lenses.	Mottled white grey, green calcareous, carbonaceous glauconitic sandstone in upper part, grading to similar coloured shale and siltstone. Thin beds of limestone.	Grey silty, shale carbonaceous and slightly calcareous; grading into siltstone and fine grained sandstone. Lower part is glauconitic, and limestone percentage increases.	Shale with minor sandstone. (No further details in report).	Grey, occasionally silty and carbonaceous shale; rare brown limestone; light grey fine grained glauconitic shale common in lower section. Minor fossils.	Shale. (No details in report).

Formation or its equivalent	Warbreccan	Galway	Chandos	Yongala	Canaway	Gumbardo	Cothalow	Leopardwood	Gilmore No. 1	Log Creek	Etonvale	Bonnie
"Hooray Sandstone"	Porous sandstone interbedded with blue-grey shale.	Interbedded white argillaceous sandstone and grey fissile micaceous shale.	(Aa) Very fine grained sandstone grading to siltstone; (A) Fine to coarse grained poorly sorted quartz sandstone; (B) Grey carbonaceous siltstone and shale. (C) Fine to coarse grained quartz sandstone, minor shale; (D) Carbonaceous shale and siltstone, interbeds of sandstone; (E) Coarse to fine clean quartz sandstone; (F) (Top part) carbonaceous shale and siltstone.	(A) Fine to medium grained, white, well sorted quartz sandstone; (B) Dark grey brown shale, in part calcareous with interbeds of sandstone; (C) Light coloured quartz sandstone. Thin interbeds of carbonaceous shale; (D) Dark coloured siliceous and carbonaceous shale, minor sandstone; (E) Coarse to medium quartz sandstone; (F) Grey carbonaceous siltstone; (G) Sandstone.	Top section is 80 feet of sandstone, then mainly dark grey shale with interbeds of silt to 3237 feet. Section becomes very strongly sandy (quartz), with minor shale and siltstone.	Sandstone, white, unconsolidated, medium to very coarse grained, slightly calcareous with very minor silty and shaly streaks.	White to buff, fine to coarse grained, moderately to well sorted; friable to massive quartz sandstones; thin interbeds grey to brown carbonaceous shale and silty shale with thin coal streaks.	Quartz sandstone, light grey-green poorly sorted poorly consolidated, carbonaceous glauconitic; interbedded with shale and siltstone.	Grey-brown carbonaceous shale, interbedded with white to light grey-green, silty to very coarse grained sandstone. Some beds unconsolidated. Sandstone dominant in lower section.	Sandstone with shale interbeds becoming more abundant towards base. (No further details in report).	White fine to coarse sandstone, unconsolidated to calcareous, grading down to grey carbonaceous and calcareous siltstone and shale. Very minor coal in shaly intervals.	Sandstone with minor interbeds of siltstone.
Westbourne Formation	Dark grey shale.	Grey micaceous sometimes silty shale with traces of coal and interbeds of fine grained compact kaolinitic sandstone.	(F) Grey to brown carbonaceous shale and siltstone; (G) Quartz sandstone, in part calcareous, interbedded with shale; (H) Carbonaceous shale, siltstone and sandstone. Some calcareous	(H) Carbonaceous shale and siltstone interbedded with quartz sandstone.	White to brown, fine to coarse grained sandstone, in part calcareous, interbedded with grey carbonaceous shale.	Glauconitic calcareous and carbonaceous shale interbedded with fine to medium grained sandstone. Sandstone becomes dominant in lower section.	Sandstone interbedded with shale and thin coal in upper section, grading to an interbedded sequence of shale, white siltstone and fine grained sandstone.	Interbedded sequence of white to grey fine to medium grained, sandstone, white siltstone and grey to green shale.	Brown, fine grained, sandy, carbonaceous siltstone and interbedded shale; sequence becomes more sandy towards base of section.	Shale with minor sandstone. (No details in report).	Shale (carbonaceous) and white siltstone, minor sandstone. Thin coal seams in shale zone.	A sandstone and shale sequence, shale predominant. (No details in report).

Formation or its equivalent	Warbreccan	Galway	Chandos	Yongala	Canaway	Gumbardo	Cothalow	Leopardwood	Gilmore No. 1	Log Creek	Etonvale	Bonnie
Adori Sandstone	White, fine grained sandstone with minor grey shale.	Fine to coarse grained greyish porous sandstone, with rare streaks of shale.	Lower "H" "I", Upper "J" Light grey to white, very fine to fine, well sorted, sub-angular to angular sandstone. Good porosity and permeability.	"I" White, fine to coarse grained, angular to sub-rounded quartz sandstone. Good porosity.	White, fine grained, medium sorted, sub-angular quartz sandstone. Friable and porous. Some thin carbonaceous and calcareous beds.	White, poorly consolidated medium to very coarse, slightly calcareous sandstone with very minor silty and shaly streaks.	White, fine medium and coarse grained sandstone; interbedded with minor silty shale.	White, medium to coarse grained, well sorted sandstone; pale brown, micaceous and carbonaceous siltstone.	White to grey brown, loose to friable, medium to coarse grained, well sorted, slightly carbonaceous, sandstone, grading to siltstone in places.	Sandstone. (No details in report).	Predominantly fine to coarse sandstone, poorly consolidated to calcareous; minor shale interbeds.	Sandstone. (No details in report).
Birkhead Formation	Alternating sequence of shale and sandstone.	Grey micaceous, sometimes silty shale with intercalations of brown argillaceous siltstone and streaks of coal.	Lower "I", Upper "J". Grey to brown carbonaceous siltstone and shale with interbedded coal.	"J" Brown carbonaceous shale interbedded with minor siltstone and sandstone.	Grey to green carbonaceous shale interbedded with grey carbonaceous siltstone.	Brown and grey, carbonaceous shale and siltstone, with a few thin coal seams. Sequence grades down into sandstone.	An interbedded sequence of shale, siltstone and sandstone, becoming more sandy towards the base.	An interbedded sequence of sandstone and shale. (No details in report).	Grey, brown and green, carbonaceous shale with minor interbeds of siltstone. Sandstone common in lower sections.	Sandstone with minor interbedded shale. (No details in report).	Alternating brown to dark grey carbonaceous silty shale and mudstone with white poorly consolidated sandstone.	An interbedded sequence of sandstone and shale. (No details in report).
Hutton Sandstone	An alternating sequence of sandstone and shale. (No further details available).	Porous, friable sandstone, with minor beds of grey shale in upper part. Lower part grey-brown silty shale and sandstone. Poorly consolidated sandstone and coal towards base.	Lower "J", "K", "L". Light grey, very fine to coarse grained, angular to rounded, poor to fair sorted quartz sandstone interbedded with dark grey and brown pyrite shale and carbonaceous siltstone.	"K", "L". Sandstone with minor interbedded shale, siltstone and coal. The sandstone is white to grey fine to coarse grained, moderately well sorted with angular to subrounded grains of quartz, weathered feldspar and garnet. Shale is grey to brown, silty and carbonaceous.	Sandstone: white to grey fine to coarse grained, poor to well sorted, angular, quartzose; minor shale and coal beds. Basal 60 feet conglomeratic with quartz and metamorphic rock pebbles.	White, poorly consolidated, fine to medium grained sandstone, minor glauconite, some calcareous cement, interbedded with grey carbonaceous shale. Minor coal beds occur throughout.	White sandstone interbedded with shale in upper part (to 5000 feet); then grey shale, thin coal seams and buff and white fine grained sandstone. Lower 50 feet white poorly sorted, fine to coarse grained quartz sandstone, some calcareous cement.	Predominantly sandstone with shale interbedded in places, especially in the lower part of the unit.	White to grey fine to coarse grained, moderately sorted, poorly consolidated subangular to subrounded, carbonaceous sandstone, with a few thin interbeds of carbonaceous shale between 5450 feet and 5600 feet. Below 5600 feet well sorted friable sand-	Predominantly sandstone with some interbedded shale at 5200 feet and 5400-5500 feet. (No details in report).	White fine to medium grained sandstone becoming fine to coarse grained and poorly sorted downwards; minor interbedded grey and brown silty carbonaceous shale. Sandstones are occasionally calcareous in lower section.	Sandstone with zones of interbedded shale. Coal seams associated with the shaly zones.

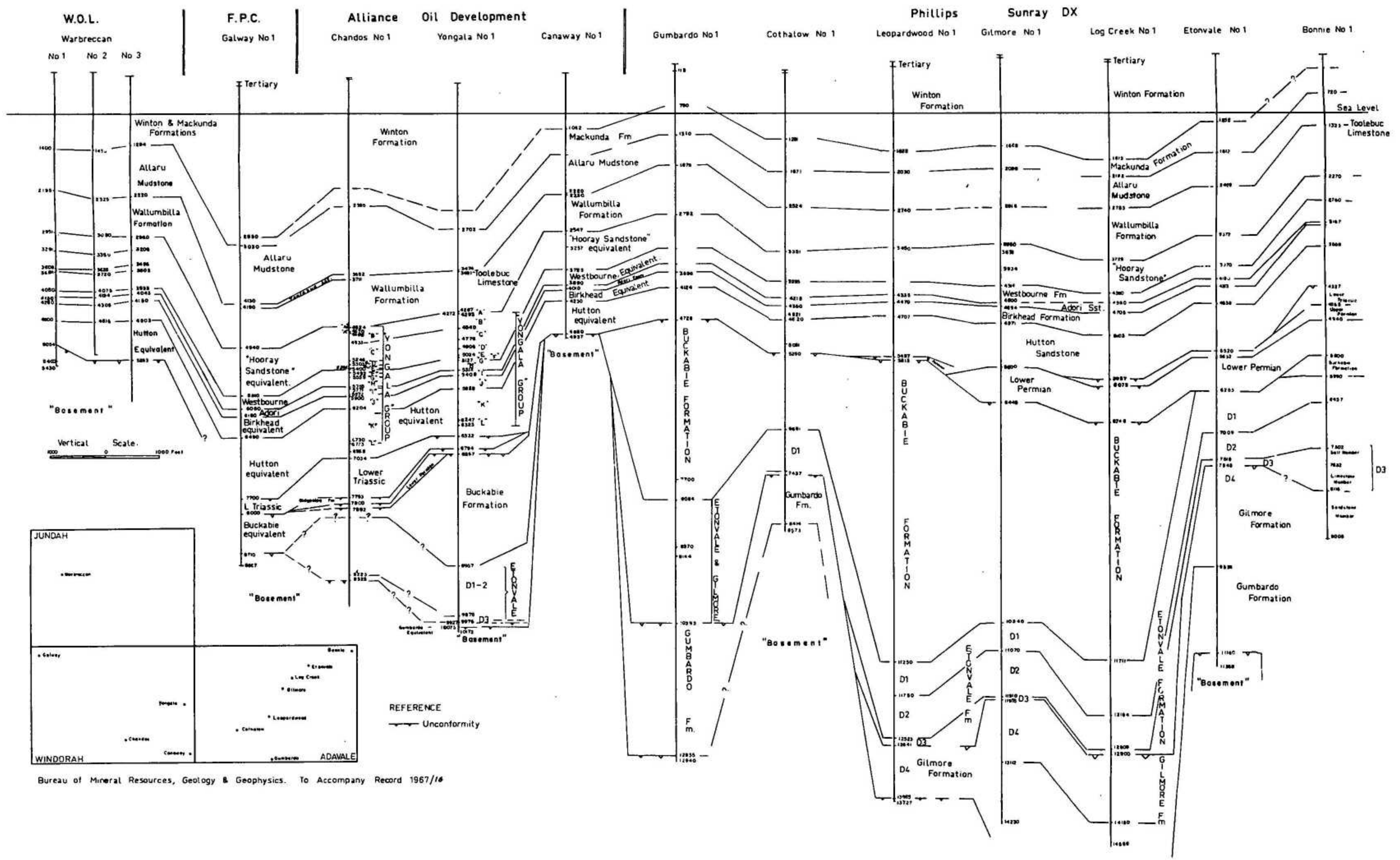
Formation or its equivalent	Warbreccan	Galway	Chandos	Yongala	Canaway	Gumbardo	Cothalow	Leopardwood	Gilmore No. 1	Log Creek	Etonvale	Bonnie
Lower Triassic		Upper section grey and red-brown silty shale, grading to grey-green siltstone and fine sandstone. Lower section medium grained porous sandstone, minor shale.	Interbedded grey shale and siltstone (both carbonaceous), together with light grey, fine to medium grained quartz sandstone.	Interbedded sandstone, shale, siltstone and coal. The sandstone is quartzose, white to light brown, fine to medium grained, with moderately well sorted and angular grains. Shale is grey-brown, silty and carbonaceous, or white to grey and micaceous. The siltstone is grey-brown, sandy, carbonaceous and micaceous.								Interbedded sandstone and shale. (No details in report).
Upper Permian			(Gidgelpa Fm.). Coal interbedded with thin beds of quartz sandstone and dark carbonaceous shale.	Mainly coal with minor shale, siltstone and sandstone.				Interbedded carbonaceous shale and sandstone.		Interbedded sandstone and shale. (No details in report).	White to buff fine to coarse, subangular to subrounded quartz sandstone. Minor silty carbonaceous shale.	Interbedded grey shales and porous sandstone.
Lower Permian			Coal with interbedded quartz sandstone and carbonaceous shale.						Grey to brown shale to 6120 feet. Then white to green slightly calcareous quartz sandstone.	An interbedded sequence of sandstone and shale. (No details in report).	Grey to brown shale, in part silty and carbonaceous, with interbedded siltstone, and white to grey sandstone. Unit becomes more sandy towards base.	An interbedded sequence of shale and sandstone, becoming more sandy with depth.

Formation or its equivalent	Warbreccan	Galway	Chandos	Yongala	Canaway	Gumbardo	Cothalow	Leopardwood	Gilmore No. 1	Log Creek	Etonvale	Bonnie
Buckabie Formation		Compact red-brown siltstone and shale, grading to fine grained sandstone in places.	Grey to green, fine to medium grained quartz sandstone, interbedded with grey-beige and green siltstone.		Green to red fine to coarse grained poorly sorted, subangular to angular labile sandstone, with interbedded grey-green, red shale and siltstone.	Sandstone: pink to red-brown, fine to coarse, poor to moderate sorting friable to moderately compacted, silty to argillaceous, ferruginous near bottom.	Fine grained, red-brown, quartzose sandstone, and red-brown, micaceous shale which occurs as thin partings in the sandstone.	An interbedded sequence of red-brown siltstone, red-brown shaly, fine to coarse grained sandstone, and grey, green and brown shale.	Dominantly white to grey (becoming red downwards) very fine to medium, moderately well sorted, in places calcareous sandstone interbedded with red-brown shale and very minor grey-brown calcareous siltstone.	Predominantly reddish shaly sandstone, with some thick permeable zones.		A uniformly interbedded sequence of sandstone and shale.
Etonvale Formation			D1-2 Member Vari-coloured siltstone grading to sandstone (quartzose), in places. Also interbeds of slightly calcareous shale. D3 Member Dolomite and dolomitic shale. Very hard, fine grained rocks.	D1-2 Member Sandstone: red brown, green, fine to coarse quartz and feldspar grains in a siliceous, calcareous or clay matrix. Minor mica; some conglomerate pebbles of quartz and phyllite. Shale: red, red-brown micaceous, calcareous and dolomitic towards base.		Shale: very sandy, buff-grey, hard, dense, slightly calcareous argillaceous, silty in part. Dolomite: brown, hard, dense, shaly, silty. Conglomerate: sandy, grey, friable, calcareous. Sandstone: white, medium to coarse, hard, tight, quartzitic, with shale interbeds. Subgreywacke: white to green, tight, conglomeratic in part, micaceous, carbonaceous, traces of pyrite, shell fragments.	D1 Member Shale and dense variegated siltstone with minor fine grained sandstone with calcareous cement. D2 Member Buff to grey, fine to coarse quartz sandstone, (poorly sorted, friable, fair porosity) with red-brown shale partings.	D1 Member Siltstones and shales. D2 Member Fine grained, shaly sandstone and shale. D3 Member White, grey and brown, dense sandy dolomitic limestone.	D1 Member Red-brown to green siltstone and fine sandstone grading abruptly to shale with minor siltstone. D2 Member Pale grey-green fine grained quartz sandstone and minor siltstone. D3 Member Brown microcrystalline, in part silty, dolomite.	D1 Member No details in report. D2 Member Thin, grey-green tight lithic sandstones with minor interbeds of shale. D3 Member Grey, finely crystalline, dense, dolomitic shale with minor sandstone and shale.	D1 Member Sandstone: grey-green to orange-red, poorly sorted angular to rounded quartz, feldspar and volcanic grains. Minor shale and claystone interbedded. D2 Member Varicoloured shale and sandstone sequence. Carbonate content increases downwards. D3 Member Brown dolomite, dense, microcrystalline; minor sandy interbeds.	No description in report D1 Member Interbedded sandstone and shale. D2 Member Alternating sandy and shaly sequence. D3 Member Salt, limestone.

Formation or its equivalents	Warbreccan	Galway	Chandos	Yongala	Canaway	Gumbardo	Cothalow	Leopardwood	Gilmore No. 1	Log Creek	Etonvale	Bonnie
Gilmore Formation								D4 Member Sandstone: white, grey, pink, medium to very coarse angular quartz, abundant feldspar minor lithics, in micaceous clay matrix, which becomes increasingly siliceous towards base. Below 13000 feet interbeds of shale and tuffaceous siltstone.	D4 Member White-green quartzose dolomitic sandstone. Lower Shale Member Grey to brown silty, micaceous shale. In part fossiliferous, with some interbeds of quartz sandstone.	D4 Member Poorly sorted fine to coarse grained quartz, feldspar, lithic sandstone with interbedded shale. Lower Shale Member Dark grey, siltu calcareous and micaceous shale with minor siltstone, dolomite, limestone, and argillaceous sandstone.	D4 Member Quartzose sandstone with green and red claystone interbeds, becoming more calcareous with depth.	D4 Member Sandstone to 8300 feet, then limestone becoming more shaly at depth.
Gumbardo Formation				Trachytic flows grading down into sediments.		Red-brown acid welded tuff, lithic tuff, crystal tuff.	Sandstone and shale grading down to tuff.	Volcanics. (No details in report).			Silty, micaceous shale, sandstone, becoming arkosic in lower section interbedded with tuff throughout.	
"Basement"	Indurated shale and sandstone. ?Granite.	Thinly bedded grey-green, fine grained quartzite and dark-grey shale.	Shale and sandstone, micaceous with calcareous cement.	Schist and basalt.	Mica-quartz phyllite.	Altered olivine basalt.	Basaltic andesite.				Granite.	

DIAGRAMMATIC CROSS SECTION
Connecting Oil Exploration Wells

Figure 3



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Correlation of these units throughout the area is based on palaeontological and palynological evidence, however their tentative extension to the west to Chandos No. 1 is based only on lithological similarities.

Briefly, lithologies represented are:

D1: Fine clastics, essentially shale and siltstone.

D2: A predominantly sandstone sequence but becoming more calcareous, with varying amounts of shale and siltstone.

D3: Generally dolomite and dolomitic shales, but at Bonnie No. 1 there is a marked thickening of the section representing the D3, and also a change in lithology to an evaporite sequence underlain by limestone. This sequence is similar to that at Phillips-Sunray Bury No. 1 to the east (Augathella Sheet area), but the evaporites thin to the west.

D4: Quartzose sandstone, in parts dolomitic, with minor interbeds of shale and siltstone.

Lower Shale Member: Silty and calcareous shale, minor siltstone and sandstone.

The age of the unit as a whole is well established as Middle to Lower Devonian from palynological and palaeontological evidence (see Well Completion report appendices, and Tanner, 1966a). The various members are subdivided on lithologies and not on palynological or palaeontological evidence.

These units formed in a marine environment which was punctuated by a period of shallowing of the overall depth of water. A period of uplift and erosion followed, prior to a further marine incursion producing an unconformity between the Gilmore Formation and the Etonvale Formation. This was followed by a further period of deeper water deposition.

DEVONIAN TO CARBONIFEROUS

Buckabie Formation

The Buckabie Formation was named by Phillips Petroleum Co. in 1964 from their Buckabie No. 1 well (Quilpie Sheet area) about 20 miles to the south-east of Canaway No. 1.

This unit subcrops the Permian and Mesozoic sequence in nearly all the oil exploration wells throughout the eastern part of the mapped area. It grades down into the Etonvale Formation without any obvious unconformity.

The Buckabie Formation is a sandstone, siltstone, and shale sequence, typical red in colour but with numerous interbeds ranging in colour from green to grey and brown.

The age of the unit is not well established since it is completely lacking in spores and also marine fossils. It is considered to be Carboniferous to Upper Devonian, but may extend into the Middle Devonian.

The environment of deposition of the unit is likewise not well known but is thought of as continental because of the lack of marine fossils.

PERMIAN

Permian sediments were intersected in most of the oil exploration wells in the area but are missing from the sections at Canaway No. 1, and Cothalow No. 1 and Gumbardo No. 1 as well as Warbreccan wells. At Yongala No. 1 and Leopardwood No. 1 only Upper Permian is present, and at P.-S. Gilmore No. 1 only Lower Permian is present. In the other wells on which information is available (see Figure 3), two Permian units are present.

LOWER PERMIAN

Unnamed sediments, identified on palynological evidence as Lower Permian (and in some areas extending down to the Upper Carboniferous), range in lithology from a quartzose sandstone, carbonaceous shale, coal sequence at Yongala No. 1, to an interbedded sequence of sandstone and shale with only minor carbonaceous material in the more eastern oil exploration wells. These two areas appear to have been separated by a regional high which extended from the Canaway area north-east to near Gilmore and which persisted in this area from Carboniferous to Jurassic times.

UPPER PERMIAN

The Upper Permian sediments onlapped the regional high that developed in Carboniferous times between the Canaway and Gilmore areas, and were deposited in an area that included Yongala No. 1 and Leopardwood No. 1, as well as areas adjacent to Chandos No. 1 in the south-west and most of the wells to the north-east, around Gilmore. The absence of Upper Permian sediments at Gilmore is probably due to local stripping of a fairly thin initial sequence.

Lithologically there is a range from a coal-bearing, sandstone and shale sequence at Chandos No. 1 and Yongala No. 1 to a sequence of shale, sandstone and carbonaceous shale to the north-east. Alliance Oil Development (Well completion report, Chandos No. 1), have correlated their Permian sequence (both upper and lower), at Chandos No. 1 with the Gidgealpa Formation recognised in the Gidgealpa wells in South Australia, (Delhi Australian Petroleum Ltd). Elsewhere no correlations have been attempted with known units.

The age of this Upper Permian sequence is well established on palynological evidence. There is a distinct break between this sequence and the Lower Permian sequence, again established on palynological evidence.

TRIASSIC

Sediments of Triassic age appear to have been very limited in their extent in the area mapped. They have been intersected only in Galway No. 1, Chandos No. 1 and Yongala No. 1 and Bonnie No. 1. Table 2 summarises the lithologies. The Well Completion report for Bonnie No. 1 gives no details of the lithology or age of the unit other than equating it with the Clematis sandstone (predominantly quartzose and sublabile sandstone - Exon, 1966a). In the Galway, Chandos and Yongala areas the sequence consists of quartz sandstone, siltstone, shale and coal, and indicates a different environment of deposition to that of the eastern area. The sediments are reported (Chandos No. 1 Completion report), to be similar lithologically to Triassic sediments intersected in Delhi Santos wells at Gidgealpa and Innamincka to the south-west, in South Australia.

Lower Triassic spores have been identified, (Appendix 2, Chandos No. 1 Completion report), from cores taken from between 7,525 feet and 7,724 feet in the Chandos well. No definite evidence of age has been obtained from the comparable section at Yongala No. 1 but it is considered to be Lower Triassic because of its proximity and lithological similarities to the Chandos section.

In the Completion report for Galway No. 1 the Triassic was extended to include the section these authors have called Buckabie Formation. This alternative correlation was made after comparison of the electric well logs and the lithological logs with A.O.D.'s Yongala No. 1 and Chandos No. 1.

JURASSIC

Sediments of Jurassic age apparently blanketed the whole of the mapped area and are represented in all oil wells by a lithological succession which ranges in age from Lower to Upper Jurassic.

Hutton Sandstone

The Hutton Sandstone or its stratigraphic correlate is present in all oil wells in the area. Its thickness and range in lithologies is given in Figure 3 and Table 2. Generally the unit consists of quartz sandstone, with varying amounts of lithic and feldspar grains, interbedded with minor amounts of siltstone and shale. These finer grained sediments are often carbonaceous and thin coal seams have developed locally. At P.-S. Gumbardo No. 1 there are minor thin beds of glauconitic sandstone interbedded in the sequence.

The age of the section identified as Hutton Sandstone has been established from palynological evidence as Lower to Middle Jurassic. Its extent in these oil wells is based on lithological and geophysical logging evidence, and these techniques are used to establish its upper limits against the overlying Birkhead correlate.

The Hutton Sandstone is a predominantly continental sequence with only minor marine incursions, as suggested by the development of glauconite at Gumbardo No. 1.

Birkhead Formation

The Birkhead Formation and the sediments correlated with it, conformably overlie the Hutton Sandstone. The unit throughout the area varies little in lithology and consists of carbonaceous shale and siltstone with interbeds of coal and minor sandstone.

The type section for the unit is Amoseas Westbourne No. 1 (Exon, 1966), (Augathella 1:250,000 Sheet area). There the section includes lithic and feldspathic arenites with interbedded siltstone and shale. There is some carbonaceous material and minor coal.

Correlation of the unit from the subsurface intersections with the type area is based largely on lithology and stratigraphic position; palynological evidence has only been obtained from Chandos No. 1 and from the Warbreccan wells

(Evans, 1966b). Spores from those wells belong to the J4 division (Evans, 1966a), which is considered Middle Jurassic. The unit appears to have developed in a lacustrine environment.

Adori Sandstone

The Adori Sandstone is apparently conformable on the underlying Birkhead Formation. In the oil exploration wells in the mapped area the unit consists of fine to medium grained quartz sandstone with minor interbeds of grey and sometimes carbonaceous siltstone and shale. Lithologically it is very similar to the unit at other localities where it has been examined (Exon, 1966).

The only palynological evidence that has been obtained from the unit in the area mapped is from Canaway No. 1 from 3,979 feet. Spores from this well indicated an Upper Jurassic age (Hodgson, Appendix 2, in Canaway No. 1 Completion report).

Westbourne Formation

The Westbourne Formation conformably overlies the Adori Sandstone. The unit consists of an interbedded sequence of quartz sandstone, siltstone and shale with abundant carbonaceous material and thin coal seams locally. The sequence tends to become more sandy lower in the section.

As with the older Jurassic units it varies little in lithology across its known extent.

The unit has been dated as Upper Jurassic in the Warbreccan wells and Yongala No. 1 (Evans, 1966), and in other wells drilled to the north-east and east (Exon, 1966). It formed in a fresh water lacustrine environment.

"Hooray Sandstone"

The "Hooray Sandstone" overlies the Westbourne Formation. From outcrop and subsurface information in areas to the north-east and east (Exon, 1966), it appears as if the "unit" contains an unconformity, and therefore should be mapped as two formations. Within the mapped area the criteria for distinguishing the two divisions are not evident in the descriptions given in the well Completion reports. In A.O.D.'s Chandos No. 1 and Yongala No. 1, and the Warbreccan wells the "unit" has been subdivided into a number of members based on lithology. This has been possible because of a change in lithological character for the "unit" as a whole from a predominantly sublabile sandstone sequence in the east to an interbedded sequence of sandstone and shale in the west.

The age of the "unit" has been established as Upper Jurassic to Lower Cretaceous on palynological and stratigraphic evidence (Evans, 1966b, and Evans, pers. comm.). It is thought of as having developed in a fluviatile, possibly deltaic environment, with periods of marine incursion in the east ranging to a lacustrine environment in the west.

CRETACEOUS

Sediments of Lower and lower Upper Cretaceous age were deposited over the whole of the mapped area. Vine et al. (1967, in prep.), after discussing previous nomenclature, propose a five-fold division into (in descending order)

Winton Formation
Mackunda Formation
Allaru Mudstone
Toolebuc Limestone
Wallumbilla Formation

This nomenclature is followed in this report.

Wallumbilla Formation

The unit in the area mapped was intersected by all the oil exploration wells. Lithologically the unit consists predominantly of blue-grey mudstone, commonly glauconitic, calcareous and in some beds carbonaceous, with minor interbeds of siltstone and very minor sandstone. Thin coal beds have been noted in some parts of the sequence.

Marine fossils occur throughout the unit but are most abundant in the lower part of the sequence. The species present (Vine and Day, op. cit) indicate an Aptian to Lower Albian (Lower Cretaceous) age.

On subsurface electric and gamma-ray logs the lower limit of this unit is marked by a sudden change to an irregular from a smooth-line graph.

Toolebuc Limestone

Conformably overlying the Wallumbilla Formation is a relatively thin (seldom more than 80 feet thick), sequence of grey, highly calcareous mudstone and limestone. Where gamma-ray logs are available it is marked by a very sharp positive peak and then forms an excellent marker bed in the subsurface Cretaceous sequence. This characteristic has allowed it to be correlated with certainty over a very wide area, even in areas where it is as thin as 10 feet.

The unit is Albian (Lower Cretaceous) in age, based on a restricted marine fauna found in its areas of outcrop on the Julia Creek, Richmond, Hughenden, and Boulia Sheet areas (Vine and Day, 1965).

Allaru Mudstone

The Allaru Mudstone is an interbedded sequence of calcareous, and in places glauconitic mudstone, and siltstone with minor sandstone, conformably overlying the Toolebuc Limestone. This sequence contains a Lower Cretaceous (Albian) marine fauna (Vine and Day, 1965). Its limits are readily defined in subsurface electric logs by a change downwards from an irregular (Mackunda Formation) to a smooth-line graph. The lower limit of the unit is defined by the sharp strong positive (Toolebuc Limestone), peak on the gamma-ray log.

Mackunda Formation

The Mackunda Formation is the oldest unit cropping out in the area mapped. It occurs only at one locality and there as a fault inlier, towards the northern edge of the Jundah Sheet area.

The unit as seen in outcrop consists of fine to medium grained labile sandstone, interbedded with siltstone, thin calcareous mudstone, minor intraformational conglomerate and cone-in-cone limestone. These beds range from poorly to richly fossiliferous (photo 2), and contain numerous marine species, as well

Photo 2. Fossiliferous bed in the Mackunda Formation

Photo 3. Inoceramus remains in Mackunda Formation

as fragmentary plant material. Inoceramus fragments (photo 3), are the most abundant fossils and almost the only ones that persist into the upper part of the unit. In areas adjacent to the boundary between the Mackunda Formation and the overlying Winton Formation the presence or absence of marine fossils may be used to identify the unit. Lithologies in this stratigraphic position are not diagnostic.

The Mackunda Formation is thought of as Upper Albian (Lower Cretaceous) in age, as indicated by its marine fauna (Vine and Day, 1965). Within the area mapped three collections of fossils were made (see Appendix 2), and they confirm this earlier finding.

In subsurface sections the lithology is similar to that seen in outcrop but also includes thin seams of coal and carbonaceous siltstone and mudstone.

The area of Mackunda sediments on the Jundah Sheet area is part of a south-east dipping fault block, bounded by the Stormhill Fault in the west and the Westland Structure in the east.

The Mackunda Formation was deposited in a paralic environment transitional from the marine environment responsible for the Allaru Mudstone to the freshwater environment of the overlying Winton Formation. The co-existence of beds containing a high proportion of marine fossils and thin coal seams indicates oscillating conditions. Towards the top of the unit there is a gradual change to a predominantly freshwater environment.

No section could be measured in the field due to the lack of outcrop, nor could any idea of thickness of the unit be obtained except from oil exploration wells and water bores. In Mungerie Bore (Registered number 1474), the unit is estimated to be 440 feet thick; this information is obtained from a gamma-ray log. This figure is comparable to thicknesses observed in oil exploration wells throughout the area (see figure 3).

Winton Formation

Distribution: The Winton Formation crops out over a very large area of western Queensland (Hill and Denmead, 1960; Vine, Jauncey, Casey, Galloway, 1965; Jauncey, 1965, etc.) and during this present project the known outcrop extent of the unit was increased.

Within the mapped area relatively fresh Winton Formation sediments crop out mainly in anticlinal areas, in structurally complex areas towards the eastern edge of the Adavale Sheet area, and in a belt from the northern part of the Jundah Sheet area, south to near Trinidad Homestead (Windorah Sheet area).

Chemically altered Winton rocks crop out adjacent to the areas of fresh rock, and also in areas where the Tertiary cover has been stripped off or did not form.

Lithology

A. Fresh exposures of Winton rocks crop out in areas of "downs" country, which is usually devoid of trees, and over most of its extent is soil covered. Outcrops are seldom more than a few feet thick, but may continue along strike for up to 100 yards. In these areas the only lithologies seen are labile sandstone, siltstone and mudstone, much of which has a calcareous cement.

The sandstone ranges from fine to medium grained, is usually well sorted, and grains are often well rounded. The sand grains consist largely of lithic fragments, and varying amounts of feldspar and quartz. Quartz is seldom more than 15% and is usually approximately 5%. Sandstone beds range in thickness from a few inches to 6 feet; some of the thicker beds are cross-bedded, others show fine festoon bedding. These rocks are generally very uniform in colour and texture but include mud pellets of varying sizes, scattered randomly throughout. These mud pellets commonly occur as patches, rather than as isolated individuals.

Siltstone and mudstone are interbedded with the sandstone, but are usually more thinly bedded. Mud pellets are scattered throughout both these finer grained rock types.

Fragmentary plant material is preserved throughout the unit and occurs as thin streaks on bedding plains, occasional leaf impressions, and twigs, that range in size up to logs one foot in diameter (photo 4).

Photo 4. Silicified wood, Winton Formation

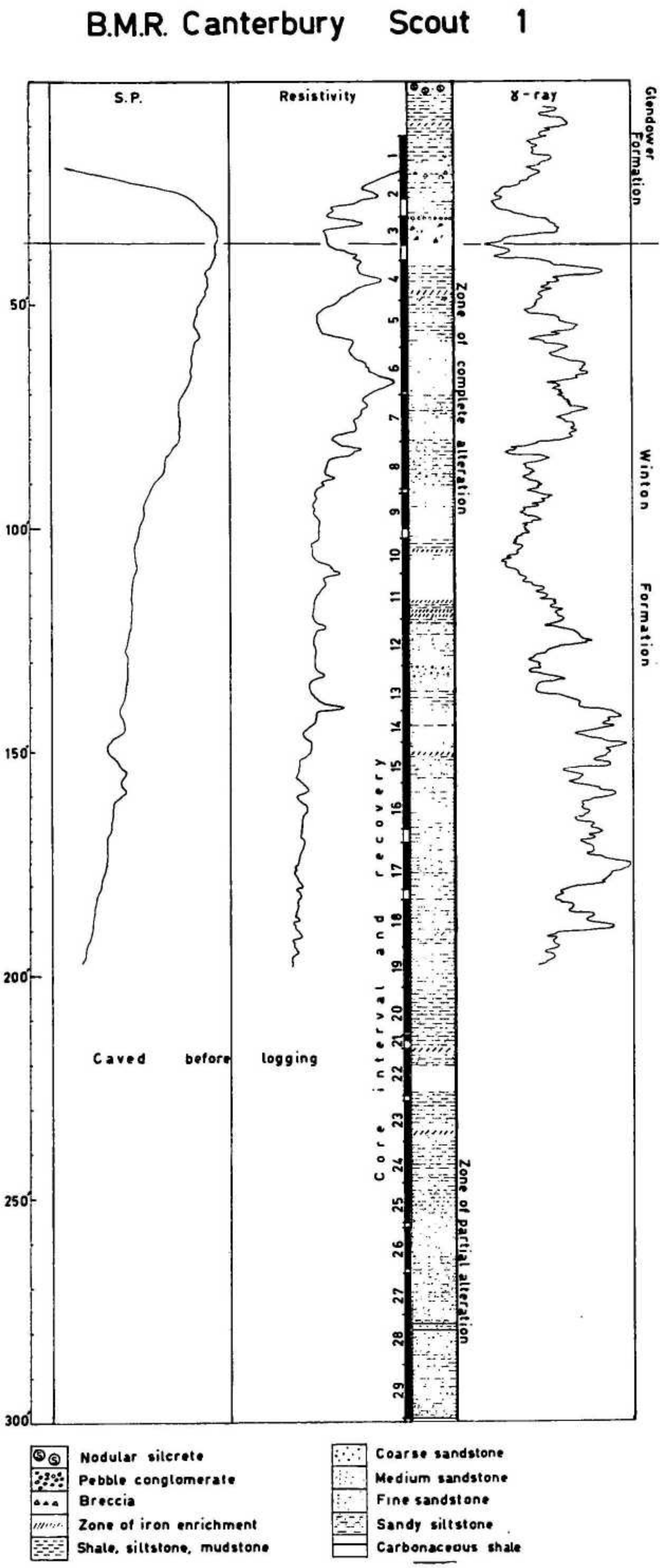
Thin, discontinuous veins of calcite are common in some areas, and this mineral also forms as a skin on some spheroidal bodies weathered out from beds in the unit. These spheroidal bodies range in diameter from about two inches up to 3 feet; most are imperfect spheres, producing elongate, flattened and bubble-shaped masses. Two or more such bodies may be joined together by narrow necks to form a variety of unusually shaped masses (photo 5).

Photo 5. "Spheroidal bodies", in fine grained calcareous sandstone, Winton Formation. (Morney Dome, Canterbury Sheet area).

These structures usually stand in tor-like clumps, and are formed by weathering out from the enclosing, apparently softer, material. The reason for their shape and their selective resistance to weathering is not known. Close petrographic examination across the boundary of these structures with the enclosing rock has shown no lithological differences.

B. A zone of chemically altered rocks overlies and grades down into fresh rocks of the Winton Formation throughout much of the area. These rocks crop out in cliffs (photo 6), in steep sided hills, and occasionally as low mounds (photo 7) in areas of unaltered rock. A drill hole (BMR Canterbury No. 1), produced the section shown in Figure 4. Within this zone the beds have been extensively leached, and replaced, producing rocks of strongly contrasting chemical character. The texture

Figure 4


B.M.R. Canterbury Scout 1
S.P.
Resistivity
γ - ray
Glendower Formation
Winton Formation
Zone of complete alteration
Zone of partial alteration
Core interval and recovery
Caved before logging
50
100
150
200
250
300
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
Nodular silcrete
Pebble conglomerate
Breccia
Zone of iron enrichment
Shale, siltstone, mudstone
Coarse sandstone
Medium sandstone
Fine sandstone
Sandy siltstone
Carbonaceous shale

of most of these beds has not been effected, except in the highly ferruginous beds. The range of rock types present includes:

a) pure white, kaolinitic rocks, replacing mudstone and siltstone (photo 8)

b) speckled white and grey kaolinitic rocks, replacing sandstone

c) a variety of rocks coloured pink, purple, brown and yellow, reflecting varying concentrations of iron and various iron minerals (photo 9)

Photo 6. At the Three Sisters, Canterbury Sheet. 40 feet cap of Glendower Formation overlying chemically altered Winton Formation.

These above rocks are all soft, and highly kaolinitic. They have been leached of most of their iron and free silica content, and as a result many are very porous. They break down readily under conditions of prolonged water saturation.

Photo 7. Concentric chemically altered masses in an area of otherwise fresh rock; basal part of zone of chemical alteration, (Winton Formation).

Photo 8. A hill composed largely of beds of kaolin (chemically altered Winton Formation), near Kurran Homestead, Conemara Sheet. "Ironstone" gravel in foreground .

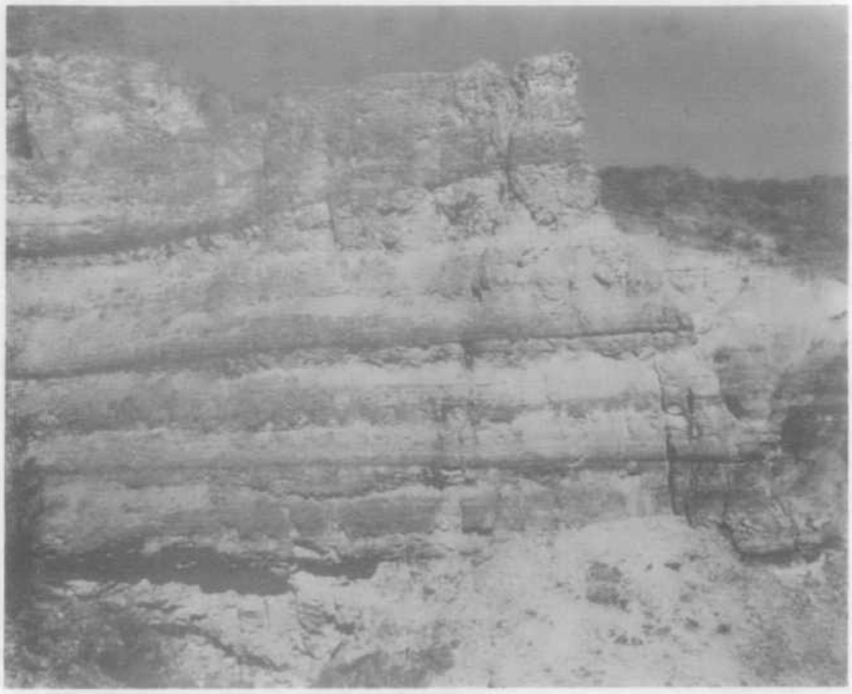


Photo 9. Rhythmical pattern of alteration in chemically altered Winton Formation. Note abrupt changes in colour index.

d) Hard cream-coloured very fine grained, usually intensely fractured porcelanite which has formed replacing beds up to 5 feet thick, generally towards the top of the zone. These beds are overlain and underlain by silica-poor kaolinitic rocks.

The beds of porcellanite are probably lithologically controlled. They have developed by silicification of a very fine grained sediment, and because of their high silica content are much more resistant to weathering than the kaolinitic beds. In some areas erosion has been arrested by one of these beds, which then forms a bench or, if at the top of a hill, a small cliff. Similarities between these hill cappings and the silicrete cappings on the Glendower Formation has led some workers to consider that they were formed by the same process. This author feels that this is not the case, and that the porcellanite beds formed by selective replacement of suitable fine grained beds within the zone of chemical alteration.

e) Siliceous, often deep red, highly fractured duricrust in areas where there has been no development of Glendower sediments. This duricrust has developed from sandstone, siltstone or mudstone, as a soil profile formed under a peneplain. They developed in very small areas on the Canterbury and Jundah Sheet areas, and more commonly towards the northern edge of the Connemara Sheet area, as well as in many areas north of Bulgroo Homestead (Windorah Sheet area), and towards the eastern edge of the Adavale Sheet area.

f) Brown speckled, iron-enriched sandstone, leached of most of its free silica, and with iron oxides redistributed throughout the rock but apparently selectively excluding some grains (these grains appear to be relic feldspar).

g) Highly ferruginous beds up to one foot thick either as a massive pseudo-bedded ironstone (generally only one or two inches thick), (photo 10), or as a bed containing lenticular or spheroidal concretionary masses in a matrix of similar material. The iron oxide content of these rocks is up to 90%. The concretionary masses consist of boxworks, or a number of shells - within - shells, in the outer spheroidal shell. They appear to have grown in the alteration zone, at the expense of the surrounding beds. Occasionally spheroidal concretionary masses have developed within pallid kaolinitic beds along certain horizons. It is usual for the ferruginous beds to be underlain and overlain by pallid beds, and the contact between these beds is always very sharp. Often a thin ferruginous bed is terminated against a very fine grained underlying bed. It is obvious that in these cases the downward migration of iron-enriched solutions has been controlled by permiability. Elsewhere however the mechanism for iron concentration is not apparent and the reasons for its selectivity are obscure. In the iron-enriched beds not localized by an underlying impervious bed, while precise controls are not known, it is known that the iron-enrichment has followed certain beds, and hence, it is controlled to some extent by lithology.

Photo 10. Glendower Formation overlying chemically altered Winton Formation. A highly ferruginous concretionary bed crops out near top of altered profile. Note ferruginous bed is discontinuous.

In some cliff sections (Mount Henderson, Canterbury Sheet, see figure 6), the iron-enriched beds occur towards the base of the exposed section. To the north near the Three Sisters (photo 6), a 300 feet high cliff exposing the altered zone contains no iron-enriched beds. Elsewhere (Connemara Sheet, near Kurran Homestead) iron-enriched beds occur near the top of the altered zone (photo 10). In B.M.R. Canterbury No. 1 (figure 4), they occur near the base of the zone. There are indications that some of the beds were calcareous and that the concretionary structures were originally limestone concretions. In other areas (e.g. Jundah Sheet area, near Mount Aaron), there is evidence that an iron-enriched bed there has developed as a replacement of coal. Both these lithologies, and probably others as yet unrecognised appear to be suitable hosts for the iron-rich solutions. There is no indication that the iron-enriched beds originally contained a higher percentage of iron than any of the surrounding beds. The sequence as a whole appears to be fairly homogeneous chemically, especially as to iron content.

Other features of this zone are discussed in a later chapter.

Palaeontology and Age

The only macrofossils found in the Winton Formation are fresh water pelecypods and plant fragments. Spores recovered from core samples from B.M.R. Connemara No. 1 indicated a lower Upper Cretaceous age (Appendix 1). Apart from determination no direct evidence of age has been obtained within the mapped area. Age indications from adjacent areas of Queensland (Vine, et al., 1965; Jauncey, 1965), and also on the underlying Mackunda Formation indicate an upper Lower Cretaceous to lower Upper Cretaceous age for the unit as a whole.

Structure and Relationship

The Winton Formation is folded into broad open folds (photo 11), and conforms to the structure of the Artesian Basin sequence. It is overlain by the Glendower Formation with a very low angle regional unconformity, and also appears to be disconformably overlain by the Moses Sandstone.

Environment of Deposition and Thickness

The Winton Formation is a fresh water sequence deposited in a vast continental lacustrine and fluviatile system. Within the area mapped the thickness of the unit varies appreciably due to subsequent erosion, from approximately 1140 feet at Merabooka Bore (Connemara Sheet area), to 2850 feet at F.P.C. Galway No. 1 (Windorah Sheet area).

Other thicknesses are shown in Fig. 3.

Photo 11. Gently dipping Winton Formation sediments, seen in an earth tank in an area of rolling downs.

TERTIARY

Moses Sandstone

Summary

The Moses Sandstone is a sequence of quartz sandstones and siltstone of possible lower Tertiary age. This deposit forms a level surfaced plateau, occurring on the north-west corner of the Connemara and south western Brighton Downs Sheets.

Nomenclature

The Moses Sandstone was originally described from the south-west of the Brighton Downs Sheet (Jauncey, 1964). The name Moses Sandstone was formalized for sediments of the Hamilton and Goyder Ranges, the latter being the type locality (Vine, 1964).

Distribution

This sandstone is restricted to a small area in the extreme north-west corner of the Connemara Sheet area and continues to the south-west corner of Brighton Downs Sheet.

In outcrop the maximum measured thickness was 60 feet, similar thicknesses were noted on the Brighton Downs Sheet area. Drilling results indicate a maximum thickness of 65 feet. The unit rests unconformably on slightly weathered, but otherwise unaltered Winton Formation sediments.

Topography

The Moses Sandstone forms a north-south trending plateau, with steep peripheral escarpments, having small detached mesas (photo 12), and buttes. Edkin Creek is superposed, and has maintained its course obliquely through the plateau area. The Moses Sandstone may have acted as a restriction to the west-flowing Edkin Creek in late Tertiary or Quaternary times forming a shallow transient lake. Subsequently an evaporitic environment developed in the lake and crystalline sheets of gypsum were precipitated. Gypsum sheets ranging in thickness up to one fott, are common over a wide area to the east of the Moses Sandstone plateau.

Photo 12. A mesa of Moses Sandstone, showing complete section, with ferruginous gravel in foreground overlying Winton Formation.

Lithology

Outcrops on the plateau surface and periphery, are mainly medium grained, soft, quartzose sandstones. Small amounts of intraformational conglomerate occur, with pebbles derived from chemically altered Winton Formation sediments. There is a tendency for the grainsize to diminish towards the base where siltstone and mudstone occur.

Hard, flat, ovoid, calcareous concretions, and spheroidal concretions replaced by iron, occur as thin beds and along the bedding interfaces in the coarser grained beds. Small soft calcareous concretions and septaria occur in the laminated siltstone (photo 13).

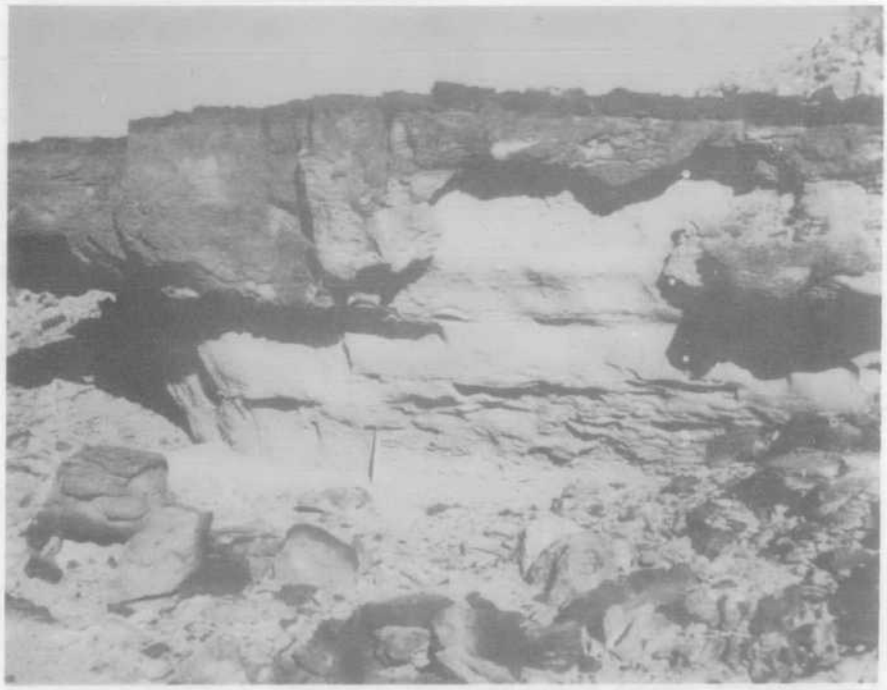


Photo 13. Concretionary "ironstone" layer within the Moses Sandstone. This dominantly arenaceous deposit grades down into laminated silts, containing calcareous concretions and septaria.

Sandstone beds are often cross-bedded, and siltstone beds are either thinly bedded or laminar. Individual beds inter-digitate and are lensoid in character.

The sandstone is slightly silicified in part, and contains some silicified wood, and rare calcified wood. The matrix of the sandstone is a white, leached clay, which was probably derived from redeposition of chemically altered Winton Formation sediments.

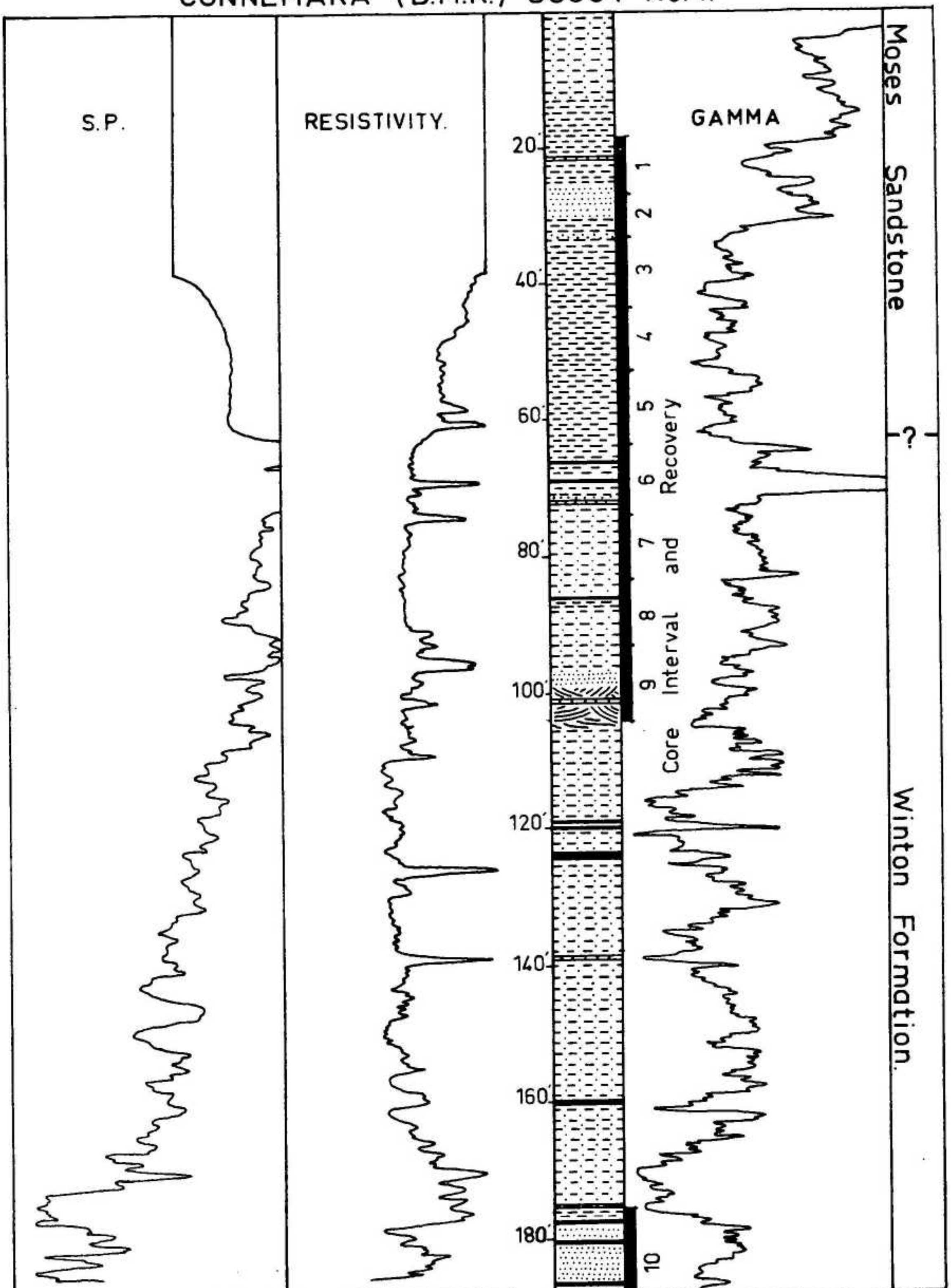
The occurrence of spheroidal iron suggests that the deposit has been subjected to a mild form of chemical alteration in situ. However, this alteration did not effect the Moses Sandstone to the same extent as the chemically altered Winton Formation sediments in nearby hills. Calcareous horizons are preserved within the Moses Sandstone; these would be highly susceptible to alteration.

Drilling of B.M.R. Connemara No. 1, showed that the subcrop lithologies are carbonaceous silt and clay, containing very thin (0.5 of an inch) seams of coal. A stratigraphic column with gamma and electric logs is illustrated in Figure 5.

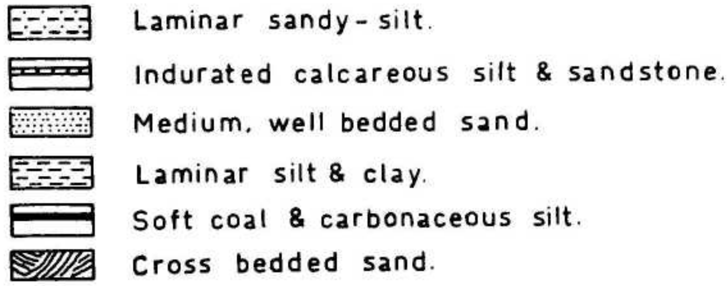
Age and Palaeontology

The deposit contains no fossils, except rare calcified wood and uncommon silicified wood. The Moses Sandstone is regarded as older than the Glendower Formation by degree of alteration, and therefore presumed

CONNEMARA (B.M.R.) SCOUT No. 1.



SCALE 20 Feet to 1 Inch.



to be lower Tertiary in age, and probably is contemporaneous to the older Tertiary sediments in the Springvale Basin (Jauncey, 1964).

Structure

The deposit is very shallowly folded with dips up to 5°. The fold axis together with the majority of microfaults and joints, trend approximately north-south.

Environment of Deposition

The Moses Sandstone was deposited in a river valley, receiving fluviatile fine grained sediment. Periods free from sedimentation allowed vegetation to become established. During the closing phases of deposition the sediment became coarser, and the water currents stronger, giving rise to quartzose cross-bedded sands.

Glendower Formation

Summary

1) The Glendower Formation is a sequence consisting largely of quartzose clastic sediments that unconformably overlies the Cretaceous Winton Formation.

2) A siliceous profile has developed in the upper part of the unit (silicrete duricrust), that is particularly resistant to weathering.

3) The unit formed a blanket deposit ranging up to 200 feet thick over most of the area.

4) Late Tertiary folding has produced broad open folds in the unit with dips seldom above five degrees.

Nomenclature

The term Glendower Formation was introduced by Whitehouse (1954) to cover a sequence of Tertiary quartzose clastic sediments cropping out in the north-east part of the Artesian Basin.

The unit as mapped here includes a range of sediments that are continuous with those of the type area (Hughenden 1:250,000 Sheet area). However, in the south-west of the Canterbury Sheet area Wopfner (pers. comm.) considers that some of these sediments mapped as Glendower Formation may belong to the Mount Howie Sandstone (Wopfner, 1963). The Mount Howie sediments are lithologically identical and at present cannot be subdivided.

Distribution

Sediments mapped as belonging to the Glendower Formation, were deposited over the whole of the mapped area excepting the western and north-western portion of the Connemara Sheet area and the south-eastern corner of the Adavale Sheet area, and in a few areas where islands of Winton rock persisted throughout the Glendower depositional period (e.g. near Opalville, and an area about 10 miles north-east of Bulgroo Homestead).

Late Tertiary folding and erosion has limited the present areas of outcrop to most of the areas of hills within the area, except as outlined above.

Topography

The unit crops out in low silcrete covered rises, low cliffs (figure 6), and high cliffs capping steep sided slopes. The unit always forms cliffs or very steep sided hills where disection penetrates the silcrete capping. Also small caves are often formed in softer beds in the unit beneath the silcrete duricrust.

Where the unit caps areas of outcrop of the Winton Formation it forms mesas, buttes and tablelands (photo 14), and is generally strongly dissected. The tablelands when folded, locally form cuestas (e.g., western flank of Curalle Dome).

Photo 14. Glendower Formation (forming the upper cliff), overlying chemically altered Winton Formation. Note the extent and uniform thickness of the Glendower Formation.

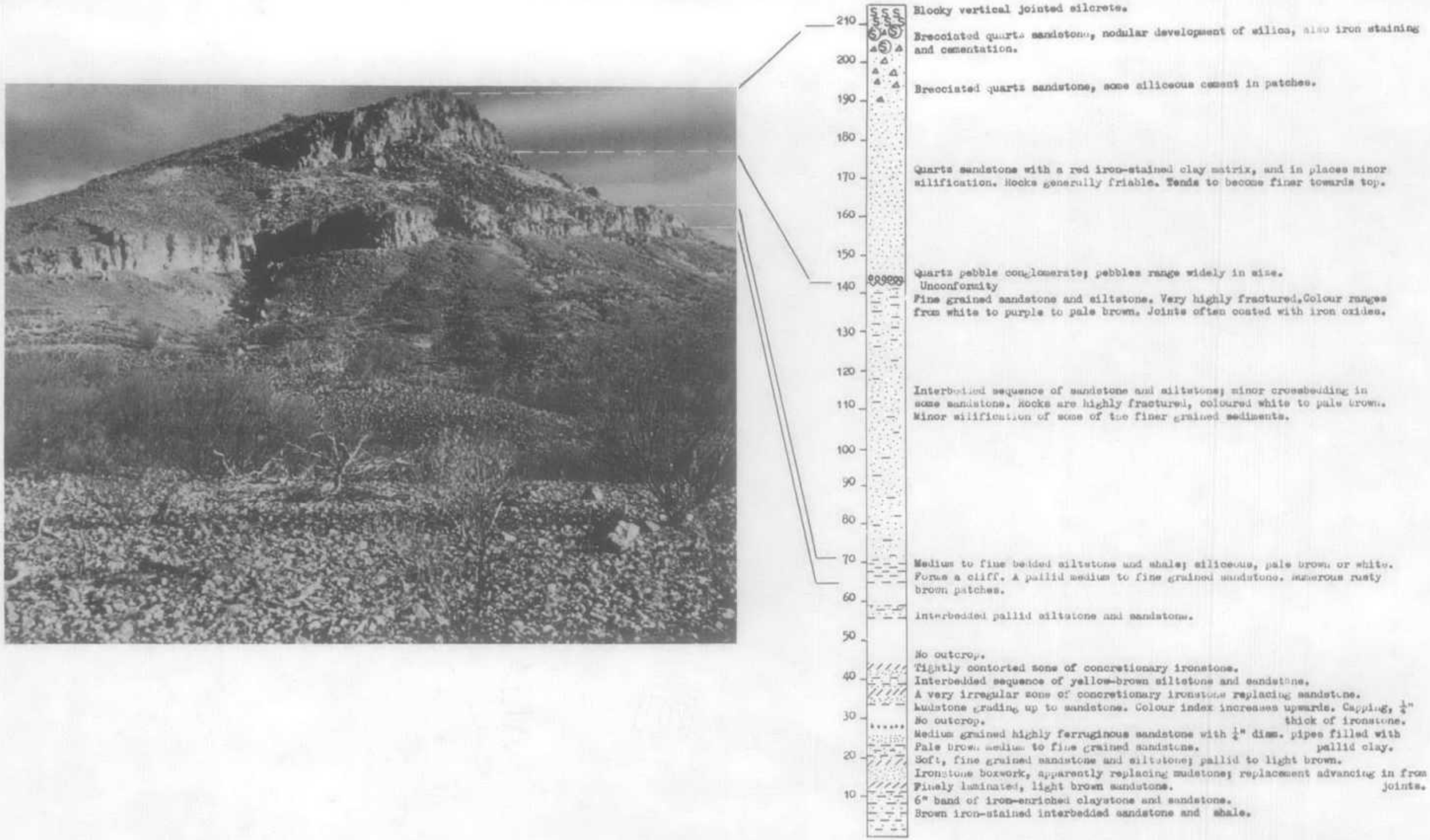
Slumping on the margins of the larger hills has caused anomalous dips in huge blocks of these sediments (photos 29-31).

Lithology

The Glendower Formation includes a range of rock types from lithified, reworked, chemically altered Winton Formation sediments, that directly underlie the unit, to pure quartzose sandstone and silcrete.

Figure 6

Mount Henderson
(Canterbury Sheet Area)



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The reworked Winton material (labile arenite and lutite), usually contains an admix of quartz, thus allowing it to be recognised from the underlying formation. Many of these rocks appear brecciated and they probably formed in a soil profile. Elsewhere, where there has been no addition of quartz clasts the two units are often indistinguishable.

There is a gradation of lithologies from the reworked arenite and lutite to the quartzose clastic sediments. Quartz sandstone, sandy conglomerate, quartz pebble conglomerate (usually only are one layer of pebbles thick), conglomerate and quartzose siltstone are all common throughout the area mapped. The pure quartz sandstone ranges from coarse to fine grained, is generally well sorted and the grains exhibit good rounding. It often contains a high proportion of white clay in its matrix derived from the altered Winton Formation rocks. Low-angle cross bedding (photo 15), as well as crude grading have developed locally.

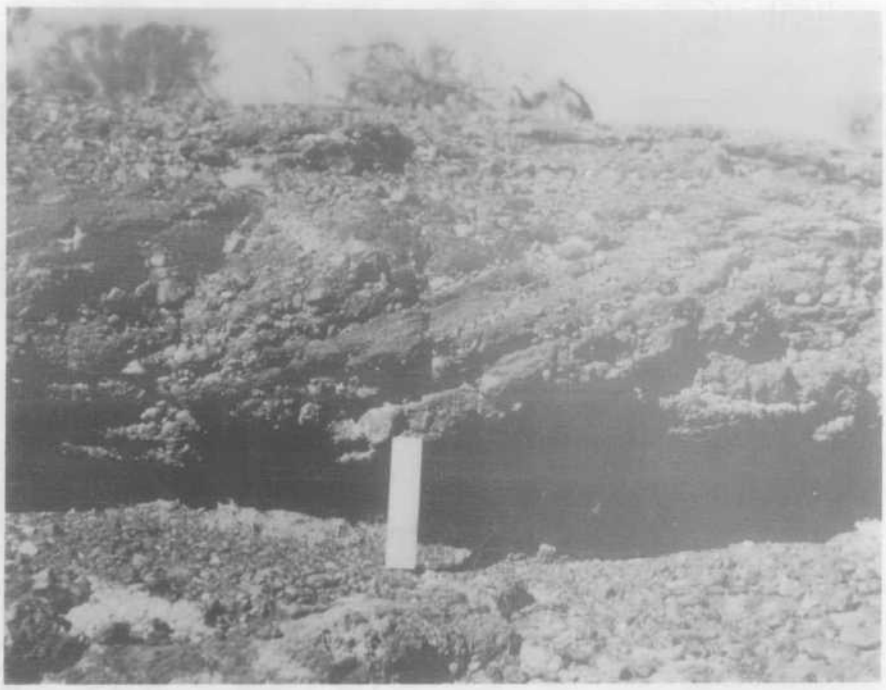


Photo 15. Glendower Formation. Cross bedded very poorly sorted conglomeratic sandstone containing a high proportion of clasts derived from the Winton Formation.

The pebble conglomerate beds usually consist of milky white quartz with very minor silicified wood fragments in a quartz sand and clay matrix.

Locally, and in particular adjacent to the Thomson River, conglomerate beds include rare cobbles of dacite and fairly abundant cobbles of silcrete and quartzite, as well as of reworked altered Winton material. The dacite is porphyritic with phenocrysts of quartz and feldspar in a light to medium grey aphanitic groundmass. The quartz crystals are corroded and partially resorbed; the feldspar crystals are intensely saussuritized. The source area of this dacite is not known; it could have been a number of areas to the north-east adjacent to the margin of the Mesozoic sedimentation. (Dacite in Cunno 1 bore radiometric date of 187 ± 20 m. years). The silcrete cobbles were probably derived locally from a silcrete horizon in the basal part of the Glendower Formation (as found in B.M.R. Jundah 3 drill hole, see figure 7).

Quartzose siltstone is common in the thicker parts of the unit, and is developed locally elsewhere. Its thickest development is in the upper part of the unit in the area east of Jundah and in the Thomson-Cooper channel. In the Jundah area there is a marked tendency for the unit to become finer grained in the upper half. Siltstone is usually thinly bedded, and interbedded with fine grained sandstone. These rocks all contain a high proportion of clay in their matrix.

Silcrete forms a capping (duricrust) in the upper levels of the unit. The term is used here to mean a rock composed of angular quartz grains, few of which are in contact with others, in a matrix of amorphous and cryptocrystalline silica. These rocks have a sub-conchoidal fracture. They grade into silicified sandstone in places (see chapter on silicification). This duricrust is very resistant to erosion and so preserves the underlying more friable beds.

The Glendower sediments throughout the area beneath the silcrete capping are often mottled red, red-brown, and creamy-white. This mottling is only controlled by lithology to a small degree, and is generally random. Locally the whole section beneath the silcrete may be stained red with the sand grains coated with iron oxides and the clay minerals impregnated with iron minerals. The lower levels of the upper silcrete crust are also often stained red with silcrete nodules coated with iron oxides. Iron colouration is however excluded from most of the massive silcrete outcrops which are characteristically creamy-white.

Thickness

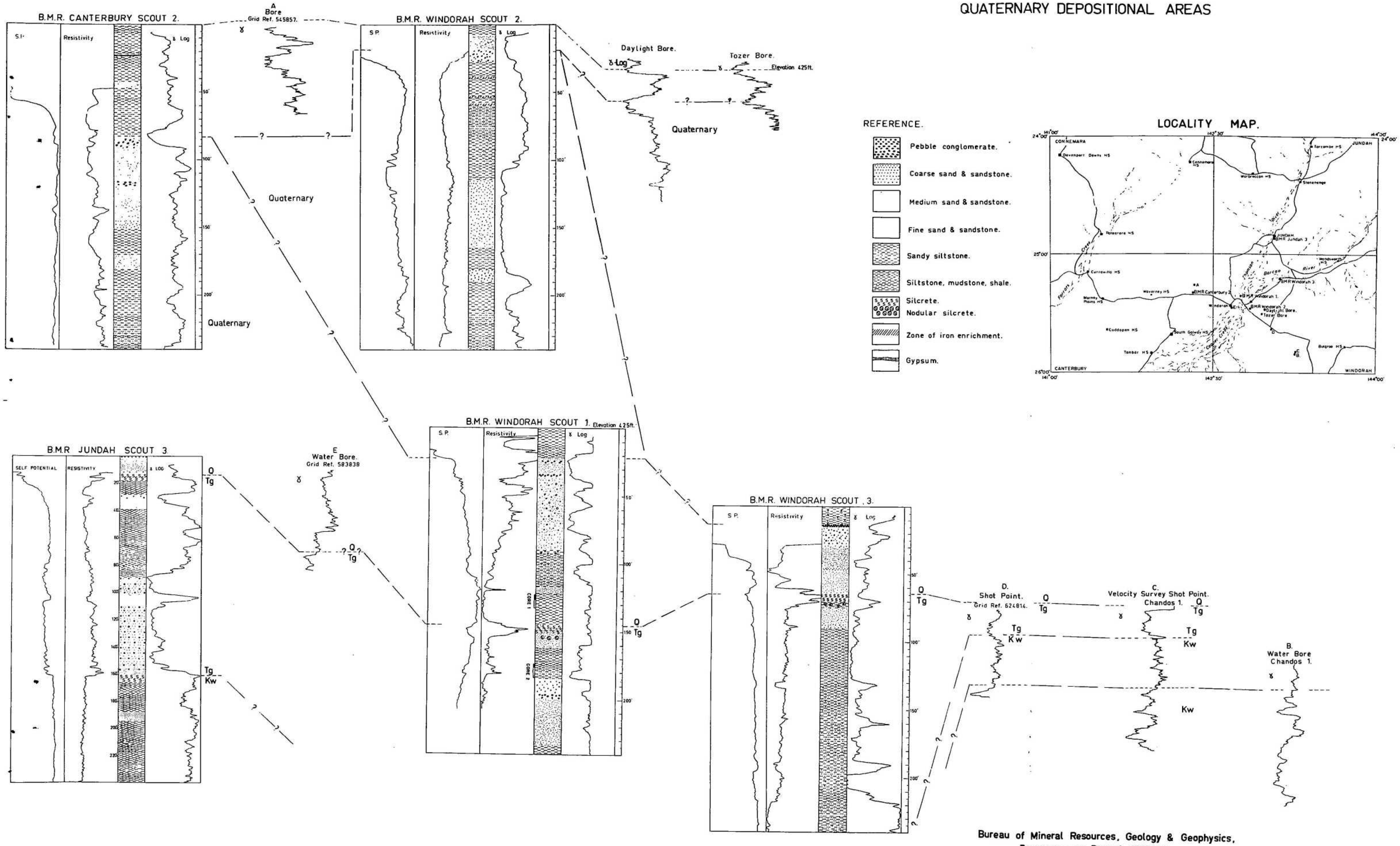
The unit ranges widely in thickness both locally and regionally. Its thickest development, approximately 200 feet, is adjacent to the Thomson, Cooper, and Barcoo drainage lines and in the hills east of Jundah. The unit thins to the north-west to near Davenport Downs Homestead, and to the south-east to near Bulgroo Homestead. East of the Canaway Fault the unit again thickens towards Adavale, and then thins again to near Boondoon Homestead.

Locally there is a variation in thickness of up to 30 feet due to irregularities in the underlying older land surface.

Gamma-ray logging of some of the shallow scout holes drilled during the Windorah and Jundah Sheet areas as well as of a number of other open holes are shown in Figure 7. Correlation between these holes, based on a measured section near Chandos No. 1, shows the uniformity in thickness of the unit between point C and D. In this area the unit is approximately 20 feet thick. The B.M.R. Jundah 3 hole shows clearly the boundary between the Glendower Formation and the underlying Winton Formation.

FIGURE 7

SHALLOW BORE HOLE CORRELATION CHART
QUATERNARY DEPOSITIONAL AREAS



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Environment of Deposition

In the mapped area the Glendower Formation appears to have been deposited in a shallow freshwater environment such as a very broad river or lake system which covered most of the area from near Davenport Downs Homestead in the north-west to Boondoon Homestead in the south-east.

There appears to have been two main axes of sedimentation, (1) along the east flank of the Thomson Syncline, trending south-south-west and (2) in the north-western portion of the Adavale Sheet area. Along these axes there were probably a number of main channels which persisted throughout the deposition of the unit. Away from these channels there must have been numerous secondary channels available for transport of sediment in times of flood. These secondary channels were probably quite short-lived, and as they silted up new channels were formed. There is ample evidence of penecontemporaneous erosion within the unit (photo 16).

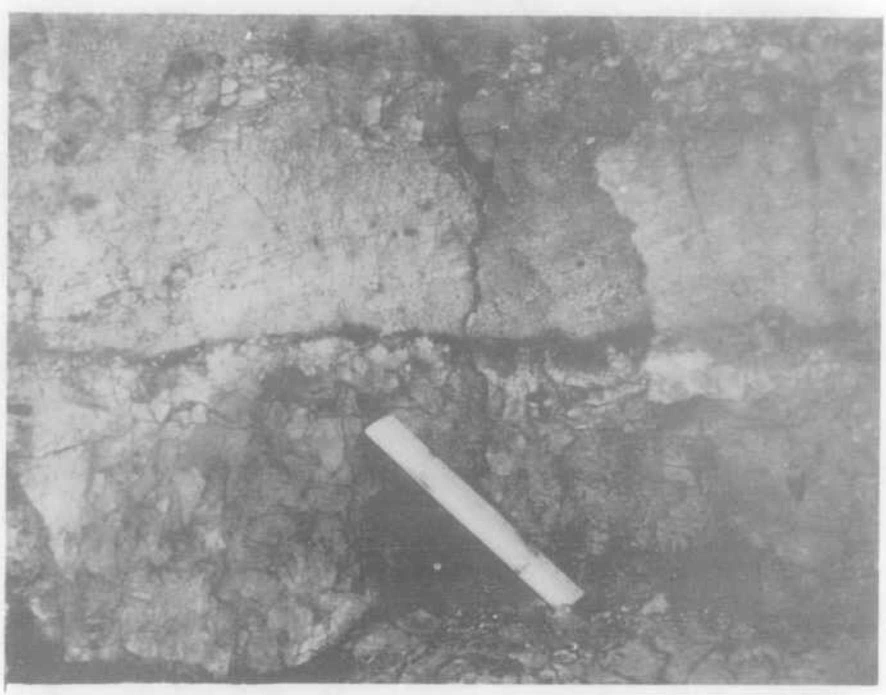


Photo 16. Unconformity between chemically altered Winton rocks and Glendower Formation. Note Glendower Formation contains a high proportion of clasts derived from the lower unit.

The Glendower Formation blanketed most of the early Tertiary land surface on the Winton Formation, covering most of the irregularities in that surface, relief of which must have been slight. Within this area of deposition there were also numerous low islands of Winton Formation rocks which were contributing material to the accumulating Glendower sediments. Most of these islands are now covered by the younger of the Glendower sediments. Only the larger islands, in the marginal zones of the Glendower depositional area, and in small isolated areas such as near Opalville and about ten miles north-east of Bulgroo Homestead (Windorah Sheet area), remain as recognisable features. The main areas of islands, as indicated by shallow thickness of Glendower sediments, were in areas away from the main axes of sedimentation. These islands however, would all have been low relief features since the area had been peneplained prior to the Glendower deposition.

Relationships with Older Units

The Glendower Formation unconformably overlies the chemically altered profile of the Cretaceous Winton Formation (photo 17), and in some beds contains a high proportion of clay material derived from the erosion of this Winton profile. In view of the range in thickness of the Glendower Formation, and the consistency of the underlying Winton rocks it seems very unlikely that the Glendower rocks were subjected to the same period of chemical alteration that so profoundly altered the underlying rocks.

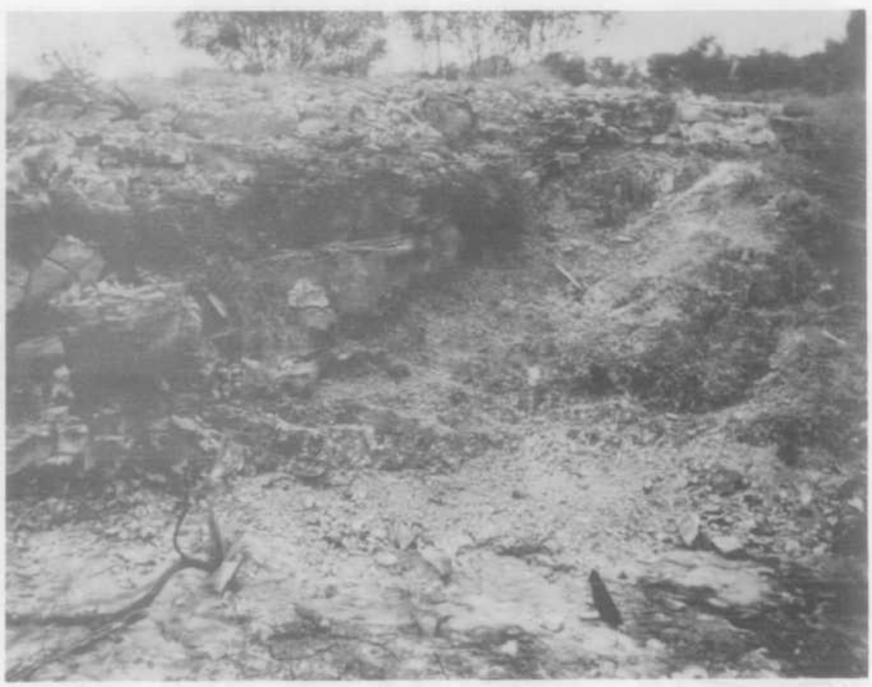


Photo 17. Local unconformity within the Glendower Formation.

The Glendower Formation is considered to be younger than the Moses Sandstone because it has not undergone the same degree of alteration as the Moses Sandstone. At no place were the two units found in juxtaposition.

Age

No fossils were found in the unit other than worm borings and possible root impressions, to support a definite age, however it is tentatively thought of as Lower Tertiary. On the other hand Wopfner (1963), indicates that the Mount Howie Sandstone, which crops out to the south-west of the area and which apparently correlates with the Glendower Formation, may be Upper Cretaceous based on inconclusive palaeontological evidence. At present the unit is ascribed to the Lower Tertiary in conformance with other recent mapping by the B.M.R. in Western Queensland.

Structure

The unit has been folded in late Tertiary times to produce broad open folds. The limbs of these folds are preserved intact and identifiable due to the very resistant nature of the silcrete duricrust which can be used on a regional scale as a structural marker throughout the area.

The silcrete deforms plastically to a lesser degree than the underlying beds, and with folding tends to fracture. In these areas numerous small tear faults have developed causing sharp gullies in the otherwise smooth fold limbs.

On the air photos in the areas of silcrete outcrop parallel lines of shrubs follow tension joints developed on anticlinal flexute along the flanks of the breached folds and locally within the crestal region of unbreached structures. These often allow the small irregularities in the structures to be interpreted.

Undifferentiated Limestone

Superficial limestone deposits, up to six feet thick have developed in flood plains adjacent to the larger water ccurses and to some of the smaller creeks throughout the area. The thickest development has been along Farrars Creek and its tributaries (Connemara and Canterbury Sheets), adjacent to the Cooper Creek (but only in isolated areas, too small to be shown on maps), and near Keeroongooloo (Windorah Sheet).

These deposits have developed in the present flood plains but also occur as perched deposits up to six feet above the present flood plain. In these cases they appear to have formed in an evaporitic environment in shallow, probably interconnected lakes, in clay-pans and in shallow streams. The percentage of calcium carbonate varies from area to area; in some areas the unit is almost pure with a very minor silty fraction. Elsewhere the limestone deposit has precipitated in a silty soil and is now intimately mixed with the silt and fills most of the cracks or openings in the soil.

Lithologically the purer beds consist of very finely crystalline grey, creamy, pink and white calcium carbonate mixed with a varying percentage of clay minerals. Chalcedony has formed filling fractures, as nodules and apparently replacing the limestone itself towards the top of the bed. In many deposits, especially adjacent to Farrars Creek and its tributaries a cap of impure chalcedony has formed on the limestone. In the silty limestone, chalcedony is not well developed.

The limestone deposits as a whole developed on old alluvium adjacent to the larger watercourses, on Glendower Formation sediments, on reworked partly consolidated material derived from both the Glendower Formation and the chemically altered Winton Formation, and on chemically altered Winton sediments. Where the deposits overlie the Glendower sediments or the poorly consolidated sediment, the underlying material often appears strongly mottled, suggesting that there has been iron migration and also probably silica migration. In one area adjacent to Little Gotha Creek, on the Connemara Sheet, chalcedony was found in both the limestone and the underlying altered Winton profile, indicating that, there at least, the chalcedony is a secondary feature.

Microscopic examination of the purer limestone from the Spring Creek area, Connemara Sheet, revealed a microflora of Charophytes. At the present day these small aquatic plants live entirely submerged in clear, quiet or slowly moving bodies of water. They have a wide tolerance to lime concentration (Paten, 1964).

QUATERNARY

Undifferentiated

Areas shown on the maps as Q consist of numerous small areas of alluvium, sand, gravel and mixtures of these. Where one type of sediment predominates this has been noted on the face of the maps.

Alluvium (Qa)

Superficial alluvium covers much of the mapped area adjacent to all the major water courses (photo 18), and also areas where these water courses lose their identity amidst sand dunes and claypans (photo 19). This superficial material is very largely fine grained and seldom reaches sand size except in the beds of the larger water courses. In the creek and river flood-out areas alluvium merges with colluvium and eolian deposits.

Photo 18. Isolated areas of sand with sand ridges (Qs), in the flood plain of Whitula Creek (Qa), Canterbury Sheet area.

Photo 19. Clay pan development (Qa), in an area of sand cover (Qs).

In the area adjacent to the Cooper Creek, and the Thomson and Barcoo Rivers the superficial alluvium locally covers up to 240 feet of post-Glendower sediments. A number of drill holes (B.M.R. Windorah 1, 2, 3, Canterbury 2, Jundah 3), as well as water bores and the deeply incised main river channels all show a varied sequence of fine to coarse quartzose clastic sediments as well as numerous beds of silt and clay. There are also some interbeds of deep red-brown ferruginous silt. Logs and a suggested correlation across some of these bores is shown in Figure 7. This chart demonstrates the range of sediments within a relatively small area and also the range of thickness of these sediments.

These sediments are not formally mapped as separate from the Quaternary alluvium since they are very poorly consolidated and in the area adjacent to the main rivers forms part of the alluvium.

However, it is significant that there is a considerable thickness of post-Glendower sedimentation along these major rivers, and indicates that these rivers follow axes of downwarping which have been active in late Tertiary to Quaternary times.

A similar situation may exist along other main water courses also but no information was gathered about these.

Sand (Qs)

Large areas covered by a superficial layer of eolian sand have been mapped on the Canterbury and Windorah Sheet areas and also smaller areas on the Connemara Sheet area. These areas include sheet sand and dunes (photo 20).

Photo 20. Linear sand dunes, Canterbury Sheet area.

The sand is largely quartzose but contains up to about 30 percent clay. Percentages of iron, and the colour index, range considerably from area to area, especially in the dunes. In areas close to abundant ferruginous gravel the colour index is high. In the broad creek and river flood plains, especially near B.M.R. Canterbury 2, the dunes are very light coloured, and here the clay content is abnormally high.

The core of most dunes is partly consolidated (photo 21), and contains a higher percentage of clay than the outer surface region. There seems to be only a relatively thin outer zone of most dunes that is completely unconsolidated and available for movement by the wind. This outer zone is continuously being reworked, but there does not appear to be much mass movement of sand from any one dune to any other, or any significant building up of areas of dunes. Locally there may be minor longitudinal movement of sand along dunes.

The Glendower Formation is the source of most of the quartz fraction and some of the finer grained material in this unit. The majority of the fine grained fraction however, is derived from the chemically altered Winton Formation profile.

Photo 21. Semi-consolidated sand in exposed core of sand dune.

Four sand samples were collected from widely spaced localities on the Connemara and Canterbury Sheet areas and the heavy minerals present were separated and identified by I.F. Scott (A.M.D.L.). The results are tabulated as follows (Table 3).

a) Mantles of superficial silcrete gravel (Qc) have developed mainly on the Winton Formation along the margins of its outcrop areas in breached anticlinal structures such as in the Morney Dome, the Curalle Dome, the Palparara Dome, the Warbreccan Dome, and the Mianga Anticline.

These deposits formed by the gradual lowering and fragmentation of the original main silcrete horizon during the removal of the underlying material.

Locally a veneer of silcrete gravel has developed by the breaking up in situ of the silcrete horizon. These deposits are generally small and the gravel concentration less dense than in the first described deposits.

Silcrete is the rock most resistant to erosion in the whole area, and in these areas of dense gravel it has formed a protective mantle which greatly retards erosion of the underlying material.

The silcrete gravel is generally very poorly sorted but well rounded. Much of the gravel has a good polish due to the very active wind and dust abrasion.

b) Highly ferruginous gravel, derived from ferruginous beds in the chemically altered Winton Formation profile and to a lesser extent from the Moses Sandstone cover relatively small, low lying areas within the area of outcrop of these units. These deposits are thin but the gravel is densely packed. They have a characteristic dark grey air photo pattern, and this was used extensively to map their distribution.

The margins of many of these deposits are gradational and in many areas where ferruginous gravel is not densely concentrated or where the area of the deposit is very small the unit has not been mapped.

c) Areas covered by a veneer of a mixture of numerous types of gravel occur in many areas and often grade into areas of silcrete gravel or undifferentiated Quaternary deposits.

Gravel has formed generally as colluvial deposits and seldom is significant along the major water courses.

PERIODS OF CHEMICAL ALTERATION

(a) Deep Chemical Alteration

Deep chemical alteration beneath a peneplained surface on the Winton Formation has produced a profile up to 300 feet thick of completely altered rock and beneath this another zone up to 150 feet thick of partially altered rock (Figure 4). The present thickness of the profile ranges widely beneath the cover of Glendower Formation sediments due to erosion of part of an originally uniformaly thick zone, rather than to differential depths of chemical alteration from area to area. Evidence of this erosion is seen in almost all outcrops of the basal part of the Glendower Formation which characteristically contains fragments from the underlying altered zone. In no areas was erosional stripping of the altered zone sufficient to expose fresh rock prior to the deposition of the Glendower sediments. Subsequent erosion after deposition of the Glendower Formation has, however, exposed fresh Winton rocks in many areas.

The period of alteration affected the complete Cretaceous sequence in adjacent areas of Queensland (see B.M.R. Records by Vine, Jauncey, and others), and may have affected the Mackunda Formation (Jundah Sheet area), within the mapped area. However, any profile on this unit has been stripped by erosion.

A description of rock types represented in this profile is given in the chapter on the Winton Formation lithology.

Within the Moses Sandstone iron concretionary masses similar to those developed in the Winton Formation, occur scattered throughout the unit and gravel derived from them covers much of the surrounding plains. It seems likely that this unit was affected to some extent by a similar period of alteration, however within this unit there are also numerous calcareous nodules co-existing with the iron-enriched bodies. This situation seems to exclude the possibility of an initially leaching environment, which presumably would have removed all calcareous material. Other indications of chemical alteration of the Moses Sandstone are the very pallid nature of the finer grained beds and the pallid nature of the clay matrix in the arenites. However this fine grained material is probably largely derived from adjacent upland areas of altered Winton material. The Moses Sandstone overlies relatively fresh Winton sediments in the lower part of the transition zone beneath the completely altered profile (Figure 5). It does not seem possible for the iron-enriched concretions to have been derived from the Winton profile, since they are very brittle and readily break down to form gravel.

From this evidence in the Moses Sandstone, it seems unlikely that a simple leaching environment was responsible for the diverse rock types present in the Winton profile. Leaching can be evoked as one of the major causes of the highly kaolinitic beds and the complete lack of calcareous beds in the Winton profile, however the mechanism for the iron and silica concentration is more difficult to explain.

It may be that in the case of the siliceous beds the original sediment contained a higher than normal proportion of silica, and this silica may have been partially mobilized and recrystallized to form the present porcellonite beds. Alternatively, silica may have been made available during an overall leaching process, and subsequently selectively precipitated in a suitable bed. This precipitation presumably took place towards the end of the period of alteration, otherwise in a continuing leaching environment silica would have been continuously mobilized.

The controlling factors governing such silica precipitation were not apparent from any of the areas examined.

The environment and mechanism of formation of the ferruginous beds is a little less obscure than that of the siliceous beds. The iron was probably derived from the overall leaching process of the enclosing beds and concentrated into selected beds, during the leaching period by selective replacement of

(1) a suitable host rock in the case of the concretionary bodies, and

(2) a bed probably less susceptible than (1) above, in which iron could concentrate over a period of time due to the downward migration of the iron-rich solutions being arrested by an impervious horizon. The iron must have precipitated as an insoluable mineral that resisted the continuing leaching process.

The actual physical environment during this leaching and replacement cycle is not known. It can only be suggested that the climate was wetter than at present allowing the unit to become water logged for sufficient periods of time to dissolve the large amounts of silica, iron, etc. that must have been removed. It is apparent that the land surface during this cycle was very nearly flat, and this would be a factor conducive to a zone of saturation.

In the authors opinion there is no evidence to suggest a fluctuating water table as responsible for the range of rock types present within this profile, except possibly locally (photo 9), and neither is there any evidence to equate the profile with any part of a laterite profile, although there are some superficial similarities.

(b) Surface and Near-Surface Silicification

During the Tertiary and possible during the Quaternary there were periods of silicification that effected:-

(1) the Glendower Formation, and

(2) the Cainozoic limestone

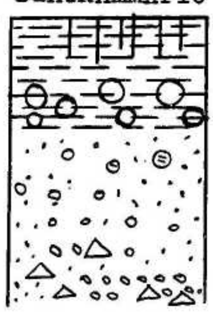
(3) the Winton Formation

(1) The Glendower Formation throughout most of the area has been silicified in its upper layers to produce silcrete (billy). The thickness of this silicification ranges from one foot to thirty feet and averages approximately six feet. In most areas the silicification shows a profile.

A typical profile is shown diagrammatically below (Fig. 7a).

Fig. 7a

DIAGRAMMATIC SECTION THROUGH SILCRETE



Massive silcrete, strong vertical joints.
Large concretionary masses of silcrete enclosed by silicified sandstone grading to silcrete.
Isolated spherical concretionary bodies of silcrete grading downwards in size, in a sandstone matrix. Lower portion of this zone often composed of brecciated material.

Below this profile two types of material are found:-

(a) quartz sandstone, usually with a clay matrix and often strongly nottled red and brown, and

(b) brecciated weathered quartzose rock material, again often strongly mottled red-brown.

The silcrete is found replacing the upper beds of the Glendower Formation. From field relationships it is believed that the silicification took place in the actual upper beds of the unit and its present stratigraphic position below unconsolidated Quaternary deposits is not due to a prior stripping of part of the Glendower Formation.

The silcrete horizon today forms a continuous resistant sheet capping large areas of hills and can be traced from these hills under the adjacent plains. Drill holes at a number of places (B.M.R. Windorah 1 and 3, Jundah 3), as well as water bores and seismic shot holes have intersected silcrete where it has been buried by Quaternary sediments following downwarping of the Tertiary. Between ranges of hills it is possible to project the silcrete horizon across the intervening valleys and so reconstruct a picture of the local structure.

Silcrete has been developed over most of the Glendower Formation on the four western sheets, but its development appears to become more patchy towards the eastern edge of the Windorah Sheet area and on the Adavale Sheet area.

These pieces of evidence suggest that the silcrete formed quite soon after the Glendower Formation was laid down, possibly at the time when the aqueous environment associated with the Glendower deposition was drying up. It appears that in the eastern areas the environment required for its development was becoming marginal, since there is no significant change in lithology across the area. The silicification apparently took place by concretionary growth about quartz grain muclei. These concretions increased in size and enclosed other quartz grains of the parent sandstone as they grew (photo 22 and 23). In the upper part of the profile concretions coalesced and lost their individual identities, eventually forming a massive rock. This process continued downwards into lower levels of the unit until silica precipitation ceased.

The source of the silica is the subject of some discussion. Petrographic studies show that the quartz phenoclasts in the silcrete have been partially dissolved and this process would supply much of the material for the hydrated silica matrix.

Silcrete commonly underlies the large areas of superficial sand cover.

Photo 22. A concretionary nodule of silcrete, upper part of Glendower Formation.

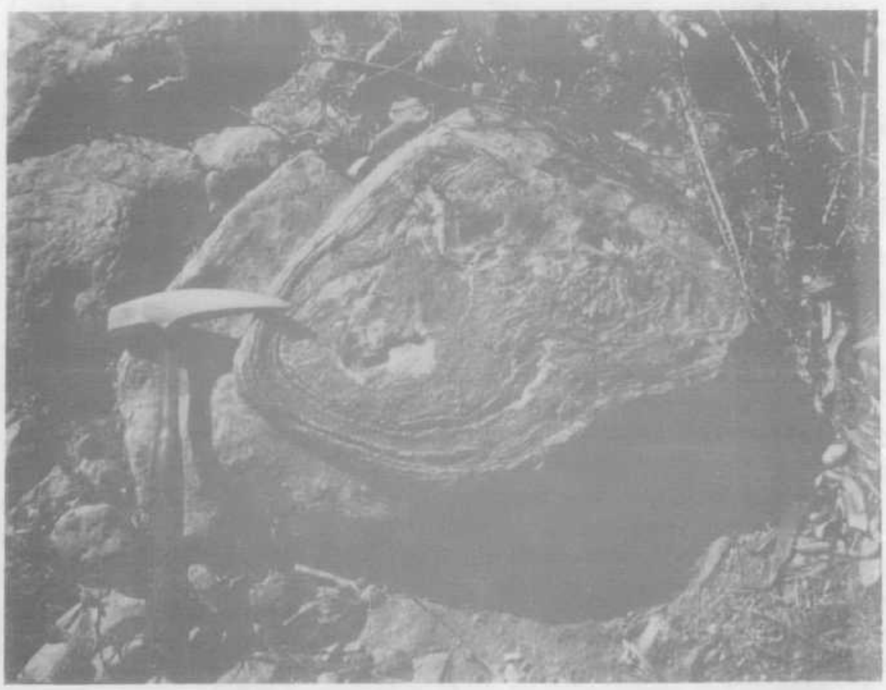


Photo 23. Cross section through nodule of silcrete.

In these areas the sand appears to be an eolian deposit on the margins of broad valleys. A good example of this is the Cooper Creek valley between Cuddapan Homestead (Canterbury Sheet area) in the west and Beentree Bore (Windorah Sheet area) in the east. Between these two, which are both built on Quaternary sand, there is the alluviated Cooper Creek channel country which occupies the lower central portion of the valley, and the sand covered areas occupy the topographically higher valley margins. The valley as a whole is controlled by Late Tertiary folding, which folded the silcrete and underlying units. There does not appear to be any generic relationship between the sand sheets and the underlying silcrete.

(2) The siliceous development in the Cainozoic limestones (Czp) is in the form of chalcedony filling original voids, and as a replacement of the host limestone. This chalcedony is a secondary feature which developed probably after the limestone was completely consolidated.

Chalcedony has been seen as a infilling in voids in the underlying Winton Formation, and as veins interconnecting the two units, as well as vein fillings in the limestone beds. In some outcrops vugs lined with crystalline quartz have developed.

(3) Silcrete was intersected at depth in B.M.R. Jundah 3 (see Figure 7), where it formed a crust on the altered Winton profile. This was the only place where silcrete was formed on the Winton in the whole area, and cuttings from this drill hole did not allow any conclusions to be drawn about the nature of the silcrete or the host rock.

STRUCTURE

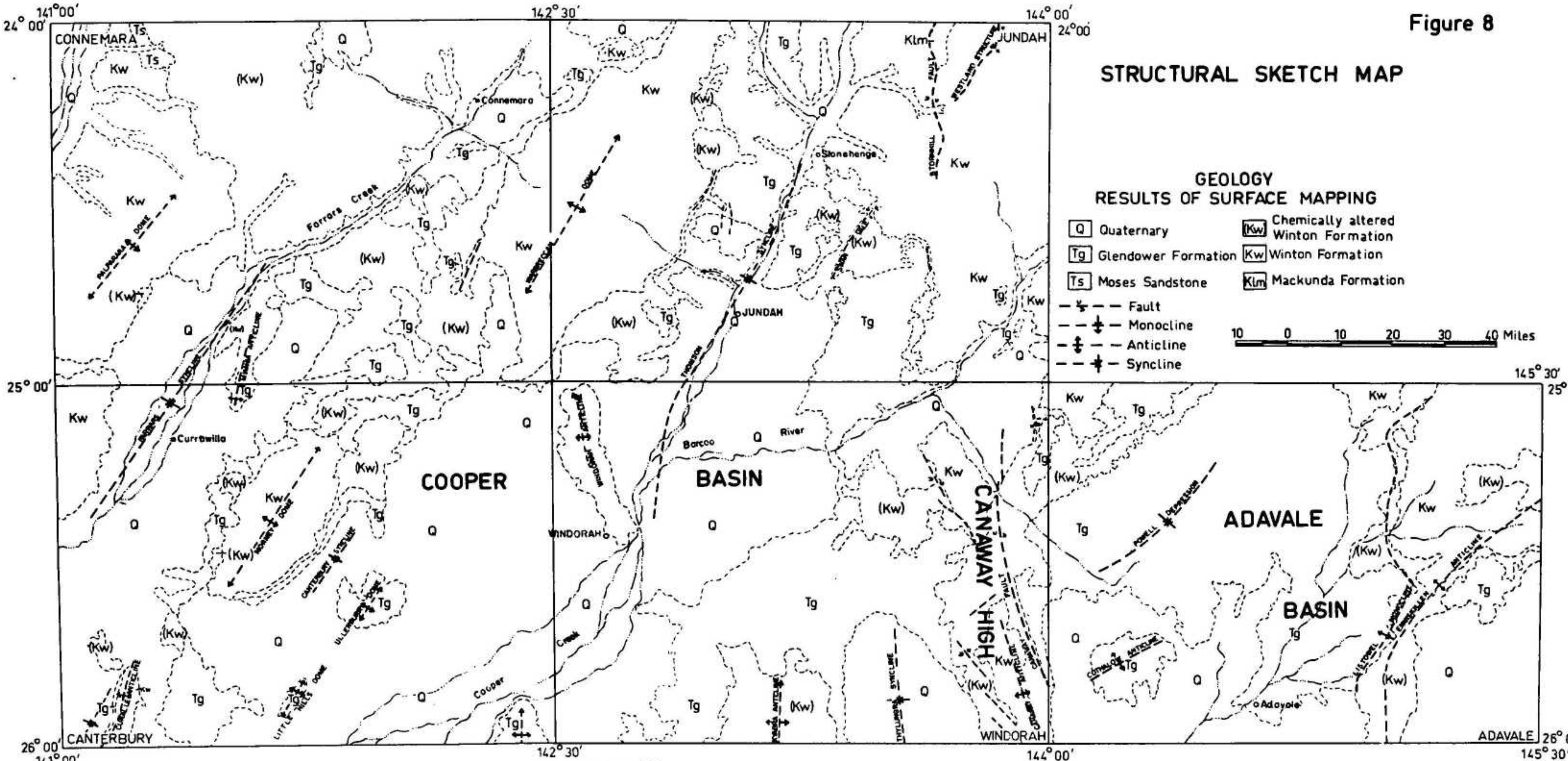
Introduction

The area mapped covers part of a large Jurassic to Cretaceous sedimentary infra-basin known in the literature as the Eromanga Basin, a sub-basin of the Great Artesian Basin. This sedimentary infra-basin covered the whole of the mapped area and the sediments in it rests unconformably on older Permo-Triassic basins, Devonian and Carboniferous basins, as well as a basement complex.

The gross structures in the basement complex, and sedimentary basins older than the Artesian Basin sequence are summarized by Tanner (1966a and b, and Kapel (1966)). Suffice to say here that the area is divided into the Adavale Basin (Fig. 8a) east of the Canaway High (corresponding with the Canaway Fault), which is primarily a Devonian to Carboniferous basin, and the Cooper Basin, west of the Canaway High, which has a long active history from the Devonian to the Triassic (Figure 8). Both these basins are tectonic features that have developed over long periods of time and which consequently filled with thick deposits of sediments. This current mapping has shown that tectonism has continued to the present day, and probably has been active intermittently since inception of the basins.

Within the area as a whole there has been numerous subsequent tectonic movements that have modified these gross structures, and many of these modifications have expression at the present land surface; these are described below and are shown on the accompanying maps (also Figure 8). Structures with sub-surface expression only are not dealt with in detail in this report, but the

Figure 8



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position of some of these is shown on text figures 9-13, and mention is made of the more important of these in Appendix 3.

Details of Surface Expressed Structures

Faults

1. The Canaway Fault and adjacent related faults combine to form one of the major structural features of the area. Its position on the eastern edge of the Windorah Sheet area divides the subsurface Adavale Basin from the Cooper Basin (Fig. 8, Kapel, 1966). It derived its name from Canaway Downs holding, which also lent its name to an anticlinal structure, and a basement ridge that has formed to the west of the major fault.

The Canaway Fault has strong expression at the land surface as a scarp with relief in the order of 200 to 300 feet. The adjacent faults are all expressed on the land surface by scarps or strong lineaments which are readily apparent on aerial photos.

The Canaway Fault forms the east side of a horst that corresponds with the Canaway basement ridge (Canaway High). Throw on the structure is in the order of four to five thousand feet at the basement surface, but considerably less for the younger units, indicating the structure had a long active history.

The western side of the horst block is controlled by three en echelon faults in the south and a major fault, parallel to the Canaway Fault, to the north. A small cross fault west of Trinidad Homestead terminates the Canaway Anticline at the surface and probably also at depth. The northern portion of the Canaway Fault is complex with numerous parallel faults and other shorter cross faults. The fault zone loses its identity under Quaternary cover to the north on the Jundah Sheet area.

The Canaway Fault and the horst (Canaway High), to its west have been recognised in all seismic surveys across the structure.

2. Stormhill Fault and Westland Structure (Jundah Sheet area), are two major structures that had previously been mapped in the area to the north (Jauncey, 1965). These structures have expression in the rolling downs topography, where they cause long, very low parallel strike ridges. They are readily apparent on aerial photos and have been traced to their limit by photo interpretation.

The Stormhill Fault forms the western boundary of the Mackunda Formation against the Winton Formation. The Ruthven Seismic Survey (on the Maneroo Sheet area), indicates a throw at the base of the Wallumbilla Formation of 1500 feet for the Stormhill Fault, diminishing to the south, and 1000 feet for the Westland Structure diminishing to the north. The Westland structure is probably a fault in the south grading northwards into a monocline.

The Swan Vale Fault has strong surface expression as a steep sided slope with up to 200 feet of relief (photo 24). The throw on this fault as with other faults in the area is not known; the sense of movement is west block down.

3. Miscellaneous faults. There are only a few other faults shown on the maps. Strong persistent lineaments have been interpreted as faults, others are shown simply as lineaments. Most of these faults and lineaments trend north-east, parallel to the major structural trend of this part of the Great Artesian Basin. The few structures that trend obliquely to this direction can be considered as local disruptions. There are numerous such disruptions developed on the flanks of the anticlinal structures. These minor faults are not shown on the maps, but are developed in many areas, normal to the local strike, in the area of maximum flexure of the fold. They seldom persist for more than about 100 yards.

Photo 24. Fault line scarp, Swan Vale Fault (Jundah Sheet area), looking south. The left hand block is upthrown.

Folds.

1. Haddon Syncline. A small structure in the south-west corner of the Canterbury Sheet area, between the Betoota Dome (Betoota Sheet area) and the Curalle Dome. The eastern limb of the fold is steeply dipping (up to 30 degrees), and this has produced an asymmetrical structure.

2. The Curalle Dome is a well exposed, breached, asymmetrical, anticlinal structure, that plunges south. The surface expression of the structure is a line of cuestas (photos 25 and 26), with relief of up to 100 feet, forming

its western limb (dips range up to 30 degrees), and a long high cliff (relief of approximately 400 feet) whose surface dips at up to 5 degrees, forming the eastern limb. The structure is about 16 miles long on the Canterbury Sheet area, and has an amplitude in the order of 600 feet at the surface.

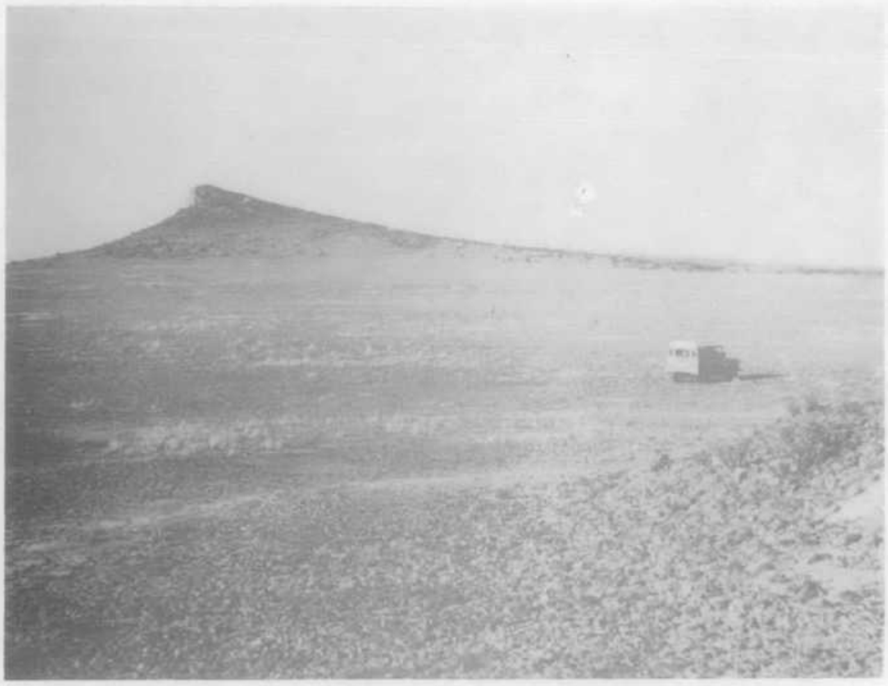


Photo 25. Dip slope on western flank of Curalle Dome, Canterbury Sheet area.

3. Little Hills Dome. A small elongate, anticlinal structure, in the southern part of the Canterbury Sheet area, has formed in the broad downwarp associated with the Cooper Creek. This structure is expressed at the land surface as a low (relief up to 50 feet) silcrete covered hill, protruding through the sand plain.

4. The Mianga Anticline straddles the boundary of the Canterbury and Connemara Sheet areas. This structure, which plunges to the south, is about 20 miles long. Its nose is a complete unbreached fold in Tertiary sediments, but up plunge it has been breached by erosion, revealing Cretaceous sediments. The flanks dip at up to 5 degrees.

5. Farrars Syncline is a major structure with an axial length of approximately 50 miles (Canterbury and Connemara Sheet areas). It ranges in width from about 20 miles to 40 miles. At its narrower part in the north-east, the Mianga Anticline forms a small secondary fold disrupting the symmetry of the eastern limb. There appears to have been a sudden steepening of the dip in the western limb (see section on Canterbury Sheet) and subsequent complete stripping of the Glendower Formation in the area of steepening.

Photo 26. Line of cuestas, western flank of Curalle Dome, Canterbury Sheet area. Photo taken looking south, Haddon Syncline on right.

6. The Morney Dome is one of the most obvious and impressive structures in the Canterbury Sheet area. It is a breached dome, 36 miles long by 24 miles wide, with dips on its flanks up to 5 degrees. All along the eastern edge dips can be measured in the competent silcrete capping of the Glendower Formation, and this part of the unit can be followed around the full periphery of the structure. Relief in some parts adjacent to the Three Sisters is in the order of 400 feet, and hence the fold amplitude on the Glendower Formation is estimated to be at least 500 feet.

7. Canterbury Syncline is a small structure east of the Morney Dome. It probably has quite small amplitude compared with the structure to the west.

8. The Ullenburry Dome is a near circular structure (Canterbury Sheet area) with a maximum topographic relief of about 100 feet. The structure has been breached by some of the larger creeks exposing chemically altered Winton rocks.

9. Palparara Dome is a very large, low amplitude, asymmetrical fold (Connemara Sheet area), which plunges to the south-west. Its north-eastern limb merges with the Farrars Syncline.

10. Warbreccan Dome, site of W.O.L.'s Warbreccan Nos. 1, 2, and 3, oil exploration wells, is a major structure (Connemara and Jundah Sheets), approximately 50 miles long and 35 miles wide plunging south at about 0.5 degrees. Erosion has stripped back the limbs of the fold to produce a maximum topographic relief in the order of 200 feet. The limbs of this fold are remarkably straight in places and appear to be fault controlled.

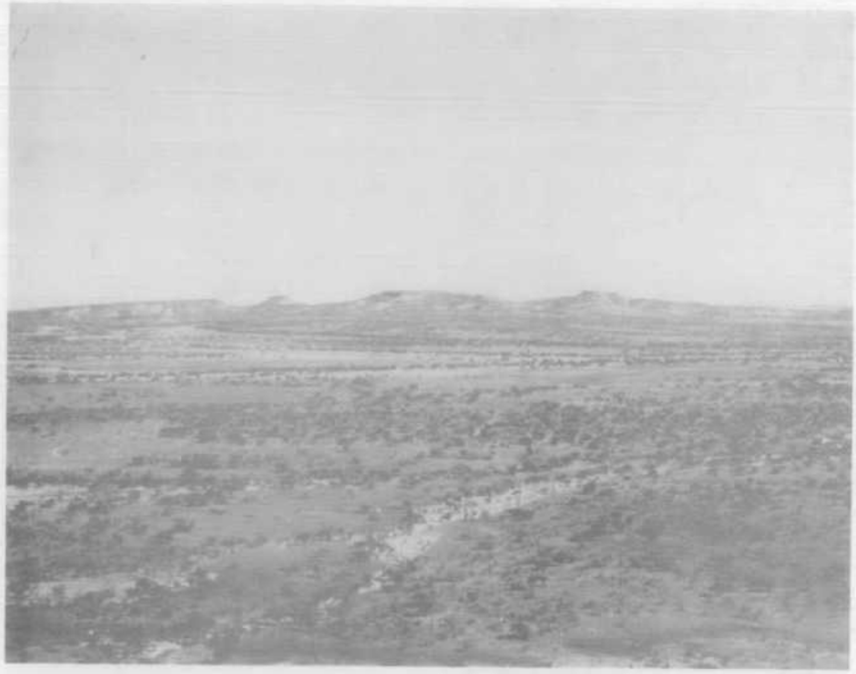
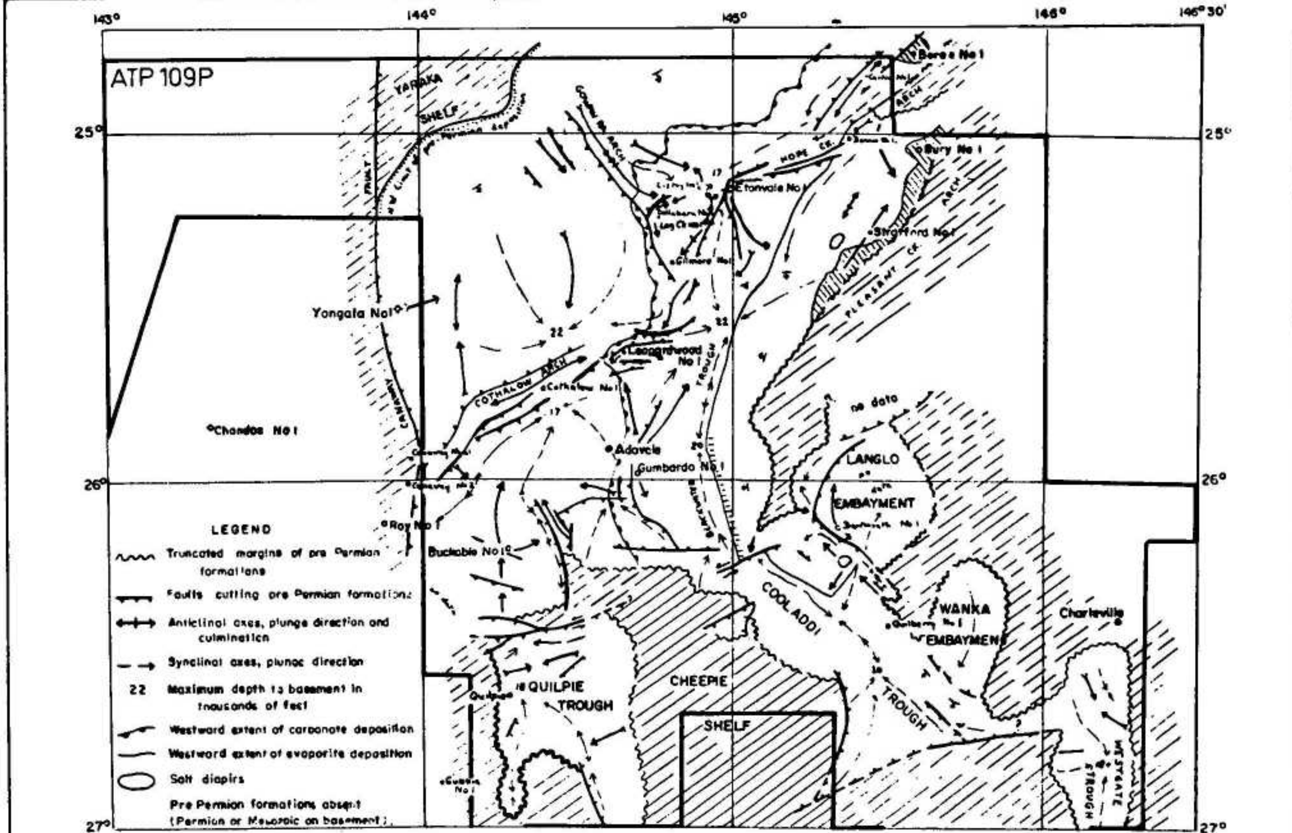


Photo 27. A view of part of the eastern side of the Morney Dome, Canterbury Sheet area (taken looking south-east). Note constant thickness of Glendower Formation (forming upper cliff).

Photo 28. Dip slope on western side of Morney Dome, Canterbury Sheet area. (Photo taken looking south).

Fig. 8A



SUBCROP AND TECTONIC MAP
ADAVALE BASIN

After Phillips – Sunray Leopardwood No1 Completion Report

Bureau of Mineral Resources, Geology & Geophysics. To accompany record 1967/16.

17. The Cothalow Anticline occurs immediately south of the Powell Depression in the south-west corner of the Adavale Sheet area. It is named after Cothalow Block on Milo Holding. Remnants of silcrete occur on the high points over the anticline.

Though not evident from the surface geology, seismic mapping has shown that there is a general structural high extending north-east via Leopardwood No. 1 to the Gilmore area. The relief on the structure between neighbouring synclinal troughs at the depth of the "Hooray Sandstone" reflector is about 700 feet.

18. The Listowel Monocline is an irregular north-south structure in the eastern part of the Adavale Sheet area. West of the monocline the Tertiary section is known to exceed 100 feet while to the east these sediments are generally missing, represented only as a soil profile on the Winton Formation (3-6 feet thick) or, where developed, do not exceed 50 feet in thickness.

The structure is named after the holding "Listowel Valley", the homestead of which is situated near the monocline at map reference (310848).

From seismic mapping the structure is seen to coincide with the eastern edge of the Adavale Basin throughout most of the southern half of the Sheet area, and a marked deepening in the basin in the northern half of the Sheet area. In the northern half of the Sheet area, south of the site of Etonvale No. 1, the surface expression of the monoclinal axis is displaced about four miles east from the axis in the "Hooray Sandstone" and Permian horizons, and a fault (downthrown to the west), in the Devonian D3 reflector. North of Etonvale No. 1 the monocline coincides closely with the continuation of the D3 reflector fault and north-west dips in the "Hooray Sandstone" and Permian reflectors.

In the southern half of the Sheet area the relief of the structure on the "Hooray Sandstone" reflector is about 1,500 feet; north of 25°30'S., the relief on the same reflector is 350-700 feet.

19. Enniskillen Anticline. This south plunging structure was named after the Enniskillen Range on the Tambo Sheet area from whence it continues southwards across the north-west corner of the Augathella Sheet area onto the Adavale Sheet area, where it is immediately east of, and parallel to, the Listowel Monocline.

The structure is evident from the inlier of Winton Formation along its length in the south as well as near the eastern edge of the Sheet area. Throughout the intervening 12 miles the structure is continued by interpolate.

From seismic mapping on the Permian and "Hooray Sandstone" reflectors, the structure is known to coincide with a small anticline east of the edge of the Adavale Basin. Its east-west amplitude is variable but generally 70-150 feet.

Slumping

Gravity slump blocks, some of huge proportion, have developed in many places from cliffs of altered Winton sediments overlain by the Glendower Formation. These blocks probably developed after periods of heavy rain and subsequent ground saturation. Anomalous dips of up to 50° have resulted in some slump blocks, (see photos 29, 30, 31 and 32).

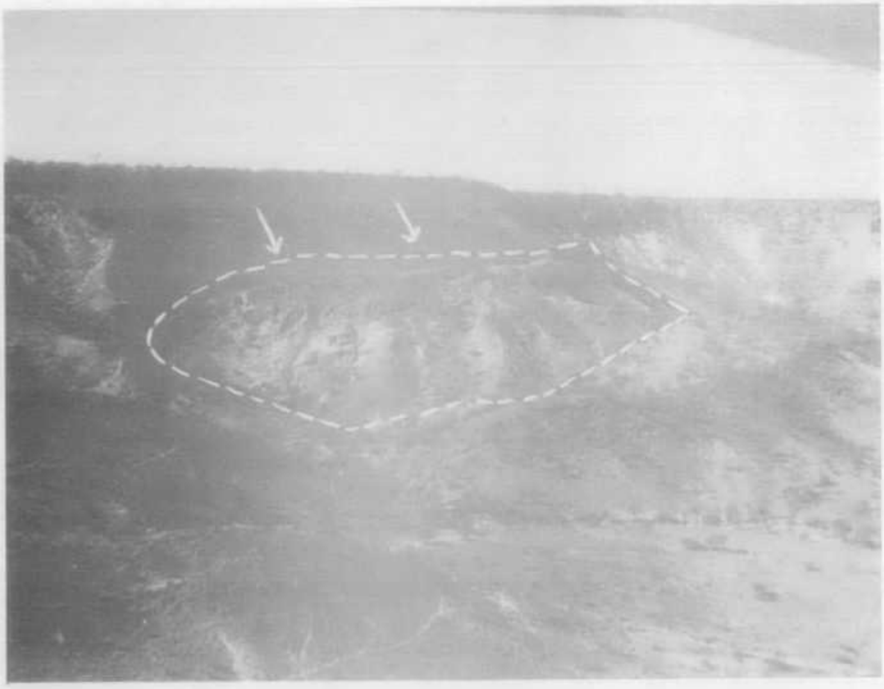


Photo 29. Gravity slumped block, Morney Dome, Canterbury Sheet area.

Photo 30. Gravity slumped block, Morney Dome, Canterbury Sheet area. Note silcrete in upper zone of Glendower Formation.

Photo 31. Gravity slumped block in Morney Dome, Canterbury Sheet area. Note silcrete in upper zone of Glendower Formation.

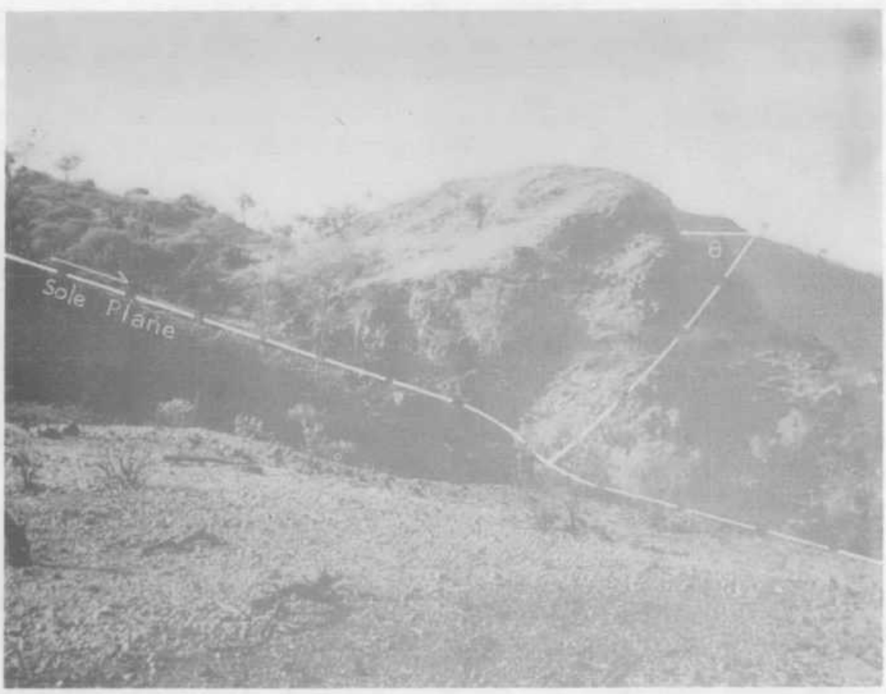


Photo 32. Gravity slumped block at Mount Felix, (Jundah Sheet area). The rotation of the block from the horizontal is shown by the angle ϕ.

GEOPHYSICAL SURVEYS

Introduction

Geophysical surveys undertaken on the five 1:250,000 Sheet areas include gravity, aeromagnetic and seismic surveys. Two aeromagnetic surveys cover the whole area west of longitude 143°E.

Regional seismic surveys cover large portions of the eastern part of the mapped area. Detailed seismic work, following reconnaissance surveys, have defined promising structures on the Adavale Sheet and part of the Windorah Sheet.

The majority of the geophysical work has been subsidized by the Commonwealth Oil Search Subsidy Scheme.

A) Gravity Surveys

A gravity survey using helicopters, taking readings on a seven mile grid was carried out by the 'Wongela Geophysical Company Ltd', under contract to the Bureau of Mineral Resources. In 1962 - 5 Bouguer anomaly maps of the region were published by the Bureau of Mineral Resources.

Almost the whole of the mapped area is contained within one well defined gravity province, "The Thomson regional gravity low". Subsidiary Bouger anomalies show good qualitative correlation with observed geological structure. Important anomaly features reflecting the geological structure of the mapped area (see Figure 9), have been described by Gibb (1964), and Lonsdale (1965). Anomaly features of interest in the area under study include -

1. 'The Diamantina Gravity gradient'. This linear steep gravity gradient on eastern Machattie and north-western Connemara Sheet areas, forms the boundary between the 'Cloncurry gravity high' and the 'Vergemont gravity depression' (Gibb, 1966). The linear anomaly probably reflects a major density change within the basement possibly caused by a major transcurrent fault.

2. 'The Vergemont gravity depression'. This is a north-east trending series of gravity lows on Connemara Sheet, south-east Brighton Downs, and east Maneroo Sheets, and extending further north-east. Drilling of A.A.P. Mayneside No. 1 and Fermoy No. 1 to the north-east, indicates the negative anomalies result from low density basement (Vine, et al., 1965).

3. 'The Jundah gravity depression'. A north-east to north-west trending belt of gravity lows extending from north Windorah Sheet through Jundah Sheet to south Maneroo Sheet areas. On Windorah and Jundah Sheets the position of the anomaly coincides with the Thomson Syncline.

4. 'The Barrolka gravity low'. A north-west trending gravity low in north-east Barrolka Sheet and south Canterbury Sheet.

5. 'The Betoota-Warbreccan gravity ridge'. A gravity ridge extending from the west on to Canterbury Sheet area, and trending north-east through Connemara and west Jundah Sheets. This anomaly correspond to a granitic(?) basement uplift, and has the surface expression on Canterbury, Jundah and Connemara

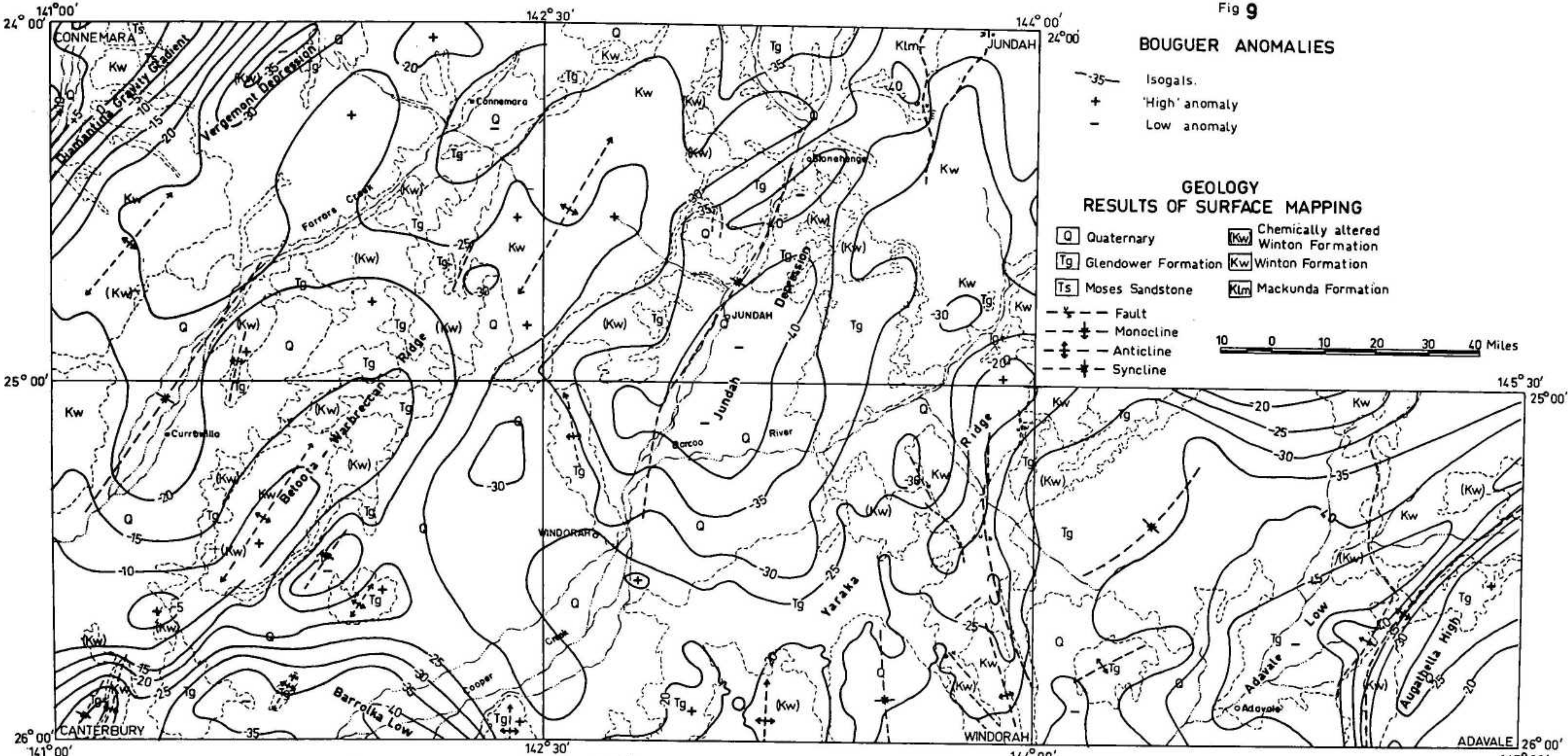


Fig 9

BOUGUER ANOMALIES

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Sheets as a series of anticlinal ridges and includes the Morney and Warbreccan Domes.

6. 'The Yaraka gravity ridge'. A north-east trending belt of gravity highs, situated on north-east Durham Downs and north-west Thargomindah Sheets. The ridge continues through Barrolka, Eromanga and east Windorah Sheet areas, and further north through east Jundah. On Windorah the surface expression of the anomaly corresponds with the Kyabra Anticline and the northern part of the Canaway horst.

7. The Adavale gravity low is a north-east elongate deep depression in east Adavale Sheet area, corresponding to the Adavale Basin.

8. The Augathella gravity high is a north to north-east trending series of gravity "highs" on eastern Adavale Sheet area, that corresponds with the Enniskillen Anticline.

Several other smaller gravity surveys include a detailed reconnaissance of the Warbreccan area in 1955 on the behalf of Westland Oil Limited. On the basis of this survey the three Warbreccan petroleum exploratory bores were drilled. These bores subsequently abandoned as dry holes, proved the presence of a granite(?) basement ridge, i.e. the Betoota-Warbreccan gravity ridge.

In 1957 Smart Exploration Company promoted a reconnaissance gravity survey in the Canaway Downs area. Further work in this area in 1958-9 (Eromanga Gravity Survey, for L.H. Smart, 1961) delineated the Kiabra Anticline.

In 1963 the Windorah Gravity Survey was carried out for Alliance Oil Development, by Geoseismic Limited. The survey confirmed the presence of the Canaway Anticline and showed that the -35 Milligal Bouguer gravity contour extended along the fault, confirming the idea that it marked the western edge of the Adavale Basin.

B) Seismic Surveys

Introduction

The five 1:250,000 Sheets are included within the petroleum exploration and development tenements 66/67P, 83P, 98P, 109P, and 121P (as at 30th June, 1966).

Mainly reconnaissance seismic has been carried out over Jundah and Windorah Sheet areas. Adavale Sheet area has received a very comprehensive seismic coverage. In contrast Connemara Sheet area has been completely neglected in the utilization of this technique. Interest in the Canterbury Sheet is being shown at the present time, and a portion of the extreme north-east corner has been surveyed on behalf of French Petroleum Co. Ltd.

Reflection seismic techniques are the most popular in the region, and only one refraction survey, in the Chandos area, for Alliance Oil Development, has been attempted. The various surveys are listed:

1961 Adavale area	Phillips Petroleum Co.
1961 Blackwater-Langlo	" "
1963 Gowan Range	" "
1962 Gumbardo area	" "
1961 Jundah-Yaraka	" "
1963 Pleasant Creek	" "
1964 Mount Watson	" "
1965 Strathconon area	" "
1965 Listowel area	" "
1965 Log Creek area	" "
1964 Gilmore area	" "
1966 Powell Creek	" "
1965 Leopardwood area	" "
1965 Bride Creek	" "
1965 Rockwell area	" "
1966 Panhandle Survey	" "
1963 Bulgroo area	Alliance Oil Development
1965 Trinidad area	" "
1966 Chandos area	" "
1961 Stonehenge area	Conorada Petroleum Corporation
1965 Barcoo Survey	Marathon Petroleum Co. Ltd

(The present authors undertook some re-interpretation of results of this survey and this interpretation is shown in the accompanying text figures).

1966 Windorah-Wolgolla area	French Petroleum Company

Important reflector horizons, namely the top of the "Hooray Sandstone", Permian, and the Devonian D3 are illustrated on contour maps (Figs. 10-12), which also allow comparison with the surface geology.

C) Aeromagnetic Survey

An aeromagnetic survey on behalf of Delhi Australian Petroleum Ltd and Santos Limited, was carried out by Adastra Hunting Geophysics Pty Ltd in 1963. This survey covered 21,340 square miles and included most of the area of this present mapping project west of 143°E. An earlier survey, covering the south-west corner of the Canterbury Sheet area, was carried out by Aero Services (Bahamas) Ltd on behalf of Delhi Australian Petroleum Ltd.

The interpretation of the Cooper Creek Survey suggested that the magnetic basement coincided with the geological basement. The survey reported that in the north-west corner, the basement forms an undulating shelf 2,000 to 3,000 feet below sea level which dips down to the south-east to where it reaches depths of between 15,000 and 17,000 feet below sea level. The author of the report on the survey points out that the lack of suitable anomalies in the Connemara and Canterbury Sheet areas limits the accuracy of their results. It is possible that major basement highs have been overlooked by the aeromagnetic survey.

The older survey has picked out a number of anomalies, but none of these are of major importance and do not correspond in any simple way with the surface geology. To avoid confusion they are not shown on the accompanying sketch map (Figure 13).

Fig 10

RESULTS OF SEISMIC SURVEYS

"Hooray Sandstone" Reflector

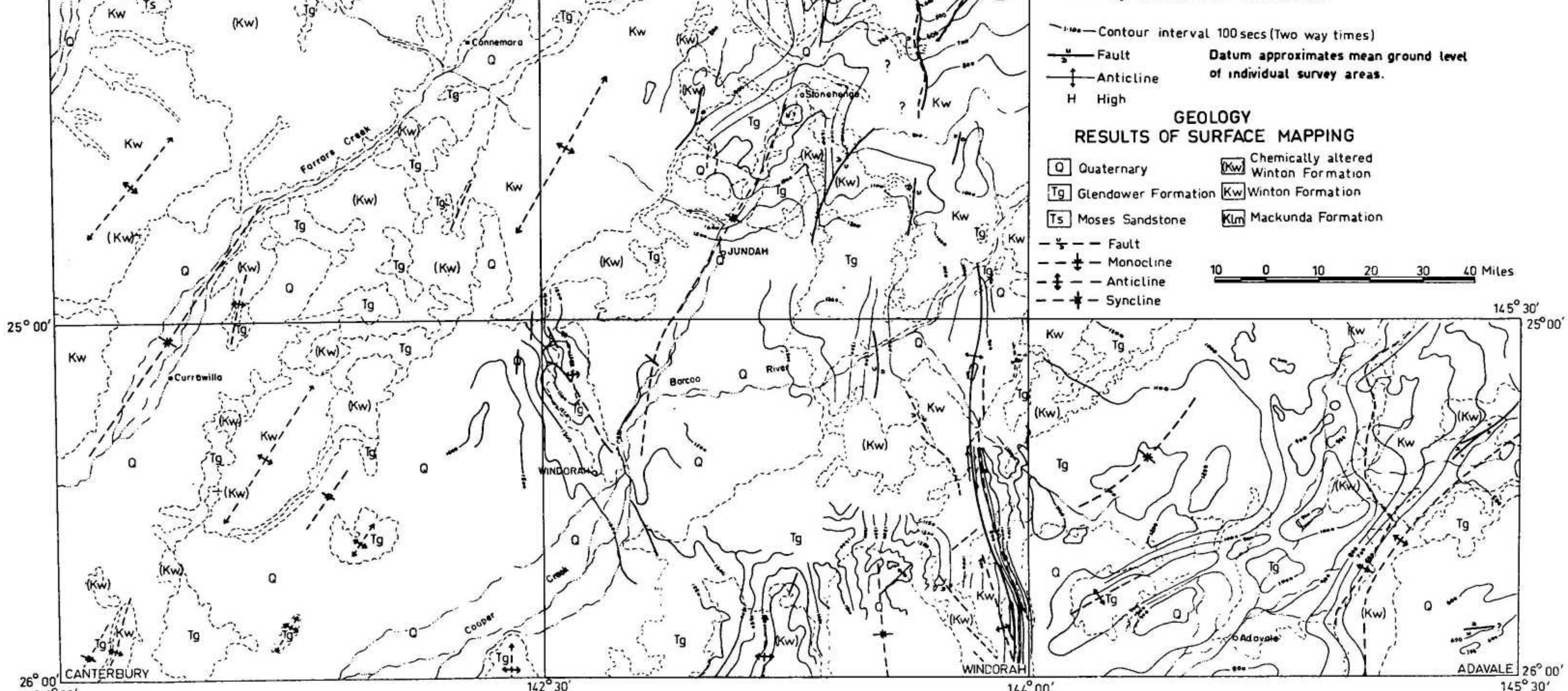

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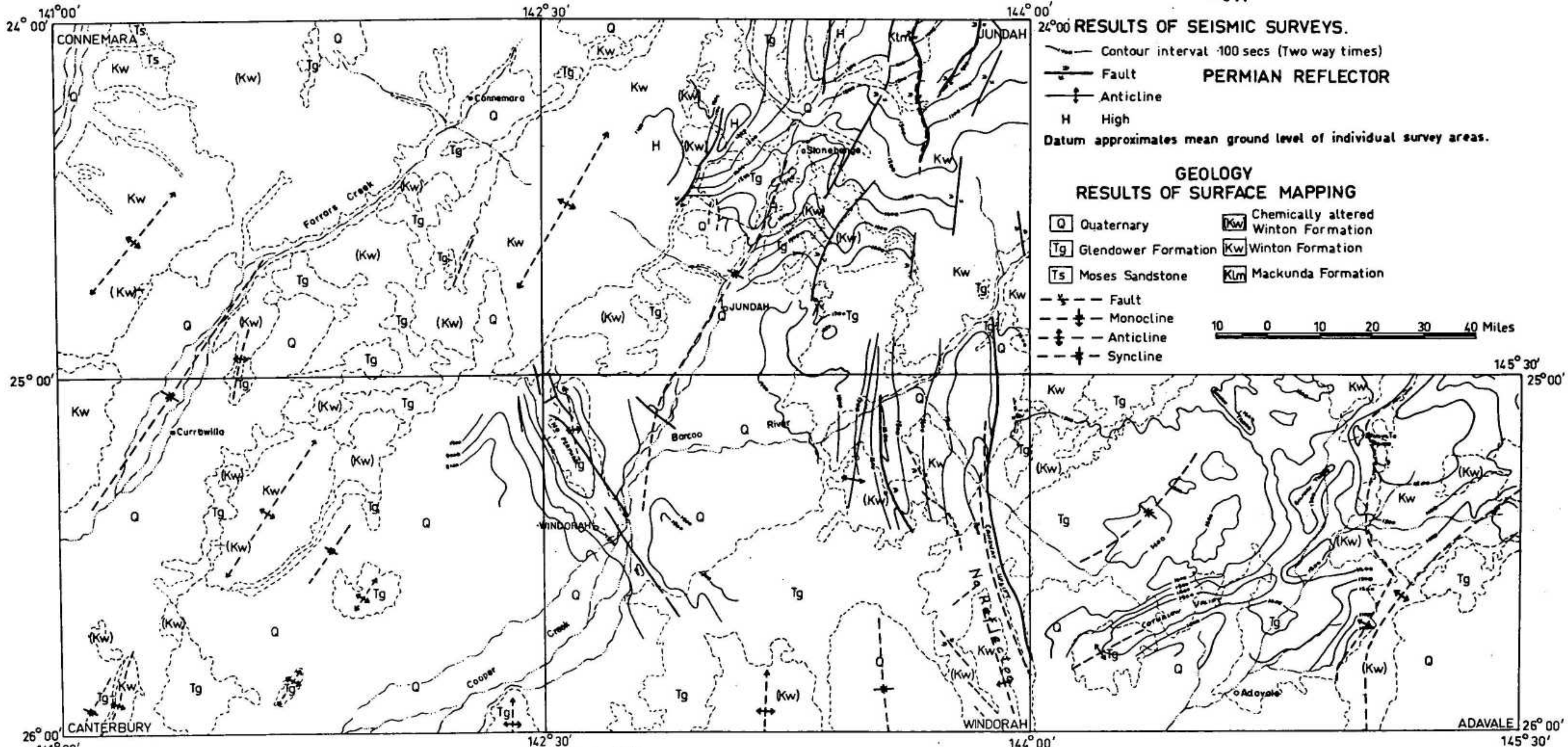
Fig 11



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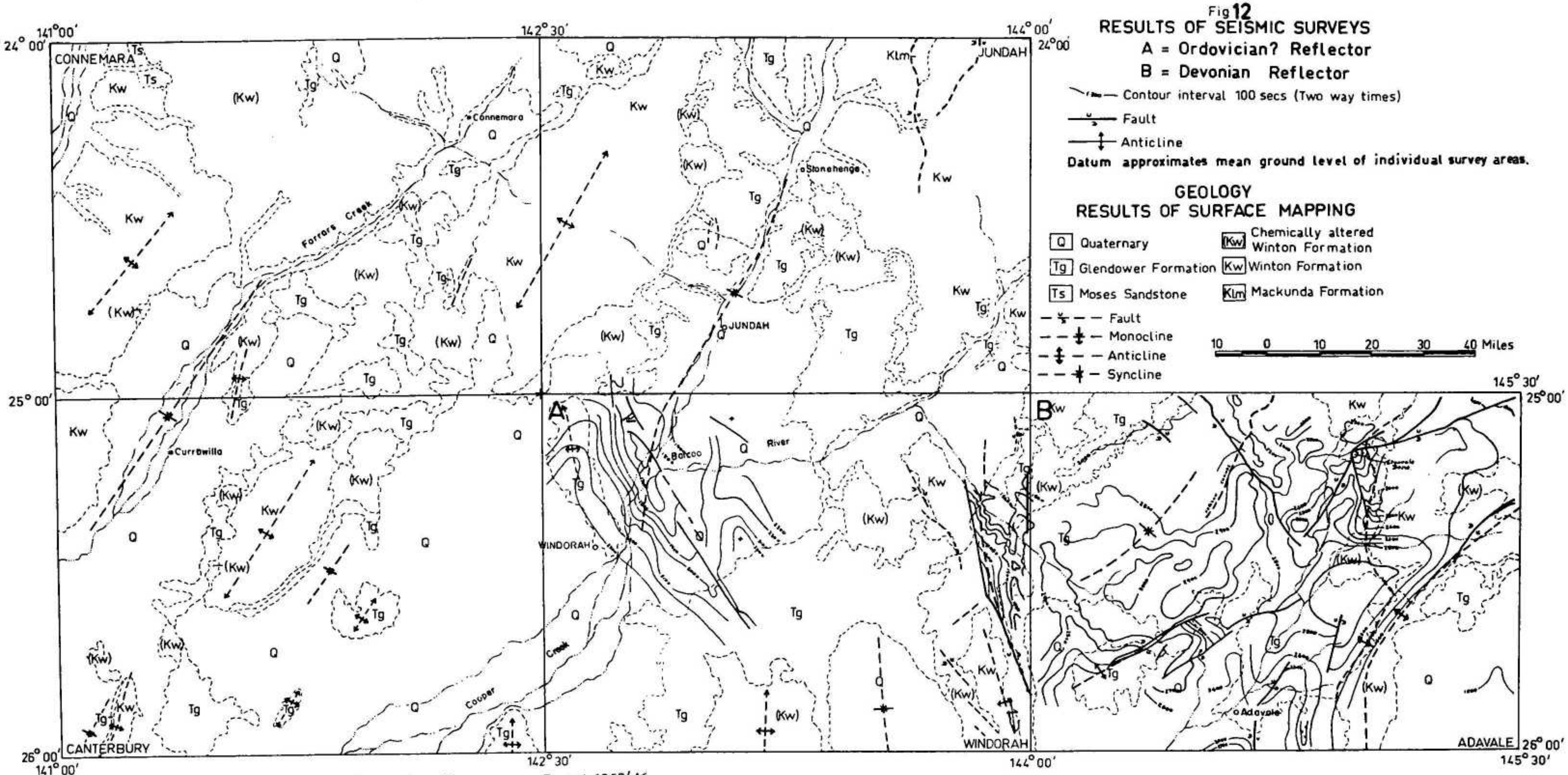

Fig 12
RESULTS OF SEISMIC SURVEYS

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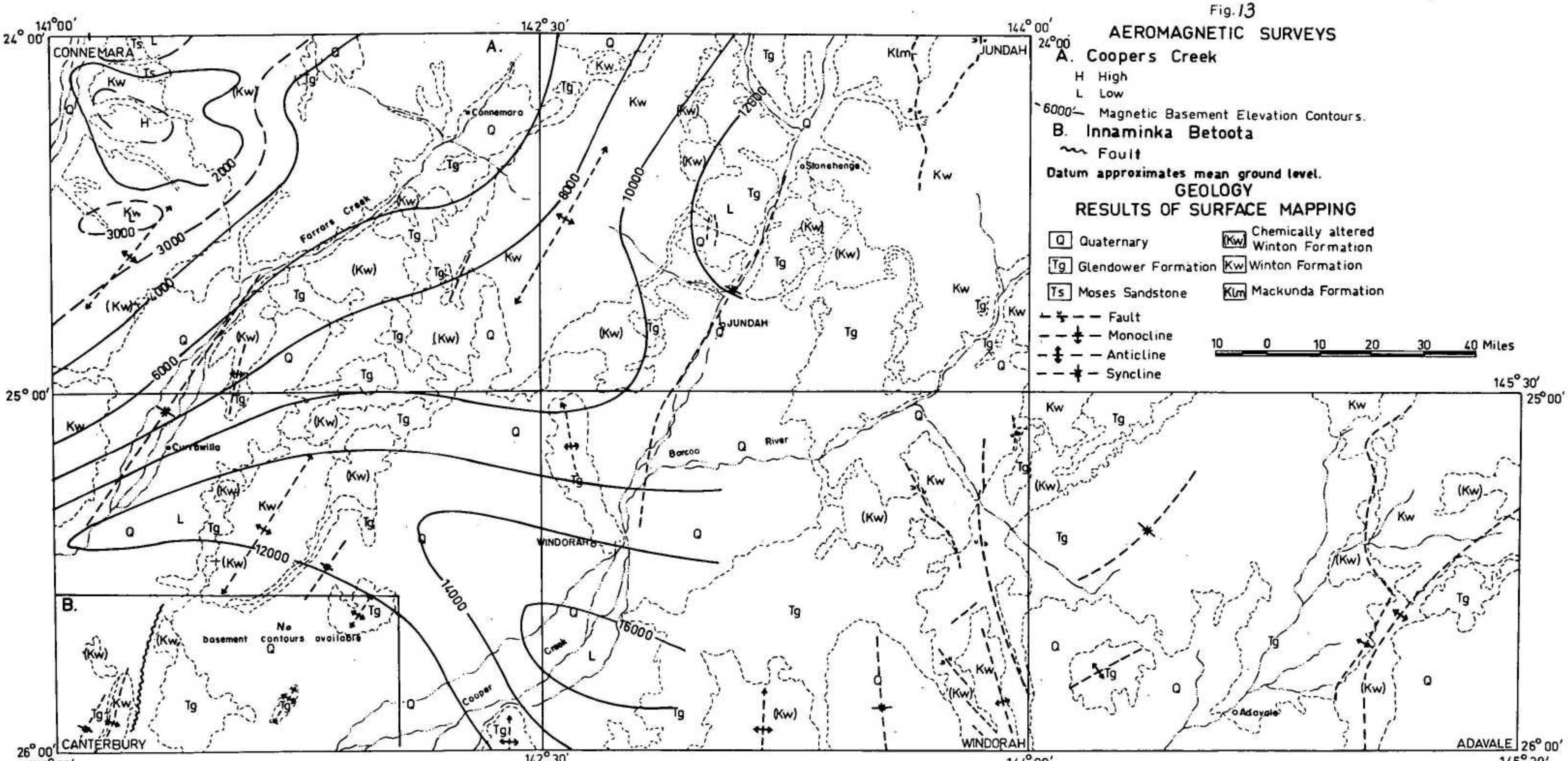
Fig. 13



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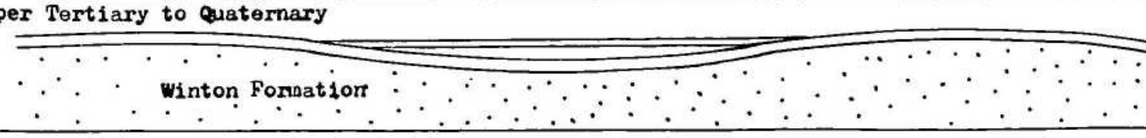
Diagrammatic Representation of Geological History

7 Upper Tertiary to Quaternary

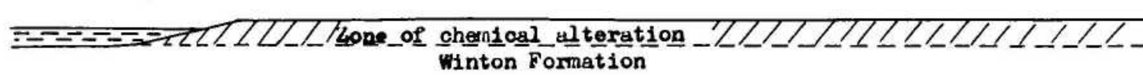


Gentle folding, erosion and deposition of Quaternary sediments in synclines.

6 Tertiary

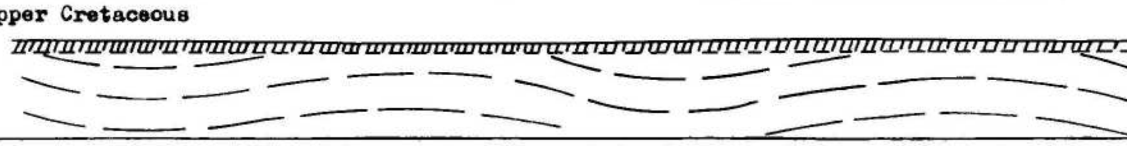
Deposition of Glendower Formation on eroded surface of Winton Formation. Silcrete developed in upper zone.

5 Lower Tertiary



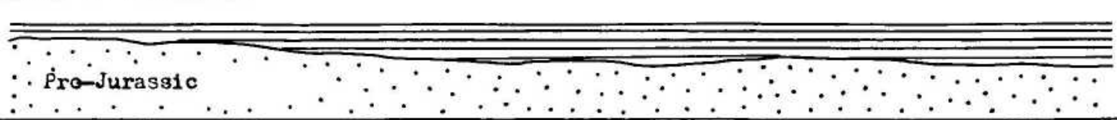
Local stripping of zone of chemical alteration, deposition of Moses Sandstone, and continuation of environment causing chemical alteration for a short period of time, minor alteration of Moses Sandstone.

4 Upper Cretaceous



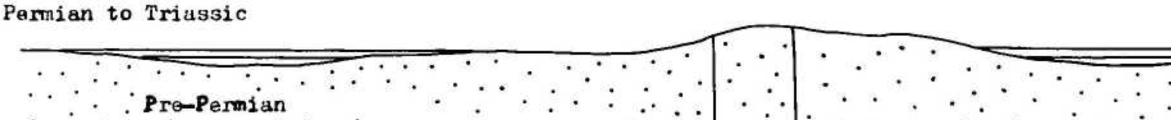
Broad open folding, followed by peneplanation and development of zone of chemical alteration.

3 Jurassic to Cretaceous



Late Triassic uplift and erosion followed by deposition of Artesian Basin sequence in a broad shallow downwarp.

2 Permian to Triassic



Deposition of sediments on a regional erosional surface. Canaway structures active, also uplift of western Adavale Basin.

1 Devonian to Carboniferous

Down-warping of Adavale and Cooper *Basins commenced.* Deposition of sediments, (restricted largely to eastern area) . First movement on Canaway Fault.

FIGURE 14

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GEOLOGICAL HISTORY

The geological history of the area is summarized in figure 14.

ECONOMIC GEOLOGY

Water

Water and especially sub-artesian water is the most valuable substance obtained from the ground in the area mapped. Sub-artesian water is obtained from numerous bores and wells which range in depth from about twenty feet to over 1,000 feet. The water ranges widely in quality and supply; most is fit for human consumption although not always palatable.

Artesian bores range in depth from about 1,000 feet to over 5,000 feet. They all yield a good supply of usually very high quality, hot water.

The artesian bores in the area mapped are shown in Table 4:-

TABLE 4: SUMMARY OF ARTESIAN BORES

Name	Sheet	Depth	Aquifer	QIWS Reg. No.
Merabooka	Connemara	2625	Jurassic S. St.	14486
Whitewood	Jundah	5045	Jurassic S. St.	1475
Mungerie	Jundah	4310	Jurassic S. St.	1474
Bothwell	Jundah	4860	Jurassic S. St.	1473
Buffalo	Jundah	3480	Jurassic S. St.	4910
Warbreccan	Jundah	4333	Jurassic S. St.	4782
Colliban	Windorah	913	Winton Fm.	3947
Sundown	Windorah	870	Winton Fm.	3945
Lynnfield	Windorah	871	Winton Fm.	3950
Adderley	Windorah	1557	Winton Fm.	5983
Bulgroo	Windorah	5517	"Hooray S. St."	1728
Britamart	Adavale	4250	"Hooray S. St."	3770
Milo Holding No. 3	Adavale	4857	"Hooray S. St."	3771
Adavale Town	Adavale	3398	"Hooray S. St."	305
Stannum	Adavale	3670	"Hooray S. St."	1184
Doondoon	Adavale	3768	"Hooray S. St."	1183
Ambathala	Adavale	3677	"Hooray S. St."	1180
Mt Morris No. 3	Adavale	3242	"Hooray S. St."	3954
Merrigal	Adavale	2029	Winton or Mackunda Fms.	3767
Pigurra	Adavale	3811	"Hooray S. St." or Adori Fm.	120

Artesian and sub-artesian water is the main supply of stock water in this district. The larger streams have permanent water holes but they are accessible to only a very small percentage of the total stock numbers. Earth tanks, and to a lesser extent dams, also provide water for stock.

Artesian water can be obtained from any part of the area except possibly the more elevated areas, but drilling costs to the depth required to obtain it is often felt to be uneconomic. At Windorah a bore was drilled for the Barcoo Shire Council to a depth of 4000 feet, without obtaining any worthwhile supply. Evidence from Galway No. 1 indicates that in this area it is necessary to drill to at least 5000 feet before any artesian supply can be expected. By contrast, at Merabooka Bore, near the western edge of the Connemara Sheet area, the same aquifer system is little more than 2000 feet deep. To the west it is even shallower, as the present margin of the Great Artesian Basin is approached. Windorah appears to be situated in the deepest part of the broad Cooper Creek downwarp.

The artesian bores in the north-east quarter of the Jundah Sheet area are fairly deep and tap a main Artesian Basin aquifer system.

In the eastern part of the Windorah Sheet area there is a number of relatively shallow (of the order of 1000 feet deep) artesian bores, distribution of which appear to be related to the major faulting in this area. Palynological evidence (Evans, pers. comm.) suggests that these bores derive their water from an aquifer within the Winton or possibly the Mackunda Formations possibly supplied from deeper aquifers and being fed through the shatter zone of a fault.

On the Adavale Sheet area the main source of artesian water is the "Hooray Sandstone", which produces an abundant supply of good quality water. The Merrigal Bore obtains good supplies of good quality water from a localized aquifer in the upper part of the Cretaceous sequence.

Sub-artesian bores have been unsuccessful in obtaining adequate water supplies in many cases. Where the bores are drilled into the Winton Formation it is generally a matter of luck whether or not a suitable aquifer will be intersected; and the water is often poor. Bores drilled into the Glendower Formation usually produce good water in adequate quantity. Good quantities of high quality water are often obtained where there has been a significant pile of sediment deposited in a downwarped area underlain by the main silcrete horizon.

Abundant supplies of good quality water can be obtained from the alluvium adjacent to all the major water courses.

Petroleum

The area as a whole is recognised as having considerable petroleum potential. Private exploration companies have drilled a number of test wells on the Adavale, Windorah and Jundah Sheet areas, but so far only Chandos and Gilmore have produced any significant results (see Appendix 3, and Tanner, 1966a).

Preliminary geophysical surveys in the area have covered large portions of the Sheet areas (see chapter on geophysical results), and this is being followed up by systematic detailed seismic work.

So far three stratigraphic sequences have been considered as suitable reservoirs for petroleum, they are:

(a) the Devonian D4 sandstone in the Adavale Basin, and in Chandos No. 1;

(b) the Permian sequence, which at Gidgealpa, South Australia contained substantial accumulations of petroleum gas, and

(c) the Triassic sequence which at Chandos No. 1 produced minor quantities of oil.

Most of the early oil exploration wells were drilled on structural evidence, with little or no accurate stratigraphic control. Within the Adavale Basin, Phillips Petroleum Co. have established a network of drill holes which allows them to predict with reasonable certainty the pre-Jurassic subsurface stratigraphy after a preliminary investigation by seismic methods. The more isolated wells at Chandos and Galway demonstrated a different sequence beneath the Jurassic unconformity to that of the Adavale Basin. The Devonian basin may have had an arm extending to Chandos, but was absent at Galway. The Permian Gidgealpa Formation or its correlate was recognised in Chandos No. 1, but was very thin. It was absent in Galway No. 1, as predicted from seismic evidence.

The Warbreccan wells were drilled in 1955 near the old Warbreccan flowing bore, from which samples of wet gas had been taken in 1928 (Geological Survey of Queensland, 1960, publication 299). Geological field work in the area and bore-log correlations suggested that the bore might be situated somewhere about the crest of a broad structural ridge. No shows of oil or gas were obtained in any of the three wells.

The western part of the mapped area has as yet received little attention from exploration companies due to the lack of geological knowledge of the area. However, this situation is slowly changing as companies work further and further out from the known areas and as the B.M.R. and Geological Survey's continue their policy of regional mapping.

This present survey defined a number of promising structures which had not previously been mapped and which the authors feel warrants more detailed investigation.

Opal

Opal has been mined on the Jundah and Windorah Sheet areas and there are verbal reports (from local residents), of precious opal occurrences on the western Sheet areas also, although none were sighted.

On the Jundah Sheet area opal was first mined about 1880 and most activity took place between then and 1900. During that time the main area of interest was "Opalville" (Connah, 1966), a now abandoned settlement. It is reported that in 1900 there were over 100 men working the field there and many others prospecting surrounding areas. A severe drought curtailed mining activities in this area, and subsequently there has only been sporadic interest by holiday makers, gougers, etc..

Elsewhere on the Jundah Sheet area opal has been reported from near Opal Creek and from Mount Fairview. At Mount Fairview at the present time a local landholder is using heavy earth moving machinery to remove overburden and to open-cut a mineralized zone. He claims to be making quite adequate profits from the venture.

On the Windorah Sheet area there is no current mining activity and only three localities of precious opal were located during the present survey; all three had previously been worked. These deposits are in an area north of Bulgroo Homestead and north-east of Trinidad Homestead. The prospects near Bulgroo Homestead, especially Germans Mine appeared to have yielded the most opal. No published information is known about these mines.

All the precious opal localities occur in the zone of chemically altered Winton sediments, and generally in areas where the Glendower Formation is very thin and lacking in quartzose sediments, or is absent. From the few localities examined it appeared that these areas of mineralized Winton rocks were islands in the Tertiary lake and river system responsible for the Glendower sediments.

In the localities examined opal occurs well beneath the top of the hills, either low down the slope or in the surrounding plain. At "Opalville" the mining activity was restricted to a creek flood plain. The mode of the opal in the occurrence there was explored by two scout drill holes (B.M.R. Jundah No. 1 and 2); the stratigraphic columns from these tests are shown in Figure 15. At this locality secondary iron enriched layers developed within a labile sandstone and appear to be intimately associated with precious opal. Precious opal occurs in three modes:

(1) In horizontal, branching pipe-like bodies up to an inch in diameter, of concentrically layered iron oxides. These structures sometimes have a core of precious opal, or thin spheroidal layers of precious opal sandwiched between layers of "ironstone".

(2) Associated with the iron-opaline pipes is a near continuous laminar iron-rich bed. At "Opalville" this bed was traced by the miners over an area of approximately 500 square yards. Thin laminae of precious opal are associated with this type of iron enrichment.

(3) The surrounding labile sandstone, for much of the upper section, has a matrix of precious opal. Also a poor quality, vitreous, precious opal is localized in what were originally cavities within this opaline sandstone. The opaline sandstone here is underlain by an apparently impervious mudstone, which would have acted as a barrier to the downward migration of solutions containing silica.

In the Windorah Sheet area opal occurs in similar modes to that at "Opalville, and also in what are locally known as "boulder opal" deposits. These are concretionary masses of iron oxide, up to one foot long, and ovoid in shape, with precious opal localized along concentric openings and radial fractures and joints. These concretions are developed in zones or as discrete entities scattered along a bedding plain.

Another mode of occurrence of precious opal is in highly ferruginous bands up to about 2 inches thick, developed usually in sandstone or siltstone and overlying an apparently impervious mudstone. In these deposits the underlying mudstone is often a bright yellow-brown with pipes of highly ferruginous opaline material projecting down into it. Above the mudstone is a zone of iron-rich material with opal localized along micro-bedding features. This zone is in turn overlain and grades up to a speckled iron-enriched sandstone which is abruptly terminated against a pallid sandstone.

There are many difficulties associated with prospecting for, and mining opal, because as yet the environment and controls required to localize opal are not sufficiently understood and because deposits are seldom continuous for large distances. Also as yet no prospecting technique has been developed suitable for application even in the areas of known opal deposits.

An approach might be, in this area of Queensland, to map out the areas of Winton Formation that were 'islands' in the Tertiary Glendower depositional environment. This might reduce considerably the area to which serious prospecting need be concentrated, and with a knowledge of the mode of opal localization and of its host material, more opal strikes might be made.

Previous literature on the subject is confusing to many readers because of inconsistency in nomenclature and also in description of the host unit.

The problem, as it appears from very limited observations during this regional mapping project, can be simplified to: finding areas of chemically altered Winton sediments that were not overlain by Tertiary quartzose sediments, and in those areas examine gravel and outcrops of highly ferruginous material. It must also be kept in mind however that opal also occurs as a matrix in sandstone, and this mode is apparently common in subcrop beneath younger superficial sediments adjacent to the base of the typically steep-sided hills. In this case shallow drill holes in likely areas could produce positive results.

Construction Materials

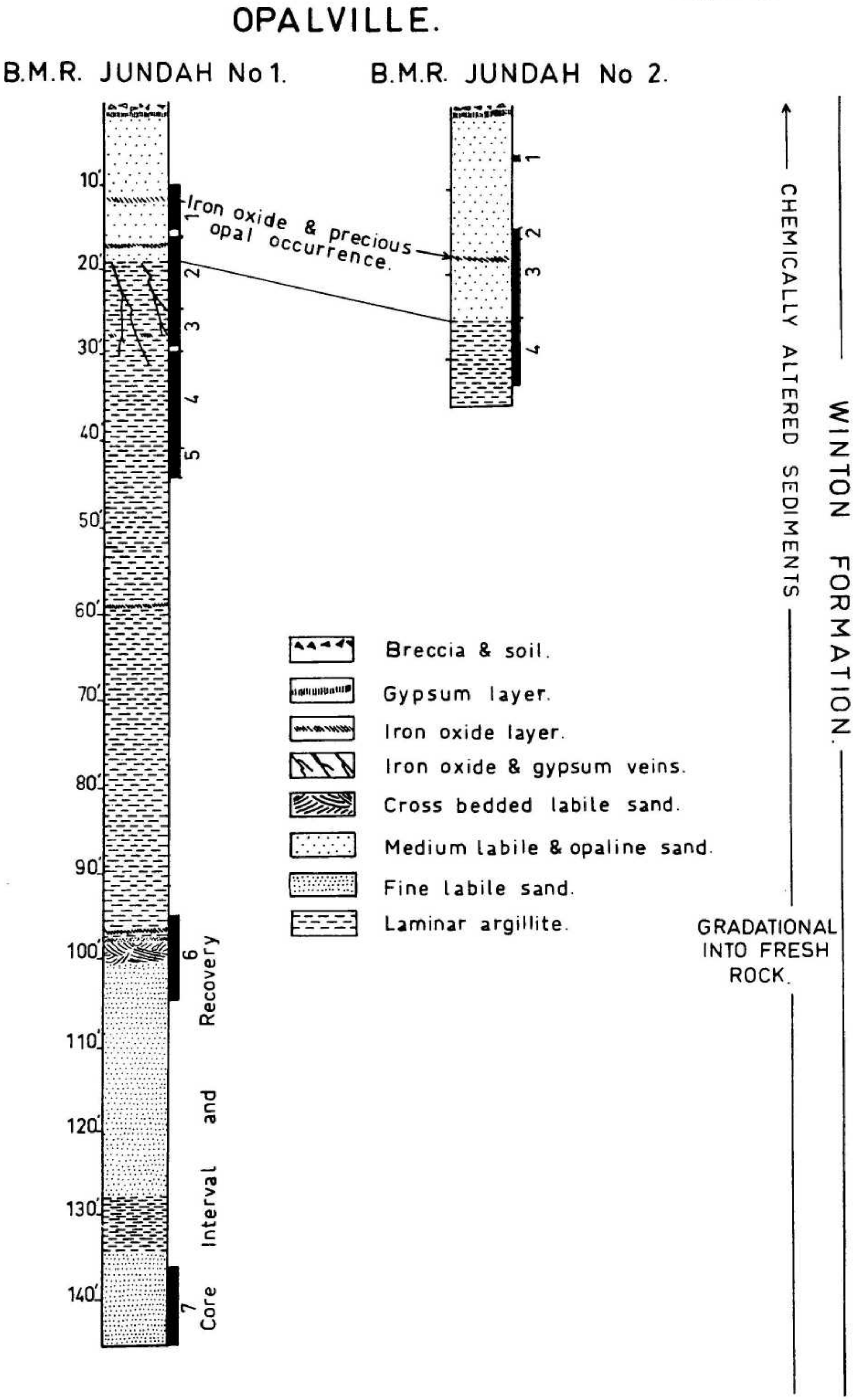
For Roads

Silcrete is readily available throughout most of the area for use as a base in road construction work. Silcrete gravel covers wide areas as a veneer one layer of pebbles thick, which can readily be scraped into piles. No quarrying is required and usually very little grading.

Silcrete is an excellent material for use in road construction because of its extreme resistance to erosion. It has been used extensively in the sealed Quilpie-Windorah road, especially where the road crosses the Cooper Creek channels.

In other areas, for example, the Cuddapan-Betoota road, silcrete has not been used very much, and there chemically altered Winton rocks have been selected in preference. This material does not have the same resistance to erosion but is more easily quarried and worked. It is used where large quantities of material are required for roads which are not designed to carry much heavy traffic. This material drains better than the natural soils so roads of this material remain open longer than the simple graded roads during periods of rain.

Figure 15



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To accompany Record 1967/

Pure quartz sand is available in many of the larger creeks for use in concrete for local bridge work. This material is exploited as required and seldom has to be carted more than a few miles.

For Buildings

Most timber and other building materials are imported, however local trees provide all the timber required for building stock yards and fences. Local quartz sand deposits again are a base for concrete for building.

In the early days of settlement in this area mud derived from the altered Winton profile was made into mud-bricks by mixing it with grass and then baking the bricks using only the heat form the sun. Fine example of the use of this building material are the old Hammond Downs Homestead (Windorah Sheet) and the old abandoned "J. C." Hotel, at Canterbury. Many other original homes and buildings were also made of this material.

Stone quarried from the altered Winton profile was probably used in some early buildings, however the only known property on which it was used extensively was the now abandoned Meeba Downs (Canterbury Sheet). There, two water storage tanks as well as the homestead foundations, fireplaces and chimneys were built from a pure white fine grained sandstone. Similar stone is still quite common in fire places and foundations in some of the older homesteads.

Miscellaneous

Kaolin has developed as part of the chemically altered Winton profile, and in some areas, notably in the area near Kurran Homestead, Connemara Sheet, there are beds, up to twelve feet thick, of pure white highly kaolinitic rock. Elsewhere kaolin is very abundant throughout the profile, but seldom is it pure. Generally it is mixed with a proportion of iron and quartz.

The extent of these kaolin beds was not mapped, and it is not known whether or not they could be economic.

Iron in the form of iron-oxides and hydroxides in highly ferruginous gravel derived from the altered Winton profile and from the Moses Sandstone, covers many areas as a thin veneer, one layer of pebbles thick. This material, although containing a high proportion of iron, is too patchy in its distribution and too limited in its extent to be of any economic use.

Gypsum has developed as a thin evaporite deposit in places on the Moses Sandstone in the north-east corner of the Connemara Sheet area. The deposit is too small to be of any economic value.

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APPENDIX 1

PALYNOLOGY OF SOME CORES FROM B.M.R.

CONNEMARA SCOUT HOLE NO. 1

by

D. Burger

Strata penetrated by B.M.R. Connemara Scout Hole No. 1 comprise part of the Cretaceous Winton Formation and the overlying Tertiary Moses Sandstone. Core samples, which are listed in Table 1, were examined for their palynological content in order to determine the position of the Mesozoic-Tertiary boundary and the palynological age of the Winton Formation in this section.

The cores at 180-182 feet and 80-82 feet contained a fairly rich microflora. The stratigraphically important fossils are listed in Table 1.

TABLE 1

Formation	Winton Formation			?	?	Moses Sandstone
Depth of cores	180-182'	90-92'	80-82'	62-64'	55-57'	
Sample No. (MFP)	4224	4232	4231	4230	4229	
Assemblage	Paradoxa Assemblage			?		
Pollen unit	post K 2b					
Coptospora paradoxa			x			
Tricolpate pollen grains	x		x			

The microflora includes Coptospora paradoxa and belongs therefore to the Paradoxa Assemblage (Dettmann, 1963). The co-occurrence of paradoxa and tricolphate Angiosperm pollen grains indicates a post K 2b age (Evans, 1966), i.e. within the upper part of the Paradoxa Assemblage. Both Dettmann and Evans consider the possibility of an Upper Cretaceous (Cenomanian) age for this palynological division.

A recent field mapping in the Northern Eromanga Basin by Vine and Day (1965) show a probable Upper Cretaceous age for the top of the Winton Formation, the cores at 180-182 feet and 80-82 feet from B.M.R. Connemara Scout Hole No. 1 may be correlated with the upper part of that formation. The contact of the formation with the Moses Sandstone must lie above the 80 feet level.

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APPENDIX 2

UPPER ALBIAN MACROFOSSILS FROM THE MACKUNDA FORMATION IN THE JUNDAH 1:250,000 SHEET AREA

by

R.W. Day

Locality: 1. Six miles E.S.W. of bore, registered number 13748, near northern edge of sheet (grid ref. 139007).

Lithology: Coquina band in fine grained, silty sandstone.

Determinations: *Appurdiceras* sp.
Dimitobelus cf. *diptychus* (McCoy)
Dimitobelus ? sp. 1
Inoceramus scutulatus Whitehouse
Inoceramus carsoni McCoy
Nototrigonia (*Callitrigonia*) *minima* Skwarko
"*Nucula*" sp.
Aucellina sp. ind.
Laevidentalium sp.
Indet. naticoid gastropods
shark teeth
encrusting polyzoan

Age: Upper Albian

Locality: 2. Outstation $2\frac{1}{2}$ miles W. of "Ban Ban" (grid ref. 141997).

Lithology: Fine grained, calcareous sandstone and siltstone.

Determinations: *Inoceramus sutherlandi* McCoy
Tancrediid aff. "*Myacites*" planus Moore
fossil wood

Age: Probably Upper Albian

Locality: 3. $4\frac{1}{2}$ miles N.W. of "Ban Ban"(grid ref. 139002)

Lithology: Fine grained, calcareous sandstone and siltstone.

Determinations: *Inoceramus* sp. ind.
Epicyprina ? sp.
plant fragments
fossil wood

Age: Probably Upper Albian

Remarks:

An upper Albian age for the Mackunda Formation in the Jundah 1:250,000 Sheet area is indicated by the presence at locality 1 of an external mould of part of a shaft and hook referrable to the heteromorph ammonite genus Appurdiceras Whitehouse. The genus has been reported from the Mackunda Formation in the Manuka area, and is also known from the Toolebuc Limestone and Allaru Mudstone.

The belemnite Dimitobelus cf. diptychus is represented at locality 1 by several slender guards which are not as swollen as typical specimens of D. diptychus. Similar forms have been reported from the Mackunda Formation in the Manuka and Tambo areas, and from the Allaru Mudstone in the Tambo area.

Two large, stout guards from locality 1 are designated Dimitobelus ? sp. 1. They are only slightly clavate, and closely resemble guards reported from the Mackunda Formation in the Richmond, Muttaburra and Longreach areas under this name.

The pelecypod genus Inoceramus is represented in these collections by three species, together with an abundance of fragmented shell. There are two left valves of the mytiloid shaped species I. carsoni in collection 1. This species occurs in the Wallumbilla Formation, Toolebuc Limestone and Allaru Mudstone as well as in the Mackunda Formation. Collection also contains a well preserved right valve of the equilateral shaped species I. scutulatus, reported from the Mackunda Formation of the Tambo area. Large specimens of I. sutherlandi from locality 2 have the typical quadrate shape of that species. I. sutherlandi has the same stratigraphic range as I. carsoni.

The pelecypod genus Aucellina is represented in these collections by a single, specifically indeterminate left valve from locality 1. Aucellina is much commoner in the Allaru Mudstone and Toolebuc Limestone than in the Mackunda Formation.

A small right valve of Nototrigonia (Callitrigonia) minima from locality 1 is a typical specimen. The species is characteristic of the Mackunda Formation, but occasionally occurs in the Allaru Mudstone.

"Nucula" sp., a very small trigonal shaped taxodont from locality is, is extremely abundant. Similar gregarious occurrences are common in the Mackunda Formation elsewhere. The generic identification of this species is still tentative. Small trigonal shaped taxodonts also occur in the Wallumbilla Formation and Allaru Mudstone but it is not known whether all are conspecific.

A specimen from locality 2 identified as Tancrediid aff. "Myacites" planus is conspecific with similarly designated forms reported from the Mackunda Formation in the Manuka, Winton and Tambo areas.

Two thick shelled pelecypods from locality 2 are tentatively referred to the European Cretaceous genus Epicyprina Casey (1952), as they approach the shape of the type species Venus angulata Sowerby, as figured by Woods (1907, pl. 22, figs. 1-4; text figs. 23-24). However, the hinge has not been observed.

The collections also contain the smooth scaphopod Laevidentalium sp., indeterminate naticoid gastropods, shark teeth, encrusting polyzoa, fossil wood and plant fragments.

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APPENDIX 3

SUMMARY OF RESULTS FROM PETROLEUM EXPLORATION WELLS ON OPEN FILE AT THE BUREAU OF MINERAL RESOURCES

The following information has been extracted from completion reports of wells drilled up to December 1966. All are available for inspection at the Bureau of Mineral Resources, Canberra. The nomenclature used here is that of the oil companies.

GALWAY NO. 1

Company: French Petroleum Company; Completed: 23/10/66

Tenement: A. to P. 66/67 P. Total Depth: 8867 feet.

Galway No. 1 was drilled on the south-west margin of a gravity depression, near the crest of a north-north-west trending, elongate dome. Very weak gas shows and fluorescence were detected at intervals throughout the drilling. Drill stem tests conducted on the Lower Jurassic formations and the lower Triassic unit recovered gas cut water.

Permian was absent from the section, which went from sediments of Triassic age into sediments correlated with the Carboniferous (see chapter on stratigraphy).

Permeability and porosity tests on Triassic sediments gave: upper unit, 24 feet of porosity 8.5% to 11%, average 9%, but permeability low; lower unit, 90 feet has porosity of 5% to 11% with average 9%, permeability poor to medium.

CHANDOS NO. 1

Company: Alliance Oil Development; Completed: 24/8/66

Tenement: A. to P. 98P. Total Depth: 9749 feet.

This well was the first drilled west of the Canaway High in this part of the Eromanga Basin and was planned as a stratigraphic test in the area west of the Adavale Basin, as well as a test of the "Chandos Anticline".

Shows of oil were obtained from the Lower Triassic sequence, (3.9 barrels of 53 gravity oil from the lower of two thick sandstone beds). 350 feet of porous sandstone were intersected, but permeability was poor.

Shows of oil and gas were also obtained in the Permian sequence, but again here, permeability was poor.

The Chandos No. 1 well demonstrated the existence of a thick Triassic, a very thin Upper Permian, and a moderately thin Lower Permian section, in this area. These beds are lithologically similar to beds of similar age at Gidgealpa, in South Australia.

The Devonian sequence at Chandos gave no traces of oil, and the hole bottomed in sediments considered to be of Ordovician age.

YONGALA NO. 1

Company: Alliance Oil Development; Completed: 11/9/65.

Tenement: A. to P. 98P; Total Depth: 10,187 feet.

The well was planned to test a fault trap on the western side of the Adavale Basin, against the Canaway Fault.

A trace of residual oil was found in cores in the "L Formation" of the "Yongala Group". Traces of gas were noted from 6770 feet down and a drill stem test of the Buckabie Formation gave mud with a trace of gas (possibly derived from Upper Permian). A large gas kick was noted while drilling the main target, the Gilmore D4 member, and also the top of the Gumbardo Formation. However, the former was tight and a drill stem test of the latter gave slightly gas cut mud only. The Gilmore (D4) member has thinned from 1155 feet (with zones of good porosity in Gilmore No. 1) to 49 feet of tight sandstone at Yongala (probably due to onlap onto the Gumbardo Formation).

There is no evidence for porosity and permeability in the basal Winton Formation sand as there is in Canaway No. 1. The "Yongala Group" included highly porous and permeable sands filled with freshwater (Log analysis gave the following Ø -"C" 23.5 - 27.5%, "E" 15.5 - 23.5%, "H" 19%, "I" 19%, "J" 11.5 - 23%, "K" 14-19%, "L" 15-18%, core analysis in "L" gave Ø = 3-16%, k = nil - 14 md). Zones tested in the Buckabie Formation were tight as was also the Gilmore D4 member.

CANAWAY NO. 1

Company: Alliance Oil Development; Completed: 17/6/63

Tenement: A. to P.98P; Total Depth: 4937 feet.

No significant shows of hydrocarbons were detected. All drill stem tests produced saline water. This seems to indicate that all the porous formations have been water flushed.

The well proved the presence of a basement ridge beneath the Canaway Anticline - probably a northward extension of the lobe of the Eulo Shelf (Quilpie Sheet area). At Canaway No.,1 the basement is 4000 feet higher than Buckabie No. 1, 25 miles to the south-east. There is an angular unconformity between the Mesozoic sediments and basement, and the Lower Carboniferous Buckabie Formation is missing at Canaway No. 1 - they either wedge out sharply towards basement ridge or are cut by a suspected subsurface fault along eastern flank of the Canaway Anticline. Therefore, possible presence of stratigraphic traps exists around flanks of the Canaway basement ridge and fault traps along the eastern flank.

GUMBARDO NO. 1

Company: Phillips-Sunray; Completed: 28/5/62.

Tenement: A. to P. 84P; Total Depth: 12,940 feet.

The Gumbardo No. 1 well was drilled on a seismically defined structural high and demonstrated the absence of suitable structure and reservoir beds for petroleum accumulation in the south central portion of the Adavale Basin. The Etonvale and Gilmore Formations were found to be only 2300 feet thick compared with 3300 feet at Etonvale No. 1. The Etonvale and Gilmore Formations in Gumbardo No. 1, although marine in the upper part at least, contains a predominance of tight clastics without any petroleum potential either as source or reservoir beds. About 140 feet of porous sandstone and conglomerate occurs beneath a shaly dolomite zone at 9140 feet yielded salt water. Permian is absent and the Mesozoic sandstones contain freshwater. No. oil or gas shows or flourescence were detected in the entire stratigraphic section.

Buckabie Formation cores range in porosity from 3.8% to 16.8% and in permeability from 0.9 to 38.7 m.d. Etonvale and Gilmore Formation cores have negligible porosity and permeability, with the exception of Core 8 in the sandstone and conglomerate section below 9140 feet which has a porosity of 5.1% and K = 5.1 m.d.

COTHALOW NO. 1

Company: Phillips-Sunray; Completed: 4/8/65.

Tenement: A. to P. 84P; Total Depth: 8573 feet.

The Cothalow No. 1 well was drilled on a dome developed in Mesozoic sediments to test for possible accumulations of petroleum in the Artesian Basin sequence as well as in the underlying Palaeozoic sequence.

No significant shows of hydrocarbons were encountered and no tests were carried out. Shows in Gilmore No. 1 occurred in the upper part of the Gilmore Formation which is absent at Cothalow.

Porosities and permeabilities derived from wireline logs are as follows - 62% of the Buckabie Formation (below 6025 feet) is variably permeable with porosity of 3-21% (average 12%). The Etonvale D1 member has only 8 feet of permeable sand with ϕ = 12%. The non-permeable remainder has 3.7% porosity. The D2 member includes 40 feet of permeable sand with ϕ = 6 - 17%, average 10%. The Gumbardo Formation is essentially impermeable except for an upper bed (7510-7524 feet) which has ϕ = 10 - 15% probably due to weathering, and probably contains formation water similar to that in the overlying basal Gilmore Formation.

LEOPARDWOOD NO. 1

Company: Phillips-Sunray; Completed: 18/7/66

Tenement: A. to P. 109P; Total Depth: 13,727 feet.

No significant shows of hydrocarbons were encountered. Principal targets were sands of the Permian, the Lower Buckabie Formation and the Gilmore D4 member but at this locality the Permian consisted of 16 feet of carbonaceous shale, the Buckabie Formation was water filled and the D4 member contained slightly gas cut salt water (as did also the D3), while the Hutton Sandstone and Birkhead Formations were fresh water saturated. Log interpretation gave the Buckabie Formation a porosity of 9-27%, while core and log analysis gave the D4 member ϕ = 4-14% and k = 0.1 - 2.4 m.d. This last was disappointing since the D4 member in Gilmore No. 1 had ϕ = 2-15% and K = 0-1500 m.d. Since the Leopardwood sands are lithologically similar to the arkosic lower sands of the D4 member the upper quartzose paysands of Gilmore are probably missing here, due to truncation of the structure at the end of Lower Devonian.

The Leopardwood structure is on trend with the Cothalow structure to south-west and Gilmore to the north-east. It has been seismically defined as a large N.E. - S.W. trending, doubly plunging anticline, flanked on the north-west by a north-west dipping normal fault. On the D3 horizon there is a dip closure of 100 feet over 3½ square miles and a fault closure of 2000 feet over 20 square miles. At the Permian level dip closure covers 22 square miles. The well is located in the crest area of this structure.

LOG CREEK NO. 1

Company: Phillips-Sunray; Completed: 23/5/65

Tenement: A. to P. 109P; Total Depth: 14,566 feet.

The well was programmed to test reservoirs in the Permian, Buckabie Formation and Gilmore Formation (at the base of the D4 sandstone which gave good gas flows in Gilmore No. 1) beneath a seismically defined anticlinal structure on trend with the Gilmore Structure.

Permian: Both Upper and Lower are correlatable with similar units in Etonvale No. 1, but the Upper Permian does not persist south-west on to the Gilmore Anticline. The presence of variable amounts of clay cement causes lateral permeability changes. The Permian was laid down on the old post(?) Carboniferous erosion surface making stratigraphic and structural traps possible. There were no hydrocarbon shows at Log Creek and the Lower Permian contained brackish-salt water.

Buckabie Formation: Previously considered a poor potential reservoir but at Log Creek it contains thick permeable zones. A trace of gas was noted in mud but tests gave salt water. Core analysis gave ϕ = 6.0 - 13.7%, k = 0.1 - 2.2 m.d.

Etonvale D2: logs indicate some porosity and permeability (core analysis gave ϕ = 6.7 - 9.5%, k = 0.1 - 1.7 m.d.), but tests were unsuccessful.

Gilmore D4: Generally low porosity and permeability but best developed in upper part of unit (core analysis gives ϕ = 3.0 - 16.8%, k = less than 0.1 - 149 m.d.). Gas shows were noted in the mud and rare fluorescence on cuttings and cores. A test in the upper part of the unit gave salt water, one at the base gave 15 Mcf per day of gas and gas cut mud with an oil film; good lithological correlations with Gilmore No. 1 - upper 300 feet of unit a Log Creek is missing at Gilmore.

Gilmore Shale Member: the source beds of the area.

GILMORE NO. 1

Company: Phillips-Sunray; Completed: 24/10/64.

Tenement: A. to P. 84P; Total Depth: 14,260 feet.

Gilmore No. 1 was drilled on the Gilmore Anticline, the highest of a number of independent anticlinal structures with similar trend in this area.

The Gilmore D4 sandstone was found to contain a substantial accumulation of dry gas (no formation water was recovered during testing), and production potential is believed to be high. A modified isochronal back pressure test gave an open flow potential of 4.3 mm. cf. per day and a formation flow capacity of 88.7 md/ft. However, formation damage is extensive and probably only a small part of the perforated section is producing. Two additional minor flows at approximately 12,935 feet and 13,370 feet suggest that the gas column may be greater than 1,300 feet.

Mackunda Formation siltstone and sandstone has good reservoir qualities but is fresh water filled. The Jurassic sandstones contain fresh water but core in the Hutton Sandstone had ϕ = 15.3 - 16.2%, k = nil and traces of fluorescence (these might contain oil by migration from underlying beds). Sands of the Lower Permian were tight here (ϕ = 8.9 - 9.9%, k = nil) though they were permeable at Etonvale and Log Creek. Buckabie Formation sands are generally tight (ϕ = 16 - 22.4%, k = nil - 4.9 m.d.) except for some in the lower part which contain salt water. Most of the Etonvale and Gilmore Formations is tight, with the exception of the D4 sandstone (ϕ = 5.1 - 14.0%, k = 0.1 - 14.28 m.d.) and the "Unnamed Shale" member (13112 feet - 14260 feet), (ϕ = 2.4 - 3.4%, k = 1.3 - 3.8 m.d.). The latter is probably Lower Devonian rather than Silurian as was first supposed.

ETONVALE NO. 1

Company: Phillips-Sunray; Completed: 26/4/62.

Tenement: A. to P. 84P; Total Depth: 11,368 feet.

Etonvale No. 1 was located on the crest of a moderately large fault-closed structure in the axial part of the Adavale Basin. No indication of hydrocarbon was found during the drilling of this well. One brief deflection recorded by the gas detector suggested possible methane in a Birkhead sand at 4405 feet, but a D.S.T. produced only fresh water without gas.

Porosity and permeability tests showed the thickest porous sandstones were the basal Permian, 200 feet gross including shale interbeds, ϕ = 4 to 32%, average 15.6%, k = 0 to 1.4 m.d.; and Devonian D4, gross total 555 feet thick, ϕ = 9 to 29%, average 16.3%, k = 0 to 3 m.d.

Dark grey to black Permian shale were intersected in the well, suggesting the Permian could be marine or near marine in part. If these shales qualify as source beds they add to the potential of both the Permian sandstone and the overlying Jurassic sandstone as reservoirs for petroleum accumulation.

The D3 dolomite and underlying sandstone are believed to be largely marine and hence a potential source and reservoir for petroleum. The D1 and D2 sandstone units may contain marine beds but are tight and argillaceous. The D3 is dense, with only one permeable zone which is only about one foot thick. The D4 is the most promising reservoir with many porous sandstone lenses separated by shale. The lower part of the D4 contains a high proportion of marine shale, which have source bed possibilities.

Although no indications of hydrocarbons were found, the drilling of the well established for the first time that Palaeozoic potential source and reservoir beds may be expected in favourable localities beneath the Great Artesian Basin sequence.

BONNIE NO. 1

Company: Phillips-Sunray; Completed: 25/6/66.

Tenement: A. to P. 109P; Total Depth: 9005 feet.

No significant shows of hydrocarbons were encountered. Main targets were Permian and Devonian reservoirs if present. It was also thought possibly that the Devonian D3 salt (1800 feet in Bury No. 1, 1500 feet in Boree No. 1) could have acted as a stratigraphic trap to hydrocarbons in marine D3 and D4 sediments. In this well, however, the Upper Permian contained only brackish water, the Lower Permian was tight, and a porous sand unit in the Limestone Member of the D3 yielded strongly saline water.

The well is located in the north-eastern part of the Adavale Basin on the south-west flank of the Hope Creek Arch, on a south plunging faulted structure. At the Permian level it has 75 feet of vertical closure over 3½ square miles. At the D3 level (top of the salt) the well is located on the south flank (up thrown side) of a small, fault closed structure with approximately 60 feet of closure over one square mile. A pre D3 structure contour map shows the well to be located on the crest of a small, fault closed structure, with 500 feet of closure over one square mile.

No new geological information was obtained from the well other than confirmation of the extensiveness of the D3 evaporite basin, though the thickness of salt is greatly reduced in Bonnie No. 1, marine sediments making up the rest of the unit here.

APPENDIX 4

GEOMORPHOLOGY OF THE AREA

by

J.A. Mabbutt

1. MAJOR RELIEF

The Tertiary land surface, identified and extensively preserved by the silcrete duricrust, had little original relief; the present major patterns of high and low ground and of erosional and depositional landforms have resulted from subsequent tectonic doming and down-warping (27*). The amplitude of these earth movements attained 500 feet locally, but this tectonic relief has since been reduced by erosion of the domal uplands and alluviation in the synclinal lowlands, leaving a maximum relief of the order of 400 feet.

Structural lineaments are clearly expressed in relief patterns at all scales: the major synclines are characteristically occupied by broad, rather straight-sided alluvial tracts locally narrowed at cross-warps, as in Farrars Creek below Multi Waterhole, whilst the domal anticlines are marked by elliptical areas of plains and dissected uplands, often with arcuate, paired in-facing escarpments (26) and with radial drainage lines. The Jundah Sheet, for instance, is dominated by the straight NE line of the floodplain of the Thomson River, along the Thomson Syncline, and this is bordered on the west by cuestiform uplands marking the flank of the Warbreccan Dome and by parallel tributary valleys at right angles, consequent on the uplift. In the south-west of the Connemara Sheet, Farrars Syncline and the adjoining Palparara Dome have similar topographic expression. In fact, given the small regional dips, the variable thickness of the duricrust and of the Tertiary deposits, the obscuring effect of weathering and the extensive depositional mantle, topography offers a most valuable key to major structure in the area.

II. EROSIONAL LANDFORMS

The degree of topographic survival of the domal anticlines, measurable by the extent of intact silcrete, has varied with the extent and amount of uplift and the position of the anticline in relation to adjoining synclines, and hence to the disposition of alluviation. Survival more or less intact, with the domed silcrete cover (27) and the consequent radial drainage almost complete, is to be found only on a few small domes in the south-east of the Canterbury Sheet, for example, the Little Hills and Ullenburry Domes.

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*Numbers in parenthesis are those of photographs in the Record

Generally, however, the domes have been breached along the anticlinal axes and the silcreted surface has been eroded back and reduced to flanking uplands (26). At an early stage, groups of duricrusted mesas may survive in the axial tract; with more complete destruction of the Tertiary land surface, undulating strike lowlands are fashioned in the Cretaceous rocks in the centre of the dome and only the drainage divide may mark the original axis. These successive stages are shown on the two flanks of Farrars Syncline; extensive silcreted plateau residuals remain on the axis of the Mianga Anticline in the south-east, marking an incipient stage in breaching, whilst the Palparara Dome on the north-west shows more advanced stripping. A further step towards the achievement of inversion of tectonic relief comes with the establishment of strike drainage and depositional lowlands along the dome axis, the best example in the area being the plain of Morney Creek within the Morney Dome.

The upland residuals of the Tertiary land surface are generally mesas, escarpment-ringed and with very gentle summit slopes approximating closely to dips on the duricrust (14). Gentle dips on the flanks of domes may give rise to cuestas (28) with long dip slopes passing smoothly beneath the deposits of marginal lowlands, whilst on the steeply dipping limb on the Curalle Dome, narrow homoclinal ridges have been formed (25, 26).

The escarpments which border the duricrusted residuals are dominant features in an otherwise flat or tabular landscape (6). They exceed 200 feet locally, as in the Three Sisters area on the eastern flank of the Morney Dome on Canterbury Sheet; however, it is their steepness and the prominent colouring of the exposed weathering horizons* rather than relief alone which render them so outstanding. Their form is essentially controlled by the contrast between the hard duricrust and softer horizons of varying resistance in the weathered rocks below - contrasts which find full expression under the prevailing dry climate.

The uppermost slope element or free face may be 50 feet in height and is generally vertical, controlled by joints, columnar structures, and vertical pipes in the duricrust and in the hard mottled zone in the Tertiary rock beneath. The faces are rendered particularly resistant through secondary cementation and encrustation by silica and iron oxides on exposed surfaces and incipient partings - a form of case-hardening.

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*In this appendix the terms "pallid zone" and "weathered zone", are used, and are comparable with the term "zone of chemical alteration", which is used in the main body of the report. The term "mottled zone", as used here, refers to the mottled Glendower Formation sediments described in the main text of the report.

Escarpment recession is controlled by the rate of retreat of the duricrust capping. In plan, the escarpments show considerable structural control. Gross outline may reflect major structures; for instance, many straight escarpments run parallel with fold axes over long distances, as in the NNE-trending escarpment following the axis of the Warbreccan Dome, west of the Thomson River on Jundah Sheet. East of the Thomson River in the same area, the Swan Vale Fault controls the margin, over a distance of some 12 miles, of the silcreted plateau preserved on its downthrow side (24). In some detail the escarpments are characteristically crenulate, with rectangular or ampitheatral valley re-entrants and blunted spurs, in response to intersecting joint systems in the silcrete.

The free face is attacked by cavernous weathering and is also undermined at the basal contact with softer rock. It retreats by fall of silcrete blocks which break off along joints and other vertical partings within the duricrust. Locally, whole strips of silcrete have been detached and carried down in earth slips, with backward rotational movement, and now cap narrow ridges or steps parallel with and in front of the plateau margin. The most spectacular of these features borders Mount Felix in the north-west of the Jundah Sheet (32); there are three elongate silcrete blocks up to 25 yards wide and 400 yards long in a zone extending up to 400 yards in front of the main plateau. The duricrust on the slipped blocks is tilted back at up to 15° towards the main plateau, where the dip on the undisturbed silcrete is negligible. In this area, slippage has occurred between weathered Winton rock and fresher beds below. The closeness of such slipped blocks to present plateau margins indicates that the slips are geologically recent and hence that they probably relate to current morphogenesis. Very heavy tropical rainfalls could conceivably so saturate the weathered rock in the escarpment as to bring about mass movement on a larger scale.

Block fall is facilitated by "piping" - subsurface removal of less indurated material through pipes and vertical fissures in the duricrust, leading to the formation of shafts and weathering pits along the plateau rim (Whitehouse, 1940a).

Below the free face is the straight or steeply concave constant slope cut in softer, mainly pallid rock (31). This slope is largely mantled with fallen silcrete blocks subject to various types of mass movement. Scars, commonly marked by exposure of pallid rock, show where landslides have occurred on steeper slopes (greater than 25°), as in gulley heads; slow creep of mantle material over soft and periodically saturated claystone has resulted in slope terracettes; some larger blocks slide across the slope as indicated by furrowing; locally, on lower slopes, lobes of finer material bearing rafted silcrete boulders point to the activity of earth flows.

The silcrete fragments, being hard and chemically stable, persist in this dry climate and form an almost ubiquitous mantle. On many graded constant slopes such mantles become cemented with earthy material and persist to protect the soft rock below; they often survive on detached spurs, where they preserve former slope profiles. Where the claystone is exposed, however, as in valley heads and walls (31), finer rock material is removed by gullies and slope wash, and the generally fine texture of alluvial fills in piedmont valleys reflects the efficacy of such processes.

Under slope wash, harder bands are etched out and evolve as lower plateau elements, spurs, forescarps, and buttes (6). Such stripped structural surfaces are particularly common where the Tertiary beds beneath the duricrust are thick and resistant, as in the Cheviot Range in the east of Windorah Sheet, or where there are prominent porcellanitic or ferruginous bands below. Such ferruginous bands supply abundant fine gravel to the piedmont plains.

Rounded spurs and ridges with up to 50 feet of relief characteristically form a transitional piedmont zone less than half a mile wide (28). They are generally capped by weathered Cretaceous rock and bear abundant silcrete gravel with a very wide size range, indicating that the mantle has in part been let down <u>in situ</u> as well as having travelled from the nearby escarpment. This irregular piedmont zone, therefore, results from unequal retreat of the escarpment and from incomplete stripping of the weathered rock beneath the former duricrust.

Anticlinal lowlands or "rolling downs" in Cretaceous rock constitute the most extensive erosional landforms of the area (11). They are generally broadly undulating, with rounded rises attaining less than 20 feet above alluvial floodplains. As revealed by outcrop bands of Winton beds, they are cut-rock plains, but the flat-lying, thin-bedded and generally weak bedrock exercises little control over relief forms or over the drainage pattern, which is finely dendritic. As mentioned above, drainage divides within the plain commonly coincide with anticlinal axes and may have been superimposed from the original deformed silcrete surface.

The lowlands are mantled with gravel, mainly of silcrete and of ferruginized Winton beds; the fresh country rock is a calcareous claystone which yields little coarse clastic material. The gravel mantle becomes increasingly fine with distance from the bounding escarpments, but it is now isolated on interfluve crests and is therefore essentially a lag gravel, lowered <u>in situ</u>. The finer gravels in the lower parts of the plains form smooth pavements, easily trafficable; the upper parts, however, are extensively gilgaid, and here the gravels are much disturbed, partly incorporated into the soil profile, and commonly arranged at the surface in raised stony rings or "puffs" around the gilgai depressions. Circular gilgais may pass into linear gilgais on steeper interfluve margins.

The freshness of this patterned microrelief and the lack of incorporation of the interfluvial gravels into adjoining floodplain alluvia indicate that erosion of the interfluves is presently restricted to the removal of fines yielded by breakdown of the Winton beds. The short valleys on the interfluve margins are open, with smooth concave slopes and blunt rounded heads, and are generally unchannelled or have underfit gullies; they appear to be adjusted to sheet runoff rather than to linear erosion.

The weathering front, or boundary between fresh and weathered rock, has exercised much control over base-levelling in the piedmont zone, where the denudational processes are a combination of pediplanation and etchplanation. On the anticlinal lowlands, however, the dominant process is a slow downwearing, shown by the excavation <u>in situ</u> of giant nodules from the Winton Formation (5), constituting a form of peneplanation.

Tableland relicts of the Tertiary land surface, where undisturbed, have smooth upper surfaces with occasional flat outcrops of silcrete and elsewhere a soil cover of red clayey sand with scattered cobbles of silcrete. Drainage on such surfaces takes the form of sheet flow in broad, shallow depressions. A stripped, uneven rocky zone up to 50 yards wide commonly intervenes against the escarpment edge. Valleys cut into the upland surfaces commonly preserve the parallel or radial patterns of the initial drainage consequent upon uplift. In the upper sectors, at least, they are generally entrenched, flanked by silcrete cliffs. These sectors are generally ill-graded, with alternating rocky reaches, with rock pools, and alluviated tracts. Gravel terraces are common. However, such valleys pass rapidly downslope into alluvial plains, where they are cut beneath the silcrete.

Despite the important structural control over relief exercised through the duricrust in this area, it would nevertheless be very misleading to interpret all relief features on the silcrete as being of tectonic origin, particularly in detail. Many dip surfaces have been considerably modified by erosion; for instance, the low bluffs which overlook the Cooper Creek floodplain north of Windorah are cut within silcrete dipping uniformly eastwards to pass beneath the alluvia. Again, certain radial valleys appear at first to have been preferentially incised along dip faults or secondary flexures in the silcrete, but only careful mapping can discount subsequent cambering or mass movement.

III. FLUVIAL LANDFORMS

(a) Older Alluvial Forms

Alluvial surfaces staged above the active floodplains occur mainly in the catchment of the Thomson River. Terraces planed across Tertiary rocks and capped with river gravels, mainly of silcrete, with a partial cover of red clayey sands, rise about 25 feet above the floodplain of the Thomson at Stonehenge. Upstream, the terraces increase in height, particularly along the right-bank tributaries of the Thomson. In the extreme north-west, at Commissioner Mount, they terminate as piedmont spurs up to 150 feet high, with cappings up to 30 feet thick, including very large silcrete boulders. Restriction of the terraces to the area of the Thomson Syncline suggests that earth movements may have been an important factor in their formation; it is noteworthy that this part of the area has a more complex Tertiary history than elsewhere.

These older alluvia, like those of the smaller tributary plains, contrast with those of the larger floodplains by virtue of their coarser texture and the red soils developed on them. They appear to have been more strongly influenced by soils on the Tertiary land surface and by material eroded from the Tertiary rocks beneath.

(b) Active Alluvial Forms

The survey area is situated towards the lower reaches of the Channel Country where floodplains such as those of the Barcoo and Thomson Rivers unite and widen at the approaches to Lake Eyre; for instance, the plain of Cooper Creek below Windorah is more than 40 miles wide. Major floodplains comprise more than 20 percent of the total area and attain 30 percent in the south. Suggested explanations for such widespread alluviation are, that the rivers flow from wetter to drier areas and so become progressively overloaded downstream, the extent of seasonal flooding, the inadequacy of longitudinal gradients or less than one foot per mile for transport of loads supplied from upstream, and tectonic subsidence and back-tilting (Whitehouse, 1940b).

Tectonic control over major depositional patterns within the area has already been mentioned, and differential downwarping towards the Lake Eyre Basin may be invoked as a major cause of fluvial deposition. There is little sectional evidence, but alongside the main channel of Cooper Creek near Windorah, 150 feet of alluvium ranging from clay to fine gravel rests on a silcrete construed as a continuation of that dipping eastwards off the Windorah Anticline. Absence of any major break within the alluvial column suggests fairly continuous alluviation accompanying and following downwarping of the duricrust along the Thomson Syncline. Thicknesses of alluvium exceeding 50 feet are common in the main floodplains of interior Queensland (cf. Jauncey 1964). An associated Diprotodont fauna indicates a Pleistocene age for at least part of the deposits........."However, the thickness and physiographic distribution of the fossiliferous deposits is such that a considerable time span could be involved" (Woods 1960).

Whitehouse (1940b) distinguished between the straight-sided, narrower floodplains, such as those of the Thomson River, in which the alluviating channels are topographically confined, and the broader floodplains, as those of Cooper Creek, in which the channels are more freely divergent (18). Both are characterized by one or more channelled zones of through-going drainage with interlacing courses, and by marginal or intervening back-plains.

The drainage lines of the channelled zones are of two types, namely channels and floodways.

The channels are incised well below general plain level, are hemispherical in cross section, and locally exceed 200 feet wide. They correspond to the suspended-load type of Schumm (1963). In detail they are meandering or strongly sinuous. On a larger scale they are anastomate, and fork and rejoin at fairly small angles in what Whitehouse (1940b), describing the narrower floodplains, has termed a reticulate pattern, enclosing lozenge-shaped tracts of floodplain a few miles in dimensions and elongated downstream.

The main waterholes are deepened stretches in these channels and generally occur in "trunk" sectors between more strongly branching reaches. They range from meandering channels several miles long, such as that of the Barcoo above its confluence with the Thomson River, to billabongs occupying parts of single meander loops. Abandoned or lugged-off channel sectors with isolated billabongs are common, but the lack of scrolls and cut-offs indicates that channel migration has been unimportant.

On concave banks the larger channels may be bordered by short stretches of natural levee up to 100 yards wide but rising very little above general plain level. These are formed of sandy silts.

Floodways, referred to as "minor channels" by Whitehouse (1947), are shallower and less clearly defined, and range from single floodways to depressions up to 200 yards wide furrowed by many parallel courses, or "swathes of gutters" (Whitehouse 1947). They have been termed "floodplain scour routes" (Thornbury 1954). They are less sinuous than the channels, and their closely interlacing patterns resemble normal braiding patterns more closely. They have the form of mixed-load channels (Schumm 1963).

The braided trains of floodways are characteristically superimposed across the anastamosing meanders of the channels, as though indicating a more direct course taken by floodwaters at discharges above bankfull. Some floodways originate at overspills from channels; others arise from the branching of floodways themselves.

The channels are often discontinuous and may pass into floodways by terminal or lateral distributaries, in which case small, tightly meandering channels may persist over long distances within the floodways. Conversely, floodways may unite in a channel sector. In general, floodways are less pronounced where one or two channels are particularly prominent and where, as a corollary, the channel pattern is less anastomate, and there also tends to be a relative increase in the importance of floodways downstream towards the widest floodplains.

The channelled zone tends to include the higher parts of the floodplain in which fine sands and silts, as well as clays, are deposited. By virtue of soil texture, as well as relief, it comprises the better-drained tracts. The channelled zones tend to widen down valley, that of Cooper Creek south of Windorah attaining 15 miles. Nevertheless, they dominate the narrower floodplains up-valley but are relatively less important in the wider floodplains in the south. In these lower floodplain sectors, abandoned channels and meander scars indicate periodic shifts of the channelled zone as a whole.

The backplains are relatively featureless surfaces diversified locally by floodways and meander scars. They include islands of higher ground subject to flooding only at longer intervals, and tracts of aeolian sands. Within the area, the backplains are of two kinds: those of the Cooper have dark, self-mulching heavy clays with cracking or gilgaid surfaces; floodplains of more local origin, such as those of Farrars and Whitula Creeks, consist of calcareous silty clays. These are non-cracking, but are subject to extensive surface erosion by wind and water, particularly under heavy stocking, giving risé to extensive clay pans. Former terminal pans in this latter type of floodplain are marked by partly silicified clayey limestones which may be a few feet above or below present plain level and which extend into major tributary plains.

Within the backplains are depressions - shallow basins of circumdeposition - including, in order of increasing size, small sloughs in abandoned floodways, marginal basins at the entries of tributary plains, terminal basins of disintegrated drainage, as of Farrars and Whitula Creeks, and the extensive depressions which characterize the broad, lowermost floodplains, as of Cooper

Creek near Windorah. Fed by distributary channels or floodways, the depressions constitute lateral storage basins and are subject to shallow inundation following flooding from the channelled zone. With fall of river level, they drain back along the feeder channels. They are areas of clay deposition, with strongly cracking surfaces dominated by close-meshed linear gilgai systems.

IV. AEOLIAN LANDFORMS

As elsewhere in the Australian arid zone, aeolian sand surfaces occur mainly in areas of prior alluviation; hence they are most extensive in the south of the region adjacent to the main river plains and occupy almost 25 percent of Canterbury Sheet area. They comprise sandplains and dunefields.

Sandplains are fairly flat surfaces of red clayey sands, commonly diversified in this area by scattered sand dunes and also by clay pans in areas of entering drainage (19). Sandplain is well developed along the margins of Cooper Creek.

Sandplain often grades imperceptibly into tributary alluvial plains with sandy red earth soils, and also into upper surfaces of remnants of the Tertiary land surface with sandy residual soils. Occasionally, as on the Ullenburry Dome west of Windorah, sandplain continues unbroken over the summits of such remnants. Such transitions, which are well demonstrated east of Windorah, indicate that sandplain has formed by limited aeolian reworking of coarse-textured alluvia and of sandy soils on the Tertiary land surface or derived from it.

Dunefields occur in areas of more abundant sand supply and more effective seolian reworking and consist of red sand with very little clay near the surface. They are of two types. The most extensive consists of longitudinal ridges mainly up to 30 feet high and generally not exceeding 5 miles long, trending mainly NW, down the dominant wind (20). Locally the ridges fork, the forks being mainly open upwind. Such fields consist of parallel or subparallel ridges with a spacing of between ¼ and ½ mile, but nowhere attaining the regularity of the networks in the Simpson Desert. Dune trend may be influenced by local relief, as in the fanlike patterns north of the Little Hills Dome in the south of Canterbury Sheet; the trend may also change locally to run parallel with drainage. These dunefields are best developed on the north and west (downwind) margins of sand source areas, particularly of drainage floodouts like that of Farrars Creek; they also occur as small islands within the floodplains. The dunes become smaller and more widely spaced with increasing distance downwind from source areas.

Where there is much interference between aeolian sand movement and surface run-off, clay pans occur within the dunes, and in such areas there are transverse dune elements, parallel with the pan or floodplain limit on downwind or downslope margins. Linked arcuate transverse dunes of this type have formed south of pans west of Cooper Creek in the extreme south of Canterbury Sheet. A combination of such transverse elements with longitudinal ridges, with numerous pans in the swales, gives rise to reticulate dune systems such as that extending northwards from Lake Cuddapan. Many smaller pans isolated within areas of aeolian sand, are fed by shallow ground water.

The dune flanks are mainly vegetated but there is much mobile sand on the crests, which are generally uneven with many blowouts. This loose sand tends to move along the dune, often in small barchans, and many of the dunes are keel-shaped as a result, with high slip faces at their northern ends; many such ridges are actively encroaching on river channels from the south and east. This living crestal sand is displaced laterally during spells of transverse wind and forms long slip faces, east-facing or west-facing according to the recent wind regime, topping the vegetated flanks. No consistent asymmetry of transverse dune profile was observed in the area.

Where wind erosion has been particularly severe, the clay-rich cores of the sand dunes are exposed, particularly at the upwind ends, and these and the clay-rich dune aprons tend to be gullied (21).

Many of the aeolian surfaces appear to be fossilized beneath their vegetation cover; Whitehouse (1940a) contrasted the "live" sandhills near and west of Cooper Creek, with their sharp, mobile crests, with the more rounded and stable "dead" sandhills further east. The increased amount of sand movement following drought and overstocking indicates that the balance is precarious.

The extent of aeolian sand over former alluvial surfaces no longer subject to river action, the obvious disintegration of drainage patterns as shown in the terminations of Farrars and Whitula Creeks, and the ponding back of minor drainage in clay pans, as in Lake Cuddapan, point to a phase of increased aeolian activity and diminution of river action. There is no evidence of the age of the dunes, nor of when this trend to more arid conditions took place. However, some of the dunes within the present floodplains must be quite young, and it is unlikely that all have formed at one period.

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CONNEMARA

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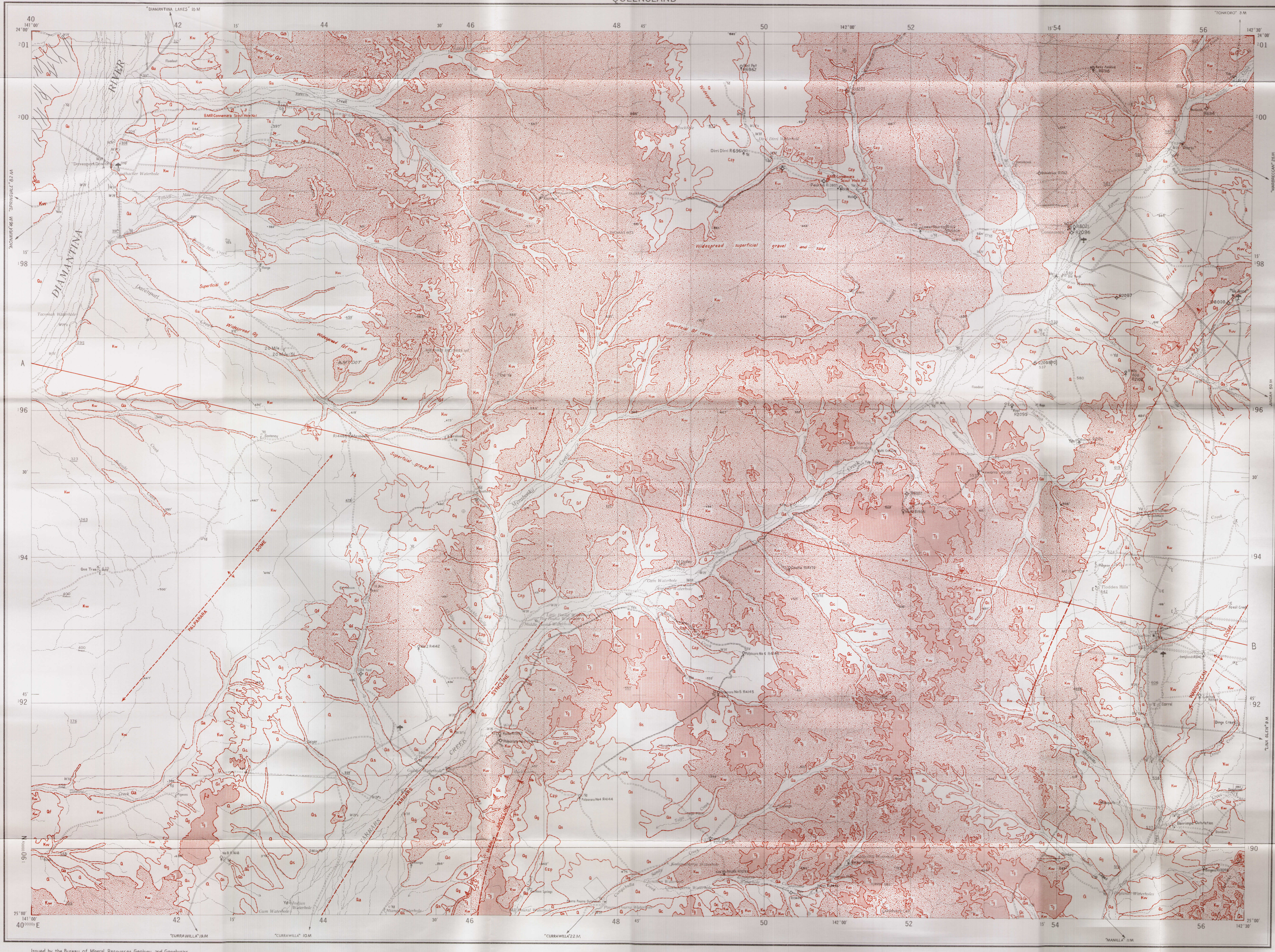

Reference

			Symbol	Description
CAINOZOIC	QUATERNARY		Q	Undifferentiated, sand, silt, clay, gravel.
			Qa	Alluvium; grey and red soil, silt, sand, minor gravel. Some consolidated material.
			Qs	Sheet and dune sand, some poorly consolidated silty sandstone.
			Qf	'Ironstone' gravel.
			Qg	Gravel and cobbles, undifferentiated.
			Qc	Gravel and cobbles, mainly silcrete
	UNDIFFERENTIATED		Czp	Limestone, chalcedony.
				Silcrete, silicified quartz sandstone. (Only developed in Glendower Formation).
				Chemically altered, leached and ferruginized sediments. (only developed in Winton Formation).
	TERTIARY	Glendower Formation	Tg	Quartz sandstone, quartz pebble conglomerate, sandy conglomerate, siltstone, breccia.
		Moses Sandstone	Ts	Quartz sandstone, siltstone, sandy limestone, lime concretions.
MESOZOIC	LOWER-UPPER(?) CRETACEOUS	Winton Formation	Kw	Labile sandstone, calcareous labile sandstone, calcareous mudstone and siltstone, coal. Locally abundant silicified wood.
	LOWER CRETACEOUS	Mackunda Formation	Klm	Labile sandstone, calcareous labile sandstone, mudstone, coquinite.
		Allaru Mudstone	Kla	Mudstone, calcareous lithic siltstone.
		Toolebuc Limestone	Klo	Limestone, calcareous shale
		Wallumbilla Formation	Klu	Mudstone, siltstone, minor sandstone.
	UNDIFFERENTIATED		M	Quartz sandstone.

Section only (Klm, Kla, Klo, Klu, M)

Geological boundary, position approximate

Anticline showing plunge

Syncline

Fault (U, D indicate relative movement up, down)

Where position of folds and faults is approximate, line is broken, where inferred, queried.

Lineament

Strike and dip of strata

Dip <5° } air-photo interpretation

Trend lines }

Plant fossil locality, showing collection number

Wood fossil locality

Minor mineral occurrence, Gp: Gypsum

Stratigraphic hole

Artesian water bore

Sub-artesian water bore or well

Abandoned water bore

R6314 Refers to bore registered number of Queensland Irrigation and Supply Commissions records. Where position is doubtful bore is marked (PD)

Waterhole

Dam on stream

Earth tank

Windpump

Sand dunes

Road

Vehicle track

Fence

"Onoto" Homestead

Building

Landing ground

Yard

Astronomical station

Trigonometrical station

•311' Height in feet, barometric } datum; mean sea level

•321' Height in feet, instrument levelled }

Magnetic basement, interpreted from the Cooper's Creek Aeromagnetic Survey for Delhi, Australian Petroleum Ltd. and Santos Ltd.

Issued by the Bureau of Mineral Resources, Geology and Geophysics, Department of National Development. Issued under the authority of the Hon. David Fairbairn, Minister for National Development. Base map compiled by the Division of National Mapping, Department of National Development. Aerial photography by Adastra Airways Pty. Ltd.; complete vertical coverage at 1:50,000 scale.
Transverse Mercator Projection.

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ANNUAL CHANGE 2' E.

Scale 1:250,000

MILES

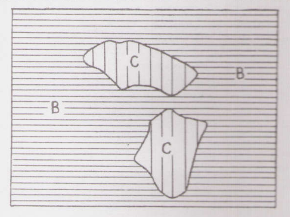
KILOMETRES

Section

Quaternary sediments omitted

Scale: H/V = 4

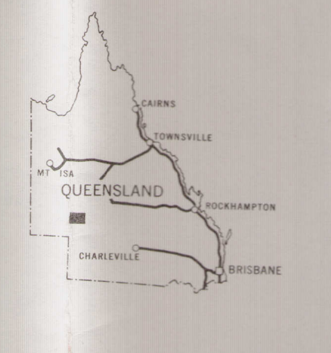
GEOLOGICAL RELIABILITY DIAGRAM

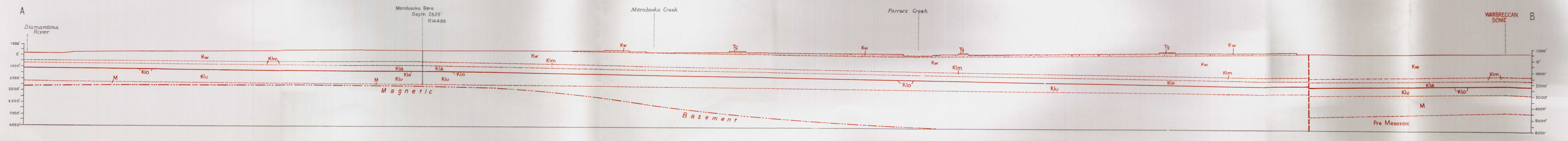


B Detailed reconnaissance, supplimented by air-photo interpretation.

C Air-photo interpretation.

Geology, 1966, by: B.R. Senior
Compiled, 1966, by: B.R. Senior and R.D. Cooper
Drawn by: R.D. Cooper





CONNEMARA

Sheet SG 54-3

Complimentary

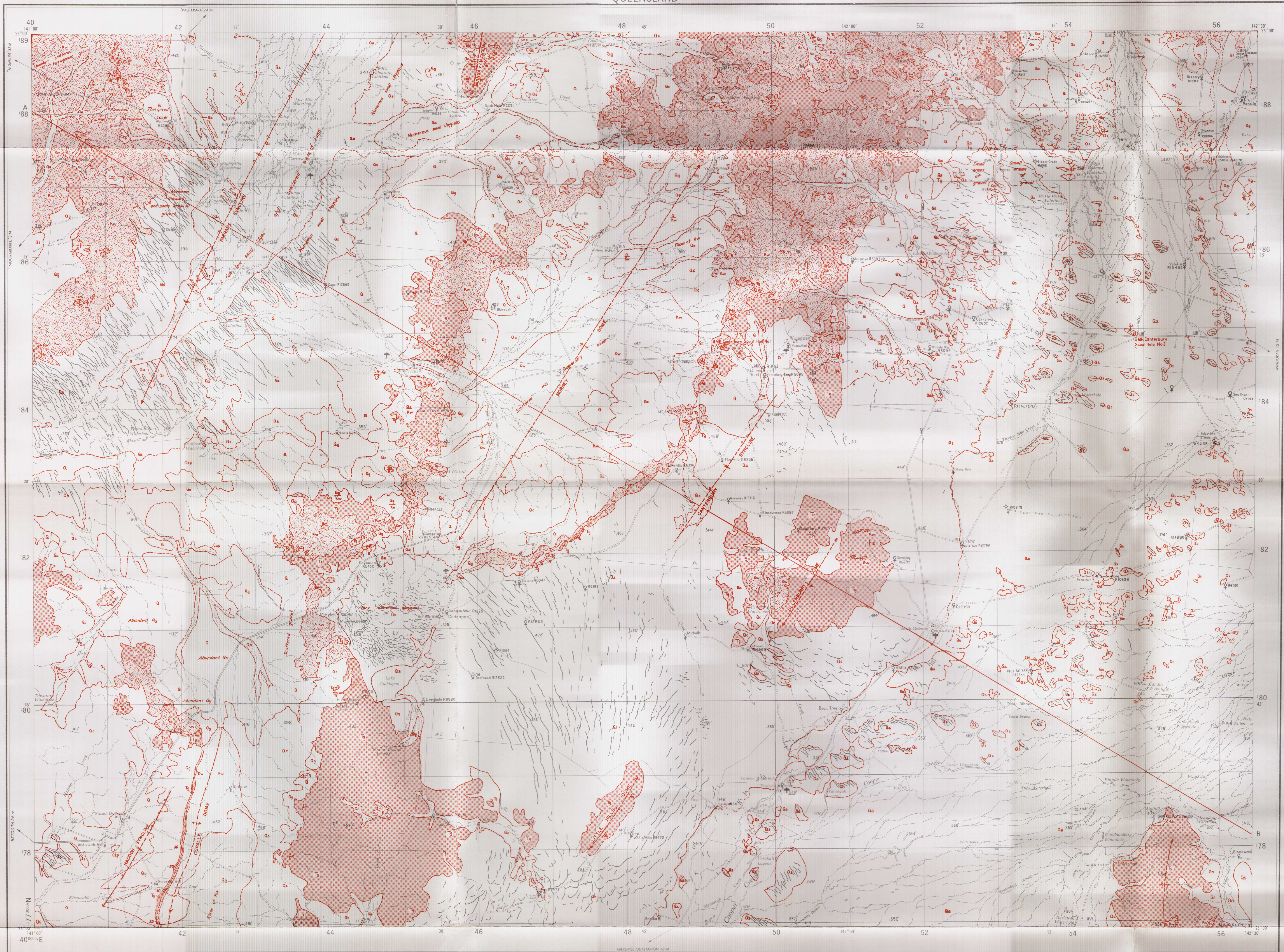
AUSTRALIA 1:250.000 GEOLOGICAL SERIES

CANTERBURY
QUEENSLAND

SHEET SG 54-7

PRELIMINARY EDITION, 1967

SUBJECT TO AMENDMENT



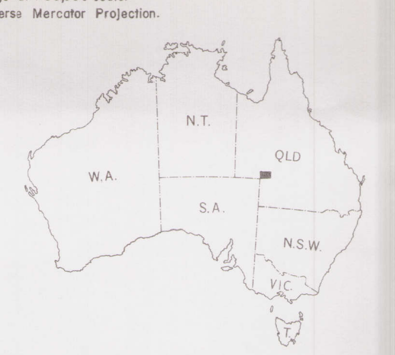
Reference

Era	Period	Formation	Symbol	Description
CAINOZOIC	QUATERNARY		Q	Undifferentiated, sand, silt, clay, gravel.
			Qa	Alluvium; grey and red soil, sand, minor gravel. Some consolidated material.
			Qs	Sheet and dune sand, some poorly consolidated silty sandstone.
			Qg	Gravel and cobbles, undifferentiated.
			Qc	Gravel and cobbles, mainly of silcrete.
	UNDIFFERENTIATED		Czp	Limestone, minor chalcedony.
				Silcrete, silicified quartz sandstone. (Only developed in Glendower Formation).
				Chemically altered, leached and ferruginized sediments. (Only developed in Winton Formation).
	TERTIARY	Glendower Formation	Tg	Quartz sandstone, quartz pebble conglomerate, sandy conglomerate, siltstone, breccia.
MESOZOIC	LOWER-UPPER CRETACEOUS	Winton Formation	Kw	Labile sandstone, calcareous labile sandstone, calcareous mudstone and siltstone. Locally abundant silicified wood.
	LOWER CRETACEOUS	Mackunda Formation	Klm	Labile sandstone, calcareous labile sandstone mudstone, coquinite.
		Allaru Mudstone	Kla	Mudstone, calcareous lithic sandstone.
		Toolebuc Limestone	Klo	Limestone, calcareous shale.
		Wallumbilla Formation	Klu	Mudstone, siltstone, minor sandstone.
	JURASSIC-LOWER CRETACEOUS		J-Kl	Sandstone, siltstone, mudstone.
	TRIASSIC		R	Sandstone, siltstone, shale
PALAEOZOIC	PERMIAN		P	Sandstone, siltstone, shale, coal.

Klm to P: Section Only

- Geological boundary
- Anticline, showing plunge
- Syncline
- Where location of boundaries and folds is approximate line is broken, where inferred queried
- 30 Strike and dip of strata
- Dip < 5° air-photo interpretation
- Abandoned bore
- Sub-Artesian bore
- Stratigraphic hole
- R6010 refers to bore registration number of Queensland Irrigation and Water Supply Commisions Records. Where position is doubtful bore is marked (PD)
- WH Waterhole
- Dam on stream
- E Earth tank
- Windpump
- Sand dunes
- Road
- Vehicle track
- Fence
- "Tanbar" Homestead
- Building
- Landing ground
- Yd Yard
- Astronomical station
- .580′ Spot elevation, barometric
- .360′ Spot elevation, instument levelled
- datum: mean sea level
- Magnetic basement, interpreted from Cooper's Creek Aeromagnetic Survey for Delhi, Australian Petroleum Pty and Santos Ltd (Section only).

Issued by the Bureau of Mineral Resources, Geology and Geophysics, Department of National Development. Issued under the authority of the Hon. David Fairbairn, Minister for National Development. Base map compiled by the Division of National Mapping, Department of National Development. Aerial photography by Adastra Airways Pty Ltd; complete vertical coverage at 1:50,000 scale.
Transverse Mercator Projection.



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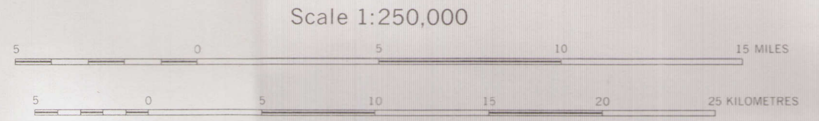
PANDIE PANDIE SG 54-9	CORDILLO SG 54-10	BARROLKA SG 54-11	EROMANGA SG 54-12	QUILPIE SG 55-9
GASON SG 54-13	INNAMINCKA SG 54-14	DURHAM DOWNS SG 54-15	THARGOMINDAH SG 54-16	TOOMPINE SG 55-13

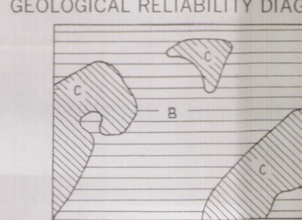
ANNUAL CHANGE 2′E

Scale 1:250,000



Geology, 1966, by: C.M.Gregory
Compiled, 1966 by: C.M.Gregory and R.D.Cooper
Drawn by, R.D.Cooper

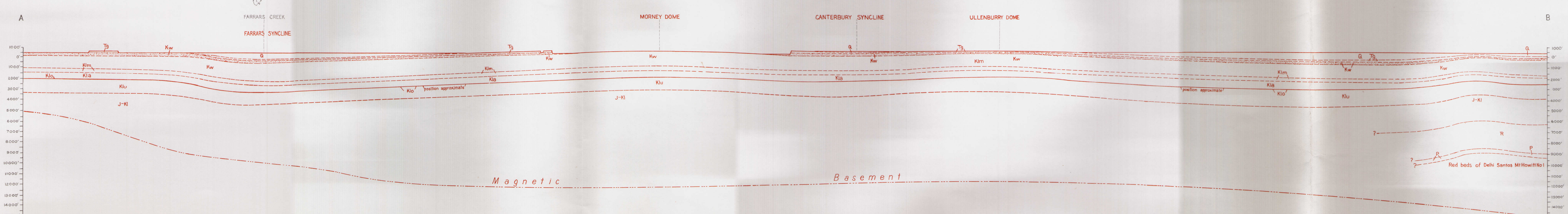
GEOLOGICAL RELIABILITY DIAGRAM



B Detailed reconnaissance, supplemented by air-photo interpretation.

C Air-photo interpretation.

Section
Superficial deposits omitted



CANTERBURY

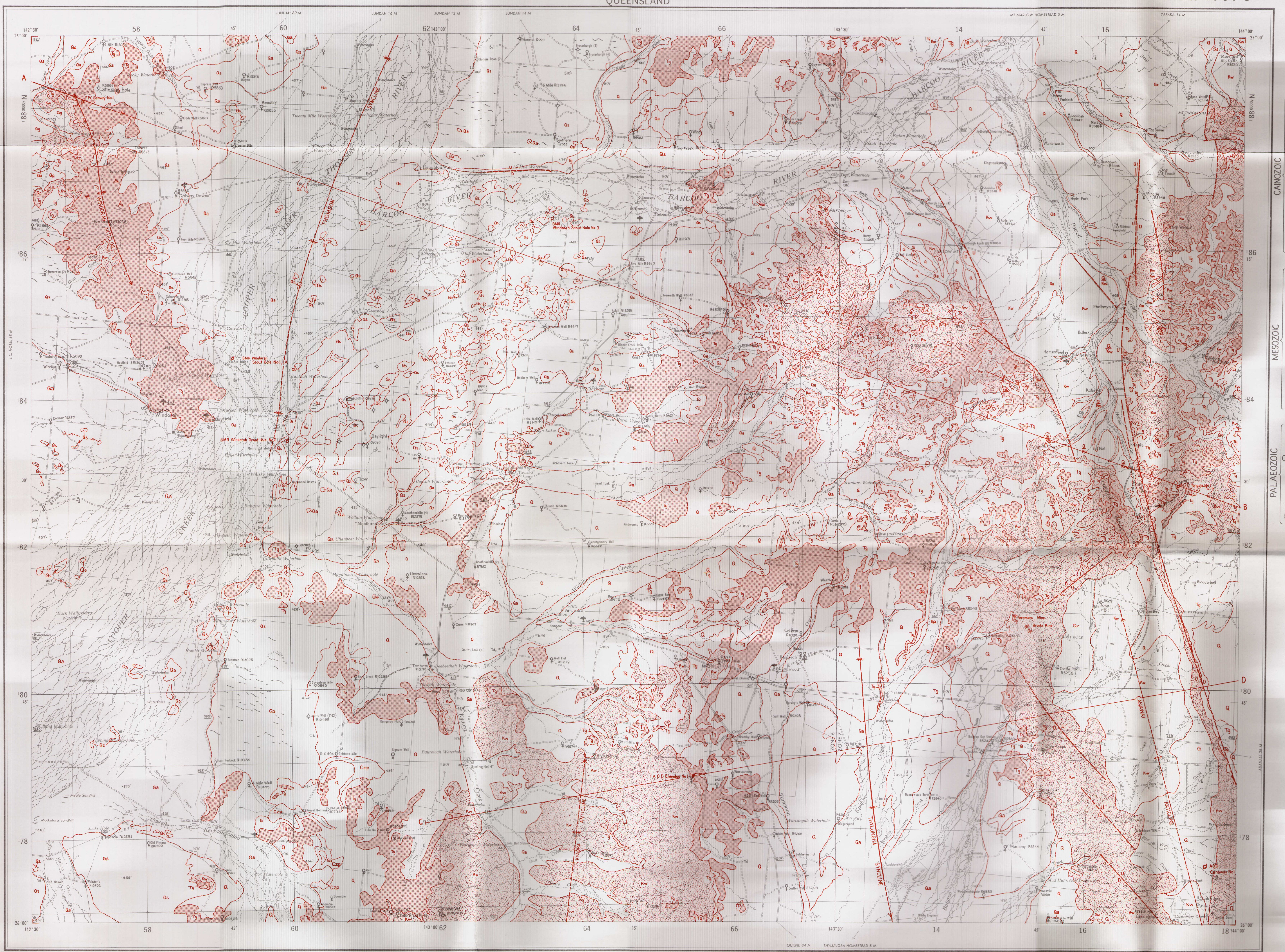
Sheet SG 54-7

Complimentary

AUSTRALIA 1:250,000 GEOLOGICAL SERIES

WINDORAH
QUEENSLAND

SHEET SG 54-8



PRELIMINARY EDITION, 1967

SUBJECT TO AMENDMENT

Reference

Era	Period	Formation	Symbol	Description
CAINOZOIC	QUATERNARY		Q	Undifferentiated, sand, silt, clay, gravel.
			Qa	Alluvium; grey and red soil, silt, sand, minor gravel. Some consolidated material.
			Qs	Sheet and dune sand, some poorly consolidated silty sandstone.
			Qg	Gravel and cobbles, undifferentiated.
			Qc	Gravel and cobbles, mainly of silcrete.
	UNDIFFERENTIATED		Czp	Limestone, minor chalcedony.
				Silcrete, silicified quartz sandstone (Only developed in Glendower Formation.)
				Chemically altered, leached, ferruginized and silicified sediments. (Only developed in Winton Formation.)
	TERTIARY	Glendower Formation	Tg	Quartz sandstone, quartz pebble conglomerate, sandy conglomerate, siltstone, breccia.
MESOZOIC	LOWER TO UPPER CRETACEOUS	Winton Formation	Kw	Labile sandstone, calcareous labile sandstone, calcareous mudstone and siltstone. Locally abundant silicified wood.
	LOWER CRETACEOUS	Mackunda Formation	Klm	Labile sandstone, calcareous labile sandstone, mudstone, coquinite.
		Allaru Mudstone	Kla	Mudstone, calcareous lithic siltstone.
		Toolebuc Limestone	Klo	Limestone, calcareous shale.
		Wallumbilla Formation	Klu	Mudstone, siltstone, minor sandstone.
	JURASSIC-LOWER CRETACEOUS		J-Kl	Sandstone, siltstone, mudstone.
	LOWER TRIASSIC		Ʀ	Sandstone, siltstone, shale, coal.
PALAEOZOIC	PERMIAN		P	Sandstone, siltstone, shale, coal.
	DEVONIAN–CARBONIFEROUS	Buckabie Formation	D-C	Redbed sequence, sandstone, siltstone, shale.
	MIDDLE DEVONIAN	Etonvale and Gilmore Formations	D	Sandstone, siltstone, shale, dolomite.
	LOWER DEVONIAN	Gumbardo Formation	Dg	Trachytic flows, minor sediments.
	UNDIFFERENTIATED		Pz	Indurated shale, sandstone, schist, basalt.

Geological boundaries

Anticline showing plunge

Syncline

Fault (U,D indicates relative movement up or down)

Where position of boundaries, folds and faults is approximate line is broken; where inferred, queried.

Dip< 5°
Trend lines } Air-photo interpretation.

Mine

Prospect

Op Opal

Stratigraphic hole

Abandoned oil exploration well, show of oil

Abandoned dry oil exploration well

Artesian water bore

Sub artesian water bore

Abandoned water bore

} R3950 refers to bore registered number of Queensland Irrigation and Water Supply Commissions records. Where position is doubtful bore is marked (PD)

WH Waterhole

Dam on stream

E Earth tank

Windpump

Sand dunes

Road

Vehicle track

Telephone line

Fence

"Sedan" Homestead

Building

Landing ground

Yd Yard

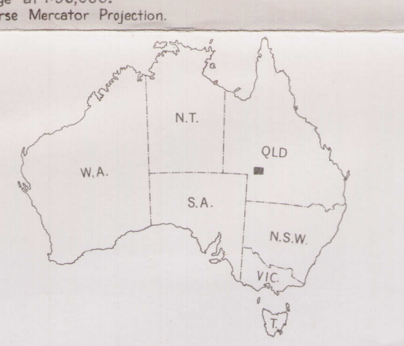
Astronomical station

•506′ Spot elevation, barometric

·582′ Spot elevation, instrument levelled

} datum: mean sea level

Issued by the Bureau of Mineral Resources, Geology and Geophysics, Department of National Development. Issued under the authority of the Hon. David Fairbairn, Minister for National Development. Base map compiled by the Division of National Mapping, Department of National Development. Aerial photography by Adastra Airways Pty. Ltd. complete vertical coverage at 1:50,000.
Transverse Mercator Projection.



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BETOOTA SG 54-6	CANTERBURY SG 54-7	WINDORAH SG 54-8	ADAVALE SG 55-5	AUGATHELLA SG 55-6
CORDILLO SG 54-10	BARROLKA SG 54-11	EROMANGA SG 54-12	QUILPIE SG 55-9	CHARLEVILLE SG 55-10
INNAMINCKA SG 54-14	DURHAM DOWNS SG 54-15	THARGOMINDAH SG 54-16	TOOMPINE SG 55-13	WYANDRA SG 55-14

ANNUAL CHANGE 2′E

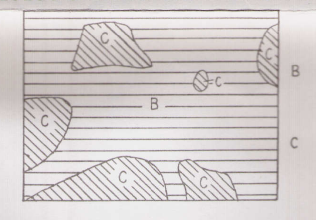
Scale 1:250,000

5 0 5 10 15 MILES

5 0 5 10 15 20 25 KILOMETRES

Sections
Superficial deposits omitted
Scale $\frac{V}{H}=4$

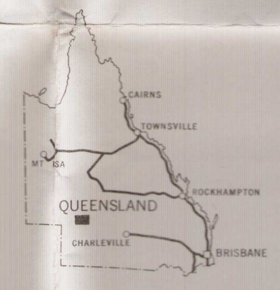
GEOLOGICAL RELIABILITY DIAGRAM

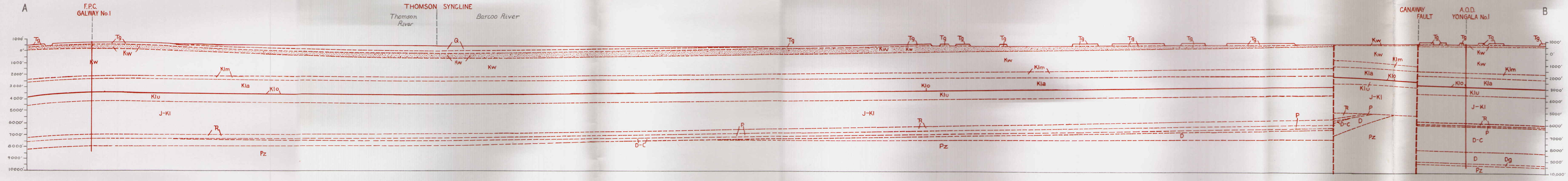


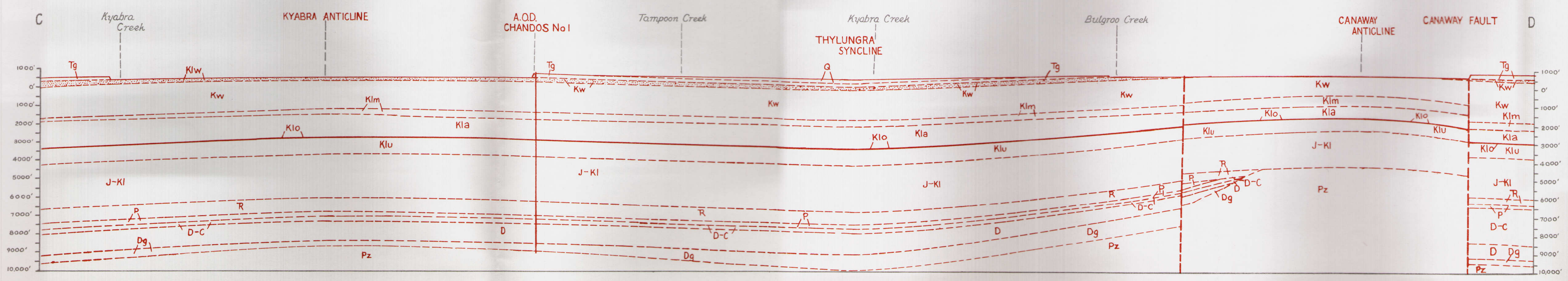
B Detailed reconnaissance, supplemented by air-photo interpretation

C Air-photo interpretation

Geology, 1966, by: C.M.Gregory.
Compiled, 1966, by: C.M.Gregory, R.D.Cooper
Drawn by, R.D.Cooper.







WINDORAH

SHEET SG54-8

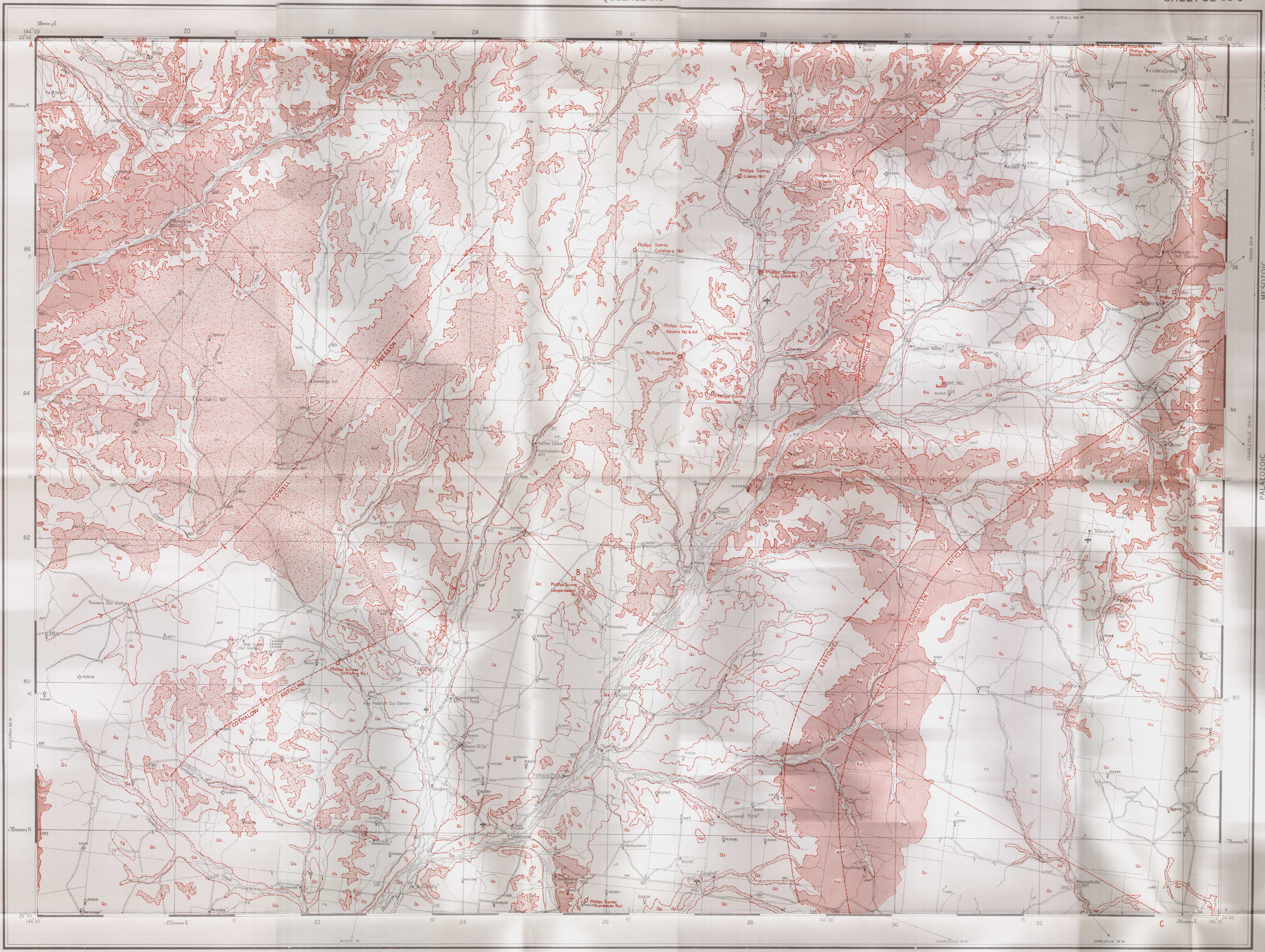
Complimentary

AUSTRALIA 1:250,000 GEOLOGICAL SERIES

ADAVALE

QUEENSLAND

SHEET SG 55-5



Reference

CAINOZOIC — QUATERNARY		Qa	Alluvium
		Qs	Sheet sand, some poorly consolidated silty sandstone
		Qc	Pebbles and cobbles mostly silcrete
UNDIFFERENTIATED			Silcrete silicified quartz sandstone (Only developed in Glendower Formation)
			Chemically altered, leached, silicified and ferruginised sediments (Only developed in Winton Formation)
TERTIARY	Glendower Formation	Tg	Quartz sandstone, quartz pebble conglomerate, sandy conglomerate, siltstone, mudstone
MESOZOIC — LOWER UPPER CRETACEOUS	Undifferentiated	Kr	
	Winton Formation (Rolling Downs Group)	Kw	Labile sandstone, siltststone and mudstone in part calcareous, minor coal, locally abundant silicified wood
LOWER CRETACEOUS	Mackunda Formation (Rolling Downs Group)	Klm	Labile sandstone, siltstone and mudstone in part calcareous, coquinite
	Allaru Mudstone (Rolling Downs Group)	Kla	Mudstone; minor siltstone in part calcareous; minor limestone
	Toolebuc Limestone (Rolling Downs Group)	Klo	Coquina limestone, calcareous shale
	Wallumbilla Formation (Rolling Downs Group)	Klu	Mudstone, labile siltstone, fine labile sandstone.
JURASSIC CRETACEOUS	"Hooray Sandstone"	J-Kh	Sublabile sandstone siltstone, conglomerate.
	Undifferentiated (Injune Creek Group)	Ji	
UPPER JURASSIC	Westbourne Formation (Injune Creek Group)	Juw	Siltstone, mudstone, fine grained quartzose
MIDDLE UPPER JURASSIC	Adori Sandstone (Injune Creek Group)	Ja	Labile to sublabile sandstone, pebbly in part; siltstone
MIDDLE JURASSIC	Birkhead Formation (Injune Creek Group)	Jmb	Sublabile to labile sandstone, calcareous in part; ca[illegible] siltstone and mudstone; minor coal
LOWER JURASSIC	Hutton Sandstone	Jh	Quartzose to sublabile sandstone; scattered pebbles; minor siltstone
PALAEOZOIC — LOWER PERMIAN		Pl	Siltstone, mudstone, some interbedded sandstone, some carbonaceous siltstone.
UPPER DEVONIAN TO LOWER CARBONIFEROUS	Buckabie Formation	D-Cb	Red sandstone and conglomerate, variegated mudstone
MIDDLE DEVONIAN	Etonvale Formation	Dme	Siltstone, mudstone, sandstone, limestone. and dolomite argillaceous in part
LOWER DEVONIAN	Gilmore Formation	Dlg	Mudstone and siltstone minor sandstone: labile and sublabile sandstone common at top
	Gumbardo Formation	Dlu	Andesite and andesitic tuff in the west, arkose and arkosic conglomerate in east
LOWER PALAEOZOIC		Pzl	Crystalline basement. Metamorphics, volcanics, granite

Section only (Kr to Pzl)

Geological boundary
Syncline
Anticline
Monocline
Fault

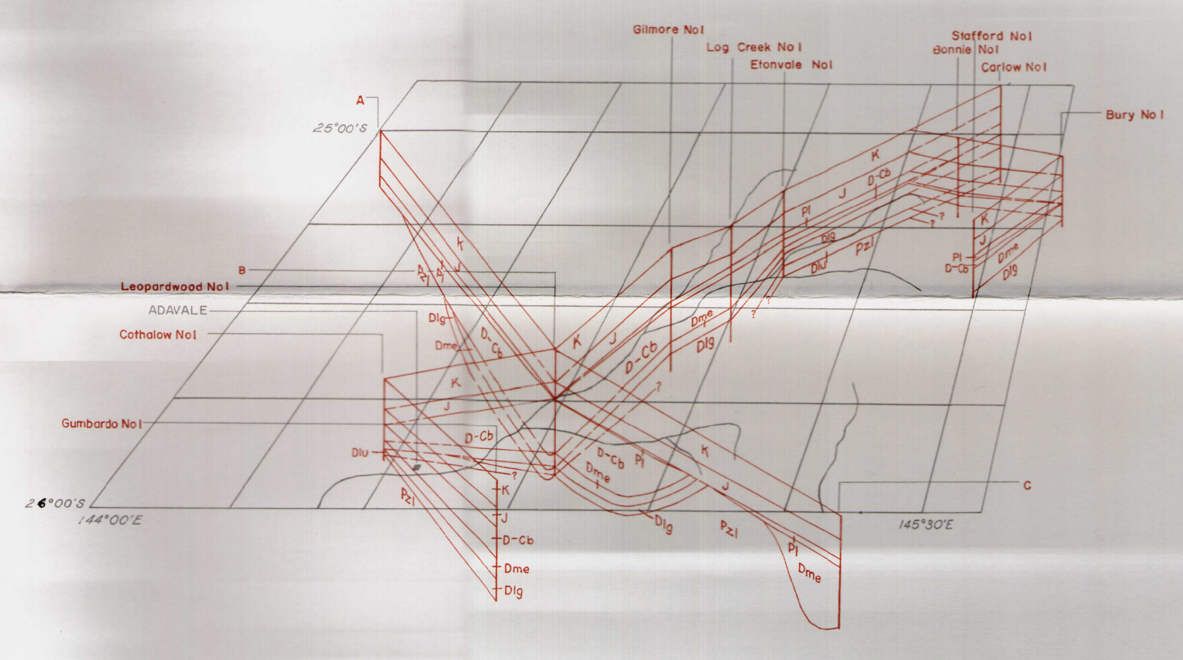
Where location of boundaries folds and faults is approximate line is broken; where inferred, queried; where concealed boundaries and folds are dotted

Dip<5° air-photo interpreted

Gas well
Abandoned oil exploration well with show of gas
Abandoned dry oil exploration well or B.M.R. Scout Hole
Artesian water bore
Artesian water bore ceased to flow
Sub-artesian water bore
Abandoned water bore

R3403 refers to bore registration number of the Queensland Irrigation and Water Supply records

E Earth tank
Dam on stream
WH Waterhole
Spring
Windpump
Road
Vehicle track
Fence
"Milo" Homestead
Building
Landing ground
Yd Yard
Town
798' Height in feet, instrument levelled
.918' Height in feet, barometric
Datum: mean sea level



SUBSURFACE CORRELATION

Scale: $\frac{V}{H}=6$

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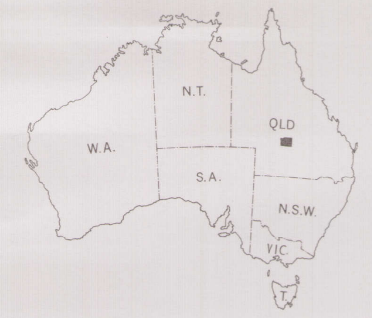
Transverse Mercator Projection



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CANTERBURY SG 54-7	WINDORAH SG 54-8	ADAVALE SG 55-5	AUGATHELLA SG 55-6	EDDYSTONE SG 55-7
BARROLKA SG 54-11	EROMANGA SG 54-12	QUILPIE SG 55-9	CHARLEVILLE SG 55-10	MITCHELL SG 55-11
DURHAM DOWNS SG 54-15	THARGO-MINDAH SG 54-16	TOOMPINE SG 55-13	WYANDRA SG 55-14	HOMEBOIN SG 55-15

ANNUAL CHANGE 2'30"E

Scale 1:250,000

5 0 5 10 15 MILES

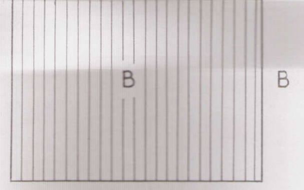
5 0 5 10 15 20 25 KILOMETRES

Section

Cainozoic sediments omitted from sections

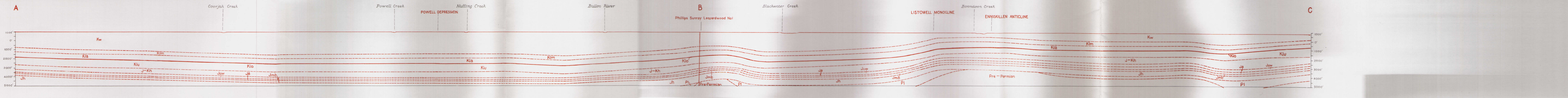
Scale: $\frac{V}{H}=4$

GEOLOGICAL RELIABILITY DIAGRAM

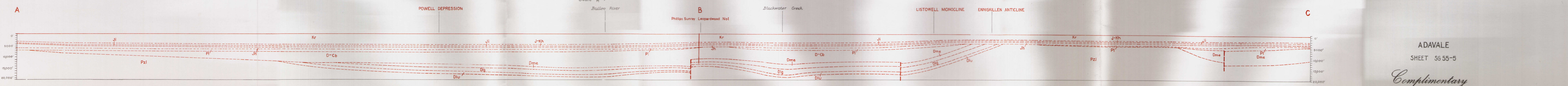


B Reconnaissance - traverse and air-photo interpretation

Geology, 1966, by; M.C. Galloway.
Compiled, 1967 by; M.C. Galloway and R.D. Cooper.
Drawn by; R.D. Cooper.



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



ADAVALE

SHEET SG 55-5

Complimentary

AUSTRALIA 1:250,000 GEOLOGICAL SERIES

JUNDAH
QUEENSLAND

SHEET SG 54-4

PRELIMINARY EDITION, 1967

SUBJECT TO AMENDMENT

Reference

Era	Period	Formation	Symbol	Description
CAINOZOIC	QUATERNARY		Q	Undifferentiated, sand, silt, clay, gravel.
			Qa	Alluvium; grey and red soil, silt, sand, minor gravel.
			Qs	Sheet sand, some poorly consolidated silty sandstone
			Qc	Gravel and cobbles, mainly silcrete.
	UNDIFFERENTIATED			Silcrete, silicified quartz sandstone. (Only developed in Glendower Formation).
				Chemically alltered leached, silicified and ferruginized sediments. (Only developed in Winton Formation).
	TERTIARY	Glendower Formation	Tg	Quartz sandstone, quartz pebble conglomerate sandy conglomerate, siltstone, breccia.
MESOZOIC	LOWER UPPER CRETACEOUS	Winton Formation	Kw	Labile sandstone, calcareous labile sandstone, calcareous mudstone and siltstone, coal. Locally abundant silicified wood.
	LOWER CRETACEOUS	Mackunda Formation	Klm	Labile sandstone, calcareous labile sandstone mudstone, coquinite.
		Allaru Mudstone	Kla	Mudstone, calcareous labile sandstone.
		Toolebuc Limestone	Klo	Coquina limestone, calcareous shale.
		Wallumbilla Formation	Klu	Mudstone, siltstone minor sandstone
	UPPER JURASSIC	"Hooray Sandstone"	J-Kh	Sublabile sandstone, conglomerate
		Westbourne Formation	Juw	Siltstone, shale, quartz sandstone
	MIDDLE JURASSIC	Adori Sandstone	Ja	Labile sandstone, siltstone, claystone.
		Birkhead Formation	Jmb	Calcareous sublabile sandstone, siltstone.
	LOWER JURASSIC	Hutton Sandstone	Jlh	Quartz sandstone, thin shale beds
PALAEOZOIC			Pz	Steeply dipping muiti coloured shale.

Section only (Kla to Pz)

Geological boundary

Anticline showing plunge

Syncline

Fault (U, D indicates relative movement up or down)

Lineament

Where location of boundaries, folds and faults is approximate line is broken where inferred, queried

22 Strike and dip of strata

Dip <5° } air-photo interpretation
Trend lines }

Ju7 Macrofossil locality, showing collection number

Minor mine; Op: opal

Abandoned mine

Abandoned dry oil exploration well or B.M.R. scout hole

Artesian water bore
Sub-artesian water bore
Abandoned water bore
} R7568 refers to bore registered number of Queensland Irrigation and Water Supply Commissions records.

WH Waterhole

Dam on stream

E Earth tank

Windpump

Road

Vehicle track

Telephone line

Fence

"Mutti" Homestead

Building

Landing ground

Yd Yard

Astronomical station

643' Spot elevation, instrument levelled } Datum; mean sea level.
566' Spot elevation, barometric }

(PD) Position doubtful

Seismic reflector interpreted from Barcoo Seismic Survey for Marathon Petroleum Company (Section Only)

Issued by the Bureau of Mineral Resources, Geology and Geophysics, Department of National Development. Issued under the authority of the Hon. David Fairbairn, Minister for National Development. Base map compiled by the Division of National Mapping, Department of National Development. Aerial photography by the R.A.A.F.; complete vertical coverage at 1:50,000 scale. Transverse Mercator Projection.

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BOULIA SF 54-10	MACKUNDA SF 54-11	WINTON SF 54-12	MUTTABURRA SF 55-9	GALILEE SF 55-10
SPRINGVALE SF 54-14	BRIGHTON DOWNS SF 54-15	MANEROO SF 54-16	LONGREACH SF 55-13	JERICHO SF 55-14
MACHATTIE SG 54-2	CONNEMARA SG 54-3	JUNDAH SG 54-4	BLACKALL SG 55-1	TAMBO SG 55-2
BETOOTA SG 54-6	CANTERBURY SG 54-7	WINDORAH SG 54-8	ADAVALE SG 55-5	AUGATHELLA SG 55-6
CORDILLO SG 54-10	BARROLKA SG 54-11	EROMANGA SG 54-12	QUILPIE SG 55-9	CHARLEVILLE SG 55-10

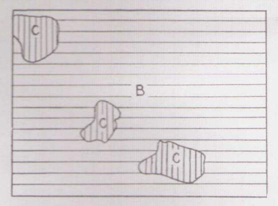
ANNUAL CHANGE 2° E

Scale 1:250,000

5 0 5 10 15 MILES

5 0 5 10 15 20 25 KILOMETRES

GEOLOGICAL RELIABILITY DIAGRAM

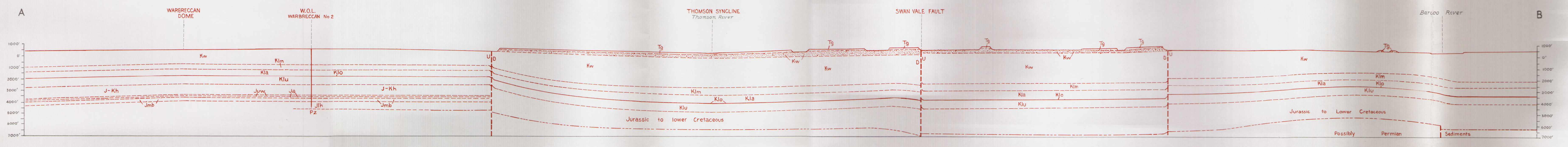


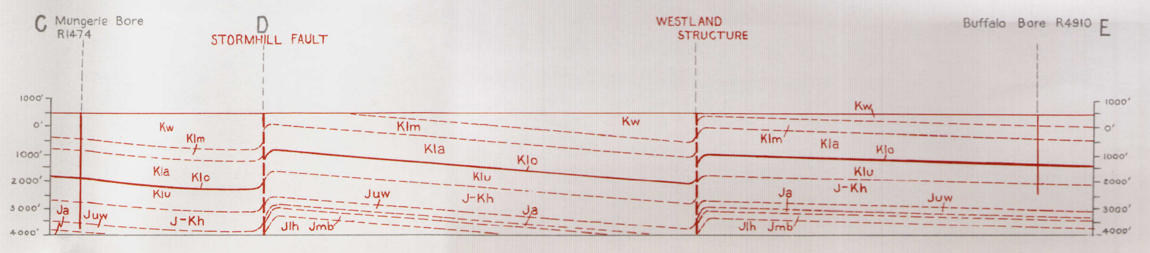
B Detailed reconnaissance, supplemented by air-photo interpretation.

C Air-photo interpretation

Geology, 1966; by; B.R.Senior.
Compiled, 1966; by; B.R.Senior, R.D.Cooper.
Drawn by; R.D.Cooper.

Section
Quaternary deposits omitted
Scale: V/H = 4





JUNDAH
SHEET SG54-4

Complimentary