COMMONWEALTH OF AUSTRALIA.

DEPARTMENT OF NATIONAL DEVELOPMENT.

BUREAU OF MINERAL RESOURCES GEOLOGY AND GEOPHYSICS.

RECORDS.

1960/92

GEOLOGY OF THE SPRINGVALE 4-MILE SHEET AREA, QUEENSLAND.

by

M.A. Reynolds.

GEOLOGY OF THE SPRINGVALE 4-MILE SHEET AREA, QUEENSLAND

by

M.A. Reynolds

RECORDS 1960/92

CONTENTS

GEOLOGY OF THE SPRINGVALE 4-MILE SHEET AREA, QUEENSLAND

by

M.A. Reynolds

RECORDS 1960/92

INTRODUCTION

The Springvale 4-mile Sheet area was mapped during several regional traverses and by aerial photograph interpretation during 1959 and 1960. Members of the Georgina Geological Party made some traverses in the Springvale area in 1957, 1958; they make reference to the area in their reports (Casey, Reynolds, Dow, Pritchard, Vine and Paten, 1960; Casey, Reynolds, Pritchard, Lucas and Paten, in preparation).

The account of work in the Springvale area has been written in two parts: the Cainozoic part by R.J. Paten and the rest by M.A. Reynolds; Paten's report will be finished later (in 1960) as a separate record. In addition to work in the Springvale area, time was spent in the type areas of the Blythesdale Group, Roma and Tambo Formations, and the Mesozoic and younger deposits in the Gilberton-Georgetown 4-mile areas were mapped, (Reynolds, 1960a, b). Sediments which have been mapped as 'Winton Formation' in the Geological Map of Queensland (1953) were seen during a trip into south-west Queensland through north-east South Australia.

Apart from the 'Winton Formation' and a new Tertiary formation, the 'Horse Creek Formation', all other units mapped in the Springvale area have been described by Casey et al (1960) and Casey et al (in preparation); their names were published by Casey (1959). Dunstan (1915) named the 'Winton Series'; Whitehouse (1954) renamed the unit 'Winton Formation' and included it in his 'Rolling Downs Group'. Paten (1960) named the 'Horse Creek Formation'.

A comprehensive account of the history of geological work in the Boulia 4-mile Sheet area is given in Casey et al (1960). The Boulia area adjoins the northern edge of the Springvale 4-mile Sheet area and the account given for the Boulia area also covers in a general way, the Springvale area.

Aerial photographs at 1:50,000 scale formed the basis for field mapping in 1959; the photographs were taken by the R.A.A.F. in 1952. Plotting of geological and topographic information will eventually be on to air photo-scale compilation sheets and a 4-mile base map prepared by the Department of National Mapping, Melbourne. An uncontrolled planimetric map showing some topographic details prepared by J.N. Casey, was made available to us for rough plotting in 1959 and this has been used as the base for the geological map with this report. Department of Interior surveyors determined altitudes for gravity stations in the Springvale area; these provided accurate height control for barometric traverses. Geophysical work in the area in 1959 was conducted by the Geophysical section, Bureau of Mineral Resources and by Mines Administration Pty. Ltd.

Authorities to Prospect for Petroleum which cover the Springvale area are held by Papuan Apinaipi Petroleum Co. Ltd., Associated Australian Oilfields N.L., Associated Freney Oil Fields N.L. (54 p.); authorities are held by Conorada Petroleum Corporation east of the Springvale area and by the Santos, Delhi, Frome group to the south.

Fossils collected in the Springvale area are stored in Bureau offices and museum; they were identified by Dickins (1960). Crespin (1960) listed microfossils found in the samples submitted to her and made brief comments about them. Short descriptions of fossil wood samples have been given by M.E. White in Appendix I. P.R. Evans will study microplankton and spores in fresh rock samples obtained from bores in the area. Notes on lithologies have been supplied by K.G. Lucas, W.R. Morgan, and by Dallwitz and Bofinger (1960). Chemical analyses of rocks have been done by S. Baker and A. McClure (see Appendix II). F. Olgers has assisted in the drawing of Figures for the report.

Our thanks are expressed to Mr. and Mrs. A. Milson and Mr. C. Milson, owners of Springvale Station and to their book-keeper Mr. S. Young and others of their staff for their hospitality and help in 1959. The co-operation of other station people in the area is also gratefully acknowledged. We are also grateful to the Irrigation and Water Supply Commission, Brisbane for information on water bores in the area. Local water bore drillers, particularly Mr. J. Robinson, were most co-operative and gave us some very useful information and samples.

CRETACEOUS

1. General Discussion

Approaches to regional correlation in Queensland of the Cretaceous part of the Blythesdale Group and Roma, Tambo and Winton Formations of Whitehouse (1954) have been discussed in Reynolds (1960b). Results of the discussion may be summarised as follows:

(1) Although the upper part ("Transition Beds" of Reeves, 1947) of the Blythesdale Group is essentially sandstone, the beds are more shaly than the lower part and contain marine fossils whereas in the lower part only plant remains are found.

(2) The Roma and Tambo Formations and their equivalents are easily divisible on the basis of different macrofossil assemblages (see Dickins, 1960).

(3) The Toolebuc Member of the Wilgunya Formation is thought to be basal Tambo Formation equivalent and a fairly extensive marker bed in part of the Great Artesian Basin; its distinguishing features are its almost pure carbonate composition in parts and its fossil assemblage - pelecypods almost entirely *Inoceramus* and *Aucellina hughendenensis* (generally large specimens), ammonites, and microfossils dominated by the foraminifera *Globigerina planispira* and radiolaria.

(4) The Winton Formation can sometimes be separated from the Tambo Formation on the basis of its containing more sandy beds and more common plant material; also, it does not have foraminifera or radiolaria.

(5) The greatest difficulty in dividing the Winton and Tambo Formations is in weathered outcrop. A sandy calcilutite or calcareous sandstone at the top of the Tambo Formation in its type area may be a very useful marker bed.

In South Australia, continuous sedimentation from Aptian to Albian was shown by the Oodnadatta Bore (G.S.A., 1958); excellent control has been provided by this bore because it was cored for the whole depth. Division into Blythesdale Group, Transition beds, Roma Formation, "Terebratella bed", Tambo Formation and Winton Formation by lithology and macrofossils has been possible. The "Terebratella bed" is not known from Cretaceous sediments in the Queensland part of the Great Artesian Basin. Brunnschweiler (1959) mentioned 'a most conspicuous faunal difference between the Tambo and the Roma Formations.' Ludbrook (1960) has been able to subdivide beds into Aptial and Albian age on the basis of her microfossil work on cores from the Oodnadatta Bore.

Work done in western Queensland in 1959 showed that the Longsight Sandstone and Wilgunya Formation of Casey (1959) and Casey et al (1960) can be related to the Blythesdale and Rolling Downs Groups of Whitehouse (1954) as follows:

Wilgunya Formation (upper part)) Toolebuc Member)	Winton Formation / Tambo Formation	(Rolling Downs Group
Wilgunya Formation (lower part)	Roma Formation	
Longsight Sandstone	Blythesdale Group (upper part)	

The relationship with other formations named in the Great Artesian Basin is shown on a chart in Reynolds (1960b).

The general conclusions which may be drawn from studies in the Cretaceous of the Great Artesian Basin so far are:-

(1) Although lithological continuity of the main Cretaceous units has not been established throughout the Basin, distinctive macrofossil assemblages occur in roughly the same stratigraphic positions in various parts around the margin where fairly continuous sections can be examined.

(2) The emphasis in studies so far has been on macrofossils and microfossils. Very little work has been done on lithology and one cannot at the moment give precise answers to the very important problems: What is the source of sediments in the Great Artesian Basin and are any beds distinctive and widespread enough to be useful marker beds?

(3) Foraminiferal assemblages in South Australia are being studied using distribution of forms in the cores of Oodnadatta Bore as a basis; they may be significant throughout the Basin. Microfossils (including microplankton and spores) may later prove to be very important, particularly the plankton, which may give a clue to part of the geological history of the Basin.

(4) The structures in the Great Artesian Basin are not well known. Although some have been reported on the evidence of the logs of some of the hundreds of water bores, there are limitations to this approach because of -

(a) inaccurate or obscure identifications of rocks by drillers;

(b) positions given for proposed bores in applications for drilling permits are sometimes quite different to the actual site drilled;

(c) few bores drilled for water penetrate beyond good artesian aquifers.

In fact, the amount of well-controlled bore information in the Great Artesian Basin is exceedingly small. A framework of more accurately known bores has been drawn in a block diagram; it is proposed to add to this as more deep bores are drilled and more information becomes available. The basic units that occur throughout the Basin can thus be established and the nature of structures determined.

At this stage, therefore, the 'Tambo and Roma Formations' can not be introduced as such into western Queensland to replace the 'Wilgunya Formation'; the 'Winton Formation' probably can be separated from the upper part of the 'Wilgunya Formation'. As the upper part of the Wilgunya Formation including the Toolebuc Member has a different macrofossil assemblage to the lower part, and because the Toolebuc Member is quite different to other beds, three lower Cretaceous units have been mapped in the Springvale 4-mile sheet; upper part of Wilgunya Formation (Klw_2), Toolebuc Member (Klwt), lower part of Wilgunya Formation (Klw_1). The Longsight Sandstone which is conformably below the Wilgunya Formation to the north and west does not crop out in the Springvale area; it is known from bores as shown in Figure 3, and an isopach map of the Longsight Sandstone is included as Figure 2 of this report.

It will be seen from Figure 3 that basement rocks are not all necessarily either granites or carbonate rocks which can probably be correlated with formations which crop out, or are known from the Boulia 4-mile area to the north. "Red marls" occur between "limestone" and the Mesozoic beds in Breadalbane bores Nos. 7 and 9. The bottom of Jack's Bore, Canary, is in hard, compact, grey fine-grained sandstone. Interbedded "hard rock" and "shale" are 200 feet thick at the bottom of Springvale No. 8 bore. 51 feet of "red ironstone" occur above "limestone" in Lucknow Bore No. 11. The real nature of such beds and their age cannot be determined without samples.

2. Wilgunya Formation

The Wilgunya Formation is formed of shales, claystones and siltstones with minor sandy and calcareous beds. Gypsum and pyrites occur throughout and some sandy beds are glauconitic. In outcrop in the Boulia area it is mainly weathered, lateritised, and generally modified to varying degrees by silicification. "The name is derived from the west-flowing Wilgunya Creek which joins the Hamilton River north of the Hamilton Hotel. The type section lies eight miles north-east of Dover Homestead at latitude 22°32'S., longitude 140°50'E." (Casey, et al, 1960). The formation overlies the Longsight Sandstone conformably and forms an impermeable cap over the Great Artesian Basin aquifers. On the basis of macrofossil assemblages, the beds can be divided into a lower part equivalent to the Roma Formation, and an upper part equivalent to the Tambo Formation; the Toolebuc Member of the Wilgunya Formation occurs near the base of the Tambo Formation equivalent.

A. Lower part of Wilgunya Formation (Klw_1): The lower beds of the Wilgunya Formation are confined to small areas in the Springvale 4-mile Sheet area - 1. along the western margin north of Hilary Tank where they occur as weathered outcrops below a cap of silicified sandstone of the Marion Formation, and, 2. in small pockets on Canary and Lorna Downs Stations between the Hamilton River and outcropping Toolebuc Member. Where it is not capped by other resistant sediments, e.g. near the Hamilton River, it forms grey clayey soil which cracks when dry. The soil grows coarse scattered clumps of Mitchell grass. The resultant topography over a large area (as in other places) would be one of gently undulating "rolling downs" country.

Casey et al (1960, p.62) noted a change in lithology 'from predominantly claystone in the east' of the Boulia 4-mile area (i.e. upper Wilgunya Formation) 'to siltstone and sandy siltstone with thin, but prominent, bench-forming sandstones in the Momedah area' (i.e. lower Wilgunya Formation). In outcrop, the lower part is high on the Boulia Shelf area and, although marginal outcrop is fairly wide, probably represents a near-shore lithofacies; in bores drilled into the Great Artesian Basin, the lower part of the Wilgunya Formation is more sandy near the margin where the sandy beds are most common at the base of the formation. Where the Basin is deeper in the southern part of the Springvale area, the lithology is grey silty to blue, green and black shale with rare thin hard calcareous (and sideritic?) or green sandy bands.

Macrofossils have not been found in the lower part of the Wilgunya Formation in the Springvale area, but have been found in the Boulia area where their similarity to the Roma Formation assemblage was noted. The microfossil assemblage is rich in arenaceous foraminifera, and radiolaria are common. Radiolarian outlines have been seen in thin sections of weathered and altered outcrop rocks of the lower Wilgunya Formation (Reynolds, 1960b); some show partial assimilation into the body of the rock and a fine granulated silica texture within and outside the test. Silica in this form is isotropic in thin section and is probably opal. Such rocks are not true radiolarites and are referred to as 'radiolarian porcellanites' or 'radiolarian siliceous rocks'. Microfossils identified by Crespin (1960) are as follows: Foraminifera (large and well-preserved) - Ammobaculites fisheri, A. subcretaceus, A. minimus, Bathysiphon sp., Flabellammina alexanderi, Haplophragmoides chapmani, H. concavus, H. globosa, Involutina cretacea, I. sp. nov., Pelosina sp., Reophax deckeri, Spiroplectammina ammovitrea, S. edgelli, Trochammina depressa, Verneuilina howchini, V. sp. (S156, S20a, b localities); other forms found in bores include - Ammobaculites australe, A. sp. nov., Anomalina mawsoni, Esosyrinx sp. nov., Epistomina australiensis, Eponides sp., Gyroidina nitida, G. cf. Loetterlei, Haplophragmoides sp. Lenticulina australiensis, Lingulina aff. furcillata, Marginulina sp., Marginulinopsis australis, M. subcretaceus, Patellina jonesi, Proteonina sp., Robulus sp., Saracenaria sp., Spiroplectammina cushmani, S. sp. nov. Tristix excavatum, Trochammina minuta, T. raggatti, Valvulineria infracretacea; radiolaria-Cenosphaera, aff. Porodiscus, Dictyomitra.

The following additional forms were found in water bores that began in the Toolebuc Member and penetrated the lower part of the Wilgunya Formation; they could therefore belong to either part of the section - Lagena globosa, Robulus gunderbookaensis Siphotextularia sp., Nodosaria aff. obscura, Robulus warregoensis, Arenobulimina sp., Neobulimina minima, Globigerina planispira, G. planispira, however, does not normally occur below the Toolebuc Member in western Queensland, and is not regarded as part of the lower Wilgunya Formation assemblage.

The thickness of the lower part of the Wilgunya Formation varies from about 100 feet in weathered outcrop to ?427 feet in Springvale Bore No. 7 or ?604 feet in Springvale No. 6 and 603 feet in Diamantina Plains Bore. Where bores begin in or near the Toolebuc Member, the thickness of the lower Silgunya Formation before the aquifer was reached, was from 400 to 500 feet.

The geological history of the Great Artesian Basin as it affected the Gilberton-Georgetown area in northern Queensland is briefly discussed in Reynolds (1960a). The deposition of Wilgunya Formation and Toolebuc Member is also discussed by Dickins (1960) and Reynolds (1960b). Deposition of the Wilgunya Formation began in early Cretaceous times after a widespread invasion of the sea. Shallow water conditions generally persisted while the lower part was deposited - marginal beds are sandy, foraminifera are mainly arenaceous and abundant with well-formed tests, and increase in thickness of the beds towards the centre of the Basin seems to be small and fairly gradual. Deposition of the Toolebuc Member shows a fairly sudden change in conditions and introduction of limestone with a different fossil assemblage (possibly mainly due to increase in depth of the Basin.)

The lower part of the Wilgunya Formation is conformable over the Longsight Sandstone and unconformable on older rocks to the west and north of the Springvale area. The Toolebuc Member, although it introduces a different fossil assemblage, appears to be conformable above the lower part of the Wilgunya Formation; this, however, may be due to the nature of the environment and sediments deposited. On the evidence of macrofossils the age is Lower Cretaceous, and the lower Wilgunya Formation is equivalent to the Roma Formation.

B. Toolebuc Member (Klwt): The Toolebuc Member has been described by Casey et al (1960), Reynolds (1960a, b) and the name was published by Casey (1959). Because of its apparently wide extent and distinctive lithology, it may be an important bed.

The name "Toolebuc" is derived from Toolebuc Station in the north-east corner of the Boulia 4-mile Sheet area. The type area is along the eastern side of the Hamilton River where the Member forms a belt 1 to 4 miles wide. In the Springvale 4-mile Sheet area, the Toolebuc Member follows the east side of the Hamilton River as far south as Lower Gidyea Bore on Lorna Downs Station; it reappears west of the channels of King Creek and Georgina River at Hilary Tank (on stock-route from Boulia to Bedourie), but has not been traced positively south-west from there. Another belt of Toolebuc Member branches from the above belt on Warra Station and extends south across Canary Station to Elizabeth Springs on the west side of Spring Creek. A small dome-like structure of limestone, which is thought to be an inlier of Toolebuc Member, occurs on the west side of No. 1 (or Prairie) Creek and Spring Creek channels, 8 miles south of Springvale homestead. The eastern margin of the structure is on a fault line which continues south from the east edge of the Elizabeth Springs belt of Toolebuc Member. This line is an apparent extension from the Boulia 4-mile area of the western edge of the Burke River Structure.

Reynolds (1960a) extended the Member north from Toolebuc towards McKinlay and also correlated it with limestone outcrop at Bunda Bunda, just south-west of the Gilberton 4-mile area, and with the Kamileroi Limestone of Laing and Power (1959). Dr. D. Hill, in Casey et al (1960), noted that a collection of fossils from 7½ miles south of Moorooka-Beaudesert boundary on the McKinlay-Boulia road is similar to the assemblage in samples from the Toolebuc Member.

In a general discussion of the Toolebuc Member in the Great Artesian Basin, Reynolds (1960b) compares it with horizons in some of the deeper bores in the Basin. A few bores into the deeper part of the Basin in the Springvale 4-mile area (about half of the logged bores of Coorabulka and Springvale Stations) showed bands which can be, or possibly can be, correlated with the Toolebuc Member. The bands, 'hard bands', 'hard and soft rock', 'limestone' etc., vary from 1 to 54 feet thick (in logs) and are from 370 to 600 feet above the base of the Wilgunya Formation (see Fig. 3). However, other hard bands and lenses (with which the Toolebuc Member could be confused in bore logs) occur in the Wilgunya Formation. The Toolebuc Member is generally about 400 feet above the base of the Wilgunya Formation in the outcrop belt. The presence of a uranium mineral with fish scales and bones which are common in the Member give it a radiometric count of three to four times background and it should show well on gamma-logs of water bores (Casey et al, 1960).

Although the Toolebuc Member is not very thick, it is a resistant unit and, being continuous at the surface, rises from the enclosing shales to form a prominent small scarp. This fact, its composition and the slumped nature of some of the outcrop make it a fairly distinctive unit in aerial photographs.

The Member is composed of thin-bedded, pink to grey, sandy calcarenite, calcareous siltstone and coquinite in the type area. It is richly fossiliferous with large Aucellina hughendenensis and Inoceramus (pelecypods, see Dickins, 1960). It weathers out at the surface as spherical boulders in some places; these do not show concretionary structure. Other weathered beds are irregularly platy. Slumping is common in the Boulia and Springvale areas; slumped parts may show dips up to 80° in beds which have only a low regional dip. Cone-in-cone structure has been seen in Toolebuc Member beds. One of the most prominent beds in the Toolebuc Member is a fossiliferous limestone. Samples examined so far show that it is primary limestone with a very high percentage of carbonate. A sample from S1 locality on Warra Station had 98.74% carbonate, 1.24% argillaceous material and 0.02% hydrated iron oxide, quartz and plagioclase grains. Limestone from Hilary Tank on Boulia-Bedourie stock route was 97% carbonate, 3% clay with very fine quartz grains, and hydrated iron oxide was present throughout in small amount (0.02%). Some iron oxide was present as pseudomorphs possibly of pyrites; pyrites grains were very rare (descriptions by W.R. Morgan, 1959). Samples from S107 and S221 localities showed small amounts of chlorite in radiolarian limestones and small inclusions of iron oxide scattered throughout. The presence of the inclusions in the calcite crystals, and of unaltered fossil fragments, suggests that the limestone is primary. Iron oxide deposition in microfossil tests or replacement of fossil fragments was noted (descriptions by V.M. Bofinger from slides lent by Miss Crespin). The yellow-green uranium mineral found associated with fish scales and bone fragments in the Toolebuc Member in the Boulia area, was also seen in outcrops in the Springvale area; W.M.B. Roberts reported the presence of novacekite and carnotite in this mineral (Casey et al, 1960, p.96).

Fossils (including the microfossil assemblage) are quite distinctive. As noted by Dickins (1960), the Toolebuc Member is rich in large specimens of Aucellina hughendenensis, and in Inoceramus; other pelecypods are rare. Other fossils recorded in the Toolebuc Member in the Springvale area are:

Pelecypods - Maccoyella sp., (rare), Rocellaria?; Ammonites - Aconeceratidae gen. et sp. ind., Desmoceratidae gen. et sp., cf. Falciferella sp., Labeceras (Appurdiceras) sp., L. sp., L.? sp. ind., Myloceras sp., Puzosia? sp.; and the Belemnite - Dimitobelus sp. Fish scales, teeth and bones and vertebrate bone fragments have been collected and also some fossil wood and samples with irregular worm? burrows. Only planktonic foraminifera have been found in the Toolebuc Member so far: Globigerina planispira is abundant; G. infracretacea and G. sp., are also recorded by Crespin (1960). Radiolaria are fairly common in microfossil samples; Inoceramus prisms and small fish remains are abundant to common.

The thickness of the Member in the type area is 30 feet at the most; it is no thicker in the Springvale area. About 400 feet above the base of the Wilgunya Formation in Springvale No. 6 bore, there is recorded 54 feet of "sandy shale with boulders and pyrites" which may be equivalent to the Toolebuc Member. On the other hand, the lower part of the Wilgunya Formation may have thickened at this locality and a 20 foot bed of limestone recorded 200 feet higher in the bore log may be the Toolebuc Member.

The environment may have been deep basinal, but deposition extended to the western margin of the sea of that time. Dickins (1960) noted the sudden and almost complete change of the macrofossil assemblage from below the Toolebuc Member to the Member and also remarked on the rarity of sandy material. He thinks that deepening of the Basin, and/or breakdown of barriers around the margin of the Basin and change in climate might have been causes. The important features related to the change in western Queensland, including those mentioned by Dickins and by Reynolds (1960a, b), are as follows:

(1) lithology - rich carbonate and low sand composition;

(2) macrofossils - pelecypods restricted to abundant, well-developed Aucellina and Inoceramus; ammonites common; an almost complete change in assemblage from the fauna of the lower Wilgunya Formation;

(3) microfossil samples - foraminifera restricted to planktonic genus Globigerina; radiolaria, Inoceramus prisms, small fish remains common; no arenaceous foraminifera recorded;

(4) distribution - widespread laterally around western margin of Great Artesian Basin extending to edge of Carpentaria Basin and towards Hughenden; some bores suggest that it may extend into the Basin; there is no evidence that the unit ever extended any further west than its present margin.

A change in the environment or conditions of deposition is postulated to account for these features. A general sag in the centre of the Great Artesian Basin was probably the prime cause; this is reflected by the increased thickness in the centre of the Basin of the upper Wilgunya Formation. Also, barriers at the northern (and ?south) ends of the main central basin were lowered sufficiently to allow the oceans to enter - (this argument is based on the fact that Globigerina, which occurs in beds equivalent to the lower Wilgunya Formation in the Carpentaria Basin and in the Innamincka bore in north-east South Australia, only appears with the Toolebuc Member in the central sub-basin - see Reynolds, 1960a, b). On the other hand, elevation of the western margin of the Basin is suggested to account for the fact that the Toolebuc Member and its fossils do not extend as far west as the lower Wilgunya beds. The Member probably extends fairly close to the margin of the sea in which it was deposited because a large part of its fauna is made up of floating and remains of swimming forms. The only other evidence that the Member extended into shallow water are the pelecypods which are like attached types normally found in shallow water in present day seas, and remains of vertebrates. Against this theory is the absence of sandy material and arenaceous foraminifera; but the land mass around the margin of the sea would have been composed of the lower Wilgunya Formation shaly beds and contributed very little arenaceous material. An explanation of the almost pure carbonate composition in part of the Toolebuc Member is possible if influx of the sea from the north (Carpentaria Gulf) is accepted - Twenhofel (1950) points out that when cold waters rise and mingle with warm surface water, carbon dioxide would be lost and calcium and other carbonates precipitated - this may have happened when warmer waters from the north flowed in over waters existing in the central sub-basin and convection currents formed. The influx of the oceans explains the prominence of planktonic foraminifera and fish remains and, also, fairly common ammonites. The rich limestone content of the Toolebuc Member is sufficient to account for the well-developed forms and abundance of Aucellina and Inoceramus. The abundance of Inoceramus prisms is hard to explain; there is no evidence of turbulence during which the shells would have been broken. The shells may have been macerated by scavengers (vertebrates, fish and ?ammonites) in their search for food which would have been limited in that environment.

Because of the lithology and conditions of deposition of the lower part of the Wilgunya Formation, the nature of its contact with the overlying Toolebuc Member is not known; the upper part of the Wilgunya Formation seems to be conformable on the Member.

The Kamileroi Limestone of Laing and Power (1959) is the only formation with which the Toolebuc Member can be directly correlated. The Member is thought to be at, or near, the base of beds equivalent to the Tambo Formation on the basis of its macrofossils. It may be possible to compare the age of the unit with European time-subdivisions of the Cretaceous when more work has been done on macrofossils and microfossils; for the present it is regarded as Lower Cretaceous.

C. Upper part of Wilgunya Formation (Klw_2): The section at the type area of the Wilgunya Formation occurs in the upper part. In lithology and outcrop, the upper Wilgunya Formation is very similar to the lower part. Although it covers most of the Springvale 4-mile area, unweathered outcrops of the upper part are rare. Weathered outcrops occur below caps of younger formations. Fresh material is found in some steep scarps and creek-bank exposures. The topography of uncapped beds is of low "rolling" hills; these are preserved to some extent by tougher calcareous lenses and bands in the shales of the formation. The black soil surface developed over the beds cracks when dry; it supports coarse Mitchell grass.

Although the lithologies have not been extensively examined, the predominantly shaly beds of the upper and lower parts of the Wilgunya Formation seem to be very much the same. Some minor lithologies are different. In the type area, 8 miles north-east of Dover homestead in the Boulia 4-mile area, 93 feet of weathered claystone and siltstone are exposed; the colour of outcrop varies from red-brown at the top to white and grey. The section includes a 6 inch band of limonite and disc-shaped limonite concretions up to 18 inches in diameter; these may be formed from replaced limestone - fossiliferous ironstone beds which were obviously once limestone crop out at S32 locality, 3 miles west of No. 6 Bore, Springvale. Barytes nodules were obtained from the basal bed exposed in the type area. Such occurrences may be important; a sample from Pigeongah Waterhole (S28) locality, which was analysed originally for silica content because it is white and similar to the typical siltstone outcrop, proved to be rich in alumina and phosphate and contained appreciable amounts of strontium and barium, (Analysis given in Appendix II). Minor lithologies common to upper and lower parts of the Wilgunya Formation include yellow-brown clayey to silty limestones, some of which show cone-in-cone structure, and sandy glauconitic(?) calcarenites. Thin bands of limestone which appear to be almost entirely composed of Inoceramus prisms are restricted to the upper Wilgunya Formation; they have been found in a few places in the Springvale area but whether they are on one horizon or in several lenses is not known. A bed, or beds, of impure calcareous arkosic sandstone at or near the top of the upper Wilgunya Formation might be the most important of the minor lithologies because of its stratigraphic position; a similar bed occurs near the top of the Tambo Formation in its type area. Samples which are comparable in the Springvale 4-mile area occur in surface outcrop about 1 mile south of No. 4 Bore Lucknow, in the south-east corner (between Spring Creek, Ida Creek to No. 9 Bore Springvale and south-west to Tent Hill), and possibly 35 miles south of the Springvale boundary in the Machattie 4-mile Sheet area. Specimens examined from these areas and localities vary between sandy calcilutite and calcareous fine-grained arkosic sandstone; the latter is more common. Mineral detritus in most samples was composed of roughly equal amounts of quartz and feldspar (mainly plagioclase) and minor igneous rock fragments, chert, muscovite, biotite, chlorite and magnetite which was bedded in the sample from the Machattie area. Glauconite and glauconite(?) are not common. Quartz and plagioclase grains are fresh and clear, and the feldspars are embayed in the sample from S237 locality (authigenic?); the grains generally are angular, equigranular from 0.1 - 0.2 mms. in size (fine-grained) and well-sorted. The matrix is clay and limestone in varying proportions; secondary limonite, chlorite and sericite occur in the matrix. The amounts of mineral detritus and matrix are roughly equal in most samples. In outcrop, the rock is tough, compact. At S26 locality near Cartenari Yard, Springvale Station, similar lithology showed small-scale current bedding, laminae of limonitic shale with plant fragments abundant and a thin bed of intraformational conglomerate. Crespin (1960) noted limonite (glauconite?) casts of a few microfossils in some of these samples, but no tests. Attempts should be made to trace this bed south of the Springvale area and more detailed sedimentary rock analyses are required before its importance can be established.

Fossils from the upper part of the Wilgunya Formation in the Springvale area include: Pelecypods - Cyrenopsis sp. B, ?C. sp., Grammatodon robusta, cf. G. robusta, Inoceramus sp., Nucula cf. quadrata, N. cf. truncata, Nuculana? sp. nov., "Yoldia" sp. nov.; gastropods; ammonites - Beudanticeras sp., cf. Falciferella sp., Labeceras sp., Myloceras sp.; scaphopods; starfish; fish teeth, scales and bones; plant remains; tracks. Microfossils from outcrop samples were not well-preserved and were not common. Crespin (1960) records: Haplophragmoides sp., cf. H. sp., Trochammina minuta, T. sp., Spiroplectammina sp., Verneuilinoides aff. perplexa.

The greatest thicknesses seen in outcrops in the Springvale 4-mile area are about 100 feet at W107 locality just west of Hilary Tank (west side of area) and 40+ feet at S210 locality near No. 5 Bore Lucknow in the north-east corner. At W107 locality the upper 60 feet was composed of leached siltstone and shale which became increasingly silicified towards the top where it was capped by silicified Marion Formation; the colour of the shale and siltstone in this section varied from grey at the bottom to white and white and red mottled at the top. If the "limestone" band recorded in the log of Bore No. 7 Springvale between 668 and 678 feet is the Toolebuc Member equivalent, the greatest thickness known for the upper part of the Wilgunya Formation is 668 feet; the bore probably started in the top part of the Wilgunya Formation.

The extent of the seas during deposition of the upper part of the Wilgunya Formation is not known but it exceeds the northernmost known limit of the Toolebuc Member on the west side of the Georgina River; elsewhere in the Springvale area, deposits of upper Wilgunya Formation do not crop out west of the western margin of the Toolebuc Member. Deposition was apparently similar to that during lower Wilgunya times but fossils and microfossils show that the oceans had access to the Basin during upper Wilgunya times. Conditions changed gradually at the end of the time of Wilgunya Formation deposition. The beds became more sandy as connections with the oceans were closed and a large barred basin formed. The reason for this is not clear; possibly uplift around the western margin of the Basin (coinciding with, or as a result of continued sag within the Basin) caused rejuvenation of drainage and supplies of coarser material from beyond the mantle of lower Wilgunya Formation shales. At the change from open marine to barred basin conditions, wide marginal areas would probably have been favourable for deposition of limestone of the type common to the upper part of the Wilgunya Formation and of celestite and mineral deposits such as found at S28 locality. The Winton Formation was deposited in the lake (or number of large lakes) which developed from the barred basin.

The upper Wilgunya Formation is conformable on the Toolebuc Member; it is conformably overlain by the Winton Formation and unconformably capped by the Tertiary Springvale and Marion Formations.

The age is Lower Cretaceous (based on macrofossil assemblages including ammonites); the Toolebuc Member and upper Wilgunya Formation together are thought to be equivalent to the Tambo Formation.

3. Winton Formation

Whitehouse (1954) states that 'Dunstan (1916, page 166)' separated the "Winton Series" from the 'Rolling Downs Group'; Whitehouse called the unit "Winton Formation". The Winton Formation follows conformably above the Tambo Formation; blue shales and sandstones with intercalated coal seams and fossils, (Unio), as found in wells and bores near Winton are the type lithology of the unit according to Whitehouse (see also Jack, 1885).

The sandy beds have been identified and mapped in outcrop; shaly beds in weathered outcrop cannot easily be differentiated from weathered shales of the Tambo Formation.

Although the type lithology was not seen in 1959 traverses, areas mapped by Whitehouse as Winton Formation between Winton and Boulia and south of Coorabulka were visited. The lithologies in these places were very similar and it was possible to map identical beds in the Springvale 4-mile area as Winton Formation on the basis of Whitehouse's mapping. The formation has been recognised also in north-east South Australia and here attains its maximum development - 3,860 feet thick in Patchawarra bore (G.S.A., 1958).

In the Springvale area, small patches of Winton Formation have been mapped: 1. in the north-east corner and extending south below the Tertiary lake deposits; 2. in a belt in the southern central part; and, 3. thin beds which could be Winton Formation occur between upper Wilgunya Formation and the Tertiary Marion Formation along the western margin of the area at W108 and S226 localities.

Winton Formation occurs mainly as thin caps over Wilgunya Formation and, as such, has been weathered (by lateritisation) and further changed by silicification. Its outcrop in central and north-eastern parts of the Springvale area is therefore in scarps and as siliceous rock in flat caps or low-dip slopes. A fairly continuous prominent scarp line formed by silcified Winton Formation over soft lateritised shale with sandy beds extends from the Lucknow-Springvale boundary for 20 miles in a north-north-east direction.

The lithology in the Springvale 4-mile area is interbedded arkosic sandstone and silty to clayey shale. Weathered shale (and some fresh material) can only doubtfully be separated from similar lithology in the Wilgunya Formation by the absence of marine fossils (including foraminifera and radiolaria) in the Winton unit. However, it has been necessary to separate the beds on this basis where the sandy beds are missing. Although the sandy beds are more characteristic of the Winton Formation, a thin similar bed with fossil casts was seen in outcrop of the Tambo Formation in its type area. In outcrop, the sandy beds are white, yellow and red (and intervening shades), soft, fine to coarse-grained, kaolinitic (or feldspathic in fresh samples) sandstones. Grains are angular to subangular and some sections show sorting. Close interbedding of shales and sandstones is common with thin beds or lenses of shale in sandstone, or thin sandstone lenses in shale and siltstone. Bands of intraformational conglomerate also occur. Small-scale current bedding was noted. Outcropping beds have a blocky cleavage and conchoidal fracture. Thin sections examined by Dallwitz and Bofinger (1960) have been named "probable altered acid tuffs". (However, volcanic activity at this time is not recorded in Australia). Rare calcareous beds have been seen in surface outcrop. Ironstone lenses and concretions in weathered sections are thought to be altered limestone; many of the concretions show a radiating slickenside pattern on the upper surface - Twenhofel (1950) refers to such occurrences as due to sediments slipping down over concretions or to concretions growing upward into sediments, but in the case of the ironstone concretions, the slickensiding may be due to change in volume as iron replaced calcite. Calcareous beds are sandy and with rare glauconite(?). Some shales are gypsiferous and these show a fibrous, altered gypsum structure not unlike wood structure in weathered rock. Very small fault displacements (up to 1 inch) were seen in some places. Some silicified outcrops contained thin veins of common opaline rock; these were seen in hills north of No. 3 Bore Springvale and near the road to Monkira, 20 miles south of Coorabulka homestead.

Fossils were not found in the Winton Formation in the Springvale area but calcareous or fresh rocks contained black carbonised plant material disseminated as small fragments. Reptilian remains found by Mr. F. Johnson, a station hand on Alni Station about 30 miles west of Winton were examined in 1959; they were large bones from beds of the Winton Formation.

The Winton Formation in the Springvale area is thin and sections are generally less than 50 feet thick. It is not easy to recognise in the logs of water bores even though the bore began in Winton Formation at the surface. The greatest thickness known in the Great Artesian Basin is 3,860 feet in the Patchawarra bore in South Australia.

At the end of deposition of the marine Wilgunya Formation, a gradual change to lacustrine conditions developed. The sandy beds, small-scale current bedding and the presence of calcareous beds suggest that deposits in the Springvale area may have been marginal during Winton times.

The Wilgunya-Winton contact is conformable in most places. An ironstone band at or near the change from Wilgunya to Winton Formation in the scarp between Bores 4 and 5, Lucknow, may represent a slight unconformity. Unconformity occurs between the Winton Formation and overlying Tertiary formations.

The age of the Winton Formation is given as 'probably early Upper Cretaceous' by Whitehouse (1954) mainly because it follows conformably above the Tambo Formation which is 'Upper Albian' in age; Dr. P.R. Evans (pers. comm.) has intimated that, on microplankton and spore evidence, the Winton Formation may not be younger than Lower Cretaceous. Until this is established, therefore, the age of ?Upper Cretaceous is assigned to the formation.

CAINOZOIC

R.J. Paten's report on Cainozoic formations in the Springvale 4-mile area was not available for this record; the following notes are a brief resume of previous reports on Tertiary beds and some new observations made in 1959.

1. Marion Formation (Casey, 1959)

The Marion Formation is mainly sandstone, coarse pebbly to fine-grained, which rests unconformably on Cretaceous beds along the western margin of the Springvale 4-mile Sheet area.

The sandstone is composed mainly of quartz grains and in some places chert is prominent; 18 miles south of Breadalbane on the road to Bedourie grey, pink, brown and black chert fragments are fairly common in interbedded medium to fine-grained sandstone containing clay pellets and fine-grained gritty conglomerate. The section at this locality shows cross-bedding and ?slumping. Cherty sandstones also occur at S22 locality near Calendula Tank. Casey et al (1960 p.67) record a low percentage of argillaceous matter in a sample of silicified Marion Formation which was chemically analysed. The beds have been ferruginised (?lateritised) in at least some outcrops and later silicified. The Marion Formation has been extensively silicified and eroded to form rounded and shiny "gibbers" which are very common over the low, undulating country west and south-west of the Springvale area. During silicification sand grains and pebbles have been broken into highly angular fragments and dispersed through the rock to form a "billy".

Silicified fossil wood has been found in some outcrops; Casey et al found "conifer wood" in an exposure 5 miles north-west of Strathelbiss Homestead in the Boulia 4-mile area.

The Marion Formation is up to 20 feet thick in the Springvale area (S20 locality about 15 miles west of Marion Downs homestead).

Cretaceous beds (both lower and upper parts of the Wilgunya Formation and also possibly the Winton Formation) are separated by an erosional unconformity from the Marion Formation. 'Yellow sandstone' and 'red sandy rock' (90 feet thick) in Bottom Gidyea bore, Wirrilyerna Station, and 40 feet of 'drift sand' in the Cooridgie (stock-route) bore are tentatively correlated with the Marion Formation, thus placing it stratigraphically below Tertiary limestone beds. (see Figure 3).

Casey et al state that the formation is 'lithologically similar to the Eyrian Series as developed near Lake Eyre in South Australia and to the Moorie Formation of the Inglewood (S.E. Queensland) area.' The age is given as Tertiary. Paten (1960) thinks that the Springvale Formation may have been deposited at the same time as the Marion Formation but in a separate basin, and suggests an upper Cretaceous or Tertiary age for the Springvale Formation.

2. The Springvale Formation

The 'Springvale Formation' named by Casey (1959) has been redefined by Paten (1960) and the upper part of Casey's formation has been separated as another formation, the Horse Creek Formation.

The Springvale Formation beds occur from about 10 miles north of Springvale homestead to 20 miles south to Uka Tank and from about 5 miles west of Springvale homestead to about 23 miles east. As shown on the geological map, the outcrops are fringing the plateaus capped by the Horse Creek Formation.

The redefined Springvale Formation consists of clayey fine-grained sandstone and overlying light brown to green swelling clay. These beds contain hollow calcareous "biscuits" partly infilled in some cases with crystallised quartz. Sectioning showed these biscuits to be septarian nodules which are indicative of desiccation during diagenesis. Above are hard dark pink rock, resistent pink to yellow ?dolomite and limestone (in part vughy). In the western-most outcrops, the top part of the formation is altered to red earthy and siliceous, vesicular rock; red pisolitic rock occurs near the top of the formation in the east. Red siliceous rock from S21 locality 2 miles south of Springvale homestead was composed of 48% SiO_2, 22% Al_2O_3 (20% 'available') and 8½% Fe_2O_3. *

Partial silicification has produced pisolitic to nodular and massive chalcedony in carbonate rocks and the siliceous, vesicular rock referred to above.

---

* The analysis was made in 1959 by A. McClure; silica, alumina and iron were the only constituents determined. 'Available' Al_2O_3 was calculated on basis of solubility in 50% H_2SO_4.

Some small structures have been formed in the Springvale Formation mainly along the southern extension of the Burke River Structure.

The maximum observed thickness is 70 feet.

The Springvale Formation overlies the upper part of the Wilgunya Formation and Winton Formation; it may have been deposited contemporaneously with the Marion Formation. Its age has been given as upper Cretaceous or Tertiary.

3. Lateritisation and silicification of beds

Brief notes on lateritisation are included because the process probably occurred during the Tertiary Period between deposition of the Marion-Springvale Formations and the upper Tertiary limestone formations. Silicification affected the Marion-Springvale Formations mostly but both the deeply weathered Cretaceous sediments and upper Tertiary limestone formations also appear to have been partly silicified. Spasmodic silicification has probably been fairly common during the late geological history of the Springvale area.

Weathered profiles of Cretaceous and lower Tertiary formations are very similar to "laterite" profiles. Blue clays of the Wilgunya Formation grade up into white shale and silicified rock. White beds become mottled red and yellow higher in the profiles and dark red "ferruginous" caps occur in some places in lower Tertiary beds as well as Cretaceous sediments of the Wilgunya and Winton Formations. As noted in Casey et al (in preparation) the profiles at W107, W108 localities near Hilary Tank on the Boulia-Bedourie stock route showed:

Top - gritty to sandy "billy" - Marion Formation;

"ferruginous zone" - appeared to be iron rich beds of ?Winton Formation or Wilgunya Formation;

("mottled zone" not found near Hilary Tank but known at this level from elsewhere);

"Pallid zone" about 40 feet of white beds of the Wilgunya Formation;

Parent rock - shale and claystone.

Samples from these horizons have been chemically analysed to show degree of lateritisation but the beds were so affected by silicification that the results could not be interpreted. It is thought, however, that the colour of the beds is due to lateritisation and two or more periods of silicification have occurred since lateritisation.

The "lateritised" Cretaceous sediments have been indurated and broken into angular pieces before the deposition of later ?Tertiary beds; the indurated nature of the rock suggests a period of silicification between the two ages of sediment. However, the main period of silicification occurred after deposition of the Marion and Springvale Formations. Minor silicification has occurred in upper Tertiary limestone formations.

The process of silicification is not yet clear but outcrop sections in some places in south-west Queensland showed that 3 zones could be formed: an upper compact "billy" zone; grades down into tubular "billy" with basal parts of tubes rounded and increasing in thickness with depth; below this zone, nodules of "billy" occurred in the weathered rock in a zone which was previously regarded as possibly "pisolitic" or containing pebbles of "billy". The fragments of sand (mostly highly angular) which are suspended in silica to form "billy" are derived from sand grains and pebbles which were finely fractured during the process of silicification. This was well shown in the nodular zone where parts of pebbles had been fractured and the fragments suspended in siliceous nodules whereas the other parts remained as part of the original sediment.

4. Other Tertiary limestone formations.

The Noranside Limestone of the Boulia 4-mile area (Casey, 1959) and Austral Downs Limestone of the Glenormiston 4-mile area (Casey et al, in preparation) which extends into the north-west corner of the Springvale area, are thought to be equivalent to the Horse Creek Formation, named by Paten (1960) in the south-east, and small outcrop of unnamed Tertiary limestone in the south-west corner of the Springvale area.

The Austral Downs Limestone was named by Noakes and Traves (1954). Up to 30 feet of fossiliferous, lacustrine limestone and chalcedony beds of this formation were recorded in the Glenormiston 4-mile area in the valleys of the Georgina River and Pituri Creek. The basal part contains redistributed material of lateritic origin in some places. The formation is slightly sandy in part and contains small amounts of dendritic and platy manganese oxides. Only microfossils, charophyte and other algal remains, ostracods and some foraminifera are recorded in Casey et al. In the north-east corner of the Springvale area, the formation may be up to 115 feet thick. Badalia No. 3 bore showed a section of 15 feet of 'white (and green) clay with limestone' (drillers terminology) overlain by 100 feet of 'white limestone'; cuttings from this bore were seen. In the Cooridgie Stock-route bore 80 feet of 'clay' were overlain by 30 feet of 'limestone'; the relationship of the clay, however, is not known.

The Horse Creek Formation (Paten 1960) caps plateau areas in the south-east part of the Springvale area; its distribution is similar to the Springvale Formation, but not as extensive. It consists of grey, cream and brown well-bedded limestone, chert and porous white siliceous rock. Some beds of green clay occur at the base of the formation and these are best exposed near the western margin. The maximum observed thickness is 35 feet. Fossils include gastropods, ostracods and charophytes. The Horse Creek Formation was laid down on a slight erosional unconformity above the Springvale Formation.

Large boulders of Tertiary limestone weather out at the surface between some sand dunes and channels of the Georgina River in the south-west corner of the Springvale 4-mile area. The limestone is white, brecciated in part and contains red pisolites of ?laterite. The 'hard rock' from 15 to 30 feet depth in Breadalbane No. 9 bore may be equivalent to this limestone; it is underlain by 25 feet of 'red and yellow clay with a little gravel'.

5. Younger sediments

These include "gibber" gravel and ironstone patches,to which reference has already been made, alluvium and sand.

Alluvial deposits are fairly extensive west of the Hamilton River and south of the Burke River in the area between where they join the Georgina River. Gravel from this area has been used for road surfacing. Beds thought to be alluvial are up to 100 feet thick in bores on Mudgeacca and Montagu Downs in the north-west corner of the Springvale area. Some supplies of brackish to salty water are obtained from these beds.

Aeolian sand deposits and dunes occur mainly in the north-western part and south-eastern corner of the Springvale area. Some long dunes (up to 10 miles long and 30 feet high) occur in the "channel country" of the Georgina River and King Creek. The predominant trend is north-north-west to south-south-east. Recent sand movement is most pronounced in the south-east corner of the Springvale area where "noses" of unconsolidated sand at the northern ends of dunes are lapping over the low Tertiary plateau areas.

The "gibber" gravel formed by pebbles of eroded, silicified Marion Formation forms a different surface to that formed by the ironstone gravel from ferruginised beds of the Cretaceous formations. The "gibbers" are generally light brown to red-brown, sub-rounded to rounded polished pebbles but some areas are covered by cobbles and even boulders of the silicified rock. The low rounded hills which they cover have mostly soft white to light brown clayey soils which form sparsely scattered mounds (preserved from wind erosion by tufts of grass) between the bare veneer of "gibbers". Vehicles have to be driven fairly slowly over this type of surface. The ironstone gravel, on the other hand, is finer and, although on the same kind of soil as the gibbers, is more evenly scattered and forms a much better surface for travel.

STRUCTURE

The sub-surface contour map on the base of the Mesozoic sediments included as fig. 8 in the Boulia 4-mile report (Casey et al 1960) has been amended, both in the accuracy of bore positions,and to show different, more likely interpretations in some areas. In the north-east corner of the Boulia area, for example, J.N. Casey has shown that sub-surface contours can be drawn differently from those originally proposed, and the resultant form is much more in accord with structural trends which are discussed later. The revised map, last amended in April 1960, is included in some later copies of the Boulia report and is reproduced in this report as Figure 1. Fig. 2 shows isopachs of the basal Mesozoic sandstone (Longsight Sandstone formation) which are continued to the south with some modifications from those shown in fig. 7 in the Boulia report.

The most prominent structures in western Queensland trend north-north-west to south-south-east,viz.Toko Range, de Little Range, Burke River Structure, Momedah Anticline, Lucknow Granite ridge. The Burke River Structure, in particular, can clearly be traced from the Boulia 4-mile area to the Springvale area through Pike's Springs near No. 1 Warra bore, to Warra Creek springs, to Elizabeth Springs and to 8 miles south of Springvale homestead where a small inlier of Toolebuc Limestone crops out. The inlier is on the west (upthrow) side of a fault-line which can be traced on aerial photographs for a further 10 miles to the south-south-east.

However, another lineation which trends north-north-east to south-south-west also seems to exert some control in the area, particularly on younger (?Upper Cretaceous - Tertiary) formations. This is the direction of the scarp formed by Winton Formation in the north-east corner of the Springvale area. It extends for about 20 miles north-north-east from the Springvale-Lucknow boundary and runs just west of Bores Nos. 4 and 5 of Lucknow Station. On the west side of this scarp the beds have a low fairly constant dip (less than 2^{o}) but beds of the upper Wilgunya Formation east of the scarp show local dips up to 9^{o} to north-east and south-east. The projection of this scarp line to the south-south-west appears to delimit the western outcrop of the ?Upper Cretaceous-Tertiary (Springvale-Horse Creek) lake deposits. This may be purely coincidental but evidence of control by lineations in this direction are shown elsewhere in the Springvale area:

(1) In the south-east part of the Springvale area, a faint trend in a direction parallel to the scarp appears to terminate the stronger, Burke River structure line.

(2) The eastern most outcrops of the Tertiary Marion Formation is roughly along a line through Bedourie and Boulia in a north-north-east to south-south-west direction. The isopach map, Figure 2, shows that some prominent north-north-west to south-south-east trends in the Boulia area bend where this north-north-east trend is crossed, but continue south-south-east in the Springvale area.

(3) The latest interpretation of sub-surface contours in the north-east part of the Boulia 4-mile area suggests a south-south-west lineation; some of the major streams in the Boulia area, the Hamilton River, stretches of the Burke River, the Mort River and some of their tributaries follow this trend.

(4) Increases in the thickness of the Longsight Sandstone occur in a direction normal to the north-north-east trend, which in this area, may represent the edge of the Boulia Shelf of Whitehouse (1954). The interpretation of isopachs shown in Figure 2, however, is based on water bore information and total thicknesses of Longsight Sandstone beyond the south-east margin of the Shelf are not known.

(The isopach map has been extended slightly beyond the limits of the Springvale 4-mile area to include certain important bore log information. Lines have been drawn to show the main structural trend directions referred to.)

The structure of the Springvale 4-mile Sheet area therefore may be more complex than previously thought. The results of gravity surveys by the Bureau of Mineral Resources in the area in 1959, a seismic survey by the South Australian Mines Department at present (1960) being conducted, and stratigraphic drilling proposed near the area will probably help elucidate the structural history and importance of the two lineations.

ECONOMIC GEOLOGY

1. Hydrology

The hydrology of the Springvale area is included in fairly detailed discussions of hydrology in reports by Casey et al (1960, and, in preparation). Good supplies of potable water are only obtained from the Lower Cretaceous Longsight Sandstone (equivalent to upper part of Blythesdale Group) in most of the bores. Supplies from the Wilgunya Formation and younger sources are mainly salty or brackish water, and/or are only small supplies. Bad water in Breadalbane Bores Nos. 1, 6, 8, 9 is apparently due to their position along a subsurface ridge against which the sandstone aquifer is pinched. The water from all of these bores was apparently too salty even for stock. The only reason that good water was obtained at Breadalbane homestead was that the bore went down into "limestone" bedrock which yielded good water.

Springs in the Springvale area generally yield seeps of water suitable for stock; their positions are shown on the geological map. Material deposited in the Warra Creek springs was sampled and its analysis is given in Appendix II (S244). R.R. Vine in 1958 noted a small soak at the bottom of a low Tertiary cliff where water seeped out at plain level (S8 locality). Permanent water occurs in water holes in the channels of the major river systems i.e. the Burke, Georgina and Diamantina Rivers.

2. Petroleum

The most recent and comprehensive list of oil and gas occurrences in western Queensland is contained in Casey et al (1960). Oil source beds in western Queensland are lower Palaeozoic marine formations and Lower Cretaceous marine shales. Possible reservoirs for oil from Palaeozoic sources include fractured and cavernous limestones, porous dolomites, or Ordovician or Lower Cretaceous sandstone beds. Reservoir beds for Lower Cretaceous source beds may be provided by sandy lenses or beds within the Wilgunya and Winton Formations. The latter, however, are generally not very thick and would not provide sufficient volume for large accumulation of oil but could provide good stratigraphic traps within thick source beds. The calcareous sandstone beds near the top of the upper part of the Wilgunya Formation may be doubtful exceptions. Although compact in outcrop, they may be more porous at depth - sandy beds at a similar horizon have proved to be a good aquifer in north-east South Australia, (Jack, 1930); the beds are capped by shales and impervious beds in the Winton Formation. Source and reservoir beds therefore occur in western Queensland; traces of oil and gas have been noted in some water bores.

The extent to which combinations of suitable conditions and properties occur determines the areas which offer the best possibilities of oil accumulation. On present available knowledge, the limits of some areas can be considered. In the Springvale 4-mile area, the south-eastern margin of recorded carbonate rocks (?lower Palaeozoic source rocks) seems to be in a line through No. 7 bore, Lucknow, south-south-west to Cluny No. 1 bore i.e. more or less following the outer fringe of the Boulia Shelf area (see Figures 1-3); the limit is slightly beyond the "Lucknow granite ridge" of Casey et al (1960, Fig. 7, p.58). (It is possible that some of the basal limestones recorded near the

"Lucknow granite ridge" may be Precambrian, but local drillers who know the grey limestone of the area, would probably have noted any change in colour or nature of limestone bedrock). The south-eastern margin of ?lower Palaeozoic source rocks has been determined on the evidence of the logs of the following water bores:

Mackunda bore (at the north end of the line) which finished in 15 feet of "gravel, quartz, limestone";

Lucknow No. 7 bore finished in 7 feet of "limestone";

Lucknow No. 8 bore finished in 73 feet of "limestone";

Lucknow No. 5 bore finished in 59 feet of "limestone";

(the only information available on Springvale No. 5 bore is that it ended in "granite");

Springvale No. 6 bore ended in 20 feet of "white and grey limestone";

Springvale No. 8 bore ended in 200 feet of interbedded "hard rock" and "shale";

Coorabulka No. 9 bore was stopped after penetrating 14 feet of "very hard rock like limestone";

Coorabulka No. 10 bore finished in 18 feet of "hard rock";

Cluny No. 1 bore finished in 4 ft. of "limestone".

The occurrence of "granite" bedrock along this line suggests that the lower Palaeozoic limestones have thinned considerably from the north-west in the Boulia 4-mile area, or have been stripped after deposition and that the Cretaceous Shelf margin may represent their south-eastern limit. If so, oil from this source should be sought to the west rather than the east of the line. However, the line also represents the eastern limit of the western Queensland bores that reached basement and the results of deep stratigraphic drilling east of the Springvale area will have to be awaited before conclusions can be reached.

Marine Cretaceous shales are potential source beds for petroleum but whether reservoirs of sufficient volume for accumulation of commercial quantities exist, or stratigraphic traps occur has yet to be proved. The limit of possible oil occurrences in these beds could be regarded as the margin of the Great Artesian Basin.

3. Other fuels and minerals

a. Coal has been reported in the logs of some of the water bores in the Springvale 4-mile area (See Figure 3). No occurrences are of economic importance. Dunstan (1920) refers to 'several occurrences of a seam of brown coal several feet thick..... the coal being of poor quality and containing much iron pyrites' in bores on Sandringham south-west of the Springvale 4-mile area.

b. Descriptions of the small quantities of uranium minerals found in 1957 in the Toolebuc Member (and also in 1959) are given in Casey et al (1960, p.65).

c. The sample from S28 locality near Pigeongah Waterhole, Coorabulka Station, which was chemically analysed for silica content, proved to be rich in alumina, barium, strontium and phosphate (see Appendix II for full analysis). The extent of this deposit will be checked in 1960. L.C. Ball (1942) in a memorandum to the Under Secretary for Mines, Brisbane, concluded that a gypsum and celestite (strontium sulphate) horizon existed 'between the upper plant bearing freshwater Cretaceous sediments and the underlying calcareous series' i.e. between the Winton and ?Wilgunya Formations. Small amounts of celestite 'mostly in the Albian part of the Cretaceous sequence' were mined in South Australia during the war for use in the pyrotechnic industry (G.S.A., 1958, p. 101).

d. Gypsum is fairly plentiful. The richest deposit seen so far (1958) is at Pulchera Waterhole on the Mulligan River (south-west of Springvale in the Bedourie 4-mile area). At the northern end of the hole, west of the river a bank 5 to 10 feet high appeared to be composed largely of gypsum. Dunstan (1920) referred to this extensive deposit and gives the origin of the term " copai" so commonly used locally for "gypsum" - it is an aboriginal name for massive gypsum (as distinct from the translucent selenite) which the natives burnt and used for personal adornment.

e. Local reports of opal in the Springvale area have been hear but no details have been obtainable. Veins of hyaline potch opal were seen at S231 locality (about 7 miles south of Coorabulka in small hills just west of the Monkira road), and in hills just north of No. 3 Bore, Springvale.

f. Gravel for road surfacing has been obtained from some localities in the Springvale area by scraping surface accumulations into heaps for easy loading. The deposits include ironstone gravel, alluvial gravel which is very common west of the Hamilton River, and "gibbers" of Marion Formation silicified sandstone which are plentiful west of the Georgina River near the main road from Boulia to Bedourie. As suggested by the nature of the deposits, access is easy; well-defined tracks to some of the deposits are shown on aerial photographs.

The impure calcareous sandstone beds at the top of the Wilgunya Formation may be suitable for road metal; aerial photographs show that they extend for many miles south of their outcrop in the south part of the Springvale area. Limestone of the Toolebuc Member, which is also fairly extensive in outcrop, might be very useful for this purpose; this has been used to form part of the bridge for the main Winton-Boulia road over the Hamilton River channels.

REFERENCES

BALL, L.C., 1942 - Memorandum to Undersecretary for Mines, Brisbane. (unpublished).

BRUNNSCHWEILER, R.O., 1959 - New Aconeceratinae (Ammonoidea) from the Albian and Aptian of Australia. Bull. Bur. Min. Resour. Aust., No. 54.

CASEY, J.N., 1959 - New names in Queensland Stratigraphy (Part 5). North-west Queensland. Aust. Oil Gas. J., 5 (12), 31-36.

CASEY, J.N., REYNOLDS, M.A., DOW, D.B., PRITCHARD, P.W., VINE, R.R., and PATEN, R.J., 1960a - Geology of the Boulia area, north-west Queensland. Bur. Min. Resour. Aust. Rec. 1960/12 (to be published).

CASEY, J.N., REYNOLDS, M.A., PRITCHARD, P.W., PATEN, R.J. and LUCAS, K.G., 1960b - Georgina Basin Party Report for 1958, Glenormiston-Toko area. Bur. Min. Resour. Rec. (in preparation).

CRESPIN, I., 1960 - Micropalaeontology of samples of sediments from the Great Artesian Basin, Queensland. Bur. Min. Resour. Aust. Rec. 1960/25 (unpublished).

DALLWITZ, W.B., and BOFINGER, V.M., 1960 - Petrography of some samples from the Great Artesian Basin, Queensland. Bur. Min. Resour. Aust. Rec. (in preparation).

DICKINS, J.M., 1960 - Cretaceous marine macrofossils from the Great Artesian Basin in Queensland. Bur. Min. Resour. Aust. Rec. 1960/69 (unpublished).

DUNSTAN, B., 1916 - Queensland geological formations. Appendix B in Harrap G. - A school geography of Queensland. Dep. Public Instruction, Brisbane.

DUNSTAN, B., 1920 - North-western Queensland. Geological notes on the Cloncurry-Camooweal-Burketown-Boulia area. Publ. geol. Surv. Qld. 265.

G.S.A., 1958 - The geology of South Australia. J. geol. Soc. Aust., 5(2).

HILL, D., in Casey et al (1960) - The macrofossils from the Boulia area, western Queensland.

JACK, R.L., 1885 - Six reports on the geological features of part of the district to be traversed by the proposed Trans-continental Railway. Publ. geol. Surv. Qld. 10 (Reprinted 1898 as Publ., 136. Parl. Pap., 1885.)

JACK, R.L., 1930 - Geological structure and other factors in relation to underground water supply in portions of South Australia. Bull. geol. Surv. S. Aust. Bull. 14.

LAING, A.C.M., and POWER, P.E., 1959 - New names in Queensland stratigraphy (Part 2). Carpentaria Basin (continued). Aust. Oil Gas. J., 5 (9), 28.

LUDBROOK, N.H., 1960 - Delhi-Frome-Santos Innamincka No. 1 Well Subsurface stratigraphy and micropalaeontological study. Final report for publication.

MORGAN, W.R., 1959 - Petrographic and mineragraphic investigations during the quarter July-September, 1959. Bur. Min. Resour. Aust. Rec. 1959/138 (unpublished).

NOAKES, L.C., and TRAVES, D.M., 1954 - Outline of the geology of the Barkly Region; in Survey of Barkly Region, 1947-48. Sci. ind. Res. Org., Melbourne, Ld. Res. Ser. 3, 34-41.

PATEN, R.J., 1960 - in G.S.A. - The geology of Queensland. (in preparation - title not known).

REEVES, F., 1947 - Geology of Roma District, Queensland, Australia. Bull. Amer. Ass. Petrol. Geol., 31 (8), 1341-1371.

REYNOLDS, M.A., 1960a - Mesozoic and younger sediments of the Gilberton and Georgetown 4-mile Sheets, Queensland. Bur. Min. Resour. Aust. Rec. 1960/67 (unpublished).

REYNOLDS, M.A., 1960b - Review of type localities and stratigraphy of the Cretaceous of the Great Artesian Basin in Queensland. Bur. Min. Resour. Aust. Rec. 1960/68 (unpublished).

TWENHOFEL, W.H., 1950 - Principles of sedimentation. Second Edition. McGraw-Hill Book Company, Inc.

WHITE, M.E. 1960 - Plant fossil collections from the Great Artesian Basin, Queensland. Bur. Min. Resour. Aust. Rec. 1960/39 (unpublished).

WHITEHOUSE, F.W., 1954 - The geology of the Queensland portion of the Great Artesian Basin. Appendix G to 'Artesian water supplies in Queensland', Dep. of Coordinator-General of Public Works.

APPENDIX I

Plant Fossil Collections from the Great Artesian Basin, Queensland

(Extract from report by M.E. White, 7/4/60)

SPRINGVALE 4-MILE SHEET

Locality S205: Small hill, ½ mile E. of No. 4 Bore, Lucknow station.

A small piece of silicified wood has some internal structure preserved, but does not warrant sectioning.

Locality S222: ¾ miles E. of Dilarrbidgerrie Waterhole, Lorna Downs Station.

Three pieces of fossil wood, portions of a large trunk, not suitable for sectioning.

Locality S238: South end of Elizabeth Springs, from banks of Spring Creek.

One piece of silicified wood similar to those from S222.

Locality S246: From near track to Canary Bore, 7 miles from Lorna Downs homestead.

Indeterminate stem casts.

MACHATTIE 4-MILE SHEET

Locality Mac 2: 10 miles south of Coorabulka No. 10 bore, near Monkira track.

Two pieces of fossil wood showing some preservation of cell structure.

APPENDIX II

Chemical Analyses of samples from Western Queensland

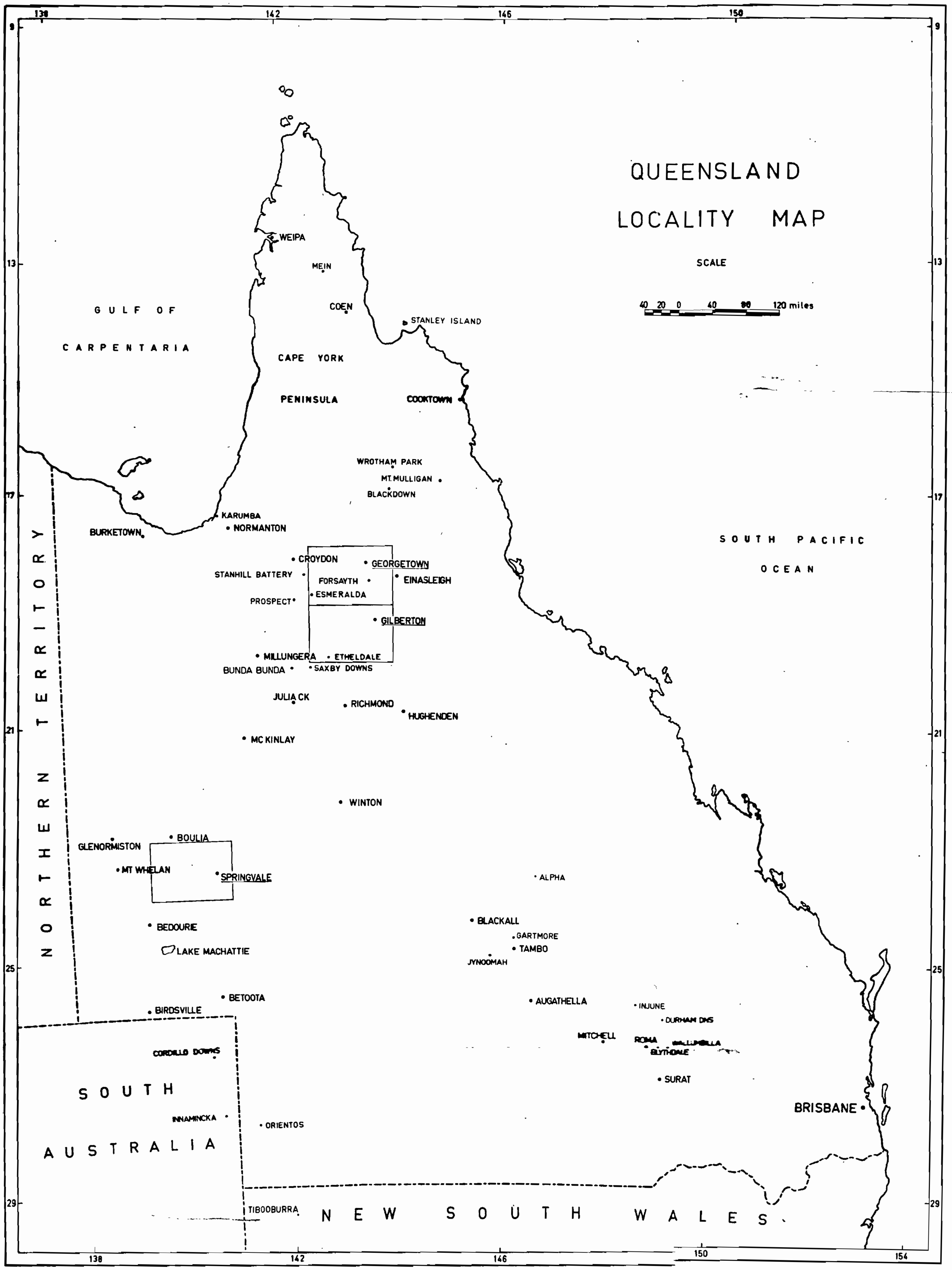
by A. McClure (4/3/60) and S. Baker (25/11/59)

Sample	S244		S28*
SiO_2	5.55	10.74	7.64
Al_2O_3	4.29	3.38	36.5
Fe_2O_3	0.82	1.03	0.54
FeO	n.d.	n.d.	
CaO	45.90	24.02	
BaO			6.6
MgO	3.32	0.87	
SrO			8.1
Na_2O	1.02	n.d.	
K_2O	0.41	n.d.	
TiO_2	0.10	n.d.	
P_2O_5	0.03	n.d.	16.6
MnO	0.07	n.d.	
PbO			0.2
CO_2	33.16	n.d.	
SO_3	n.d.	35.16	8.1
Loss 100°	0.49	16.91	0.80
Loss 1000°) 950°)	38.50	7.59	13.1
Total	100.50	99.72	98.18
	Spring deposit from Warra	Evaporite from old tank on north side L. Machattie	South of Pigeongah Waterhole, Coorabulka Station.

Analysis of S21 sample by A. McClure in 1959 showed: 47.89% SiO_2, 22.17% total Al_2O_3 (Available Al_2O_3 20%), 8.43% Fe_2O_3, Moisture 0.82%, Loss on ignition 9.21%.

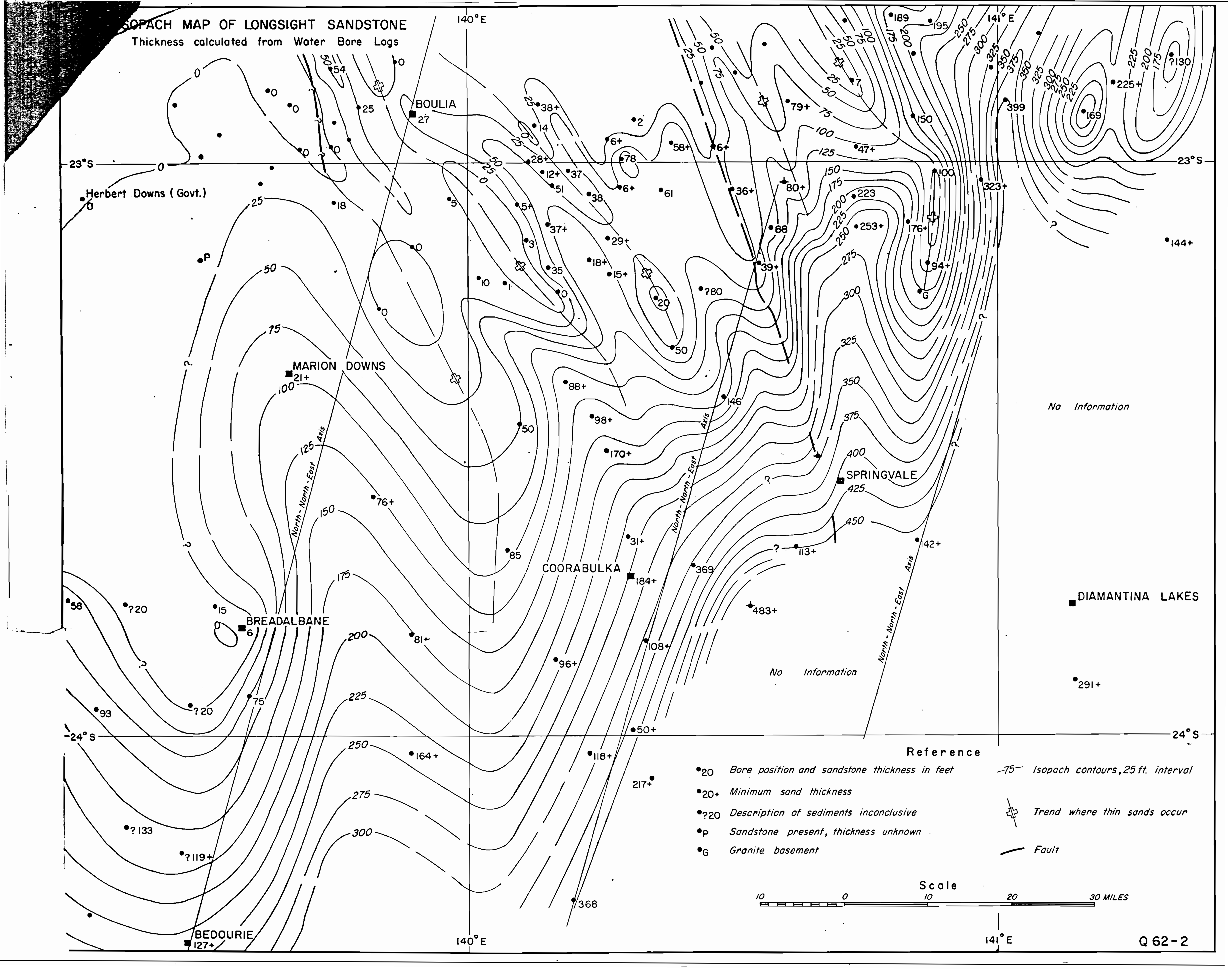
* Specific Gravity 2.34

Spectrographic analysis showed the following additional elements: K, Ca, Na, Ga, Mg.

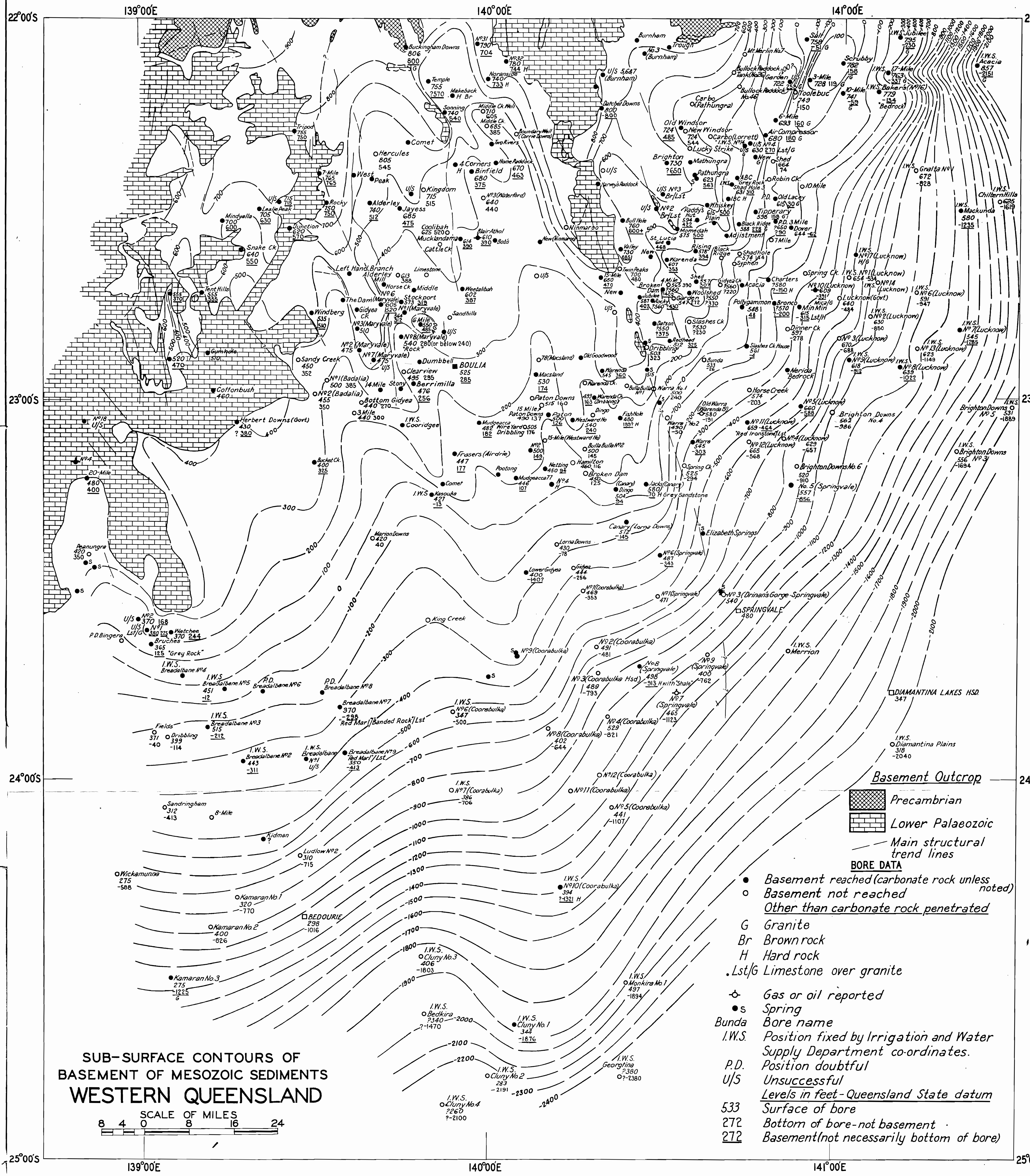


A C B

Reduce AB to AC.



ISOPACH MAP OF LONGSIGHT SANDSTONE
Thickness calculated from Water Bore Logs
BOULIA
Herbert Downs (Govt.)
MARION DOWNS
BREADALBANE
BEDOURIE
COORABULKA
SPRINGVALE
DIAMANTINA LAKES
No Information
No Information
North - North - East Axis
140° E
141° E
23° S
24° S
Reference
20 Bore position and sandstone thickness in feet
20+ Minimum sand thickness
?20 Description of sediments inconclusive
P Sandstone present, thickness unknown
G Granite basement
75 Isopach contours, 25 ft. interval
Trend where thin sands occur
Fault
Scale
10 0 10 20 30 MILES
Q 62-2



Bureau of Mineral Resources, Geology and Geophysics, Canberra, A.C.T. December 1959. (Amended May 1960)

Q42-17

FIGURE 3

DIAGRAMMATIC CORRELATION OF BORE LOGS AND SOME OUTCROP SECTIONS IN THE SPRINGVALE 4-MILE AREA.