1961/52

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COMMONWEALTH OF AUSTRALIA.

DEPARTMENT OF NATIONAL DEVELOPMENT.

BUREAU OF MINERAL RESOURCES GEOLOGY AND GEOPHYSICS.

RECORDS.

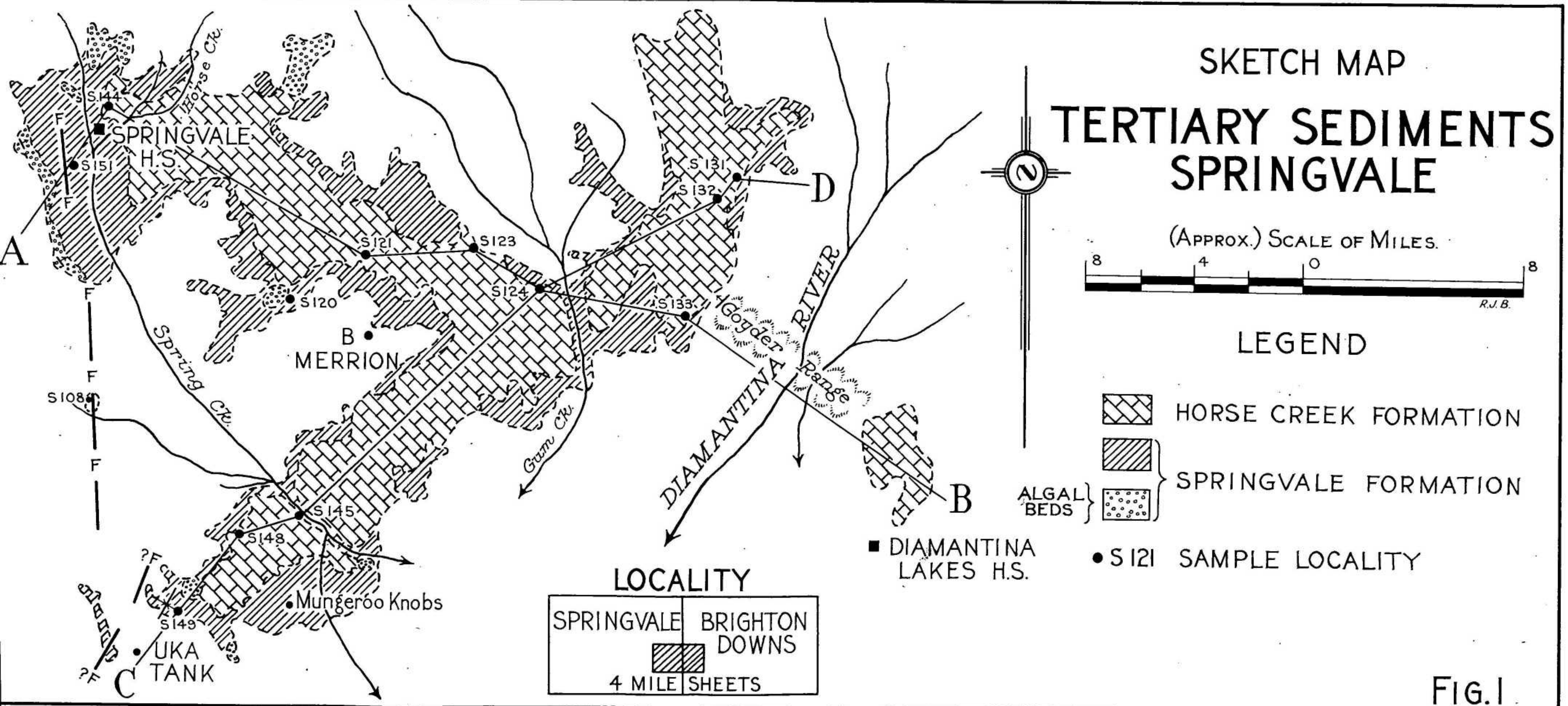
1961/52

THE TERTIARY GEOLOGY OF WESTERN QUEENSLAND.

By

R.J.Paten.

(Geological Survey of Queensland)



SKETCH MAP
TERTIARY SEDIMENTS
SPRINGVALE
(APPROX.) SCALE OF MILES.
8 4 0 8
R.J.B.
LEGEND
HORSE CREEK FORMATION
SPRINGVALE FORMATION
ALGAL BEDS
• S 121 SAMPLE LOCALITY
LOCALITY
SPRINGVALE
BRIGHTON DOWNS
4 MILE SHEETS
SPRINGVALE H.S.
Horse Ck.
S 144
S 151
S 121
S 123
S 124
S 120
S 131
S 132
S 133
S 108
S 145
S 148
S 149
B MERRION
Spring Ck.
Gum Ck.
Gogder Range
DIAMANTINA RIVER
DIAMANTINA LAKES H.S.
Mungeroo Knobs
UKA TANK
A
B
C
D
F
?F

FIG. 1

THE TERTIARY GEOLOGY OF WESTERN QUEENSLAND

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THE TERTIARY GEOLOGY OF WESTERN QUEENSLAND

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I. SUMMARY

Large areas of Tertiary sediments confined to four tectonically controlled sedimentary basins occur partly within the Boulia, Glenormiston, Springvale and Mt. Whelan 4-mile areas in far western Queensland. Carbonate, argillaceous and arenaceous sediments and siliceous sinters were deposited. Fossils occur throughout but are rare except in one basin where they are plentiful. One deposit has been lateritized, another silicified to billy and the remainder partly silicified to chalcedony and common opal (all silicification being post-laterite).

II. INTRODUCTION

This report is based mainly on the author's mapping and observations as a member of the 1957-59 joint Bureau of Mineral Resources - Geological Survey of Queensland field parties, which mapped the Boulia, Glenormiston, Springvale and Mount Whelan 4-mile sheets in western Queensland. Relevant parts of adjacent areas were briefly examined. It embodies and revises all previous reports by the author. The Tertiary deposits of the Boulia area were described by Casey, Reynolds, Dow, Pritchard, Vine and Paten (1960). Casey (1959) defined the Tertiary Formations prior to their use in "The Geology of Queensland". They are briefly described and revised by Paten (1960). The sections on the Springvale and Horse Creek Formations were written as "part 2" to accompany "The Geology of the Springvale 4-mile Sheet Area" (Reynolds, 1960) but was not issued in this form. It is here produced for the first time.

During the mapping project, extensive areas of superficial Tertiary sediments were mapped and their considerable extent beyond the area of operations established. Four main areas of Tertiary lacustrine deposition, one of which is of possible fluviatile deposition (see Figure 7), were recognized:

1. Springvale Basin
2. Marion Basin (possible fluviatile deposition)
3. Austral Downs Basin
4. Noranside Basin

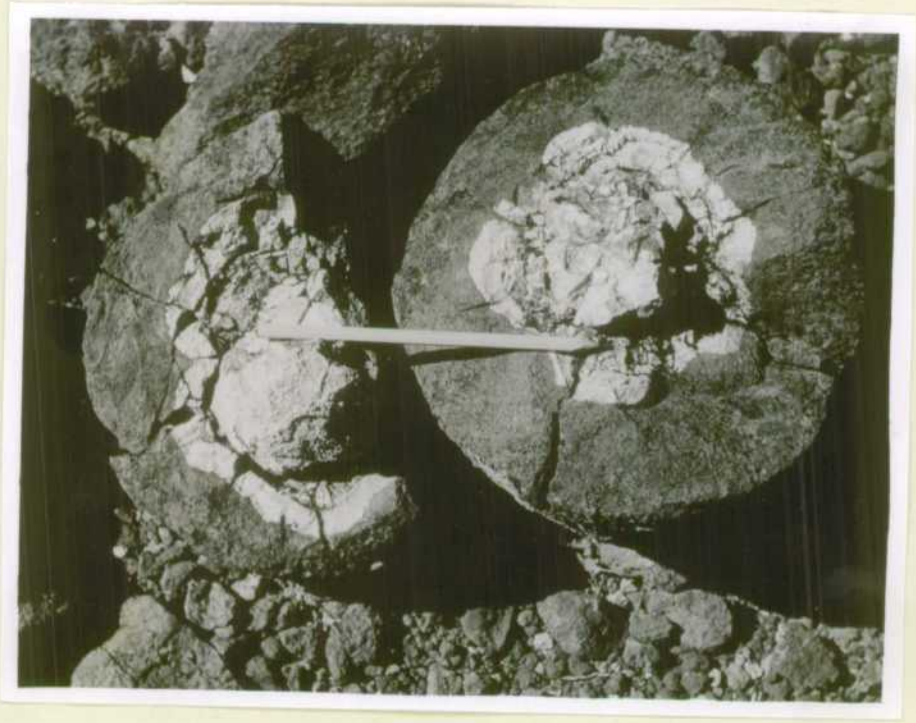
Scattered siliceous spring deposits also occur outside these areas. Argillaceous and carbonate sediments were deposited in the Springvale Basin, arenaceous sediments in the Marion Basin and carbonates in the Austral Downs and Noranside Basins. Other small carbonate deposits occur in the Breadalbane and Toko Range areas.

Discussions of the basins refer mainly to those parts within the area mapped - only the Noranside and Springvale Basins lying wholly within that area. The development of billy on the Marion Formation is discussed in detail.

PLATE 1.

(J.N.Casey)

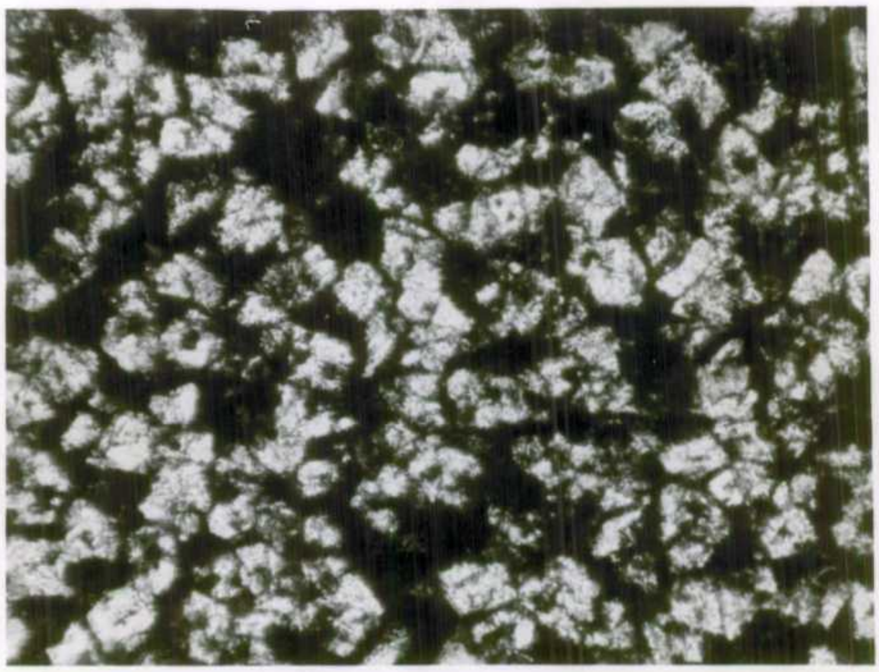
(a) Red-capped hills Springvale Formation
(Type area)



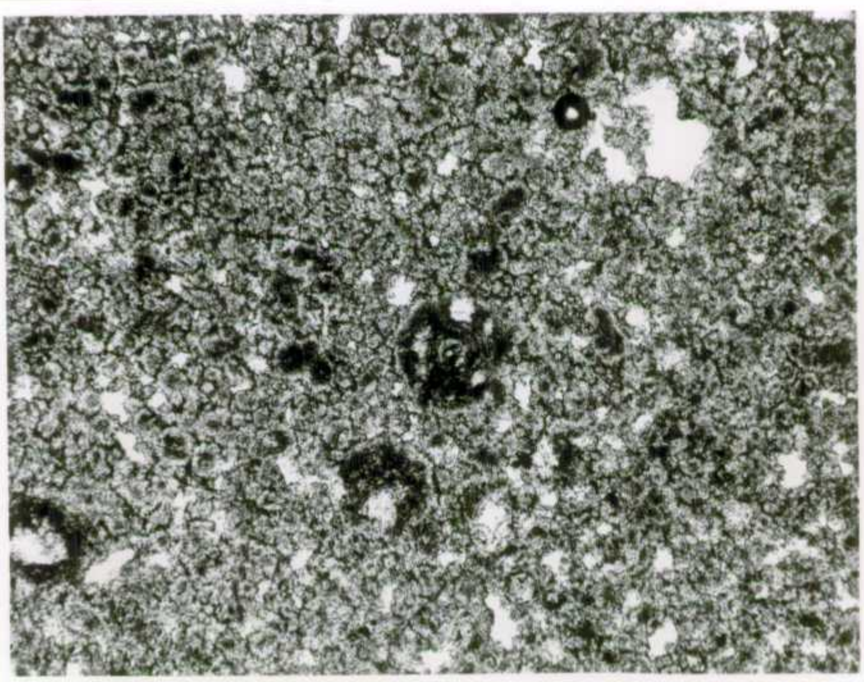
(B.M.R. neg.6/2284)

(b) Ferruginized calcareous concretions
Springvale Formation,
showing poorly developed syneresis system.

PLATE 2.



(a) Recrystallized limestone, Springvale Formation. Iron oxide (dark) mostly confined to intercrystal areas. X105
(G.S.Q, Microslide 2210, B.M.R.negative 6/2288)



(b) Silicified ?limestone, Springvale Formation. Clotted texture of iron stained opaline silica, silicified concretion in centre. X56
(G.S.Q. microslide 2208, B.M.R. negative 6/2287)

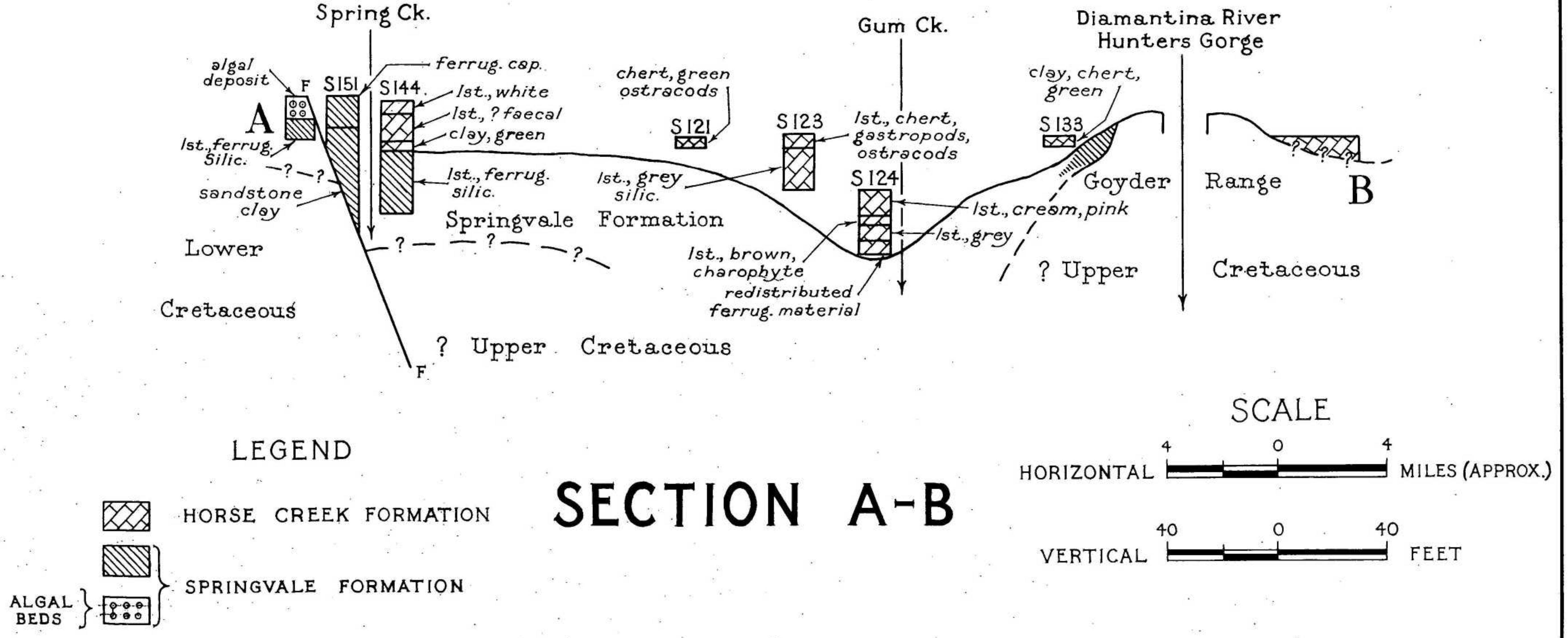
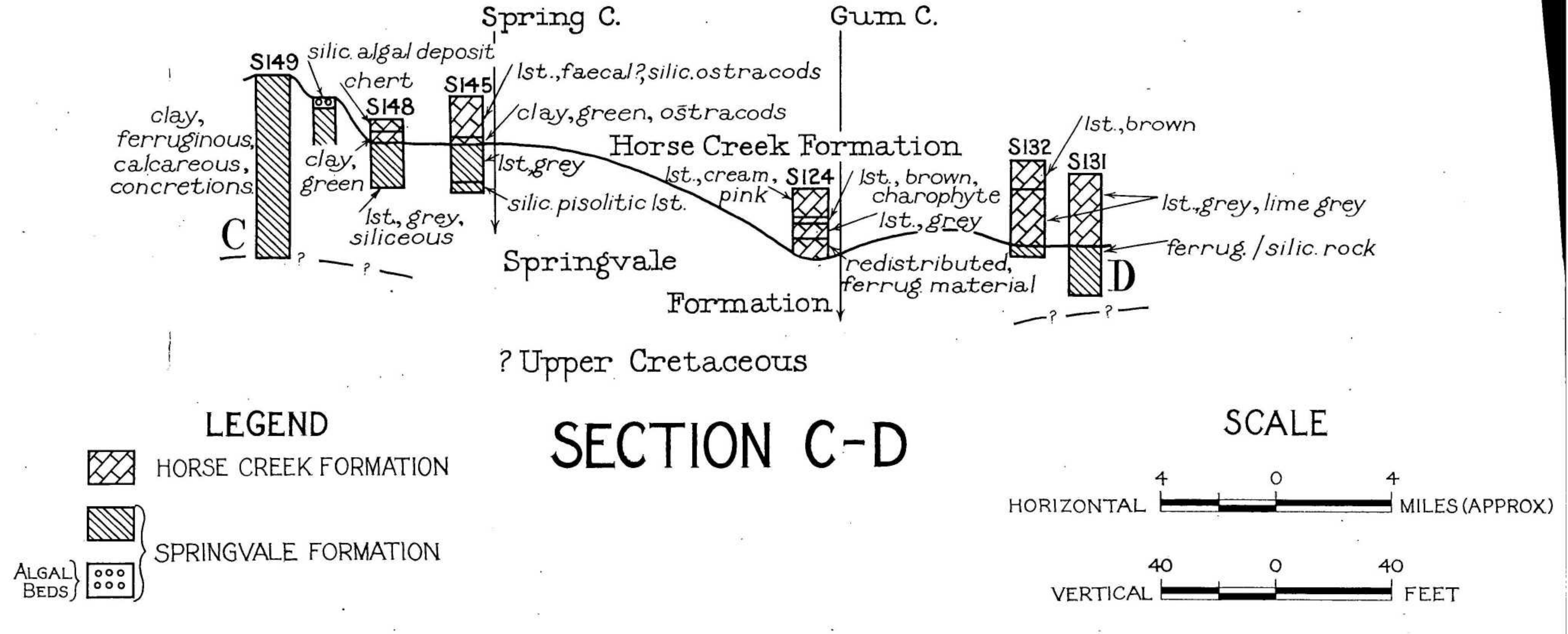


FIG. 2

SECTION A-B

FIG 3



SECTION C-D

III. SPRINGVALE BASIN.

The Springvale Basin was a small isolated basin developed superficially within the Great Artesian Basin in the Springvale area, about 80 miles to the south-east of Boulia.

Casey (1959) after a short reconnaissance traverse in the area described briefly and named the sediments within this basin the "Springvale Formation". The type area was given as - "In flat-topped hills two miles south west of Springvale homestead", with a reference section "in the hills south of Junction Yard 16 miles south-south-east of the homestead".

The lithologies described were "red vughy sinter over hard grey sinter containing biscuit-like vughy spring nodules, over silicified fine sand", and elsewhere "chert with ostracods and gastropods, dense siliceous ? dolomite and greenish chert".

Later more detailed mapping has shown that two unconformable units are included in the "Springvale Formation" and the name is now redefined as:-

(a) Springvale Formation, the older unit and typified by Casey's type locality. The name was used in this sense by Paten (1960).

(b) Horse Creek Formation, the younger unit to which Casey's reference section belongs.

(a) Springvale Formation (Paten 1960)

This formation is named after Springvale Station, a cattle property about 80 miles south-east of Boulia. Springvale Homestead is situated on the east bank of Spring Creek, a tributary of the Diamantina River at approximately 23°33' south latitude and 140°42' east longitude. The type area is in red flat-topped hills 2 miles south-west of the homestead.

The deposit extends from 4 miles north of the homestead, south as scattered low hills for about 22 miles to Uka Tank and from 3 miles west of the homestead east-south-east for about 27 miles to the Goyder Range on the western side of the Diamantina River. In this area the post-Cretaceous rocks form a plateau which stands above the surrounding sand and soil plains developed on the underlying Artesian Basin sediments. The Springvale Formation is blanketed by the overlying Horse Creek Formation but is extensively exposed by dissection of the younger rocks (see figures 1,2,3).

Lithologies represented are a suite of iron stained siliceous rocks, limestone, swelling clay and rare sandstone. The ironstained siliceous rocks are the commonest and are fine-grained, harsh feeling, matt textured, dense rarely porous rocks. They are characteristically brightly coloured ranging from pinkish red to cream due to irregular mottling by iron oxide.

In thin section these rocks display a uniform texture of clotted, opaque silica with varying amounts of brownish iron oxide staining. Sand grains are rare and commonly the grain margins are replaced by opaline silica. Silicified secondary (concretionary) textures may be preserved in the clotted matrix (plate 2b). Rare remnant areas of crystalline calcite occur, and the clotted matrix in some sections has a texture suggestive of that of mosaic calcite. At S148, about 16 miles south-south-east of the homestead, these siliceous rocks grade into fine-grained grey limestone, and unaltered parent limestone crops out at S145 in the same area. It is fine-grained grey and crystalline with small clots of fine lime and is characterized by rosette and cruciform calcite recrystallization. Thin shelled molluscan fragments occur in the limestone at this locality.

This siliceous suite is hence the product of chemical alteration of the predominantly limestone portion of the Springvale sequence. However some may be altered calcareous clay.

Grey algal limestone and limestone beds (figure 1) containing thin shelled gastropods crop out in the western part of the deposit. Practically all of this material is replaced by brownish and bluish silica ranging from lustrous translucent to dull opaque. It consists of very fine micromosaic of quartz and is chert (Pettijohn, 1957, p.432). The silica commonly preserves the original clotted texture of the limestone.

Clay, with rare sandstone and limestone lenses crops out in sequences up to 60 feet thick in the western part of the deposit. Clays are not common east of Spring Creek. The clays are brownish, greenish and grey in colour and disperse rapidly in water.

The best exposure occurs at S151 in the type area and similar clays occur in small hills on the east side of Gum Creek on the road from Springvale to Diamantina Lakes. Clays from the type area swelled to three times their volume when tested in water. Near S145 on the west side of Spring Creek, hard grey clay with a white efflorescence of magnesium chloride on weathered surfaces outcrops. Analysis of this clay by the Queensland Government Chemical Laboratory gave (1569/59 G.S.):

loss on ignition	15.1%
silica (SiO_2)	55.6
alumina (Al_2O_3)	12.9
ferric oxide (Fe_2O_3)	3.6
calcium oxide (CaO)	7.5
magnesia (MgO)	4.6
	99.3

Chemical alteration has also affected the clay sequences. This is illustrated in red capped mesas on the western side of Spring Creek, e.g. in the type area (plate 1a). These red caps occur nowhere else in the Springvale area and are different from the alteration products of the limestone.

Figure 4 shows the sequence at S151 (type area) where the red cap is developed on a clay sequence. The pinkish red cap rock consists of an extremely porous fine siliceous boxwork densely impregnated by red iron oxide. It is 15 feet thick and grades downwards into light brown puggy swelling clay. This overlies a light brown to green clay in which aggregation has produced a granular texture. Concretions occur throughout the sequence as well as in the altered cap; near the base the section, a thin band containing septaria occurs.

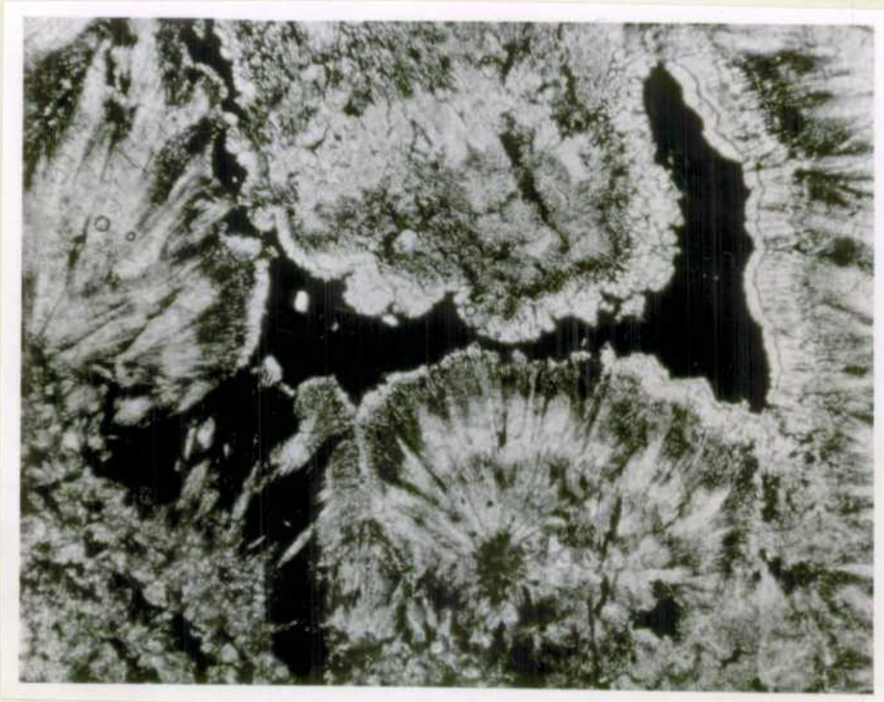
At the northern end of the S151 mesa limestone concretions and lenses are commoner in the clays. Here a more open siliceous boxwork was developed in the cap into which the limestone persists but is densely ironstained.

The softer material of the red cap has been powdered and used locally as a pigment for brown oil paint.

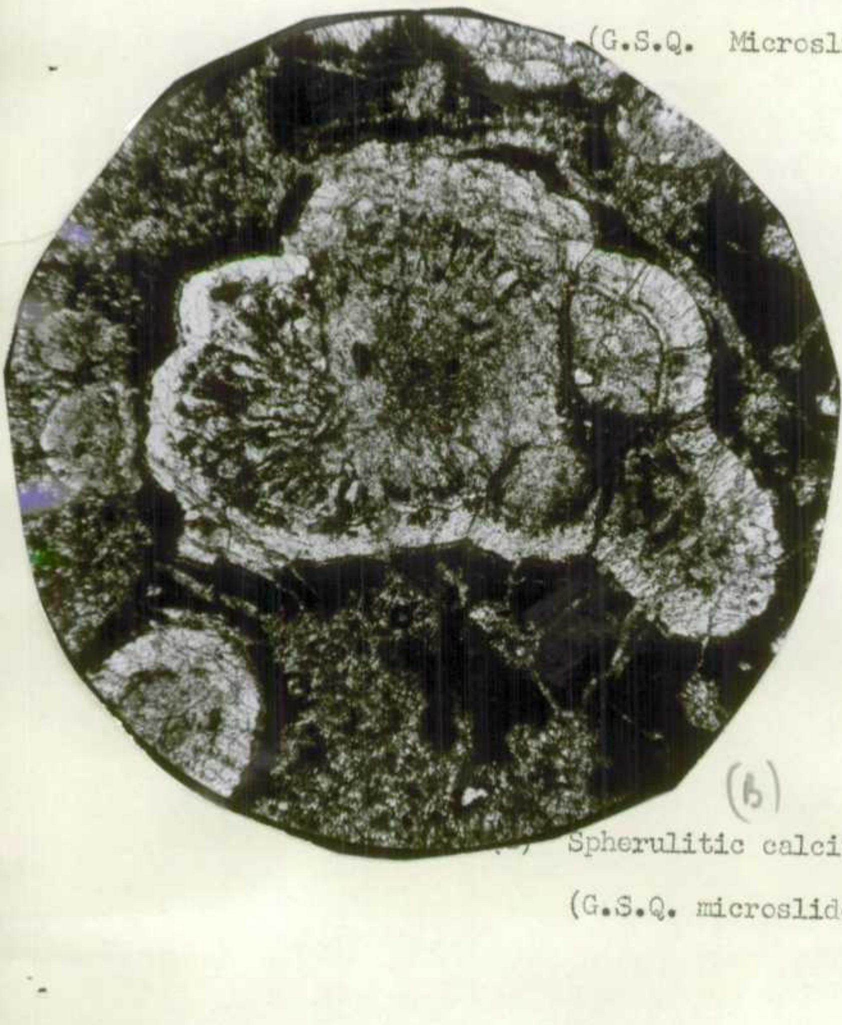
Secondary structures are common throughout the Springvale Formation. Calcareous concretionary structures are the commonest and occur within both the limestone and clay lithologies. They show a wide range of size and form.

In the limestone they range in size from 0.8 to0.4 mm. in diameter. With rare exceptions they are simple spherical bodies showing little concentric or radial structure and have a fine even grained texture. Nuclei are rare but at S108 to the south of Springvale, numerous ?molluscan shell fragments occur in the concretions. Differential silicification commonly affects the concretions but not the matrix. In this case they stand out on the weathered surface of the rock. The silica is light brown, opaline and is not isotropic due to the inclusion of finely disseminated calcite particles

PLATE 3.



(a) Spherulitic calcite growth, Springvale Formation X30 (G.S.Q. Microslide 2211, B.M.R. negative 6/2292).



(b) Spherulitic calcite growth, Springvale Formation X46 (G.S.Q. microslide 2209, B.M.R. negative 6/2289)

In the clays the concretions range up to 2 feet in diameter and are grey to brown in colour. Simple spherical bodies occur but compound forms are far commoner.

Septaria occur in the clay sequence at S151. They are light brown disc-shaped argillaceous-calcareous bodies with a reticulate to finely nodular ornamentation. The size ranges from 2 to 6 inches in diameter.

Internally the septaria display a system of radial and concentric syneresis (shrinkage) cracks. In most cases, the cracks have a papery coating of white, finely crystalline quartz with most of the void space free of deposit (plate 4a) but more rarely the void space is filled with interlocking quartz crystals up to ¼ inch long (plate 4b). The outer part of the septaria is of dense material but this becomes spongy towards the centre.

It is impossible to delimit true concretions from true septaria as many of the large concretions possess features analogous to those of the septaria. Thus many apparent large concretions exhibit a poorly developed internal syneresis system with secondary quartz infilling (plate 1b).

Spherulitic calcite occurs in the limestone and concretions and recrystallization is apparently confined to the ferruginized areas. It is a late stage feature and post dates all previously formed structures. Thus spherulitic calcite growth forms around small concretions, cuts across concretion boundaries and excludes iron oxide to areas peripheral to the spherulitic growth. Recrystallization forms regular or compound spherical bodies, or is irregular.

The above post-depositional structures form in a definite sequence which persists throughout the deposit and can be summarised as follows:-

1. formation of concretions.
2. differential silicification of some
3. concretions by opaline silica.
4. ferruginization.
5. spherulitic calcite recrystallization.

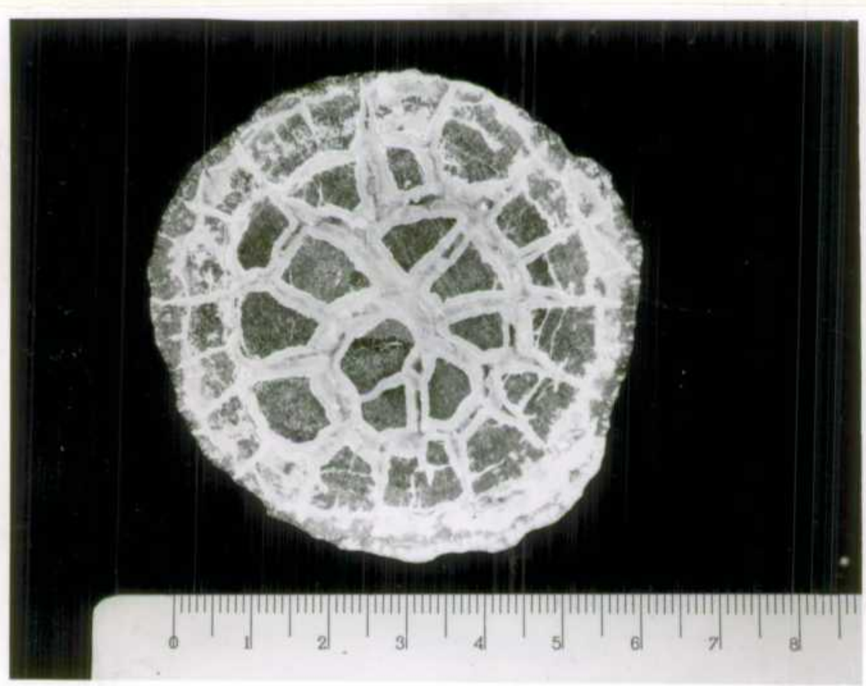
Plate 3b illustrates this sequence. It figures a fine-grained limestone with small calcareous concretions (lower right) that have been partly replaced by opaline silica. The concretions and ground mass are lightly mottled by brown iron oxide. A large compound coarsely spherulitic calcite body of later origin (centre) cuts across the concretions and is surrounded by a rim of dark iron oxide apparently excluded by the recrystallization. The central area of the spherulite is slightly stained by iron oxide but the peripheral area is clear and strikingly free of it. This outer clear zone adjacent to the excluded iron oxide rim is a constant feature of spherulitic growth in the deposit.

Plate 3a further illustrates post-ferruginization spherulitic growth. In this case it is in a ferruginized large concretion. Spherulitic growth is irregular. It was initiated at a number of points and growth was towards a centre. Iron oxide (dark) was excluded by the crystallization of the central area. As before the spherulitic area is slightly ironstained and the clear zone adjacent to the excluded iron oxide well shown.

Plate 2a is a further example of late stage recrystallization (non-spherulitic) in a ferruginized limestone. Crystallization has excluded iron oxide to the intercrystal areas.

PLATE 4.

(a) Section of septarian nodule, Springvale Formation (diameter 9 c.m.)
(B.M.R. negative 6/2267)



(b) Section of septarian nodule, Springvale Formation (diameter 6 c.m.)
(B.M.R. negative 6/2269)

The process or processes involved in the chemical alteration of the Springvale Formation involved leaching (particularly of lime); silicification and ferruginization. It is evident that lithology controlled the end products, for whereas the clays produced porous strongly ferruginous-siliceous rocks, the dominantly limestone lithology produced lightly ironstained dense siliceous rocks. However the end products are analogous, both consisting principally of iron oxide and silica, the difference due only to the form and ratio of the constituents.

The simplest explanation of chemical events is to relate them to lateritization. Lateritized Cretaceous sediments are extensive and occur within a few miles of the Springvale area. Fisher (1958) stated that typical laterite profiles in northern Australia consist of an upper derived soil zone, overlying a ferruginous zone, overlying a mottled zone, overlying a pallid zone, overlying fresh rock, with a siliceous zone occurring anywhere in the mottled or pallid zone.

The red-capped hills in the type area exhibit a distinct zonation. The upper ferruginous-siliceous cap passes downwards into irregularly coloured red, brown and green clays. These two zones are analogous to the ferruginous and mottled zone of a laterite profile. The irregularly ironstained siliceous rocks (from the dominantly limestone sequence) may represent the mottled zone of an eroded profile.

Several features anomalous to lateritization occur. These are the occurrence of considerable amounts of silica and calcareous rocks in the ferruginous and mottled zone of the profile. In general, in this part of Western Queensland, the laterite profiles have unexpectedly high silica values throughout, when compared with those that would be expected from the "theoretical profile" (Reynolds, 1960). But whereas the profiles on the surrounding Cretaceous rocks appear merely indurated by silica, the silica in the Springvale "profile" forms a distinct silica rock.

The preservation of calcareous concretions and small limestone bodies in the profile is unusual, since it would be expected that lateritization would involve the removal of the alkaline earths. The alteration products of the limestone from the Springvale Formation (silica rock) is unlike those on other limestone sequences (e.g. in Playford, 1954).

The Springvale "profile" is considerably thinner (possibly only 20 feet on the clay sequence) than those on the Cretaceous rocks in the area (which may be five or more times this value).

This suggests that either the laterite-forming process affecting the Springvale Formation was locally weak or that the process did not act on it for as long a period as it did on the surrounding Cretaceous clays. The first seems unlikely and the inference to be drawn from the second is that sedimentation took place in the Springvale (tectonic) Basin during the lateritization of the area; the Springvale sediments being subsequently exposed to weathering only in the late stages of lateritization.

The greatest exposed sequence of the Springvale Formation is in the Mungeroo Knobs to the east of Uka Tank where 70 feet of granular concretionary clay crops out. The formation thins towards the east against the Goyder Range.

(b) <u>Horse Creek Formation (Paten 1960)</u>

After chemical alteration and erosion of the Springvale Formation, the Springvale Basin became a depression in which lacustrine limestone, the Horse Creek Formation, was deposited. The position of the basin migrated several miles to the east so that it overlapped the Upper Cretaceous rocks to the east of the area of deposition of the Springvale Formation.

Horse Creek Formation is named after Horse Creek, a tributary which enters Spring Creek at Springvale Homestead. Type area and reference section for the formation are given as follows:

Type area :- From the crossing of Gum Creek on the Springvale-Diamantina Lakes road, about 2½ miles upstream to the junction of a well defined creek coming in from the west, then one mile up this creek into a shallow gorge.

Reference Section:- Springvale airstrip at the homestead.

(a) Argillaceous charophyte limestone, Horse Creek Formation.
(type area locality S124)
(B.M.R. negative 6/2283)

(b) Horse Creek Formation overlies Springvale Formation in scarp on the west side of the Diamantina River to the north of the Goyder Range.
(B.M.R. negative 6/2255)

The formation caps the low plateau on which Springvale airstrip lies, from where it extends south-eastwards to about 5 miles east of the Diamantina River. It extends from near Uka Tank north-eastwards for about 28 miles. Outcrop covers approximately 200 square miles.

Strata consist of fine-grained brown and grey fossiliferous limestone with minor common opal and clay bands. The limestone consists of very fine-grained granular lime carbonate which is in part recrystallized and veined by coarse calcite mosaic. The vein boundaries are sharp. Where ostracods occur, the shells are commonly infilled by coarse calcite mosaic (plate 6b). Low percentages of interstitial argillaceous and rarely opaline silica occur, however at S124 (type area) a very fine grained argillaceous limestone with charophyte remains crops out (plate 5a). Argillaceous limestones are well bedded whereas the purer precipitated carbonates are characteristically massive or poorly bedded. An earthy carbonate sequence up to 30 feet thick crops out along the eastern margin of the deposit to the north of the Goyder Range. Quartz grains and lithic fragments are rare in the Horse Creek Formation.

Faecal limestone occurs near the base of the sequence along the western margin of the deposit. It consists almost entirely of small red shaped faecal bodies of fine grained argillaceous limestone set in a limestone matrix (plate 7). Ostracods are common in this limestone (plate 6) their shells being filled with the faecal material. The localization of up to 10 feet of this material along the entire western margin of the deposit, but not in the east suggests that the faecal material was concentrated by wave or current action.

This belt of faecal limestone has undergone an unusual silicification. At the top of the sequence is unaltered limestone; below this, the pellets, but not the calcite matrix, have been silicified. Near the base, the lime matrix is leached away to produce a porous, light-weight, white rock, composed largely of silica. It resembles closely Tripoli (Pettijohn, 1957 p.433). Ostracods are silicified and their shell structure preserved. The form of the faecal pellets is preserved giving the rock, which has the general appearance of a diatomite, a coarser texture. Analysis, by the Queensland Government Chemical Laboratory, of one specimen of this material from the Springvale airstrip gave the following results (1570/59 G.S.) :-

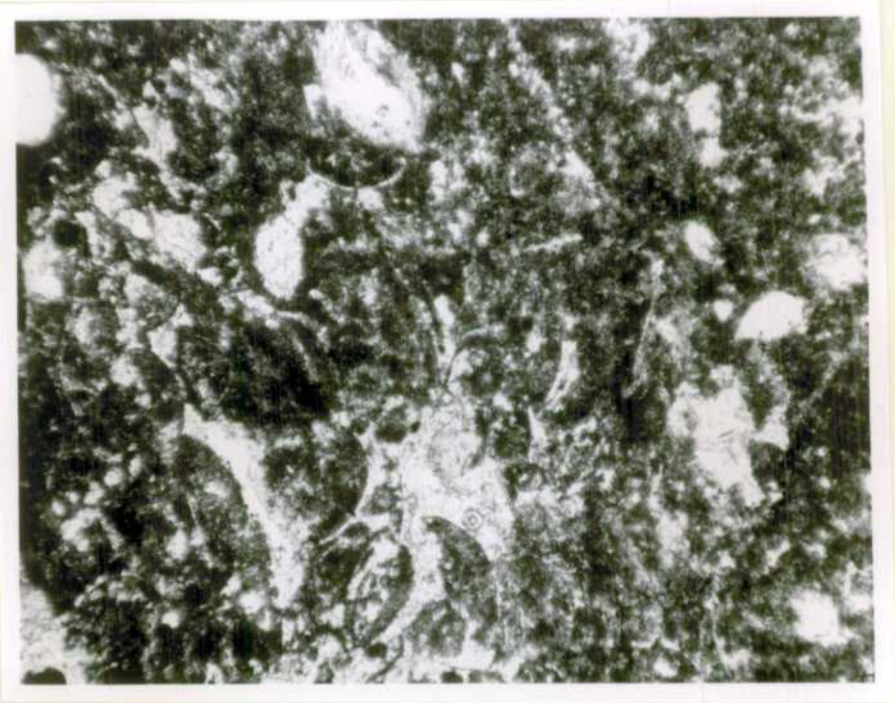
Loss on ignition	13.7%
silica (SiO_2)	62.0
alumina (Al_2O_3)	11.5
ferric oxide (Fe_2O_3)	0.6
calcium oxide (CaO)	9.2
magnesia (MgO)	2.2
	99.2

This silicification is unusual, for all other observed Cainozoic silicification in Western Queensland affected a surface and the effects decreased with depth below that surface. In this case, particular beds near the base of the succession were silicified and the silicification increased with depth to the limit of the faecal lithology. The tripoli-type rock was not observed in any other Cainozoic basins in the area.

At the base of the Horse Creek Formation, in all areas except along the eastern margin of the deposit a band of green clay with rare ostracods occurs and rarely exceeds one foot in thickness. It grades upwards and is partly brecciated into the overlying limestone and forms an excellent marker.

Surface silicification of the exposed parts of the formation to form common opal with minor veining by chalcedony occurred on a small scale. The limestone produced honey-brown opal whereas the green clays developed a dull green variety. Ostracod and gastropod shells are preserved in the opal and weather out in profusion on the surface of the rock.

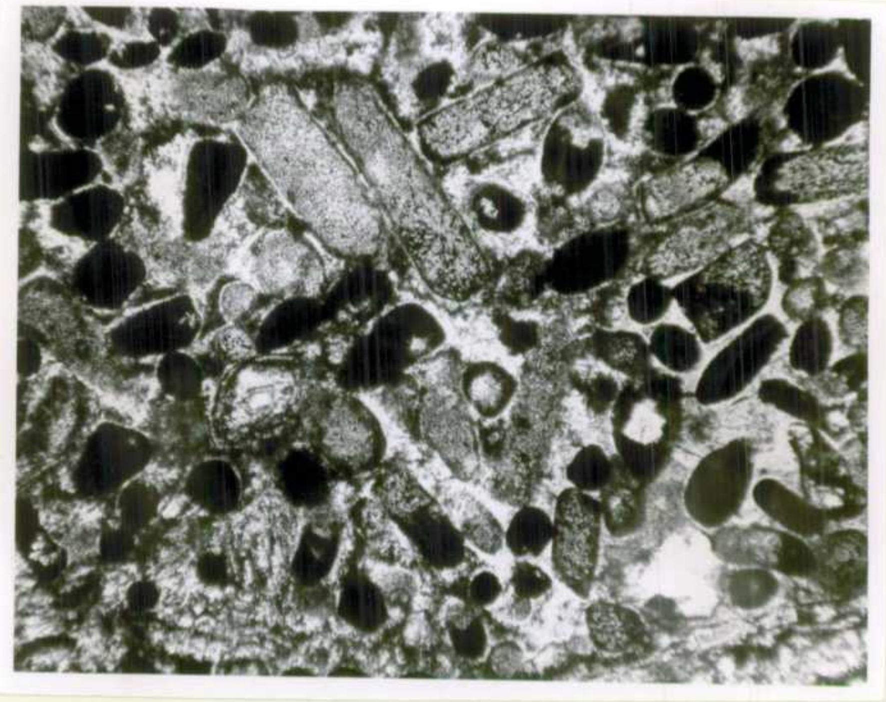
PLATE 6.



(a) Lacustrine limestone containing shell remains, Horse Creek Formation. Dark, clotted precipitated carbonate with irregular clear recrystalized areas X70 (G.S.Q. microslide 2224, B.M.R. negative 6/2294)

(b) Ostracods in faecal limestone, Horse Creek Formation. (G.S.Q. microslide 2220, B.M.R. negative 6/2286) Mag. about x 40.

PLATE 7



Faecal limestone, Horse Creek Formation X40
(G.S.Q. microslide 2220, B.M.R. negative 6/2291)

Thin laminae of dull to lustrous common opal occur in the leached faecal rock and exhibit an internal undulose structure which in some cases persists into the leached material.

The maximum observed thickness of 40 feet of the Horse Creek sequence was on the eastern margin of the deposit north of the Goyder Range.

IV MARION BASIN

Sediments of the Marion Basin were deposited within a linear N - S depression which extended from Windsor Park in the north to beyond the area of investigation in the south. Near Windsor Park, it was about 10 miles wide but it widened rapidly to the south of Boulia, being about 40 miles wide at 24°S. latitude. The southern extent is not known. Sediments similar to those of the Marion Basin crop out on Kamaran Downs near Bedourie and in the Innamincka and Beetoota areas. The Innamincka and Betoota occurrences are east of the trend of the Marion Basin, but were apparently continuous with those of the Boulia Region (Reynolds, per.comm.).

The elongate shape, the adjacency of the northern limit to the mouth of an old erosion valley developed in the Palaeozoic rocks, i.e. the Upper Burke River Valley, plus the rapid broadening below the mouth of the old upper Georgina River Valley indicate that the Marion Basin was formed within the Tertiary erosion valley of the southward flowing ancestor of the present Lower Burke and Georgina River system. The Marion Basin was confined to the surface of the Artesian Basin and did not extend onto the exposed shelf of Palaeozoic rocks.

Marion Formation (Casey, 1959).

A sequence of arenaceous sediments - the Marion Formation was deposited in the Marion Basin. It was named after Marion Downs Station, a grazing property on the Georgina River, 40 miles to the south-west of Boulia. The type area is in hills 14 miles west of Marion Downs Homestead on the track from Marion Downs to Herbert Downs. A reference section is given 5 miles north-west of Strathelbiss Homestead, 14 miles north of Boulia.

Outcrop is divided into two major areas. The northern area between Windsor Park and Boulia is separated from the southern area, which extends southwards from Marion Downs, by the spread of alluvium at the junction of the Burke and Georgina Rivers. Outcrop in the southern portion is confined to between the Mulligan and Georgina Rivers. Desert sands blanket the area to the west of this.

The formation has given rise to broad undulating grassy plateaux which are being deeply dissected, by the present cycle of erosion. Dissection is particularly active in the southern outcrop area where the formation persists only as thin mesa cappings. Mt. LaTouche, Mt. Tobin, The Knob, The Sisters, Mt. Tarley and 12 Mile Mountain are all residuals capped by silicified Marion Formation (plate 8b).

Quartz sandstones, ranging in grain size from fine to very coarse and fine conglomerate comprise the formation. Grains are sub-angular to sub-rounded and consist of quartz with rare cream and dark chert, the chert occurring mostly in the coarser fraction. The chert fragments were derived from the Palaeozoic and older carbonate rocks to the north, a fact which supports the hypothesis that the Marion Formation was deposited in a river valley with its source area in the north. Near the base of the sequence, valley fill occurs on a small scale and consists of fragments of the underlying lateritized sandy siltstone.

A rough grading is indicated in the deposit, the coarser fraction being mostly confined to the basal few feet.

The sequence has been almost completely silicified to form billy which is described under "SILICIFICATION".

PLATE 8.

(a) Unconformity, Marion Formation overlies fractured and lateritized Wilgunya Formation 12 Mile Mountain. (B.M.R. negative 6/2271)

(b) Mt. Tobin - Silicified Marion Formation caps Wilgunya Formation. Gibbers derived from Marion Formation blanket the lowlands.

Bedding is poorly developed. Interwedging of fine and coarse beds, associated with foresetting occurs on a small scale. The formation is sub-horizontal except for the presence of initial dips of up to 20 degrees which are commonly associated with valley fill structures close to the base of the sequence.

The Marion Formation unconformably overlies the uneven eroded surface (mottled zone) of the lateritized Lower Cretaceous Wilgunya Formation (plate 8a). No junction with other Tertiary formation is exposed, and at Windsor Park, where the Noranside Limestone overlies the Marion Formation, the junction is obscured by rubble from the two units. In bores near the Paravituari Waterhole, sandy sediments tentatively regarded as Marion Formation underlie the Austral Downs Limestone. The maximum observed thickness is 25 feet.

V AUSTRAL DOWNS BASIN.

The Austral Downs Basin occupied the Upper Georgina River Valley (including Pituri Creek) and except in the extreme south-east part, it was confined to the exposed shelf of Lower Palaeozoic carbonate rocks which lies to the north-west of the Great Artesian Basin. It extended from near Herbert Downs into the Northern Territory beyond Urandangi and Linda Downs. Lacustrine limestone, the Austral Downs Limestone, was deposited in the basin.

Austral Downs Limestone (Noakes and Traves, 1954). See Appendix.

This name was given by Noakes and Traves for limestone and chalcedony outcropping on Austral Downs, a station property in north-eastern Northern Territory. The type locality is "The Georgina Valley at Austral Downs and Urandangi". Whitehouse (1940) recorded the occurrence of the limestone along Pituri Creek. The Austral Downs Limestone crops out as linear areas up to 12 miles wide within the valleys of the Georgina River and Pituri Creek. The sequence is better exposed in Pituri Creek. Small areas of similar rocks in this area are exposed on the western side of the Toko Range near Areeta Bore, to the south of Yardida Bore (both in the Northern Territory) and 8 miles north of Craven's Peak.

Outcrop along Pituri Creek, on Herbert Downs, east of the Georgina River on Roxburgh Downs and in the Jimboola-Carrandetta area, is typified by linear plateaux, but at Roxburgh Downs on the western side of the Georgina River, the formation outcrops as scattered small plateaux, ridges and hills. This is an expression of rock type. In the extensive plateau areas, the sequence is chalcedonic and has undergone less erosion than the non-siliceous areas on the west side of the Georgina River at Roxburgh Downs.

The plateaux along Pituri Creek are extensive - the one on which Glenormiston Homestead stands, extends along the Creek for about 20 miles, with a maximum width of 3 miles. It is blanketed by a mantle of dark residual soil growing Mitchell Grass, but smaller plateaux of the formation are commonly capped by residual siliceous rubble that grow and support only scrubby vegetation. In areas of little dissection as in the Carrandetta area, the formation gives rise to extensive dark soiled Mitchell Grass plains.

The Austral Downs Limestone sequence consists broadly of an upper chalcedonic cap overlying grey, cream or white limestone, which overlies a zone rich in ferruginous detritus. These three divisions are gradational and one or more of them may be absent from any one outcrop area. The following section from Pituri Creek, 5 miles north-west of Glenormiston Homestead is typical for the formation.

15 feet chalcedony, siliceous limestone, silica content increases towards top of section, white and brown chalcedony weathers out on surface.

5 feet limestone, white, fragmental with minor chalcedony.

5 feet limestone, impure, white with some sandy ferruginous detritus.

5 feet ferruginous detritus, calcareous matrix, possibly some spring travertine textures.

—— Dolomite (Lower Palaeozoic).

Up to 10 feet of the basal part of the sequence is composed mainly of sandy ferruginous detritus derived from the erosion of the laterites. This part of the sequence varies from a sandy, nodular, dense to porous ferruginous rock, with calcite veins and intergranular material, to an impure limestone with disseminated rounded ferruginous fragments and quartz grains coated with iron oxide. This rock contains some textures that are similar to those found in modern calcareous spring travertines in the area.

This ferruginous material grades upwards into cream, grey and white fine grained limestone. Where the basal ferruginous layer is absent, the limestone commonly contains fragments of the underlying carbonate bedrock at the base.

The limestone is composed of a chemical deposit of fine grained carbonate, the texture of which is considerably modified by recrystallization. This produces a clotted appearance in thin section, which is due to an irregular arrangement of areas of dark, fine grained limestone and light crystalline calcite. Breakup of the fine carbonate before consolidation, and subsequent cementation of the fragments by later deposited carbonate, produced large areas of limestone conglomerate or breccia up to 20 feet thick. Aggregation of pellets by thin coats of later deposited carbonate is a common feature.

This fragmentation of the deposit is probably due to collapse, caused by the instability of the freshly deposited sediments on an uneven floor of deposition. Pettijohn (1957) regarded such limestone conglomerates (pseudo-breccia) as resulting from the sloughing off of lime from the surface of lime depositing plants, e.g. charophytes. Considering the size and thickness of these deposits in the Austral Downs Limestone, the former explanation seems more probable. The conglomerates are best developed at Roxburgh Downs on the west side of the Georgina River.

The limestone passes upwards into an irregularly silicified cap of white and blueish, translucent to opaque chalcedony. This cap seldom exceeds 15 feet in thickness but at Aroota Bore and Lake Wonditti the whole sequence is silicified. The chalcedony forms massive bands up to 10 feet thick, veins, mamellate vugh fillings and irregular masses. The massive bands, in some cases, persist laterally and have distinct boundaries. The veins, vugh fillings and irregular masses form a complex reticulate pattern within the silicified cap and include numerous residual limestone areas. Limestone textures (clotted, pellet) are commonly preserved in the chalcedony after all other traces of the limestone have disappeared. Traces of iron oxide in the chalcedony stain weathered surfaces brown. The nature of the silicification and the origin of the silica are discussed under "Silicification" and "Appendix".

PLATE 9.

(a) Austral Downs Limestone overlies Ordovician Dolomite at Lake Wonditti, Glenormiston.

(b) Austral Downs Limestone. Poorly bedded, non siliceous white limestone, Roxburgh Downs.

Plate 10.

(a) Silicified Austral Downs Limestone, Lake Wonditty, Glenormiston - a typical exposure.

(b) Austral Downs Limestone, Glenormiston. Massive chalcedony band (central top) over partly silicified grey limestone.

PLATE 11.

(a) Austral Downs Limestone, Glenormiston. Irregular siliceous replacement of limestone.

(b) Looking along the Black Mountain ridge with Mt. Ninmaroo in the foreground and Mt. Datson in the background. The plain-land in the distance is Noranside Limestone which surrounds Mt. Datson.

Apart from the sandy ferruginous base of the deposit, clastic grains are rare and consist of subangular to subrounded quartz grains. Dendritic and platy manganese oxides occur in trace amounts in some areas.

Coarsely laminar-nodular limestone occurring as coats up to several inches thick on the surface and in joints of the Palaeozoic carbonates (particularly dolomite) have wide distribution throughout the Georgina Basin. They commonly contain sand and ferruginous detritus, and in rare cases are silicified to chalcedony. They have wider distribution than the Austral Downs Limestone and are not of lacustrine origin but are surface caliche, similar to material figured in Swineford, Leonard and Frye (1958).

A thin to medium irregular bedding is evident in the more calcareous sequences (plate 9b); however in most cases bedding is not well developed. Thickness of the deposit observed in the Glenormiston area increased from the margins of the depositional valleys to the centres where it is a fairly constant 30 feet. The sequence near Aroota Bore has an exposed thickness of 55 feet.

VI NORANSIDE BASIN. (See appendix)

The Noranside Basin was long and narrow in shape and extended from Noranside in the north to the Hamilton River in the south. It was separated from another basin which developed within the upper Burke River Valley by a ridge of Cambro-Ordovician carbonate rocks at Digby Peaks. A smaller basin occurred on Burnham Station about 16 miles east-north-east of Digby Peaks.

The Noranside Basin was positioned across the boundary of the Cretaceous siltstone of the Great Artesian Basin and the Lower Palaeozoic carbonate rocks of the Black Mountain ridge (plate 11b). The Springvale Basin is on the southern extension of the trend of the Noranside Basin but there is no evidence that the two were ever connected.

As in the case of the Marion Basin, the long narrow shape of the Noranside Basin, plus the proximity of its northern limit to the mouth of the old Upper Burke River Valley, suggest that it was developed in a valley which was at that time, the course of the lower Burke River. Its northern limit overlapped that of the Marion Basin but the two basins existed at different times. A limestone sequence, the Noranside Limestone, similar to the Austral Downs Limestone was deposited in the basin.

Noranside Limestone (Casey, 1959).

The limestone is named after Noranside Out-station which is situated between the Burke River and Wills Creek, 50 miles north-north-east of Boulia. Casey (1959) described the two reference areas for the formation. They were described in detail in Casey et al (1960) and are here repeated: (1) White siliceous limestone in a gully crossing the Boulia-Selwyn road 1.2 miles south of Old Noranside Well at latitude 22°12' south, longitude 140°04' east (2) Pink, red and white banded impure limestone 6 Mile Creek, 1.4 miles south-south-west of 6 Mile Bore (Corrie Downs) on Fort William Station: 0.4 miles south of an east-west dog-proof fence at latitude 22°27' south, longitude 140°12' east. Chalcedonic limestone was first noted in the Boulia area by Dunstan (1920). Whitehouse (1940) described the limestone from Warenda and Fort William and a summary of this is given in Connah (1958).

Outcrop occurs in a belt 5 to 15 miles wide and unlike the Austral Downs Limestone, exposure is poor particularly in the south where the formation is covered by an extensive plain of alluvium and black soil. Plates of limestone are widely scattered over the surface of the plain.

As with the Austral Downs Limestone, redistributed pink and red lateritic detritus is concentrated within the basal 10 feet of the limestone sequence. The bulk of the sequence consists of white pellety fine grained chemical limestone with veins and irregular areas of crystalline calcite. Pellets are commonly aggregated by later lime coats. Clastic quartz grains are rare except in areas rich in lateritic detritus.

An irregular zone of chalcedony as massive bands, veins and irregular masses tops the sequence. It passes downwards into unaltered limestone. Silicification is commonly differential, calcite mosaics and veins being replaced more readily than the fine grained precipitated lime.

Bedding is indistinct; the lower part of the sequence show a fine bedding which is commonly disrupted either by desiccation or by the action of organisms. The flat plates of siliceous limestone scattered over the surface of the plain may be an expression of the bedding.

The Noranside Limestone is exposed at the surface to erosion, it overlies the lower Palaeozoic and Cretaceous rocks of the area and is covered in part by two ages of alluvium - the younger being that of the present river system. It apparently overlies the Marion Formation at Windsor Park.

The greatest thickness observed was 45 feet at the reference area (1).

VII SINTERS.

Siliceous sinters crop out at Mt. Coley, Mt. Whelan, Sugarloaf Hill and near Boulia on Alderley and Stockport Stations. These are collectively known as the Mt. Coley Sinter (Casey 1959) although there is no suggestion that they ever existed as a continuous deposit. It forms sharp hills and low rises and overlies unconformably the lateritized Lower Cretaceous Wilgunya Formation.

The sequence consists of brown and white cellular opaline sinter commonly with ferruginous inclusions (derived from the erosion of the laterites) and milky blue and white chalcedony. No bedding is evident but massive white chalcedony, when preserved, overlies the sinter.

The sinters were deposited in small depressions from siliceous spring waters derived from the Artesian Basin due to fracturing of the aquiclude (Wilgunya Formation). Faulting occurs below the sinter in the Wilgunya Formation at Mt. Whelan. Estimated thicknesses for the formation are Mt. Coley 120 feet, Sugarloaf Hill 60 feet and Mt. Whelan 35 feet.

VIII PALAEONTOLOGY AND ENVIRONMENT

(a) Springvale Formation

Up to 15 feet or silicified algal limestone with rare residual limestone areas cropout as discontinuous arcuate ridges to the west and south-west of Springvale Homestead and as expanses of rubble between there and Gum Creek (fig. 1). In most cases the ridges have steep westerly slopes and dip at a low angle to the east which may be either the result of post depositional movement or indicate that the algal deposits

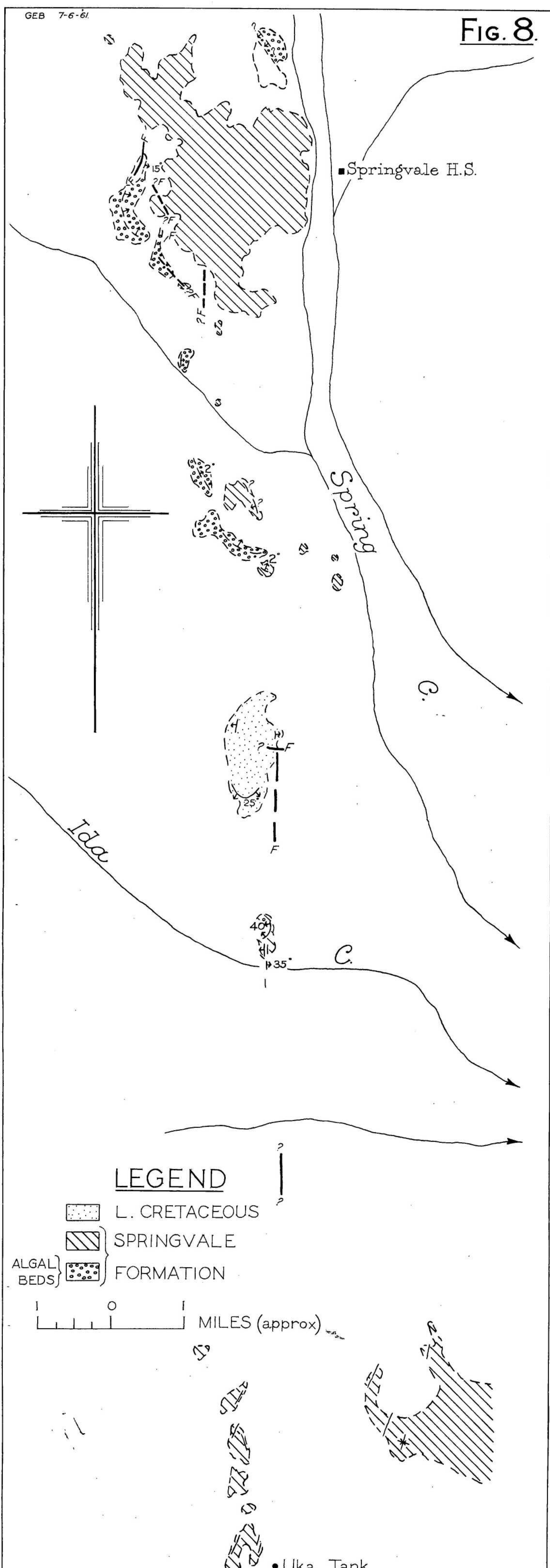


FIG. 8.

BLACK MOUNTAIN LINE-SPRINGVALE

were small bioherms. A tectonic explanation of their shape is more acceptable (fig.8). Outcrop is rubbly due to the breakup of the algal mass into colonies. The colonies are concentrically layered and range in shape from simple sub-spherical forms to complex irregular bodies. Commonly growth is elongate in one direction with small outgrowths in which the layered structure persists.

Partly silicified algal limestone crops out in hills on the north side of the road from Springvale to Diamantina Lakes about 10 miles from Springvale Homestead (S120). This material consists of alternating concentric layers of dark and light grey sandy limestone (plate 12a). The light grey bands are of "spongy" limestone, made dense by later calcite and silica infilling and replacement. The dark grey bands are finer grained and grade outwards into the spongy mass. Silicification is more intense in the fine bands which weather out as ribs on exposed surfaces.

Recrystallization has, in most cases, destroyed the structure of the individual algae, however in rare cases, filaments and solid spherical bodies were observed in thin section of the rock. Filaments are fragmentary, simple and unbranched, ranging in diameter from 30 to 50 microns. Crosswalls were only observed in a few cases. The filaments are filled by calcite mosaic.

The spherical bodies are solid and composed of uncleaved calcite. They range in diameter from 12 to 32 microns, with most towards the upper limit of the range. The nature of these small bodies, which appear organic, is unknown however they may be unusual calcite infillings of unicellular algae.

Thin-shelled, plane-spired gastropods occur in chert (silicified limestone) and hard limestone about 12 miles south of Springvale Homestead (S108). Other thin shelled fragmentary molluscan remains occur in grey limestone about 16 miles south-south-east of the homestead (S145).

The presence of massive calcareous algal deposits in the Springvale Formation indicates that it was deposited in an aqueous environment, probably freshwater or brackish. Bradley (1929) described a similar, but much larger sequence of algal deposits, limestone and clays from the basal 700 feet of the lacustrine Tertiary Green River Formation from the western United States of America.

(b) Horse Creek Formation

This formation is by far the most fossiliferous of the Tertiary lake deposits in western Queensland and the one in which the lacustrine origin is most obvious. Fossils include ostracods, gastropods, charophytes and probable faecal pellets.

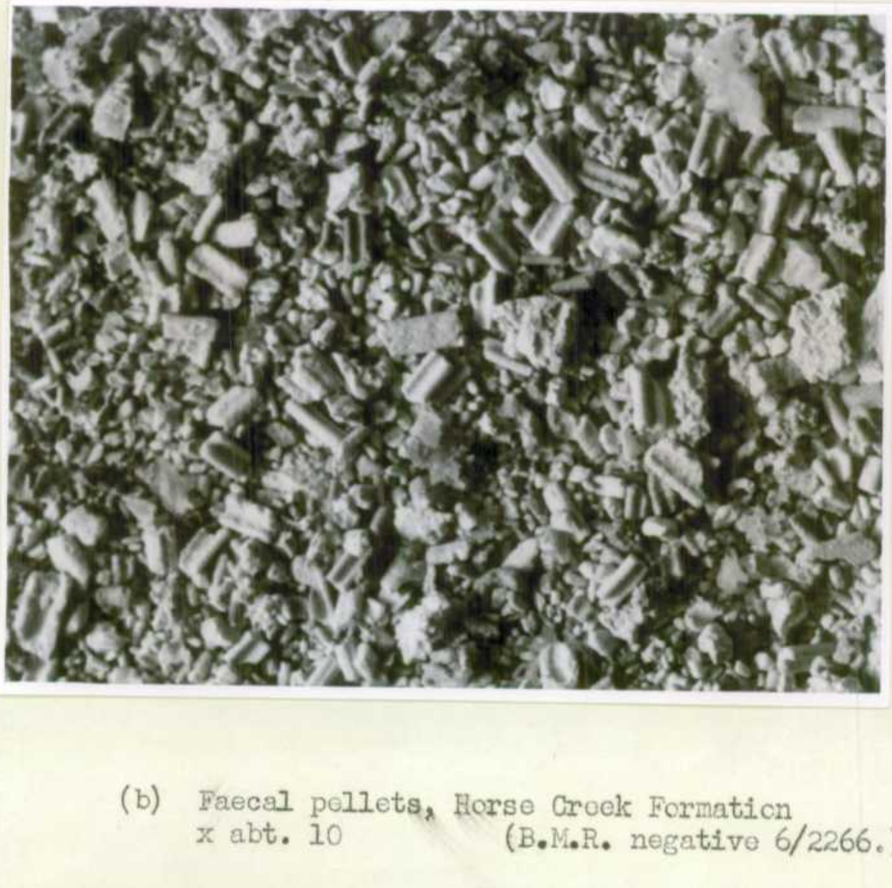
Smooth shelled ostracods are the commonest fossils and occur in profusion throughout the sequence. They can be collected from most outcrop areas, particularly in the upper silicified levels where they weather out on the surface of the plates of common opal. Apparently only one form is present.

Gastropods occur in siliceous limestone rubble near the edge of the Springvale plateau on the west side of Gum Creek, 16 miles south-east of Springvale Homestead and 5 miles north-east of Marion Downs Bore (S123). Two forms occur, a low spiralled form up to $\frac{3}{4}$ inch in diameter and a small thin-shelled turretted form up to $\frac{1}{4}$ inch long.

Charophyte gyrogonites (female fruiting bodies) occur in great number in a fine grained creamy brown argillaceous limestone in the type area near Gum Creek (S124). Leaching has removed the gyrogonites leaving moulds which preserve the characteristic spiral structure. No stems or other parts of the plant are preserved.

PLATE 12.

(a) Algal limestone, Springvale Formation
(B.M.R. negative 6/2268)



(b) Faecal pellets, Horse Creek Formation
x abt. 10 (B.M.R. negative 6/2266.)

PLATE 13.

(a) Silicified ?algal colony, Springvale Formation.
(B.M.R. negative 6/2265)

(b) Silicified ? algal colony, Springvale Formation (slightly enlarged)
(B.M.R. negative 6/2270)

Faecal pellets are concentrated in vast numbers along the western margin of the formation. Excellent exposures occur on the east side of Spring Creek below the Springvale Airstrip. They are preserved in limestone, which is largely silicified and leached, and consist of calcareous-argillaceous material. Partly silicified pellets were separated from the calcareous matrix by slow leaching in dilute acetic acid.

The pellets are fragmentary, straight rod shaped bodies, 1 to 1½ mm. long and about ½ mm. in diameter (plate 12b). They have a well-defined longitudinal groove with, in some cases, a corresponding flattening or shallow groove on the opposite side (fig.5). An indistinct low angle spiral ornamentation occurs on the outer surface of some of the pellets.

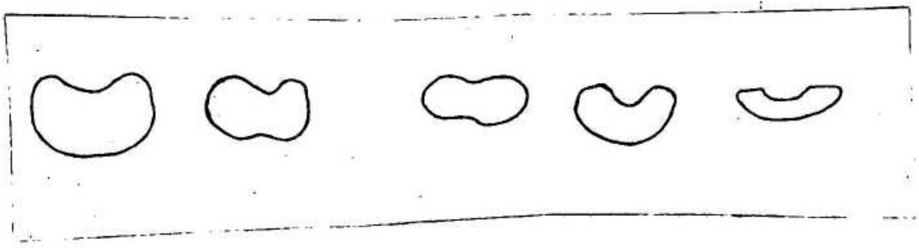


Fig. 5 Characteristic cross sections of faecal pellets.

The parent organism for this material is not preserved in the deposit and was presumably soft bodied. Ostracod shells filled with faecal material are incorporated in the deposit but seem too small to be the origin of the faeces.

(c) Marion Formation

The only fossils collected from this formation are silicified weed of wide distribution but rare occurrence. Smaller specimens may have been redistributed from the Cretaceous sediments of the area, but concentrations of large pieces are almost certainly first-cycle. Carter (1959) examined two probable first-cycle specimens from 6 Mile Bore on Strathelbiss Station, 9 miles north-north-east of Boulia and his identifications are as follows:

(1) Mesembrioxylon - Podocarp or possibly non-resinuous Cupressinoxylon.

(2) Cupressinoxylon - very similar to Arthrotaxis.

These fossils give no indication of environment of deposition; however, sedimentary structures in the deposit suggest it was lacustrine or fluviatile.

(d) Austral Downs Limestone.

Considering the wide distribution of this type of lacustrine limestone in western Queensland, it is surprising that fossil remains in them are so rare. This is probably due to the destruction of forms by calcite recrystallization and subsequent silicification.

Whitehouse (1940) regarded these deposits as unfossiliferous and on this basis stated that they were probably surface soil limestones. Fossils indicative of a lacustrine origin have now been found in three of these deposits and it seems likely that other occurrences referred to by Whitehouse will also be found to be fossiliferous after detailed (thin section) examination.

Fossils from the Austral Downs Limestone include charophyte and other algal remains, plant tissue, ostracods and foraminifera. Charophyte stems and fruiting bodies (gyrogonites) and rare ostracods occur in limestone at the Carrandotta Homestead Tank. Gyrogonites were separated from earthy lime carbonate from this locality. (Carrandotta is about 48 miles north-west of Roxburgh Downs on the eastern side of the Georgina River). The gyrogonites have affinities with those of the modern genus Chara (P.R. Evans of B.M.R. pers. comm.). Excellent illustrations of

Tertiary charophyte fruitifications and stem structure are given in Horn af Rantzien (1959).

Siliceous limestone from near Arcota Bore on the west side of the Toko Range in the Northern Territory contains probable charophyte stems (plate 13a) and fragmentary, simple, unthickened cellular plant tissue (all observed in thin section only). The fossils are from near the base of this sequence which contains much redistributed ferruginous lateritic material.

Foraminifera were collected from only one locality: at the top of a small plateau at the junction of Manner Creek with the Georgina River on Roxburgh Downs. Here abundant remains occur with rare ostracods in hard manganiferous limestone breccia and could be examined only in thin section (plate 13a). Rotaline and globergerina forms were present but specific identification and age determination was impossible (Crespin, pers. comm.).

Two possible origins for the foraminifera in the Austral Downs Limestone are considered.

(1) That they were introduced into the deposit as a result of the erosion of older marine rocks.

(2) That they lived in the environment of deposition of the limestone.

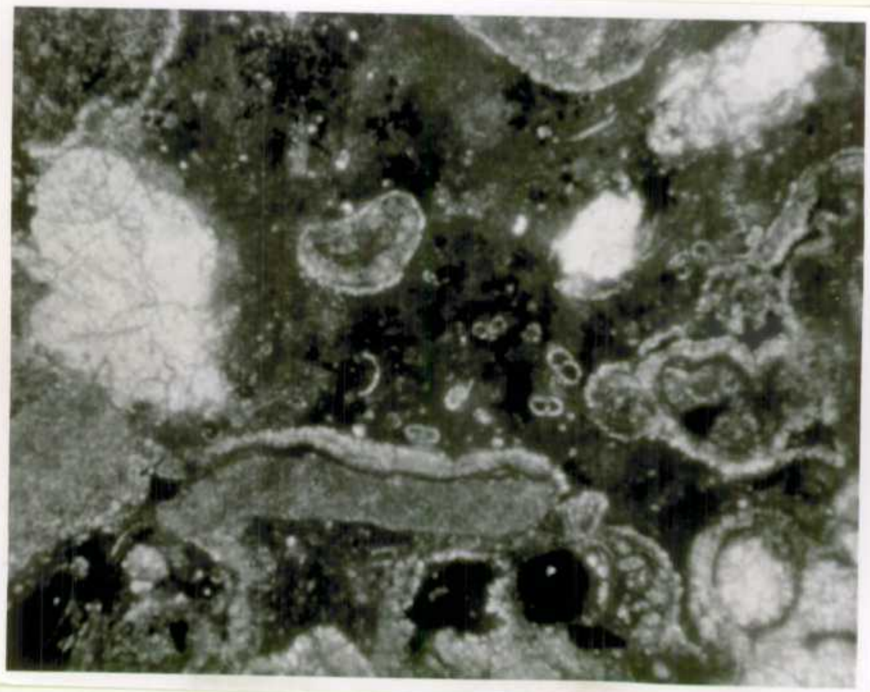
The only possible marine source rocks from which the foraminifera could be derived into the limestone are the Lower Cretaceous clays of the Great Artesian Basin. Globergerine and rotaline forms occur in these rocks. These clays were deeply lateritized prior to the deposition of the Austral Downs Limestone, and hence the derivation of fresh, calcareous tests from them seems unlikely. Also, the abundance of foraminifera at the locality suggests that they were not introduced into the deposit by this, or any other chance means.

This abundance of foraminifera of fresh appearance is taken as strong indication that they lived within the environment of deposition of the limestone. Glaessner (1945) indicated that foraminifera, including rotaline and doubtful globergerine forms, occur in continental brackish environments. Ludbrook (1953) reported abundant rotaline forms associated with ostracods and charophytes from Sub-Recent sediments in Lake Eyre in South Australia.

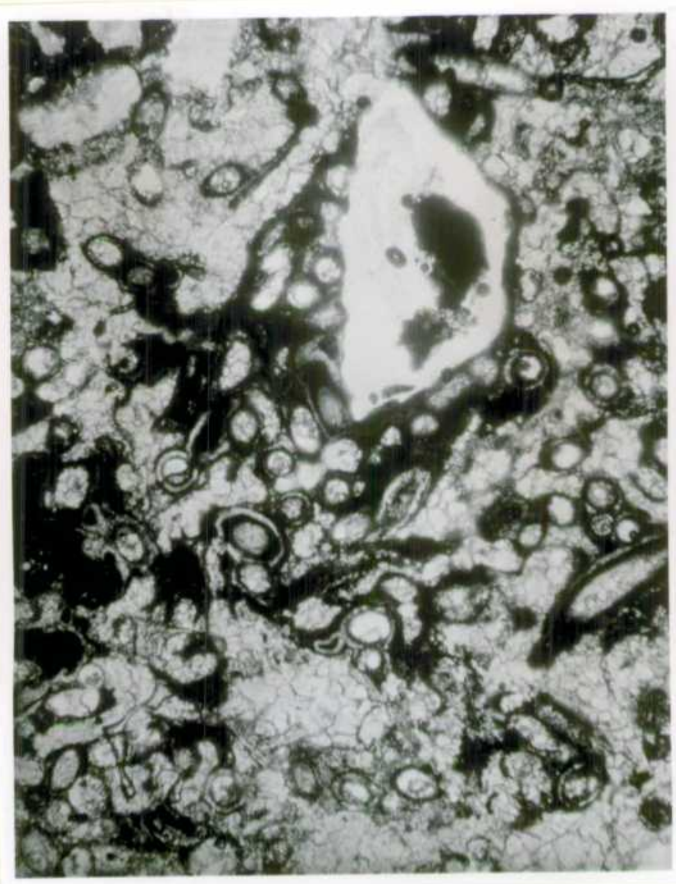
Modern charophytes are small, erect aquatic plants which live entirely submerged in clear, quiet or slowly moving bodies of water. They inhabit fresh or brackish water, but one species shows tolerance to high salinity (18 parts per thousand chloride in the Baltic Sea). Charophytes have wide tolerance to lime concentration but pH is the controlling factor, most charophytes being confined to alkaline water. Some, however, grow in acidic water, while others exist in fluctuating acid-alkaline water (Peck, 1957).

Hence the association of charophytes, foraminifera and ostracods suggests a brackish, continental lacustrine environment for the deposition of the Austral Downs Limestone. This association is similar to that described by Ludbrook (1953) from the brackish, continental lacustrine deposits of Lake Eyre.

The low percentage of clastic material in the Austral Downs Limestone, except in the derived lateritic detritus at the base, suggests that it was formed during a period of low rainfall. This was also suggested by Whitehouse (1940) and Noakes et. al. (1959).



(a) Foraminiferal limestone breccia, Austral Downs Limestone. Junction of Manner Creek and Georgina River, Roxburgh Downs.
Foraminifera and ostracod (centre) in fine carbonate
(B.M.R. negative 6/3332,
B.M.R. microslide MF5510)
Mag. about x 15.



(b) Probable Charophyte stem limestone, Austral Downs Limestone, Arocta Bore N.T.
(G.S.Q. microslide 2277 , B.M.R. negative 6/3336)
Mag. about x 15.

It is thought that water for the lake or lakes was derived initially from springs rather than from rainfall, which is supported by the presence of probable spring travertine textures within the basal detrital zone. The spring textures probably reflect spring action during an early phase of the rising watertable at the inception of lacustrine conditions.

The lake or lakes were initiated on a surface that was rich in lateritic detritus resulting from the erosion of the mature laterite profiles. The phase of accumulation of this detritus probably took place prior to the inception of lacustrine conditions, and it is likely that only minor redistribution of this material took place during the deposition of the limestones. The detritus was cemented by the precipitation of calcium carbonate in interstitial areas and by spring travertine and is regarded, for convenience, as part of the limestone sequence.

(e) Noranside Limestone.

Fossils include ostracods, plant tissue, gastropods, diatoms and possibly other algae. Ostracods do not weather out on the surface of the rock and were observed only in thin sections of rocks from near Noranside Homestead.

Thin-shelled turretted gastropods, plant tissue and diatoms are common in limestones containing ferruginous detritus along 6 Mile Creek near the Fort William - Corrie Downs boundary. The best exposure is at a fence corner, 1.4 miles west of 6 Mile Bore on Corrie Downs. Forms identified from this locality are (Crespin, pers. comm.):

gastropod : ? Bulinella sp.

diatoms : Diploneis cf. eliptica

Epithema sp.

Navicula sp.

The diatoms present are identical to those from deposits at Innot Hot Springs in north-western Queensland, at South Yarra in Victoria, at 8 Mile Creek in South Australia and in various spring and lake deposits in south-west Western Australia (Crespin, 1947).

A similar environment to that in which the Austral Downs Limestone was deposited is postulated for the Noranside Limestone.

When considering the age and relationships of the Tertiary formations in this area, two considerations must be made.

(1) The relationships of the formations to one another.

(2) Their position with respect to the time scale.

IX AGE AND RELATIONSHIPS

(a) Age from laterite.

Various ages have been assigned to lateritization in Australia. For example, Bryan and Jones (1946) regarded the period of laterite formation as Miocene, whereas Whitehouse (1940) deduced two periods of lateritization during the Pliocene. It has been suggested also, that lateritization is still active in some parts of Australia or has been so in the not distant past, though on a less intense scale.

Lateritization was certainly active in Australia during these times. However, it is the author's opinion that the formation of laterite profiles (i.e. the preservation in situ of the products of chemical deep weathering) is controlled in any one area during an overall time of lateritization, by the stability or instability of the surface exposed to weathering at that time. This is thought to be because gentle regional earth movements during a time of lateritization will upset the surface stability, resulting in the erosion of the developing laterite profiles, while laterite formation continues in adjacent regions. This was apparently the case in western Queensland where gentle regional earth movements were a feature of Tertiary history. Here the laterite profiles were being stripped in the Boulia region while lateritization was active in the south-west of the state. This is suggested by the lateritization of the equivalents of the Marion Formation (M.A. Reynolds, B.M.R. pers.comm.) and younger deposits in the south-west, while in the Boulia region, the silicified Marion Formation was deposited on the eroded laterite profile developed on the Cretaceous rocks.

Hence it is suggested that the time limits of the formation of lateritic profiles may change from region to region and caution must be exercised in using the laterites as agents of correlation. As a result, it is contended that :-

(1) The products of lateritization can be satisfactorily used only in local correlation. Figure 6 (Diagrammatic Relationships of Tertiary Formations) is largely based on this principle.

(2) The products of lateritization can be used in giving relationship to the time scale only when the limits of lateritization can be locally established. For example, Condon (1954) was able to show by the study of lateritized marine sediments of known age, that in the Carnarvon Basin of Western Australia, lateritization took place from the Eocene to the late Miocene or possibly Pliocene.

There is no evidence to establish the local age limits of lateritization in this area of western Queensland, and so the laterites cannot be used to date the Post-Cretaceous deposits here.

(b) Age from Fossils.

Fossils are not plentiful in the deposits, and in many cases where they do occur, their taxonomy and ranges are imperfectly known. However, such fossil evidence as is available must be used in any suggested age estimate.

The Springvale Formation is probably the oldest of the Tertiary formations in the area. It overlies Wilgunya Formation (Aptian and Albian) and the Winton Formation regarded as Cenomanian or younger by Whitehouse (1954). The formation is possibly lateritized and is overlain by probable late Tertiary or early Quaternary limestone. An Upper Cretaceous or early Tertiary age is hence suggested.

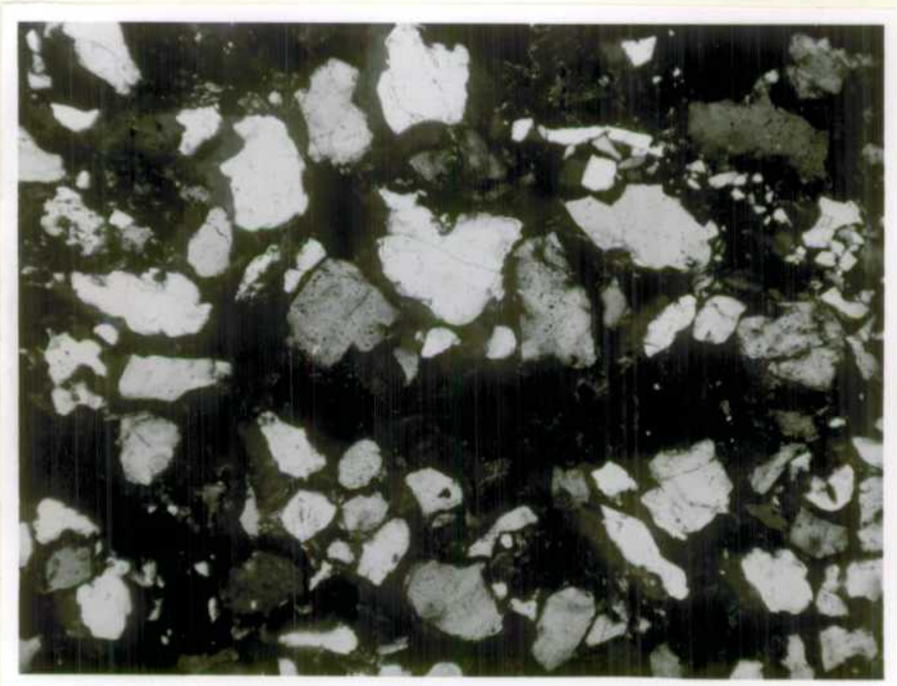
The Marion Formation was deposited on the eroded laterite profile (mottled zone) developed on the Wilgunya Formation. A late Tertiary age is suggested.

FIG. 6 DIAGRAMATIC RELATIONSHIPS OF TERTIARY FORMATIONS

	SPRINGVALE BASIN	MARION BASIN	AUSTRAL DOWNS BASIN	NORANSIDE BASIN
POST-LATERITE.	HORSE CREEK FORMATION	MARION FORMATION	AUSTRAL DOWNS LIMESTONE	NORANSIDE LIMESTONE
LATERITE	SPRINGVALE FORMATION			
PRE-TERTIARY "BEDROCK"	UPPER and LOWER CRETACEOUS	LOWER CRETACEOUS	LOWER PALAEOZOIC CARBONATES	LOWER CRETACEOUS and LOWER PALAEOZOIC CARBONATES.

PLATE 14.

(a) Scarp of Tertiary sediments on west side of Diamantina River, Springvale. Horse Creek Formation (H C) fills synclinal warp in the Springvale Formation. (S)



(b) Billy, Marion Formation, 12 Mile Mountain. Chemically eroded quartz grains (light) set in opaline silica matrix (dark) x nicols x 45
(G.S.Q. microslide 2276, B.M.R. negative 6/3335)

On the grounds of position, type of deposit and lithology, the Austral Downs and Noranside Limestone are regarded as equivalents. The Noranside Limestone overlies the Marion Formation on Windsor Park. Diatoms from the Noranside Limestone are late Tertiary or early Quaternary (Crespin pers. comm.) and charophytes from the Austral Downs Limestone have modern affinities. On this basis, it is suggested that these limestones are late Tertiary or early Quaternary in age.

There is no direct evidence for the age of the Horse Creek Formation. It unconformably overlies the Springvale Formation. It may be equivalent to the Noranside Limestone (tectonically related) or, since it lacks the characteristic silicification of the Noranside and Austral Downs Limestones it may be younger. A later Tertiary or early Quaternary age is suggested.

The Mount Coley Sinter overlies the eroded laterite profile developed on the Lower Cretaceous Wilgunya Formation. Since the sinter contains detritus from the ferruginous zone at its base, the cycle of erosion on the lateritized surface was probably not far advanced. This indicates that it may have been deposited contemporaneously with the Austral Downs and Noranside Limestones and hence a late Tertiary or early Quaternary age is suggested.

X TECTONICS

Post-Cretaceous tectonics are most clearly expressed in the history of the Springvale Basin. Field evidence points to at least two periods of earth movement - that which initiated the basin and that which followed the deposition of the Springvale Formation but predated the Horse Creek Formation.

The Springvale Basin was emplaced on the southern-most extension of a linear tectonic belt (the Burke River Structure) in which faulting and folding were active at least from the lower Palaeozoic and affected rocks ranging in age from Procambrian to Tertiary.

In the Black Mountain area about 80 miles to the north of Springvale, the Burke River Structure is a north-north-west trending graben structure with a western fault (Black Mountain) with upthrow to the west. An eastern fault (Momedah) is some distance to the east with upthrow to the east (Casey et al.1960). The western fault can be traced almost continuously to Uka Tank south of Springvale, but the Momedah Fault cannot be traced in the field beyond the Momedah area.

On Springvale Station, the Burke River Structure is expressed as a strong north to north-north-west trending fault zone passing to the west of the homestead. Lower Cretaceous marine shales and concretionary limestone (Wilgunya Formation) are faulted and domed against the Upper Cretaceous fresh water sediments (Winton Formation). The upthrow (Wilgunya Formation) is on the west side of the fault zone.

These post Upper Cretaceous movements initiated the Springvale Basin; the basin being confined to the southern extension of the Black Mountain-Momedah graben structure. There is no field evidence indicating faulting on the Momedah line in the Springvale area, however gentle warpings occur (air photo interpretation).

Post-Springvale Formation movements are clearly indicated. Gentle irregular tectonic dips occur within the eastern part of the Springvale Formation (the overlying Horse Creek Formation fills the synclinal areas and thins over the anticlines) (plate 14). Along the Black Mountain fault line, gentle warping and minor faulting occurred. Dips here are low and a tectonic origin is considered more probable for them than sedimentary (figure 8).

The most significant feature of the post-Springvale Formation movement is the development of a strong north-north-east trend along which minor faulting occurred at Uka Tank 20 miles south of Springvale Homestead. This trend sharply cuts off the north to north-north-west trending Black Mountain fault zone which cannot be traced to the south. Like the Black Mountain trend, this north-north-east trend is probably a reflection of old basement faulting.

North-north-east trends are the important post Cretaceous structural directions in the south-western portion of the Great Artesian Basin. This is the direction of the fold axes in the Innamincka and Betoota areas which are thought by Sprigg (1958) to have been initiated late in the Cretaceous and continued during the early Tertiary and controlled by strong bedrock faulting. Movement in this trend direction may have continued somewhat longer in the Springvale area.

The position of the Tertiary Basins on the shelf of Palaeozoic and older rocks is clearly related to the present river valley system (fig.7) whereas those developed on the Artesian Basin are not. The river valleys on the shelf (Georgina and upper Burke) predate the Tertiary cycle of deposition and have been little modified since, whereas the lower courses of these rivers (on the Great Artesian Basin) are a younger feature and post-date this.

There is no clear evidence indicating the cause of the damming of the upper Georgina Valley which initiated the Austral Downs Basin. The basin was almost wholly confined to the shelf area and persisted to its southern margin so that there is strong suggestion that it was initiated by very broad warpings or epeirogenic movement within the Great Artesian Basin. The same movements may have initiated the Noranside Basin although its adjacency to the Burke River Structure suggest that late movements on that structure (such as those that initiated the Horse Creek phase in the Springvale Basin) may have been the controlling factor.

Significant movement took place after the deposition of the Austral Downs and Noranside Limestone. This was a slight regional tilt to the south which destroyed the lakes and initiated the present Lake Eyre internal drainage system. (A previous southern drainage system existed in the Great Artesian Basin prior to the deposition of the Marion Formation). Springs along the junction of the Artesian Basin sediments and the Palaeozoic carbonate rocks in the Black Mountain area which had previously drained into the Noranside lake were destroyed leaving the mud springs near Mount Datson as the most northern point of artesian leakage in the area.

This tilt to the south was measured by levelling the surfaces of the Noranside and Austral Downs Limestones. There is a difference in elevation of about 130 feet between Tobermory and Glenormiston, 90 feet between Jimboola and Glenormiston and 200 feet between Noranside and Glenormiston and 200 feet between Noranside and Boulia. Gentle meridional warping, possibly related to late movement along the Burke River Structure, caused the Burke River to migrate from the position of the Noranside Basin west to its present position.

The two dominant structural trends in far western Queensland (N.N.W. and N.N.E.) are reflected in the present river system (fig.7). River valleys in the shelf area, e.g. the upper Georgina System, trend roughly south-east to south-south-east and are related to the north-west to north-north-west structural trends (e.g. Burke River and Toko Structures). In the Great Artesian Basin, the younger river valleys e.g. Coopers Creek, Diamantina River, Hamilton River, [illegible] the lower reaches of the Burke River and Eyre Creek trend generally south to south-south-west in consequence of the north to north-north-east trends.

PLATE 15

(a) Columnar billy in upper part of billy profile
Orientos area, S.W. Queensland.
(B.M.R. negative 6/2273)

(b) Columnar billy Mt. Ninmaroo.
(B.M.R. Negative 6/2282)

Exceptions occur :-

(a) Well defined north-north-east trends in Strzelecki Creek and north-north-west trends in the Mulligan River are a reflection of the strongly developed parallel desert dune system of the area. The rivers run parallel to the dune direction. Dune directions in the south-western area are given in King (1960).

(b) Strong south-east and north-west directions in Eyre Creek lie on the south-eastern production of the Toko (synclinal) Structure and may have resulted from small late movement in that belt.

(c) Anomolous south-east and north-west trends occur in Coopers Creek in the area of the strong north-north-east trending structures of Betoota and Innamincka.

XI SILICIFICATION.

Silicification of the Marion Formation and the Austral Downs and Noranside Limestones warrants discussion.

(a) Marion Formation.

The arenaceous Marion Formation was almost entirely silicified to form billy - a brownish, siliceous rock containing scattered, apparently angular quartz and other siliceous grains. Excellent exposures of the silicified Marion Formation are widespread in the Marion Downs area, for example at 12 Mile Mountain on the Boulia - Bedourie Stock Route.

A distinct profile of billy formation is developed on the Marion Formation. This profile shows a well-defined decrease of silicification downwards from the upper surface (old erosion surface) of the formation to the base. At the base, the porous sandstone texture and sedimentary structures are preserved, but this grades upwards into a dense, but sometimes porous siliceous rock in which the proportion of matrix to grain size increases towards the top of the profile. In the upper levels, a pseudo-conglomerate texture develops which characteristically occurs in closely associated vertical columns which are a feature of the upper surface of the profile (plate 15). In the area of investigation, columns up to 4 feet high were observed, but Woolnough (1927) reports columns up to 15 feet high and 3 feet in diameter from billy occurrences in South Australia.

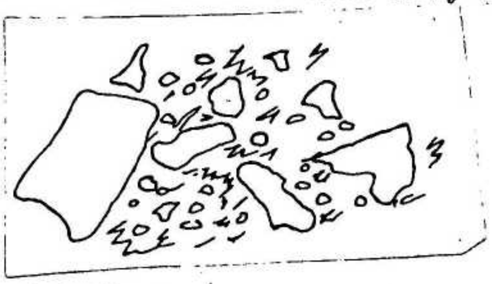


Fig.9. Typical billy texture of apparently angular quartz grains of various sizes commonly with indistinct outlines set in a siliceous matrix. Grain contact is low.

Basically, the process of billy formation involves the siliceous replacement or transformation to amorphous silica of the siliceous grains in sandy rocks. This results in a reduction in grain size and grain contact and hence an increase in intergranular area. There is a reduction in grain size from the base to the top of the billy profile. The resultant siliceous intergranular material is a dense, but sometimes porous, amorphous mass which may contain laminar structures in the upper levels of the profile.

Characteristically the sand grains are of irregular size and shape, giving the impression on first examination of an unsorted, little worked silicified sandy siltstone. However, the condition of the grains is obviously post-depositional since grains margins are commonly indistinct, lustrous transparent quartz grains have become dull and opaque and grade into the matrix and sharp re-entrant angles in the grains are extremely common (figure 10). Quartz grains are replaced more readily than chert.

FIG. 10

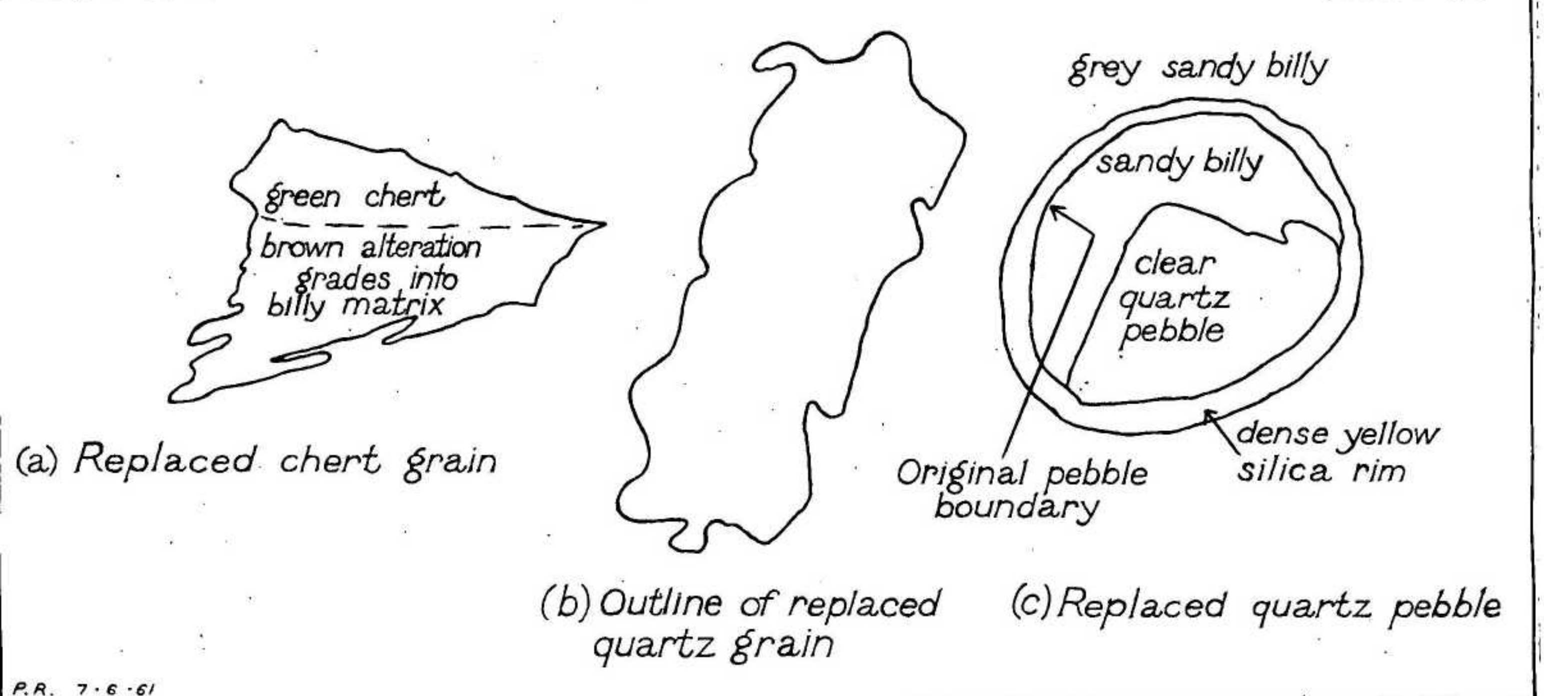


Figure 10. Clastic grains from billy.

Silicification involves replacement or transformation of the siliceous grains to opaline or chalcedonic silica. Hybrid forms of silica occur between chalcedony and opal. Thus a common form has the low refractive index of opal but the spherulitic interference pattern of chalcedony.

The pseudo-conglomerate structures bear no relationship to the form of the original sediment and develop high in the billy profile irrespective of the size of the initial clastic grains. They are smooth surfaced, roughly spherical bodies of billy set in a matrix of the same material. These bodies weather out on the surface of the columnar masses with a characteristic elongate-downwards shape (plate 15).

Common colours are honey-brown and grey. Rare areas of red-brown ferruginized billy occur sporadically on a small scale and hence there may be minor iron oxide concentration during its formation. Iron oxide commonly occurs in granular form and as stainings at the base of the Marion Formation. It is thought that this is of detrital origin, due to the deposition of the formation on a lateritized (ferruginized) surface which was being locally eroded, and not a zone of chemical iron oxide concentration (ferruginous zone) at the base of a profile of billy formation.

The joints in the underlying fractures, lateritized lower Cretaceous clays are in some casesfilled with lustrous common opal which may be iron rich.

Partial analysis of one specimen of billy revealed a low percentage of alumina which was probably derived from original argillaceous material in the sandstone.

There is no evidence for an outside source for the silica involved in the process of silicification. On the other hand, silica is obviously derived from the replacement or transformation of the siliceous grains of the rock mass as is shown by their corroded nature.

Increase in volume of silica takes place during the transformation of quartz to common opal. Depending on the initial free pore space in the original rock, this increase in volume may be sufficient to produce the dense billy without significant increase or decrease in volume of the rock mass. However it is unlikely that the increase in volume of silica will equal the free pore space, and change in volume will occur.

Increase or decrease in the volume of the mass, without its fracturing requires a liquid or gel phase during the billy formation. The occurrence of such a stage, allowing movement of the grains during silicification is supported by thin section evidence - (a) fragments of the same replaced grain rarely have the same optical orientation, in fact it is rare to find fragments of the same grain adjacent; (b) the extremely commoh occurrence of replaced surfaces of different grains lying in close proximity, allowing insufficient space for the existence of the original grains without movement towards one another during silicification. This is the general rule and is responsible for the unsorted and irregular texture of the rock. Sharp angled, apparently fractured grains suggest that some grain fracturing occurs during the process. Only rarely was open pore space filling (indicated by regular layering of siliceous cements) observed.

The strongly developed columnar jointing and pseudo-conglomerate structures developed at the top of the profile may result from tension caused by reduction in volume due to the drying out of the gel phase.

The billy texture can only be developed on sandy rocks as the process involves the break down and not build up of the sand grains. It is not clear whether equivalents of billy occur on argillaceous rocks. Some of the so called porcellanites of Western Queensland may be of this type. However the original rock must be sufficiently siliceous, and the silica in a form suitable for alteration, for it to respond to the billy-forming processes.

The Marion Formation is an extensive deposit. It was observed in reconnaissance as far south as Bedourie and it extends to the south beyond this. In all outcrops where the base of the formation was exposed between Windsor Park and the southern margin of the Springvale 4 Mile Sheet Area, the Marion Formation was silicified and overlaid the eroded laterite profile developed on the Cretaceous rocks of the area. The Marion Formation is hence locally a post-laterite deposit and the billy that was developed on it is also a post-laterite feature.

Formation of the extensive, thick sheet billy that occurred in western Queensland required equally extensive areas of predominantly sandy rocks on which to form. In this case, the widespread Tertiary arenaceous deposits and others were the host material. In areas of dominantly argillaceous rocks the extensive billy sheets did not develop but billy formed as scattered nodules in any sandy parts of the exposed deposit.

The extensive billy sheet persists into the Innamincka-Betoota area in south-western Queensland where folding has taken place after its formation. Here Tertiary sandy sediments similar to those of the Marion Formation unconformably overlie Upper Cretaceous shales and silts (Wepfner, 1960). Both Tertiary and Cretaceous sediments have been lateritized and the billy is developed in the highest of the Tertiary beds. Beyond this, the relationship between the billy and the lateritized sediments is not indicated by Wepfner. An interesting feature of this area is the development of pisolitic laterite on sands which unconformably overlie the billy surface.

Silicification to form billy is not confined to the Marion Formation, but also affected other quartzose rocks of various ages. Excellent billy formed on the Lower Cretaceous Longsight Sandstone on Mount Ninmaroo near Boulia on Ordovician sandstone in the Toko Range and on ?Permian fluvio-glacials near Aroota Bore, Tobermory.

There are many indications that silicification of the billy type was superimposed on the laterite profiles in south-western Queensland. At Mount Leonard, Betoota, nodules of billy occur in the sandy ferruginous zone of the laterite, the top 45 feet of the eroded profile being also siliceous.

The two most significant features of billy formation which give indication of its origin are its widespread distribution on the Australian Continent on rocks of various ages and the fact that it formed a distinct profile in which silicification decreased downwards from a surface which was either at or near the land surface. This indicates that the controlling influence was external to the rock mantle, i.e. climatic.

The type of climatic environment involved is not known. It may be analogous to that causing lateritization although billy formation presents many features incompatible with lateritization. It is suggested by the common association of billy and laterite, that the two processes go on contemporaneously but this may be due to the fact that both processes occurred at about the same time, being both weathering effects acting on closely comparable surfaces.

Many authors associate billy formation with lateritization, but other than this, few attempt to explain its mode of origin. Whitehouse (1940) concluded that silicification, including billy formation, occurred during lateritization and was not confined to any particular portion of the laterite profile but was "sporadically developed throughout the whole section". Extensive sheets of billy, such as those described in the present paper, were regarded by Whitehouse as occurring low in the laterite profile below mottled zone material. He sites the billy sheet at Currawinya, which is developed on sandstone and granite, as an example (see Whitehouse p.7). However he presents no evidence to support the existence of a mottled zone above the billy and apparently assumes that it occurred but was stripped completely by post-laterite erosion.

Condon (1954) described six occurrences of laterite from the Carnarvon Basin of Western Australia. Of these, four were capped by up to 10 feet of billy. The billy was regarded as having formed in the upper zone of the laterite profile developed on arenaceous sediments. A common feature was silicification of the mottled zone but this was not described as billy by Condon.

Wide occurrences of billy in the Central Highlands of Queensland are closely associated with basalt flows. A number of authors have ascribed the formation of billy to thermal metamorphism of sandstone by overlying lavas (e.g. Reid 1928). Turner and Verhoogen (1951 p.116) state "On theoretical grounds alone, it would seem likely therefore that basaltic magma should be capable of dissolving (melting) considerable quantities of sedimentary material".

Billy developed on Permian marine sandstone was examined in the Clermont district, but no thin sections were prepared. In the hand specimen, it is identical in appearance with the sheet billy of western Queensland. Dunstan (1900) described the billy from this area and concluded that its formation was not related to contact metamorphism but to "some surface action, and that this action has affected sandstones of all ages which were exposed on the surface at that time". He sites considerable field evidence to support this claim. In the light of the later recognition of the widespread occurrence of billy in Australia that clearly had no relationship to basalt flows, Dunstan's statement is most significant and represents advanced thinking at a time when the processes of chemical weathering were not widely understood in this country.

It is here suggested that the relationship between at least some of the basalt flows and billy may not be a genetic one, and that it merely indicates the protection by basalt of an old silicified land surface, such as occurs so commonly elsewhere in Australia, from erosion. The absence of billy in areas that are locally free of basalt cover may be explained by the erosion of the unprotected parts of the old surface. However, more field investigation and petrographic studies must be undertaken before the true significance of billy in basaltic areas is understood.

Woolnough (1927) proposed the name "duricrust" for the hard siliceous surface crust developed throughout Central Australia. This term includes billy but the definition is wide and appears to include as well, other hard products related either to the billy-forming process or to lateritization. If billy has been formed by a number of processes as many workers have suggested, it is a multigenetic term and re-definition may be desirable. However, such action should not be taken until the problem has been thoroughly investigated and criteria established for the recognition of the different types, if they exist.

Where the billy crust overlies soft rock as in the Great Artesian Basin, erosion is extremely rapid once the crust is pierced, and break-up of the billy results. Broken and rounded billy (gibbers) thus formed blanket enormous areas of inland Australia. Such areas are known as gibber plains or stony desert. In western Queensland, gibber plains extend from Boulia to the South Australian and New South Wales borders.

(b) Austral Downs and Noranside Limestones :

A chalcedonic cap is a constant feature of this type of chalcedonic limestone. The presence of residual limestone textures within the chalcedony, and the irregular veining of the limestone by chalcedony, strongly suggests silicification of the limestone. The silicification forms a distinct profile with the concentration of silica decreasing from the top to the bottom, and so giving the appearance of silicification of a surface. This is similar to the profile of silicification produced in the formation of billy.

As in the case of billy formation, there is no obvious outside source for the silica involved, and it must be assumed that the silicification involved the concentration or redistribution of primary silica that was deposited with the limestone, into the upper levels of the sequence.

The deposition of silica and calcium carbonate together in a lacustrine environment presents many problems since they are soluble in water at different pH values. The mechanism involved in this deposition is not understood. It is possible that silica was extracted from the water by siliceous organisms such as diatoms or sponges but if this is the case the proportion of residual diatoms in the limestone is very small and sponges are not known from the deposits in Queensland.

The presence of an upper zone of white chalcedony in the Mount Coley sinter deposits probably indicates silicification of this type.

XII ACKNOWLEDGEMENTS

The author wishes to acknowledge the work of fellow members of the joint Bureau of Mineral Resources - Geological Survey of Queensland and Georgina Basin and Springvale field parties of 1957-59, namely J.N. Casey, M.A. Reynolds, D.B. Dow, P.W. Pritchard, R.R. Vine and K.G. Lucas.

M.A. Condon, Assistant Chief Geologist, Dr. A.A. Öpik, Supervising Geologist and the above party members of the Bureau of Mineral Resources, and T.H. Connah, Senior Geologist of the Geological Survey of Queensland assisted in no small way by their criticism and willingness to discuss the many problems encountered.

The author is grateful to members of the Micropalaeontological Section of the Bureau of Mineral Resources under Dr. Crespin, for the examination of some of the palaeontological material collected and to members of the staff of the Geological Survey of Queensland who assisted in the preparation of numerous thin sections and examination of specimens submitted to the laboratory.

XIII BIBLIOGRAPHY

Ball, L.C., 1911: The Burketown Mineral Field. Qld. Geol. Surv. Pub. 232.

Bradley, W.H., 1929 : Algal Reefs and Oolites of the Green River Formation. U.S. Geol. Surv. Prof. Paper, 154 (G).

Bryan, W.H., & Jones, O.A., 1946: The geological history of Queensland - a stratigraphical outline. Univ. Qld. Dep. Geol. Paper 2(12).

Cameron, W.E., 1901 : Geological observations in north-western Queensland. Qld. Geol. Surv. Annual Progress Rep. for 1900, 186-191.

Carter, C.E., 1959 : Fossil wood from the Boulia-Glenormiston area, north-west Queensland and eastern Northern Territory. Bur. Min. Resour. Aust. Rec. 1959/42

Casey, J.N., 1959 : New names in Queensland stratigraphy Aust. Oil Gas J., 5(12), 31-36.

Casey, J.N., Reynolds, M.A., Dow, D.B., Pritchard P.W, Vine, R.R., & Paten R.J., 1960 : The geology of the Boulia area, western Queensland. Bur. Min. Resour. Aust. Rec. 1960/12 (unpublished).

Condon, M.A., 1954 : Progress report on the stratigraphy and structure of the Carnarvon Basin, Western Australia. Bur. Min. Resour. Aust. Rep. 15.

Connah, T.H., 1958 : Summary report limestone resources of Queensland. Qld. Geol. Surv. Pub. 292.

Crespin, I., 1947 : A study of Australian diatomites with special referance to their possible value as filter media. Bur. Min. Res. Aust. Bull. 7.

Daintree, R., 1872 : Notes on the geology of the Colony of Queensland. Quart. J. Geol. Soc. Land 28, 271-317

David, T.W.E., 1914 : The geology of the Commonwealth; in Federal Handbook on Australia. Brit. Ass. Adv. Sci. Melbourne

Dunstan, B., 1900 : The Permo-Carboniferous coal measures of Clermont and associated formations. Qld. Geol. Surv. Pub. 149.

———— 1920 : Geological notes on the Cloncurry - Camoweal - Burketown - Boulia area. Qld. Geol. Surv. Pub. 265.

Fisher, N.H., 1958 : Notes on lateritization and mineral deposits. Aust. Inst. Min. Metall., F.L. Stillwell Anniversary Vol. 133-142.

Glaessner (see end)

Horn af Rantzien, H., 1959 Morphological types and organ-genera of Tertiary charophyte fruitifications. Stockholm Contr. Geol., IV (2), 47-197

Jack, R.L., 1896 : Stratigraphical notes on the Georgina Basin with reference to the question of artesian water Proc. Roy.Soc.Qld., (11 (1), 70-74.

King, D., 1960 : The sand ridge deserts of South Australia and related aeobian land forms of the Quaternary arid cycles. Trans. Roy.Soc. S.Aust.,83,99-108.

Konecki, M.C., Dickins, J.M. & Quinlan, T., 1958: The geology of the coastal area between the Lower Gascoyne and Murchison Rivers, Western Australia Bur.Min.Res.Aust.Rep.37.

Ludbrook (see end)

Madigan, C.T., 1932 : The geology of the eastern McDonnell Range, Central Australia. Trans. Roy. Soc.S.Aust.,51,71-117.

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.Sur.,3,34-41.

Noakes, L.C.,Carter,E.K., and Opik,A.A., 1959 : Explanatory notes on the Urnadangi 4 mile geological sheet., 2nd edition. Bur.Min.Res.Aust. Explanatory Notes,1.

Paten,R.J.,1960 : Lacustrine sandstones and limestones and spring sinters of far western Queensland; in the geology of Queensland. J.Geol.Soc.Aust.,7 391-393.

Peck, R.E., 1957 : North American Mesozoic Charophyte U.S. Geol.Surv. Prof.Paper.294(A).

Pettijohn,F.J.,1957 : Sedimentary rocks 2nd edition, Harper and Bros.,New York.

Playford (see end)

Reid,J.H., 1928 : The Isaacs River Permo-Carboniferous coal basin. Qld.Govt.Min.J., 29,192-197,236-241,282-285.

Reynolds M.A., 1960 : Geology of the Springvale Area, Bur.Min.Res.Aust.Record 1960/92 (unpublished)

Smith (see end)

Sprigg,R.C., 1958 : Petroleum Prospects of western parts of Great Australian Artesian Basin. Bull.Amer.Ass. Petrol.Geol. 42, 2465-2491.

Swineford,A., Leonard, B., and Fryre, J.C.,1958 : Petrology of the Pliocene pisolitic limestone in the Great Plains State Geol. Surv. Kansas Bull. 130

Traves (see end)

Traves, D.M., Casey,J.N. and Wells, A.T.,1956 : The geology of the south-western Canning Basin, Western Australia. Bur.Min.Resour.Aust.Rep.29.

Turner, F.J., and Verhoogen, J., 1951 : Igneous and Metamorphic Petrology. McGraw-Hill Book Coy., Inc., New York.

Whitehouse, F.W., 1940: Studies in the late geological history of Queensland. Uni. Qld. Dep. Geol. Pap. 2 (1).

__________ 1954: The geology of the Queensland portion of the Great Artesian Basin. Appendix G, in Artesian water supplies in Queensland. Dep. Co-ord. Gen. Public Works Parl. Pap. A., 56 - 1955.

Woolnough, W.G., 1927 : The chemical criteria of peneplanation. J. Roy. Soc. N.S.W., 61, 17-53.

Wopfner, H., 1960 : On some structural development in the central part of the Great Artesian Basin. Trans. Roy. Soc. S. Aust. 83, 179-193.

Glaessner, M.F., 1945 : Principles of Micropalaeontology, Melbourne Univ. Press Melbourne.

Ludbrook, N.H., 1953 : Foraminifera in Sub-Recent sediments at Lake Eyre, South Australia. Aust. J. Sci., 16 (3) 108-109.

Playford, P.E., 1954 : Observations on laterite in Western Australia. Aust. J. Sci. 17 (1) 11-14.

Smith, K.G., Vine, R.R. and Woolley, D.R.G., 1960 : Geology of the Huckitta area; second progress report. Bur. Min. Resour. Aust. Rec. 1960/66 (unpubl.)

Traves, D.M., 1955 : The geology of the Ord-Victoria Region Northern Australia. Bur. Min. Resour. Aust. Bull. 27.

APPENDIX

ADDITIONAL NOTES ON CHALCEDONIC LIMESTONES

(a) Australian Distribution.

Limestones similar to the Austral Downs and Noranside Limestones have wide distribution in Australia. In Queensland, a number of small outcrops occur between Boulia and Birdsville. The best known of these are at Cacoory and Old Roseberth (Whitehouse, 1940) and there are two small previously unreported areas about one and ten miles south of Breadalbane Homestead.

The Carl Creek Limestone (Jack, 1896) at Riversleigh in North-West Queensland was deposited in an area of Cambrian Limestone in the Gregory River Valley. It consists of lacustrine or spring limestone with abundant fossil bones and gastropods. Since the deposit overlies lateritic detrital material, it may be of similar type to the Austral Downs and Noranside Limestones, but it lacks the characteristic silicification. This deposit is described by Whitehouse (1940) and has been referred to by Daintree (1872), Jack (1896), Cameron (1901), Ball (1911), David (1914), Dunstan (1920), Connah (1958) and Paten (1960). Noakes and Traves (1954) named this deposit the Verdon Limestone but "Carl Creek Limestone" must take priority.

Konecki, Dickens and Quinlan (1958) described chalcedonic limestone from the Gascoyne River Region of Western Australia. The sequence is 30 feet thick with a thin band of shale and red stained quartz greywacke at the base. This deposit, which is not closely related to calcareous bedrock, was regarded as a lacustrine deposit related to the last cycle of erosion.

Traves, Casey and Wells (1956) described the Oakover Beds, a chalcedonic limestone sequence up to 100 feet thick in the Canning Region of Western Australia. A five foot band of derived lateritic detritus marks the base of the deposit. Basement to the Oakover Beds includes dolomitic limestone, tillite and metamorphics. The authors concluded that these beds were a chemical lacustrine deposit formed in the old Oakover River Valley.

The White Mountain Formation from the Ord River Region of Western Australia (Traves, 1955) consists of up to 370 feet of chert, siltstone and marl containing gastropods, algae, foraminifera, sponges, ostracods and insects. It overlies sandstone basement. Traves thought that the formation was of the same type as the Austral Downs Limestone, but pointed out the significant difference in the high proportion of clastics in the White Mountain Formation.

Madigan (1932) and Smith, Vine, and Woolley (1960) described up to 90 feet of gastropod bearing chalcedonic limestone, limestone and rare clastic sediments - the Arltunga Beds - from the Arltunga - Plenty River Region of the eastern Northern Territory. The deposit contains lateritic detritus at the base or overlies ferruginous laterite in situ. The Arltunga Beds overlie a basement of Archaean gneiss.

Noakes and Traves (1954) described the Burnette Limestone, a chalcedonic limestone similar to the Austral Downs Limestone from the Barkly Region of the Northern Territory.

(b) Origin of the deposits

The Austral Downs and Noranside Limestones overlie carbonate rocks which provide a ready source of carbonate for their deposition. A major area of the Oakover Beds (Traves et al., 1956) also overlies carbonate bedrock, and it is significant that these three deposits are by far the largest of those described.

APPENDIX continued

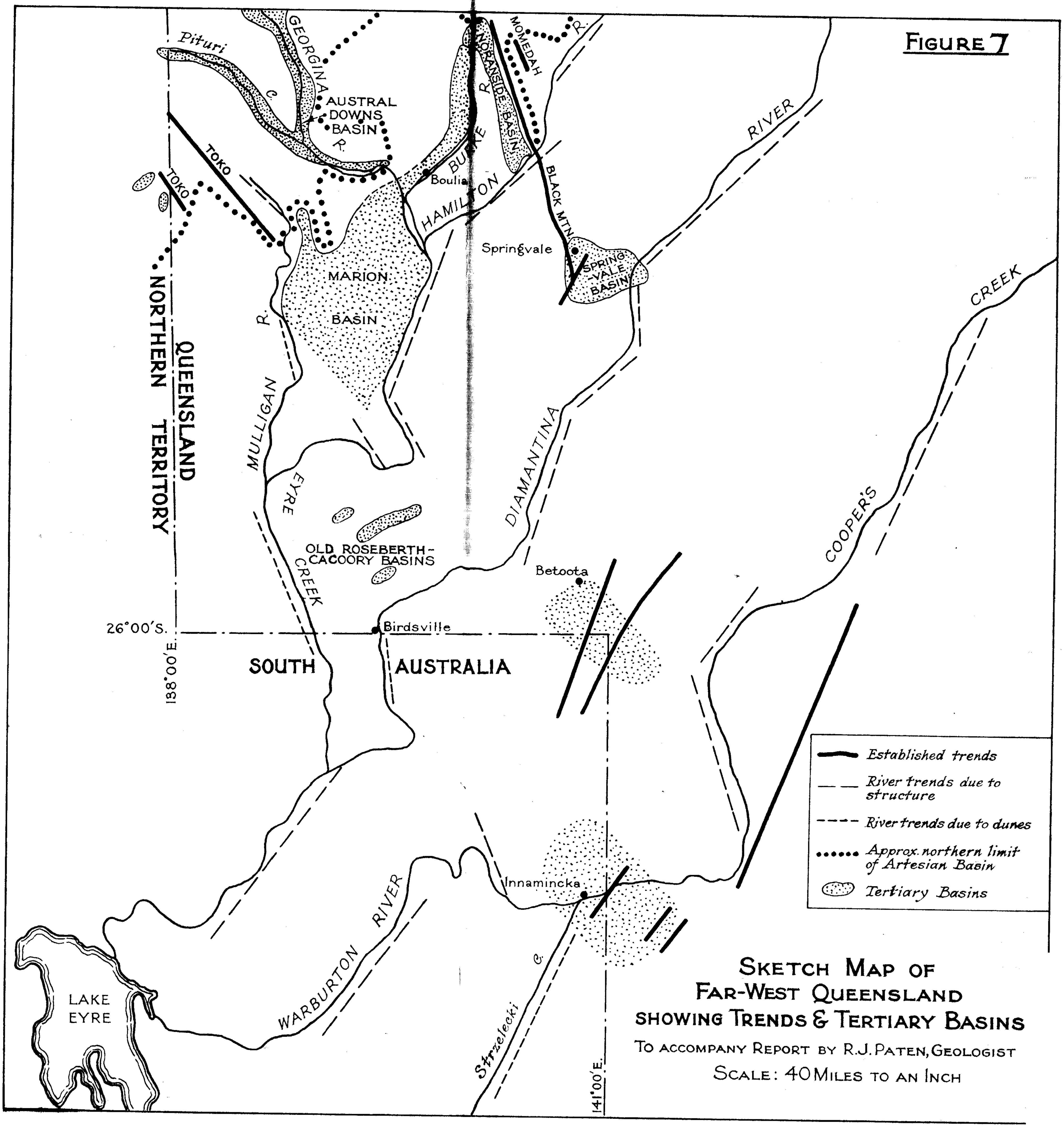
A number of chalcedonic limestone, however, are not related to calcareous bedrock; e.g. those deposits between Boulia and Birdsville and in the Gascoyne River area which overlie argillaceous sediments, the White Mountain Formation which overlies sandstone, and the Arltunga Beds which overlie metamorphics.

In almost every case, irrespective of bedrock, there is a close relationship between the chalcedonic limestones and the laterites; i.e. the limestones overlie ferruginous lateritic detritus, or rest directly on the ferruginous zone of the laterite in situ. This is regarded as the key to the origin of the chalcedonic limestones of this type.

A number of authors have noticed this relationship in the past, e.g. Konecki et al. (1958), Traves (1955), Noakes and Traves (1954) and Noakes, Carter and Opik (1959) and have regarded lateritization as the source for the calcium carbonate and silica in the deposits.

Noakes et al. (1959) when considering the source of silica and carbonate in the Austral Downs Limestone, suggested that "The calcium carbonate and silica freed by the processes of lateritization were carried into a lake "..... and were "deposited during a subsequent arid period". Since the laterite was to some extent dissected prior to the deposition of the limestone the persistance of such a lake, as envisaged above, seems unlikely. On the other hand, ample storage for carbonate and silica released by lateritization is provided by underground water. The mineralized water can then be released from springs during a subsequent lacustrine phase.

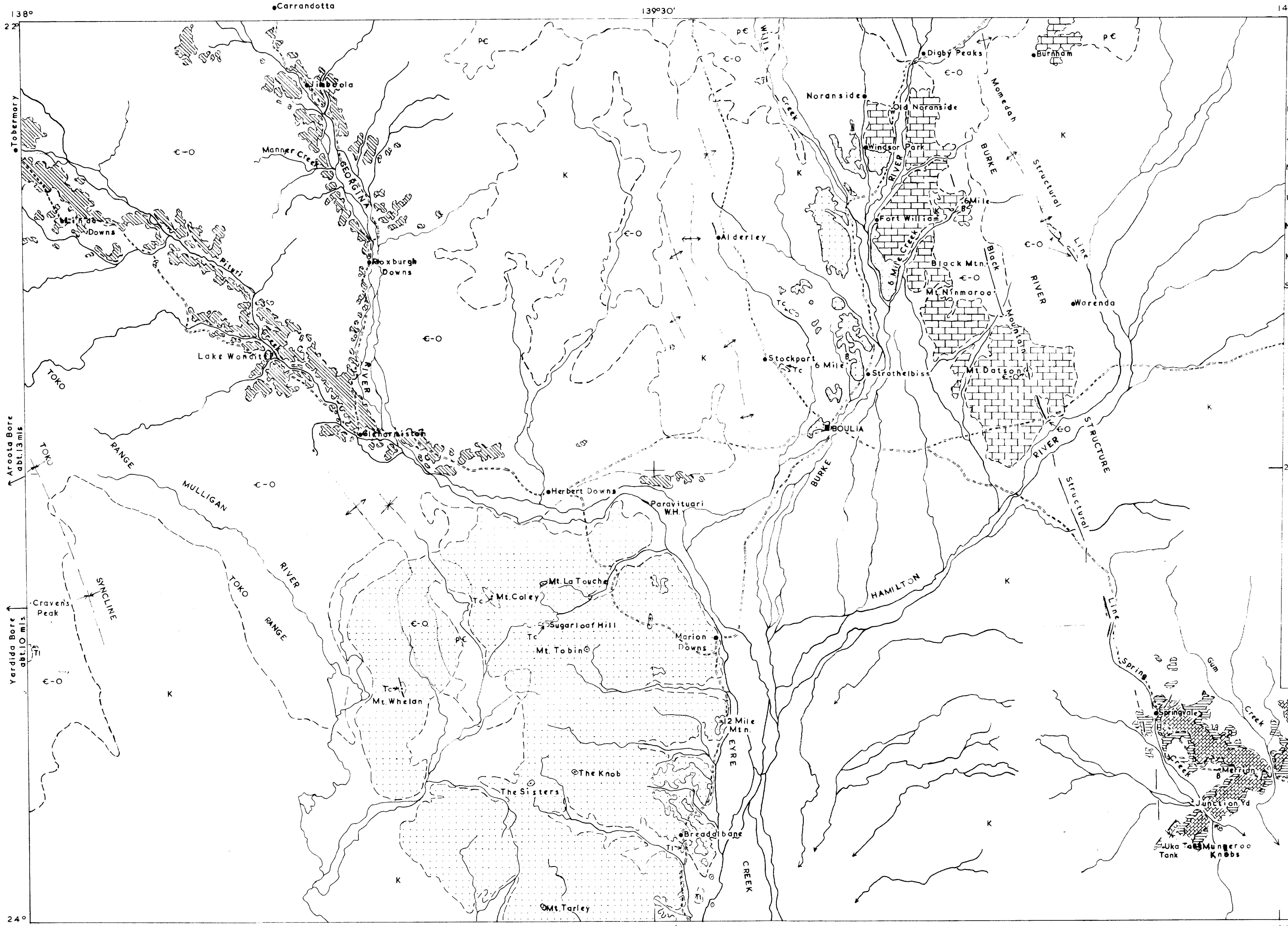
Hence the lime carbonate and silica released by the lateritization of the country rock are the ultimate source in the formation of the chalcedonic limestones. However, where the bedrock is carbonate, the proportion of available carbonate is enormously increased, and so there is a direct relationship between the size of the deposit, and the carbonate content of the bedrock.



SKETCH MAP OF FAR-WEST QUEENSLAND SHOWING TRENDS & TERTIARY BASINS

TO ACCOMPANY REPORT BY R.J. PATEN, GEOLOGIST

SCALE: 40 MILES TO AN INCH



TERTIARY

Horse Creek Formation		limestone, common opal.
Austral Downs Limestone		chalcedonic limestone.
Noranside Limestone		
Unnamed limestones	Tl	
Mt. Coley Sinter	Tc	siliceous sinter, chalcedony.
Marion Formation and derived gibber		silicified sandstone. (solid boundary denotes known Marion Formation outcrop).
Springvale Formation		silicified limestone, limestone, clay.

CRETACEOUS

K — clay, sandstone, rare limestone.

CAMBRIAN-ORDOVICIAN

€–O — dominantly carbonate rocks.

PRE-CAMBRIAN

p€ — sediments, metamorphics.

Geological boundary

Fold

Fault

Road or track

Township

Station Homestead

Locality

INDEX TO 4MILE SHEETS

Glenormiston	Boulia	
Mt. Whelan	Springvale	Brighton Dns.

TERTIARY GEOLOGY, BOULIA REGION QUEENSLAND.

Geology by J.N. Casey, M.A. Reynolds, D.B. Dow, P.W. Pritchard, R.R. Vine, K.G. Lucas, R.J. Paten.
Compiled and drawn by R.J. Paten at the Geological Survey of Queensland, May 1961 from Bureau of Mineral Resources unpublished geological maps. Photoreduction by Department of Public Lands, Brisbane. 10Mile base grid prepared by National Mapping, Canberra.

SCALE

1.0 Miles to 1 Inch

10 0 10 20 30 MILES

TERTIARY GEOLOGY RELIABILITY

Numerous traverses with photointerpretation.	
Few traverses detail sketchy.	

BASE MAP

Controlled
Uncontrolled