COMMONWEALTH OF AUSTRALIA.

DEPARTMENT OF NATIONAL DEVELOPMENT.

BUREAU OF MINERAL RESOURCES GEOLOGY AND GEOPHYSICS.

RECORDS.

1963/69

THE SEDIMENTARY PETROLOGY OF THE ALROY AND BRUNETTE DOWNS SHEET AREAS, NORTHERN TERRITORY.

by

R.A.H.Nichols

THE SEDIMENTARY PETROLOGY OF THE ALROY AND BRUNETTE DOWNS SHEET AREAS, NORTHERN TERRITORY.

by

R.A.H. Nichols.

RECORDS 1965/69.

CONTENTS

THE SEDIMENTARY PETROLOGY OF THE ALROY AND BRUNETTE DOWNS SHEET AREAS, NORTHERN TERRITORY.

SUMMARY

On the Barkly Tableland, samples were collected for petrological study of the Cambrian Anthony Lagoon Beds, Mesozoic plant-sandstones, Tertiary Brunette Limestone and Quaternary? sandstones. These rocks occur as outcrop and scree on the Alroy and Brunette Downs Sheet areas, Northern Territory. It is difficult to interpret the stratigraphical relationships within the different lithologies. Therefore, a petrological study is presented to illustrate the general variation in the area. The Anthony Lagoon Beds consist of dolomitic sponge(?) and algal limestones, dolomitic intraclastic and pelletal calcarenites, dolomitic calcilutites and dolomites; quartz siltstones and sandstones. Some of the carbonates contain fragments of trilobites and Echinodermata but the siltstones and sandstones are unfossiliferous. However, they are thought to be Cambrian in age.

The environment of deposition was shallow, warm and often current activated. Shallow, lagoonal areas of clean water, rich in $CaCO_3$ favoured the growth of algae and sponge-like structures, while more open, shelf conditions favoured the accumulation of intraclastic and pelletal calcarenites. The sandstones and siltstones probably formed nearer land, the former under current action, and the latter in a quieter, possibly restricted area.

The Mesozoic, fine-grained, fossiliferous sandstone, contains plant remains which probably drifted into a sandy environment.

The Brunette Limestone is of Tertiary age. Four samples examined consist of algal and conglomeratic, shelly limestones. They contain marine and freshwater fossils and are thought to have formed in a littoral, marine environment near a freshwater source. Rare sandstones, unlike the above rocks, occur in dried-up areas and may be Quaternary fluvial deposits.

INTRODUCTION

The Alroy and Brunette Downs Sheet areas are situated on the Barkly Tableland between latitudes 18°S and 20°S and longitudes 135°E and 136°30'E (Maps 1 and 2.) Rock samples were collected from outcrops and scree wherever there was a change in lithology. They range from PreCambrian to Recent in age. Samples were selected from the carbonates and sandstones of the Anthony Lagoon Beds (Cambrian) the fossil plant sandstones (Cretaceous); the Brunette Limestone (Tertiary) and sandstones and conglomerates (Recent) Maps, 1 and 2). The samples were cut and the surfaces etched in hydrochloric acid (10%) stained with Alizarin Red S and Potassi-Ferricyanide (St.J.Warne, 1962), and examined. Thin sections were prepared and examined under a Leitz Petrological Microscope.

The sample localities are shown on the accompanying maps (Maps, 1 and 2); and this Record should be read in conjunction with "Geology of the Alroy and Brunette Downs 1:250,000 Sheet areas, Northern Territory. (Randal and Nichols, Bureau of Mineral Resources Record 1963 unpubl.)

TERMINOLOGY

The terms suggested by Condon (1953) are used where practicable, but it is proposed to combine these terms with others from more recent studies on carbonate rocks. In the study of the clastic carbonates, the grade-size terms of Grabau (1913) and the end member concept of Krynine, (1948), are used in naming the rocks. Some of the rock names proposed by Folk (1959) which are not internationally accepted, are placed in brackets, e.g. a rock containing ooliths of sand grade size in calcite cement will be described as an oolitic calcarenite with calcite cement (Bosparite, Folk,1959).

Where diagenetic fabrics render it impossible to name all the original constituents, or it is difficult to distinguish between primary and secondary fabrics, purely descriptive terminology is used, e.g. dolomitic or siliceous limestone, or calcarenite etc. In describing diagenetic fabrics the terms proposed by Bathurst (1958) are used.

With reference to the autochthonous carbonates descriptive terminology is used e.g. algal limestone, in which the algae are in situ and the transported constituents are subordinate.

The terminology is used as follows:

Authigenic	:	Minerals generated in situ. A term applied to growth in place of occurrence including secondary enlargement; product of chemical and biochemical action.
Calcareous	:	Applied to rocks, other than carbonates (see definition of carbonate below) which contain up to 50% $CaCO_3$.
Carbonate rock	:	Rock containing more than 50% carbonate minerals.
Calcilutite	:	A calcium carbonate rock composed of grains or crystals with an average diameter less than 1/16 mm.
Calcarenite	:	A limestone composed of transported calcareous grains between 1/16 mm. and 2 mm. in size.
Calcirudite	:	A limestone composed of transported calcareous grains larger than 2 mm. in size.
Clastic	:	A term describing a rock which is principally composed of material transported mechanically to its place of deposition.
Cement	:	Coarse crystalline calcite precipitated between the grains, regarded as a diagenetic process and consisting of drusy and granular varieties. (Bathurst 1958).
Diagenesis	:	Chemical and physical changes that take place in sediments during their accumulation and until complete lithification.

Dolomite : A sedimentary rock containing more than 50% of the minerals calcite (and aragonite), and dolomite (and Ferrodolomite) in any form, in which the mineral dolomite is most abundant.

Dolomitic Limestone : Limestone in which the mineral dolomite is up to 50% of the combined calcite and dolomite total.

Grain growth : The sum of the processes which cause the secondary enlargement of a grain or crystal (Bathurst 1958).

Intraclast : Proposed by Folk (1959) to embrace the entire "spectrum" of aggregated or reworked particles from within the basin of deposition. They are generally composite grains.

Limestone : A sedimentary rock containing more than 50% of the minerals calcite (and aragonite) and dolomite (and Ferrodolomite) in any form, in which the mineral calcite is more abundant than dolomite.

Matrix : Matrix is defined as the fine-grained sediment in which larger grains are embedded, e.g. brachiopod calcarenite with microcrystalline calcite matrix. Matrix is often contemporaneous but may be penecontemporaneous with the deposition of the larger grains.

Oolith : A spherical or oval grain 1/16 mm. to 2 mm. in diameter exhibiting radial or concentric structure or both, which may or may not form round a nucleus, e.g. a quartz grain. This includes the "superficial oolite" of Illing (1954) which is regarded as a change in degree rather than kind. It is usually calcareous but maybe replaced by silica or dolomite.

Oolite : A sedimentary rock composed of more than 50% ooliths.

Oolitic : Describes a rock containing subordinate ooliths

Pellets : Rounded, spherical or elliptical bodies of carbonate which are generally aphanitic and structureless, and formed within the basin of deposition. They may be faecal, or a product of agglutination, or reworked calcilutites, i.e. a type of intraclast, or relict areas after grain growth. A careful examination of the texture and the associated grains must be made before determining the nature of the pellet.

Recrystallization : The formation of new mineral grains in a rock while in the solid state. They may be of the same or of different composition from the original grains.

Terrigenous : Material derived from source lands outside the basin of deposition and transported as solids to the sediment. (After Folk 1959).

PETROLOGY

ANTHONY LAGOON BEDS

CARBONATE ROCKS

Autochthonous Limestones

(a) Dolomitic Sponge (?) Calcilutites:

Sample No. BT 330(b).

Locality: 1.6 miles east of Desert Bore, Barkly Stock Route.

Photograph - Plate 1, Figure 1.

Hand Specimen:

This limestone is exposed as boulders and slabs in the central and north-north-western part of the Brunette Downs 1:250,000 Sheet area. It is a tan, fine-grained dolomitic limestone with large hollow cylindrical sponge(?) structures often in the growth-position. The sponges (?) are circular or sub-circular in cross section, approximately 7 cms. high, 6 cms. in diameter and have walls about 1 cm.in thickness. They are brown in colour with an irregular silicified surface. The walls are not uniform in height, are often broken, and may have been thickened by silicification. In some boulders the sponge-growths are flanked by horizontally bedded intraclastic calcarenites with calcite cement (intrasporites, Folk 1959) but in others are surrounded by calcilutite (micrite, Folk 1959). This may also occur in the central part between the walls.

Petrography

In thin section, the sample consists of an intermixture of microcrystalline calcite, partly recrystallized by grain growth, and dolomite crystals varying from 20 - 200 microns. The average size of the dolomite crystals is from 20 - 80 microns and they are surrounded by an iron oxide, - probably limonite.

The sponge structures are composed of irregular patches of microcrystalline silica (fibrous chalcedony), showing undulose extinction, which enclose (in 2 dimensions) irregular areas of microcrystalline calcite. The latter seem to represent the interior of a structureless wall. There are no sharply defined junctions between the sponge structure and the matrix, and it is possible that the present irregular nature of the contacts is due to silicification, which probably caused secondary thickening.

Unidentified "problematica" occur and are small, thin walled, septate and apparently cylindrical; (length - 1 mm. width - 200 microns; walls 50 microns).

Environment of deposition

The presence of sponge-like structures in microcrystalline calcite and dolomite in the growth position implies very shallow, warm and low energy conditions, such as occur at present, on near-shore lagoonal flats.

The paucity of other fossils may indicate an absence of current activity or unfavourable conditions for other fauna.

The sponge-structures may form part of a reef or an entity within a larger reef complex. When they are surrounded by intralcastic calcarenites with calcite cement (intrasparite, Folk 1959) the environment must have been more turbulent, with stronger currents winnowing away the microcrystalline calcite or preventing it from being deposited. This again would indicate shallow water conditions.

The microcrystalline calcite may have accumulated by precipitation from warm waters saturated with $CaCO_3$, disintegration of sponge tissue, or the deposition of algal "dust" (Wood 1941) in a shallow water, quiet environment.

The presence of microcrystalline dolomite in irregularly shaped patches and larger crystals replacing the matrix denotes a secondary origin, but the small grain size implies that it was penecontemporaneous and not post-lithification.

(b) Dolomitic Algal Calcilutites:

Samole Nos. BT. 118(f); BT 122; BT 316; BT 18;

Localities.	BT 118(f)	- 21 miles W.N.W. of "Brunette Downs"
	BT 122	- 4.5 miles S.S.E. of Corella No.2 Bore. "Brunette Downs"
	BT.18	- 1 mile N.E. of Coolibah W.H.
	BT.316	- 13 miles @ 260° from "Brunette Downs"
Photomicrograph.		- Plate 1. Figure 2 : Plate 2, Figure 1.

Hand Specimen:

These rocks occur as boulders and slabs and are generally tan and light grey in colour. In two specimens, the algae in plan view are circular to sub-circular structures with concentric rings of dark and light brown microcrystalline calcite and dolomite. The structures vary in diameter from 2.5 cms. to 9 cms. In section the algae consist of a number of layers, concave upwards, each of which may have represented a "calyx" during growth. They vary from 2 cms. to 7 cms. in height, and each layer is continuous with the next structure, rising to a sharp ridge between two "calices". This results in a variety of algal mat which is composed of a series of cup-like structures.

A third specimen (BT 118(f))consists of small, layered, algal structures, convex upwards. They are approximately 7 cms, high, but only 2 cms. in diameter. Again, thelayers are continuous but each structure is divided from the next by layers forming a narrow depression.

Quartz sand lenses sometimes occur between the cup -like structures.

A fourth specimen BT.18, is a mottled grey and light brown, layered dolomite with thin siliceous beds (microcrystalline silica) from 0.5 - 3mm. thick, often discontinuous and undulating.

Petrography:

In thin section, the algal layering is caused by alternating bands of crypto-crystalline calcite and limonite and coarser micro-crystalline calcite with crystals of silt size (average 60 microns). These bands are undulating and range in thickness from 100 microns to 250 microns; they also occur close together, and have small lobes or areas on the under-side of the band.

The coarser micro-crystalline bands are often a product of recrystallization by grain growth and a flocculent texture sometimes occurs between the crypto-crystalline bands.

Lenses of quartz sand contain angular and sub-rounded quartz grains (about 150 microns), pellets of micro-crystalline calcite and unidentified organic(?) bodies 200 microns in diameter. A rim of fibrous calcite, 40 microns thick and partly recrystallized, surrounds a nucleus of micro-crystalline calcite. In other cases (BT.118(f).) thin beds 3.5 mm. thick, consist of fragments of disarticulated fossils (Echinodermata indet). In BT.18, the algal layers have been partly replaced by micro-crystalline silica - probably chalcedony.

Environment of Deposition

The environment is thought to have been similar to that which existed during the formation of the sponge-calcilutites. The undisturbed nature of the algae and the growth position implies that they grew in shallow, warm waters (in the photosynthetic zone) where low energy conditions existed. However, weak currents transported terrigenous material and pellets to the area, but were not persistent enough to erode or abrade the algae.

[illegible]. Allochthonous Limestones

(a) Dolomite Calcilututites (Dolutite, Condon (1953), Dolmicrite, Folk (1959).)

Sample Numbers BT.78; BT 301(a); BT.301(c); BT.317; BT.199.

Localities:	BT.78 -	2 milessouth of Lignum. W.H.
	BT.301(a) BT 301(c)	14.5 miles W.S.W. of"Brunette Downs."
	BT.317	14 miles west of "Brunette Downs"
	BT 199	15 miles W.S.W. of "Brunette Downs".

Photomicrographs - Plate 2. Figure 2. : Plate 3, Figures 1 and 2.

Hand Specimens:

These rocks occur as scattered boulders and rubble. They exhibit small variations but are similar in many details. They are fine-grained dolomitic limestones varying in colour from tan to light brown and grey. They may be mottled, banded or nodular, each of these textures being caused by a change in grain size and composition from crypto- and micro-crystalline calcite to microcrystalline, and medium crystalline dolomite and limonite.

Individual dolomitic bands vary from 3 - 5 mm. thick, and calcareous ones from 3 mm - 1 cm. The nodules are irregular in shape and have rounded corners. They have an average thickness of 2.5 cm, length of 4 cms, and a width of 2 cms. Undulating solution surfaces occur and may represent a stage of stylolitisation on minor bedding planes: cross-bedding occurs only in specimen BT.199. Pellets and cross-sections of trilobites are also visible, but from less than 10% of the sample.

Petrography:

In thin section, the dominant constituents are cryptocrystalline calcite and microcrystalline to medium-crystalline dolomite with limonite. The cryptocrystalline calcite has been partly recrystallized, and the dolomite crystals are of silt or fine sand-size and equigranular.

The pellets are of cryptocrystalline calcite and often have diffuse boundaries due to recrystallization. Consequently, it is not always possible to identify them as pellets or relict patches of cryptocrystalline calcite. They are small (50 microns) and sub-rounded (BT 317). The fossils are broken pleurae of trilobites and are scattered in the section (BT.301(c).).

The nodular variety (BT.301(a)) has the same composition. The nodules are composed of microcrystalline calcite, partly recrystalliad by grain growth, and dolomitised, the dolomite rhombs being scattered within the nodule. Partial silicification has also occured, and chalcedony has replaced the calcite. Some parts of the nodule show flocculent texture which may be palimpsest algal structures. The matrix is predominantly equigranular, silt-size dolomite crystals with a small amount of microcrystalline calcite. The boundaries of the nodules are well defined, but are irregular, resulting from the projections of the dolomite crystals into the nodule.

The banded variety (BT.301(c)) consists of thin beds, often discontinuous, and irregular patches of equigranular dolomite crystals (micro - crystalline) with limonite. The boundaries between the dolomite and the cryptocrystalline calcite are not planar and in some cases "cloud"-like patches of calcite are intermixed.

In the cross-bedded sample (BT.199) the laminae are emphasised by concentrations of limonite, dolomite crystals and cryptocrystalline calcite.

Environment of Deposition:

It is impossible to determine the origin of these carbonates, but the environment was probably calm and of low energy, favourable for the accumulation of microcrystalline calcite or dolomite. The absence of broken fossils and intraclasts denotes low energy and no scavenging action. The limestones should be classed as autochthonous if they were chemically precipitated. In this case, they probably accumulated in shallow, warm water, saturated with $CaCO_3$, in a restricted or sheltered area of deposition. A similar environment exists to the west of Andres Island, in the Bahamas (Newell, Rigby & Keith, 1957). Alternatively, the limestones should be classed as allochthonous if they resulted from algal disintegration, precipitation of algal dust, or abrasion of material within the basin. In this case, the microcrystalline calcite or dolomite probably drifted or was deposited in this area. The trilobite fragments and pellets may have been deposited by weak currents, the disparity in grain sizes being due to different densities, Scavenger action may also have occurred, causing the break-up of the trilobites and the formation of faecal pellets. However, the environment would have been one of low energy; the depth is uncertain, as microcrystalline calcite can accumulate in an open marine environment at depth, where it may be undisturbed.

The origin of the dolomite is difficult to determine. The fine-grained nature suggests that it might be dolomite silt, but the irregular nature of the patches and the association of the thin beds with solution cavities on the weathered surface implies that dolomitisation may have occurred. Several dolomite crystals appear to be replacing trilobite fragments. It is likely that the dolomitisation occurred soon after deposition and was influenced by the fine-grained nature of the matrix.

The nodules are only partly dolomitised and the matrix is nearly completely replaced or composed of dolomite. The nodular shape seems an unlikely result of erosion because of a highly lobate outline. There is no evidence of concretionary or chemical action and there are no fossils or intraclasts. It is possible that it was an algal nodule which was subsequently partially replaced.

(b) <u>Dolomitic pelletal calcarenites</u>: (Dolpelmicrite or dismicrite Folk, 1959).

Sample Numbers BT.107(c); AL.17.

Localities : BT.107(c) - 2 miles N.W. of Corella No.2 Bore. "Brunette Downs".

AL.17 - No.1 Bore, "Alroy".

Photomicrographs : Plate 4, Figure 1.

<u>Hand specimen</u>:

These rocks occur as slabs or boulders and vary from fine-grained to coarse-grained and crystalline, and from tan to light grey in colour, the mottling being produced by limonite associated with dolomite. In BT.107(c), small tube-like structures composed of medium-crystalline calcite occur; they are curved in shape and approximately 2 cms. long . In AL.17, pellets and intraclasts are visible, ranging from 0.5 mm. - 2 mm. in length and diameter.

<u>Petrography</u>:

In thin section, the rocks consist of well rounded pellets of microcrystalline calcite and dolomite , varying from 100 microns to 1 mm. in size.

Intraclasts occur and are irregular in shape, and vary in length and diameter from 150 microns to 2 mm. They appear to be composite grains containing algal remains, pellets, ooliths and fine-grained fossil fragments (AL.17). The fossil fragments sometimes have a rim of cryptocrystalline calcite around them. Ooliths and fragments of Echinodermata also occur in AL.17. Fragments of trilobites and "problematica" occur in BT.107(c), the latter being thin walled cylindrical organisms (cf. those in BT.330(b). The nature of these structures is indeterminate, but they may be recrystallised algal threads.

The matrix is partly recrystallized microcrystalline calcite and is intermixed with equigranular dolomite rhombs (microcrystalline). The latter are replacing the calcite in parts. Calcite cement exhibiting drusy growth around the grains forms a small proportion of the sample.

Environment of deposition:

The sediment was poorly sorted, assuming the different-sized grains have different densities, and poorly winnowed. This resulted in a mixture of grains, matrix and cement, suggesting scavenging action or impersistent currents of medium strength. The mixture of grains implies several currents from several source areas; or a local complex with one current supplying the grains; or an environment favourable for the accumulation of pellets, intraclasts (and possibly ooliths) and microcrystalline calcite. The environment was periodically disturbed either by currents transporting light trilobite fragments and partially winnowing away the matrix, or by scavenging action.

Dolomitisation may have been early diagenetic in the fine-grained part of the sediment, but may have been pre-or post-induration in the intraclasts.

(c) Dolomitic intraclastic calcarenites.(Intrasparite, Folk,1959).

Sample Numbers BT.110(a), BT.330(a).

Localities: BT.110(a) - 4 miles N.W. of Corella No.2 Bore, "Brunette Downs".

BT.330(a) - 1.6 miles East of Desert Bore - Barkly Stock Route.

Photomicrographs: Plate 4, Figure 2 : Plate 5, Figure 1.

Hand Specimen:

These rocks are light tan in colour, and contain pellets and intraclasts sometimes concentrated in thin beds approximately 1 - 2 cms. thick. Sample BT.110(a) occurs as an isolated boulder and sample BT.330(a) surrounds the sponge-calcilutite (BT.330(b).).

Petrography

In thin section sample 110(a) consists of irregularly-shaped intraclasts, approximately 0.5 mm. in length, largely recrystallized by grain growth, and dolomitised. They may be reworked algal structures as the discontinuous layers of microcrystalline calcite are surrounded in two dimensitns by drusy calcite cement. They are not in contact.

In sample BT.330(a), the intraclasts appear to be reworked limestones e.g. - calcilutites, possibly shelly calcilutites, algal and pelletall calcilutites. They are sub-rounded, have a low sphericity, and are poorly sorted.

A sediment is poorly sorted if different grain sizes have different densities. In limestones different sized grains may have the same density; if so, the sediment is well sorted and its origin is different.

Calcite cement surrounds the grains and the drusy mosaic has been partly recrystallised by grain growth. Microcrystalline calcite may also have been replaced this way and the sediment may be partly winnowed. The dolomite occurs as small crystals and appears to have replaced the cement,

Environment of deposition:

The environment appears to have been one of medium to high energy with persistent current action eroding penecontemporaneous limestones, or rolling aggregate grains, and winnowing away most of the microcrystalline calcite. The turbulent nature may be caused by shallow waters covering a shelf or shoal. (Illing, 1954).

(d) Siliceous oolitic calcarenite:

Sample No. BT.105.

Locality : BT.105 - 0.25 miles South of Corella No.2 Bore, "Brunette Downs".

Photomicrograph: Plate 5, Figure 2.

Hand specimen:

The sample was located in a stream bed and is not in situ. It is a banded, grey to tan, siliceous oolitic rock.

Petrography

In thin section, the grey bands are completely silicified and in ordinary light, pale brown circular objects with a darker rim are visible. These may represent "ghost" ooliths or pellets. Under crossed polars cryptocrystalline silica is seen to replace the oolith or pellet, and coarser microcrystalline silica (chalcedony) has replaced the matrix or cement.

In the tan coloured bands, the oolitic structure has been preseerved by ferruginisation, although the remainder has been silicified. Sime ooliths may be compound but the original nuclei (detrital?) are not identifiable.

Environment of deposition:

Ooliths are forming at present on the Bahama Banks in warm waters supersaturated with $CaCO_3$ (Newell, Purdy & Imbrie, 1960). They consist of aragonite lamellae arranged tangentially around a nucleus, e.g. faecal pellet or shell fragment. Aragonite is added at the grain surface as a physico chemical precipitate. Unoriented aragonite also occurs "associated with organic matter incorporated in thegrain as -

(1) the organic fraction of a faecal pellet,

(2) an adherent film of organic detritus

(3) the remains of boring algae. "

The environment occurs in, and just below, the intertidal zone, where the water is approximately six feet deep and turbulent. It is presumed that the radial structure of the ooliths in sample BT.105, is a result of recrystallization, that original ? aragonite has changed to calcite, and that the mode of formation was similar to that described above.

(e) Dolomitic Intralcastic Calcirudites. (Dolintrasparudite Dolintradismicrite, Folk 1959).

Sample Numbers BT.302(c), BT.319(b).

Localities : BT.302(c) - 14 miles West of "Brunette Downs"
BT.319(b) - 14 miles W.N.W. of "Brunette Downs".

Photomicrograph : Plate 6, Figures 1 and 2.

Hand specimen:

The samples are light brown to grey and coarse-grained, the intraclasts ranging in size from 1 - 2 mm. in diameter, up to 4 cms. in length, 2 mm. in thickness and 0.5 - 4 cms. in width. (BT.302(c)). The latter may be part of an intraformational conglomerate. Some of the large grains are inclined at 10° - 20° to the edges of the slab: (the edges may represent bedding planes.)

Petrography:

In thin section, sample BT.319(b), consists of large intraclasts (not in contact) of low sphericity, but sub-rounded in outline. They are composed of microcrystalline calcite, partly recrystallized by grain growth, and dolomitized. They may be reworked calcilutites or algal limestones , or agglutinated microcrystalline calcite. Some grains have thin "coats" or rims of possible algal dust. Grain growth crystals occur in between grains, but drusy calcite cement is also present.

In sample BT.302(c), the intraclasts are composed of Echinodermata fragments and microcrystalline calcite and dolomite. The fragments of Echinodermata may have recrystallized to produce smaller grains (which all extinguish at the same time), separated by areas of microcrystalline calcite. Others appear to have been bored and impregnated with algal dust, and some may be algal nodules which exhibit a flocculent texture. These are irregular in shape.

Ooliths, approximately 120 microns in diameter, comprise thin oolitic rims (radiating calcite fibres) surrounding a nucleus of microcrystalline calcite.

Fragments of Echinodermata (indet) have thin rims of cryptocrystalline calcite (algal dust), and the centres have been partly silicified.

The matrix consists of microcrystalline calcite partly recrystallized by grain growth, and dolomite. Some granular cement is present but the original amount is unknown.

Environment of Deposition:

The presence of large composite grains whether formed by the reworking of partly lithified limestones or agglutinated grains, implies a turbulent environment. If some matrix is present this denotes, strong, short-lived currents possibly associated with scavenger action. The environment was probably a shallow shelf area, and storm action, independent of strong current action, may have helped to form this deposit.

(f) Dolomite and pellet dolomite: (Dolpelmicrite, Folk 1959).

Sample Numbers : BT.36, BT.329.

Localities - BT.36 - 1 mile North of No.51 Bore "Brunette Downs".
BT.329- 15 miles S.W. of "Brunette Downs".

Photomicrograph : Plate 7, Figure 1.

Hand Specimen:

The above rocks are tan, to light grey, fine to medium crystalline dolomites. They are mottled and pelletal in parts.

Petrography:

Sample BT.36 is composed of equigranular dolomite crystals (average size -60 microns), with a speckled appearance probably due to disseminated iron oxide. The crystals do not appear to be rim-cemented silt and there are no palimpsest structures.

Sample BT.329, is composed of fine-medium grained dolomite crystals, and cryptocrystalline calcite and iron oxide (probably limonite). The latter occurs as irregular and pellet-like patches varying from 100 microns in diameter to 1 mm. in length. In calcareous parts of the sample cryptocrystalline calcite forms similar structures.

Environment of Deposition:

The origin of the pure dolomite is impossible to interpret. It is possible that it was precipitated as an original dolomite and then recrystallized to its present grain size, but it is more likely that it represents a dolomitized calcilutite. This process may have occurred at an early or late stage in diagenesis. Similar rocks have been described by Brown (1962, p.5).

The pelletal (?) dolomite may represent an arrested stage in the dolomitization of a calcilutite, or a pelletal calcarenite pelmicrite or pelsparite (Folk, 1959). Again, it is impossible to interpret. However, the environment was probably shallow and of low energy with little scavenging activity. This would account for the lack of coarse grains (ghosts) and the fine grained nature of the dolomite. The dolomitisation is thought to be an early diagenetic process resulting from percolating magnesian solutions.

(g) Conglomeratic-calcilutite:

Sample No. BT.193

Locality : BT.193 - 3 miles N.N.W. of No.26 Bore "Brunette Downs".

Photomicrograph - Plate 7, Figure 2.

Hand Specimen:

Angular fragments of calcilutite, cream and dark brown in colour, and varying from 3 - 6 mm. in size occur in a light brown-grey calcilutite matrix.

Petrography:

The large fragments consist of crypto-and micro-crystalline calcite with aflocculent texture which is similar to the textures of some algae. The grains range from 150 microns to 5 mm. in length, and from round (cf.pellets) to rectangular in shape. The matrix is microcrystalline calcite and patches of grain growth mosaic. The flocculent texture is also evident in the matrix.

Sharply defined areas of drusy calcite cement, pellets and crypto-crystalline calcite indicate that internal solution (and possibly erosion) and deposition caused the formation and infilling of cavities with sediment and cement. (Bathurst, 1959).

Environment of Deposition.

This lithology was probably formed by the break-up of partly consolidated algal limestones which formed in the shallow, warm photosynthetic zone. The large size of the fragments, the presence of matrix and absence of sorting or winnowing suggests low energy conditions.

(h) Nodular, Sandy Calcarenite:

Sample No. BT.302(e).

Locality : BT.302(e) - 14 miles West of "Brunette Downs".

Photomicrograph : Plate 8, Figure 1.

Hand Specimen:

The rock is tan to light grey in colour, fine grained, and contains quartz grains of uniform size. The fresh surface is mottled, and large (4 cms. long), oval nodules of light grey cryptocrystalline silica stand out in relief on the weathered surface.

Petrography:

Detrital quartz sand forms 20% of the rock, and ranges from 200 - 300 microns in size and from sub-angular to sub-rounded in shape. Many grains have sutured edges where calcite is replacing the silica; some are fractured, some are strain shadowed, and some are composed of micro-crystalline silica. There is little secondary growth and the grains have a low sphericity.

The matrix is micro-crystalline calcite, partly recrystallized by grain growth, and contains pellets (150 microns-diameter) and possibly some Echinodermata fragments.

The siliceous nodules have an irregular edge and cryptocrystalline silica replaces the calcite. Detrital quartz grains occur in the nodules and across the boundary with the matrix. "Ghost" structures of organic (?) remains are present. Bands of relict (?) calcite and dolomite crystals occur in the nodules separated by purer siliceous bands.

Environment of Deposition:

This lithology formed in a shallow water environment, possibly nearer land than the purer carbonate rocks. The presence of detrital quartz denotes either a change in current direction (from different source area), or uplift of an adjacent land area (increased erosion), or a climatic change (more pluviose conditions), or a combination of these factors. The nodules are secondary and were formed by replacement of the carbonate section of the lithology, either by solution and transference of silica internally from nearby rocks (Walker, 1960), or by percolating silica-rich solutions from overlying water.

LEACHED ROCKS

(a) Ferruginous-quartz rocks:

Sample Numbers : BT.326(b), BT.158.

Localities : BT.326(b) - 25 miles S.W. of "Anthony Lagoon" A/D.
BT.158 - 7.5 miles West of "Rockhampton Downs".

Photomicrographs - Plate 8, Figure 2.

Hand Specimen:

The rock BT. 326(b) overlies a siltstone and underlies a sandstone . It is red-brown, fine to medium grained and ferruginous, containing quartz and white clay minerals. It is cross-bedded and very porous. Sample BT.158 is red-brown, and uniformly fine grained, porous, quartzose and structureless.

Petrography:

In sample BT.326(b) detrital quartz forms 30% of the rock, the grains being approximately 100 microns in diameter, and ranging from angular to sub-rounded in shape, with low sphericity. They are not in contact and there is no evidence of grain enlargement. Corrosion of the quartz boundaries by the matrix may cause the angular shape. The matrix consists of clay minerals (micas-sericite or illite) and kaolin,most of which has been ferruginised (limonite). Some of the holes in the specimen are similar to the shape of the detrital quartz and some are anhedral.

In sample BT.158, detrital quartz grains in contact,form approximately 50% of the rock. They have an average size of 100 microns, and are angular to sub-angular (probably sub-rounded originally). The grains are well sorted but have a low sphericity. There is a high degree of suturing and triple points (the points where the ends of three grain boundaries meet), are abundant; authigenic overgrowths in optical continuity also occur and all have changed the original grain shape.

The matrix consists of clay minerals and ferruginous material with some magnetite zircon and tourmaline.

Environment of Deposition:

The presence of detrital quartz indicates a shallow, near shore environment for these rocks, and current-activated water. The original matrix has been leached and may have been carbonate. It has been replaced by kaolin which was derived from the disintegration of feldspars or the weathering of clay or siltstones. Ferruginisation occurred later. The nature of the original rock is unknown, but the environment was more littoral than shelf or open marine.

SANDSTONES

(a) Quartz Sandstones. (Fine-medium-grained arenites).

Sample Numbers : BT.127, BT.147, BT.326(c) and (d).

Localities : BT.127 - 4.5 miles West of "Brunette Downs"
BT.147 - 2 miles South of No.25 Bore, "Brunette Downs".
BT.326(c) and (d) - 25 miles S.W. of "Anthony Lagoon" A/D.

Photomicrographs : Plate 9, Figures 1 and 2.

Hand Specimen:

Samples BT.127 and BT.147 are light grey-tan and dark brown on the weathered surface, and light grey, uniformly fine-grained on the fresh surface. They are often ripple marked, and some have cross-ripples in the troughs of the main ones. Directions could not be measured as the samples occurred as scree. Specimen BT.326(c), crops out above the leached rocks and is a coarse, red-brown sandstone which has a white fresh surface and a partly silicified weathered surface. It also contains organic-like structures up to 30 cms. long, 15 cms.high, and 23 cms.wide. These consist of a series of saucer-like layers (concave upwards), 8 cms. diameter and 0.5 cms.thick, arranged in columns adjacent to one another (cf.algae (?) BT.316). Sample BT.326(d) is a coarse red-yellow sandstone which is sometimes wholly silicified. When this occurs it is white in colour and some parts contain rod-like darker areas -approximately 12 cms. long and 1 cm.wide. The origin of these structures is unknown.

Petrography:

Samples BT.127 and BT.147 are fine-grained, and contain approximately 80% of detrital quartz. The grains are 160 microns in size, are sub-angular and in close contact (grain supports grain). They are bound by a siliceous cement; sutured contacts and triple points indicate solution and thinning of beds. Some grains are of microcrystalline silica but the majority are single quartz crystals. Mica forms only about 1% of the rock. The rock is well sorted.

Samples BT.326(c) and (d) are medium-grained and consist of 75% detrital quartz, poorly sorted, sub-angular to sub-rounded in shape and in contact with one another. There are two grain sizes: (1) the average is 50-150 microns, and this is the dominant one consisting of 60% of sub-angular to sub-rounded grains. Scattered throughout are :(2)- quartz grains of 250-500 microns in size (occasionally grains 1mm. in diameter occur). These are sub-rounded to rounded and form 10% - 15% of the rock. Many grains are fractured, some show sutured contacts, and a few are strain-shadowed. There is some authigenic growth. Triple points occur, but there is microcrystalline and drusy silica cement around the grains. Magnetite grains and heavy minerals occur. There is no evidence of grading, but the sediment has been winnowed.

Environment of Deposition:

The uniform grain size and absence of matrix suggests persistent current action, presumably in a littoral environment. The ripples and cross ripples imply shallow water and variable current directions, again indicative of a littoral environment. The siliceous cement may be primary or secondary in the fine-grained samples.

The poorly-sorted samples with large grains and drusy siliceous cement suggest strong, but impersistent current action. This was capable of winnowing the sediment but not sorting it. The environment was probably littoral and possibly favourable for algal growth. It is thought that the algal-like structures in the sandstone (BT.326(c)) were buried by quartz sand which penetrated between algal layers. During induration the organic tissue disintegrated and the structures were preserved in sandstone.

The rod or stem-like structures in the white silicified sandstone were unidentifiable.

SILTSTONES

(a) Siliceous Siltstones:

Sample Numbers BT.326(a), BT.80(a) and (b).

Localities - BT.326(a) - 25 miles S.W. of "Anthony Lagoon" A/D.
BT. 80(a) and (b) - No.D22 Bore, "Brunette Downs"

Photomicrograph : Plate 10, Figure 1.

Hand Specimen:

These rocks (BT.326(a)) crop out below the leached rock in the north-west part of the Brunette Downs 1:250,000 Sheet area, and are very light grey, fine-grained, siliceous siltstones. The weathered surface is orange in colour, and the fresh surface exhibits a weak lamination and faint mottling. Sample BT.80(a) is similar and slightly fissile. Sample BT.80(b) is mottled brown and tan on the weathered surfaces but mottled brown and white on the fresh surface. The different colours occur as streaks or thin lenses.

Petrography:

In thin section, sample BT.326(a) consists of approximately 65% detrital quartz with an average grain size of 60 microns. Large grains also occur with a diameter of 240 microns. They are angular to sub-angular and unsorted. The matrix is siliceous and black granular material may be silicified iron oxides, carbonaceous or clay minerals.

Samples BT.80(a) and 80(b) consist of approximately 25% detrital quartz with an average grain size of 60 microns. Grains 10 - 20 microns in diameter are difficult to determine as detrital or authigenic. Between 5% and 10% mica and clay minerals occur as fibrous laths, some of which appear to have been silicified. The groundmass is cryptocrystalline silica and isotropic. "Ghost" structures of possible organic remains occur as small circular and oval cross sections of thin walled organisms, and may be sponge spicules. Ferruginisation has caused the mottled appearance, and although silicification has taken place, the original matrix or cement may have been siliceous.

Environment of Deposition:

The siltstones are thought to have accumulated in quiet, deep water, relative to depths in a shelf environment, under more open marine conditions. However, it is also possible for them to accumulate in a shallow littoral depositional area where a barrier had reduced circulation and oxygenation. In the absence of stratigraphic relationships it is difficult to determine the precise environment.

SHALES

(a) Ferruginous Shale

Sample No.BT.327.

Locality: BT.327 - 6 miles S.S.E. of "Anthony Lagoon" A/D.

Hand Specimen:

This sample crops out in the northern part of the Brunette Downs 1:250,000 Sheet area and is orange-red, fine-grained and fissile, with scattered black patches, approximately 1 mm. in diameter.

In thin section, the sample consists of 20% small micas and clay mineral laths, approximately 40 microns long and 20 microns wide.

Detrital quartz grains also form 20% of the rock and are approximately 60 microns in size. The outline and definition of the quartz grains are poor owing to the strong ferruginous matrix. They may represent silicified micas. The black areas appear to consist of disseminated carbonaceous material and possibly magnetite.

Environment of Deposition:

The origin of shales is still not fully understood, but they were probably formed in a low energy environment with clay minerals and silica, or a reaction of aluminium and silicic acid occurring in deep water, or in a shallow restricted lagoon. The ferruginisation was probably secondary.

MESOZOIC

SANDSTONES.

Silicified Quartz Sandstone:

Fine-grained fossiliferous sandstone:

Sample BT. 60.

Locality : BT.60 - 2.3 miles N.W. of Bore No.5 Cresswell.

Hand Specimen:

The sample is brown-grey, fine grained and silicified. It has a mottled appearance, and large quartz grains and fossil plant remains are visible to the naked eye.

Petrography:

In thin section, the rock consists of 75% detrital quartz of uniform grain size, approximately 80 microns; the majority of grains are in contact. The grains are sub-angular to rounded. The angularity seems to be caused by solution as there are numerous plane intergranular boundaries and triple points.

Large sub-angular quartz grains, approximately 500 - 750 microns in size, are scattered throughout the slide. Cementation occurred by growth of authigenic quartz around the grains. The matrix is ferruginous and consists of limonite. Internal plant structure was not found.

Environment of Deposition:

The presence of detrital quartz and plant fossils suggests that the environment was either lacustrine, fluvial, littoral or lagoonal. The fine-grained, uniform grain size implies that continued current action resulted in a well sorted and winnowed sediment. An interpretation of the environment is not possible from the study of a single specimen, but it may be evaluated from the detailed study of adjoining areas of Mesozoic sedimentation. (Skwarko, 1963).

TERTIARY

CARBONATES

Brunette Limestone

(a) Algal Limestones

Sample Numbers BT.167(b) and (c), A L 101

Localities : BT.167(b) and (c) - Bore No.18 "Rockhampton Downs".
AL.101. - 4 miles West of Bore No.9 "Alroy"

Photomicrograph : Plate 10, Figure 2.

Hand Specimen:

Samples BT.167(b) and (c) consist of cream to light grey, fine-grained rocks with algal layering and possibly algal nodules. Sample AL.101, is dark grey in colour and is mottled. It also shows layering and nodular structures.

Petrography:

In thin section, the rocks consist of thin alternating layers of cryptocrystalline and microcrystalline calcite, sometimes partly ferruginised. The alga is not periferous, but under high power, small circular and sub-circular areas, and thin discontinuous lenses of fibrous calcite are seen which may represent recrystallised parts of the organism. Sample BT.167(c) is similar but contains circular, algal nodules. They appear to be part of the layered growth, but in hand specimen also appear to be detached. It is impossible to determine if the nodular concentric layering occurs around a nucleus, or if it is a growth stage which may become detached.

Detrital quartz, varying in size from 50 - 250 microns, and from sub-rounded to rounded in shape occurs in bands, possibly between the algal layers. The genus is unknown but it may be a type of Red Coralline Alga (Rhodophyte(e.g. Lithothamnium sp. (Johnson, 1958).

Environment of Deposition

Algae live in the photosynthetic zone in shallow, calm warm waters of lagoons, lakes and rivers. Owing to the presence of the alga (?) Lithothamnium it is thought that the Brunette Limestone at this locality was deposited under lagoonal conditions in warm, calm clear water, in the photosynthetic zone.

(b) Siliceous and Pelletal Calcilutites:

Sample Nos.BT.167(a). BT. 312.
Locality: BT.167(a) - Bore No.18 "Rockhampton Downs"
BT.312 - 7 miles N.N.E. of No.25 Bore, "Brunette Downs".
Photomicrograph : Plate 11, Figure 1.

Hand Specimen:

Sample BT.167(a) is light grey and is composed of pellets or nodules (fine-grained) and a fine grained matrix. Opaline silica forms irregular patches and weathers to a red-brown crust, characteristic of much of the Brunette Limestone. Sample BT.312 is mottled, more pelletral and not siliceous.

Petrography:

In thin section the rocks consist predominantly of microcrystalline calcite which has been partly recrystallized by grain growth. Sample 167(a) contains a few pellets of cryptocrystalline and microcrystalline calcite within the matrix.

The pellets are also surrounded by areas of micro-and crypto-crystalline silica, fibrous chalcedony, drusy quartz and amorphous silica. These different varieties often occur in layers within an infilled cavity which often has a crystalline calcite centre. Some silicified areas may have been organic structures and flocculent textures may be algal. Irregularly shaped areas of microcrystalline calcite crystals, possibly rim-cemented, (Bathurst, 1958) also occur.

In Sample BT.312, the pellets vary in size from 100 microns to 5 mms. and have high sphericity. They consist of darker, microcrystalline calcite and contain detrital quartz grains and fossil fragments. The latter may be pelecypod or ostracod shell fragments. Veins and patches of drusy calcite and granular cement may represent areas of interval erosion during lithification, the cavities being infilled by the calcite.

Environment of Deposition:

It is difficult to interpret the environment of these limestones as there is little fossil or textural evidence. The composition and textures suggest that conditions were calm and the water shallow, but periodically disturbed by currents. The silica is thought to be penecontemporaneous or late diagenetic, although under suitable pH conditions, calcite may be dissolved and silica precipitated simultaneously. (Krauskopf, 1959).

(c) Conglomeratic, gastropod Calcirudite (Coquina)

Sample No. BT.169
Locality : BT.169 - 2 miles N.E. of Bore No.18 "Rockhampton Downs".
Photomicrograph : Plate 11, Figure 2.

Hand Specimen:

This limestone is light grey with white and brown, sub-rounded fragments of limestone varying from 2 mms. to 2 cms. in size. The fossils consist of complete gastropod tests, white and thin walled, dextrally coiled and with smooth or spiral and transversely ribbed whorls. They are approximately 5 - 10 mms. long. Pelecypods also occur and are white, thin shelled, disarticulated, and have smooth or faint concentric striae. They are approximately 4 mms. in height and 4 mms. in length.

Petrography:

In thin section, the conglomeratic fragments are composed of either microcrystalline calcite partly or wholly recrystallized by grain growth; or cryptocrystalline calcite with flocculent texture, i.e. pellets, and some are of microcrystalline silica. Detrital quartz, average size 150 microns, occurs in some fragments and may have a thin rim of fibrous calcite. Some fragments are ferruginised while others may have thin rims or coats of cryptocrystalline calcite (algal dust). The fragments are angular to subrounded in shape and have low sphericity.

The gastropods occur as complete and broken tests and have walls of fibrous calcite approximately 100 microns thick. Some chambers contain detrital quartz grains, gastropod shell fragments and foraminifera in a matrix of microcrystalline calcite. The whorls do not cover each other, overlap is small, and the coiling is helicoid.

The pelecypod shells are disarticulated but there is no section of the hinge line. The walls show two layers, i.e. fibrous and lamellar calcite.

Ostracod fragments are rare. These are disarticulated, thin and fibrous.

The foraminifera are trochospirally coiled and approximately 160 microns in diameter. The walls are of fibrous calcite and about 10 microns thick, but are secondarily thickened to 20 microns in the inner chambers. The septa are covered and continuous with the outer wall of the chamber. In some sections each chamber appears to abut onto the previous chamber.

The matrix consists of microcrystalline calcite, partly recrystallized by grain growth, and contains scattered detrital quartz grains (40 - 400 microns in size). They are sub-angular to sub-rounded and of low to medium sphericity. Some of the matrix has a flocculent texture which may have been caused by scavenging action.

Environment of Deposition:

Foraminifera and algae have been located in the Austral Downs Limestone (Paton, 1961), but have not been widely described from the Tertiary of the Northern Territory. If the limestone is a lacustrine deposit the presence of marine genera must be explained. (Lloyd, 1963). The fossils imply that an access to the sea occurred at some time, but as a fresh water genus is also present, the influence of rivers cannot be ignored. The conglomeratic nature of the rock suggests a turbulent environment and the coarse nature suggests strong currents. The fossils would not break as they are of lighter density and were probably carried in suspension.

It is suggested that the limestone formed in a shallow, marine environment near to the shoreline and a river mouth, or in a partly enclosed lagoon with access to the sea and a fresh water supply from a river. Either of these environments could give rise to a conglomeratic, fossiliferous and sandy limestone. However, this does not preclude the development of a lagoon and the change to a lacustrine environment at a later date.

SANDSTONES

(a) Fine-grained and Conglomeratic Sandstones:

Sample Numbers : BT.188(a), BT.324.

Locality - BT.188(a) - 1.8 miles West of Bore No.42, "Brunette Downs".
BT.324 - 4.8 miles West of Bore No.9 "Anthony Lagoon".

Photomicrograph : Plate 12, Figure 1.

Hand Specimen:

The specimens occur as scree. Sample BT.188(a) is a mottled, purple and tan, fine-grained sandstone, partly silicified and partly leached.

Sample BT 324 is a conglomeratic sandstone, containing light grey to white spherical and angular pebbles of sandstone in a tan sandy matrix. The pebbles vary in size from 1 mm - 3 cms.

Petrography:

Sample BT.188(a) contains more than 50% detrital quartz which is well sorted, with an average grain size of 150 microns. The grains are sub-angular to sub-rounded and have a low sphericity. They are in contact in parts, and suturing has occurred as well as secondary overgrowth. The matrix consists of amorphous silica and clay minerals and iron oxide.

In sample BT.324 the conglomeratic pebbles of sandstone are rounded and composed of detrital quartz grains - average size 100 microns. The quartz is sub-angular generally, but some show high sphericity. The matrix is siliceous and ferruginous and contains clay minerals.

Around the pebbles is a thin, layered siliceous rim ranging from 100 microns to 4 cms. in thickness. These rims contain detrital quartz grains with thin concentric rings and often include a small, rounded pebble of similar composition.

The matrix surrounding the pebbles is ferruginous and contains detrital quartz similar to that of the pebbles.

Environment of Deposition:

The samples are unfossiliferous, and there is no indication of deposition under marine conditions. The fine-grained sandstone BT.188(a) appears to have been deposited in an area of persistent current activity which sorted and winnowed the sediment. The environment may have been lacustrine, fluvial or littoral.

The conglomeratic sandstone is thought to have formed in an area of stronger current activity which eroded partly consolidated sandstones, or aggregates of sand grains bound together by a biochemical or chemical deposit. The layered rims may represent algal growth, or a precipitated deposit around the pebbles during or after transportation. The specimens are rare and occur in a dried up lake and water course. They are unlike rocks in the Cambrian, Mesozoic or Tertiary and may be Quaternary in age.

REFERENCES

BATHURST, R.G.C. 1958 - Diagenetic fabrics in some British Dinantian Limestones: Liverpool and Manchester Geol.Jour. V.2. p.11.

______________ 1959 - Diagenesis in Mississippian Calcilutites and pseudobreccias. J.Sediment.Petrol. Vol.29.No.3, p.365.

BROWN, G.A. 1962 - The Petrology of the Carbonate Rocks of the Western Undilla Basin. Bur.Min.Resour.Aust.Rec. 1962/43 (unpubl.)

CONDON, M.A. 1953 - Nomenclature of the Sedimentary Rocks. Bur.Min.Resour.Aust.Rec. 1953/131 (unpubl.)

FOLK, R.L. 1959 - Practical Petrographic Classification of Limestones. Bull.Amer.Ass.Petrol.Geol. V.43.P.1.

GRABAU, A.W., 1[illegible] - On the classification of Sedimentary Rocks. The American Geologist. Vol.33, p.228.

ILLING, L.V. 1954 - Bahaman Calcareous Sands. Bull.Amer.Ass.Petrol Geol. Vol.38, p.1.

JOHNSON, J.H., 1958 - Petrography of the Limestones in Geology of Saipan Mariana Islands. Prof.Pap.U.S. Geol.Surv. 280-C, p.177.

KRYNINE, P.D., 1948 - The Megascopic Study and field classification of Sedimentary Rocks. Jour.Geol. Vol.56. p.130.

KRAUPSKOPF, K.B., 1959 - Geochemistry of Silica. A Symposium Soc.Econ. Palaeo. and Miner. Special Pub. No.7. p.5.

LLOYD, A., 1963 - Possible Tertiary Marine Fossils from the Brunette Limestone, Barkly Tableland, Northern Territory. Bur.Min.Resour.Aust. Rec. (in prep.)

NEWELL, N.D., RIGBY, J.K., and KIETH, J, - 1957 - Geological studies on the Great Bahama Bank. Regional aspects of Carbonate Deposition. A Symposium. Soc.Econ. Palaeo. and Min. Spec. Pub.No.5, p.15.

NEWELL, N.D., PURDY, E.G., and IMBRIE, J, - 1960 - Bahamian Oolitic Sand. J.Geol. Vol.68, No.5, p.481.

PATEN, R.J., 1961 - The Tertiary Geology of Western Queensland. Bur.Min.Rescur.Aust.Rec. 1961/52. (Unpubl.)

RANDAL, M.A. and BROWN, G.A. - 1962a. - Geology of the Ranken 1:250,000 Sheet Area, Northern Territory. Bur.Min.Resour. Aust. Rec.1962/55 (Unpubl.)

RANDAL, M.A., and BROWN, G.A., - 1962b. - Additional notes on the geology of the Camooweal 4-mile Sheet. Bur.Min,Resour. Aust.Rec. 1962/49. (Unpubl.)

RANDAL, M.A. and NICHOLS, R.A.H., 1963 - Geology of the Alroy and Brunette Downs 1:250,000 Sheet Areas, Northern Territory. Bur.Min.Resour.Aust.Rec. (in prep.)

SKWARKO, S.K. 1963 - Observations on occurrences of Cretaceous Strata in Queensland and the Northern Territory. Bur.Min.Resour.Aust.Rec. 1963/11. (Unpubl.)

WALKER, T.R. 1960 - Carbonate replacement of detrital crystalline silicate minerals as a source of authigenic silica in sedimentary rocks. Bull.Geol. Soc.Amer. Vol. 71, p.145.

WARNE, S. St.J. 1962 - A quick field or laboratory staining scheme for the differentiation of the major Carbonate Minerals. J.Sediment. Petrol. Vol.32. No.1.

WOOD, A. 1941 - "Algal Dust" and the Finergrained varieties of Carboniferous Limestone. Geol.Mag. Vol.78. No.3, p.192.

APPENDIX

COMPARISON WITH CARBONATES OF RANKEN AND CAMOOWEAL 1:250,000 SHEET AREAS, N.T. & Q'LD.

In the Alroy and Brunette Downs Sheet areas, the Anthony Lagoon Beds consist of dolomitic sponge (?) and algal limestones, dolomitic intraclastic and pelletal calcarenites (intrasparites), dolomitic calcilutites (dolmicrites and dolomites), quartz siltstones and sandstones.

The sponge and algal limestones are in situ and in some localities are surrounded by calcilutites or intraclasts in calcite cement; the intraclasts and pelletal calcarenites contain fragments of other limestones, faecal pellets and aggregated grains. The dolomitic calcilutites contain fragments of trilobites and Echinodermata but these are not abundant. The dolomites consist of microcrystalline dolomite with or without pellets of cryptocrystalline calcite. Quartzose oolitic and shelly limestones are rare.

It is impossible to determine the relationships of the different rock types within the Anthony Lagoon Beds. However, the above rock types suggest that the environment of deposition was predominantly shallow and calm, favourable for sponge(?) and algal growth. Currents or storms periodically occurred and helped to form the intraclastic and pelletal rocks. The proximity of land, or climatic change or uplift caused the deposition of terrigenous deposits in the Alroy and Brunette Downs area.

On the Ranken Sheet area, rocks of a similar age to the Anthony Lagoon Beds, comprise the Burton Beds, the Ranken Limestone, and part of the Camooweal Dolomite. In comparison with the Anthony Lagoon Beds, the limestones in the Ranken area are generally more detrital and organic, and siltstones and sandstones are less abundant. The Burton Beds consist of ripple-marked calcareous and silicified coquinites, pellet and oolitic limestones, intraformational pebble conglomerates, fine and coarse grained crystalline limestones and siltstones. (Randal and Brown 1962a.). The coquinites are composed of trilobites, hyolithids, brachiopods and echinoid fragments, either in calcite cement or fine-grained calcite. The fine-grained rocks contain ooliths and pellets in addition to shell fragments.

The Ranken Limestone, also on the Ranken Sheet area, consists of carbonates petrologically similar to those of the Burton Beds, and differs from the Anthony Lagoon Beds in being more detrital and organic. Sandstones and siltstones are rare. The Ranken Limestone consists of fine-grained limestones with pellets and fossil fragments in a fine grained matrix; coquinites with echinoid plates and spines in calcite mud, and trilobites in coarser sediments; and silty lime-muds with siliceous sponge spicules and calcispheres.

The Camooweal Dolomite varies from white to cream, buff and light brown in colour. The white rocks are more coarsely crystalline than the dark rocks. Pelletal dolomite and intraformational conglomerate occur near the James River but are not known elsewhere in the Sheet area. Quartz sandstone boulders occur with the dolomite and may represent parts of sandstone beds within the unit. (Randal and Brown 1962a).

Rocks similar to the Camooweal Dolomite are rare in the Alroy and Brunette Downs area, but are more abundant in the Ranken area. It is difficult to determine the stratigraphical relationships of the Anthony Lagoon Beds with the Burton Beds, Ranken Limestone and the Camooweal Dolomite. The most noticeable features are that in the Alroy and Brunette Downs Sheet areas, the Anthony Lagoon Beds contain sponge(?) and algal limestones in situ, few coquinites, oolites and dolomites, and several sandstone and siltstone beds. In comparison to the south east on the Ranken Sheet area, the Burton Beds, Ranken Limestone and Camooweal Dolomite represent changes in lithology and consist dominantly of coquinites with a variety of organic fragments, pellets and oolitic limestones, intraformational conglomerates and dolomite.

The environment of deposition also changed from the Alroy and Brunette Downs area to the Ranken area. In the former area it was shallow, dominantly calm and lagoonal, favourable for algal and sponge(?) growth and probably nearer land. In the latter it was more turbulent and the presence of ripple marked coquinites, pelletal and oolitic calcarenites, and siltstones suggests that the environment was still shallow but a more open shelf area. It may also have been a shoreline deposit near an island (or larger land mass) which supplied little terrigenous material. The Ranken Limestone possibly grades upwards and eastwards into the Camooweal Dolomite. Consequently, the dolomite was probably deposited as a carbonate mud in a warm, shallow sea, under quiet conditions. This sea may have been a restricted part of the open shelf area mentioned above, and implies that a lagoon-like area existed in the eastern part of the Ranken Sheet.

In the Camooweal Sheet area, rocks of a similar age to those mentioned above are the Age Creek Formation, the V-Creek Limestone and the Mail Change Limestone (Randal and Brown, 1962b). These rocks are different from those of the Ranken, Alroy and Brunette Downs areas and contain sedimentary structures which denote deposition in a different environment.

The limestones in the Camooweal Sheet area do not contain algal and sponge(?) limestones or sandstones and siltstones as in the Anthony Lagoon Beds, or coquinites of shell fragments as in the Burton Beds and Ranken Limestone. Furthermore, pure dolomite is rare.

The Age Creek Formation consists of dolomite containing pellets, ooliths, algal material, fossil fragments and terrigenous material in calcite cement. These rocks contain large foreset beds dipping to the south-west and south-east, but contain lenses of dolomitic limestone. These represent carbonate mud deposits formed in quieter, shallow waters "on top of the "delta" " (Brown, 1962). On the eastern margin of the Age Creek Formation, the V-Creek Limestone and the Mail Change Limestone occur as "lenses and fingers" (Brown, 1962). The V-Creek Limestone contains pellets, ooliths and terrigenous material in calcite mud and calcite cement. The above often form layers which are overlain by sandstones containing quartz, feldspar, muscovite hypersthene and garnet in a groundmass of dolomite rhombs. Shells and algal remains are present in some lithologies (Brown, 1962).

The environment of deposition of the Age Creek Formati n was one of strong currents transporting coarse terrigenous material, pellets and ooliths from the north-east and sinking slowly to allow for the development of large foreset beds. The V-Creek and Mail Change sediments accumulated under strong current action. The currents were variable in direction and reworked semi-consolidated limestones. Compared with the Ranken, Alroy and Brunette Downs areas, the Camooweal area was unstable, deeper , more open-marine and turbulent, and not as favourable for the growth and preservation of organic material.

In conclusion, the area was probably a shallow platform with turbulent, open-marine conditions favouring the formation of the Burton Beds and the Ranken Limestone. However, local, restricted environments (lagoons(?)) occurred to the north-west and south-east. The Anthony Lagoon Beds accumulated in one of these, favourable for organic growth and nearer land. The Camooweal Dolomite formed in one of different salinity and temperature probably by the precipitation of carbonate mud. Further east, the shallow platform was separated from a more rapidly subsiding and turbulent area by a physical barrier striking north-south near Camooweal (Randal & Brown, 1962b). In this part of the area the platform complex gave way to a deeper area with powerful currents transporting material from the north east.

PLATE 1

Fig.1. Anthony Lagoon Beds, showing sponge-like structures in the growth position. X [illegible]. (BT 330(b).) g/5419.

Fig.2. Anthony Lagoon Beds, showing algal layering, and circular nature of the structures.
Plan view X $\frac{3}{4}$. (BT.316). g/5420.

PLATE 2.

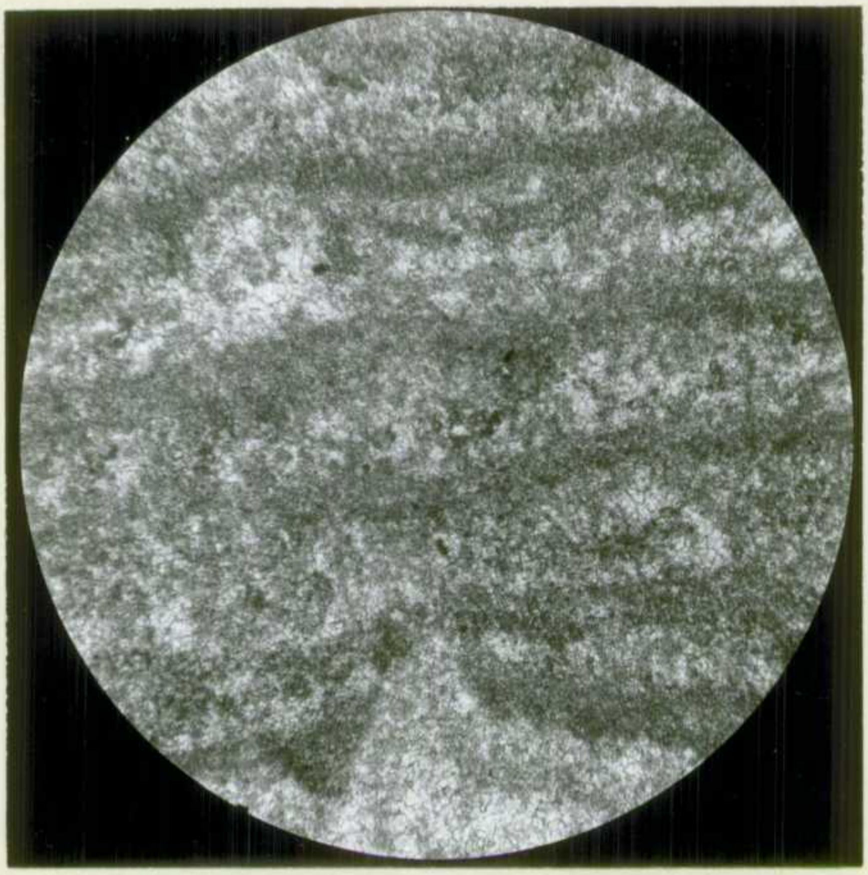


Fig.1: Anthony Lagoon Beds, showing algal layering and the grain growth mosaic of coarser calcite.
X 45. (BT.316). g/5432

Fig. 2: Anthony Lagoon Beds, showing patches of dolomite and broken trilobites, partly replaced.
X 50 (BT.301(C)). g/5438.

PLATE 3

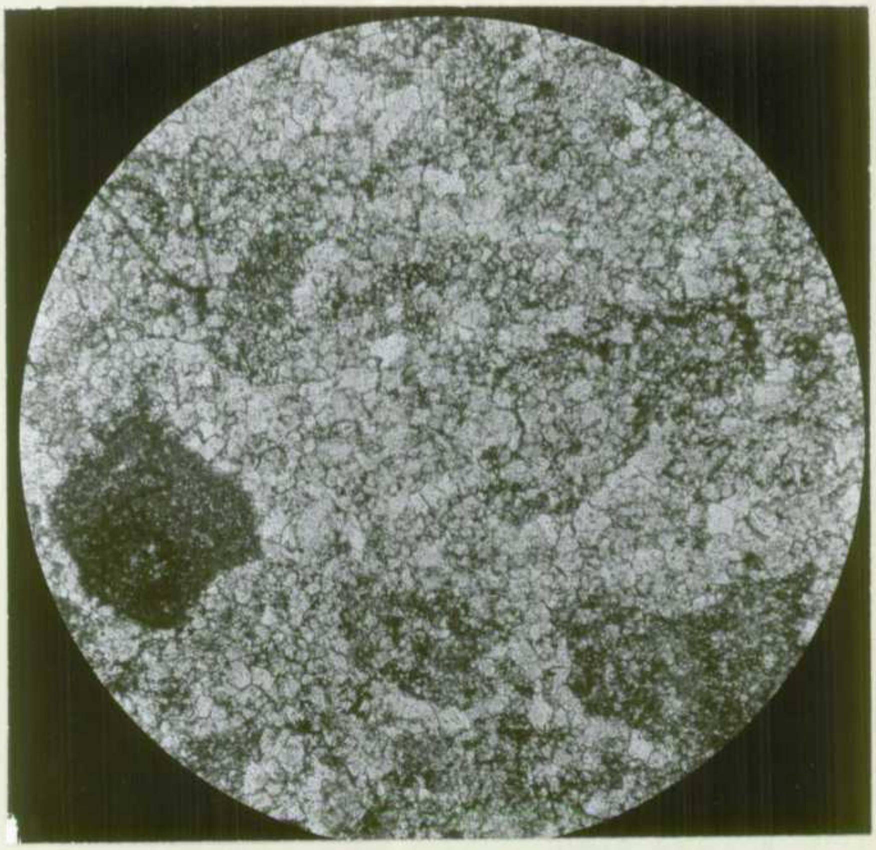


Fig. 1: Anthony Lagoon Beds, showing crystalline dolomite with relict and "ghost" areas or pellets of cryptocrystalline calcite. X 50 (BT.78) g/5442.

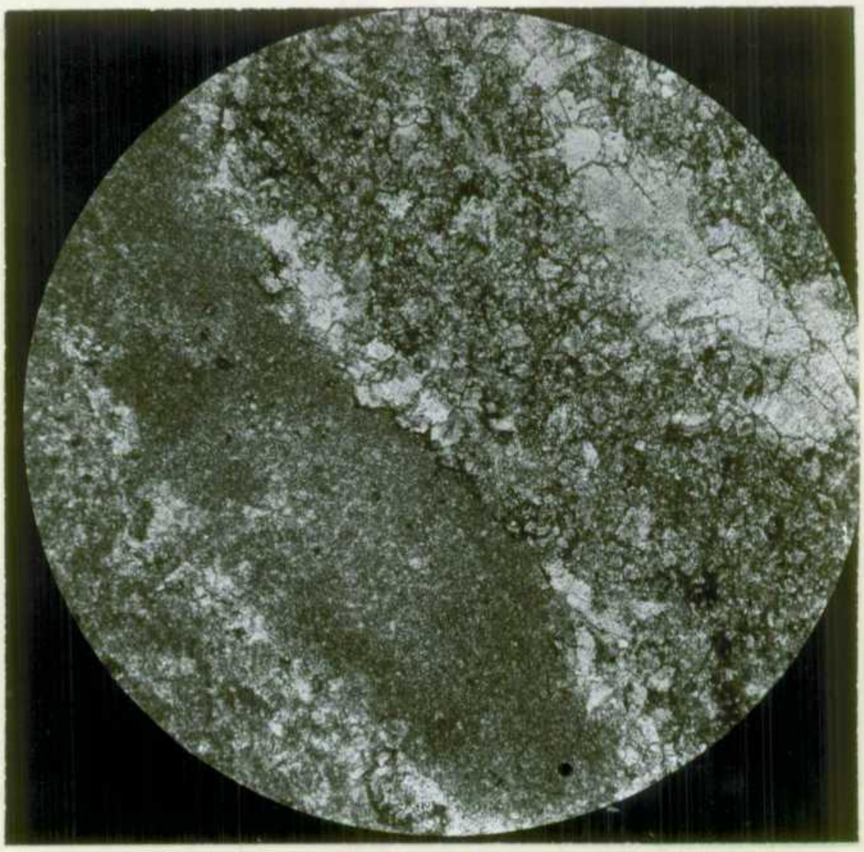


Fig. 2: Anthony Lagoon Beds showing junction between the nodule (crypto- and micro-crystalline calcite) and the matrix (micro and medium crystalline dolomite).
X45. (BT.301(a)). g/5433

PLATE 4.

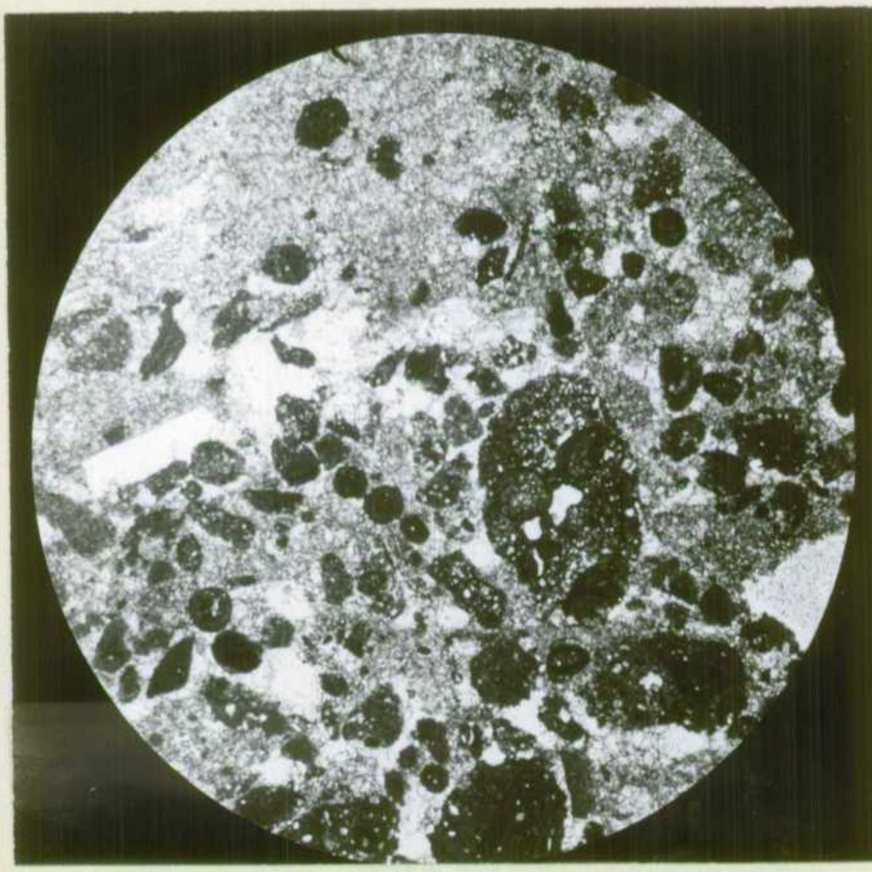


Fig. 1: Anthony Lagoon Beds, showing pellets and compound intraclast.(Right centre). X45. (AL 17) 5/5431.

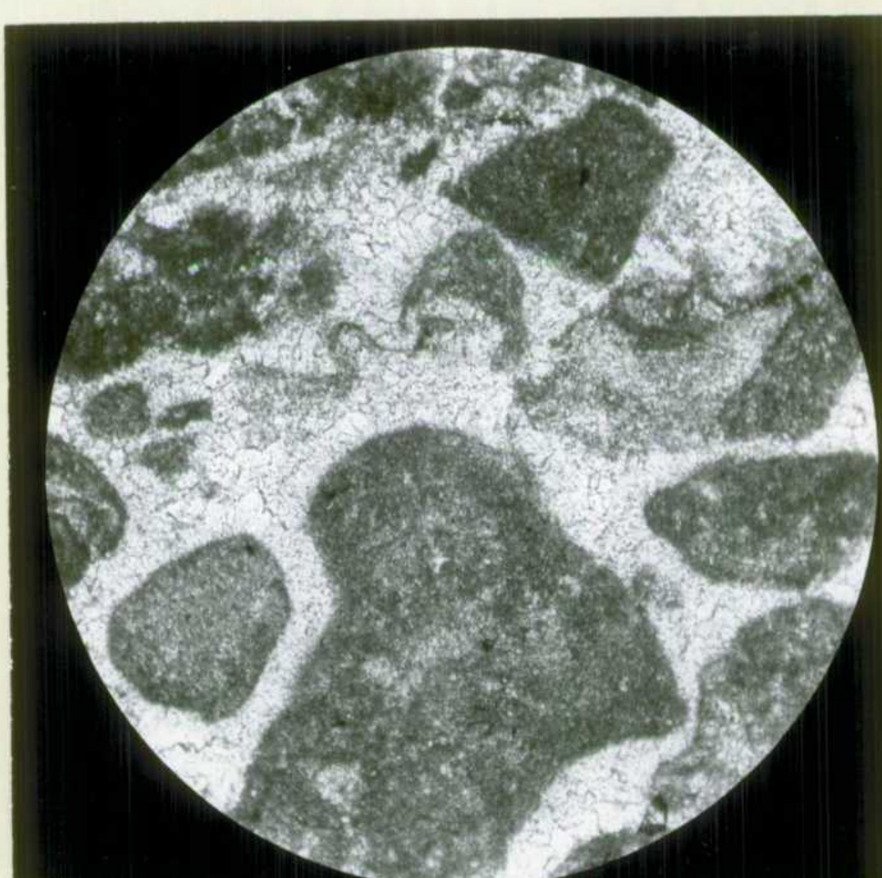


Fig. 2: Anthony Lagoon Beds, showing intraclasts and calcite cement (intrasparite); drusy cement occurs around the grains and gives way to granular cement.
X 45 (BT.330(a)). g/5443

PLATE 5

Fig. 1: Anthony Lagoon Beds, showing intraclasts and calcite cement. Intraclasts may be reworked algal structures. X 45 (BT 110(a)). g/5440.

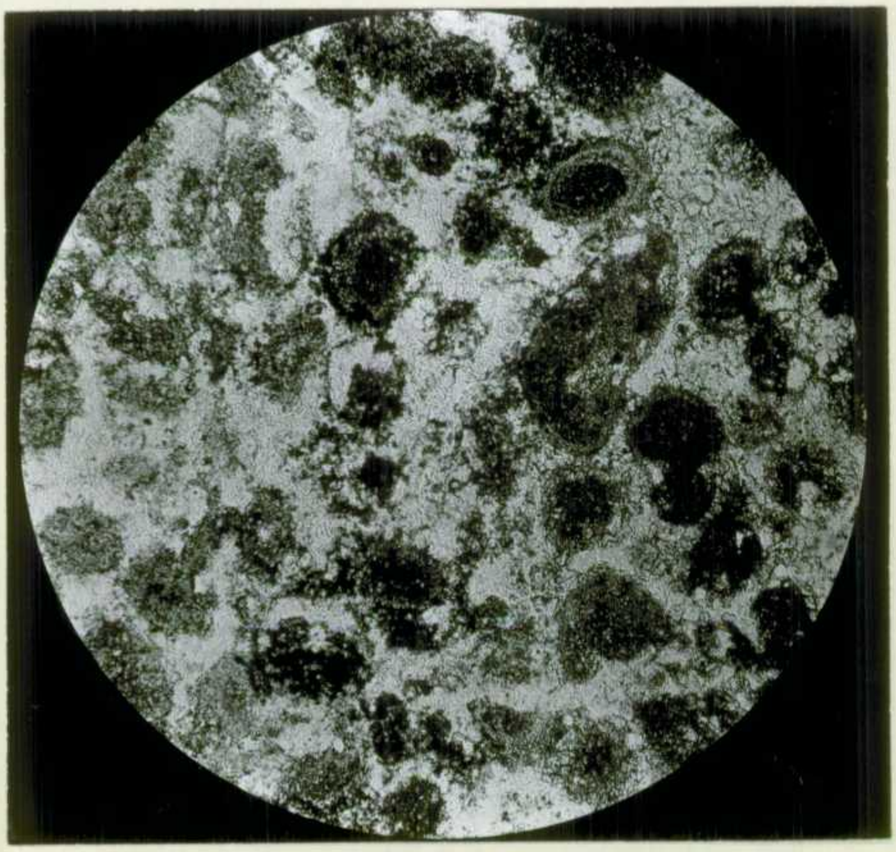


Fig. 2: Anthony Lagoon Beds, showing ooliths and partly silicified ooliths. X45 (BT.105). g/5439.

PLATE 6

Fig. 1: Anthony Lagoon Beds, showing intraclasts and microcrystalline calcite matrix. Forming intraformational conglomerate. X 12 (BT.302(c)). g/5427.

Fig. 2: Anthony Lagoon Beds, showing intraclasts partly dolomitised, with rims of cryptocrystalline calcite, (algal dust?) in cālcite cement. X 20 (BT 319(b). g/5430.

PLATE 7.

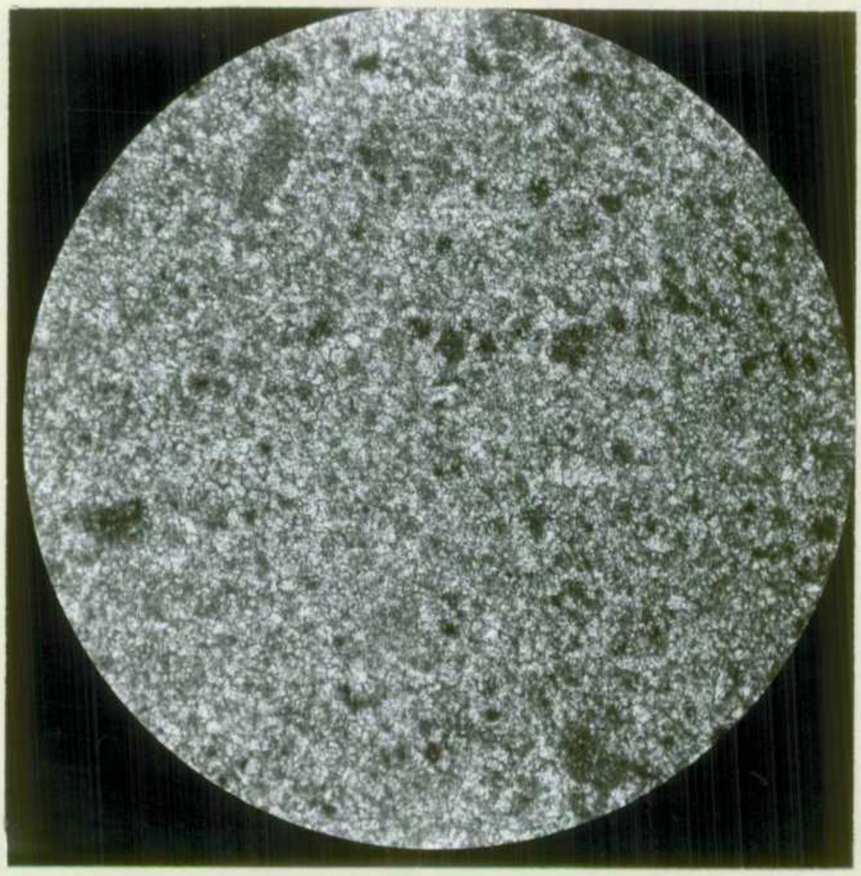


Fig. 1: Anthony Lagoon Beds, showing pellets and or relict patches of crypto crystalline calcite in micro-crystalline dolomite. X 45 (BT.329). g/5444

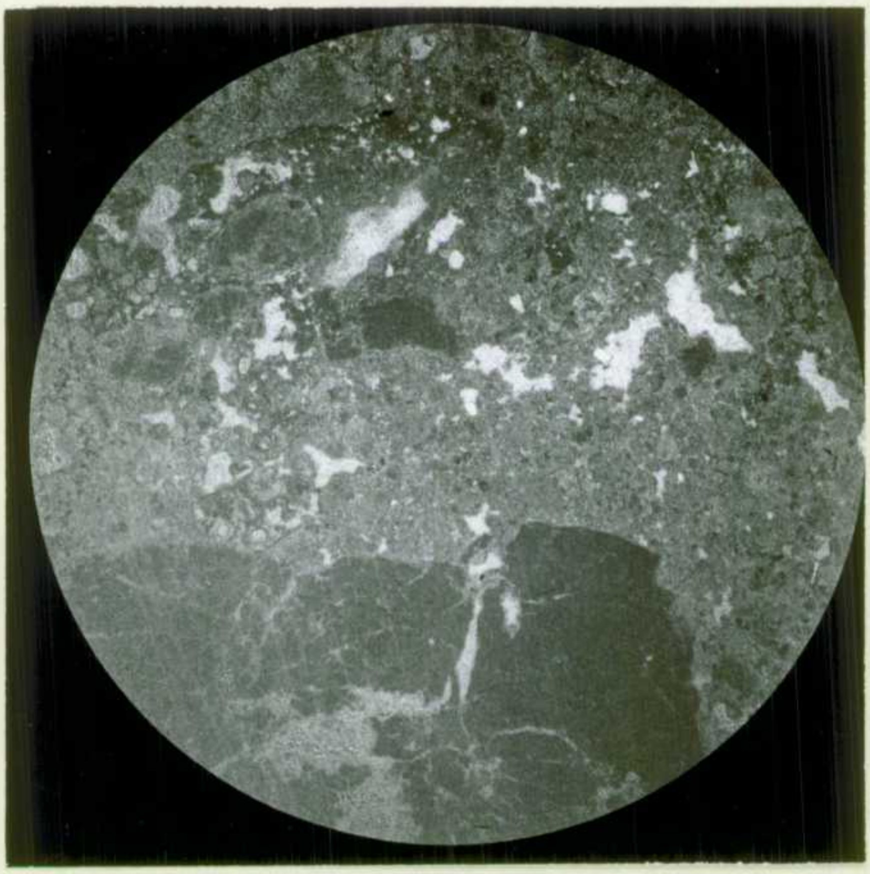


Fig.2: Anthony Lagoon Beds, showing conglomeratic calcilutite and infilled cavities. X 30 (BT.193) g/5423.

PLATE 8

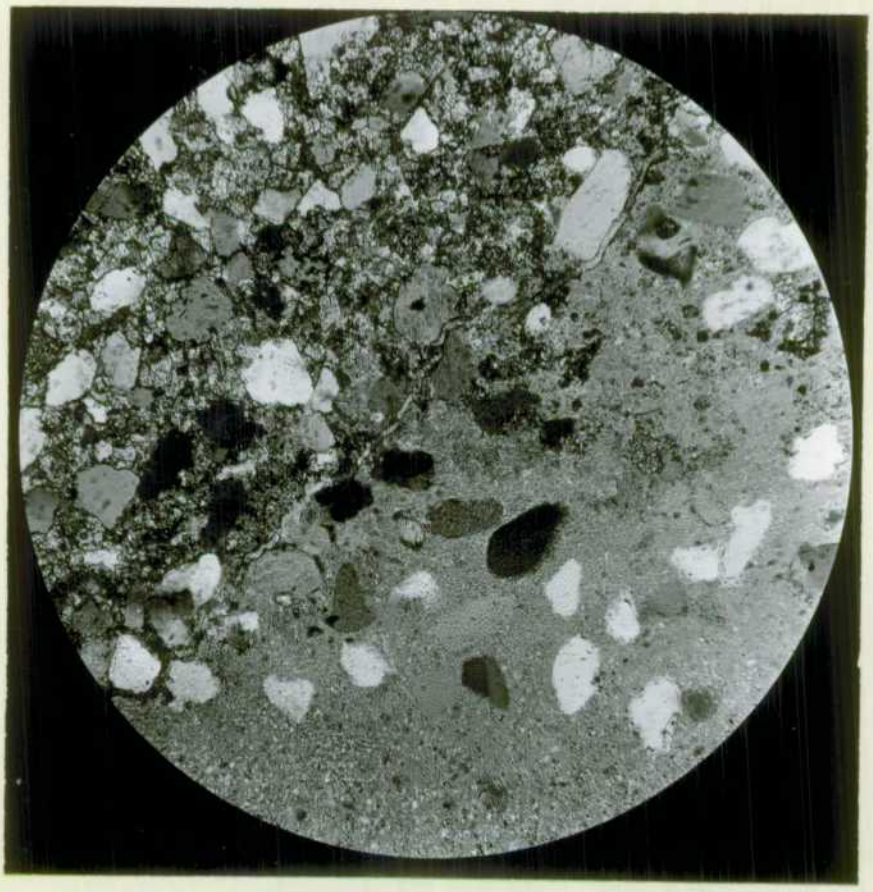


Fig. 1: Anthony Lagoon Beds, showing detrital quartz in calcareous matrix (upper left), and micro-crystalline silica of a secondary nodule replacing the matrix (lower right). X 45 X-polars. (BT.302(e).) g/5437

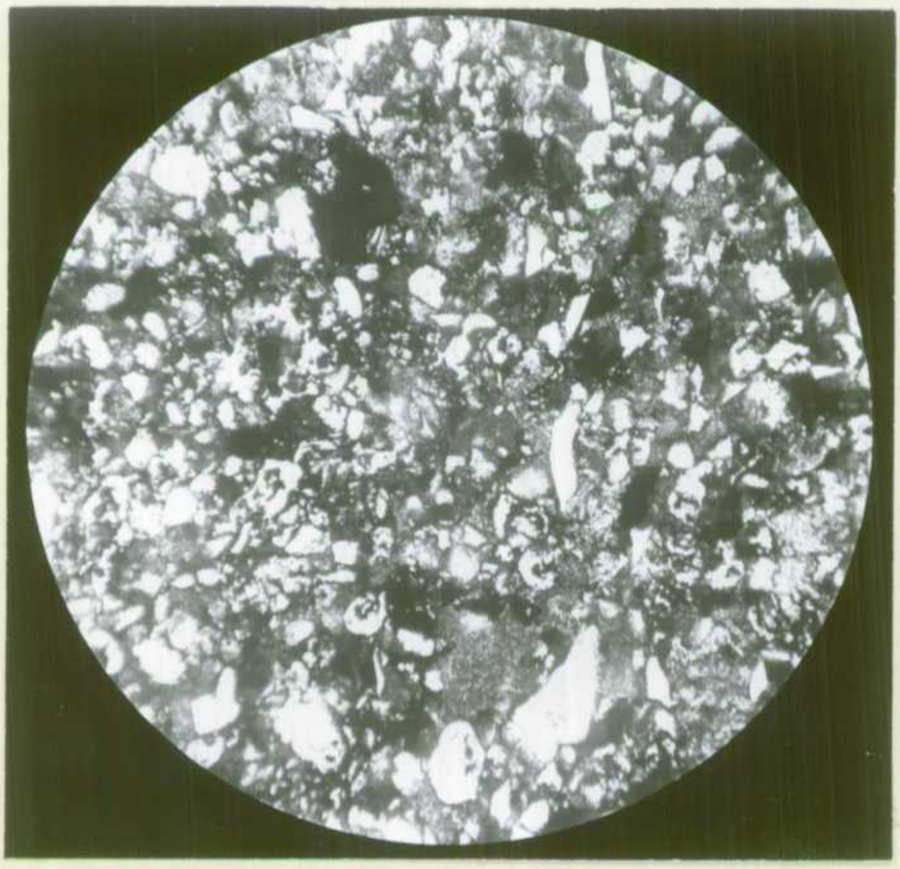


Fig. 2: Anthony Lagoon Beds, showing leached quartzose rock with kaolin. X 45 (BT.326(b)). g/5426.

PLATE 9

Figure 1: Anthony Lagoon Beds, showing organic-like structures in medium grained sandstone. X 1/3.(BT.328). g/5421

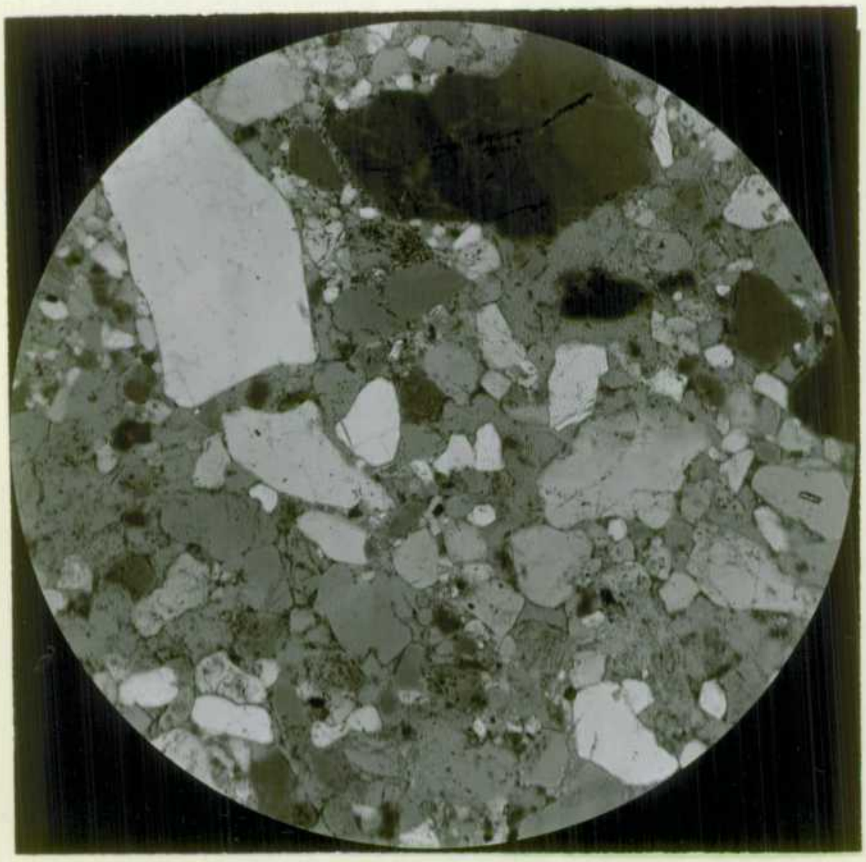


Figure 2: Anthony Lagoon Beds, showing medium grained sandstone with large grains. X45 (BT.326(d).) g/5422.

PLATE 10.

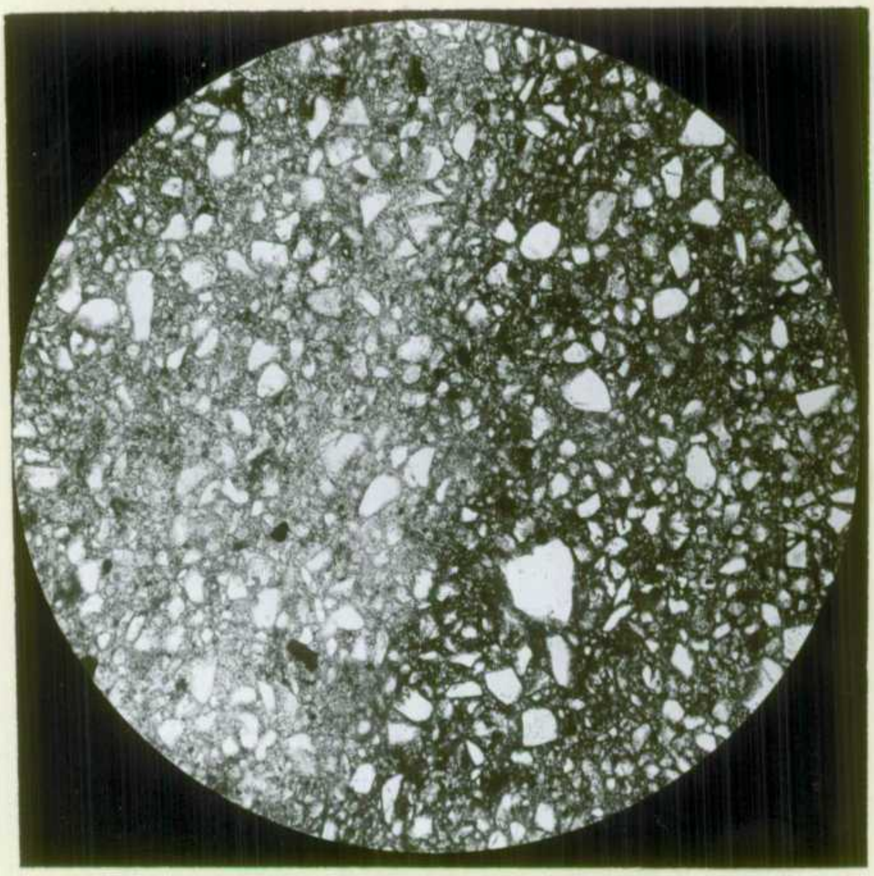


Fig.1: Anthony Lagoon Beds, showing siliceous and ferruginous siltstone. X 45 (BT.326(a)).g/5435.

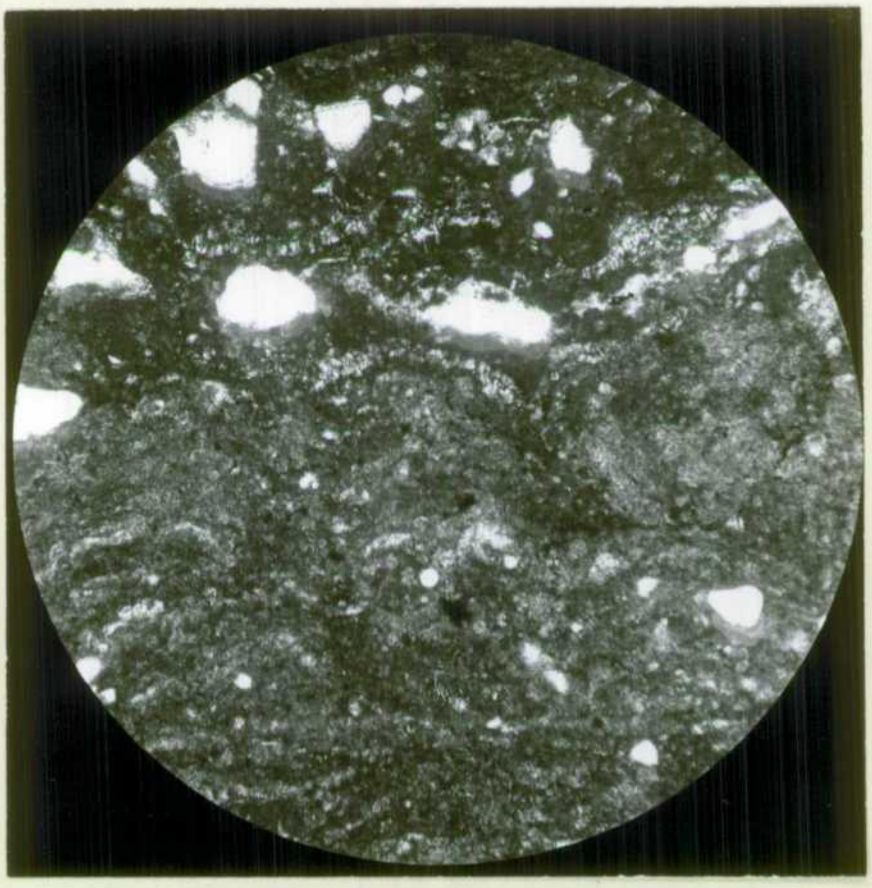


Fig.2: Brunette Limestone showing undulating algal layering (Lithothamnium sp.?). X 45 (BT.167(b)).g/5437.

PLATE 11

Fig. 1: Brunette Limestone, showing cryptocrystalline calcite with siliceous organic ? structure (top centre) and silicified cavities. X45. (BT.167(a)). g/5429

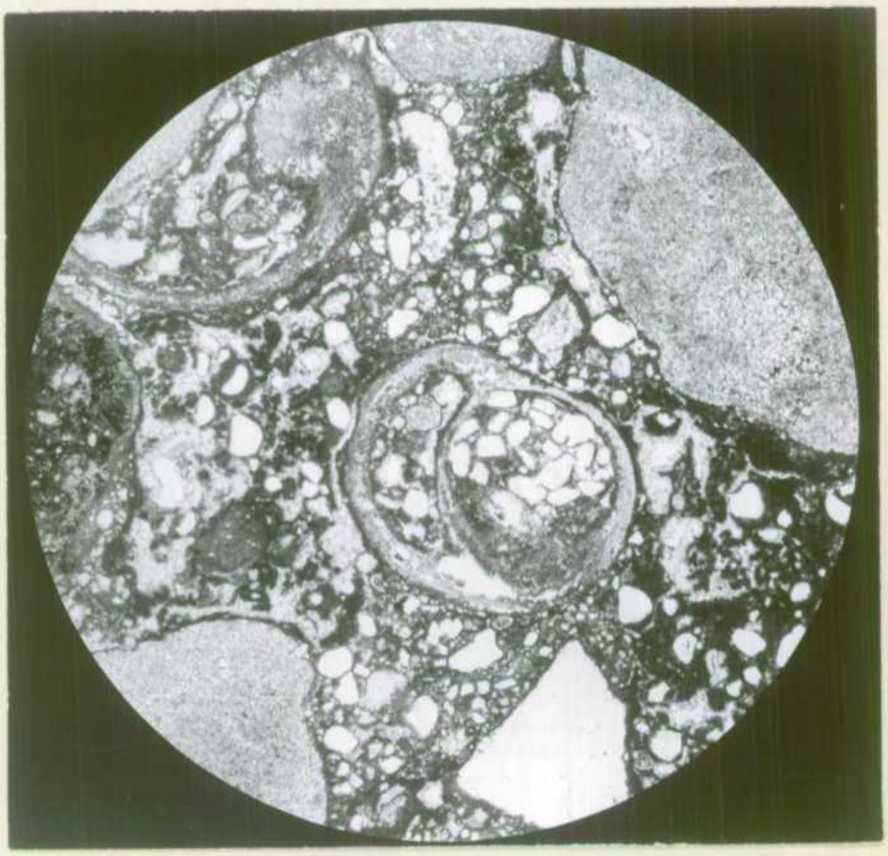


Fig. 2: Brunette Limestone, showing gastropods with foraminifera (centre), intraclasts, quartz and calcite matrix. X 40. (BT.169(. g/5424.

PLATE 12

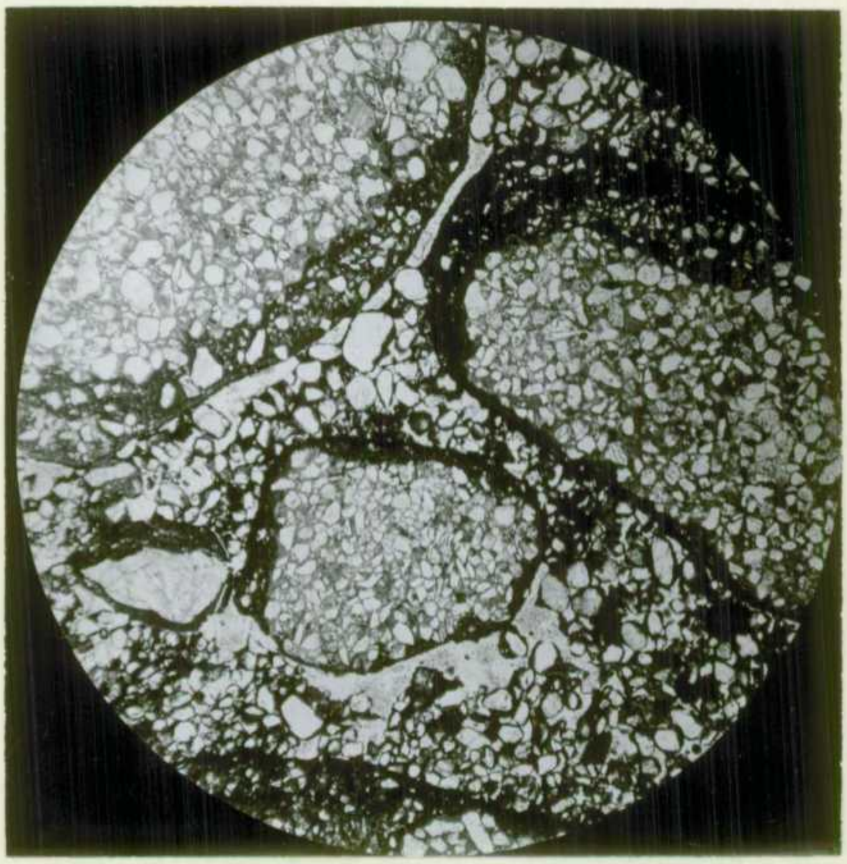


Fig. 1: Quaternary(?) conglomeratic sandstone, showing fragments of quartz sandstone surrounded by a siliceous layered rim. X45. (BT.324). G/5425.

PRELIMINARY EDITION, 1963

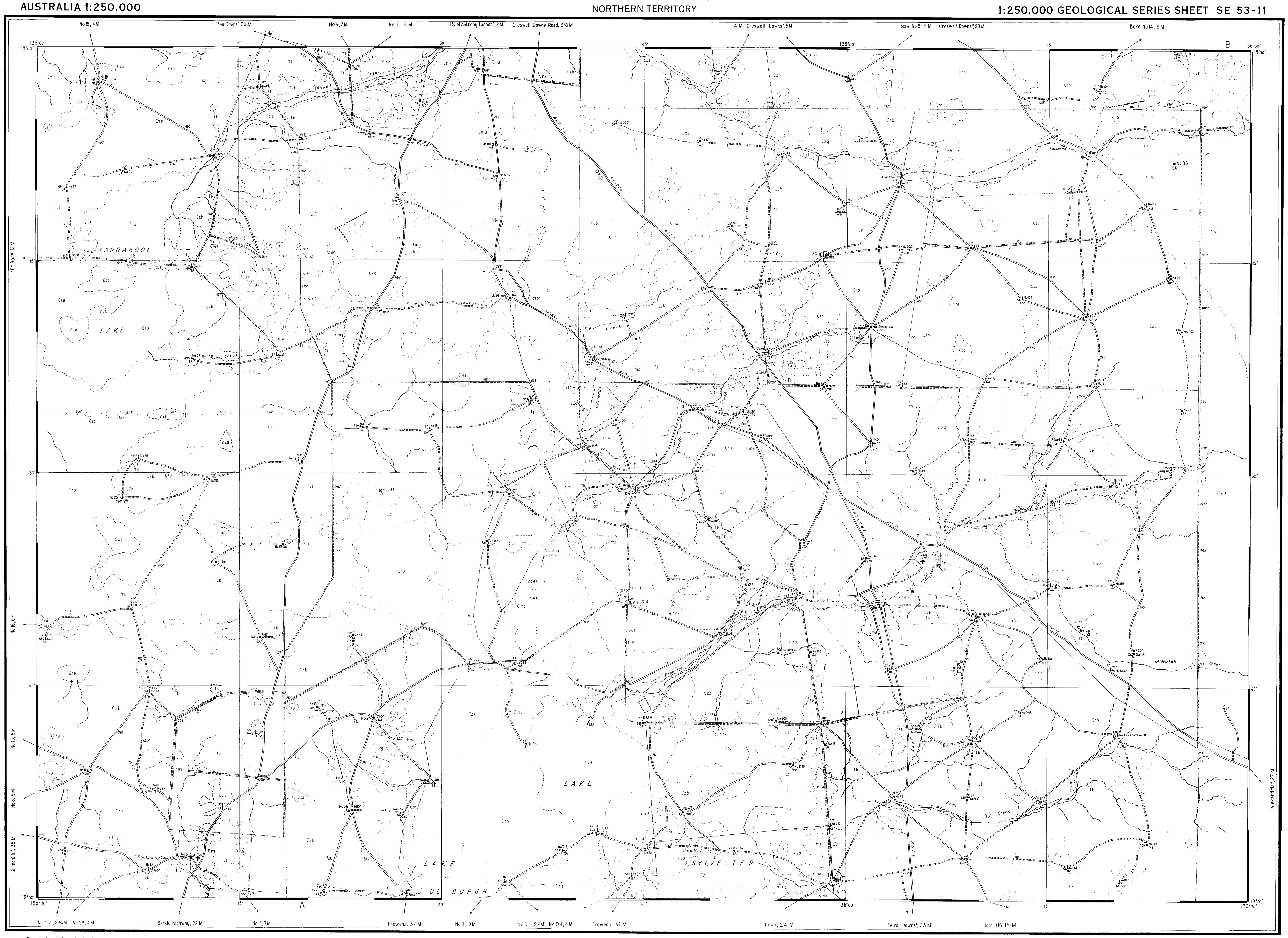
SUBJECT TO AMENDMENT

AUSTRALIA 1:250,000

BRUNETTE DOWNS

NORTHERN TERRITORY

1:250,000 GEOLOGICAL SERIES SHEET SE 53-11

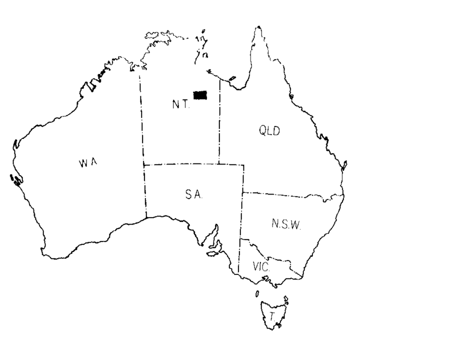


Reference

CAINOZOIC			Cza	Alluvium and river gravels, some black soil
			Czb	Black and grey clayey soils, some sand and gravel
			Czg	Gravel, pebbles of pisolitic ironstone and chert
			Czs	Residual sand, some black soil and gravel
			Czt	Travertine
	TERTIARY	Brunette Limestone	Tb	Nodular white limestone silicified in part and containing chert nodules and bands. Minor quartz sandstone and conglomerate. Fossiliferous
			Tl	Laterite. Mainly ferruginised sandstone and siltsone and leached carbonate rocks, some gravel and residual sand
MESOZOIC	LOWER CRETACEOUS		Kl	White quartz sandstone, partly silicified with plant remains
PALAEOZOIC	CAMBRIAN	Undifferentiated	€	Chert scree, dolomite and sandstone,(dolomite and sandstone in section)
	MIDDLE CAMBRIAN	Anthony Lagoon Beds	€ma	Dolomite and limestone, both with chert nodules and bands; some algal dolomite. Ferruginous, grey and white quartz sandstone and siltstone
PRECAMBRIAN	UPPER PROTEROZOIC	Mittiebah Sandstone	Pum	Cross-bedded and ripple marked ferruginous quartz sandstone
	UNDIFFERENTIATED		P	Section only

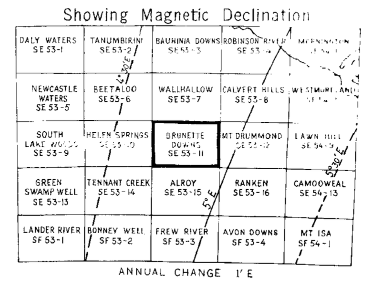
- Geological boundary, position approximate
- Fault
- Where location of fault is approximate, lines are broken; where concealed, faults are shown by short dashes
- Dip < 15°, air-photo interpretation
- Strike and dip of strata
- Macrofossil locality
- Plant fossil locality
- ×18 Sample locality (Text reference prefixed by "BT")
- SA No D8 Bore with windpump } SA = Sub-artesian
- SA No 17 Bore
- No 12 Abandoned bore (D = dryhole)
- Dam
- WH Waterhole
- Sink hole
- Road
- Vehicle track
- Track
- Fence
- "Brunette Downs" Homestead
- Yd Yard
- Landing ground
- Astronomical station
- •720′ Height in feet, barometric: datum, mean sea level

Compiled and issued by the Bureau of Mineral Resources, Geology and Geophysics, Department of National Development. Topographic base compiled by the Division of National Mapping, Department of National Development. Aerial photography by the Royal Australian Air Force; complete vertical coverage at 1:46,500 scale. Transverse Mercator Projection.

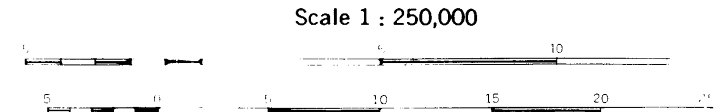


INDEX TO ADJOINING SHEETS

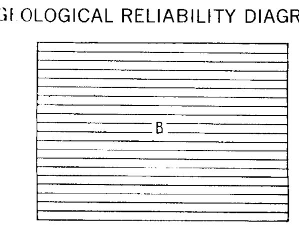
Showing Magnetic Declination



Scale 1 : 250,000

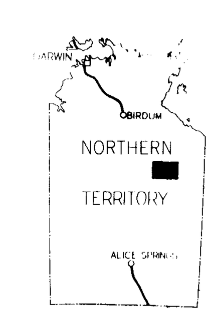


GEOLOGICAL RELIABILITY DIAGRAM

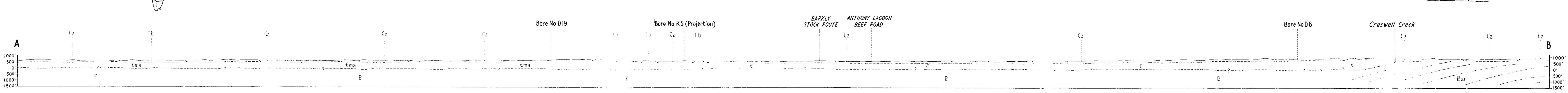


B Detailed reconnaissance, numerous traverses

Geology, 1962, by: M.A. Randal and R.A.H. Nichols
Compiled, 1962, by: M.A. Randal and R.A.H. Nichols
Drawn by: G. Matveev



Section



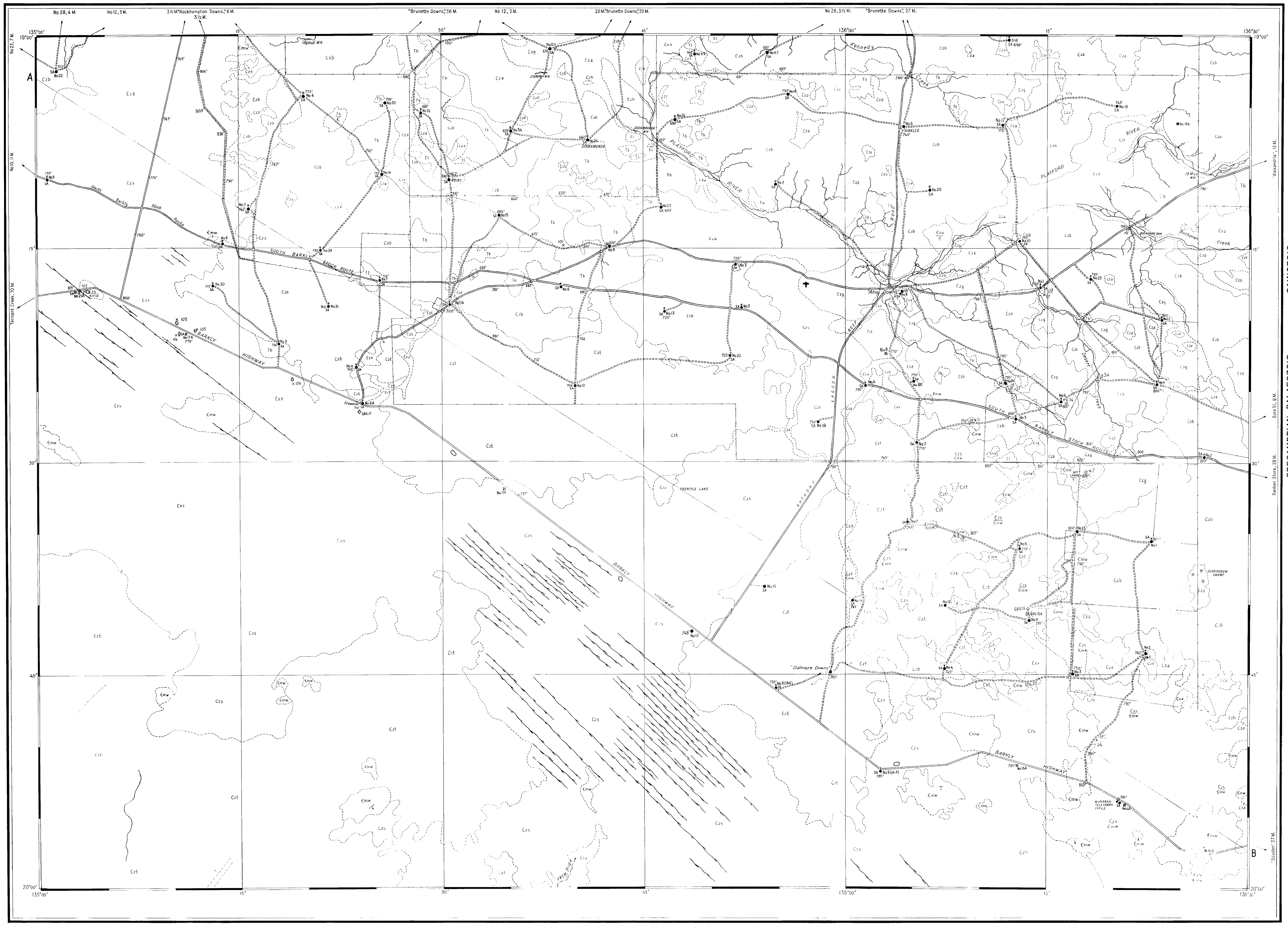
PRELIMINARY EDITION, 1963
SUBJECT TO AMENDMENT

AUSTRALIA 1:250,000

ALROY

NORTHERN TERRITORY

1:250,000 GEOLOGICAL SERIES SHEET SE 53-15



Reference

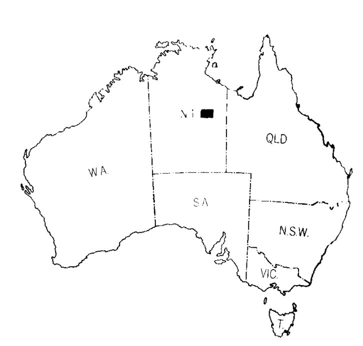
CAINOZOIC			Cza	Alluvium and river gravels, some black soil
			Czb	Black and grey clayey soils, some sand and gravel
			Czg	Gravel, pebbles of pisolitic ironstone and chert
			Czs	Mainly sand; black soil and gravel, travertine and detrital laterite, red clayey soil
			Czt	Travertine, some detrital laterite
	TERTIARY	Brunette Limestone	Tb	Nodular white limestone silicified in part and containing chert nodules and bands. Minor quartz sandstone and conglomerate
			Tl	Laterite. Mainly ferruginised sandstone and siltstone, leached carbonate rocks; some gravel and sand
PALAEOZOIC	CAMBRIAN	Undifferentiated	Є	Limestone and chert scree
	MIDDLE CAMBRIAN	Wonarah Beds	Єmw	Fossiliferous silicified limestone and dolomite, siltstone chert and silicified shale. Leached carbonate rocks
PRECAMBRIAN	PROTEROZOIC	Undifferentiated	P	Section only

Geological boundary, position approximate
Strike and dip of strata
Dip < 15° } Air-photo interpretation
Joint or trend line } Air-photo interpretation

Macrofossil locality
Specimen locality and reference number (Text reference prefixed by "Al")
SA No 12 Bore with windpump } SA, Sub-artesian
SA No 15 Bore } SA, Sub-artesian
No 16A Abandoned bore
Dam
WH Waterhole
Swamp
Quarry
GRG17 Stratigraphic hole
Sand dune

Road
Vehicle track
Track
Fence
"Alroy Downs" Homestead
Yd Yard
Landing ground
Astronomical station
•720′ Height in feet, barometric: datum, mean sea level

Compiled and issued by the Bureau of Mineral Resources, Geology and Geophysics, Department of National Development. Topographic base compiled by the Division of National Mapping, Department of National Development. Aerial photography by the Royal Australian Air Force, complete vertical coverage at 1:46,500 scale. Transverse Mercator Projection



INDEX TO ADJOINING SHEETS
Showing Magnetic Declination

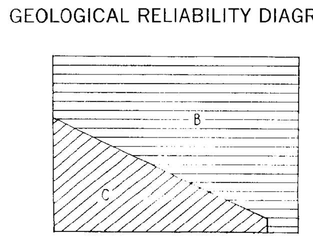
NEWCASTLE WATERS SE 53-5	BEETALOO SE 53-6	WALLHALLOW SE 53-7	CALVERT HILLS SE 53-8	WESTMORELAND SE 54-5
SOUTH LAKE WOODS SE 53-9	HELEN SPRINGS SE 53-10	BRUNETTE DOWNS SE 53-11	MT DRUMMOND SE 53-12	LAWN HILL SE 54-9
GREEN SWAMP WELL SE 53-13	TENNANT CREEK SE 53-14	ALROY SE 53-15	RANKEN SE 53-16	CAMOOWEAL SE 54-13
LANDER RIVER SF 53-1	BONNEY WELL SF 53-2	FREW RIVER SF 53-3	AVON DOWNS SF 53-4	MT ISA SF 54-1
MT PEAKE SF 53-5	BARROW CREEK SF 53-6	ELKEDRA SF 53-7	SANDOVER RIVER SF 53-8	URANDANGI SF 54-5

ANNUAL CHANGE 1′ E

Scale 1 : 250,000

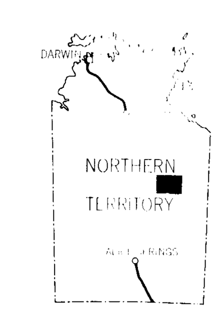
5 0 5 10 15 MILES
5 0 5 10 15 20 25 KILOMETRES

GEOLOGICAL RELIABILITY DIAGRAM



B Detailed reconnaissance, numerous traverses
C Air-photo interpretation

Geology, 1962, by; M.A. Randal and R.A.H. Nichols
Compiled, 1963, by; M.A. Randal and R.A.H. Nichols
Drawn by; P.J. Brown and G. Matveev



Section

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