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# Petrology of Proterozoic and Cambrian Sediments, Central Part of the Amadeus Basin, Northern Territory

by

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# PETROLOGY OF PROTEROZOIC AND CAMBRIAN SEDIMENTS

## CENTRAL PART OF THE AMADEUS BASIN, NORTHERN TERRITORY

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## SUMMARY

This report describes the general relationships of Proterozoic and Cambrian subsurface sediments in the central part of the Amadeus Basin. Results from some outcrop sections are also included.

The defined formations, intersected in the different wells, have been previously analysed and described in detailed petrological reports. All lithological variations are described, their modes of origin and diagenesis discussed and their types of environment postulated. Numerous clay analyses have been determined. The variations in abundance and distribution of the different clay types are plotted against lithology logs.

All lithological units, characterized by different petrological features are correlated with formations defined during geological field studies. The Bitter Springs Formation has been divided into two members in this area: a lower unit, the Gillen Member, characterized by chemically precipitated sediments including chlorides, sulphates and primary carbonate rocks; and an upper unit, the Loves Creek Member, showing a gradual return to normal marine sediments.

The northern lenticular Areyonga Formation and the southern Inindia Beds, represented by varying types of lithology, have been deposited in a marine, paralic shelf environment. No glacial influence has been noticed in the subsurface.

The monotonous chloritic, pyritic and phosphatic lutite and fine arenite of the Pertatataka Formation indicates sedimentation on a marine shelf area under quiet water conditions; the equivalent coarser southern Winnall Beds was deposited during continuous subsidence in the southern basin; a southern sedimentary and igneous landmass probably constituted the provenance.

Local disconformities have been observed between the three formations, but a major break in sedimentation occurred before Cambrian deposition when the Petermann Ranges Orogeny folded the Proterozoic sediments.

Intense diagenetic changes have affected all Proterozoic rocks: dolomitization, silicification, recrystallization of carbonate rocks, and development of chlorite and secondary sulphates are common features. Characteristics of the depositional environment have been obliterated. Definitely no metamorphism is required to explain these changes.

The basin had a markedly different shape during the Cambrian when sediments were deposited mainly in a restricted northern area. The ferruginous feldspathic arenites of the Arumbera Sandstone are submature marine sediments. Intense chemical weathering took place at this time on the ?southern continental land mass composed of Proterozoic igneous and metamorphic rocks.

The post Arumbera Sandstone sediments of the Pertaoorrta Group show marked lithological changes from east to west grading from carbonate rocks to sandstone. A cycle characterized by its reverse sedimentary order occurred in the central part of the basin with deposits of chlorides, sulphates and carbonates. A similar pattern of sedimentation to that of the Bitter Springs Formation occurred, but was characterized by more rapid lateral and vertical changes in sedimentation. Whereas saline and penesaline sediments were deposited in a restricted area in the lower part grading to open sea conditions in the upper part, the latter conditions were prevalent during the whole sequence elsewhere. The youngest formation of the Pertaoorrta Group indicates again, in this part of the basin, a decrease of biological features and an increase in coarse detritals.

The study of the clay types has shown that they are of limited value for correlation purposes with the exception of smectite in the upper part of the Pertaoorrta Group. There is a general relationship between clay types and facies.

The heavy mineral assemblage is represented by mature minerals; with the exception of garnet in the upper Pertaoorrta Group they do not have any correlation value. As no detailed petrological study of the basement is available, the heavy minerals cannot be used for the determination of source area and current direction. However, they indicate the maturity of these sediments. It is thought that the oil reservoir possibilities of the Proterozoic and Cambrian deposits are poor due to the diagenetic changes which have taken place in these rocks.

## INTRODUCTION

### General

This report presents the results of the petrology of Proterozoic and Cambrian subsurface sediments determined from detailed studies of six wells and several outcrop sections in the Amadeus Basin. An attempt is made to assess the importance of diagenetic changes and to emphasize the environment of deposition of the formations.

The Amadeus Basin is situated in the southern part of the Northern Territory; the sedimentary basin is roughly oval in shape, 400 miles long from west to east by 150 miles from north to south. The sedimentation continued from Proterozoic to Devonian. The region was mapped by officers of the Bureau of Mineral Resources between 1956 and 1964. Several company exploration wells were drilled in the Amadeus Basin; six of them have been studied in detail. They are: Alice No. 1, Ooraminna No. 1, Highway Anticline No. 2, Waterhouse Anticline No. 1, Mount Charlotte No. 1 and Erldunda No. 1 wells. Well data and the units drilled are presented in Tables 1 and 2.

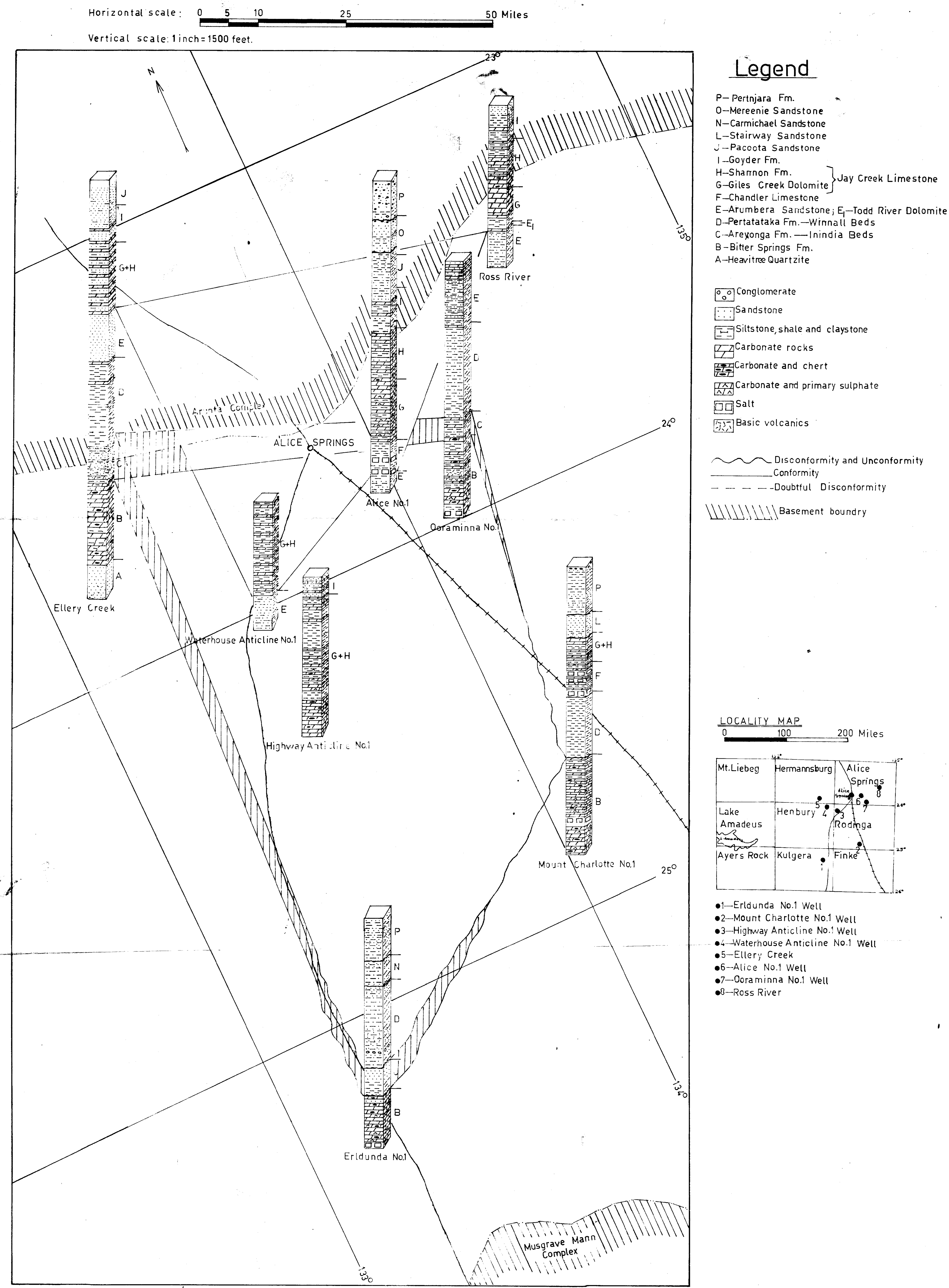
# GENERAL DATA ON THE WELLS OF THE CENTRAL PART OF AMADEUS BASIN, NORTHERN TERRITORY

| NAME OF WELLS | | Ooraminna No.1 | Mt.Charlotte No.1 | Erldunda No.1 | Alice No.1 | Highway Anticline No.1 | Waterhouse Anticline No.1 | |
|---|---|---|---|---|---|---|---|---|
| Name of oil company | | Exoil N.L. | Transoil (N.T.) | Exoil | Exoil | Exoil | Centralia Oil | |
| Location | | Lat.:24°00'06''<br>Long.:134°09'50'' | Lat.:24°53'41''<br>Long.:133°59'11'' | Lat.:25°18'36''<br>Long.:133°11'48'' | Lat.:23°54'47''<br>Long.:133°58' | Lat.:24°20'23''<br>Long.:133°27'06'' | Lat.:24°01'00" South approx.<br>Long.:133°32'East | |
| Elevation | | G.L.1613'a.s.l.<br>K.B.1624'a.s.l. | G.L.1246'a.s.l.<br>K.B.1260'a.s.l. | G.L.1330'a.s.l.<br>K.B.1343'a.s.l. | G.L.1742'a.s.l.<br>K.B.1753'a.s.l. | G.L.1603'a.s.l.<br>K.B.1616'a.s.l. | G.L. not indicated<br>K.B. not indicated | |
| Purpose | | Stratigraphic — Structural test | Stratigraphic — Structural test | Stratigraphic— Structural test | Stratigraphic — Structural test | Stratigraphic — Structural test | Structural test | |
| Total Depth | | Driller 6097'<br>Schlumberger 6107' | Driller 6943'<br>Welex 6939' | Driller 5463'<br>E.logs 5457' | Driller 7518'<br>Schlumberger 7503' | Driller 3770'<br>E.logs 3725' | Driller 3081'<br>E.logs 3077' | |
| Quaternary | | | | *140' | | | | DEVONIAN |
| FORMATIONS and THICKNESS: Pertnjara Fm. | P | | * 1144'+ | 760'+ | * 1154'+ | | | |
| Mereenie Sandstone | O | | | | * 950' | | | |
| Carmichael Sandstone | N | | | 340' | | | | ORDOVICIAN TO CAMBRIAN |
| Stokes Siltstone | M | | | | | | | |
| Stairway Sandstone | L | | *345' | | | | | |
| Horn Valley Siltstone | K | | | | | | | |
| Pacoota Sandstone | J | | | | * 889' | | | |
| Goyder Fm | I | | | | 800' | +436' true thickness<br>+480' drilled thickness | | CAMBRIAN |
| Jay Creek Limestone: Shannon Fm | H | | 792' | | 1343' | +2952' true thickness | 2254'+ | |
| Jay Creek Limestone: Giles Creek Dolomite | G | | | | 1471' | +3245' drilled thickness | | |
| Chandler Limestone | F | | 740' | | 522' | | | |
| Arumbera Sandstone | E | 1530'+ | | | 378'+ | | 827'+ | UPPER PROTEROZOIC |
| Pertatataka Fm<br>Winnall Beds | D | 2200' | 1598' | 2510' | | | | |
| Areyonga Fm.<br>Inindia Beds | C | 535' | | 550' | | | | |
| Bitter Springs Fm. | B | 1835'+ | 2269' drilled thick.<br>+2130' true thickness | 1163'+ | | | | |
| Heavitree Quartzite | A | | | | | | | |

NOTE:* Formations not studied in detail.
A — P refers to the units named on the Correlation Chart.

To accompany B.M.R. Record No. 1967/23

# LITHOLOGICAL CORRELATION CHART of Central part of Amadeus Basin, Northern Territory




To accompany Record: 1967/23

Drawn by: S.Ozimiç

Regional Geology

The Amadeus Basin in its present form, occurs as a latitudinally elongated synclinorium between the northern Arunta and the southern Musgrave-Mann metamorphic igneous complexes.

The stratigraphic column includes strata ranging in age from Proterozoic to Devonian and embraces an aggregate thickness of about 30,000 feet of sediments. In the northern part of the basin the Proterozoic sedimentation commenced with the Heavitree Quartzite, a basal sandstone unit transgressing the basement. The conformably overlying Bitter Springs Formation consists mainly of algal carbonate rocks. The Areyonga Formation follows with a transitional contact and is a mixed unit of arenite, lutite, calcilutite with some tillitic horizons. The youngest Proterozoic formation, the Pertatataka Formation, conformably overlies the Areyonga Formation and comprises mainly lutite, fine arenite and rare calcilutite.

In the southern part of the basin the sedimentation is coarser and four formations are equated with the above formations: they are the Dean Quartzite, the Pinyinna, Inindia and the Winnall Beds with regional unconformities.

The Cambrian marine deposits of the Pertaoorrta Group show a lateral east-west change in the sedimentation with the exception of the lower-most Arumbera Sandstone and its lateral equivalents the Quandong Conglomerate and the Eninta Sandstone. In the eastern part of the basin the Arumbera Sandstone is conformably overlain by mainly fossiliferous carbonate rocks comprising the Todd River Dolomite, the contorted Chandler Limestone, the Giles Creek Dolomite and the Shannon Formation. This sequence changes facies westwards into the Jay Creek Limestone which becomes more detrital and passes into the Hugh River Shale, and in the central part of the basin this formation grades into a composite arenite, lutite and calcilutite facies comprising the Tempe Formation and Illara Sandstone, Deception Formation and Petermann Sandstone. The arenitic Goyder Formation is the uppermost formation of the Pertaoorrta Group, but it is not present in the extreme western part where the arenitic Cleland Sandstone forms the whole Cambrian sequence.

The Cambrian sediments are followed by thick, mainly arenitic deposits comprising the Larapinta Group, the Mereenie Sandstone and the Pertnjara Group which is the youngest unit in the Amadeus Basin and is Upper Devonian to possibly Carboniferous in age.

Since the Devonian-Carboniferous? the basin has alternated between periods of minor continental deposition and periods of weathering.

## Structure

Two main episodes of folding and two minor epeirogenies are recognised in the Amadeus Basin:

- post Bitter Springs Formation - pre Areyonga Formation (Kulgera Tectonism).

- folding post Pertatataka Formation and pre Arumbera Sandstone (Petermann Ranges Orogeny).

- post Larapinta Group - pre Mereenie Sandstone (Rodingan Movement).

- folding post Pertnjara (Alice Springs Orogeny).

The main structural features are east-trending fold axes. Major recumbent folding involving the basement and basal part of the sedimentary sequence at the north-eastern and south-western margins of the basin, and complex folded thrust faults mainly in the east.

## Previous Petrographic Investigations

The French Petroleum Co. (Aust.) (1963) studied the Ellery Creek (Hermannsburg Sheet area) and the Ross River sections (Alice Springs Sheet area) in detail and determined possible correlations between lithological units in the Georgina Basin and the Amadeus Basin especially by clay analyses.

Cook (1966) made a petrological study of the phosphatic Stairway Sandstone and McCarthy (1965) presented the results of petrological studies of samples, mainly from the Arunta Complex basement but also some sedimentary Proterozoic rocks. In a first interpretation he thought that a low grade metamorphism had affected the northern and the more central Proterozoic sediments in the Amadeus Basin. But after studying more samples, he considered that only recrystallization is responsible for the changes occurring in these rocks and no metamorphism is required to explain the post-sedimentary features.

Leslie (1965) studied the heavy minerals in the Pertnjara Group and confirmed the unreliability of the heavy mineral assemblage for correlations.

Scott and Schultz (in Youles, 1966) studied samples from Ooraminna No. 1 well for trace elements.

Stock (1966) determined the clay mineralogy from subsurface samples in five wells.

Fehr (1966) and Schmerber (1966 a, b, c, d, e, f) studied the detailed petrography of the Proterozoic and Cambrian sediments in Alice No. 1, Ooraminna No. 1, Waterhouse Anticline No. 1, Highway Anticline No. 1, Mount Charlotte No. 1, Erldunda No. 1 wells in addition to selected field samples. They correlated the units established in the well sequence with formations defined in outcrop.

Consequently it is proposed to include their results and give a general petrological description of the formations or units intersected in the wells.

Techniques used for studying the lithologies

As reported in the detailed petrological studies of the wells, several techniques have been used, the most useful being thin sections from cores and cuttings, heavy minerals, phosphate and staining tests and calcimetry.

The calcimetry tests have been carried out to obtain the proportion of limestone to total carbonate for each unit; the standard Bernard method has been used; the amount of carbon dioxide lost by dissolution in HCl, after one and nine minutes, gave an approximation of the actual ratio of limestone to total carbonate content.

All petrological results have been plotted on composite logs [redacted]. Semi quantitative clay mineralogy has been determined on 38 samples by X-ray diffraction in the A.M.D.L. laboratories and from these results an estimate made of the importance of metamorphic processes. (For more details see A.M.D.L. report MP2458-66 by Stock, 1966).

Nomenclature

Terminology of clay minerals

The clay minerals in this report are described in accordance with the following definitions.

Smectites: 12 to 15 sheet silicates; swell with glycerol to 17.7-18.8A$^{o}$; heated 550$^{o}$C collapse to 9.5-10A$^{o}$. Smectite is the British term referring to the montmorillonite group of clay minerals.

Chlorite and Chlorite-related Minerals include -

- true chlorite which does not expand with glycerol.
- regular chlorite - ? smectite is a regularly interstratified clay mineral with layers of chlorite and of a swelling clay mineral notably smectite.

- corrensite is a regularly interstratified chlorite and swelling chlorite. Traces of corrensite have been identified only in two outcrop sections by the French Petroleum Co. Aust. 1963.

- random chlorite - smectite is an irregularly interstratified clay in which chlorite is the host for the smectite component.

Illite is a non specific term for mica - like clay minerals. Illites may be distinguished from normal well crystallized micas by containing less potassium and more water. However, the X-ray diagrams for mica and mica related minerals remain similar even where the potassium content of the mineral changes considerably. Kaolin is the group name for the 7A° clay minerals kaolinite, dickite and nacrite; these minerals do not swell with glycerol.

Nomenclature of sedimentary rocks

In the description of sandstone, siltstone and shale, limestone and dolomite, the classification of Pettijohn (1956) has been used; the descriptive size terms are according to the Wentworth Scale as follows:-

| | | |
|---|---|---|
| $<$0.1 mm | = | very fine |
| 0.2 mm | = | fine |
| 0.3 to 0.5 mm | = | medium |
| 0.5 to 1.0 mm | = | coarse |
| 1 to 2 mm | = | very coarse |
| $>$2 | = | pebbles |

## DESCRIPTION OF FORMATIONS

### Bitter Springs Formation

This formation was originally named Bitter Springs Limestone by Joklik (1955), but the name has been changed to Bitter Springs Formation by Ranford et al., (1965); the formation has been subdivided by Wells et al., (1968) into two members: a lower unit, the Gillen Member and an upper unit, the Loves Creek Member.

In outcrop the Gillen Member consists mainly of fine-grained, laminated dolomite with lesser amounts of fine sandstone, green and minor red siltstone and shale with salt pseudomorphs, and masses of brecciated and sheared gypsum; the Loves Creek Member is composed of cherty, algal dolomite, some limestone and red siltstone (Wells et al., 1968) which commonly shows white or yellow bleached spots. In the subsurface the units which have been considered as equivalents of both members are characterized by the following features:

- equivalent of the Gillen Member : salt; dark grey, laminated, cherty, very fine-grained dolomite; dolomitized limestone with interlaminated anhydrite and minor gypsum; minor reddish dolomitic siltstone and sandstone.

- equivalent of the Loves Creek Member: clear, variegated, cherty, sandy dolomite, dolomitized limestone with algae; reddish siltstone and sandstone. It must be emphasised that this member is characterized by rapid changes in lithology.

The Bitter Springs Formation has been intersected in three wells and several samples from outcrop sections have been studied (Ellery Creek-Hermannsburg Sheet area, and Gardiner Range-Henbury Sheet area). As the contact between both members is gradational, the thicknesses shown below are tentative.

| Stratigraphy | | | Ooraminna No. 1 | Mt Charlotte No. 1 | Erldunda No. 1 |
|---|---|---|---|---|---|
| Bitter Springs Fm. | Loves Creek M. | Depth | 5280' to 4265' | 5100' to 4670' | 4750' to 4300' |
| | | Thickness | 1015' | 430' | 450' |
| | Gillen M. | Depth | T.D. 6100' to 5280' | T.D. 6939' to 5100' | T.D. 5463' to 4750' |
| | | Thickness | 820'+ | 1839'+ | 713'+ |
| Total thickness | | | 1835'+ | 2269'+ | 1163'+ |

Lithologies

In the three wells, sediments correlated with the Gillen Member are represented mainly by chemical, precipitated rocks and minor dolomite and very rare arenites. Primary chlorides, sulphates and carbonates are dominant.

Chlorides: These rocks are light reddish, greyish and beige, coarsely crystalline, pure or with intermingled red claystone and halite.

In Mount Charlotte No. 1 well the salt includes numberous broken pieces of grey and blackish, laminated anhydrite with very fine grained dolomite.

A clay analysis has shown the presence of 80% illite and 20% chlorite. No corrensite, sepiolite or attapulgite have been noticed.

The salt occurs generally as compact masses or in thin bands interlaminated in the carbonates.

Carbonates and Sulphates

Dolomite with interlaminated anhydrite and minor gypsum form the main components of the upper part of the Gillen Member.

Dolomite occurs as:

- blackish-grey, cryptocrystalline, locally finely laminated with argillaceous and blackish matter, and in places with intraformational synsedimentary contortions, microslumping and microbreccias formed by the disruption of primary laminae.

- variegated, locally very haematitic, cryptocrystalline to microcrystalline, with variable detrital content. The detritals are angular to rounded, poorly sorted quartz, rare orthoclase and microcline. The lithic content is composed of igneous and sericitized rock fragments, fine grained microquartzite, ooliths and intraclasts. Very rare glauconitic pellets, muscovite, biotite, and phlogopite? occur either scattered throughout or emphasizing the bedding.

Brownish, cryptocrystalline to microcrystalline recrystallized quartz-chert is abundant as finely laminated bands, as nodules, or in places replacing oolitic structures.

The anhydrite and rare gypsum are white to light grey, finely laminated, with polygonal mosaic or pile of brick texture. The contact with the overlying carbonate is either abrupt or gradational with a progressive increase of minute dolomite rhombs. The sulphates occur also as isolated patches and lenses in an anhydritic-dolomitic groundmass.

The percentage of calcite through this dolomitic and anhydritic sequence is less than 10%.

The following clay minerals were recorded: a dominance of illite, smaller amounts of chlorite, locally regular chlorite ? smectite and rare kaolin. Shale and siltstone occur in minor amount as ferruginous, slightly dolomitic and illitic or blackish, illitic, chloritic, pyritic and micaceous rocks in some instances with anhydrite patches.

Thin, interbedded, fine grained mature quartzitic sandstone streaks contain glauconite grains and pellets. An X-ray analysis carried out by the B.M.R. (C.D. Branch, pers. comm.) showed the presence of well crystallized strengite ($Fe\ PO_4$, $2H_2O$) in association with abundant pyrite. The cementing media comprises haematite, quartz overgrowth, chlorite, smectite, kaolin, carbonates and sulphates.

The contact with the overlying Loves Creek Member is gradational and characterized by the decrease of greyish fine dolomite and the disappearance of interlaminated sulphates.

<u>Loves Creek Member</u>

This member comprises a more diversified lithology than the lower Gillen Member and it is characterized by a considerable increase in fine detritals. Basic volcanic rocks occur in the member in the Ooraminna No. 1 well, as well as in outcrops in the north-eastern part of the basin. The carbonate rocks have a similar lithology to those of the Gillen Member, but blackish dolomite does not occur. They are mainly beige and reddish, locally very rich in haematite clusters and in detritals. Very rare recrystallized algal structures have been noticed.

Anhydrite and minor gypsum occur only in spots, lenses and intergranular crystals; very rare anhydrite laminae have been observed, localized at the base of this member.

Quartzitic sandstone and ferruginous siltstone and shale are similar to those described in the Gillen Member.

Clay X-ray diffraction has shown that illite and chlorite are dominant and associated with random chlorite-smectite.

Basic Volcanics

Three bands of highly altered dolerite or spilite are present in Ooraminna No. 1 well. It cannot be ascertained from this study if the dolerite is intrusive or extrusive, but the absence of contact metamorphism in the surrounding sediments suggests an extrusive rock.

## Age of the Bitter Springs Formation

A Rb/Sr age determination has been carried out on one sample from Mount Charlotte No. 1 well by the B.M.R. The apparent maximum age found was 1170 million years. This age is compatible with the Proterozoic age determined mainly on the occurrence of Collenia type stromatolites (Wells et al., 1968).

## Lithological correlations

Thickness: In the Erldunda No. 1 and Mount Charlotte No. 1 wells the Loves Creek Member has a comparable thickness. However, in Ooraminna No. 1 the change in lithology corresponds to an increase in thickness.

Lithology: The lithology of the Gillen Member is very constant and no important changes have been noticed in the three wells. It is probable that similar sediments were deposited throughout the central part of the Amadeus Basin.

In the Loves Creek Member where sedimentation occurred under less restricted conditions, the ratio of carbonates to lutites and arenites is very variable, but higher in the Mount Charlotte No.1 and Erldunda No. 1 than in Ooraminna No. 1. In the northern part of the basin, the sedimentation has been more detrital.

Clays: There is a close relationship between clay types and lithology in the Bitter Springs Formation. Salt layers are accompanied by well crystallized illite and chlorite; primary dolomite and sulphates contain well crystallized illite and chlorite, rare regular chlorite-smectite and some kaolin; poorly to medium crystallized illite and chlorite, random chlorite-smectite occur in detrital carbonate rocks. In the Ellery Creek outcrop section the French Petroleum Co. Aust. (1963) found the same dominance of illite and chlorite occurs with slightly more kaolin and especially traces of corrensite. This clay type has not been found in any subsurface samples. The association of different clay types with changing facies in a formation in European and American Permian and Triassic sediments has been emphasised by Fuchtbauer and Goldschmidt (1959), Grim Droste and Bradley (1960), and Lucas (1962). However, corrensite is a normal mixed-layer clay to be expected in a chemical marine evaporitic facies whereas attapulgite and sepiolite are localized in highly saline lakes.

The rather monotonous association of mainly illite and chlorite may be explained by strong aggradation (Millot 1963, p. 321) of the detrital clays under sedimentary and diagenetic action. Illite and chlorite are the most common stable clays in a marine environment. Millot states that under diagenetic action smectite and the mixed-layer clays tend towards a regularisation of their framework and the end product is an association of well crystallized illite and chlorite.

Diagenesis

In this mainly dolomitic formation, the changes that have taken place have been primarily due to lithification by compaction as shown by numerous styolites rich in black matter. However, the most important changes which have been noticed may be divided into two major events: pre-diagenetic recrystallization by dolomitization and silicification and a post-diagenetic development of anhydrite, gypsum and salt.

Recrystallization - Dolomitization: Recrystallization and dolomitization is observable in the carbonate rocks of the Loves Creek Member where the grain size tends towards a microgrenue size; all clasts, ooliths and algal structures have been re-crystallized and dolomitized.

This dolomitization is of formational extent with preservation of the original texture by the pseudomorphing of calcite fabrics and textures (Murray 1964), believed to have occurred on the sea floor either rapidly or in stages.

The magnesium may be derived either by the strong development of algae or from magnesium bearing soltuions, perhaps from the underlying progressively compacted Gillen Member.

Silicification: The development of chert bands and nodules replacing carbonate crystals may be considered as an early stage. The origin of such a quantity of silica has not yet received an explanation.

It is thought that crystallization of clays occurred during the pre-diagenetic events.

Development of secondary sulphate: Intrusive and recrystallized anhydrite and gypsum, in the form of intergranular anhydrite sparites in dolomite, siltstone and sandstone or filling cavities and fissures, are associated probably with tectonic movements.

In the same way some salt layers in Mount Charlotte No. 1 including broken dolomite and anhydrite fragments are considered to be intrusive.

Environment: The Bitter Springs Formation is considered to be an association of evaporites and primary sedimentary accumulations including chlorites, sulphates and inorganically precipitated carbonate rocks. The succession is characterized by marked cyclical repetition representing stages in sedimentation during the restriction of a seaway.

A gradual return to normal marine conditions, emphasized by the presence of algae, has taken place in the upper part of the formation. These stages which appear to be in reverse orders to that normally present in evaporitic deposits have been summarized in Table 3.

The change in the vertical succession is similar to the lateral changes in the formation. In the basal saline and penesaline environments, ooliths and sedimentary structures, such as microslumping sedimentary breccias, suggest agitated shallow water conditions in a restricted sea where excessive evaporation has taken place under arid conditions. The sediments deposited in agitated conditions alternated with sediments showing evidence of deposition under stagnant conditions such as blackish shale and dark colored dolomite.

In the upper part of the formation and increasing towards the top, deposits of clastics (siltstone and mature quartzitic sandstone) and development of algae interrupt the neritic marine environment. This highly saline basin must have had an extension overlapping the southern margins of the Amadeus Basin.

Areyonga Formation - Inindia Beds

The Areyonga Formation and the Inindia Beds are lenticular units of predominantly sandstone.

The Areyonga Formation has been defined by Prichard and Quinlan, (1962) in the northern part of the Amadeus Basin; the Inindia Beds are the lateral southern equivalent (Ranford et al., 1965) of the Areyonga Formation and have been defined by Wells et al., (1963).

Lithological units, which have been considered as lateral equivalents of both formations, have been intersected in Ooraminna No. 1 and Erldunda No. 1. Because the lithology is very variable and the limits difficult to define, the correlation with the Areyonga Formation in Ooraminna No. 1 is tentative.

| | Ooraminna No. 1 | Erldunda No. 1 |
|---|---|---|
| Depth | 4265' to 3730' | 4300' to 3750' |
| Thickness | 535' | 550' |

Lithologies

The lenticular Areyonga Formation is characterized by marked changes in lithologies and locally there are interbeds of carbonate rocks, lutites fine to conglomeratic sandstone and tillites (well exposed near Areyonga Native Settlement). In outcrop sections the thickness varies considerably from place to place. In Mount Charlotte No. 1 neither the Areyonga Formation nor the Inindia Beds are present.

TABLE 3: ENVIRONMENT OF THE BITTER SPRINGS FORMATION

| Environment | Ooraminna No.1. | | Mount Charlotte No.1. | | Erldunda No.1. | |
|---|---|---|---|---|---|---|
| | Main Lithologies | Thickness | Main Lithologies | Thickness | Main Lithologies | Thickness |
| Normal marine | Dolomitised limestone and algae, detrital dolomite claystone and volcanic rock. | 1015 feet | Dolomite with algae | 432 feet | Detrital,dolomite sandstone, siltstone. | 450 feet |
| Penesaline | Interlaminated anhydritic dolomite and dolomite, | 640 feet | Fine laminated dolomite and anhydrite | 1012 feet | Interbedded anhydritic dolomite and dolomite. | 560 feet |
| Saline | Halite and claystone. | 180 feet | Halite with interbedded rythmic anhydritic dolo,-ite and anhydrite. | 830 feet | Halite | 153 feet |

The Inindia Beds generally have a coarser arenitic composition than the Areyonga Formation.

The sandstones are brownish-red, grey to white, generally poorly sorted, very fine to very coarse grained, in part conglomeratic, orthoquartzite and in some instances feldspathic and/or lithic sandstone. The variable feldspar content is composed of sericitized orthoclase, microcline and very rare altered acid plagioclase. The lithics are conspicuous and include chert, metaquartzite, microquartzite and carbonate rock pebbles; muscovite and greenish biotite are accessories including some glauconite grains, phosphate pellets, rather abundant pyrite, tourmaline, zircon and apatite.

The cementing media is a common feature in both formations and is composed of thin chlorite coatings, haematite rims, strong silica over-growth, kaolin, locally altered to sericite, calcite and dolomite.

The siltstone and shale are finely laminated, green and black, rich in pyrite, blackish matter?, chlorite, illite, mica, locally ferruginous and slightly dolomitic.

The clay analyses have shown that the lutites in Ooraminna No. 1 are composed of well crystallized illite and chlorite and in Ellery Creek the sandstones and lutites are composed of dominantly illite, chlorite, kaolin and very rare smectite.

The carbonate bands in Ooraminna No. 1 are sandy, slightly dolomitized, cryptocrystalline to microgranular limestone and some calcitic and oolitic dolomite. Pyrite may be abundant in some instances. Secondary silicification is common in the carbonate rocks.

<u>Contact with the underlying Bitter Springs Formation</u>

The nature of the contact between the Areyonga Formation and the Inindia Beds with the Bitter Springs Formation varies and depends on the area:

> In Ooraminna No. 1 well the contact shows a gradational change in lithology and the appearance of coarse quartz detritals.
>
> In Mount Charlotte No. 1, the formation is not present. In Erldunda No. 1 a sharp break in sedimentation suggests a disconformity in this area.

## Diagenesis

The most important diagenetic feature in the Areyonga Formation and the Inindia Beds is the development of chlorite and pyrite. Diagenetic chlorite occurs mainly as thin coatings around detritals and as very fine interstitual matter. This chloritization indicates a change in the primary oxidizing environment followed by reducing conditions; the iron has been deposited around the quartz grains in the form of iron oxide and has subsequently been reduced to chlorite. Chloritization is a diagenetic event (Millot, 1963).

Other diagenetic features include locally very intense silicification and a late stage development of calcareous matter in the sandstone.

## Environment

The formation was deposited on a marine, paralic shelf environment. The rapid changes in lithology indicate alternations of highly oxygenated conditions with more stagnant water development.

## Pertatataka Formation - Winnall Beds

The Pertatataka Formation has been defined by Prichard and Quinlan (1962) in the north-eastern part of the Amadeus Basin and the Winnall Beds, the southern lateral equivalent, by Ranford et al., (1965). The age is probably Proterozoic.

These formations have been intersected in three wells with the proposed subdivisions as shown below.

| | | Ooraminna No. 1 | Mount Charlotte No. 1 | Erldunda No. 1 |
|---|---|---|---|---|
| | | Pertatataka Formation | | Winnall Beds |
| Depth | Julie Member | 1530' to 1950' | | (4) 2058' to 1240' |
| | | | | (3) 3015' to 2058' |
| | | | | (2) 3080' to 3015' |
| | | 3730' to 1950' | 4670' to 3072' | (1) 3750' to 3080' |
| Thickness | Julie Member | 420' | | (4) 818' |
| | | | | (3) 957' |
| | | | | (2) 65' |
| | | 1780' | 1598' | (1) 670' |

## Lithologies

Two main lithologies are typical of these formations:

- siltstone and shale in the Pertatataka Formation.
- sandstone in the Winnall Beds.

## Pertatataka Formation

The siltstone and shale are grey and greenish, minor brownish-red, and finely laminated. The silty detrital content is finely bedded and numerous muscovite and greenish biotite flakes emphasize the bedding. The cementing media is composed of well crystallized illite, some detrital ? chlorite flakes and abundant finely disseminated secondary chloritic matter; random chlorite-smectite and mixed layer clay types are exceptional. Haematite is locally very abundant especially when chlorite is absent. Pyrite, in the form of granules and blackish matter, are present throughout in fine laminations. Calcareous cement occurs in localized intervals.

Fine grained, angular, well sorted orthoquartzite with rare potash feldspars, chert and sericitized rock fragments occur interlaminated within these siltstone-shale. Authigenic glauconite grains and pellets are associated with phosphatic matter. The heavy mineral assemblage of tourmaline, zircon, apatite corresponds to a mature association.

The cement is mainly chlorite, kaolinite, illite and rare minute dolomite crystals; quartz overgrowths and haematite occur in some instances especially in the upper part of the Ooraminna No. 1 well where sandy, dolomitized, oolitic limestone and dolomite have been noticed.

## Winnall Beds

The Winnall Beds occur in the southern Amadeus Basin, and represent a lithological equivalent of the northern Pertatataka Formation. Four units have been defined by Ranford and Cook (1964). The petrological study of the sediments of Erldunda No. 1 has shown that this subdivision also applies to the subsurface sequence. They are from bottom to top:

unit (4) sandstone with minor siltstone.

unit (3) siltstone with minor sandstone.

unit (2) conglomerate and sandstone.

unit (1) calcareous siltstone with some dolomite beds.

The siltstone and sandstone from units (1), (3) and (4) have a similar lithology to those of the Pertatataka Formation, especially a high content of chlorite, illite and pyrite in the siltstone-shale units, and glauconite and phosphate in the sub-mature to mature orthoquartzite. However, a greater amount of mica, some pebbly zones and, in some instances, a greater proportion of calcareous cement occur in the Winnall Beds.

Unit (2), composed of conglomerate and sandstone, has no equivalent in both Ooraminna No. 1 and Mount Charlotte No. 1 wells. This conglomerate is present as a polymictic rock composed of angular to sub-angular lithics mainly of sedimentary rock, but also igneous chert, mica-schist, granite and dolomite with recrystallized algal structures. The conglomerate grades upwards into submature lithic sandstone cemented by secondary quartz overgrowths and calcareous matter.

Contact with the underlying Formations

The rapid change of lithology between the formations in the Ooraminna No. 1 and Erldunda No. 1 suggests that the Pertatataka Formation disconformably overlies the Areyonga Formation. However, in the southern part of the Amadeus Basin, where no Inindia Beds have been deposited, an unconformity is present locally at the base of the Pertatataka Formation.

Age determination

An age determination using Rb/Sr ratio has been carried out by the B.M.R. An age of 700 to 800 million years has been determined which supports the field evidence of a Proterozoic age.

Diagenesis

Several diagenetic changes have taken place after the deposition of these formations the most important being compaction of the shale-siltstone sequence and the development of authigenic iron minerals, glauconite, chlorite and pyrite in association with black organic matter. Strakhov (1958) suggests that the presence of organic matter creates a post depositional reducing environment so that nearly all the iron disseminated through the deposit is reduced; authigenic iron minerals appear in the following order when the oxidation-reduction ratio decrease: glauconite - leptochlorite - siderite - pyrite.

| Carbon % | authigenic iron minerals |
|---|---|
| 0.3 - 0.5 | traces of iron hydroxides, limonite ... |
| 0.5 - 1.5 | development of leptochlorite, siderite |
| 1.5 | Pyrite |

(After Strakhov 1958)

In the siltstone-shale of the Pertatataka Formation, substitution of the different minerals is incomplete and glauconite and chlorite remain with high pyrite content. As no siderite has been noticed by microscopic examination it is probable that this mineral occurs only in association with calcareous matter.

After the prediagenetic events, characterized by development of iron minerals and clay agradation (only illite and chlorite), the sandstones in the sequence have undergone minor dolomitization and silicification.

## Environment

Conditions during deposition of the Pertatataka Formation and Winnall Beds were markedly different from those of the other formations in the Amadeus Basin.

The thick siltstone and shale sequence was deposited under quiet conditions; only the finest detritals were deposited in this part of the basin in association with iron oxides, phosphatic and ? organic matter. Consequently iron oxides were reduced to glauconite, chlorite and pyrite emphasizing a more reducing environment.

In the northern central part of the basin (Ooraminna No. 1 area) a progressive change in sedimentation has taken place with deposits of oolitic limestone and minor ferruginous sandstone under highly oxygenated water conditions. At this stage little subsidence had occurred in this area and the northern landmass had been completely peneplaned. In the southern area of the basin, the sandstone and siltstone and siltstone-shale had been deposited in a subsidizing trough; the polymictic conglomerate in Erldunda well emphasizes the intense mechanical erosion on a nearby southern continent with uplift of Bitter Springs Formation and igneous rocks.

## Commercial Prospects in the Proterozoic Rocks of the Amadeus Basin

### Oil Prospects

Exploration for petroleum has included these sediments in the prospective section.

A general survey of core analyses (see Tables 4, 5 and 6) show that the Proterozoic sediments have very poor porosity and permeability. The petrological study has shown that the primary intergranular porosity has been reduced by diagenetic changes.

Permeability by fracturing can be expected in carbonate units, but as shown in Ooraminna No. 1, fissures and fractures are filled by a late stage development of sulphates. In areas where the Bitter Springs Formation does not contain salt and sulphates, probably mainly in the eastern and western part of the Amadeus Basin, the Formation may contain brecciated and fractured dolomitic deposits.

Chemical tests carried out on samples from Mount Charlotte No. 1 by Olexon International shows a total organic content of 1.72% which represents a source rock of moderate quality. Also indications of hydrocarbons in the form of small gas flows and good gas readings from cuttings emphasize the source rocks potential of the Proterozoic sediments.

Mineral Prospects

As part of an investigation into metal distribution in the Precambrian rocks, samples from Ooraminna No. 1 bore were analysed by A.M.D.L. for copper, lead, zinc, cobalt and nickel. Youles (1966) quoted the following results for the Bitter Springs - Areyonga and Pertatataka Formations.

- distinct correlations of metal content with lithology.

- three subdivisions have been recognized which may correspond to the three lithological formations.

- in the upper part of the Pertatataka Formation, very high values of lead and zinc (2000 ppm lead and 8000 ppm zinc) have been recorded, due to the presence of lead oxide and zinc carbonate grains. This part of the Formation corresponds to the third lithological interval determined in the petrological report. (Schmerber, 1966a). The distinct feature is the presence of slightly dolomitic calcareous cement.

- copper values are nearly constant, but nevertheless in the dolomite on top of the volcanic rocks, the amount is higher.

- cobalt and nickel have average low values with locally some local high nickel values.

Table 4

Measured petrographic rock characteristics of cores -
Bitter Springs Formation

BITTER SPRINGS FORMATION

| Core No. | Depth in Feet | Lithology | Porosity % V. | Porosity % H. | Permeability (md) V. | Permeability (md) H. | Fluid Saturation (water) |
|---|---|---|---|---|---|---|---|
| Ooraminna No. 1 | | | | | | | |
| 15 | 4433'4" | Siltstone | 3 | 3 | Nil | Nil | 71 |
| 16 | 4644'4" | Dolomite | 2 | 2 | Nil | Nil | 80 |
| 17 | 4940' | Dolomite | 4 | 3 | Nil | Nil | Nil |
| 18 | 5223' | Claystone | 1 | 2 | Nil | Nil | 68 |
| 19 | Not attempted | | | | | | |
| 20 | 5881'4" | Dolomite | 3 | 3 | Nil | Nil | 18 |
| 21 | | Halite | 11 | | 10 | | |
| Mount Charlotte No. 1 | | | | | | | |
| 14 | 4680' | No recovery | | | | | |
| 15 | 4767' | Dolomite | 1 | 1 | Nil | Nil | 100 |
| 16 | 5029' | Dolomite | 1 | 1 | Nil | Nil | Nil |
| 17 | 5145' | Dolomite to Anhydrite | 2 | 2 | Nil | Nil | Nil |
| 18 | 5298' | " " | 1 | 1 | Nil | Nil | Nil |
| 19 | 5417' | " " | 1 | 1 | Nil | Nil | Nil |
| 20 | 5677' | No recovery | | | | | |
| 21 | 5817' | Dolomite to Anhydrite | 2 | 5 | Nil | Nil | Nil |
| 22 | 6235' | Halite | | | | | Nil |
| 23 | 6382' | Dolomite to Anhydrite | 5 | 3 | Nil | Nil | 100 |
| 24 | 6712' | " " | 3 | 3 | Nil | Nil | Nil |
| 25 | 6244' | " " | 2 | 8 | Nil | Nil | Nil |
| 26 | 6939' | Dolomite | 1 | 1 | Nil | Nil | Nil |
| Erldunda No. 1 | | | | | | | |
| 10 | 4794' | Dolomite to | 2 | [illegible] | Nil | Nil | Nil |
| 11 | 5437'-5450' | No recovery | | | | | |

Table 5

Measured petrographic rock characteristics of cores,
Areyonga Formation and Inindia Beds

| | Core No. | Depth in Feet | Lithology | Porosity (%) V. | Porosity (%) H. | Permeability (md) V. | Permeability (md) H. | Fluid Saturation (water) |
|---|---|---|---|---|---|---|---|---|
| AREYONGA FORMATION AND INiNDIA BEDS | | | Ooraminna No. 1 | | | | | |
| | 12 | Fructured limestone | | | | | | |
| | 13 | 3921' | Siltstone | 2 | 2 | Nil | Nil | 77 |
| | 14 | 4168'4" | Too friable for determinations | | | | | 65 |
| | | | | | | | | |
| | | | | | | | | |
| | | | Erldunda No. 1 | | | | | |
| | 8 | 3985'4" | Sandstone | 1 | | Nil | Nil | Nil |
| | 9 | 4196' | Shaly dolomite | 2 | | Nil | Nil | Nil |
| | | | | | | | | |

Table 6

Measured petrographic rock characteristics of Cores, Winnall Beds and Pertatataka Formation

| | Core No. | Depth in Feet | Lithology | Porosity (%) V. | Porosity (%) H. | Permeability (md) V. | Permeability (md) H. | Fluid Saturation (water) |
|---|---|---|---|---|---|---|---|---|
| | | | **Ooraminna No. 1** | | | | | |
| PERTATATAKA FORMATION | 6 | 1570'4" | Dolomite | 6 | 7 | Nil | Nil | Nil |
| | 7 | 2056'4" | Shale and Siltstone | 3 | 3 | Nil | Nil | 68 |
| | 8 | 2357'4" | " " | N.D. | 3 | N.D. | N.D. | 100 |
| | 9 | 2704' | " " | 1 | N.D. | N.D. | N.D. | 100 |
| | 10 | Not attempted | | | | | | |
| | 11 | 3443'4" | Shale and Siltstone | N.D. | 3 | N.D. | N.D. | 100 |
| | | | **Mount Charlotte No. 1** | | | | | |
| WINNALL BEDS | 10 | 3177'-3192' | Not attempted | | | | | |
| | 11 | 3505' 3522' | Not attempted | | | | | |
| | 12 | 4022'4" | Shale | 1 | | Nil | | Nil |
| | 13 | 4532'4" | Siltstone | 2 | | Nil | | Nil |
| | | | **Erldunda No. 1** | | | | | |
| | 3 | 1864'4" | Sandstone | 1 | | Nil | | Nil |
| | 4 | 2395'4" | Shale and Siltstone | 4 | | Nil | | Nil |
| | 5 | 3059'4" | Sandstone | 2 | | Nil | | Nil |
| | 6 | 3653'4" | Dolomitic shale | 3 | | Nil | | Nil |

## Arumbera Sandstone

This formation was originally defined by Prichard and Quinlan (1962) as the Arumbera Greywacke and later redefined by Wells et al. (1965) as the Arumbera Sandstone and included in the Pertaoorrta Group. The Arumbera Sandstone is tentatively considered as Cambrian although the formation may range from Proterozoic to Lower Cambrian (Wells et al., 1968).

Samples from three wells and from outcrop sections have been studied as indicated below.

| Wells | | | | Outcrop Sections | |
|---|---|---|---|---|---|
| Name of Well | Ooraminna No. 1 | Alice No. 1 | Waterhouse Anticline No. 1 | Ellery Creek (Hermannsburg Sheet area) | Ross River (Alice Springs Sheet area) |
| Depth | 1530' to surface | 7518' (T.D.) to 7140' | 3081' (T.D.) to 2254' | | |
| Thickness | 1530'+ | 378'+ | 827'+ | about 1200' | About 1100' |

## Lithologies

The Arumbera Sandstone is mainly a ferruginous sandstone-siltstone sequence with minor carbonate rocks.

### Sandstone

The sandstone is generally brownish-red, minor grey to white, thin to thickly bedded, cross bedded to finely laminated, generally poorly sorted, fine to coarse grained, and locally conglomeratic with pebbles up to 3 mm.

The mineralogical composition as shown in the triangular diagrams (Figs. 2 and 3) indicates a feldspathic and minor lithic sandstone. 1 2

The quartz content is variable between 65 and 90%; most of the quartz shows very fine inclusions, and undulose extinction of varying degrees of intensity is common.

The feldspar content comprises orthoclase, microcline and very rare acid plagioclase. The feldspar grains are generally angular to subangular and less rounded than the quartz. As a whole the feldspar shows all degrees of weathering and alteration; the last stage of alteration is a completely sericitized, confused aggregate of flakes. Most of this alteration is pre-depositional as shown by the differences in alteration in the same sample.

The lithic content is mainly composed of microcrystalline chert, metaquartzite, microquartzite and granoblastic quartz; rare silicified oolitic limestone pebbles have been noticed at Ellery Creek (French Petroleum Co., 1963).

Both muscovite and biotite are common accessories; biotite predominates over muscovite; the latter is normally present as fresh flakes locally parallel to the bedding and several have lost their birefringence because of alteration into sericite and in places kaolinite. Biotite occurs as greenish-brownish flakes, with abraded edges and in places has a squeezed fan shape; iron oxide granules occur along cleavage planes or along the edges. This chloritized biotite may have a chloritic structure in X-ray analysis.

Glauconite is present as fine, greenish to brownish pellets, in places with iron oxide concentration and in most cases is coated by haematite. The iron coatings indicate an allochthonous origin of the glauconite. The heavy mineral association comprises dominant rounded tourmaline and zircon, minor rutile, apatite and anatase; the opaque mineral content is important and consists of pyrite, leucoxene, and rare magnetite.

The primary matrix of the sandstone is composed of iron oxide, haematite coatings in association with clay and interstitial haematite. The clay analysis shows the presence of sericite, chlorite, illite, very rare mixed ? layer clay and locally some kaolinite (French Petroleum Co., 1963). Silica and locally minor feldspathic overgrowths occur in the sandstone where the primary porosity was sufficient to allow circulation of connate water; calcareous cement is present in the upper part of the formation.

Siltstone

The siltstone is mainly very ferruginous, haematitic, locally dolomitic, clayey and micaceous. Greenish, chloritic and pyritic thin siltstone beds, in some instances dolomitic, are well developed especially in the upper part of the formation.

Carbonates

Grey to beige cryptocrystalline to microcrystalline sandy dolomitized limestone occurs in the upper part of the formation.

ARUMBERA SANDSTONE

Ooraminna No. 1 ......●
Waterhouse No. 1........+
Ellery Creek ...........o
Ross River ...........■

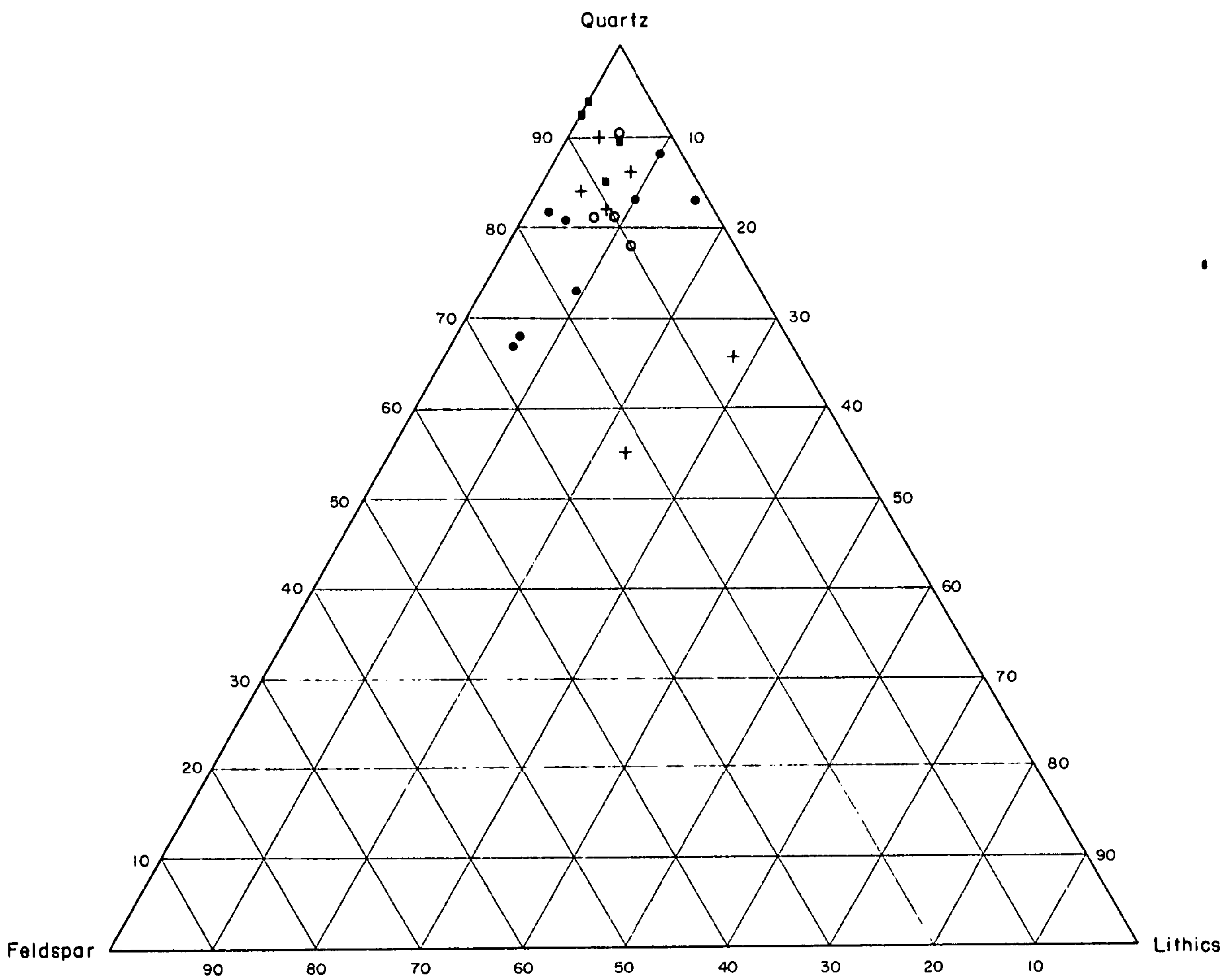



Fig. 1 TRIANGULAR DIAGRAM OF ARUMBERA SANDSTONE

To accompany Record No. 1967/23

## ARUMBERA SANDSTONE

Ooraminna No. I .......... ●

Waterhouse No. I........ +

Ellery Creek .............. o

Ross River ................ ▪

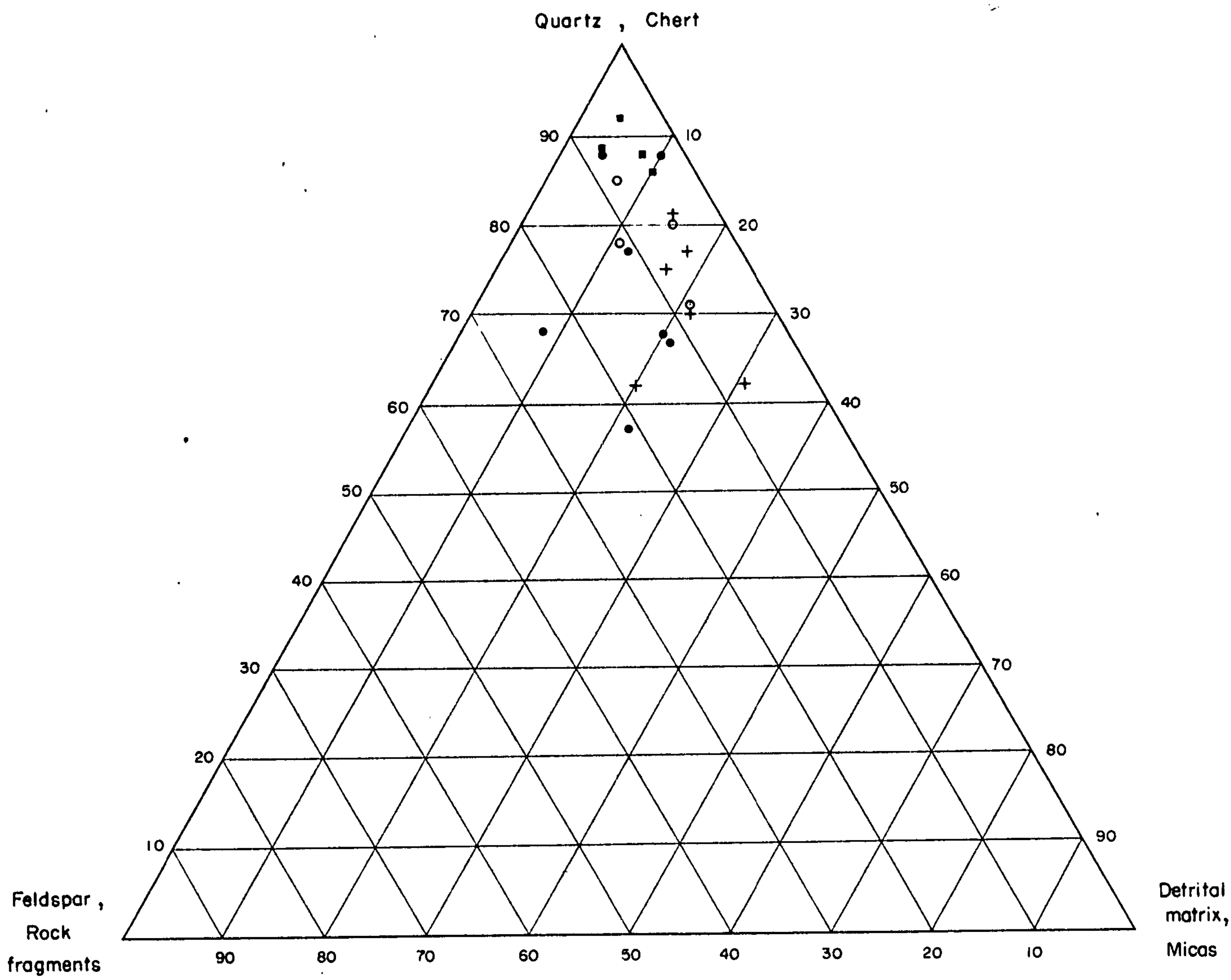



Fig. 2 TRIANGULAR DIAGRAM OF ARUMBERA SANDSTONE

To accompany Record No. 1967/23

## Palaeontology

Fossils are very rare in the Arumbera Sandstone. Worm tracks and burrowings have been noticed in Alice No. 1. Impressions assigned to arthropod tracks have been described by Wells et al. (1968) in outcrops.

## Lithological Correlations

### Thickness

As no complete Arumbera Sandstone section has been intersected, no thickness changes through the basin could be indicated.

### Lithology

In general the lithology of the formation is very constant through the area studied. Several parameters have been plotted against lithology in Table 7 to point out the typical characteristics of the Arumbera Sandstone.

- the clay association is composed mainly of either dominant sericite or illite, minor chlorite, kaolin and traces of mixed layer clays. Sericite and illite are probably of detrital origin which is shown by the poor degree of crystallization of the sericite; illite which is the most stable clay type in detrital marine sediments has been recrystallized probably by agradation. Some of the chlorite may have originated by the alteration of biotite and some by late stage chloritization of iron minerals. Kaolin has been formed only in the outcrop sections. (French Petroleum Co., 1963). Its presence is incompatible with an oxygenated environment such as that envisaged for the Arumbera Sandstone. Its origin must be considered secondary, by weathering ? of mica (muscovite) under aqueous conditions.

- the heavy mineral association is represented by the most stable minerals such as tourmaline, zircon, rutile, apatite and anatase. Intense diagenetic changes, and alteration at the source areas and during transport, could explain the limited association. However, the fact that biotite and a great amount of feldspar still remain in the sediments with different degrees of alteration emphasize strong weathering of the source area and during transport. The stable heavy mineral association is primary.

- haematite coatings are very common through the sequence; this indicates a continuous deposition of haematite during the formation of the Arumbera Sandstone.

- the maturity indices (Pettijohn, 1956, p. 290) show a rather low ratio (average quartz/feldspar = 8 ; average quartz + chert/feldspar + rock fragments = 10) with the exception of the exposure at Ross River; here the sandstones are more mature and, if this is not a local interpretation, the Ross River sections is a greater distance away from the source area than the other occurrences.

Contact with the underlying formations

The lower contact has been intersected only in the Ooraminna No. 1 well. The sharp change in lithology and the presence of conglomeratic pebbles suggest a disconformity between the Arumbera Sandstone and the carbonate rocks of the Julie Member.

Diagenesis

The diagenetic processes have tended towards mineralization of the rock. Two main events have been noted.

- silicification and minor feldspathisation in the form of quartz and some potassium feldspar overgrowths on detrital grains; this is a pre-diagenetic development which has taken place before induration in sediments where the primary porosity and permeability were sufficient to allow a volume increase of up to 20%. No silicification has been noticed in the siltstone and is very rare in carbonate rocks. The origin of the secondary silica is not known.

- dolomitization is developed, probably by pseudomorphing of calcite.

Environment

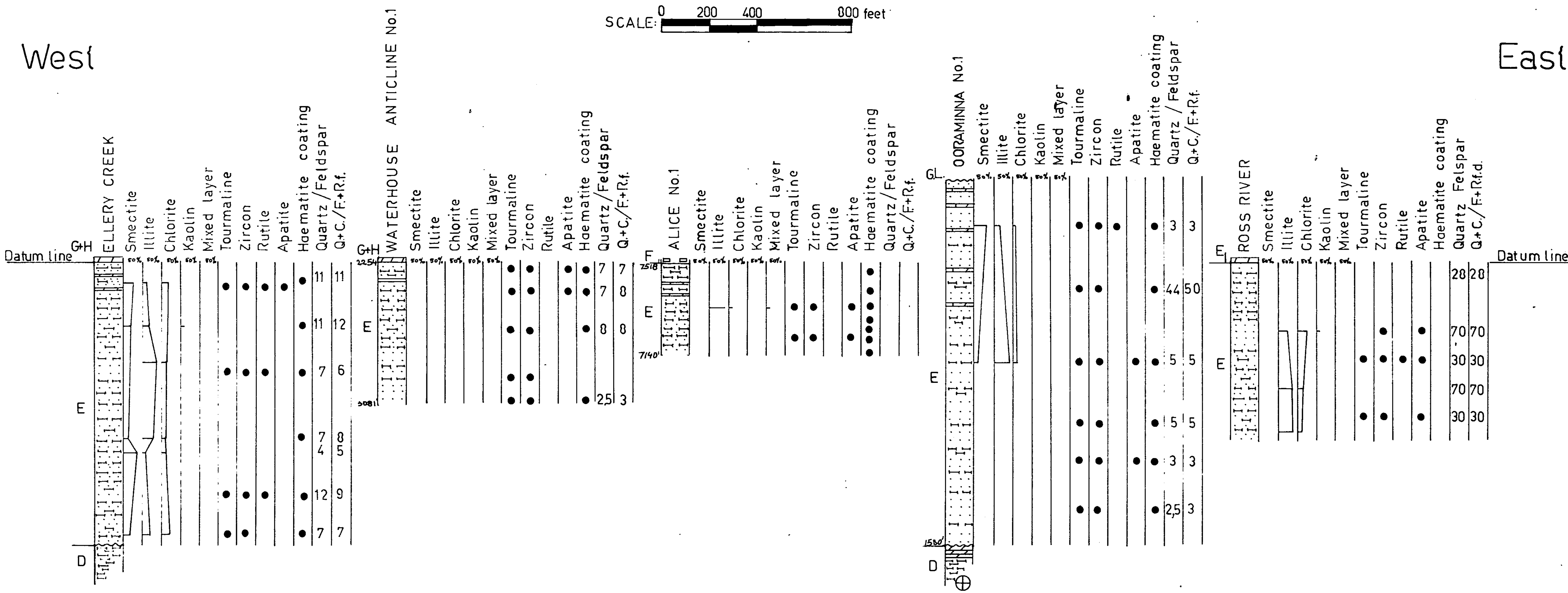
The presence of abundant cross-bedding alternating with fine laminated beds, the general poor sorting, the presence of worm tracks, and arthropod impressions suggest a marine environment under shallow water conditions with fairly vigorous conditions at times. Highly oxygenated conditions are indicated by the iron oxide coatings.

Intense continental weathering has taken place on the nearby continent with a breakdown of the less stable minerals such as the ferromagnesians and consequently a great amount of iron was introduced into the basin.

The poor roundness of the detritals also suggests a rapid burial of the sediments. Climatic conditions were fairly humid, as indicated by the strong iron weathering, on the nearby continent which was composed of both igneous and sedimentary rocks.

Table 7.

# LITHOLOGICAL CORRELATION of ARUMBERA SANDSTONE in Central part of Amadeus Basin, Northern Territory.




Sandstone | Siltstone and Shale | Limestone | Dolomite

$\frac{Q.+C.}{F.+R.f.}$ = Q.—Detrital and secondary quartz
C.—Lithic chert
F.—Feldspar
R.f.—Rock fragments

● Mineral present

Datum line: represents the contact between Arumbera Sandstone and overlying formations.
⊕ Arumbera Sandstone—Pertatataka Formation boundry used as reference boundry.

Formation names:
- G+H — Jay Creek Limestone
- F — Chandler Limestone
- E1 — Todd River Dolomite
- E — Arumbera Sandstone
- D — Pertatataka Formation

To accompany Record No. 1967/23

Drawn by: S. Ozimic

Pertaoorrta Group (Post Arumbera Sandstone)

From the north-eastern to the north-western parts of the Amadeus Basin, the Cambrian sediments overlying the Arumbera Sandstone are characterized by a marked change in lithology and several formations have been defined.

From west to the east they are:

- Giles Creek Dolomite and Shannon Formation (Wells et al., 1968). The Todd River Dolomite (Wells et al., 1968) and the Chandler Limestone (Ranford et al., 1965) occur at the base in the central and western parts of the basin.
- Jay Creek Limestone (Prichard and Quinlan, 1962).
- Hugh River Shale (Prichard and Quinlan, 1962).
- Tempe Formation, Illara Sandstone. Deception Formation. Petermann Sandstone (Wells et al., 1965).
- Cleland Sandstone (Wells et al., 1965).

These formations, which grade laterally from one to another, are overlain by the Goyder Formation (Prichard and Quinlan, 1962). The lithologies reveal a complete sedimentary cycle with evaporites, carbonate rocks and arenites and consequently they will be considered as one sedimentary unit, but every defined lithological formation will be considered as one sedimentary unit, but every defined lithological formation will be described separately.

Chandler Limestone

This formation crops out in the north-western part of the Amadeus Basin as laminated limestone and dolomite with contorted chert laminae. In Alice No. 1 and Mount Charlotte No. 1 wells a sequence composed of salt and red shale, overlain by the Cambrian carbonate rocks, is considered to be an equivalent of the Chandler Limestone.

This formation is tentatively regarded as Lower Cambrian in age (Ranford et al., 1965).

In Alice No. 1 and Mount Charlotte No. 1, the Chandler Limestone has the following thicknesses.

| | Alice No. 1 | Mount Charlotte No. 1 |
|---|---|---|
| Depth | 7140' to 6618' | 3072' to 2332' |
| Thickness | 522' | 740' |

## Lithology

### Evaporites

Pink to reddish, coarse crystalline salt occurs in beds several hundred feet thick together with minor anhydrite. A chemical analysis of salt samples in Mount Charlotte No. 1, carried out by A.M.D.L., shows that the salt is mainly halite.

| Elements | Core 8 (2609'-2629') | | Core 9 (2909'-2909'4") | |
|---|---|---|---|---|
| Na | 32 | % | 32.2 | % |
| K | 0.020 | % | 0.012 | % |
| Ca | 0.46 | % | 0.45 | % |
| Mg | 0.02 | % | 0.02 | % |
| $SO_4$ | 0.22 | % | 0.21 | % |
| Cl | 49.9 | % | 50.3 | % |
| water insoluble residue | 15.76 | % | 15.14 | % |
| $NO_3$ | 0.003 | % | 0.003 | % |
| $CO_3$ | 0.07 | % | 0.07 | % |
| Br | 30 | ppm | 35 | ppm |
| B | 9 | ppm | 3 | ppm |
| Sr | 100 | ppm | 90 | ppm |
| $H_2O$ | 1.38 | % | 1.42 | % |

ppm = parts per million

Reddish-brown, micaceous and slightly dolomitic claystone and shale grading to siltstone occur interbedded in the salt beds and finely intermingled in the salt mass.

Clay analysis shows the following clay types.

- salt + clay : Chlorite, illite, random chlorite-smectite, mixed layer (illite-smectite or polygorskite).
- claystone + siltstone : chlorite, illite, kaolin, regular chlorite-smectite. Scattered, angular to rounded, coarse grained quartz, feldspar, chert and rare greenish biotite are present throughout the salt and the lutite sequence.

Rare ferruginous, slightly calcareous, sandy dolomite beds with halite and anhydrite pseudomorphs occur between the salt sections. In the Chandler Range outcrop, the Chandler Limestone is represented by beige, foetid, slightly dolomitized, micritic limestone with numerous contorted brownish chert laminae.

Contact with the underlying formations

A very sharp break in lithology in Alice No. 1 well suggests a disconformable contact between the Chandler Limestone and the Arumbera Sandstone whereas in Mount Charlotte No. 1 well the unconformity is probably present between the Proterozoic Pertatataka Formation and the Chandler Limestone.

Correlation with typical Chandler Limestone

A lithological correlation of the Chandler Limestone between outcrop and subsurface is not possible because of the different sedimentary sequences. It is probable that while in some parts of the basin, evaporates have been deposited, silicified primary ? carbonate rocks were found in surrounding lagoonal areas. Similar lateral and vertical palaeogeographical relationships occur in the Cambrian calcareous formations and in the Proterozoic Bitter Springs Formation.

Further drilling operations and detailed outcrop mapping may support this hypothesis.

Todd River Dolomite

This formation has not been intersected in any of the wells, but it crops out in the eastern part of the Amadeus Basin; it is considered to be a partly lateral equivalent of the Chandler Limestone (Wells et al., 1968). In the Ross River section the Todd River Dolomite is a pink and grey, thickly bedded and compact, in some instances sandy, calcitic micro-crystalline dolomite with recrystallized biological structures.

The contact with the underlying Arumbera Sandstone is conformable and a thick (280 feet) transitional zone of reddish sandstone and siltstone is present.

Jay Creek Limestone

The Jay Creek Limestone and its western lateral equivalents, the Giles Creek Dolomite and the Shannon Formation have been intersected in several wells and samples have been studied from outcrop sections as shown below.

<table>
<tr><th rowspan="2"></th><th colspan="8">Wells</th></tr>
<tr><th>Ellery Creek Outcrop</th><th>Mount Charlotte No. 1</th><th>Highway Anticline No. 1</th><th>Waterhouse Anticline No. 1</th><th colspan="2">Stratigraphy</th><th>Alice No. 1</th><th>Ross River Outcrop</th></tr>
<tr><td rowspan="2">DEPTH</td><td rowspan="2"></td><td rowspan="2">2332'-1540'</td><td rowspan="2">3770' (T.D.) - 480'</td><td rowspan="2">2254' to surface</td><td rowspan="4">Jay Creek Limestone</td><td>Shannon</td><td>6618'-5147'</td><td rowspan="2"></td></tr>
<tr><td>Giles Creek Dolomite</td><td>5147'-3804'</td></tr>
<tr><td rowspan="2">THICKNESS</td><td rowspan="2">1950'</td><td rowspan="2">792'</td><td rowspan="2">3290'+</td><td rowspan="2">2254'+</td><td>Shannon</td><td>1471'</td><td>1230'</td></tr>
<tr><td>Gilles Creek Dolomite</td><td>1343'</td><td>830'</td></tr>
</table>

Lithology

The formation consists dominantly of carbonate rocks with interbedded siltstone.

Carbonate Rocks

They are light tan, grey, red brown and in some instances greenish, dense and compact, and in places finely laminated. The texture is generally microcrystalline, strongly recrystallized and in minor amount cryptocrystalline. The average proportion of calcite is about 10 to 20%, but in the upper part of the formation, in Highway Anticline No. 1, the calcite percentage is 80-90%. The carbonate rocks are mainly calcitic dolomite and minor dolomitic limestone. The distribution of limestone and dolomite does not seem to have any order in this formation.

The detrital content is very variable throughout the section; there is always angular to subrounded silty to coarse grained quartz grains, some orthoclase and microcline, very rare metamorphic lithics and micas. Iron oxides, probably mainly haematite occur in fine concretions, clusters and intergranular minute crystals; the iron is responsible for the reddish colour. Quartz-chalcedony chert is common in nodules or fine laminae; they include cryptocrystalline calcite, but no dolomite rhombs. Fine authigenic glauconite is present with some local pyrite and blackish matter in grains or in fine lenses.

Calcarenitic and oolitic beds characterized by their pellets, lumps and undifferentiated carbonate concretions are present associated with rounded rosettes and elongated algal structures. Locally these biological structures have been silicified; some of these algae may be Girvanella: in the lower part of Highway No. 1, stromatolites have been noticed.

Anhydrite and minor gypsum occur in these carbonates with variable textures:

- in lenses parallel to the bedding, mainly as equidimensional tabular crystals, locally showing a pile of brick texture.
  These sulphates are interbedded with anhydritic dolomite in the lower part of Mount Charlotte No. 1 and in the central part of Highway No. 1. They are considered to be primary.

- as intergranular very coarse crystals with inclusions of well developed dolomite rhombs.

- as fibrous, microgranular crystals, filling irregular anastomosed veins and fissures.

Siltstone and shale

Siltstone and silty shale are homogeneous throughout the formation. They are generally brownish-red, also greenish and grey, haematitic or chloritic, micaceous and slightly calcareous. The clay association is composed of smectite, chlorite, illite, random chlorite-smectite, mixed layer ? clay and regular chlorite-smectite. This association is much more diversified than in other formations, such as the shale in the Bitter Springs and the Pertatataka Formations.

Anhydrite and gypsum occur in small patches.

Pebbly beds composed of medium to very coarse grained quartz and lithics, coated by haematite, are present; they indicate a temporary change in water energy.

Sandstones are very poorly developed; they occur only in minor amount in Highway Anticline No. 1 and in outcrops; they are calcareous and ferruginous orthoquartzite or lithic sandstone with variable amount of carbonate pebbles. A heavy mineral association of tourmaline, zircon, apatite, garnet, actinolite and some rutile could be characteristic for these sandstone lenses. This is the first appearance of garnet and actinolite in the sedimentary sequence of the Amadeus Basin.

Giles Creek Dolomite and Shannon Formation

In the eastern part of the basin, the Jay Creek Limestone shows a considerable increase in carbonate rocks and two formations have been defined in this area; the lower Giles Creek Dolomite and the upper Shannon Formation.

Giles Creek Dolomite

Lithology

The lithological constituents are composed of bedded, variegated, slightly calcareous dolomite and interlaminated siltstone and shale. The dolomite bands are characterized by the abundance of "felty" type of anhydrite, e.g. small anhydrite prisms as single crystals or interwoven in lenses. The association of the "felty type" of anhydrite with fine grained dolomite and the disturbed and crenulated sedimentary planes are typical of a primary intermingling of sulphates and carbonates. Beside this type there is also very coarse, intergranular anhydrite with numerous dolomite rhombs as inclusions; a similar type and locally a radiating variety, fills fissures and small cavities.

The strong development of primary sulphates and carbonates, the dominance of dolomite over limestone and the absence of fossils are features also observed in some parts of the Jay Creek Limestone. Two main differences are noticeable in the Giles Creek Dolomite: the increase in carbonate and the corresponding decrease in detritals and the presence of dark grey dolomitic shale enclosing lamellae of anhydrite. Eastwards, in the Ross River section the lower half of the type section of the Giles Creek Dolomite contains nodular, slightly silty limestone with a decreasing clay content towards the top. Numerous fossil fragments have been described, such as trilobites echinoids and algae; the upper half is composed of thickly bedded grey, yellow, recrystallized dolomite with Girvanella like structures, stromatolites (Wells et al., 1968) and is locally very rich in oolites, lumps and pellets (French Petroleum Co. Aust., 1963).

Shannon Formation

Lithology: This formation exhibits mainly carbonate rocks (limestone and dolomite) with interlaminated dark grey, green, pyritic, micaceous silty shale with worm burrows.

The carbonate rocks are white to grey, microcrystalline, slightly to completely dolomitized (5 to 80%), silty, rich in pellets, oolites, algal structures, and "rosettes". Plentiful fossils including gastropods, echinoids, and trilobites have been noticed associated with fragments of algal limestone and phosphatized debris; some scour and fill contacts are present.

In places the oolites show three concentric zones: a microcrystalline calcitic center, a surrounding zone of coarse dolomite crystals and a rim of cryptocrystalline calcite; it appears that the dolomitization of the oolites occurred during deposition when they were mobile.

Anhydrite is present as very coarse crystals, locally with pelletal inclusions, replacing external rims of oolites and rosettes. Minor transitional fine grained, dolomitic and micaceous subarkose occurs near the top with some occasional glauconite grains. Several clay types have been determined in the Giles Creek Dolomite and the Shannon Formation including illite, chlorite and random chlorite-smectite. Only smectite has been found in the Ross River section (French Petroleum Co. Aust., 1963).

Lithological evolution of the Cambrian sediments

Thickness: Table 8 shows that the Cambrian carbonate rocks are characterized by important variations in thickness. According to the measured sections a greater thickness occurs in Waterhouse No. 1, Highway No. 1 and Alice No. 1 wells than in the two widely separated outcrop sections. It is probable that these three wells are situated in a more central part of the basin where the rate of subsidence was higher. This hypothesis is supported by the presence of primary anhydrite in the lower part of the sediments in the three wells.

In Mount Charlotte No. 1 the uppermost part of the Jay Creek Limestone was eroded before the deposition of the Stairway Sandstone.

Lithology

Several parameters have been represented on Table 8: clay types, grain types and fossils in the carbonate rocks and the occurrence of sulphates with primary texture.

The results of the two field sections, Ellery Creek and Ross River are used with the authorisation of French Petroleum Co. Aust. (1963).

Clay types distribution.

In spite of the small amount of determined clay types some conclusions may be given.

- Smectite has a special distribution in these sections; at Ellery Creek and Ross River it occurs through the whole sequence; in Waterhouse, Highway and Mount Charlotte No. 1, smectite is present only in the uppermost part of the formations; it has not been determined in Alice No. 1.

With the exception of Alice No. 1, smectite is associated with carbonates and lutites where no primary anhydrite occurs.

- Mixed-layer clay types form a small percentage; they are probably of detrital, and also diagenetic origin. The presence of traces of corrensite has been noted only in the two sections studied by French Petroleum Co. (1963).

- Chlorite and illite form the major components; chlorite is mainly of diagenetic origin by recrystallization of altered ferromagnesium minerals such as biotite. Illite is considered to be the most common clay type in marine sediments, and also the most stable under diagenetic actions.

Relation between fossils and grain types in carbonates and primary anhydrite.

Sedimentary anhydrite and minor gypsum in the lower half of the sequence in the Highway, Mount Charlotte and Alice No. 1 wells occurs to the exclusion of fossils and granular carbonates. An important change occurs in the overlying beds in these three wells and can be compared to the sediments at the base of that sequence at Ellery Creek, Waterhouse and Ross River where calcarenitic and organic carbonate rocks, but no sulphates, were deposited.

A direct relationship between the halitic Chandler Limestone and the lower sulphate rich part of Cambrian carbonate rocks is apparent, and is shown in the environment table.

The lithological evolution of the Cambrian marks not only an important change in sedimentation from the east to the west, but minor changes also occur within the area studied.

<u>Goyder Formation</u>

This formation is the uppermost formation of the Pertaoorrta Group, and is considered to be Upper Cambrian (Wells et al., 1965).

The Goyder Formation has been intersected in two wells, Alice No. 1 and Highway Anticline No. 1, situated in the northern Amadeus Basin. In the southern part, in Mount Charlotte No. 1 and Erldunda No. 1, the formation either has not been deposited or has been eroded.

| | Highway Anticline No. 1 | Alice No. 1 |
|---|---|---|
| Depth | 480' to surface | 3804' to 3004' |
| Thickness | 480' | 800' |

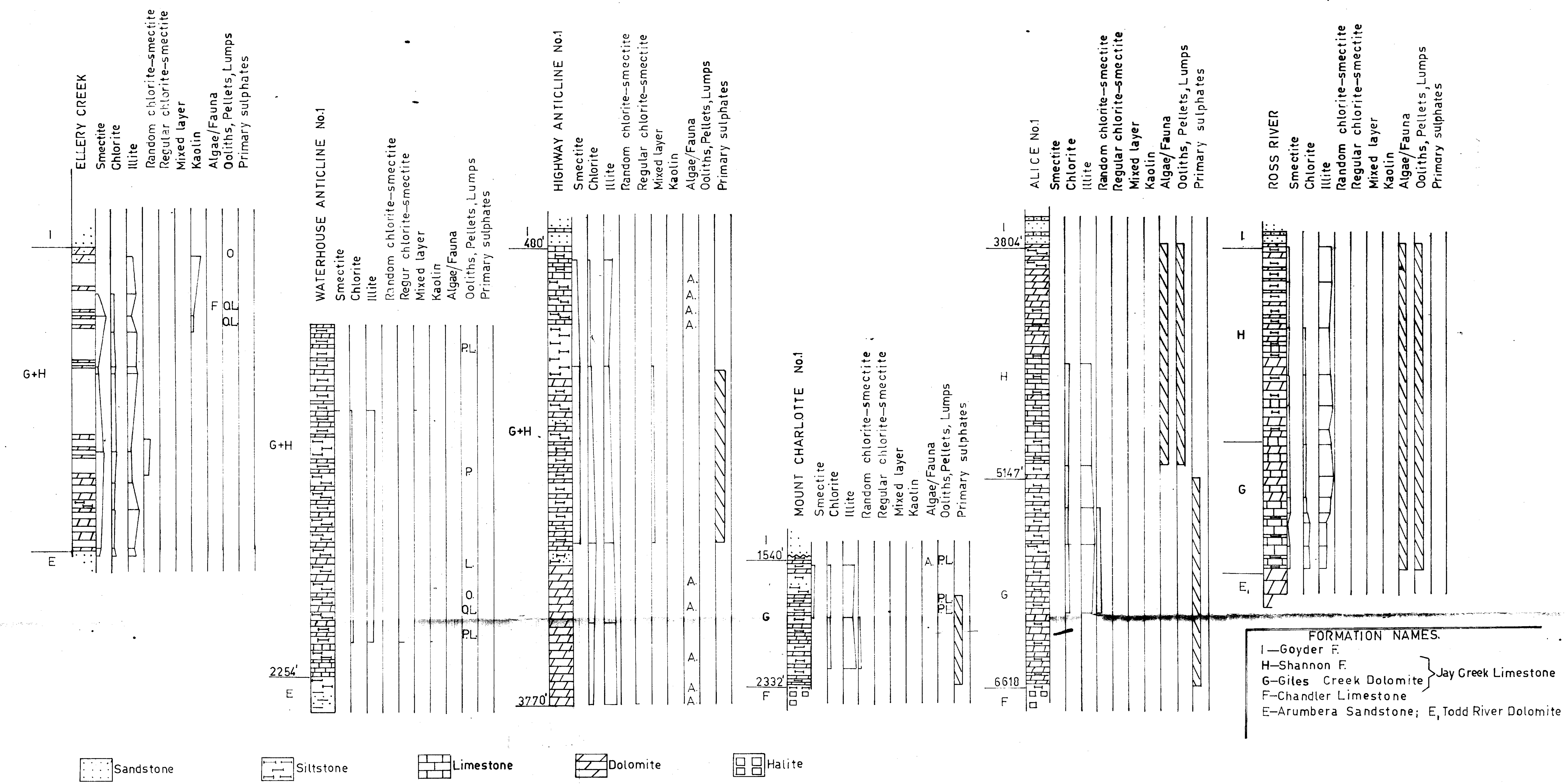
Table 8

# TENTATIVE CORRELATION THROUGH THE CAMBRIAN CARBONATE SEQUENCE
## of Central part of Amadeus Basin, Northern Territory

West

East

VERTICAL SCALE: 1 inch = 500 feet




To accompany Record No. 1967/23

Drawn: S.Ozimic

Lithology

The Goyder Formation comprises mainly sandstone and carbonate rocks.

Sandstone: They are variegated, but mainly slightly reddish, fine grained, well sorted, locally thinly cross-bedded quartzitic (orthoquartzite) and feldspathic sandstone. The framework is composed of high quartz and variable feldspar content consisting of microcline and slightly altered orthoclase commonly with crystal faces. Some metaquartzite and igneous chert occur with minor muscovite and brownish-green biotite altered to chlorite.

In the Alice No. 1 well the sandstone of the Goyder Formation has abundant glauconite and collophane, probably of organic origin.

Accessories are tourmaline, zircon, apatite, rare rutile, garnet andalusite and opaques. Garnet is a characteristic feature of the Cambrian arenitic sedimentation. The cementing media is composed of silica overgrowths commonly with crystal faces and intergranular silica; haematite is present. Kaolinite occurs in fine intergranular crystals where space has not been filled with calcareous cement.

Limestone: Carbonate rocks occur as thin beds of white to light reddish, silty to sandy, in some instances slightly dolomitized limestone. Primary glauconite and collophane are common in Alice No. 1. Algae, oolites and pellets occur through the beds.

Different clay types have been determined in different lithologies:

sandstone: dominant kaolin and illite (French Petroleum Co., 1963).

sandy carbonates: dominant illite and chlorite.

siltstone-shale: smectite, random chlorite-smectite, chlorite and illite.

The differentiation into three clay types associated with different rock types can be related to their origin as detrital material from the continent and by subsequent diagenetic changes.

It is possible that a large part of the kaolin is of secondary origin formed in the permeable sandstone by infiltration of more acid water. The lutites are the most porous rocks, but are less permeable; the clay type association may be considered as primary and therefore the presence of smectite should be of interest for Cambrian correlations.

Contacts

The Chandler Limestone overlies the Arumbera Sandstone with a disconformity suggested by the sharp break in sedimentation between arenitic and evaporitic deposits. In the southern part of the basin in the Mount Charlotte area, the Chandler evaporites unconformably overly the Pertatataka Formation.

Within the Cambrian formations, all contacts are transitional and generally difficult to determine.

Diagenesis

The most obvious changes which have taken place in these sediments are shown in the Cambrian carbonate sequences. In the Chandler Limestone salt units, the recrystallization of halite has obliterated most of the evidence of early replacement. No euhedral prismatic quartz has been observed in this salt; this is typical of numerous examples of European evaporitic sequences. In the Cambrian carbonate sequence several changes occurred such as silicification, dolomitization and development of sulphates.

Silicification: The development of secondary silica is characterized by growth of cryptocrystalline chalcedonic-quartz chert replacing algae and pseudomorphing calcite, in the form of nodules; in some cases the silicification has occurred before the development of dolomite, although later silicification is not excluded. Later the chalcedony has been recrystallized into more stable quartz.

Dolomitization: With the exclusion of the dolomite associated with interlayered anhydrite, the secondary dolomite content is very high. The fact that dolomite appears to be interbedded with limestone and oolites have an early dolomitized concentric zone are evidence for dolomitization before induration. These dolomites fall into the category of those formed by regional dolomitization which, is believed to have occurred on the sea floor either rapidly or in stages.

Development of sulphates: In some wells very coarse anhydrite crystals fill fissures and occurs with dolomite rhombs throughout the formation. This sulphate development is related to dissolution partly of the primary sulphates by connate water and redeposition where space is available.

Environment (Post Arumbera Sandstone)

After the deposition of the Arumbera Sandstone a new sedimentary cycle commenced in the central part of the Amadeus Basin. This cycle is characterized by its reverse sedimentary order with the following sequences: salt → anhydritic dolomite → calcarenitic and oolithic carbonates with algae and fossils → arenite and calcarenitic carbonates with algae (see Table 9).

Table 9: Environment of the Pertaoorrta Group (Post Arumbera Sandstone).

| | Ellery Creek Outcrop | Waterhouse Anticline 1. | Highway Anticline 1. | Mount Charlotte No.1 | Alice No.1. | Ross River Outcrop | |
|---|---|---|---|---|---|---|---|
| | Goyder Formation<br>Arenite | - | Goyder Fm. (+ 436') Arenite with interbedded algal limestone. | - | Goyder Fm. (800') Arenite and lutite with interbedded pelletal oolitic carbonate rocks. | Goyder Fm. - | Decreasing Transgression |
| Normal marine | Jay Ck.Limestone (1950'). Pellets, oolites, carbonate rocks with interlaminated lutite. | Jay Ck.Limestone (2254') Pellets,oolites, lumps, carbonate rocks with interlaminated lutite. | Jay Ck.Limestone (600'). Algal dolomite with interlaminated lutite | Jay Ck.Limestone(600'). Pellets, lumps, algae. Dolomite with interlaminated lutite and rare arenite. | Shannon Formation (1471') Pellets, lumps,algae. Dolomite with interlaminated lutite and rare arenite. | Shannon Fm. Giles Ck. Dolomite. (1950'). Oolite, pellets, algae; dolomite,limestone,with interlaminated lutite. | Increasing Transgression |
| Penesaline | - | - | Jay Ck.Limestone(1000') Anhydritic dolomite with interlaminated anhydritic lutite. | Jay Cl.Limestone (630) Anhydritic dolomite with interlaminated lutite. | Giles Ck. Dolomite (1343') Anhydritic dolomite with interlaminated lutite. | - | |
| Saline | - | - | - | Chandler Limestone (740') Salt and lutite | Chandler Limestone (522') Salt and lutite. | - | |
| | - | - | Lowermost carbonate sequence has not been represented. | - | - | - | |

The sedimentary sequence is characterized by numerous vertical and lateral changes in lithology. In the more central part of the basin in the Alice No. 1 and Mount Charlotte No. 1 area, the deposits are composed of halite grading rapidly to a penesaline environment with primary sulphates, anhydritic dolomite and lutite. During the same time predominantly carbonates were deposited in the central eastern as compared to the central western part of the basin. In the upper half of the sequence, normal marine sedimentation took place under highly oxygenated conditions with an abundant development of algae, benthonic fauna such as trilobites, echinoids and deposits of oolites. Again the carbonate content is higher in the eastern than in the western part. In the uppermost part coarse arenitic detritals provide evidence of an important break in the calcareous sedimentation; carbonate rocks are developed in minor amount, mainly in lenses, but still rich in fossils, oolites and pellets; the major lithology is composed of submature to mature sandstone deposited under shallow marine conditions. The presence of metamorphic lithics and the appearance of garnet in the upper part of this sequence indicate the erosion of a supracrustal source rock area.

Commercial Prospects of the Pertaoorrta Group

Petroleum Prospects (see Tables 10-11)

The Pertaoorrta Group has very poor porosity and permeability with the exception of the Arumbera Sandstone. In this arenitic formation several intervals with good porosity have been noticed on electrical logs. In general terms the porosity and especially the permeability must be considered as low because of the high percentage of interbedded shale and siltstone, and a high percentage of detrital and diagenetic cement. Also the restricted distribution of the Arumbera Sandstone to the central and north-eastern part of the Amadeus Basin is a limiting factor. The reservoir possibilities of the other calcareous formations are very poor even if they are fractured because secondary chlorite and sulphates may fill any fissures and fractures.

The traces of non commercial oil noticed in several wells are related to the source potential of the calcareous formations.

## RESULTS OF CLAY MINERAL STUDY

The determination of clay types has been attempted to show the composition of the different clay association in the Proterozoic and Cambrian sediments. Also special emphasis has been placed on:-

- relationship between clay types and lithology.
- relationship between relative sharpness of the 10A illite peak to measure the presence and the degree of metamorphism. This method has been successfully used by Weaver (1960) and Kubler (1964).

- possibilities of correlations.

The 38 samples determined by A.M.D.L. from the subsurface Proterozoic and Cambrian sequence have shown the dominant and ubiquitous presence of illite and chlorite. Smectite occurs only above 2000 feet in the well sections with the exception of one sample (Alice No. 1, between 3000 and 4000 feet). Chlorite ? smectite, random chlorite-smectite mixed-layer ? clay type, and very rare kaolin have been determined. In three samples, the regular chlorite ? smectite shows a different amount and/or a different kind of smectite from sample to sample. In the regular mixed layer chlorite-smectite, the smectite component is shown as ? smectite in this report and accompanying tables. This regular mixed layer has a resemblance to corrensite, but no true corrensite has been determined in the subsurface samples. (In both Ellery Creek and Ross River outcrop sections traces of corrensite have been determined by the French Petroleum Co. Aust., 1963). Sepiolite and polygorskite have not been detected, but polygorskite cannot be distinguished from an interstratified illite-smectite in samples with a large number of clay types. Polygorskite may be present in the salt of the Chandler Limestone sample.

Relationship between clay and lithology

The relationship between clay types and lithology is clearly shown by the presence of kaolin in sandstone. Indeed kaolin has been determined in major amount only in clean sandstone such as Heavitree Quartzite in the Ellery Creek section (French Petroleum Co. 1963), Areyonga Formation and Goyder Formation; it may occur exceptionally as a minor component in lutites and carbonate rocks.

In the same way, illite and chlorite occur as the only clay component in the salt sections in the Bitter Springs Formation and the Chandler Limestone. This relationship may be due to either a detrital origin or diagenetic changes.

Smoot (1960) has shown that in a detrital sedimentation the clay types form a regular association from the shore lines to the open sea; four zones distributed in concentric areas are characterized by high kaolin ⟶ low kaolin ⟶ mixed layers ⟶ illite. This zonation is due to the speed of sedimentation and environment. Heavy kaolin crystals are deposited with the heavy quartz grains, whereas the altered minerals, lighter than the former are transported to the open sea and recrystallized to illite, the most stable mineral in a marine environment.

Kulbicki and Millot (1960) and Keller (1958) have pointed out similar developments of clay types under diagenetic processes

- a great amount of vermicular kaolin in primary porous and permeable sandstone is due pro parte to circulating acid water which destroys the silicates framework.

## Table 10

Measured petrographic rock characteristics of cores -
Arumbera Sandstone

| | Core No. | Depth in feet | Lithology | Porosity (%) V | Porosity (%) H | Permeability (md) V | Permeability (md) H | Fluid saturation (water) |
|---|---|---|---|---|---|---|---|---|
| ARUMBERA SANDSTONE | | | **Ooraminna No.1.** | | | | | |
| | 1 | 279'4" | Feldspathic sandstone | 2 | 3 | 0 | 0 | 12 |
| | 2 | 609'4" | Sandstone | 12 | 13 | 4 | 9 | Nil |
| | 3 | 713'0" | Interlaminated siltstone and sandstone | 5 | 4 | Nil | Nil | 29 |
| | 4 | 847'4" | Feldspathic sandstone | 6 | 6 | 0 | 0 | 8 |
| | 5 | 1357'4" | Feldspathic sandstone | 22 | 21 | 43 | 251 | 1 |
| | | | **Alice No..1.** | | | | | |
| | 27 | 7305'4" | Siltstone | 1 | 1 | 0 | 0 | 100 |
| | 28 | 7518'4" | Shale | 2 | 2 | 0 | 0 | 100 |
| | 28 | 7520'4" | Sandy siltstone | 3 | 3 | 0 | 0 | 32 |

Table 11

Measured petrographic rock characteristics of cores - Pertaoorrta Group - post Arumbera Sandstone

| Formation | Core No. | Depth in Feet | Lithology | Porosity (%) V. | Porosity (%) H. | Permeability (md) V. | Permeability (md) H. | Fluid saturation (water) |
|---|---|---|---|---|---|---|---|---|
| | | | Mount Charlotte No. 1 | | | | | |
| JAY CREEK LIMESTONE | 4 | 1565'5" | | 5 | 5 | Nil | Nil | |
| | 5 | 1845'11"-46'3" | | 10 | 11 | Nil | Nil | |
| | 6 | 2207'4" | | 11 | 11 | Nil | Nil | 14 |
| | 7 | 2303' 2308' | Insufficient sample remaining for analysis. | | | | | |
| | | | Alice No. 1 | | | | | |
| GOYDER FORMATION | 9 | 3125'4" | Sandstone | 9 | 7 | Nil | Nil | 4 |
| | 9 | 3129'4" | Sandstone | 8 | 9 | Nil | Nil | 2 |
| | 10 | 3412'4" | Sandstone | Nil | 3 | Nil | Nil | 76 |
| | 11 | 3587'4" | Shale | 8 | 9 | Nil | Nil | 2 |
| SHANNON FORMATION | 12 | 3889'4" | Limestone | 3 | 5 | Nil | Nil | 4 |
| | 14 | 4193'4" | Limestone | 5 | 2 | Nil | Nil | Nil |
| | 15 | 4527'4" | Dolomite | 3 | 2 | Nil | Nil | Nil |
| | 16 | 4845'4" | Dolomite | 8 | 3 | Nil | Nil | 13 |
| GILES CREEK DOLOMITE | 17 | 5173'4" | Dolomite | 6 | 6 | Nil | Nil | Nil |
| | 18 | 5455'4" | Dolomite | 2 | 1 | Nil | Nil | 41 |
| | 19 | 5723'4" | Dolomite | 6 | 4 | Nil | Nil | 25 |
| | 20 | 6064'4" | Anhydritic dolomite | Nil | Nil | Nil | Nil | Nil |
| | 21 | 6096'4" | Dolomite | Nil | Nil | Nil | Nil | Nil |
| | 22 | 6118'4" | Anhydritic dolomite | 1 | 1 | Nil | Nil | Nil |
| | 23 | 6133'4" | Anhydritic dolomite | Nil | 1 | Nil | Nil | 100 |
| | 24 | 6443'4" | Anhydritic dolomite | 1 | 1 | Nil | Nil | 26 |

Burst (1959) suggested that a primary detrital clay content is strongly altered by diagenetic actions with disappearance of smectite, agradation and neoformation of illite and chlorite, and regularisation of the interstratified framework.

The end products of intense diagenetic changes, such as those observed in the Proterozoic sediments, are highly crystallized illite and chlorite.

Absence of low grade metamorphism in the Proterozoic rocks

Several geologists have considered that the Proterozoic has been submitted to a low grade metamorphism. A method measuring the sharpness of the illite peaks on the diffractometer charts in the form of a ratio has been reported by Weaver (1960) and Kubler (1964); this method has been applied by A.M.D.L. (Stock, 1966) at the request of B.M.R. and the result is plotted on Table 12.

As the pattern shown on Table 12 does not indicate any increase of the ratio A/B from top to the bottom of the wells and especially in the deepest wells (Alice No. 1, Ooraminna No. 1 and Mount Charlotte No. 1) one must preclude any form of metamorphism in those sediments.

This conclusion is supported by the presence of kaolin in the Heavitree Quartzite (French Petroleum Co. Aust., 1963) and a small amount in the Bitter Springs Formation. Kaolin is the first clay type, after smectite, to disappear when a formation is subjected to any form of metamorphism.

Correlations

In this report the clays have little value for correlation purposes because they have been involved in strong diagenetic changes.

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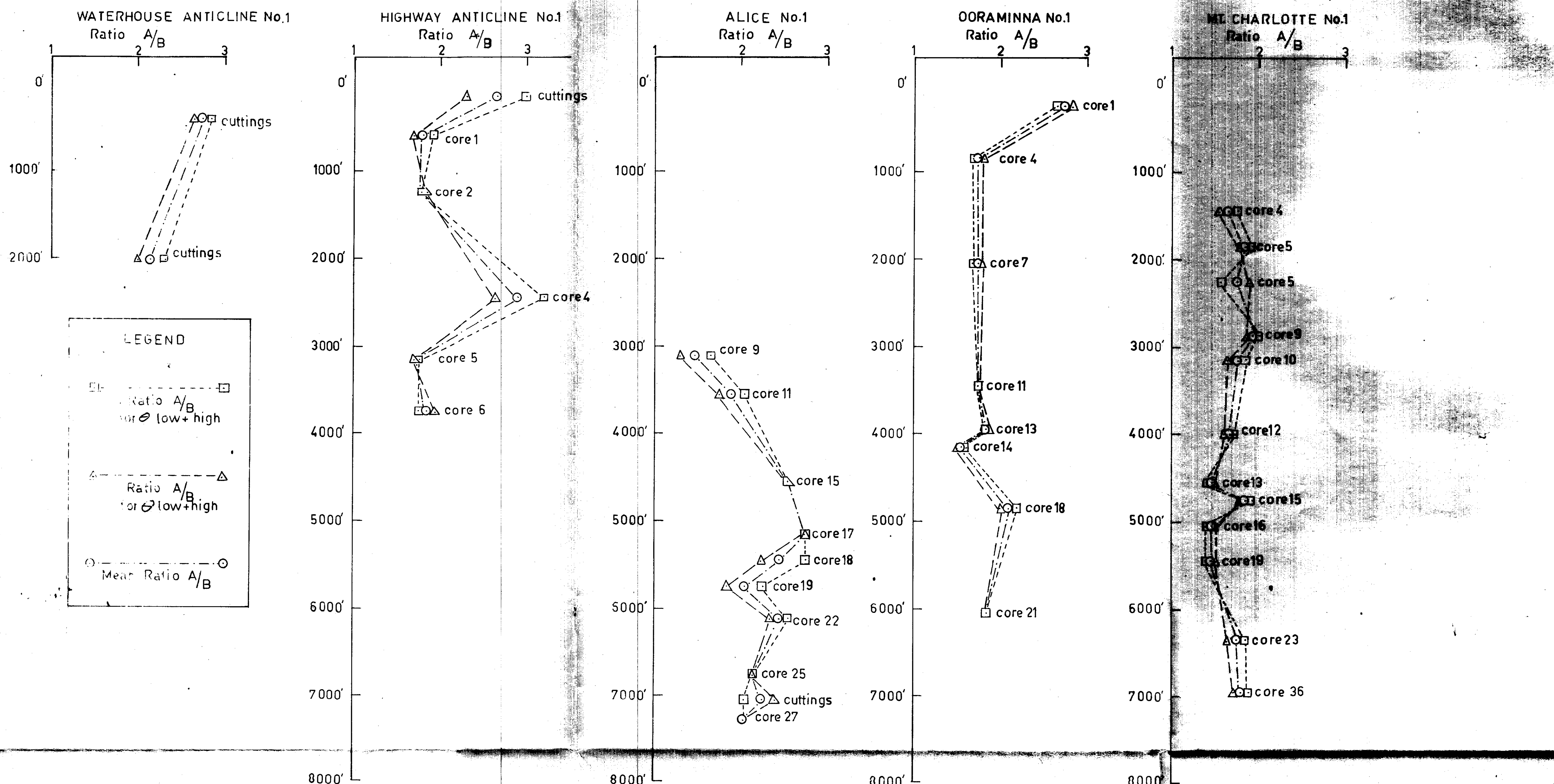
Table 12

# ILLITE SHARPNESS CURVES, FOR SAMPLES FROM FIVE. WELLS OF CENTRAL PART OF AMADEUS BASIN, NORTHERN TERRITORY

(By: A. M. D. L. Report MP 2458-66)

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Drawn by: S. Ozimic

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