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A PETROLOGICAL STUDY OF THE SEDIMENTS FROM ERLDUNDA No.1 WELL, AMADEUS BASIN, NORTHERN TERRITORY.

by

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SUMMARY

This report is the result of the examination of cores and cuttings from Erldunda No. 1 well.

The petrological study has revealed some new information concerning conditions of sedimentation and mineral constituents.

Important characters of the stratigraphy have been disclosed.

- a break of sedimentation between the Winnall Beds and the uppermost formation of the Larapinta group.
- the presence of the Carmichael Sandstone in the southern Amadeus Basin.
- a definite change in lithology in the upper formation which is tentatively correlated with the Pertnjara Formation.

Subdivisions defined from surface mapping can be justified. In this well from bottom to top they are:

- 1163 feet of Bitter Springs Formation
- 550 feet of Inindia Beds
- 2510 feet of Winnall Beds
- 340 feet of Carmichael Sandstone
- 760 feet of an equivalent of lower Pertnjara
- 140 feet of Quaternary

INTRODUCTION

Erldunda No. 1 well, situated approximately 110 miles south-south-west of Alice Springs in the Amadeus Basin (N.T.), was drilled by Exoil (N.S.W.) Pty Ltd and partners. The aim was to establish the subsurface stratigraphy in the southern Amadeus Basin and to evaluate the reservoir and source potential possibilities on a large anticline defined by seismic surveys.

Details of the well and its location are given below:

Location: Lat. 25°18'36"S
Long. 133°11'48"E
Map reference G.53-1 Kulgera

Elevation G.L. 1330' a.s.l.
K.B. 1343' a.s.l.

Total depth: 5463 feet (driller)
5457 feet (electric logs)

The aim of this petrological study was to examine in detail the lithology and to identify the formations especially in the upper part of the well. Samples of cuttings from 10 feet intervals were examined together with all cores. A binocular microscope examination was carried out together with a thin section study of all cores and selected cuttings. A calcimetry log was prepared with an average interval of 40 feet. Colour tests for phosphate were undertaken with an average interval of 30 feet between 1210 and 5000 feet and some tests in the upper part. Heavy mineral separation was carried out on cuttings and cores at every lithological change.

DESCRIPTIONS OF LITHOLOGICAL UNITS

The sediments in Erldunda No. 1 well have been divided into lithological units based on rock composition, texture and structure. All units, correlated with formations determined by B.M.R. field parties, were delineated by observed lithological changes shown in cutting samples and on the electric log.

The detailed core and cuttings descriptions are given in appendix 1 and 2. The lithologies are also shown on the accompanying composite well log.

Bitter Springs Formation

In Erldunda No. 1, the Bitter Springs Formation may be subdivided into two members: a lower halitic, anhydritic and dolomitic unit which is referred to the Gillen Member and an upper dolomitic unit with interlaminated fine sandstone and siltstone which is correlated with the Loves Creek Member.

Gillen Member (T.D. (5463) to 4750 feet)

This member is represented by two lithologies: salt in the lower part and interlaminated dolomite and anhydrite in the upper part. The sequence is well characterized on the Gamma Ray by a featureless curve which indicates negligible clay content, but stands out on the Acoustic log as an high velocity zone; the caliper, which has not been represented on the composite well log, shows a washed out hole zone at 5310 feet

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corresponding to the halitic section.

Salt: 153 feet of pure, light reddish, greyish, coarsely crystalline salt was intersected.
The increased salinity of circulating fluid, as reported by Exoil and the presence of small washed out zones could suggest that salt occurs as thin interbedded laminae in the dolomitic anhydritic upper zone.

Dolomite, anhydrite and minor gypsum form the main components of the upper part. Dolomite occurs as grey, pink to mauve, dense, locally reddish laminated cryptocrystalline to microgranular rock; numerous pseudolaminae, microslumping and intraformational breccias have been noticed. Cryptocrystalline chert is plentiful as finely interlaminated bands, and as nodules or even replacing oolithic structures in carbonate rocks. These dolomites grade to an intermingling of minute dolomite rhombs, polygonal anhydrite and some gypsum with gradational limits or to crystalline anhydrite in fine beds, lenses or patches in places showing a 'pile of brick' texture. Some thin bedded dolomite contains argillaceous and black matter in very fine laminae and in some places haematite.

Both the dolomite and sulphates show evidence of being bedded. Anhydrite and some gypsum occur also in fissures as secondary recrystallized minerals.

<u>Loves Creek Member</u> (4750 to 4300 feet)

The lithology comprises mainly dolomite with anhydrite and nearly equal amounts of sandstone and siltstone. The electric logs, Gamma Ray and acoustic log reflect the lithological heterogeneity by considerable oscillation. The dolomite is thick bedded and occurs mainly as cryptocrystalline to microgranular recrystallized, slightly haematitic rock with anhydrite and gypsum in fine lenses or prediagenetic felty crystals including numerous minute dolomite rhombs. Chalcedonic-quartz chert is present.

These bedded, probably precipitated dolomites, alternate with fine grained detrital dolomite containing angular to rounded, fine to medium grained discrete quartz and chert grains.

Sandstone occurs as white to light pink, also reddish-brown, angular, medium sorted quartz sandstone, with rare potassium feldspar and altered mica; the cement is mainly dolomite, secondary silica overgrowths, haematite and minor chlorite, sericite and kaolinite.

The positive colour phosphate tests (see appendix 3) could be explained either by very fine phosphatic matter disseminated in the sandstone or by cavings from the overlying Inindia Beds.

<u>Porosity</u>

In this mainly dolomitic sequence, no intergranular porosity has been noticed. As no open fracture cleavages occur in the dolomite the porosity in the Bitter Springs Formation is nil.

<u>Contact between Bitter Springs Formation and the overlying Inindia Beds</u>

The contact is indicated either in the cuttings log by the appearance of cherty dolomite, or on the electric and acoustic logs by an increase in resistivity and travel time.

Lithification

In this mainly dolomitic sequence strong changes due to compaction, as shown by the numerous styolites, have taken place; although there is recrystallization, dolomitization and development of silica in an early stage of diagenesis. In the lower part of the formation, the dolomite may be considered as primary or prediagenetic because of its relationship with sulphates, silica and salt deposits.

The presence of intrusive anhydrite and some gypsum in the form of felty crystals through the upper dolomitic section or filling small fissures and fractures may be associated with tectonical movements.

Environment

The Bitter Springs Formation may be considered as an association of primary evaporites and sedimentary accumulation of sulphates with inorganically precipitated carbonate rocks. From the base to the top there is a gradual return to normal marine conditions with influx of fine detrital material in the upper part. The change in lithology reveals climatic modifications on the flat narrow land area.

Inindia Beds

The Inindia Beds, which have been intersected between 4300 and 3750 feet are a mainly sandstone unit with interfingering of dark siltstone and thin bedded dolomite.

This sequence is characterized on the electric logs, gamma ray and acoustic log by rapid and intense well defined changes; the upper sandstone stands out on the resistivity and gamma ray logs as a clean sandstone; however the lower sandstone (4300-4220 feet) shows a progressive increase in clay content towards the bottom on the gamma ray log.

Sandstone: This is a light grey, compact and dense, closely packed, angular to rounded, fine to coarse, locally very coarse grained, poorly sorted orthoquartzite with a very low orthoclase and microcline content, and some sedimentary and igneous chert; accessories are very rare glauconite, phosphate pellets, tourmaline and zircon. The cement is composed of very thin chlorite rims and very strong secondary silicification in the form of quartz and chalcedony with minor dolomite; poorly developed, vermicular kaolinite occurs locally altered to sericite.

In the lower, slightly greenish sandstone sequence (4300 to 4220 feet) the detrital material is finer grained, well sorted and the cementing media is characterized by a rich chlorite content either in fine tabular crystals or in rims, and a poorly developed secondary silicification. A progressive increase in fine greenish, pyritic and chloritic siltstone and shale content appears towards the bottom of this sequence.

Both sandstone sequences are separated by dark blackish grey, finely laminated, ferruginous, slightly micaceous and calcareous shale and minor siltstone rich in black matter. This is the richest clayey sequence in this well as indicated on the gamma ray log.

Between 4160 and 4220 feet the shale grades to clayey dolomite (Core 9) and cryptocrystalline, pyritic dolomite with minor detrital content as silty to coarse grained single quartz, igneous chert, and shows secondary chalcedony silicification; very rare muscovite streaks and fine haematite granules are present.

Porosity

In this mainly sandstone sequence the primary porosity has been reduced by secondary silicification; a very weak intergranular porosity has been noticed in Core 8.

Petroleum Prospects

According to Exoil a fairly good cuttings gas reading has been noticed between 4150 and 4180; this corresponds to the dark blackish grey shale section.

Contact with the Bitter Springs Formation

The lower contact in the well is indicated in the cuttings log by the appearance of abundant cherty dolomite and especially in the acoustic log by an increase in travel time. Stratigraphically, there is conclusive evidence on the relationship between the Bitter Springs Formation and the Inindia Beds (probably the lateral equivalent of the Areyonga Formation), as no angular discordance has been noticed by the dip angle survey on Cores 8 and 9, the Inindia Beds may overlie the Bitter Springs Formation without an unconformity. Nevertheless the sharp break in the sedimentation between both formations suggests a disconformity in this area.

Lithification

Cementation of the sandstones occurred during diagenesis stage; however, where carbonate (mainly dolomite) cements are also present, many of the overgrowths are corroded; quartz welding occurs in these sandstones. Chlorite occurs as very thin rims around the detrital grains; this chloritization indicates a change in the primary oxydizing environment characterized by the deposit of coarse grained, poorly sorted sandstone, to more reducing conditions. Pyrite in the form of finely disseminated grains and aggregates emphasizes these conditions. The initial porosity has been considerably reduced by diagenetic changes.

Environment

In this area the Inindia Beds are considered to be marine as indicated by the presence of glauconite and phosphate in the sandstone and the rich black matter content in the calcareous shale sequence. This sedimentation has taken place on a shelf area. The presence of methane is considered to be primary in origin.

Winnall Beds

The Winnall Beds, intersected between 3750 and 1240 feet, may be subdivided into four lithological units:

top:	2058 to 1240 feet:	sandstone with minor siltstone
	3015 to 2058 feet:	siltstone with minor sandstone
	3080 to 3015 feet:	conglomerate and sandstone
	3750 to 3080 feet:	calcareous siltstone with some dolomite beds

These four units are correlated with the four units defined by Ranford and Cook (1964).

Siltstone unit (3750 to 3080 feet)

This is a calcareous siltstone and shale unit with thin interlayered sandstone beds and dolomite laminae.

This sequence is characterized on the gamma ray log by a featureless curve with an average low value, lower than a normal shale and siltstone unit. The presence of finely disseminated calcareous matter through this sequence could explain the low gamma ray value and the higher

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resistivity. The calcareous content, mainly dolomite, is indicated on the calcilog with an average content between 10 and 15 percent.

The siltstone is dark grey and brown, micaceous, calcareous, chloritic or haematitic, very pyritic and slightly phosphatic; the micaceous content is variable and composed of muscovite, altered greenish biotite and small sericite content.

Very thin lenses and laminae of cryptocrystalline dolomite occurs interbedded in the siltstone; they are silty in some places, micaceous and pyritic, grading to clayey dolomite.

Secondary anhydrite and gypsum occur in fine fissures and small patches as a crystallization.

Conglomerate and sandstone unit (3080 to 3015 feet)

This thin coarse detrital sandstone unit with a 25 feet thick conglomerate at the base, is well indicated on the lateral, gamma ray and acoustic log by strong deflections.

The white and grey, polymictic conglomerate is composed mainly of angular als subangular to subrounded, very poorly sorted pebbles up to 30 mm (Core 5) composed of mainly cryptocrystalline chalcedonic quartz cherts, granoblastic quartz, metaquartzite, fragments of mica-schist, rare granite, cryptocrystalline to microgranular dolomite, some finely laminated, some with algal structures.

The cementing media is composed of cryptocrystalline to microgranular carbonate minerals and minor secondary silicification.

This conglomerate grades upwards into lithic quartzite characterized by angular to rounded, well sorted, medium grained quartz (80%), rare microcline, sericitized orthoclase, very rare sodic plagioclase, 5% chert and metaquartzite. Fine muscovite streaks are present. The cementing media is composed of secondary silica and 10% calcareous matter.

Siltstone and minor sandstone unit (3015 to 2058 feet)

The siltstone-shale unit with interlayered calcareous pebbly sandstone is characterized on the electric logs by low resistivity with some positive peaks and on the gamma ray by a featureless curve. Below 2700 feet the guard log shows an increase in resistivity which corresponds to more calcareous siltstone as indicated by the calcilog.

The siltstone and shale are greyish-green, fissile and finely laminated, very chloritic, sericitic or illitic, pyritic, and grade into each other; below 2700 feet they contain 10% finely disseminated minute dolomite rhombs. The light to medium grey, calcareous sandstone occurs in fine beds, no more than 10 feet thick; they are mainly angular also subrounded, well sorted, very fine grained orthoquartzite containing some phosphatic and glauconitic pellets; locally it contains rounded, coarse grained quartz and rare chert pebbles up to 2mm.

Sandstone with minor siltstone unit (2058-1240 feet)

The lithology consists of predominant grey and brown, medium grained sandstone with interlaminated siltstone. The electric logs and gamma ray show a characteristic pattern with high and low resistivity peaks.

The sandstone is grey to brown, angular to subangular, well to medium sorted, fine to medium grained, grading from submature to mature orthoquartzite; the detrital feldspar content is low but the mica content varies from 1 to 10%; muscovite is locally altered to sericite; biotite

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occurs as greenish crumpled elongate wisps, in some instances frayed apart along cleavage planes with infiltrated matrix; in some cases the biotite is completely chloritzed. Slightly chloritized glauconite and transparent to light reddish-grey, also yellowish phosphate pellets are present in minor amount. Accessories are tourmaline, zircon, apatite, pyrite and leucoxene.

Haematite occurs in brownish sandstone and chlorite as interstitial patches or green halos around the detrital grains in the grey sandstone. Silica overgrowths are present in some places; kaolinite as minute vermicular crystals and calcareous matter is rare. The siltstone and silty shale are chloritic, sericitic and pyritic.

Porosity

The diagenetic changes have completely oblitered the primary intergranular porosity in the sandstone units and therefore poor porosity should be expected in the Winnall Beds.

Occurrence of Petroleum

Exoil reported traces of pinpoint blue fluorescence and black residual hydrocarbon on sand grains between 1560 and 1575 feet; over the interval 3420 and 3743 feet and in Core 6 (3651-3654) a small amount of methane has been extracted. The study of the lithologies throughout these intervals has shown that these occurrences are primary and are found in greenish shale and siltstone.

Contact with the Inindia Beds

This contact has been picked at the first appearance of grey, poorly sorted quartzitic sandstone in the cuttings log; this limit is well indicated on the electric logs and gamma ray by an intense and sharp break in the curves. The cores do not show any evidence of unconformity between the Inindia Beds and the Winnall Beds but the presence of mainly sedimentary cherts and dolomite pebbles related to the Bitter Springs Formation in the conglomerate and sandstone unit suggests a disconformity.

Diagenesis

In this silty and sandstone formation the post-depositional changes that have taken place are due to compaction in the shale siltstone sequences with development of chlorite and pyrite; the sandstones have mainly epigenetic chlorite and silica overgrowths; the development of chlorite appears to be a prediagenetic transformation of thin iron rims around the detrital grain, followed by silicification and induration. The development of calcareous matter which may be derived from entrapped water or brought in by solutions from extraneous sources is a late stage change.

The common presence of pyrite implies deposition of ferrous sulphide, later modified to pyrite under reducing conditions.

Environment

During the deposition of the Winnall Beds the sedimentation started, as demonstrated out by the lower siltstone unit, in slightly stagnant water conditions surrounded by a peneplanized land mass.

This quiet sedimentation was abruptly interrupted by conglomerate deposits which give evidence of tectonic influence on a narrow southern continent; dolomites of the Bitter Springs Formation were éroded at the same time as metamorphozed and igneous rocks.

The sandstone and siltstone which have been deposited later represent a typical shelf environment with formation of glauconite and phosphorite.

The detrital content shows evidence of a submature to mature, reworked material.

Carmichael Sandstone

The Carmichael Sandstone has been intersected between 1240 and 900 feet. The predominant lithology of this sequence is ferruginous fine grained sandstone with minor siltstone.

As the lithology does not present any marked change from the underlying Winnall Beds, the electric, acoustic and the gamma ray log show the same pattern in this sequence as below. The gamma ray log indicates a clean sandstone unit only in the upper part between 1040 and 900 feet.

Sandstone: This is a reddish to brownish-red, compact also poorly consolidated, fine to medium grained, angular to subrounded quartz sandstone with very rare orthoclase and microline, 5% chert, metaquartzite and altered rock fragments. Muscovite is locally altered to hydromuscovite and kaolinite; some chloritized and sericitized biotite and exceptional glauconite are present in minor amount, especially in the upper part (between 1040 and 900 feet). The accessories are mainly leucoxene and tourmaline, zircon, apatite, magnetite (tourmaline 70%, zircon 28% and apatite 2%).

The cementing media consists mainly of primary haematite as a coating or fine disseminated concretions; the amount is variable but in some cases is up to 20%. Secondary silicification may be important in some instances especially where the haematite content is lower. Hydromuscovite, sericite, some fine vermicular kaolinite and very rare calcareous matter occur in this sandstone.

The sandstone is rather thickly bedded with cross bedding and other current structures (Core 2).

Below 960 feet they grade to very haematitic, micaceous shale, silty shale and siltstone alternating with grey greenish chloritic and pyritic, slightly calcareous siltstone.

Porosity

Weak intergranular porosity occurs in Core 2; an estimation of up to 5% porosity could be made for the upper clean sandstone sequence in the Carmichael Sandstone. According to Exoil approximately 1000 gallons/hour of salty water were obtained in this sequence, however a better evaluation of the porosity in this sandstone is not possible because most of the cuttings are broken to loose grains.

Contact with the Winnall Beds

The lower limit has been picked in the cuttings log at the appearance of plentiful greyish-green and brownish, chloritic, pyritic, glauconitic and phosphatic sandstone typical of the Winnall Beds. The phosphate tests carried out between 1200 and 1300 feet show a sharp appearance of phosphate at 1240 feet. A unconformity between the Winnall Beds and the Carmichael Sandstone is present as shown by the general geological relationship through the stratigraphical section in the Amadeus Basin but has not been revealed by the dip angle survey in the cores.

This major break developed in the southern margins of the basin does not show any evident erosion surface with basal conglomerate, buried soil profiles, zones of mineralization etc. in the well section.

Diagenesis

The most important changes which have taken place are secondary prediagenetic silicification followed by development of sericite and minor alteration of kaolinite.

Environment

The presence of some glauconite, current structures and the good sorting of this sandstone suggests a shallow marine shelf environment where submature to mature detritals were deposited. The high content of haematite indicates strong iron dissolution on the land area.

Equivalent of lower Pertnjara

The sediments which have been intersected between 900 and 140 feet are tentatively considered as an equivalent of the lower Pertnjara formation and correlated with the lower siltstone unit. This unit has been defined in Wells et al, in press.

The sequence characterized by ferruginous, sandy, locally pebbly siltstone with interlayered sandstone stands out on the E logs as poorly defined curves and on the gamma ray log as a featureless line showing little more than statistical variation. The gamma ray log indicates a rather low clay content for a mainly sandy siltstone unit.

Lithology

The siltstones are characterized by the high haematite content, the presence of numerous pebbles up to 3mm and the low clay content. They are brownish-red, haematitic, very poorly sorted sandy siltstone with scattered rounded, coarse to very coarse grained quartz, very rare granoblastic chert and some potassium feldspar. Muscovite and altered greenish biotite streaks are plentiful in some layers; chlorite is present as fine tabular crystals and pigments; the carbonate mineral content in the form of minute dolomite rhombs is variable. In some instances pseudomorphs after gypsum occur.

This siltstone grades to sandstone characterized by poor sorting. They are brown to pink, white to grey, mainly angular also subangular to rounded, very fine to medium grained, well to very poorly sorted sandstone. The detrital content is composed mainly of quartz, 5% angular orthoclase and rare in some places strongly altered, calcitized and sericitized plagioclase; igneous and sedimentary chert are present in minor amount. Altered greenish biotite and muscovite are locally plentiful. Greenish, yellowish primary glauconite occurs in fine pellets with locally up to 10% light greenish and greenish-brown tabular shaped and interstitial chlorite patches; some crystals represent probably completely altered ferromagnesian minerals.

The heavy mineral suit is characterized by the association of zircon, tourmaline, rutile, apatite and especially a great amount of garnet; opaques, mainly ilmenite-leucoxene and pyrite are numerous; very rare secondary epidote is present.

The banding media is composed mainly of haematite occurring in coatings or in intergranular concentrations, quartz overgrowths, rare sericite, kaolinite, chlorite and in some instances important dolomite content, up to 25%, in the form of microgranular crystals or minute rhombs. Gypsum pseudomorphs occur in noticeable amount through the sandstone.

The sandstone grade to interlaminated sandstone with scattered pebbles up to 2mm.

The petrological characteristics for this sequence are the poor sorting of the siltstone and sandstone and the more submature nature of the sandstone with a local presence of altered plagioclase, a rather high micaceous and tabular chlorite content, a haematitic cementing media and the presence of garnet. The presence of primary glauconite and some calcareous sandstone does not appear to fit typical Pertnjara. This lithological sequence is considered as an intermediate facies between the typical northern Pertnjara and the Finke Group; it may be characteristic for the southern margin of the Amadeus Basin.

Porosity

In this poorly sorted and cemented formation intergranular porosity is very low. Between 300 and 400 feet, less than 10 gallons of water per hour have been recorded (Exoil, completion report). This indicates a very low permeability in relationship with an important cement development.

Contact with the Carmichael Sandstone

The contact with the underlying Carmichael Sandstone is very sharp in the cuttings log and also rather well indicated on the gamma ray log but the electric logs show a scale change just at this limit. As the Mereenie Sandstone has not been deposited in this area, the Pertnjara overlies the Carmichael Sandstone with a disconformity as indicated by the sharp contact in the cuttings. But no erosion surface has been revealed.

Diagenesis

Several diagenesis changes have taken place in this formation as indicated by the poorly developed secondary silicification, the presence of some sericite, secondary epidote and the important development of chlorite. Following dolomitization, gypsum crystals have been formed from a later infiltration of gypsiferous water (Krumbein-Sloss 1963).

Environment

The Pertnjara Formation is considered as a fresh water formation, "post orogenic (or molasse) facies" (Wells et al., 1964). But the presence of glauconite and calcareous matter suggests an intertonguing of marine influence in this area.

Quaternary

Between 140 feet and the surface Quaternary sand composed of clear, subangular to rounded, poorly sorted fine to medium grained quartz grains and brown clay have been intersected. The heavy minerals are mainly zircon-tourmaline rare garnet-rutile-epidote-apatite and anatase.

As no cuttings are available between 100 and 160 feet, the contact has been picked on the gamma ray log at 140 feet where there is a noticeable change in the clay content.

CONCLUSIONS

The petrological study of Erldunda No. 1 well emphasizes two points of interest with regard to the correlation and hydrocarbon possibilities in the southern part of the Amadeus Basin.

The presence of a high saline environment in the Bitter Springs Formation underlines the persistence of this facies through the basin; it is thought that the present southern Amadeus Basin margins do not represent the primary limits.

The disconformable Inindia Beds have a similar lithology to the Areyonga Formation defined in the northern Amadeus Basin; the Inindia Beds are considered as marine.

The Winnall Beds which overlie the Inindia Beds with a disconformity have been subdivided into four units and may be correlated with the field units; the presence of glauconite and phosphate seem characteristic for the whole unit.

An important break in the sedimentation occurs at the top of the Winnall Beds. No Pertaoorta sediments have been deposited in this area, and the Carmichael Sandstone is the only formation present of the Larapinta Group. The youngest formation in the well is tentatively correlated with the lower Pertnjara Formation with a definite change in lithology and characterized by marine influence.

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APPENDIX 1

CORE DESCRIPTION OF WELL ERLDUNDA NO. 1

Equivalent of Pertnjara Formation

C1 598' - 602' : Hard, compact and dense, brownish red, argillaceous sandstone and sandy siltstone with pebbles up to 2mm across. White small fissures filled with gypsum intersect the core. Very poorly sorted, fine to very coarse grained, angular to rounded, very ferruginous sandstone, with 60% quartz, 5% microcline and orthoclase and very rare sodic plagioclases. Micas (8%) is present in very fine streaks composed of muscovite and altered greenish biotite and emphasize a disturbed bedding. Altered blackish matter occurs. The cementing media is composed of a very high haematite content, locally in concentration; carbonates occur mainly as minute dolomite pseudorhombs or cryptocrystalline calcitic matter. Gypsum is present in small patches filling voids and fissures and corroding detrital minerals.

Carmichael Sandstone

C2 1202' : Compact and dense, slightly reddish, micaceous sandstone. Along a vertical fissure, the sandstone is greenish-grey, probably due to weathering.
Angular, fine grained, well sorted sandstone with 80% quartz, rare very altered orthoclase, microcline and sodic plagioclase. 5% strongly sericitized and chloritized rock fragments; 10% micaceous content composed of altered, greenish-brownish squeezed biotite and muscovite which often have a characteristic hydro-muscovite birefringence. Accessories are tourmaline-zircon-apatite and opaques.
Cementing media is haematite, some secondary silicification and very rare sericitized? kaolinite.

1204' : Compact and dense, slightly reddish, micaceous sandstone with some argillaceous pellets; cross bedding is important.
The presence of small vugs could introduce secondary porosity due to leaching of the matrix. Subangular to subrounded, well sorted, fine to medium grained sandstone with 85% quartz, 5% orthoclase, microcline, chert, and rare sericitized rock fragments, some squeezed muscovite, locally altered to hydromuscovite and altered greenish fan-like biotite. Accessories are tourmaline and zircon. Cementing media is mainly haematite, strong secondary silicification, very rare kaolinite, sericite and some calcareous matter.

Winnall Beds

C3 1862' - 1864': Compact and dense, brownish-red, micaceous very fine sandstone with small fissures filled with gypsum, intersecting the core. Well sorted, angular, fine grained detrital content with 70% quartz, rare altered orthoclase and microcline, some microcrystalline chert and sericitized rock fragments; about 10% micas, mainly muscovite and greenish biotite emphasized a poorly defined bedding; light reddish and greyish, also yellowish phosphate pellets occur with some minute glauconite crystals. Accessory minerals are tourmaline-zircon-epidote?-apatite and opaques. The cementing media is composed of primary haematite and quartz overgrowths in variable amount; chlorite occurs as small tabular crystals or coatings.

C4 2395' : Greyish-green, fissile, chloritic, illitic?, pyritic shale grading to chloritic siltstone and very fine, angular and well sorted quartz sandstone rich in chlorite, pyrite and some phosphate pellets.

C5 3057' : White to light beige, compact and dense, hard, fine grained sandstone. Angular to rounded, well sorted, fine to medium grained sandstone with 30% of quartz, 4% microcline, orthoclase and very rare sodic plagioclase, 5% quartz-chalcedonic chert, microquartzite and a small amount of muscovite.
Cementing media is composed of a strong secondary silicification and cryptocrystalline to microgranular carbonate, mainly dolomite.

3057' - 3059' : White and grey polimictic conglomerate with abundant angular to subrounded, coarse to very coarse grained with pebbles up to 30mm.
Detrital material is composed of: quartz, orthoclase, microcline, chalcedonic quartz chert (dominant), granoblastic quartz, pure chalcedony, granite with biotite, mica schists with biotite and muscovite, finely laminated cryptocrystalline dolomite and recrystallized calcarenitic (algae tubes) dolomite; rare tourmaline is present.
The cementing material is mainly cryptocrystalline to microgranular dolomite with some secondary, cryptocrystalline silica.

C6 3651' - 3654': Dark grey, finely laminated, locally resinous lustre shale with very thin interbedded dolomite beds.
Cryptocrystalline dolomite with a small amount of silt sized quartz, rare muscovite; 5% pyrite and haematite granules. Fine fissures area filled with microgranular carbonates, some gypsum and anhydrite.
This dolomite grades to clayey dolomite and to finely laminated sericitic shale.
Dip is horizontal.

C7 : No recovery

C8 3985' : Compact and dense, light grey sandstone.
Angular to rounded, medium sorted, medium to fine grained sandstone with 85% quartz, rare orthoclase and microcline and about 3% of quartz-chalcedonic and igneous chert and very rare metaquartzite. Accessories are tourmaline with secondary overgrowth and zircon.
Very thin chlorite occurs as prediagenetic coatings, intense secondary silicification; presence of 5% minute dolomite rhombs.

C9 4190' - 4196' : Greyish-blue, homogeneous to finely laminated dolomite and clayey dolomite.
Cryptocrystalline, slightly pyritic, dolomite with some silt sized quartz content and some muscovite streaks grading either to clayey dolomite rich in illite? or to sandy dolomite with single rounded, coarse grained quartz grains and rare igneous chert. Secondary silicification occurs as cryptocrystalline quartz.
Dip is horizontal to very low angle.

Bitter Springs Formation

C10 4792' : Slight grey, pink and mauve, compact and dense, slightly reddish laminated, very fine grained dolomite with irregular patches of crystalline anhydrite.
Vertical thin fissures intersect the core.
Microlaminated with slightly disturbed sedimentary beds, cryptocrystalline dolomite with secondary, prediagenetic anhydrite crystals mainly parallel to (001); therefore they occur as microgranular, single crystals or in fine laminae with their great axe parallel to the bedding. Dip 8°.

4794' : Medium grey, compact and dense dolomite with white crystalline anhydrite patches and dark grey, undulated chert laminae.
Laminae or fine lenses of microgranular anhydrite grading to intermingled minute dolomite rhombs and microcrystalline to intergranular anhydrite or cryptocrystalline dolomite fragments in a blackish dolomitic matrix with spottedgypsum, anhydrite and some secondary silica. Silica occurs also as fine cryptocrystalline bands.
Minoslumping are present with intraformational breccia.

4798' : Reddish and greenish, hard and dense crystalline anhydrite and dolomite. Polygonal, more or less rectangular, microgranular anhydrite grading with a sharp limit to cryptocrystalline dolomite.
The core shows a dip angle of 45° which is probably due to sedimentary structures.

4800' : Reddish to greyish, cryptocrystalline to micro-crystalline dolomite with black matter in laminae and granular anhydrite crystals in recrystallized fractures.
Presence of nitraformational sedimentary breccias and slumping. Dip of 50° is due to sedimentary structures.

C11 : No recovery

C12 5462' : Reddish and greyish, coarse crystalline salt.

APPENDIX 2

CUTTINGS DESCRIPTION

by

S. Ozimic

20' - 100'	: 70% clear, loose, angular to rounded, fine to coarse quartz grains; few pebbles up to 2mm across. 30% light brown clay.
100' - 160'	: No samples.
160' - 290'	: 35 to 50% white to reddish, angular to rounded, poorly sorted, fine to medium grained sandstone; fragments are rich in biotite and some green patches are present. 15 to 50% clear, loose, angular to subrounded quartz grains; few pebbles up to 2.5mm across. 55% reddish brown, micaceous siltstone.
290' - 350'	: 5% clear, loose, angular to subrounded quartz grains; some pebbles up to 2.5mm across. These could be caved ? 85% reddish brown, micaceous siltstone. 10% white to light grey fragments of gypsum.
350' - 430'	: 100% reddish brown, micaceous siltstone; few fragments of gypsum.
430' - 920'	: 10 to 50% brown to pinkish grey, angular to rounded, poorly sorted, very fine to coarse grained lithic sandstone. 5 to 20% clear, loose, angular, poorly sorted, very fine to coarse quartz grains; few pebbles up to 2mm across. 40 to 90% brown to grey, micaceous, slightly calcareous siltstone. Few fragments of gypsum and anhydrite.
920' - 1000'	: Reddish, compact, angular, well sorted, very fine to fine grained, slightly calcareous, sandstone. 10% brown and grey, micaceous, slightly calcareous siltstone.
1000' - 1250'	: 80 to 90% red, grey and brown, loose, angular to rounded, well sorted, very fine to coarse grained, slightly calcareous lithic sandstone. 10 to 20% brown and grey, micaceous, slightly calcareous siltstone; some fragments of calcite, anhydrite and gypsum; traces of pyrite.
1250' - 1580'	: 45 to 100% grey and brown, angular to subangular, moderately sorted, very fine to medium grained, slightly calcareous, lithic sandstone. The sandstones are different in appearence as the ones at 100' - 1250'. The sudden increase in lithics clearly reveals a change in lithology. Towards the end of the sequence the sandstones became more loose. 10 to 55% grey and brown, micaceous, slightly calcareous siltstone. Some yellowish fragments have been noted, which could be of organic origin. Traces of: pyrite, mica and gypsum.

1580' - 2180'	: 20 to 100% grey to brown, angular to subrounded, moderately sorted, very fine to medium grained, slightly calcareous, lithic sandstone. 10 to 80% brown, micaceous, slightly calcareous siltstone. Few fragments of: gypsum and anhydrite. Trace of pyrite. 1780' - 1830' no samples. 1870' - 1900' no samples. 2060' - 2070' no samples.
2180' - 2290'	: 10 to 20% grey to brown, angular to subrounded, moderately sorted, very fine to medium grained, slightly calcareous, lithic sandstone. 10% light to medium grey, angular, well sorted, very fine grained, calcareous sandstone. 70 to 80% dark to light grey, micaceous, slightly calcareous siltstone.
2290' - 2570'	: 10 to 40% light to medium grey, angular, well sorted, very fine grained, slightly calcareous sandstone. 60 to 100% dark to light grey, micaceous, slightly calcareous siltstone.
2570' - 2830'	: 5 to 35% pink, angular to rounded, moderately sorted, fine to coarse, quartz grains; few pebbles up to 2mm across. 10 to 30% light to medium grey, angular, well sorted, very fine grained, slightly calcareous lithic sandstone. 60 to 85% grey and brown, micaceous, calcareous siltstone. Traces of yellowish, calcareous fragments.
2830' - 3000'	: 100% grey and brown, micaceous, calcareous siltstone.
3000' - 3090'	: 20 to 90% clear, loose, angular, poorly sorted, very fine to coarse, quartz grains. 10 to 80% grey and brown, micaceous, calcareous siltstone.
3090' - 3760'	: 100% dark grey and brown, micaceous, calcareous, siltstone. At 3370' - 3400' 10% pink, loose, angular, poorly sorted, very fine to medium, quartz grains. Some fragments of: gypsum and calcite. Trace of pyrite.
3760' - 4080'	: 30 to 95% clear and pink, loose, angular, poorly sorted, very fine to medium quartz grains; traces of siliceous fragments. 5 to 70% dark blackish grey, compact, slightly micaceous, slightly calcareous siltstone.
4080' - 4230'	: 100% dark blackish grey, compact, slightly micaceous, slightly calcareous siltstone.
4230' - 4320'	: 60 to 100% clear and pink, loose, angular, well sorted, very fine to fine quartz grains. Traces of siltstone.

4320' - 4380'	: 100% white to grey, cryptocrystalline dolomite.
4380' - 4620'	: 20 to 55% white to grey, cryptocrystalline dolomite. 5 to 60% clear and pink, loose, angular, well sorted, very fine to fine quartz grains. 5 to 60% dark grey, slightly calcareous siltstone.
4620' - 4690'	: 10 to 40% reddish, angular, poorly sorted, very fine to fine grained, slightly calcareous sandstone. Few pinkish quartz pebbles. 40 to 70% white, grey and pinkish, cryptocrystalline dolomite. 20% dark grey, slightly calcareous siltstone.
4690' - 4810'	: 70 to 80% red, grey, yellow and white, cryptocrystalline dolomite. Some fragments of: anhydrite, gypsum and chert. 20 to 30% dark grey, siltstone.
4810' - 5240'	: 100% red, grey, yellow and white, cryptocrystalline dolomite. Some fragments of: anhydrite and chert.
5240' - 5450'	: 40 to 90% cryptocrystalline dolomite as above. 10 to 60% salt.

APPENDIX 3

RESULTS OF PHOSPHATE TESTS FROM ERLDUNDA NO. 1 WELL

by

S. Ozimic

Molybdate tests carried out on sediments from Erldunda No. 1 well, indicate that significant amounts of P_2O_5 may be present.

As result of these tests, further work should be carried out to determine the nature and the percentage of the phosphate. It is recommended that X-Ray analysis be used to determine the type of phosphate mineral present and chemical analysis to assess quantitatively the percentage of phosphate.

Interval 20' - 1240': in this interval tests were made at average 120' and no indication of phosphate was recorded.

The lithology comprises mainly loose sand, sandstone and a minor amount of siltstone and shale.

Interval 1240' - 4300': Winnall Beds and Inindia Beds, occur in this interval. Tests were made every 30' and the results have shown that phosphate is present throughout the interval.

In comparison to a reference sample, which contains approximately 30% of phosphate, the samples from Erldunda No. 1 may contain up to 10% of phosphate.

The lithology comprises very fine grained sandstone, siltstone, shale and a minor amount of dolomite.

Interval 4300' - 4600': this interval consisting of sandstone, siltstone and dolomite, yielded positive results; however they may be due to cavings.

Interval 4600' - 5000': this interval comprising mainly dolomite and minor shale has not nown any trace of phosphate.

PHOSPHATE TEST PROCEDURES

Method for colour test on samples from Erldunda No. 1 well

1. .... The samples of cuttings and cores were crushed into very fine silt size.

2. .... An amount of approximately 0.25 grm was placed in a test tube.

3. .... The "Ammonium Molybdate" $(NH_4)_6 Mo_7O_{24}2H_2O$ in acid solution was then poured over the crushed sample.

4. .... The readings were taken immediately after the reaction was settled.

The result: good, medium, low and trace were determined by the shade of yellow colour.
The colour of the sample was then compared with a reference sample which contains approximately 30% of phosphate, according to chemical analysis and which produced a very dark yellow colour.

However, it is impossible to say how much in percentage the samples of Erldunda No. 1 well contain in phosphate - this would have to be determined by chemical analysis.

ERLDUNDA No. 1

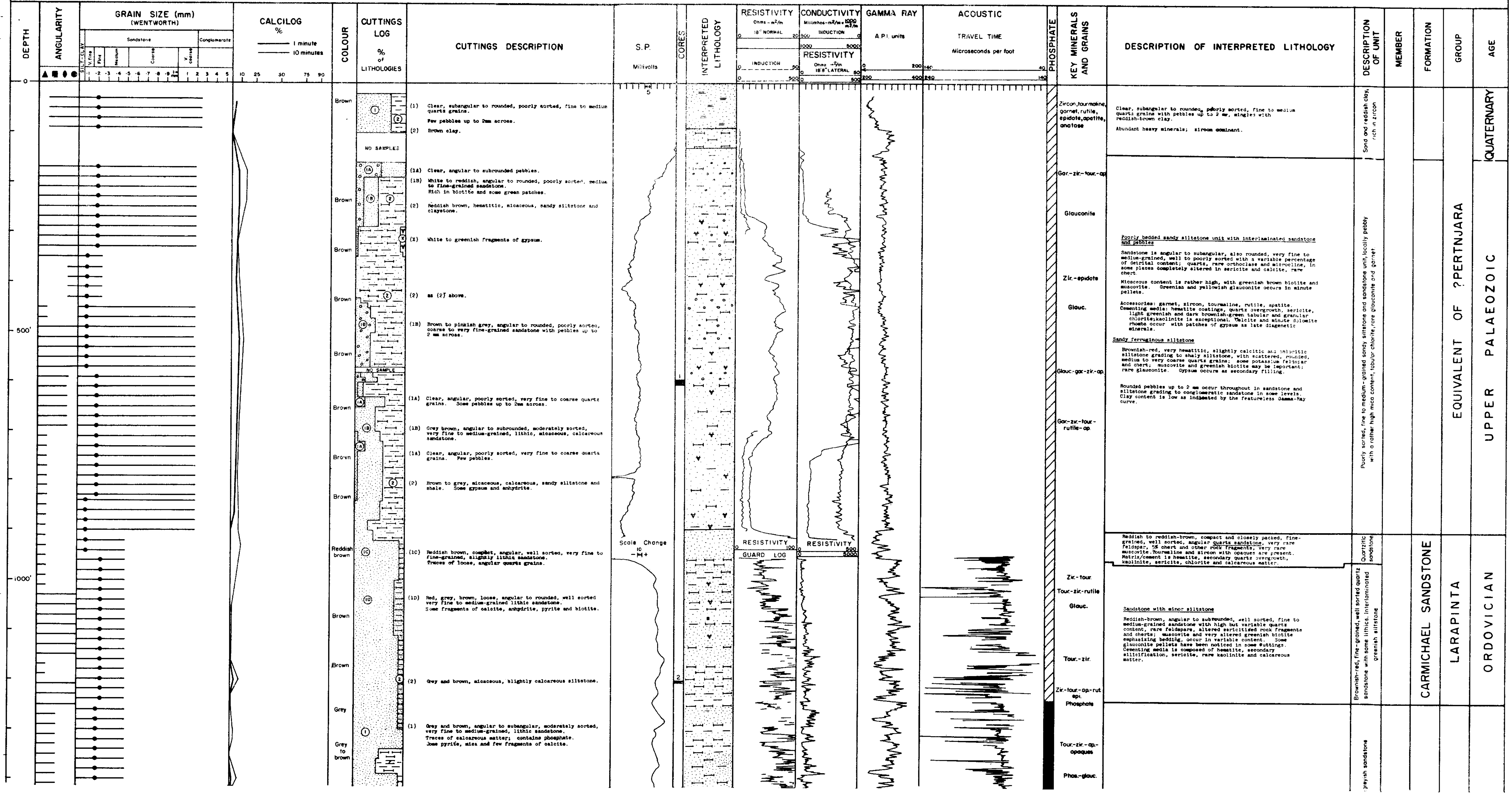
Lat. 25° 18' 36" S
Long. 133° 11' 48" E
Elevation : GROUND 1,330' A.S.L.
K.B. 1,343' A.S.L.
B.M.R. WELL INDEX No. 428

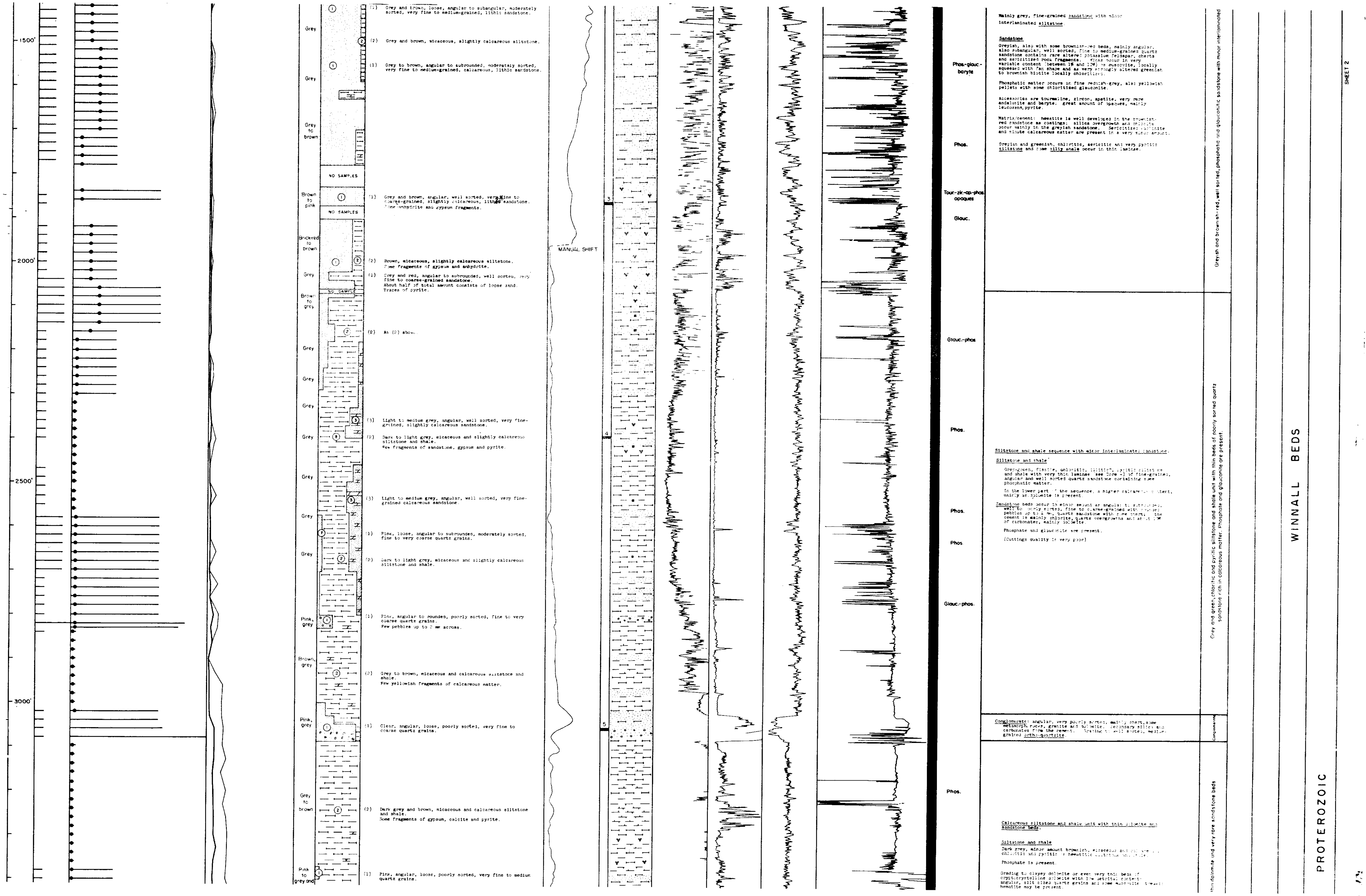
PLATE I (SHEET 1)
EXOIL PTY. LTD.
AMADEUS BASIN
NORTHERN TERRITORY

SCALE
FEET 100 50 0 100 200 300 FEET

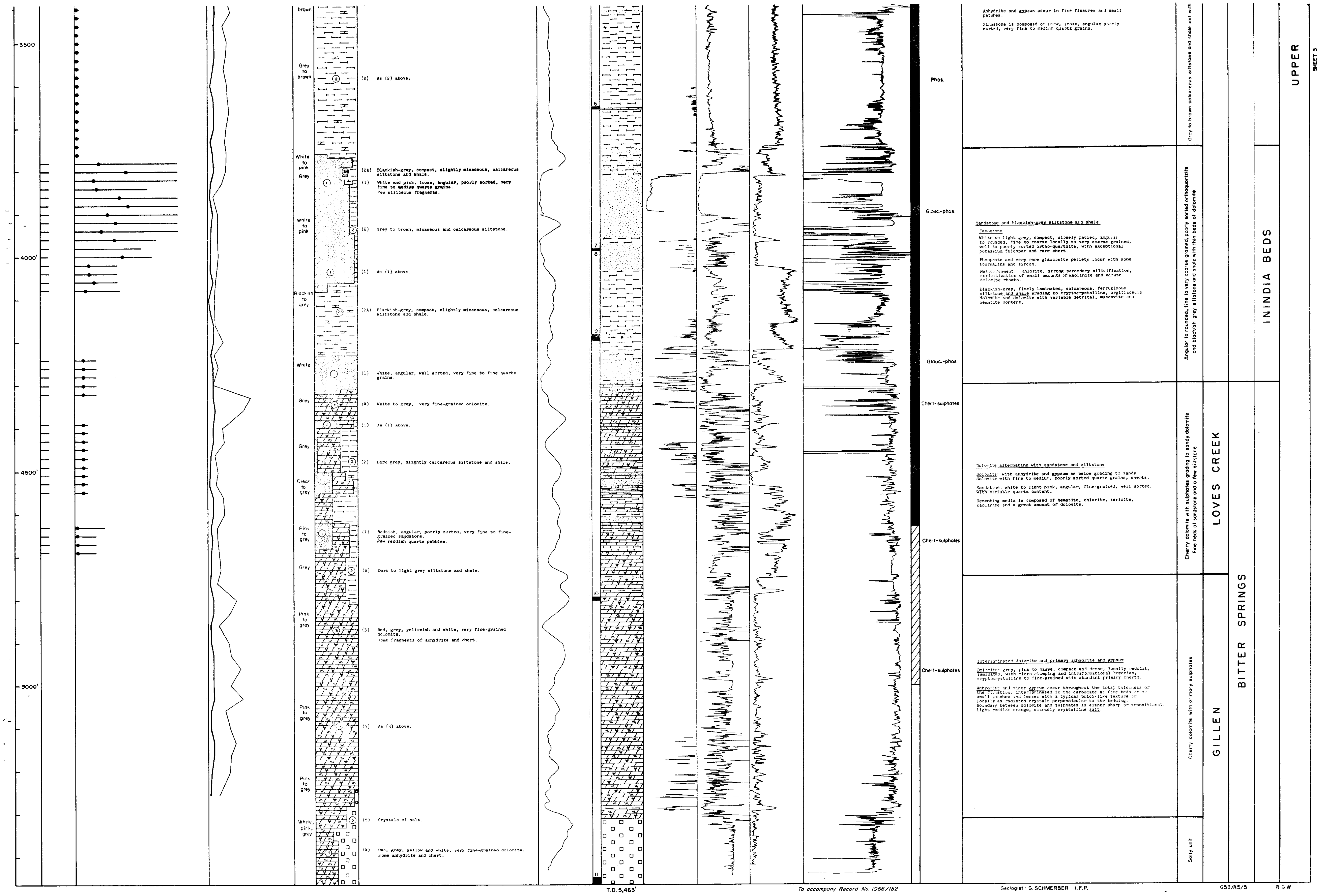
Reference

- Loose sand and pebbles
- Sandstone
- Calcareous sandstone
- Sandy siltstone
- Siltstone and shale
- Calcareous siltstone
- Dolomite
- Salt
- Anhydrite and gypsum
- Chert
- Pyrite





1500'
2000'
2500'
3000'
Grey
(1) Grey and brown, loose, angular to subangular, moderately sorted, very fine to medium-grained, lithic sandstone.
(2) Grey and brown, micaceous, slightly calcareous siltstone.
Grey
(1) Grey to brown, angular to subrounded, moderately sorted, very fine to medium-grained, calcareous, lithic sandstone.
Grey to brown
NO SAMPLES
Brown to pink
(1) Grey and brown, angular, well sorted, very fine to coarse-grained, slightly calcareous, lithic sandstone. Some anhydrite and gypsum fragments.
NO SAMPLES
Brick-red to brown
(2) Brown, micaceous, slightly calcareous siltstone. Some fragments of gypsum and anhydrite.
Grey
(1) Grey and red, angular to subrounded, well sorted, very fine to coarse-grained sandstone. About half of total amount consists of loose sand. Traces of pyrite.
NO SAMPLE
Brown to grey
(2) As (2) above.
Grey
Grey
Grey
(3) Light to medium grey, angular, well sorted, very fine-grained, slightly calcareous sandstone.
Grey
(2) Dark to light grey, micaceous and slightly calcareous siltstone and shale. Few fragments of sandstone, gypsum and pyrite.
Grey
(3) Light to medium grey, angular, well sorted, very fine-grained calcareous sandstone.
Grey
(1) Pink, loose, angular to subrounded, moderately sorted, fine to very coarse quartz grains.
Grey
(2) Dark to light grey, micaceous and slightly calcareous siltstone and shale.
Pink, grey
(1) Pink, angular to rounded, poorly sorted, fine to very coarse quartz grains. Few pebbles up to 2 mm across.
Brown, grey
(2) Grey to brown, micaceous and calcareous siltstone and shale. Few yellowish fragments of calcareous matter.
Pink, grey
(1) Clear, angular, loose, poorly sorted, very fine to coarse quartz grains.
Grey to brown
(2) Dark grey and brown, micaceous and calcareous siltstone and shale. Some fragments of gypsum, calcite and pyrite.
Pink to grey and
(1) Pink, angular, loose, poorly sorted, very fine to medium quartz grains.
MANUAL SHIFT
3
4
5
Phos.-glauc.-baryte
Phos.
Tour.-zir.-op.-phos. opaques
Glauc.
Glauc.-phos.
Phos.
Phos.
Phos.
Glauc.-phos.
Phos.
Mainly grey, fine-grained sandstone with minor interlaminated siltstone.
Sandstone
Greyish, also with some brownish-red beds, mainly angular, also subangular, well sorted, fine to medium-grained quartz sandstone contains rare altered potassium feldspar, cherts and sericitized rock fragments. Micas occur in very variable content (between 1% and 10%) as muscovite, locally squeezed with fan shape and as very strongly altered greenish to brownish biotite locally chloritized.
Phosphatic matter occurs in fine reddish-grey, also yellowish pellets with some chloritized glauconite.
Accessories are tourmaline, zircon, apatite, very rare andalusite and baryte; great amount of opaques, mainly leucoxene, pyrite.
Matrix/cement: hematite is well developed in the brownish-red sandstone as coatings; silica overgrowth and chlorite occur mainly in the greyish sandstone. Sericitized kaolinite and minute calcareous matter are present in a very minor amount.
Greyish and greenish, chloritic, sericitic and very pyritic siltstone and some silty shale occur in thin laminae.
Greyish and brownish-red, well sorted, phosphatic and glauconitic sandstone with minor interlaminated
Siltstone and shale sequence with minor interlaminated sandstone.
Siltstone and shale
Grey-green, fissile, chloritic, illitic?, pyritic siltstone and shale with very thin laminae (see Core 4) of fine-grained, angular and well sorted quartz sandstone containing some phosphatic matter.
In the lower part of the sequence, a higher calcareous content, mainly as dolomite is present.
Sandstone beds occur in minor amount as angular to subrounded, well to poorly sorted, fine to coarse-grained with rounded pebbles up to 2 mm, quartz sandstone with some chert; the cement is mainly chlorite, quartz overgrowths and about 10% of carbonates, mainly dolomite.
Phosphate and glauconite are present.
(Cuttings quality is very poor)
Grey and green, chloritic and pyritic siltstone and shale unit with thin beds of poorly sorted quartz sandstone rich in calcareous matter. Phosphate and glauconite are present
Conglomerate: angular, very poorly sorted, mainly chert, some metamorph. rocks, granite and dolomite. Secondary silica and carbonates form the cement. Grading to well sorted, medium-grained ortho-quartzite.
Conglomerate
Calcareous siltstone and shale unit with thin dolomite and sandstone beds.
Siltstone and shale
Dark grey, minor amount brownish, micaceous and calcareous, chloritic and pyritic or hematitic siltstone and shale.
Phosphate is present.
Grading to clayey dolomite or even very thin beds of cryptocrystalline dolomite with low detrital content: angular, silt sized quartz grains and some muscovite. Traces of hematite may be present.
thin dolomite and very rare sandstone beds
WINNALL BEDS
PROTEROZOIC
SHEET 2



3500
4000'
4500'
5000'
brown
Grey to brown
(2) As (2) above.
White to pink
Grey
(2A) Blackish-grey, compact, slightly micaceous, calcareous siltstone and shale.
(1) White and pink, loose, angular, poorly sorted, very fine to medium quartz grains. Few siliceous fragments.
White to pink
(2) Grey to brown, micaceous and calcareous siltstone.
(1) As (1) above.
Blackish to grey
(2A) Blackish-grey, compact, slightly micaceous, calcareous siltstone and shale.
White
(1) White, angular, well sorted, very fine to fine quartz grains.
Grey
(4) White to grey, very fine-grained dolomite.
(1) As (1) above.
Grey
(2) Dark grey, slightly calcareous siltstone and shale.
Clear to grey
Pink to grey
(1) Reddish, angular, poorly sorted, very fine to fine-grained sandstone. Few reddish quartz pebbles.
Grey
(2) Dark to light grey siltstone and shale.
Pink to grey
(3) Red, grey, yellowish and white, very fine-grained dolomite. Some fragments of anhydrite and chert.
Pink to grey
(4) As (3) above.
Pink to grey
White, pink, grey
(5) Crystals of salt.
(4) Red, grey, yellow and white, very fine-grained dolomite. Some anhydrite and chert.
6
7
8
9
10
11
T.D. 5,463'
Phos.
Glouc-phos.
Glouc.-phos.
Chert-sulphates
Chert-sulphates
Chert-sulphates
Anhydrite and gypsum occur in fine fissures and small patches.
Sandstone is composed of pink, loose, angular poorly sorted, very fine to medium quartz grains.
Sandstone and blackish-grey siltstone and shale
Sandstone
White to light grey, compact, closely packed, angular to rounded, fine to coarse locally to very coarse-grained, well to poorly sorted ortho-quartzite, with exceptional potassium feldspar and rare chert.
Phosphate and very rare glauconite pellets occur with some tourmaline and zircon.
Matrix/cement: chlorite, strong secondary silicification, sericitization of small amounts of kaolinite and minute dolomite rhombs.
Blackish-grey, finely laminated, calcareous, ferruginous siltstone and shale grading to cryptocrystalline, argillaceous dolomite and dolomite with variable detrital, muscovite and hematite content.
Dolomite alternating with sandstone and siltstone
Dolomite: with anhydrite and gypsum as below grading to sandy dolomite with fine to medium, poorly sorted quartz grains, cherts.
Sandstone: white to light pink, angular, fine-grained, well sorted, with variable quartz content.
Cementing media is composed of hematite, chlorite, sericite, kaolinite and a great amount of dolomite.
Interlaminated dolomite and primary anhydrite and gypsum
Dolomite: grey, pink to mauve, compact and dense, locally reddish, laminated, with micro slumping and intraformational breccias, cryptocrystalline to fine-grained with abundant primary cherts.
Anhydrite and minor gypsum occur throughout the total thickness of the formation, interlaminated in the carbonate as fine beds or as small patches and lenses with a typical brick-like texture or locally as radiated crystals perpendicular to the bedding.
Boundary between dolomite and sulphates is either sharp or transitional.
Light reddish-orange, coarsely crystalline salt.
Grey to brown calcareous siltstone and shale unit with
Angular to rounded, fine to very coarse grained, poorly sorted orthoquartzite and blackish grey siltstone and shale with thin beds of dolomite.
Cherty dolomite with sulphates grading to sandy dolomite Fine beds of sandstone and a few siltstone.
Cherty dolomite with primary sulphates
Salty unit
LOVES CREEK
GILLEN
BITTER SPRINGS
ININDIA BEDS
UPPER
SHEET 3
To accompany Record No. 1966/182
Geologist: G. SCHMERBER I.F.P.
G53/A5/5
R G W