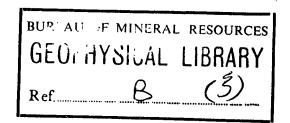
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COMMONWEALTH OF AUSTRALIA

## DEPARTMENT OF NATIONAL DEVELOPMENT

## BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

RECORD No. 1964/178



A PETROLOGICAL STUDY
OF THE SEDIMENTS
FROM OIL DEVELOPMENT N. L.
MT SALT No 1 WELL, OTWAY BASIN,
SOUTH AUSTRALIA.



by

J. DELLENBACH

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A Petrological Study of the Sediments from Oil Development N. L. Mount Salt Well No.1, Otway Basin, South Australia.

bу

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#### ABSTRACT

This study is a re-examination of the materials obtained from the O.D.N.L.'s Mount Salt Well No. 1 (Mount Schank Farm-out, O.E.L. 22, South Australia). The aim is to determine the nature of the sediments encountered over the total depth of 10,044 feet and possible relations with previously, or currently studied wells.

The various informal units, defined from other wells in the Otway Basin have been encountered down to unit Gd (Paaratte Formation equivalent).

Below the unit Gd, several interpretations have been given in a previous study of Mount Salt Well No. 1 (O.D.N.L., 1963), each of them attempting to recognise formal units described in the eastern sub-basin of the Otway Basin (or Portland Sunklands). Such an attempt is not valid and the observational data must fit a conceptual framework or model.

As a result of the impossibility of differentiation between the units Gf and Gh (equivalent of the Belfast Mudstone and Flaxman's Beds respectively) and owing to the fact that the sediments of the unit M (equivalent to the Otway Group) might be of a similar nature as suggested by a previous study (Dellenbach and Hawkins, 1964) the possibility that the unit M has been reached at the bottom of the well must be considered. This implies that Unit J (Waarre equivalent) is absent. However, absence of any indication of an unconformity — which appears from other wells to have a regional character — and of microplankton zonation (Evans, in O.D.N.L., 1963) do not favour this conception.

The petrological study shows that the sediments encountered from below unit Gd belong to a greywack (Pettijohn, 1957) suite and genetically related chloritic shales.

It is not possible at this stage to make any inference about the source area for the sediments.

#### INTRODUCTION

Major aspects of the petrology of the sediments from the  $0.D.\bar{N}.L.$  Mount Salt Well No. 1 are described in this study. Some data of this well are listed below:-

OIL DEVELOPMENT N.L. Mount Salt Well No. 1

Location: Latitude 37° 57' 25"S. Longitude 140° 37' 43"E. 1:250,000 Sheet: Penola, J54/6.

Elevation: 186 feet K.B., 170 feet G.L. (above mean low water Port Adelaide).

Total Depth: 10,044 feet (Driller) below K.B. Subsidized from 980 feet to total depth 10,044 feet. Abandoned 23rd September, 1962.

The petrological analysis of samples from Mount Salt Well No.1 forms part of the study of selected wells in connection with the review of the Otway Basin currently being undertaken by the Bureau of Mineral Resources.

Samples of cuttings were examined at 10 feet intervals, except from 0 to 50 feet and 130 to 610 feet where no cuttings were caught. Owing to the poor degree of consolidation of most of the sandstones and siltstones intersected, the quality of cuttings from these sediments can be considered as bad. The true nature of the sediments can best be recognized by examination (including thin section examination) of the cores, and chips of indurated siltstones below 7,000 feet were useful for detailed study. No fossils have been encountered among the cuttings. Cnly a few arenaceous foraminifera were recognized in thin sections. The completion report (0.D.N.L., 1963) was the basic reference, especially the attached composite well log.

However the lithologic description in the O.D.N.L. report did not give an account of the greywacke nature of most of the sandstones below 6,520 feet, neither did it stress the predominance of chlorite or chloritic matter - genetically associated with the greywackes - over glauconite.

#### Unit Gg

Unit Gg is represented in the Mount Salt No. 1 well between 6520 and 10,044 feet. It is thought to be, at least in part, equivalent to two other units Gh (Flaxmans Beds) and Gf (Belfast Mudstone) which occur in the eastern part of the Otway Basin.

Upper limit. The upper limit of unit Gg is placed at 6520 feet on lithological evidence. Ludbrook (in O.D.N.L., 1963) put the upper limit of the "Belfast Mudstone" at 7460 feet, at the top of core 26 (7460-7475 feet). She notes a conspicuous change in fauna with Marssonella appearing in cuttings at 7465 feet, and Haplophragmoides sp. 11 at 7477 feet. However, fossils were absent between core 22 (6096-6114 feet) and core 26, so that the proposed lithological break at 6520 feet is not invalidated.

As far as microfloral evidence is concerned, core 23 (6404 feet) indicates "Paaratte Formation" age; core 26 "contained the upper Cretaceous Odontochitina porifera Cookson and O. cribropoda Deflandre and Cookson that are known with certainty to occur below the Belfast Mudstone of Port Campbell and Flaxmans areas" (Evans, in O.D.N.L., 1963). This could indicate that core 26 is part of the Belfast Mudstone equivalent.

Thus the upper limit of unit Gg as described in this study is not in disagreement with fossil evidence.

Lower limit. Several hypotheses have been put forward in the completion report (O.D.N.L., 1963), with regard to the extent of the "Belfast Mudstone". We will disregard the first hypothesis - that these are Paratte equivalent sediments to total depth - because the sediments intersected from 6520 feet to total depth do not bear any appreciable resemblance to the sediments of the unit Gd (equivalent to Paaratte Formation) from 4230 feet to 6520 feet.

Another hypothesis - that it is "Belfast Mudstone" at the bottom of the well - is from a petrological point of view, the more acceptable. There is an undeniable unity between the sediments of the unit, and no major break occurs.

Evans (op.cit.) states that there seems to be little distinction between Albian and (?) Cenomanian spore assemblages in the Otway Basin and that the assemblage in core 34 (10,037 feet) could be lower Cretaceous or basal upper Cretaceous. The few microplankton found in core 34 were of no positive help in correlation. He concluded that Mount Salt No. 1 finished in strata which correlate with either the top of the "Waarre Formation" or the "Flaxmans Beds" of Flaxman No. 1 well.

Because Units Ch (Flaxmans Beds) and Gf (Belfast Mudstone) could not be differentiated, as such, and an equivalent of the upper part of the Waarre Formation might also be present, it was decided to regard all of the sediments from 6520 to 10,044 feet as part of the one unit, Gg.

There is however, a conspicuous change in the lithological sequence, clearly reflected by the electric log, and the unit Gg has been sub-divided into two subunits. However, it must be stressed that there is no noticeable change in the rock types.

#### <u>Subunit Gg2</u> (10,044 feet (t.d.) to 7450 feet)

Only two types of rocks are represented: (a) argillaceous siltstones (and shales) and (b) lithic feldspathic sandstones, in order of importance.

#### (a) The argillaceous siltstones (and shales)

The silt-sized sediments occur in zones showing gradation from sandstone to siltstone or as inter-laminations of "shaly siltstone" within the sandstone.

The sample taken as an example is from core 34 at 10,033 feet. Microscopically, the rock is a dark sandy siltstone, silt-sized particles constituting up to 70% of the rock.

Chief constituents of the sand fraction are:

- -angular poorly sorted quartz grains (36%);
- -angular to subangular, poorly sorted lithic grains (25%); among the latter, chloritic elements are dominant, but non-chloritic siliceous rock fragments are also present. The chloritic grains are either fragments of chloritic rock or pure reworked chlorite;
- -angular poorly sorted feldspar grains, mainly acid plagioclase and orthoclase. Feldspars (10 to 15%) are always less abundant than rock fragments.
- opaque minerals: pyrite, iron oxide, and also carbonaceous matter;
- -other minerals: mica (mainly muscovite), rare heavy minerals;
- -the groundmass is a mixture of authigenic chlorite and clay material (kaolinite and possibly illite).

#### (b) The Sandstones

The sample taken as an example is from core 33 at 9861 feet. It is a greenish grey sandstone made of angular medium sized grains showing poor sorting. Its composition is 35% quartz, 5% feldspar (mainly orthoclase and acid plagioclase), 15% lithic fragments (chert, fine-grained siliceous rocks, micrometaquartzite - one third of these fragments being chloritic.) and minor heavy minerals: zircon, tourmaline, epidote.

The matrix, of silt-sized grains in a clayey chloritic cement, is abundant (up to 50%) and contains much pyrite and mica. This rock would therefore merit the name of "lithic greywacke" (Pettijohn, 1957).

There is no great variation in the relative proportion of the constituents in the sand fraction. Some have no detrital matrix; their lithic fragments content varies down to 5-7% (with few rounded chlorite elements among them) and feldspar to a few percent. Pyrite is abundant and often fills in pits of the detrital grains. The cement is well developed and dolomitic (recrystallized), or dolomitic and sideritic, with patches of chloritic matter and kaolinite. These sandstones do not belong strictly to the greywacke group and are best termed lithic sandstones. The porosity is medium to good and in some horizons may be 20 to 25% (e.g. core 30 at 8923 feet).

#### Lithology and E-log characteristics

Very characteristic for this subunit is the pattern of strata shown by the electric-log. The normal resistivity curve shows a well marked cyclic pattern: high resistivity corresponding to tight argillac ous siltstone and shale, decreasing progressively upwards to sandstone which shows low resistivity values due to salty formation water. The upward passage from the sandstone to the next argillaceous siltstone or shale is marked by a sudden high resistivity deflection in the log. Each cycle is composed on the average of 50 to 100 feet of sandstone followed by 30 to 50 feet of argillaceous siltstone and shale. Towards the bottom of the well the cycles are thicker and there is an overall increase of shale layers which slightly alters the pattern of variation. The cycles are thinner above 8270 feet, each cycle only about 50 feet thick.

#### Sedimentary structures and environmental criteria.

The grey sandstones from core No. 33 (9848 to 9863 feet) are interlaminated with dark argillaceous siltstone, or shale. Convolute laminations and load structures occur together with cross-bedding and scour-and-fill structures. Burrowing and churning is very extensive. Core 29 (8422 to 8432 feet) is dominantly composed of dark argillaceous, micaceous siltstone and shale with sandy interbeds and lenses, and exhibits convolutions, small scale cross-bedding, scur-and-fill, and numerous burrows.

The fine-grained sandstone from core 26 (7460 to 7475 feet) shows extensive churning and burrowing, and frequent cross-bedding. All these features are thought to indicate shallow water marine conditions. It would be necessary to envisage subsidence to explain such a thickness of shallow water sediments.

It is apparent that terrigenous material, mainly from a metamorphic origin, has poured into the subsiding basin, as an assemblage of greywacke composition with associated siltstones and shales. The high rate of accumulation has favoured rapid burial under reducing conditions beneath shallow water.

Although the evidence gained from the cores and cuttings does not facilitate complete description and definition of the cycles observed in the E-log it is probable that the coarser sands contain more abundant cross-bedding and scouring, whereas the finer grained sediments show features such as: fine laminations, burrows, pene- or post-depositional convolutions, and load effects.

The sandstones were probably deposited under intermittently turbulent conditions, and the siltstones and shales correspond to deposition under quieter conditions.

#### Sub-unit $Gg_1$ (7450 feet to 6520 feet)

As in the sub-unit  $\text{Gg}_2$  the rocks of the sub-unit  $\text{Gg}_1$  may be subdivided into sandstones and siltstones.

#### Sandstones:

The average quartz content of the angular to subrounded very coarse-grained, poorly sorted greenish-grey sandstones, is 25%. Feldspar (about 7%) is always less abundant than lithic fragments (5 to 10%); chloritic rock fragments and chlorite (8-15%) are also present. These sandstones belong to the lithic greywacke suite and in some cases where the matrix is scanty, (core 24 at 6672 feet) to the lithic sandstone group. In these sandstones the grains are coated with chlorite of depositional origin, and this, together with spots of globular siderite represent the only cementing media. The porosity of these sandstones is high (about 30%) and the permeability good, but their distribution is thought to be erratic.

#### Siltstones and shales

As in the subunit  $Gg_2$  the sandy siltstones and shales are dark interbeds, laminations or lenses within the sandstones and there is no change in the general petrological character.

#### Lithology and E-log characteristics

Unlike the lower limit, the sub-unit  $Gg_1$  does not show well-marked cyclical lithologic sequence. A noticeable decrease in the frequency and thickness of the argillaceous siltstone intervals is shown by the electric logs, the cuttings percentage log, and by the grain size percentage log.

In short, the lithology becomes more sandy, and coarser grained towards the top of the subunit.

#### Sedimentary structures and environmental criteria

Core 25 at 6987 feet shows slightly cross-bedded sandstone with dark silty laminations and abundant vertical burrows. This and the evidence obtained from other cores within this subunit suggest that there is no major difference in environmental conditions as compared with the lower subunit. Lack of marked cycles, in contrast with the lower subunit could indicate a change in the rate of subsidence or supply in the area.

The decreasing frequency of argillaceous siltstone and shale intercalations points towards modifications in the lithological character, which could herald the change from "Belfast Mudstone" type lithology, to the "Paaratte Formation" type lithology, as in the eastern part of the Otway Basin.

#### Unit Gd

The unit Gd is represented in the Mount Salt Well No. 1 between 6520 feet and 4230 feet.

Upper Limit The placing of the upper limit at 4230 feet does not correspond with any of the previous interpretations. In other interpretations it has been assumed that the upper limit of the Paaratte Formation is at the base of the well-established Bahgallah Formation (Unit Dd). This does not take account of the existence of the well-marked intermediate unit Gb.

Lower Limit In one interpretation the lower limit of the "Paaratte Formation equivalent" has been placed at 5900 feet without statement of evidence (O.D.N.L., 1963). Neither the electric log nor petrological study show any appreciable variation which would support this view. In some wells (e.g. Flaxmans No. 1 Well) the lower limit of the Paaratte Formation is in the Deflandrea cretacea zone, whereas in the Port Campbell No. 1 well, the same limit is possibly higher than the D. cretacea zone (Evans, pers. comm.). This tends to show that if all factors influencing palynological criteria are assumed constant, the boundaries of the lithological units are diachronous.

## Subunit Gd<sub>2</sub> (6520 feet to 5230 feet)

The subunit Gd<sub>2</sub> can be described as a sand and siltstone and shale interval, with the prevalence of carbonate cement increasing from bottom to top.

#### Interval 6520 to 5710 feet

This interval can be regarded as a transition zone from detrital sediments with a matrix similar to that described in sandstones from unit  $Gg_4$  towards sandstones with clay and carbonate cement.

The sandstones of this interval belong to two groups.

#### (a) Sandstones with prominent matrix:

These greenish grey sandstones do not differ noticeably from similar sandstones of the unit Gg. Lithic (and among them chloritic) elements always exceed feldspars in abundance. The matrix (40% or more) is a dark pyritic and chloritic clayey siltstone containing minor spots of siderite cement which seem to increase towards the top.

## (b) Sandstone with scanty matrix:

These light greenish grey sandstones are composed of angular to subrounded medium to very coarse-grained quartz, some feldspar, and chloritic elements together with chert and micrometaquartzite (generally in greater amount than the feldspar). The chlorite grains are generally squeezed between quartz and feldspar grains. Cementing media are siderite (sometimes globular), dolomite and kaolinite with pyrite and some organic matter (minor cod & plant fragments). In some of the sandstones examined, there is a coating of chloritic matter of early diagenetic origin, around the detrital grains.

The porosity of these sandstones is quite high and core 22 at 6111 feet has about 20% porosity. (0.D.N.L., 1963).

The siltstones and shales of this interval are similar throughout the subunit and are described in the next interval.

#### Interval 5710-5230 feet

The sandstones intersected over the interval 5710-5230 feet are light grey, angular to subrounded coarse grained and poorly sorted feldspathic sandstones with chert (chalcedony), metaquartzite and chloritic rock fragments. Lenses or patches of siderite and dolomite cement occur throughout the interval. The low frequency of the occurrence of sandstones with prominent silty and chloritic matrix is the character distinguishing this interval from the previous interval 6520-5230 feet.

#### The siltstones and Shales

The siltstones and shales of subunit Gd<sub>2</sub> are not noticeably different from those of unit Gg. Within the subunit, the cuttings — and the electric log — show the overall amount of siltstone and shale, and the frequency and thickness of silty and shaly layers to be less than in the unit Gg. The occurrence of siltstones with a yellowish siderite cement is well marked over the interval 6360 to 5250 feet, and it is likely that these carbonate cemented siltstones represent thin layers or lenses which correspond to high resistivity peaks shown on the "short normal" log.

#### Lithology and E-log characteristics

The overall picture given by the electric log and cutting composition shows a predominance of coarse sandstones, with recurrent thin layers or lenses of carbonate cemented, fine-grained sandstones and siltstones.

#### Sedimentary structures and environmental criteria

In the core 23 (6400 feet) the dark silty argillaceous interlaminations emphasize small scale convolutions, slumps and load features together with recurrent small scale scouring. Burrows are also present. Strongly marked cross-bedding occurs in the greenish grey sandstone of core 22, with angles of up to 30° to horizontal. This is also evident from the dipmeter survey, which shows dips ranging up to 30° over the interval of the subunit (the overall body of sediments being considered to be flat-lying).

The minor amount of fine grained sediments intersected in this core shows only vague convolutions and churning at 6111 feet.

Core 21 provides (at 5792 feet) good examples of cross-bedding (nearly 30° dip) and scoured, convoluted silty interlaminations with current ripples, some of which are streaked out. At 5784 feet churning and burrowing affects thin laminations of dark clayey shales which also show small scale cross-bedding and convolutions.

Cross-bedding is well marked in core No. 20 (5485-5503 feet). These structures together with the predominance of sandstone in subunit  $Gd_2$  tend to indicate deposition under more agitated water (and generally stronger open marine conditions) than existed during deposition of the lower unit Gg.

#### Subunit Gd<sub>1</sub> (5230 feet to 4230 feet)

The sediments over this interval are argillaceous siltstones and sandstones. The nature of the cementing media, chiefly kaolinite and patchily developed carbonate, is an important feature of this subunit.

#### Sandstones

The light greenish-grey sandstones are mainly coarse to very coarse-grained. The quartz grains are angular to rounded and generally not well sorted. Chert and metaquartzite grains are common (up to 10%); radiolarite is present at 5050 feet (cutting). Chloritic elements represent as much as 10% of the total, either in the form of chloritic rock fragments, commonly sideritized and kaolinitized, or as fairly pure, rounded or squeezed chlorite elements.\* Feldspar (potash feldspar and acid plagioclase, sometimes well rounded) never exceeds 10%. Mica is abundant in the "dirtiest" sandstones (mainly muscovite). Accessory minerals are: tourmaline, zircon, chloritoid. Their maximum abundance is less than 3% in the fine-grained clean sandstone intercalations (e.g. 4784 feet). Pressure solution features are common and grain growth and quartz euhedra occur in the more porous sandstones.

The cementing media are either pure siderite or silty pyritic and sideritic cement. In the core 16 at 4943 feet, a chlorite coating or pellicule of possible post-depositional origin partly obliterates the pores of the sandstone.

It is difficult to allocate a specific name to these sandstones which range from the lithic sandstone (Pettijohn, 1957) end-member to sub-arkose (Pettijohn, 1957) end-member, Ubiquitous chloritic material gives a special character to these sediments.

#### Cementing media

Two major types of cementing media are associated with the sandstones of the subunit  $Gd_{\lambda}$ .

The first and most abundant cement type is clay and chlorite (e.g. at 5192 feet), totally or partly filling the intergranular space. The lack of order in crystallization and the relation to grains suggest a common depositional origin for both the clay and the chlorite. The clay mineral belongs to the kaolinite group. Patches of recrystallized kaolinite are frequent and pyrite and marcasite are common either as globular aggregates or as well shaped crystals (recrystallized) or also incrusting quartz grains.

In some cases (e.g. 5188 feet) finely crystalline siderite and clay forms the cementing medium. Spots of recrystallized kaolinite appear to have been formed during later diagenesis.

The porosity of the sandstones with these cementing media, although very variable, can be regarded as low, and no permeability can be expected.

\*These chlorite elements are of pale brownish green to bright medium green colour. Dark specimens are slightly pleochroic. The index of refraction is near 1.6, birefringence is very low or nil; sometimes the aggregates are cryptocrystalline (greenalite?) but generally they are lamellar (never as ooliths). Well crystallized grains show very low 2V angle or pseudouniaxial negative figure, anormal biaxial figure in less well crystallized grains.

The second type of cementing medium in subunit Gd, is a carbonate cement. At 5041 feet fine- grained siderite crystals and recrystallized siderite rhombs form a discontinuous cement in a poorly sorted coarse quartz sandstone. The quartz grains and the feldspars (about 7%) are strongly corroded. Internal corrosion is frequent in the chlorite fragments (5%), and in zones of chloritic cement siderite rhombs have formed. Although recrystallized, the cement is considered to be of depositional origin. This type of cement appears also in numerous cuttings intervals, and there are all transitions between sandstones with siderite (and in parts dolomite) cement and pure siderite rock. In most cases these rocks show the diagnostic coloration with acid ammonium molybdate due to reaction with dispersed "primary" phosphatic material.

Chloritic elements occur in the more sideritic sandstones and even in the near pure siderite. It is sometimes difficult to differentiate some ferriferous chlorite grains of the greenalite type from glauconite, though glauconite appears to be subordinate to chlorite. Pyritic matter and flaky pyritized plant debris is also common and characteristic of these carbonate cemented sandstones.

The porosity of the sandstones with these cementing media can be as high as 35% with high permeability (up to 2000 md) in core 15 at 4784 feet (appendix 4, in 0.D.N.L., 1963).

#### Siltstones and shales

The siltstones and shales of the subunit Gd, bear some similarities with those of unit Gg. At 5039 feet (core 18) for instance, the dark brownish grey sandy siltstones present a groundmass of clay, silt-sized chloritic elements, or chloritic matter with abundant pyrite and mica (muscovite) flakes. The major difference lies in the presence of finely divided siderite within the groundmass, segregations of clay material or patches of recrystallized clay material (of kaolinitic type) are also characteristic, especially in the more sandy layers.

#### Lithology

The upper limit of this subunit is well marked by a sudden increase, below 4230 feet, in the amount of dark pyritic siltstones or shales. These siltstones and shales form thin layers distributed with no apparent pattern over the interval; however the subunit can be considered as sandy and porous. Recurrent lenses or horizons with yellowish dolomitic-sideritic cement, showing glauconite (or greenalite?) and chlorite elements occur throughout the interval.

#### Sedimentary structures and environmental criteria

Silt and shale laminations or interbeds occur in core 18 and these display the well marked features already observed from lower intervals.

- -churning and burrowing (core 18 at 5039 feet, core 15 at 4790 feet, core 14 at 4534 feet)
- -very thin lamination (fraction of mm), (most cores, particularly core 15 at 4792 feet)
- -low angle cross-bedding and scouring (cores 14,15, and 18)
- -current ripples (core 15 at 4790 feet)
- -"sand nests" (core 15 at 4792 feet)

All these features indicate conditions ranging from calm to slightly turbulent in a shallow water environment.

The overall depositional environment of this subunit is thought to have been similar to that of unit Gg. Restricted quiet water sedimentation was interrupted by the influx of clastics. Stronger marine incursions account for carbonate cemented horizons, and sandstones composed of grains which exhibit better sorting and rounding.

#### Unit Gb

This unit occurring between 4230 feet and 3270 feet is characterized by the presence of coal stringers within coarse to very coarse grained sandstones, which are in turn interbedded with siltstones and shales.

#### Sandstones

The grey quartz sandstones contain subangular to subrounded coarse to very coarse grains of quartz, feldspar (15% orthoclase and microcline) and lithic fragments (grey cherty rock, metaquartzite and schist) are especially abundant - 20% in cores 13 and 12. The more labile elements are often kaolinitized and squeezed. Mica, (biotite, muscovite and sericite), is frequently contorted. Although some chlorite grains occur, the lithic elements are not chloritized. Glauconite is rare and finely crystalline, and pyrite is abundant among the interstitial matrix of silt-sized detritus, Kaolinite at various stages of recrystallization is present. The porosity of most sandstones from core 13 and 12 is high and their permeability good. Other sandstones at 4221 feet (core 13) and 3650 feet (cuttings) are strongly scaled with kaolinite, patchily developed siderite, and pyrite with "organic matter". This substance is a brownish black bituminous coal to which quartz grains adhere. Treatment with solvents do not disclose any appreciable fluorescence under the U.V. lamp.

#### Siltstones and Shales

The brownish grey argillaceous siltstones and shales bear abundant pyrite and flaky coal fragments. Coal fragments (among which is cannel coal) and carbonaceous siltstone occur among the cuttings throughout most of the subunit but more markedly between 3600 and 3900 feet. In this interval there is a noticeable change in grain-size fraction percentage and some fluctuation in the spontaneous potential curve and the micro-log, but not well marked resistivity peaks.

#### Lithology

Very little evidence of the lithological characters of this unit can be gained from the materials available for study. The soft sandstones in the cuttings appear to be entirely decomposed by the action of the drilling bit.

Argillaceous matter of kaolinitic nature is common among the cuttings as white clusters or partly coating isolated quartz grains.

The cores taken in unit Gb are of poorly cemented grey sandstones with brownish grey (sideritic and pyritic) interlaminations.

#### Environmental criteria

The most striking features of this unit are the thin coal horizons and the mineral assemblage in the sandstones.

Both point toward strong terrestrial influence. The accumulation of the lithic feldspathic sandstone marks regressive conditions with development of coal horizons in a swampy deltaic, or lagoonal environment.

#### Unit Dd

The unit Dd intersected from 3270 feet to 3130 feet, is well characterized petrographically as a gritty chamosite colite. This type of rock occurs in core 9 at 3142 to 3151 feet, and more generally in cuttings between 3220 and 3130 feet. From 3220 to 3270 feet the sediments are sandy siltstones with a sideritic-chamositic groundmass.

The brown rock at 3143 feet is made of 60% groundmass of ferriferous chlorite of chamositic nature and 40% ooliths, and coated detrital grains and granules. Among the detrital elements are subangular granules and grains of corroded quartz, metaquartzite, and 5% feldspar (orthoclase, microcline and minor plagioclase). These grains are either coated with chamosite and siderite, or form the nuclei to chamosite ooliths. The ooliths may be single or composite with two or more ooliths in a common envelope (generally siderite). They display concentric layers of ferriferous chlorite (chamosite) of presumably slightly varying composition and at various stages of limonitization and sideritization. Some of these layers of chamosite pass to radial fibres of siderite. Thus the thickness of the individual layer may increase by as much as 20 times. This has caused swelling and deformation of oolith whilst in process of formation. Minor secondary silica occurs between layers of chamosite and also as the last mobilized mineral within pores of the groundmass. The groundmass is of chamositic composition with bothryoidal patches of limonitized material and rhombs of siderite, both of which also affect the coliths.

The clastic content, the coliths and the groundmass are very similar to those of the sediments encountered in the Port Campbell No. 1 well between 3300 and 3380 feet.

In view of this information the unit is considered in both Mount Salt No. 1 and Port Campbell No. 1 wells as equivalent to the Bahgallah Formation (Boutakoff and Sprigg 1953) described by Kenley (1951, 1954). This well-marked horizon apparently has appreciable aerm? extension within the Otway Basin. The depositional environment is considered as being one of agitated water to which iron, evolving from geo- and biochemical processes on a nearby continent, was being added.

#### Unit Db

#### Upper limit

As a result of the non-recovery of cuttings above 600 feet depth, the upper limit of this unit has been taken as ?590 feet, as given in the well completion report (0.D.N.L., 1963).

#### Lower limit

The lower limit of the unit is well marked both in the cuttings percentage log and the electric log at 3130 feet. On the evidence gained by petrological study, unit Db can be divided into two subunits.

### Subunit Db, 3130 feet to 2000 feet

As a whole this subunit is characterized by fairly porous and permeable silty argillaceous sandstones and shales, with carbonate lenses or cement.

#### Interval 3130 to 2870 feet

The generally well-sorted fine and occasionally coarse-grained grey sandstone from 3130 to 2870 feet have an abundant silty argillaceous and pyritic matrix. Close scrutiny of cuttings samples shows that clay content decreased from bottom to top.

#### Interval 2870 to 2490 feet

The angular to subrounded medium to coarse-grained, grey sandstones of this interval are characterized by the abundance of a lenticular development of carbonate cement. Brownish dolomitic sideritic and slightly phosphatic sandstone with glauconite and pyrite appears in the cutting samples. The resistivity log shows corresponding well marked high resistivity pocks. Coro No. 6 at 2504 feet is a representative sample of this type of sediment.

#### Interval 2490 to 2090 feet

Brown argillaceous micaceous siltstones and shales with carbon-aceous matter are the dominant rock types of the interval between 2490 and 2090 feet. Among the sand grains observed in the cuttings are quartz grains, chert and siliceous rocks. The tight, fine-grained massive dolomitic sandstone at 2184 feet contains well-sorted angular to rounded quartz, feldspar and chert grains. Amber occurs at 2189 feet.

#### Lithology and E-log Characteristics

No indication of lithology can be gained from the electric logs or the cutting percentage log. The latter shows two intervals with abundant fine-grained sediments between 3130 and 2930 feet and between 2470 and 2120 feet, to which correspond positive spontaneous potential in the electric log, indicating high clay contents.

#### Sedimentary structures and environmental criteria

The finely laminated silts and shales of core 5 display a number of sedimentary features: low angle cross-bedding and scouring at 2193 feet, disturbed bedding at 2191 feet, convolutions at 2187 feet and 2193 feet, and small scale slumping at 2187 feet. These features reflect a paralic environment of deposition with evidence for possibly stronger marine influence (corresponding with the carbonate cemented sediments and fossiliferous parts) occurring sporadically between 3060 and 2480 feet.

#### Subunit Db<sub>1</sub> 2090 to ?590 feet

The primary differences of this subunit with the subunit Db<sub>2</sub> lie in the increased content of finely divided carbonaceous matter and the variation in grain-size. Represented rock types are sandstones, siltstones and shales.

#### Sandstones

The brown sandstones contain subangular to subrounded coarse to very coarse grained quartz, well-sorted in part, with siliceous rock grains, set in a silty argillaceous matrix. Porosity is high throughout the interval. Minor horizons with granules occur between 1820 and 1810 feet, 1220 and 1170 feet and between 2090 and 2000 feet. Some quartz grains are faceted, indicating secondary growth or solution. Porosity and permeability are recurrently high:

#### Siltstones and shales

The brownish argillaceous micaceous siltstones are rich in pyrite and carbonaceous matter. Details of these sediments, as gained from cutting observations, are very poor due to the fact that the sediments are not cemented, and have disintegrated under the action of the drilling bit to produce a mixture of silt and clay with isolated sand grains.

#### Lithology and E-log characteristics

The electric logs, although depicting the phenomenon of vertical invasion (0.D.N.L., 1963, appendix 5), also indicate cyclic alternations of siltstones (and shales) and sandstones. Between 2000 and 1400 feet gritty sandstones (30 feet in thickness) alternate regularly with argillaceous siltstones or shales (50 to 100 feet thick beds).

This type of lithology and the corresponding rocks are very similar to those encountered in the Nelson Bore from 2681 to 992 feet.

#### Sedimentary structures and environmental criteria

Cores taken from this interval, when carefully washed, show finely laminated (as thin as 1/10 mm.), soft argillaceous siltstones and shales with many sedimentary structures. Core no. 3 at 1605 feet is a brown silty shale extensively burrowed by tracks along the bedding planes. These cylindrical and flattened-cylindrical burrows are 2 to 3 mm. wide and up to 3 to 4cm. long, and filled with clean digested silt. Most of them are cut-off by the section of the rock, and show some "dichotomous parting" along the bedding plane. These structures closely resemble those described from the Nelson Bore between 2681 and 992 feet, in a similar type of sediments. They are abundant at 1605 feet (core 3) and at 1927 feet (core 4) and occur occasionally at other depths in cores 1 to 4. A different type of buttowing with thinner and more curved tracks occurs at 1608, 1615 (core 3) 1621 and 1625 feet (core 4). Low angle cross-bedding and scouring occur at 1923 (core 4) and 1615 feet (core 3); "disturbed bedding" at 1613 feet (due to organic action?) and convolutions at 1608 feet. The depositional environment of the sediments of the entire unit may be considered as paralic, and similar to that for subunit Db2.

#### Unit Bc

The interval allocated to this unit ?590 to 510 feet has been tentatively equated to part of the Buccleuch Group as known in South Australia (Ludbrook, 1962). From a strictly petrographic point of view, the sediments intersected in this interval in the Mount Salt Well No. 1 and corresponding intervals in the Mount Salt Structure Holes Nos. 3, 4 and 5 are similar to those described in the Nelson Formation in various other wells. These sediments are typical for a change in conditions to a highly agitated environment: rounded, polished, coarse to very coarse, limonite coated quartz and quartzite grains, abundant limonite pellets with minor fossil fragments and abundant fish teeth.

An Eccene age has been ascribed to unit Bc by Ludbrook. In the Port Campbell area, unit Bc has been described as Oligocene in age. This could indicate a diachronic character for unit Bc. However, close studies of the stratigraphy in the Port Campbell area carried out by Frome-Broken Hill Co. (Leslie, pers. com.) tend to show that the sequence of sediments corresponding to unit Bc should be subdivided, the lowest part being Eccene in age.

These sediments are overlain by an horizon of glauconitic marly limestone. This is evident from the study of samples from structure holes Nos. 3, 4 and 5. An average thickness of 30 feet has been ascribed to this horizon in the Mount Salt Well No. 1.

Both the nature of glauconitic marly limestone that grades in place towards pure glauconite rock, and the abundant fossils (globigerinid foraminifera mainly, but also echinoderms and polyzoa debris) support the separation of this horizon from the limonitic sandstones of unit Bc.

#### Unit Bb

The interval from 480 feet to surface is placed in the "Gambier Limestone" (0.D.N.L., 1963) equivalent to unit Bb. The cuttings of eighty feet of this interval only, were available, due to deficient recovery. Examination of the corresponding materials of the Mount Salt Structure Holes Nos. 3, 4 and 5 supports the subdivision of this unit into a spicular limestone subunit (480 to 110 feet) and a polyzoan limestone subunit (110 feet to surface). The evidence gained from examination of the available cuttings in the Mount Salt No. 1 well and the materials of Structure Holes Nos. 3, 4 and 5, is sufficient to envisage an open shelf, near shore environment of deposition for the sediments of the unit.

#### CONCLUSIONS

Attention will be focussed on the sediments encountered below 3270 feet, that is below unit Dd (equivalent to the Bahgallah Formation). The various units above this datum have been adequately described, as far as the material permitted, in the Completion Report (O.D.N.L., 1963). The character of these sediments may be considered under two headings:-

- (a) petrology and inferred depositional environment
- (b) time relationships

It is not possible to divide the sequence below 3270 feet, by petrological study into equivalents of the "Belfast Mudstone" and "Flaxmans Beds". This distinction is not warranted either in the strict formation sense, based on lithological evidence, nor in a time stratigraphic sense. These sediments belong to a greywacke association and were deposited in shallow water within a subsiding basin, in which alternating turbulent and quiet water conditions prevailed. Both the absence of any graded-bedding and the presence of abundant typical shallow water features, such as burrows, together with quiet water features (i.e. fine laminations) deny the possibility that these greywackes were deposited by turbidity currents. This type of sedimentation corresponds to the deposition of the more distantly transported fine fraction of greywackes of Unit G in the eastern sub-basin (Portland Sunklands). Indeed sediments of unit Gg in the eastern sub-basin have a close petrographic affinity with silts and shales from the unit Gg in the Mount Salt Well No. 1, but show a greater marine influence as indicated by their content of siderite and glauconite.

The palynological zonation established in wells from the eastern sub-basin can be linked with that of Unit Gg. Palynological evidence suggests that the "Waarre" Formation may be present (Evans, in O.D.N.L., 1963) but this is by no means certain. Petrological studies show no evidence at all of a "Waarre" equivalent. The sedimentation might have been continuous after the deposition of sediments of the "Otway Group", and represented throughout by a greywacke association.

The greywacke sedimentation did not cease abruptly at the lower limit of unit Gd, but was replaced gradually by more mature sediments of the "Paaratte type". The unit Gd sediments closely resemble the sandstone from the unit Gd of the Nelson Bore (Hawkins and Dellenbach, 1963). Similarly the inferred environment is paralic.

Above unit Gd, unit Gb appears as recognized in other wells such as Port Campbell No. 1, Pretty Hill No. 1 and the Nelson Bore. In the latter case, a possible break occurs between deposition of units Gd and Gb. No such feature could be detected in Mount Salt Well No.1. This unit reflects a regressive type of sedimentation, containing coal deposits. Lack of fossils renders it uncertain that the boundary between the Cretaceous and the Tertiary periods lies within this unit.

The unit Dd is similar to that encountered in the Port Campbell No. 1 Well and marks a period of transgression.

The unit Db closely resembles that of the Nelson Bore and corresponds to sedimentation under shallow water, paralic conditions. The present study, supplemented by the examination of corresponding materials from the Mount Salt structure Holes Nos. 3, 4 and 5, shows the lithological affinities of the unit Bc with sediments from the "Nelson Formation".

Unit Bc and the next unit Bb of the Gambier Limestone, reflect the Oligocene transgression.

As far as petroleum possibilities are concerned, two points arise from this study; the first is that the Waarre Formation, which is regarded as one of the best target horizons in the eastern sub-basin, is not necessarily represented in the Mount Salt No. 1 section. Secondly the reservoirs within the units Gd and Gg although possessing high porosities are thought to be limited and erratic in distribution. No indications for hydrocarbons related to petroleum have been found in the Mount Salt No. 1 Well.

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#### APPENDIX I

Core Analysis sample description

(based on Core Analysis Results, General File No. 62/399, 12th February 1965).

#### Unit Db - Sub-unit Db 1

Core No.1 - 996' Mudstone.

Dark brown carbonaceous, micaceous mudstone. Porosity (34%) is submicroscopic. No permeability to be expected (N.D.).

Core No.2 - 1322 - 1342' No recovery.

Core Nc.3 - 1601' Mudstone.

Dark brown carbonaceous micaceous mudstone, with abundant burrows. Porosity is submicroscopic (34%). No permeability to be expected (N.D.).

Core No.4 - 1921' Mudstone and finely laminated shale. Dark brown mudstone and shale with abundant carbonaceous flakes. Submicroscopic porosity (29%). No permeability to be expected (N.D.).

Core No.4 - 1925' Mudstone.
Similar to core No.4 - 1921'.

#### Sub-unit Db 2

Core No.5 - 2185' Sandstone with carbonate cement.

Light grey-brown, well sorted, angular, very fine grained quartzose sandstone with approx. 10% rock fragments ("chert", opaque rock fragments). Well crystallized calcite cement. Low submicroscopic porosity (8%, 4%H). No permeability.

Core No.6 - 2494-2504' Sandstone with carbonate cement.

Light grey brown, moderately sorted (bimodal),
angular to subrounded, very fine to very coarse
grained quartzose sandstone. Abundant grains of
metaquartzite, minor "chert" grains. Cryptocrystalline carbonate cement varies in amount from 35% to
more than 50% (limestone lenses). Abundant foraminifera, polyzoa and shell debris. Porosity (17%)
due to incomplete development of cement. Low
permeability inferred (N.D.).

Core No.7 - 2800 - 2818! No recovery.

Core No.8 - 2901' Argillaceous sandy siltstone.

Soft medium brown, argillaceous, carbonaceous, sandy siltstone. Very good porosity (34%H) and permeability (670 md H).

#### Unit Dd

Core No.9 - 3143' Sandy chamosite onlite.

Dark greenish sandy sideritic chamosite coliths embedded in chamositic sideritic cement. Porosity is variable due to incomplete cementation and alteration (41% in the analysed sample). No permeability to be expected. High grain density due to presence of siderite (G=3.83 - 3.88) and chamosite (G=3 - 3.34).

Corc No.9 - 3147! As 3143!. Porosity: 25%; no permeability.

Core No.9 - 3151' As 3143'. Porosity: 30%; no permeability.

#### Unit Gb

Core No. 10 - 3429 - 3450! No recovery.

Core No. 11 - 3682' Interlaminated shale and sandstone.

Dark grey argillaceous shale interlaminated with light grey argillaceous sandstone. Good porosity in sandstone laminae (20%). Variable permeability to be expected (N.D.).

Core Nc. 12 - 3993 - 4011' Shale.

Dark carbonaceous, pyritic, chloritic shale. Submicroscopic porosity (22%). No permeability to be expected (N.D.). The rock is massive in part, but also finely laminated, with sandy lenses.

#### Unit Gd - Sub-unit Gd 1

Core No.13 - 4225' Sandy shale.

Light grey, angular, very fine-grained quartz, metaquartzite, "chert", and minor feldspar grains, some schist fragments, in silty clayey groundmass. Abundant carbonaceous flakes and pyrite. Authigenic illite and kaolinite. Submicroscopic porosity (23%). No permeability to be expected (N.D.).

The very thin laminae and lenses of sandstone fill in low-energy current ripples.

Core No. 14 - 4538! Silty sandstone.

Light grey, poorly sorted, angular fine to very coarse quartz grains, also metaquartzite and feld-spar grains, in silty, pyritic, micaceous and carbonaceous matrix. Lenses of siderite are present. Submicroscopic porosity (28%). No permeability to be expected (N.D.).

The rock presents thin laminations, low-angle cross-bedding, disturbed bedding and burrowing.

Core No.15 - 4783' Sandstone.

Light grey, well sorted, angular, medium grained quartzose sandstone with minor lithic fragments ("chert", metaquartzite) and feldspar. Some chlorite elements. Patchily developed calcite cement. Minor chlorite and kaolinite cement. Very good porosity (35%) and permeability (2000 md).

Core No. 15 - 4786' Sandstone.

Similar to core No.15 - 4783'. Very good porosity (33%V, 32%H), and permeability (2390 md V, 1540 md H). The sandstone is massive, with small (5 mm) lenses of silt underlying low-angle cross-bedding.

Core No. 15 - 4792' Interlaminated sandstone and shale.

Light grey, well sorted, angular, fine to medium grained quartz, minor lithic fragments and feldspar grains in clayey chloritic matrix. The sandstone laminae alternate with shale laminae, and show low angle cross-bedding.

The core shows a near-vertical burrow (15 mm in diameter) filled with sand.

The porosity (25%, 21%H) is submicroscopic, and permeability low (NilV, 3 md H).

Core No.16 - 4943 - 4949' Sandstone

Medium grey, friable medium to very coarse grained argillaceous sandstone. (Sample crumbled after physical analysis). Submicroscopic porosity (27%) inferred, no permeability to be expected (N.D.).

Core No. 17 - 4950 Sandstone.

Greenish-grey, moderately sorted (bimodal), angular to subangular, medium to very coarse grained quartzose sandstone. Abundant metaquartzite grains and chlorite grains. Some alkali feldspar. Patches of pyritic silty matrix. Chlorite grains-coating is extensively developed. Recrystallized kaclinite present. Porosity is very good (34%). Very good permeability (N.D.) inferred.

Core No.18 - 5039' Sandstone with shale laminations.

Medium grey, moderately sorted, angular to subrounded, medium to very coarse-grained quartzose
sandstone. Metaquartzite grains are abundant.
Foldspar (mostly K-foldspar) is present, together
with chlorite grains. The sandstone is partly
cemented by finely crystallized siderite. Very good
poresity (22%), and good permeability inferred
(N.D.). The rock is finely laminated and shows lowangle cross-bedding, and burrows.

Core No. 19 - 5192' Sandstone.

Similar to core No.19 5039'. No siderite in cement. very good perosity (22%); good permeability inferred (N.D.).

#### <u>Unit Gd - Sub-unit Gd 2</u>

Core No. 20 - 5504' Sandstone.

Light greenish grey, well sorted, angular, fine grained quartzese sandstone. Fragments of metaquartzite and K-foldspar grains are present. Some quartz grains show overgrowth, welding and interpenetration. Very thin chleritic film of possible depositional origin is present. Patches of recrystallized kaolinite occur. The sandstone is clean and has very good perosity (29%V, 28%H), very good permeability (378 md V, 712 md H). Anisotropy is explained by packing effect in vertical direction.

The rock is cross-bedded (low-angle) and shows thin

The rock is cross-bedded (low-angle) and shows thin shale laminations.

Core No. 20 - 5514' Carbonate cemented sandstone.

Light greenish groy, moderately sorted (bimedal), angular to subrounded, fine to coarse-grained quartzose sandstone. Abundant metaquartzite grains. Some alkali feldspar grains. Some rounded chlorite grains. Globular siderite and calcite cement. Negligible perosity (4%, 6%H); no permeability to be expected (N.D.).

The rock is cross-bedded (low-angle) and shows thin shale laminations.

Core No.20 - 5514' Carbonate cemented sandstone.

Light greenish grey, moderately sorted (bimodal), angular to subrounded, fine to coarse-grained quartzose sandstone. Abundant metaquartzite grains. Some alkali feldspar grains. Some rounded chlorite grains. Globular siderite and calcite coment. Negligible perosity (4%, 6%H), no permeability to be expected (N.D.).

The rock is rather massive, but with scarce shale laminae underlying low-angle cross-bedding.

Core No. 21 - 5788! Sandstone.

Very similar to core No.20 - 5504'. Clean sandstone with very good perosity (28%V, 26%H), and very good permeability (507 md V, 524 md H). Thin shale laminae underlie low angle cross-bodding. Some burrowing is present.

Core No.22 - 6113' Sandstone.

Light greenish grey, moderately sorted, fine to coarse grained quartzose sandstone. Metaquartzite, "chert", feldspar grains are present, together with chloritic rock-fragments and chlorite grains. Patches of silty pyritic matrix. Thin chloritic film, in parts and patches of carbonate cement have developed. Very good perosity (28%, 26%), and very good permeability (704 md V, 1145 md H). Anisotropy due mainly to silty pyritic lenses. The rock is rather massive.

Core No. 23 - 6398' Sandstone with silty laminations.

Medium grey, moderately sorted, angular, very fine grained quartzose sandstone. Abundant chloritic and opaque constituents, and flaky material: muscovite, illite, chlorite in silty pyritic matrix. The sandy lenses bear little cement, and porosity (20%V, 24%H) is submicroscopic in parts. Laminations and presence of lenses of sandstone induce absence of vertical permeability and good horizontal permeability (35 md).

Thin laminations, undulate laminations, low-angle cross-bedding and sccuring are common. Burrowing is present.

#### Unit Gg - Sub-unit Gg 1

Core No. 24 - 6672! Sandstone.

Light grey, well sorted, angular to subrounded, medium grained quartzose sandstone. Frequent metaquartzite and "chert" grains; some feldspar grains. Some chloritic rock-fragments present. Chloritic film and spots are present. Siderite rhombs occur between detrital grains. Very good perosity (28% V, 27/H); very good permeability (308 mdV, 995 mdH).

The rock is rather massive, but with lenses of shale underlying low-angle cross-bedding.

Core No. 24 - 6687' Sandstone

Similar to core No.24 6672'. Very good porosity (25%).

Much higher vertical permeability (618 md) than horizontal permeability (432 md) due to vertical plug having been cut in coarser, mere permeable laminae. Cross-bedding present.

Core No. 25 - 6987! Sandstone.

Light greenish grey, moderately sorted (bimcdal), angular to subrounded, fine to very coarse-grained quartzose sandstone. Frequent metaquartzite and K-feldspar grains. Chloritic rock fragments present. Very good porosity (N.D. V, 22% H), very good permeability (N.D. V, 123 md H). Shale laminations underlie low-angle cross-bodding. Abundant tiny (1 mm in diameter) burrows.

Core No. 25 - 6999! Interlaminated shale and sandstone.

Modium grey, shale and argillaceous sandstone interlaminations. Submicroscopic porosity (16% V, 17% H). No vertical permeability; low horizontal permeability (1 md). The rock shows undulations, low-angle crossbedding, and minor burrowing.

#### Unit Gg - Sub-unit Gg 2

Core No. 26 - 7465' Sandstone with shale laminations.

Medium groy, moderately sorted, angular, very fine grained quartzese sandstone. Some metaquartzite and feldspar grains. Chloritic, pyritic argillace—ous matrix. Incomplete matrix infilling in some sandy laminations and submicroscopic porosity account for analysis result (16% V, 17%H). Very little permeability (Nil V, 1 md H). Churned-bedding and burrowing are present.

Core No. 26 - 7473' Sandstone with shale laminations.

Similar to core No.26 - 7465'. Measured perosity is 22%, and permeability variable (2md V, 24 md H) due to the presence of shale laminae. Extensive churning and burrowing.

Core No. 27 - 7936-7939' Massive mudstone.

Dark, silty, very finely sandy, chloritic, pyritic mudstone. Herizontal perosity measured (34%), may be due to unrepresentative sampling. Some microperosity and ne permeability are to be expected.

Core No. 28 - 7944 Massive mudstone.

Similar to core No.27 - 7936-7939'. Submicroscopic porosity (19%), no permeability to be expected (N.D.).

Core No. 29 - 8423' Sandy shale.

Dark grey sandy shale with abundant mica, chlorite and pyrite. Submicroscopic porosity (13% V). No permeability to be expected (N.D.). Thin laminations and extensive churning and burrowing are present.

Core No. 30 - 8917' Sandstone.

Light greenish grey, moderately sorted (bimodal), angular to subrounded, medium to very coarse grained

quartzose sandstone. Metaquartzite and chloritic rock-fragments are frequent. Feldspar and "chert" grains are present. Spots of chlorite cement and chlorite coating are present. Very good porosity (23%V, 24%H). Good vertical permeability (21 md), and very good horizontal permeability (538 md). Anisotropy due to presence of shale lenses which underlie low-angle cross-bedding.

Core No.30 - 8927' Sandstone

Similar to core No.30 - 8917. Very good porosity (22%V, 23%H); good vertical permeability (55 md), and very good horizontal permeability (387 md). Shale lenses, low-angle cross-bedding and churning features are noticeable in the rock.

Core No.31 - 9421-9440 Sandstone with shale laminations.

Light grey, angular, very fine to medium grained quartzose sandstone. Metaquartzite, "chert", chlorite, and minor feldspar grains are present. Patchily developed calcite cement. Submicroscopic porosity (18%), and low permeability inferred (N.D.). (Depth allocation of sample doubtful).

Core No. 32 - 9833-9846' No recovery

Core No.33 -9853' Sandstone

Light greenish grey, well sorted, angular, very fine grained quartzose sandstone. Abundant meta-quartzite and "chert" grains. Minor feldspar grains. Pyritic, chloritic, silty matrix. Submicroscopic porosity (11%V, 12%H). No permeability to be expected (1 md vertical permeability measured is not significant). Churned bedding and extensive burrowing (3 cm in diameter).

Core No.33 - 9859' Silty sandstone.

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Similar to core No.33-9853'. Submicroscopic porcesity (12%); no vertical permeability, and horizontal permeability 4 md. Undulate laminations, low-angle cross-bedding, churning and burrowing are common in the rock.

Core No. 34 - 10,039' Sandy shale.

Dark chloritic, pyritic sandy shale. Sandy parts are quartzose, with metaquartzite, chert and some feldspar grains. Submicroscopic porosity (8%). No permeability to be expected (N.D.). The rock is massive with subconchoidal fracture.

Lat: 37° 57′ 25″ S. Long: 140° 37' 43" E. Elevation: (70° above sea level. G.L. Scale: I" = 100 feet. B.M.R. Index No. 157

TO ACCOMPANY RECORD 1964/178

Conglomerate

Sandstone

# COMPOSITE WELL LOG

O.D.N.L MOUNT SALT No.1

- Coal

PLATE 1 (SHEET 1)

Company: OIL DEVELOPMENT.N.L.

SOUTH AUSTRALIA OTWAY Basin:

Drawn by: J.G.A. DEN HERTOG B.M.R.

SEPTEMBER 1964

LEGEND

Claystone

Pellets

> Glauconite

•• Phosphate

Pyrite

		III	Siltston	ne	Limes	tone			Pyrite	Y Skeletal debris	(mainly Polyzoa	)									
	DEPTH R.T.	Very fine Fine Medium	SAND	Granule	GRAIN SIZE  //o  Fine  Very coarse  20 40 60 80	DEPTH	CUTTINGS LOG % of Lithologies	COLOUR Tone HUE	CUTTINGS	DESCRIPTION	SPONTANEOUS POTENTIAL	DEPTH cores	INTERPRETED LITHOLOGY	RESISTIVITY (Short Normal)  40hms m/m 200 0hms	DESCRIPTION OF INTERPRETED LITHOLOGY	Description of Unit	ormal menclature	TRATIO	nation	roup	Age
	100-	7 2 3 4	.5 .6 .7 .8 .9	2 3 4 5	20 40 60 80	100 -			,			100 –		200 Ohms	Polyzoan limestone.  White to cream, with occasionnal echinoid spines, scattered flint nodules; dolomitic in some places.  See Section 1. See Section 2. See Section 2. See Section 2. See Section 3. S	- 0			ONE	GROUP	
	200-					200 -						200 – 300 –		·	Dense grey somewhat marly limestone crowded with spicules; some chert.	nestone	ВЪ		LIM	i	OCENE
<b>建</b> 设据 葡萄	300 —				Salah Sa	400 -	CIRCULATION LOST NO RECOVERY					400-			Descriptions based on a	Spicular lin		1 1	AME	9 .	00000
·	500-					500 -					Run 1	500 <b>-</b>		~>	Marly limestone glauconite in part.  Sandstone with limonite pellets.  Brown stained subrounded to rounded, polished coarse to ve coarse-grained sandstone; abundant limonite pellets and ooliths, abundant fish teeth, some glauconite.	Limonitic sandstones	Вс		Equivalent to Nelson Fn.	າວ 	?Oligocene
	600 <b>-</b>					700 -		dbg	from above.  2 Loose subangular to subrou	d limestone fragments possibly caved inded medium to very coarse quartz lity mudstone and dark brownish e lithology.		600 <b>-</b>		\	Silty argillaceous sandstones.  Dark brown subangular to subrounded medium to very coarsegrained sandstones with many granules of siliceous rocks.  Facetted quartz grains, in dark brownish silty argillaceous matr						
	800-		•	•		800-		. dbg	with abundant facetted clear o	erse to very coarse grained gritty sand or brownish quartz grains; many ork brownish silty pyritic mudstone	ds	800-				yrite.					
	900-			-		900-	No sample	mbg	silty argillaceous sands with g	subrounded medium to coarse graine rits. Dark brownish silty micaceous y ( possibly due to softness of rock ).		995		3	Silty sandstones  Dark brownish grey angular to subrounded medium to coarse- grained silty argillaceous sandstone, gritty in part.  Dark brownish grey argillaceous, micaceous siltstone; \$pots of pyrite and organic matter. Pyrite and organic matter form matrix to some silty laminations.	seous matter and p					
	1100-					1100-		mbá	with some carbonaceous matte	r to subrounded (also facetted)coarse		1100 –		J. J. Mary	Siltstones and sandstones.  Dark brownish grey sandy argillaceous pyritic siltstones with mica and flakes of carbonaceous matter.  Medium brownish grey angular to subrounded coarse-grained the gritty sandstones. Silty argillaceous matrix decreases towards base	ly divided carbonac					
	1300 -			-		1300 -		dbg mbg dg	Medium to dark brownish grey	angular to subrounded (also facetted) h silty argillaceous matrix with pyrite		1300 - 1320 2			Siltstones and sandstones.  Dark brownish grey sandy argillaceous carbonaceous pyritic siltstones with some glauconite.  Medium to dark brownish grey angular to subrounded coarse to gritty sandstones with dark silty argillaceous matrix or interbe						
	1400-		•			1400~			Dark grey sandy argillaceous carbonaceous matter.	micaceous siltstones with pyrite and		1400 —			Siltstones and sandstones.  Dark grey sandy argillaceous micaceous siltstones with pyrite and carbonaceous matter.	ng with argillaceous	b <sub>1</sub> . 1500 feet				
	1600 —					1500 -		dg Maginas promini	<b>Subrounded coarse to very</b> cod Dark grey argillaceous pyritic	increased content of subangular to arse quartz grains c carbonaceous siles with minor rounded(also facetted) coarse quartz		1600		) M	Subangular to subrounded coarse to very coarse-grained sandston with silty argillaceous matrix.  Siltstones and sandstones.  Finely laminated dark grey argillaceous micaceous siltstone with some glauconite.	andstones altern			+		CENE
	1700—					1700-		mg dg		unded coarse to very coarse quartz argillaceous pyritic micaceous siltstone		1700-		7 23	Subangular to subrounded coarse to very coarse-grained sandston with silty argillaceous matrix.  Siltstone and sandstones.  Grey to dark grey argillaceous micaceous siltstone with pyrite and carbonaceous matter.  Subangular to subrounded coarse to very coarse-grained sandstone with black siliceous pebbles and silty argillaceous matrix.	se-grained		-	2540 fe		EO
	1900			•		1900-		mg dg mg	As above; gritty from 1810'to I	1820'.		1900-		)	Siltstone and sandstone.  Grey to dark grey argillaceous micaceous pyritic siltstones.  Subangular to subrounded coarse to very cocrse-grained sandstone  Siltstones and sandstones.  Finely bedded dark grey micaceous argillaceous siltstones with	brounded fine to ve				GROUP	
	2000 —					2000-		dg mg mg	motter.	micaceous siltstone with carbonaceous aded coarse to very coarse quartz 180'.		2000-	I I I I I I I I I I I I I I I I I I I	7	minor sand grains scattered throughout. Abundant pyrite and carbonaceous matter.  Subangular to subrounded coarse to very coarse-grained sandstor with quartz pebbles towards bottom part of interval, silty argillaced matrix.	Subangular to su			FORMATIC		MIDDLE
	2200 -					2100-			carbonaceous matter.	is siltstone with pyrite and some tone with dolomitic cement at 2170'.		2184 5 2200 –		<i>≥</i>	Argillaceous siltstones and sandstones.  Medium grey sandy argillaceous siltstones and angular fine to very fine-grained well sorted sandstones with dolomitic cement Sandstones contains chert, siliceous rock and opaque rock fragments, rounded zircon and some glauconite.				ŀ	IGHT	
	2300 –					2300 -			Medium grey argillaceous micad carbonaceous matter.	ceous siltstone with finely divided		2300 -	II		Medium grey argillaceous micaceous siltstones with very fine laminations (O.I mm.) of dark argillaceous slightly carbonaceous silts; small scale low angle cross beddings.						
	2500-					2400- 2500 -		mg Ig	with dolomite cement, glauconit  () Medium grey, coarse to grith	gular medium to coarse-grained sandston te; contains arenaceous foraminifera ty, subrounded to subangular silty		2490 6 2504			Sandstones.  Angular to subangular medium to coarse-grained sandstone with glauconite and abundant dolomite cement; abundant fossils	atter; dolomite ceme			DAR	L	OWER
and the second	2600 -	,				2600 -		dg	glauconite  (i) Medium grey subangular, m	phosphatic sandstone with some		2600-		<b>\{\}</b>	Dark grey subangular to subrounded, medium to coarse grained poorly sorted silty sandstone with abundant pyrite and carbonaceous matter.	nd carbonaceous m	40 feet				
	2800 -			-		2800 -			matter. ② Yellowish brown sideritic, sli glauconite and pyrite		}	2800 7 2815			(The two distinctives lithologies above alternate over the whole interval; silt content decreases progressively towar base of interval.)	dstones with pyrite a	Ò				
	2900-				>				argillaceous sands. Abundant pyrite, mica and some	angular, fine to coarse-grained silty e carbonaceous matter. ritic slightly phosphatic sandstone.		2900 8 2916		}	Argillaceous sandstones and siltstones.  Fine laminae of dark pyritic siltstone with flakes of carbonace matter, alternating with grey argillaceous siltstones  Subangular to angular, fine to coarse grained argillaceous sand with mica pyrite and clay matrix.	tones					
	3100				}	3000-				•					(Clay content increases towards bottom of interval)  Geologis	Argillaceous	DELLENE	BACH	I F D		

GRAIN SIZE (mm) (Wentworth)  SAND Granule  TH  Cooles of the cooles of t	GRAIN SIZE  % ———— Fine ————————————————————————————————————	DEPTH CUTTINGS LOG % of Lithologies	COLOUR Tone C	UTTINGS	DESCRIPTION	SPONTANEOUS POTENTIAL	cores   GRAPT	RESISTIVITY (Short Normal)	DESCRIPTION OF INTERPRETED LITHOLOGY	scription Unit ormal	STRATIGRA	mation
2000 - 2. 3. 4. 5. 6. 7. 8. 9. 1. 2. 3. 4. 5.	20 40 60 80	3200- H-H-H-H-H-H-H-H-H-H-H-H-H-H-H-H-H-H-	Dark brown	nted, rounded quartz d	liths in chamosite-siderite matrix, with and quartzite pebbles. Some grains	- <del>[5]</del> + Run 1	3142 9 3151 3100 I O I O I O I O I O I O I O I O I O I	4 Ohms m/m	Chamosite oolite: Massive dark brownish grey chamosite colite with chamo siderite cement. Brown coated quartz and quartzite peblished and silt content and porosity increase toward botto interval.	bles.		140 feet
300		3300	() Loose feldspa (2) Brownis (3) Minor	argillaceous silfstone subangular to subrounde ir grains.	ed coarse to very coarse sand grains; some		3400-11-11-13-13-13-13-13-13-13-13-13-13-13-		Sandstones and siltstones:  Medium grey subangular to subrounded coarse to very coarse-g feldspathic sandstones with coal fragments. Minor silty n Interbeds and laminations of brownish grey argillaceous, ceous carbonaceous siltstone and dark tight pyrite silts. Minor streaks of silty siderite.	natrix. .mica <u>∪</u>		
		3600	() Loose some g (2) Dark g. (3) Brownis	reenish coated quartz, rey tight siltstone.	inded coarse to very coarse sands some feldspar grains.  Stone with minor coally matter.		3500-			with kaolinific pyritic m		
		3700-	(f) Loose s quartz mbg (g) Dark b	pebbles, some greenish	d to very coarse sand grains, some coated quartz, some feldspar s siltstones with pyrite.		3679 11 3693 3693	11; 1; 10; 1; 1; 1; 1; 1; 1; 1; 1; 1; 1; 1; 1; 1;	Finely bedded dark grey argillaceous siltstones, alternating with gritty sandstone with silty pyritic matrix.  Sandstones and silty mudstone: Poorly cemented light grey subangular to subrounded contour very coarse feldspathic sandstones with minor amount pebbles and coal fragments or lenses.	nating siltstones and siltstones are		
		3900-	() Loose sands quartz (2) Medium carbon	with some greenish coo rite granules and some n grey silty micaceous	ded coarse to very coarse feldspathic ated quartz grains, quartz and ecoal fragments, smudstone with pyritic and fragments of white kaolinitic matrix.		3800-		Minor kaolinitic matrix.  These sandstones are interbedded, as shown by core 12, with medium grey silty mudstone.	ry coarse feldspatt fragments and strin		
		4100-	() Loose spathic grains	sandstones with some che minor coal fragments, Grey sifty micaceous mu	ded coarse to very coarse-grained feld- ert grains and greenish coated quartz , pyrite udstone pyritic and carbonaceous		3993 12 4011		(Sitty mudstone as recognized from core No 12 could occur the interval)  Sandstones: Poorly cemented light grey subangular to subrounded felds sandstones with chert and chlorite grains, pyrite and mind fragments. Minor thin beds or laminations of medium grey silty micae pyritic mudstone.	spathic coar bell coarse to coar coar		
		4300-	.mg			M M M M	4200- 4216 13 4231 4300- 4300- 11-11-11-11-11-11-11-11-11-11-11-11-11	V: i     i     i   i   i   i   i   i   i	Argillaceous siltstones, shales and sandstones:  Dark grey brown argillaceous pyritic siltstones forming this layers in top of interval.  Minor sideritic glauconitic siltstone lenses.  Poorly cemented coarse gritty sandstones with silty clayer matrix. Clay content decreases towards base of interval.			
		4400	dg ② Dark g ③ Tight L mg  ① Loose a and br	own mica. rown dark argillaceous ,	pyritic siltstone, auconitic siderite rains with minor chloritic elements	Man Manner	4400-			siliceous rocks and chlo		
		4600	mg () Loose (2) Grey b (3) Silly s	coarse quartz grains o rown argillaceous pyriti iderite-dolomite with ch	as above lithology () ic micaceous silts.	ا حر ا	4533 4550 4600 — I I I I I I I I I I I I I I I I I I	1.A:1 A 1111  ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~	Dark argillaceous pyritic siltstones and shales, finely bedde alternating with subangular to subrounded feldspathic same with minor chloritic fragments, glauconite, and lenses of siderite with chloritic elements.  Sandstones, siltstones, and shales: Light grey angular to subangular very fine to coarse felds sandstones with chert fragments. Lenses of sandstone with	spathic spathic		
		4800	Ig () Loose s	subangular to subrounded ldspar, chert, quartzite g rown argillaceous pyritic		My	4783 4783 15 4798	M. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1.	mite cement, kaolinite matrix. Good porosity.  Dark brownish grey regularly laminated carbonaceous silts with "nests" of sandstone with kaolinite matrix and patches dolomite and anhydrite cement.  Sandstones, siltstones and shales: Light grey angular to subrounded generally coarse feldspa	asionally fine-grained fel	+ d	<b>U</b>
		4900- 5000- 5000- 1 1 2 1 2 1 3 3 3 3 3 3 3 3 3 3 3 3 3 3	Depth Loose is feldspoor.  Depth Loose is feldspoor.  Depth Loose is with feldspoor.	ar chert and quartzite gr rown argillaceous and co h-brown tight siderite a subangular to subrounde ldspar chert and quartz	arbonaceous silts, and dolomite; some glauconite ed coarse to very coarse quartz grain inte elements, minor grits.	W manh	4900 4943 16 11 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1		sandstones with abundant chert, microquartzite and chlorisments with silty pyritic sideritic and kaolinitic matrix and sicement. Some sandstones with grains coated with chlorite chloritic cement.  Dark brownish grey carbonaceous pyrite sideritic clayey si and shales micaceous throughout.	te ele- iderite and  carbonate cement.	T 2290 fe	7 0622
		5100	Reddis chloriti	o brownish grey argillad th to yellowish brown do ic elements. Cavings due to casing	olomitic sideritic sandstone with	Run 2	5044 5100-11-11-11-11-11-11-11-11-11-11-11-11-	Run 2	Light grey angular to subrounded coarse grained sorted so stones with few feldspars, quartzite and chloritic element and sideritic pyritic cement.		N   N   N	UIVALEN
		5300 -	() Loose (2) White (3) Brown (1) Loose (2) Light (1)	angular to subrounded kaolinitic) to brawnish s sideritic siltstone with	medium to coarse-grained sands clayey silts. carbonaceous matter medium to coarse-grained sands.	m more many m	5300	111 B 11.   NI	Siltstones, shales and sandstones Light brownish grey siltstones with argillaceous or argillac and sideritic matrix; fine laminations of dark pyritic care ceous clayey shales.		T NOITY	N 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
		5500	② Light o	grey clayey pyritic silts.	medium to coarse-grained sands. with chloritic elements	Mumm	5485 20 5503	A 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	Light grey angular to subrounded coarse-grained and pool sorted feldspathic sandstone with chert, metaquartzite and delements; siderite and dolomite cement.	s and angular to s itic sandstones w siderite)	Maca	ח דטר דט
		5600	() Loose (2) Light g (3) Yellowis	<b>irê</b> y clean clayey silts wi sh brown pure siderite.	medium to coarse-grained sands. ith siderite cement. medium to coarse-grained sands.	and home and hold	5700	IALI 1 I IAIA I 1A I	Light grey angular to subrounded medium to coarse-grain feldspathic sands with glauconite and chlorite elements; cle silty clayey matrix, and silty sideritic cement.  Siltstones, shales and sandstones: Medium to dark grey siltstones and shales with clayey pyrichloritic matrix. Shales form thick laminations and convolutions.	stones Siltstones, sharmoning ark feldspathic charmed cement. (mair	)	AAKAI
		5900	mg    June 1   June 2   June 2	yritic carbonaceous clayo angular to subrounded n othic sands. sh silty siderite.	nedium to very coorse-grained	Man May Com	5781 21 5798	i!iAt!ii!i!i	Angular fine-grained feldspathic sandstones slightly quart with chert fragments and chloritic elements, chloritic coats grains, patches of siderite cement, some kaolinite.  Siltstones, shales and sandstones.	feldspathic chloritic sands of unit.  base of unit.		
		6000-	(3) Dark p	yritic carbonaceous claye angular to subrounded, e feldspathic sands.	medium to very coarse-grained slightly	mmwwwmmm	6000- 6000- 1111111111111111111111111111	MWWWWW	Medium to dark grey siltstones and shales with clayey pyricarbonaceous and chloritic matrix.  Angular fine to very coarse-grained feldspathic sandstones sorted with chloritic elements and chlorite coatings of grain kaolinite, abundant pyrite.	nes, shales and angular glay and siderite cements chloritic matrix towards		
		6200	① Loose feidspi	athic sands. arey pyritic carbonaceou	ayey silt. , medium to very coarse-grained us clayey siltstone.		6200 - 11 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	IIA IIIII AII	Sandstones, clayey siltstone and shales:  Angular to subrounded, medium to very coarse-grained feromotories with abundant chloritic elements, grains of chemicroquartzite; clayey chloritic matrix with pyrite and organiser.	spath siderif		
		6400	3 Yellowi visible intervo	ish very finely sandy to . on large cuttings, incre	silty siderite very fine laminations easingly common towards base of	J. My	6395 23 6405		Dark clayey chlorite pyritic siltstones and shales with fine laminations of very fine-grained sands. Beds are churned burrowed.  *The terms sandstones and siltstones in these places cover	bundant on incritic si		

															( S	ATE 1
DEPTH R.T.	Silt & Clay  Very Fine 'Nery Fine	GRAIN SIZE (mm) (Wentworth)  SAND  Granule  SON SIZE (mm)  Granule  2 3 4 5	GRAIN SIZE % —— Fine —— Very coarse 20 40 60 80	DEPTH	% of Lithologies	COLOUR Ton	CUTTINGS DESCRIPTION	SPONTAN POTEN	NTIAL   COI	PTH	INTERP	RESISTIVITY (Short Normal)  — 4 Ohms m/m — 200 Ohms — 3	DESCRIPTION OF INTERPRETED LITHOLOGY	Description of Unit - Informal Nomenciature	Member Formation	Group Age
6600				66 <b>00 -</b>			① Loose sands as above ①;dark inclusions in a ② Dark clayey siltstone with abundant chloritic a pyritic matrix.	1 /	666 668 670				*  Sandstones, siltstones and shales.  Angular medium to very coarse-grained feldspathic sandstones, rather well sorted in parts, with many chloritic elements, chloritic coating and chloritic clayey matrix.  Medium porosity.	s and shales and angular ones with chloritic elements  ed)   930 feet		CEOUS
6 <b>8</b> 00				68 <b>00 -</b>		ο Δ	As above (ithology ()      Dark clayey siltstone pyritic with finely divided carbonaceous and chloritic matter.  .		>			M M	Dark pyritic carbonaceous chloritic silty laminations emphasizing cross bedding of sandstone. True dip about 15°.  Angular to subrounded, medium to very coarse-grained	Dark pyritic carbonaceous siltstones are coarse-grained feldspathic sandstones and clayey chloritic matrix.  G g - (undifferentiated Non cyclic unit		CRETA
7100				7000 -			Loose angular to subangular very fine to occase coarse-grained sands.      Dark clayey pyritic siltstone with carbonaceous and chiorite.		710	IIIII   II   III   III		Run 3	feldspathic sandstone with abundant chlorite in silty syritic chloritic micaceous matrix.  Shales, siltstones and sandstones. *  Park pyritic carbonaceous chloritic siltstones; sideritic and kaolinitic in part.  Angular very fine to occasionally coarse-grained feldspathic sandstone with chloritic fragments and chloritic kaolinitic matrix. Abundant chloritic pyritic carbonaceous silty patches and layers.	es, shales and chloritic sandstones		
7300				7300 -			<ul> <li>Loose angular to subangular generally fine-growith dark inclusions in quartz grains.</li> <li>Dark chloritic pyritic silfstone with clay, carbona matter and some siderite.</li> </ul>						(The lithologies described between 7450' and total depth are the same as in interval 6550'-7450' but occur as regular alternations of siltstones, shales and sandston representing broad cycles; this interpretation is based on the electric log characteristics)	urk pyritic carbonacecular medium to coarse		UPPER
7500	•			7500 <b>-</b>	(O)		<ul> <li>Loose angular to subangular fine to medium-grantather well sorted sands.</li> <li>Dark clayey pyritic siltstone. Some fragments are Glauconite and abundant chlorite.</li> <li>Yellowish silty siderite, with carbonaceous flakes very fine-grained sandstones with sideritic cemeis slightly phosphatic.</li> </ul>	very sandy.	76		III II	RESISTIVITY contin. (Lateral) 20 Ohms m/m 200 Ohms m/m		c chloritic shales with carbo- gular medium-grained feldspathic Sedimentary structures.	<b>←</b>	
7700 7800 7900				7700 7800			<ul> <li>Loose angular to subangular fine to medium-grain sands with occasional coarse to very coarse subaquartz and siliceous rock grains.</li> <li>Dark clayey pyritic siltstone, with carbonaceous mand mica.</li> </ul>	ounded	78				Core 26 shows cross bedding and scour and fill texture masked by strong churning and burrowing of beds.	claystone; argillaceous pyriti ies alternate cyclically with an / matrix. Burrowing, churning;	om 3524 fee	
8000	•			80 <b>00</b> -			<ul> <li>Loose angular to subangular medium to coarse-grifeldspathic sands with rock fragments.</li> <li>Dark cloyey pyritic sillstone with carbonaceous matter and mica.</li> <li>The same type of lithology continues from 816.</li> </ul>	[	{			My My My	Core 27. Dark brown silty claystone with some glauconite  Core 28. Dark brownish grey clayey micaceous shale sandy in part and with irregularly distributed very coarse quartz grains. Abundant chloritic and possibly glauconitic elements. 7940' fossil remain.	Dark silty glauconitic chloritic naceous matter. These lithologi chloritic sandstones with silty	as to whether the bottom s Beds" has been reached	
8200 8300				82óo-		· I · I · I · I · I · I · I · · ·	(The same type of lithology continues from \$160. depth but shows an increase in content of fine.  (3) Yellowish sandy siderite.  (1) Loose angular to subangular fine to medium but coarse-grained feldspathic sands, with rock fragme. (2) Clean silty very fine-grained sandstones interbed.	occasionally	83				Shales, argillaceous siltstones, and sandstones. *  Dark sandy siltstone with pyritic chloritic clayey matrix, mica and carbonaceous matter, grading to silty mudstones towards base of interval.  Arenaceous foraminifera at 8230'.	tic matrix, '	e ( No indication of "Flaxman	
<b>8400</b> <b>8500</b> 8600				8400 -			dark compact carbonaceous clayey pyritic siltsto  () As above lithology () (2) Dark clayey pyritic carbonaceous siltstones with rare interbeds of clean silts.  (3) Brownish silty sandy siderite with siliceous and	Run 4	85		IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII		Angular, very fine to occasionally very coarse-grained feldspathic sandstones, well sorted in part, with abundant chloritic rock fragments, mica, and silty pyritic argillaceous matrix.  These sandstones are interlaminated with or intimately cemented by pyritic clayey shales and siltstones with mica and chloritic matter. Plant debris and spores present. Burrows are common together with convolute jaminations, small scale low angle cross bedding and scour and fill  Same lithologies as shown above for this interval, but arranged in a broad cyclic manner:  Cycle thickness 100 to 200'.  Cycle arrangement from top to bottom:  Compact argillaceous siltstones, 30 to 50' thick,	with silty pyritic, chlondifferentiated)2	elfast Mudston	
<b>87</b> 00				ε700 - ε800 -			(2) Dark clayey pyritic carbonaceous siltstones.  (3) Brownish siny sandy siderite with sinceous and with chloritic rock fragments.		87				exceptionally 50 to 80' feet thick; sandy interbeds with sharp boundaries at the bottoms of interbeds. Average porosity 10%, no permeability. Porous sandstone with recurrent shale beds, increasingly tight towards overlying compact silty interval. Thickness range 70 to 150'. Average maximum porosity 23%, permeability range 10-400 md. (horizontal). Minor sideritic cement patches in sandstones.	d feldspathic sandst e sedimentary struct G g -	eds" and "B	
8900 9000				8300 - 9000 -		g E	Angular to subangular, coarse to very coarse-grafeldspathic sand.      Dark brownish grey pyritic sandy siltstone with cement and abundant finely divided carbonaced.	sideritic	· 891 893			James	Angular coarse to very coarse-grained moderately sorted feldspathic sandstone with chert, microquartzite grains, chloritic elements, with silty pyritic chloritic matrix. Pyritized plant debris throughout Arenaceous foraminifera at 8970'. In places siderite acts as cementing medium.  These sandstones are interlaminated with-or grade	angular fine to medium-grained	"Flaxmans B	
9100	•	1		9200-		M	<ul> <li>Angular very fine to medium, occasionally coars coarse-grained feldspathic sands with well rounchloritic elements.</li> <li>Dark brownish grey pyritic sandy siltstone with inflakes and plant debris.</li> <li>Angular very fine to medium grained feldspathic with grains of chloritic rock and chert.</li> <li>Dark brownish grey pyritic sandy siltstone with inchloritic matrix.</li> </ul>	sands	un 5 92		III III VIVIIVIIIIIIIIIIIIIIIIIIIIIIII		into dark pyritic carbonaceous chloritic mudstones with abundant mica flakes, thoroughly burrowed and showing convolute laminations, small scale low angle cross bedding, scour and fill textures.  (The cyclic sedimentation described above continues throughout the interval).	carbonaceous matter, undant burrowing and	quivalent to	
9400		The state of the s		9400 -		dg	chloritic matrix.  3 Brown sandy siderite with minor chloritic element and carbonaceous matter.  1 Angular medium to coarse-grained feldspathic so with siliceous rock grains.  2 Predominant angular grained sandy siltstones we pyritic clayey chloritic matrix; in places siderities	nds	94	IIIIII - IIIIII - III	$\begin{bmatrix} III & II & IIII & IIIII \\ III & IIIII & IIIIII \\ III & IIIII & IIIIII \end{bmatrix}$		Angular medium to coarse-grained slightly feldspathic sandstone with some chert, microquartzite, micropegmatite grains. Many dark pyritic inclusions in quartz grains, which are partly overgrown and welded; cement is clayey chloritic and dolomitic.  Pockets, lenses and laminations of dark pyritic chloritic shale with mica and carbonaceous matter.	stones and shale with manner. Ab	M M	
9600 9700				9600 - 9700 -		<b>=</b>	Angular medium to coarse-grained feldspathic      Dark pyritic clayey chloritic siltstones with mica carbonaceous matter.     Minor brownish sandy siderite.	1 <	9	600 700 700 700 700 700 700 700 700 700			Dark fissile fine sandy siltstone with abundant finely	pyritic chloritic micaceous silts road, well differentiated cyclical	-	
9900				9800		3   1   1   1   1   1   1   1   1   1	Minor angular medium to coarse-grained for Dark pyritic clayey chloritic siltstones with it carbonaceous matter.  Minor brownish sandy, chloritic siderite.		98 98 9	333 32 333 900 –	IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII		Dark rissile fine sandy sinsibile will about all finely divided pyrite and chlorite, mica and carbonaceous matter flakes.  Angular fine to medium-grained feldspathic sandstone with chloritic elements and lithic grains; pyritic chloritic micaceous matrix.  Burrowing and churning are important together with purely sedimentary structures such as: convolute laminations, scour and fill, cross bedding, microdiapirisation.  (Well bottoms in dark argillaceous micaceous siltstone, with subconchoidal fracturing, and representing part of a cycle as described above).	ark argillaceous Iternating in a bi		
		ECORD 1964/178	т.с	). 1004 <b>4</b>	(driller)	dg dg						* The memb	terms sandstones and siltstones in these places cover all the places cov		y: G.J.VEF	ENBACH LEP. RBURG LEP. PTEMBER, 1964