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A PETROLOGICAL STUDY OF THE SEDIMENTS FROM FROME-BROKEN HILL EUMERALLA No. 1 WELL, OTWAY BASIN, VICTORIA.

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K.J. EDWORTHY

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ABSTRACT

The relatively large thickness of the Eumeralla No. 1. sediments compared with those of nearby Pretty Hill No. 1 well, (Edworthy, 1964) appears to have been the result of movement of an E-W normal fault with southerly downthrow (south of Pretty Hill No. 1. and north of Eumeralla No. 1.) during pre-Upper Cretaceous times. Unit P represents an interdigitation of unit M sediments, with sediments showing resemblance to unit R (protoquartzitic sandstone described from Pretty Hill No. 1. well) and unit M (Otway Group equivalent).

Unit M is a uniform succession of volcanic sandstones, subgraywackes, chloritic siltstones and claystones.

Unit Bc is developed (160 feet); unit Dd is present and unit Gb is of small thickness. No evidence for unit Gh was discovered. The unconformity between unit M and the Upper Cretaceous present in much of the basin was not recognised.

In the absence of other criteria, the cementing media of unit M have been closely studied in an effort to establish subdivisions. Chloritic, kaolinitic clay, and zeolitic types of cement were observed, the zonation of the various types of cement in the sequence bearing similarity to those established in Geltwood Beach No. 1 and Heathfield No. 1. Authigenic sphene occurs in the deepest part of the sequence, (below 9,800 feet).

Some porous and permeable horizons exist above 6,000 feet in unit M, and also in unit P. Porosity is high and permeability is generally nil throughout the Lower Cretaceous. Primary porosity is infilled with products of diagenesis in many cases especially below 6,500 feet (see Fig. 1.)

INTRODUCTION

The Eumeralla No.1 well was drilled for Frome-Broken Hill Pty Ltd, approximately 10 miles west of the Pretty Hill No.1 well, and approximately 8 miles east of Tyrendarra. Details of the well, and its location are given below.

Location. - Latitude 38⁰12'43" S. Longitude 141°56'01" E.

Reference on 1 mile military map of Heywood: 895885 1:250,000 sheet. Portland No.J.54-11

Total depth = 10,308 feet.

Elevation Ground level - 154 feet A.S.L. Datum level (R.T.) - 167 feet A.S.L.

The cost of the drilling operation was subsidised under the Petroleum Search Subsidy Act, 1959-61.

Samples of all cuttings collected, and approximately 14% of cores taken, were available for examination, and thin-sections were made where considered necessary.

The composite-log and the well-completion report (F.-BH., 1963) were the principal references used in studying the well.

The two main purposes of the study were,

- (i) To investigate further, the petroleum possibilities of the Tyrendarra embayment; and
- (ii) advancement in the work of compiling a sedimentary history of the Otway Basin.

Some important differences from the sequence intersected in Pretty Hill No.1 Well were encountered.

Unit P

The upper boundary of the unit has been placed at 9,110 feet. Five intervals of high resistivity and marked S.P. deflection occur within the interval, and these mark the positions of the coarsest sandstones. The resistivity of the whole sequence is relatively high.

Cuttings are of hard, light to medium-grey sandstones and siltstones; the coarsest sandstones are v. light grey. Cores 22 to 25 were taken within the unit, and all cores except core 23 (9767-69 ft.) show small scale cross-bedding and some scouring. Cores 24 and 25 (9881-83 ft, 10300-02 ft.) show some penecontemporaneous deformation structures, and core 23 shows faint root traces. Most samples are thinly-bedded and all are carbonaceous to some degree, the carbon being finely disseminated or in fine lenses and interlaminae. Dip is uneven and of low angle (less than 20°). Almost vertical fracturing is present in most core samples.

In Pretty Hill No. 1 well, the basal sandstone (unit R) was found to possess the following properties:

- (i) conspicuous garnet,
- (ii) the feldspar fraction contains over 50% microcline, and plagioclase is more or absent,
- (iii) poor sorting and maximum grain size of up to 2mm.,
- (iv) bedding features produced in an environment of relatively high energy,
 - (v) quartz and metaquartzite grains are dominant and labile lithic grains are rare.

The above features are clearly represented toward the base of the Eumeralla well section. Initiation of these trends is suspected to occur at a slightly higher horizon than 9110 feet but sampling is not sufficiently adequate to define the upper boundary or the unit more precisely.

Thin-section studies reveal that the rocks of unit P are hybrid types which exhibit features of both units R and M. For instance, a certain amount of volcanic rock grains and abundant biotite flakes, typical of unit M, are present in the sections examined, and other unit R characteristics assert themselves strongly enough throughout to make the affinities of the unit unmistakeable. The sandstones are generally angular to subrounded, fine to coarse-grained, poorly sorted subgraywackes* and volcanic sandstones*. Quartz together with metaquartzite and chert varies from 5% to 45% of the total rock. Lithic grains vary between 10% and 70% in abundance; these are dominantly of volcanic origin and vitreous (?)rhyolitic, or tuffaceous (?)dacitic or andesitic and other rarer types. A fragment of radiolarite was found in the thin section from cuttings between 10,040-50 feet, and a (?)variolitic basalt grain in the thin-section of cuttings from between 9170-200 feet. Feldspar may constitute up to 30%, chiefly untwinned feldspar and sodic plagicclase, but also conspicuous microcline.

The argillaceous rocks are abundantly chloritic** and illitic** and show no clear differences from those of Unit M.

Pink garnet is particularly abundant (up to 3%) in rocks which show the most pronounced unit R characteristics. Zircon and epidote also appear as detrital grains.

A variety of diagenetic changes have occurred in unit P and there is a corresponding variety of cementing media. These are set out below -

- (i) Chlorite
- (ii) Zeolite
- (iii) Kaolinitic clay
 - (iv) Calcite
 - (v) Sphene
- (vi) Leucoxene

^{*} The above terms "subgraywacke" and "volcanic sandstone" which are used throughout are those defined by Pettijohn (1957) and Williams, Turner & Gilbert (1955) respectively.

^{**} The terms "chloritic" and "illitic" are used in a general sense and are not intended to be specific.

Chlorite occurs throughout unit P in Eumeralla No. 1 either as a cement or as an alteration product of the lithic grains. In many cases the chlorite, which varies from green to brown in colour, coats the grains and in some cases shows "chevaux de frises"* form. In the finer-grained sandstones and siltstones the chlorite appears to be amorphous or finely crystalline, perhaps replacing a primary matrix. Brown chlorite occurs as cement in thin-sections at 9,700 -10 feet and 10,220-30 feet.

Zeolite which is very abundant as a cementing medium throughout unit P, bears an ophitic** relationship to the clastic grains and greatly reduces any primary porosity. The zeolite pore-filling is commonly surrounded by "chevaux de frises" chlorite. Feldspars are extensively replaced by the zeolite. The zeolite is uniaxial negative, colourless, and shows good cleavage in one direction.

Kaolinitic clay mineral occurs in samples thin-sectioned from 9,100 - 200 feet, and 9,300 -400 feet, replacing both interstitial matter and detrital grains.

Calcite occurs in almost all sections examined and may exist as either very small patches, or up to 60% of the rock, replacing both feldspars and many labile lithic grains as well as interstitial material, whether cement or matrix.

Below 9,700 feet, a light brown, slightly pleochroic mineral occurs in pore spaces and replacing detrital grains. The mineral which has high relief and high birefringence, amounts to approximately 5% in many cases (e.g. cuttings thin section, 9,870 - 80 feet), and has been tentatively identified as sphene. It is clearly authigenic in origin.

Leucoxene, easily visible in reflected light appears as an alteration product of many of the volcanic grains. It appears as a fine white powder distributed over the iron-rich grains, and is very common.

The fractures observed in cores taken in unit P (see page 1) have no effect on the values of porosity and permeability obtained by the Petroleum Technology Section (see Appendices 2 and 3). The presence of fracturing however suggests the possibility that fracture porosity may be effective elsewhere in the basin.

The coarse grained intervals of unit P, which show greatest affinity to unit R of the Pretty Hill No. 1 well produce clear deflections in the S.P. curve. Core 24 is an example of this lithology, which shows relatively good porosity and permeability (see Appendices 2 and 3; also Fig. 1). The intervals appear to merit

^{*}The term "chevaux de frises" used in the text describes the habit of the chlorite coating clastic grains; "...a radiating halo formed by fine, green platelike and acicular crystals of chlorite...." (Carozzi, 1960).

^{**}The relation between the zeolite cement and the clastic grains is most akin to that between pyroxene and plagioclase in an igneous rock of ophitic texture.

further study as possible stratigraphic traps, since they most probably thin-out and disappear to the west of Eumeralla No. 1. No drill-stem tests were made below 8700 feet.

The microfossils of the sequence provide evidence that the well bottoms in Lower Cretaceous sediments (i.e. the association of <u>Cicatricosisporites dorogensis</u> and <u>Aequitriradites verrucosus</u> in core 25, Evans, 1963) Evans also points out that core 20 (7200-14 feet) in Pretty Hill No. 1, (i.e. unit R) contains a possible Upper Jurassic assemblage which could be as old or older than the assemblage at the bottom of Eumeralla No. 1.

Unit M

Argillaceous rocks are dominant in this unit. Sandstones contain much volcanic material, and some are volcanic sandstones; sandstones of subgraywacke type are however most abundant. Subdivision based on cementing media, established from thin-section study, is supplemented by the electric logs in the subdivision made below.

Interval 9,110 - 8,400 feet The interval is characterised by uniform S.P. and high to very high resistivity with numerous peaks, which are most conspicuous between 8,600 and 8,800 feet.

Argillaceous rocks predominate over poorly sorted, very fine to medium-grained volcanic sandstones, and several coal horizons occur. In cuttings samples, the lithology is dark grey, light grey or slightly greenish grey. Coal is most abundant in cuttings between 8,500 - 8,600 feet and 8,700 - 8,800 feet.

Cores 20 (8,459 - 65 feet) and 21 (8,914 - 24 feet) were taken from within the interval; these are of grey, and greenish grey sandstones, showing fine lamination, abundant flakes and lenses of carbonaceous material, and small-scale cross-bedding. Broken and deformed siltstone laminae, (Core 20, 8,461 - 63 feet), mud pellets (Core 21, 8,914 - 16 feet), and much penecontemporaneous deformation (Core 21, 8,918 - 20 feet) is visible. Both cores contain several thin calcareous horizons.

Illite, kaolinitic clay and abundant chloritic material are the chief constituents of the argillaceous rocks, with patches of '(?) zeolite. Zeolite which is present in the arenacous rocks may exist in a cryptocrystalline state throughout the argillaceous rocks. Carbonaceous flakes are also abundant.

The sandstones are poorly-sorted, angular to subrounded very fine to medium-grained, and contain up to 65% volcanic rock fragments. Feldspar (up to 25%) is commonly more abundant than quartz (up to 20%).

(?) Dacitic and (?) andesitic fragments, tuffaceous rocks, devitrified glass, very minor metaquartzitic grains and some (?) chert constitute the lithic grains. The feldspar fraction is of sodic plagioclase, orthoclase, and very minor microcline; grains are commonly angular and in some cases euhedral, and there is generally some calcitization. Quartz is very angular and some rare grains have iron-oxide coatings. Most of the thin-sections examined are of volcanic sandstones; some very fine-grained sandstones with more than 15% matrix are more aptly termed lithic graywackes.

Biotite and white mica (either bleached biotite or muscovite flakes) are abundant, especially in carbonaceous laminae. Epidote, zircon, (?) apatite, garnet and opaque minerals also occur as heavy minerals.

Porosity is very low in the cores (between 2 and 3%) and permeability nil. Drill-stem tests 3 and 4 were made between 8,653 and 8,718 feet, but in both cases, the packer failed to hold. At several horizons gas was detected in the mud, but on each occasion the gas appears to have been associated with coal stringers.

Cementation and palaeontology are discussed on pages 7 - 9.

Interval 8,400 - 6,000 feet

The top of the zone of conspicuous resistivity maxima is regarded as the lower boundary of the interval. The top boundary is marked by the appearance of abundant zeolite. Resistivity logs show a zone of maxima between 6,650 - 7,300 (0-200 sensitivity). At the top of the above interval, there are several peaks in the S.P. curve, relative to the shale base-line.

Cuttings are of grey, greenish grey, and brown siltstones and claystones, and greenish grey sandstones. Sandstones in the cuttings are most abundant between 6,700 - 7,000 feet. Coal is present in cuttings between 7,150 and 7,400 feet and at 8,000 and 8,110 feet. A fragment of sandstone rich in pink garnet was found in cuttings at 8,250 - 60 feet.

Cores 11 to 19 inclusive were taken within the interval and were of light to medium grey and greenish grey, very fine to medium-grained sandstones, and siltstones. Claystone pellets, and evidence of penecontemporaneous deformation was present in cores Nos. 11 - 14, 16 and 17 in the form of convolutions and microfaulting. Cross-bedding was observed in cores 11, 13, 14, 16 and 19 but in each case was on a small scale. Slight scouring was observed in core 16 (7,225 - 27 feet). All cores except core 11, show very fine interlaminae of carbonacecus material, and core 13 (6,252 - 54 feet) contains root traces.

The thin-section of core 15 (6,716 - 18 feet) is of a typical argillaceous siltstone of the interval. This is a dark grey chloritic, illitic carbonaceous siltstone containing abundant well preserved plant remains. Many of the silt-sized grains are identifiable as quartz or siliceous (?) volcanic grains. Trace amounts of amber were found.

Arenaceous rocks are almost exclusively volcanic sandstones typical of which is the cuttings thin-section at 6,410 - 20 feet. This is a greyish-green, moderately sorted angular to subrounded, fine to medium-grained volcanic sandstone. Quartz and feldspar contents are 10% and 15% respectively. Lithic material makes up 60% and is wholly volcanic, except for some phyllitic fragments. Epidote and zircon are the heavy minerals; muscovite and biotite flakes are abundant.

Quartz varies within the interval up to 15%, but is generally 10% or less. Feldspar, twinned and untwinned, varies between 7% and 35% (7,750 - 70 feet cuttings). Lithic grains are the same as those described from the lower interval.

Core analyses performed by the Bureau of Mineral Resources, (Petroleum Technology Section) reveal good porosities for cores 11 and 12, moderate porosities for cores 13 and 15, and generally negligible porosities for the remainder. The only sample to show any permeability was core 12 (6,242-44 feet) for which 2 md. was recorded. (See Appendices 2 and 3).

Chlorite, zeolite and kaolinitic clay cements are present in the interval as well as calcite, and are discussed more fully, together with the palaeontological data on pages 7 - 9.

Interval 6,000 - 3,108 feet

This interval is definable in terms of its relatively high proportion of sandstone lithology, also in terms of cementing media. Considering both criteria, the lower boundary has been placed at 6,000 feet. The upper boundary corresponds to a genetic change in the sediments and is well represented in cuttings and in electric logs.

Grey and greenish-grey sandstones make up about 30% of the thickness, the remainder being green, greenish-grey, grey and light brown siltstones and claystones. Some coal horizons occur.

In cuttings, the best cemented sandstones are found as rock fragments and the friable, less well-cemented varieties occur as loose sand. The loose sand lithology diminishes in amount toward the base of the interval and ceases to occur below 6,000 feet. Coal occurs in cuttings at the top of the interval between 3,108 feet and 3,570 feet and in very small quantities at other levels. Caved material largely from units Dd and Gf occurs in many of the cuttings within the upper part of the interval.

Cores 5 to 10 inclusive, were taken within the interval. All cores contain carbonaceous material, usually as very fine laminae. Cores 6 and 8 (3,802 - 12 feet and 4,796 - 800 feet) exhibit very fine lamination and abundant penecontemporaneous deformation structures (slight convolution, microfolds and faults). Slight cross-bedding was observed in Core 9 (5,299 - 302 feet) Core 10 (5,807 - 9 feet). Root traces are present in core 5 (3,311 - 13 feet) and abundant in core 10 (5,799 - 803 feet).

Argillaceous rocks throughout the interval are abundantly chloritic and illitic. Flakes of mica and carbonaceous matter are distributed throughout, and spores are present in the thin section of core 7 (4,287 - 89 feet). Only sandstones were thin-sectioned from the cuttings generally, since these reveal most detail. The sandstones are volcanic sandstones and some of the finest sandstones are lithic graywackes. Typically the sandstones are greenish-grey in colour, angular to subrounded, poorly sorted and very fine to medium-grained.

Much of the sandstone has been invaded by calcite which has replaced cement, infilled porosity and replaced labile grains, entirely changing the rock. The sandstones described below are those unaffected by calcitization (i.e. those most closely approximating the true sediment). Cuttings thin-section at 4,080 - 90 feet shows a typical volcanic sandstone containing approximately 75% volcanic grains. Quartz and metaquartzite, plus chert constitute approximately 7% and the feldspar, mostly twinned sodic plagioclase, slightly greater than 10%. Some grains are cemented at points of contact by pellicular chlorite (? syngenetic) around the grains.

Lithic grains are chiefly of acidic volcanic rocks, with a very small quantity of metaquartzite grains. Some volcanic rock grains contain abundant haematite, which may be the decomposition products of (?) mafic minerals. Plagioclase laths within such rock grains are calcic andesine or sodic labradorite. Other lithic grains, such as sphene and epidote bearing lithologies (3,160 - 210 feet, and 5,790 - 99 feet respectively) and cryptocrystalline zeolite grains, are relatively rare.

Feldspar is chiefly sodic plagioclase (approximately oligoclase composition) with minor orthoclase and zoned feldspar.

Abundant epidote and hornblende, with zircon, garnet and rare corundum (Core 8, 4,796 - 98 feet) are the heavy; minerals present. Biotite, muscovite and chlorite flakes usually accompanied by flakes of carbonaceous material, are constant components.

High porosities, and zero permeabilities, have generally been determined in core analyses (Appendix 3). The exception is Core 7 (4,295 - 97 feet) which possesses an average porosity of 29%, 'V' permeability of 20 md and 'H' permeability of 3 md. Core 5 (3,311 - 13 feet) which has the highest porosity (32%), possesses nil permeability.

Cementing media and diagenetic products are discussed below.

Cementing Media and Products of Diagenesis.

Several cementing media and diagenetic minerals are observed in unit M. Unless otherwise stated, the minerals described below are from samples with the most readily determinable composition.

By reference to the four minerals - chlorite, zeolite, kaolinitic clay, and calcite, it has been found possible to characterise the various intervals of Unit M, in conjunction with sandstone/siltstone ratios and E-lpg curves.

Chlorite (general usage)

Green chlorite is present in all sections examined, from units P and M; brown chlorite also occurs in cuttings from 3220-40 feet, 9700-10 feet, and 10220-30 feet.

Chlorite occurs as

- (i) a cement, either syngenetic, or diagenetic replacing primary matrix;
- and (ii) a constituent of lithic grains.

Interstitial chlorite is common in the fine grained sandstones. In the uppermost interval (6,000-3,108 feet), chlorite occurs as a pellicular cement and also as an apparent replacement mineral of a primary matrix. Sandstones containing pellicular cement are very friable and commonly occur as loose sands in cuttings. These loose sands become less abundant toward the base of the interval and cease to occur below 6,000 feet. A similar, but more indurated lithology, occur at widely spaced intervals below 6,000 feet.

The pellicular chlorite in these sandstones invariably shows "chevaux de frises" form (cuttings thin sections from 3160-210 feet, 6260-70 feet, 10,040-50 feet.)

Chlorite is also abundant as a constituent of the lithic grains; volcanic rock-types are often extensively chloritised. This feature of the lithic grains is one found throughout the unit.

The origin of the interstitial chlorite is not clear but it is evident that, in some cases at least, it is depositional, and it is concluded that the depositional medium was rich in iron magnesium and aluminium ions.

Zeolite

Zeolite also occurs throughout unit P but is largely confined to the horizons below 6,000 feet. Between 6,000 feet and 3,108 the zeolite occurs sporadically and is relatively rare. There appear to be two general forms of occurrence:

- (a) Between 6,000 and 3,108 feet zeolite occurs as small euhedra growing inwards from the sides of chlorite-lined pore spaces, (sometimes calcitelined). Examples occur in thin-section from 3390-410 feet, 3480-520 feet, and 4080-90 feet. In thin-section, this mineral resembles the zeolite found in core 7 (2928-40 feet.) of unit M in Pretty Hill No. 1.
- (b) Between 10,308 feet (T.D.) and 6,000 feet, zeolite is present as a diagenetic cement. The relation of the cement to the clastic grains is 'ophitic' (see foutnote page 3), the primary cement or matrix having been replaced to produce a continuous zeolite cement.

In such cases, the grains are generally also chlorite-coated. Examples are to be seen in cutting thin-sections from 6290-300 feet, and 9620-40 feet.

In some fine and v. fine-grained sandstones zeolite replaces lithic and feldspathic grains as well as the interstitial material and produces a fine, homogeneous texture. Such a texture is exemplified in cuttings thin-section at 7930-40 feet, in which the grain boundaries are blurred, and difficult to recognise.

In argillaceous rocks there is no definite evidence for the occurrence of zeolite but the texture of some samples in thinsection suggests its possible presence (core 25, 10302-05 feet). Zeolite also occurs in argillaceous rocks as grains which are palepink in colour and relatively rare. The zeolite appears to be cryptocrystalline. Other than the latter variety, all the zeolite identified in unit M is a uniaxial negative variety; it is colourless has very low firefringence and shows distinct cleavage in one direction.

Kaolinitic Clay

Kaolinitic clay appears at approximately the same horizon as the abundant zeolite, approximately 6,000 feet, and its last occurrence is at 9,400 feet. Good examples of this mineral exist in cuttings thin-sections from 7930-40 feet, and 7750-60 feet. In mode of occurrence, the mineral resembles kaolinite, and occurs as a mosaic-like mass, replacing feldspars and labile lithic grains as well as the interstitial material. Its birefringence is higher than that of pure kaolinite however.

The crystalline size of the mineral appears to be a maximum near 7700-8000 feet, judging from thin-section examinations.

Calcite

Calcite is clearly the latest mineral to form and all other cements and alteration products are replaced by it; in many cases calcite forms up to 60% of the total rock. The process of calcitization is seen in many stages of development in the thin-sections. Partial calcitization can be seen in a cuttings thin-section at 7150-60 feet. Labile grains are in many cases completely assimilated by the calcite such that the remaining clastic material, the chemically resistant residue, is almost entirely siliceous. Microfaunal evidence indicated that unit M is essentially "non-marine" and this fact together with much petrographic evidence tends to deny the possibility that the calcite is primary in origin.

Available evidence points to the conclusion that the calcite has been introduced at a late stage of diagenesis.

Leucoxene is present throughout as an alteration product of the iron-rich grains. Iron-pyrite occurs generally associated with calcite, in the upper part of the upper interval of unit M.

It is clear that there is a relationship between depth of burial and the degree and the nature of cementation, both from petrographic work and from the effective porosity figures.

In Fig. 1., the divergence of the porosity values from the "normal" shale, porosity/depth curve (Gussow, 1955) is clearly shown. The abundance of diagenetic cementing material is responsible for the intersection of the two trends between 6000 and 7000 feet. This feature is of importance in appraising the petroleum possibilities of unit M.

Stratigraphy.

Microfloral study (Evans, 1963) has shown that above core 8 (4796-814 feet) the Albian stage is present, and below core 19 (8143-156 feet), the Aptian is present. Between these cores the forms are of uncertain stratigraphic affinity.

Possible marine or brackish water conditions are indicated to have been the depositional environment of sediments between cores 5 and 10. Evans, (1963) regards the presence of the hystrichosphere Michrystridium sp. and the pterospermcpsid Cymatiosphaera sp. between cores 5 and 10 as possible indicators of such an environment. The remainder of the unit may be non-marine.

Unit Gf.

Unit Gf extends from 3108 feet to 2960 feet.
Lithologically and in the electric logs, the unit is distinctive.
Uniform S.P. and low resistivity characterises the entire interval.
The lithology is dark grey, compact and very glauconitic..
Cuttings do not appear until low in the interval and this is probably due to assimilation of the lithology by the drilling mud.

Glauconite pellets constitute up to 50% of the rock in a cuttings thin-section from 3140-50 feet (caved). Abundant carbonaceous material, chlorite flakes and angular quartz and metaquartzitic grains (silt to v.f. sand-sized), are also present. The pellets, which vary up to 0.5 mm. in diameter, and clastic fragments are set in a clayey, hydromicaceous matrix. Various stages of sideritisation are evident.

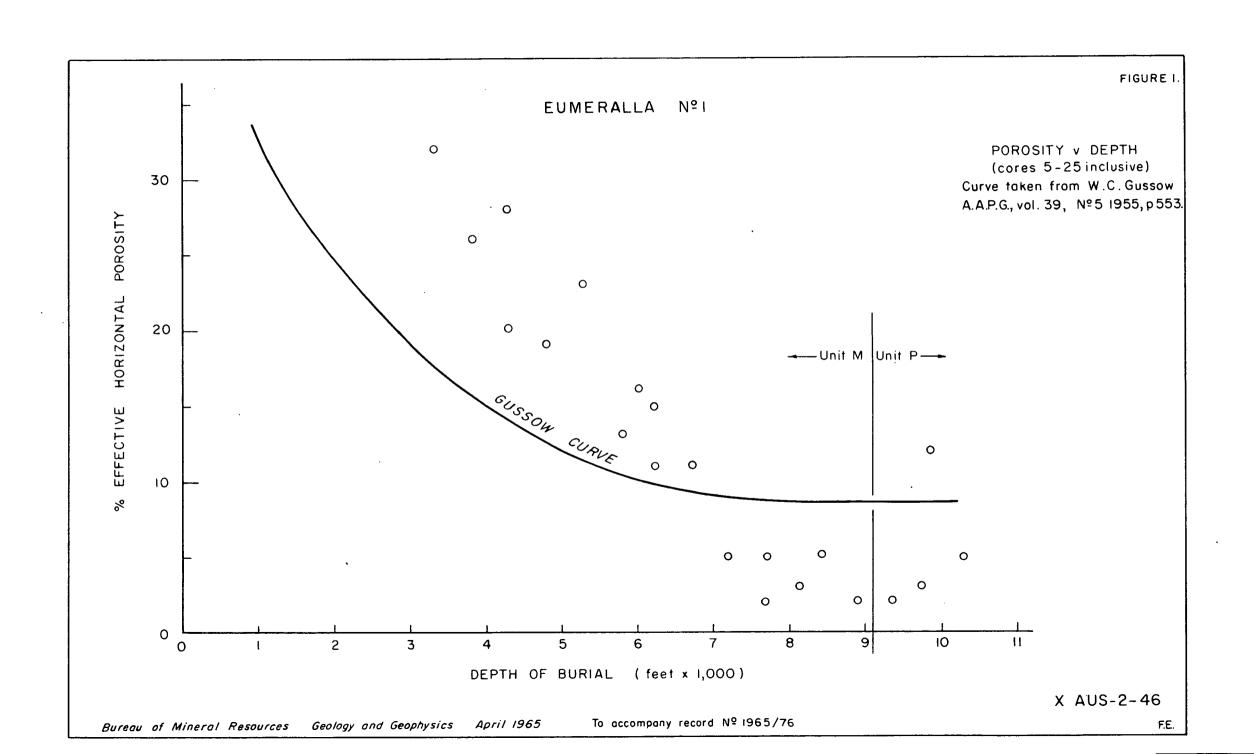
Fragments examined in thin-section exhibit very low porosity and permeability and no hydrocarbons have been detected. The chief interest of this unit probably lies in its ability to act as an impermeable cap-rock.

Absence of planktonic fauna and relative abundance of arenaceous forams has led Taylor (in F. - B.H., 1963 and 1964), to suggest that the depositional environment of the Belfast Mudstones was one of restricted water circulation. This agroes well with the depositional environment of unit Gf envisaged from a consideration of chemical and petrographic features. The depositional medium is considered to have been iron-rich, slightly alkaline and reducing, and of lowsalinity.

Unit Gd.

The interval is 200 feet in thickness extending from 2960 feet to 2760 feet, the upper limit being marked by a sharp decrease in the S.P. curve toward the shale base-line, and a resistivity minimum. The unit as a whole is characterised by thick intervals of uniform S.P. and resistivity, and some sharp high resistivity maxima. Examples of this are the S.P. curve between 2780 and 2760 feet, the resistivity curve between 2880 and 2850 feet, and the resistivity maximum at 2888 feet. Lithologically, the unit is characterised by the presence of sandy carbonate rocks, subarkosic sandstones and pyritic, sideritic siltstones. These rock types are present in cuttings though generally subordinate to caved material. Core 4 was taken from the interval 2849 - 2835 feet.

Between 2839 and 2835 feet, the lithology is greenish-grey compact, angular to rounded (mostly subangular), fine to very coarse-grained, poorly sorted calcareous subarkose (Pettijohn, 1957), containing abundant pellets of (?) glauconite and chlorite. The quartz and metaquartzite makes up between 40% and 50% of the rock. Feldspar (sodic plagicclase and untwinned feldspar) makes up approximately 5%. Pellets of (?) glauconite and chlorite constitute up to 10%, and in hand samples bedding is defined by the variation in concentration of the pellets. Calcite, the cementing medium, appears to have replaced some of the pellets.



The cement itself is replaced by rhombohedral or spheroidal siderite which grows outward from grain surfaces and in the thinsection of a sample from 2839-41 feet, completely replaces the calcite. In this sample many of the detrital grains are chlorite-coated. Samples from which thin-sections were taken correspond to a resistivity maximum and the samples corresponding most closely to the maximum are those from the lower part of the core. These are friable, dark greenish brown, angular to subangular, very fine to medium-grained, moderately sorted subarkoses. Abundant (?) glauconite and chlorite pellets, and muscovite flakes are present and the matrix is argillaceous. Trace quantities of coal grains, detrital collophane, glaucophane, apatite and garnet are also present.

Judging from the microlog, the latter lithology is predominant between 2940 feet and 2820 feet with interbedded carbonate-cemented horizons.

An Upper Cretaceous age for core 4 (2835-37 feet) is put forward by Douglas (Appendix 2 in Fain, 1963), on the basis of Deflandrea cretacea being present. From evidence obtained from side-wall cores, Taylor (1962) states that the derived arenaceous foraminifera are of Cretaceous age.

In spite of high compositional maturity, sorting is generally poor and grains angular or subangular. Salinity appears to have fluctuated between brackish water and freshwater conditions and this is reflected in the incidence of carbonate-cemented horizons. Marine influence is therefore thought to have been slight and sporadic; unit Gd is considered to mark the end of a transgression and the beginning of a regression.

The petroleum possibilities are confined to consideration of reservoir characteristics. Most of the unit Gd sediments appear to have moderate to good porosity and permeability. Core analysis of the core sample from 2841 - 39 feet reveals that it has porosity of 18% (H) and permeability of 100 md. There is little difference in the thickness of this unit between Pretty Hill No. 1 and Eumeralla No. 1 wells.

Unit Gb.

The unit is relatively thinly developed and extends from 2760 feet to 2660 feet. Comparison of the equivalent log interval of the Pretty Hill No. 1 well enables the boundaries to be placed. The electrical characteristics of the unit shows little similarity to unit Gb of Pretty Hill, and the presence of the unit is postulated chiefly on the evidence of its recognisable limits; at 2660 feet, the base of unit Dd, and at 2760 feet the top of unit Gd.

Cuttings were badly contaminated with caved material, particularly from unit Db, and from unit Dd, and very little evidence of the lithology, as shown in Pretty Hill No. 1, was found. The cuttings lithology was angular to subrounded, fine to v. coarse-grained, moderately sorted loose quartz sand. A notable proportion (between 10% and 30%) of the grains show extreme angularity, though no grain-surface frosting was detected. Two sharp resistivity maxima occur in unit Gb in Pretty Hill No. 1

well but only one is definitely identified in Eumeralla No. 1 well. This peak is thought to coincide with a very thin coal horizon.

The state of the cuttings indicates that cementation was poor. No definite sign of cement was found in cuttings but the electric logs indicate that clay material was present reducing porosity to a variable extent.

The unit consists, most probably, of poorly consolidated, angular, coarse-grained quartzose sandstones and argillaceous beds, with lithological gradations between the two. Reservoir properties are probably of a low order.

Unit Dd.

Extending from 2660 feet to 2530 feet, the unit is of closely similar thickness to unit Dd of the Pretty Hill No. 1 well. Comparison of the resistivity, S.P. and microcaliper logs with those of the above well reveals good correlation.

Cuttings contain large quantities of caved material from unit Db, and the true lithology is in mahy cases subordinate. No cores were taken in the interval.

The chief lithologies are sandy siderite, sideritecemented limonite colites (sandy in some cases and a few samples
bear calcite), and siderite rock with (?) glauconite and chlorite
pellets. Thin-section examination of the above lithologies shows
that the sand fraction is almost exclusively of quartz or metaquartzite (with rare untwinned feldspar). Grains are angular, very
fine to very coarse-grained and generally poorly sorted. Ooliths
and pellets present a varied aspect.

The nuclei of many coliths are angular quartz grains, some of which show corrosion by the coating. The remainder have a green or brown chloritic pellet as nucleus or a limonite pellet. Coatings are all of limonite (cuttings thin-section from between 2610-60 feet) and concentric lamination is preserved. It is clear that recrystallisation or replacement of the coating has taken place and no evidence of initial composition was discovered, such as a partially replaced coating. A second stage of replacement has occurred in parts, involving the coatings and the siderite cement; the outermost layers of the coating and in some cases the whole coating, have been replaced by siderite. Pellets are either of chlorite (brown and/or green) or limonite. These also show a good deal of replacement by siderite cement.

Siderite appears to be the dominant cementing medium in cuttings with subordinate calcite in some fragments. Chlorite cement is present in small quantity in the cuttings thin-section from 2610-60 feet which also contains small patches of siderite in an early stage of development.

All these cementing media were present in the Pretty Hill No. 1 well (Edworthy 1964) but the alteration appears to be more advanced in Eumeralla No. 1.

Unit Dd is considered to lie unconformably on unit Gb. The nature of the unconformity is not apparent, because there is probably little, if any angular discordance. These deposits are thought to refollow the culmination of a phase of regression. Very little terrigenous material was supplied to the iron-rich, high-energy environment of deposition and the deposition was mainly chemical in nature, in this part of the basin.

The age of unit Dd is tentatively considered as of Palaeocene age.

The petroleum possibilities of this unit are slight; rocks observed in thin-section and with binocular microscope are hard, chemically cemented lithologies with very low porosity.

Unit Db.

The unit which extends from 2530 feet to 1270 feet is of relatively uniform lithology and contains numerous thin silty intervals. Carbonate-cemented horizons occur near the base of the unit (Between 2300-2400 feet), and thin coal seams occur near the top of the unit (above 1700 feet). The uniformity of the sequence is best shown in the electric logs; the microcaliper log shows some irregularity between 1890-2000 feet where a thick mud cake is formed. One core was taken between 2121-2109 feet (Core 3), but was completely disaggregated, and no trace of the comenting medium was found. Caved material from above 1270 feet is abundant.

Grey, friable, poorly cemented, angular to subrounded (mostly subrounded), fine-grained to granule sized, moderately sorted quartz sandstone is the dominant lithology. Grains are characteristically well polished. Pyrite and muscovite are abundant, and tourmaline and amber are common accessories.

On the basis of the interbedded lithologies, a subdivision of unit Db into two sub-units is possible.

Sub-unit Db (2530 - 2400 feet)

Carbonate-cemented horizons occur at the bottom and top of the sub-unit. These are fine-grained, calcite cemented sandstones and sandy siderite rock horizons; the sideritic lithology appears to be most abundant (cuttings thin-sections, 2410-60 feet, 2420-2500 feet). The sand fraction of the rocks are angular quartz and metaquartzite grains, and rare feldspar. Pyrite is common.

Dark, micaceous siltstone occurs between 2430-60 feet. The dominant lithology is the poorly cemented quartz sandstone described as characteristic for the unit as a whole.

Sub-Unit Db₁

Interval 2400-1700 feet. The sequence is a monotonous series of poorly cemented quartz sandstones (as described above). A change in the mud-cake thickness, perhaps reflecting increased formation permeability, occurs between approximately 2000-1890 feet, but

the electric logs show no appreciable changes, neither are there any lithological changes observed in the cuttings. Core 3, taken between 2121 - 2109 feet, was studied and although no cemented portion was found, thin-sections were made of the grains. Quartz, generally stressed, and metaquartzite grains, made up the core, along with rare untwinned feldspar.

Siltstones occur as a very subordinate lithology and these are dark brown, micaceous and pyritic. Thin coal flakes are often found in the siltstones.

Interval 1700 - 1270. The electric logs indicate little or no change in the general lithology; resistivity is high with numerous minima and the upper limit of unit Db, is well marked. No cores were taken from the interval. Up to 90% caved material is present in the cuttings (between 1290 - 1330 feet), mostly marl from unit Bb. Dark, carbonaceous, pyritic, micaceous siltstone forms up to 30% of the cuttings. Coal fragments occur in samples 1320-30 feet, 1450-70 feet, 1630-70 feet.

Loose quartz sands dominate the lithology of the interval. These are subangular to rounded, moderately sorted and fine-grained to granule-sized sandstones. As in the lower intervals of the unit, there is no trace of the cementing medium (or matrix), and the sandstone lithology is completely disaggregated in cuttings samples. It would appear that the interstitial material was clay, and was completely removed in drilling. Pyrites and muscovite flakes are abundant, and tourmaline is a common heavy mineral.

No faunas were found in core 3 (2121-109 feet). Taylor (1963) has found Globigerina linaperta in cuttings below 1400 feet and regards this part of the sequence to be Eccene age; he has found the planktonic form, Globorotalia chapmani, characteristic of the Victorian Palaeccene, to be present in cuttings at 2000 feet.

The depositional environment of these deposits is difficult to interpret from cuttings alone. The information available suggests that it was of the paralic type, perhaps deltaic.

No probable source rocks were found in unit Db. The reservoir characteristics are not known but it is likely that they are not good, if the postulated argillaceous matrix is present.

Unit Bc.

The top of the unit (at approximately 1110 feet), is well marked lithologically but the change in electrical properties is gradational. In the resistivity logs, the base of the unit is well marked at 1270 feet and the lithology indicates that the contact between units Bc and Db is unconformable. Within unit Bc, the S.P. curve has a more negative value than that possessed by unit Bb rocks.

Incursion of arenaceous sediments is evident from the cuttings and a thin section of cuttings between 1100 - 1150 feet has been taken as well as one of core 2 (1160 - 72 feet). Examples of the lithology are given below. A marly, dolomitic, angular to subangular, moderately sorted, fine to medium-grained sandstone occurs at the top of the unit, and it contains pellets of glauconite.

As in the remainder of the unit, the clastic grains are mainly of quartz with rare feldspar (untwinned, or microcline). Grains from cuttings throughout the interval and those studied in thinsection of core 2 are limonite coated. Foraminifera, gastropod and pelecypod fragments, as well as organic matter is present in the core. The cement is rhombohedral siderite. Grains up to granule-size are present in cuttings from the base of the interval, and these are generally well rounded.

The general lithology of unit Bc is typical of the Nelson formation as found elsewhere.

The base of unit Bc is tentatively considered as the base of the Oligocene. Turbulent, shallow marine brackish water conditions are envisaged as the depositional environment for these sediments. Supply of terrigenous material and chemical precipitation are of the same order of magnitude. The porosity of core 2 is high and there is moderate permeability.

Unit Bb.

Interval 1110-980 feet Numerous resistivity peaks occur over this interval and appear to correspond to thin limestone horizons in marl. Rare limonite pellets are present in the limestone. The marl lithology is buff-coloured and richly fossiliferous, and at the base of the interval becomes slightly sandy. No cores were taken and cuttings contain abundant caved material. Gastropoda, foraminifera, polyzoa and echinoid fragments are abundant.

Interval 980 - 550 feet This is a succession of soft, grey, fossiliferous, slightly glauconitic marks. In cuttings, the argillaceous materials has been mostly removed and the abundant faunal remains are concentrated.

No marl lithology is recovered from the cuttings until 50 feet below its upper boundary, and caved material from above persists throughout.

Upper and lower limits of the interval are well marked in the electric logs.

The fauna is rich and varied, because of the caving, but an interesting point is the incidence of gastropod remains with the incidence of argillaceous material. (i.e. gastropods are confined to this interval). Gastropods are also noticeably more abundant in the lower part of the interval.

Core 1 (941-956 feet) was taken within the interval.

oole ((34,-350 leet) was taken within the interval.

Interval 550-10 feet. The resistivity curve shows numerous high maxima and the overall resistivity is high. Several marly horizons occur in the lower half of the interval but the dominant lithology is light grey porous biocalcarenite, made up chiefly of polyzoa and (7) scaphopod debris. The buff colour of the topmost 70 feet of cuttings is probably due to weathering.

Unit Bb sediments are open-shelf marine deposits.

A gradual decrease in the amount of terrigenous material and increase in the amount of carbonate is clearly evident from the base of unit Bc to the topmost horizons of unit Bb, probably a function of distance from the shore-line.

Conclusion

The greenish grey volcanic sandstones, sitstones and claystones of unit M show remarkable uniformity of lithology from approximately 9110 feet to the top (3108 feet). Some features characteristic of the unit 'R' lithology of Pretty Hill No. 1 well are recognisable in certain strata below 9110 feet in unit P. Units J and Gh (Waarre Fm. and 'Flaxman's Beds' respectively) of other parts of the Otway Basin, are not present. The Upper Cretaceous units (Gf, Gd and Gb) are lithologically well characterised. Unit Dd is overlaix by 1260 feet of fine-grained to granule-sized orthoquart-zitic sandstone (unit Db). The limonitic carbonate-cemented sandstones and marls of unit Bc and the limestones and marls of unit Bb make up approximately 1270 feet.

Several horizons in unit P contain abundant metaquartzite grains at the expense of the acidic to intermediate volcanic rock fragments which are so abundant in typical unit M 'Volcanic sandstones. These same horizons contain conspicuous garnet and microcline, and are of medium to coarse-grained, and poorly sorted sandstones which are probably the lithofacies equivalent of unit R of Pretty Hill No. 1

Material from a regionally metamorphosed source area and from an acid to intermediate volcanic source area were carried into the basin during unit P times. Slight and fluctuating supply from the metamorphic source virtually ceased after unit P times. Upper Cretaceous and Tertiary sediments show greater maturity than those of units P and M.

Unit M shows no important change in composition of the clastic material. The abundant lithic material, volcanic in part, is confined to the Lower Cretaceous sediments (Units M and P). Twinned sodic plagioclase (Ab7 An3 - Ab9 An1) is also confined to units M and P. Hornblende is a conspicuous heavy mineral between 6000 feet and the top of unit M.

In the Lower Cretaceous sediments, subdivision has been performed on the basis of differences of cementing media chlorite, kaolinitic clay and zeolite. Authigenic sphene occurs in some unit P sediments. Calcite occurs at numerous horizons, and may replace other cementing media.

Non-marine conditions of deposition appear to have changed in upper unit M times from non-marine to marine. The supply of terrigenous material fell abruptly at the beginning of unit Gf times and quiet, (?) shallow brackish water conditions gave way to slightly more saline conditions in lower unit Gd times. A regression followed which reached its limit before unit Dd times and unit Dd is believed to rest unconformably on unit Gb with possible angularity. Carbonate rocks in lowest unit Db times indicate brief renewal of marine conditions, but the remainder of the sediments are of a paralic aspect and thin coal seams are present at the top of the unit. Limonitic sandstones and carbonate rocks of unit Bc unconformably overly unit Db and true marine conditions become established.

Fluorescence of cuttings and cores (see App. 2) was reported at several horizons within units P and M. Drill stem tests Nos. 1 and 2 Show that these horizons are impermeable.

at numerous horizons chiefly below 3300 feet, but there was a small mud-gas detector deflection between 2130-60 feet. These gas occurrences were all related to cral horizons.

Though porosity was generally high to very high in units P and M, permeability was determined as nil for all cores except Nos. 7, 12 and 24 (see App. I and II), and cuttings examination revealed no horizons with good reservoir characteristics. Unit Gd and Bc possess horizons of more promising reservoir characteristics, having good porosity and moderate permeability.

Palaeontological evidence below unit Gf is sparse. Evidence suggests that core 20 of Pretty Hill No. 1 Well is possibly of Jurassic age and is as old or older than the base of the Eumeralla section. Douglas (1963) regards the interval between cores 4 and 5 (2849-3311 feet) to be non-marine, pre-Upper Cretaceous in part. The lower boundary of the Upper Cretaceous has been placed at 3108 feet corresponding to the top of unit M. Unit Dd has been considered as of Palaeocene age although the Palaeocene appears to extend up to 2000 feet at least (Taylor, 1963).

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Appendix 1

Cuttings Description

10 - 80 feet.	Medium buff coloured (10YR 7/6)* biocalcarenite; abundant foraminifera, polyozoa and (?) scaphopoda.
80' - 600 feet.	Grey (5Y6-5/2) friable, porous, slightly glauconitic biocalcarenite with minor caved, buff biocalcarenite.
600 - 1020 feet.	Light olive to yellowish grey (5Y 6/1 to 5Y 8/1) fossiliferous, glanconitic marl, with subordinate biocalcarenite dying out towards the base of the interval.
1020 - 1110 feet.	Grey fossiliferous, glauconitic marl and grey biocalcarenite.
1110 - 1140 feet.	Well sorted, angular, v. fine to medium grained loose quartz sand, and fossiliferous, glauconitic marl. Lt. brown, carbonate-cemented quartz sandstone and grey fossiliferous. Limestone occur at the base of interval, (1130-40 feet)
1140 - 50 feet.	Lt. grey fossiliferous limestone
1150 - 1200 feet.	Lt. brown, well-sorted carbonate cemented sandstone and minor ltgrey fossiliferous limestone.
1200 - 1320 feet.	Grey fossiliferous marl and loose quartz sand, some iron-stained, containing limonite pellets.
1320 - 1450 feet.	Subangular to subrounded, moderately sorted, coarse grained to granule-Laed loose quartz sand, and fossiliferous marl (caved). Sand contains abundant muscovite flakes, and pyrite. Dark micaceous carbonaceous siltstone makes up 25% of samples.
1450 - 70 feet.	As above, except that siltstone contains coaly tenticles.
1470 - 1630 feet	As 1320 - 1450 feet, with siltstone forming up to 30%
1630 - 70 feet	As 1320 - 1450, except siltstone contains coaly inticles.
1670 - 1870 feet	As 1320 - 1450 feet.
1870 - 2420 feet	Subangular to subrounded, moderately sorted, fine to granule-sized loose quartz sand. Pink and grey (?) chert or metaquartzite grains, pyrite and abundant muscovite flakes. Dark brown carbonaceous, micaceous siltstone and fossiliferous marl occur in small amount at intervals.
2420 - 2560 feet	As 1870-2420 feet; incidence of moderately sorted, fine-grained sandstone with sideritic cement (5%)

^{*} Geol. Soc. Amer. 1963 (Munsell colour chart.)

2560 - 2660 feet.

Sandstone with abundant limonite pellets and limonite coated quartz grains, cemented by siderite. Slightly pyritic. Loose quartz sand, as 2420-2560, containing limonite pellets and abundant pyrite.

2660 - 2710 feet

Silty, siderite- cemented sandstone containing limonite coliths and pellets, loose quartz sand (containing an increased amount of fine material). First occurrence of lt.-brown, fine to medium - grained calcite comented sandstone

2710 - 2850 feet (No samples 2835-50 feet) As 2420-2560, but no caved marl. Sideritic lithology becomes silty toward the base of the interval.

2850 - 2890 feet

Dark brown pyritic, (?) glauconitic siltstone, angular to subrounded, coarse-grained loose quartz sand (containing abundant pyrite) and minor siderite cemented sandstone.

2890 - 3020 feet

Carbonate cemented sandstones, silty in part. Siderite dominant as cementing medium. Angular to subrounded, coarse-grained loose quartz sand constitutes the remainder of the samples, apart from minor caved marl.

3020 - 50 feet.

Angular to subrounded fine-grained loose quartz sand, with coarse, caved grains. Minor caved marl.

3050 - 70 feet

As 2890 - 3020 feet, except for different grain size of loose sand.

3070 - 3170 feet

Loose quartz sand (as 3020 - 50 feet) and dark, V. glauconitic pyritic siltstone. Glauconite pellets constitute up to 30% of the samples.

3170 - 80 feet

As above (3070 - 3170 feet), but containing in addition, 10% calcite cemented lithic sandstone and approximately the same quantity of pale green claystone, with plant remains.

3180 - 3330 feet. (No sample, 3310-20 feet.)

Angular to subrounded, fine to medium grained loose quartz sand and pale green or grey claystonesand siltstones. Minor dark grey glauconitic siltstone.

3330 - 70 feet

As 3180 - 3330 ft. with up to 15% siderite and and sandy siderite rock

3370 - 90 feet

As 3180 - 3330 feet.

3390 - 3820 feet

As 3180 - 3330 feet with up to 40% calcitecemented sandstone, abundant in the upper part of the interval. Coaly fragments are common down to 3570 feet. Below this horizon the lithology is dominantly subangular, moderately to well sorted, fine-grained, loose sand containing abundant lithic grains.

3820 - 3910 feet

Grey, pale green, pale brown and dark brown siltstones and claystones containing abundant flakes of carbonaceous material.

3910 - 4200 feet

Siltstones and claystones as above (3820 - 3910 feet) and moderately to well sorted, angular to subangular medium-grained loose lithic sand.

4200 - 4490 feet (No sample 4300 -40) As 3910 - 4200 feet, with loose lithic sand and calcite-cemented sandstone; coal fragment at about 4400 feet.

4490 - 4700 feet

Claystones and siltstones (as 3820 - 3910 feet) and moderately to well sorted, very fine to fine-grained, calcite and chlorite cemented sandstone.

4700 - 4810 feet (No sample 4796-810 feet) As 4200 - 4490 feet.

4810 - 5160 feet.

Mostly grey siltstones and claystones (some greyish brown or green), and calcite or chlorite-cemented sandstones. 20% coal in the cuttings at 4820-30 feet.

5160 - 5980 feet.

Claystones and siltstones grey or greyish, green, and chlorite and/or calcite cemented sandstones. Loose sands are either of dominantly lithic composition of quartzose composition or composed of both types. The lithic type is abundant above 5400 feet. The quartzese type is caved (from Unit Db) and occurs mainly at 5460 -70 feet, 5530-40 feet, 5600-10 feet. Coal occurs at 5830-40 feet and at 5920-30 feet.

5980 - 6510 feet.

Dark and light grey brown, greyish-brown and and greenish grey claystones and siltstones, containing abundant carbonaceous material, and zeolite and/or chlorite cemented lithic sandstones. Caved quartz sand occurs at 6480 - 90 feet, and 6500 - 10 feet. Coal occurs at 6010 - 30 feet, and 6130 - 40 feet.

6510 - 9130 feet.

Siltstones, claystones and sandstones, as above, in varying proportions. Other than in nature and degree of cementation, no compositional change is apparent. Cementation is discussed in the text. Coal fragments occur at numerous horizons between 7150-7390 feet, and is also present between 8000-10feet, and 8100 10 feet. Below 8510 feet coal is relatively abundant in the cuttings, especially between 8750-60 feet. Caved loose sand occurs at several horizons, the most important being at 6860 -6900 feet and 7520-60 feet; these are clearly derived from unit Db.

9130 - 10.300 feat.

Dark and light grey, greenish grey and brownish grey siltstones and claystones show little variation from those already described (ie 5980 - 6510 feet). Sandstones occur throughout and are generally well cemented. Most of the sandstones are closely similar to those already described, but nearly all show some slight differences. These may be either one of the following features.

- (i) abundant garnet,
- (ii) very poor sorting,
- (iii) above average to genin size. (relative to sandstones of unit M.
 - (iv) lighter colouration (due to the lower proportion of dark lithic fragments)

(i) abundant garnet,(ii) very poor sorting,

(iii) above average grain size; (relative to sandstones of unit M.)

(iv) lighter colouration (due to the lower proportion of dark lithic fragments)

The features are well represented by sandstones in cuttings samples between 9130-200 feet, 9870-10300 feet. Smaller quantities of this sandstone lithology are present between 9200-9870 feet.

Traces of coaly matter are frequent and more appreciable amounts (10-20%) occur above 9250 feet, between 9350-70 feet, and 9640-50 feet.

APPENDIX II

CORE ANALYSIS SAMPLE DESCRIPTIONS

Core 1 (941-961 feet)

Too friable to analyse.

Core 2 (1162-1164 feet)

Soft, medium brownish grey (5YR 4/1)* angular very fine to medium-grained, poorly sorted argillaceous sandstone. The quartz grains are limonite coated, and the largest grains are well rounded. Limonite, calcareous matter, and pyrite are abundant in the matrix. Pelecypod and foraminifera remains are also abundant. Porosity is very high and permeability is moderate; 31-32% and 84-100 mD respectively.

Core 3

Unable to analyse.

Core 4 (2839-41 feet)

Light olive grey (5YR 6/2) well-cemented, angular to subrounded, very fine to medium-grained, moderately sorted orthoquartzitic sandstone. Abundant (?) glauconite and chlorite pellets. The porosity if partly filled by primary siderite and the residual effective porosity is 18% (H). Relatively low porosity and high grain density have produced a high bulk density. The siderite cement is the cause of the high grain density. Permeability is moderate.

Core 5 (3311-13 feet)

Grey (5YR 5/1) silty claystone containing carbonised plant remains. Bedding not visible. Abundant coaly grains and muscovite flakes. Porosity very high (32%); permeability nil.

Core 6 (3810-12 feet)

Grey 2.5Y 7/0) silty claystone containing abundant small carbonuceous flakes, and abundant micaceous material. Porosity high (26%); permeability nil.

Core 7 (4295-97 feet)

Light grey (5Y 6/1) compact siltstone, containing numerous claystone pellets. Clay matrix. Porosity high (30% - V, 28% - H) and permeability slight (20mD - V, 3mD - H).

Core 8 (4800-04 feet)

Light grey (2.5Y 7/0) compact claystone. Very fine flakes and fragments of carbon-aceous matter are distributed throughout the samples which show no bedding.

Core 9 (5299-5302 feet)

Light grey (5Y 6/1) compact angular to subrounded, very fine-grained, moderately sorted sandstone. No bedding visible. Abundant flakes of carbonaceous material. Biotite, chlorite and muscovite flakes abundant. The matrix is chloritic and argillaceous, and contains trace of calcareous material.

^{*} Geol. Soc. Amer. 1963 (Munsell Colour Chart)

Core 10 (5809-11 feet)

Light yellowish grey (2.5Y 7/0), compact angular, very fine-grained sandstone, with fine discontinuous carbonaceous laminae. Abundant chlorite, biotite and hydromica. High porosity (21% V, 13% H) and nil permeability.

Core 11 (6046-48 $\frac{1}{2}$ feet)

Light yellowish grey (2.5Y 6.5/0) siltstone, with finely interlaminations of carbonaceous material. Slight small-scale cross-bedding Good porosity (17% V, 16% H), nil permeability.

Core 12 (6242-44 feet)

Light grey, compact, moderately sorted, angular to subrounded, fine to medium-grained sandstone. Cement chlorite and zeolite; abundant carbonaceous grains. Bedding faint; elongated claystone pellets lie along bedding planes. Moderate porosity (16% V, 15% H) and low permeability (2md).

Core 13 (6252-54 feet)

Light grey (5Y 6/1) interbedded siltstones and argillaceous siltstones. Good root traces present. Bedding thin, and shows signs of slight penecontemporaneous deformation Abundant carbonaceous laminae. The much lower porosity is perhaps due to the presence of cryptocrystalline zeolite, but no definite evidence exists. Permeability nil.

Core 14 (6478-88 feet)

NO RECOVERY.

Core 15 (6712-14 feet)

Light yellowish grey (2.5Y 7.5/0) compact, angular to subrounded moderately sorted, very fine-grained sandstone. Coaly grains are concentrated in thin laminae. Chlorite cement partly infills porosity. Porosity fair (11%) and permeability nil.

Core 16 (7227-29 feet)

Light yellowish grey (2.5Y 6.5/0), compact, angular to subrounded, moderately sorted, very fine-grained sandstone, containing large coal flakes and grains. Calcite cement has replaced chlorite cement and is responsible for the low porosity (8% V; 5% H), and nil permeability. The increase in bulk density corresponds to this decrease in porosity.

Core 17 (7709-12 feet)

Grey (2.5Y 5/0) compact argillaceous siltstone, containing abundant carbonaceous material. Bedding indistinct. Chloritic material and biotite flakes abundant. Porosity low (4% V; 2% H), and permeability nil.

Core 18 (7716-17 feet)

Medium grey (N4), hard, silty claystone; no bedding visible. Numerous root traces. Porosity (5%) and permeability nil. Core 19 (8147-49 feet)

Light grey (2.5Y 5.5/0) faintly laminated siltstone containing abundant carbonaceous material. Slightly calcareous. Porosity negligible (3%); permeability nil.

Core 20 (8463-65 feet)

Light yellowish grey (2.5Y 7/1) hard, silty very fine-grained sandstone. Abundant carbonaceous grains; very slightly calcareous. Negligible porosity (4% V, 5% H) and permeability nil.

Core 21 (8914-8916 feet)

Light grey (2.5Y 6/0), hard silty very fine-grained sandstone. Carbonaceous flakes and grains abundant; bedding not visible. The cementing medium is distinctly calcareous. Porosity is negligible and permeability nil.

Core 22 (9383-85 feet)

Light grey (2.5Y 6/0), hard slightly sandy siltstone with thinly interbedded carbonaceous siltstones. Small-scale cross-bedding. Very slightly calcareous cementing medium. Porosity negligible (2%) and permeability nil.

Core 23 (9769-72 feet)

Medium grey, (2.5Y 4.5/0) hard, unlaminated argillaceous siltstone. Abundant finely disseminated carbonaceous material. Root traces in growth position present. Porosity negligible (3%), and permeability nil.

Core 24 (9881-90 feet)

Light grey (5Y 7/1), hard, angular to subrounded, fine to medium-grained, poorly sorted sandstone. No bedding visible. Pink garnet conspicuous. Zeolite cement has infilled much of the primary porosity. Porosity moderate, (13% V, 12% H) and permeability moderate (2md).

Core 25 (10300-02 feet)

Light grey, (2.5Y 6.5/0), hard silty v. fine-grained sandstone. Bedding indistinct. Poorly-defined interbedded carbonaceous laminae. Zeolite and chlorite cementation infills virtually all porosity and remanent porosity is negligible, (5%); permeability nil.

In the cores taken from units M and P (cores 5 to 25 inclusive), there is a clear relationship between depth and porosity (porosity decreasing with depth); the latter can be related to the increase in the degree of cementation which becomes especially apparent in thin-section, below 6000 feet. Core 24 constitutes a conspicuous exception to this depth - porosity relationship, and this is clearly connected with the exceptional composition of this sandstone. It is the only one of the cores to show well marked mixture of anit R and unit M facies.

Petroleum Technology Laboratory, Bureau of Mineral Resources, Geology and Geophysics, Camberra

Date: 6th March, 1963

CORE ANALYSIS RESULTS

Notes (i) Unless otherwise stated, the porosities and permeabilities were determined on two small plugs (V & H) cut at right angles from the core or sample. Ruska field prometer and permeameter were used, with air and dry nitrogen, respectively, as the saturating and flowing media. (ii) Oil and water saturations were determined using Soxhlet type extraction apparatus. (iii) Acid solubilities were determined using 15% commercial hydrochloric acid (iv) N.D. means Not Determined.

Well or Area	Core	Depth in ft.	Effe			olute ability		density	Fluid	saturat	tion	Acid solub-	Oil (Characteristi	cs
11022 02 22200	sample number	From: To:		Vol.		darcys.		<u> </u>	Water:		011:	ility %	Fluorescence in solvent	Colour	Fluorescence of extracted
	number	108	٧.	н.	٧.	н.	Bulk	Grain	% pore space	% pore space	Metric tons/ acreft	by vol.	In solvent	oil	oil.
EUMERALLA NO. 1	1	941 961	Ver	y Fri	able,	could n	ot ana	lyse					·		
tt	2	1162 1164	32	31	100	84	1.89	2.75	45	Nil	Nil	N.D.	Trace	Nil oil	Nil oil
11	3	2110 2112	Sam	ole H	eceive	d in Po	wdered	Form				-	-	-	-
11	4	2839 2841	N.D.	18	N.D	100	2.34	2.86	63	Nil	Nil	N.D.	Trace	Nil oil	Nil oil
11	5	3311 3313	32	32	Nil	Nil	1.94	2.70	40	11	tt	11	Faint Trace	11	17
tt	6	3810 3812	26	26	Nil	Nil	1.94	2.61	46	11	11	ti	Strong	11	11
tt .	7	4295 4297	30	28	20	3	2.04	2.87	22	ij.	11	11	Trace	17	11
11	8	4800 4804	19	19	Nil	Nil	2.18	2.68	50	11	11	11	Strong	tt	11

Additional information:

General file no. 62/399
Well file no. 62/1308

Date:

6th March, 1963

CORE ANALYSIS RESULTS

Notes (i) Unless otherwise stated, the porosities and permeabilities were determined on two small plugs (V & H) cut at right angles from the core or sample. Ruska field porometer and permeameter were used, with air and dry nitrogen, respectively, as the saturating and flowing media. (ii) Oil and water saturations were determined using Soxhlet type extraction apparatus. (iii) Acid solubilities were determined using 15% commercial hydrochloric acid (iv) N.D. means Not Determined.

Well or Area	Core or	Depth in ft.	por	ective osity	per	olute meab_	in gm	density	Waters		0i1:	Acid solub-	03	il Characteri	stics
2000	sample number	From: To:	% b;	y Vol.	ili mil	lidarcys	Dry Bulk	Grain	% pore		Metric tons/	ility %	Fluorescence in solvent	Colour of extracted	Fluorescence of extracted
			v.	н.	٧.	н.			space	space	acre t.	by vol.		oil.	oil.
EUMERALLA No. 1	9	5299 5302	21	23	Nil	Nil	2.05	2.63	22	Nil	Nil	N.D.	Faint Trace	Nil oil	Nil oil
11	10	5809 5811	21	13	Nil	Nil	2.29	2.76	34	ę	11	11	Strong	11	17
п	11	6046 6048 * 6	17	16	Nil	Nil	2.19	2.63	32	11	11	11	Strong	11	71
11	12	6242 6244	16	15	2	2	2.21	2.61	34	11	11	11	Strong	11	11
11	1 3	6252 6254	10	11	Nil	Nil	2.22	2.54	69	11	ti	11	Strong	11	11
n	14		No	core	vailal	ole			-	-	-	-	-	-	-
11	15	6712 6714	11	11	Nil	Nil	2.34	2.63	61	Nil	Nil	N.D.	Strong	Nil oil	Nil oil
11	16	7227 7229	8	5	Nil	Nil	2.49	2.66	58	11	11	11	Strong	13	11

Additional information:

General file no. 62/399 Well file no. 62/1308

Date: 6th March, 1963

CORE ANALYSIS RESULTS

Notes (i) Unless otherwise stated, the porosities and permeabilities were determined on two small plugs (V & H) cut at right angles from the core or sample. Ruska field porometer and permeameter were used, with air and dry nitrogen, respectively, as the saturating and flowing media. (ii) Oil and water saturations were determined using Soxhlet type extraction apparatus. (iii) Acid solubilities were determined using 15% commercial hydrochloric acid (iv) N.D. means Not Determined.

	Core or	Depth in ft.		ctive sity		olute eability		density	Fluid	satura	tion	Acid solub-	Oil (Characteristi	cs
Well or Area	sample number	From: To:				idarcys.			Water:	0il:	Oil: Metric	ility	Fluorescence in solvent	Colour of extracted	Fluorescence of extracted
	number	101	٧.	н.	٧.	н.	Bulk	Grain	p:re space	pore	tons/ acre ft	% by vol.	in solvent	oil.	oil.
EUMERALLA NO. 1	17	7709 7712	4	2	Nil	Nil	2.48	2•55	100	Nil	Nil	N.D.	Strong	Nil oil	Nil oil
11	18	7716 7717	5	5	11	11	2.41	2.55	99	Ħ	11	11	Strong	11	11
n	19	8147 8149	3	3	11	17	2.48	2•55	100	Ħ	11	11	Strong	11	11
11	20	8463 8465	4	5	. 11	11	2.52	2.64	78	11	11	11	Strong	f1	11
11	- 21	8914 8916	3	2	t)	11	2.57	2.63	100	21	11	11	Trace	11	11
u	22	9383 9385	2	2	11	17	2.51	2.55	100	ŧì	11	11	Trace	ţ1	11
11	23	9769 9772	3	3	11	11	2.53	2.61	100	17	11	11	Trace	n	

Additional information: Core No. 24 was received in a sealed condition. Salinity for extracted water 4740 p.p.m. NaCl.

All cores which gave "strong" fluorescence in solvent contained coal or carbonaceous partings and pieces.

General file No. 62/399

Well file no. 62/1308

Petroleum Technology Laboratory, Bureau of Mineral Resources, Geology and Geophysics, Canberra

Date: 6th March, 1963

CORE ANALYSIS RESULTS

Notes (i) Unless otherwise stated, the porosities and permeabilities were determined on two small plugs (V & H) cut at right angles from the core or sample. Ruska field porometer and permeameter were used, with air and dry nitrogen, respectively, as the saturating and flowing media. (ii) Oil and water saturations were determined using Soxhlet type extraction apparatus. (iii) Acid solubilities were determined using 15% commercial hydrochloric acid (iv) N.D. means Not Determined.

Well or Area	Core	Depth in ft.	1		Absolu	ute ability	. –	lensity	Fluid	satura	tion	Acid solub-	Oil	Characteristi	cs
Herr or Area	sample	From:				darcys.	Day	<u> </u>	Water	1 .	Oil:	ility	Fluorescence		Fluorescence
	number	Тоз	٧.	н.	٧.	н.	Bulk	Grain	% pore spare	% pore spare	Metric tons/ acre ft	% by vol.	in solvent	Oil.	of extracted oil.
EUMERALLA No. 1.	24	9881 9890	13	12	2	2	2.37	2.67	49	Not Measy	rable	N.D.	Good	Not Extract	ed Trace Only
11	25	10300 10302	5	5	Nil	Nil	2.52	2.61	20	Nil	Nil	N.D.	Trace	Nil oil	Nil oil

Additional information

General file no. 62/399 Well file no. 62/1308

COMPOSITE WELL LOG

EUMERALLA Nº 1

LAT . 38° 12′ 43″ LONG. 141° 56′ 01″ ELEV.(GROUND) 167ft. A.S.L. SCALE . I inch = 100 ft.

B.M.R. WELL INDEX Nº 158

С N Siderite rock (and sandy siderite rock) FAUNAL GROUPS Sandstone Y Skeletal debris Phosphate Siltstone

Claystone 7. Lamellibranchia I. Gastropoda Grains > sand-size. (Wentworth) > Glauconite Pyrite 2. Foraminifera 8. Ostracoda 3. Polyzoa 9. Fish fragments Oolith ø Limonite 10. Sponge spicules 4. Scaphopoda Limestone (and sandy

Company: FROME-BROKEN HILL Co. PTY. LTD.
Basin: OTWAY
State: VICTORIA

	Marl Dolomite (and sandy dolomite)	one (and sandy Pellet	4. Scaphopoda 10. Sponge s 5. Echinoidea	†]	
CARBONATE LOG (Wentworth) DEPTH (ft.) R.T. CARBONATE LOG GRAIN SIZE (mm) GRAIN SIZE (mm) GRAIN Co Co 3 SIZE Mg Co 3 PERCENTAGE V.COARSE COARSE MEDIUM R.T. FINE CARBONATE LOG GRAIN SIZE (mm) GRAIN Co Co 3 FERCENTAGE V.COARSE MEDIUM R.T. R.T.	COLOUR CUTTINGS TONE LMD DESCRIPTION	SPONTANEOUS POTENTIAL millivolts	RESISTIVITY A - metre 2/m-1 O 16 Short normal 20 12345678	INTERPRETED LITHOLOGY	CHEMICAL CONSTITUENTS DESCRIPTION OF UNITS UNITS UNITS UNITS UNITS CROUP GROUP H AGE
100 - 25% 50% 75% 0	1. Light grey biocalcarenite, as above, lithology 2, becoming marly.	300 - 100 -		Top 70', yellowish-brown biocalcarenite, identical in all respects to remainder except in colour. Marl: Light to medium-grey, moderately soft, fossiliferous marl. Fauna as for limestones above, with the addition of gastropods.	Carbon at e Carbon at e Carbon at e CAMBIER FORMATION SBURY GROUP E MIOCE IN E MIOCE NEE Carbon Body Carbon Body
1,400	1 Buff calcarenite with some limonite pellets. 2 Fossiliferous. 3 Light grey calcarenite 1 Light greyish fossiliferous, pure limestone, finely crystalline. 2 Light brown quartzose sandstone, well sorted, carbonate cement. Glauconitic. 3 Well sorted, angular, loose, very fine to medium quartz sand. 1 Brown-stained, subrounded quartz grains with some limonite pellets. 1 Brownish-grey fossiliferous marl. 2 Loose, coarse to conglomeratic quartz, sandy with abundant muscovite flakes. 3 Dark grey, micaceous, carbonaceous, muddy siltstones. 1 Brownish grey, fossiliferous marl, slightly glauconitic. 2 Coarse to very coarse, loose quartz sand.	1,300'-	€ 0 • • 0 0	sorted, angular to subrounded fine grained sandstone, calcite and siderite cement. Grains limonite-coated; limonite pellets in lower part. Foraminifera and gastropods abundant, also bivalve fragments. Sandstones: Moderately sorted, subangular to well-rounded, coarse-grained to pebble sized sandstones, with very minor siltstones and coals. Quartz content of sand up to 95% though untwinned feldspar may constitute up to 10%. Most quartz of metamorphic origin (stressed quartz, metaquartzite fragments)	Coarse grained to granule strate orthogoartzite Minor Limonite sandstone, and marls, sigh state and carbonaceaus spiritic siltstones. Arenite

			EUME	RALLA	Nº 1			
GRAIN SIZE (m m) (Wentworth) BEPTH (ft.) R.T. GRAIN SIZE PERCENTAGE V.COARSE COARSE MEDIUM	CUTTINGS COLOU CHARLE COLOU TON LM	_ CUTTINGS	SPONTANEOUS POTENTIAL millivolts	1 (11) 101	R E S I S T I V I T Y THOLOGIC LOG 16" Short Normal	FAUNAL GROUPS	INTERPRETED	CEMENT BAJOR CHEMICAL CONSTITUENTS DESCRIPTION OF UNITS LITHOLOGIC UNITS LITHOLOGIC UNITS LITHOLOGIC S UNITS LITHOLOGIC S UNITS LITHOLOGIC S UNITS LITHOLOGIC S L
1,900 - 1,900 - 2,000 - 1,900		Brownish-grey, fossiliferous, slightly glauconitic marl. Medium to granule sized, loose quartz sand with chert and other lithic grains Smoky pink and pale green quartz occurs Dark-brown carbonaceous, micaceous and pyritic muddy siltstones, with occasional thin coaly laminae		1,900	Musco Tourme Amb	oline o	Abundant, very thin laminae, and pyritic horizons. In sandstone no evidence for nature of cement, or matrix (?) Argillaceous cement indicated by logs and condition of cuttings samples	-grained to pebble sized orthoquartz. We and carbonaceous pyritic sandstored by PALAEOCENE PALAEOCENE ———————————————————————————————————
2,100-	2,100- 2,100- 2,200- 2,300- 1- 2,300- 1- 1- 1- 1- 1- 1- 1- 1- 1- 1- 1- 1- 1-	Moderately sorted, fine to granule-sized loose quartz-sand Lithic grains, brick-red chert, grey chert, meta- quartzite. Quartz pink, smoky, cloudy or brown in parts. Some tourmatine. Pyrite concretions. Moderately sorted, fine-grained sandstones		2,100 - 3 - 2,200 - 2,3		00000000000000000000000000000000000000		Moderately sorted, subangular to well rounded, coarse poor cementation by (?) clay. Minor coaly lamin A R E N I T E N I G H T G R O O C E N E
2,500	2,500	with sideritic dolomite cement As above, with rare limonite pellets As above As above As above As above As above As above, with limonite pellets of limonite and abundant pyrite. Sandstone with limonite pellets sideritic cement. Slightly pyritic. As above, lithology above with ooliths and pellets. Light brown, fine to medium grained, carbonate - cemented sandstone	· · · · · · · · · · · · · · · · · · ·	2,500 -	Tourmo	00 00 00 00 00 00 00 00 00 00 00 00 00	Sandstone, minor siderite & siltstone: Angular to subrounded, moderately sorted, coars grained to very coarse grained orthoquartzite. Uncemented or poorly cemented. Pyritic Minor fine-grained siderite cement so stones and silty bede Sandstone and oolite: Chlorite cemented limonite volite with som limonite pellets. Sideritisation, and minor calcitisation, is complete in most volitic lithologies. Minor limonitic sondstone (upper calcite cemented sandstone(lower). Pyritisation through Sandstone and silty sandstone: Angular to subrounded; moderately sorted medium to coarse-grained.	Stones Gb Calcide ARENITE Oolite
2,900-	2,800 NO SAMPLE NO SAMPLE 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1		John John John John John John John John	2,800 - 11 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1			Sandstones and siltstones: Angular to subrounded moderately sorted, medium - grained subarkose (or feldspathic sastone). Grains chlorite coated. Quartz mostly metamorphic. Feldspar mostly untwinned, some twinned. Abundant chlorite pellets. Calcite cement replaced in various degrees by spheroidal siderite. Sandy siltstone: Very glauconitic, carbonaceous, slightly pyrit sandy siltstone. Glauconitic pellets up to 0 mm. Abundant plant fragments. Rare glauconitic siderite rock (Siderate)	ific, carbonac and silt - Ga for and silt - Ga f
3,300	3,100 3,200 11 11 11 11 13 3,300 11 13 14 15 16 16 16 16 17 17 17 17 17 17 17 17 17 17	① As lithology ② above ② Dark grey, very glauconitic siltstone, with pyrite. ③ Glauconitic pellets. ① Angular to subrounded, fine to medium grained loose quartz sand ② Dark grey, very glauconitic siltstone ③ Very pale whitish, pale- green and grey, claystones and siltstones. ④ Hard siderite and sandy siderite Angular to subangular, fine to medium grained, moderately to well sorted loose sand. Lithic grains abundant.	Many and	3,200 - 11 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1		•	Sandstones and siltstones: Cuttings 3160-210, 3220-40 Very friable, greenish grey, subangular to subrounded, moderately sorted, fine to medigrained volcanic sandstone. Both twinned and untwinned plagio clase present, twinned plageoclaise. Basalt or andesitic fragments, microlitic glass, tuffaceous rocks Cements both chlorite and calcite. Chlorite cement pellicular, preserving porosity and permeability. Calcite-cemented types harder, and primary porosity very low to zero. Zircon, epidote and relatively abundant hornblende, as accessory minerals Cuttings (3480-520) As above lithology(cuttings 3160-210)	Chlorite. Calcite B rare
3,600	3,500 3,600 3,700 NO MPE	Calcite - cemented sandstone, containing abundant dark grains. Subangular, well-sorted, fine grained loose sand with abundant lithic grains Pale-green, and grey claystones and siltstones Angular to subrounded well sorted lithic sandstone	The Market of the second of th	3,600 - 11 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	Zirco Epido Hornbl Relation to the control of the c	ende	3220-40), with zeolite. Zeolite fills pore spaces rimmed by calcite. Zeolite finely crystalline, good longitudinal cleavage. Core 6 Slightly greenish grey siltstone a claystone. Siltstone (3802-04). Chloritic,	See sheet 3 for Descriptio LACEOUS with mi M ERCE
3,900 4,000 Bureau of Mineral Resources, Geology and Ge	3,900			3,900 - IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII			illitic siltstone containing abundand carbo aceous material. Composition approximates lithic graywacke (Pettijohn). Spore cases found in Core 7, (4287-89)	to \

	11	N.A		D	Λ	t 1	ι Λ	N I	9	1	
\vdash	U	M	H	K	Д		ΙД	N	=	ı	

					EUMEI	NALLA	N- I		i · · · · · · · · · · · · · · · · · · ·	Т				
	GRAIN SIZE(mm)		COLOUR		SPO NTANEOUS POTENTIAL	S INTERPRETED	RESISTIVITY	l l		L L NTS	s ⁻	TRATIO	GRAPHY T	
DEPTH (ft)	GRAIN SIZE PERCENTAGE	DEPT CUTTINGS (ft) PERCENTAGE	TONE	CUTTINGS		DEPTH C LITHOLOGIC	$\Omega = 100 \text{ etre}^2/\text{m}^{-1}$	FAUNAL GROUPS	INTERPRETED LITHOLOGY	EMENT BA /or IEMICA! TITUER	ITS LOGIC	RMAL ITS BER	ATION 0 U P	ш
R.T.	V. Coarse Coarse Medium	R.T. PERCENTAGE	LMD	DESCRIPTION	- 20 +	(ft.) O LOG	16" Short normal 0 200	Σ		CONS	UN UN LITHO	ME N N N N N N N N N N N N N N N N N N N	FORM	4
4,100 -	25% 50% 75%	4,100	5GY 5 /I		3	4,100	}		Cuttings 4080-90;		•			
		H - H					{		Moderately sorted, subangular to subround fine to medium-grained volcanic sandstone.	ed	y calci			
4,200-		H - H - H - H - H - H - H - H - H - H -		Well sorted, subangular, medium-grained Joose lithic sand with coarse caved		4,200 - H H	\}	ZIRCON	Quartz up to 5%, feldspar twinned (sodic place and untwinned, 5%. Lithic fragments (85%)	1.)	cement b		ŀ	-
4,200		(3) (1)		grains. Odd pyrite & glauconitic pellets ② Grey, pale-grey, pale-brown claystones	A			E PIDOTE.	almost wholly volcanic in origin and chloritic. Andesitic and/or basaltic fragmentsdevitrifie	1 1	of cer			
				and siltstones. ③ Well sorted subangular, fine to medium		7	}		glass, tuffaceous fragments, and(?) shale fragments —		formati			
4,300 -		4,300 - H - H - H - H - H - H - H - H - H -		grained lithic sandstone.		4,300	5		Grains commented at points of contact chlorite coating, giving high porosity and		Replac			
			5GY5/I		Man-Joseph				pemeability Calcite - cemented volcanic sandstone	10750112	orizons			
4, 400 -		4400			200	4,400	\frac{\frac{1}{2}}{2}.		show higher proportion of quartz (10%); cement appears to have corroded and assimilated many lithic fragments. Some	CHLORITE CEMENT	econter econter			
									zeolite associated with this cement as pore filling, or replacement of some grains. In	I TEOLITE !	with z			
4,500 -		4,500			James 1	4,500-			other cases the pellicular chlorite coating preserved and calcite only fills voids.	S	ommo		Additional Section 1	
							\		Characteristic biotite flakes are present and there is a notable quantity of hornblend	e	mest c			
4.600				① As above, lithology ② ② As above, lithology ③	No.	4,600-	{		as accessory, along with zircon and epidote. Sedimentary structures: Thinly & v.thinly		coal sear			
4,600 -		4,600			Min		\(\) \(\) \(\) \		interbedded claystones, siltstones & sandstones. Carbonaceous laminge define bedding in core 6		chlorite connae and c			
							E		(3806-3808). Core 6 (3802-3812) and 8 (4796-4800) exhibit penecontemporaneous	1 1	ular chi laminae			
4,700 -		4,700-			RUN No 3	4,700	\{		deformation structures, and some evidence o scouring exists in core 6 (3806-08)		pellicu s thin lo			
		3 - 1 2 0		① Loose, moderately to poorly sorted coarse			N N N N N N N N N N N N N N N N N N N				dstone ghout a			
4,800-		4,800		sand and well sorted fine sand. Former clearly caved	~	4,800-8					throug	- 1		
			5GY6/I	② Green-grey,grey,&pale-brown claystones and siltstones ③ Well sorted, subangular, fine-grained	W.						ystones. material	0		
4,900 -		4,900-		lithic sandstone. Poorly cemented generally. Small proportion calcite	War.	4,900	3 M		Cuttings 5170-5200; Light-medium grey, poorly sorted, angula	1 1	ceous m	S		
				cemented					to subrounded, fine to medium-grained volcanic sandstone(or subgraywacke) Quartz		arbonac	מ		
5.000						5,000			approx. 7%, feldspar, mostly sodic plagioclast 7%. Basaltic or devitrified glass,	2,	itic silt			
5,000 -		5,000			N. Marine	3,000			andesitic fragments and tuffaceous rocks constitute 20%. Hornblende, garnet, and zircon are accessary minerals along with		Abun			
					\$		\{\rightarrow\}		ubiquitous biotite and chlorite flakes. Calcite replacement of cement is		chloritic minerals	=		
5,100 -		5,100				5,100			complete and porosity reduce,d to low value Much of the lithic material has clearly	.	sory mi			
				○ Well sorted, fine to medium grained,	3		3		been assimilated by the calcite.		acces	-	0	
5,200-		5,200		lithic material.		5,200		स्तिकारीक स्विक्तर । १४०	Позышни при при при при при при при при при пр		blenge		gan ber dan dan pagaman dan dan dan dan dan dan dan dan dan d	9
				Moderately sorted, subrounded, coarse - grained, loose quartz sand		H - H -		EPIDOTE	Greenish-grey, friable, poorly sorted, angular to subrounded, fine to medium-grain	ed	nor gre		9	E
5,300-		5,300		② As above lithology ②. ③ Cemented sandstone, coresponding in		5,300 -9	\{ \sum_{\overline{\overli		volcanic sandstone. Quartz approx. 7%. Feldspar twinned, approx 10%. Lithic grains	·	dote an	٥ ١		0
				composition to the loose sand, lithology①	\$		3	S S	approximately 70%. Andesitic (or basaltic) fragments, tuffaceous shales, like the		on, epi	כ		7
5,400-		5,400		(1) As above, lithology (3)	25	5,400-		FLAK	assemblages already found. Pellicular chlorite cement (of "chevaux d frises" variety), replaced in patches by calci		Ziro	>		
		H - H - H - H - H - H - H - H - H - H -			Marc	- H - H - H - H - H - H - H - H - H - H	\}	TITE	Moderate to high porosity and permeability.	1 1	volcanic Reability.	با	7	E
		NO SAMPLE	!!	 Well sorted, very fine to fine-grained, angular to subangular, loose sand 	5		\rightarrow	6		CALCITE	ord perm)	2	æ
5,500 -		5,500		containing abundant lithic grains.	3	5,500	*	LNDAN	Cores 9 and 10; Greenish-grey volcanic sandstone and	CHLORITE CEMENT	edium g	I		
				: . •	3		\$ \frac{1}{2}	AB	grey and greenish-grey siltstones and claystones. Quartz approx. 20%, feldspar 15%, volcanic rock fragments 50% in		ح			
5,600 -		5,600			}	5,600-			sandstones. Argillaceous sediments and cement of sandstone, chloritic Traces of		very fine	_		
		(2) (1) (2) (1) (1) (1) (1) (1) (1) (1) (1) (1) (1		Well sorted, angular to subrounded, fine grained sandstone. Abundant lithic	} .	- H - H -	Mod		kaolinitic clay mineral in Core 10 at 5805- Carbonaceous material abundant as thi	07	one ex	او		
5,700 -		5,700		fragments ② Bimodal loose sand (fine & coarse), the	}	5,700	کے حص		laminae. Cross-bedding and slight scouring of 5809'-11'. Abundant root fraces in core 10		sonds:			
				coarse fraction apparently caved. The fine fraction is as found above (lith. ①	3		6		5799-801, 5801-03		olcifise	=		
5,800 -		5,800- NO SAMPLE		for example) with abundant lithic grains 3 Grey & grey-green siltstones & claystones	X	5,800	3		Cuttings 5800-10;		e. Unc	1		
			5Y 5/1	Moderately sorted, angular, very coarse loose quartz sand.	\$	107 - 11 11 - 11 1 - 11 1 11 11.	{		Greenish grey, poorly sorted, angular subrounded, fine to medium grained volcani sandstone. Abundant biotite and chlorite	ا ا	alar 10			
	<u> </u>	5 000		As lithology above		5.90			flakes. Chlorite lines pores, which are much reduced because of compaction		y, angu to som			
5,900 -		5,900		The second secon							icurred			
		43 - 2 - H	11	① Poorly to moderately sorted, subangular coarse-grained loose quartz sand.		H - H - H	5		Siltstones, claystones and sandstones:		hos o			
6,000-		6,000		② As lithology ③ above.	}	6,000	5		Siltstones and claystones Generally light grey, and thickly bedde with thin intervals of fine lamination.	d,				
		NO SAMPLE H - H	5 Y 5/1	3 As lithology ① 5630/ Brownish-gray, very fine grained limestone	}	I - I - I - I - I - I - I - I - I - I -			Penecontemporaneous deformation often extensive, where coarse silt and clayston	e				
6,100 -		6,100	5Y 6/1	Solution gray, very line grained ilmestone	}	6,100			are interbeded. [Cores 12,13,16 (7225-27)					
		0 H - H - H - H - H - H - H - H	50VE/	① Well sorted, subangular, fine-grained sandstone. Abundant lithic fragments.		- H - H - H - H - H - H -	5		Chlorite, illite and fine mica flakes are abundant; coarse—grained sand is					
6,200-	←	6,200 - H - H - H - H - H - H - H - H - H -	3513/1		{	6,200-			sometimes found scattered in the most agrillaceous sediments. In siltstones the					
		NO SAMPLE			}	12 - 14 - 14 - 12 - 12 - 14 - 14 - 14 -			assemblage of clastic material is closely similar to that found in the sandstones. Most cores show abundant fine carbon—					
6,300 -		6.300 - NO SAMPLE - H - H - H - H - H - H - H - H - H -				6.300			aceous laminae, often defining cross-beddir root traces (Core 13) and plant remains	9;	eet			
		1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1		① As above, lithology ①.					are, often well preserved in the claystone (Core 15, 6716'-18') and there are trace		e sh			
				② Grey, brown & grey-brown siltstone, with minor claystone					of amber. Coal seams of appreciable thickness between 7,100-7300.		Se			
6,400 -	 	6,400 - 1 - H - H - H - H - H - H - H - H - H		(1) Well sorted, angular-subangular, very fine	}	6,400								
		NO SAMPLE		grained lithic sandstone clay matrix.	}	- 1-1 - 1-1	E S							
6,500 -		NO SAMPLE 6,500 H - H - H - H	" Kry		ξ	6,500	<u> </u>							
Bureau of	Mineral Resources, Geology and Geopl	hysics. February 1965.	and the second s		То	accompany Record	1 Nº 1965/ 76				X	AUS	2 - 34 C	· 18.

	GRAIN SIZE (mm				COLOUR		SPONTANEOUS POTENTIAL			RESISTIVITY	l s	•	٥.	STRA	TIGRA	APHY
DEPTH (ft.)		GRAIN SIZE PERCENTAGE	DEPTH (ft.)	CUTTINGS PERCENTAGE	TONE	C UTTINGS DESCRIPTION	millivolts +	DEPTH	INTERPRETED LITHOLOGIC LOG	_∩ - metre ² /m ⁻¹	FAUNAL GROUPS	INTERPRETED	STITUENT STITUENT STITUENT	DLOGIC JIT RMAL	I B E R	0 C E
RT	V.F. F M C V.C.	V.COARSE COARSE MEDIUM FINE	R.T.		LMD		- +	RT.	U	1 6 "Short Normal O 200	Σ		CONS	UN ON IN	M E M	8 A
6,500		25% 50% 75%	6,500-	50	3Y5/I		}	6500 –		5		Sandstones: Cuttings 6410'	ned band			
			-				}					Greenish-grey, moderately-sorted, angular to subrounded, fine to medium-	ograi			
6,600			6,600		"	• .	\ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \	- 00aa				grained volcanic sandstones. Quartz constitutes approx.10% and feldspar (twinned and untwinned) approx.15%. The lithic	E E			
	(I)				"	Triable, subangular, very fine grained lithic sandstone.	}					material is mostly volcanic with some grains and uncertain origin. Andesitic (or basaltic) fragment tuffs, and tuffaceous sandstones and shales	s e to	2		
6,700			6,700	NO SAMPLE		② As above, lithology ①	}	6,700 -		3		occur together with devitrified glass. Biotite and muscovite are both abundant. Epidote and zircon are present.	9 9			
	(I)	> 5		Θ	"	(2) As above, innology	}					Cementation is by chlorite and zeolite. Chlorite (of "chevaux de frises" form) lines pore spaces (as in cuttings from 5780-90) and cements	e ded,			
6,800			6,800		n		}	6,800				grains at points of contact. The high primary porosity is secondarily filled with zeolite and obliterated. This this section also shows and	Cements Cements	']		
			: 	5	" Y 5/1	① Subrounded, very coarse grained,	{					obliterated. This thin section also shows good examples of zeolite cementation. In some cases chlorite has filled the pore spaces (some	Chlorite College Zeolite Kaolinitic			
6,900	1-		6,900	56	Y5/I	moderately sorted loose quartz sand. Caved from Unit Db.		6,900 —		\$		fragments in cuttings, thin section 7930'- 40'.)	Calcite (b)			
						 ② Grey, grey-brown, brown siltstone and minor claystones. ③ As above, lithology (1) 	\					,	sorte			
7,000	, –		7,000	5	1 6/1 1 6/1		}	7,000-				,	poorly-	S		
	• (i)	5			"	Subangular, well sorted, fine to fine—grained lithic sandstone.	}		H			Core 17 (7703'-05'):) c			
7,100			7,100		* 🙀		}	7,100 -				Medium-grey, poorly sorted, angular to subrounded, very fine to fine grained volcanic sandstone. Quartz and minor chert and	n es ar Chlorite	*		
			-		"		\			MMM.		sandstone. Quartz and minor chert, and feldspar (twinned and untwinned), each	s t o	7		
7,200	,		7,200		"	Subrounded, very coarse grained, moderately sorted, loose quartz sand.	}	7,200 –		N) The consequence of the conseq	- Zircon	constitute approx. 15%. The lithic material is wholly volcanic in nature and constitutes up to	Sand	0 1		
				NO SAMPLE	"	Caved from Unit Db.	*				Epi dote	40%. There are numerous pellets of claystone well rounded, which are possibly reworked. The	andstones.	0 5		
7,300			7,300	3	"	3 Subangular well sorted fine or very fine grained lithic sandstone clay 8/or calcite cement.	RUN N°5	7,300				matrix has been almost completely chloritised and porosity greatly reduced. Calcitisation of				
					"		}					feldspars and lithic material has occurred to some extent throughout.	grey s	0		
7,400	•••••••••••••••••••••••••••••••••••••••	35	7,400-		"	① As above, lithology ③	}	7,400-				Cuttings 6290-320:	1 + 4 €	• ~		
				======================================	/ 5/1		{	'				Medium-grey, moderately sorted, angular to subrounded, very fine to fine grained volcanic	5			
7,500			7 500 -		"	Subrounded, moderately sorted, very course	}	7,500 —				sandstone. Quartz approx. 10%, feldspar approx. 10%. Lithic grains, mostly of volcanic nature and	-grey to	4		
,,,,,,					"	quartz sand. Caved from Unit Db. ② Grey,green grey,brown siltstones and	. }	1,000		3		chloritic, constitute approx. 60%. Biotite, muscovite and some chlorite flakes are present,	enish-			
7.00	(3)			3 =	GY5/1	Claystones. 3 As above, lithology (1)	}					with abundant carbonaceous material, The dominant cementing medium is zeolite,	gre	7		5/5
7,600		3	7,600		"		\	7,600			Rare Garnet and	which bears an "ophitic" relationship to the clastic material. Sharp boundaries between cement and	s, and			20
	(1)		1 -		" "	(1) Subangular, well sorted, fine grained lithic sandstone calcite &/or clay cement.	}		2	5	(?) Corun- dum	clastic material are not present everywhere. Chlorite rims surround the zeolite cement in	stone of ab	5	1 1 1	RO
7,700		> 5	7,700	NO SAMPLE	"	Sunusione cultile ayor truy cement.	}	7,700-	78			cutting thin section at 6410'-20'-Zeolite is uniaxial-ve, and shows good cleavage in one	silt		1 1 1	0 7
					n u		}				Abun-	direction. Cuttings thin-sections: 1)7750-70	es and			PE 1
7,800	—— (II)		1 .,000		"	① As above, lithology ①	}	7,800			dant Biotite flakes	2) 7930'-40' I) Greenish grey, moderately sorted, angular to	stones	E		CA
					n 4		}					subrounded, fine to medium grained, volcanic sandstone. Quartz approx 5%, feldspar 35%.	clay s	1 1		7
7,900		\ \ \	7,900-		n 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	Medium and dark grey sandstones and claystonesAs above, lithology (1)		7,900 -		5		Lithic material, mostly volcanic and devitrified microlithic rocks, approx. 25% (see report)	1 0		1 1 1	W A E R
					"		}					Cementing medium is kaolinitic clay mineral which has corroded many of the clastic grains,	bonac e Minor c	7		1 3
8,000	(1)		8,000		"	Subangular, well sorted, fine to very fine grained lithic sandstone.	}	6,000-		2		mostly feldspar. Chlorite rims the clay mineral patches in most instances.	Cements Con Say			0.0
			-		"					3		2) Medium-grey, poorly to moderately sorted,	Chlorite Zeolite			
8,100	(1)	} <	8,100		4	(1) As above, lithology (1)	}	8,100 -	19			Composition similar to 1). In one fragment kaolinitic clay occurs, and bears similar	Kactinitic clay Calcite b b b b b b b b b b b b b b b b b b b	9		
							}					relation to clastic grains as in I). Calcitisation has occurred thoughout the unit,	and minor	$ \mathcal{A} $		
8,200		> 5	8,200		, 🚫			8,200				irrespective of the nature of the cementing medium and/or matrix. Among the clastic grains,	grey s and			
						Grey, brown and grey brown siltstone with grey and green grey claystones. All carbonaceous to some degree.	}					feldspars and lithic grains are most affected.	grey, dstone			
8,300	· (2)		8,300	2 5 · · · · 5 · · · · 5 · · · · · ·	Y 5/1	② Subangular, very fine to fine grained, well sorted sandstones containing abundant	· \	8,300				•	enish c sand			
					1 Y5/1	sorted sandstones containing abundant lithic grains. Clay and calcite cement. (Chloritic) 3 Subrounded moderately sorted very coarse	\			Z Z			Gree			
8,400	(I)		8,400		"	3 Subrounded moderately sorted very coarse grained loose quartz sand. Caved from Unit Db. 1 As above, lithology 2		8,400-				Sandstones, siltstone and coals:	9000 v			
					H.	② As above, lithology ③	}		20			General lithology as above interval. Cores are carbonaceous, show very fine lamination	entation			
8,500			8,500		<i>u</i>	3 Subangular, very fine to fine gained, well		8,500		2		and some penecontemporaneous deformation. There are clay pellets in the siltstones and some	ies Cem			
					и	sorted sandstone, abundant lithic gains.						cross bedding in the sandstone.(Core 20,8461-63, Core 21, 8918-20)	sandstor			
8,600	, –	>>	8,600		16			8,600-		E	Zircon Epidote Garnet	Sandstones retain the clearly volcanic aspect, though an increase in non-lithic grains and	olcanic ,zeolite E			
	(2)	\ \ \ \ \	,		u u	Harder, medium to dark grey siltstone and minor claystone.			1			slight increase in grain-size, together with	ones & v			
8,700	, –		8,700		"	② As above, lithology ①		8,700 -				incidence of microcline in very small amounts, is apparent towards the base of the interval.	, siltsto			
					" N7					要を選集を		Such hybrid lithologies, exhibiting some features of Unit R (as found in Pretty Hill	ystones / high re			
8,800	,		8,800-		346V	Subangular, very fine to fine grained, well sorted sandstone abundant lithic grains.		8,800-		・ ・ ・ ・ ・ ・ ・ ・ ・ ・ ・ ・ ・ ・ ・ ・ ・ ・ ・		N° I well.) in part, are distinct, but very minor (see cuttings thin sections, 8940'-70', 9060'-70'.)	grey, clays:			
					"	301733 231731313						Matrix and lithic fragments are much chloritised. Pellicular chlorite occurs in one	grey B.			
8,900	• (1)		8,900-			② As above, lithology ①	\[\)	8,900 -				case (Cuttings thin-section,8680'-730'.) * See text,page 3.	Greenish - Interval ch			0
. '									•			·· · · · · · · · · · · · · · · · · · ·) U <u>s</u> i	l ı		1 1
Bureau of Mi	ineral R eso urces, G	Geology and Geophysics. Apr	ril 1 965				To accompany record Nº	1965/78						1	X AU	15-2-341

To accompany rec**ord Nº 1965/76**

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GRAIN* SIZE(mm)	COLOUR	SPONTANEOUS POTENTIAL SUINTERPRETED	RESISTIVITY S	STRATIGRAPHY
GRAIN SIZE PERCENTAGE V.COARSE COARSE MEDIUM	DEPTH CUTTINGS (ft) PERCENTAGE LMD CUTTINGS DESCRIPTION	Millivoits DEPTH (ft) - 20 + R.T. DEPTH C LITHOLOGIC LOG	FAUNAL GROUPS LITHOLOGY	
9,000 FINE 25% 50% 75%	Subangular, well sorted, very fine to fine- grained sandstone, abundant lithic grain Cement becoming siliceous. As above, lithology in but coarser and slightly garnetiferous.	9,000 - 9,000 - 9,000	Zeolite is found in cuttings thin at 8940'-70' Kaolinitic clay occ aggregates, replacing lithic grain pore spaces. Calcitisation is a throughout the interval. Selective of feldspar-thin-section	extensive calcitisation
9,100	9,100 — 2 H — H — H — H — H — H — H — H — H —	9,100	Sandstone & Siltstone Small-scale cross-l	p p p
9,200	9,200- As lithology@, with abundant garnet	9,200	visible in several core samples (e.g. 9881-83') Root traces are prese (9767'69'). Some penecontempo deformation is visible in a (Core 25, 10,300'-02')	g. Core 24, ent in Core 23 raneous
9,300	9,300 Angular, well sorted, very fine-graine sandstone with calcareous cement.		Carbonaceous mater abundant in all samples	dant chi bundqmt.
9,400	9,400— NO SAMPLE NO		Cuttings 9300'-9400': Angular to subrounded very sorted very fine to medium grained sandstone. Quartz approx 15%. Feld and untwinned 20%. Lithic frag	poorly volcanic dspar twinned pments a poorly of a poo
9,500	9,500	9,500	chloritic :- microlitic rocks, tuff rocks and metaquartzitic types, approx 45%. Muscovite, biotite and flakes abundant. Zircon, epidot abundant garnet. Chlorite cement and grains.	constitute and chlorite is and calc
9,600	9,600	9,600	by kaolinitic clay mineral and are replaced in patches by calc	both media 5 to 5
9,700	9,700 Moderately to dark grey siltstone and claystones. 2 Subangular, moderately to well sorted sandstone. Abundant lithic grains and brown mica flakes.		Angular to subrounded, very fine to coarse- grained subgrayw plus metaquartzite and chert ap Feldspar twinned, untwinned and approx 15%. Fragments of vol tuffaceous, and microlitic rock	proced Quartz process and procedure of the process
9,800	Moderately sorted, fine to medium - grained quartz-rich garnetiferous sand		up to 35% Pore spaces are infilled (uniaxial negative) & have chlorite Zeolite has corroded feldspars are grains. Small amounts of authige	Authigening d, garnetife sums and lithic by G / L
10,000	stone. Clay matrix. O,000	- IO,000 - I	are present and are distinct high relief and birefringence	- C - C - C - C - C - C - C - C - C - C
10,100	NO SAMPLE stone. Garnetiferous.	10,100 - 1	More abundant microcline, metamorphic grains as well as a garnet characterises the subgrathed in above des (Cuttings 10000'-10106')	quartz, and bundant bundant p L
10,200		10,200- H.	Zeolite is especially abut most coarse—grained lithologies (?) sphene is most abundant in section also, and is especially we ted in Core 25 (10300-02'). Ch	the lower of the l
10,300	10,300	10,300-	ted in Core 25 (10 300'- 02'). Che calcite are present throughout	