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COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

RECORD No. 1965/166

A PETROLOGICAL EXAMINATION OF SEDIMENTS FROM O.D.N.L. ANGLESEA NO. 1 WELL, OTWAY BASIN, VICTORIA.

by

J. DELLENBACH

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Contents

Summary

The Anglesea No. 1 well was drilled in an attempt to test the extent of Upper Cretaceous sediments in this area of the Torquay embayment and further to disclose any porous and permeable zone within the Lower Cretaceous. The present study will emphasize that the facies of the sediments and the diagenesis of its clay minerals render the Lower Cretaceous sediments unattractive as reservoirs. It will be shown secondly that an interval of sandstones, partly cemented with carbonate and kaolinite, exists above the Lower Cretaceous Unit M and below the Tertiary Unit Gb (Eastern View Coal Measures). This sandstone interval does not belong to Unit M and is of a facies quite distinct from the sandy horizons of the Eastern View Coal Measures. It is impossible in the absence of cores, and because of the poor quality of the cuttings, to correlate this sandstone interval with a specific unit of Lower or Upper Cretaceous age.

Introduction

The Anglesea No. 1 well was drilled for Alliance-Oil Development N.L. in the Geelong District of the Torquay embayment.

Some details of the well are given below:

Location	Latitude 38° 24' 26" S. Longitude 114° 11' 53" E. 1:250,000 Sheet Name: Queenscliff, SJ55/9
Total Depth	10,065 feet (driller) below K.B.
Elevation	K.B. at 78 feet above sea level. G.L. at 65 feet above sea level.
Date Drilling Completed:	7-11-62.
Completion report dated:	1963 by Oil Development N.L.

The cost of the drilling operations was subsidized under the Petroleum Search Subsidy Act, 1959-1961. The investigation of the petrology of the sediments of the Anglesea No. 1 well was undertaken as part of a review of selected wells of the Otway Basin currently being carried out by the Bureau of Mineral Resources.

Samples of cuttings were examined at 10 foot intervals. Thin-sections were prepared from the cores. The cuttings were thin-sectioned at every lithological change and at least at 100 foot intervals in the Unit M sediments. Thin-sections were prepared at 10 feet intervals between 1950 and 1700 feet. Cuttings separations were also undertaken in that interval. Several X-ray analyses were made to assess the nature of clays in the sediments of Unit M. The materials pertaining to these investigations are available for examination at the core and cuttings laboratory, Bureau of Mineral Resources, Fyshwick, A.C.T.

UNIT M

The Unit M was intersected in the Anglesea No. 1 well from total depth, 10065 feet, to 1921 feet.

It consists of a monotonous succession of shallow water immature sediments of greywacke and subgreywacke composition (these terms are defined later). On the basis of a lithological change the Unit M has been subdivided into two major subunits M_2 and M_1. No indications of a disconformity could be detected between the two subunits although the possibility exists. Both petrological and environmental criteria for the two subunits suggest that similar conditions have existed during their deposition. The change to the upper subunit reflects merely a possible shift of the emission centres of the volcanic constituents at the time of deposition. Diagenetic processes have been very strong in the sediments of the Unit M but the zonation of the changes is different to that observed in the western part of the Basin (Geltwood Beach and Eumeralla areas). The reason is principally that the sediments of the Anglesea area (and similarly Ferguson's Hill area) have different depositional characters. These characters are:

- greater immaturity of the sediments
- presence of an abundant clay matrix
- presence of abundant siderite and, as a result a greater amount of subgreywacke.

The diagenetic processes are of several types:

- recrystallization of clay minerals;
- introduction (kaolinization) of clay - also in fissures;
- recrystallization of carbonate minerals and replacement and fissure infilling by calcite;
- minor silicification;
- minor development of crystalline zeolite.

These diagenetic changes have a strong bearing on the reservoir possibilities even though intense fracturing has affected some horizons. The reservoir prospects in Unit M are worse than those in the Unit M of the Geltwood Beach No. 1 well in the western part of the Basin.

Note on the usage of the terms greywacke, subgreywacke, and arkose

The terms greywacke and subgreywacke are used in the sense of Pettijohn (1957). Greywacke is a sandstone characterized by 25% or more labile materials (feldspar and rock-fragments) and 15% or more interstitial matrix. Subgreywacke is a sandstone with similar framework (with an excess of rock fragments over feldspar) and an "excess of voids or of mineral cement or both over detrital matrix". Although these definitions are debatable (Huckenholz, 1963), they are considered as useful.

In the Completion Report (O.D.N.L., 1063), the sandstones of Unit M have been referred to as "arkoses".

In the current investigation of sediments of Unit M in the Otway Basin, it is preferred to restrict the term arkose to Pettijohn's definition: a sandstone composed principally of quartz and feldspar and derived from a source of granitic composition. This definition has the merit to be closest to the original definition of the word arkose by Brongniart (1826).

Other definitions have been proposed by several authors Krumbein and Sloss (1963), Folk (1964) which markedly depart from the original meaning.

The composition of the studied sandstone of Unit M in the Anglesea No. 1 well does not correspond to any of these newer definitions but is closest to the greywacke-subgreywacke suite as defined by Pettijohn.

Subunit M_2

Sediments of the lower part of Unit M from total depth (10,065 feet) to 5710 feet have been grouped together in a Subunit M_2 on the basis of their lithology and degree of diagenetic change. Six subordinate intervals have been delimited in the Subunit M_2.

An estimation of the proportions of sand and shales in the Subunit M_2 is difficult because of the important diagenetic changes. However on the available evidence it is apparent that there are between two and three times more shales (or mudstone) than sandstones.

Interval 10,065 (T.D.) - 9,100 feet

The interval comprises medium and dark grey indurated carbonaceous shale, sandy siltstone and claystone. Sandstone layers are subordinate according to the cuttings percentage log.

Upper limit

The upper limit (at 9,100 feet), has been chosen for it marks a change from an overall high resistivity to a series of high and low readings above the depth of 9,100 feet.

Shale, siltstone and claystone

Cores 33, 32 and 31 display laminated shale, sandy siltstone and claystone which are observed also in cuttings. The sandy siltstone is of greywacke composition and has a tight groundmass of illite, chlorite, mica flakes (altered biotite and muscovite), carbonaceous matter and pyrite.

Calcite replaces some of the feldspar grains. Carbonaceous flakes and flat lenses are infilled with chalcedony and secondary quartz. Fissures infilled by calcite and quartz are also present.

Sandstones

The moderately sorted, angular, very fine to medium-grained sandstones (greywackes and subgreywackes) show a strong induration and cementation by crystalline diagenetic calcite and illite. Fragments of sandstone with strong replacement of both grains and cement by clean kaolinite and recrystallized siderite also occur among the cuttings throughout the interval. Quartz (15%), quartzite and feldspar (20%) grains are strongly corroded, welded and interpenetrated, particularly when packed together in horizons with little matrix. Mica is altered in most instances. The lithic fragments (30-35%) comprise abundant phyllite, schist, schist with blue penninite, metaquartzite (medium and very fine-grained) indicating a metamorphic source. Volcanic rock fragments are also present. They are fragments of basalts, of siliceous rocks (the groundmass of volcanic rock) with or without magnetite and chlorite. Of particular interest are fragments of devitrified vesicular glass, some associated with spherulitic chlorite. The cementing media are calcite and siderite - in some instances syngenetic chlorite - in the subgreywackes. The matrix of the greywacke is illite (pellicular and recrystallized), possible "illitized kaolinite" and also replacement kaolinite. Carbonaceous matter is abundant either in the form of flakes or of flat lenses. Pyrite is abundant throughout. Calcite replacement is common and in some instances related to sets of calcite infilled fissures.

Heavy minerals are sparsely represented in the sandstones though in some instances (i.e. 9800-9810 feet) chloritoid, chlorite, penninite, zircon, epidote, tourmaline, and apatite were relatively abundant.

Evidence gained from cores Nos. 33, 32 and 31

The available samples of cores 33-32-31 consist of dark grey indurated siltstone. The rock is massive and broken up along the bedding but also shows thin laminations. In thin-section the rock appears to be of greywacke composition and is very finely sandy. The groundmass is a recrystallized illitic clay. Strong interpenetration of the silt-sized to finely sandy detritus with the groundmass accounts for the tightness of the rock. Siderite rhombs develop at 9642 feet in core 32.

The dips of these cores vary between 45° in core 31 and 32 to 25° in core 33. Calcite and quartz infilled fractures occur, some of which are along the bedding. Coal fragment and coaly plant fragments up to several inches in size are present (core 31).

Thin laminations richer in darker components are apparent in all 3 cores and they emphasize low-angle small-scale cross-bedding and scouring, particularly in core 33.

Intervals 9100-8210 feet

This interval is characterized by an increase of the sandstone content among the cuttings from bottom to top. Caliper and resistivity micrologs show recurrent compact horizons with high resistivity.

Upper limit

The upper limit of the interval is marked by a strong microlog resistivity peak at 8210 feet.

Sandstones

Predominant among the sandstones are subgreywackes of moderate sorting and very fine to medium grain-size. The rock-fragments (30-35%) comprise very fresh basalt, flow-rocks, aphanitic siliceous rocks (glassy groundmass) with or without abundant magnetite, and microlithic rocks. Other rock-fragments include low-grade metamorphic rocks: metaquartzite, sericite schist and abundant phyllite. Some of the rock-fragments are kaolinized. Feldspar (15-20%) is oligoclase, andesine, sanidine and also orthoclase and microcline. Many feldspars are illitized, kaolinized and calcitized. Quartz is subordinate to feldspar though in some cases, possibly as a result of alteration of the latter, the amounts of these minerals may be equal. In most parts feldspar is extensively corroded.

Cementing media are ankeritic calcite (8250-8350 feet particularly) and siderite in the typical subgreywackes. Patches of crystalline calcite constitute poikilitic crystals of up to several mm in dimensions. Sandstones (? subgreywacke) with clean recrystallized scaly and cryptocrystalline illitic cement recur over the interval. Detritus, illitic and kaolinitic clay are associated in the matrix of the greywackes. Chlorite is present in some instances but subordinate. Muscovite and altered biotite are present. Fragments of reworked chloritic rock, chlorite and penninite grains are rare. Heavy minerals are present: zircon, sphene, apatite and penninite. The sandstones possess no porosity.

Mudstone

The mudstone displays an illitic groundmass containing abundant carbonaceous material and pyrite. Siderite and mudstone fragments are present.

Evidence gained from core No. 30

The available sample of core 30 presents massive dark grey indurated argillaceous siltstone. The rock is much brecciated, with evidence of microfaulting and slickensiding. Some fissures are infilled with silica, clay and calcite. Thin laminations, some of which are rich in carbonaceous matter, are present. Overall dip is up to 60°. It is possible that the fracturing, and the calcite and clay infilling observed in cuttings and in core 30, extend over most of the interval, and support the idea of a fault zone, as suggested in O.D.N.L. (1963).

Interval 8210-7100 feet

This interval is well marked by a fairly homogeneous pattern of resistivity and the common occurrence of illitic cement in the greywacke and subgreywacke.

Upper limit

The upper limit is marked by a change in the degree of cementation at 7100 feet and the occurrence of medium-grained sandstones. The number of sandstone and mudstone beds are approximatively equal in the interval.

Sandstones

The sandstones are mainly medium grey very fine to medium-grained moderately sorted subgreywacke with calcite and siderite cement and also greywacke. The rock-fragments (35%) comprise metamorphic fragments and volcanics among which are basalt, and chalcedony-rock. Feldspar (15-20%) is replaced in

parts by calcite, kaolinite and illitized kaolinite. Oligoclase, andesine and orthoclase are present. Quartz (10-15%) is very angular, in parts very clear (volcanic quartz), and in some instances strongly welded (8110 feet) with detrital grains, and overgrown. Besides the low-birefringent, patchily recrystallized kaolinite, a more birefringent cryptocrystalline mosaic of possible "illitized kaolinite" develops in the intergranular space and replaces some constituents. Biotite is chloritized and illitized, and assimilated in the matrix. Calcite and siderite are the chief cementing media. Sideritic mudstone fragments are also present, and carbonaceous laminae and lenses are abundant.

Mudstones

The mudstones are silty and finely sandy and contain abundant finely disseminated carbonaceous matter and pyrite. The shales are interlaminated with carbonaceous layers. The carbonaceous laminae are squeezed and contorted and in some cases replaced by crystalline calcite which also fills fissures (some along the bedding plane). Illitic clay and minor chlorite are the main constituents of the groundmass.

Evidence gained from cores Nos. 29, 28, 27 and 26

The subgreywacke occurring in cores Nos. 29, 28, 27 and 26 are calcite and clay (illitic?) cemented. Siderite lenses and pellets are present. Where packed together, the quartz, feldspar, and quartzite fragments are strongly welded and interpenetrated. This feature probably accounts for the "siliceous matrix" mentioned in the completion report (O.D.N.L., op. cit., appendix 1a). The sediments of this interval are typical Unit M sediments. The presence of features indicating quiet water deposition: very thin (fraction of a mm) regular laminations, low-angle small-scale cross-bedding with feathery appearance, and undulations, contrast with high-energy structures: mudstone pellets, slumps, scour-and-fill structures, and high-angle cross-bedding. At 7258 feet (core No. 26) branching parts of plants (rootlets?) are present in the bedding plane. These delicate structures cannot be reworked plant fragments but are probably parts of plants in situ. Other examples of plant fragments and leaf-imprints occur in the cores of this interval and particularly at 7262 feet (core No. 26). Porosity is very low in the sandstones of the interval 8210-7100 feet, but it is possible that the noticeable peak in the S.P. curve is due to a localized open fissure. Permeability is thought to be nil. Dip varies between 20 to 25°.

Interval 7100-6620 feet

This interval is typified by low resistivity especially on the micro-log, strong sideritization, kaolinization, a high content of volcanic rock-fragments, and the presence of pellicular illite in the matrices of the sand-stones.

Upper limit

The upper limit of the interval is well marked at 6620 feet by the different resistivity, and on the caliper log. Sandstones are predominant over this interval.

Sandstones

The sandstones are greywacke and subordinate subgreywacke. Sorting is moderate and grain-size is very fine to medium. Rock-fragments are abundant (30-35%). Flow-rocks, fragments of basalt, rich in finely divided magnetite, minor chloritic volcanic rocks are represented among the lithic fragments. Feldspar (15-20%) includes plagioclase, orthoclase and microcline. In many cases the feldspar is altered to calcite. Quartz is subordinate (10-15%). Calcite, siderite, minor chlorite and recrystallized replacement kaolinite are the cementing media. In several instances diagenetic pellicular illite is surrounding the detrital grains. Carbonaceous matter and pyrite are abundant. Apatite, zircon and penninite are present.

Siltstone and claystone

Massive siltstone and claystone also occur over the interval and are rich in carbonaceous matter and pyrite.

Evidence from cores Nos. 25 and 24

Cores 25 and 24 are in most parts massive. At 6762 feet (core 25) the sandstone (subgreywacke) is fine to medium-grained and strongly cross-bedded, with convoluted lenses of carbonaceous shale. The dip varies between 15 and 25°. Although some open fissures may be present, the porosity and permeability of the rocks are nil.

Interval 6620-6330 feet

The interval is characterized by the high resistivity, and the absence of strong kaolinization (between the strongly kaolinized intervals above and below).

Upper limit

The upper limit is well-marked on the resistivity logs although the change of run at 6313 feet alters the pattern of the microlog.

Sandstones

Very striking for this small interval is the presence of abundant fragments of genuine subgreywacke among the cuttings. These sandstones are made of angular, fine to medium grains of quartz (15%), feldspar (15-20%) and rock-fragments (30-35%). In some parts, the feldspar (oligoclase and subordinate orthoclase) grains are totally altered to clay and calcite. The lithic fragments are flow-rocks (basalt) and aphanitic siliceous rocks representing parts of the groundmass of flow-rocks. The cement is mainly calcite and also siderite. Some cuttings fragments show recrystallized patches of kaolinite in the cement, and coatings of siderite around the detrital grains, also in some instances, chlorite and illite coatings.

Subordinate amounts of mudstone and shale are present. They display an illitic groundmass rich in carbonaceous matter and opaque material, and also in siderite. Although replacement by kaolinite appears to be mild in this interval, fissures infilled with kaolinite were recorded. Neither porosity nor permeability are thought to be present in the interval. No core was taken in that interval.

Interval 6330-5710 feet

This interval contains more mudstone and shales than above and below, and is strongly kaolinized.

Upper limit

The upper limit is well marked at 5710 feet by an increase in the frequency of highly resistive horizons.

Mudstone and shale

The medium-grey mudstone and shale are well represented among the cores.
Core 22 shows shale, interlaminated with pyritic carbonaceous layers. Lenses and aggregates of siderite are abundant. Illite, muscovite and leached biotite are very common. In some fragments, kaolinization and development of spherulitic siderite have been so intense that the original rock has disappeared. The glittering surface of the cuttings under high binocular magnification is due to the presence of abundant recrystallized flaky illite as well as mica. Chlorite is subordinate in the groundmass.

Sandstones

The sandstones are well-sorted, angular, very fine to fine-grained greywacke and possibly subgreywacke with abundant carbonaceous matter. Sideritization and kaolinization are important. Core No. 22 at 5772 feet is typical of kaolinized and sideritized greywacke. It is apparent from the thin sections of cores and cuttings that the process of kaolinization which affects both the matrix and lithic content (except megacrystalline siliceous rocks such as metaquartzite), has occurred or continued at a late stage and after recrystallization of the siderite. This is supported by relations of minerals in kaolinite-infilled fissures, and the outlines of the siderite aggregates. Feldspar is almost completely altered to kaolinite and similarly the volcanic rock-fragments. In most cases the nature and proportions of the metamorphic and volcanic lithics cannot be assessed. However it is evident from the less-altered sandstones (? subgreywacke) that metamorphic rock fragments (schist, low-grade metamorphic rocks) are predominant over volcanic rock-fragments (microlithic flow-rocks, andesite, fragments of glass with abundant finely divided haematite-magnetite). Chlorite is rare, and neither chlorite nor biotite occur in the strongly kaolinized horizons.

No porosity or permeability can exist in these rocks.

Evidence gained from cores Nos. 23 and 22

Cores 23 at 6241 feet and 22 at 5766 feet show cross-bedding up to 20° and also regularly alternating thin laminations of silt and silty coaly matter. Fracturing is very strong and infillings of the fissures are of pure white kaolinite, and brown siderite.

The electric log indicates a greater frequency of high-resistive (presumably more cemented) layers towards the top of the interval.

Subunit M_1

Sediments from the depth of 5710 feet to 1921 feet are grouped in a distinctive Subunit M_1. The boundary of this Subunit M_1 with the Subunit M_2 is somewhat obscured by the occurrence of a zone of strong diagenetic kaolinization between 5710 and 5340 feet. Nevertheless the examination of less kaolinized detritus in sandstone cuttings, and of cuttings from non-kaolinized horizons, shows that sandstones above 5710 feet are different. Moderately sorted, up to medium-grained subgreywacke occurs, showing a marked content in volcanic rock-fragments. Examples of volcanic sandstones with chlorite cement recur in the cuttings above 5710 feet. Unfortunately the dipmeter survey was carried out from 4980 to 4800 feet and below 5762 feet, and only three readings are available from above the depth of 5710 feet, (two of which are classified as "possible dips"). Therefore a change in the direction of supply of detritus cannot be recognized as at 6620 feet in the Fergusons Hill No. 1 Well. The estimated sand/shale ratio of Unit M_1 is in the vicinity of 0.5 to 0.4, Subunit M_1 being slightly more sandy than Subunit M_2.

Interval 5710-5340 feet

The kaolinization phenomenon is strong over the interval 5710-5340 feet, and the frequency of the occurrence of very fine to medium-grained sandstones, (originally subgreywacke rich in volcanics, and volcanic sandstone) is increased.

Upper limit

The upper limit of this interval is taken at the change in resistivity at 5340 feet which corresponds also to a marked change in drilling-rate.

Sandstones

Sandstones prevail over the interval 5710-5340 feet. The light grey sandstones are angular, very fine to medium-grained strongly altered subgreywacke in most instances. Cryptocrystalline kaolinite is abundant and its presence is substantiated by X-ray analysis. Quartz grains (20%) are strongly corroded and feldspar (up to 15%) is transformed into kaolinite. Lithic fragments (up to 35%) are also altered in various degrees. At recurrent depths over the interval, cuttings of subgreywacke with chloritic cement, and abundant fragments of sideritic volcanic rock and unaltered phyllite have been observed. Calcite, siderite, minor silica and illite are the cementing media besides the partly diagenetic kaolinite.

No porosity is to be expected in the sandstones.

Mudstone

Mudstone is not common in core No. 21 and appears to be subordinate within the interval.

Cuttings of mudstone show silt-size detritus set in a kaolinite and flaky illite groundmass with finely divided pyrite and carbonaceous matter. Plant fragments are present.

Evidence gained from Core No. 21

The core No. 21 indicates that strong cross-bedding (with dips up to 25°) affects the sandstones and also shows thin laminations of silty coaly matter. Fracturing-subvertical and oblique - is common and in most cases the fractures are infilled with kaolinite, brown siderite and some calcite.

The cored interval is marked by a rather low resistivity although is is essentially made of sandstone. It is therefore felt that the resistivity logs are strongly affected by the degree of clay diagenesis.

Interval 5340-4250 feet

Strong kaolinization and sideritization, and presence of abundant calcite-siderite, and clay-infilled fractures characterize this interval. The cuttings contain up to 15% of fragments of crystalline calcite (from fissures or replaced areas) and up to 20% of yellowish siderite with patchily recrystallized clay.

Upper limit

The upper limit is marked at 4250 feet by a conspicuous change in the resistivity pattern.

The predominant rock-type is sandstone.

Sandstones

The light grey, angular, very fine to fine-grained sandstones (greywacke and subgreywacke) are well-sorted. The important character is the strong degree of alteration of the matrix; the feldspars and the lithic fragments are also altered to cryptocrystalline and recrystallized kaolinite, siderite and to a lesser extent calcite. Quartz and metaquartzite grains are strongly corroded. Chlorite and micas are absent from the kaolinized sandstones. Carbonaceous matter, opaque minerals and illitic flakes form highly contorted and fragmented laminae and concentrations.

Cores 20, 19 and 18 show fissures and patches infilled by petaloid aggregates of kaolinite (max. size 0.08 mm, index of refraction between 1.560 and 1.568, max. observed birefringence 0.004).

Siderite and calcite are also present in the fissures. Negligible porosity and no permeability are to be expected in these sandstones.

Mudstone

The mudstone recorded over the interval 5340-4250 feet is not different from that described before. It apparently contains more flaky illitic matter than the sandstones. Finely divided carbonaceous matter, coaly plant fragments and pyrite are common.

Evidence gained from the cores Nos. 20, 19 and 18 and the electric logs

According to the thin-sections of cores and also of the cuttings, there is an increase of replacement siderite, calcite and kaolinite between 5340 and 4850 feet which is apparently responsible for the corresponding high resistivity readings. In the absence of any change in lithology as shown by cuttings and core, it is possible that the S.P. peak at 5240-5200 feet is due to a localized fissure zone. The sidewall cores taken over that interval were not available for examination. The cores Nos.20, 19 and 18 show similar sedimentary features to those found in the Unit M below: thin laminations, low-angle cross-bedding, disturbed and undulate bedding, and also higher energy features such as scour-and-fill and cross-bedding with marked local variations in the cross-bedding dips.

Possible burrows occur at 4821 feet (core 19) and plant fragments are present in all cores of the interval. Microfaulting, brecciation and fissuring have strongly affected the sediments, as shown by the cores. The fractures are generally infilled by clay (kaolinite) and siderite. Some of these fractures are thought to have occurred during the deposition of the sediments, though the most important ones are clearly post-lithification.

Negligible porosity and no permeability are to be expected from the sandstones of this interval.

Interval 4250-3020 feet

This interval has been separated on the marked predominance of sandstones over siltstone and mudstone, and the occurrence of coal fragments among the cuttings. The interval is distinctive also by the first occurrence from top to bottom - of fragments of siderite and sideritic sandstone among the cuttings. Volcanic constituents are abundant among the rock fragments of sandstones of the interval.

Upper limit

The upper limit of this interval is well shown at 3020 feet on both the resistivity and the S.P. curves. It is also marked by a change in proportions of the lithologies and the increase of sideritic-rock in the cuttings.

Sandstones

The sandstones consist of light grey, angular, medium to very fine-grained clean subgreywacke with abundant calcite cement and minor greywacke. The framework of these sandstones is approximately 35% lithic fragments, 15% feldspar and 10% quartz. Phyllite and metasediments are well represented among the lithics. Well-preserved fragments of basalt and of devitrified magnetite-rich groundmass of effusive rocks are abundant.

The cement (40%) is calcite with minor siderite rhombs in subgreywacke. An ill-defined mixture of detritus, kaolinite, illite, minor chlorite, mica, pyrite and carbonaceous matter composes the matrix of the greywacke. Patches and squeezed veinlets of dark reddish brown coaly matter recur in the greywacke. At 3158 feet (core 12) laminations rich in opaque minerals and grains of zircon, sphene, apatite are present. Kaolinization and sideritization are less important in this interval than below though siderite-rock occurs in the form of lenses, laminae and reworked fragments.

Mudstone

The medium grey mudstone contains fine-grained and silty detritus. The groundmass of the mudstone and siltstone is illitic, pyritic and carbonaceous and in some instances contains finely dispersed chlorite. Sideritic mudstone fragments, siderite patches, lenses and infillings in fissures are present.

A chemical analysis was carried out by the Mines Department of Victoria on a portion of core No. 12 from 3160 feet (O.D.N.L., 1963; Appendix 4). Although no details of the nature of the analysed rock are given, it is thought to be a portion of a sandy mudstone containing "irregular inclusions of brownish colour" which could be in fact, siderite aggregates coated with iron oxide. The chemical analysis shows the acid insoluble residue to be low, iron oxide to be high, and the hypothetical combination of carbonates to contain 5.3% of calcium carbonate (calcite), 12.1% of magnesium carbonate (magnesite) and 26.1% of ferrous carbonate (siderite). This is well substantiated by the observation of the thin-sections of nearby portions of the same core, with the provision that fine-grade magnesite is not readily identifiable from calcite under the microscope. The carbonate present in the rock may be in parts one member of the continuous $FeCo_3$ - $MgCo_3$ isomorphic series.

"Small irregular light brown oil stains which showed yellow fluorescence" were referred to in the core No. 13 (O.D.N.L., op.cit.; Appendix 1a), on broken surfaces of a sandstone. The observation of the available part of core No. 13 and of thin sections of it, and results of the core analysis (including solvent extractions) at 3460' 6" to 3460' 10" and 3465' 2" to 3465' 8" did not substantiate the observations mentioned in the completion report.

Evidence gained from the observation of cores Nos. 17 to 12

The available parts of cores show the massive subgreywacke, greywacke and related mudstone described above. Cores Nos. 17 and 13 are particularly good examples.

Thin sections of these cores show in abundance the rather fresh lithic fragments comprising many volcanics, characteristic of this interval.

In contrast to most of the sediments cored below, core Nos. 17 to 12 show only a few laminations and lenticular concentrations of carbonaceous plant fragments. These features emphasize dips varying from 10 to 25°.

At several depths (i.e. 3775, 3420, 3405 feet) marked S.P. peaks (opposite to shale base line) occur which correspond to high resistivity readings. Core No. 13 did intersect one of these resistive horizons. The sandstone concerned is a very fine-grained clean subgreywacke with crystalline calcite cement.

Interval 3020-1921 feet

The interval 3020-1921 feet is marked by a predominance of subgreywacke with an important development of carbonate cement. Both observation of the materials and evidence from the electric log suggest that the sandstones of the interval have an overall increased porosity as compared with intervals below.

Upper limit

The placing of the upper limit of this interval at 1921 feet is extensively discussed in the part concerning Unit M and in Appendix 1. The basic reason for this choice is the presence in the cuttings sample at 1920-1930 feet of fragments of the subgreywacke which recur to the depth of 3020 feet.

Sandstones

Moderately sorted, medium to very fine-grained subgreywacke is predominant among the sandstones of the interval 3020-1924 feet. The lithic fragments (35%) are mostly distributed between 2/3 of metamorphic origin and 1/3 of volcanic origin, though some of the sandstones contain as many volcanic fragments as metamorphic fragments.

Feldspar (15%) is acid plagioclase, orthoclase, microcline. Quartz is subordinate (10%), especially in the sandstones rich in volcanic fragments. Particular to this interval is the high frequency of clean poikilitic calcite cement and the presence of small siderite rhombs coating the detrital grains. The greywackes of the interval have an illitic-kaolinitic and detrital matrix with amorphous clayey opaque material, mica and pyrite. The clay matrix is in many instances partly recrystallized in the form of clean concentrations of kaolinite. Siderite aggregates (but no siderite-rock), and lenses of carbonaceous matter are present. Both detrital constituents and matrix may be kaolinized but kaolinization is not a generalized diagenetic process as compared with intervals below.

Mudstone and siltstone

The mudstone and siltstone of this interval are rich in carbonaceous matter, pyrite and opaque material. Some horizons are apparently rich in brownish chlorite and siderite.

Evidence gained from cores 11 to 7

The sandstones of the interval are well illustrated by cores 11, 9, 8 and 7. These are massive subgreywacke in most parts but cross-bedding, is present. Laminations rich in coaly plant fragments emphasize small scale low angle cross-bedding in cores Nos. 11, 9 and 7. A mudstone pebble (1 cm. in diameter) was observed at 2864 feet (core 11). Siltstone and claystone are well represented in all available samples of cores of the interval. Laminations rich in coaly plant fragments (up to several inches in length) occur at 2862 feet (core 11), 2232 feet (core 8) and in core 7. Cross-bedding undulations and slumping are shown in core 7 (1945 and 1947 feet).

The dips recorded in the various cores of the interval 3020-1921 feet range from 0° to 30°. Unfortunately the topmost sample of sandstone of core 7 at 1931 feet was not available for petrological examination. This sandstone can reliably be ascribed to the uppermost interval of Unit M based on the description in the completion report (O.D.N.L., 1963) and on the fact that cuttings of calcite-cemented subgreywacke similar to that below are present in the sample taken from 1920 to 1930 feet.

General conclusions for Unit M

As a result of the study of the sediments of the Unit M in the Anglesea No. 1 well, two important observations can be made:

- Unit M can be subdivided into two subunits M_1 and M_2 between which a possible angular unconformity can be envisaged.

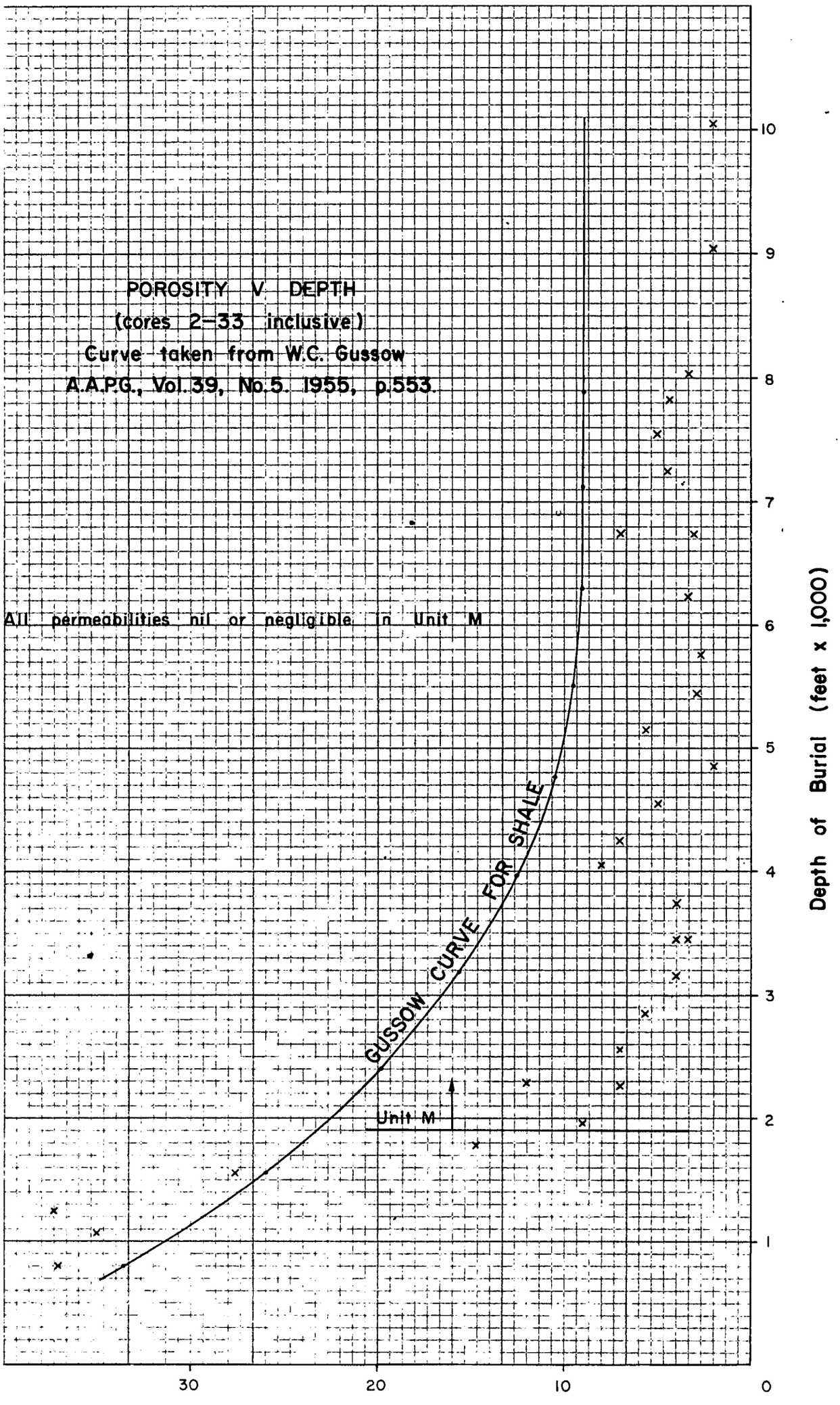
- There is evidence for an increase in volcanic activity during the deposition of the lower part at least of the Subunit M_1.

- Sediments of the Unit M in the Anglesea No. 1 well are more immature than those of Unit M in the western part of the Otway Basin (i.e. Geltwood Beach area).

  Partly as a result of the higher clay content, diagenesis of clay has occurred. Diagenesis has also affected the carbonates (essentially siderite). Further introduction of kaolinite, carbonate and silica has reduced porosity and permeability.

Fig. 1

O.D.N.L. ANGLESEA No. 1



Bureau of Mineral Resources, Geology and Geophysics August 1965 *To accompany Record 1965/166*

Although there has been important fracturing in several intervals of Unit M, the scope for fracture porosity is negligible because of the general infilling of fractures and fissures by kaolinite and carbonate.

The porosities measured in the sandstones and sandy mudstone of Unit M are mostly poor or negligible and less than those of shales at same depths. Although the porosity of shales as compiled by Gussow (1953) is not exactly comparable to that of the sediments of Unit M, it is useful as a means of comparison (Fig. 1).

As in previous studies the examination of sediments of the Umit M has shown the strong volcanic influences which were prevailing during deposition. The reworking of extensive masses of lavas from an area probably situated under the present Bass Strait is not a satisfactory explanation for the varying degree of maturity and alteration of the volcanic constituents. The possibility of volcanic activity related to diastrophic events - to which could correspond a possible disconformity between units M_1 and M_2 must be envisaged. In contrast to observations made in the Geltwood Beach and Eumeralla wells, there is no evidence for the presence of diagenetic zeolites. The reason, as based on observations, is that volcanic rock-fragments underwent diagenetic processes by clay minerals (-and carbonates). This, in turn, is largely the result of the greater immaturity of the sediments and the close relationship to the volcanic source. The abundance of clays and carbonate (siderite mainly, resulting from the destruction of labile constituents and flocculation) imply together with the sedimentary structures present, that the environment of deposition of sediments of Unit M is of inner paralic (including inner deltaic) nature.

Unit H

Although distinctive petrologically, this unit is difficult to define because of the lack of cores and the presence of loose sand as a major part of the cuttings.

Lower limit

The lower limit of the Unit H has been set at 1921 feet on the basis of the electric logs and on the first occurrence of subgreywacke from Unit M in the cuttings sample from 1920-1930 feet. The resistivity and S.P. logs show strong resistivity peak and S.P. deviation towards the shale line, building up between 1920 and 1922 feet. Conversely the microlog shows a layer with increased resistivity from 1921 to 1934 feet which could correspond to the uppermost carbonate cemented (subgreywacke) of Unit M, and which was partly intersected in core 7 (1931-1951 feet).

Upper limit

The upper limit of the Unit H is set at 1816 feet. At this depth a change in granularity occurs and the first occurrence among the cuttings of up to 10% of fragments of calcite cemented sandstone fragments, is observed.

Lithology

The cuttings comprise between 80 and 90% of loose, coarse to very coarse sands with a few fragments of various rock-types. Sand separations were made to ascertain changes in lithology. The results are described in appendix 1. Except for quartz grains, which form the bulk of the cuttings of the interval, low but variable percentages of K-feldspar grains, rock fragments of a granitic composition, rounded metamorphic rock fragments, and coal fragments were recorded. However the most significant constituent of the cuttings were fragments of cemented sandstones.

The cemented sandstones

The cemented sandstones can be divided into two types. The first type is medium-sorted (bimodal), with angular, medium to very coarse-grained quartz, composite quartz, metaquartzite, orthoclase and microcline grains. Many quartz grains are facetted and overgrown. The cement (40%) is of pure calcite, minor siderite (rhombs), and contains patches of pure recrystallised kaolinite (including booklets). Corrosion features are common. There are pits and embayments in the quartz and feldspar grains. Many quartz grains are broken into several pieces and the fissures filled with calcite. In some instances corrosion and recrystallization features involving the calcite and siderite alter the rock. Many isolated quartz and feldspar grains show remnants of a calcite and kaolinite cement in embayments in thin section. A second type of sandstone is one with angular, fine to medium-size grains of quartz, feldspar and rock-fragments set in a siderite and calcite cement also containing some kaolinite.

The lithic fragments are metamorphic rock (schist and phyllite) and aphanitic siliceous rock. Altered mica is present. These constituents form up to half of the framework of the sandstone. The cementing media are siderite, calcite, kaolinite and minor pyrite. Siderite may be present as minor well-shaped rhombs or may form an extensive cement. Fragments of sandy siderite are present. The lithic constituents of very fine to medium-grade may be considered as derived from the reworking and maturation of volcanic and metamorphic rock-fragments from the Unit M.

The cemented sandstones of Unit H in the Anglesea No. 1 well compare very closely to cemented sandstones of Unit J in the Ferguson's Hill No. 1 well (cuttings between 2050 and 2500 feet), Port Campbell No. 4 well (4970-5340 feet), and Flaxmans No. 1 well (6880-7430 feet). These are moderately sorted, angular to subrounded, fine to medium (in parts up to very coarse) - grained sandstones. Lithic fragments (mainly fine-grained metaquartzite, schist, and aphanitic siliceous rock) are abundant. The cement is of calcite, siderite, kaolinite with varying amounts of carbonaceous matter.

No core was taken in the interval 1921-1816 feet of the Anglesea No. 1 well. This fact does not allow a precise comparative lithological study or an investigation of paleontological relations of this unit with units above and below, or with other wells. In the Birregurra No. 1 bore, an eight (!) feet interval with quartzitic sandstone and gravels occurs between the feldspathic sandstone of Otway type (Unit M) and a decomposed basalt underlying the Tertiary sequence (Weegar, 1960).

Unit Gb

The Unit Gb - equivalent to the Eastern View Coal Measures - has been intersected in the Anglesea No. 1 well between 1816 and 370 feet. On the basis of a change in the electric log and the grain-size percentage curve at 1300 feet, the Unit Gb has been subdivided (O.D.N.L., 1963) into two intervals. The lower interval (1816-1300 feet) includes a bottom sandy horizon from 1816 to 1770 feet.

Interval 1816-1300 feet

Loose angular to subrounded medium to very coarse quartz, metaquartzite and subordinate feldspar grains constitute the major part of the cuttings. Granules and pebbles up to 6 mm across are common throughout. A count of the sand grains at 1760-1750 feet shows that approximately 60% of the grains are without particular shape, nearly equiaxial, angular and pitted, 20% are facetted and 20% are rounded to subrounded and frosted. This indicates an admixture of sand grains of different sedimentary history.

The occurrence of dark brown coal fragments associated with pyritic siltstones increases towards the top of the interval, especially between 1420 and 1300 feet. The cores Nos. 6 and 5 consist of claystone and clayey pebbly sandstones with coal laminae and abundant plant fragments. Cross-bedding, irregular bedding, scouring, together with the marked immaturity of the clayey pebbly sandstones, suggest that the deposition took place in alluvial or inner deltaic environment.

Interval 1300-370 feet

Upper limit

The top of the Unit Gb at 370 feet is well marked by the sudden increase from 370 to 380 feet of loose subangular to subrounded coarse sand grains and quartzite and metaquartzite granules.

Lower limit

The lower limit of the interval is well emphasized at 1300 feet by the change from low microlog-resistivity above, to high resistivity below, and change in grain-size percentage.

Evidence from cuttings and cores

The cuttings are loose sand and gravel, dark argillaceous carbonaceous siltstone, lignite and coal fragments, minor fragments of amber. According to cuttings percentage and electric log characteristics, the coal or brown-coal horizons are most abundant between 1210 to 1080 feet, 850 to 710 feet and 630 to 480 feet, but recur sporadically throughout the interval.

The cores Nos. 3 (1110-1090 feet) and 4 (1234-1214 feet) are of grey sandy micaceous claystone with lignitic fragments. The available samples of core No. 2 (799-791 feet) show pale yellowish-brown claystone with lenses of brown coal. Core No. 1 (510-490 feet) consists of dark brown lignitic plant tissue and comprises abundant spores and amber.

Porosities are high (see Appendix 2, cores 2 to 5) but permeabilities are erratic due probably to the lenticular development of the sand bodies and the presence of clayey horizons.

The Unit Gb is a formation which extends over most parts of the Otway basin except in areas of non-deposition or erosion. The regional facies change is an eastwards increase in the frequency and thickness of the coal layers.

The Unit Gb in the Anglesea No. 1 well has been ascribed to the Palaeocene-Eocene. The evidence is good as far as the upper limit is concerned. The allocation of a Palaeocene age to the sediments of the bottom part of Unit Gb is however in doubt because of the scarcity of fossils (and the need for their revision). There is no reason to consider any discrepancy in the age attribution of Unit Gb in the Anglesea No. 1 well and elsewhere in the basin.

Unit Db

The Unit Db is represented in the Anglesea No. 1 well from 370 feet to surface, by soft, brownish to yellowish clayey siltstones rich in iron oxide. Iron sulphates and divided coaly matter are present. Occurrences of loose, rounded to subrounded, medium to coarse, glossy, clear and milky quartz grains have been seen (i.e. 150 to 140 feet). Cuttings of yellowish grey limestone with glauconite pellets occur at 240-230 feet. Fragments of gastropods and rare foraminifera are present at 240-230 feet and 170-160 feet.

Of particular interest was the presence between 250 and 230 feet, of fragments (few percent) of brown, carbonaceous, fine-grained sandstone with carbonate and opal cement and contrastingly rich in foraminifera, sponge spicules and shell debris. This sandstone was probably in the form of lenses in the iron-rich clayey siltstones.

The Unit Db, in the Anglesea No. 1 well is considered to be a shallow marine clayey equivalent of the "Dartmoor Formation" and possibly more closely of the so-called "Dilwyn Formation" (Leslie, 1964). Although equivalent of Unit Db are known from the outcrops in the Anglesea area as "Boonah Sandstone", these have apparently not been intersected in the Anglesea No. 1 well. Regional considerations and the change in environmental conditions support the placing of a disconformity between Units Db and Gb in the Anglesea No. 1 well.

Conclusions

The petrological study of the materials of the Anglesea No. 1 well emphasizes two points of interest with regard to hydrocarbon possibilities:

- an interval of 105 feet of sandstones (Unit H) is present at the bottom of Unit Gb and above Unit M. These sandstones have a different facies than those of Unit Gb and are thought to be porous. No core has been taken in this unit. Although this possible reservoir is insignificant in the Anglesea No. 1 well, it has a potential regional interest.

- the intersected section of Unit M has no reservoir possibilities as a result of its overall facies and important clay diagenesis. However it is a fair assumption that better reservoir conditions may be present at the base of Unit M above the basement (O.D.N.L. 1963, plate 2). This trend is apparent in all the previously and currently examined wells which intersect the full Unit M in the Otway Basin. However it is also apparent that these possible reservoirs below Unit M become thinner to the East of the Otway Basin.

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APPENDIX 1

O.D.N.L. Anglesea No. 1

Grain analysis of cuttings from
the interval 1700-1950 feet.

Separation and compilation by S. Ozimic I.F.P.

To ascertain the validity of the Unit H below Unit Gb and above Unit M, a separation of the different constituents of the very coarse to granule-fraction of the loose sands from the cuttings samples of the interval 1700-1950 feet was made. This interval comprises the bottom sandy part of Unit Gb, the proposed Unit "H", and the top part of Unit M. A representative sample of the washed and sieved very coarse to granule-fraction of the loose cuttings was divided into single quartz grains, single feldspar grains, rock-fragments (mainly granite and metamorphic) sandstone fragments, siderite-rock fragments, and fragments of coal. The weight-percentages (density not taken into account) are plotted at suitable percentage scale versus depth on the attached diagram 1. The graphs show the variations in the contents of the different types of constituents of the cuttings as a result of drilling through the different units, and due to admixture of cavings.

Short description of the very coarse to granule-size constituents of the cuttings from interval 1700-1950 feet

(1) Quartz

Interval 1700-1810 feet

The very coarse quartz grains are subangular to angular, nearly equiaxial in shape, clean, with minor kaolinitic inclusions and incrustations. Many grains are shiny, but frosted grains, especially among the milky quartz grains, are common. Rare strongly frosted well-rounded grains are present at some depths. Facetted grains are present in all samples, but euhedra with short prismatic habit are restricted to only a few samples.

Interval 1810-1950 feet

The very coarse quartz grains are mostly angular, frosted and recessed with inclusions of feldspar, kaolinite and incrustations of kaolinite. Milky and smoky grains are present. Facetted grains occur sporadically.

Feldspar

Most of the feldspar grains are strongly corroded and worn, white to grey orthoclase and microcline crystals. The amount of feldspar (and the proportion of granules) increases strongly in the sample at 1810 to 1820 feet and, after some variation, reaches a maximum at 1880-1890 feet where 12% of the very coarse to granule-size cuttings are feldspars. Although the sediments of Unit M are rich in feldspar, they do not contain very coarse to granule-size constituents. The feldspars occurring below the 1920-1930 feet interval are cavings.

Rock-fragments

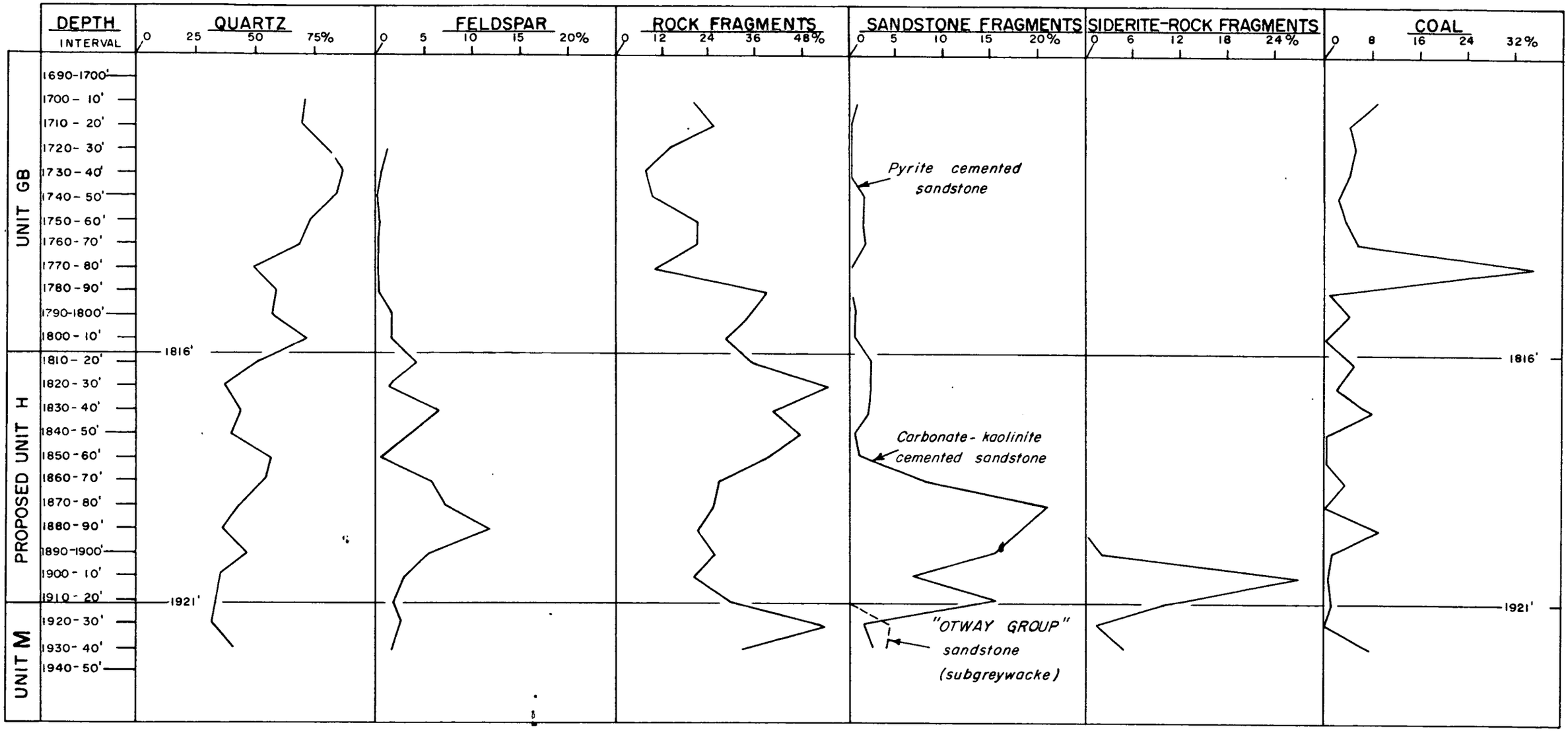
Rock-fragments of non sedimentary origin have been placed in a separate category. The percentage of these increases markedly at 1820-1830 feet.

Interval 1700-1820 feet

Non sedimentary rock-fragments are mainly metaquartzite, "stretched metaquartzite", quartz-feldspar rock-fragments (disaggregated granite), minor

Diagram 1

APPENDIX 1 WEIGHT PERCENTAGES OF THE DIFFERENT CONSTITUENTS OF THE VERY COARSE TO GRANULE FRACTION OF CUTTINGS FROM THE INTERVAL 1700 – 1950 FEET



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fragments of muscovite schist, and minor grains of grey siliceous rock (chalcedony).

Interval 1820-1950 feet

Metaquartzite and stretched metaquartzite are predominant from 1820 to 1830 feet. From 1830 to 1950 feet variable proportions of metaquartzite and quartz-feldspar rock fragments occur. Granules of grey siliceous rock (chalcedony) are present at several depths.

Sandstone fragments

Fragments of pyrite-cemented sandstone from probable pyritic lenses are present from 1710 to 1780 feet.

In the sample at 1798 feet is the first occurrence downwards of aggregates of very fine-grained sandstone with white clay cement. The sample at 1800-1810 feet contains cemented sandstone fragments but from 1810-1820 feet downwards the occurrence of clay and calcite-cemented sandstone markedly increases. This type of sandstone is poorly sorted, and a few fragments show grains of very coarse angular detritus cemented with angular to subrounded very fine to medium grains. Grey to pinkish rock-fragments are abundant (up to 20%) among the medium-sized grains of the sandstone framework. These rock-fragments consist mainly of siliceous rock (chalcedony), and minor aphanitic metamorphic rock. It is possible that the chalcedonic fragments are derived from the reworking of lithic fragments from the Unit M sandstones.

Plagioclase is markedly absent from sandstone fragments, whereas K-feldspar is frequent (up to 10%) and up to very coarse in size. The cement is calcite, and, in recurrent intervals, siderite (as distinct from the siderite-rock fragments plotted separately in diagram 1). The carbonate cement of the sandstone is well crystallized, the siderite being in small rhombs and the calcite in poikilitic megacrysts. Minor carbonaceous matter and pyrite is present. Very characteristic are patches of kaolinite, some of which are recrystallized in big petaloid aggregates [illegible] especially below 1870 feet. Also characteristic are the corrosion features of the quartz grains. The quartz grains are not only strongly pitted but also in many instances shattered, calcite filling-in the cracks. Similar features were recorded in the calcite cemented horizons of the Unit J in Port Campbell No. 4 (4970-5340 feet), Flaxmans No. 1 (6880-7430 feet), and Ferguson's Hill No. 1 (cuttings of interval 2050-2500 feet). The evidence however is considered as insufficient to infer a correlation between the two units.

Siderite-rock fragments

Fragments of brown pure or silty sideritic rock appear among the cuttings in the sample at 1890-1900 feet and increase in proportions to 25% in the sample at 1900-1910 feet. Siderite is markedly rare in sandstones of Unit Gb, but very abundant in Unit M. In other wells such as Port Campbell No. 4, Ferguson's Hill No. 1, siderite is a conspicuous constituent of the cement of Unit J.

Coal

Coal fragments vary in weight-percentage from nil to 8%, with the exception of the sample at 1770-1780 feet where 36% of very coarse coal fragments were observed. Since the coal fragments may be carried for a long time by the well-mud, only strong increases in their percentage are stratigraphically significant.

In conclusion the close examination of the nature and percentage of the cuttings in the interval 1700-1950 feet indicates that a Unit H with specific characters is present between 1816 and 1921 feet. The depth of 1816 feet is marked by changes on the electric log and supported by modifications in the distribution of quartz, feldspar and rock fragments percentages. Below this depth there is an influx of carbonate-kaolinite cemented sandstone.

The boundary between this Unit H and the Unit M (Otway Group) is well marked by the first occurrence in the sample at 1920-1930 feet of typical subgreywackes. The fact that resistivity and S.P. curves do not show the typical Unit M pattern already at the depth of 1921 feet is indicative of an altered surface at the top of Unit M. This is one aspect of the important unconformity (possibly slightly erosional) which occurs between units M and H.

APPENDIX 2

O.D.N.L. Anglesea No. 1

Core Analysis Sample Description

This includes analyses in O.D.N.L. (1963) and supplementary analyses done by the Petroleum Technology Laboratory for this study. (Depths figures indicate actual depth marked on piece of core analysed).

Core No. 1 490' - 510' Brown coal. No determinations made.

Core No. 2 789' - 789' 4"

Soft, light brown silty micaceous claystone. Not thin-sectioned. Very good microporosity (36% V, 37% H), low permeability inferred (N.D.).

Core No. 3 1093' 5" - 1093' 9"

Soft, grey-brown micaceous clayey siltstone, with organic matter - rich groundmass. Very good microporosity (35%), low permeability inferred (N.D.).

Core No. 4 1216' 6" - 1216' 10"

Soft, medium brown, carbonaceous mudstone. Very coarse detrital grains (quartz and quartzite) set in clayey groundmass rich in coaly matter and carbonaceous fragments. Very good porosity (37%H) and good permeability (50 md H), probably erratic.

Core No. 5 1509' 4" - 1509' 8"

Similar to core No. 4. Porosity 26% V, 29% H, good permeability inferred (N.D.).

Core No. 6 1784' - 1784' 8"

Light brown mudstone. Amorphous groundmass of clay and carbonaceous matter. Sandy parts have bimodal distribution (very coarse and fine modes). Fair microporosity (15% V, 13% H). No permeability.

Core No. 7 1947' - 1947' 4"

Light brown very fine-grained sandstone (subgreywacke). Thin laminations and carbonaceous fragments present. Fair porosity (11% V, 8% H) due to incompletely infilled calcite-siderite cemented patches. No permeability. Through cross-bedding, undulations, slumping (1945 and 1947 feet) are present in the core together with thin laminations, some rich in carbonaceous matter.

Core No. 8 2231' - 2231' 5"

Similar to core No. 7, in parts slightly coarser-grained. Poor porosity (8% V, 5% H). No permeability.

Core No. 9 2298' 8" - 2299'

Similar to core No. 7. Poor to fair porosity (12% V & H). No permeability. Abundant carbonaceous fragments. Dip 20°.

Core No. 10 2561' 8" - 2562'

Medium grey siltstone with abundant carbonaceous matter. Poor microporosity (7% V, 8% H). No vertical permeability. Horizontal permeability 4 md. Possible fissure in horizontal plug was impossible to detect due to crumbling of the sample. Dip 35°.

Core No. 11 2867' 2" - 2867' 6"

Light grey, fine to medium-grained sandstone (subgreywacke). The framework of the sandstone comprises 30-35% rock fragments, 15-20% feldspar, and 10-15% quartz. Cementing media (30% or more) are amorphous clay, carbonaceous matter, and some carbonate. Poor porosity (4% V, 7% H). No permeability. The sandstone is rather massive but some thin laminations, rich in carbonaceous matter, are present. Mudstone pebbles up to 1 cm. in diameter and big (several cm.) carbonaceous fragments are present. Dip 20°.

Core No. 12 3162' - 3162' 4"

Light grey very fine-grained sandstone (greywacke). Clayey and chloritic matrix with minor carbonate. Abundant carbonaceous matter. Negligible porosity (4% V & H). No permeability.

Core No. 13 3465' 2" - 3465' 8"

Massive light grey very fine to fine-grained sandstone (subgreywacke) with abundant calcite cement. Framework similar to core No. 11. Poor porosity (4% V, 3% H), no permeability. Acid solubility: 50% by volume. Oil stains mentioned in the completion report (O.D.N.L. 1963) could not be substantiated.

Core No. 15 No recovery.

Core No. 16 4015' - 4015' 4"

Massive light greenish grey very fine-grained silty sandstone (greywacke). Framework similar to core No. 11. Poor porosity (8% H), no permeability inferred (N.D.). Sample crumbled after anaylsis. Dip 15°.

Core No. 17 4227' - 4227' 4"

Massive light grey fine-grained sandstone (greywacke). Framework similar to core No. 11. Clay matrix. Minor calcite and siderite. Poor porosity (8% V, 6% H), no permeability. Dip 25°.

Core No. 18 4523' - 4523' 6"

Light grey, very fine to fine-grained sandstone (greywacke) framework similar to core No. 11. Matrix strongly kaolinitized and sideritized. Poor porosity (5% V & H), no permeability. Core displays thin laminations, low angle cross-bedding, disturbed bedding, microfaulting (some penecontemporaneous). Fissures are infilled with kaolinite and siderite. Dip up to 25°.

Core No. 19 4821' - 4821' 4"

Medium grey, very fine to fine-grained sandstone (subgreywacke). Framework similar to core No. 11. Abundant calcite, siderite, and kaolinitic clay, either as cement or as replacement material. Negligible porosity (3% V, 1% H). Fissures filled with spherulitic siderite, calcite, and kaolinite. Thin laminations show low-angle cross-bedding. Burrowing is present at 4821'. Plant fragments are abundant throughout. Dip 10°.

Core No. 20 5161' - 5161' 4"

Medium grey, very fine to fine-grained sandstone (greywacke). Framework similar to core No. 11. Matrix replaced by siderite (dilute acid solubility nil) and kaolinitic clay. Poor porosity (5% V, 6% H), no permeability. Similar sedimentary structures to core No. 19, but no burrowings. Dip up to 15°.

Core No. 21 5491' - 5491' 4"

Light grey, very fine to fine-grained sandstone (greywacke). Framework similar to core No. 11. Matrix replaced by siderite, minor calcite, and kaolinitic clay. Negligible porosity (4% V, 3% H), no permeability. Similar sedimentary structures as core No. 19, but no burrowings. Subvertical and oblique fractures are infilled with siderite, minor calcite, and kaolinite in most places. Dips between 20° and 25°.

Core No. 22 5772' - 5772' 4"

Medium brownish-grey, very fine to fine-grained sandstone (greywacke-subgreywacke). Framework similar to core No. 11. Matrix partly replaced by siderite (3% V & H), no permeability. Mudstone pebbles (1 cm. in diameter) at 5772'. Thin laminations with low angle cross-bedding are present. Vertical fractures are infilled with kaolinite. Dips up to 30°.

Core No. 23 6245' - 6245' 4"

Medium to dark grey sandy shale. Clayey-chloritic groundmass with abundant carbonaceous matter. Negligible porosity (4% V, 3% H), no permeability. The rock displays thin laminations with low-angle cross-bedding , also foreset cross-bedding with dips up to 20°, and slump structure (at 6245'). Subvertical fractures are infilled with calcite. Dips between 25° and 30°.

Core No. 24 6725' 7" - 6726'

Medium grey, very fine to fine-grained sandstone (subgreywacke). Framework similar to core No. 11. Siderite and calcite cement. Poor porosity (7% V & H). Nil permeability inferred (N.D.). Sample crumbled after analysis.

Core No. 25 6763' 7" - 6764'

Medium grey, very fine to fine-grained sandstone (subgreywacke). Framework similar to core No. 11. Siderite and calcite cement. Negligible porosity (3% V & H), no permeability. Thin laminations show low-angle cross-bedding. Undulations and small slumps (6762') are present. Some layers are rich in siderite pellets, and carbonaceous matter (also in subvertical veinlets). Dip up to 25°.

Core No. 26 7262' 6" - 7262' 10"

Dark grey shale with sandy (greywacke) interlaminations. Clay-chlorite matrix with very abundant carbonaceous matter minor patches of carbonate. No porosity, no permeability. Thin laminations show low angle cross-bedding. Undulations and slump structures are present elsewhere in the core (7255' 4"). Branching plant parts apparently grown in situ are present at 7255' 5" and plant fragments and leaves at 7262' 6". Dip 25°.

Core No. 27 7549' 2" - 7549' 6"

Medium grey, very fine to fine-grained sandstone (subgreywacke) with shale interlaminations. Cementing media comprise some carbonate, and recrystallized clay. Negligible porosity (5% V & H), no permeability (N.D.). Thin laminations, mudstone pebbles present. Dip up to 20°.

Core No. 28 7864' 5" - 7864' 9"

Similar to core No. 27. Negligible porosity (4% V, 5% H), no permeability. Similar sedimentary structures as core No. 27. Microfaulting present. Dip up to 25°.

Core No. 29 8193' 3" - 8193' 7"

Medium grey, very fine-grained sandstone (subgreywacke) with shale interlaminae. Calcite and siderite cement. Negligible porosity (4% V, 3% H), no permeability. Thin laminations show low-angle cross-bedding; undulations and mudstone pebbles (up to 6 mm. in diameter) are present. Subvertical fractures infilled with calcite are present. Dip up to 10°.

Core No. 30 8607'

Dark indurated shale. Groundmass of clay and chlorite with veinlets and patches of silica (quartz). No porosity, no permeability. Very strong brecciation, abundant calcite - infilled fractures. Dip up to 60°.

Core No. 31 9171'

Similar to core No. 30. Dip up to 45°. Negligible porosity (2% H), no permeability.

Core No. 32 9642'

Similar to core No. 30. Development of silica in coaly lenses. Dip 20°. No porosity, no permeability.

Core No. 33 10,056' 5"

Similar to core No. 30. Calcite and quartz-infilled fractures. Dip up to 30°.

APPENDIX 3

Cuttings Description

Compiled by S. Ozimic, I.F.P.

40' - 140' 100% medium brownish grey to yellowish grey, iron oxide-rich clayey silt with traces of red to yellow brown iron sulphate; few cavings; some brown coaly matter; some well cement.

140' - 230' 90% to 100% medium brownish grey to yellowish grey iron oxide-rich clayey silt with traces of red to yellow iron sulphate. 5% to 10% scattered quartz grains. Few fragments of gastropoda; some brown-coal fragments, some well cement.

230' - 370' 95% to 100% brownish grey to yellowish-grey silt; some mica; few fragments of ~~dark~~ greyish-brown coal; some well cement. 1% to 5% greyish, angular, well-sorted, coarse-grained quartz.

370' - 400' 90% to 98% medium grey, angular to subrounded, well-sorted, v. coarse to coarse-grained quartz; some milky, some clear grains. Pebbles up to 4 mm. across. 2% to 10% brownish-grey silt with traces of coal fragments.

400' - 420' 85% to 100% pinkish to light olive grey, angular subrounded, well-sorted, v. coarse grained quartz; up to 1/5 are milky grains; some grains are pitted. Up to 5% dark brownish-grey shale with traces of pyrite and brown coaly fragments. Some well cement.

420' - 440' 5% to 10% light greenish-grey to olive-grey, angular to sub-angular, well-sorted, v. coarse to coarse-grained quartz; some milky grains are present. 5% dark carbonaceous siltstone with brown coaly matter. 85% to 90% light brown well cement.

440' - 490' 75% to 98% light olive-grey to greenish-grey, angular to subrounded, well-sorted, v. coarse to coarse-grained quartz; some pitted grains. Pebbles up to 4 mm. across. 2% to 25% dark carbonaceous siltstone including loose silt and brown coaly fragments. Some well cement.

500' - 560' 50% to 95% white to light grey, angular to subrounded, well-sorted, v. coarse to coarse-grained quartz; some milky grains; some clear or spotted with kaolinite. Pebbles up to 6 mm. across. 4% to 40% dark carbonaceous argillaceous siltstone with brown coaly fragments.

560' - 590' Up to 50% light grey, angular to subrounded, poorly sorted, v. coarse to coarse-grained quartz; some milky, some clear grains are present. Pebbles up to 4 mm. across. 10% to 25% dark carbonaceous siltstone. Up to 30% dark brown coaly fragments. Some amber is present; well cement in variable proportions.

590' - 650' Up to 30% light grey, angular to subrounded, poorly sorted, medium to v. coarse-grained quartz; some milky grains; some feldspar. Pebbles up to 4 mm. across. 60% to 95% dark brown (lignitic) coaly fragments with some brown carbonaceous silt. Some well cement.

650' - 710' 95% to 100% light grey, subangular to subrounded, well-sorted, medium to v. coarse-grained quartz; some feldspar; few pitted grains. Pebbles up to 4 mm. across. 3% to 5% dark brown (lignitic) coaly fragments. Some well cement.

710' - 760' 10% to 95% light grey, angular to subrounded, poor to moderately sorted, v. coarse to fine-grained quartz; some milky, some pitted grains; few grains are euhedral. 5% to 90% dark brown (lignitic) coaly fragments with traces of amber. At 710' - 720' 40% of dark brown siltstone is present.

760' - 790' 100% dark brown coaly fragments.

790' - 860' 70% to 100% light grey, angular to subrounded, poor to well-sorted, medium to fine-grained quartz; some milky, some clear grains are present. Pebbles up to 4 mm. across. 10% to 30% dark brown (lignitic) coaly fragments with 2% of mica aggregates associated with coal; few fragments of amber.

860' - 880' 10% to 25% light grey, angular to subrounded, poor to well-sorted, medium to coarse-grained quartz; some milky grains are present. 75% to 90% dark brown (lignitic) coaly fragments with brown siltstone; some amber fragments.

880' - 1080' 50% to 100% light grey, angular to subrounded, poor to moderately sorted, medium to v. coarse-grained quartz. Gravel increases up to 80%; pebbles up to 8 mm. across. 2% to 40% dark brown (lignitic) coaly fragments with traces of mica; some amber.

1080' - 1130' 15% to 60% light grey, angular to subrounded, poorly sorted, medium to v. coarse-grained quartz; some clear, some milky grains are present; some pitted, some euhedral grains. Pebbles up to 6 mm. across. 40% to 85% dark brown (lignitic) coaly fragments with brownish grey silt; few amber fragments. Up to 10% well cement.

1130' - 1200' 20% to 95% light grey, angular to rounded, poor to moderately sorted, medium to v. coarse grained quartz; some milky, some clear and yellowish grains are present. Pebbles up to 6 mm. across. 5% to 40% dark brown (lignitic) coaly fragments with dark brown silt; some mica; traces of limonite. Some well cement.

1210' - 1300' 97% to 100% light grey, angular to rounded, poor to moderately sorted, medium to v. coarse-grained quartz; some milky, some smoky grains are present; from 1270' to 1290' over 30% of quartz grains are milky. Pebbles up to 4 mm. across. 3% dark brown (lignitic) coaly fragments.

1300' - 1410' Up to 95% light grey, poorly to moderately sorted, angular to rounded, medium to v. coarse-grained quartz; few milky and clear grains. Pebbles up to 6 mm across. Some feldspar grains. 5% to 100% dark brown (lignitic) coaly fragments with siltstone and traces of pyrite.

1410' - 1700' 95% to 100% light grey, angular to rounded, poorly to moderately sorted, medium to v. coarse-grained quartz; some milky, smoky and pinkish grains a few grains are euhedral and some cemented with pyrite. Pebbles up to 6 mm. across; a few feldspars. 5% dark brown (lignitic) coaly fragments with siltstone and traces of pyrite. A few fragments of microcline, rock-fragments of granitic composition, and biotite schist.

1700' - 1950' See appendix 1.

1950' - 2150' 15% to 80% light grey, angular to subrounded, poorly sorted, v. coarse-grained quartz; some milky, smoky and pitted grains are present. Pebbles up to 7 mm. across. A few feldspar grains. 5% to 70% light grey, angular, poorly sorted, silty to v. fine-grained sandstone with clayey matrix and carbonate cement; sandstone is spotted in various colours, such as green, yellow, brown and grey. 5% to 25% medium yellowish-brown to light olive-grey, sandy siderite and sideritic sandstone. Up to 5% dark brown (lignitic) coaly fragments with some brown silt and traces of pyrite. Some light grey siltstone fragments are present.

2150' - 2300' Up to 80% light grey, angular to subrounded, poorly to moderately sorted, v. coarse to coarse-grained quartz; some milky and smoky grains are present. Pebbles up to 6 mm. across. Some quartzite and feldspar fragments. Up to 85% light grey, angular, well-sorted, silty to v. fine-grained sandstone with clayey matrix and carbonate cement. 5% to 20% dark brown (lignitic) coaly fragments with traces of pyrite and amber. 5% to 70% light grey siltstone fragments. Well cement is present throughout this interval.

2300' - 2400' This interval does not differ markedly from above: 2150' - 2300'; many samples are missing.

2400' - 2460' 5% to 20% light grey, angular to subangular, poorly sorted, medium to v. coarse-grained quartz. 40% to 85% light grey, angular, well sorted, v. fine-grained sandstone with clayey matrix and carbonate cement. 10% to 40% black coaly fragments. Some siderite and pyrite fragments.

2460' - 2510' 100% light grey, angular, well-sorted, v. fine-grained sandstone with clayey matrix and carbonate cement. Few scattered quartz grains and coaly fragments.

2510' - 3000' 30% to 95% light grey, angular, well-sorted, v. fine-grained sandstone with clayey matrix and carbonate cement. 5% to 20% black coaly fragments. 5% to 80% light grey siltstone with some brown claystone. Some siderite-rock with carbonaceous flakes and fragments of plant - tissue, some fragments are slightly sandy with angular, v. fine-grained quartz. Few grains of feldspar with kaolin spots and siliceous rock fragments. Some spots of brown chlorite.

3000' - 3400' 10% - 95% light grey, angular, well-sorted, fine-grained, sandstone with clayey matrix and carbonate cement. 5% to 70% light to medium grey siltstone and claystone with traces of black coaly fragments. 5% to 25% yellowish-brown siderite fragments; some sandy siderite. Few scattered quartz grains.

NOTE All the sandstones from 1950 feet downwards belong to a greywacke - subgreywacke - volcanic sandstone assemblage.

3400' - 4000' 35% to 90% light grey, angular, well-sorted, v. fine-grained sandstone. 15% to 60% light to medium grey siltstone and claystone with traces of black coaly fragments. 5% to 10% yellowish-brown siderite fragments and some sandy siderite. Few scattered quartz grains.

4000' - 4410' As above 3400' - 4000' (only percentage varies slightly).

4410' - 4490' 20% to 60% light grey, angular, well-sorted, v. fine-grained sandstone with clayey matrix and carbonate cement. 20% to 60% light to medium grey siltstone and claystone with traces of black coaly fragments. 5% to 15% yellowish-brown siderite fragments. 5% to 20% light grey, angular to rounded, poorly sorted, v. coarse to fine-grained quartz; some yellowish and clear grains are present. 5% to 10% yellowish-grey to milky brown crystalline (replacement) calcite fragments.

4490' - 5090' As above 4410' - 4490' (only the percentage varies slightly).

5100' - 5500' 10% to 85% light grey, angular, well-sorted, v. fine-grained sandstone with clayey matrix and carbonate cement; sandstone is very sideritic (yellowish). 10% to 75% light to medium grey siltstone and claystone with traces of black coaly fragments. 5% to 10% yellowish-brown siderite fragments and some sandy siderite. 5% to 30% white to yellowish-grey crystalline (replacement) calcite fragments mostly as lenses and patches in sandstone, siltstone and coal fragments.

5500' - 6000' 20% to 60% light grey, angular, well-sorted, v. fine to medium-grained sandstone with clayey matrix and carbonate cement; sandstone is very sideritic (yellowish). 30% to 75% medium to light grey siltstone and claystone with traces of black coaly fragments and some pyrite grains. 5% to 25% white to yellowish grey crystalline (replacement) calcite fragments. Some siderite and sandy siderite fragments.

6000' - 7000' As above 5500' - 6000', only the percentage varies.

7000' - 7280' 20% to 60% light grey, angular, well-sorted, v. fine to medium-grained sandstone with clayey matrix and carbonate cement; sandstone is very sideritic (yellowish). 30% to 60% light to medium grey siltstone and claystone with traces of black coaly fragments and some pyrite. Up to 10% white to yellowish-grey calcite, as patches and lenses in sandstone, siltstone and coaly fragments.

7280' - 7400' As above 7000' - 7280' only the percentages vary and yellowish brown siderite and sandy siderite fragments may be up to 25%.

7400' - 8100' 20% to 60% light grey, angular, well-sorted, v. fine to medium-grained sandstone with clayey matrix and carbonate cement; sandstone is spotted with grey, yellow, black and green. 35% to 75% light grey to dark brown siltstone and claystone with fragments of black coal and some crystalline calcite. Traces of pyrite.

8100' - 8600' 20% to 70% light to medium grey, angular, moderately sorted, v. fine to medium-grained sandstone with clayey matrix and carbonate cement; spots of various colours. 30% to 80% light to medium brown siltstone and claystone with fragments of black coal and lenses of white crystalline calcite.

8600' - 9600' 10% to 30% medium to brownish-grey, angular, well to moderately sorted, v. fine to medium-grained sandstone with clayey matrix and carbonate cement. 70% to 90% medium to dark grey siltstone and claystone with traces of black coaly fragments and white to yellowish crystalline calcite. Few fragments of siderite.

9600' - 10,065' 5% to 20% medium to dark grey, angular, poorly to moderately sorted, v. fine to medium-grained sandstone with clayey matrix and carbonate cement. 80% to 95% medium to dark brownish-grey siltstone and claystone with some calcite, black coaly fragments and pyrite.

Lat: 38° 24' 26" S

Long: 144° 11' 53" E

Elevation: 76' (K.B.), 65' (G.L.)

Scale: 1 inch = 100 feet

B.M.R. well index No. 160

COMPOSITE WELL LOG

ANGLESEA No. 1

PLATE 1
(SHEET 1)

Company: OIL DEVELOPMENT N.L.

Basin: OTWAY

State: VICTORIA

LEGEND

CONGLOMERATE
SILTSTONE
CALCITE
Foraminifera
SAND (LOOSE)
CLAYSTONE
COAL
Gastropoda
SANDSTONE
SILTY SIDERITE

DEPTH R. T. (feet)

GRAIN - SIZE (Wentworth): CLAY & SILT, V. FINE, FINE, MEDIUM, COARSE, V. COARSE, GRANULE

GRAIN - SIZE PERCENTAGE: V. COARSE — COARSE; 20 40 60 80

CUTTINGS PERCENTAGE: 20 40 60 80

COLOUR TONE: LIGHT, MEDIUM, DARK

CUTTINGS DESCRIPTION

(1) Brownish grey to yellowish grey, iron oxide-rich clayey silt with traces of red to yellowish brown iron sulphate. Some carbonaceous silt. Fragments of well cement present.

(1) Brownish grey to yellowish gray iron oxide-rich clayey silt with traces of red to yellowish iron sulphate. Few fragments of brown coal. Some isolated quartz grains.

(2) Grey, angular to subrounded, well-sorted, coarse to very coarse-grained quartz; granules and pebbles up to 4 mm across.

(3) Dark brown (lignitic) coaly fragments with some carbonaceous silt. Fragments of well cement present.

(2) Grey, angular to subrounded, poorly to moderately sorted, fine to very coarse-grained quartz; granules and pebbles up to 4 mm across. Some quartz grains are subedral.

(3) Dark brown (lignitic) coaly fragments with traces of amber and loose mica.

(2) Grey, angular to rounded, poorly to moderately sorted, fine to very coarse-grained quartz; some clear, milky and smoky grains are present; some pitted and some euhedral grains. At 900-1080' gravel content increases up to 80%. Pebbles up to 8 mm in diameter are present. Few fragments of gastropoda are present.

(3) As above lithology (3)

(2) Grey angular to rounded, poorly to moderately sorted, medium to very coarse-grained quartz; some smoky milky, and pinkish grains are present. Granules and pebbles up to 6 mm across. A few feldspar grains are present.

(3) Dark brown (lignitic) coaly fragments with traces of gray siltstone. Few fragments of microcline, rock of granitic composition and biotite schist. Some pyrite present.

(2) Light gray, angular to subrounded, poorly to moderately sorted, medium to very coarse-grained quartz; some milky and smoky grains are present. Some feldspar, quartzite and siliceous rock fragments are present.

(2A) Yellowish to white, angular, poorly to moderately sorted, very fine to coarse-grained, carbonate - kaolinite cemented sandstone.

(3) Dark brown (lignitic) coaly fragments.

(4) Light gray, angular, poorly sorted silty to very fine-grained lithic feldspathic sandstone with clayey matrix or carbonate cement; the sandstone comprises lithic grains of grey, brown, green and yellow colour.

(5) Medium yellowish brown to light olive grey, sandy siderite and sideritic sandstone.

(2) As above lithology (2); some grey feldspar grains.

(6) Light gray siltstone and claystone with some pyrite. Fragments of well cement are present.

(3) Black coal fragments. Few isolated quartz grains.

(4) Light-gray, angular, well-sorted, silty to very fine-grained lithic feldspathic sandstone (subgreywacke and greywacke) with carbonate cement or clayey matrix; some fragments display patches of yellowish siderite.

(5) Light gray siltstone and claystone. Some siderite rock with carbonaceous flakes and fragments of plant-tissue. Few fragments of very fine sandy siderite.

(3) As above lithology (3). Few isolated quartz grains.

(4) As above lithology (4).

SPONTANEOUS POTENTIAL: − + ; 10 mv

DEPTH

CORES

LITHOLOGICAL LOG

RESISTIVITY: Ohms — m^2/m Am, = 16"; 0 — 10; 0 — 50

Run 1

Run 2

INTERPRETED LITHOLOGY

Clayey siltstone

Soft, brownish to yellowish grey iron oxide-rich clayey siltstone. Abundant mica, flaky plant debris and pyrite present. Some loose rounded to subrounded, medium to coarse glassy, clear and milky quartz grains are scattered in the siltstone, particularly at 140-150 feet.
Sandstone
Lenses of sandstone with carbonate and silica (opal) cement and abundant foraminifera, sponge spicules and shell debris occur possibly between 150 and 230 feet.

Sands and poorly consolidated sandstone

Poorly consolidated clayey sandstone, sands and gravels. The sand grains are angular to subrounded coarse to very coarse grains of quartz, metaquartzite, minor siliceous rocks, and feldspar (less than 5%). Some of the angular quartz grains are facetted and strongly corroded. The quartz and metaquartzite granules are rounded to subrounded.

Brown coal and carbonaceous siltstone

Layers of brown coal, lignite and associated dark argillaceous carbonaceous siltstones are abundant, particularly between 430 and 480 feet, 850 and 710 feet, 1210 and 1080 feet approximately, but occur sporadically throughout the interval.

Sandy claystone

Sandy claystone constitutes a significant part of the sediments of the interval. This rock-type is not well represented in the cuttings. Core 3 and 4 show soft grey-brown sandy micaceous claystone with lignitic fragments and lenses of brown coal.

Poorly consolidated sandstone

Poorly consolidated clayey sandstone with angular to subrounded medium to very coarse quartz, metaquartzite and subordinate K-feldspar grains. Granules and pebbles up to 6 mm across are present throughout. Abundant mica, pyrite and carbonaceous matter.

Sandy claystone

Sandy claystone is more abundant than in the interval above, according to electric log. Core 6 shows massive gray sandy claystone with lenses of coal.

Brown coal and carbonaceous siltstone

Layers and lenses of brown coal and lignite, and associated carbonaceous siltstone; the frequency of these layers and lenses is greater towards the top of the interval.

Friable sandstone with some calcite cement (in parts)

Poorly cemented coarse to very coarse sandstone with lenses and interbeds of fine to very coarse-grained sandstone cemented with carbonate and some kaolinite.

Sandstone

Moderately sorted angular to subrounded medium to very fine-grained sandstone (subgreywacke and greywacke). Lithic fragments are abundant (approx. 35%) and comprise metamorphic and volcanic rock-fragments. The volcanic rock-fragments may form as much as half the lithics at recurrent depths. Feldspar (approx. 15%) is acid plagioclase, orthoclase, microcline. Quartz is subordinate (10%). Cementing media are calcite, siderite rhombs, clay (kaolinitic and illitic) and detrital matrix. Syngenetic siderite aggregates are also present. Pyrite and lenses of carbonaceous matter are common. Kaolinization is mild.

Mudstone and siltstone

Mudstone and siltstone form thin interbeds or laminae. The light to medium grey mudstone and siltstone are rich in carbonaceous matter, plant fragments, pyrite and opaque material. Some horizons are rich in siderite and chlorite. Some mudstone pebbles are present.
Core 11, 9 and 8 display massive sandstone; cross-bedding, and mudstone pebbles are present together with minor thin laminations showing low-angle cross-bedding.

KEY MINERALS

Iron oxide
Iron sulphate
Pyrite
Mica
Minor glauconite
Silica
Pyrite
Mica
Siderite
Calcite
Kaolinite
Pyrite
Siderite
Calcite
Pyrite
Some Kaolinite
Some Chlorite

STRATIGRAPHY

DESCRIPTION OF UNIT

Clayey sandstone with abundant beds of brown coal. Some layers of sandy claystone.

Clayey sandstone, with lenses and layers of brown coal. Abundant layers of claystone.

Med to v coarse Sandstone with calcite cem. in parts.

Very fine to medium-grained sandstone with abundant calcite and siderite cement. Clay and detritus matrix is recurrently abundant. Mudstone and siltstone are and contain abundant opaque and carbonaceous matter.

INFORMAL UNIT: Gb; (1446 feet); H; (105ft.); M_1

MEMBER: Db; Anglesea

FORMATION: DEMONS BLUFF FORMATION

GROUP: VIEW COAL MEASURES; EASTERN VIEW

AGE: EOCENE — OLIGOCENE TO EOCENE; ? — PALAEOCENE ?; LOWER CRETACEOUS

To accompany Record 1965/166

Geologist : J. DELLENBACH I.F.P.

Drawn by : L. KEREC I.F.P.

SEPT., 1965

PLATE 1
(SHEET 2)

DEPTH R.T. (feet)	GRAIN-SIZE (Wentworth): CLAY&SILT, V. FINE, FINE, MEDIUM, COARSE, V. COARSE, GRANULE	GRAIN-SIZE PERCENTAGE (— V. COARSE, — COARSE; 20 40 60 80)	DEPTH	CUTTINGS PERCENTAGE (20 40 60 80)	COLOUR TONE (LIGHT, MEDIUM, DARK)

CUTTINGS DESCRIPTION

(5) Yellowish brown siderite fragments; some sandy siderite fragments.

(6) Light grey siltstone and claystone, with traces of black coal fragments and some scattered quartz grains.

(2) Grey, angular, poorly sorted, fine to very coarse-grained quartz grains.

(4) Light grey, angular, very well sorted, silty to very fine-grained sandstone (subgreywacke and greywacke) with carbonate cement or clayey matrix.

(3) Black coaly siltstone and coal fragments.

(5) Yellowish brown siderite fragments and some sandy siderite fragments.

(6) Light grey siltstone and claystone with some scattered quartz grains.

(4) As above lithology (4); few isolated quartz grains.

(5) As above lithology (5).

(6) As above lithology (6); some coal fragments.

(4) Light grey, angular well-sorted silty to very fine-grained sandstone (subgreywacke and greywacke) with carbonate or clayey matrix. Few isolated quartz grains.

(3) Black coaly siltstone and coal fragments.

(7) Yellowish grey to brown crystalline (replacement) calcite fragments.

(4) Light grey, angular, well-sorted, silty to very fine-grained sandstone (subgreywacke and greywacke) with carbonate cement or clayey matrix. Increase in yellowish (sideritic) patches is noted in cement.

(5) Yellowish brown siderite fragments and some sandy siderite fragments.

(6) Medium to light grey siltstone and claystone with fragments of coal.

(7) White to yellowish grey crystalline (replacement) calcite and siderite fragments. These minerals commonly occur also in lenses in the siltstone and claystone of lithology (6).

(4) Light grey, angular, moderately to well-sorted, medium-grained sandstone (subgreywacke, greywacke - and volcanic sandstones between 5330 and 5710 feet) with carbonate (calcite and siderite) cement or clayey - chloritic matrix.

(5) Yellowish brown siderite fragments and some sandy siderite fragments.

(6) Light grey siltstone and claystone. Fragments of siltstone show thin interlaminations of coal.

(4) Light gray, angular, well-sorted, very fine to medium-grained sandstone (mostly greywacke) with clayey matrix and minor carbonate cement. Patches of yellow siderite are present among the cementing media.

(6) Medium gray siltstone and claystone with fragments of coal.

(7) White to yellowish crystalline (replacement) calcite and siderite fragments. Few grains of pyrite.

(4) Light gray, angular, moderately sorted, very fine to medium-grained sandstone (mostly subgreywacke) with carbonate cement or clayey matrix. Few fragments are sideritic, some show infilled fractures.

(6) Light gray siltstone and claystone with fragments of coal. Some pyrite.

(7) White to yellowish brown crystalline (replacement) calcite and siderite fragments.

(4) Light grey, angular, well sorted, very fine to medium-grained sandstone (greywacke and subgreywacke) with clayey matrix or carbonate cement. Few fragments of siderite.

SPONTANEOUS POTENTIAL (10 mv)	DEPTH	CORES	LITHOLOGICAL LOG	RESISTIVITY Ohms m²/m Am_1=16" (0–10, 0–50)

INTERPRETED LITHOLOGY

Sandstone

Light grey, angular, medium to very fine-grained clean subgreywacke with abundant calcite cement. Minor greywacke with clay and detritus matrix. The framework of the sandstone comprises approx. 35% lithic fragments, 15% feldspar, and 10% quartz. Lithic fragments are mostly fragments of phyllite and metasediments, well-preserved fragments of basalt, devitrified groundmass of effusive rocks are abundant. Cementing media are calcite and minor siderite rhombs (subgreywacke) or kaolinite, illite, mica, conspicuous chlorite and detritus (greywacke). Opaque material, pyrite and carbonaceous matter is abundant. At some depths (i.e. 3158 feet, core 12) heavy minerals: zircon, sphene, apatite and opaques are abundant in certain laminae. At several depths (3410, 3470, 3770 feet) layers of subgreywacke with pure calcite cement are present. Kaolinization of clay minerals, calcitization and recrystallization of siderite though present are not extensive.

Mudstone

Medium grey massive mudstone is recurrent over the interval. The groundmass of the mudstone and siltstone is illitic and contains in some instances finely dispersed chlorite. Pyrite, opaque material and carbonaceous matter is abundant. Plant fragments are abundant in some laminae. Rounded sideritic mudstone fragments, siderite patches, lenses and fissure infillings are observed. Core 17 to 12 are representative of massive subgreywackes, greywackes, and associated siltstones. Some faint laminae rich in coal plant fragments occur in the available parts of core 17 and 16. Dips, where recognisable vary between 10 and 25°.

Key minerals: Calcite, Siderite, Kaolinite, Illite, Some Chlorite. Minor heavy minerals: Apatite, Zircon, Garnet, Tourmaline, Chloritoid, Penninite, Sphene, Opaques.

Description of unit: Very fine to medium-grained sandstones with abundant calcite cement. Minor kaolinization. Mudstone with carbonaceous matter. Volcanic rock fragments are abundant.

Sandstone

Light grey angular very fine to fine-grained sandstone. Sorting is good. The framework is formed by up to 35% rock fragments, 20% feldspar, 15% quartz. The feldspar and rock fragments are strongly altered and replaced by kaolinite and siderite, to a lesser extent by calcite. The quartz and metaquartzite grains are strongly corroded. Besides kaolinite, siderite and calcite, the cementing media are carbonaceous matter, opaque material and illitic clay which also forms contorted laminae. Petaloid aggregates of kaolinite crystals (up to 0.08 mm in size) are present in fissures and replaced parts of cores.

Mudstone

Medium grey, bedded mudstone. The groundmass of the mudstone is made of detritus, illite flakes, kaolinite, altered micas, opaque material, pyrite, and carbonaceous matter. Kaolinite and siderite replacement also affect the mudstone. The frequency of replaced horizons increases from 4850 to 5340 feet.
Cores 20, 19 and 18 show thin laminations, low-angle cross-bedding, disturbed and undulate bedding and also higher energy features like strong local scouring and cross-bedding. Possible burrows occur at 4821 feet. Plant fragments are present in all cores of the interval. Microfaulting, brecciation are common and most of the fractures are infilled with siderite calcite, and pure white kaolinite.

Key minerals: Abundant Kaolinite, Siderite, Calcite. Pyrite. Minor Apatite, Zircon, Penninite.

Description of unit: Very fine to fine-grained sandstones strongly altered and replaced by kaolinite and siderite. Mudstone strongly replaced by kaolinite and siderite. Fractures infilled by kaolinite.

Sandstone

Light grey angular very fine to medium-grained moderately sorted sandstone (subgreywacke mainly), containing lithics (up to 25%) feldspar (up to 15%) and quartz (20%). Cementing media are kaolinite, siderite, calcite, also illite and silica. At recurrent depths volcanic sandstones with chloritic matrix are present (only recognizable in thin-section).

Mudstone

The grey mudstone displays a kaolinitic and illitic groundmass with detritus and abundant pyrite and carbonaceous plant fragments. Core 21 shows strong cross-bedding with dips up to 25° but also thin laminations. Kaolinite, siderite, calcite -infilled fractures are abundant.

Key minerals: Kaolinite, Siderite, Calcite, Chlorite, Illite, Silica, Pyrite. Minor Apatite, Zircon, Garnet.

Description of unit: Very fine to medium-grained sandstones with kaolinite, and volcanic sandstone with chlorite.

Informal unit: M_1

Mudstone and shale

Medium grey mudstone and shale interlaminated with pyritic carbonaceous layers. Lenses and aggregates of siderite are abundant. Abundant flakes of illite, muscovite and leached biotite. Very strong diagenetic replacement by kaolinite and siderite, also by calcite.

Sandstone

Light to medium grey, well-sorted, very fine to fine-grained sandstone - mostly greywacke. Rock-fragments are very abundant (30%), feldspar - altered to various degrees - (5-20%); quartz is apparently subordinate (10%). Cementing media are replacement kaolinite, illite, siderite, calcite and contain abundant carbonaceous matter and pyrite.
Core 22 and 23 show thinly laminated shales but also higher energy features such as mudstone pebbles up to 1 cm. in diameter (5770 feet), strong cross-bedding in mudstones, and slump structures (6245 feet). Subvertical fractures infilled with kaolinite, siderite, calcite are abundant.

Key minerals: Kaolinite, Siderite, Calcite, Illite, Some Silica, Minor heavy minerals.

Description of unit: Mudstone and very fine-grained well-sorted sandstone (greywacke) with abundant replacement kaolinite, siderite, calcite, also illite, silica, and pyrite.

Sandstone

Light to medium grey moderately sorted very fine to medium-grained sandstone - subgreywacke mostly - with abundant lithic fragments (30-35%) containing volcanic rock fragments, feldspar (up to 20%) and quartz (15%). Cement is of calcite, siderite with minor replacement by clay (kaolinite and calcite.

Mudstone and shale

Mudstone and shale are subordinate over the interval and show little alteration to clays and carbonate.

Key minerals: Siderite, Calcite, Minor: kaolinite, Pyrite, Apatite, Zircon.

Description of unit: Very fine to medium-grained, mod.-sorted sandstone (subgreywacke) with carbonate cement.

Sandstone

Light to medium gray, moderately sorted very fine to medium-grained sandstone (greywacke and subgreywacke). Constituents are abundant rock-fragments (35%), feldspar (15-20%) and quartz (10-15%). Calcite, siderite, minor chlorite and recrystallized replacement kaolinite are the cementing media together with pellicular illite in some instances. Carbonaceous matter and pyrite are present.

Siltstone and claystone

Medium grey massive siltstone and claystone with clayey groundmass and abundant carbonaceous matter and pyrite. Cores 24 and 25 are massive sediments but also show thin carbonaceous-rich laminations, undulations, low-angle cross-bedding, small scale slumping, layers with abundant mudstone pellets. Infilled fractures are present.

Key minerals: Siderite, Calcite, Minor: chlorite, Kaolinite, Pyrite, Minor heavy minerals: Penninite, Apatite, Zircon.

Description of unit: Very fine to medium-grained moderately-sorted sandstone with calcite, siderite, and replacement kaolinite.

Informal unit: M_2

STRATIGRAPHY — DESCRIPTION of UNIT | INFORMAL UNIT | MEMBER | FORMATION | GROUP | AGE

GROUP: OTWAY GROUP

AGE: LOWER CRETACEOUS

Geologist : J. DELLENBACH I.F.P.

Drawn by : L. KEREC I.F.P.

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To accompany Record 1965/166

PLATE 1
(SHEET 3)

DEPTH R.T. (feet)

GRAIN-SIZE (Wentworth): CLAY SIZE, V.FINE, FINE, MEDIUM, COARSE, V.COARSE, GRANULE

GRAIN-SIZE PERCENTAGE: V COARSE / COARSE — 20 40 60 80

DEPTH

CUTTINGS PERCENTAGE — 20 40 60 80

COLOUR — TONE: LIGHT, MEDIUM, DARK

CUTTINGS DESCRIPTION

(5) Light brown siderite fragments.

(6) Medium gray siltstone and claystone with fragments of black coal. Few grains of pyrite.

(7) White to yellowish grey crystalline (replacement) calcite fragments.

(4) Light grey, angular, well-sorted, very fine to medium-grained sandstone (subgraywacke and graywacke) with carbonate cement or clayey matrix. Patches of yellow to orange siderite are present.

(6) Medium to dark grey siltstone and claystone with fragments of coal.

(4) As above lithology (4): abundant crystalline (replacement) calcite fragments.

(6) As above lithology (6).

(4) Medium grey, angular, well sorted, very fine to medium-grained sandstone (subgraywacke and graywacke) with carbonate cement or clayey matrix. Abundant crystalline (replacement) calcite fragments.

(6) Medium to dark grey siltstone and claystone with fragments of coal.

(4) Medium grey, angular, well sorted, very fine to medium-grained sandstone (subgr-ywacke and graywacke) with carbonate cement or clayey matrix. Abundant crystalline (replacement) calcite fragments. Few fragments of siderite.

(6) Medium brown siltstone and claystone with fragments of coal. Some white and yellowish crystallike (replacement) calcite.

SPONTANEOUS POTENTIAL — − + — 10 mv

DEPTH

CORES

LITHOLOGICAL LOG

RESISTIVITY — Ohms — m^2/m — Am, =16" — 0—10, 0—50

Run 5

Run 6

INTERPRETED LITHOLOGY

Sandstone

Light to medium gray, very fine to medium-grained moderately sorted sandstone (subgreywacke and greywacke). Constituents are rock-fragments (35%) comprising metamorphic rocks, feldspar (15-20%) and quartz (10-15%). In some horizons the quartz grains are strongly welded with the detrital grains, and over-grown. Calcite and siderite are the predominant cementing media but clays (kaolinite and illite) are abundant. Replacement by kaolinite and carbonate is important. Flaky mica and illite are present. Carbonaceous matter and pyrite are abundant throughout.

Mudstone

Grey mudstone is well represented over the interval. The groundmass of the mudstone contains abundant illitic clay, kaolinite, siderite, mica, carbonaceous matter and some chlorite. Cores 29, 28, 27 and 26 show calcite and clay-cemented subgrey-wacke. Where packed together the quartz, feldspar and meta-quartzite fragments are strongly interpenetrated and welded. Very thin, regular laminations, low-angle small scale cross-bedding, undulations, contrast with high energy features: trough cross-bedding, scour-and-fill, layers with mudstone pellets, slump structures. At 7258 feet (core 26) imprints of branding plants, possibly grown in situ are present. Carbon-aceous plant fragments are abundant throughout.

Sandstone

Medium grey angular very fine to medium grained moderately sorted sandstone - in most parts subgraywacke. The rock-fragments (35%) comprise fresh volcanic (basalt, fragments of chalcedonic groundmass) and metamorphic rock-fragments. Feldespar (15-20%) is replaced in parts by calcite, kaolinite and recrystallized illitic clay. Quartz is subordinate and in some instances strongly corroded, welded, and interpene-trated. Cementing media are calcite and siderite; siderite mudstone fragments are also present. Kaolinite (partly as replacement), illite, altered mica are abundant. Carbonaceous matter is disseminated in the sandstone or forms lenses and thin laminae.

Mudstone and shale

The medium grey mudstone is rich in carbonaceous matter, flaky illite and altered mica, pyrite and opaque material. The proportion of mudstone and shale increases towards the bottom of the interval.
Core 30 shows massive indurated dark grey siltstone. The rock is brecciated and fissures are infilled with silica, clay and calcite. Dips are up to 60°. Intense fracturing.

Shale, siltstone, claystone

Dark grey, indurated, thinly laminated shale, sandy siltstone and claystone. The sandy siltstone is of greywacke composition and has a tight groundmass of illite, chlorite, mica flakes, carbonaceous matter and pyrite. Calcite replacement and silica (quartz) infillings are present.

Sandstone

Dark grey, tight, angular, very fine to medium-grained, moderately sorted sandstone. Similar percentages of constituents as above: lithics 30-35%, feldspar 20%, quartz 15%. Among the lithic grains are well-preserved volcanic-rock fragments comprising vesicular glass, with or without chlorite and minor zeolite. Cementing media are calcite, siderite, some chlorite in the subgraywacke. The matrix of the greywacke is illitic, kaolinitic, with detritus and abundant carbonaceous matter and pyrite. Calcite infilled fissures and zones replaced by calcite are common. Cores 31, 32, and 33 display laminations, low-angle small scale cross-bedding and scouring. Coal lenses and coaly plant fragments up to several inches in size are present.

KEY MINERALS

Siderite, Calcite, Clay, Mica, Silica, Pyrite, Minor heavy minerals, Sphene, Zircon, Penninite, Tourmaline, Apatite

Calcite, Ankerite, Siderite, Clay, Mica, Pyrite, Silica, Minor heavy minerals, Penninite, Chlorite, Zircon, Sphene, Apatite

Illite, Kaolinite, Chlorite, Calcite, Quartz, Pyrite, Minor Zeolite, Minor heavy minerals, Chloritoid, Chlorite, Penninite, Zircon, Epidote, Tourmaline, Apatite

STRATIGRAPHY

DESCRIPTION OF UNIT	INFORMAL UNIT	MEMBER	FORMATION	GROUP	AGE
Very fine to medium-grained sandstone with calcite, siderite and clay cement. Mudstone and very fine to medium-grained sandstone with calcite, siderite and clay. Mudstone, siltstone and shale increasing towards base of interval. Some interpenetration and welding of the quartz grains. Abundant carbonaceous material and pyrite.	M_2			OTWAY GROUP	LOWER CRETACEOUS
Shale, siltstone and claystone are illitic, chloritic and contain abundant coaly matter and pyrite. Calcite and silica replacement and infilling of fractures present.					

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