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COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

RECORD No. 1965/100

A PETROLOGICAL STUDY OF THE SEDIMENTS FROM PLANET HEATHFIELD NO. 1 WELL, OTWAY BASIN, VICTORIA.

by

P. J. HAWKINS

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SUMMARY

Planet Heathfield No. 1 well was drilled to test a seismic-defined structure.

Petrological studies show that 92 feet of Unit P - of possible Jurassic age - and 5728 feet of Lower Cretaceous Unit M sediments are present in this well. Within Unit M it has been possible to establish subdivisions based on the nature of the cement. Chloritic and kaolinitic clay together with calcite and zeolite cement were observed. A porous quartz sand occurs over the interval 4144 - 4115 feet.

Unit J and the Upper Cretaceous Units Gh and Gf, are absent in this well. Units Gd, and Gb are thin arenaceous sequences in Heathfield No. 1; they are considered to be Upper Cretaceous in age.

Unit Dd is a well developed sequence - 419 feet thick - of pelletal, oolitic, sideritic sandstones and clays. The overlying Unit Db is thin, and consists of sandstones and carbonaceous clays; a paralic environment is envisaged for this unit.

Unit Bc which unconformably overlies Unit Db, is composed of conglomeratic sandstones and thin siltstones representing a transgressive phase in sedimentation. Unit Bb is absent in this well.

Unit Ab is represented by a thin sequence of marine calcarenites.

The best reservoir prospect occurs in a sand at 4115 feet where very good porosity and permeability exists. The only hydrocarbons from Heathfield No. 1 were recorded in Drill Stem Test No. 2 (4078 - 4144 feet) from Unit M; salt water with gas was recovered.

INTRODUCTION.

Heathfield No. 1 well was drilled for Planet Exploration Company Pty. Ltd., approximately 10 miles west-south-west of Casterton, Victoria, with a view to testing the crest of a closed anticline. Details of the well and its location are given below:

Location	:	Latitude 37° 37' 38" S. Longitude 141° 11' 08" E. 1:250,000 sheet. Hamilton J.54 - 7
Elevation	:	Ground Level - 230 feet A.S.L. Kelly Bushing - 244 feet A.S.L.
Total depth	:	7,500 feet (drillers') below K.B.
Date Drilling Completed:		21st April 1964.

The current petrological study was undertaken as part of the review of the Otway Basin by the Subsurface Section of the Petroleum Exploration Branch, Bureau of Mineral Resources.

Samples of cuttings from 10 feet intervals were examined together with parts of 18 of the 19 cores taken. A binocular microscope examination was carried out together with a thin section study of selected cores and cuttings. Staining tests for phosphate were undertaken on all samples. X-ray analyses of the clay matrices in sandstones at 5407, 4621 and 4616 feet were carried out.

The well completion report and composite logs (Cundill, 1964) were the principal references for this study.

DESCRIPTION OF LITHOLOGICAL UNITS.

Unit P 7,500 to 7408 feet.

Only 92 feet of this unit was intersected in Heathfield No. 1 well, the top of this unit being marked by an increase in the resistivity at 7408 feet accompanied by a negative deflection (relative to the shale base line) of the S.P. curve.

Unit P is represented by sandstone with Unit R affinities, interdigitating with Unit M lithic sandstone and mudstone. Unit R sediments, as such, have been recorded from only Pretty Hill No. 1 in the Otway Basin and have been described by Edworthy (1964). They interdigitate with Unit M sediments to form Unit P in the Eumeralla and Geltwood Beach wells, (Edworthy, 1965; Dellenbach, 1965).

The chief features by which this unit has been distinguished from Unit M in Heathfield No. 1 are as follows:-

(a) Increase in garnet content.
(b) Poorer sorting in the sandstones.
(c) Increase in grain size and more rounding of the grains.
(d) Increase in quartz content.
(e) Occurrence of microcline in minor amounts.
(f) Increase in metamorphic lithics.

These sediments show all degrees of gradation from mudstone to siltstone to sandstone. The silt-sized sediments are indurated and laminated.

Mudstone

Core No. 19 from 7480 to 7490 feet, is thought to be typical of Unit P mudstone. Macroscopically, the rock is dark grey, compact mudstone which breaks with a conchoidal fracture. In thin section, the silt-sized particles consist of quartz, untwinned feldspar and scattered lithics of microcrystalline siliceous fragments, and occur in an illitic and chloritic clayey matrix. Macerated carbonaceous matter occurs as rare patches in the clay.

This mudstone grades upwards into a dark grey, conpact sandy mudstone; in its sand fraction it contains quartz, oligoclase and untwinned feldspar and lithics of aphanitic and microcrystalline siliceous fragments. . The matrix is chiefly chlorite, or illitic clay. Other minerals present include flaky chlorite, muscovite and pyrite.

Sandstone

The most characteristic type for this interval is the cemented lithic sandstone of the subgreywacke type (Pettijohn 1957).

It is generally light to dark grey, compact, rarely friable, subangular, fine to medium-grained and poorly to moderately sorted. The chief constituent is quartz which makes up 30% of the rock. The lithics (25 - 30%) consist of aphanitic chloritic, microlitic volcanic fragments together with schist, metaquartzite and quartzite. There is a noticeable increase in the metamorphic constituents making up the lithics as compared with Unit M. The feldspars (20 - 30%) are albite, oligoclase, sanidine and microcline. In Unit P there is a decrease in the amount of twinned feldspar present.

Other minerals present include abundant garnet and flaky chlorite, squeezed muscovite, some authigenic mica, pyrite, epidote, apatite, zircon and tourmaline. The increase in the garnet content in this unit is one of its most diagnostic features. In Heathfield No. 1 the garnets are angular and occur mostly in the coarse-grained quartz sandstone beds; they increase in abundance towards the base of the unit.

The sandstone contains varying amounts (20 - 35%) of matrix and cement depending on the degree of diagenesis which may have taken place. The clay matrix is kaolinitic, illitic and chloritic. The diagenetic cement is generally calcite but patches of epidote do occur in the sandstone together with spots of zeolite. The cement may be patchily developed in the clay matrix or may completely replace the matrix. In some places the lithics have become welded together giving a matrix appearance; welding together of quartz grains also occurs in some of the sandstone. In the calcite-cemented sandstone, corrosion of quartz and feldspar occurs with, in some places, replacement of the feldspar by calcite. Authigenic kaolinite is obvious where it replaces feldspar.

Fair porosity exists in the calcite-cemented sandstone. The porosity is intercrystalline and ranges from 10 to 15%. Elsewhere porosity is poor.

Sedimentary structures and environmental criteria

The grey sandstone is interlaminated with dark grey mudstone as shown in Core No. 19 from 7487 to 7500 feet. Carbonaceous and clay laminations and lenses occur in the sandstone in Core No. 19 together with mudstone pebbles.

Microfaulting is evident where thin mudstone laminations within the sandstone have been displaced. Scour-and-fill structures and small scale low-angle cross-bedding occur at 7492 feet. A dip of 45° is present in the well-laminated sandstone at 7490 feet; this dip becomes flat at

7487 feet, indicating that the 45° dip is a sedimentary feature - probably foreset bedding. Elsewhere dips of 10° are more common.

The sedimentary features observed in Core No. 19 indicate that these sediments were deposited under shallow water conditions in probably a paralic environment. The mudstone pebbles in the sandstone suggest periods of minor turbulence accompanied by quieter conditions when mudstones and siltstones were deposited. The lithic constituents present suggest both a metamorphic and volcanic source for these sediments.

Age determinations

Determinations of the microflora were carried out on Cores Nos. 6 - 19 by Hodgson (in Cundill, 1964) and correlation with the neighbouring wells was undertaken.

Core No. 19 which occurs within Unit P in Heathfield No. 1 is regarded by Hodgson (op. cit.) as being possibly uppermost Jurassic in age. This interpretation has been based on the fact that, although key Jurassic forms are lacking, the core does not contain *Cicatricosisporites australiensis* or *C. ludbrooki* which are diagnostic of Lower Cretaceous sediments.

Both Heathfield and Penola wells apparently penetrated the interval of *Dictyotosporites speciosus* and may have reached sediments older than those at the bottom of Eumeralla No. 1 which was still in sediments with *D. speciosus* at total depth (10308 feet).

Unit M 7408 to 1680 feet

This unit has been subdivided into a number of smaller units based on lithology and changes in degree of diagenesis. The top of Unit M is well differentiated from Unit G by a marked change in the electric log characteristics.

Interval: 7408 to 6593 feet

The interval is characterized by a constant S.P. curve with only minor negative deflections (relative to the shale base line) opposite some sandstone beds. The resistivity curve is variable with moderately high peaks opposite sandstone horizons. The peaks between 7210 and 6593 feet correspond to carbonaceous or coaly horizons.

The lithology consists of mudstone and siltstone with interbedded lithic sandstone, coal horizons and carbonaceous mudstone. Below 7200 feet there is an increase in the silt content of these sediments. The interval 7408 - 6593 feet in Heathfield No. 1 can be correlated with a zeolite-cemented interval, 8955 - 8100 feet, in Geltwood Beach No. 1.

Mudstone and siltstone

The sediments show all forms of gradation from siltstone to mudstone and sandy mudstone. The mudstone is medium to dark grey and brownish-grey, compact, laminated in parts, with occasional sideritic and sandy streaks. The siltstone is medium to dark grey with sandy streaks and carbonaceous flakes.

In Core. No. 18 (6590 - 6900 feet) the mudstone contains thin sand laminations and sand lenses. In thin section the sand fraction consists of angular quartz, albite and aphanitic fragments in a chloritic and illitic clay matrix. Rare spots of calcite occur, sometimes replacing feldspars. Other minerals present include muscovite and chlorite. Carbonaceous laminations and lenses occur.

Sandstone

The sandstone - predominantly greywacke in character - is light to medium grey, compact, rarely friable, angular to subangular, very fine to fine-grained, occasionally medium-grained, and moderately sorted.

The mineral constituents consist of quartz and sutured quartz which range from 10 to 30%. The feldspar content (20 - 25%) is albite, oligoclase, untwinned feldspar and rare microcline. The lithic content differs from Unit P sandstone in that metamorphic rock fragments are less abundant. The lithics (25 - 50%) comprise aphanitic, chloritic aphanitic and microlitic volcanic fragments, microcrystalline siliceous fragments and chloritic fragments.

The accessory minerals are squeezed muscovite, biotite, chlorite, penninite, zircon, angular fractured garnets, pyrite and sphene. Carbonaceous matter and resin also occur.

The matrix material in the sandstone varies from 10 to 30% and consists of poorly crystallized kaolinitic, chloritic and illitic clay. Minor diagenetic changes occur in the form of patches of recrystallized calcite and horizons containing zeolite cement; ferriferous chlorite cement is present at 6770 feet. Other diagenetic features include alteration of feldspar to kaolinite and some replacement of feldspar by calcite. Quartz welding occurs together with some welding of the lithic grains. Alteration of lithics to kaolinite make them difficult to distinguish from the groundmass in some instances.

Porosity is poor in all of these sandstones.

Sedimentary structures and environmental criteria

The sandstone is interlaminated with mudstone and siltstone as shown in Core No. 18 (6890 - 6900 feet). Carbonaceous laminations and lenses are present. Small scale low-angle cross-bedding features occur in the mudstone and are emphasized by the clean sand laminations present. Questionable dips of 10° were observed in Core No. 18.

The presence of carbonaceous material throughout the sequence either in the form of finely disseminated matter in mudstones or as coaly horizons, would indicate a paralic environment of deposition; shallow water conditions are envisaged.

Interval: 6593 to 5602 feet

This sequence is characterized on the electric log by a positive S.P. curve with rare deflections. The resistivity curve is generally low with a few high resistivity peaks - the frequency of high peaks being much less than in the interval below. This reflects the sparse carbonaceous and fewer, thinner sandstone horizons in this sequence compared with the interval below 6593 feet.

The lithology consists of predominant siltstone at the top which grades into mudstone towards the base. Interbedded with these sediments are some thinly bedded lithic sandstones. There is a greater proportion of siltstone to sandstone over this interval compared with the lower interval. The correlative interval in Geltwood Beach No. 1 is from 8100 to 7000 feet.

Mudstone and siltstone

The siltstone is medium greenish-grey and brownish-grey, compact, with sandstone and claystone streaks together with carbonaceous fragments.

The mudstone is medium to dark grey and greenish-grey, compact, thickly bedded, with siltstone and sandstone streaks and lenses. In Core

No. 16 (5990 to 6000 feet) the sand fraction of the layers within the mudstone consists of angular to subangular grains of quartz, albite and microcrystalline siliceous fragments in a chloritic and illitic clay matrix. Other minerals present include muscovite, sericite and chlorite. Carbonaceous and woody fragments occur in this core.

Sandstone

These sediments belong to the greywacke assemblage and consist of light to medium grey, friable to compact, angular to subangular, very fine to fine-grained, moderately sorted sandstone.

The quartz content ranges from 5 to 30%; albite, oligoclase, untwinned feldspar and rare microcline varies from 20 to 30%. Some of the feldspars show alteration to kaolinite; corrosion and replacement of some feldspars by calcite also occurs. The lithic fragments make up between 25 and 35% of the rock and comprise aphanitic, chloritized aphanitic, volcanic and chloritic fragments. The minerals include chlorite, squeezed muscovite, garnet, zircon, pyrite, epidote, tourmaline, glaucophane and opaques.

The matrix (20 - 35%) consists chiefly of chlorite with kaolinitic and illitic clay. Diagenetic changes are in the form of calcite patches together with spots of siderite and zeolite cement. However, at 6389 feet in Core No. 17 diagenetic calcite cement accounts for 45% of the rock. Welding of lithic grains and alteration to kaolinite is common.

Porosity is poor throughout.

Sedimentary structures and environmental criteria

Throughout this interval there are interlaminations of thin sandstone and mudstone as shown in Cores Nos. 15 - 17. The presence of carbonaceous clay laminations and lenses, convolutions at 5693 feet and low-angle (10° - 15°) cross-bedding in the cores indicate quiet water deposition; however, the occurrence of slumping and scour-and-fill features observed in Core No. 15 suggests periods of more turbulent conditions.

Shallow water conditions are envisaged where growth of vegetation was possible as indicated by the root markings.

Interval: 5602 to 4976 feet

On the electric log this sequence contrasts with the underlying one by an increase in the overall resistivity. There is a much greater increase in the number of high resistivity peaks which correspond to an increase in the amount of cement present in the sandstones. Some negative deflections of the S.P. curve occur opposite sandstone intervals.

The lithology comprises sandy siltstone, mudstone and claystone with interbedded lithic, feldspathic sandstone; carbonaceous mudstone and rare coaly horizons occur scattered throughout the sequence. Above 5300 feet there is an increase in the proportion of chemical cement to clay matrix present in the sandstone.

The correlative interval in Geltwood Beach No. 1 occurs between 7000 and 6650 feet.

Siltstone and mudstone

The siltstone is medium greenish-grey and grey, compact, with rare brown streaks, becoming sandy basewards; mica flakes and carbonaceous fragments are present.

The mudstone is dark grey to black, compact, very broken at 5031 feet in Core No. 13. At 5414 feet black carbonaceous mudstone occurs which contains clusters of finely disseminated pyrite. The mudstone grades into silty claystone. The silt-sized fraction of these sediments consists of angular quartz, untwinned feldspar, aphanitic fragments and sericite flakes in a chloritic clay matrix.

Sandstone

These sediments are light grey to medium greenish-grey, compact to friable, lithic, feldspathic, angular to subangular, very fine to fine-grained, becoming medium-grained towards the base, moderately sorted sandstones.

The constituents consist of quartz, which ranges from 5 to 30%; albite, oligoclase and untwinned feldspar vary from 20 to 35%. Some of the feldspars show replacement by calcite and some show alteration to kaolinite. The lithic fragments constitute from 30 to 40% of the rock and include aphanitic microlitic volcanic and chloritic fragments together with some phyllite fragments. There is an increase in the volcanic lithics towards the top of the interval; this is accompanied by a corresponding decrease in the metamorphic fragments present. Accessory minerals are muscovite (squeezed), biotite, chlorite, zircon, garnet, sphene, epidote, rutile, collophane and opaques.

The matrix in the sandstone is mainly kaolinitic clay and chlorite which make up between 20 and 40% of the rock. X-ray diffraction analysis of a clay sample taken from sandstone at 5407 feet indicated the presence of kaolinite; some patches of authigenic chlorite cement occur at this depth also. Some of the kaolinite in the sandstone appears to be depositional in origin. Diagenetic changes are principally in the form of introduced calcite which increases in abundance towards the top of the sequence. Spots of pink zeolite cement are present and, in parts, zeolite is found to be replacing feldspar. Some quartz overgrowths and welding occur.

In the kaolinitic sandstones fair porosity exists (10 - 15%), but where diagenetic cement is present porosity is reduced and is poor.

Sedimentary structures and environmental criteria

In core No. 14 (5406 - 5416 feet) thin clay and carbonaceous laminations occur. At 5413 feet there is an abundance of carbonaceous material in the form of "wisps", lenses and fragments. At 5408 feet slickensiding occurs with a dip of 40°; the slickensiding is parallel to the thin laminations. In Core No. 13 (5026 - 5036 feet) thin carbonaceous clay laminations and "wisps" occur; low-angle cross-bedding is present which is emphasized by clay laminations. Carbonized plant remains occur in these sediments. Other dips vary between 10° and 25°.

Environmental conditions appear to have been similar to those during the deposition of sediments in the lower part of Unit M; shallow water conditions are thought to have prevailed in a paralic-type environment.

Interval: 4976 to 4144 feet

On the electric log this sequence does not contrast greatly with the underlying interval. However, the S.P. curve is more variable and there are occasional strong negative deflections opposite more porous sandstone beds; the short normal resistivity curve shows an increase in the occurrence of peaks and the microlog has some very high resistivity peaks. The high peaks correspond to cemented sandstone.

The general lithology comprises siltstone and minor claystone with interbedded lithic sandstone; carbonaceous siltstone and coaly horizons are rare over this interval. The siltstones are less sandy compared with those in the sequence below 4976 feet.

Siltstone and minor claystone

These sediments form the bulk of the sequence and consist of light to medium grey and greenish-grey compact siltstones with rare brown streaks; they are chloritic and sandy. The sand fraction consists of angular quartz, untwinned feldspar, rare aphanitic fragments, mica flakes and finely disseminated carbonaceous material. The claystones are medium greenish-grey and dark brown, compact, with carbonaceous fragments.

Sandstone

The sandstone belongs to the greywacke-subgreywacke assemblage and is light to medium grey and greenish-grey, friable to compact, angular to subangular, very fine to medium-grained, moderately to well sorted and rarely poorly sorted.

The sandstone comprises quartz (5 - 25%), feldspar (15 - 30%) - albite, oligoclase, untwinned and zoned plagioclase, and lithic constituents (35 - 50%). Lithics consist of aphanitic, microlitic volcanic fragments, chloritic and microcrystalline siliceous fragments and phyllite fragments. Volcanic lithics are an important part of the rock constituents and in Core No. 10 (4144 - 4154 feet) make up approximately half of the lithics present. The other minerals occurring include squeezed muscovite and biotite, zircon, garnet, pyrite, chlorite, epidote, tourmaline and sphene.

The matrix and cementing media make up between 20 and 40% of the rock. The matrix consists of kaolinitic and chloritic clay. The kaolinite present in the sandstone in Core No. 12 (4620 - 4626 feet) appears to be depositional and well crystallized. Kaolinite was shown to be present by X-ray diffraction analysis of a clay sample from the sandstone at 4621 feet. Diagenetic recrystallized calcite occurs as patches and, in places, completely replaces the clay matrix. Minor amounts of chlorite cement are present; spots of pink cryptocrystalline zeolite occur. Replacement of feldspars by calcite is present and some feldspars are altered to kaolinite. Corrosion of detrital grains is common and some grain welding occurs.

In the coarser grained sandstones fair porosity (10 - 15%) exists. Elsewhere porosity is poor.

Sedimentary structures and environmental criteria.

Carbonaceous and clay laminations and "wisps" occur in sandstone in Core No. 12 (4620 - 4626 feet) together with thin lenses of macerated plant fragments. At 4621 feet greenish mudstone pellets occur in random distribution in the sandstone. These pellets indicate a brief period of higher energy conditions. Laminations correspond to periods of quieter conditions during sedimentation.

Low-angle cross-bedding occurs on a small scale in Core No. 12 and is emphasized by thin carbonaceous laminations. Slickensiding with a dip of 30° is present in sandstone in Core No. 10 at 4146 feet. Scour-and-fill occurs at 4621 feet. The presence of compressed, partly pyritized roots at 4144 feet suggests that a swamp-type environment prevailed at that time. The dip of the beds over this interval is 15°; the 30° dip recorded at 4146 feet is probably along a plane of minor movement.

Interval: 4144 to 4115 feet

This sequence, on the electric log, contrasts markedly with the intervals both above and below. The S.P. curve shows a strong negative deflection over this interval and this together with the strong mud cake indicated on the microcaliper reflects the high porosity of the sand. The low resistivity over this interval is due to the saline water as shown in Drill Stem Test No. 2 (4078 - 4144 feet).

The lithology is a clean quartz sand over the entire interval.

Quartz Sand

This sand is light grey, clean, unconsolidated, angular, very coarse-grained and moderately to well sorted.

The constituents are quartz with vermicules of kaolinite and/or chlorite, sutured quartz, metaquartzite, quartz with sericite flakes and chalcedony; volcanic lithics are conspicuously absent. Very rare orthoclase feldspar is present. Some of the quartz grains show overgrowths and other grains are pitted.

As only loose cuttings were obtained over this interval the nature of the bonding material is uncertain. Clay was only observed in the pits of quartz grains and as loose clumps of white kaolinitic clay.

Porosity is very good - 20 to 25%.

Sedimentary structures and environmental criteria

This sand is not common to the greywacke suite of Unit M in other wells in the Otway Basin. A sand with similar constituents does occur in Tullich No. 1 but it is finer grained and not so clean. The deposition of the sand in the Heathfield area must have been rapid due to lack of grain rounding. The areal extent of the deposit is unknown. The composition and texture of the rock suggests that the sediments were derived from a different source to that of the enclosing greywacke sediments, and that some tectonic movements may have been responsible. Consistent changes in dipmeter readings beneath the "Heathfield Sand" in several wells lend support to this view.

Interval: 4115 to 3184 feet

This sequence is marked by an increase in the occurrence of negative deflections on the S.P. curve, but these are never of great amplitude. The resistivity is almost uniformly low throughout except for widely separated high resistivity peaks which occur opposite well-cemented sandstone horizons.

The lithology comprises siltstone and claystone with interbedded lithic sandstone; carbonaceous and coaly horizons are rare. The sandstone over this interval is more thickly bedded and more common than in the interval below 4144 feet.

Siltstone and claystone

The siltstone is massive, light to medium grey, greenish-grey and brownish-grey, sandy; mica flakes and finely disseminated carbonaceous matter are present. The thin beds of claystone are light to medium grey and brown, soft, with mica flakes and rare carbonaceous lenses.

In Core No. 9 (3754 - 3764 feet) the siltstone is compact and sandy. The constituents of the sand-sized fraction consist of quartz, albite, muscovite, sericite and chlorite in a chloritic clayey matrix. Finely divided pyrite occurs in patches.

Sandstone

These sediments belong to the subgreywacke type and are light to medium grey and brown, friable to compact, angular to subangular, very fine to fine-grained, moderately to well sorted.

Lithic grains consist of aphanitic, chloritic aphanitic, and microlitic volcanic fragments, microcrystalline siliceous fragments, and phyllite fragments and make up between 30 and 50% of the rock. Over this interval volcanic rock fragments are an important lithic constituent.

Other constituents include quartz which ranges from 5 to 10%; albite, oligoclase and sanidine vary from 15 to 30%. There is evidence for corrosion and replacement of feldspar by calcite. Accessory minerals include chlorite, muscovite, shredded and squeezed biotite, chloritized biotite, zircon, epidote, garnet, sphene, pyrite and tourmaline.

The cementing media (25 - 40%) comprise chiefly recrystallized calcite and minor patches of zeolite. This interval may be compared with the zeolite-cemented interval, 6050 - 5250 feet, in Geltwood Beach No. 1. In some instances euhedral grains of zeolite have formed in pore spaces. Some poorly crystallized kaolinitic clay occurs. Corrosion and replacement of grains by calcite is common; minor amounts of authigenic quartz have formed associated with grain welding.

In the sandy argillaceous sediments fair porosity exists but in the cemented sandstones porosity is poor.

Sedimentary structures and environmental criteria

In Core No. 9 (3754 - 3764 feet) thin sand laminations and convolutions occur; slumped sand lenses and low-angle (5°) planar cross-bedding occur at 3760 feet. A root marking is present at 3762 feet. A bedding dip of 5° was recorded at 3754 feet.

The presence of roots and carbonaceous material would indicate a return to shallow water conditions.

Interval: 3184 to 2610 feet.

Over this interval the electric log shows only minor variation in the resistivity; the higher resistivity peaks reflect the sandy horizons. The S.P. curve is variable but with an increase in the number of peaks; the variations reflect changes in porosity. No high microlog peaks occur over this interval.

The lithology consists of predominantly chloritic sandy siltstone and minor claystone, together with rare thinly bedded lithic sandstone. Carbonaceous horizons are rare.

Siltstone and claystone

The silt-sized sediments are generally medium greenish-grey and occasionally brown, soft, chloritic, sandy at top but becoming more argillaceous basewards. The siltstone constituents are quartz, plagioclase, biotite and scattered carbonaceous fragments. The light to medium grey and brown, chloritic claystone occurs most frequently in the lower half of the sequence. Detrital grains comprise angular quartz, plagioclase and muscovite. In Core No. 7 (2874 - 2884 feet) a sandy chloritic claystone occurs which grades into a greywacke.

Sandstone

The sandstone (greywacke in character), is medium grey and green, compact, angular to subangular, very fine to fine-grained and poorly to moderately sorted.

Lithics predominate and range from 35 to 40%; they consist of clear aphanitic, chloritic aphanitic, and microcrystalline siliceous fragments, microlitic volcanic rock fragments together with some phyllite and metaquartzite fragments. Quartz constitutes between 5 and 20% of the rock with albite, oligoclase, untwinned feldspar and rare microcline forming 20 to 25%. Accessory minerals include muscovite, squeezed biotite, chloritized biotite, flaky chlorite, zircon, garnet, opaques and pyrite.

The bonding media which vary from 20 to 30% consist of chloritic clay; minor diagenetic calcite-cemented horizons occur. In some

sandstones, determination of matrix is difficult due to the welding of lithic grains. In a sandstone at 2700 feet coarsely recrystallized calcite, sometimes spherulitic, predominates with rare patches of zeolite cement. Corrosion and replacement of some feldspars and lithics by calcite is evident. In other sandstones authigenic zeolite occurs filling pores.

Fair porosity exists in the clay bonded sandstones; the results of a core analysis of a sandstone (greywacke) sample in Core No. 7 (2874 - 2884 feet) show a high porosity (see Fig. 1 and Appendix 2). Elsewhere porosity is poor due more to compaction of sediments rather than diagenetic changes.

Sedimentary structures and environmental criteria

In Core No. 7 (2874 - 2884 feet) sandy claystone grades into sandstone (greywacke). The sandstone is thinly bedded and a dip of 5° was recorded. Slickensiding occurs at 2875 feet with a dip of 50°. Sedimentation appears to have been confined to shallow water conditions in a paralic environment.

Interval: 2610 to 2050 feet

Over this interval the electric log shows rare high resistivity peaks which correspond to the well-cemented sandstones; elsewhere the resistivity is moderate to low. The S.P. curve is variable with strong negative deflections where porous sandy horizons occur. Carbonaceous and coaly horizons are rare.

The characteristic features of this interval are the cemented lithic sandstones, sandy limestones and replacement limestones which occur interbedded with chloritic siltstones and mudstones.

Siltstone

The sediments are medium greenish-grey, rarely brown, soft, chloritic, sandy at top becoming argillaceous basewards, with claystone and mudstone streaks. The silt-sized constituents consist of angular quartz, albite, oligoclase and untwinned feldspar with minor aphanitic fragments; other minerals include chlorite flakes, muscovite, biotite, epidote and zircon.

In Core No. 5 (2365 - 2373 feet) carbonaceous fragments, flecks, streaks and lenses occur; root markings are present at 2370 feet. Cores Nos. 5 and 6 indicate that the siltstones are of a massive nature.

Sandstone, sandy limestone and replacement limestone

This type of sandstone is characteristic for the interval, 2610 to 2050 feet, and may be referred to as a subgreywacke (Pettijohn 1957). The sandy limestone and replacement limestone which are also present represent the ultimate in diagenetic changes, where lithic sandstone has been almost completely replaced by calcite.

The sandstone is light to medium grey, compact, lithic, angular to subangular, fine-grained and moderately sorted, although a poorly sorted sandstone occurs at 2500 feet.

Lithics predominate (25 - 45%) and consist of aphanitic, chloritic aphanitic, and microlitic volcanic fragments, schist, and phyllite fragments, and chloritic mudstone pellets. Many of the aphanitic fragments seem to have close affinities with the volcanic lithics. Other constituents include quartz which ranges from 5 to 10%; albite, oligoclase and untwinned feldspar constitute from 10 to 28% of the rock. Accessory minerals include chlorite flakes, penninite, biotite - often shredded by calcite and in rare cases by zeolite, chloritized biotite, zircon, glaucophane and pyrite.

The cementing media (30 - 55%) comprise coarsely recrystallized calcite which is diagenetic. Much corrosion and replacement by calcite of both feldspar and lithic grains have taken place. Zeolite, which is only a minor cementing constituent, is evident over the interval 2290 to 2100 feet. The zeolite is mainly cryptocrystalline and, in some cases, isotropic. There is evidence to suggest that in some places the calcite was diagenetically developed after the zeolite. Other cements which occur in minor amounts include diagenetic pyrite at 2450 feet and pellicular chlorite at 2100 feet. Minor quartz welding, and rare authigenic feldspar were also noted.

Porosity is poor except in the sandy argillaceous sediments where fair porosity exists; intergranular porosity is present in a sandstone at 2500 feet.

The sandy limestone contains silt-sized angular to subangular grains of quartz, oligoclase and lithics. Dark carbonaceous clay matter is present along detrital grain and calcite crystal boundaries. Relic structures occur in the calcite.

The replacement limestone contains less than 5 per cent of detrital grains. The calcite is coarsely recrystallized and exhibits cone-in-cone-structures. Porosity is negligible in the limestone.

Sedimentary structures and environmental criteria

Throughout this sequence thin laminations of very fine-grained sand and carbonaceous matter occur in the siltstone and claystone. At 2372 feet in Core No. 5 micro cross-bedding of the planar type occurs with a dip of 15^{0}; this cross-bedding is emphasized by thin sand laminations.

The presence of roots and carbonaceous material would seem to indicate that sedimentation continued in a paralic environment; marine influence may be reflected by the presence of calcite cement.

Interval: 2050 to 1680 feet

This sequence on the electric log is shown by a low resistivity; rare high resistivity peaks occur opposite sandstones. The S.P. curve is generally constant but shows some negative deflections (relative to the shale base line), opposite the sandy intervals.

The lithology comprises chloritic mudstone and siltstone with thinly interbedded lithic sandstone. The mudstones are most abundant in the top part of the interval and grade into siltstones basewards. The most characteristic sandstones are those with pellicular chlorite and may be referred to as subgreywacke (Pettijohn 1957). Finely disseminated carbonaceous matter occurs in the sequence; a coal seam has been recorded below 1680 feet but its authenticity cannot be ascertained on account of the preponderance of cavings over this interval.

Mudstone and siltstone

The mudstone is greenish-grey and dark grey, compact, chloritic. The constituents consist of angular grains of quartz, abundant albite, muscovite, chlorite flakes, aphanitic fragments and pyritic clumps and lenses.

The siltstone which is most frequent below 1900 feet, is light to medium grey, soft, sandy and chloritic, with minor amounts of carbonaceous fragments. The detrital grains comprise quartz, plagioclase, aphanitic and chloritic fragments, muscovite, biotite, and rare garnet.

Sandstone

Sandstone containing chlorite cement, (subgreywacke), is the most important over this interval. These sediments are light to medium greenish-grey and dark grey, friable, lithic, angular to subangular, very fine to fine-grained, poorly to moderately sorted sandstones.

Lithics are abundant (40 - 85%) and comprise chloritic aphanitic, aphanitic, and rare microlitic volcanic fragments, mudstone fragments and rare phyllite and metaquartzite fragments. Other constituents are quartz-strained and sutured quartz - which ranges from 5 to 15%; the feldspar content varies from 5 to 30% and consists of albite, oligoclase, and untwinned feldspar. Accessory minerals include flaky chlorite, muscovite, biotite, pyrite, epidote and zircon.

The cementing media, which vary between 5 and 10%, consist of depositional pellicular chlorite and minor amounts of chloritic clayey matrix. Other cements include diagenetic pyrite and calcite cement which occur at 1750 and 1930 feet, respectively. Where calcite is present, much corrosion and replacement of the grains has taken place. Welding of lithic and quartz grains is apparent in some sandstone.

Fair to good primary proosity exists in the sandstones. The porosity is intergranular and ranges from 10 to 20 percent; good connection between pores was observed in thin sections.

Sandstone with clay matrix - lithic greywacke (Pettijohn 1957) - is not abundant. The sandstone is angular to subangular, very fine to fine-grained and poorly sorted. The mineral constituents are similar to those present in the cemented sandstone but there is a lower percentage of lithic fragments - 30 to 60 percent. The matrix material ranges from 20 to 50 percent and consists of chloritic clay. In some places, the strong welding of the lithic grains has made assessment of the matrix difficult; minor quartz welding occurs. In Core No. 3 at 1858 feet diagenetic calcite cement occurs in the form of a thin lamination where there is an abundance of aphanitic rock fragments. Porosity is poor in these sandstones.

Sedimentary structures and environmental criteria

In Cores Nos. 3 and 4 thin sandy laminations occur in the mudstones together with coaly lenses and root markings. In Core No. 3 (1858 to 1863 feet) mudstone pellets occur. These chloritic mudstone pellets must represent local reworking of the sediments by current action, for transportation over any distance is not thought feasible.

The presence of pellicular chlorite may indicate more marine influence during deposition of the 2050 - 1680 feet interval.

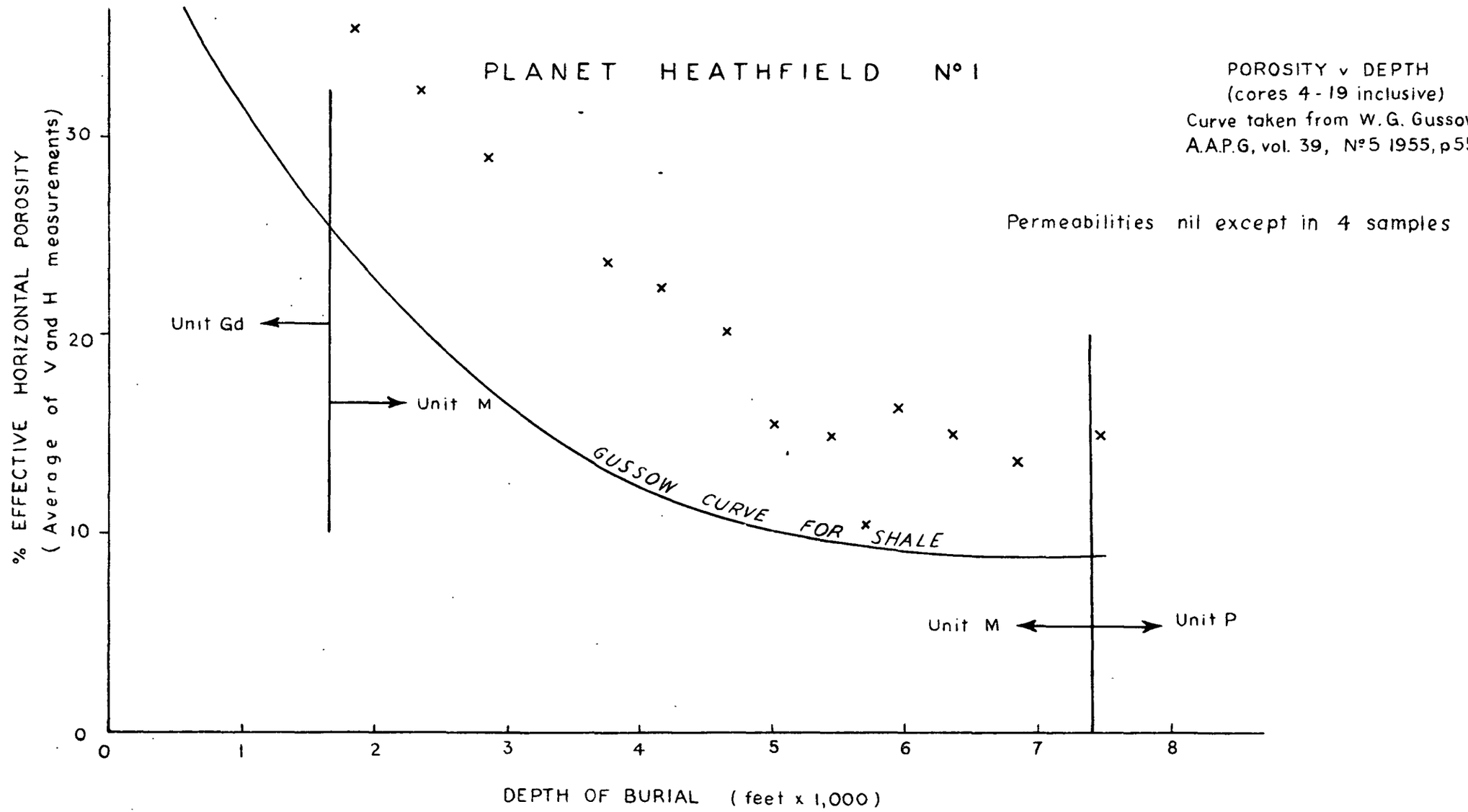
Age determinations

A study of the microfloral assemblages in Heathfield No. 1 was carried out by Hodgson (in Cundill, 1964) from Core No. 6 (2374 feet) to Core No. 18 (6893 feet) in Unit M. The results show that the *Dictyotosporites speciosus* assemblage is present, and certain members of Dettmann's (1963) *Crybelosporites stylosus* assemblage occur which indicate that these sediments are Lower Cretaceous in age.

Unit Gd 1680 to 1600 feet

This unit is differentiated from the underlying Unit M by an increase in the resistivity and by stronger negative deflections (relative to the shale base line) of the S.P. curve, indicating some porous horizons.

FIGURE 1



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Bureau of Mineral Resources, Geology and Geophysics. October 1965 To accompany Record Nº 1965/100

The nature of the true lithology is difficult to ascertain on account of the abundance of cavings of sideritic clay and pellety siderite from Unit Dd. However, below 1620 feet loose sands and sandstone fragments occur which are thought to be representative of the true lithology.

Sandstone

Fragments of light grey, compact, angular to subangular, fine-grained, moderately sorted sandstone occur in the cuttings. The individual quartz grains are clean, sometimes frosted and with overgrowths.

The constituents in thin section consist of quartz, metaquartzite and quartzite and some orthoclase feldspar. The grains are cemented with siderite and on rare occasions contain pyrite. Minor quartz welding occurs. Scattered rare bright green glauconite pellets are present in the cuttings between 1650 and 1620 feet. Elsewhere scattered quartz grains occur coated with siderite. These detrital constituents and cementing medium show close similarity to those found in Unit Gd in the Mount Salt Well No. 1 and the Nelson Bore. From petrological evidence it is concluded that this sequence is a thin development of Unit Gd.

Sedimentary structures and environmental criteria

These arenaceous sediments were thought to have been deposited in a shallow water marginal marine environment.

Age Determinations

This unit has not been recognised in the Completion Report (Cundill 1964). As no cores were taken over this interval age determinations have been impossible. However, a study of Core No. 2 (1378 - 1393 feet) from Unit Gb above yielded flora of Upper Cretaceous age (P.R. Evans, pers. comm).

Unit Gb 1600 to 1217 feet

The sequence is marked by a gradual increase in resistivity towards the top, with an accompanying increase in the negative deflection on the S.P. curve. These changes reflect the sandy nature of the sediments.

The lithology comprises, predominantly, arenaceous sediments with some clay intervals and rare black coaly horizons. Interpretation of the true lithology is difficult due to the presence of pellety clay and sand cavings from Units Dd and Db, respectively.

Sandstone

The sandstone is light to medium grey, friable, angular to subangular, medium to very coarse-grained, and moderately to well sorted. The constituents comprise strained and fractured quartz, rare orthoclase and microcline, chert and metaquartzite. The individual quartz grains are frosted and pitted; occasionally quartz occurs with overgrowths.

The bonding medium is difficult to determine but it is probably clay. Some kaolinitic clay has been recorded in pits in quartz; rare fragments of pyrite-cemented sandstone occur. Porosity is fair throughout the arenaceous interval.

Clay

These sediments tend to be masked by sand cavings but can be distinguished from the electric log. In Core. No. 2 (1378 - 1393 feet) dark brown clay occurs which is silty and sandy. The silt-sized

constituents comprise angular quartz grains and squeezed mica flakes. Scattered pyrite specks and clumps occur.

Sedimentary structures and environmental criteria

In Core No. 2 (1378 - 1393 feet) thin, fine-grained sand laminations occur accompanied by gypsum nodules.

The presence of coaly horizons in this predominantly arenaceous sequence would indicate sedimentation under quiet reducing conditions in a paralic environment. The gypsum nodules present in clay in Core No. 2 probably developed from gypsiferous waters which infiltrated into the sediment after deposition (Krumbein and Sloss 1963).

Age determination

At least part of this unit is Upper Cretaceous in age from the results of studies carried out on Core No. 2 (1378 - 1393 feet) by P.R. Evans.

Unit Dd 1217 to 798 feet

This interval is characterized by a moderate to high resistivity with high peaks opposite the pellety sandy intervals. Above 931 feet there is a sharp decrease in the resistivity opposite a siltstone interval. The S.P. curve is reversed due to the drilling fluid being more saline than the formation water. The high gamma-ray count, especially over the interval 900 to 798 feet, can be attributed to the high clay and carbonaceous content.

The lithology consists of a thin pelletal sandstone at the base with alternating sandstone and clay above; this is followed by an interval (1014 to 895 feet) of pelletal sideritic sandstone, siderite-rock beds, and pellety clay. Above 895 feet siltstone with minor siderite-rock beds predominate which are included in Dd because of the presence of pellets.

Pelletal sandstone

The sandstone is mostly dark green, compact, pellety, oolitic, shelly, subrounded to rounded, medium to coarse-grained and poorly sorted. Elsewhere the sandstone is friable, subangular to subrounded, coarse to very coarse-grained and poorly sorted.

The constituents of the pelletal sandstone are quartz (15%), orthoclase feldspar and microcline (5%); green chlorite, green chamosite, and brown oxidized chamosite pellets and ooliths make up 40% of the rock. The ooliths generally have quartz nuclei, and in places quartz grains are coated with phosphate.

The bonding media consist of chloritic clay (20%), and siderite cement which forms 10% of the rock. The siderite is diagenetic, recrystallized and granular; it often corrodes and replaces pellets, ooliths and quartz grains. The friable sandstone is bonded by a clay matrix. Porosity is fair in the pelletal sandstone.

Siderite-rock

The siderite-rock consists predominantly of siderite with scattered pellets and subangular to rounded, fine to medium-grained detrital grains. In places the siderite-rock grades into sideritic clay.

The detrital constituents are quartz and metaquartzite (5 - 20%); chamosite-coated quartz and sericitized quartz also occur. Green chamosite and brown oxidized chamosite pellets together with rare phosphate pellets may form 5 to 15% of the rock.

Microcrystalline siderite predominates but coarse recrystallized and spherulitic siderite occurs together with minor green chloritic and brown phosphatic patches. Coarsely crystallized siderite rims are common around the pellets and quartz grains; some corrosion and replacement by siderite occurs. The siderite appears to be a primary deposit.

Siltstone and clay

The siltstone is dark brown, sandy, carbonaceous and contains angular quartz, rare microcline, rare chamosite pellets and mica flakes. The thinly bedded clay is medium to dark reddish-brown, soft and sandy; constituents include minor quartz, and chamosite pellets set in a chloritic clay matrix with patches of globular siderite.

Sedimentary structures and environmental criteria

The pellety and oolitic nature of the sequence is well illustrated in Core No. 1 (960 - 975 feet) which also contains abundant shell fragments. The rounded nature of the grains together with the ooliths present would seem to indicate that these sediments were deposited in a shallow water zone where high energy currents were active most of the time. At other times slightly reducing conditions prevailed for the formation of siderite and chlorite.

Age determinations

This sequence of sandstone and claystone is assigned a Palaeocene age in the Heathfield Completion Report (Cundill, 1964), but the interval 1042 to 1217 feet is regarded as questionable Palaeocene.

Unit Db 798 to 276 feet

This has been subdivided into sub-unit Db_2, a predominantly argillaceous sequence, and sub-unit Db_1, an arenaceous sequence.

Sub-unit Db_2 798 to 675 feet

The electric log shows a gradual increase in the resistivity curve towards the top; rare peaks occur opposite sideritic sandstone intervals. The S.P. curve is reversed and unchanged from the unit below.

This is predominantly a sequence of claystone beds with thinly bedded sandstone and sandy siderite-rock.

Claystone

The clay is dark brown, soft, carbonaceous, with muscovite and biotite flakes and lignitic fragments.

Sandstone and sandy siderite-rock

These sediments are poorly developed and consist of dark brown, compact, subangular, very fine to fine-grained, moderately sorted sandstone and sandy siderite-rock. The constituents are quartz and chert grains and scattered grains of haematite and pyrite. The siderite is fine-grained and granular.

Sedimentary structures and environmental criteria

No cores were taken over this interval. The presence of carbonaceous clays reflect a paralic type of environment accompanied by some marine influence as indicated by the siderite. The lithology of this sub-unit is similar to sequences in Mount Salt Well No. 1 and the Nelson Bore which were called Db_2.

Sub-unit Db_1 675 to 276 feet

No electric log was run over this interval as the hole was cased. The gamma-ray log shows variations with increases in counts opposite the argillaceous intervals.

This is a predominantly arenaceous sequence: sandstone, sideritic sandstone, thinly bedded siltstone and claystone. Carbonaceous material is present in the silt-sized sediments.

Sandstone and sideritic sandstone

These sediments vary from light to medium grey to medium brown, friable to compact, subangular to subrounded, fine to very coarse-grained sandstone, poorly to moderately sorted but becoming well-sorted at the top of the sequence. The constituents comprise both, frosted and polished quartz, rare feldspar and chert fragments and mica flakes. Siderite occurs as a microcrystalline cement in thin sandy beds and lenses. Fair to high porosity is thought to occur in the friable sandstones.

Siltstone and claystone

The siltstone is black, carbonaceous, micaceous with minor pyrite clusters. The claystone is medium reddish-brown, compact with sandy intervals. Silt and very fine sand-sized angular quartz grains occur in a haematitic claystone containing mica flakes. The haematitic claystone is similar to the claystone encountered at 2681 to 2671 feet in the Nelson Bore.

Sedimentary structures and environmental criteria

The interbedded claystones and siltstones containing carbonaceous material reflect a paralic environment. This sequence corresponds to the sequence (2681 - 992 feet) in the Nelson Bore.

Age determinations

In the Heathfield Completion Report (Cundill, 1964), this predominantly arenaceous sequence, recorded as the "Dartmoor Formation" (Unit Db), is considered to be Eocene in age.

Unit Bc 276 to 152 feet

Only the gamma-ray log was run over this interval as the hole was cased. The sequence is arenaceous consisting of sandstone and conglomeratic sandstone with calcarenite and siltstone at the base. Fossil debris occurring over the interval is caving from the unit above.

Sandstone

The sandstone is medium grey, friable, subangular to subrounded, coarse to very coarse-grained with conglomeratic horizons, and poorly to moderately sorted. Detrital grains are clean, polished quartz, quartz with pyrite, milky quartz, quartzite and mica flakes. Near the base the quartz grains are coated with iron oxide and clay is present on some of the grains. The base of this unit is marked by a thin dark reddish-brown, haematitic, sandy siltstone which is overlain by an iron-stained calcarenite.

Sedimentary structures and environmental criteria

These sediments represent an intermediate phase between the paralic conditions of Unit Db and the marine conditions of Unit Ab. The conglomeratic horizons may represent a reworking of a pre-existing conglomerate. The presence of iron-coated quartz together with the

rounded nature of the grains would indicate that sedimentation took place in shallow oxygenated waters where high energy conditions were prevalent.

Age determinations

This arenaceous sequence has been compared with the ferruginous sandstone encountered in Penola No. 1 (O.D.N.L., 1963). In Penola No. 1 it was called the "Compton Conglomerate" and assigned an Oligocene age. In the Heathfield Completion Report (Cundill, 1964), this conglomeratic sandstone sequence is regarded as part of the "Dartmoor Formation" (Unit Db) and is thought to be Eocene in age. On lithological grounds, however, I have correlated the 276-152 feet interval with the upper part (857 - 812 feet) of Unit Bc in the Nelson Bore.

Unit A

The interval in the Otway Basin which lies between the disconformity at the top of Unit B (the rocks which comprise the Glenelg Group) and the recent sediments, has been designated Unit A. It may include the equivalent of the Normanby Group sediments defined by Boutakoff and Sprigg (1953).

In Heathfield No. 1 Unit Bb is absent. However, Unit Ab has been recognized.

Unit Ab 152 to 70 feet.

This interval consists of predominately sandy calcarenite with thin beds of calcarenite.

The sandy calcarenite is medium brown, friable, subangular to rounded, coarse to very coarse-grained and moderately sorted. Detrital grains are skeletal debris of pelecypods, gastropods, bryozoa and foraminifera; clear and milky, polished and frosted quartz and rare mica flakes occur. The calcarenite has good porosity.

The thinly bedded calcarenite is light brown, compact, rounded, fine to coarse-grained and moderately sorted. The constituents comprise fossil debris (40 - 60%) of algae, foraminifera and echinoid spines, and quartz and metaquartzite (5 - 20%). The cementing medium is finely recrystallized calcite; scattered iron-coated dolomite rhombs occur in the cement. Good intergranular porosity exists in these sediments.

Sedimentary structures and environmental criteria

From the rounded nature of the quartz and bioclastic fragments, and the presence of calcite cement, these sediments appear to have been deposited under shallow marine conditions where strong current action was prevalent.

Recent 70 feet to surface

This interval contains light to medium brown, angular to subrounded, medium to very coarse-grained, moderately sorted sand. The sand consists of milky and clear quartz - sometimes frosted and polished, and rare muscovite flakes.

CONCLUSIONS

A thick accumulation of sediments mainly of Lower Cretaceous age was penetrated in Heathfield No. 1

Only 92 feet of Unit P was penetrated; this contains a sandstone facies interdigitating with mudstone and siltstone. Microfossil evidence suggests that these sediments may possibly be Upper Jurassic in age.

The Lower Cretaceoces Unit M sediments form a greywacke - subgreywacke facies and were deposited in a shallow water environment in a subsiding basin. The shallow water environment is suggested by the presence of small scale cross-bedding, by fine laminations, and reworked pellety mudstone horizons; plant material and root markings were observed in some of the cores. The environment of deposition of the "Heathfield Sand" which developed locally at this time, is not known. The upper part of Unit M shows indications of stronger marine influence such as pellicular chlorite and calcite cement.

During deposition of Unit M sediments rocks fragments both of volcanic and metamorphic origin were deposited, but the bulk of the lithics are volcanic. In addition to the highly altered volcanic detritus, fragments of fresh flow rocks and fine euhedra of feldspar occur at various horizons throughout the unit. This would suggest that vulcanism occurred within the basin at different times during the deposition of Unit M sediments. It is clear that a different source was responsible for the local development of the "Heathfield Sand" and that deposition was initiated by local tectonic movements.

Between Unit M and Unit Gd a disconformity is thought to exist. As in other wells, Unit Gd represents a shallow water marine deposit. Unit Gb sediments represent a regressive facies in a paralic environment. At least part of Unit G (1680 - 1378 feet) is Upper Cretaceous in age from microfloral evidence.

At 1217 feet a disconformity is thought to occur between Unit Gb and Unit Dd. The pellety and oolitic sandstones of Unit Dd represent a transgressive facies deposited under high energy conditions in shallow water. The overlying Unit Db represents a regressive facies in a paralic environment.

An unconformity is thought to exist at 276 feet between Unit Db and the overlying Unit Bc. The sediments in Unit Bc in Heathfield No. 1 may represent the upper part of Unit Bc encountered in the Nelson Bore.

Due to the probable erosion of Unit Bb (Gambier Limestone Formation equivalent), Unit Ab rests unconformably on Unit Bc. Unit Ab sediments were deposited under shallow water marine conditions.

As far as petroleum possibilities are concerned the most favourable reservoir rock was encountered over the interval, 4144 to 4115 feet, in Lower Cretaceous sediments where gas-cut salt water was recovered from a drill stem test. Very good porosity and permeability exist in this sand but its areal extent is uncertain.

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APPENDIX I.

CUTTINGS SAMPLE DESCRIPTIONS

0' - 14'		No sample.
14' - 60'	100%	Sand, light brown, angular to subrounded, medium to very coarse-grained, moderately-sorted with frosted, milky and clear quartz, rare muscovite flakes.
60' - 70'	50%	Sandstone, dark brown, friable, subangular to subrounded, medium-grained, poorly-sorted; brown clay matrix.
	40%	Sand, as above.
	10%	Clay, dark grey.
70' - 100'	75-95%	Sand, light to dark brown, subrounded to rounded, coarse to very coarse-grained, moderately-sorted with polished and frosted quartz and skeletal debris.
	10%	Sandstone, dark brown, friable, subangular, coarse-grained, poorly-sorted.
	5-10%	Clay, dark grey.
100' - 110'	85%	Sand, medium brown, subrounded to rounded, coarse to very coarse-grained, moderately-sorted with frosted and rarely polished quartz and skeletal debris.
	15%	Calcarenite, light brown, compact, subrounded to rounded, medium-grained, moderately-sorted, pellety, abundant shell fragments; calcite cement.
110' - 150'	100%	Sand, medium brown, subangular to subrounded, coarse to very coarse-grained, poorly-sorted with polished and frosted quartz, rare mica flakes, skeletal debris.
150' - 190'	100%	Sand, medium grey, subangular to subrounded, coarse to very coarse-grained, rare granules, moderately-sorted, clean, polished and milky quartz, rare mica flakes.
190'-230'	100%	Sand, medium grey, subangular to subrounded, coarse to very coarse-grained with pebbles, (2.6 to 9.1mm.) poorly-sorted; clear and milky quartz, polished quartz and quartzite.
230' - 240'	100%	Sand, medium grey, angular to subangular, medium-grained, well-sorted with clear polished quartz.
240' - 270'	100%	Sand, medium grey, subangular to subrounded, very coarse-grained with pebbles, poorly-sorted; polished and iron-stained quartz and quartzite.
270' - 280'	85%	Sand, medium grey, subangular to subrounded, coarse to very coarse-grained with pebbles, poorly-sorted; polished and iron-stained quartz.
	10%	Siltstone, dark reddish-brown, soft, sandy, micaceous, haematitic.
	5%	Calcarenite, medium reddish-brown, compact, subangular, fine-grained, moderately-sorted, skeletal debris; carbonate cement.

280' - 540'	95%	Sand, medium grey, subangular to subrounded, coarse to very coarse-grained, moderately-sorted; polished and frosted quartz, red iron-staining on some quartz grains, rare mica flakes and rare carbonaceous matter.
	5%	Clay, medium reddish-brown, compact with mica flakes, iron-staining.
540' - 550'	90%	Sand, medium grey, subangular to subrounded, coarse to very coarse-grained, moderately-sorted; polished and frosted quartz, rare mica flakes.
	10%	Sandstone, medium brown, compact, subangular, medium-grained, poorly-sorted; siderite cement.
550' - 630'	100%	Sand, medium grey, angular to subangular, coarse to very coarse-grained, moderately-sorted; polished and frosted quartz, rare mica flakes.
630' - 660'	100%	Cement
660' - 690'	20-80%	Sand, as above.
	20-70%	Cement
690' - 740'	50-60%	Clay, dark brown, soft, lignitic, muscovite and biotite flakes.
	25-40%	Sand, medium to dark brown, angular to subrounded, fine to coarse-grained, poorly-sorted; rare shell fragments.
	10-15%	Cement
740' - 770'	100%	Cement
770' - 830'	65-90%	Sand, medium grey, angular to subangular, coarse to very coarse-grained, poorly to moderately-sorted; polished and frosted quartz, clay coating some quartz grains.
	5-10%	Sandstone, dark brown, compact, subangular, fine-grained, moderately-sorted; rare shell fragments.
	5-35%	Cement
	20%	Siderite rock, dark brown, compact, sandy and pellety.
830' - 960'	65-95%	Siltstone, dark brown, sandy, carbonaceous, mica flakes, green and brown pellets, pyrite.
	5-20%	Sand, medium grey, subangular to subrounded, medium to very coarse-grained, poorly-sorted; some iron-stained quartz, green pellets.
	5-15%	Siderite rock, dark brown, compact, sandy, green pellets, pyrite streaks and clusters.
	10-75%	Clay, dark green, sandy, with green and brown pellets, sideritic.
960' - 970'		No sample
970' - 1020'	15-50%	Siltstone, dark brown and green, soft, with green pellets, rare pyrite clusters.
	5-35%	Siderite rock, dark brown, compact, with brown pellets and pyrite streaks.

970' - 1020' (contd.)	5-60%	Sand, dark brown, dirty, subangular, coarse to very coarse-grained, moderately-sorted; some iron-stained quartz, rare polished quartz, green pellets, rare muscovite flakes.
1020' - 1180'	80-95%	Sand, medium grey, subangular to subrounded, coarse to very coarse-grained, poorly to moderately-sorted; clean, polished, frosted and pitted quartz, rare quartz with siderite cement, rare mica flakes.
	5-20%	Siltstone, dark brown, soft, with fine mica flakes and rare pellets.
1180' - 1270'	80-95%	Sand, medium grey, angular to subangular, coarse-grained, moderately to well-sorted; some polished and frosted quartz, rare iron-stained quartz, and rare mica flakes.
	5-15%	Clay, dark green, soft, pellety, sandy with sideritic patches.
	10-20%	Coal, black, earthy.
1270' - 1370'	95%	Sand, medium grey, angular to rounded, coarse to very coarse-grained, poorly to moderately-sorted; frosted and pitted quartz, kaolinitic clay coating some quartz, mica flakes, rare coaly fragments.
	5%	Siltstone, dark brown, with rare coaly fragments.
1370' - 1390'		No sample.
1390' - 1480'	85-95%	Sand, light to medium brown, angular to subrounded, medium to coarse-grained, well-sorted; frosted and polished quartz, rare iron-stained quartz, rare feldspar and mica.
	5-15%	Clay, dark green, soft, chloritic, with green pellets.
1480' - 1620'	95%	Sand, light grey, subangular to subrounded, coarse to very coarse-grained, well-sorted; clean, polished and frosted quartz, rare haematite-coated quartz, rare feldspar.
	5%	Cavings of clay.
1620' - 1680'	95%	Sand, light grey, angular to subangular, coarse to very coarse-grained, moderately to well-sorted; frosted and polished quartz, siderite-coated quartz, quartz with overgrowths, some feldspar, glauconite pellets.
	5%	Cavings of clay.
1680' - 1873'	60-95%	Sand, light grey, angular to subangular, coarse to very coarse-grained, moderately to well-sorted; polished and frosted quartz, rare feldspar, rare pyrite cemented sandstone fragments, rare mica flakes and coaly fragments.
	5-40%	Clay, dark brown and grey, soft, pellety (cavings). Dark green chloritic clay.
	10-15%	Coal, at 1690' - 1710'.

1873' - 1910'	60-70%	Sand, medium grey, angular to subangular, coarse to very coarse-grained, moderately-sorted; clay-coated quartz and polished quartz.
	30-40%	Clay, dark grey, soft, silty, mica flakes, rare coaly fragments.
1910'-1970'	70-95%	Sand, light grey, angular to subangular, coarse to very coarse-grained, moderately-sorted; milky, frosted and polished quartz.
	5-15%	Siltstone, medium to dark brown, soft, sandy.
	5-15%	Sandstone, medium greenish-grey, friable, angular, very fine-grained, moderately to well-sorted; chloritic clay matrix. Good porosity.
1970' - 2350'	15-95%	Siltstone, medium greenish-grey, soft, sandy, chloritic, rare green quartz; argillaceous below 2230'; micaceous, carbonaceous fragments.
	5-50%	Sand, as above (cavings).
	5-80%	Sandstone, medium greenish-grey and light grey, friable to compact, lithic, angular, very fine to fine-grained, moderately-sorted, micaceous; clay matrix and carbonate cement. Neglibible porosity.
2350' - 2360'		No sample.
2360' - 2570'	35-95%	Siltstone, medium greenish-grey, chloritic, sandy, with clayey streaks, mica flakes and carbonaceous fragments.
	5-60%	Sand, light grey, subangular, coarse to very coarse-grained (caving).
	5-20%	Sandstone, light grey and greenish-grey, friable to compact, lithic, subangular, fine to medium-grained, moderately-sorted; clay matrix, pyrite and carbonate cement. Negligible porosity.
2570' - 2580'		No sample.
2580' - 2680'	95%	Siltstone, medium greenish-grey, sandy, with brown argillaceous streaks, green quartz, mica flakes, rare carbonaceous fragments.
	5%	Sandstone, medium grey, compact, lithic, subangular, fine-grained, moderately-sorted; carbonate cement. Also replacement limestone. Negligible porosity.
2680' - 2690'		No sample.
2690' - 3180'	75-95%	Siltstone, medium greenish-grey, sandy with brown streaks, mica flakes, rare coaly fragments.
	5-15%	Sandstone, medium grey, compact, lithic, subangular, fine-grained, moderately-sorted; carbonate cement and clay matrix. Poor porosity.
	5-20%	Clay, light grey and brown, sandy, with mica flakes.

3180' - 3670'	5-95%	Siltstone, medium greenish-grey, chloritic, sandy, fine mica flakes, with carbonaceous fragments.
	10-95%	Clay, light grey and brown, carbonaceous, with fine mica flakes.
	5-90%	Sandstone, medium grey, friable to compact, lithic, subangular, fine-grained, moderately sorted, becoming very fine-grained, and well sorted basewards; mica flakes and pyrite clusters; carbonate cement and clay matrix. Negligible porosity.
3670' - 3680'		No sample.
3680' - 4080'	70-100%	Siltstone, medium greenish-grey, and brown, chloritic, with occasional sandy streaks, mica flakes and fine carbonaceous fragments.
	5-80%	Sandstone, medium grey, compact, subangular, very fine-grained, well-sorted; carbonate cement. Poor porosity.
4080' - 4100'		No sample.
4100' - 4130'	70-95%	Siltstone, medium greenish-grey, chloritic, with carbonaceous fragments.
	5-10%	Sandstone, medium grey, friable, angular to subangular, very fine to fine-grained, moderately sorted, clay matrix.
	30%	Sand, light grey, angular, very coarse-grained, moderately-sorted; milky quartz and quartzite.
4130' - 4150'	90-100%	Sand, light grey, angular, very coarse-grained, well-sorted; fractured quartz, quartz with overgrowths, frosted quartz, clay in pits in quartz, rare orthoclase; white kaolinitic clay. Very good porosity.
4150' - 4170'	80%	Sandstone, light grey, friable, lithic, subangular, fine-grained, moderately-sorted; carbonate cement and clay matrix. Poor porosity.
	20%	Siltstone, medium grey, chloritic.
4170' - 4700'	10-100%	Siltstone, medium grey and greenish-grey, chloritic, rare sandy streaks, with mica flakes and fine carbonaceous fragments.
	5-95%	Sandstone, light to medium grey and greenish-grey, friable to compact, lithic, angular to subangular, very fine to fine-grained, moderately to well-sorted with mica flakes; carbonate cement and white clay matrix. Also replacement limestone. Poor porosity.
	10-95%	Clay, medium grey, compact, silty with carbonaceous fragments.
	90%	Coal at 4370'.
4700' - 5330'	5-100%	Siltstone, medium greenish-grey, compact, sandy, with mica flakes, carbonaceous streaks and laminations and white clay clumps.
	5-90%	Sandstone, light grey, compact to friable, lithic, angular, very fine-grained, moderately to well-sorted with mica flakes and carbonaceous fragments; clay matrix and carbonate cement. Poor porosity.

4700' - 5330' (contd.)	5-100%	Clay, dark brown, compact, carbonaceous with fine mica flakes.
	90%	Coal, vitreous at 4770'.
5330' - 5340'		No sample.
5340' - 5360'	60-90%	Clay, dark brown, carbonaceous, with fine mica flakes.
	10-40%	Siltstone, medium greenish-grey, sandy with carbonaceous fragments.
5360' - 5400'	40-100%	Siltstone, medium-greenish grey and brown, sandy with coaly fragments.
	10-70%	Sandstone, light grey, compact to friable, angular, very fine-grained, moderately-sorted with feldspar, chlorite, carbonaceous flakes and laminations; carbonate cement and clay matrix. Poor porosity.
5400' - 5410'		No sample.
5410' - 5630'	30-100%	Siltstone, medium greenish-grey, compact, sandy, carbonaceous fragments and streaks.
	10-50%	Mudstone, black, compact, carbonaceous.
	40%	Coal, vitreous at 5450'.
	10-70%	Sandstone, light to medium greenish-grey, friable to compact, lithic, angular, very fine-grained, moderately-sorted with feldspar and mica flakes, and brown lithic fragments; carbonate cement and clay matrix. Poor porosity.
5630' - 5640'		No sample.
5640' - 5990'	10-100%	Siltstone, medium greenish-grey, compact, sandy streaks, and rare claystone streaks; carbonaceous fragments and pyrite clusters; carbonaceous clay streaks.
	10-100%	Sandstone, light grey, friable to compact, lithic, angular to subangular, very fine to fine-grained, moderately-sorted with feldspar, mica flakes and carbonaceous laminations; pink garnets at 5680'-90'; carbonate cement and clay matrix.
5990' - 6000'		No sample.
6000' - 6380'	10-100%	Mudstone, medium grey and greenish-grey, compact, silty with argillaceous siltstone and sandy streaks and carbonaceous fragments.
	10-70%	Sandstone, light grey, compact, angular to subangular, very fine to fine-grained, moderately-sorted with brown lithic fragments, feldspar, chlorite, mica flakes and brown sideritic streaks; carbonate cement.
	10-90%	Coal, vitreous at 6300'-10'.
6380' - 6390'		No sample.

6390' - 6890'	10-100%	Mudstone, medium grey and greenish-grey, compact, with siltstone and sandy streaks, light brown sideritic mudstone streaks and carbonaceous mudstone streaks; mica flakes and carbonaceous fragments.
	10-90%	Sandstone, light grey, compact angular to subangular, very fine to fine-grained, moderately-sorted with feldspar, lithic fragments, mica flakes and carbonaceous streaks; calcite, minor siderite cement and clay matrix. Poor porosity.
	10-70%	Coal, at 6720'-30'.
6890' - 6900'		No sample.
6900' - 7160'	50-100%	Mudstone, medium brownish-grey and grey, compact, sandy with siltstone streaks. Rare light brown sideritic mudstone streaks and rare patches of disseminated pyrite.
	10-50%	Sandstone, light grey, compact, angular to subangular, very fine to fine-grained, moderately-sorted with feldspar, brown lithic fragments and mica flakes; clay matrix and carbonate cement. Poor porosity.
	10%	Mudstone, dark brown, carbonaceous and coal fragments.
7160'-7170'		No sample.
7170' - 7400'	20-100%	Mudstone, medium to dark grey, compact, with sandy siltstone streaks, sideritic streaks, mica flakes, and plant remains at 7390'.
	10-80%	Sandstone, light to medium grey, compact, subangular, very fine to fine-grained, moderately-sorted with feldspar, lithics and mica flakes; clay matrix and carbonate cement. Poor porosity.
	10-30%	Mudstone, dark brown, carbonaceous.
7400' - 7500'	50-100%	Mudstone, dark grey and brown, compact, with sandy siltstone streaks, light brown sideritic mudstone streaks, mica flakes, pyrite streaks and finely disseminated carbonaceous fragments. Plant remains at 7480'.
	10-50%	Sandstone, light grey, compact to friable, subangular, fine to medium-grained, moderately-sorted with feldspar, chlorite, mica flakes and pyrite; angular pink garnets; carbonate cement and clay matrix. Poor porosity.

APPENDIX 2.

CORE ANALYSIS SAMPLE DESCRIPTIONS

Core No. 1 960' - 975'

Sandstone, dark green, poorly compacted, pellety, oolitic, subrounded to rounded, medium to very coarse-grained, poorly-sorted. Phosphate and chamosite pellets and ooliths; phosphate-coated quartz grains. Chloritic clay matrix and granular recrystallized siderite cement. Abundant pelecypod, gastropod, foraminifera, and echinoid spines (960'-965'). High porosity (43-47%); permeability low (1-2md.). The high porosity is related to the abundant chloritic clay matrix which contained a high water content, indicating lack of compaction. High grain density is due to oxidized chamosite pellets and iron-coated quartz grains.

Core No. 2 1378' - 1393'

Clay, dark brown, compact, laminated. Thin sandstone laminations of angular very fine-grained quartz; mica and gypsum nodules on lamination planes; scattered pyrite specks. Insufficient sample for core analysis.

Core No. 3 1858' - 1863'

Mudstone, medium greenish-grey, sandy, with thin sandstone laminations; mudstone pellets in sandstone intervals; muscovite and biotite flakes. Dark coaly lenses. Porosity is high (40%); permeability nil.

Core No. 4 1863' - 1873'

Mudstone, medium greenish-grey, compact, chloritic, with sandy patches and laminations; mica flakes and pyrite lenses. Root markings.
Porosity is high (35-36%); permeability fair (2-8md.).

Core No. 5 2365' - 2373'

Siltstone, medium greenish-grey, chloritic. Thin silty carbonaceous laminations. Mica flakes, rare pyrite clusters, carbonaceous fragments. Low angle planar cross-bedding. Root markings.
Porosity is good (31-32%); permeability good (10-39md.). Vertical permeability (39md.) due to sandy nature of siltstone.

Core No. 6 2373' - 2381'

Claystone, medium greenish-grey, compact, chloritic with thin very fine-grained sandstone laminations. Carbonaceous flecks and lenses. Plant remains.
Porosity is good (33-34%); permeability nil.

Core No. 7 2874' - 2884'

Claystone, medium green, compact, chloritic, grading to a lithic sandstone (greywacke) basewards. Biotite and muscovite flakes. Slickensiding at 2875 feet with 50° dip. Dip of bedding 5°. Plant remains.
Core analysis of greywacke. Porosity is good (29%); permeability fair to good (4-24md.). Vertical permeability (4md.) is low due to horizons with increased clay content in the sandstone.

Core No. 8 3377' - 3387'

Recovery 1'6".
No sample available at the B.M.R. Core and Cuttings Laboratory.

Core No. 9 3754' - 3764'

Sandy siltstone and claystone, medium greenish-grey, compact, chloritic; muscovite flakes, finely divided pyrite, finely disseminated carbonaceous matter and thin coal lenses. Thin sandstone laminations, slumped sandstone lenses, low angle

planar cross-bedding, burrows. Dip of bedding 5° at 3754'.
Root markings at 3762'.
Porosity is good (23-24%); permeability nil.

Core No. 10 4144' - 4154'
Claystone, in upper part (4144'-51'); lithic sandstone (greywacke) at base - medium greenish-grey, compact, angular to subangular, very fine to fine-grained, well-sorted with finely divided carbonaceous fragments; kaolinitic and chloritic clay matrix and minor calcite and zeolite cement. Slickensiding at 4146' with 30° dip. Bedding dip 20°. Plant remains and compressed roots - partially pyritized. Porosity is good (22-23%); permeability nil due to diagenetic calcite cement present.

Core No. 11 4616' - 4620'
Sandstone (greywacke) light grey, compact, lithic (volcanic), angular, very fine to medium-grained, well-sorted; mica flakes and squeezed carbonaceous laminations; kaolinitic clay matrix and calcite cement. Bedding dip 7°. Porosity is good (21%); permeability low (1-2md.).

Core No. 12 4620' - 4626'
Sandstone (greywacke), medium greenish-grey, compact, lithic, angular, fine to medium-grained, poorly-sorted; mica flakes and pyrite; kaolinitic clay and chlorite cement. Claystone pellets, thin carbonaceous clay laminations and "wisps" and low angle cross-bedding. Dip of bedding 15°. Plant fragments.
Porosity is good (18-22%); permeability nil due to compaction and matrix.

Core No. 13 5026' - 5036'
Sandstone (greywacke), light grey, compact, angular, very fine to medium-grained, moderately-sorted; kaolinitic and chloritic clay matrix and recrystallized calcite cement. Carbonaceous clay laminations and "wisps", and low angle cross-bedding.
Mudstone, dark grey, compact (5031'-33').
Porosity in sandstone is good (15-16%); permeability nil.

Core No. 14 5406' - 5416'
Sandstone (greywacke), light grey, compact, lithic (volcanic), angular to subangular, fine to medium-grained, moderately-sorted; kaolinitic clay matrix and calcite cement. Thin carbonaceous laminations and streaks, slickensiding at 5408' with dip of 40°.
Black carbonaceous mudstone below 5414'.
Porosity is good (15%); permeability nil.

Core No. 15 5693' - 5703'
Sandstone (greywacke), medium grey, compact, angular, very fine to fine-grained, poorly-sorted with mica flakes and carbonaceous clay laminations; illitic and chloritic clay matrix and patches of calcite cement. Dark grey, compact, sandy mudstone (5695'-5700'). Low angle cross-bedding, slumping, scour-and-fill and microfaulting. Bedding dip 10°. Plant remains.
Porosity is fair (10-11%); permeability nil due to clay laminations, matrix and diagenetic calcite cement.

Core No. 16 5990' - 6000'
Mudstone, dark grey, compact, chloritic with thin sandstone lenses. Carbonaceous fragments. Spots of calcite cement. Low angle cross-bedding. Plant remains.
Porosity is good (16-17%); permeability nil.

Core No. 17 6380' - 6390'

Mudstone, dark grey, compact with thin sandstone laminations and lenses; mica flakes and finely disseminated carbonaceous matter. At 6389 feet sandstone (greywacke) with kaolinitic and illitic clay matrix and calcite cement. Low angle cross-bedding and microfaulting. Dip of bedding 10°. Porosity is fair (14-16%); permeability nil.

Core No. 18 6890' - 6900'

Mudstone, dark grey, compact, chloritic with mica flakes and thin carbonaceous laminations and lenses. Rare patches of calcite. Thin sandstone laminations and small scale cross-bedding. Plant remains. Porosity is fair (13-14%); permeability nil.

Core No. 19 7487' - 7500'

Sandstone (greywacke), dark grey, compact, angular to subangular, fine-grained, moderately-sorted with mica flakes, pyrite crystals and angular pink garnets; scattered mudstone pebbles and carbonaceous laminations and coaly fragments. Illitic and chloritic clay matrix and patches of calcite cement. Dark grey, compact mudstone from 7494' to 7499'. Low angle cross-bedding, scour-and-fill and microfaulting. Dip of bedding 10°. Plant remains. Porosity is fair (14-16%); permeability nil.

PLATE I
(SHEET I)

COMPOSITE WELL LOG

HEATHFIELD Nº I

Lat: 37° 37′ 38″ S
Long: 141° 11′ 08″ E
Elevation: G.L. 230 ft. A.S.L. R.T.K.B. 244 ft A.S.L.
Scale: 1 inch = 100 ft

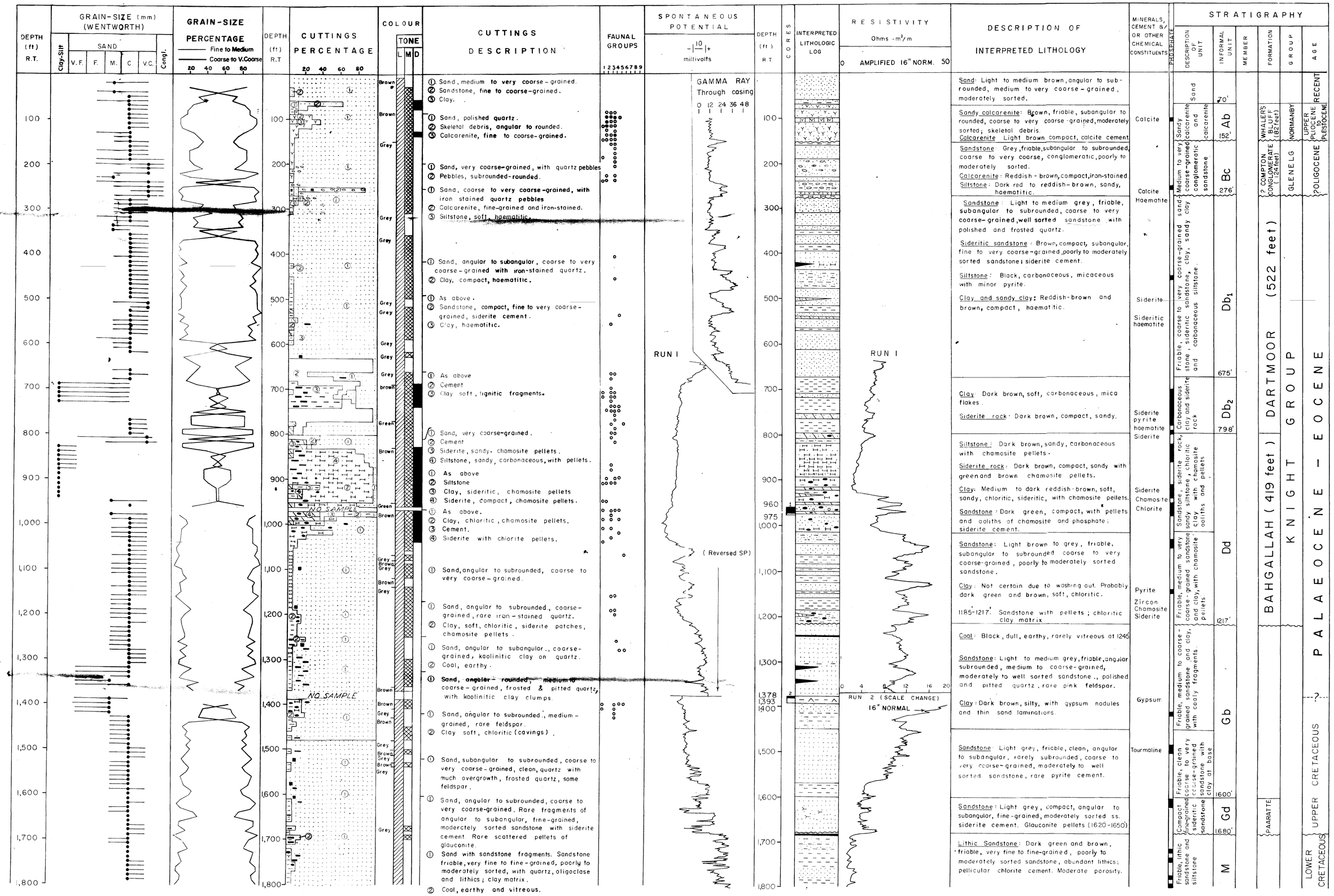
B.M.R. WELL INDEX Nº 96 (Core & Cuttings Laboratory)

Company: PLANET EXPL. Co. P/L.
Basin: OTWAY
State: VICTORIA

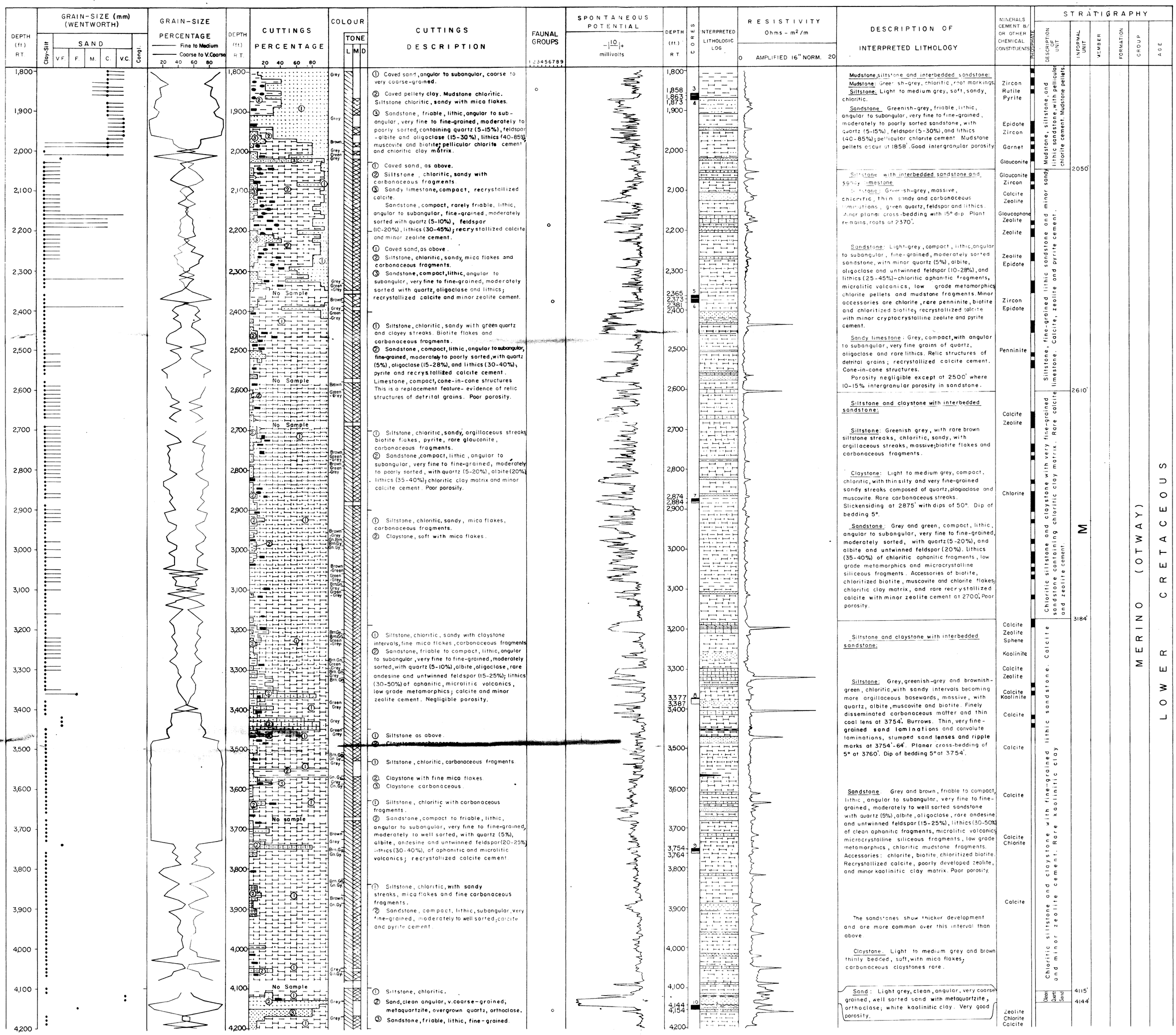
REFERENCE

Conglomerate
Sandstone
Siltstone
Claystone
Marl
Limestone
Calcarenite
Sandy calcarenite
Dolomite
Siderite
Sandy limestone or calcareous sandstone
Sandy dolomite or dolomitic sandstone
Sandy siderite or sideritic sandstone
Seam or lens fragments } Coal
Y Skeletal debris
Glauconite
Oolith
Pellet
Gypsum
Phosphate
Pyrite
Limonite
Nodules

FAUNAL GROUPS
1 Foraminifera
2 Polyzoa
3 Gastropoda
4 Lamellibranchia
5 Echinoid fragments
6 Fish teeth
7 Plant remains
{ • Abundant, ∘ Present }



HEATHFIELD Nº1

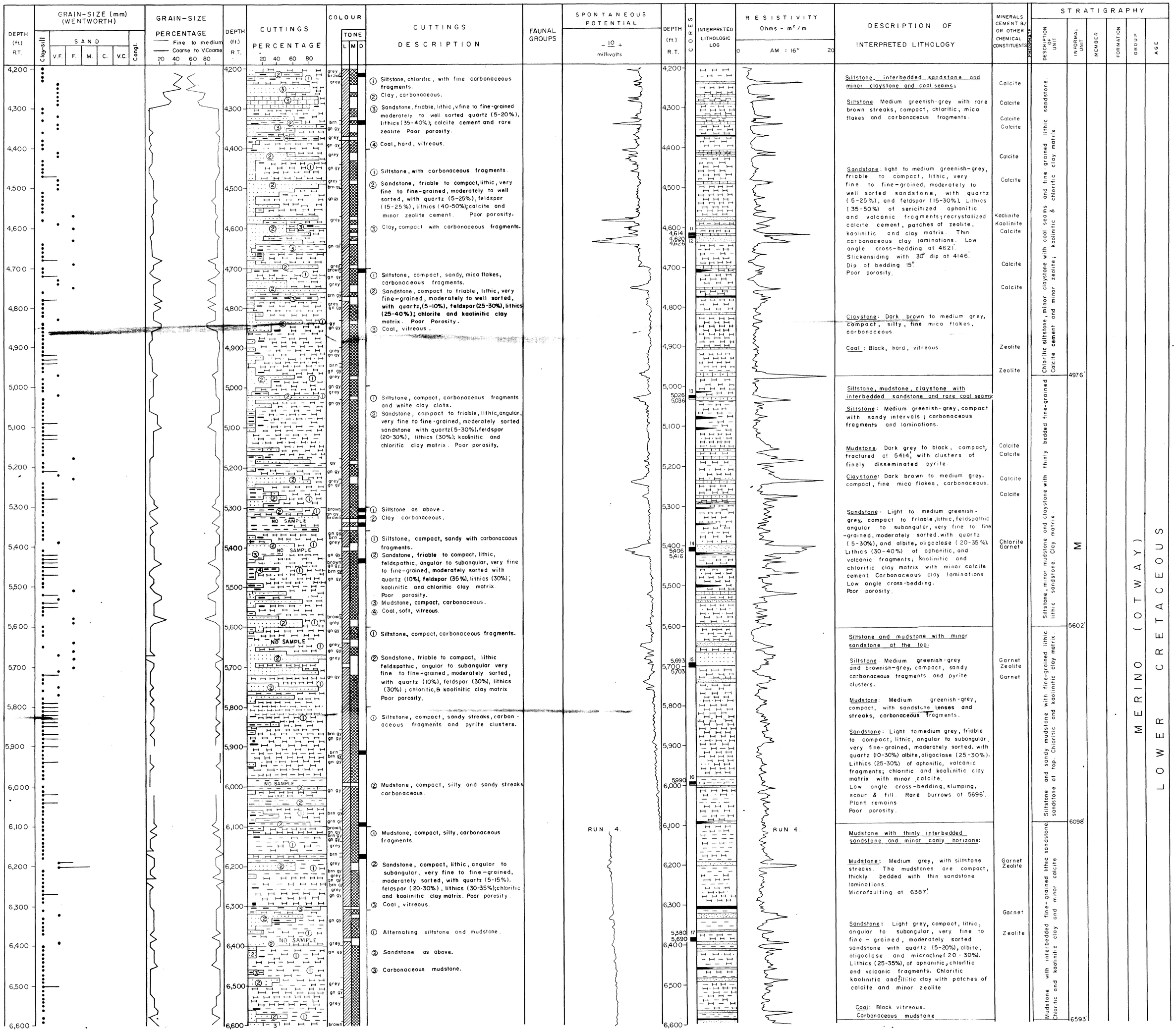


Bureau of Mineral Resources, Geology and Geophysics. June 1965

To accompany Record No. 1965/100

X AUS-2-49B

HEATHFIELD Nº1



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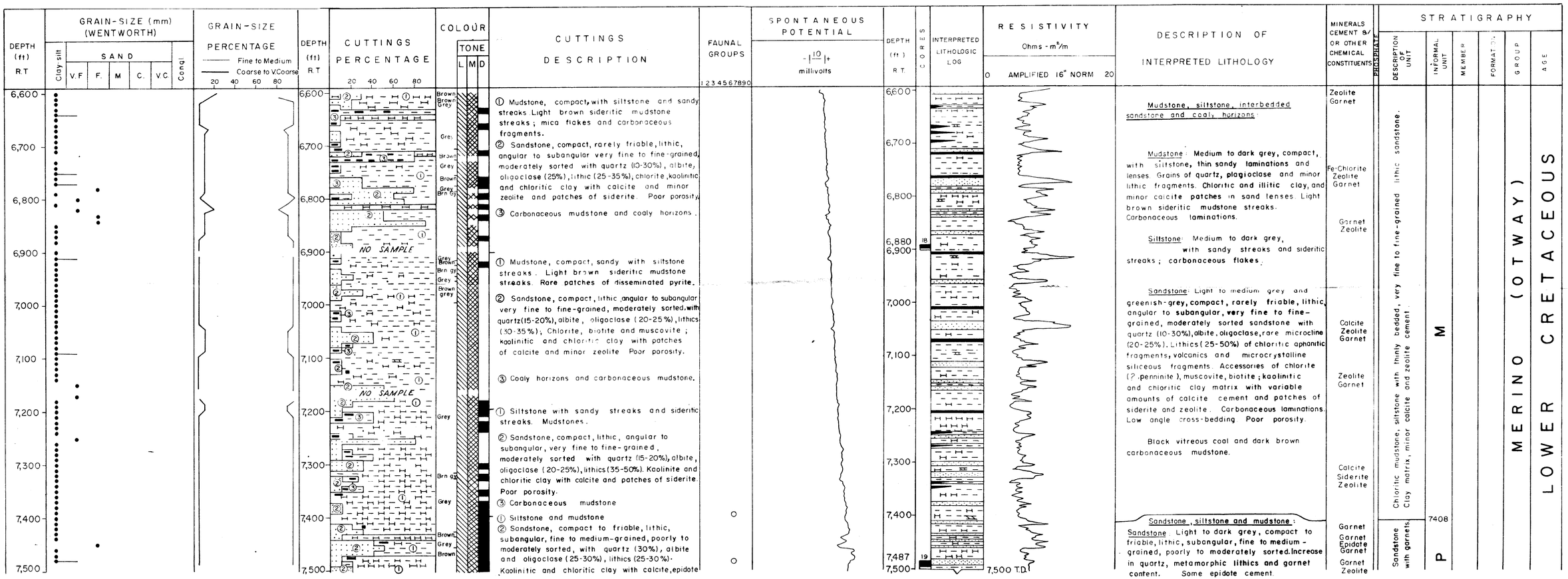

HEATHFIELD No. 1 WELL

GENERALIZED STRATIGRAPHICAL SEQUENCE

G.L. Elevation : 230'

Scale : 1:500