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Record No. 1969 / 61

Petrological Study of KIRKHAM (A.O.G.) No. 1 Well, Sydney Basin

New South Wales

by

I. Raine

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SYDNEY BASIN, NEW SOUTH WALES

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ABSTRACT

This petrological study of A.O.G. Kirkham No. 1 Well forms part of a systematic study of selected wells for a review of the Sydney Basin, currently being undertaken by the Sedimentary Basins Study Group of the Petroleum Exploration Branch.

Thirty-nine lithologic units were distinguished in the well and these were grouped into sixteen lithogenetic units. This subdivision is compared with that of Bradley (A.O.G., 1964) in figure 1. Interpreted lithology, environment of deposition and provenance of sediments is summarised in figure 2. The surface outcrop is in Wianamatta Group and the well penetrates approximately 8350' of Triassic and Permian sediments before presumed volcanic basement. Total depth is 8406'.

GENERAL INFORMATION

Well Data

Well Name, No.:	A.O.G. Kirkham No. 1
Operating Company:	Australian Oil and Gas Corporation Limited
Location:	Lat. and Long.: 34°01'39"S, 150°42'27"E 1:250,000 sheet: Wollongong, SI56-9 (grid ref. 37047966). About 2 miles north of Camden, N.S.W.
Elevation:	Ground level 270.8' a.s.l. Kelly Bushing 282.8' a.s.l. (datum for well)
Total Depth:	8406' (Driller) 8403' (Schlumberger)
Date Drilled:	16/7/64 to 4/10/64

Logging: i) Wire Line:

Run 1.	Gamma Ray	10'-2375'
	E-log	307'-2402'
	Microlog-Caliper	307'-2402'
	Sonic	307'-2402'
Run 2.	E-log	2402'-5429'
	Microlog	2402'-5429'
	Sonic-Gamma Ray	2402'-5422'
Run 3.	Gamma Ray	5300'-8395'
	Neutron	1050'-2400'
	Sonic	5350'-8396'
	Caliper	2398'-8396'
	Microlog	5350'-8402'
	Induction-E-log	5100'-8402'

ii) Cuttings and core description at well-site by A.J. Wright and K. Bradley.

iii) Gas content of drilling mud continuously recorded by automatic gas detector.

iv). Rate of penetration log.

v) Deviation surveys, taken at frequent intervals using a Totco drift recorder dropped through the drill-pipe prior to tripping for bit changes.

vi) Temperature Surveys: Bottom hole temperatures were recorded during wire-line logging operations.

Formation Testing:

D.S.T. No. 1, 2105'-2316': Mis-run

D.S.T. No. 2, 5182'-5207': Abandoned

D.S.T. No. 3, 5144'-5207': Recovered 100' of slightly gas cut mud.

Hydrocarbon Shows:

1170'-2280': numerous minor shows (Narrabeen Gp.)

2450'-4920': numerous small shows (Upper Coal Measures)

5195'-5197')
5995')
7170'-7430')
7940'-8000')
8300'-8350'): minor shows (Upper Marine Series)

Sampling:

i) Drill cuttings were collected at the shale shaker for every 10' interval drilled. Samples were washed and air-dried.

ii) 27 cores were cut for a total footage of 260'0".
26 cores were recovered, aggregating 218'10", or 84.2% of cored footage.

iii) 26 side-wall cores were taken, but only 18 were recovered, mostly with poor or fair recovery.

Major Reference used in Present Study

Bradley, K., 1964 - Well Completion Report, A.O.G. Kirkham No. 1, Sydney Basin, New South Wales.
Australian Oil and Gas Corporation Limited (unpublished).

Summary of Major References

"The well was spudded in Triassic Wianamatta Group. After penetrating 370' of this unit the drill passed through 646' of Triassic Hawkesbury Sandstone and 1437' of Triassic Narrabeen Group before entering Permian Strata at 2453'. It then penetrated 1416' of Permian 'Upper Coal Measures' and 4479' of Permian 'Upper Marine Series' before encountering volcanic rock at 8356'. The hole was terminated at a depth of 8406'.

Several minor gas occurrences were recorded while drilling the Narrabeen Group and the Permian coal and carbonaceous shale sequences. Several sandstone sections were drill stem tested following small gas shows but results were negative. Little evidence of porosity was noted in any sandstone sections.

No significant hydrocarbon shows were detected and the bore hole was subsequently plugged and abandoned."

Material Available for Study

Cuttings: 0'-8406' (T.D.) at 10' intervals and at 5' intervals over cored sections.

Drill Cores: Complete core recovery, except for a few inches from cores 21 and 27.

Side-wall Cores: Cores 6, 8, 10, 13, 17, 22.

Logs: See "Well Data".

Methods Used

All cuttings samples were examined under a low power binocular microscope, and thin sections made from selected intervals were examined under a petrologic mocroscope. The results were plotted, with wire-line log and other information, on "petrographic well log" sheets at a scale of 1":100', subsequently reduced to 1":200' (plates 1A-1E). Calcimetry was carried out by G. Parker.

Drill cores were longitudinally sectioned and examined under the binocular microscope. Thin sections were examined from each core. The results were plotted on "petrographic core log" sheets at a scale of 1cm:1', subsequently reduced to 1cm:2' (plates 2A-2G). Side wall samples were also examined and logged.

For grainsize classification, the modified Wentworth-Udden scale of Lane et al (1947) was used. The sandstone classification of Pettijohn (1957) was used for specific rock names, with the following modifications:

a) To partly reconcile the sandstone classification of Pettijohn with the sedimentary aggregate classification of Folk (1965), which was also used, all material of less than sand-size was classed as "detrital matrix" and the upper limit of this in the graywacke field was made 50%.

b) The term "quartz graywacke" was used to distinguish those quartz-rich rocks (sand and gravel composed of more than 75% quartz) in which detrital matrix was prominent (15-50% of total rock).

The lithologic column was interpreted, using cuttings and core logs, wire-line logs and other information. Thirty-nine rock units were recognised in the well. They have been grouped into sixteen major units on the basis of common interpreted environment of deposition or related sequence of such environments. The relationship of these units to the formal nomenclature adopted in the Company report is shown in text-figure 1.

Text-figure 2 summarises the interpreted lithology, environment of deposition and provenance of the sediments. These results are commented on in the final section in this record. Environments of deposition are of necessity highly speculative, but some ideas may be fruitful.

GEOLOGY

UNIT Km1 (plate 1A)

This unit extends from the surface to about 10'. It consists of gray sandy clay with limonite nodules and represents surface weathering and soil formation on the underlying shale sequence. It may also be in part alluvial in origin.

UNITS Km2-5 (plate 1A)

This sequence is 340' thick, extending from 10' to 350', it consists of carbonaceous siltstone, mudstone and claystone with lesser interbedded protoquartzite, mainly in the upper part. Lovering (1954) proposed an estuarine environment for the Wianamatta Group, with which this section has been equated by the Company.

UNIT Km2 (plate 1A)

Characteristics: This unit, 150' thick, extends from 10' to 160' and consists of dark gray carbonaceous illitic fine siltstone with calcite, siderite and rare pyrite cement, grading to carbonaceous illitic claystone with siderite nodules, interbedded with well-sorted coarse siltstone and light gray fine protoquartzite with kaolinite, calcite and siderite cement.

Environment and Provenance: The general fine grainsize suggests gentle current activity, with occasional periods of stronger activity resulting in sandstone deposition. The presence of pyrite, siderite and abundant carbonaceous material implies a reducing environment, as does the presence of rare glauconite, which also indicates marine conditions. Plagioclase, orthoclase, chert, argillite and siliceous volcanic rock fragments in sandstones of the unit suggest a mixed granitic, sedimentary and ancient volcanic provenance, although the possibility of solely recycled sedimentary material is not ruled out.

UNIT Km3 (plate 1A)

Characteristics: This unit, 12' thick, extends from 160' to 172' and consists of light gray, fine, chert-rich protoquartzite, similar to that of the overlying unit. It appears to mark the lower limit of this particular lithology in the major unit Km2-5.

Boundary Criteria: The upper boundary is marked by a sharp increase in the proportion of fine protoquartzite in the cuttings, with a corresponding decrease in gamma ray intensity from the overlying siltstone of Km2. It is differentiated from similar sandstone beds in unit Km2 by its greater thickness.

Environment and Provenance: Moderate current activity and provenance as for unit Km2.

UNIT Km4 (plate 1A)

Characteristics: This unit, 128' thick, extends from 172' to 300' and consists of dark gray carbonaceous illitic fine siltstone and mudstone with siderite nodules, interbedded in the upper half with well-sorted coarse siltstone to very fine protoquartzite, with calcite and siderite cement.

Boundary Criteria: The upper boundary is marked by a change from Km3 fine protoquartzite to coarse siltstone in the cuttings, with a corresponding increase in gamma ray intensity.

Environment and Provenance: The general fine grainsize of these sediments indicates gentle current activity, increasing periodically during deposition of the upper part of the unit. Reducing conditions are implied by the presence of siderite and abundant carbonaceous material. Provenance was as for unit Km2.

UNIT Km5 (plate 1A)

Characteristics: This unit, 50' thick, extends from 300' to 350' and consists of grayish black claystone with minor quartz silt, carbonaceous fragments and siderite nodules.

Boundary Criteria: The upper boundary of the unit is marked by a change from Km4 fine siltstone to claystone. Any corresponding increase in gamma ray intensity is masked by the change in intensity due to the passage of the logging instrument from uncased to cased hole.

Environment and Provenance: The uniform very fine grainsize of these sediments implies very gentle current activity, possibly in a protected lagoon, lake or marine basin. The presence of siderite and carbonaceous material suggests a reducing environment in the sediment.

UNITS Km6-10 (plates 1A, 2A)

This sequence is 668' thick, and extends from 350' to 1018'; it consists of fine to coarse slightly pebbly orthoquartzite and protoquartzite with lesser interbedded siltstone, mudstone and claystone, the distribution of which, together with grainsize variations, serves to subdivide the major unit. The sandstones are characterised by the presence of flakes of detrital graphite which, together with their mineralogical maturity, serves to distinguish them from other sediments in the well.

Environment of deposition is uncertain, but moderate to strong current activity and a weak reducing environment probably prevailed, most likely in fresh water. The interval approximates that equated with the Triassic Hawkesbury Sandstone by the Company, the upper boundary here being placed 20' higher than in the Company interpretation.

UNIT Km6 (plate 1A)

Characteristics: This unit, 20' thick, extends from 350' to 370', and consists of very fine to fine orthoquartzite (light olive gray) grading upwards to brownish black micaceous sandy coarse siltstone. The siltstone, which has siderite, quartz and kaolinite cement, contains muscovite, rare orthoclase and abundant sedimentary rock fragments, while the sandstone, with calcite, siderite and quartz cement, appears more mineralogically mature, lacking feldspar and rock fragments.

Boundary Criteria: The upper boundary is taken as the transition from siltstone to Km5 claystone. This is marked by an increase in radioactivity and decrease in resistivity.

Environment and Provenance: The unit represents a transition between the lithologies of the major units Km6-10 and Km2-5, in both grainsize and provenance. It may represent reworking of Hawkesbury Sandstone sediments with initiation of Wianamatta Group sedimentation, or it may be the vertical expression of a migrating lateral facies relationship, in which the area of Wianamatta sedimentation flanked that of Hawkesbury sedimentation.

UNIT Km7 (plate 1A)

Characteristics: This unit is 110' thick, and extends from 370' to 480'. It consists of light gray coarse orthoquartzite with kaolinite and quartz overgrowth cement, with minor interbedded grayish black sideritic siltstone. Detrital graphite occurs below 390'. Cuttings are largely disaggregated, loose sand grains.

Boundary Criteria: The upper boundary is taken as the upper limit of coarse sandstone, this being marked by decrease in radioactivity and negative deviation on the S.P. log, from the readings in sandstone of Km6, these changes probably being due to a lower content of cement and clay matrix in the coarse sandstone.

Environment and Provenance: The general coarse grain size of these sediments suggests a high energy environment of deposition. The presence of graphite suggests derivation from a terrain with metamorphosed coal or carbonaceous sediments.

UNIT Km8 (plate 1A)

Characteristics: This unit, 335' thick, extends from 480' to 815'. It consists of fine to coarse quartz-rich protoquartzite, some slightly pebbly, with kaolinite, quartz, calcite, siderite and, rarely, pyrite cement in varying proportions, interbedded with brownish gray to grayish black sandy illitic siltstone and mudstone, commonly micaceous and carbonaceous, with siderite cement. Calcimetry tests

indicate that the proportion of calcite cement in sandstone increases near the base of the unit. Detrital components of the sandstone include common and metamorphic quartz, chert, siliceous acid volcanic rock fragments, argillite, muscovite, graphite and rare orthoclase.

Boundary Criteria: The upper boundary is marked by a decrease in sandstone grainsize from that of unit Km7, by an increase in radicactivity into Km8, indicating interbedded argillaceous rocks, and by a decrease in resistivity and return to baseline of the S.P. log trace.

Environment and Provenance: The interbedded nature of this sequence suggests current activity varying from weak to strong. These rocks, despite the mineralogic maturity which makes interpretation difficult, appear to have been derived from a mixed regional metamorphic, sedimentary, and possibly granitic terrain.

UNIT Km9 (plate 1A)

Characteristics: This unit, 90' thick, extends from 815' to 905'. It consists of light gray to light brownish gray medium to coarse protoquartzite, some slightly pebbly, with quartz overgrowth, kaolinite, calcite, siderite and rare pyrite cement. Graphite is a conspicuous detrital component. The gamma ray log indicates minor interbedded siltstone.

Boundary Criteria: The upper boundary of the unit is marked by a sharp decrease in radioactivity readings from those of unit Km8, with a sharp increase in resistivity and S.P. log deviation at the same depth.

Environment and Provenance: The unit is similar in grain-size and lithology to unit Km7, and a similar environment of deposition is envisaged. Provenance as for unit Km8.

UNIT Km10 (plates 1A, 2A)

Characteristics: This unit is 113' thick and extends from 905' to 1018'. It consists of light gray fine to coarse protoquartzite, some slightly pebbly,

finer towards the base of the unit, interbedded with grayish black kaolinitic mudstone. Core 1 (979'-989'), cut in pebbly to silty very fine to coarse orthoquartzite to protoquartzite, displays cross-bedded sedimentation units ranging in thickness from 1" to 2'8". Detrital components include common, (simple unstrained quartz of uncertain provenance), vein, metamorphic and volcanic quartz, pale green and gray chert, brown argillite, quartz-muscovite schist, graphite and illitic clay; cement consists of quartz overgrowth, calcite, siderite and kaolinite (well-crystallised, colourless) patches.

Boundary Criteria: The upper boundary is marked by an increase in radioactivity from that of unit Km9, implying interbedded mudstone, and a decrease in resistivity and S.P. log deviation.

Environment and Provenance: Lithologically, the unit is similar to Km8 and a similar environment of deposition is suggested. Provenance appears to have been a mixed metamorphic and sedimentary terrain.

UNITS Km11-13 (plate 1A)

This sequence is 257' thick, extending from 1018' to 1275'. It contains a variety of lithologies, including carbonaceous siltstone, kaolinitic, pellet claystone, pebbly sandstone, etc., and separates the major sandstone units Km6-10 and Km14 (corresponding, respectively, to the Hawkesbury Sandstone and part of the Narrabeen Group in the Company interpretation). The section has been included in the Narrabeen Group by the Company. A variety of environments of deposition is likely for this complex unit, ranging from river point-bar to lacustrine. Provenance appears to have been a mixed acid volcanic, sedimentary and possibly granitic source, similar to that of Km14, below.

UNIT Km11 (plate 1A)

Characteristics: This unit, 71' thick, extends from 1018' to 1089', and consists of brownish black to brownish gray, siderite-cemented micaceous, carbonaceous, sandy fine to medium siltstone interbedded with light olive gray silty very fine protoquartzite. Detrital components of the sandstone include common and metamorphic quartz, chert, argillite, siliceous volcanic rock fragments, quartz-muscovite schist, muscovite, biotite, etc.,; cements are calcite, kaolinite and quartz.

Boundary Criteria: The upper boundary is marked by an increase in radioactivity from unit Km10, an increase in resistivity, and a decrease in S.P. log deviation.

Environment and Provenance: The presence of siderite and carbonaceous material in this unit suggests reducing conditions; the general fine grainsize together with the fine interbedding revealed by the gamma ray log suggests intermittent weak current activity. In the absence of marine fossils a lacustrine environment of deposition is suggested for the unit.

The sandstone of the unit appears to have been derived from a mixed sedimentary / low grade metamorphic, acid volcanic and possibly granitic terrain.

UNIT Km12 (plate 1A)

Characteristics: This unit, 71' thick, extends from 1089' to 1160'. It consists, in order of increasing depth, of the following sequence:

10' Light brownish gray sandy pellet claystone: this has brown kaolinite pellets in a sandy brown kaolinite matrix partly cemented by siderite and recrystallised colourless kaolinite.

20' Light gray, grading to deep reddish brown pellet claystone: this has kaolinite pellets in a partly recrystallised kaolinite matrix with siderite patches, impregnated with haematite in the case of the reddish brown claystone.

6' Deep reddish brown sandy mudstone grading to pink and green fine subgraywacke, with siderite and quartz cement, clay matrix. Detrital components include common, volcanic and metamorphic quartz, siliceous volcanic rock fragments ("cherty"), jasper, rare orthoclase, etc.

30' Deep reddish brown kaolinitic claystone, possibly pelletal (masked by haematite).

5' Multicoloured medium subgraywacke, as 6' interval above.

Gamma ray log readings in the claystone parts of the above sequence are low, indicating a low K content of the clay.

Boundary Criteria: The upper boundary of the unit is marked by the change from Km11 sandy siltstone and silty sandstone to sandy pellet claystone: this boundary is believed to occur at 1089', as a high radioactivity reading immediately above this level is believed to be inconsistent with the clay mineralogy of the unit.

Environment and Provenance: The pellet claystones of this unit appear to be very similar to the clay pellet conglomerates described and discussed by Carozzi (1960, p. 151). These are supposed to be of intraformational origin: layers of clay deposited on flood plains were subject to desiccation. The resultant clay flakes were rounded in transport and redeposited with a clay matrix by running water. Diagenetic alteration appears to be common in such rocks: kaolinite is first recrystallised and later, diaspore may be formed.

Thus the unit may be the result of deposition on a floodplain subject to desiccation. The coarser sediments would represent channel or crevasse sands of the major river, or of tributory streams.

Sandstones of the unit appear to have been derived from a mixed acid volcanic, sedimentary / metamorphic, and possibly granitic terrain.

UNIT Km13 (plate 1A)

Characteristics: This unit of varied lithology, 115' thick, extends from 1160' to 1275'. It is proposed to include all the sediments of the interval in which red claystones and mudstones occur below unit Km12. With increasing depth, the sequence is brownish black carbonaceous fine siltstone, light gray very fine to medium protoquartzite (slightly pebbly), deep reddish brown mudstone, brownish black carbonaceous coarse siltstone to silty very fine protoquartzite, deep reddish brown mudstone, olive gray to brownish black carbonaceous fine siltstone.

Boundary Criteria: The upper boundary is marked by change in lithology from Km12 claystone to carbonaceous siltstone, apparently corresponding to a sharp increase in radioactivity and resistivity into unit Km13.

Environment and Provenance: There appear to be four reddish-brown mudstone/claystone units (including Km12), each underlain successively by carbonaceous siltstone and slightly pebbly sandstone. These fining-upwards sequences suggest the point-bar deposits of a meandering river (successively "channel" and "overbank" deposits).

The sandstone of this unit is much more quartz-rich than the subgraywacke of unit Km12, but appears to have been derived from a similar source area with acid volcanic and sedimentary rocks. Green "chert" is a characteristic component of both.

UNIT Km14 (plates 1A, 1B, 2A)

This unit corresponds to part of the Narrabeen Group recognised by the Company.

Characteristics: The unit is 850' thick and extends from 1275' to 2125'. It consists of a variety of interbedded sandstones, siltstones and mudstones. Approximately seventeen fining upwards sequences can be recognised, comprising the whole of the unit. The presence of these sequences is especially noticeable in the cuttings grain-size log. A typical sequence, 50' thick, would consist of 35' of pebbly coarse sandstone grading upwards through medium and fine slightly pebbly sandstone to very fine sandstone, followed by 15' of sandy siltstone and mudstone.

Sandstones of the unit vary from light gray to light olive gray in colour. Petrologically they vary with increasing depth from protoquartzite to subgraywacke, if a high proportion of the fine grained siliceous fragments commonly termed "chert" are regarded as volcanic rock fragments. There is evidence for this assignation in the presence of phenocrysts and relict flow banding in some fragments. If this component is counted as chert and included with quartz in determining the classification, the sandstones vary from chert-rich orthoquartzite to protoquartzite.

Other detrital components include common, vein and metamorphic quartz, radiolarian chert, jasper, argillite, carbonaceous material, sideritic siltstone intraclasts, etc., with illitic clay matrix. Cementing minerals include siderite, calcite, quartz overgrowth and colourless vermicular kaolinite. Some siderite laminae in cores appear to be detrital. Picotite is an interesting rare heavy mineral accessory.

Siltstones and mudstones of the unit vary in colour from brownish black to olive gray and greenish gray. They are generally carbonaceous, micaceous, have illitic clay and siderite cement, sometimes siderite nodules. The three cores cut in the unit display the range of rock-types present. Sedimentary structures include cross-bedding, wavy bedding, normally graded

bedding (waning current type), and rare burrows (in siltstone and silty sandstone). These cores and the wire-line logs show the sharp variations in lithology over small intervals which are characteristic of the unit.

From the S.P. log, resistivity log, neutron log and core analyses, sandstones of the unit appear to have medium porosity. The two higher cores cut in the unit are the only ones in the well in which measurable permeability was detected (2-22 md.).

Boundary Criteria: The upper boundary is taken as the base of a carbonaceous siltstone unit underlying the lowest reddish brown mudstone of unit Km13. This siltstone may be recognised on the gamma ray log by its high radioactivity in contrast to that of sandstone immediately below.

Environment and Provenance: The fining-upwards sequences, sequences of sedimentary structures seen in cores, and lithologies of the unit are consistent with deposition of point bars by a meandering river, the volume of overbank sediments being restricted. The presence of siderite and carbonaceous material implies reducing conditions during deposition of at least the finer sediments of the sequence.

The sediments appear to have been derived from a dominantly acid volcanic (ancient) and sedimentary/low grade metamorphic terrain. Possibly, granites may have supplied much of the quartz. The presence of picotite implies ultrabasic rocks in the source area (these could be serpentinised) (Kerr, 1959, p. 200).

UNITS Km15-16 (plates 1B, 2B, 2C)

This sequence is 329' thick and extends from 2125' to 2454'. It consists of conglomerate, pebbly subgraywacke, sandy siltstone and illitic claystone. The sandy sediments appear to have a similar provenance to major units Km14 and Km11-13, the presence of green and red "chert" and the heavy mineral picotite being characteristic.

Although there is a higher proportion of sediments of silt-size and finer in this major unit, a similar environment of deposition to that of unit Km14 is envisaged.

The interval has been included in the Triassic Narrabeen Group by the Company.

UNIT Km15 (plates 1B, 2B)

Characteristics: This unit, 238' thick, extends from 2125' to 2263'. It appears to consist, like unit Km15, of a number of fining-upwards sequences, here five in number. These are differentiated from those of unit Km14 by the greater thickness and finer grainsize of the siltstone -mudstone - claystone parts of each sequence. This characteristic is readily seen in the gamma ray log.

A typical sequence consists of light gray pebbly medium subgraywacke grading upwards to slightly pebbly fine to very fine subgraywacke, succeeded by olive gray sandy siltstone, mudstone and greenish gray claystone. The central sequence of the 5 in the unit has approximately 20' of conglomerate as its basal part.

Detrital components of medium subgraywacke from core 5 include common, vein, volcanic and metamorphic quartz, many varieties of chert, argillite, siltstone, quartz-muscovite schist, muscovite, plagioclase, abundant siliceous volcanic rock fragments, zircon, leucoxene, picotite (angular), chlorite etc., with sericitic clay and silt matrix. Cementing minerals include siderite, calcite and quartz. Some siderite appears to be detrital.

The finer sediments of the unit have illitic clay, are slightly micaceous (muscovite) and carbonaceous (finely divided fragments), and commonly have sand-size siderite nodules.

Sedimentary structures in core 5 include cross-bedding and graded bedding (waning current type). Sedimentation units commonly have eroded tops.

Boundary Criteria: The upper boundary is taken as the top of a prominent interval of greenish gray claystone and sandy siltstone in the cuttings, corresponding to a marked increase in radioactivity.

Environment and Provenance: A fluviatile point-bar environment of deposition is envisaged for this unit, as for unit Km14, the proportion of "overbank" sediments being greater than in the latter. Provenance as for unit Km14.

UNIT Km16 (plates 1B, 2B, 2C)

Characteristics: This unit, 91' thick, extends from 2363' to 2454'; it consists of brownish gray to brownish black slightly carbonaceous sandy siltstone with minor medium gray very fine to fine subgraywacke. Siltstone varies from very fine to coarse silt in grainsize, with a small proportion of very fine to fine sand; cementing minerals include siderite, calcite.

Detrital components of the subgraywacke include quartz, chert, siliceous volcanic rock fragments, quartz-muscovite schist, argillite, oligoclase-andesine, muscovite, rare orthoclase, chlorite, tourmaline, picotite, zircon, biotite, rutile, magnetite, leucoxene, sphene, etc., with sericitic clay and silt matrix; cementing minerals include calcite, siderite, quartz.

Cores 6, 7 and 8 (2401'-2461') provide a near-continuous section of the lower half of the unit. Thin beds of subgraywacke are intercalated in an essentially siltstone sequence. Sedimentary structures in the siltstone include wavy bedding, small-scale cross-bedding, burrows, convolute lamination; subgraywacke units generally consist of a single cross-bedded set.

Boundary Criteria: The upper boundary is marked by an increase in radioactivity from that of sandstone of unit Km15. The sustained high gamma-ray reading through the unit serves to distinguish it from the interbedded sandstone-siltstone unit Km15.

Environment and Provenance: The presence of siderite and carbonaceous material, together with the grainsize pattern, suggests a reducing environment with gentle current activity. The presence of burrows and rare rootlet zones suggest periods of slow or non-deposition. A river flood-plain environment of deposition is believed to be consistent with these factors, and the suggested environments of units Km15 and Km17.

The provenance of the sediments appears to be similar to that of unit Km15, being mixed siliceous volcanic, sedimentary/low grade metamorphic, ultrabasic, and probably also granitic.

UNITS Km17-19 (plates 1B, 2C)

This major unit is 232' thick, extending from 2454' to 2686', and comprises a complex sequence of subgraywacke, sandy siltstone, mudstone and coal. The provenance of these sediments appears to be slightly different from that of units Km15-16, above, in that, while siliceous volcanics are dominant, these are mainly in neutral shades, not green or red. Picotite was not seen. Feldspar and granitic rock fragments are abundant, implying a granitic source. Unit Km16 probably has a transitional provenance.

The major unit comprises three units, each with a coal seam or series of seams at the top. The two upper units are sandy, the lower silty. The units immediately below, Km20, Km21 and Km22 show a similar sequence, the units Km20 and Km21 being sandy like Km17 and Km18, and unit Km22 being silty like Km19. Thus two major units with similar sequences, Km17-19 and Km20-22 were formed, each major unit possibly a cyclothem.

As the whole of the sequence Km20-22 and Km17-19 is believed to have been deposited in fluviatile/paludal environments, the reason for this apparent cyclicity is obscure. It may be related to two phases of delta development further downstream. The Company has included the sequence in the Permian Illawarra Coal Measures.

UNIT Km17 (plates 1B, 2C)

Characteristics: This unit, 79' thick and extending from 2454' to 2533', consists of, in order of increasing depth, black bituminous coal, brownish black carbonaceous fine siltstone, carbonaceous fine silty sandstone and sandy siltstone, medium gray very fine to medium subgraywacke. Cuttings samples have an anomalously high proportion of coal and coaly mudstone, presumably due to caving of the coal seam. Detrital components of the subgraywacke include common, metamorphic and volcanic quartz, chert, abundant siliceous volcanic rock fragments, argillite, micropegmatite, granitic rock fragments, microcline, orthoclase, oligoclase, etc., cementing minerals include recrystallised illite, siderite and quartz overgrowth.

Cores 8 and 9 were cut in the upper part of the unit, from the top (2454') to 2481'. Sedimentary structures in core 9 include wavy bedding and cross-bedding (large and small scale). A rootlet zone occurs immediately below the coal seam.

Boundary Criteria: The upper boundary is taken as the transition from siltstone of unit Km16 to coal, the boundary being intersected in core 8. The sonic, gamma ray and resistivity logs all show pronounced changes at this level.

Environment and Provenance: The sequence of lithologies and associated sedimentary structures in core 9 suggest a river point bar-levee-backswamp sequence of depositional environments.

The sediments appear to have been derived from a mixed siliceous volcanic, sedimentary/low grade metamorphic and granitic terrain.

UNIT Km18 (plate 1B)

Characteristics: This unit, 73' thick, extends from 2533' to 2606'. The lithological sequence has been largely deduced from the wire-line logs, as the cuttings samples are non-representative because of cavings from the coal seams. The sequence appears to be as follows (with increasing depth): black coal, brownish black sandy siltstone, light gray fine subgraywacke, black coal, brownish black sandy siltstone grading to mudstone.

Boundary Criteria: The upper boundary is taken as the top of the major coal seam between 2533' and 2541'. This is marked by a sharp increase in resistivity from the values of Km17, and sharp decreases in gamma ray and sonic log readings.

Environment and Provenance: Environment of deposition is uncertain, but probably ranged from fluviatile to paludal. Provenance was as for unit Km17, i.e. a volcanic, sedimentary/low grade metamorphic and granitic terrain.

UNIT Km19 (plate 1B)

Characteristics: This unit is 80' thick and extends from 2606' to 2686'. It consists of 5 black coal seams with interbedded brownish black sandy siltstone and coaly mudstone. Seams are thicker towards the top of the unit. Cuttings in this interval are again non-representative because of caving from the coal seams.

Boundary Criteria: The upper boundary is taken as the top of the uppermost (and thickest) coal seam included in the unit. This is marked on the resistivity log by a sharp increase in resistivity from the siltstone of Km18 to the coal. The sonic log also shows a pronounced deflection, while the gamma ray log peak is less marked, possibly because the seam is thin.

Environment and Provenance: The fine grainsize and coal seams of the unit indicate gentle current activity. These may be river floodplain ("overbank") and swamp deposits. Provenance is uncertain, probably as for units Km17 and Km18, i.e. a volcanic, sedimentary/low grade metamorphic and granitic terrain.

UNITS Km20-22 (plate 1B)

This major unit, 284' thick, extends from 2686' to 2970'. As mentioned above, it appears to contain a similar sequence to the overlying major unit Km17-19. Thus it comprises three units, each with a coal seam or series of seams at the top. The two upper units are sandy, the lower silty, as in Km17-19. Provenance appears to be similar to that of units Km17-19. The upper two units have been included in the Permian Illawarra Coal Measures by the Company.

UNIT Km20 (plate 1B)

Characteristics: This unit, 69' thick, extends from 2686' to 2755'. It consists, in descending order, of interbedded black coal and brownish black slightly sandy carbonaceous siltstone, and light gray fine subgraywacke with illitic clay matrix and calcite cement.

Boundary Criteria: The upper boundary is taken as the transition from coaly mudstone of unit Km19 to sandy siltstone. This is marked by a decrease in radioactivity (gamma ray log) and an increase in resistivity.

Environment and Provenance: The sequence of rock-types in the unit is suggestive of a river point-bar sequence, the coal being deposited in a backswamp environment. Provenance was as for unit Km17, i.e. siliceous (altered) volcanic, sedimentary/low grade metamorphic and granitic.

UNIT Km21 (plate 1B)

Characteristics: This unit, 54' thick, extends from 2755' to 2809'. It consists of the following sequence (descending order): black coal, medium dark gray carbonaceous siltstone, light gray fine subgraywacke with interbedded siltstone towards the base.

Boundary Criteria: The upper boundary is taken as the top of the major coal seam between 2755' and 2763'. This is marked by a decrease in radioactivity from that of sandstone above (Km20), increase in resistivity, and decrease in sonic log reading.

Environment and Provenance: As for Km20.

UNIT Km22 (plate 1B)

Characteristics: This unit, 161' thick, extends from 2809' to 2970'. In descending sequence, it consists of interbedded black coal, medium dark gray carbonaceous sandy siltstone (with siderite cement) and light gray fine subgraywacke (with calcite cement), followed by carbonaceous sandy siltstone, siltstone, illitic mudstone, a thin coal seam and sideritic sandy siltstone. The lower coal seam was recognised only from its low sonic velocity.

Boundary Criteria: The upper boundary is taken as the top of the top coal seam of the interbedded sequence in the upper part of the unit, this being clearly marked on the sonic log by a sharp decrease in sonic velocity from the sandstone of unit Km21 above. There is also an increase in resistivity. Any coal seam should show you the changes mentioned.

Environment and Provenance: This unit appears more complex than that immediately above. Similarity of lithologies, however, suggests a general fluvial-paludal enyironment. Provenance was as for Km20, i.e. a siliceous volcanic, sedimentary/low grade metamorphic and granitic terrain.

UNITS Km23-24 (plates 1B, 2D)

This major unit, 242' thick, extends from 2970' to 3212'. It is basically a siltstone-very fine sandstone sequence, but conglomerate, siltstone and coal occur at the top. This latter sequence is divided off as a separate unit. The sequence is believed to be deltaic in origin, environments ranging from prodelta slope through delta platform, river mouth bar and beach to swamp. The whole sequence may represent a single delta similar to the Holocene Niger delta (Allen, 1964). Provenance appears to have been volcanic, granitic, sedimentary/low grade metamorphic.

In the Company interpretation, the sequence forms part of the Permian Cumberland Coal Measures.

UNIT Km23 (plate 1B)

Characteristics: This unit, 32' thick, extends from 2970' to 3002'. It consists, in descending order, of black bituminous coal, brownish black slightly sandy siltstone (carbonaceous, with siderite cement), light gray oligomict conglomerate (quartz, calcite, siderite cement).

Boundary Criteria: The upper boundary is taken as the top of the coal seam at 2970', this being marked in the wire-line logs by increased resistivity, decreased radioactivity and sonic velocity, from the readings in the overlying siltstone/mudstone of unit Km22.

Environment and Provenance: These sediments are believed to represent the topset facies of a deltaic sequence which includes the underlying unit Km24. Environments of deposition may have included, from the base of the unit, river mouth bar or beach, lagoon and coal swamp.

The sediments appear more mineralogically mature than those of overlying units, and a similar provenance to that of unit Km24 is envisaged: volcanic, granitic, minor sedimentary: the granitic contribution being more important than in major units Km17-19 and Km20-22.

UNIT Km24 (plates 1B, 2D)

Characteristics: This unit, 210' thick, extends from 3002' to 3212'. It consists of interbedded brownish black slightly sandy siltstone (siderite, calcite, pyrite cement), brownish gray sandy siltstone to silty very fine subgraywacke, light brownish gray fine subgraywacke (calcite, siderite, pyrite cement).

Core 10 (3005'-3015') was cut near the top of the unit in brownish black carbonaceous very fine siltstone and olive gray sandy coarse siltstone to very fine subgraywacke. Detrital components include quartz, siliceous and feldspathic volcanic rock fragments, orthoclase, plagioclase, granitic rock fragments, clay pellets, chert, argillite, quartz-muscovite schist, muscovite, biotite, zircon, tourmaline, etc., cellular plant fragments, brown montmorillonitic clay. Cementing minerals include well-crystallised illite, calcite, and siderite nodules. Sedimentary structures include fine lamination, small-scale cross-bedding, wavy bedding and rare burrows. A carbonised glossopterid leaf fossil was seen at 3013'5".

Boundary Criteria: The upper boundary is taken as the base of the conglomerate of unit Km23. This is marked on the wire-line logs by a decrease in resistivity and sonic velocity and increase in radioactivity on going from conglomerate to siltstone of Km24.

Environment and Provenance: The presence of pyrite, siderite and abundant carbonaceous material indicates reducing conditions in the sediment. Sediments of the unit are believed to represent pro-delta slope and delta platform environments, i.e. the "foreset" beds of a delta. Provenance was from a mixed volcanic, granitic and sedimentary/low grade metamorphic terrain.

UNITS Km25-26 (plates 1B, 2D)

This major unit extends from 3212' to 3470' and is 258' thick. The sequence is similar to that of Km23-24 in that it consists of a silty lower section and conglomeratic upper section with a coal seam at top. Like Km23-24 the sequence is believed to be deltaic in origin, representing a series of "foreset"and "topset" environments. Provenance of the sediments appears to have been similar to that of units Km23-24, the granitic contribution possibly being greater. The sequence has been included in the Permian Cumberland Coal Measures by the Company.

UNIT Km25 (plate 1B)

Characteristics: This unit, 79' thick, extends from 3212' to 3291'. In descending order, it consists of black bituminous coal, brownish black coaly mudstone, light gray oligomict conglomerate (some sandy) with interbedded dark gray carbonaceous siltstone, sandy siltstone, pebbly subgraywacke with quartz, calcite, siderite, illitic clay, pyrite cement.

Boundary Criteria: The upper boundary is taken as the top of the coal seam at 3212', this being marked by an increase in resistivity and decrease in radioactivity and sonic velocity on passing from siltstone of unit Km24 to the coal.

Environment and Provenance: This sequence is believed to represent, like unit Km23, a variety of "topset" environments of a deltaic complex, including river mouth bar/beach, lagoon and swamp. Provenance was apparently from volcanic, granitic and sedimentary/low grade metamorphic terrain.

UNIT Km26 (plates 1B, 2D)

Characteristics: This unit, 179' thick, extends from 3291' to 3470'. It consists of grayish black pebbly medium lithic graywacke with mudstone wisps grading downwards to brownish black sandy medium siltstone with siderite cement. Wire-line logs indicate thin coal seams at 3292' and 3422'.

Core 11 (3295'-3305'), cut near the top of the unit, consists of dark gray pebbly coarse to fine lithic graywacke with mudstone wisps. Pebbles consist of quartz, pyritic chert, rare green chert, acid volcanic rock, white quartzose sandstone, shale, argillite. Sand-size detrital components include vein, volcanic and common (plutonic) quartz, metaquartzite, orthoclase, microcline, quartzose siltstone, granite, porphyritic acid volcanic rocks, chert, argillite, etc., with rare green clay-mineral pellets, possibly glauconite. Silt, carbonaceous material and brown montmorillonitic clay comprise the matrix, while cementing minerals include well-crystallised illitic clay, pyrite and two generations of calcite.

Sedimentary structures seen in the core include wavy, discontinuous mudstone laminae and deformed small-scale cross-bedding. Disrupted grains seen in thin section also suggest post-depositional deformation.

Boundary Criteria: The upper boundary is taken as the base of the well sorted pebbly subgraywacke of unit Km25. This is marked by a decrease in resistivity and increase in radioactivity in passing into the graywacke of Km26.

Environment and Provenance: Poor sorting and deformed cross-bedding in core 11 suggest turbidity current deposition. This might result from loading of poorly consolidated fine-grained deposits by coarser sediments, with consequent slumping and turbidity current formation. The presence of pyrite and siderite suggest reducing conditions, as does the presence of glauconite, which, although allochthonous, probably indicates a marine environment. As mentioned above, the sequence Km25-26 is believed to be deltaic in origin - the sediments of Km26 appear to represent the marine prodelta slope environment. The thin coal seams may easily be allochthonous.

The sediments were derived from acid volcanic (ancient), granitic and sedimentary/low grade metamorphic sources.

UNIT Km27 (plates 1B, 1C, 2D)

This sequence has been included in the basal part of the Permian Cumberland Coal Measures by the Company.

Characteristics: The unit is 413' thick, extending from 3470' to 3833'. It consists of a variety of lithologies, including black coal, brownish black coaly mudstone, brownish black to dark gray carbonaceous siltstone, some sandy (pyrite, siderite, calcite cement), light gray to greenish or brownish gray slightly silty very fine to fine volcanic subgraywacke (calcite, siderite, pyrite cement). There are at least 21 coal seams in the unit, ranging in thickness up to about 5', thicker seams being mainly in the section below 3647'.

Core 12 (3688'-3698') recovered a section immediately below a coal seam. In order of increasing depth, the core comprises olive black carbonaceous medium siltstone (with lamination, wavy bedding, small scale cross-bedding, loading structures), olive gray silty fine to medium volcanic subgraywacke (horizontal lamination), olive gray to brownish gray fine subgraywacke (small scale cross-bedding), olive gray fine to medium subgraywacke (large scale cross-bedding). Detrital components of the sandstone include minor quartz, plagioclase (oligoclase-andesine), orthoclase, rare feldspar-glass volcanic rock fragments, abundant feldspathic volcanic rock fragments, minor chert, granitic rock fragments, muscovite, biotite, chlorite, carbonaceous fragments, with minor brown clay matrix. Calcite cement is abundant, commonly replacing feldspar; siderite is also present.

Boundary Criteria: The upper boundary of the unit is taken as the top of a sandstone bed at 3470', this being the upper limit of the sandy sequence of

Km27. The boundary is marked by an increase in resistivity and sonic velocity and decrease in radioactivity on passing into the sandstone from the siltstone of Km26.

Environment and Provenance: The occurrence of pyrite, siderite and carbonaceous material suggests a generally reducing environment. Fluctuating current activity is shown by the variation in grainsize. The sequence in core 12 represents sediments deposited by currents of successively lower competence, suggestive of a river point-bar environment. A river floodplain environment is consistent with the available evidence. Sandstone at the top of the unit may be the result of reworking of sediment during the subsequent marine(?) transgression. The sediments were mainly derived from a contemporary intermediate volcanic source, with minor sedimentary, granitic and ancient volcanic contribution.

UNIT Km28 (plates 1C, 2D, 2E)

This sequence was regarded by the Company as equivalent to the Budgong Sandstone Member of the Berry Shale, a formation in the Permian Shoalhaven Group.

Characteristics: The unit extends from 3883' to 4270' and is 387' thick. It consists of silty to clean very fine to fine sandstone, with lesser sandy siltstone, mudstone and claystone.

Core 13 (3955'-3965') cut in the upper part of the unit, consists of olive black to dark greenish gray slightly carbonaceous fine siltstone (chlorite, calcite cement) and dark greenish gray fine and very fine arkose. Detrital components of the arkose include rare (2-3%) volcanic quartz, andesine, rare orthoclase, feldspathic volcanic rock fragments, some glassy volcanic rock fragments, silica spherulites, siltstone intraclasts, biotite, muscovite, leucoxene, sphene, magnetite, zircon, etc. A feature of the rock is the well

crystallised chlorite cement; later calcite cement is also present, and some sphene may be authigenic. Sedimentary structures include lamination, small scale cross-bedding, wavy bedding, loading structures, rare burrows.

Side-wall core 22 (4159') is similar to core 13, but rock fragments predominate, making it a subgraywacke.

Core 14 (4210'-4220') consists of dark gray very fine feldspathic graywacke to sandy coarse siltstone. Detrital components include quartz (about 50%), oligoclase, microline, siliceous fine-grained volcanic rock fragments, siltstone intraclasts, biotite, muscovite, carbonaceous fragments, with illitic clay matrix. There is minor pyrite cement and calcite replacing feldspar. Sedimentary structures include abundant burrows and wavy bedding, and foraminifera (some arenaceous) are common.

A thin section of sandstone from 4090'-4100' has about 55% quartz and is an arkose. Thus there appears to be considerable variation in mineralogy of the sandstones of the unit. The distribution of abundant chlorite cement is shown on the composite well log; other cements include calcite, pyrite and siderite. Siltstones have similar cementing minerals. The claystones, of which there are three distinct beds in the unit, are illitic, and have biotite flakes.

Boundary Criteria: The upper boundary is taken as the base of the lowest coal seam in the coal measure sequence above (Km27). This is best marked on the sonic log, by an increase of sonic velocity in passing from coal to sandstone of Km28.

Environment and Provenance: The presence of foraminifera in core 14 suggests a marine environment for at least part of the unit. Chlorite probably forms on marine diagenesis, particularly in lagoonal or near-shore marine environments (Folk, 1965, p. 95). These features, the textural uniformity of the unit, and

the proximity of presumed terrestial deposits (Km27) suggest that the sediments of the unit were deposited in a near-shore marine or lagoonal environment. The claystones, somewhat problematical, may be reworked volcanic ash deposits.

Variation in mineralogy of the sandstones suggests two source areas, one of contemporary intermediate volcanic activity, the other a mixed granitic, ancient volcanic and sedimentary/low grade metamorphic terrain.

UNITS Km29-33 (plates 1C, 1D, 2E, 2F)

This sequence extends from 4270' to 5963', and is 1693' thick. It corresponds with the silty section recognised by the Company as equivalent to the Permian Berry Shale (Shoalhaven Group). The sandy section at the top of this formation is here separated as a major unit (Km28). The section consists mainly of sandy siltstone and silty sandstone, with lesser mudstone, claystone and pebbly sandstone (unit Km30). All units are believed to be marine, from the occurrence of marine fossils, and glauconite in Km32 and Km33, but no marine indicator was recognised in Km30. Gentle current activity appears to have prevailed during deposition of the sequence, except for unit 30 (moderate to strong current activity), and the cores show much reworking of the sediment by organisms. The occurrence of scattered pebbles in the fine grained sediments, up to about 4600', suggests possible ice rafting of coarse material. Reducing conditions in the sediment resulted in precipitation of pyrite, siderite and minor calcite.

UNIT Km29 (plates 1C, 2E)

Characteristics: The unit extends from 4270' to 5143', and is 873' thick. In order of increasing depth it consists of brownish black mudstone and slightly sandy fine to medium siltstone grading downwards into slightly pebbly sandy coarse siltstone to silty very fine sandstone. There is a slight decrease in

model grainsize to medium silt near the base of the unit. Sediments are slightly pebbly below about 4600'; all are carbonaceous and have siderite, pyrite and calcite cement, the proportion of siderite increasing with depth.

Core 15 (4620'-4630') consists of olive to brownish black slightly pebbly silty protoquartzite grading to sandy coarse siltstone. Pebbles include quartz, black chert, argillite, microgranite, gray siliceous volcanic rock fragments. Other detrital components include quartz, plagioclase, orthoclase, muscovite, volcanic rock fragments, argillite, quartz-muscovite schist, pyritic quartz siltstone, rare glauconite, carbonaceous fragments, etc., with brown illitic clay matrix. Cementing minerals are calcite and minor pyrite. Sedimentary structures include lamination, wavy bedding, burrows, and bioturbation.

Core 16 (4927'-4934') consists of slightly pebbly very fine lithic graywacke to protoquartzite, grading to sandy coarse siltstone. Detrital components are similar to core 15, but there is a slightly greater proportion of feldspar and rock fragments. Sedimentary structures include lamination, wavy bedding, small-scale cross-bedding.

Large brachiopod shells (disarticulated) occur in core 15.

Boundary Criteria: The upper boundary is taken as the transition from silty sandstone of unit Km28 to mudstone and sandy siltstone at the top of Km29. This is marked by a small increase in radioactivity, separating intervals of the gamma ray log with different characteristics: large fluctuations in Km28, smaller fluctuations in Km29. The resistivity log shows a similar change in character, but the boundary is not so well marked.

Environment and Provenance: Uniformity of lithology suggests essentially the same environment of deposition for the whole unit, with minor decrease in

average current velocity up the section. The presence of brachiopods and burrows indicates a marine environment at least at times not toxic to animal life, although the presence of glauconite, pyrite and siderite suggests reducing conditions below the sediment/water interface. Pebbles, which occur up to at least the level of core 15 (4620'-4630') are not consistent as traction current deposited material with the fine grainsize of the sediment bulk. A special mechanism of transport, such as ice or tree-root rafting is envisaged for their occurrence.

The sediments appear to have been derived from a mixed granitic, ancient acid volcanic and sedimentary/low grade metamorphic terrain.

UNIT Km30 (plates 1C, 2E, 2F)

Characteristics: This unit, 120' thick, extends from 5143' to 5263'. It consists of olive-gray slightly pebbly fine to medium protoquartzite, with minor oligomict conglomerate and brownish black sandy siltstone (siderite cement). Sandstone cementing minerals include quartz overgrowth, calcite, siderite, pyrite, dawsonite (seen only in core 17). Mean modal grainsize decreases down the unit from medium to fine sand-size.

Core 17 (5197'-5207') consists of fine to medium protoquartzite to oligomict conglomerate, some silty. Pebbles include milky quartz, black chert, quartzose sandstone, gray porphyritic acid volcanics, pyritic arkose, porphyritic microgranite, greenish gray siltstone. Other detrital components include vein, metamorphic and common quartz, chert, quartz muscovite schist, siltstone, volcanic rock fragments, rare orthoclase and plagioclase, with illitic clay matrix. Cementing minerals comprise quartz overgrowth, minor calcite, and radial fibrous aggregates of dawsonite, some replacing feldspar. Sedimentary structures include graded bedding (waxing and waning current types), wavy bedding, burrows.

Boundary Criteria: The upper boundary is taken as the transition from sandy medium siltstone to slightly pebbly fine sandstone. Appearance of the latter lithology in cuttings at 5120', and the gradational change seen in the gamma ray log, suggest this transition may be intercalated sandstone and siltstone. However, there is an abrupt increase in the proportion of sandstone in the cuttings at 5150', at which level there is also a sharp increase in resistivity (5143'). Thus, although there may be a few thin beds of sandstone above 5143', it seems reasonable to place the boundary at 5143'.

Environment and Provenance: The sedimentary structures in core 17 suggest periods of moderate to strong current activity, resulting in sediments of varying grainsize, alternating with periods of quiescence in which burrowing took place. No specific indicators of a marine environment (e.g. fossils) were seen, but the occurrence of marine units above and below (Km29 and Km31) suggests such an environment, perhaps a barrier beach/bar complex.

The sediments were derived from a sedimentary/low grade metamorphic, ancient acid volcanic and granitic terrain.

This section was regarded by the Company as equivalent to the Kedumba Creek Sandstone Member of the Berry Shale.

UNIT Km31 (plates 1C, 1D, 2F)

Characteristics: The unit extends from 5263' to 5850' and is 587' thick. It is made up from two intervals of slightly different gross lithology. The upper, 5263'-5420', consists of brownish black sandy medium to fine siltstone, with lesser mudstone and claystone, all carbonaceous. Cementing minerals include pyrite, siderite and calcite. Shell fragments occur in the cuttings from this interval.

The lower section consists of brownish black slightly pebbly sandy coarse siltstone to silty very fine sandstone, with lesser sandy medium siltstone, all carbonaceous. Cementing minerals include pyrite, siderite and calcite: the proportion of calcite increases with depth, some occurring as vein filling. Shell fragments occur in the cuttings at the top of the section, brachiopod, pelecypod and indeterminate calcareous fossil fragments in core 18.

Core 18, 5678'-5688', consists of grayish black pebbly, sandy coarse siltstone. Pebbles include gray pyritic siltstone, fine orthoquartzite, milky and clear quartz, carbonaceous siltstone, buff-coloured pyritic quartz-feldspar porphyry. Finer detrital components include quartz, volcanic rock fragments, siltstone, argillite, chert, plagioclase, orthoclase, microcline, muscovite, biotite, carbonaceous fragments, etc., with illitic clay matrix. Cementing minerals include minor calcite, siderite and pyrite cement. Sedimentary structures include lamination and wavy bedding.

Boundary Criteria: The upper boundary is taken as the transition from pebbly protoquartzite to sandy medium siltstone, this being marked by a sharp increase in radioactivity and decrease in resistivity and sonic velocity at about 5263'. Unlike the upper boundary of unit Km30, the lower boundary of unit Km30 is not intercalated or gradational in lithology.

Environment and Provenance: The uniformity of lithology of the unit suggests a similar environment of deposition for the whole unit, except that the upper section (5263' to 5420') may have been deposited in a more sheltered environment. From the fine grainsize, currents were gentle, pebbles (as in core 18) probably being rafted by ice or tree-roots. The occurrence of marine fossils with articulated shells in core 18 indicates a marine environment and little transport. The presence of pyrite and siderite indicates reducing conditions in the substrate. Provenance for the unit appears to have been similar to that of Km30 and Km29, namely a mixed sedimentary, granitic and ancient acid volcanic provenance.

UNIT Km32 (plate 1D)

Characteristics: This thin unit, 42' thick, extends from 5850' to 5892'. It consists of olive gray to brownish gray slightly silty fine to very fine protoquartzite, divided by a central section of sandy siltstone. The sandstone is characterised by the presence of up to about 5% of allochthonous glauconite. Other detrital components include metamorphic, vein, volcanic and common quartz, siliceous volcanic rock fragments, chert, orthoclase, plagioclase, quartz-muscovite schist, chert, muscovite, etc. Cementing minerals include quartz, calcite, siderite, pyrite.

Boundary Criteria: The upper boundary is taken as the transition from silty very fine sandstone and sandy coarse siltstone of Km31 to slightly silty fine to very fine glauconitic sandstone. This is best marked in the wire line logs by a decrease in radioactivity at about 5850'.

Environment and Provenance: Fine grainsize implies gentle current activity. The presence of glauconite indicates a marine environment with reducing conditions and slow deposition. The presence of siderite and pyrite also indicates reducing conditions in the sediment.

Provenance was as for Km29-Km31, namely a sedimentary/low grade metamorphic, acid volcanic and granitic provenance.

UNIT Km33 (plate 1D)

Characteristics: This unit, 71' thick, extends from 5892' to 5963'. It consists of brownish black slightly pebbly sandy coarse siltstone to silty very fine sandstone, characterised by the occurrence of glauconite. Cementing minerals include pyrite, siderite, calcite.

Boundary Criteria: The upper boundary is taken as the transition from glauconitic fine sandstone of Km32 to slightly glauconitic sandy coarse siltstone. This is best marked in the wire-line logs by an increase in radioactivity. There is also a decrease in resistivity.

Environment and Provenance: The fine grainsize of these sediments indicates gentle current activity, glauconite a marine environment. The unit appears similar in both environment and provenance to unit Km31.

UNITS Km34-37 (plates 1D, 1E, 2F, 2G)

This section, from 5963' to 8145', approximates that recognised by the Company as Nowra Sandstone and undifferentiated Lower Shoalhaven Group. The main differences in the present subdivision are that the two Company units are combined into one major unit, with some finer subdivisions; also the section from 8145' to 8353', included by the Company in the Lower Shoalhaven Group is here separated. It is believed that this latter section (unit Km38) may be non-marine, while the section included in Km34-37 is wholly marine.

The major unit is comprised mainly of variably silty fine to very fine sandstone, with interbedded sandy siltstone and some coaly laminae. Shelly fossils are common, and glauconite occurs rarely. Most sandstone is pebbly.

The sediments appear to have been derived from a mixed ancient acid volcanic, granitic and sedimentary/low grade metamorphic source, as for units Km29-33. Mineralogic maturity increases slightly up the section.

UNIT Km34 (plates 1D, 2F)

Characteristics: This unit, 527' thick, extends from 5963' to 6490', approximately the interval assigned to the Nowra Sandstone by the Company. It consists of light olive gray slightly pebbly fine protoquartzite to

subarkose, with minor pebbly medium protoquartzite and interbedded sandy medium to coarse siltstone (pyrite, siderite cement). The proportion of interbedded siltstone is higher in the basal and upper parts of the unit. A 15' thick bed of fossiliferous brownish gray slightly silty very fine to fine subarkose with abundant calcite cement, occurs below 6360'. Glauconite occurs above 6070'. Cementing minerals include quartz, calcite, siderite and pyrite. Shell fragments occur occasionally in the cuttings.

Core 19 (6050'-6055') consists of olive gray pebbly silty medium to very fine protoquartzite. Detrital components include common, vein, metamorphic and volcanic quartz, pyritic chert, volcanic rock fragments, siltstone, quartz-muscovite schist, shale, microcline, orthoclase, oligoclase, muscovite, glauconite, etc., with minor illitic clay matrix. Cementing minerals include abundant coarse-grained calcite, quartz and siderite. Brachiopod and pelecypod shells in various orientations are abundant. Sedimentary structures include lamination, wavy bedding, bioturbation.

Side-wall cores 8 and 6 (6340', 6342') consist of medium protoquartzite. Core 20 (6439'-6444') consists of olive gray silty very fine to fine protoquartzite to subarkose, some pebbly. Some coarse quartzose sandstone laminae occur. Mineralogy is very similar to that of core 19, except that no glauconite was seen. Pebbles include colourless to milky quartz, siliceous fine orthoquartzite to quartzose siltstone, gray shale, white quartz-feldspar porphyry, black carbonaceous siltstone, light green fine graywacke, black chert and quartz-muscovite schist. Cementing minerals include calcite, quartz, pyrite and, in places, abundant siderite. Sedimentary structures include lamination, wavy bedding, burrows, graded bedding (waxing/waning current type), bioturbation. Brachiopod and foraminiferal shells, faecal pellets and possible crinoidal debris occur.

Boundary Criteria: The upper boundary is taken as the transition from sandy siltstone (of unit Km33) to fine sandstone. This is well marked on the gamma ray log by a decrease in radioactivity beginning at 5953'.

Environment and Provenance: The occurrence of glauconite and brachiopods indicates a marine environment. Grainsize of the sediments suggests currents of rather uniform strength, nearly all sandstone having a mode of fine sand size. Periods of gentler current activity are indicated by interbedded sandy siltstone. Pebbles may have been rafted by ice or tree-roots. The character of the gamma ray log suggests a nearly uniform pattern of bedding through the unit. The sediments were derived from a terrain with granitic, altered acid volcanic and sedimentary/low grade metamorphic rocks.

UNIT Km35 (plate 1D)

Characteristics: The unit, 270' thick, extends from 6490' to 6760'. It consists of interbedded light olive gray pebbly fine protoquartzite, olive gray slightly pebbly silty very fine protoquartzite and dark olive gray to brownish black sandy carbonaceous siltstone. Cementing minerals include quartz, calcite, siderite and pyrite. Glauconite occurs in cuttings from 6530'-6540', although this may be caved material. Two thin sections prepared from cuttings showed the very fine protoquartzite to have a similar provenance to unit Km34, above: microcline, orthoclase, oligoclase, volcanic rock fragments, argillite and chert occur. Shell fragments occur sporadically in the cuttings from the section, especially near the base.

The pattern of lithological variation with depth differs from that of unit Km34, above, in that Km35 has thicker individual beds, and the variation in lithology is also greater. This is best seen on the gamma ray log. The unit as a whole is finer grained than Km34.

Boundary Criteria: The upper boundary is taken as the top of a pebbly fine protoquartzite bed which has prominent characteristics on the wire-line logs. This level separates two parts of the gamma ray log with different patterns of variation. It is marked by a sharp decrease in radioactivity on passing from siltstone of Km34 into the pebbly protoquartzite. There is also a decrease in resistivity and an increase in S.P. log deviation at this level.

Environment and Provenance: The presence of shelly fossils and rare glauconite indicates a marine environment. The variable grainsize of the sediments indicates variable and intermittent current activity. Pebbles may have been rafted by ice or tree-roots. The presence of pyrite and siderite indicates reducing conditions in the sediment. The lowest part of the unit, from 6715' to 6760' is lithologically similar, and has a similar gamma ray log pattern, to unit Km37. But for the separation of unit Km36, this interval would have been included with those sediments in unit Km37, below.

The sediments appear to have been derived from a mixed granitic, altered acid volcanic and sedimentary/low grade metamorphic terrain, like unit Km34.

UNIT Km36 (plates 1D, 2F)

Characteristics: This thin unit, 72' thick, extends from 6760' to 6832'. It consists of light olive gray pebbly fine to coarse protoquartzite (quartz, calcite, pyrite cement) with a section of olive gray to brownish black silty very fine to fine protoquartzite and sandy coarse siltstone, also slightly pebbly. Cementing minerals include quartz, calcite, siderite and minor pyrite.

Core 21 (6800'-6803') consists of brownish black slightly pebbly very fine protoquartzite and slightly pebbly sandy coarse siltstone. Pebbles

include milky and clear quartz, black chert, light gray quartzose siltstone, dark gray quartz-muscovite schist, white silicified tuff. Finer detrital components include common, volcanic, vein and metamorphic quartz, chert, plagioclase, orthoclase, microcline microperthite, porphyritic acid volcanic rock fragments, siliceous volcanic rock fragments, calcitic fossil fragments, etc., with illitic clay matrix. Cementing minerals include calcite, siderite and minor quartz and pyrite. Fossils include shells of brachiopods and pelecypods, some articulated, up to 4cm long. Sedimentary structures include bioturbation (with recognisable burrows) and stylolites, the latter a megascopic expression of pressure solution effects which can be seen in thin section: compaction has been strong.

Boundary Criteria: The upper boundary is taken as the transition from silty very fine sandstone (of Km35) to pebbly fine sandstone. This is marked in the wire-line logs by a sharp decrease in radioactivity and an increase in resistivity. The lower boundary has less sharp log characteristics, probably because of intercalation of rock-types.

Environment and Provenance: The occurrence of brachiopods indicates a marine environment, at least for the finer members of the unit. Coarse grainsize implies moderate to strong current activity, with a period of weaker currents during deposition of the siltier sediments of the unit. The articulated state of some shells indicates minor transport. The sediments were derived from a mixed granitic, acid volcanic and sedimentary/low grade metamorphic terrain.

UNIT Km37 (plates 1D, 1E, 2F, 2G)

Characteristics: This thick section extends from 6832' to 8145', being 1313' thick. It consists of olive gray to brownish black slightly pebbly, variably silty very fine to medium sandstone with lesser sandy siltstone and some coal laminae.

A few intervals are characterised on the wire-line logs by their high resistivity, probably due to high content of calcite cement; otherwise the resistivity log is fairly uniform in character. The gamma ray log exhibits changes in general level of radioactivity superimposed on a pattern of minor fluctuations, reflecting varied silt and clay content of the interbedded sandstones. Siltstone beds are responsible for peaks of higher radioactivity.

The sandstones show only small variations in feldspar and rock fragment content which, however, lead to their classification in the sub-arkose, protoquartzite, subgraywacke and arkose fields. Cementing minerals include calcite, siderite, quartz and pyrite; dawsonite was recorded from only one sample of cuttings, 7130'-7140'. Glauconite occurs sporadically in the unit. Carbonaceous material, in the form of finely divided fragments of carbonised vegetable matter is abundant through the unit. Coal laminae may represent intersections of thicker woody fragments.

Shelly fossils are abundant in this unit, brachiopods (including spined productid types), polyzoa and foraminifera being recorded.

Core 22 (7160'-7165') consists of dark gray sandy coarse siltstone grading to silty very fine protoquartzite. Detrital components include quartz, chert, siliceous protoquartzite, volcanic rock fragments, quartz-muscovite schist, argillite, orthoclase, oligoclase, granitic rock fragments, muscovite, chlorite, biotite, carbonaceous material, etc. Quartz, chlorite, siderite and pyrite are cementing minerals: pyrite at least appears early diagenetic (disrupted nodules). Sedimentary structures include wavy and graded bedding, burrows and bioturbation. Rare shell fragments are present.

Core 23 (7562'-7567') consists of olive gray to olive black sandy medium to coarse siltstone (carbonaceous, with illitic clay, pyrite nodules),

slightly pebbly silty very fine to medium subgraywacke, and minor pebble conglomerate with silt matrix. Pebbles include milky and clear quartz, black chert, dark gray shale, light gray quartz-muscovite schist, light greenish gray siliceous sandstone and siltstone, light gray siliceous volcanic rock, greenish gray altered andesite, aplite, quartz-feldspar porphyry. Finer components as for core 22. Cementing minerals include siderite, quartz, calcite and pyrite. Sedimentary structures include small scale cross-bedding, wavy bedding, burrows and bioturbation.

Core 24 was not recovered. Core 25 (7872'-7879') consists of olive black slightly pebbly silty very fine subgraywacke. Pebbles are composed of a variety of siliceous sedimentary, volcanic and granitic rocks, as in core 23. Rhyolite was one additional rock type recognised. Finer detrital components include common and volcanic quartz, chert, orthoclase, microcline, granitic rock fragments, quartz-muscovite schist, siliceous volcanics, muscovite, argillite, biotite, chlorite etc., with illitic clay matrix. Cementing minerals include quartz, calcite, siderite, minor pyrite. Single brachiopod shells without orientation are common. Sedimentary structures include burrows, wavy bedding, bioturbation.

Boundary Criteria: The upper boundary is taken as the transition from pebbly medium to coarse protoquartzite of Km36 to silty very fine protoquartzite. This is marked by an increase in radioactivity and decrease in resistivity at about 6832'. There is possibly some interbedding of the two rock types.

Environment and Provenance: The occurrence of brachiopods, polyzoa, foraminifera and glauconite point to a marine environment of deposition for the unit. The fine grainsize and poor sorting of the sediments suggest weak to moderate current activity. Reworking by organisms also resulted in poor sorting. At least some of the pebbles may be transported by ice, or tree roots. The occurrence of pyrite and siderite indicates reducing conditions in the sediment.

The sediments were derived from a terrain of granitic, altered acid and intermediate volcanics and sedimentary/low grade metamorphic rocks: specific rock types are mentioned in "Characteristics", above. Mineralogic maturity (as reflected in the ratio of quartz to rock fragments and feldspar) increases slightly up the section.

UNIT Km38 (plates 1E, 2G)

This major unit, the lowest recognised in the well, has been separated from the overlying sediments because of its coarser mean grainsize, poorer mineralogic maturity, and lack of marine fossils. Such shelly fossils as do occur in the cuttings are believed to be caved from the richly fossiliferous section above. Coaly wood fragments occur more abundantly in the cuttings than in the interval above, and are common in the single core cut in the unit, core 26. These factors are taken to indicate a grossly different environment of deposition from the major unit Km34-37 above.

Characteristics: The unit extends from 8145' to 8353', being 208' thick. It consists of light olive gray to dark gray slightly pebbly medium to coarse subgraywacke with minor silty very fine to fine subgraywacke and sandy siltstone. Pale green siliceous fragments in the cuttings at 8340', when examined in thin section, include quartzose sandstone and siltstone, and chloritic quartz-feldspar porphyry, probably from pebbles in a basal conglomerate. Mineralogic maturity of the sandstone appears to increase up the section. Cementing minerals include quartz, minor pyrite and calcite.

Core 26 (8205'-8208') consists of olive gray medium subgraywacke and silty fine to very fine subgraywacke. Detrital components include common and vein quartz, orthoclase, microcline microperthite, andesine, granitic rock fragments, vesicular chloritic volcanic rock fragments, quartz porphyry, siltstone, quartz-muscovite schist, argillite, muscovite, macerated wood

fragments, etc., with illitic clay matrix. Cementing mineral is quartz. Sedimentary structures include cross-bedding, scour and fill, wavy bedding and a small fault (which occurred between periods of deposition).

Boundary Criteria: The upper boundary is taken as the transition from silty fine sandstone to medium sandstone. This transition is not well marked on the wire-line logs, but may correspond to a sharp decrease in resistivity at about 8145' (possibly due to a lower proportion of calcite cement in the coarser sandstone).

Environment and Provenance: The scarcity of marine fossils in the cuttings suggests such fossils are caved material. The coarse grainsize and abundant wood fragments suggest a fluviatile environment of deposition. Faulting contemporaneous with sedimentation and scour and fill structures indicate erosion and reworking of sediments, with channels into which unconsolidated sediment slumped.

The sediments were derived from a terrain with granitic, volcanic and sedimentary/low grade metamorphic rocks.

UNIT Km39 (plates 1E, 2G)

This major unit extends from 8353' to the bottom of the well at 8406'. It consists of andesitic volcanic rock of uncertain age.

Characteristics: The unit is 53' thick. Cuttings through the unit show a uniform lithology of dark greenish gray microcrystalline volcanic rock; a constant small proportion of cuttings of calcite, chlorite, pyrite and haematite represent vesicle and vein fillings. The wire-line logs indicate a section with low resistivity and high radioactivity between 8374' and 8378': the Company recognised a shale bed in this interval, but no evidence of this was found in the cuttings.

Core 27 (8403'-8406') consists of dark greenish gray to greenish black agglomerate to lapilli tuff with fused bombs of vesicular andesite. The mineral assemblage is oligoclase/andesine, albite, augite, chlorite, calcite, iron ore mineral. Calcite and chlorite occur in vesicles and veins, some of the chlorite pseudomorphing stumpy crystals, probably originally epidote. Matrix between the bombs consists of chloritic clay.

Boundary Criteria: The upper boundary of the unit is taken as the transition from conglomerate of Km38 to volcanic rock of Km39. This is best marked in the wire-line logs by a sharp decrease in radioactivity corresponding to the low potassium content of the volcanics.

Environment and Provenance: The unit appears uniform in lithology and thus represents essentially the same environment and provenance throughout. The rock is interpreted as an agglomerate, the result of pyroclastic activity. Bombs were probably still partly fluid on impact, as fusion appears to have taken place: this makes recognition of the nature of the rock difficult, but the texture is not consistent with that of a lava or sill: parts of the rock, which represent original bombs, have different flow fabric orientation.

Albite is not of primary origin. The assemblage displays features of the spilite suite, but the presence of calcic plagioclase precludes such a classification. From the essential components oligoclase/andesine and augite the rock is an andesite. Calcite and chlorite are of secondary origin.

SUMMARY

Stratigraphy (see figure 1)

Thirty-nine lithologic units have been recognised, identified informally Km1 to Km39. These have been grouped into sixteen "major" units on a lithogenetic basis.

Figure 1 compares the Company stratigraphy with the informal units recognised herein. It may be seen that a finer subdivision has been made, although Company boundaries correspond closely with boundaries between some informal units.

Units Km2-5 and Km6-10 correspond to the Wianamatta Group and Hawkesbury Sandstone respectively. The three major units Km11-13, Km14 and Km15-16 correspond to the Narrabeen Group, differentiating "siltier" upper and lower sections from the middle section.

Units Km17-19, Km20-22, Km23-24, Km25-26 and Km27 correspond to the "Upper Coal Measures". The boundary at about 2812' between the Illawarra and Cumberland Coal Measures is not here regarded as dividing sections of grossly different depositional environment.

Unit Km28 corresponds to the Budgong Sandstone Member of the Berry Shale, although the lower boundary of the unit was placed a little lower than in the Company interpretation.

Units Km29-33 correspond to the Berry Shale, the unit Km30 corresponding to the Kedumba Creek Sandstone Member. Km30 was regarded as representing a short period of strong current activity in a long interval of gentle current activity, and was not given major unit status.

Units Km34-37 correspond to the dominantly sandstone lower section of the Shoalhaven Group (as opposed to the dominantly siltstone upper section Km29-33). Unit Km34 corresponds to the Nowra Sandstone.

Unit Km38, included in the Shoalhaven Group by the Company is believed to be non-marine and has been given major unit status.

Unit Km39 corresponds to the Volcanics of doubtful age regarded by the Company as economic basement. The well was terminated in this section.

Sequence of Environments and Provenance (see figure 2)

Figure 2 should be largely self-explanatory. Lithological symbols used are those given in the legend to the composite well logs (plate 1A). The average grainsize mode of both major and minor lithologies in any unit have been plotted.

In summary, the section represents the following:

i) Initial deposition of fluviatile sediments on volcanic basement (Km39, Km38).

ii) With sinking of the basin a marine transgression, and a long period of marine clastic sedimentation (Km34-37, Km29-33).

iii) Shallow water marine sediments were followed by a period of terrestial deposition, with coals. (Km28, Km27).

iv) Marine transgression, followed by deposition of a deltaic sequence, culminating in delta-top coal deposition (Km25-26).

v) As for iv) (Km23-24).

vi) Fluviatile deposition, apparently in two phases (Km20-22, Km17-19), with coal deposition.

vii) Fluviatile deposition (Km15-16, Km14) culminating in a period of possible lacustrine deposition or of relative aridity with better drainage of the floodplain (Km11-13).

viii) Deposition of a coarse sandy sequence, possibly fluviatile (Km6-10).

ix) Deposition of a fine grained sequence in lacustrine or estuarine conditions (Km2-5).

x) After later deposition, erosion to present surface and soil formation (Km1).

The "PROVENANCE TYPE" column (figure 2) lists five types.

A is characterised by abundant K-feldspar, granitic rock fragments, altered volcanic rock fragments, sedimentary rock fragments, including sandstone, shale and chert, low grade metamorphic rock fragments (quartz-muscovite schist). The western margin of the basin, with Lower and Middle Palaeozoic rocks is a likely source of this material.

B is characterised by andesine/oligoclase, feldspathic volcanic rock fragments, glassy rock fragments, rare quartz or other components. It represents a contemporary intermediate volcanic source, probably related to the source of the Gerringong Volcanics.

C is characterised by abundant altered volcanic rock fragments, mainly siliceous, minor sedimentary and granitic components. The north-eastern margin of the basin, with Middle Palaeozoic volcanics, is a likely source of this material.

D is characterised by abundant pale green and red "chert", the bulk of which is probably silicified volcanic rock, and the rare heavy mineral picotite, probably from ultrabasic rocks. There are minor sedimentary and granitic components. The occurrence of picotite and the abundant volcanic "chert" suggest the northern margin, with the "Great Serpentine Belt", as a possible source area.

E is characterised by its mineralogic maturity, and by the occurrence of graphite. Minor sedimentary and metamorphic rock fragments occur. A granitic and sedimentary/metamorphic terrain with graphitic schists would be an appropriate source area.

Porosity, Permeability and Petroleum Prospects

Porosity and permeability of core samples was determined by the B.M.R. Petroleum Technology Laboratory. These results were extrapolated to

other intervals in the section by visual comparison of lithology (taking into especial consideration cementing minerals) and by examination of the S.P. and resistivity logs.

In the well, sandstones with dominant clay matrix and/or cement generally have higher porosity than those with dominant carbonate or quartz cement. Also, porosity decreases with increasing depth. This is partly due to greater compaction, but probably mainly to the greater abundance of carbonate cement at depth (see the carbonate log, plate 1). Average porosity values are plotted in figure 2.

The highest measured porosity was 18%, recorded in the Hawkesbury Sandstone (core 1) and upper Narrabeen Group (core 2). Porosity greater than 12% was recorded in sandstones from the Hawkesbury Sandstone, Narrabeen Group and "Upper Coal Measures". In the section below the "Upper Coal Measures", only unit Km30 has porosity greater than 12%, as interpreted from the wire-line logs. This unit was the subject of the only successful drill stem test: about 100 feet of gas cut mud were recovered.

Measurable permeability was detected in cores 2 and 3 only (2-22md). There was no loss of circulation during drilling, and numerous gas shows encountered during drilling later failed to register significant background gas in the recorder. It is concluded that with the exception of zones in the Hawkesbury Sandstone, low permeabilities in the Narrabeen Group and parting permeability in the Kedumba Creek Sandstone, the section is tight.

Possible hydrocarbon source rocks include all carbonaceous rocks in the section; possible petroleum source rocks include the silty sandstones and sandy siltstones of the marine Shoalhaven Group, (units Km28, Km29-33, Km34-37), and possible marine sediments in units Km26 and Km24. Suitable

reservoirs might include units Km30, Km25 and Km23, but in the well these sections were well-cemented and impermeable.

With regard to possible reservoirs for storage of natural gas, unit Km7 might be worth investigation.

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FIG.1

KIRKHAM (A.O.G.) No.1

COMPARISON OF B.M.R. UNITS WITH COMPANY INTERPRETATION

BMR UNITS		BOUNDARY DEPTHS (ft.)		COMPANY (A.O.G., 1964)		
MAJOR	MINOR			FORMATION	GROUP	AGE
Km1	Km 1	10				
Km2–5	Km 2	160			WIANAMATTA GROUP	
	Km 3	172				
	Km 4	300				
	Km 5	350				
Km6–10	Km 6	370	370			
	Km 7	480		HAWKESBURY SANDSTONE		TRIASSIC
	Km 8	815				
	Km 9	905				
	Km10	1018	1016			
Km11–13	Km11	1089			NARRABEEN GROUP	
	Km12	1160				
	Km13	1275				
Km14	Km14	2125				
Km15–16	Km15	2363				
	Km16	2454	2453			
Km17–19	Km17	2533		ILLAWARRA COAL MEASURES	"UPPER COAL MEASURES"	PERMIAN
	Km18	2606				
	Km19	2686				
Km20–22	Km20	2755				
	Km21	2809	2812			
	Km22	2970		CUMBERLAND COAL MEASURES		
Km23–24	Km23	3002				
	Km24	3212				
Km25–26	Km25	3291				
	Km26	3470				
Km27	Km27	3883	3877			
Km28	Km28	4270	4240	BUDGONG SANDSTONE	SHOALHAVEN GROUP	
Km29–33	Km29	5143	5153	KEDUMBA CK. SANDSTONE		
	Km30	5263	5266	BERRY SHALE		
	Km31	5850				
	Km32	5892				
	Km33	5963	5973			
Km34–37	Km34	6490	6473	NOWRA SS.		
	Km35	6770				
	Km36	6832				
	Km37	8145				
Km38	Km38	8353	8356			
Km39	Km39	8406+	8406+	VOLCANICS		

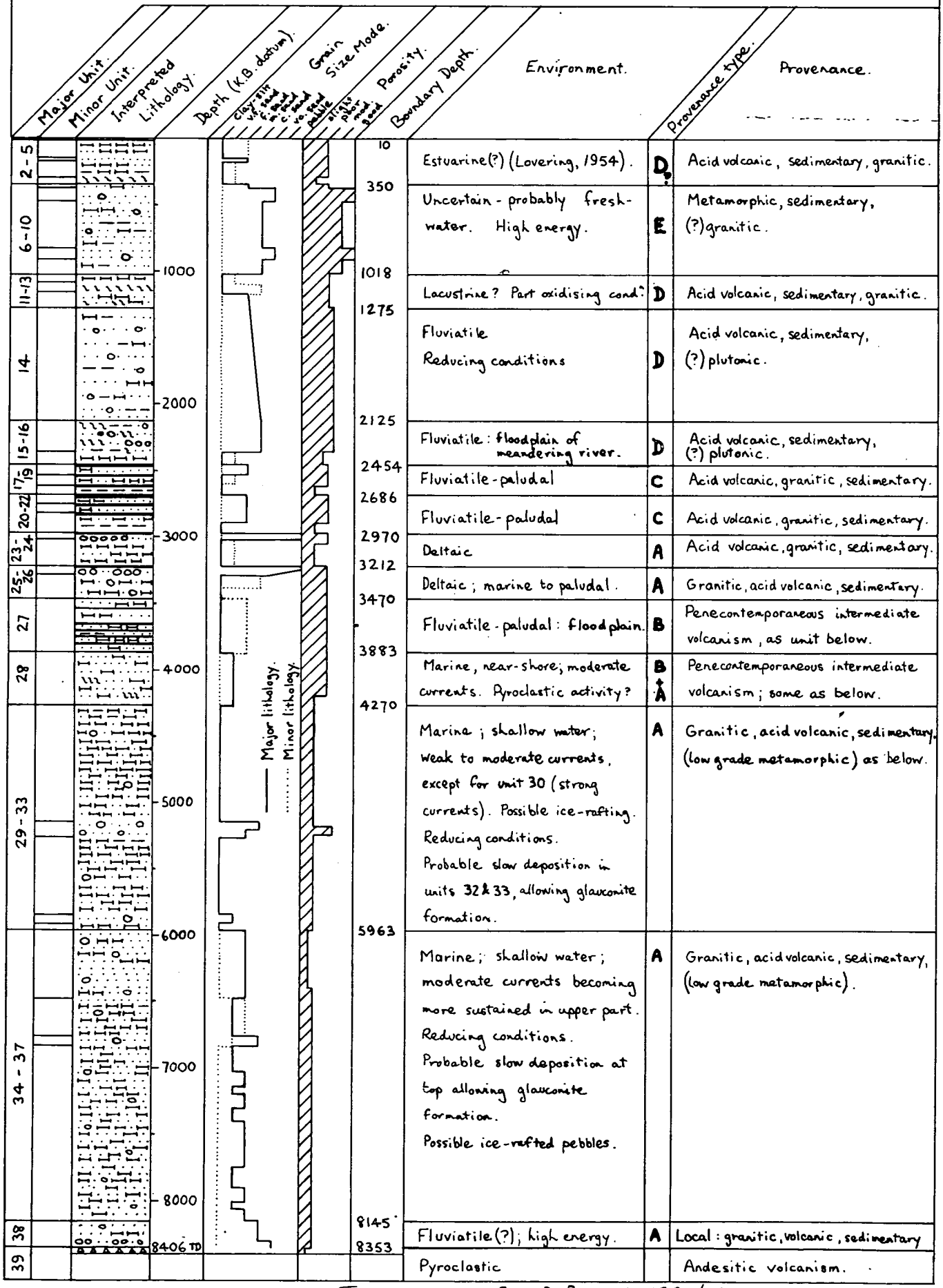
2.

To accompany B.M.R. Record 1969/61

FIG. 2

KIRKHAM (A.O.G.) No.1

SUMMARY OF PETROLOGICAL RESULTS



To accompany B.M.R Record 1969/61

Plate 1A

PETROGRAPHIC WELL LOG
KIRKHAM (A.O.G.) No.1

Geology by J.I. RAINE

WELL NAME, No. KIRKHAM No.1
OPERATING Co. A.O.G. Corp. Ltd.
WELL LOCATION
Lat.: 34°01'39" S. Long.: 150°42'27" E.
Basin SYDNEY
State NEW SOUTH WALES
Tenement No. PEL 102
1:250.000 Sheet No. SI 56/09

ELEVATION (A.S.L.)
: Ground Level 270.8 ft.
: K.B. Datum 282.8 ft.

SAMPLE STORAGE: *B.M.R., Canberra

HYDROCARBON SYMBOLS
Show of gas
Trace of gas

MISCELLANEOUS
Interval and Number of Formation Test
No sample available from interval
Drill core, no., depth. Recovery prop. unshaded. (4/2).
Side-wall core, no. Recovery prop. unshaded. (fair).

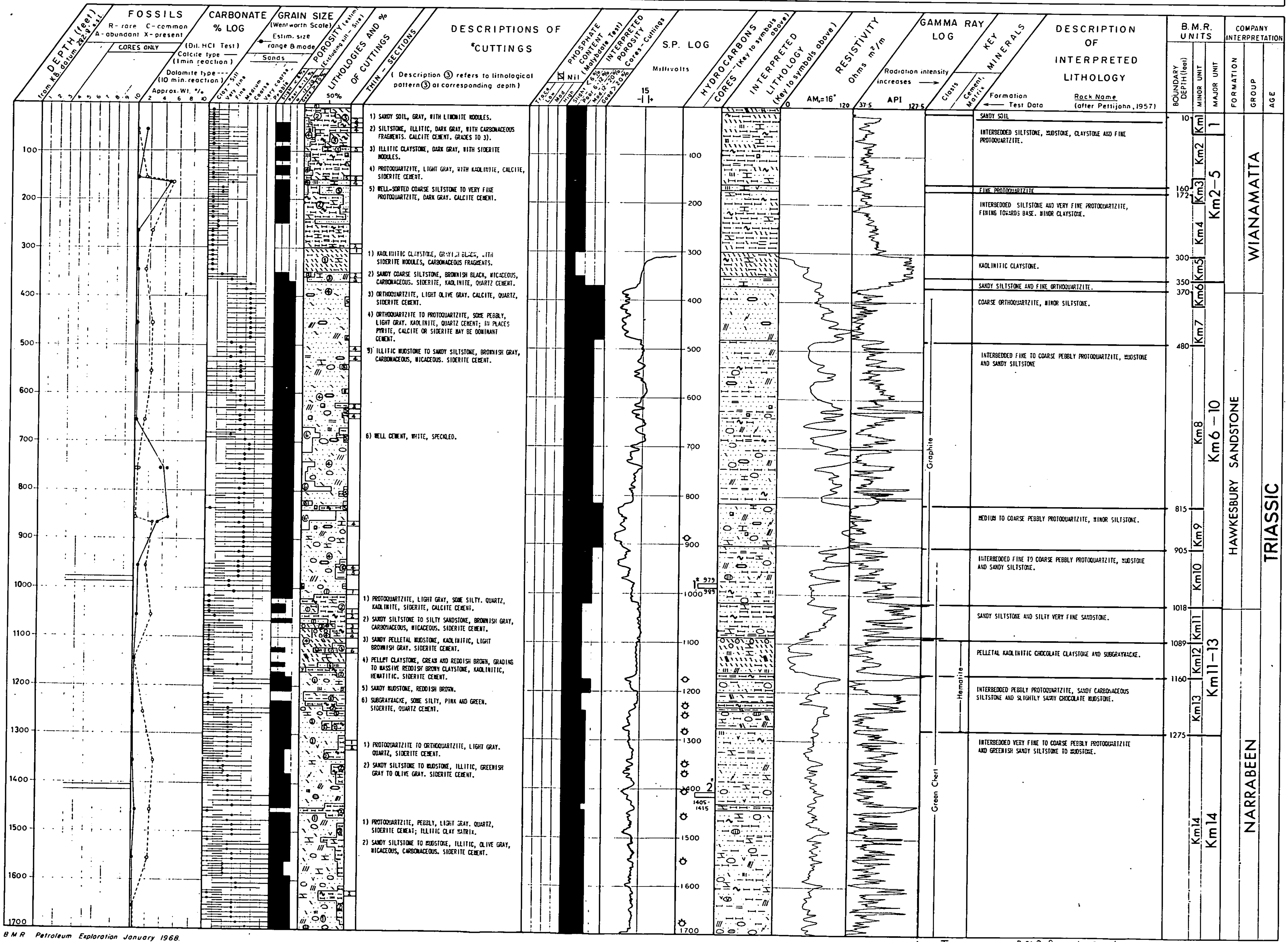
Conglomerate, quartzose
Quartz sand, sandstone
Siltstone
Claystone

Framework — Sand — Pebble
Quartz, chert fragment
Sedimentary rock frag.
Volcanic rock fragment
Plutonic rock fragment
Metamorphic rock frag.

LITHOLOGICAL SYMBOLS
Coal, coal laminae.
Shale and mudstone
Volcanic undifferentiated
Volcanic agglomerate

Cementing minerals
Calcite
Siderite
Dawsonite
Silica
Hematite
Pyrite
Clay minerals
Limonite

'Accessory' components
Felspar
Graphite
Green pellets (glauconite)
Mica
Carbonaceous fragment
Calcitic fragment (inc. fossils)
Pisolites, oolites, pellets



DEPTH (feet) from K.B. datum 282.8 a.s.l.
FOSSILS R - rare C - common A - abundant X - present
CORES ONLY
CARBONATE % LOG
(Dil. HCl Test)
Calcite type (1 min reaction)
Dolomite type (10 min. reaction)
Approx. Wt. %
GRAIN SIZE (Wentworth Scale)
Estim. size range & mode
Sands
POROSITY
LITHOLOGIES AND % OF CUTTINGS
THIN - SECTIONS
DESCRIPTIONS OF *CUTTINGS
(Description ③ refers to lithological pattern ③ at corresponding depth)
1) SANDY SOIL, GRAY, WITH LIMONITE NODULES.
2) SILTSTONE, ILLITIC, DARK GRAY, WITH CARBONACEOUS FRAGMENTS. CALCITE CEMENT. GRADES TO 3).
3) ILLITIC CLAYSTONE, DARK GRAY, WITH SIDERITE NODULES.
4) PROTOQUARTZITE, LIGHT GRAY, WITH KAOLINITE, CALCITE, SIDERITE CEMENT.
5) WELL-SORTED COARSE SILTSTONE TO VERY FINE PROTOQUARTZITE, DARK GRAY. CALCITE CEMENT.
1) KAOLINITIC CLAYSTONE, GRAYISH BLACK, WITH SIDERITE NODULES, CARBONACEOUS FRAGMENTS.
2) SANDY COARSE SILTSTONE, BROWNISH BLACK, MICACEOUS, CARBONACEOUS. SIDERITE, KAOLINITE, QUARTZ CEMENT.
3) ORTHOQUARTZITE, LIGHT OLIVE GRAY. CALCITE, QUARTZ, SIDERITE CEMENT.
4) ORTHOQUARTZITE TO PROTOQUARTZITE, SOME PEBBLY, LIGHT GRAY. KAOLINITE, QUARTZ CEMENT; IN PLACES PYRITE, CALCITE OR SIDERITE MAY BE DOMINANT CEMENT.
5) ILLITIC MUDSTONE TO SANDY SILTSTONE, BROWNISH GRAY, CARBONACEOUS, MICACEOUS. SIDERITE CEMENT.
6) WELL CEMENT, WHITE, SPECKLED.
1) PROTOQUARTZITE, LIGHT GRAY, SOME SILTY. QUARTZ, KAOLINITE, SIDERITE, CALCITE CEMENT.
2) SANDY SILTSTONE TO SILTY SANDSTONE, BROWNISH GRAY, CARBONACEOUS, MICACEOUS. SIDERITE CEMENT.
3) SANDY PELLETAL MUDSTONE, KAOLINITIC, LIGHT BROWNISH GRAY. SIDERITE CEMENT.
4) PELLET CLAYSTONE, CREAM AND REDDISH BROWN, GRADING TO MASSIVE REDDISH BROWN CLAYSTONE, KAOLINITIC, HEMATITIC. SIDERITE CEMENT.
5) SANDY MUDSTONE, REDDISH BROWN.
6) SUBGRAYWACKE, SOME SILTY, PINK AND GREEN. SIDERITE, QUARTZ CEMENT.
1) PROTOQUARTZITE TO ORTHOQUARTZITE, LIGHT GRAY. QUARTZ, SIDERITE CEMENT.
2) SANDY SILTSTONE TO MUDSTONE, ILLITIC, GREENISH GRAY TO OLIVE GRAY. SIDERITE CEMENT.
1) PROTOQUARTZITE, PEBBLY, LIGHT GRAY. QUARTZ, SIDERITE CEMENT; ILLITIC CLAY MATRIX.
2) SANDY SILTSTONE TO MUDSTONE, ILLITIC, OLIVE GRAY, MICACEOUS, CARBONACEOUS. SIDERITE CEMENT.
PHOSPHATE CONTENT (Molybdate Test)
INTERPRETED POROSITY
Cores - Cuttings
Nil
S.P. LOG Millivolts
HYDROCARBONS CORES (Key to symbols above)
INTERPRETED LITHOLOGY (Key to symbols above)
RESISTIVITY Ohms m²/m
AM = 16"
GAMMA RAY LOG
Radiation intensity increases
API
KEY MINERALS
Clasts
Cement, Matrix
Graphite
Hematite
Green Chert
DESCRIPTION OF INTERPRETED LITHOLOGY
Formation Test Data
Rock Name (after Pettijohn, 1957)
SANDY SOIL
INTERBEDDED SILTSTONE, MUDSTONE, CLAYSTONE AND FINE PROTOQUARTZITE.
FINE PROTOQUARTZITE
INTERBEDDED SILTSTONE AND VERY FINE PROTOQUARTZITE, FINING TOWARDS BASE. MINOR CLAYSTONE.
KAOLINITIC CLAYSTONE.
SANDY SILTSTONE AND FINE ORTHOQUARTZITE.
COARSE ORTHOQUARTZITE, MINOR SILTSTONE.
INTERBEDDED FINE TO COARSE PEBBLY PROTOQUARTZITE, MUDSTONE AND SANDY SILTSTONE
MEDIUM TO COARSE PEBBLY PROTOQUARTZITE, MINOR SILTSTONE.
INTERBEDDED FINE TO COARSE PEBBLY PROTOQUARTZITE, MUDSTONE AND SANDY SILTSTONE.
SANDY SILTSTONE AND SILTY VERY FINE SANDSTONE.
PELLETAL KAOLINITIC CHOCOLATE CLAYSTONE AND SUBGRAYWACKE.
INTERBEDDED PEBBLY PROTOQUARTZITE, SANDY CARBONACEOUS SILTSTONE AND SLIGHTLY SANDY CHOCOLATE MUDSTONE.
INTERBEDDED VERY FINE TO COARSE PEBBLY PROTOQUARTZITE AND GREENISH SANDY SILTSTONE TO MUDSTONE.
B.M.R. UNITS
BOUNDARY DEPTH (feet)
MINOR UNIT
MAJOR UNIT
COMPANY INTERPRETATION
FORMATION
GROUP
AGE
10
160
172
300
350
370
480
815
905
1018
1089
1160
1275
Km1
Km2
Km3
Km4
Km5
Km6
Km7
Km8
Km9
Km10
Km11
Km12
Km13
Km14
Km2-5
Km6-10
Km11-13
WIANAMATTA
HAWKESBURY SANDSTONE
NARRABEEN
TRIASSIC

B M R Petroleum Exploration January 1968.

To accompany B.M.R. Record 1969/61

X AUS-1-60A

DEPTH (feet) from K.B. datum 20.8 a.s.l.

FOSSILS — R - rare C - common A - abundant X - present — CORES ONLY — Plants, Rock Burrows

CARBONATE % LOG — (Dil. HCl Test) — Calcite type (1 min. reaction) — Dolomite type (10 min. reaction) — Approx. Wt. %

GRAIN SIZE (Wentworth Scale) — Estim. size range & mode — Sands: Clay - Silt, Very fine, Fine, Medium, Coarse, Very coarse, Pebble, Slight < 6%, Mod 6-12%, Poor 6-12%, Mod 12-20%, Good > 20%

POROSITY (estim.) (Excluding silt - size)

LITHOLOGIES AND % OF CUTTINGS — 50%

THIN - SECTIONS

DESCRIPTIONS OF *CUTTINGS

(Description ③ refers to lithological pattern ③ at corresponding depth)

1) PEBBLY PROTOQUARTZITE TO SUBGRAYWACKE, LIGHT OLIVE GRAY. QUARTZ, SIDERITE, CALCITE, KAOLINITE CEMENT; ILLITIC CLAY MATRIX.

2) SANDY SILTSTONE TO MUDSTONE, ILLITIC, BROWNISH GRAY TO GREENISH GRAY, CARBONACEOUS, MICACEOUS. SIDERITE CEMENT.

3) ILLITIC CLAYSTONE, GREENISH GRAY. SIDERITE CEMENT. GRADES TO 4).

4) SANDY SILTSTONE, OLIVE GRAY TO BROWNISH BLACK, CARBONACEOUS. SIDERITE CEMENT.

1) PEBBLY SUBGRAYWACKE TO CONGLOMERATE, LIGHT GRAY; CALCITE, SIDERITE, QUARTZ CEMENT, ILLITIC CLAY MATRIX.

5) COAL, BLACK, BITUMINOUS.

6) COALY MUDSTONE, BROWNISH BLACK. SIDERITE CEMENT.

7) SUBGRAYWACKE, LIGHT GRAY. SIDERITE, CALCITE CEMENT; ILLITIC CLAY MATRIX.

8) WELL CEMENT: WHITE, SPECKLED.

9) SILTSTONE, SLIGHTLY SANDY, ILLITIC, BROWNISH GRAY TO BROWNISH BLACK, CARBONACEOUS. SIDERITE, CALCITE CEMENT.

1) COAL, BLACK, BITUMINOUS.

2) CONGLOMERATE, OLIGOMICT. SIDERITE, QUARTZ, CALCITE CEMENT; MINOR CLAY MATRIX.

3) MUDSTONE, COALY, BROWNISH BLACK. SIDERITE CEMENT.

4) SILTY SUBGRAYWACKE, BROWNISH GRAY. CALCITE, SIDERITE, PYRITE CEMENT; CLAY MATRIX.

5) SLIGHTLY SANDY SILTSTONE, MONTMORILLONITIC, BROWNISH BLACK, CARBONACEOUS. SIDERITE, CALCITE, RARE PYRITE CEMENT.

6) SILTY SANDSTONE TO SANDY SILTSTONE, BROWNISH GRAY, CARBONACEOUS. SIDERITE CEMENT.

1)-3) AS ABOVE.

4) PEBBLY SUBGRAYWACKE, LIGHT GRAY. PYRITE, CALCITE, ILLITE CEMENT/MATRIX.

5) PEBBLY LITHIC GRAYWACKE TO SANDY SILTSTONE, GRAYISH BLACK TO BROWNISH BLACK. SIDERITE, PYRITE, CALCITE, ILLITE CEMENT; MONTMORILLONITIC CLAY MATRIX.

4) VOLCANIC SUBGRAYWACKE, SOME SILTY, LIGHT OLIVE GRAY. CALCITE, PYRITE, SIDERITE CEMENT, CLAY-SILT MATRIX.

5) SLIGHTLY SANDY SILTSTONE, KAOLINITIC, BROWNISH BLACK. CARBONACEOUS. SIDERITE, PYRITE, CALCITE CEMENT.

3) COALY MUDSTONE, BROWNISH BLACK.

PHOSPHATE CONTENT (Molybdate Test) — Nil — Trace, Low, Med, High

INTERPRETED POROSITY Cores - Cuttings — Slight < 6%, Poor 6-12%, Mod 12-20%, Good > 20%

S.P. LOG — Millivolts — 15 mv.

HYDROCARBONS — CORES (Key to symbols above)

INTERPRETED LITHOLOGY (Key to symbols above)

RESISTIVITY Ohms m²/m — AM_1=16" — 0 — 120

GAMMA RAY LOG — Radiation intensity increases → — API — 37·5 — 127·5

Clasts — Green Chert

Cement, Matrix — Abundant Volcanic Detritus

KEY MINERALS

DESCRIPTION OF INTERPRETED LITHOLOGY — Formation Test Data — Rock Name (after Pettijohn, 1957)

INTERBEDDED FINE TO COARSE, MAINLY MEDIUM PEBBLY PROTOQUARTZITE TO SUBGRAYWACKE AND GREENISH GRAY TO BROWNISH BLACK MUDSTONE TO SANDY SILTSTONE.

PROBABLE FINING UPWARDS CYCLES.

2105'

FINING UPWARDS CYCLES (30'-70') OF PEBBLY SUBGRAYWACKE OR CONGLOMERATE, SANDY SILTSTONE, AND GREENISH GRAY ILLITIC CLAYSTONE.

2316'

① Mis-run.

SANDY SILTSTONE, MINOR VERY FINE SANDSTONE.

FINE SUBGRAYWACKE, SANDY SILTSTONE, BITUMINOUS BLACK COAL

MUDSTONE, SANDY SILTSTONE COARSENING UPWARDS TO FINE SUBGRAYWACKE. SANDY SILTSTONE, BITUMINOUS BLACK COAL

INTERBEDDED BITUMINOUS BLACK COAL, COALY MUDSTONE, SANDY SILTSTONE.

FINE SUBGRAYWACKE, INTERBEDDED SILTSTONE AND BITUMINOUS BLACK COAL.

FINE SUBGRAYWACKE, SANDY SILTSTONE, BITUMINOUS BLACK COAL.

SILTSTONE, MUDSTONE, COARSENING UPWARDS TO INTERBEDDED SANDY SILTSTONE, FINE SUBGRAYWACKE AND BITUMINOUS BLACK COAL.

OLIGOMICT CONGLOMERATE, SANDY SILTSTONE, BLACK COAL.

INTERBEDDED SANDY SILTSTONE AND SILTY VERY FINE TO FINE SUBGRAYWACKE, MINOR BLACK COAL SEAMS.

PEBBLY SUBGRAYWACKE TO OLIGO-MICT CONGLOMERATE, SANDY SILTSTONE, COALY MUDSTONE, BLACK BITUMINOUS COAL.

PEBBLY MEDIUM LITHIC GRAYWACKE TO SANDY SILTSTONE. MINOR BLACK COAL SEAMS.

INTERBEDDED FINE VOLCANIC SUBGRAYWACKE, SANDY SILTSTONE AND BITUMINOUS BLACK COAL. MINOR COALY MUDSTONE.

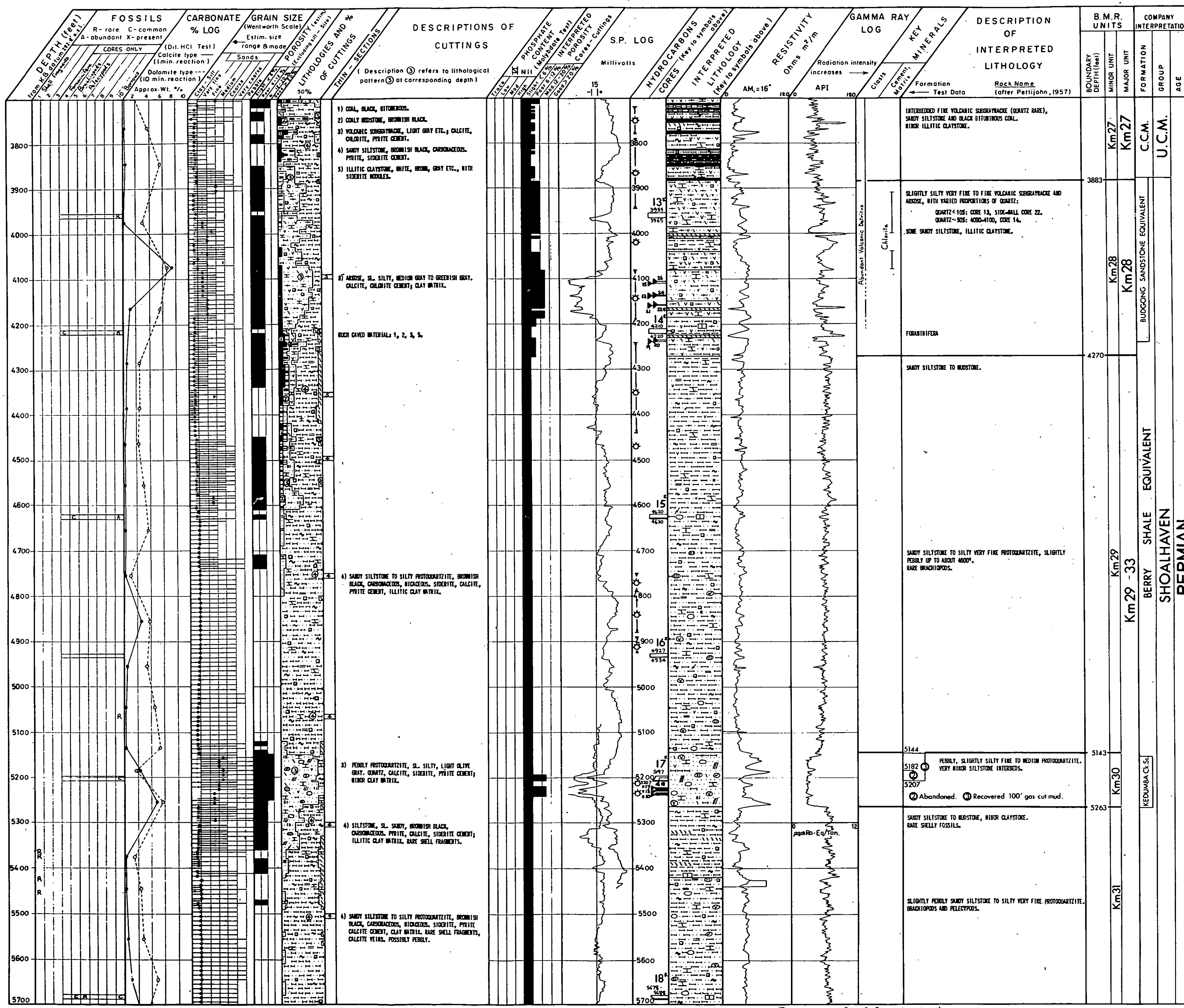
COAL SEAMS THICKER BELOW 3650'.

B.M.R. UNITS				COMPANY INTERPRETATION		
BOUNDARY DEPTH (feet)	MINOR UNIT	MAJOR UNIT		FORMATION	GROUP	AGE
2125	Km14	Km14		NARRABEEN		TRIASSIC
2363	Km15	Km15-16				
2454	Km16					
2533	Km17	Km17-19				
2606	Km18					
2686	Km19					
2755	Km20	Km20-22			ILLAWARRA C.M.	
2809	Km21					
2970	Km22					
3002	Km23	Km23-24				
3212	Km24					
3291	Km25	Km25-26				
3470	Km26					
	Km27	Km27		CUMBERLAND COAL MEASURES	UPPER COAL MEASURES	PERMIAN

B.M.R. Petroleum Exploration January 1968.

To accompany B.M.R. Record 1969/61

X AUS-1-608


DEPTH (feet) from K.B. datum
FOSSILS
R - rare C - common A - abundant X - present
CORES ONLY
CARBONATE % LOG
(Dil. HCl Test)
Calcite type
(1 min. reaction)
Dolomite type
(10 min. reaction)
Approx. Wt. %
GRAIN SIZE
(Wentworth Scale)
Estim. size range & mode
Sands
POROSITY
LITHOLOGIES AND % OF CUTTINGS
50%
THIN - SECTIONS
DESCRIPTIONS OF CUTTINGS
(Description ③ refers to lithological pattern ③ at corresponding depth)
1) COAL, BLACK, BITUMINOUS.
2) COALY MUDSTONE, BROWNISH BLACK.
3) VOLCANIC SUBGRAYWACKE, LIGHT GRAY ETC.; CALCITE, CHLORITE, PYRITE CEMENT.
4) SANDY SILTSTONE, BROWNISH BLACK, CARBONACEOUS. PYRITE, SIDERITE CEMENT.
5) ILLITIC CLAYSTONE, WHITE, BROWN, GRAY ETC., WITH SIDERITE NODULES.
3) ARKOSE, SL. SILTY, MEDIUM GRAY TO GREENISH GRAY. CALCITE, CHLORITE CEMENT; CLAY MATRIX.
MUCH CAVED MATERIAL: 1, 2, 3, 5.
4) SANDY SILTSTONE TO SILTY PROTOQUARTZITE, BROWNISH BLACK, CARBONACEOUS, MICACEOUS. SIDERITE, CALCITE, PYRITE CEMENT, ILLITIC CLAY MATRIX.
3) PEBBLY PROTOQUARTZITE, SL. SILTY, LIGHT OLIVE GRAY. QUARTZ, CALCITE, SIDERITE, PYRITE CEMENT; MINOR CLAY MATRIX.
4) SILTSTONE, SL. SANDY, BROWNISH BLACK, CARBONACEOUS. PYRITE, CALCITE, SIDERITE CEMENT; ILLITIC CLAY MATRIX. RARE SHELL FRAGMENTS.
4) SANDY SILTSTONE TO SILTY PROTOQUARTZITE, BROWNISH BLACK, CARBONACEOUS, MICACEOUS. SIDERITE, PYRITE CALCITE CEMENT, CLAY MATRIX. RARE SHELL FRAGMENTS, CALCITE VEINS. POSSIBLY PEBBLY.
PHOSPHATE CONTENT (Molybdate Test)
Trace Low Mod. High
Nil
INTERPRETED POROSITY Cores-Cuttings
S.P. LOG
Millivolts
15 - | +
HYDROCARBONS CORES (Key to symbols above)
INTERPRETED LITHOLOGY (Key to symbols above)
13 3955 3965
14 4210 4220
15 4620 4630
16 4927 4934
17 5197
18 5679 5688
RESISTIVITY Ohms m²/m
AM. = 16"
0 120
GAMMA RAY LOG
Radiation intensity increases
API
0 180
ppm Ra-Eq/Ton.
0 12
KEY MINERALS
Clasts
Cement, Matrix
Abundant Volcanic Detritus
Chlorite
DESCRIPTION OF INTERPRETED LITHOLOGY
Formation ← Test Data
Rock Name (after Pettijohn, 1957)
INTERBEDDED FINE VOLCANIC SUBGRAYWACKE (QUARTZ RARE), SANDY SILTSTONE AND BLACK BITUMINOUS COAL. MINOR ILLITIC CLAYSTONE.
SLIGHTLY SILTY VERY FINE TO FINE VOLCANIC SUBGRAYWACKE AND ARKOSE, WITH VARIED PROPORTIONS OF QUARTZ:
QUARTZ < 10%: CORE 13, SIDE-WALL CORE 22.
QUARTZ ~ 50%: 4090-4100, CORE 14.
SOME SANDY SILTSTONE, ILLITIC CLAYSTONE.
FORAMINIFERA
SANDY SILTSTONE TO MUDSTONE.
SANDY SILTSTONE TO SILTY VERY FINE PROTOQUARTZITE, SLIGHTLY PEBBLY UP TO ABOUT 4600'.
RARE BRACHIOPODS.
5144
5182 ③
②
5207
PEBBLY, SLIGHTLY SILTY FINE TO MEDIUM PROTOQUARTZITE. VERY MINOR SILTSTONE INTERBEDS.
② Abandoned. ③ Recovered 100' gas cut mud.
SANDY SILTSTONE TO MUDSTONE, MINOR CLAYSTONE. RARE SHELLY FOSSILS.
SLIGHTLY PEBBLY SANDY SILTSTONE TO SILTY VERY FINE PROTOQUARTZITE. BRACHIOPODS AND PELECYPODS.
B.M.R. UNITS
BOUNDARY DEPTH (feet)
MINOR UNIT
MAJOR UNIT
COMPANY INTERPRETATION
FORMATION
GROUP
AGE
3883
4270
5143
5263
Km27
Km28
Km29
Km29 - 33
Km30
Km31
C.C.M.
U.C.M.
BUDGONG SANDSTONE EQUIVALENT
BERRY SHALE EQUIVALENT
KEDUMBA Ck. Ss.
SHOALHAVEN
PERMIAN
3800
3900
4000
4100
4200
4300
4400
4500
4600
4700
4800
4900
5000
5100
5200
5300
5400
5500
5600
5700

DEPTH (feet) from K.B. datum 2229 a.s.l.

FOSSILS — R - rare C - common A - abundant X - present — CORES ONLY — Spores

CARBONATE % LOG — (Dil. HCl Test) — Calcite type — (1 min reaction) — Dolomite type --- (10 min. reaction) — Approx. Wt. %

GRAIN SIZE (Wentworth Scale) — Estim. size range & mode — Sands — Clay - Silt — Very fine — Medium — Coarse — Very coarse — Pebble

POROSITY (estimated) (excluding silt - size) — LITHOLOGIES AND % OF CUTTINGS — 50%

THIN - SECTIONS

DESCRIPTIONS OF CUTTINGS

(Description ③ refers to lithological pattern ③ at corresponding depth)

1) SANDY SILTSTONE TO SILTY PROTOQUARTZITE, BROWNISH BLACK, CARBONACEOUS, MICACEOUS. PYRITE, SIDERITE, CALCITE CEMENT. MINOR MUDSTONE. ILLITIC CLAY MATRIX.

2) PROTOQUARTZITE, LIGHT OLIVE GRAY (CAVING).

3) SILTY PROTOQUARTZITE, OLIVE GRAY, GLAUCONITIC. QUARTZ, CALCITE, SIDERITE, PYRITE CEMENT.

1) SANDY SILTSTONE TO SILTY SANDSTONE, BROWNISH BLACK, CARBONACEOUS. RARE GLAUCONITE. PYRITE, SIDERITE, CALCITE CEMENT; ILLITIC CLAY MATRIX.

4) SLIGHTLY PEBBLY, SLIGHTLY SILTY PROTOQUARTZITE, LIGHT OLIVE GRAY. RARE GLAUCONITE. CALCITE, QUARTZ, SIDERITE, PYRITE CEMENT. SHELL FRAGMENTS.

5) SUBARKOSE, SLIGHTLY SILTY, BROWNISH GRAY. ABUNDANT CALCITE CEMENT. SHELL FRAGMENTS.

6) SILTY PROTOQUARTZITE, OLIVE GRAY TO BROWNISH BLACK, SLIGHTLY PEBBLY, CARBONACEOUS, MICACEOUS, TRACE GLAUCONITIC. CALCITE, SIDERITE, QUARTZ, PYRITE CEMENT, ILLITIC CLAY MATRIX.

1) SANDY SILTSTONE, BROWNISH BLACK CARBONACEOUS. PYRITE, SIDERITE CEMENT.

7) PROTOQUARTZITE, SLIGHTLY PEBBLY, LIGHT OLIVE GRAY. QUARTZ, CALCITE, SIDERITE, PYRITE CEMENT.

6) SILTY PROTOQUARTZITE, AS ABOVE. TRACE DAWSONITE CEMENT. ABUNDANT SHELL FRAGMENTS. SOME COALY LAMINAE.

4) SUBARKOSE TO PROTOQUARTZITE, SLIGHTLY PEBBLY, BROWNISH GRAY. SLIGHTLY MICACEOUS. QUARTZ, CALCITE, PYRITE CEMENT. SHELL FRAGMENTS.

6) SILTY SUBGRAYWACKE TO PROTOQUARTZITE, BROWNISH BLACK, CARBONACEOUS, MICACEOUS. CALCITE, SIDERITE, QUARTZ, PYRITE CEMENT; ILLITIC CLAY MATRIX. SHELL FRAGMENTS. SOME COALY LAMINAE.

PHOSPHATE CONTENT (Molybdate Test) — Nil — Trace — Low — Mod. — High

INTERPRETED POROSITY Cores - Cuttings — Sing. < 5% — Poor 5-12% — Mod. 12-20% — Good > 20%

S.P. LOG — Millivolts — 15 — 35mv.

HYDROCARBONS — CORES (Key to symbols above)

INTERPRETED LITHOLOGY (Key to symbols above)

RESISTIVITY Ohms m²/m — AM, = 16" — 0 — 120

GAMMA RAY LOG — Radiation intensity increases → — µgm. Ra-Eq/Ton — 0 — 12

KEY MINERALS — Clasts — Cement, Matrix — Formation Test Data

DESCRIPTION OF INTERPRETED LITHOLOGY — Rock Name (after Pettijohn, 1957)

SLIGHTLY PEBBLY SANDY SILTSTONE TO SILTY VERY FINE PROTOQUARTZITE. RARE SHELLY FOSSILS.

GLAUCONITIC SILTY VERY FINE TO FINE PROTOQUARTZITE. SANDY SILTSTONE INTERBED.

SLIGHTLY GLAUCONITIC SANDY SILTSTONE TO SILTY VERY FINE SANDSTONE.

SLIGHTLY PEBBLY, SLIGHTLY GLAUCONITIC, SLIGHTLY SILTY PROTOQUARTZITE, WITH SANDY SILTSTONE INTERBEDS. BRACHIOPODS.

CALCAREOUS VERY FINE SUBARKOSE.

PEBBLY FINE PROTOQUARTZITE INTERBEDDED WITH SANDY SILTSTONE NEAR BASE OF UNIT. BRACHIOPODS, FORAMINIFERA.

COARSELY INTERBEDDED PEBBLY FINE PROTOQUARTZITE, SLIGHTLY PEBBLY SILTY VERY FINE SANDSTONE AND SANDY SILTSTONE. SHELLY FOSSILS.

PEBBLY FINE TO COARSE PROTOQUARTZITE; SILTY SANDSTONE INTERBED WITH BRACHIOPODS, PELECYPODS.

INTERBEDDED SILTY, SLIGHTLY PEBBLY VERY FINE TO MEDIUM PROTOQUARTZITE TO SUBGRAYWACKE AND SANDY SILTSTONE.

VARIED SILT CONTENT OF SANDSTONE.

ABUNDANT SHELLY FOSSILS (BRACHIOPODS, PELECYPODS, POLYZOA ETC.)

Glauconite

Gl.

B.M.R. UNITS — BOUNDARY DEPTH (feet) — MINOR UNIT — MAJOR UNIT

BOUNDARY DEPTH (feet)	MINOR UNIT	MAJOR UNIT
5850	Km31	Km 28–33
5892	Km32	
5963	Km33	
6490	Km34	
6760	Km35	
6832	Km36	
	Km37	Km34–37

COMPANY INTERPRETATION — FORMATION — GROUP — AGE

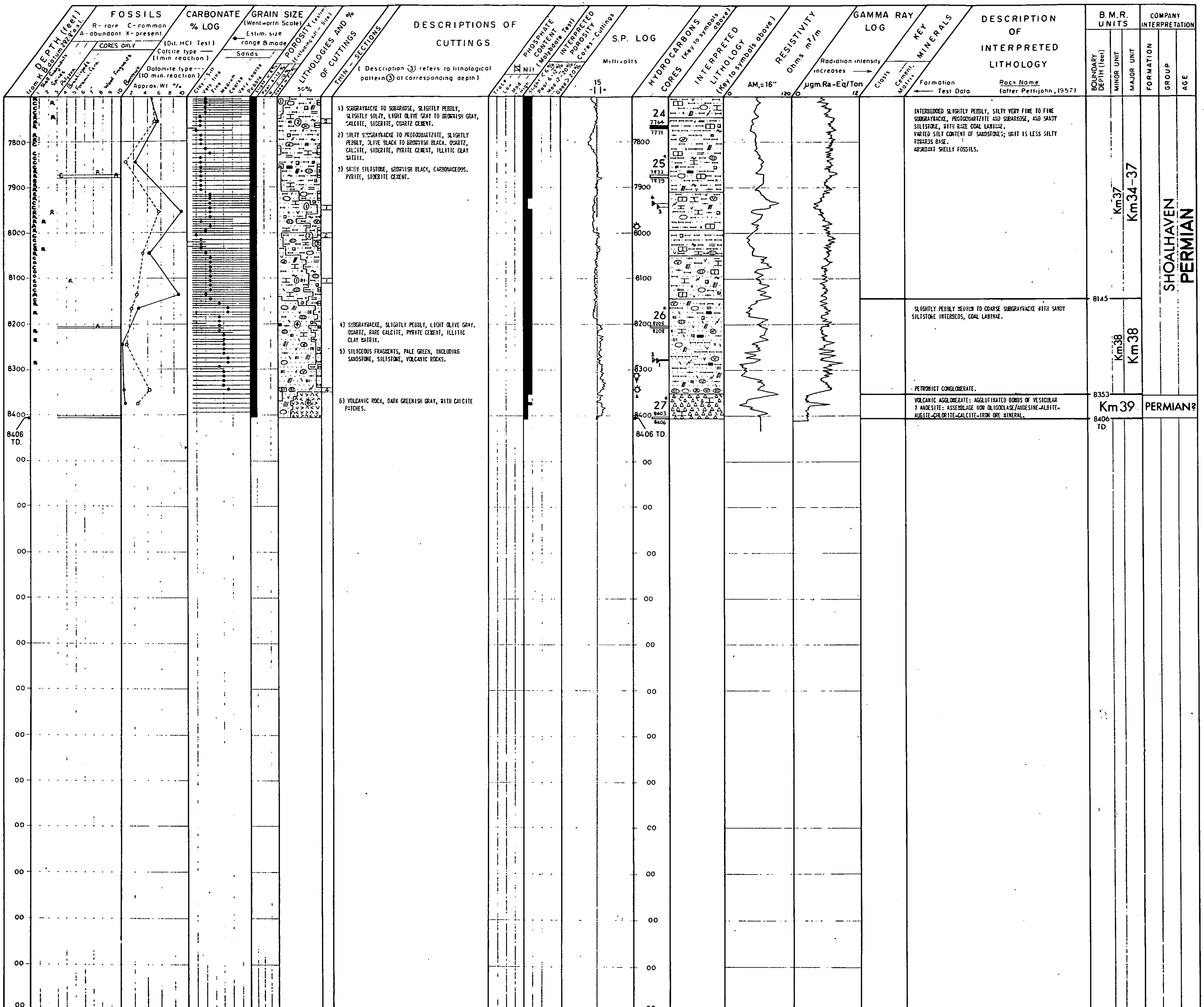
FORMATION	GROUP	AGE
BERRY SHALE		
NOWRA SANDSTONE		SHOALHAVEN
		PERMIAN

B.M.R. Petroleum Exploration January 1968.

To accompany B.M.R. Record 1969/61

X AUS - 1 - 60B

Plate 1E



A

B.M.R. Petroleum Exploration January 1968.

To accompany B.M.R. Record 1969/61

X AUS-1-608

Plate 2A

WELL NAME, No.: KIRKHAM No.1
OPERATING Co.: A.O.G. Corp. Ltd.
WELL LOCATION
Lat.: 34°01'39" S. Long.: 150°42'27" E.
Basin: SYDNEY
State: NEW SOUTH WALES
Tenement No. PEL 102
1:250,000 Sheet No. SI 56-9

ELEVATION (A.S.L.)
:Ground Level .. 270·8. ft.
: K.B. Datum .. 282·8. ft.

SAMPLE STORAGE
B.M.R., Canberra

PETROGRAPHIC CORE LOG
KIRKHAM (A.O.G.) No.1

Geology by: J.I. Raine

Sedimentary Structures — Laminae >5cm. thick; 1-5 cm.; 0·5-1 cm.; 0·1-0·5cm.; <0·1 cm. — Burrows; Roots; Bioturbation; Convolute bedding; Load cast; Slump structure; Cross-bedding, set >1cm.; set <1cm.; Graded bedding; Reverse graded bedding; Stylolites

Interval tested: 6540'6" – 6541'6"
Core not recovered
Position of lost core not known

Porosity (estimated): S - Slight < 6 %; P - Poor 6-12%; M - Medium 12-12%; G - Good > 20%

Abundance (estimated): R - Rare < 1%; C - Common 1-3%; A - Abundant > 3%

Framework — Sand: Quartz, chert fragment; Sedimentary rock frag.; Volcanic rock Fragment; Plutonic rock Fragment; Metamorphic rock Frag. — Pebble

Cement: Calcite; Siderite; Dawsonite; Silica; Pyrite; Clay; Iron Oxide

Quartz conglomerate, gravel; Quartz sand, sandstone; Siltstone, silt; Claystone, clay; Coal, coal laminae; Shale and mudstone; Volcanic agglomerate

'Accessory' components: Feldspar; Green pellets ('glauconite'); Graphite; Carbonaceous Fragment; Calcitic Fragment; Sideritic Fragment; Mica

CORRELATION: AGE; GROUP; COMPANY INTERPRET N.; FORM'N; B.M.R. UNITS

GENERALIZED DESCRIPTION: CORE Nº RECOVERY FOOTAGES; LITHOLOGY; DESCRIPTION — GENERALIZED ROCK NAME; COLOUR (Rock Colour Chart GSA 1963); SEDIMENTARY STRUCTURE; DIP & TECTONIC STRUCTURE

DETAILED DESCRIPTION: DEPTH OF SAMPLE SECTIONED, ANALYZED; SPECIFIC ROCK NAME (After Pettijohn 1957); POROSITY % where measured; PERMEABILITY Millidarcys; ROUNDNESS; SORTING; GRAIN - SIZE (Wentworth Scale) Estim size Range & Mode; SANDS; THIN - SECTION ANALYSIS % OF ESSENTIAL COMPONENTS (cross hatched if material clearly present as cement and/or matrix; porosity shown as blank); Matrix and/or Cement Estim.% of Total Rock (CLAY-UNDIFF; KAOLIN Gp; ILLITE Gp.; CHLORITE Gp.); Cement Symbols See Legend; ACCESSORY MINERALS Estim R-C-A or Measured %Total Rock ("Dark Minerals"; "Light Mins"); MATURITY INDEX; NOTES (provenance, environment of deposition, diagenesis, palaeontology, etc)

TRIASSIC

HAWKESBURY SANDSTONE — Km6-10 — Km10

NARRABEEN — Km14 — Km14

979'

PEBBLY TO VERY SLIGHTLY PEBBLY FINE TO COARSE QUARTZOSE SANDSTONE, SLIGHTLY FRIABLE, SOME SILTY.

981'

981'3-4" ORTHOQUARTZITE

983'

1 (9'7")

985'

SILTY FINE TO VERY FINE QUARTZOSE SANDSTONE WITH CARBONACEOUS SILTY PARTINGS.

LIGHT OLIVE GRAY TO OLIVE GRAY

987'

988'5"

987'10"-11" SILTY PROTOQUARTZITE

989'

1405'

INTRAFORMATIONAL BRECCIA WITH SILTSTONE CLASTS, SOME GRAY CHERT PEBBLES, IN FINE SANDSTONE MATRIX.

1406'6"

1407' NOT AVAILABLE

PEBBLY TO VERY SLIGHTLY PEBBLY FINE TO MEDIUM QUARTZOSE SANDSTONE, WITH SOME SILTY LAMINAE.

LIGHT OLIVE GRAY

1405'7"-8" PROTOQUARTZITE

1409'

2 (9'6")

1409'4"-5" PROTOQUARTZITE

MOD. BROWN PEBBLES

1411'

1413'

1414'6"

1415'0"

1715'

SANDY CONGLOMERATE WITH QUARTZ, CHERT, ARGILLITE, SILTSTONE PEBBLES, FINE TO MEDIUM SAND MATRIX.

SLIGHTLY SANDY MEDIUM SILTSTONE AND VERY FINE SANDSTONE, WITH CARBONACEOUS FRAGMENTS AND MICROSPORES, SIDERITE NODULES.

VERY FINE TO MEDIUM QUARTZ-LITHIC SANDSTONE, SOME PEBBLY.

OLIVE GRAY TO OLIVE BLACK

LIGHT OLIVE GRAY

3' 5' 2'

1715'4-3" OLIGOMICT CONGLOMERATE
1715'5-6" ILLITIC SILTSTONE

3 (3'9")

1717'

1717'4-5" PEBBLY SUBGRAYWACKE

1718'9"

1725'

2037'

MEDIUM SILTSTONE AND SHALE WITH CARBONACEOUS FRAGMENTS, COALY LENSES, ABUNDANT MUSCOVITE. SIDERITE CEMENT.

OLIVE GRAY

2·

2039'

SILTY FINE TO VERY FINE QUARTZ-LITHIC SANDSTONE, SOME PEBBLY (INTRACLASTS OF SIDERITIC SILTSTONE), WITH ABUNDANT CARBONACEOUS MATERIAL.

2038'5-6" ILLITIC SILTSTONE

2·5·

4 (9'7")

LIGHT GRAY

2041'0-1" SILTY SUBGRAYWACKE

2043'

2045'

SLIGHTLY PEBBLY MEDIUM QUARTZ-LITHIC SANDSTONE, AS ABOVE. SOME SILTSTONE AND SILTY VERY FINE SANDSTONE, CARBONACEOUS.

OLIVE GRAY

2046'7"

2047'8"

REGIONAL METAMORPHIC, SEDIMENTARY, POSSIBLY GRANITIC PROVENANCE.

KAOLINITE APPEARS TO REPLACE ILLITIC CLAY MATRIX.

ACID VOLCANIC, SEDIMENTARY/LOW GRADE METAMORPHIC, ULTRABASIC PROVENANCE; POSSIBLY ALSO GRANITIC CONTRIBUTION. LOCALLY DERIVED SILTSTONE CLASTS.

PROVENANCE AS FOR CORE 2.

CARBONISED PLANT FRAGMENTS IN SILTY LAMINAE ARE ASSOCIATED WITH ABUNDANT SIDERITE, SOME OF WHICH MAY BE DETRITAL.

PROVENANCE AS FOR CORE 2.

To accompany B.M.R. Record 1968/61

CORRELATION: AGE	GROUP	FORM^N	B.M.R. UNITS	COMPANY INTERPRET^N
TRIASSIC	NARRABEEN	Km 15-16	Km15 / Km16	

GENERALIZED DESCRIPTION

CORE N^o RECOVERY FOOTAGES	DESCRIPTION – GENERALIZED ROCK NAME	COLOUR (Rock Colour Chart G.S.A. 1963)	DIP
Core 5, 2306'–2315'9" (9'9")	PEBBLY TO SLIGHTLY PEBBLY MEDIUM QUARTZ-LITHIC SANDSTONE. SOME SILTY VERY FINE TO FINE QUARTZ-LITHIC SANDSTONE, SOME SANDY CONGLOMERATE.	MEDIUM GRAY; WHITE, GREEN, RED, BLACK PEBBLES	
Core 6, 2401'–2420'3" (19'3")	SLIGHTLY SANDY FINE SILTSTONE, SOME COARSE SILTSTONE LAMINAE, CLAY PELLET CONGLOMERATE AT BASE. ABUNDANT CARBONISED PLANT STEMS; MINOR SIDERITE CEMENT.	OLIVE BLACK	7°
	FINE QUARTZ-LITHIC SANDSTONE.	MEDIUM LIGHT GRAY	
	FINE AND COARSE SILTSTONES, SOME CARBONACEOUS, WITH CALCITE AND/OR SIDERITE CEMENT, SIDERITE NODULES. SOME SANDY LAMINAE, MINOR VERY FINE QUARTZ-LITHIC SANDSTONE.	OLIVE GRAY TO OLIVE BLACK	
	SLIGHTLY SANDY COARSE SILTSTONE TO VERY FINE QUARTZ-LITHIC SANDSTONE AND MEDIUM SILTSTONE.	LIGHT GRAY	3°
Core 7, 2421'–2437' (17'10")	VERY FINE TO FINE SILTY QUARTZ-LITHIC SANDSTONE.	MEDIUM DARK GRAY	
	CARBONACEOUS FINE TO MEDIUM SILTSTONE.	OLIVE BLACK TO OLIVE GRAY	3°, 5°
	FINE QUARTZ-LITHIC SANDSTONE, SOME PEBBLY (SILTSTONE INTRACLASTS) AND COARSE SILTSTONE WITH SIDERITE CEMENT.	MEDIUM GRAY AND OLIVE BLACK	
	SLIGHTLY SANDY FINE TO COARSE SILTSTONE WITH VERY FINE CARBONACEOUS FRAGMENTS, SIDERITE NODULES. MINOR VERY FINE QUARTZ-LITHIC SANDSTONE.	OLIVE GRAY TO OLIVE BLACK	

Depth markings: 2306', 2308', 2310', 2312', 2314', 2315'9", 2316', 2401', 2403, 2405, 2407, 2409, 2411, 2413, 2415, 2417, 2419, 2420'3", 2421', 2423, 2425, 2427, 2429, 2431, 2433, 2435, 2437

DETAILED DESCRIPTION

Column headings: Depth of sample sectioned, analyzed; Specific rock name (After Pettijohn 1957); Porosity (% where measured: slight <6%, poor 6–12%, med 12–20%, good >20%); Permeability (millidarcys: vertical, horizontal); Roundness; Sorting (poor, mod., good); Grain-size (Wentworth scale; estim. size range & mode: clay-silt, very fine, fine, medium, coarse, very coarse sands, pebbles); Thin-section analysis: % of essential components (cross hatched if material clearly present as cement and/or matrix; porosity shown as blank; 20 40 60 80 100); Matrix and/or cement, estim. % of total rock (clay-undiff, kaolin Gp, illite Gp., chlorite Gp.; cement symbols see legend; 0 10 20 30 40 50 60 70 80 90); Accessory minerals (Estim. R-C-A or measured % total rock; "Dark minerals": total "dark", zircon, tourmaline, rutile, leucoxene, magnetite, picotite, sphene; "Light mins": muscovite, plagioclase, orthoclase, chlorite, biotite); Maturity index (Qtz+Chert / Feld+Lith. Sandstone & Conglomerate); Notes (provenance, environment of deposition, diagenesis, palaeontology etc.)

Depth of sample	Specific rock name	Accessory minerals (as printed)	Maturity index
2310'1"-2"	SUBGRAYWACKE	R R R 0.5 0.2 R	0.93
2402'11"-12"	ILLITIC SILTSTONE.	R C	
2407'1"-2"	CALCAREOUS COARSE SILTSTONE (SUBGRAYWACKE).	R R R R C R R R	2.0
2420'2"-3"	SUBGRAYWACKE	R R R R R R C C R R	0.95
2424'3"-4"	ILLITIC SILTSTONE	R R C R I	
2427'3"-4"	SUBGRAYWACKE	R R I R R R R	0.92
2436'5"-6"	ILLITIC COARSE SILTSTONE	R R R R R R	

NOTES

Core 5: VOLCANIC, SEDIMENTARY/LOW GRADE METAMORPHIC, ULTRABASIC, POSSIBLY ALSO GRANITIC PROVENANCE (AS FOR CORE 2). DETRITAL SIDERITE.

Core 6: VOLCANIC, SEDIMENTARY/ LOW GRADE METAMORPHIC, GRANITIC PROVENANCE.

Core 7: VOLCANIC, METAMORPHIC/SEDIMENTARY, GRANITIC PROVENANCE.

To accompany B.M.R. Record 1969/61

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DETAILED DESCRIPTION

Column headings: CORRELATION (AGE, GROUP, FORMN., COMPANY INTERPRETN., B.M.R. UNITS) · CORE Nº RECOVERY FOOTAGES · GENERALIZED DESCRIPTION (LITHOLOGY; DESCRIPTION – GENERALIZED ROCK NAME; COLOUR, Rock Colour Chart G.S.A.1963; SEDIMENTARY STRUCTURE (See symbols); DIP & TECTONIC STRUCTURE) · DEPTH OF SAMPLE SECTIONED, ANALYZED · SPECIFIC ROCK NAME (After Pettijohn 1957) · POROSITY % where measured · PERMEABILITY Millidarcys (VERTICAL, HORIZONTAL) · ROUNDNESS · SORTING (POOR, MOD., GOOD) · GRAIN-SIZE (Wentworth Scale) Estim size Range & Mode (CLAY-SILT, VERY FINE, FINE, MEDIUM, COARSE, VERY COARSE, PEBBLES – SANDS) · THIN-SECTION ANALYSIS: % OF ESSENTIAL COMPONENTS (CROSS HATCHED IF MATERIAL CLEARLY PRESENT AS CEMENT AND/OR MATRIX. POROSITY SHOWN AS BLANK) 20 40 60 80 100; Matrix and/or Cement Estim.% of Total Rock (CLAY-UNDIFF, KAOLIN Gp, ILLITE Gp., CHLORITE Gp.) 0 10 20 30 40 50 60 70 80 90; Cement Symbols See Legend · ACCESSORY MINERALS Estim. R-C-A or Measured % Total Rock ("Dark Minerals": TOTAL "DARK", Zircon, Tourmaline, Rutile, Leucoxene, Garnet; "Light Mnrl": Muscovite, Chlorite, Biotite, Plagioclase, Orthoclase, Felsitic) · MATURITY INDEX (Quartz/Feldspar + rock fragments) · NOTES (provenance, environment of deposition, diagenesis, palaeontology etc.)

Age	Group	Formn.	Company interpretn.	B.M.R. units	Core / footages	Description	Colour	Depth of sample	Specific rock name	Accessory minerals	Maturity index	Notes
TRIASSIC	NARRABEEN		Km15-16	Km16	Core 7, to 2438'10"	FINE TO COARSE SILTSTONE, CARBONACEOUS, WITH SIDERITE CEMENT, AND VERY FINE QUARTZ-LITHIC SANDSTONE.	OLIVE GRAY; MEDIUM GRAY					
					2438'10"–2441 (no core)							
					Core 8, 2441–2449 (8')	SLIGHTLY SANDY COARSE SILTSTONE. CALCITE AND SIDERITE CEMENT.	OLIVE GRAY TO OLIVE BLACK	2441'0"-1"	COARSE QUARTZOSE SILTSTONE.	R R C? R R		PROVENANCE AS FOR CORE 7.
						INTERBEDDED VERY FINE AND SLIGHTLY SANDY COARSE SILTSTONE.						
						VERY FINE QUARTZ-LITHIC SANDSTONE WITH SIDERITE CEMENT.						
						CARBONACEOUS SILTSTONE TO MUDSTONE, WITH SOME COARSE SILTSTONE LAMINAE.		2448'0"-1"	ILLITIC MUDSTONE	R R		CARBONISED LEAF FOSSILS.
						COAL, BLACK, BITUMINOUS, WITH SIDERITE FILLED VERTICAL CRACKS. SOME MUDSTONE BANDS. MAINLY CLARAIN WITH VITRAIN AND DURAIN.	BLACK					
PERMIAN	UPPER COAL MEASURES	ILLAWARRA COAL MEASURES	Km17-19	Km17	2449–2461 (no core)							
					Core 9, 2461–2479'5" (18'5")	COALY MUDSTONE AND COAL, BLACK, MAINLY VITRAIN, WITH CLARAIN.	BLACK					
						CARBONACEOUS FINE SILTSTONE WITH ILLITIC CLAY AND MINOR SIDERITE CEMENT.		2462'6"-7"	ILLITIC FINE SILTSTONE	R R		ROOT ZONE WITH ABUNDANT CARBONISED STEM MATERIAL.
						CARBONACEOUS FINE SILTY SANDSTONE.	BROWNISH BLACK					
						SANDY MEDIUM SILTSTONE AND SILTY FINE SANDSTONE. SIDERITE CEMENT.						
						FINE TO VERY FINE QUARTZ-LITHIC SANDSTONE, SOME SILTY, SANDY COARSE SILTSTONE AND CARBONACEOUS FINE SILTSTONE.	MEDIUM GRAY, OLIVE GRAY, OLIVE BLACK.					
						FINE QUARTZ-LITHIC SANDSTONE. (Dip 2°)	MEDIUM GRAY	2474'9"-11"	SUBGRAYWACKE	R R R R R R C C	0·29	ACID VOLCANIC, GRANITIC, SEDIMENTARY/ LOW GRADE METAMORPHIC PROVENANCE.
						VERY FINE TO MEDIUM QUARTZ-LITHIC SANDSTONE, SOME SILTY, WITH COAL LAMINAE, SOME SLIGHTLY PEBBLY.	MEDIUM GRAY, OLIVE GRAY.					
					2479'5"–2481 (no core)							

Depth marks: 2441, 2443, 2445, 2447, 2449, 2461, 2463, 2465, 2467, 2469, 2471, 2473, 2475, 2477, 2479'5", 2481

To accompany B.M.R. Record 1969/61

BMR Petroleum Exploration January 1968.

X AUS-1-60 D

CORRELATION | GENERALIZED DESCRIPTION | DETAILED DESCRIPTION

AGE: PERMIAN
GROUP: UPPER COAL MEASURES; SHOALHAVEN GROUP
FORMN: CUMBERLAND COAL MEASURES; BERRY SHALE / BUDGONG SANDSTONE
B.M.R. UNITS: Km23–24 / Km23; Km25–26 / Km26; Km27 / Km27; Km28 / Km28

CORE Nº RECOVERY FOOTAGES	LITHOLOGY	DESCRIPTION (GENERALIZED ROCK NAME)	COLOUR (Rock Colour Chart GSA 1963)	SEDIMENTARY STRUCTURE (Symbols)	DIP & TECTONIC STRUCTURE	DEPTH OF SAMPLE SECTIONED, ANALYZED	SPECIFIC ROCK NAME (After Pettijohn 1957)	POROSITY % where measured	PERMEABILITY Millidarcys	ROUNDNESS	SORTING	GRAIN-SIZE (Wentworth Scale) Estim size Range & Mode SANDS	THIN-SECTION ANALYSIS % OF ESSENTIAL COMPONENTS	Matrix and/or Cement Estim % of Total Rock	ACCESSORY MINERALS Estim R-C-A or Measured % Total Rock	NOTES (provenance, environment of deposition, diagenesis, paleontology etc.)
3006																
3007		SLIGHTLY SANDY FINE SILTSTONE, MINOR MEDIUM TO COARSE SILTSTONE, VERY FISSILE (SMELLS WHEN WET). ABUNDANT CELLULAR PLANT FRAGMENTS, CARBONISED.	BROWNISH BLACK		3°	3011'2"-3'	MONTMORILLONITIC SILTSTONE									ACID VOLCANIC AND GRANITIC, MINOR SEDIMENTARY/METAMORPHIC PROVENANCE.
10																
3009																
(9'4")																
3011																
3013		VERY SILTY VERY FINE QUARTZ-LITHIC SANDSTONE AND SANDY COARSE SILTSTONE.	OLIVE GRAY TO BROWNISH BLACK			3012'3"-4'	LITHIC GRAYWACKE									GLOSSOPTERID LEAF FOSSIL (CARBONISED).
3014'4"																
3015																
3295																
		PEBBLY SILTY MEDIUM SANDSTONE WITH MUDSTONE WISPS.				3295'4"-5'	LITHIC GRAYWACKE									GRANITIC, ACID VOLCANIC (ANCIENT), SEDIMENTARY/METAMORPHIC PROVENANCE.
3297						3296'6"-7'	LITHIC GRAYWACKE									PRESENCE OF GLAUCONITE MAY INDICATE MARINE ENVIRONMENT.
11			DARK GRAY TO BLACK													
3299																
(9'6")																
3301																
3303																
3304'6"																
3305																
3688																
12		MEDIUM TO COARSE SILTSTONE WITH CARBONISED PLANT FRAGMENTS. MINOR VERY FINE LITHIC SANDSTONE, AS BELOW.	OLIVE BLACK		0°	3689'3"-4'	SUBGRAYWACKE									CONTEMPORARY INTERMEDIATE TO ACID VOLCANIC PROVENANCE.
3690																
(5'1")		FINE TO MEDIUM FELDSPATHIC-LITHIC SANDSTONE, WITH SOME MUDSTONE FLAKES AND COALY FRAGMENTS.	OLIVE GRAY													FELDSPAR COMMONLY REPLACED BY CALCITE.
3692						3691'11"-3692'	VOLCANIC SUBGRAYWACKE									
3693'1"																
3698																
3955																
		SLIGHTLY CARBONACEOUS, FINE TO MEDIUM SILTSTONE.	DARK GREENISH GRAY, OLIVE BLACK		14°	3955'4"-5'	CHLORITIC ARKOSIC SILTSTONE									CONTEMPORARY INTERMEDIATE TO ACID VOLCANIC PROVENANCE. 1) CHLORITE CEMENT (MAY INDICATE MARINE PROVENANCE). 2) CALCITE CEMENT, INCLUDING REPLACEMENT OF PLAGIOCLASE BY CALCITE. 3) ? AUTHIGENIC SPHENE.
3957		PEBBLY (SILTSTONE INTRACLASTS) FINE FELDSPATHIC SANDSTONE.				3957'-57½'	PLAGIOCLASE ARKOSE (VOLCANIC).									
13																
3959			DARK GREENISH GRAY													
(10'0")																
3961																
3963			DARK GREENISH GRAY, DARK GRAY			3963'2½"-3½'	PLAGIOCLASE ARKOSE (VOLCANIC).									
3965																

To accompany B.M.R. Record 1969/61

Age	Group	Formation (Company Interpret.)	B.M.R. Units	Core No. Recovery Footages	Generalized Description (Generalized Rock Name)	Colour (Rock-Colour Chart G.S.A. 1963)	Depth of Sample Sectioned, Analyzed	Specific Rock Name (After Pettijohn 1957)	Accessory Minerals	Maturity Index	Notes (provenance, environment of deposition, diagenesis, palaeontology etc.)
PERMIAN	SHOALHAVEN	BUDGONG SANDSTONE EQUIV. Km28	Km28	4159 SWC 22	SLIGHTLY SILTY FINE FELDSPATHIC-LITHIC SANDSTONE.	OLIVE GRAY	4159'	SUBGRAYWACKE	R R R A	0·08	CONTEMPORARY INTERMEDIATE-ACID VOLCANIC PROVENANCE.
				4210–4219'8" Core 14 (9'8")	SILTY VERY FINE QUARTZ-LITHIC SANDSTONE, FINER TOWARDS BASE. FOSSILIFEROUS.	DARK GRAY	4215'5"-8"	ARKOSIC SILTSTONE	R; R R R C A	1·36	ACID VOLCANIC, GRANITIC PROVENANCE. ARENACEOUS FORAMINIFERA SUGGEST NEAR-SHORE MARINE ENVIRONMENT.
				4220 / 4620							
		BERRY SHALE EQUIVALENT Km29-33	Km29	4620–4628'7" Core 15 (8'7")	SLIGHTLY PEBBLY SILTY VERY FINE QUARTZ-LITHIC SANDSTONE TO SANDY COARSE SILTSTONE. FOSSILIFEROUS:	OLIVE BLACK TO BROWNISH BLACK	4620'3"-4"	PROTOQUARTZITE	R R; C R R C C	4·7	GRANITIC, ANCIENT ACID VOLCANIC, SEDIMENTARY/METAMORPHIC PROVENANCE. GLAUCONITE, LARGE BRACHIOPOD SHELLS INDICATE MARINE ENVIRONMENT.
				4630 / 4927							
				4927–4933'6" Core 16 (6'6")	SLIGHTLY PEBBLY VERY SILTY VERY FINE QUARTZ-LITHIC SANDSTONE TO SANDY COARSE SILTSTONE.	OLIVE BLACK	4930'2"-3"	LITHIC GRAYWACKE	R; R R R C C	2·3	GRANITIC, ACID VOLCANIC, SEDIMENTARY/METAMORPHIC PROVENANCE. RARE GLAUCONITE MAY INDICATE MARINE ENVIRONMENT.
							4930'8"-9"	PROTOQUARTZITE	R R; R R C C	3·8	
				4934 / 5197							
		KEDUMBA CREEK SANDSTONE EQUIVALENT	Km30	5197–5206'3" Core 17 (9'3")	FINE TO MEDIUM QUARTZ-LITHIC SANDSTONE TO OLIGOMICT CONGLOMERATE, SOME SILTY.	OLIVE GRAY	5202'8"-6203	PROTOQUARTZITE	R; R R R R	5·9	SEDIMENTARY/METAMORPHIC, ACID VOLCANIC, GRANITIC PROVENANCE. DAWSONITE, SOME REPLACING FELDSPAR.
							5205'6"-7"	PROTOQUARTZITE	R R R	10·1	
				5207 / 5227							
				5227 SWC 17	MEDIUM QUARTZ-LITHIC SANDSTONE.	LIGHT OLIVE GRAY					
				5229 SWC 13	PEBBLY MEDIUM QUARTZ-LITHIC SANDSTONE.	LIGHT OLIVE GRAY					

To accompany B.M.R. Record 1969/61

B.M.R. Petroleum Exploration January 1968.

X AUS-1-60 D

DETAILED DESCRIPTION

Correlation: Age — PERMIAN; Group — SHOALHAVEN; Formation — BERRY SHALE EQUIV. (K.Ck.S. at top; company interpretation Km29-33), NOWRA SANDSTONE (Km34-37), 'LOWER SHOALHAVEN GP.'; B.M.R. units Km30, Km31, Km34, Km36, Km37.

Column headings: Age | Group | Form. | B.M.R. Units | Core No. Recovery Footages | Lithology | Generalized Description (Generalized rock name) | Colour (Rock Colour Chart GSA 1963) | Sedimentary Structure (see symbols) | Dip & Tectonic Structure | Depth of sample sectioned, analyzed | Specific Rock Name (After Pettijohn 1957) | Porosity (% where measured: slight <5%, poor 5-10%, medium 10-20%, good >20%) | Permeability (Millidarcys: vertical, horizontal) | Roundness | Sorting (poor, mod., good) | Grain-size (Wentworth Scale; Estim. size, Range & Mode: clay-silt, very fine, fine, medium, coarse, very coarse, pebbles; Sands) | Thin-section analysis: % of essential components (cross hatched if material clearly present as cement and/or matrix; porosity shown as blank; 20 40 60 80 100) | Matrix and/or Cement, Estim. % of Total Rock (clay-undiff, kaolin Gp, chlorite Gp, illite Gp; 10 20 30 40 50 60 70 80 90) | Cement symbols (see legend) | Accessory Minerals (Estim. R-C-A or Measured % Total Rock; Total "Dark"; "Dark Minerals"; "Light Min.") | Maturity Index | Notes (provenance, environment of deposition, diagenesis, palaeontology etc.)

Core No. / Footages	Generalized Description	Colour	Depth of sample	Specific Rock Name	Accessory minerals	Maturity Index	Notes
5234; SWC 10	FINE QUARTZ-LITHIC SANDSTONE. QUARTZ, CALCITE CEMENT.	LIGHT OLIVE GRAY	5234'	PROTOQUARTZITE		7·7	AS FOR CORE 17.
5678; 18; 5680; 5682; (8'1"); 5684; 5685'10"	PEBBLY SANDY COARSE SILTSTONE. FOSSILIFEROUS, CARBONACEOUS.	GRAYISH BLACK	5680'5"-6"	ILLITIC SILTSTONE	R R R R R R C	5·1	SEDIMENTARY/METAMORPHIC, ACID VOLCANIC, GRANITIC PROVENANCE. SPIRIFERID BRACHIOPOD AND LARGE PELECYPOD SHELLS, SOME ARTICULATED, INDICATE MARINE ENVIRONMENT, LITTLE TRANSPORT.
5688							
6050; 19; 6052; (5'0"); 6054'3"; 6055	PEBBLY SILTY MEDIUM QUARTZ-LITHIC SANDSTONE. SLIGHTLY PEBBLY SILTY FINE TO VERY FINE SANDSTONE, AS ABOVE. FOSSILIFEROUS.	OLIVE BLACK TO OLIVE GRAY	6050'3"-4"	PROTOQUARTZITE	R R R R C A R	4·3	SEDIMENTARY/METAMORPHIC, ACID VOLCANIC (ANCIENT), GRANITIC PROVENANCE. GLAUCONITE, ABUNDANT BRACHIOPOD AND LARGE PELECYPOD SHELLS (IN VARIOUS ORIENTATIONS) INDICATE MARINE ENVIRONMENT.
			6053'8"-9"	PROTOQUARTZITE	R R C R C A R	4·0	
6340; SWC 8	MEDIUM QUARTZ-LITHIC SANDSTONE.	LIGHT OLIVE GRAY					
6342; SWC 6	MEDIUM QUARTZ-LITHIC SANDSTONE.	LIGHT OLIVE GRAY					
6439; 20; 6441; (5'0"); 6443; 6444	SILTY VERY FINE TO FINE QUARTZ-LITHIC SANDSTONE, SOME PEBBLY. SOME COARSE QUARTZOSE SANDSTONE LAMINAE. FOSSILIFEROUS.	OLIVE GRAY TO LIGHT GRAY; OLIVE GRAY, OLIVE BLACK	6441'2"-3"	PROTOQUARTZITE	R R R C R	4·3	SEDIMENTARY/METAMORPHIC, GRANITIC, ACID VOLCANIC (ANCIENT) PROVENANCE. FAECAL PELLETS, BRACHIOPOD AND FORAMINIFERAL SHELLS AND POSSIBLE CRINOIDAL DEBRIS INDICATE MARINE ENVIRONMENT.
			6442'9"-10"	SUBARKOSE	R R R A R	5·7	
6800; 21; (3'0"); 6803	SLIGHTLY PEBBLY SILTY VERY FINE SANDSTONE AND SANDY COARSE SILTSTONE. FOSSILIFEROUS.	OLIVE GRAY TO BROWNISH BLACK	6802'0"-1"	ILLITIC SILTSTONE	R R R C C R	3·9	SEDIMENTARY/METAMORPHIC, GRANITIC, ACID VOLCANIC (ANCIENT) PROVENANCE. BRACHIOPOD AND PELECYPOD SHELLS, SOME ARTICULATED, SOME BROKEN, INDICATE MARINE ENVIRONMENT.
			6802'6"-7"	PROTOQUARTZITE	R R R C C	4·0	
7160; 22; 7162; (5'0"); 7165	SANDY COARSE SILTSTONE GRADING TO SILTY VERY FINE SANDSTONE (SLIGHTLY PEBBLY). FOSSILIFEROUS.	DARK GRAY TO OLIVE BLACK	7160'4"-5"	ILLITIC SILTSTONE	R R R R R R		SEDIMENTARY/METAMORPHIC, GRANITIC, ACID VOLCANIC (ANCIENT) PROVENANCE. RARE POLYZOAN FRAGMENTS INDICATE MARINE ENVIRONMENT.
			7164'10"-11"	PROTOQUARTZITE	R R R R A R	3·1	
7562; 23; (6'11"); 7566'6"; 7567	SANDY MEDIUM TO COARSE SILTSTONE, SLIGHTLY PEBBLY SILTY SANDSTONE, MINOR PETROMICT CONGLOMERATE.	OLIVE GRAY TO OLIVE BLACK	7562'2"-3"	ILLITIC SILTSTONE	R R C R C R		SEDIMENTARY/METAMORPHIC, ACID VOLCANIC (ANCIENT), GRANITIC PROVENANCE. EARLY DIAGENETIC PYRITE NODULES. FAECAL PELLETS.
			7565'10"-11"	SUBGRAYWACKE	R R R R R R A C	1·66	

To accompany B.M.R. Record 1969/61

2C

DETAILED DESCRIPTION

Age	Group	Formn	B.M.R. Units	Core No / Recovery / Footages	Generalized Description	Colour	Depth of Sample Sectioned, Analyzed	Specific Rock Name (After Pettijohn 1957)	Accessory Minerals (R-C-A)	Maturity Index	Notes (provenance, environment of deposition, diagenesis, palaeontology etc.)
PERMIAN	SHOALHAVEN	'LOWER SHOALHAVEN GP.' Km34–37	Km37	25 (6'0") 7872–7878'	SLIGHTLY PEBBLY SILTY VERY FINE QUARTZ-LITHIC SANDSTONE. FOSSILIFEROUS.	OLIVE BLACK	7873'10"-11"	SUBGRAYWACKE	R R R R C R R A C	2·2	SEDIMENTARY/METAMORPHIC, ANCIENT ACID VOLCANIC, GRANITIC PROVENANCE. BRACHIOPOD SHELLS (DISARTICULATED, RANDOM ORIENTATION) INDICATE MARINE ENVIRONMENT.
				7879'							
PERMIAN	SHOALHAVEN	'LOWER SHOALHAVEN GP.' Km38	Km38	26 (3'0") 8205–8207'10"	SLIGHTLY SILTY FINE TO MEDIUM QUARTZ-LITHIC SANDSTONE. COALY WOOD FRAGMENTS.	OLIVE GRAY TO MEDIUM DARK GRAY	8206'9"-10"	SUBGRAYWACKE	R R R R A C	1·1	GRANITIC, ANCIENT VOLCANIC, SEDIMENTARY/METAMORPHIC PROVENANCE. ABUNDANT WOOD FRAGMENTS MAY INDICATE FRESH WATER, FLUVIATILE ENVIRONMENT.
				8208							
PERMIAN?		Km39	Km39	27 (2'5") 8403–8405'5"	AGGLOMERATE OF ROUNDED VESICULAR LUMPS WITH DARK GREEN MATRIX. ASSEMBLAGE IS OLIGOCLASE-ALBITE-AUGITE-CHLORITE-CALCITE-IRON ORE MINERAL, WITH INTERSERTAL TEXTURE. CALCITE AND CHLORITISED ?EPIDOTE FILL VEINS AND VESICLES.	DARK GREENISH GRAY, GREENISH BLACK	8405'4"-5"	ALTERED ANDESITE	A A A		ALTERED BASIC AGGLOMERATE. BOMBS PROBABLY STILL PARTLY FLUID ON IMPACT. AUTHIGENIC CHLORITE, CALCITE, ALBITE.
				8406' (T.D.)							

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