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Record No. 1968 / 81

Petrological Study of Kurrajong Heights (A.O.G. / Exoil) No. 1 Well, Sydney Basin, New South Wales

by

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ABSTRACT

The petrological study of Kurrajong Heights (A.O.G./Exoil) No. 1 Well is part of a review of the Sydney Basin being conducted by the Basin Study Group of the Petroleum Exploration Branch, Bureau of Mineral Resources. The main objectives of this study are to delineate and define clearly-recognisable lithostratigraphic units and to reassess the petroleum prospects of the basin.

The stratigraphic succession can be broadly divided into a Triassic sandstone sequence to 2,875' (which is subdivided into 3 major lithogenetic units incorporating 7 lithostratigraphic units), a Permian coal measures sequence from 2,875' to 4,560' (subdivided into 3 major lithogenetic units incorporating 4 lithostratigraphic units), a Permian marine sequence from 4,560' to 7,870' (subdivided into 3 major lithogenetic units incorporating 7 lithostratigraphic units), and a Permian and/or Carboniferous basal volcanic sequence from 7,870' to Total Depth of 9,132' (subdivided into 2 major and 4 minor rock units).

Porosities in the Triassic sequence range from "good" to "poor" but measured permeabilities are generally low. Porosities in the Permian sequences are mostly "slight" to "poor" and measured permeabilities are negligible; an exception may be the coarse grained protoquartzites near the middle of the Permian marine sequence. Visual estimates of porosity in the protoquartzites range to about 10%, despite the presence of some cement; estimates or determinations of permeabilities were unattainable because of lack of core, and non-definitive wireline logs.

GENERAL INFORMATION

Major References Used in Present Study

Australian Oil and Gas Corporation Limited, 1962 - Well completion report 0' - 4,756', Kurrajong Heights No. 1 Well, Sydney Basin, N.S.W., by J. Stuntz (unpubl.).

Exoil (N.S.W.) Pty. Ltd., 1963 - Well completion report, Kurrajong Heights No. 1, New South Wales, by J. Stuntz, R.G. Perry, and E.A. Webb, (unpubl.).

Summary of Exoil (N.S.W.) Pty. Ltd. (1963)

"Kurrajong Heights No. 1 is located in the central western part of the Sydney Basin in New South Wales. In 1955 the well was drilled, by Australian Oil and Gas Corporation Limited, to 4,756 feet where drilling was suspended. In 1962 Exoil N.L., under a farm-out agreement with Australian Oil and Gas Corporation Limited, deepened the well to a total depth of 9,132 feet . . . . .

Kurrajong Heights No. 1 drilled 2,915 feet of Triassic sediments, predominantly sandstone, and 4,950 feet of Permian sediments. The Permian sediments are chiefly sandy siltstone and sandy shale. These sediments are correlative with the "Upper Coal Measures" and the "Upper Marine Series". Equivalents of the "Lower Coal Measures" if present, were not recognized in the well. The Permian sediments are underlain by a thick sequence of lavas of doubtful age. The well was abandoned after drilling, 1,267 feet of the lavas without reaching their base.

Porous sands are present in the Triassic strata but were not found in the Permian. No significant shows of oil or gas were recorded".

Well Data

Well Name, No.:	Kurrajong Heights (A.O.G./Exoil) No. 1.
Operating Companies:	Australian Oil and Gas Corporation Limited* (1955) Exoil (N.S.W.) Pty. Ltd.* (1962)

* Henceforth abbreviated to A.O.G. and Exoil, respectively.

Location: Lat. 33° 31' 45"S, Long. 150° 37' 15" E.
42 miles northwest of Sydney, SI/56-5

1:250,000 sheet: Sydney.

Elevation: Ground level: 1,863.5', a.s.l.
Kelly bushing: 1,879' a.s.l. (datum).

Depth on 2/8/1955 (suspended): 4,756'.

Total depth on 25/11/1962 (abandoned): 9,132' (Driller)
9,130' (Schlumberger).

Logs Run: By A.O.G. in 1955 - S.P./Resistivity
Run 1: 3,253' - 720'
Run 2: 4,755' - 3,250'

By Schlumberger in 1962 - S.P./Resistivity
Run 1: 2,292' - 642'
Run 2: 6,791' - 2292'
Run 3: 9,129' - 6,791'
Caliper:
3,742' - 642'
Microlog:
Run 1: 6,789' - 2,164'
Run 2: 9,127' - 6,789'
Gamma Ray:
9,128' - 20'
Temperature:
1,874' - 84'

Formation Testing (Open Hole Drill Stem Tests):

No. 1: 1,046' - 1,081'; misrun.
No. 1A:1,046' - 1,081'; misrun.
No. 2: 1,067' - 1,102'; no recovery.
No. 3: 2,080' - 2,111'; misrun.
No. 3A:2,080' - 2,111'; 7' fresh muddy water recovered.
No. 4: 2,892' - 2,923; misrun.
No. 4A:2,892' - 2,923'; 4' mud recovered.
No. 5: 3,343' - 3,375'; 10' mud recovered.
No. 6: 3,977' - 4,000'; misrun.
No. 7: 3,964' - 4,000'; 5' mud recovered.
No. 8: 4,179' - 4,199'; 10' mud recovered.
No. 9: 7,945' - 7,997'; 4,800' slightly gas cut mud recovered.

Hydrocarbon Shows: Insignificant.

Summary of Well History

Oil Drilling and Exploration Limited commenced drilling Kurrajong Heights No. 1 for A.O.G. on 11th February, 1955, using a National Ideal Rotary 55 plant. The top hole was drilled at 12¼" diameter and reamed to 17½" diameter, in stages, down to 709', during which time numerous circulation losses occurred. 13⅜" casing was set and cemented at 681.5' and circulation was temporarily regained. Drilling resumed at 8¾" diameter which was carried to 1,060.5'; during this stage the bottom joint of the 13⅜" casing became detached at 642' and dropped to a seat at 705'. Circulation was again lost but regained by further cementation jobs on the 13⅜" casing and by reaming to 12¼" down to 750' and setting a temporary 9 5/8" casing at this depth. Drilling of the 8¾" hole was continued to 3,253 at which depth S.P./Resistivity logs were run from 3,253' to 720'. Drilling was completed by deepening the 8¾" hole to 4,756'; S.P./Resistivity logs were run from 4,755' to 3,250'. The well was suspended at 4,756' on 2nd August, 1955. The results of coring and drill stem tests during these stages of drilling are given elsewhere in this report.

Using the same rig, Oil Drilling and Exploration Limited resumed drilling Kurrajong Heights No.1 for Exoil on 23rd July, 1962. The temporary 9 5/8" casing was pulled and the old 8¾" hole reamed to 12¼" to a depth of 2,175'. At this stage, 3rd August, Schlumberger ran S.P./Resistivity logs from 2,292' to 642' and a Caliper log from 3,742' to 642'. 9 5/8" casing was set at 2,164' with backoff and recovery above 575'; the 8¾" hole was then deepened from 4,756' to 6,800' and Schlumberger ran S.P./Resistivity logs from 6,791' to 2,292' and a Microlog from 6,789' to 2,164' on 29th September. Drilling was completed to total depth by deepening the 8¾" hole from 6,800' to 9,132'. Final wireline logging by Schlumberger was undertaken on 22nd November when S.P./Resistivity logs were run from 9,129' to 6,791', along with a Microlog from 9,127' to 6,789' and a Gamma Ray log from 9,128' to 20'. Kurrajong Heights No. 1 was abandoned on 25th November, 1962. The results of coring and the drill stem test are noted elsewhere in this report.

Material Available for Study

Cuttings were collected at 5' intervals except for the top 740', over which they were collected at 10' intervals whenever circulation was attained (see Well Log, Plate 1).

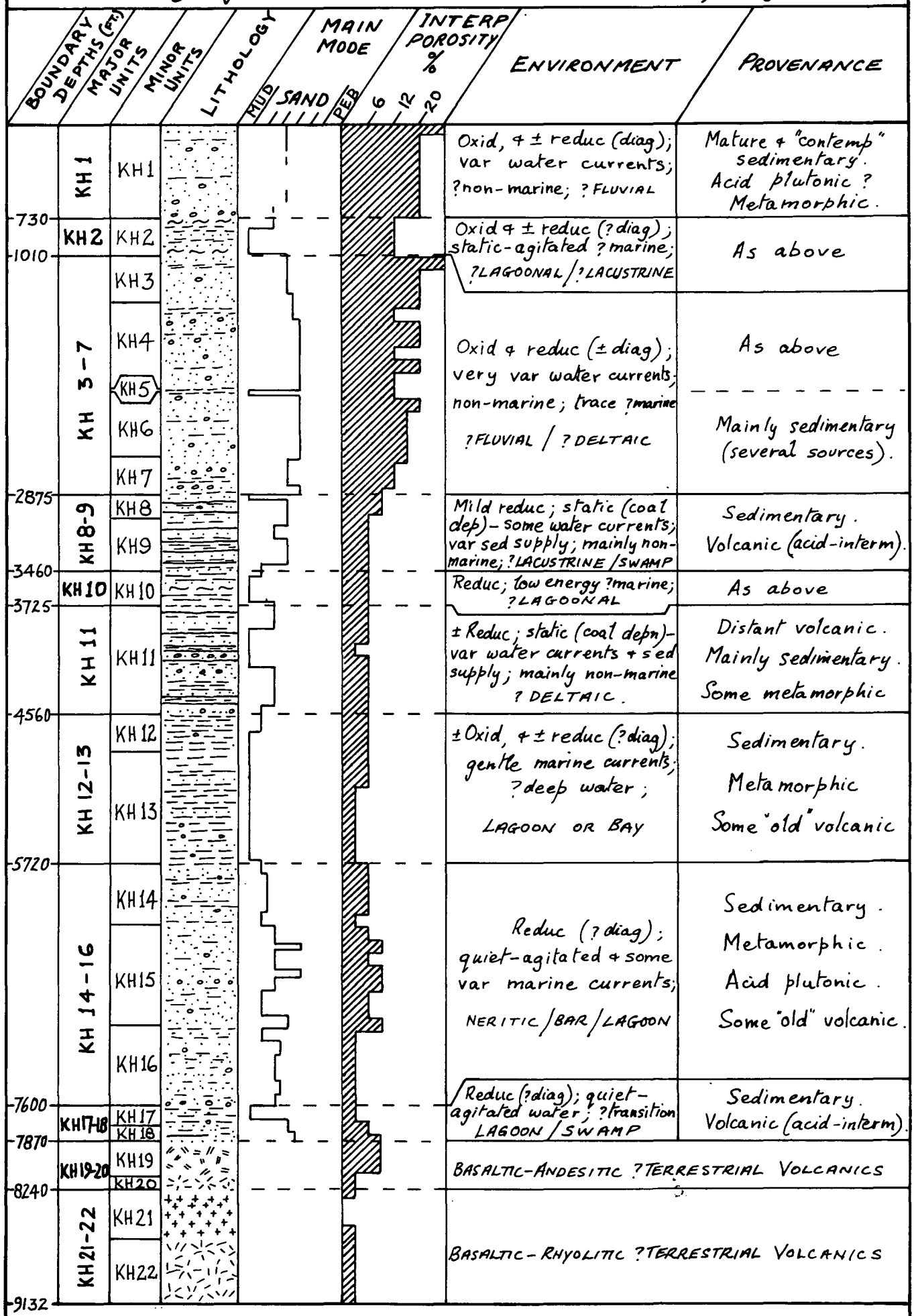
Thirty-six cores were cut over a total footage of 325'; 233' were recovered giving a 72 percent total recovery. Only cores 34 to 36 (9,125' - 9,132') failed to give any recovery (see Appendix 1, page 4).

KURRAJONG HEIGHTS (A.O.G./EXOIL) NO. 1

Fig. 1

Summary of Results

Scale: 1 inch = 1,000 feet



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Wireline logging was carried out in 1955 and 1962 (see above). Since the later Schlumberger logs compare favourably with the original logs run in the old hole, it was decided to use only the Schlumberger ones in compilation of the Well Log (see Plates 1 to 5); this maintained log continuity and avoided awkward scale changes.

Methods Used and Other Information

The results of binocular microscope examination of cuttings were plotted on a 4" = 100' log along with information gained from thin sections of 100 cuttings samples. These data were summarised and replotted on the final logs, at a scale of 1" = 100', which in turn were photographically reduced to 1" = 200' (Plates 1 to 5). All material recovered from coring was slabbed and examined by binocular microscope; 55 thin sections of cores were also studied. This information, as well as that obtained from porosity and permeability determinations, was compiled in table form and is presented in Appendix 1.

Textural nomenclature used in this study broadly follows that suggested by Folk (1954) except that the sand/muddy sand boundary is raised from 10% mud to 15% mud; to conform to the 15% boundary in Pettijohn's (1957) genetic-compositional classification (which has been applied to the microscopically examined sandstones). Although Pettijohn's genetic-compositional scheme is followed, for the sake of uniformity of presentation in this series of well studies, it should be stressed that the terminology is applied only in a compositional sense. A slight modification is introduced in that the large fields covered by the terms subgreywacke and arkose are roughly divided into quartzose (Q), lithic (L) and feldspathic (F) subfields, for example, (Q), (L) or (F) subgreywacke, etc.

Abbreviations are used commonly on the cuttings description column of the Well Logs and are mostly self-explanatory; the term "carbonated" is used to avoid the longer "carbonate cemented" qualifier where more than one cement is present.

The stratigraphic section as revealed by Kurrajong Heights No. 1 Well is subdivided into 22 lithostratigraphic units which are prefixed by the letters KH for identification purposes in later correlation work. In turn, these 22 units are grouped into 11 interpretative lithogenetic units (see Fig. 1).

LITHOSTRATIGRAPHY

UNIT KH1 (Plate 1)

Characteristics: Unit KH1 is 714.5' thick and consists of poorly sorted, medium grained, and in places pebbly, orthoquartzite and protoquartzite, with oligomict and polymict pebble and cobble conglomerate near the bottom. Thin grey mudstone and claystone layers occur irregularly throughout. Judging from evidence obtained from Cores 1 to 5, bedding is mostly massive with occassional grain size layering and steep cross-bedding. Significant accessory components in the sediment include iron oxide, graphite and rutile grains, and iron oxide and some siderite cement. Despite some clay matrix and various cements, including silica, porosities are generally "moderate" to "good"; this may be due to groundwater leaching.

Provenance and Environment: (see also descriptions of Cores 1 to 5, Appendix 1). Clasts consist of abundant subrounded to rounded quartz and other quartzose material, red, brown and rare green argillaceous lithics, and rare schist. These and other data indicate mature and possibly contemporaneous sedimentary sources. The presence of iron oxide as detrital or authigenic material, or both, suggests deposition under oxidizing conditions, and the occurrence of siderite cement indicates reduction, possibly on diagenesis. All the above information points to subaqueous deposition of the sediment by currents with very variable velocities; these conditions might be expected in a fluvial environment.

UNIT KH2 (Plate 1)

Characteristics: Unit KH2 is 280' thick and is made up of laminated sideritic, and some chloritic, siltstone to muddy very fine grained (Q) subgreywacke, and more or less clayey, slightly pebbly, fine grained orthoquartzite to protoquartzite. Judging from the gamma ray log over this interval, these lithologies are thickly interbedded. Near the top and bottom of the unit, the siltstone is interlaminated with subordinate red and green claystone grading to mudstone. In places the siltstone contains plant fragments, more or less replaced by limonite or siderite. Limonitic and sideritic concretions, some of which contain calcite cores, are common throughout much of the argillaceous sediment. Significant minerals present include authigenic and possibly detrital chlorite, iron ore, graphite and rutile grains, and iron oxide, siderite and silica cements. Because of these cements the clean and well sorted sandstones have only "moderate" porosities.

Boundary Criteria: The upper boundary of unit KH2 has been placed at a level of textural discontinuity in the succession. An abrupt increase of about 30 API units in the mean gamma ray count occurs at this level as the log is traced from unit KH1 into KH2.

Provenance and Environment: The composition of the clastic material in these sediments differs little from that in unit KH1, therefore, similar provenances can be inferred. However, there is an apparent marked change in factors indicative of the depositional environment. The texturally mature sandstone and the laminated argillaceous sediment suggest deposition in agitated and quiet water, respectively. Oxidizing conditions were probably followed by reduction on diagenesis, and if the authigenic chlorite can be regarded as indicative of marine deposition, then an open lagooonal situation can be inferred, otherwise, deposition may have been lacustrine, judging by the apparent lack of marine fossils.

UNITS KH 3-7 (Plates 1 & 2)

The five units comprising this major interval 1,865' thick are grouped together because of similar attributes, mainly textural, which indicate a rather uniform depositional environment. A gradational compositional change takes place near the middle of this stratigraphic sequence and probably reflects changes in provenance, but this had little apparent influence on the environment of deposition (see also descriptions of Cores 7 to 11, Appendix 1).

UNIT KH3

Characteristics: Unit KH3 is 370' thick and consists of very thinly interbedded fine and coarse grained, in places slightly clayey and pebbly, orthoquartzite grading to protoquartzite, containing, in the upper part, minor interbeds of more or less sandy siltstone which grades to laminated mudstone and to muddy very fine grained orthoquartzite. Cores 7 to 8 show that the arenaceous sediment is, at least in part, massive and cross-bedded, with some undulose and textural layering. Significant accessory components include iron oxide, graphite and rutile grains, and small amounts of iron oxide and siderite cements. Porosities and permeabilities in the sandstone are "moderate" to "good" (refer Core 8, Appendix 1).

Boundary Criteria: Besides the textural discontinuity between this and the overlying unit KH2, there is an abrupt decrease of about 40 API units in the mean gamma ray count as the log is traced from unit KH2 into KH3. A massive sandstone at the top of KH3 is inferred from the strong, temporary negative deflection of the S.P. log and a temporary low lateral resistivity reading; this interval was one of lost circulation during drilling.

Provenance and Environment: The composition of the sediments is very similar to that of unit KH1, therefore, provenances were alike. Oxidizing conditions during deposition, and reduction possibly during diagenesis, can be interpreted from the presence of detrital and authigenic iron oxide and siderite. Variable sorting and grain size, and the existence of cross-bedding, suggests fluvial deposition by currents with changing velocities.

UNIT KH4

Characteristics: Unit KH4 consists of 670' of medium grained protoquartzite and orthoquartzite, which is slightly pebbly to pebbly (particularly in the upper half), and minor thick interbeds (again, mainly in the upper half) of sandy siltstone grading to carbonaceous mudstone and muddy very fine grained (Q) subgreywacke. Core 9 (orthoquartzite) is pebbly in places, massive and cross-bedded, with some textural layering; pressure welding of quartz grains is evident. The argillaceous sediment contains traces of green coloured pellets (? "glauconitic") and chlorite. Other significant accessory components include traces of pyrite throughout and minute quantities of iron oxide and graphite near the top; minor amounts of siderite cement and overgrowth silica occur towards the bottom and top of the unit, respectively. Sandstone porosities are "moderate".

Boundary Criteria: The boundary between units KH3 and KH4 is not marked by any notable events on the wireline logs, but the increase in the amount of pebbles and the more uniform modal grain size of the sandstones below this level constitute sufficient textural change to validate its delineation. Also, only traces of iron oxide and graphite grains exist, and rutile is absent, below this boundary.

Provenance and Environment: Clasts consist of subrounded to rounded quartzose material, including a minute trace of green coloured chert near the base, and coloured, soft argillaceous lithics. This, and other information, suggest mainly mature and possibly contemporaneous sedimentary provenances. The environment of deposition must be considered similar to that of the fluvial unit KH3, but in addition the presence of possible "glauconite" and chlorite in some of the

argillaceous beds indicates the contingency of a marine influence. In this case, a deltaic environment might be suggested.

UNIT KH5

Unit KH5 is 20' thick and composed of green and red, chloritic and sideritic sandy mudstone. The silt and sand grade material consists of quartz, quartzite, chert and minor claystone lithics, and the matrix of sericitic and chloritic (authigenic) clay. Siderite spherules are common in places and many of these have hematite or limonite cores. The unit is well marked by deflections on all the wireline logs.

UNIT KH6

Characteristics: This unit consists of 505' of medium and very coarse grained protoquartzite, which is slightly pebbly in places, and sparse thin beds of sandy siltstone and muddy very fine grained protoquartzite. Core 10 shows bedding of variable thickness, some cross-bedding and undulose, textural layering. Significant accessory minerals include traces of pyrite and iron oxide grains, with small amounts of silica, iron oxide and siderite cements. Sandstone porosities are "moderate". Conspicuous quantities of coloured chert pebbles and sand grains are also characteristic of the unit.

Boundary Criteria: Should the mudstone unit KH5 be absent in any stratigraphic section, the upper boundary of an equivalent unit KH6 might be difficult to delineate. Textural and wireline log differences between units KH6 and KH4 are slight but the abrupt upward decrease of coloured chert fragments near this level could constitute a sufficiently evident marker to validate delineation of a boundary.

Provenance and Environment: Clasts consist of subrounded quartz, minor but conspicuous green red and yellow chert, quartzite and coloured, soft argillaceous lithics. Provenances were comparable to those supplying detritus for unit KH4 sediments but an additional source of unknown type supplied the coloured chert. The environment of deposition was very similar to that of unit KH4 but without the possible marine influence.

UNIT KH7

Characteristics: Unit KH7 is 300' thick and is made up of more or less medium grained, in places pebbly, carbonate cemented protoquartzite grading to (Q) subgreywacke, with subordinate thick and thin interbeds of muddy very fine grained protoquartzite and argillaceous sediment. Core 11 shows thin to possible massive bedding, cross-bedding, and textural and colour banding. Significant accessory components include traces of iron oxide and pyrite grains, and green coloured (? "glauconite") pellets; cementing material is mainly siderite, with some calcite and dolomite, and a trace of dawsonite (for mineralogical notes see Nicholas, 1968). Porosities of the sandstone are "poor" to "moderate". Clastic grains in these sediments consist of quartz, abundant coloured chert, coloured argillaceous lithics and minor quartzite.

Boundary Criteria: There is an increase in the amount of coloured chert and sedimentary lithics, as well as a slight textural change, below the level taken as the upper boundary of unit KH7. Moreover, calcite, dolomite and dawsonite cements have not been observed in sediments above this boundary. An increase in the mean gamma ray count occurs as the log is traced from unit KH6 into KH7, and throughout unit KH7 the log shows large scale deflections.

Provenance and Environment: Provenances can be considered the same as those noted for the sediments of unit KH6. The environment of deposition was similar to that of most of the other units of the major interval KH 3-7, that is fluvial with a periodic, small marine influence (deltaic). In the case of unit KH7 a minor marine influence is suggested by the occurrence of green ? "glauconite" pellets and the sodium and aluminium carbonate, dawsonite. The latter is thought indicative of restricted waters with high soda concentrations.

UNITS KH8-9 (Plate 2)

Units KH8 and KH9 are grouped lithogenetically because both units contain coal seams. This major unit is 585' thick and extends from 2,875' to 3,460'. An abrupt compositional change exists within the interval but the environment of deposition apparently remained constant throughout (see also descriptions of Cores 12 and 13, Appendix 1).

UNIT KH8

Characteristics: Unit KH8 is 180' thick. Slightly more than half the section comprises sideritic, fine to medium grained, in places clayey and pebbly, (Q) subgreywacke; the remainder consists of thick beds of laminated, carbonaceous, argillaceous sediment grading to muddy very fine grained subgreywacke in which are two coal seams. The position of the seams is indicated by the good correlation of two very low gamma ray deflections with two very high resistivity readings. Core 12 consists mainly of pebbly (Q) subgreywacke; it is massive bedded and shows some crude textural layering. Pyrite grains and rare green ? "glauconite" pellets occur in sediments of the unit and cements include common siderite and some dolomite and dawsonite. Sandstone porosities are mostly "poor".

Boundary Criteria: The upper boundary of KH8 has been placed at the top of the uppermost, typically carbonaceous, mudstone bed of the unit, which is about 40' above the top coal seam. Below this boundary there is a marked increase in the quantity of argillaceous lithics in the sediments. There are large fluctuations on the resistivity logs throughout unit KH8; these cease abruptly as the logs are traced from KH8 into KH7.

Provenance and Environment: Clasts consist of abundant subangular to rounded sedimentary lithics and coloured chert, minor quartzite and a trace of volcanic lithics and feldspar. Sedimentation took place under possibly reducing conditions in a subaqueous, low energy environment; periods of abundant supply of detritus alternated with at least two static or quiescent periods during which abundant vegetable matter accumulated. This situation can be considered typical of a lacustrine or swamp environment; however, the presence of ? "glauconite" pellets and dawsonite suggests possible marine incursions.

UNIT KH9

Characteristics: Unit KH9 consists of 405' of laminated and carbonaceous argillaceous sediment (very fine tuffite in part) containing coal seams; in places there are beds of sideritic, fine and medium grained (L) and (F) subgreywacke (tuffite in part) and lithic greywacke. Core 13 (L) subgreywacke is thinly bedded and contains subordinate laminated and micro cross-bedded, carbonaceous mudstone grading to siltstone. Significant accessory components include rare ? "glauconite" pellets and abundant silica and siderite cements in places, with minor amounts of calcite, dolomite and possible zeolite. A cuttings sample of highly silicified sediment from 3,355' was submitted for X-ray diffraction

examination at B.M.R. and this showed it to be composed of quartz and illite. Characteristic detritus in these sediments are abundant volcanic lithics and plagioclase.

Boundary Criteria: Delineation of the upper boundary of unit KH9 was mainly deduced from a compositional change although its exact position was based on a local textural discontinuity.

Provenance and Environment: Clasts consist of abundant subangular to subrounded dacitic to andesitic volcanic lithics, plagioclase (oligoclase to andesine), volcanic quartz and shards (all of which suddenly decrease in quantity near the top of the unit), argillaceous lithics, and minor chert (some coloured) and quartzite. Besides sedimentary and "chert" sources, an eruptive volcanic centre existed close to the site of deposition. The environment of deposition was very similar to that of unit KH8, that is, lacustrine or swamp, with possible marine incursions.

UNIT KH 10 (Plates 2 & 3)

Characteristics: This major unit is 265' thick and composed of carbonaceous mudstone grading to claystone; in places the sediment is thinly interbedded with subordinate very fine grained (L) and (F) subgreywacke and siltstone (fine tuffite in part). Core 14 is a chloritic and sideritic carbonaceous claystone which is massive to faintly laminated and contains carbonized plant fragments. Significant accessory minerals include ? "glauconite" pellets and ? authigenic chlorite, and silica, siderite and minor calcite and dolomite cements.

Boundary Criteria: Unit KH 10 is predominantly argillaceous; the textural change at 3,460' is distinct on all wireline logs.

Provenance and Environment (see also description of Core 14, Appendix 1): The composition of these beds is similar to that of unit KH9 sediments but volcanic detritus is less abundant. The environment of deposition was one of low energy with reducing conditions at least on diagenesis. Authigenic minerals thought indicative of marine deposition are present; and although marine fossils have not been noted, it is possible that sedimentation took place in a restricted lagoonal environment.

UNIT KH 11 (Plate 3)

Characteristics: Unit KH 11 is 835' thick and consists of interbedded carbonaceous argillaceous sediment and muddy very fine grained subgreywacke, which contains 10 evenly spaced coal seams, with numerous beds of slightly pebbly to pebbly and clayey, fine to medium grained subgreywacke and (Q) grading to (L) arkose, the beds becoming very thick down section; polymict and oligomict conglomerate occurs near the middle of the unit. Most of these sediments contain variable quantities of detrital feldspars, mainly oligoclase. Core 15 consists of faintly laminated mudstone containg plant fragments, and Core 16 of massive and cross-bedded, pebbly, medium grained (Q) subgreywacke. Significant accessory components include traces of pyrite, ? "glauconite" and iron oxide grains, and cements include siderite, dawsonite and other carbonates. The occurrence of dawsonite in Kurrajong Heights No. 1 Well was originally verified by X-ray diffraction examination at B.M.R. on material taken from Core 16. Sandstone porosities are mainly "slight" to "poor".

Boundary Criteria: The upper boundary of unit KH 11 has been placed at a level of textural discontinuity which is well marked on the resistivity logs by sudden alternations of very high and low resistivity deflections as the logs are traced from unit KH 10 into KH 11. A corresponding drop in the mean gamma ray count also occurs.

Provenance and Environment (see also descriptions of Cores 15 and 16, Appendix 1): Clasts consist of subangular to subrounded quartzose material, argillaceous lithics, feldspar, minor altered volcanic lithics (which increase in abundance towards the top) and schist. Provenances were mainly sedimentary, some metamorphic, with a possible distant centre of volcanism. The presence of iron oxide grains in some of the sediment indicates occasional oxidizing conditions during deposition; pyrite and siderite indicate reducing conditions at least on diagenesis. The occurrence of coal seams, cross-bedding and widely varying grain sizes and degrees of sorting, suggest that quiet subaqueous conditions alternated with periods of rapid accumulation of detritus borne by currents with varying velocities. The environment of deposition may have varied from fluvial and lacustrine to swamp, with rare marine incursions. These conditions give a broad picture of a deltaic environment.

UNITS KH 12 -13 (Plates 3 & 4)

The marine units KH 12 and KH 13 are predominantly argillaceous and are grouped together because of lithogenetic similarities. This major unit extends from 4,560' down to 5,720' and is 1,160' thick (see also descriptions of Cores 17 to 21, Appendix 1).

UNIT KH 12

Characteristics: Unit KH 12 is 310' thick and consists of interlaminated micaceous, carbonaceous siltstone and muddy very fine grained (Q) subgreywacke; rare very fine pebbles of quartz are scattered throughout. Cores 17 and 18 reveal laminated bedding, micro cross-bedding and, in places, a bedding surface fissility. Some of the micro cross-beds appear distorted; these and other similar features, possibly genetically related, have been termed scallop structures; they are not thought to be of organic origin (see also Alcock, 1968). Laminated bedding shows evidence of disturbance and lithological mixing in places; these features could be of organic origin and might be the result of bioturbation. Fossils present include plant fragments, worm-tubes, foraminifera (see Appendix 3, A.O.G., 1962), and ? brachiopod spines and fragments. Significant accessory minerals are pyrite and chlorite, and cements are mainly calcite and dolomite, with some siderite and anhydrite.

Boundary Criteria: Delineation of the upper boundary of unit KH 12 is based on the textural discontinuity at 4,560'. Compositionally, it marks the level above which there is an increase in the quantity of plagioclase and argillaceous lithics and an abrupt decrease in abundance of detrital and authigenic muscovite, biotite, chlorite and sericite. Furthermore, there are significant changes in most of the wireline logs as they are traced from unit KH 11 into KH 12.

Provenance and Environment: Clastic material consists of quartz, with some plagioclase and argillaceous lithics, and a trace of altered volcanic lithics, quartzite and chert. Provenances were therefore composed mainly of sedimentary and volcanic rocks. Sedimentation took place in a restricted marine, possibly deep lagoonal or gulf, environment with detritus being carried by gentle but steady bottom currents.

UNIT KH 13

Characteristics: Unit KH 13 is 850' thick and composed of thick interbeds of carbonaceous siltstone with minor laminae of muddy very fine grained subgreywacke, mudstone to sandy siltstone, and medium to coarse grained carbonate cemented (Q) subgreywacke; all lithologies are slightly pebbly in the lower half of the section. Cores 19 to 21 are massive bedded and show faint undulose laminations, some lithological mixing, micro cross-bedding and scallop structures; worm-tubes, foraminifera, brachiopod fragments and ? crinoid plates have been noted. Accessory minerals include chlorite and pyrite grains, and cements are mainly siderite with some calcite, silica, dolomite and anhydrite. Sandstone porosities are "slight" to "poor".

Boundary Criteria: The upper boundary of unit KH 13 is a level of textural discontinuity and to a lesser extent, compositional change. Below the boundary arenaceous sediment is more abundant (but still subordinate to the argillaceous lithologies), there is a greater variety of lithologies, and schist fragments are more conspicuous than above the boundary. Resistivities increase and the mean gamma ray count shows a corresponding decrease as the logs are traced from unit KH 12 into KH 13.

Provenance and Environment: Clasts consist of angular to subrounded quartz, argillaceous lithics (including mudstone pellets in places), some altered volcanic lithics, plagioclase and schist, and a trace of quartzite and chert. Provenances appear to have been composed mainly of sedimentary (in part possibly contemporaneous), volcanic and metamorphic rocks. The environment of deposition was very similar to that noted for unit KH 12, but the occurrence of moderately well sorted (Q) subgreywacke and scattered pebbles, in places in unit KH 13, suggest that at times the depositional interface was closer to shore, and perhaps nearer wave-base, than was the case in unit KH 12.

UNITS KH 14-16 (Plate 4)

The major unit KH 14-16 is made up of various complexly related marine lithologies too numerous to define individually, but broadly the interval consists predominantly of arenaceous sediments and is therefore texturally distinct from the overlying major unit KH 12-13. Environments of deposition were also somewhat variable, but here again, in a broad sense they can be regarded as neritic. The interval is 1880' thick, extending from 5,720' to 7,600' (see also descriptions of Cores 22 to 27, Appendix 1).

UNIT KH 14

Characteristics: Unit KH 14 is 480' thick. About half the section is composed of thinly interbedded fine and coarse grained muddy (Q) subgreywacke, one third of interlaminated very fine grained (Q) subgreywacke and siltstone, and the remainder consists of muddy very fine grained (Q) subgreywacke. These lithologies, which are more or less carbonaceous and micaceous, occur in a number of thick distinct sequences, throughout which are some scattered pebbles and rare cobbles. Cores 22 and 23 show bedding ranging from thin to laminated, with some lithological mixing, scallop structures and micro cross-bedding; fossils include brachiopod fragments, horizontal and large vertical worm-tubes. Important accessory minerals include chlorite, ? "glauconite" and pyrite grains, and cements are mainly siderite and calcite. Sandstone porosities are only "slight" to "poor" despite good permeability indicated by positive separation on the micro-resistivity logs opposite some of the sands; judging from microcaliper readings, the anomalies may be due to excessive caving along these intervals.

Boundary Criteria: The textural change at 5,720' is taken as the upper boundary of KH 14; grain size increases and the degree of sorting decreases below this level. There are no significant changes on the wireline logs.

Provenance and Environment: Clasts are composed of subangular quartz, chert and metamorphic rock, and minor argillaceous sediment, altered volcanic rock and plagioclase. Sedimentation took place below wave-base in a reducing marine environment, in which bottom currents operated with varying velocities. The occurrence of rare cobbles points to ice-rafting and possible nearby glaciation.

KH 15

Characteristics: Unit KH 15 is 785' thick, about half of which consists of interbedded fine and coarse grained muddy protoquartzite grading to (Q) subgreywacke, one fifth of fine grained (Q) subgreywacke, and a further one fifth of carbonaceous and micaceous argillaceous sediment; the remainder consists of coarse grained carbonate cemented protoquartzite. The latter occurs in at least three distinct subunits up to 40' thick, and the other lithologies occur in even thicker sequences. In places, pebbles are concentrated in layers but they are also scattered throughout all lithologies. Cores 24 and 25 are massive with some crude textural layering; the fine grained parts of Core 25 are laminated and micro cross-bedded. Fossils found in the cores include large thick-shelled brachiopod fragments, horizontal and vertical worm-tubes and carbonized plant fragments.

Accessory minerals include rutile and pyrite grains, with siderite, calcite and rare dawsonite cements; some silica occurs as overgrowths in the coarse grained sediment. Sandstone porosities in this unit are higher than in any other below unit KH 7, the base of which is at 2,875'; cuttings of the coarse grained cemented protoquartzite show that porosities are "poor", possibly ranging up to 10%.

Boundary Criteria: Unit KH 15 is delineated on the basis of the distinct lithologies present, namely the massive subunits of coarse grained protoquartzite. Compositionally, the unit is marked by an abundance of mainly unstrained quartz grains some of which contain inclusions. The upper boundary is difficult to define precisely but it has been placed at 6,200' where an abrupt decrease in the mean gamma ray count occurs as the log passes from unit KH 14 into KH 15.

Provenance and Environment: Clasts consist of subangular to subrounded grains of quartz, quartzite, chert and argillaceous lithics, and minor schist and feldspar. Provenances composed of sedimentary, metamorphic and acid plutonic rocks are indicated. Deposition took place in marine waters with reducing conditions at least on diagenesis. Fragmentary thick-shelled fossils, sorting ranging from poor to good, large grain size variations and differing bedding characteristics suggest an environment in which energy conditions varied. Unfortunately no cores were cut in any of the protoquartzite subunits, but they might represent offshore bar developments.

UNIT KH 16

Characteristics: Unit KH 16 is 615' thick, half of which consists of interlaminated argillaceous sediment and fine grained (Q) subgreywacke, one third of fine and coarse grained (Q) subgreywacke, and the remainder of interbedded, coarse siltstone and very fine grained (Q) subgreywacke grading to protoquartzite; scattered pebbles occur throughout and a pebbly coarse grained quartzose sandstone is present at the base of the unit. The argillaceous sediment is carbonaceous and pyritic. Cores 26 to 27 are massive, faintly laminated and show some lithological mixing; vertical and horizontal worm-tubes, ? brachiopod fragments, and pyritic, carbonized plant fragments are noticeable. Significant accessory minerals include pyrite and rutile grains and a trace of ?"glauconite" pellets; cements are mainly calcite and siderite with a trace of dolomite and dawsonite. Sandstone porosities are "slight".

Boundary Criteria: The upper boundary of unit KH 16 is placed at the base of the lowermost coarse grained protoquartzite of unit KH 15; the quantity of quartzose material in the sediment diminishes below this level. The boundary is otherwise ill-defined and not very apparent on the wireline logs.

Provenance and Environment: Provenances and the environment of deposition were similar to those noted for unit KH ~~16~~ 15, with the exception that the possible offshore bars are absent.

UNITS KH 17-18 (Plates 4 & 5)

The basal sedimentary units KH 17-18 are lithogenetically distinct from higher units because of the presence of at least one coal seam, well sorted sands, and a fossil assemblage different to those noted higher in the succession. This major unit is 270' thick and extends from 7,600' down to the base of the sedimentary succession at 7,870' (see also descriptions of Cores 28 and 29, Appendix 1).

UNIT KH 17

Characteristics: The unit is 155' thick and consists of slightly sandy, highly carbonaceous and pyritic mudstone, in places very thinly interlaminated with muddy very fine grained sideritic (Q) subgreywacke; rare siliceous pebbles occur throughout. The mudstone of Core 28 is massive but faintly laminated and, in places, fissile. It contains glendonites, small pelecypods (indentified by J.M. Dickins of B.M.R. as belonging to the genera Glyptoleda and Nuculopsis), worm-jaws or scolecodonts of the Prionognatha type (P. Jones, pers. comm.), and other unidentifiable fossil fragments.

Boundary Criteria: The upper boundary of unit KH 17 is a textural discontinuity which is not, however, well marked on the wireline logs.

Provenance and Environment: Clasts consist of quartzose material, argillaceous lithics and some plagioclase. Sedimentation probably took place in a restricted, very low energy lagoonal environment. If this was the case, the presence of pebbles in the sediment is anomalous and may indicate glaciation.

UNIT KH 18

Characteristics: Unit KH 18 is 115' thick and composed of medium grained carbonate cemented (Q) subgreywacke grading to (Q) arkose, carbonaceous and pyritic mudstone grading to siltstone, and at least one very thin coal seam. Core 29 is composed of thick and faintly laminated thin beds of well sorted sandstone and mudstone; the latter contains carbonized plant fragments. Sandstone porosities are "poor" and may even range to "moderate" in places.

Boundary Criteria: The upper boundary of unit KH 18 is placed at a level of textural change, below which on the wireline logs, there is a corresponding decrease in the mean gamma ray count and a gradual decrease in normal and lateral resistivities.

Provenance and Environment: Clasts consist of quartz, sedimentary lithics, plagioclase and minor quartzite and chert. Detritus appears to have been deposited under reducing conditions and in alternately quiet and agitated water. As there is no evidence of marine deposition, the environment may have been transitional between lacustrine conditions and the lagoonal conditions of unit KH 17.

UNITS KH 19-20 (Plate 5)

The major interval KH 19-20 is 370' thick and consists of basaltic lavas at the base, ranging to andesitic volcanic rocks at the top; it may represent part of a cycle of ? terrestrial igneous activity. The interval extends from 7,870' to 8,240' (see also descriptions of Cores 30 and 31, Appendix 1).

UNIT KH 19

The unit is 290' thick and composed of massive, greenish grey to brown, welded or porphyritic andesite agglomerate, breccia and vesicular to amygdaloidal lava; the amygdales contain calcite or penninite. The rocks are calcite, chlorite and iron-ore rich, and contain xenoliths of metamorphosed sediment and volcanic rock. The upper boundary of the unit makes sharp contact with the sediments of unit KH 18 but there is no basal conglomerate in the latter unit. Porosities over this interval are "slight" but range to "poor", and perhaps even higher, in places; it is probably a vuggy porosity.

KURRAJONG HEIGHTS (A.O.G./EXOIL) NO. 1

Fig. 2

COMPARISON OF B.M.R. AND COMPANY LITHO-STRATIGRAPHIC INTERPRETATIONS

(no scale)

B.M.R. UNITS		BOUNDARY DEPTHS (FT.)	COMPANY (A.O.G./EXOIL), 1962 & 1963		
MAJOR	MINOR		FORMATION	GROUP	AGE
KH1	KH1		HAWKESBURY SANDSTONE		TRIASSIC
		730	740		
KH2	KH2		UPPER BURRALOW 780 LOWER FORMN. EQUIV.	NARRABEEN GROUP	
		1010	1020		
KH 3-7	KH3		GROSE SANDSTONE EQUIV.		
		1380			
	KH4				
		2050			
	KH5				
		2070			
	KH6				
		2575			
	KH7		2665		
		2875	CALEY FORMN. EQUIV.		
KH 8-9	KH8		2915 LITHGOW COAL MEASURES EQUIV.?	"UPPER COAL MEASURES"	PERMIAN
		3055			
	KH9		3367 TOMAGO COAL MEASURES EQUIV.?		
		3460			
KH 10	KH10				
		3725			
KH 11	KH11		4495		
		4560			
KH12-13	KH12		CAPERTEE GROUP EQUIV.	"UPPER MARINE SERIES"	
		4870			
	KH13				
		5720			
KH 14-16	KH14				
		6200			
	KH15				
		6985			
	KH16				
		7600			
KH17-18	KH17				
		7755			
	KH18				
		7870	7865		
KH 19-20	KH19			"VOLCANICS"	PERMIAN &/OR CARBONIFEROUS
		8160			
	KH20				
		8240			
KH 21-22	KH21				
		8620			
	KH22				
		9132	TD		

UNIT KH 20

Unit KH 20 is 80' thick and consists of massive, greenish black, fine grained basaltic lava which, in places, is carbonatized, chloritic and iron-ore rich. The lava contains unsheared chlorite amygdales and spherules.

UNITS KH 21-22 (Plate 5)

The major unit KH 21-22 is 892' thick and extends from 8,240' down to total depth at 9,132'. The lower half consists of basaltic rocks and the upper half of rhyolitic lava and tuff; here again, it appears to be part of a cycle of ? terrestrial igneous activity (see also descriptions of Cores 32 and 33, Appendix 1).

UNIT KH 21

Unit KH 21 is 380' thick and composed of massive, pinkish grey, microporphyritic potash rhyolite and rhyolitic welded tuff; segregations of perlite occur in layers in a devitrified groundmass. These lavas contain numerous xenoliths of acid to intermediate volcanic rock. The upper boundary of the unit is marked by an abrupt and large increase in the mean gamma ray count as the log is traced from unit KH 20 into KH 21.

UNIT KH 22

The basal unit KH 22 is 512' thick and consists of green brown basaltic rock, possibly volcanic. Attempts to cut cores in these rocks were unsuccessful.

CONCLUSIONS

Degree of Agreement with Company Interpretations

Comparison of lithostratigraphic interpretations made in this study with those made by A.O.G. and Exoil (1962 and 1963) are shown diagrammatically in Figure 2.

The stratigraphic succession revealed by the drilling of Kurrajong Heights No. 1 Well can be broadly divided into four sequences, namely, the Triassic sandstone sequence, the Permian coal measures sequence, the Permian marine sequence, and the Permain and/or Carboniferous basal volcanic sequence. As can be seen in Figure 2,

only the contact between the marine and volcanic sequences show agreement between the two interpretations; the upper and lower contacts of the coal measures differ significantly. The companies' interpretation takes the uppermost coal seam as the top boundary, and the "..... lowest occurrence of carbonaceous shale" as the bottom boundary of the sequence; apart from being an inconsistent basis for its delineation, it is believed that the definition of the bottom boundary is invalid because of the occurrence of carbonaceous "shale", in places, in the top part of the underlying marine sequence. The interpretation presented here is based on the first and last occurrence of typical interseam lithologies (see boundary criteria for units KH 8 and KH 12). The upper contact is placed 40' higher, and the lower contact 65' lower, than the company boundaries.

There are similarities, but also some important differences, between the subdivisions of the broad sequences as presented here and those of the companies. Considering the Triassic sequence first, unit KH 2 is obviously that which the companies have equated to the Burralow Formation; there are only insignificant differences in the levels at which boundaries have been drawn. However, there are important consequences in the companies' naming the Hawkesbury Sandstone above the Burralow Formation; these will be explained in the following section entitled "Discussion of New Data". At the base of the Triassic sequence the companies have defined a unit described as ".....shales, sandstones, conglomeratic in part; basal 39' contains well developed carbonaceous shales", and have equated it to the Caley Formation. Unit KH 7 of the present interpretation must be considered as representing the same unit, however, both the bottom and top boundaries differ appreciably. The difference in the basal contact has already been explained in reference to the definition of the upper boundary of the coal measures sequence. The upper boundary of unit KH 7 is placed some 90' higher than that of the Caley Formation Equivalent. From the Companies' description of the unit overlying the Caley Formation, in part described as ".....sandstones, conglomeratic over lower half, and with thin beds of shale", the boundary must have been based on textural changes only. The upper boundary of unit KH 7 is distinguished by changes in the composition of clasts and cements, as well as texture (see boundary criteria for unit KH 7).

The companies have subdivided the coal measures sequence, "....on the basis of relative plentitude of coal seams into possible equivalents of Lithgow and Tomago Coal Meausres". From the interpreted lithology column accompanying this report (see Well Logs, Plates 2 and 3), there appear to be the same number of seams/unit thickness of section at the top, as at the bottom of the coal measures sequence; however, besides differences in gross interseam lithologies, a distinction can be made by the presence of a separating argillaceous unit (KH 10) devoid of coal seams (see "Discussion of New Data").

The companies have not subdivided the marine sequence, although it is mentioned in Exoil (1963) that ".... a dense, white, conglomeratic sandstone from 6,217 feet to 6,285 feet may correlate with the 'Kedumba Conglomerate'". This sandstone is here included in a broad unit KH 15 which is delineated to encompass at least three other identical lithologies of similar thicknesses near the same level (see description of Unit KH 15, and "Discussion of New Data").

The companies have not subdivided the basal volcanic sequence of the succession. In this report it is subdivided into two major units, KH 19-20 and KH 21-22 (see "Discussion of New Data").

Discussion of New Data

The Triassic sequence is divided into 7 units numbered KH 1 to KH 7. Unit KH 2 is equivalent to the company unit which has been equated to the Burralow Formation. Furthermore, the companies have equated the overlying unit to the Hawkesbury Sandstone, the base of which is ".....taken at an increase in shale content "(A.O.G., 1962). However, as can be seen from the descriptions of units KH 1, KH 3 and KH 4, there are only subtle textural differences between them and very little compositional distinction. The point is that should the Burralow Formation fail to be a basin-wide unit, or fail to be everywhere laterally continuous difficulties will immediately arise in defining a "Hawkesbury Sandstone unit". Relevant to this problem is the absence of conspicuous coloured chert fragments above unit KH 6 and the absence of conspicuous graphite, iron oxide and rutile grains below unit KH 3. In summary, sandstones of units KH 1 to KH 4 are orthoquartzites and protoquartzites, those of KH 6 are protoquartzites only, and unit KH 7 consists of protoquartzites and (Q) subgreywackes; these compositional changes are due mainly to a down-section progressive increase in the quantity of argillaceous lithics. Variation in the degree of marine influence, usually slight, is suggested in the deposition of units KH 2, KH 4, KH 5 and KH 7. Lithogenetically, the Triassic sequence can be divided into three major units, KH 1, KH 2 and KH 3-7 (see Fig. 1).

As mentioned previously, the Permian coal measures sequence is divisible into two coal-bearing units which are separated by a possibly marine, argillaceous unit (KH 10) devoid of coal seams. The upper coal-bearing sediments are themselves divided on the basis of interseam sandstone composition into (Q) subgreywackes (unit KH 8), and (L) and (F) subgreywackes which are in part tuffaceous (unit KH 9). Continued increase down-section in the quantity of argillaceous lithics, compled in the case of unit KH 9 with a sudden appearance of volcanic

lithics, give rise to the compositional changes. The lower coal-bearing unit KH 11 contains "mixed" subgreywackes; the quantity of volcanic lithics in this unit is much reduced.

The Permian marine sequence is divided into three lithogenetic "groups", namely, an upper predominantly argillaceous section (units KH 12-13), a middle pre-dominantly arenaceous section (units KH 14-16), and a lower predominantly argillaceous section containing at least one coal seam, some well sorted sands, and a distinct fossil assemblage (units KH 17-18). It is possible that the basal unit KH 18 is partly non-marine. Throughout the whole sequence, sandstones are mainly (Q) subgreywackes, in most cases the lithic component being supplied by schist fragments. However, about the middle of the sequence the sediments become quartz-rich and unit KH 15 is defined to encompass at least three massive subunits of slightly pebbly, coarse grained protoquartzite from which schist fragments are absent.

The Permian and/or Carboniferous volcanic sequence is divided into two major "groups", each possibly representing part of a cycle of extrusive igneous activity. The upper units KH 19-20 range from basalts to andesitic volcanic rocks at the top. The lower units KH 21-22 range from basaltic ? volcanic rocks to rhyolites at the top. These divisions may be useful for correlation purposes.

Economic Prospects

Core analyses (see Appendix 1) indicate that porosities in the Triassic sequence range from "good" to "slight". Visual estimations of porosities in cuttings over this interval tended to be somewhat less than those determined by core analysis, perhaps because the cuttings selected were those held together by the common clay matrix and iron oxide, siderite and silica cements. The significance of the high porosities can be judged by the generally low permeabilities.

Porosities in the Permian sequences are mostly "poor" to "slight" because of the "dirty" nature of the coal measure sands and the common siderite, calcite, dolomite and silica cements throughout the sequences. Permeability determinations made over the interval give negligible values. There are, however, some important exceptions to these generalizations. First, a subgreywacke in unit KH 11 is described in Exoil (1963) as the "..... sandstone from 3,987 feet to 4,000 feet (showing) good porosity and probably good permeability; very little cementing material was present". Secondly, the previously mentioned

coarse grained protoquartzites in KH 15 (q.v.) between 6,200' and 6,985' are visually estimated to have porosities up to about 10%, despite some carbonate cements and silica overgrowths; unfortunately the wireline logs are not definitive in this region and no cores were cut, therefore, permeability estimates are lacking. Thirdly, well sorted (Q) subgreywackes and (Q) arkoses in unit KH 18, between 7,755' and 7,870', have porosities ranging to "moderate", although a permeability determination on Core 29 gave negligible results. Lastly, there is a vuggy porosity, up to 15%, in some of the andesites of unit KH 19 but, here again, permeability is negligible.

It is suggested that effort might be profitably directed to closely examining the protoquartzites of unit KH 15 and their possible stratigraphic equivalents in the southeast (sands near the Nowra Sandstone level) and northeast (Muree Sandstone) parts of the Sydney Basin.

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PETROGRAPHIC WELL LOG
KURRAJONG HEIGHTS (A.O.G./Exoil) No.1

R.P.B. PITT — S. OZIMIC

WELL NAME, No: Kurrajong Heights No.1
OPERATING Co:
A.O.G. Corp. Ltd. & Exoil (N.S.W.) Pty. Ltd.
WELL LOCATION:
Lat. 33° 31' 45" S Long. 150° 37' 15" E
Basin: SYDNEY
State: NEW SOUTH WALES
Tenement/Licence: No.2 (N.S.W. Dept. Mines)
1:250,000 sheet: S I 56 – 5

ELEVATION: Ground level 1863·5 ft. a.s.l.
K.B. datum 1879 ft. a.s.l.
SAMPLE STORAGE: B.M.R., Canberra
& N.S.W. Dept. Mines

HYDROCARBON SYMBOLS
- Show of oil
- Trace of oil
- Show of gas
- Trace gas
- Fluorescence

MISCELLANEOUS
- Interval and Number of Formation Test
- No sample
- Core no., interval & recovery (black) (483 / 1 / 492)

- Oligomict/petromict conglomerate, to sandy/muddy conglomerate (> 1/2 rudaceous material)
- Conglomeratic Q/L/F* sandstone (< 1/2 rudaceous material)
- Q/L/F* sandstone (< 15% matrix)

Q/L/F* sandstone (15–50% matrix): Silty / Muddy / Clayey

- Siltstone/sandy &/or conglom. siltst.
- Mudstone/sandy &/or conglom. mudst.
- Claystone/sandy &/or conglom. clayst.
- Coal seams / coal laminae
- Limestone / clastic limestone
- Dolomite / clastic dolomite
- Metamorphic

ACCESSORY GRAIN SYMBOLS
- Graphite
- Mica
- Green pellet
- Calcite
- Dolomite
- Siderite
- Carbonaceous material
- Coal lamina
- Iron oxide
- Pyrite
- R Rutile
- Z Zircon
- ■ Ferromagnesian
- T Tourmaline

CEMENT SYMBOLS
- Calcite
- Dolomite
- Siderite
- Iron oxide
- Silica
- Zeolite
- Dawsonite

ACID INTERM. BASIC

(Intrusive (or uncertain) / Extrusive)
- Breccia (>4mm)
- Tuff (<4mm)

BASIC CLAST IDENTIFICATION SYMBOLS (Composition of clasts of silt conglomerate grade)
- qtz/qtzitic, Qtzite, Chert → (qtzose)
- Sediment, Volcanic, Plutonic, Metamorphic → (lithic)
- K feldspar, Plagioclase → (feldspar)

* Q = qtzose, L = lithic, F = feldsp.
- Q ~ orthoqtzite, protoqtzite, subarkose (< 15% matrix) ~ qtzose greywacke (15–50% matrix)
- L ~ subgreywacke (< 15% matrix) ~ lithic greywacke (15–50% matrix)
- F ~ arkose (< 15% matrix) ~ feldsp. greywacke (15–50% matrix)

DEPTH (feet below K.B. datum) | FOSSILS | BIT TYPES | DRILLING RATE (min / 5 feet) | CUTTINGS GRAIN SIZE (Wentworth) Range & mode: prim, second — CLAY–SILT, SAND, PEBBLE | POROSITY CORES & CUTTINGS (excl. oil) | LITHOLOGIES OF CUTTINGS | THIN SECTIONS

MAIN ABBREVIATIONS:- ± with or without; / more or less etc; – to

DESCRIPTION OF CUTTINGS
(SPECIFIC COMP NOMEN AFTER PETTIJOHN,'57 & TEXT, NOMEN AFTER FOLK,'54 – See text)

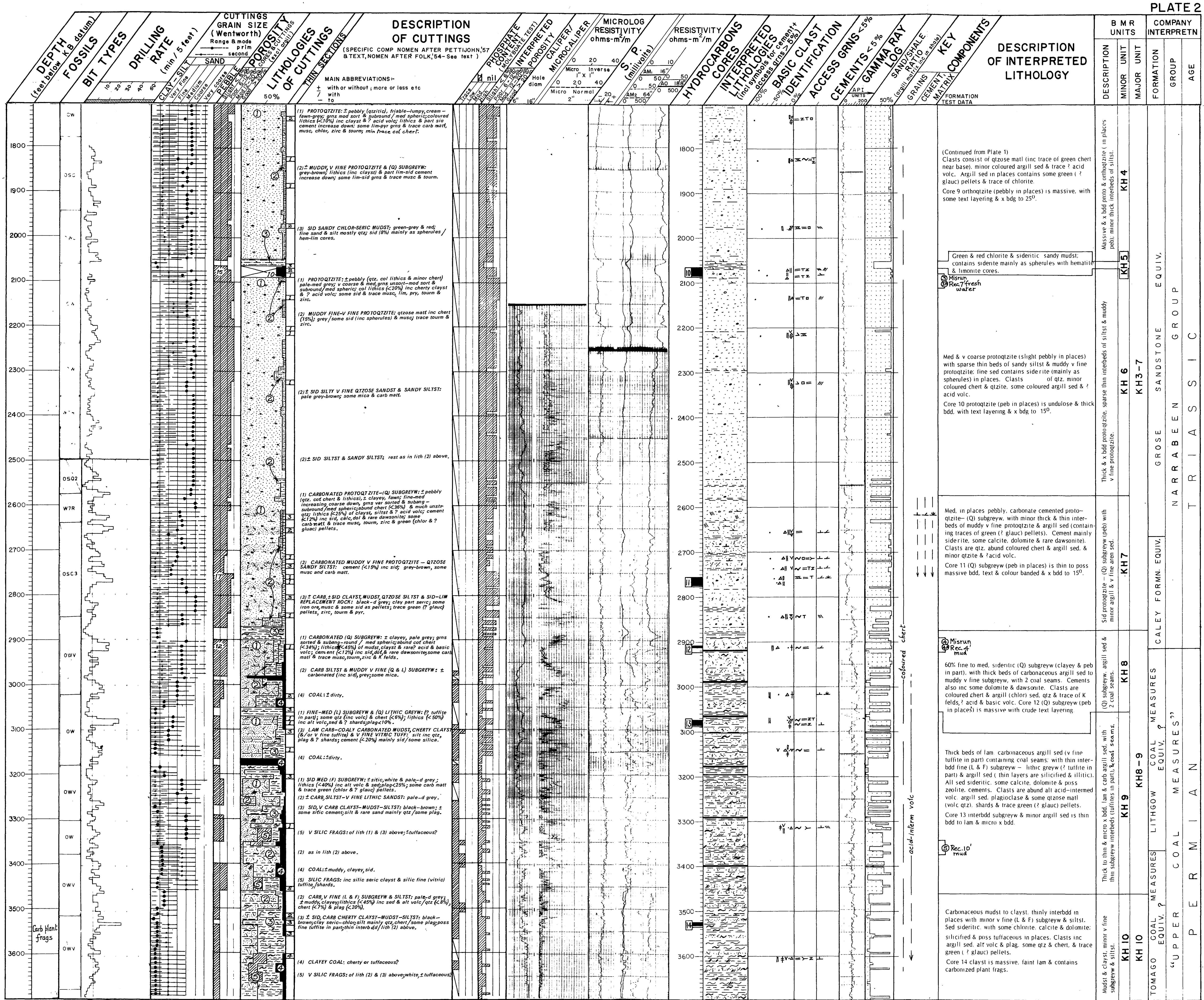
PHOSPHATE CONTENT (MOLYBDATE TEST) | INTERPRETED POROSITY | CALIPER/MICROCALIPER | MICROLOG RESISTIVITY ohms-m²/m | S.P. (millivolts) | RESISTIVITY ohms-m²/m | HYDROCARBONS CORES | INTERPRETED LITHOLOGIES (incl. symbols for cement* > 5%) | BASIC CLAST IDENTIFICATION | ACCESS GRNS < 5% | CEMENTS < 5% | GAMMA RAY LOG (API UNITS) | SAND/SHALE RATIO (drill matrix incl. in shale) | KEY: GRAINS, CEMENT, MATRIX | COMPONENTS | FORMATION TEST DATA

DESCRIPTION OF INTERPRETED LITHOLOGY

BMR UNITS: DESCRIPTION	MINOR UNIT	MAJOR UNIT	COMPANY INTERPRETN: FORMATION	GROUP	AGE
Med, clayey orthoqtzite & protoqtzite; in places pebbly, with pebble & cobble poly & oligomict conglomerate near base; rare v thin mudst beds thro' out; clasts consist of qtzose material, red, brown & rare green argill sed, rare schist & ? acid volc; abund iron oxide (in places) & traces silica cements. Cores 1–5 show massive beds, some textural layering & x bdg to 40°. Core 5 contains wood frags.	Massive & x bdd, clayey orthoqtzite & protoqtzite, in places pebbly; some conglomerate near base & rare very thin mudst.	KH1	KH1	BURRALOW FORMN. "Lower" EQUIV.	HAWKESBURY SANDSTONE	
Mostly sideritic (chloritic) siltst & subord red & green clayst (interlam near top & bottom), with slight pebbly (qtz & qtzite) & clayey fine ortho–protoqtzite; cements also inc some silica & iron oxide. Core 6 chloritic siltst is massive but faintly banded. Main lithologies appear thickly bdd.	Thick interbdd siltst (with some clayst) & ortho–protoqtzite.	KH2	KH2			
Misrans Rec. 4' mud. Interbdd fine & coarse (slight pebbly in places) ortho–protoqtzite, with minor interbeds (in upper part) of siltst which grades to lam mudst & to muddy v fine orthoqtzite; some silica cement; clasts consist of qtzose matl, ferrug & rare chloritic argill sed & trace ? acid volc. Cores 7 & 8 undulose & massive bdd but some fissile & thin bdd (fine sed); some textural layering & x bdg to 25°.	Massive & x bdd ortho–protoqtzite, with minor thin interbeds of siltst.	KH3	KH3–7	GROSE SANDSTONE EQUIV.	NARRABEEN GROUP	TRIASSIC
Med protoqtzite & orthoqtzite, slight pebbly to pebbly in places, partic in upper part, with minor thick interbeds (mainly in upper half) of sandy siltst which grades to mudst & muddy v fine (Q) subgreyw.	Massive & x bdd proto & orthoqtzite (pebbly); thick interbeds of siltst.	KH4				

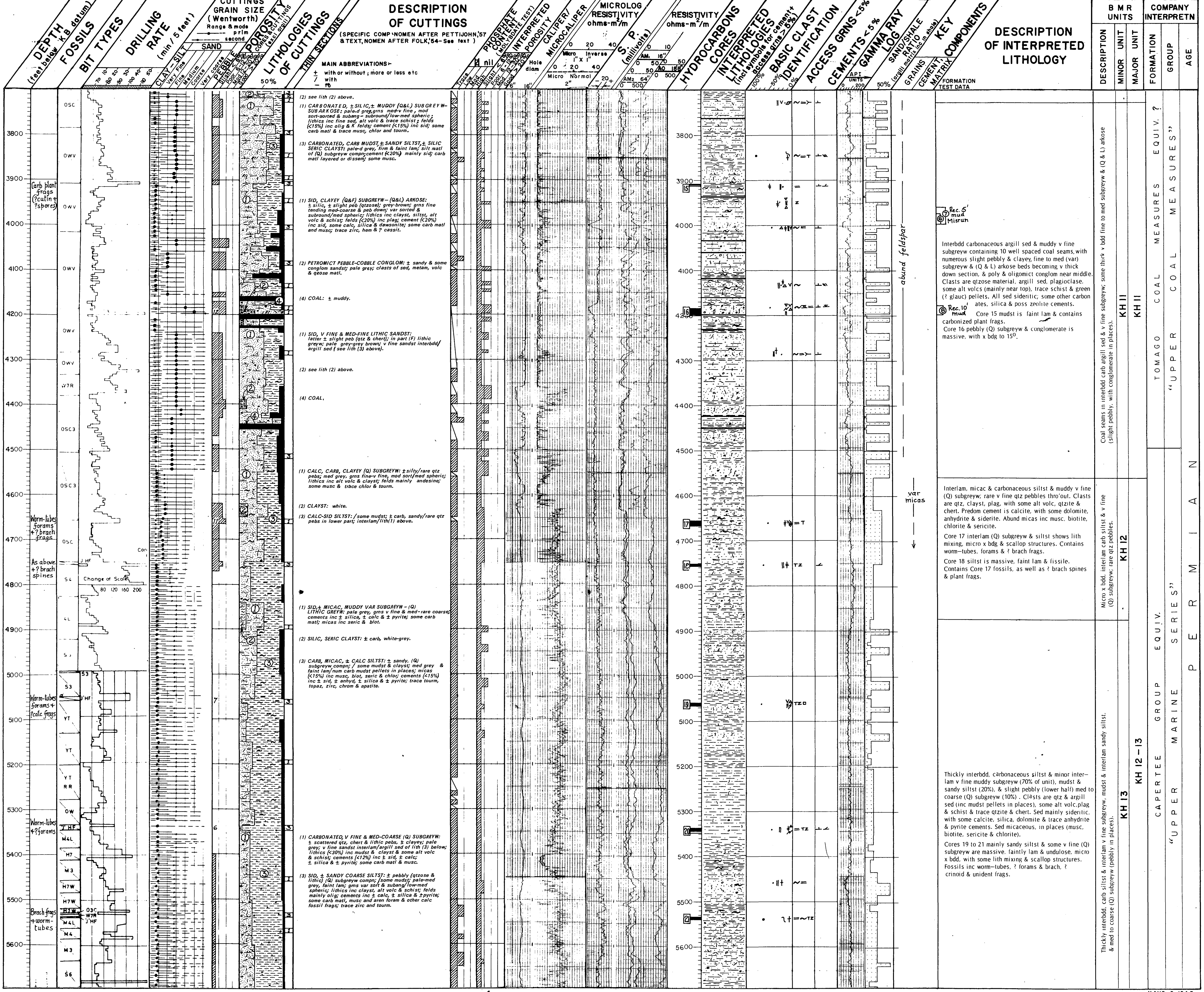
(Continued on Plate 2)

PLATE 2



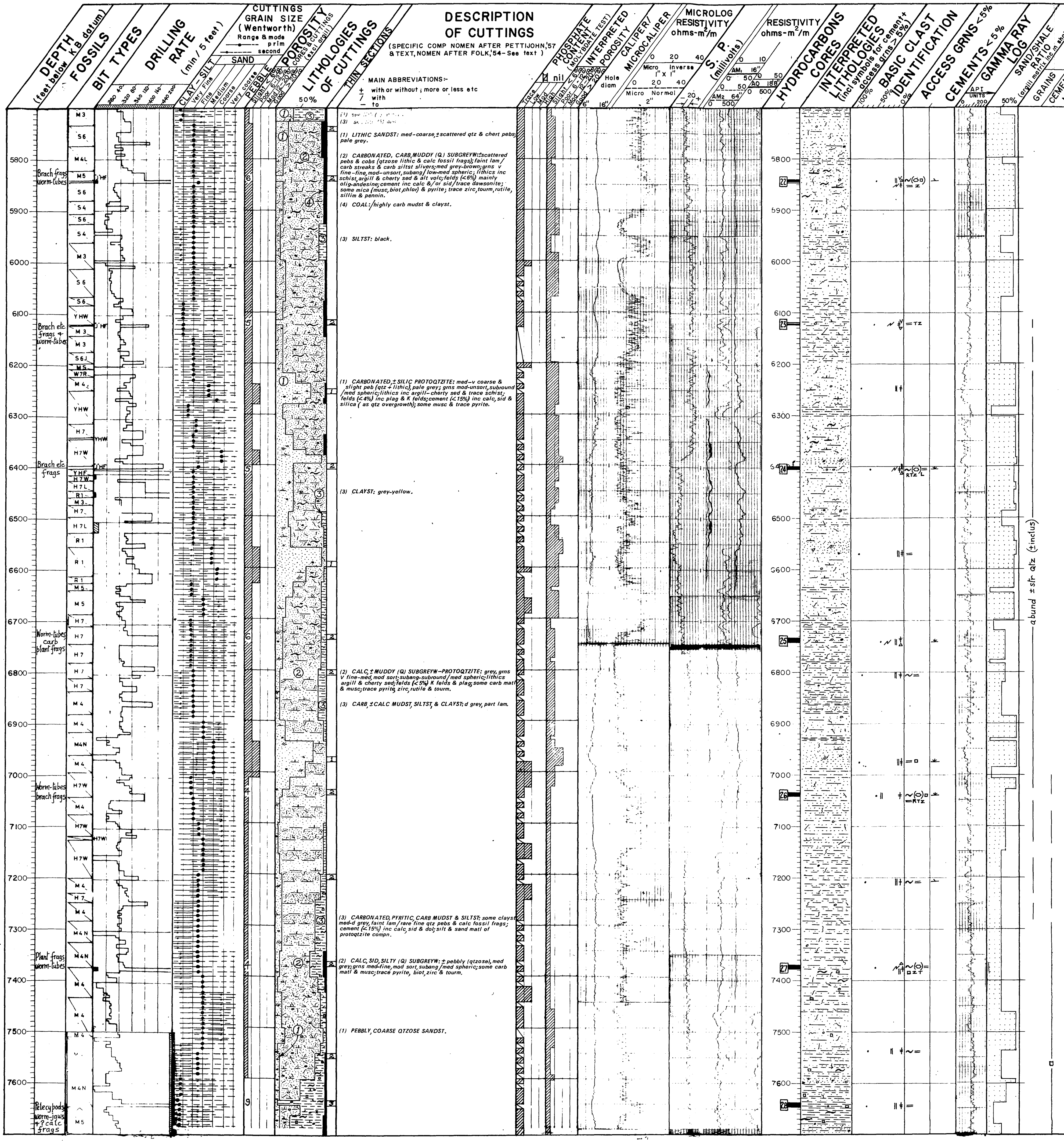
X AUS-2-104A

PLATE 3



XAUS-2-104 B

PLATE 4

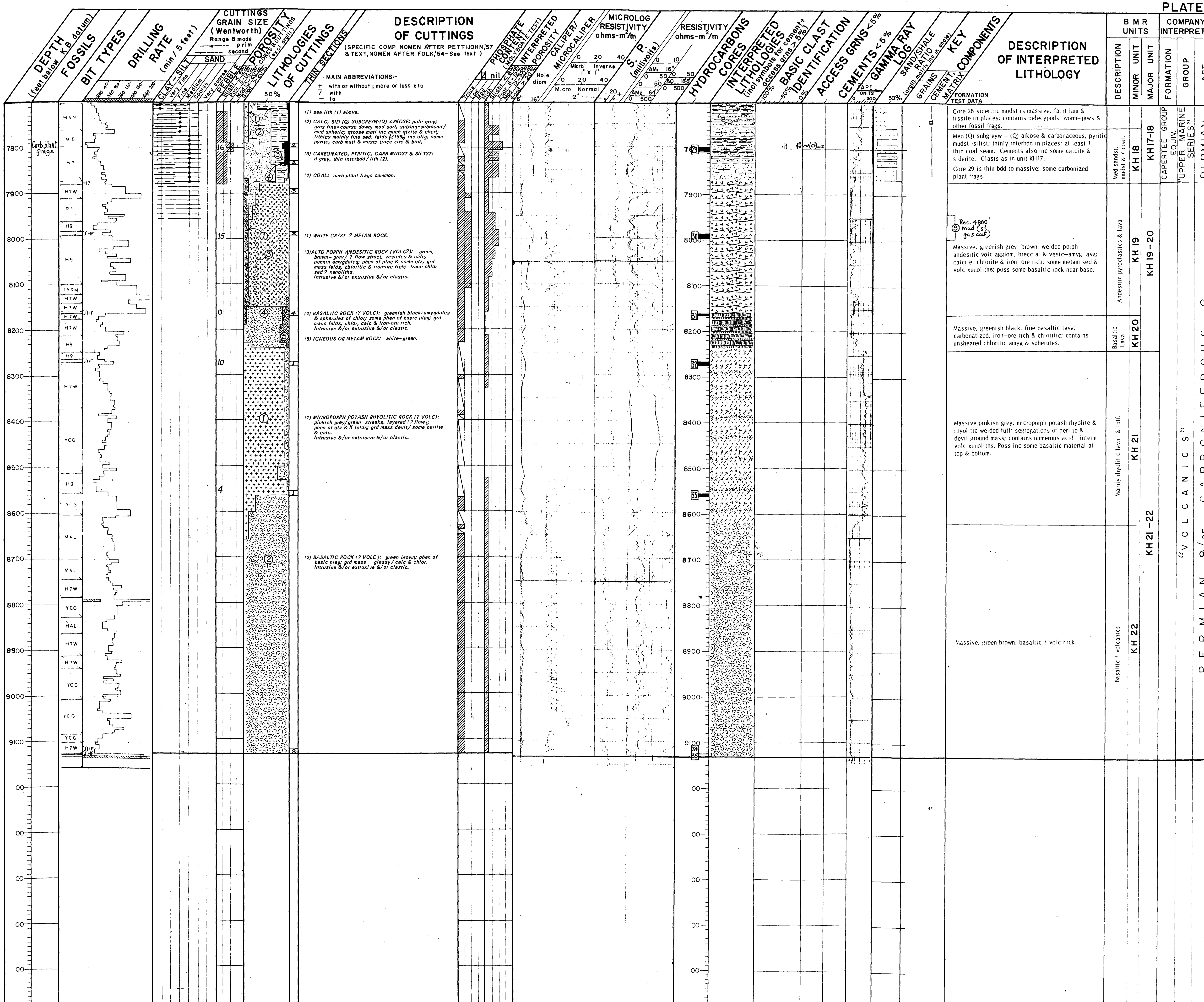

DEPTH (feet below K.B. datum)
FOSSILS
BIT TYPES
DRILLING RATE (min / 5 feet)
CUTTINGS GRAIN SIZE (Wentworth)
CLAY - SILT
SAND
Very Fine
Fine
Medium
Coarse
Very coarse
PEBBLE
POROSITY
LITHOLOGIES OF CUTTINGS
50%
THIN SECTIONS
DESCRIPTION OF CUTTINGS
(SPECIFIC COMP NOMEN AFTER PETTIJOHN,'57 & TEXT, NOMEN AFTER FOLK,'54 - See text)
MAIN ABBREVIATIONS:-
± with or without ; more or less etc
/ with
– to
(1) LITHIC SANDST: med-coarse, ± scattered qtz & chert pebs; pale grey.
(2) CARBONATED, CARB, MUDDY (Q) SUBGREYW: ± scattered pebs & cobs (qtzose lithic & calc fossil frags); faint lam / carb streaks & carb siltst slivers; med grey-brown; grns v fine-fine, mod-unsort, subang / low-med spheric; lithics inc schist, argill & cherty sed & alt volc; felds (<6%) mainly olig-andesine; cement inc calc &/or sid / trace dawsonite; some mica (musc, biot, chlor) & pyrite; trace zirc, tourm, rutile, sillim & pennin.
(4) COAL: / highly carb mudst & clayst.
(3) SILTST: black.
(1) CARBONATED, ± SILIC PROTOQTZITE: med-v coarse & slight peb (qtz + lithic), pale grey; grns mod-unsort, subround / med spheric; lithics inc argill-cherty sed & trace schist; felds (<4%) inc plag & K felds; cement (<15%) inc calc, sid & silica (as qtz overgrowth); some musc & trace pyrite.
(3) CLAYST: grey-yellow.
(2) CALC, ± MUDDY (Q) SUBGREYW-PROTOQTZITE: grey, grns V fine-med, mod sort; subang-subround / med spheric; lithics argill & cherty sed; felds (<5%) K felds & plag; some carb matl & musc; trace pyrite, zirc, rutile & tourm.
(3) CARB, ± CALC MUDST, SILTST, & CLAYST: d grey, part lam.
(3) CARBONATED, PYRITIC, CARB MUDST & SILTST: some clayst med-d grey, faint lam / rare fine qtz pebs & calc fossil frags; cement (<15%) inc calc, sid & dol; silt & sand matl of protoqtzite compn.
(2) CALC, SID, SILTY (Q) SUBGREYW: ± pebbly (qtzose), med grey; grns med-fine, mod sort, subang / med spheric; some carb matl & musc; trace pyrite, biot, zirc & tourm.
(1) PEBBLY, COARSE QTZOSE SANDST.
PHOSPHATE CONTENT (MOLYBDATE TEST)
nil
Trace
Low
Mod
High
INTERPRETED POROSITY
CALIPER / MICROCALIPER
Hole diam
MICROLOG RESISTIVITY ohms-m²/m
Micro Inverse 1" x 1"
Micro Normal 2"
S. P. (millivolts)
RESISTIVITY ohms-m²/m
HYDROCARBONS
CORES
INTERPRETED LITHOLOGIES (incl symbols for cement + access grns > 5%)
BASIC CLAST IDENTIFICATION
ACCESS GRNS <5%
CEMENTS <5%
GAMMA RAY LOG
API UNITS
SAND/SHALE RATIO (argill matrix inc in shale)
KEY
GRAINS
CEMENT
MATRIX
COMPONENTS
FORMATION TEST DATA
abund ± slr qtz (± inclus)
Brach frags worm-tubes
Brach etc frags + worm-tubes
Brach etc frags
Worm-tubes carb plant frags
Worm-tubes brach frags
Plant frags worm-tubes
Pelecypods worm-jaws + calc frags
5800
5900
6000
6100
6200
6300
6400
6500
6600
6700
6800
6900
7000
7100
7200
7300
7400
7500
7600
22
23
24
25
26
27
28

DESCRIPTION OF INTERPRETED LITHOLOGY

Description of interpreted lithology	BMR units: Description	Minor unit	Major unit	Company interpretn: Formation	Group	Age
Thick sequences of – coarse & fine (thinly interbdd) muddy (Q) subgreyw (50% of unit), interlam v fine (Q) subgreyw & siltst (30%), & muddy v fine (Q) subgreyw (20%). Sed contains scattered pebbles & rare cobbles of qtz, chert, metam, minor sed, volc & fossil frags (sand grade matl is similar, with plag & trace green (? glauc) pellets). All sed more or less carbonaceous & micaceous (musc, biotite, chlorite); main cements are calcite & siderite, with some silica & trace dawsonite & pyrite. Core 22 fine (Q) subgreyw (slight pebbly) is v thinly bdd & micro x bdd; contains brach frags & worm-tubes (as does Core 23). Core 23 siltst (pebbly & sandy) is faintly lam, with scallop structures.	Thick sequences of – coarse & interbdd fine (Q) subgreyw, interlam v fine (Q) subgreyw & siltst, muddy v fine (Q) subgreyw.	KH 14	KH 14–16	CAPERTEE GROUP EQUIV.	"UPPER MARINE SERIES"	PERMIAN
Thick sequences of – coarse protoqtzite (15% of unit), interbdd coarse & fine muddy protoqtzite & (Q) subgreyw (50%), fine (Q) subgreyw (20%), & argill sed (15%); last two occass interlam; scattered pebbles thro'out with some pebbly layers. Clasts are qtzose matl, argill sed, metam & minor feldspar. Fine sed is carbonaceous & micaceous in places. Main cements are siderite & calcite, with some silica (in coarse sed & mainly as overgrowths) & trace dawsonite. Core 24 (Q) subgreyw (pebbly & muddy) & minor mudst is massive to lam (in places) & contains large brach & other fossil frags. Core 25 interlam (Q) subgreyw & mudst is text layered to lam & poss micro x bdd; contains worm-tubes & carb plant frags.	Thick sequences of – coarse protoqtzite, interbdd coarse & fine protoqtzite & (Q) subgreyw, fine (Q) subgreyw, & argill sed; last two occass interlam.	KH 15				
Massive sequences of – interbdd fine (Q) subgreyw – protoqtzite & coarse siltst (20% of unit), interlam argill sed & fine (Q) subgreyw (50%) & fine & coarse (Q) subgreyw (30%), with a pebbly, coarse qtzose sandst at base; scattered pebbles occur thro'out Argill sed is carbonaceous & pyritic. Clasts are qtzose matl & argill sed, some metam & trace feldspar & green (? glauc) pellets. Cements are mainly calcite & siderite, trace of dolomite & dawsonite. Cores 26 & 27 mainly v fine (Q) subgreyw which is massive but faintly lam; contains worm-tubes, brach frags & pyritic – carbonized plant frags.	Massive sequences of – interbdd fine sandst & siltst, interlam argill sed & fine (Q) subgreyw & interbdd fine & coarse (Q) subgreyw (slight pebbly).	KH 16				
Mainly slight sandy, carbonaceous & pyritic mudst, in places v thinly interlam with muddy v fine (Q) subgreyw; rare qtzose pebbles. Clasts are qtzose, argill sed & some plag.	Mudst & muddy v fine (Q) subgreyw	KH 17				

X AUS-2-104 C

PLATE 5



X AUS-2-104D

CORE NO.	CORED INTERVAL (ft.↓KBD)	RECOV. RATIO	NO. OF CORE SEGS.	CORE ANALYSIS - POR (%)	PERM (m.d) V	PERM (m.d) H	OF SEG NO.	LITHOLOGICAL DESCRIPTION (macroscopic)	SED. STRUCTURES	THIN SECTION DESCRIPTION (of lithology indicated in macro.column)	FOSSILS	NOTES
1	483 - 492	4/9	frag. only	25	ND	ND	1	Fine qtzose sandst; mod sort; fawn-white and colour (ferrug) banded.		Med, clayey protoqtzite; grns sort, sub-round/med spheric; qtz ± str/5% chert & qtzite; mudst & clayst lithics (10%); some musc & trace iron ore, graph & rutile.		Mature & other sed sources (& poss metam?); iron ores detrit or authig = oxid cond; good sort = const. energy cond of depos & clay infiltn?.
2	492 - 505	1/13	2	24	198	364	2	Fine-med qtzose sandst / peb (qtzite) sandst layers; mod-unsort; friable cream-pale grey, colour (ferrug) banded.	Beds 1" - >2"; some x bdg (10°).	Med, clayey protoqtzite; grns mod sort, sub-ang - subround/low-med spheric; qtz + str/ 4% chert & qtzite; clayst lithics (8%); some musc /trace iron ore & graph.		Mature sed source (& poss other sed & Metam?); iron ore detrit or authig = oxid cond; x bdg var sort & grn size = water currents/var velocity (energy).
3	647 - 667	17/20	69	20 23 26 26 22	? 35 19 28 3	100 487 28 37 11	1 29 55 61 65	Fine-med qtzose sandst/few peb (qtzite, qtz & minor lithics) sandst & rare grey clayst layers; mod-unsort; friable, fawn-grey, colour (ferrug) banded.	Beds > 2" - ½"/some text layering; x bdg var up to 40°.	Fine-med, clayey protoqtzite, some lim orthoqtzite; mod-unsort, subround/med spheric; qtz ± str (some welding)/4% qtzite & chert; chlor & seric clayst lithics (9%); cements inc ± silic & ± lim; some musc & hem grns; trace carb matl, graph, rutile & zinc.		As for Core No.2.
4	699 - 709	2/10	7	19	0	0	1	Fine qtzose sandst; mod-sort; grey & fawn-brown/polymict, peb(chert, schist & red clayst) conglom bed.	Beds > 2"; massive.	Fine-med, clayey protoqtzite; seric clay matrix part silic; grns mod-unsort, sub-ang-subround/med-low spheric; qtz ± str/ 5% qtzite & chert; micac clayst lithics (10%); some musc & trace graph, biot, zirc, rutile & carb matl.		Metam, mature & other sed sources; biot= ? rapid erosion in ? metam source; red clayst pebs from ? contemp sed redepos under oxid cond; var sort & grn size = var energy cond of depos & ? abund supply detrit.
5	713 - 733	12.5/20	47	19 15 14 20	0 9 ND 0	0 7 1 0	1 9 12 18	Qtzose sandst/ 1/6 oligo & polymict peb-cob conglom & peb sandst (pebs of qtz, black & white chert & brown sid mudst-clayst); sandst mainly fine grn & sort; unsort in peb parts; pale grey-brown, colour (ferrug) banded.	Beds > 2" - 1/16"; x bdg btw 10° & 25°.	Fine, sid, clayey protoqtzite: mod sort, sub-aug-subround/low-high spheric; qtz ± str (part dissolved)/4% qtzite & chert; 13% clayst lithics; sid cement to 10%; some iron ore grns/sid rims, sid wood frags, musc & graph (in layers); trace zirc, rutile, biot, K felds & pyrite.	Ferrug wood frags part replac by siderite.	Mature & other sed sources (& prob acid plut & ? metam); iron ore detrit or authig = oxid cond/ subsequent diagen in reduc cond (sid & pyr); x bdg, var sort & grn size = water currents/var velocity.
6	907 - 908	1/1	2	10	ND	ND	1	Dense, grey mudst-siltst/greenish grey fissile layers; thin colour & ? text banding but massive overall.	Beds > 2" but/some banding.	Chlor qtzose siltst; qtz, qtzite & chert to 65%; musc & chlor to 6%; 30% chlor, seric & silic clay matrix. Micas mainly parallel to bdg.		Sed & poss metam sources; chlor authig & detrit = poss reduc cond of depos in ? marine environ; banding & grn size = low & slight var energy cond of depos.
7	1056 - 1060.5	4.5/4.5	13	15	0	0	5	Fine qtzose sandst/ a peb (qtz) sandst & a fissile micac sandy siltst layer; var sort; pale grey.	Beds > 2" - 1/16"; part undulose & ?xbdd (5°).	Fine, clayey protoqtzite; sort, subround/ med spheric; qtz (60%) & qtzite & chert to 13%; seric clay lithics to 10%; some musc & trace tourm, zirc, rutile & ? iron ore Few thin laminae of aggreg ? pyr or ? leucoxene.		Sed (inc mature) sources; ? iron ore = ? oxid cond; poss ripples &/or x bdg & var sort & grn size = water currents/ var velocity.
8	1074 - 1081	7/7	25	23 22	862 93	437 312	2 17	Mod-sort, fine qtzose sandst/ a thick micac siltst - ? chlor mudst, & a peb (ferrug sed lithics & qtz) sandst bed; pale grey - brown.	Beds > 2" - < 1/16" (fiss); text layering; x bdg from 10°-25°.	Med protoqtzite; sort; subround/high spheric; qtz + str/20% qtzite & chert; clayst lithics to 7%; trace musc, sid; ? pyr, rutile, zirc & tourm.		Sed (inc mature) sources; x bdg & grn size layering (large & small) = water currents/reg velocity var.
9	1690 - 1708	4.5/18	18	20 17	65 2	138 12	7 18	Fine-coarse qtzose sandst/sparse layers of peb (qtzite, minor sed lithics)sandst; mod-sort, white-pale grey.	Beds > 2" / some text layering; x bdg to 25°.	Peb, med orthoqtzite; mod-unsort, sub-round/ med-high spheric; qtz ± str (some press weld) 15% qtzite (mainly as pebs) & chert; clayst & siltst lithics to 4%; trace musc, zirc & tourm.		As for Core No.8, but less sed lithics.
10	2066 - 2086	19/20	57	7 10 17 15 12	0 0 10 2 0	0 0 16 2 0	5 17 28 41 55	Mainly grey mod sort fine qtzose sandst (± ferrug, clayey) / four 1' interbeds of unsort, peb (qtz, qtzite, col chert & sed lithics) qtzose sandst & few, thin inter-beds of sid (spherules), ? chlor mudst (± sandy).	Beds ¼" - >2"; text layering; undulose & x bdg (15°).	Fine-med, clayey protoqtzite; chlor, seric clay matrix part silic; mod-unsort, subround/med spheric; qtz ± str (some weld & overgrowth)/ chert to 15%; silic & seric clayst lithics to 15%; some sid (spherules/hem cores) & trace musc, pyr, tourm & zirc.		Mature & other sed sources (abund col chert); detrit or authig iron ore = oxid cond/subsequent reduc cond (sid & pyr); poss? marine (?authig chlor); ? ripples, x bdg & var sort & grn size= water currents/var velocity.

11	2757 - 2775	17.5 / 18	40	17 16 15 16	7 1 2 6	15 8 8 6	3 11 27 38	Green-grey unsort peb (col chert & mudst, qtz & qtzite) med qtzose sandst/ minor interbeds of pale grey, mod sort, fine qtzose sandstone ; latter/ thin stringers of carb matl	Beds > 2"- < 1/10"; text & some col banding; x bdg to 15°.	Med-coarse (Q) subgreyw; mod sort, sub-round-subang/med-high spheric; qtz ± str/col chert to 36%; 25% seric, chlor clayst lithics; some carbonate cement to 7% (inc dol, ? sid, ? calc & dawsonite); trace musc, ? iron ore & carb matl.		Sources as for Core No.10; var carbonate cements = mild reduc & var pH cond on depos &/or diagen; rest as for Core No.10.
12	2908 - 2923	5.5 / 15 (+ 3' coal seam missing from BMR library.)	10	12 13	0 0	0 1	4 8	Mainly grey-green, unsort med-coarse slight peb & peb (col sed lithics & chert, qtz) clayey (lithic) qtzose sandst/ some pale grey, sort, med (lithic) qtzose sandst.	Beds > 2"- massive / crude text layering.	Med (Q) subgreyw; mod-sort, subang - subround/med spheric; col chert (34%), qtz (± str) to 10%; seric & carb mudst, seric & chlor clayst lithics to 45%; 2% K felds; 6% cement inc sid & dol; some carb matl & trace musc.		Sed sources; carb matl, sid & other carbonates = mild reduc & high pH on depos &/or diagen; var sort & grn size etc = subaqueous depos/period abund supply detrit.
13	3074 - 3089	13.5 / 15	33	10 12 10	0 0 0	0 0 0	4 13 29	Pale grey, mod-sort v fine-med qtzose lithic sandst (± lam, flakes of carb matl) / thin subord interbeds of lam dark grey carb siltst & mudst.	Beds < 2" - lam; micro x bdd.	Fine, clayey (L) subgreyw; sort, subround / med spheric; "volc" qtz (unstr, embay & idiom) to 15%, minor chert; alt volc & clayst lithics to 57%; alt olig-andesine to 15%; some sid & ? carbonate cement to 5%; some carb matl & trace musc, apatite, zirc, biot & pyr.		Calc-alk volc (acid-interm) & sed sources; carb matl, biot & plag = reduc cond on depos &/or rapid burial (or climate infl); pyr, sid & other carbonates = reduc cond on diagen; lam bdg, good sort & micro x bdg = water currents /low, steady veloc.
14	3525 - 3534	8.5 / 9	31					Carb mudst; med-dark grey, very firm & brittle; massive to faint lam; some carb plant frags.	Massive - faint lam.	Chlor & sid, carb clayst; dissem carb matl (15%); small authig sid (10%) & ? authig chlor (5%) crystals; 2% silt grade qtz (unstr).	Carbonized plant frags.	Carb matl, sid & chlor = reduc cond on depos &/or diagen poss? marine; lam bdg & grn size = low energy environ.
15	3908 - 3911	1/3	3					Carb-mudst; pale-dark grey, firm & faint lam/carb plant frags.	Faint lam.	Sid, carb mudst; silt grade clayst (20%), qtz (10%) & plag (12%) in matrix of sid (15%), calc or dol (4%) & seric (1%) clay; 10% carb matl (inc ? cutin & ? spores); trace musc.	Carbonized plant frags inc ? cutin & ? spores.	Sed & ? volc rock sources; plag = little transp &/or climate infl; carb matl, sid etc = reduc & var pH cond on depos &/or diagen; rest as for Core No.4.
16	4185 - 4199	13.5 / 14	29	13 13 12 12	2 2 3 0	5 3 6 1	3 13 22 27	Mainly grey, unsort, slight peb - peb (qtzitic & minor schist) fine-coarse qtzose sandst/some 6" interbeds of sandy oligo & polymict peb - cob (qtzitic & volc) conglom/stringers of carb matl & a thin coal bed.	Beds > 2"- massive / text layering; some x bdg to 15°.	Carbonated, peb, coarse (Q) subgreyw; unsort, subround/med spheric; qtzose matl of qtz (35%), qtzite (15%) & chert (5%); lithics (25%) of argill sed, schist & altvolc; carbonate cement (10%) inc sid, calc or dol & dawsonite; trace musc, iron ore & zirc.		Volc rock, metam & sed sources; iron ore = poss oxid cond/subseq reduc cond on diagen (carb matl & sid); coal x bdg, var sort & grn size = still water / little detrit & var veloc water currents/abund detrit.
17	4656 - 4665	8.5 / 9	24	11	0	0	11	Interlam, med grey, v fine muddy sandst, carb siltst & mudst/ v fine pebs & coarse sand of qtz & calc fossil frags scattered thro' out.	Lam/some lith mixing; micro x bdd & scallop str.	Carb, clayey, v fine (Q) subgreyw; sort, sub-round/med spheric; qtzose matl to 47%; alt volc & clayst lithics to 12%; K felds & plag to 10%; some ? calc cement, musc & seric; trace chlor & tourm.	Horiz worm-tubes; forams & ? brach frags.	Sed & volc rock sources; carb matl, fossils & ? authig chlor = poss reduc cond in marine environ; grn sizes, lam, micro x bdg & scallop str = gentle, fluct water currents, scattered v fine pebs = poss storms?
18	4751 - 4756	5 / 5	29	9	0	0	18	Carb & micac siltst; med-dark grey, firm; ± foss & pyr; abund carb mudst pellets in layers (altn, poss flattered horiz worm - tubes?	Faint lam/ some fissile - massive.	Carb & micac siltst; qtzose silt to 30%; clayst lithics to 10% & olig to 5%; "micrite" (30%) inc clay/seric, anhyd & calc (or dol); micas inc musc, biot & chlor; trace tourm & zirc.	Carb plant frags; ? brach spines, forams & ? worm-tubes.	As for Core No.17; in addn, pyr & anhyd = reduc cond on diagen/high salinity.
19	5058 - 5065	5 / 7	31	7	0	0	15	Micac, sandy siltst; med grey; scattered mudst pebs, calc fossil frags & one calc concretion.	Faint undulose lam/ lith mixing; ± scallop str.	Calc, micac, sandy siltst; sort, subang/ med spheric; qtzose matl (much unstr qtz) to 54%; alt volc lithics to 10%; andesine to 7%; micas inc musc, biot & chlor; "micrite" (20%) inc clay/seric, calc, sid & anhyd; some carb matl & trace pyr, topaz, zirc & tourm.	Worm-tubes, forams & other ? fossil frags.	As for Cores Nos. 17 & 18.
20	5337 - 5345	4 / 8	16	6	0	0	10	Micac siltst; in places sandy/rare v fine pebs (qtzose & lithic); some carb matl.	Massive / ± undulose lam, lith mixing & ± fissile; micro x bdg & scallop str.	Sid, sandy, coarse siltst; mod-sort & subang; qtzose matl (much unstr qtz) to 40%; clayst, schist & alt volc lithics to 28%; olig to 7%; cement (12%) inc sid, dol & seric clay; some carb matl & musc; trace ? iron ore, tourm & zirc.	Worm-tubes & ? silic aren forams.	Sed, volc rock & metam sources; ? iron ore = ? oxid cond on depos/reduc cond on diagen (carb matl & sid); foss, micro x bdg, lam & good sort = steady ? open marine currents; v fine pebs = poss storms ?

21	5534 - 5539.5	4.5 / 5.5	21	6	0	0	9	Foss, ± peb (qtzose, schist siltst) sandy siltst & silty v fine lithic qtzose sandst; unsort, med grey.	Massive, > 2" / indistinct undulose layers; ± lith mixing & scallop str.	Sid, micac, clayey v fine (Q) subgreyw; unsort, subang/low-med spheric; qtzose matl to 43%; argill sed & alt volc lithics to 14%; olig-andesine 5%; 16% sid (& ? dol) cement & 5% musc; some calc foss frags & carb matl; trace tourm & zirc.	Brach frags, ? crinoid plates & ? forams.	Sed, metam & ? volc rock sources; carb matl & sid = reduc cond at least on diagen; foss, poor sort, var grn size, scallop str etc = marine currents/var velocity.
22	5841 - 5845	3 / 4	11	6	0	0	8	Muddy, fine qtzose sandst; / v scattered pebs & cobs (metaqtzite & siltst); some foss layers; some carb streaks; pale-dark grey; unsort.	Crude lavering ¼"-1/16"; disturbed in places; some micro x bdg.	Calc, carb, clayey, fine (Q) subgreyw; text & comp as for TS Core 21, but / 18% calc & some sid cement; 6% carb matl & 3% musc; trace chlor, biot, pennin & zirc.	Brach frags & large vert worm - tubes .	As for Core No 21; rare cobbles poss. dropped glacical erratics.
23	6120 - 6125	4.5 / 5	19	5	0	0	1	Micac, coarse siltst (± sandy) - micac, slight peb-peb (silic) sandy siltst. mod-sort, med-dark grey; scattered carb mudst pellets, foss (inc brach) frags & some carb matl.	Disturbed faint lam < 1/16"; scallop str.	Sid, peb & sandy coarse siltst; mod sort, subang/low-med spheric; 40% qtzose matl; 18% lithics inc schist, volc & argill sed frags; olig-andesine 4%; matrix-cement (32%) of seric, sid & calc or dol clay; some carb matl & musc; trace pyr, zirc, tourm & silliman.	Calc foss (inc brach) frags & ? horiz worm-tubes.	Metam, volc rock & ? sed sources; rest as for No. Core 21.
24	6399 - 6403	4 / 4	10	5	0	0	5	Calc, unsort, ± peb (qtzose & sed lithic) & muddy, fine-coarse, lithic-qtzose sandst;/irreg lam of carb & micac mudst; med-pale grey; large calc fossil frags (brachs etc) in layers thro' out.	Massive/crude faint undulose text layering.	Calc, carb, muddy, peb (qtz) fine (Q) subgreyw; unsort, subang/low-med spheric; qtzose matl to 45%; 13% schist & clayst lithics; 6% olig & K felds; 17% calc, sid & dawsonite; 7% graph carb matl; some musc & trace zirc, tourm & rutile.	Large, thick brachs & other foss frags.	Metam, sed & ? igneous sources; carb matl, calc & sid = reduc & high pH cond at least on diagen; frag foss, poor sort, var grn size & crude bdg = high energy marine environ/abund supply detrit.
25	6736 - 6742	5 / 6	22	6	0	0	1	Fine-med, mod sort lithic qtzose sandst (+ layers of qtzite pebs), interlam/carb, micac mudst-siltst in lower ½ of core.	Beds > 2" (text layer) - lam; poss micro x bdg.	Sid, v fine (Q) subgreyw; mod-sort, ang-subang/med spheric; qtzose matl to 40%; metam & clayst lithics to 35%; olig to 3%; cement (10%) inc sid, calc & dawsonite; some graph carb matl & musc; trace zirc & tourm.	H & V Worm - tubes & carbonized plant frags.	Metam & sed sources; carb matl, sid & calc = mild reduc/high pH at least on diagen; foss, var sort & grn size, micro x bdg = subaqueous (? marine) currents / var velocity.
26	7037 - 7041	3.5 / 4	13	4	0	0	4	Calc, carb, coarse (qtzose) siltst,/ scattered qtz sand, ? brach frags & carb lam.	Beds > 2" but faint lam.	Calc, v fine (Q) subgreyw; sort, subang / med spheric; qtzose matl mainly unstr qtz (some inclus) to 35%; argill sed lithics to 27%; andesine & K felds to 4%; calc cement (25%) inc some dawsonite; some graph carb matl & musc; trace pyr, zirc, tourm & rutile.	V & H worm - tubes & ? brach frags.	Sed & ? acid plut sources; carb matl & pyr = reduc cond prob on diagen; foss, good sort = depos in agitated marine waters.
27	7371 - 7378	7 / 7	22	4	0	0	15	Calc, pyr & carb sandy siltst & silty fine qtzose sandst; / carb mudst frags & scattered coarse qtz sand & rare fine qtz pebs; pale-med grey, mod sort.	Faint lam; lith mixed.	Calc & sid., carb, fine (Q) subgreyw; mod sort, subang/med spheric; qtz (+ str) chert & qtzite to 52%; clayst, schist & other metam lithics to 20%; felds (inc olig) to 3%; calc & sid cement (10%); graph & pyr carb matl (5%); some musc & trace tourm, pyr & zirc.	Pyr, carb plant frags / V & H worm-tubes..	Sed, metam & ? acid plut sources; carb matl, calc, sid & pyr = reduc & high pH at least on diagen; foss, mod sort, var grn size = subaqueous & mod (but slight fluct) energy environ/abund supply detrit.
28	7640 - 7648	8 / 8	46	9	0	0	1	Pyr & carb mudst (rare sand grns) & some muddy v fine qtzose sandst,/ small foss frags, glendonites & rare v fine silic pebs; pale-med grey.	Massive but faint lam; ± fissile.	Carbonated, pyr & carb mudst (± slight sandy); "micrite" to 40%; silt & rare sand of qtzose matl (25%), sed lithics (4%) & plag (3%); 10% carb matl & 5% pyr; cements (11%) inc sid, calc &/or dol; trace musc.	Pelecypods, worm-jaws & ? calc foss frags.	Sed & ? metam sources; carb matl, sid, calc & pyr = reduc & high pH at least on diagen; foss, fine grn size etc = marine depos in low (poss slight var) energy environ.
29	7797 - 7804	5.8 / 7	17	16	0	0	8	Mod sort, calc, carb, med lithic & qtzose sandst,/ thick & thin pyr, carb mudst interbeds; pale-dark grey; one thin coal bed.	Bed 2" - 1/16"; ± faint lam & fissile.	Calc [illegible] sid, med-coarse (Q) arkose & (Q) subgreyw;mod-sort,subang-subround/med spheric; qtzose matl (inc unstr qtz) 35-50%; sed lithics 15-30% & plag (olig) 6-18%; cement from 6-23%; some graph carb matl & pyr; trace musc, biot & zirc.	Carbonized plant frags.	Sed & volc rock (acid-interm) sources; carb matl, calc, sid & pyr = reduc & high pH cond on diagen; coal, sort & grn size etc = depos in altg still & agitated water /fluct. supply detrit.
30	7987 - 7997	10 / 10	31	15	0	0	1	Basic-intermed, welded volc agglom-breccia, (some sed & volc xenoliths, & flow str) & vesic lava; massive, greenish grey-brown.		Alt calc & chlor, iron-ore rich andesitic volc agglom, breccia & lava; porph (inc olig-andesine) & vesic (pennin lined).		

31	8162 - 8165	1.5/3	4	0	0	0	1	Massive, greenish black, fine ? basic lava.	Carbonatized, iron ore-rich, chlor basalt (lacking ? unreplaced ferromags); chlor amygdales & spherules (unsheared).
32	8268 - 8275	7/7	23	10	0	0	10	Fine, porph ? acid lava or tuff; pinkish grey; poss subhoriz flow or tuff layering.	Microporph potash rhyolite or rhyolitic tuff; phenocrysts qtz (inclus) & K - perth felds; devit ground mass.
33	8556 - 8560	3/4	9	4	0	0	4	Massive ?acid lava or volc breccia, / num volc xenoliths; horiz banded; pale red/green streaks.	Microporph (qtz & carbonatized felds) devit acid lava or welded tuff; / xenoliths of ang acid-interm lava & seg of perlite; layered.
34	9125 - 9126	0/1							
35	9126 - 9127	0/1							
36	9130 - 9132	0/2							
	(TD)								