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SHALLOW STRATIGRAPHIC DRILLING IN THE OFFICER BASIN, WESTERN AUSTRALIA, 1972

by

M.J. Jackson[+], W.J.E. Van de Graaff*, & J.-C. Boegli*

\+ Bureau of Mineral Resources

* Geological Survey of Western Australia

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SUMMARY

During 1972 the Bureau of Mineral Resources drilled 18 shallow stratigraphic holes in the Western Australian part of the Officer Basin. For the superficial Cainozoic units the main results are: 1) silcrete and ferricrete are commonly enriched in Thorium; 2) the weathered zone of the lateritic profile is in places over 100 m thick; 3) alunite occurs in some silcrete profiles; 4) valley fill deposits are up to 100 m thick but could not be dated; and 5) calcrete in the valley fills is up to 30 m thick and is locally silicified and/or dolomitized.

The Lower Cretaceous Bejah Claystone and Samuel Formation have a combined thickness of about 100 m. Palynomorphs indicate that the Samuel Formation formed in a shallow-marine environment near land. Reworked Late Permian spores also occur in the Samuel Formation.

In BMR Browne 1 the Permian Paterson Formation is weathered and ferruginized immediately below the disconformity with the Samuel Formation. This may indicate pre-Aptian lateritic weathering. A homogeneous, fine-grained sandstone penetrated by Wanna 1 was first interpreted as Lower Palaeozoic Wanna Beds. However, dating as Early Permian showed that it is a lacustrine facies of the Paterson Formation. Geochemical and palynological studies on clays from the Paterson Formation do not contradict its interpretation as a continental deposit.

The Wanna Beds conformably overlie the Lennis Sandstone and the two formation may extend as far west as longitude 124°30'E. Both units are good reservoir rocks as measured porosities of core samples range from 22.9 to 30.9%, and permeabilities are in the range of 4.1 to 390 Md with an average of 177 Md. No fossils have been found in either formation so their dating in the range of Early Cambrian to Early Permian cannot be refined.

The Lower Cambrian Table Hill Volcanics and the Upper Proterozoic Babbagoola Beds have also been traced from the central part of the Officer Basin to its western edge.

The prospects for groundwater in the basin sediments in the south-western part of the Officer Basin are poor.

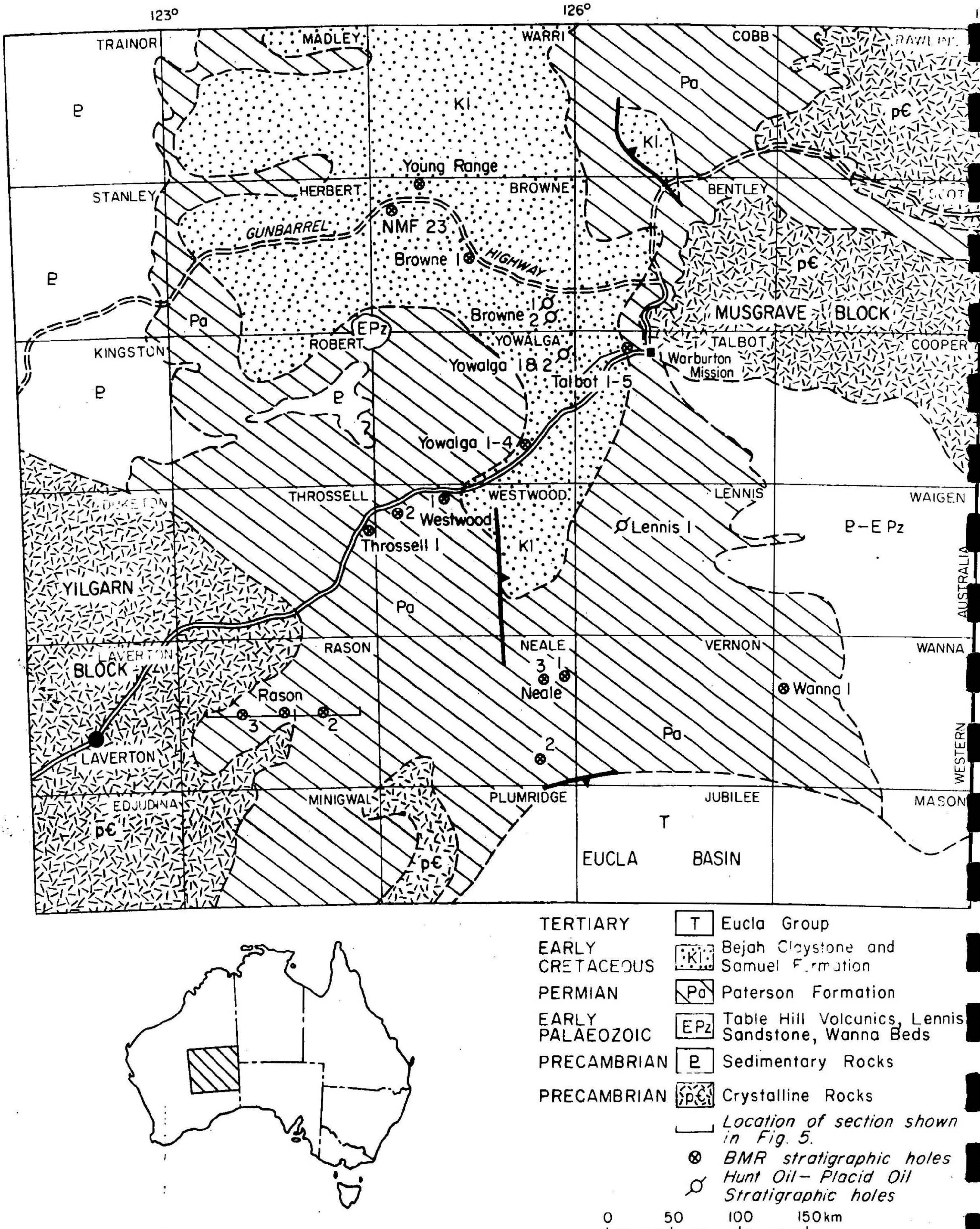

Fig. 1 Drillhole locations and generalized geology

INTRODUCTION

Between May and Septemper 1971 a geological party from the Bureau of Mineral Resources (BMR) and Geological Survey of Western Australia (GSWA) mapped twenty-two 1:250 000 Sheet areas in the Western Australian part of the Officer Basin.* The stratigraphy of this poorly exposed area was established by combining the information obtained from widely separated outcrops with the meagre subsurface information available (Lowry, Jackson, Van de Graaff, & Kennewell, 1972). However, knowledge of the rock succession was fragmentary and stratigraphic relations of the units that were defined are mostly not exposed. Therefore, a combined stratigraphic drilling and detailed mapping program was planned for 1972 to fill gaps in this knowledge and to try to confirm the stratigraphy, which was largely inferred from regional comparisons. Drilling was also carried out near the southwest margin of the basin to help the Western Australian Mines Department appraise the groundwater potential.

This report discusses the results of the stratigraphic drilling; the results of the detailed mapping will be reported elsewhere.

A flexible drilling program was drawn up prior to the start of the season with the above objectives in mind. The program was modified at several stages as the results of individual holes, and the implications of these, became available. The isolated nature of the area, the lack of good access roads, and uncertain water supplies caused a number of logistical problems, which also caused the program to be modified. Towards the end of the field season the stratigraphic drilling party worked in close cooperation with a BMR seismic party in the northwestern part of theWestwood Sheet area (Fig. 1); the drilling party investigated the shallow features of the southwest margin of the basin, while the seismic party probed for deeper structural information.

Between May and December 1972 the Petroleum Technology Section of BMR drilled eighteen shallow stratigraphic holes (Table 1, Fig. 1), totalling 1689 m. A Mayhew rotary drilling rig was used throughout. 319 m were cored with a recovery of 263 m (approx. 80%). The holes in the southwest of the basin were cased with water pipe as requested by GSWA. Cuttings were taken from 1.5 m intervals when drilling with air and from 3 m intervals when drilling with mud. A geologist remained on site and made a rapid examination of cores and cuttings using a binocular microscope. Geological logs were drawn up as drilling progressed.

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* as defined by Lowry, Jackson, Van de Graaff, & Kennewell, (1972).

A Widco XNVA wireline logger and an operator, both supplied by GSWA were attached to the drilling party, and gamma ray, spontaneous potential, point resistivity, and normal resistivity wireline logs were run whenever possible. One caliper log was run. Geophysical logging of some existing Hunt Oil drill holes was also attempted (Table 1). The field logs were drawn up at 1:120 scale and then reduced to 1:400 for this report. The wireline logs were recorded at 1:600 scale and the traces were then manipulated manually to fit into the reduced geological logs included with this report. This manipulation involved changing the vertical scale from 1:600 to 1:400 and reducing the horizontal scale by between two and five times.

All cores and cuttings are stored at the BMR Core and Cuttings Laboratory, Fyshwick, A.C.T., and a detailed re-examination of the material was made between August 1973 and January 1974. More than 200 samples were selected for additional examination, which included petrological, geochemical, and palynological work (Tables 1-5). A catalogue of all samples selected for further study is given in the Appendix. The palynological study undertaken by Dr E. Kemp (BMR) forms part of BMR Bulletin 160; only the more important results of that study are outlined here. The location of each sample within a drill hole is shown next to the lithologic log of that hole (Figs 2-19).

In this report the new information obtained has been separated into two sections. The information on the individual drill holes is presented in the order in which the holes were drilled. The more important results and the implications of the detailed analyses are discussed under the stratigraphic units concerned.

Sandstone classification follows Pettijohn, Potter, & SIEVER (1972), bedding terms follow Ingram (1954), and grain shape, sorting, and size follow Powers (1953).

The holes are named by reference to the 1:250 000 Sheet area in which they are located, e.g. BMR Rason 3 refers to the third hole drilled by BMR in the Rason, SH/51-3, 1:250 000 Sheet area. To avoid unnecessary repetition in the text the prefix BMR has in places been omitted from the name of a drill hole where there is no possibility of confusing the BMR hole with any Hunt Oil hole.

TABLE 1: SUMMARY OF STRATIGRAPHIC DRILLING

Hole Number	Position (Lat °S)	Position (Long °E)	Total Depth m	Details of coring: No. of Cores	Length cored (m)	Recovery (m)	Recovery %	Wireline logs run	Well site Geologist	Results/Remarks	Status
BMR Rason 1	28°33'18"	123°47'36"	58.5	1	3.0	1.5	50	GR - - -	Jackson	Paterson Formation 10 to 44 m then into basement; hole dry	cased 2" pipe to TD
BMR Rason 2	28°33'18"	124°02'42"	146.7	5	9.6	6.8	71	GR PR NR -	Jackson	Paterson Formation 0 to 144 m then into basement; hole dry	cased 2" pipe to TD
BMR Rason 3	28°33'18"	123°29'48"	74.7	0	0	0	0	GR PR - -	Graaff	Paterson Formation 0 to 31 m then into basement; hole dry	cased 2" pipe to TD
BMR Neale 1A	28°18'18"	125°56'36"	86.9	1	3	1.8	60	- - - -	Graaff	Paterson Formation overlying Wanna Beds, hole abandoned continued in Neale 1B	open, abandoned
BMR Neale 1B	" " "	" " "	205.7	3	6.7	5.7	85	GR PR - SP	Graaff/Boegli	Paterson Formation overlying Wanna Beds overlying Lennis Sandstone	cased, 2" pipe to TD
BMR Neale 2	28°47'48"	125°46'12"	74.8	1	3.0	3.0	100	GR PR NR SP	Boegli	Alluvium and Colluvium overlying Paterson Formation	cased, 2" pipe to TD
BMR Neale 3	28°19'00"	125°49'12"	38.1	0	0	0	0	GR - - -	Graaff	Paterson Formation throughout. Drilled for water supply but hole dry	open, abandoned
BMR Wanna 1	28°22'04"	127°37'44"	154.5	3	8.3	4.3	52	GR PR NR SP	Boegli	Paterson Formation throughout	" "
BMR Yowalga 4	26°50'04"	125°37'33"	43.0	11	29.3	15.3	88	GR PR - SP	Boegli/Jackson	Paterson Formation throughout	" "
BMR Talbot 1	26°09'12"	126°32'30"	33.1	2	4.6	2.0	43	GR PR - SP	Boegli	Cainozoic deposits overlying Townsend quartzite dipping at 25° to 30°	" "
BMR Talbot 2	26°09'24"	126°32'20"	13.7	1	3.0	2.7	90	- - - -	Boegli	Cainozoic calcareous conglomerate (alluvium)	" "
BMR Talbot 3	26°09'38"	126°32'08"	77.4	2	4.1	3.8	93	GR PR NR SP	Boegli	Cainozoic alluvium overlying lutites of Lefroy Beds dipping at 25°-30°	" "
BMR Talbot 4	26°09'50"	126°31'54"	69.6	1	2.5	2.1	81	GR PR NR SP	Boegli	Cainozoic alluvium overlying arenites of Lefroy Beds	" "
BMR Talbot 5	26°10'00"	126°31'30"	95.1	1	2.1	2.1	100	GR PR NR SP	Boegli	Cainozoic alluvium overlying Paterson Formation overlying tillites of the Lupton Beds	" "
BMR Browne 1	25°32'04"	125°16'30"	121.9	39	114.3	95.4	83	GR PR NR SP	Boegli/Cope	Bejah Claystone overlying Samuel Formation overlying Paterson Formation	" "
BMR Westwood 1	27°02'42"	124°49'06"	85.3	34	80.6	74.1	92	GR PR NR SP	Cope/Boegli	Table Hill Volcanics overlying ?Proterozoic sandstone	" "
BMR Westwood 2	27°07'20"	124°42'36"	101.5	5	12.8	11.2	88	GR PR NR SP	Boegli	Paterson Formation overlying Wanna Beds or Lennis Sandstone	" "
BMR Throssell 1	27°16'24"	124°25'30"	198.1	15	31.8	21.1	66	GR PR Caliper	Boegli	Cainozoic calcrete and lacustrine deposits overlying Proterozoic siltstone and claystone (Babbagoola Beds)	" "
TOTALS			1688.6	125	319	263	80				

Additional wireline logs run

Hunt Lennis 1	27°17'00"	125°21'00"	GR - - -
Water bore east of NMF 23	25°10'00"	124°40'00"	GR - - -
Water bore at Notabilis Hill	25°40'00"	125°35'00"	GR - - -
Seismic shot hole 393	27°06'10"	124°48'10"	GR - - -
Seismic shot hole 395	27°05'20"	124°48'50"	GR - - -

INDIVIDUAL BORE HOLE DATA

BMR RASON 1 (Fig. 2)

Position. Lat 28°33'18"S, Long 123°47'36"E; 100 m west of the 35-mile peg on the bulldozed geophysical traverse line which runs east from Squeakers Hill across the Rason 1:250 000 Sheet area (Fig. 1); about 475 m above mean sea level.

Objects. 1) to confirm a 240 m deep, water-bearing depression in the basement profile, postulated by Australian Groundwater Consultants on the basis of a resistivity survey in this area (A.G.C. 1971). 2) to determine depth to, and nature of Precambrian basement; 3) to obtain groundwater samples and provide a hole for future pump-testing and other hydrological investigations.

Drilling. The hole was drilled with air to 24 m and then water injection to total depth. Drilling with mud was avoided to enable aquifers to be recognized more easily. A 6 inch (0.1524 m) OD casing was inserted to 4.88 m during drilling; it was left in the hole. Difficulty was experienced in retrieving cuttings which consisted largely of loose quartz grains. In an attempt to run wireline electrical logs 4000 litres of water was poured into the hole during a 10 minute period. However, the water was lost into the formation at a rate faster than it could be added. Consequently only a gamma ray log was recorded. As requested by the Western Australian Mines Department a capped, galvanized iron water pipe (5 cm diameter) was run into the hole to total depth.

Results. The expected profile, based on resistivity interpretation (A.G.C., 1971 p. 5), was: 0 - 10 m dry mudstone, sandstone, silcrete; 10 - 200 m saturated sandstone and mudstone; with 'base rock' at about 240 m (Fig. 5). The sequence established by drilling is shown in Figure 2; it contrasts markedly with the expected profile.

A thin layer of aeolian or residual red quartz sand (0 to 6 m) overlies the Lower Permian Paterson Formation. Between 6 and 15 metres the Paterson Formation is altered to a ferricrete composed of strongly ferruginized, iron-cemented granules and cobbles of poorly sorted sandstone. This ironstone conglomerate represents the upper part of a laterite profile. A marked deflection in the gamma ray curve occurs opposite the laterite. This anomaly is due to a concentration of thorium (see discussion on page 29). The dominant lithology in the remainder of the Paterson Formation (15 m to 44 m) is white to pale brown, fine to very coarse-grained, angular to subrounded, poorly sorted, quartz sandstone. Detailed examination of cuttings suggests that thin interbeds of red, purple, pink and white, subangular, well sorted micaceous siltstone and sandy siltstone are also present, especially below 30 m. The 3 m of Paterson Formation directly overlying the basement granite is markedly conglomeratic. These rock types are identical to those in many surface exposures of the Paterson Formation and are interpreted as being of fluvial origin. Decomposed and highly weathered porphyritic adamellite was intersected at about 44 m. The hole was completed at 68.5 m in fresh to slightly weathered adamellite.

BMR RASON 2 (Figs 3A & 3B)

Position. Lat 28°33'18"S, Long 124°02'42"E; 40 m south of the bulldozed geophysical traverse line in the Rason 1:250 000 Sheet area, approximately 79.8 km from the start of the line (Fig. 1); about 465 m above mean sea level.

Objects. (essentially the same as Rason 1)

1) to confirm the subsurface structure suggested by the A.G.C. resistivity survey; 2) to determine depth to, and nature of the Precambrian basement; 3) to obtain groundwater samples and provide a hole for future hydrological testing.

Drilling. Air and water injection were used from 0 to 69 m, mud from 69 to 88 m, and mud or water, depending upon the formation, from 88 m to total depth. A 6 inch (0.1524 m) OD casing was inserted to 4.88 m while drilling. Gamma ray and resistivity logs were run to 85 m. Swelling clay below 85 m prevented deeper penetration of the probe, although the hole was reamed out and cleaned several times with the drill stem. Galvanized iron water pipe (5 cm diameter) was inserted to total depth. Large quantities of water were used drilling the section above 70 m indicating a high permeability for the friable sandstone in this interval. No groundwater was reported by the driller.

Results. The expected profile, based on resistivity interpretations (A.G.C., 1971 p. 5) was: 0 to 3 m dry sand, mudstone, silcrete; 3 m to greater than 150 m sandstone; basement deeper than 150 m. The sequence established by drilling is shown in Figures 3A and 3B. A one metre layer of aeolian sand overlies 143 m of Lower Permian Paterson Formation which non-conformably overlies metamorphic basement.

The Paterson Formation can be divided into four units:

1) An arenaceous unit of poorly sorted sandstone, conglomeratic sandstone and minor siltstone, probably of fluvial origin, between 1 and 76 m. The upper 10 m is ferruginized and silicified and represents the upper part of a laterite profile. Results of geochemical analyses on cuttings from the laterite are discussed on page 30.

2) A lutaceous unit of interbedded claystone and siltstone with thin calcareous sandstone beds between 76 and 134 m. A sharp break between this unit and the overlying arenites is seen in cuttings and wireline logs. Cores 1 and 2 show details of the rock types and sedimentary structures (Fig. 3B). Grey siltstone to silty claystone with coarse 'floating' quartz grains is the dominant lithology in core 1; grey, thinly interlaminated, fine silty sandstone and claystone is the dominant lithology in core 2. Flame structures and synsedimentary breccias with clay clasts were seen in both cores. A low energy environment of deposition is suggested for the horizontal, parallel, distinct laminations (lacustrine varves?) in the lower section of core 2, whilst penecontemporaneous to early post-depositional disturbance of sediment is evident in both cores. Ten hard, well-cemented beds of red to grey, fine-grained, well sorted, calcareous sandstone were intersected between 92 and 121 m. These beds are less than 10 cms thick, they are regularly spaced (2 to 4 m apart) within the lutite sequence, and have sharp planar contacts. Their regular spacing in a fairly uniform sequence of fine-grained rocks suggests some periodic control (e.g. climatic?) over current velocities or supply of detritus.

3) a lutaceous unit with sparse pebbles of sandstone, between 135 and 142 m, grading into...

4) a thin, unbedded, unsorted interval of lithic sandy siltstone with abundant quartz grains (fine to granule size) and rock clasts (up to 45 cm in size); interpreted as a tillite. The lack of bedding and sorting, the variety of rock types present (granite, schist, black siltstone, quartz, quartzite, shale) and lack of rounding of clasts are all compatible with a glacial origin. The pebbles present in unit 3 are interpreted as dropstones, in an otherwise fine-grained sequence. Sakmarian? spores and pollen were identified in cores 1, 2 & 3 (Kemp, in press).

The basement is a fresh, hard, quartz-feldspar-biotite migmatite with a regular mineral banding dipping at 15° to 20°.

BMR RASON 3 (Fig. 4)

Position. Lat. 28°33'18"S, Long. 123°29'48"E; 30 m north of the bulldozed geophysical traverse line in the Rason 1:250 000 Sheet area, approximately 33 km from the start of the line; about 485 m above mean sea level.

Objects. (essentially the same as in Rason 1 & 2)

1) to confirm the subsurface structure suggested by the AGC resistivity survey; 2) to determine depth to, and nature of the Precambrian basement; 3) to obtain groundwater samples and provide a hole for future hydrological testing.

Drilling. The hole was drilled with air to 71.60 m, and from there to total depth (T.D. 74.68 m) water injection was used. Casing was not inserted during drilling. As the hole was virtually dry only a gamma ray log was run. Galvanized iron water pipe (5 cm diameter) was inserted to T.D.

Results. The expected profile, based on resistivity interpretations (A.G.C., 1971, p. 5) was: 0 to 15 m duricrust, silcrete, dry mudstone and sandstone; 15 to about 130 m mudstone and sandstone; basement between 130 and 150 m. The sequence established by drilling is shown in Figures 4 and 5. A partly ferruginized silcrete 6 m thick overlies 25 m of Permian Paterson Formation, which in turn nonconformably overlies crystalline basement.

The Paterson Formation can be divided into two units:

1) An arenaceous unit, consisting of moderately to poorly sorted sandstone with minor siltstone and claystone, which is probably of fluviatile origin, between 6 and 16 m.

2) A lutaceous unit, consisting of interbedded claystone and siltstone with minor sandstone, which is probably of lacustrine origin, between 16 and 31.40 m.

A fairly gradational contact between the two units is apparent from both the cuttings and the gamma ray log. This gradual coarsening upwards from fine-grained lacustrine deposits into coarse-grained fluviatile sandstones is interpreted as a deltaic sequence. At the base of the lutaceous unit a thin bed of coarse-grained to granule-sized, partly well rounded sandstone occurs. This sandstone bed is interpreted as a basal sand resting on the nonconformity surface.

The basement is granite which is intensely weathered in its upper 15 m. The minor flow of water encountered around 70 m probably originated from a highly micaceous shear zone which has been opened by weathering. The resistivity of 6 ohms/m for a sample indicates a T.D.S. of about 1600 ppm. The sequence established in this drillhole, i.e. fluviatile sandstone and siltstone overlying lacustrine claystone and siltstone is similar to the upper part of the sequence encountered in Rason 1 & 2.

The upper part of the sequence encountered in this hole is intensely ferruginized and silicified. The gradational nature of the contacts indicates that the ferruginized silcrete and the silcrete are weathered and chemically altered sediments from the Paterson Formation. The lateritized part of the profile shows the distinct positive kick in the gamma ray log already observed in Rason 1 & 2 (see discussion on page 29).

The subsurface geology indicated by the stratigraphic drilling contrasts markedly with the interpretation based on the resistivity survey (A.G.C., 1971). The drilling results suggest that the basement surface slopes gently to the east, and does not contain the depressions filled with water-saturated sediments indicated by the resistivity survey (Fig. 5). Only in Rason 2 where the basement rocks penetrated are fresh, does the predicted depth to basement correspond reasonably well with the actual depth to basement. In Rason 1 & 3, however, the basement rocks are weathered and there is poor correspondence between the predicted depth to basement and the real depth.

<u>BMR NEALE 1A and 1B</u> (Figs 6a & 6b)

<u>Position</u>. Lat. 28°18'18"S, Long. 125°56'36"E; approximately 12.8 km east of Neale Junction and 35 m north of the Emu Road; about 328 m above mean sea level. The hole is sited over a pronounced positive gravity anomaly.

<u>Objects</u>. 1) to test the stratigraphic sequence, which was expected to be as follows: (top) Paterson Formation, Lennis Sandstone, Table Hill Volcanics, Proterozoic sediments; 2) to obtain samples from the various rock units suitable for palaeontological and/or radiometric dating; 3) to obtain groundwater samples and provide a hole for future hydrological testing; 4) to investigate the pronounced positive gravity anomaly.

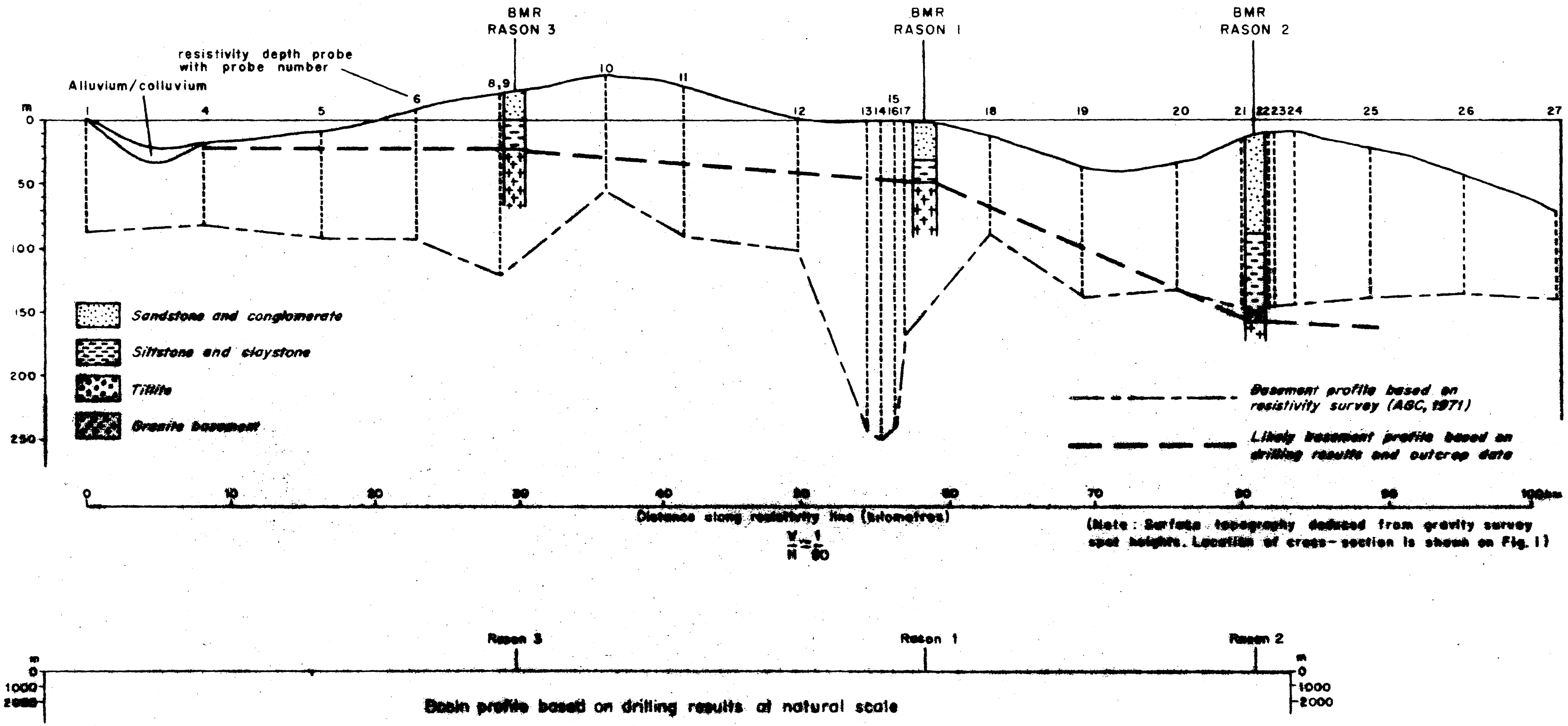

Fig. 5 Cross section central Rason Sheet area

Drilling. Neale 1A was drilled with air to 21.33m. Intense caving of loose sand necessitated a change to mud drilling. A 6 inch (0.1524 m) OD casing was inserted to 29.42 m while drilling ahead to 33.83 m. The casing was then pulled out and the hole reamed, and casing was re-inserted to 33.83 m and cemented in. Drilling with mud was continued to 86.87 m at which depth circulation started coming up on the outside of the casing. Neale 1A was therefore abandoned and the hole was redrilled as Neale 1B three metres away. A 6 inch (0.1524 m) casing was inserted to 4.72 m and cemented in, and mud drilling was done from 4.76 to 205.75 m (T.D.). Gamma ray, spontaneous potential and point resistivity logs were run to T.D. Galvanized iron water pipe (5 cm diameter) was inserted to T.D.

Results. The sequence commences with aeolian sand from 0 to about 1.5 m. From 1.5 to 9 m the sand has been cemented by $CaCO_3$ to form a calcrete. A poorly consolidated sandy sequence follows down to about 30 m. The top of the Paterson Formation is located somewhere in this interval, but as no distinct laterite horizon is developed the exact position of the contact between the overlying aeolian sand and the Paterson Formation is uncertain. A well developed silcrete horizon is present between 28 and 29 m. In cuttings from the top of this silcrete the silicification occurs along cracks or joints and along tubular features. The interval from about 15 to 39.50 m is interpreted as a fluvial deposit, as it consists of moderately to poorly sorted, coarse-grained sandstone. The interval from 39.50 to 56.30 m consists of finer grained sediments and is interpreted as a lacustrine deposit. From 56.30 to 57.80 m there is a conglomeratic sandstone which is interpreted as a sandy tillite on the basis of a comparison with the sequence exposed at Lat. 28°41'35"S, Long. 125°51'30"E, where the Paterson Formation overlies the Wanna Beds with a sandy basal tillite. However it is not possible to discount the possibility that this is a basal conglomerate of non-glacial origin. Sparse fragmented spores and pollen indicating a Sakmarian age were retrieved from a sample taken at 56.69 m (Kemp, in press).

In the cuttings from the Paterson Formation a milky blue variety of quartz is common. Identical quartz occurs in granitic rocks in the southwest corner of the Neale Sheet area. Oolitic chert pebbles in the sandstone indicate that there was also a source of sedimentary rocks in the provenance area.

The grey sandstone, siltstone and claystone sequence intersected between 57.80 and 138 m is interpreted as Wanna Beds. Compared to the exposures of the Wanna Beds in the Mason, Wanna and Waigen 1:250 000 Sheet areas the sequence encountered in Neale 1A and 1B is relatively rich in clay. Notable is the occurrence of clay matrix in an otherwise mature sandstone (e.g. core 1). The well preserved cross-bedding with dips up to 30° and the good sorting and rounding evident in core 2 are features similar to those noted in outcrops of Wanna Beds. Samples from core 1 (66.82 m) and core 2 (112.08 m) were examined for palynomorphs, but none were found.

A sequence of red, fine to medium-grained sandstone with minor claystone, interpreted as Lennis Sandstone, was intersected between 138 m and 205.74 m (T.D.). Red sandstone cuttings were first identified at 138 m; they had completely replaced the grey sandstone cuttings at about 150 m. The boundary between the Wanna Beds and the Lennis Sandstone, therefore, appears to be gradational; a similar feature to that observed at Grid Reference 649596 in the Waigen Sheet area where the contact between the two formations is exposed. The Lennis Sandstone comprises red, fine to medium-grained, moderate to well-sorted, cross-bedded, micaceous sandstone with claystone beds. A sample from core 4 (203 m) was examined for palynomorphs but none were found. Permeability and porosity measurements were made on samples of Wanna Beds and Lennis Sandstone (Table 4).

The objective of penetrating the Table Hill Volcanics and underlying sequence was not achieved. The reason for the presence of a pronounced positive gravity anomaly in the Neale Junction area cannot be deduced from the results of drilling.

BMR NEALE 2 (Fig. 7)

Position. Lat. 28°47'48"S, Long. 15°46'12"E; 3.5 km northeast of benchmark XP 63; 15 m northwest of the Rawlinna-Warburton Road; about 270 m above mean sea level. The hole was sited in a slight depression in order to avoid drilling through a thick cover of superficial deposits.

Objects. 1) to obtain information on the lithology of the Plumridge Beds which on geomorphological grounds were considered to extend into this area; 2) to obtain samples for palynological dating, and 3) to provide a hole for future hydrological testing.

Since the drilling project was completed mapping has shown that the Plumridge Beds are only a useful stratigraphic unit if they are considered part of the Miocene Eucla Basin sequence. The extent of the mostly marine Miocene sediments in the Eucla Basin is determined on geomorphological characteristics, and is considered to coincide with the extent of the Bunda Plateau. Although alluvial/colluvial sediments similar to those occurring in the Plumridge Beds are present in many valley fills in the Officer Basin, and though they may in places grade into the Plumridge Beds, they are not considered part of that unit. The alluvial/colluvial sediments that were drilled through in Neale No. 2 are therefore not described as Plumridge Beds.

Drilling. Neale 2 was drilled with air to 16.76 m. From there to 74.76 m (T.D.) the hole was drilled with mud. During drilling a 6 inch (0.1524 m) OD casing was inserted to a depth of 4.88 m. Gamma ray, spontaneous potential, point resistivity and normals resistivity logs were run to T.D. Galvanized iron water pipe (5 cm diameter) was inserted to T.D. following the completion of the hole.

Results. The sequence was expected to consist of a few metres of aeolian sand and kankar overlying several tens of metres of Plumridge Beds, which at the type locality consist of partly calcareous conglomeratic sandstone containing laterite and silcrete pebbles, overlying a finer grained, moderate to poorly sorted siltstone and sandstone sequence (Van de Graaff & Bunting, in prep.). The top of the Paterson Formation was expected at about 50 m.

The hole penetrated about 4 m of aeolian sand, 1 to 2 m of calcareous sand (kankar), a predominantly poorly sorted conglomeratic sandstone sequence between 6 and 45 m and a pebbly claystone sequence between 45 m and 74.76 m (Fig. 7). It is not possible to positively relate the sequence drilled to the expected stratigraphy. The slightly calcareous conglomeratic sandstone containing silcrete pebbles between 10 and 18 m is similar to the upper part of the Plumridge Beds at the type section. The lutaceous sequence below 45 m is lithologically similar to the lacustrine Paterson Formation seen in BMR Rason 2. Palynological examination of specimens from core 1 (56.99 m and 58.21 m) produced sparse fragmented ?Sakmarian spores and pollen confirming the interpretation of this sequence as Paterson Formation. A detailed examination of core 1 was made in Canberra. It consists of parallel-laminated, light and dark grey, silty claystone containing sparse pebbles of decomposed granite, quartzite and siltstone and rare ferruginized rod-like structures, 0.5 cm in diameter and 3 to 4 cm long (?fossil wood). This lithology is very similar to that seen in BMR Rason 2 between 80 and 140 m and is similarly interpreted as a possibly varved lacustrine deposit with sparse drop pebbles. The poorly indurated conglomeratic sequence between 18 and 45 m can either be interpreted as a Tertiary alluvial/colluvial deposit or as fluvial Paterson Formation. The cuttings for this interval are not suitable for palynological work so it is not possible to pinpoint the contact between the two units. The gamma ray curve has been used to draw a somewhat arbitrary boundary between the alluvium/colluvium and the Paterson Formation at about 25 m (Fig. 7). Below this depth the gamma ray curve shows a gradual overall deflection to the right which is overprinted by many small scale variations. The clay fraction of five samples of Paterson Formation from core 1 was submitted for trace element analysis. The results are shown in Table 2 and discussed on page 37.

BMR NEALE 3 (Fig. 8)

Position. Lat. 28°19'00"S, Long. 125°49'12"E; 1.1 km south of Neale Junction and 25 m east of the Warburton-Rawlinna road (at the foot of the first sand dune on the western side of the road); about 335 m above mean sea level. This hole was sited on patchy calcrete in an area of aeolian sand.

Objects. 1) to obtain water supplies for drilling a deep stratigraphic hole in the Neale Junction area. This hole was drilled before the other holes in the Neale Sheet area, but it was not named until Neale 1A, 1B & 2 had been drilled.

Drilling. The hole was drilled with air to 9.15 m. From there to 38.10 m (T.D.) air and water injection were used. During drilling a 6 inch (0.1524 m) OD casing was inserted to 10.67 m. As the hole was virtually dry only a gamma ray log was run to T.D.; the hole was abandoned when it failed to locate adequate water supplies.

Results. The sequence was expected to consist of 10 to 15 m of water-bearing calcrete overlying the Paterson Formation, but only about 2 m of poorly developed calcrete was intersected. Surprising features of the sequence were that ferruginous laterite is very poorly developed and that silcrete occurs in sandstones of the Paterson Formation.

The Paterson Formation can be divided into two units:
1) An arenaceous unit, consisting of moderately to poorly sorted, fine-grained to granule-sized sandstone and minor siltstone and claystone, which extends from about 4 m to about 29 m.

2) A more lutaceous unit, consisting of claystone, siltstone and sandstone, which extends from 29 to 38.10 m T.D.).

The upper unit is interpreted as a fluviatile deposit, whereas the lower unit is of lacustrine to fluviolacustrine origin. The sequence encountered is very similar to the sequence in the upper part of Neale 1A & 1B.

A marked deflection on the gamma ray curve was recorded at 11 m within the silicified Paterson Formation.

A minor seepage of water was reported from the lower part of the hole, but the hole was abandoned as being an inadequate source of drilling water. Consequently, Neale 1 and 2 were drilled using water carted from Laverton, involving a return trip of 380 km.

BMR WANNA 1 (Fig. 9a & 9b)

Position. Lat. 28°22'04"S, Long. 127°37'44"E; 3.8 km southast of benchmark XO 37, 40 m south of the Emu road; about 400 m above mean sea level. The drill site was chosen on an elevated spot in order to penetrate as complete a stratigraphic sequence as possible.

Objects. 1) to obtain stratigraphic information on the expected sequence of Paterson Formation, Wanna Beds and Lennis Sandstone in an area of poor outcrop; 2) to obtain samples suitable for palaeontological dating from the Wanna Beds and the Lennis Sandstone, and 3) make comparisons with the upper part of the sequence encountered in Continental Oil's Birksgate No. 1 Well, 245 km to the east-northeast.

The drill hole was sited close to the border between the Vernon and Wanna 1:250 000 Sheet areas. Both Sheet areas have an extensive aeolian sand cover and contain only a few rock outcrops. Paterson Formation crops out along the western edge of Vernon, 150 km to the west of the drill hole; Wanna Beds crop out 20 km due east; and possible Lennis Sandstone crops out 23 km to the northeast. The expected stratigraphy was - thin conglomeratic Paterson Formation overlying Wanna Beds up to about 150 m thick overlying Lennis Sandstone several hundred metres thick. The sequence that was established by drilling contrasts markedly with that expected; it also has important implications for the regional geology of this part of the Great Victoria Desert. The interpretation of the stratigraphy made at the well site had to be completely revised when Early Permian spores were recovered from core 2.

Drilling. The hole was drilled with mud from ground level to 154.53 m (T.D.). Six inch (0.154 m) casing was inserted to 2.43 m during drilling. Gamma ray, spontaneous potential, point resistivity and normals resistivity logs were run to T.D. As no aquifers were reported by the driller water pipe was not inserted on completion of the hole, and it was abandoned when carted drilling water supplies were exhausted.

Results. Sandy laterite (0 to 3 m) overlies a ferruginized and silicified pebbly sandstone sequence between 3 and 8 m. This thin interval at the top of the hole is interpreted as lateritized fluviatile Paterson Formation. Between 8 and 129 m the cuttings show that the drill hole penetrated a monotonous sequence of brownish grey, silty, medium to fine-grained, carbonaceous quartz wacke containing some well-rounded to spherical quartz grains, and numerous woody fragments. Bedding was not evident in most of core 2, but the interval 31.80 to 32.00 m was brecciated (?slump breccia) and complexly bioturbated.

Parts of the core showed strong effervescence with 10% dilute HCl, whilst other parts were apparently non-calcareous. As the rock types intersected were most unlike the typical Paterson Formation this sequence was initially interpreted as Wanna Beds. However, palynological investigation of specimens 364a, b, & c from core 2 recovered excellently preserved Sakmarian? spores, showing that this sequence is Early Permian in age and therefore belongs to the Paterson Formation. An interesting feature is the common presence of well rounded quartz grains in an otherwise generally subangular to subrounded medium to fine-grained wacke. Well rounded quartz grains have seldom been seen in the Paterson Formation before, and then only as sparse grains within lacustrine claystones. They may be derived from sandstones of the Wanna Beds, which are relatively rich in such grains. Although only one core was taken in this sequence, the geophysical logs and cuttings indicate a uniform lithology throughout the interval 8 to 129 m. A change in lithology takes place at about 129 m. The deflection of the gamma ray curve to the left between 129 and 148 m is probably caused by a sandy unit. Between 148 and 154.53 m (T.D.) a more clayey unit is indicated by a marked deflection in the gamma ray curve to the right. Detailed petrological investigation of core 3 shows that it is weakly consolidated, greenish-grey, lithic conglomeratic mudstone. Bedding is not apparent and hand specimen examination and a sieve analysis shows the rock to be very poorly sorted. Half the core was broken up and the non-clay fraction was sieved, washed, and examined under a binocular microscope. It consisted of about 70 percent quartz and 30 percent rock fragments. These constituents range in size from very fine-grained (0.063 mm) to 6 cms; roundness ranges from angular to well rounded, but is dominantly subrounded to rounded. Over 100 rock fragments were examined; they were composed of the following rock types (in approximate order of abundance) - quartzite, gneiss, oolitic and pisolitic chert, granite, sandstone, schist, vitric tuff?, glauconitic sandstone, siltstone, black chert, banded haematitic chert, and quartz feldspar porphyry. The palynological results and detailed petrological examination of core 3 indicate that the rocks in the lower part of the hole are tillites and glaciolacustrine sandstones of the Paterson Formation. The clasts in the tillite are of rock types that are common in the Archaean basement rocks and the overlying Proterozoic sedimentary rocks to the west.

BMR YOWALGA 1, 2 & 3

Three seismic shot holes were drilled 2 km southwest of Yowalga 4. Cuttings taken by the seismic party drilling crew were logged by P. Kennewell (BMR geologist). The three holes were all located within 500 m of each other. Yowalga 1 was drilled to 90 m, Yowalga 2 to 30 m, and Yowalga 3 to 100 m; all holes were used for deep seismic shots.

The cuttings show a similar sequence to Yowalga 4, i.e., 10 to 15 m of siltstone overlying coarse-grained and conglomeratic sandstone. Ferruginization and silicification of rocks is common in the top 20 m, and its intensity decreases with depth. The sandstone at the bottom of Yowalga 3 (100 m) was still slightly weathered indicating that the weathering profile extends to considerable depths in the porous and poorly sorted sandstones of the Paterson Formation.

BMR YOWALGA 4 (Fig. 10)

Position. Lat. 26°50'04"S, Long. 125°37'33"E, at SP (Shot Point) 604 on the BMR seismic line; about 460 m above mean sea level.

Objects. 1) to obtain information on the lithology of the Samuel Formation and the underlying Paterson Formation, and to establish the nature of the contact; 2) to obtain samples suitable for palynological dating of these units, and 3) to core through the complete weathering profile.

Drilling. The hole was drilled with air to 12.20 m and with mud from 12.20 to 42.97 m (T.D.). It was cored continuously from 13.71 m to T.D. Gamma ray, spontaneous potential and point resistivity logs were run to T.D. Casing (0.1524 m - 6 inch) was inserted to 1.22 m during drilling. Water pipe was not inserted in the hole after completion; the hole was abandoned.

Results. A sandy laterite that causes a distinctive deflection in the gamma ray curve was penetrated between 0 and 6.30 m. It grades downwards into a variegated, slightly micaceous siltstone sequence (6.30 m - 14.00 m) that was initially interpreted as being part of the Samuel Formation. However, close examination of nearby breakaways showed that this fine-grained rock contains cobble-sized erratics which are interpreted as glacial dropstones. The interval 6.3 to 14.00 m was therefore included with the underlying coarser grained rocks in the Paterson Formation. The variegated coarse-grained and conglomeratic sandstone sequence with cross-stratification and thin beds of siltstone and claystone intersected between 14 and 42.97 m (T.D.) is interpreted as fluviatile Paterson Formation.

The hole was abandoned when local outcrop examination showed that the hole had been spudded into Paterson Formation and not the overlying Samuel Formation. The objectives of this hole were fortunately attained in BMR Browne 1. A specimen of pale yellow siltstone from 41.74 m was examined for palynomorphs, but none were found.

BMR TALBOT 1. (Fig. 11)

Position. Lat. 26°09'12"S, Long. 126°32'30"E, just west of the Warburton-Rawlinna road where it branches off from the Warburton-Laverton road about 1 km southwest of Blacks Lookout; about 445 m above sea level. This site is located on the alluvial flat of Elder Creek. It was a convenient starting point for a series of five holes drilled along a line perpendicular to the strike of the Townsend Quartzite.

Objects. The Upper Proterozoic sediments overlying the Townsend Quartzite and underlying the Table Hill Volcanics, are incompletely known because of very poor exposure. To supplement the sketchy knowledge obtained from surface studies five shallow holes were drilled along a line perpendicular to the strike of the Townsend Quartzite in the Browne Range.

Drilling. Talbot 1 was drilled with air to a depth of 10.67 m and with mud from 10.67 to 33.06 m (T.D.). Casing was not inserted during drilling. Gamma ray, spontaneous potential and point resistivity logs were run to T.D. Water pipe was not inserted after completion of the hole; the hole was abandoned.

Results. The sequence encountered consists of fine-grained alluvium or aeolian sand (0 to 4 m) overlying a conglomeratic sandy limestone to patchily cemented conglomeratic sand (4 to 24 m) of alluvial origin. This moderately well developed calcrete overlies poorly consolidated sandstone (24 to 28.50 m) which is still interpreted as alluvium. The lower part of this sandstone consists of probably little reworked debris from the Townsend Quartzite, and the contact with the Townsend Quartzite (28.50 to T.D.) is gradational. The absence of the Lefroy Beds in this hole is due to fairly extensive erosion by Elder Creek before the deposition of the alluvium occurred. A thin section from core 1 shows that the Townsend Quartzite here is a poorly sorted quartz arenite composed predominantly of well rounded quartz grains, but with a few grains of chert and accessory zircon. It is cemented with quartz in crystallographic and optical continuity with the detrital quartz; dust rims separating the highly rounded detrital grains from the secondary overgrowths are common.

BMR TALBOT 2. (Fig. 12)

Position. 610 m to the southwest of Talbot 1; about 445 m above mean sea level.

Objects. As for Talbot 1.

Drilling. The hole was drilled with air to a depth of 7.50 m and with mud from 7.50 to 13.72 m (T.D.). Casing was not inserted during drilling. As this was only a very shallow hole, gamma ray and electrical logs were not run. Water pipe was not inserted after completion of the hole; the hole was abandoned.

Results. Partly calcreted, poorly consolidated alluvial sand and conglomeratic sand were penetrated from 0 to 7.50 m. A well indurated conglomeratic sandstone, misinterpreted at the well site as Proterozoic fluvioglacial Lupton Beds, was intersected between 7.5 and 13.72 m (T.D.). The hole was then completed at this depth as it had apparently fulfilled its objectives. Detailed examination of core 1 shows, however, that the interval 7.5 to 13.72 m is still part of calcareous conglomeratic alluvium and not the Lupton Beds. Core 1 is a mottled reddish-brown to white, very poorly sorted, pebbly conglomeratic sandstone with a calcareous matrix. Numerous haematitic and goethitic sandstone pisoliths and fragments derived from the Miocene? duricrust were found in the conglomerate. A large fragment of weathered Townsend Quartzite was found at the bottom of core 1. The hole therefore did not achieve its objectives.

BMR TALBOT 3. (Figure 13)

Position. 1220 m southwest of Talbot 1; about 445 m above mean sea level.

Objects. As for Talbot 1.

Drilling. The hole was drilled with air to a depth of 6.09 m, and with mud from 6.09 to 77.36 m (T.D.). Casing was not inserted during drilling. Gamma ray, spontaneous potential, point resistivity, and normals resistivity logs were run to T.D. Water pipe was not inserted after completion of the hole; the hole was abandoned.

Results. Well indurated Proterozoic bedrock dipping at 25° to 30° was penetrated at about 52 m. Overlying this is a weakly consolidated, conglomeratic sandstone of unknown age. Calcreted alluvium containing laterite fragments and rock debris (igneous and volcanic clasts), probably derived from the Blackstone Ranges area to the northeast, occurs from the surface down to about 22m. The interval 22 to 52 m could be either a continuation of this Quaternary alluvial deposit or a fluvial facies of the Paterson Formation. The cuttings in this interval were not suitable for palynological study so a choice between the alternatives is not possible.

A reddish brown and green, laminated and fissile, micaceous siltstone and claystone sequence dipping at 25° to 30° was penetrated between 52 and 7.36 m (T.D.). The top of this interval is well defined by the gamma ray log. Thin sections from core 2 show the lutites are mainly composed of angular to subrounded quartz and completely altered feldspar? grains (mainly less than 0.1 mm in size) in a clayey matrix. Many of the grains are extremely angular and several elongated slivers of feldspar were seen, suggesting minimal abrasion of grains prior to deposition. Bedding is irregular in several places because of flame structures, breccias and cross-lamination. Lowry et al., (1972) describe white and purple-weathering, laminated to thinly bedded siltstone, and very fine-grained sandstone overlying the Townsend Quartzite in Ainslie Gorge, 10 km southeast of the drill hole, and call these the Lefroy Beds. It is most likely that the siltstones intersected in this hole correlate with the Lefroy Beds.

BMR TALBOT 4. (Fig. 14)

Position: 1830 m southwest of Talbot 1; about 445 m above mean sea level.

Objects: As for Talbot 1.

Drilling: The hole was drilled with mud from 0 to 69.63 m (T.D.). No casing was inserted in the hole during drilling. Gamma ray, spontaneous potential, point resistivity and normals resistivity logs were run to T.D. Water pipe was not inserted on completion; the hole was abandoned.

Results: Conglomeratic sand with minor silt and clay, which is of alluvial origin, is present from 0 to 6 m. A slightly calcreted sandstone which is probably also of alluvial origin extends from 6 to 18.25 m. The interval from 18.25 to 54.80 m consists of poorly sorted, very coarse-grained sand with silt and clay. The cuttings at 34 m contained granules of ironstone which can either be reworked laterite pellets or they can represent a poorly developed in situ laterite. In either case the interval from 18.25 to 34 m is interpreted as an alluvial deposit. The interval from 34 to 54.60 m is lithologically very similar to the overlying sequence and is tentatively interpreted as alluvium, but if the ironstone at 34 m is an in situ laterite the sequence from 34 to 54.60 m would have to be interpreted as Paterson Formation. The cuttings for this interval were all found to be unsuitable for palynological examination. A red silty sandstone from 42.67 to 45.72 m was nevertheless examined and, as expected, proved to be barren.

The cuttings and gamma ray log indicate a well indurated lutaceous unit below about 55 m. Grey, red and green claystone, siltstone, and fine-grained sandstone were prominent in the cuttings down to 67 m, but below this fine-grained sandstone is dominant. A large thin section of core 1 (spec 73880223) shows that the sandstone is a fine-grained quartz wacke containing numerous thin (1 to 2 mm) laminae of brown siltstone that commonly have sharp bases and gradational tops. The sandstone is composed largely of angular to sub-angular quartz grains (75%) tightly to loosely packed in a clay matrix (20%). Numerous thin flakes of muscovite are also present. Bedding is irregular because of the presence of flame structures, siltstone clasts, roll-over type structures and numerous other erosional breaks. The flame and roll-over structures suggest high sedimentation rates. The lack of abrasion of constituent grains, the random orientation of muscovite flakes, and the lack of winnowing of matrix, also indicate rapid deposition in an area not far from the provenance. A ?tectonic dip of 10° was measured in a part of the core that has less-disturbed bedding laminations.

The red and green lutites between 55 and 67 m look identical to those intersected in the bottom of Talbot 3 and are therefore correlated with the Lefroy Beds. The reddish-brown sandstone at the bottom of Talbot 4 may be a facies of the Lefroy Beds that has not been seen in the very poor surface exposures.

BMR TALBOT 5. (Fig. 15)

Position. 2440 m southwest of Talbot 1; about 445 m above mean sea level.

Objects. As for Talbot 1.

Drilling. The hole was drilled with mud from 0 to 95.10 m (T.D.). No casing was inserted during drilling. Gamma ray, spontaneous potential, point resistivity and normals resistivity logs were run to T.D. Waterpipe was not installed after completion of the hole; the hole was abandoned.

Results. A Cainozoic alluvial deposit composed of conglomeratic sand, silt and clay containing ironstone pisoliths and igneous and metamorphic pebbles was penetrated between 0 and about 20 m. Between 20 and 95.10 m (T.D.) the hole penetrated a sequence of lutites containing sparse granules and pebbles. At the well site the interval from 20 to 60 m was interpreted as lacustrine Paterson Formation and the interval from 60 m to T.D. as interbedded Proterozoic sandstone, siltstone and claystone. A more detailed analysis of core 1 and the cuttings from above suggest the following more likely interpretation. Core 1 is a diamictite and is probably a tillite of the Proterozoic Lupton Beds. The rock is a very poorly sorted, green, lithic conglomeratic mudstone. Angular to subrounded clasts of mainly green and brown siltstone up to 7 cm across form about 50 percent of the rock; they are loosely packed in a green clayey matrix. Clasts of weathered igneous and/or metamorphic rocks are also present. Bedding was generally absent although dips of 25° to 30° were indicated by some sandy laminae. The cuttings above core 1 do not show any marked change throughout the whole interval from the core up to 20 m, but all the geophysical logs show a change in character at about 58 m. This may indicate the top of the Lupton Beds, in which case the interval above could best be interpreted as possible lacustrine clay of the Paterson Formation; if not, it may just reflect a change in weathering, in which case the whole interval from 20 to 95.10 m can be interpreted as Lupton Beds. None of the material retrieved was considered suitable for palynological examination. The possibility that the diamictite may be the result of a mud flow rather than deposition from ice cannot be discounted. The probable tectonic dip of 25° to 30° would favour an interpretation as Proterozoic glacial Lupton Beds rather than Permian glacial Paterson Formation. The presence of slickensides along joints and minor faults in core 1 is also more compatible with the suggested Proterozoic age. Disseminated scales and tabular crystals of hematite were seen along joint faces and in small cavities at 92.96 m.

<u>BMR BROWNE 1.</u> (Figs 16a & b)

<u>Position.</u> Lat. 25°32'04"S, Long. 125°16'30"E, approximately 130 m southwest of Mount Beadell triangulation beacon; about 540 m above mean sea level. The hole was sited on the highest accessible point in order to drill through as complete a sequence as possible.

<u>Objects.</u> 1) to core continuously a section through the Bejah Claystone, Samuel Formation, and the upper part of the Paterson Formation, which can be used as a reference section for the first two units; 2) to determine the thickness of the Cretaceous deposits in this area; 3) to obtain dateable samples from the various units and especially from the basal part of the Samuel Formation and the upper part of the Paterson Formation.

Drilling. The hole was drilled with mud from 0 to 121.92 m (T.D.). It was cored continuously from 7.62 to 121.92 m. Casing (0.1524 m - 6 inch) was inserted to 4.57 m during drilling. Gamma ray, spontaneous potential, point resistivity and normals resistivity logs were run to T.D. The hole was abandoned.

Results. Between 0 and 4 m the hole penetrated strongly silicified Lampe Beds with a conglomeratic and brecciated appearance that indicates minor reworking of the rock. The Bejah Claystone, a cream, pink, and purple, thinly bedded to laminated claystone sequence was intersected between 4 and 30 m. Thin sections show that the Bejah Claystone contains sparse angular grains of quartz and mica in a submicroscopic matrix. Multichambered Radiolaria are present in specimens 73880238 and 73880247. X-ray diffraction analyses (see Appendix) and chemical analyses (Table 2) show that the Bejah Claystone is mainly composed of quartz and kaolinite. Specimen 73880242 has a very unusual chemical composition when compared with the other samples analysed. X-ray diffraction examination shows that this rock is probably composed of alunite, a potassium aluminium sulphate hydroxide with a composition of $KAl_3(SO_4)_2(OH)_6$. Veevers and Wells (1961, p. 70) also report alunite in the Bejah Claystone in the southeast corner of the Morris Sheet area, 200 km to the north of Browne 1. The significance of the results of the chemical analyses are discussed on page 31.

A surface section measured on the north side of Mount Beadell indicates that the Bejah Claystone has a maximum preserved thickness of 35 m in this area.

The Samuel Formation was intersected between 30 and 109 m. It has a gradational upper contact with the Bejah Claystone, but a sharp lower contact with the underlying Paterson Formation. The Samuel Formation is predominantly fine-grained, feldspathic, silty and well bioturbated. In Browne 1 it can be divided into two units. Between 30 and 70 m is a sequence of mottled and variegated, moderately sorted, feldspathic quartz wacke, siltstone and claystone. Between 70 and 109 m grey to black, micaceous, carbonaceous, glauconitic, and feldspathic siltstone and claystone is dominant. This lower interval is well bioturbated and contains a cyclic sequence between 80 and 90 m, and black, pyritic claystone (?euxinic) at 90 m.

The sandstones in the Samuel Formation are commonly feldspathic, suggesting that the detritus was derived from a source rich in feldspar, e.g., igneous rocks. Weathered feldspar grains (30 to 40 percent of total rock) outnumber quartz grains (20 to 30 percent of total rock) in thin sections of silty sandstone at 38.68 m, 64.01 m and 70.41 m.

The Bejah Claystone and the upper part of the Samuel Formation are barren of palynomorphs. The darker, carbonaceous lutites penetrated between 70 and 109 m are richly fossiliferous and the palynomorphs indicate an Early Cretaceous age. The palynology, mineralogy and sedimentary structures all indicate a shallow marine environment of deposition.

A change in lithology, drill penetration rate and geophysical log characteristics at 109 m marks the contact between the Samuel Formation and underlying Paterson Formation . The actual contact is probably located in a poorly consolidated, limonitic sandy interval containing three hard, intensely ferruginized bands, one of which had a Collenia-like structure. Two characteristic features of the Samuel Formation, glauconite grains and Aptian palynomorphs, were identified down to 107 and 108.97 m respectively. Detailed examination of the cores shows a marked change to coarser grained, less silty sandstones below 109 m. Loose, porous, poorly indurated, medium to coarse-grained sandstone containing sparse quartz granules comprises the interval 109 to 121.92 m (T.D.). The change in lithology, lack of Aptian spores, and lack of glauconite below 109 m are considered good indicators of the difference between shallow marine Lower Cretaceous Samuel Formation and fluviatile Lower Permian Paterson Formation.

BMR Browne 1 is the most complete section of Cretaceous strata in the Officer Basin and as such is an ideal reference section for the Bejah Claystone and Samuel Formation. The preserved combined thickness of the Bejah Claystone and Samuel Formation in Browne 1 is only 106 metres, much thinner than the 300 m estimated from seismic surveys and regional mapping (Lowry et al., 1972).

BMR WESTWOOD 1. (Fig. 17)

Position. Lat. 27°02'42"S, Long. 124°49'06"E; at BMR shotpoint 395, approximately 200 m south of the Warburton Road; about 450 m above mean sea level.

Objects. 1) to core continuously a section through the Table Hill Volcanics, the presence of which had been established by a seismic survey; 2) to obtain basalt samples suitable for geochemical and radiometric studies; 3) to obtain information on the sediments underlying the Table Hill Volcanics.

Drilling. The hole was drilled with air from 0 to 4.57 m. From 4.57 to 85.34 m (T.D.) the hole was cored continuously, using mud. Gamma ray, spontaneous potential, point resistivity and normals resistivity logs were run to T.D. Casing was not inserted during drilling and the hole was abandoned.

Results. From 0 to 2 m the hole penetrated a poorly sorted colluvial deposit or an in situ weathering residue. The presence of sandstone fragments in this interval indicates that the top of the basalt in this hole is probably very close to the stratigraphic top of the basalt unit. Similar sandstone overlying the basalt was encountered in nearby shotholes. The Table Hill Volcanics were intersected between 2 and 74 m. Their macroscopic characteristics here are very similar to those observed elsewhere. The presence of a thin sandstone interval from 22 to 23 m indicates that the Table Hill Volcanics in this area consist of at least two separate flows. Detailed petrological and geochemical analyses (Table 5) confirm that there are two flows and also allows comparisons with similar basalts in the Northern Territory.

A pale red to brown, fine to coarse-grained, cross-laminated sandstone was intersected between 74 and 85.34 m (T.D.). Thin sections show that the rock is a lithic feldspathic quartz arenite with a quartz and calcite or dolomite cement. Specimens 73880332 and 333 are predominantly fine to very fine-grained and well sorted. Specimen 73880329 is bimodally sorted (1.0 mm and 0.1 mm). In all thin sections the detrital grains are predominantly subangular to subrounded and are made up of quartz (60-70%), feldspar (20%), chert and sandstone ($< 5\%$). The coarse grains in specimen 73880329 were very well rounded and form cross-laminae in the hand specimen. The remnants of an intergranular cement of calcite crystals are evident in the thin sections. Much of the quartz has complex undulatory extinction with strongly sutured intercrysta boundaries.

The sedimentary textures and structures suggest a shallow marine environment of deposition with the detrius derived from a provenance containing metamorphic rocks and chert. The red colour is due mainly to limonitic staining of the slightly altered feldspars, but rims of limonite around the quartz grains are also present. As the sandstone underlies the Table Hill Volcanics it is either Early Cambrian or Precambrian. It appears to be flat-lying. Its stratigraphic significance is discussed on page 44.

BMR WESTWOOD 2. (Fig. 18)

Position. Lat. 27°07'20"S, Long. 124°42'36"; at BMR shotpoint 369, approximately 240 m south of the Warburton Road; about 450 m above mean sea level.

Objects. To provide stratigraphic information on the unexposed Proterozoic sequence in this area. The subcrop of the Table Hill Volcanics is located to the northeast; the hole was therefore expected to penetrate thin Paterson Formation and then Proterozoic units.

Drilling. The hole was drilled with air from 0 to 4.57 m and with mud from 4.57 to 101.50 m (T.D.). Gamma ray, spontaneous potential, point resistivity and normals resistivity logs were run to T.D. A 6 inch (0.1524 m) casing was inserted to 4.87 m during drilling. The hole was abandoned.

Results. Unconsolidated red sand overlying a pisolitic laterite comprises the interval 0 to 3.6 m. A distinctive deflection in the gamma ray log caused by a high concentration of thorium (Table 2), was recorded opposite the laterite. At 3.60 m the cuttings show a transition from pisolitic ironstone to mottled and ferruginized claystone. The claystone is only 3 m thick and appears to have a sharp contact with the underlying sandstone at about 6 m. A uniform, poorly indurated, predominantly grey, silty sandstone sequence containing minor claystone was penetrated between 6 and 101.50 m (T.D.). A marked fining of grainsize, increases in clay content and change in colour to pale red and pale green is evident below about 87 m. Thin sections from cores 3, 4 and 5 show that the rocks at the bottom of the hole are poorly sorted calcareous quartz wackes and lutites. The ratio of grains to calcareous clay matrix ranges from about 1:2 to about 1:10, i.e. parts of the rock are mudstone. The red colour is due to replacement/staining of the matrix by limonite. The rocks are indistinctly thinly laminated to thinly bedded. Discontinuous laminae of clay and silt and cross-laminae of medium to coarse quartz grains are common. Core 4 was examined for palynomorphs and conodonts, but none were found; cores 1 and 2 are not suitable for palynological study. On lithological evidence alone it is not possible to equate the sequence in this hole with any of the known formations. As no tectonic dips were seen in the cores it is not even certain that the sequence is Proterozoic as initially expected; it could represent a Lower Palaeozoic sequence (equivalent perhaps to Wanna Bed or Lennis Sandstone) that oversteps the Table Hill Volcanics. Westwood 2 was abandoned incomplete so that a deep hole to test seismic interpretations to the southwest (Throssell 1) could be drilled in the remaining time.

BMR THROSSELL 1. (Figs 19a & b)

Position. Lat. 27°16'24"S, Long. 124°24'30"E; at BMR shotpoint 302, approximately 400 m east of the Warburton Road; about 385 m above mean sea level.

Objects. 1) to establish the geological nature of two prominent seismic events occurring at approximate depths of 120 and 270 m (Harrison and Zadoroznyj, in prep.); 2) to obtain a continuous core from the calcretes at the northern end of Lake Throssell; and 3) to establish the thickness and nature of Cainozoic sediments in a large trunk valley of the ancient drainage system.

Drilling. The hole was drilled with air between 0 and 7.62 m and then to total depth (198.12 m) with mud. An attempt was made to core the calcrete continuously from 7.62 m downwards, but some short intervals of difficult ground were drilled. Cores were obtained from about half of the cored interval (7.62 to 35.05 m). Water inflow was reported by the driller at 11 m. The hole was cemented twice and abandoned at 198.12 m, when it collapsed. Gamma ray, point resistivity and caliper logs were run down to 169.50 m. A 6 inch (0.1524 m) casing was cemented to 14.63 m. The hole was abandoned.

Results. Although confirmation of age is not possible due to a lack of fossils the sequence intersected has been divided into a Cainozoic calcrete and lacustrine deposit between 0 and 101 m, and the Proterozoic Babbagoola Beds between 101 and 198.12 m (T.D.).

A weakly cemented, calcareous sand with silt and clay, interpreted as an aeolian deposit, was intersected between 0 and 0.5 m. It grades downwards into a cavernous, brecciated and nodular calcareous rock containing coarse-grained terrigenous material and clay-filled fractures. This calcareous and dolomitic rock shows evidence of in situ $CaCO_3$ precipitation of several generations, with evidence of pushing apart and replacement of pre-existing textures and structures. Normal sedimentary structures, such as bedding, grading or sorting are not present. Silicification and opalization, especially along fractures, are common. The interval 24 to 27.5 m is intensely silicified. The amount of terrigenous material seldom exceeds about

30 percent (visual estimate) of the total rock. The interval 0.5 to 27.5 m is interpreted as a calcrete[1].

The grey and red gypsiferous clay with minor silt and sand intersected between 36 and 101 m is poorly consolidated and is interpreted as a Cainozoic playa lake deposit. Palynomorphs were not recovered from cores 12 and 13, so confirmation of the age of the deposit is not possible. A bed of concretionary limestone (calcrete) was intersected between 59.44 and 59.69 m; it shows up well on the point resistivity curve (probably due to its increased effective porosity).

A distinct deflection in the gamma ray log and a marked reduction of drill penetration rate at 101 m marks the top of a well indurated sequence of claystone, siltstone and sandstone. Between 101 and 148 m the rocks are predominantly red siltstone and sandstone. Core 14 is composed of a light red, micaceous, dolomitic, fine-grained, sub-angular quartz wacke with irregular silty laminae. Spherical, pale-grey ?reduction mottles, between 5 and 30 mm in diameter, are prominent throughout the whole core. A shallow water, evaporitic environment of deposition is envisaged. Between 155 and 195.12 m (T.D.) grey, bluish grey, and greenish grey, slightly fissile, well indurated claystone and siltstone is dominant. Core 15 is composed mainly of interlaminated to thinly interbedded micaceous siltstone and claystone beds dipping at 8°. Flame structures and load casts are present, but generally the bedding is distinct and parallel. The fissility is parallel to the bedding which in thin sections can be seen to contain numerous laths and elongated slivers of muscovite. The whole core is cut by thin fractures (0.1 mm thick) that are filled wth calcite.

The interval 148 to 155 m, which separates the red from the grey unit, was logged as mainly fine-grained grey sandstone at the well site. A detailed re-examination of the cuttings was made as the gamma ray and point resistivity curves recorded marked deflections opposite this interval. The dominant lithology in the cuttings is a pale green to grey, fine-grained dolomitic or calcareous sandstone. Effervescence in dilute HCl was seen between 146 and 153 m, but vigorous effervescence, indicating a substantial carbonate content, was restricted to the interval 148 to 151 m.

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[1] Calcrete - Goudie (1972) defines calcrete as: a term for terrestrial materials composed dominantly but not exclusively of calcium carbonate which occurs in states ranging from powdery and nodular to highly indurated and involve the cementation of, accumulation in and/or replacement of greater or lesser quantities of soil, rock, or weathered material primarily within the vadoze zone.

The interval 101 to 198.12 m (T.D.) is lithologically very similar to the Babbagoola Beds in Hunt Oil Yowalga 2 (Jackson, 1966). As the units themselves are lithologically distinctive (especially the red silty sandstone with pale mottles) and are found in the same succession with approximately the same thicknesses, a correlation with the Yowalga 2 sequence is most probable.

The difference in physical properties between the poorly indurated Cainozoic lacustrine deposits and the underlying, well lithified Proterozoic sediments is the cause of the shallow seismic event. Due to difficult drilling, logistic problems, and lack of time, the character of the deeper seismic event was not determined.

NEW STRATIGRAPHIC INFORMATION FROM THE DRILLING

The results of the drilling mostly confirm our original ideas on the stratigraphy of the Officer Basin, but they also provide some unexpected results that have important implications for the regional geology of parts of the basin. These new results and also the more important results of detailed laboratory studies are summarized below under the stratigraphic units concerned.

AEOLIAN SAND

When drilling in dune fields the rig was located in the interdunal corridors, rather than on the dunes, to avoid drilling through thick, unconsolidated aeolian sand. The thickest intersection of definite aeolian sand was only 6 m (Rason 1). The absence of a laterite layer in Neale 1, however, makes it impossible to pinpoint the base of the aeolian sand, but it could be as deep as 15 m. All other drill holes sited on aeolian sand penetrated bedrock within about 3 m of the surface. This confirms one of our early impressions, gained initially from helicopter traversing, that in most areas the interdunal corridors are usually only blanketed by a very thin layer of aeolian material. Therefore, in most cases, the height of the dune reflects approximately the maximum thickness of the blanket of aeolian sand.

DURICRUST

Thickness

Hard ferricrete and silcrete beds were intersected near the surface in seven of the eighteen holes. In six of these the near surface hardpans grade into the underlying weathered bedrock. In Neale 1, however, a silcrete bed occurs 30 m below the surface within bedrock. Eight metres of ferricrete was intersected in Rason 1, but in the remaining holes the indurated ferricrete or silcrete beds were less than 5 m thick. This compares favourably with outcrop data where the hard cappings to the mesas and buttes are seldom more than about 4 m thick. Most outcrops consist largely of thoroughly leached rocks of the mottled and pallid zones of the lateritic profile. Fresh bedrock was never seen, even in the highest breakaways. The drilling results show that weathering has penetrated to 60 m in Rason 1, 70 m in Rason 3, 70 m in Browne 1, and 100 m in Yowalga 3. The resistivity survey results in the

Rason Sheet area, as discussed on p 8, may indicate weathering down to about 250 m.

Goudie (193, p. 32 to 37) discusses duricrust thicknesses and the figures he presents for various occurrences are very similar to those described above; hardpans are only a few metres thick, but the complete profile may be up to 120 m thick. Commenting on Australian duricrusts (p. 16) he remarks that ... 'the thickness of the combined ferricrete crust and pallid zone appears to depend on the permeability and porosity of the parent rock. It is greatest both on argillaceous rocks and on well-jointed types, and least on rocks like sparsely jointed massive igneous rocks'. This however does not appear to be the case in the Great Victoria Desert. For although thick weathering profiles have developed on the porous and permeable Permian and Cretaceous strata they have also been seen on massive, acid igneous basement rocks, indicating that original mineral and chemical composition rather than texture can be more significant in the development of deeply leached profiles.

Thorium - Uranium Content

Natural gamma-ray wireline logs recorded marked deflections opposite silcrete and ferricrete bands in Rason 1, 2, 3, Wanna 1, Westwood 2, Yowalga 4 and Neale 3. Examination of cuttings from these intervals indicated no noticeable increases in the clay content of the rocks, so chemical analyses for the most common radioactive sedimentary trace elements, uranium and thorium, were done on samples from the first five holes to determine the reason for the deflections. The results (Table 2) suggest that the gamma ray anomalies were produced by relatively high concentrations of thorium. Retention and concentration of the comparatively insoluble thorium, with the associated oxidation and removal of uranium during intense weathering and alteration of rocks has been reported before (Adams & Richardson, 1960; Pliler & Adams, 1962). The calculated world average for Th/U in sandstone is about 4 (Murray & Adams, 1958; Turekian & Wedepohl, 1961; Rodgers & Richardson, 1964). Th/U for the Officer Basin laterite cuttings ranges from 9 to 14. Adams & Weaver (1958) report comparable ratios in bauxites and residual clays from Arkansas (USA) and Surinam, with related U contents of 1 - 10 ppm.

Chemistry of ferricrete

Cuttings of ferricrete (ferruginous laterite crust) from Rason 1, 2, 3, Wanna 1, and Westwood 2 were analysed for SiO_2, Al_2O_3 and Fe_2O_3. The results are listed in Table 2 and compared with other laterite analyses on a ternary diagram (Fig. 20). The Officer Basin samples are generally more siliceous than the typical laterite crust analyzed by Persons (1970)

TABLE 2. CHEMICAL ANALYSES OF BEJAH CLAYSTONE AND LATERITE CUTTINGS

Sample No.	73880* 246	* 231	* 235	* 242	+ 177	+ 178	+ 189	+ 210	+ 335
% SiO_2	75.0	72.5	74.0	3.3	22.0	15.5	42.5	52.0	35.8
% Al_2O_3	8.3	13.8	10.7	36.8	10.5	22.5	16.2	12.5	21.7
% Fe_2O_3	1.1	1.3	1.5	<0.5	58.0	41.5	31.0	27.0	30.0
% CaO	0.1	<0.1	<0.1	<0.1					
% MgO	0.25	0.13	0.19	0.04					
% Na_2O	0.12	0.08	0.11	0.30					
% K_2O	0.3	0.35	0.3	>10.0					
% LOI					7.6	17.3	8.9	6.9	ND
% Reactive silica (SiO_2)					14.2	8.7	21.0	20.8	ND
U ppm o					10	4	6	4	6
Th ppm o					105	46	55	55	70
	8.7m	10.97m	20.40m	25.90m	Rason 1	Rason 2	Rason 3	Wanna 1	Westwood 2
Rock type	Bejah Claystone from Browne 1				Laterite cuttings				

Specimens analysed at Australian Mineral Development Laboratories, Adelaide
* – direct reading emission spectrography
+ – computer-controlled emission spectrography
o – X-ray florescence spectrometry

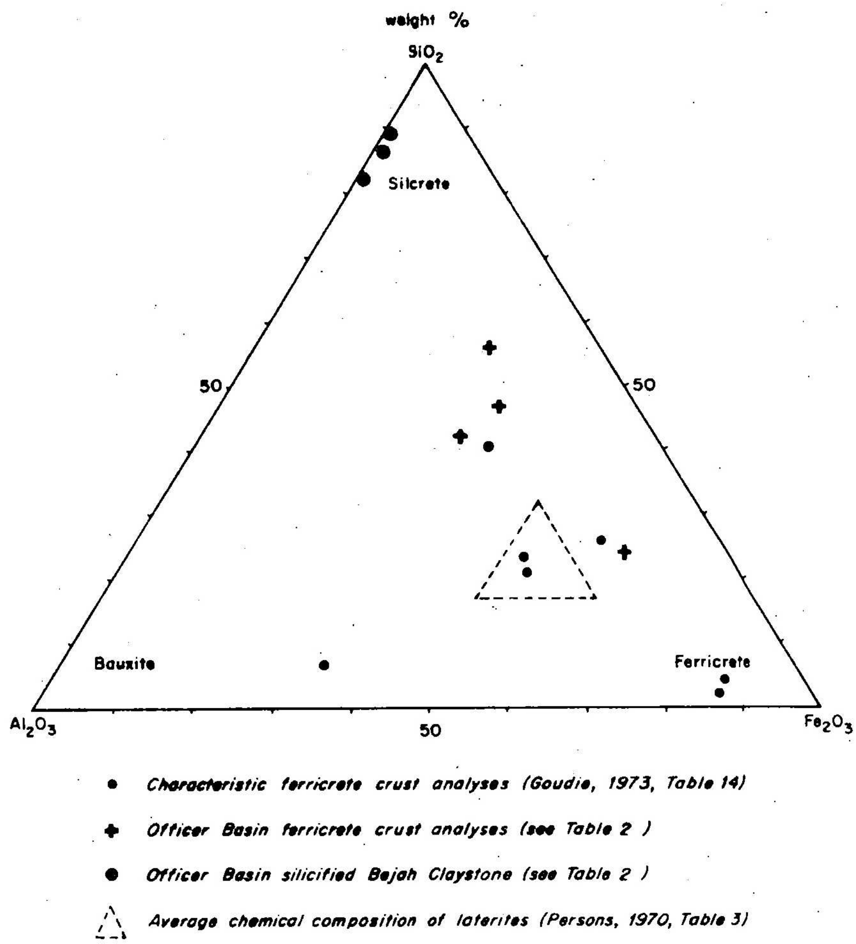

Fig. 20 Chemical composition of Officer Basin duricrust samples

and Goudie (1973); this is probably because the Australian samples are from duricrusts that have developed on silica-rich, arenaceous sediments. Many of the analyses quoted by Goudie and Persons are from laterites developed on parent rocks which are silica-poor.

Chemistry of Silcrete

The silicified Lower Cretaceous Bejah Claystone intersected in the upper part of Browne 1 is the lower part of a siliceous duricrust which is widespread in the northern part of the Officer Basin (the Lampe Beds usually form the upper part of the silcrete). To allow comparison with other silcrete analyses four samples from Browne 1 were analyzed for SiO_2, Al_2O_3, Fe_2O_3 and also alkalies. The results are listed in Table 2. Three of the samples were, as expected, highly siliceous and plot well into the silcrete field on the ternary diagram (Fig. 20). X-ray diffraction analyses show that these porcelanites from the Bejah Claystone are composed predominantly of quartz and kaolinite with the proportions of these two minerals ranging from about 2:1 to 7:1 (Appendix). The fourth sample (73880242) has an unusual composition, Al_2O_3 - 36.8%, K_2O - 10%+, SiO_2 - 3.3%. In hand specimen and thin section it looks identical to the other porcelanite specimens, but X-ray diffraction analyses show it is composed mainly of alunite, a potassium aluminium sulphate hydroxide. According to Dana (1966) alunite is most commonly associated with acid volcanic rocks that have been altered by sulphuric acid solutions and it is usually taken to indicate high pressure and temperature conditions. This type of origin cannot, however, explain its presence in the lower part of the Bejah Claystone in Browne 1.

Barrie (1965) gives reference to three modes of occurrence of alunite in southwestern Australia that could explain its origin in the Bejah Claystone: 1, as isolated pockets beneath and associated with a lateritic soil; 2, nodules or veins in kaolinized sedimentary rocks, and 3, as a finely divided mud in saline playa deposits. As the Bejah Claystone contains marine macrofossils a saline lacustrine origin for the alunite seems unlikely. An origin as a product of chemical differentiation in soil profiles seems more likely. White siliceous mudstone belonging to the 'chemically differentiated' Lower Cretaceous Allaru udstone in Western Queensland also contains alunite (Senior & Hughes, 1972).

Calcrete

One of the objects of drilling Throssell 1 was to core through calcrete, which from field examination appeared to be extensive. A cavernous and nodular calcareous rock composed of about 80 percent carbonate and

and 20 percent terrigenous material, with locally intense silicification, was intersected between 0.5 and 30 m. X-ray diffraction of a typical sample showed it to consist mainly of dolomite, quartz and gypsum. Detailed petrological examination and additional mineralogic and chemical studies are planned.

Bunting, Van de Graaff, & Jackson (1974) argue that the palaeo-drainages in the Officer Basin area, which aremarked by salt lakes such as Lake Throssell, stopped flowing during or soon after the middle Miocene. The maximum age of the valley fill sediments is therefore probably Miocene. Samples of a greyish clay from the lacustrine deposits at 32.91, 60.50 and 62.48 m were barren of palynomorphs so we are unable to confirm this maximum age for the deposition of the calcrete which formed in pre-existing sediments. The lacustrine clay sequence between 30 and 101 m contained a well indurated silicified concretionary limestone bed at 59.5 m. This is also interpreted as a calcrete as it is identical in mineralogy and texture to the limestones near the top of the hole.

BEJAH CLAYSTONE

Thickness

In Browne 1 the Bejah Claystone was intersected between 4 and 30 m. Detailed mapping in the area near Mount Beadell showed however that the maximum preserved thickness is 35 m. For comparison the thickest observed Bejah Claystone in the Canning Basin is 14 m at Bejah Hill, 180 km north of BMR Browne 1 (Veevers & Wells, 1961, p. 166).

SAMUEL FORMATION

Thickness

The Samuel Formation was intersected between 30 and 109 m in Browne 1. Based largely on seismic data Lowry et al. (1972) suggested that the Bejah Claystone and Samuel Formation had a combined thickness of about 300 m. The results of Browne 1 show that this was a gross overestimate and that in most areas the maximum preserved thickness of the two formations is more likely to be about 100 m.

Age

Based mainly on a study of the contained pelecypods, Skwarko (1967) assigned an aptian (Early Cretaceous) age to rocks that are now referred to as the Samuel Formation (Lowry et al., 1972). The lower part of the formation in Browne 1 is richly fossiliferous and Kemp (in press) recovered abundant and well-preserved spores, pollen and microplankton. These microfossils confirm the Early Cretaceous age inferred from the macrofossils, and further, Kemp comments that all of the available microplankton evidence tentatively indicates a late Aptian age.

Environment of deposition

Lowry et al. (1972) proposed the name Samuel Formation, and, on the basis of sedimentary structures and macrofossils, a quiet, shallow marine environment of deposition. Kemp (in press) recovered well-preserved marine phytoplankton and suggested deposition under quiet marine conditions, but, as she found that the terrestrial spores and pollen usually outnumbered the marine forms, qualified this by suggesting also that deposition was at no time far from the Cretaceous landmass that was the source of the spores and pollen. Kemp also uses the diverse spore and pollen assemblage to suggest that the parent vegetation grew under conditions which were certainly more humid, and possibly warmer, than at present.

The rock textures, sedimentary structures and presence of glauconite are indicative of a shallow marine origin. Angular quartz, feldspar, and mica grains showing negligible abrasion are a common constituent of the sandstone and siltstone of the formation. This probably indicates that much of the terrigenous debris was derived from a nearby provenance rich in igneous or metamorphic rocks.

Formation contacts

The contact between the Samuel Formation and overlying Bejah Claystone in Browne 1 is conformable and gradational. This confirms the conclusions from field evidence, for we found it difficult to pinpoint the contact between these two formations in outcrops. In contrast, the base of the Samule Formation in Browne 1 is sharp, and a distinct change in lithology occurs (Fig. 16b). Grey, micaceous, feldspathic, glauconitic, carbonaceous, bioturbated siltstone and fine-grained sandstone of the Samuel Formation is underlain at 109 m by poorly sorted, mainly coarse-grained, poorly-indurated sandstone of the Paterson Formation. The contact is located in a weakly consolidated interval of sand and silty sand which contains three reddish-brown to black, hard silicified and ferruginized bands, each about 3 cm thick. In thin section one of the bands consists of subangular to rounded, coarse grains of quartz and feldspar forming about 70 percent of the rock, set in a red to black hematitic matrix. X-ray diffraction analyses of two samples from this band gave about three parts to one of quartz and hematite, and about equal amounts of quartz and vernadite (MnO_2nH_2O). Similar highly ferruginous bands were found near the top of the Paterson Formation during field mapping. However, there was not enough field evidence to allow definite correlation of the various occurrences, and the environmental significance of the bands is not understood, although it was thought to be a surface feature related to the Tertiary duricrust. In Browne 1 the bands are definitely located in a porous, poorly indurated, weathered interval at the eroded top of the Paterson Formation. Although their origin and environmental significance are still uncertain they may represent ferruginous levels in a fossil lateritic soil developed on the Paterson Formation before the Samuel Formation was deposited. In contrast to Browne 1 the contact between the Samuel Formation and Paterson Formation in many outcrops is not sharp. Where interbedded siltstone and sandstone belonging to a fluvial facies of the Paterson Formation are overlain by the Samuel Formation it has often proved impossible to locate the contact. It is surprising that a break of about 150 million years duration is not marked by more obvious evidence of erosion and later transgression. However, in areas where a gradational contact is suspected and where the outcrop is good, detailed examination of the sequence for evidence of pre-Cretaceous deep weathering with the formation of ferruginous bands may assist in recognizing the contact

PATERSON FORMATION

Lithology

The Paterson Formation is the most extensive formation known in the Officer Basin area and, therefore, was intersected in many of the drill holes. Field mapping provided much information on the lithology of the Paterson Formation and the sequences comprising fluvial conglomeratic sandstone overlying lacustrine claystone overlying glacigene pebbly mudstone intersected during drilling in the southwest of the region (Rason & Neale holes) were largely as expected.

However a surprising departure from the expected was found in Wanna 1, where the Paterson Formation consists of at least 120 m of brownish-grey, silty, medium to fine-grained, carbonaceous and calcareous wacke containing numerous well rounded quartz grains (Fig. 9). At the well site this rock was interpreted as possible Wanna Beds, but Kemp (in press) recovered excellently preserved Early Permian palynomorphs from core 2. The spherical grains, good sorting, calcareous cement and common presence of carbonaceous material have not been seen previously in the Paterson Formation. This illustrates one difficulty of mapping in this area: the formation apparently does not consist of uniform facies throughout the basin.

Khaki micaceous siltstone and grey calcareous siltstone found in shot hole cuttings in the southwest part of the Birksgate Sheet area (Ludbrook, 1966; Major, 1968) may indicate that this unusual facies of the Paterson Formation extends into South Australia.

Kemp found no evidence of marine influence in the palynomorphs from core 2. The uniform lithology of the sequence suggests a lacustrine rather than a fluviatile-alluvial type of deposit.

Age

Kemp (in press) recovered palynomorphs from Wanna 1, Neale 2 and Rason 2 and re-examined assemblages from Hunt Oil Browne 1, 2, Yowalga 2, and BMR seismic shotholes in the Browne Sheet area. She assigns the Paterson Formation to Stage 2 of the Permo-Carboniferous zonal scheme established by Evans (1969). This is equivalent to a late Asselian to early Sakmarian age in the Russian terminology.

Kemp found rare Late Permian spores and pollen, apparently of recycled origin, in the Cretaceous Samuel Formation in BMR Browne 1. Rocks of Late Permian age have not been recognized in the Officer Basin area although they are present in the Canning Basin to the north. The recycled spores could either have originated from these rocks in the Canning Basin or from Upper Permian rocks that were deposited in the northern part of the Officer Basin, but which were eroded away during the Early Cretaceous transgression.

Geochemistry of clays

Recent studies (Frakes & Crowell, 1973) have suggested that many non-stratified diamictites have originated through subaqueous deposition rather than the subaerial deposition usually envisaged for tills. Frakes & Crowell discuss methods of distinguishing between marine and non-marine

TABLE 3. CHEMICAL ANALYSES OF CLAY FRACTIONS FROM SAMPLES OF THE PATERSON FORMATION

	Fe%	Mn ppm	Ni ppm	Cu ppm	Ca%	Sr ppm	K%	B ppm	Li ppm	U ppm	Th ppm	Ga ppm	Depth (metres)	Hole
73880 179	3.5	360	35	35	.23	60	>1	40	50	5	17	10	98.15	RASON 2
180	3.5	390	32	35	.23	60	>1	40	50	4	16	10	99.06	
181	3.7	410	32	32	.25	62	>1	30	20	5	17	10	99.37	
182	3.7	390	32	42	.26	62	1	40	30	5	15	15	110.92	
183	3.6	360	30	50	.23	60	>1	40	30	4	18	10	111.20	
184	3.8	390	35	45	.26	65	>1	40	30	<3	18	5	111.63	
186	4.0	430	60	45	1.15	85	1	30	30	3	18	10	143.63	
187	4.1	420	45	50	.95	85	1	30	20	4	17	10	143.75	
205	2.0	250	35	25	.14	55	1	40	50	3	12	10	56.63	NEALE 2
206	2.2	270	35	28	.14	58	>1	40	50	3	15	10	56.93	
207	2.2	280	38	22	.14	50	1	40	30	<3	15	10	57.51	
208	2.2	290	38	30	.15	55	>1	30	30	4	13	15	58.02	
209	2.2	320	25	22	.21	55	>1	30	30	<3	12	10	58.95	

Specimens analysed at Australian Mineral Development Laboratories, Adelaide.

Fe, Mn, Ni, Cu - atomic absorption spectroscopy; K, Li, Ga - semi-quantitive emission spectroscopy

Ca, B, U, Th - accurate analysis: Sr - X-ray fluorescence spectrometry

Procedure for separation of clay fraction: The full amount of all samples was used. Where necessary samples were crushed first to -60 mesh. All samples were dispersed in water at the rate of 20g solids per 400ml water, using a mechanical blender and deflocculants ("Calgon" and sodium hydroxide) the required particle size range (< 3μm) was removed by a process of siphoning to a given depth after a calculated settling time. This process was repeated four times, or until a negligible amount of solids was being collected. The solid matter was collected by a combination of gravitational settling and centrifugation, dried at room temperature or in a low oven (to 60°C).

glacial rocks and amongst others cite elemental abundances in the clay fraction of the diamictites as being a tentative criterion. Therefore, geochemical and palynological studies of tillitic mudstones from Rason 2 and Neale 2 were made to assist in interpreting their depositional environment.

According to Frakes & Crowell (1973) total iron appears to be less abundant in both modern and ancient marine glacial sediments than in tills; whereas manganese appears to be consistently above normal crustal abundances in marine glacial rocks. As well as being analysed for iron and manganese, the thirteen samples selected from Rason 2 and Neale 2 were also analyzed for ten additional elements which have been used to distinguish marine from non-marine clays (Degens et al., 1957; Abelson, 1959; Turekian & Wedepohl, 1961; Ahrens, 1968; Ernst, 1970; May, 1970). The results of the analyses are presented in Table 3.

The ratio of iron to manganese content in all thirteen Officer Basin samples falls well within the 'old glacial marine' category of Frakes & Crowell suggesting that these samples are not subaerial tills. In contrast, the values for the abundances of the other ten trace elements fall within ranges quoted as typical of non-marine rocks. The small number of specimens analyzed and the fact that the samples may not be absolutely fresh, means that the geochemical results are inconclusive. However, if they are considered in conjunction with Kemp's palynological studies and the facies of the associated sediments, a non-marine environment of deposition seems more likely.

LENNIS SANDSTONE AND WANNA BEDS

Stratigraphic relations

The main object of drilling BMR Neale 1 was to examine the pre-Permian sequence in the south-central part of the Officer Basin, and to provide more information on the Wanna Beds and Lennis Sandstone. The sequence of grey sandstone between 58 and 138 m overlying reddish-brown sandstone between 138 and 205.74 m (T.D.) is interpreted as Wanna Beds overlying Lennis Sandstone. A gradational, conformable contact separates the two formations. These results confirm the interpretation based on regional mapping (Lowry, et al., 1972).

Petrology and age

The two formations have similar rock types, but thin sections cut from cores in Neale 1 show that in this part of the basin the Wanna Beds are slightly coarser grained, better rounded, better sorted, and contain more clay matrix, but less feldspar and lithic fragments than the Lennis sandstone.

Small patches of intergranular calcite matrix were found in thin sections of Lennis Sandstone from cores 3 and 4 in Neale 1. In total the calcite probably only comprises about 1 to 2 percent in each thin section, but as the intergranular areas are mainly voids it is likely that the rock originally contained much more calcareous matrix. This is the first time that a calcareous matrix has been seen in samples of Lennis Sandstone. The red-brown colour which is characteristic of the Lennis Sandstone appears to be caused mainly by iron-oxide staining or replacing matrix material, which we now assume was originally calcareous. A lack of calcareous matrix in the Wanna Beds may be the reason why this formation is white to grey instead of red as the Lennis Sandstone. The thin sections of Lennis Sandstone from cores 3 and 4 show that the rock is medium to fine-grained, moderately sorted, arkosic arenite which was originally calcareous. It contains many subangular to angular grains of quartz and feldspar and some very thin slivers of muscovite suggesting that the detritus originated from an igneous or metamorphic provenance rather than from an area of sedimentary rocks. Micro-cross-laminae containing coarse spherical quartz grains were seen in a thin section from core 3. This feature has also been seen in the field at several localities. The coarse spherical grains could have been washed in from a nearby area containing aeolian sands.

All of the cores from the Wanna Beds and Lennis Sandstone were examined for palynomorphs, but none were found; it is still not possible to date the formations more precisely than the interval Early Cambrian to Early Permian.

Permeability and Porosity

Based on petrographic assessment of hand specimens, Lowry et al. (1972) and Krieg, Jackson & van de Graaff (in press) suggest that the Lennis Sandstone and Wanna Beds would be suitable hydrocarbon reservoir rocks. Permeability and porosity measurements were made on five pieces of core from the two formations in Neale 1; the results are shown in Table 4. The average effective porosity (% bulk volume) ranges between 22.9 and 30.9 percent with a mean of 25 percent. Except for core 1 values for permeability are high (62 to 390 md). It is difficult to assess how representative the core samples are of the rest of the formation in the drill hole and also how the results of this hole relate to the formations in general. However, if we assume these specimens are typical of the formations the results indicate that they would be suitable reservoir rocks. For comparison, oil and gas producing wells in the Pacoota Sandstone of the Amadeus Basin commonly have porosities in

TABLE 4. POROSITY, PERMEABILITY AND DENSITY MEASUREMENTS

Measurements by BMR Petroleum Technology Laboratory   Operator: BMR   Date Analysis Completed: December, 1973

SAMPLE REGISTERED NUMBER	DRILLHOLE	CORE NO.	SAMPLE DEPTH (feet) From	SAMPLE DEPTH (feet) To	LITHOLOGY	AVERAGE EFFECTIVE POROSITY OF TWO PLUGS (% Bulk Vol)	ABSOLUTE PERMEABILITY (Md) V	ABSOLUTE PERMEABILITY (Md) H	AVERAGE DENSITY (gm/cc) Dry Bulk	AVERAGE DENSITY (gm/cc) Apparent Grain	FORMATION
73880191	Neale 1A	1	222'3"	222'8"	Sst; v.f.gr. to f.gr. sl slty	28.1	4.1	11.0	1.89	2.65	Wanna Beds
73880194	Neale 13	2	369'2½"	369'6"	Sst; f.gr.	26.9	336	390	1.92	2.61	Wanna Beds
73880197	" "	2	374'5½"	374'9"	Sst; f.gr. to m.gr.	23.4	80	175	2.00	2.61	Wanna Beds
73880201	" "	4	666'8"	667'1"	Sst; f.gr. red.	24.5	185	128	1.71	2.58	Lennis Sandstone
73880203	" "	4	668'5"	668'8"	As above	22.9	62	102	2.01	2.60	Lennis Sandstone
73880220	Wanna 1	2	101'½"	101'4½"	Sst; vf.gr. slty	16.6	<0.1	0.15	2.18	2.62	Paterson Formation
73880330	Westwood 1	31	250'5"	251'0"	Sst; f.gr. to m.gr. red	24.0	53	304	2.00	2.63	Lennis Sandstone or Proterozoic
73880331	" "	32	262'9"	263'1"	Sst; f.gr. to c.gr. red	30.9	349	306	1.80	2.61	"

NOTE: Unless otherwise stated, porosities and permeabilities were determined on two plugs (V & H) cut vertically and horizontally to the axis of the cores. Ruska porosimeter and permeameter were used with air and dry nitrogen as the saturating and flowing media respectively.

the range 5 to 12 percent and permeabilities between 1 and 300 millidarcy.

TABLE HILL VOLCANICS

Distribution

Seismic shot holes drilled over the subcrop of a shallow high-velocity refractor/reflecting horizon in the northwest part of the Westwood Sheet area (Fig. 1) intersected basalt. This was cored continuously in BMR Westwood 1, and the results from this enable it to be correlated with the Table Hill Volcanics, which have been mapped along the margins of the basin to the north and northeast. These results prove the presence of the Table Hill Volcanics much further to the southwest than was previously known, and laboratory work done on the core samples provides the first systematic information on the composition of the volcanics. This new information together with the results of recent isotopic dating on the unit (Compston, 1974) allows a comparison between these volcanics and the Antrim Plateau Volcanics of northern Australia.

Thickness

In Westwood 1 the Table Hill Volcanics consist of two flows separated by 2 m of sandstone. This two fold division appears to be a remarkably consistent feature of the unit; it occurs in outcrops at Mount Smith (120 km to the north) and Table Hill (210 km to the east northeast), and in Hunt Oil-Placid Oil Yowalga 2 (160 km to the northeast). P. Jackson (1966b) does not subdivide the volcanics in Yowalga 2 into two units, but we interpret a break at about 782 m, where marked deflections in all of the geophysical logs were recorded. This interpretation produces a lower flow 63 m thick and an upper flow 53 m thick. In comparison, the values for Westwood 1 are 51 m and more than 20 m respectively.

Composition

Twenty-eight samples of igneous rocks, comprising twenty-six basalt samples from various parts of both flows and two samples collected from thin intrusive veins were chemically analyzed; the results are listed in Table 5.

Detailed core examination shows that both flows have central, slightly altered interiors grading upwards into vesicular, amygdaloidal, altered tops. Representative samples of these zones from both flows were analyzed.

TABLE 5. CHEMICAL ANALYSES OF TABLE HILL VOLCANICS FROM BMR WESTWOOD 1

UPPER FLOW

Registered Number	282	297	295	293	288	287	289	291	299	292	283	285	302
SiO_2	48.0	51.80	51.47	53.52	52.08	52.50	51.93	51.76	74.5	51.68	51.99	50.71	50.28
AL2O3	34.0	14.80	14.70	14.35	14.43	14.79	14.68	14.70	6.6	14.88	15.04	14.99	14.52
FE2O3	{ .5	7.46	5.44	4.37	5.70	4.88	4.99	5.11	{ 4.8	4.83	5.71	7.08	8.02
FEO		1.95	4.30	5.34	4.37	4.85	4.85	4.56		4.97	3.82	2.98	1.95
CAO	.2	6.38	9.00	9.63	9.28	9.48	9.07	8.80	1.0	9.99	10.2	9.55	8.28
MGO	.52	5.94	5.82	6.26	6.21	6.59	6.57	6.83	1.3	6.70	5.99	6.32	6.73
NA2O	.18	1.55	1.97	2.00	2.10	2.05	1.97	1.81	.95	1.87	2.15	2.40	2.90
K2O	.2	.95	.80	1.20	1.58	1.56	1.96	2.12	2.0	1.42	1.22	2.00	1.81
TIO2		.86	.80	.78	.82	.84	.82	.81		.80	.80	.80	.77
MNO		.06	.11	.14	.13	.13	.14	.13		.12	.11	.12	.13
P2O5		.03	.03	.08	.07	.08	.07	.08		.07	.08	.07	.08
H2O+		5.08	1.64	1.10	1.28	1.22	1.31	1.45		1.07	1.40	1.21	1.65
H2O-		4.58	2.54	1.22	1.86	1.50	1.59	1.87		1.73	1.92	1.95	2.67
TOTAL		100.45	99.50	99.99	99.91	100.56	99.95	100.04		100.11	100.24	100.15	99.90
Depth(m)	4.67	4.88	7.32	9.07	12.19	12.80	13.72	15.54	18.29	17.98	19.81	21.34	21.79
Location in flow, based on hand specimen	White band	Amygdaloidal upper part			Massive middle part				Intrusive vein			Amygdaloidal lower part	

LOWER FLOW

Registered Number	286	305	303	306	308	334	310	312	314	316	318	320	321	323	325	327
SiO_2	52.14	52.13	50.01	48.41	48.12	48.7	51.27	52.89	52.64	52.79	52.23	52.58	52.40	50.98	47.60	46.35
AL2O3	13.95	13.70	14.05	14.78	14.86	13.4	14.48	14.38	14.29	14.72	14.75	15.05	15.03	14.60	16.67	15.62
FE2O3	9.65	9.33	8.94	6.28	5.39	{ 8.6	4.82	4.19	3.41	3.81	3.87	4.07	4.98	5.40	7.63	11.24
FEO	.30	.03	.85	3.50	3.95		5.11	5.82	6.47	6.23	8.10	5.60	4.78	4.73	1.13	.10
CAO	5.37	2.19	4.69	5.07	6.47	5.9	7.22	7.62	6.84	9.95	3.74	10.12	10.10	9.45	8.19	3.15
MGO	4.78	5.93	6.73	8.04	7.47	8.5	6.53	6.40	6.30	6.64	6.62	6.82	6.73	8.33	8.87	7.67
NA2O	4.25	4.45	2.90	3.80	4.00	3.4	3.90	3.30	4.00	2.20	2.00	2.00	2.10	2.00	2.15	1.72
K2O	2.27	1.95	2.98	2.45	1.97	2.0	2.08	2.07	2.18	1.19	1.27	1.11	1.16	1.08	1.26	3.44
TIO2	.70	.73	.77	.76	.74		.79	.79	.79	.79	.78	.78	.81	.76	.80	.79
MNO	.10	.18	.12	.13	.13		.13	.15	.15	.14	.14	.12	.11	.12	.08	.04
P2O5	.08	.07	.07	.08	.07		.08	.07	.08	.08	.08	.08	.08	.08	.08	.08
H2O+	2.68	3.09	3.91	4.31	4.25		2.53	1.25	2.18	.84	.82	.77	.80	1.58	3.19	4.31
H2O-	3.68	5.63	4.13	2.61	1.93		1.33	1.49	.48	1.14	1.20	1.19	1.34	1.12	4.51	5.33
TOTAL	99.98	99.40	100.14	100.22	99.35		100.27	100.42	99.78	100.17	99.60	100.29	100.43	100.23	99.53	99.84
Depth(m)	23.16	24.08	26.37	29.26	32.00	32.00	36.58	42.67	48.77	54.86	60.96	57.06	70.10	72.85	73.48	74.07
Location in flow, based on hand specimen	Amygdaloidal and vesicular upper part of flow					(repeat)	Massive medium-grained basalt, middle part of flow								Amygdaloidal lower part of flow	

Specimens analysed at Australian Mineral Development Laboratories, Adelaide. (Values expressed in weight per cent) Specimens 282, 299 and 334 were analysed using computer-controlled direct reading emission spectroscopy methods (accuracy of ± 10% relative); in all other specimens the major components were determined by XRF methods, the minor components by wet chemical methods. (Specimen 334 is a direct repeat of 308 for comparison).

The variation of the major oxides plotted against depth is shown in Fig. 21. There does not appear to be any great difference in the composition of the two flows, but the upper flow contains slightly less Na_2O and slightly more TiO_2 than the lower flow. The average composition for all twenty six basalt specimens compared with the average for the freshest five specimens is given below.

	Average all specimens	Average freshest specimens
SiO_2	51.3	52.5
Al_2O_3	14.7	14.8
Fe_2O_3	6.0	4.0
FeO	3.8	5.8
CaO	7.9	9.8
MgO	6.7	6.6
Na_2O	2.6	2.5
K_2O	1.7	1.4
TiO_2	0.8	0.8
MnO	0.12	0.13
P_2O_5	0.07	0.08
H_2O^+	2.1	1.1
H_2O^-	2.3	1.1

The interior (30 to 70 m) of the lower flow has a uniform chemical composition, but shows a slight decrease in SiO_2 and CaO and slight increase in Na_2O and K_2O in its upper part (30 to 55 m). Marked variation in all oxides occurs in the altered amygdaloidal lavas at the top and bottom of both flows.

The intrusive veins are composed of very fine-grained acidic material.

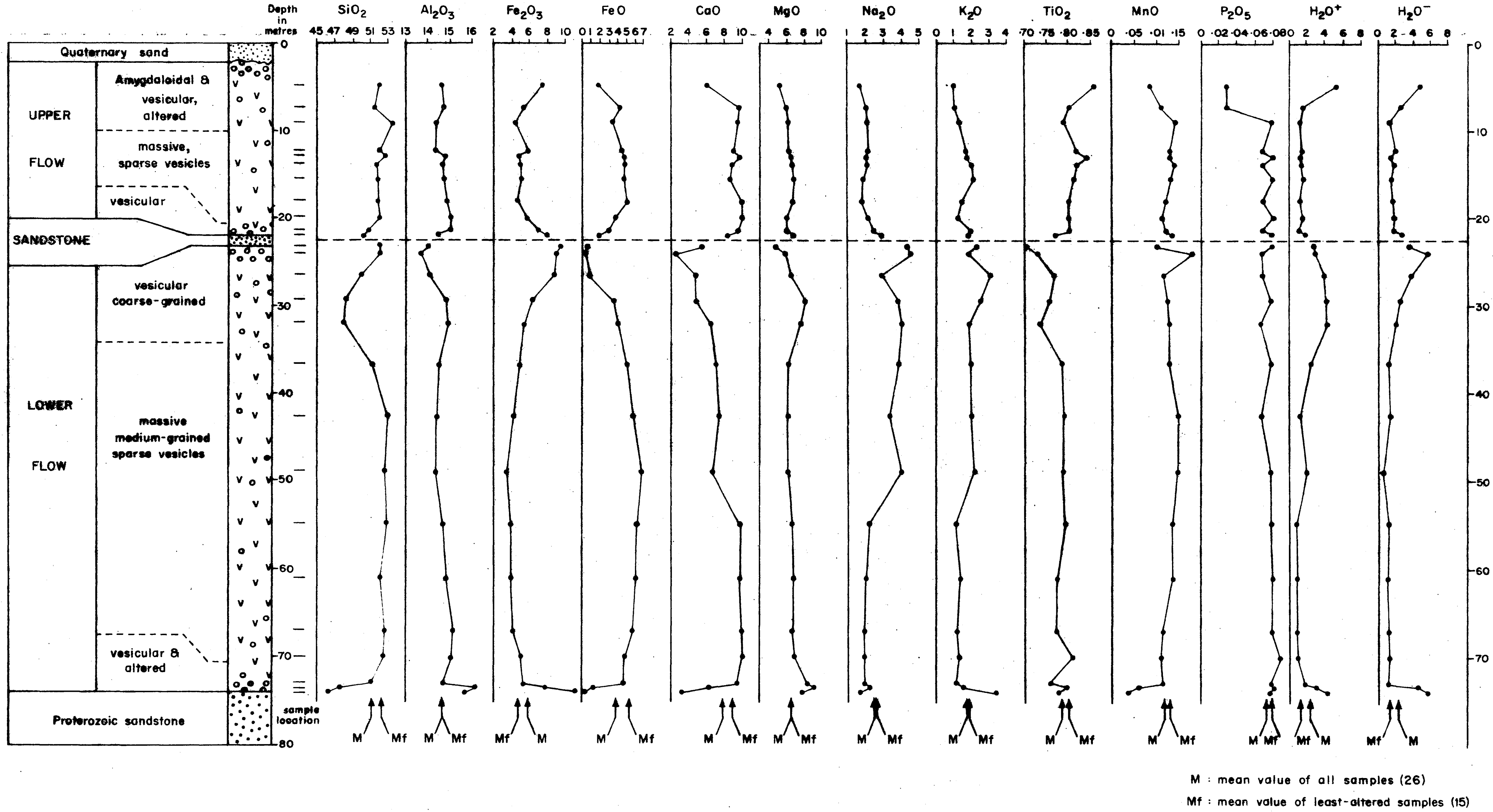

Fig. 21 Chemical variation within the Table Hill Volcanics in BMR Westwood 1

GAY G51/A16/2

PROTEROZOIC NEAR WARBURTON

Of the Proterozoic sequence on the southwest side of the Musgrave Block, near Warburton Mission, only the Townsend Quartzite, Lefroy Beds, and Lupton Beds are exposed. To try and get information on the Proterozoic younger than these units five holes were drilled at about 600 m intervals along a southwest-trending line away from the ridge of Townsend Quartzite at Blacks Lookout. Well site interpretation suggested that Talbot 4 and 5 had intersected Proterozoic rocks younger than Lupton Beds, and as the surficial cover was becoming thick and difficult to drill, additional holes were not attempted. However, later re-logging of cores showed that the well site interpretation was wrong and that Talbot 5 had intersected Lupton Beds only. Detailed descriptions of the logs of individual holes are presented elsewhere in the text, but the main results are summarized in Table 6.

Table 6. Results of drill holes near Warburton Mission

Drillhole	Depth bedrock intersected (m)	Formation and dip	
Talbot 1	24	Townsend Quartzite	20°
Talbot 2	not reached	-	-
Talbot 3	52	Lefroy Beds	25°-30°
Talbot 4	55	Lefroy Beds	10°
Talbot 5	60	Lupton Beds	25°-30°

Although the drilling results confirm the sequence established by mapping in the previous year they do not provide any data on the sequence that overlies the Lupton Beds in this area. It was hoped that drilling would enable a more precise correlation to be made between the post-Townsend Quartzite rocks of the Warburton area and the post-Pindyin Beds sequence of the Birksgate Sheet area (Major, 1968); this however is not possible.

SEDIMENTARY ROCKS NEAR LAKE THROSSELL

Sedimentary rocks were intersected underlying basalt in Westwood 1, throughout most of Westwood 2, and in the lower half of Throssell 1. Very little can be deduced about the stratigraphic significance of the sedimentary rocks in the first two of these holes as the rocks cannot be accurately related to the surface geology in the southwestern part of the basin. In fact it is not even possible to determine whether they are Palaeozoic or Proterozoic in age. As the sandstone in Westwood 1 underlies the Table Hill Volcanics it must be older than Early Cambrian, but it is lithologically identical to the Lennis Sandstone intersected in Neale 1. A correlation based purely on lithology would then imply that the Lennis Sandstone was deposited both before and after extrusion of the Table Hill Volcanics. Although this cannot be discounted, evidence from other parts of the basin suggests that elsewhere the Lennis Sandstone is younger than the volcanics.

Westwood 2 was located southwest of Westwood 1. It was expected that the hole would penetrate thin Paterson Formation before entering Proterozoic bedrock. Lithologically the sandstone sequence that was penetrated is similar to the Wanna Beds or Lennis Sandstone. As the subcrop of the Table Hill Volcanics is located to the northeast this interpretation would imply that these sandstone formations overstep the volcanics near the southwest margin of the basin. An alternative interpretation is that the interval drilled is a Proterozoic sandstone and claystone sequence.

Only in the lower part of Throssell 1 are we reasonably certain that a Proterozoic sequence was intersected. Throssell 1 intersected the same Proterozoic sequence as did Yowalga 2, drilled by Hunt Oil-Placid Oil 200 km to the northeast. Seismic interpretation along the Warburton Range Road between Hunt Oil-Placid Oil Yowalga 2 and BMR Throssell 1 shows that the Proterozoic sequence, of which 143 m of Babbagoola Beds froms part, is about 5000 m thick, is gently folded, and was eroded before the Early Cambrian basalts were extruded. The three distinctive rock types found in Yowalga 2 were also found in the same sequence and with about the same thicknesses in Throssell 1 and a direct correlation is inferred.

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APPENDIX: CATALOGUE OF DRILL HOLE SAMPLES ANALYSED OR EXAMINED IN CANBERRA

The specimens listed below were selected for additional examination following the finish of the drilling program. The samples are listed in numerical order under the BMR sample registration number. All the samples listed below have been cross-indexed with the drill hole logs (Figs 2-19); on the logs they are shown immediately to the left of the lithological column by a symbol (see Fig. 2) and the registered number (excluding the first five digits). All samples are from cores unless otherwise indicated. The depth shown is for the midpoint of the core piece. Registered numbers are bracketed together where the sample was taken from the same core specimen. ND - indicated work not done.

REGISTERED NUMBER	DRILLHOLE	DEPTH (metres)	FORMATION OR ROCK TYPE	REASON SAMPLE TAKEN	REMARKS/RESULTS ETC.
73880177	Rason 1	7.62 to 10.67	Laterite (cuttings)	chem. analysis for U, Th, Al_2O_3, Fe_2O_3 SiO_2	see Table 2 for results
178	Rason 2	8.00	Laterite (cuttings)	"	
179	"	98.15	Paterson Fm (grey clayey siltstone)	chem. analysis for Th, U, Ca, B, Ga, Cu, Li, K, Sr, Fe, Mn, Ni (clay fraction only) (179–184 bracketed)	see Table 3 for results
180	"	99.06	" "		
181	"	99.37	" "		
182	"	110.92	" "		
183	"	111.20	" "		
184	"	111.63	" "		
185	"	111.10	" "	slabbing for photography	
186	"	143.63	" (lithic sandstone; tillitic)	chem. analysis as 179	
187	"	143.75	" "	" " "	see Table 3 for results
188	"	145.00	" "	slabbing	
189	Rason 3	0 to 1.50	Laterite (cuttings)	chem. analysis as 177	see Table 2 for results
190	Neale 1	67.40	Wanna Beds (grey fine sst)	thin section	
191	"	67.80	" "	permeability/porosity	see Table 4
192	"	68.00	" "	sieve analysis	N.D.
193	"	111.94	" "	thin section	
194	"	112.58	" "	permeability/porosity	see Table 4
195	"	113.07	" "	thin section	
196	"	113.39	" "	sieve analysis	N.D.
197	"	114.18	" "	permeability/porosity	see Table 4
198	"	179.96	Lennis Sandstone (red fine quartz sst)	thin section	
199	"	180.40	" "	seive analysis	N.D.
200	"	202.96	" "	thin section	
201	"	203.27	" "	permeability/porosity	see Table 4
202	"	203.36	" "	thin section	
203	"	203.77	" "	permeability/porosity	see Table 4
204	"	203.97	" "	thin section	

REGISTERED NUMBER	DRILLHOLE	DEPTH (metres)	FORMATION OR ROCK TYPE	REASON SAMPLE TAKEN	REMARKS/RESULTS ETC.
73880205	Neale 2	56.63	Paterson Fm (laminated grey claystone)	chem. analysis as for 179	see Table 3 for results
206	"	56.93	" "		
207	"	57.51	" "		
208	"	58.02	" "		
209	"	58.95	" "		
210	Wanna 1	2.00	Laterite (cuttings)	chem. analysis as for 177	see Table 2 for results
211	"	28.98	Paterson Fm (lithic silty carbonaceous wacke)	thin section	
212	"	29.03	" "	sieve analysis	N.D.
213	"	29.44	" "	thin section	
214	"	29.46	" "	thin section	
215	"	29.52	" "	sieve analysis	N.D.
216	"	29.90	" "	large thin section	
217	"	30.63	" "	sieve analysis	N.D.
218	"	30.93	" "	thin section	
219	"	31.25	" "	palynology	N.D.
220	"	30.85	" "	permeability/porosity	see Table 4
221	Talbot 1	33.06	Townsend Quartzite (sandstone)	thin section	
222	Talbot 2	13.10	Alluvial conglomerate	mineralogy	XRD - Goethite
223	Talbot 4	67.20	Lefroy Beds (fine brown sst)	large thin section	
224	Talbot 3	76.20	Lefroy Beds (")	thin section	
225	"	76.32	Lefroy Beds (green silty sst)	"	
226	"	77.03	" (red/brown silty sst)	"	
227	"	77.17	" "	"	
228	Talbot 5	93.00	Lupton Beds (lithic claystone, tillite)	petrology	
229	Browne 1	10.97	Bejah Claystone (pink claystone)	thin section	
230	"	"	" "	mineralogy	XRD - Quartz, kaolinite (~2:1)
231	"	"	" "	chem. analysis	
232	"	"	" "	palynology	N.D.
233	"	13.69	" (pale purple claystone)	mineralogy	XRD - Quartz, kaolinite (~5:1)
234	"	"	" "	palynology	Barren
235	"	20.40	" (pink claystone)	chem. analysis	
236	"	"	" "	palynology	N.D.
237	"	"	" "	mineralogy	XRD - Quartz, kaolinite (~2:1)

REGISTERED NUMBER	DRILLHOLE	DEPTH (metres)	FORMATION OR ROCK TYPE	REASON SAMPLE TAKEN	REMARKS/RESULTS ETC.
73880238	Browne 1	22.53	Bejah Claystone (white claystone)	thin section	
239	"	"	" "	palynology	N.D.
240	"	25.90	" (white/purple mottled claystone)	thin section	
241	"	"	" "	palynology	N.D.
242	"	"	" "	chem. analysis	
243	"	38.68	Samuel Formation (sandstone)	large thin section	
244	"	8.71	Bejah Claystone (pink sandstone)	palynology	N.D.
245	"	"	" "	mineralogy	XRD - Quartz, kaolinite (~7:1)
246	"	"	" "	chem. analysis	
247	"	"	" "	thin section	
248	"	46.56	Samuel Fm (grey brown claystone)	palynology	N.D.
249	"	48.77	" "	"	N.D.
250	"	52.12	" (yellow/brown siltstone)	"	N.D.
251	"	54.86	" "	"	N.D.
252	"	58.22	" (micaceous ")	"	N.D.
253	"	60.66	" (yellow brown silty sandstone)	"	N.D.
254	"	64.01	" (yellow brown siltstone)	palynology	N.D.
255	"	"	" "	thin section	
256	"	67.06	" (yellow brown silty sandstone)	palynology	N.D.
257	"	69.19	" (khaki claystone & siltstone)	"	N.D.
258	"	70.41	" (brown silty sandstone)	palynology	Spores, pollen and microplankton abundant Late Aptian
259	"	"	" "	thin section	
260	"	73.46	" (dark grey/brown clayey siltstone)	palynology	Spores, pollen and microplankton abundant Late Aptian
261	"	78.64	" "	"	"
262	"	82.91	" "	"	N.D.
263	"	84.43	" (micaceous ")	"	"
264	"	89.00	" "	"	Palynomorphs abundant, but fragmented
265	"	90.83	" (grey micaceous, silty claystone)	"	Palynomorphs abundant, well preserved
266	"	95.71	" "	"	Palynomorphs fragmented
267	"	99.14	" (brown & grey sandy siltstone)	"	Palynomorphs common, fragmented
268	"	100.89	" (fine well sorted grey sst)	"	"
269	"	103.63	" "	"	N.D.
270	"	106.68	" (grey sandy siltstone)	palynology	Palynomorphs common, well preserved
271	"	"	" "	thin section	
272	"	106.00	" (silty sandstone, glauconitic)	large thin section	
273	"	108.20	" (brown clay with sand)	palynology	Palynomorphs common, well preserved
274	"	108.59	" "	"	barren
275	"	108.97	" "	"	Very rare dinoflagellates, some woody debris, Aptian

REGISTERED NUMBER	DRILLHOLE	DEPTH (metres)	FORMATION OR ROCK TYPE	REASON SAMPLE TAKEN	REMARKS/RESULTS ETC.
73880276	Browne 1	109.00	Samuel Fm (hard ferruginous silty sandstone)	mineralogy	XRD - 276a, Quartz, vernadite (MnO(OH)) (~1:1). 276b Quartz, Hematite (~3:1)
277	"	"	" "	thin section	
278	"	109.07	Paterson Fm? (grey quartz sst with clay)	palynology	Barren
279	"	114.08	" (grey silty feldspathic? sandstone)	large thin section	
280	"	114.30	" (grey coarse sandstone)	palynology	N.D.
281	Westwood 1	4.67	Table Hill Volcanics (white zeolite?)	mineralogy	XRD - Muscovite, kaolinite (~1:1). White clayey band/vein near top of upper flow
282	"	"	" "	chem. analysis	282 to 327 see Table 5
283	"	19.81	" (purple basalt)	chem. analysis	massive basalt from middle of upper flow
284	"	"	" "	thin section	
285	"	21.34	" "	chem. analysis	amygdaloidal and vesicular basalt from top of lower flow
286	"	23.16	" (amygdaloidal basalt)	"	
287	"	12.80	" (medium-grained greenish purple basalt)	"	massive basalt from middle part of upper flow
288	"	12.19	" "	"	
289	"	13.72	" "	"	
290	"	"	" "	thin section	
291	"	15.54	" "	chem. analysis	
292	"	17.98	" "	"	
293	"	9.07	" "	"	greenish purple basalt from upper part of upper flow, (rare amygdales)
294	"	"	" "	thin section	
295	"	7.32	" "	chem. analysis	
296	"	"	" "	thin section	
297	"	4.88	" "	chem. analysis	
298	"	"	" "	thin section	
299	"	18.29	" (red aplite? vein)	chem. analysis	red aphanitic vein intruding upper flow
300	"	"	" "	thin section	
301	"	21.34	" (amygdaloidal basalt)	thin section	amygdaloidal basalt from near base of upper flow
302	"	21.79	" "	chem. analysis	
303	"	26.37	" "	"	altered, amygdaloidal and vesicular basalt from upper part of lower flow
304	"	"	" "	thin section	
305	"	24.08	" "	chem. analysis	
306	"	29.26	" "	chem. analysis	
307	"	"	" "	thin section	
308	"	32.00	" "	chem. analysis	
309	"	"	" "	thin section	
310	"	36.58	" (massive basalt)	chem. analysis	
311	"	"	" "	thin section	

REGISTERED NUMBER	DRILLHOLE	DEPTH (metres)	FORMATION OR ROCK TYPE	REASON SAMPLE TAKEN	REMARKS/RESULTS ETC.
7388312	Westwood 1	42.67	Table Hill Volcanics (massive basalt)	chem. analysis	
313	"	"	" "	thin section	
314	"	48.77	" "	chem. analysis	
315	"	"	" "	thin section	massive, medium to fine-grained, grey to purple basalt from middle of lower flow; rare green and brown discolouration
316	"	54.86	" "	chem analysis	
317	"	"	" "	thin section	
318	"	60.96	" "	chem. analysis	
319	"	"	" "	thin section	
320	"	67.06	" "	chem. analysis	
321	"	70.10	" "	"	
322	"	"	" "	thin section	
323	"	72.85	" "	chem. analysis	
324	"	"	" "	thin section	
325	"	73.46	" "	chem. analysis	
326	"	"	" "	thin section	amygdaloidal basalt from lower part of lower flow; red and cream intrusive veinlets included in specimen 326
327	"	74.07	" "	chem. analysis	
328	"	"	" "	thin section	
329	"	75.16	unknown (coarse red sst)	large thin section	
330	"	76.40	" "	permeability/porosity	see Table 4
331	"	80.13	" "	"	see Table 4
332	"	82.60	" (brown medium sst)	thin section	
333	"	84.43	" (white ")	"	
334	"	32.00	Table Hill Volcanics	chem. analysis	(Identical to 308 check analysis)
335	Westwood 2	4.00	Laterite (cuttings)	chem. analysis	see Table 2
336	"	93.27	unknown (red silty sst)	palynology	N.D.
337	"	"	" "	thin section	
338	"	93.42	" (yellow sst)	palynology	N.D.
339	"	"	" "	conodonts	Barren
340	"	98.45	" (grey-green siltstone)	palynology	Barren
341	"	99.59	" (grey sandstone)	thin section	
342	"	100.89	" (glauconitic? sst & slts)	large thin section	
343	Throssell 1	7.92	Calcrete (brown-cream silicified congl)	large thin section	
344	"	8.53	" "	"	
345	"	20.42	") white to cream mottled	"	
346	"	22.25	") vuggy calcretes - range	"	
347	"	24.38	") of rock types represented	"	
348	"	24.99	")	"	

REGISTERED NUMBER	DRILLHOLE	DEPTH (metres)	FORMATION OR ROCK TYPE	REASON SAMPLE TAKEN	REMARKS/RESULTS ETC.
7388349	Throssell 1	26.00	Calcrete (fawn claystone with calc. blebs)	palynology	N.D.
350	"	27.12	" "	"	Barren
351 }	"	27.43	" (white silty clay)	"	N.D.
352 }	"	"	" "	thin section	
353 }	"	28.40	" (white clay)	palynology	N.D.
354 }	"	"	" "	thin section	
355 }	"	"	" "	mineralogy	XRD - Dolomite, quartz, gypsum, possible $CuSO_4 3H_2O$ ($\sim$70:3:2:1)
356	"	32.91	" (mottled grey/white clay)	palynology	Barren
357	"	30.05	" "	"	N.D.
358	"	59.43	" (grey clay with gypsum)	large thin section	
359	"	60.50	" "	palynology	Barren
360	"	62.48	" "	"	Barren
361 }	"	121.00	Proterozoic (mottled red/brown/green siltstone)	large thin section	
362 }	"	"	" "	palynology	N.D.
363	"	185.50	" (green siltstone)	thin section	
364a	Wanna 1	30.32	Paterson Fm (brown silty sst	palynology	Recovery sparse, preservation excellent; Sakmarian?
364b	"	30.58	" with woody	"	"
364c	"	30.78	" fragments)	"	"
365	Neale 1	66.82	Wanna Beds (grey fine sst)	"	Barren "
366	"	112.08	" "	"	Barren
367	"	203.00	Lennis Sandstone (red fine sst)	"	Barren
368	"	56.69	Paterson Fm (grey laminated claystone)	"	Sparse, fragmented spores and pollen; Sakmarian?
369a	Neale 2	56.99	" "	"	"
369b	"	58.21	" "	"	"
370	Rason 2	99.21	Paterson Fm (grey siltstone)	palynology	Spores and pollen abundant, well preserved, Sakmarian?
371	"	110.95	" "	"	"
372	"	143.36	" (sandy tillite)	"	Spores and pollen sparse, poorly preserved Sakmarian?
373	Yowalga 4	41.75	Paterson Fm (pink claystone & siltstone)	"	Barren
374	Talbot 4	42.67 - 45.72	Cainozoic? (red silty sandstone)	"	Barren
375	Westwood 2	98.45	Lennis Sandstone (grey sandy siltstone)	"	Barren

XRD - X-ray diffraction analyses by D. Barnes (BMR). The ratios shown are not absolute, but only give an indication of relative concentrations of minerals in samples

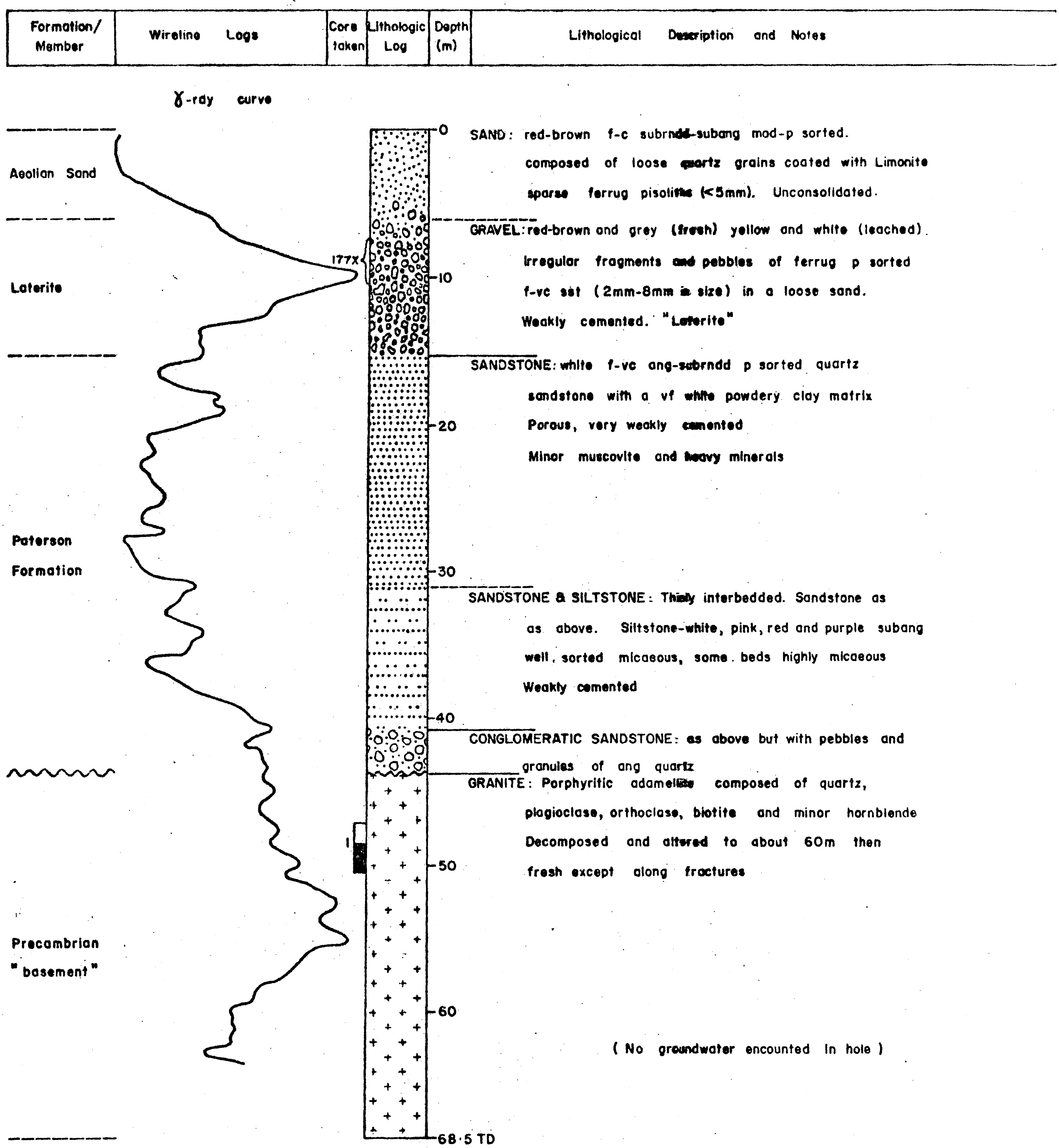

Fig 2 B M R RASON I

Reference for work done on samples (Figs. 2 to 9.)

X *Chemical analysis*	P *Permeability & Porosity*
+ *X-ray diffraction analysis*	◊ *Detail petrology*
T *Thin section*	□ *Examined for conodonts*
• *Palynology*	• *Sample taken, not submitted*
s *Slabbing*	*N.B. number to left of symbol refers to BMR sample submission catalogue* (See Appendix)

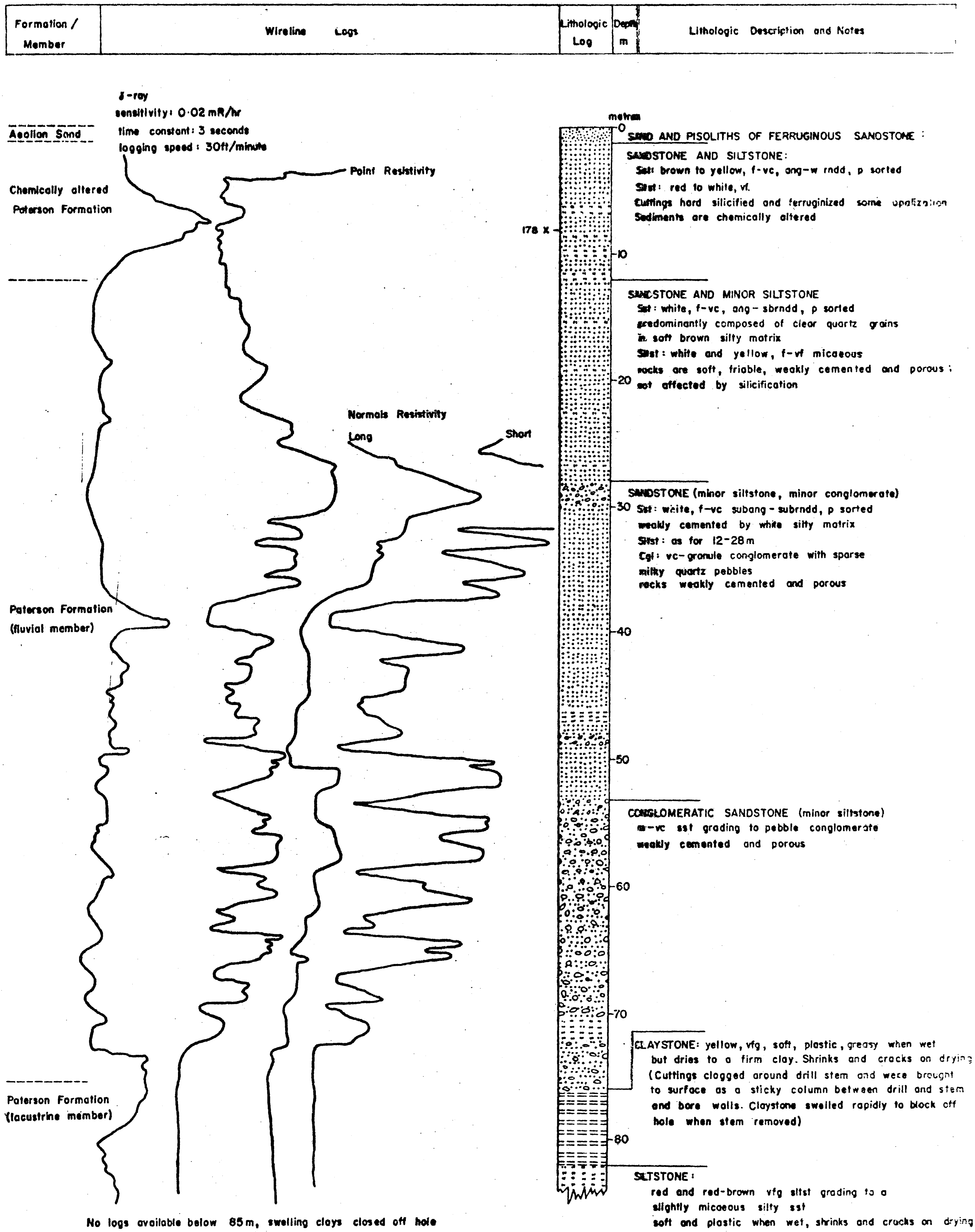

Fig 3A BMR RASON 2 (0-85m)

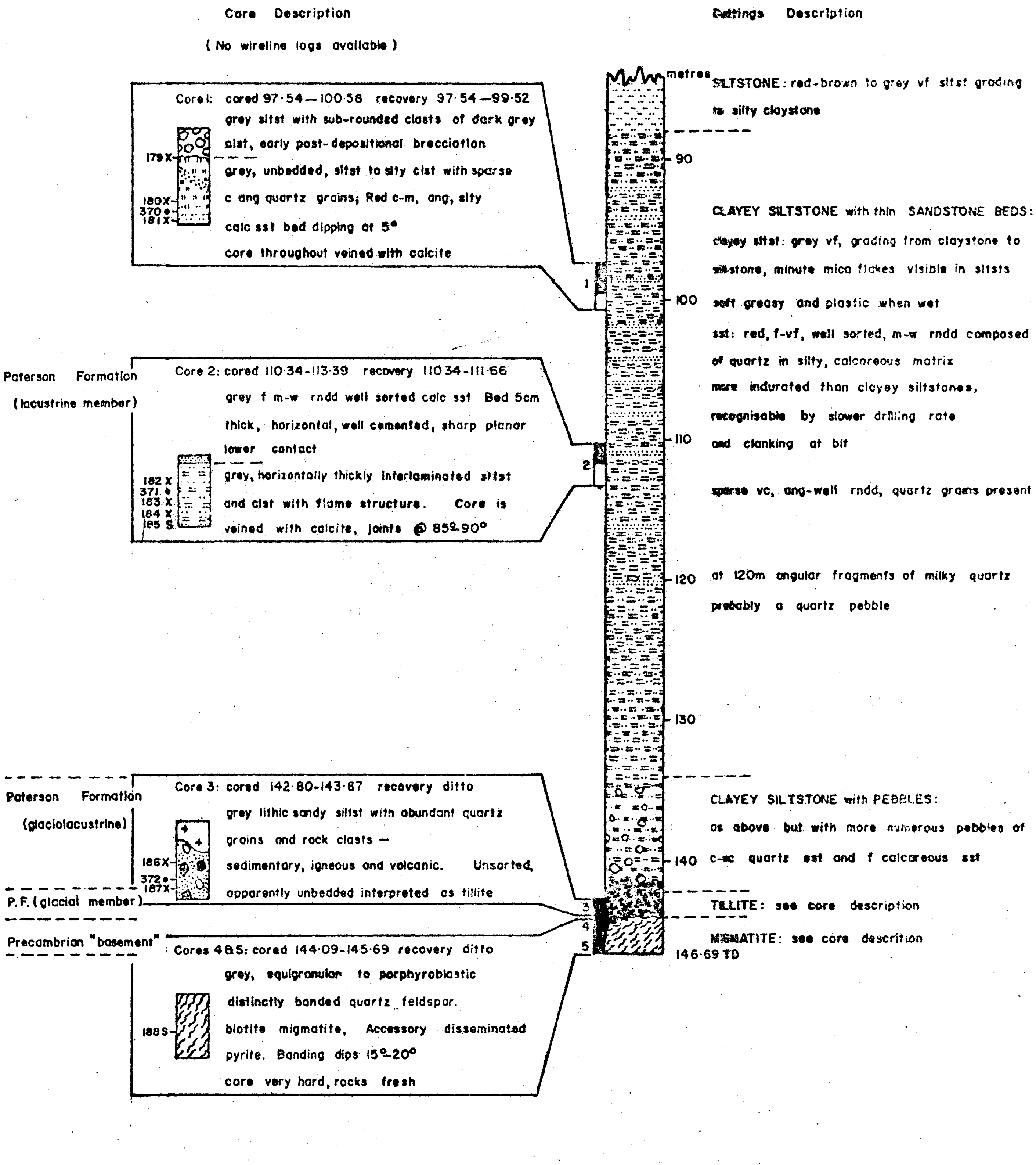

Fig 3B BMR RASON 2 (85–146·69m)

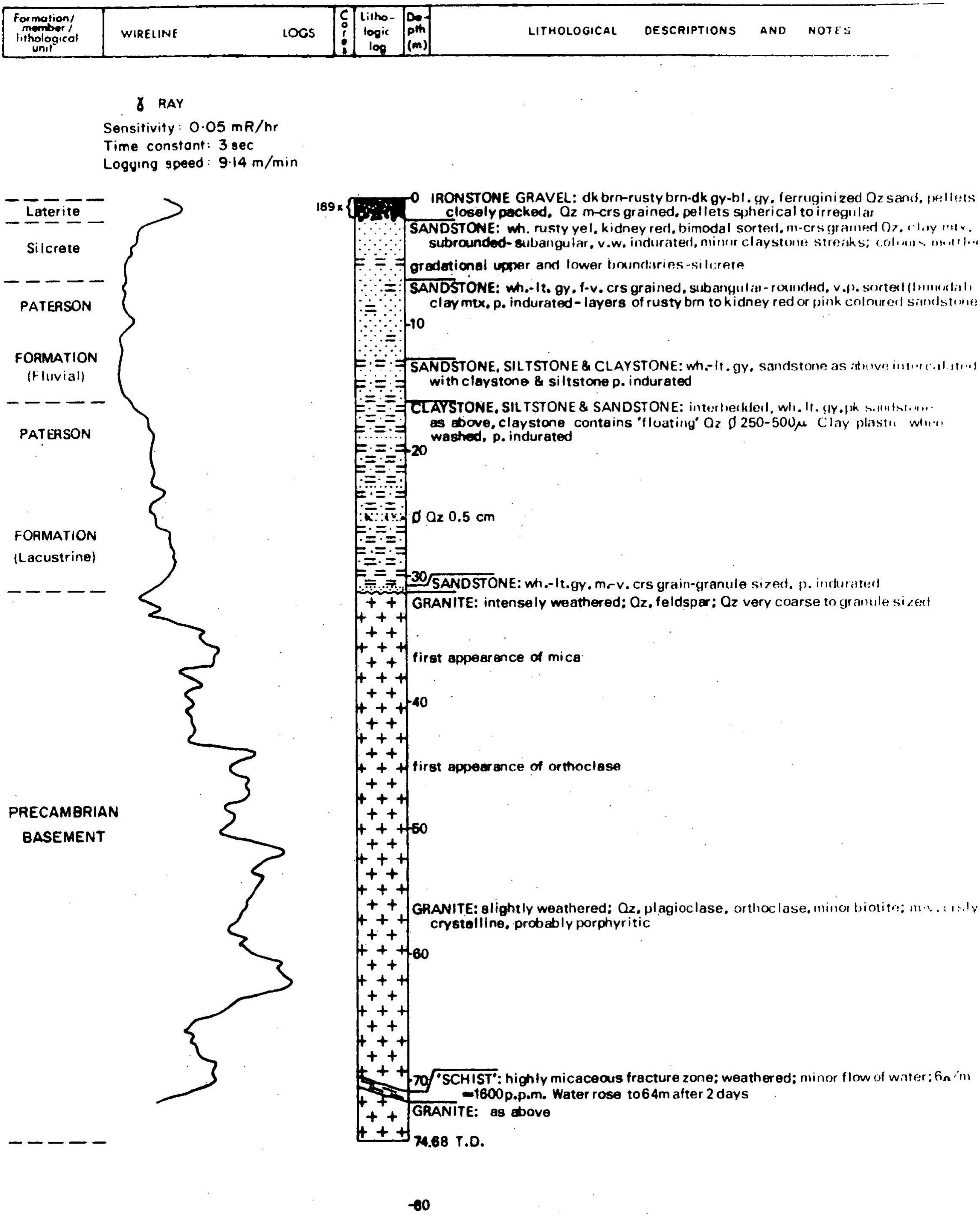

Fig. 4 BMR RASON 3

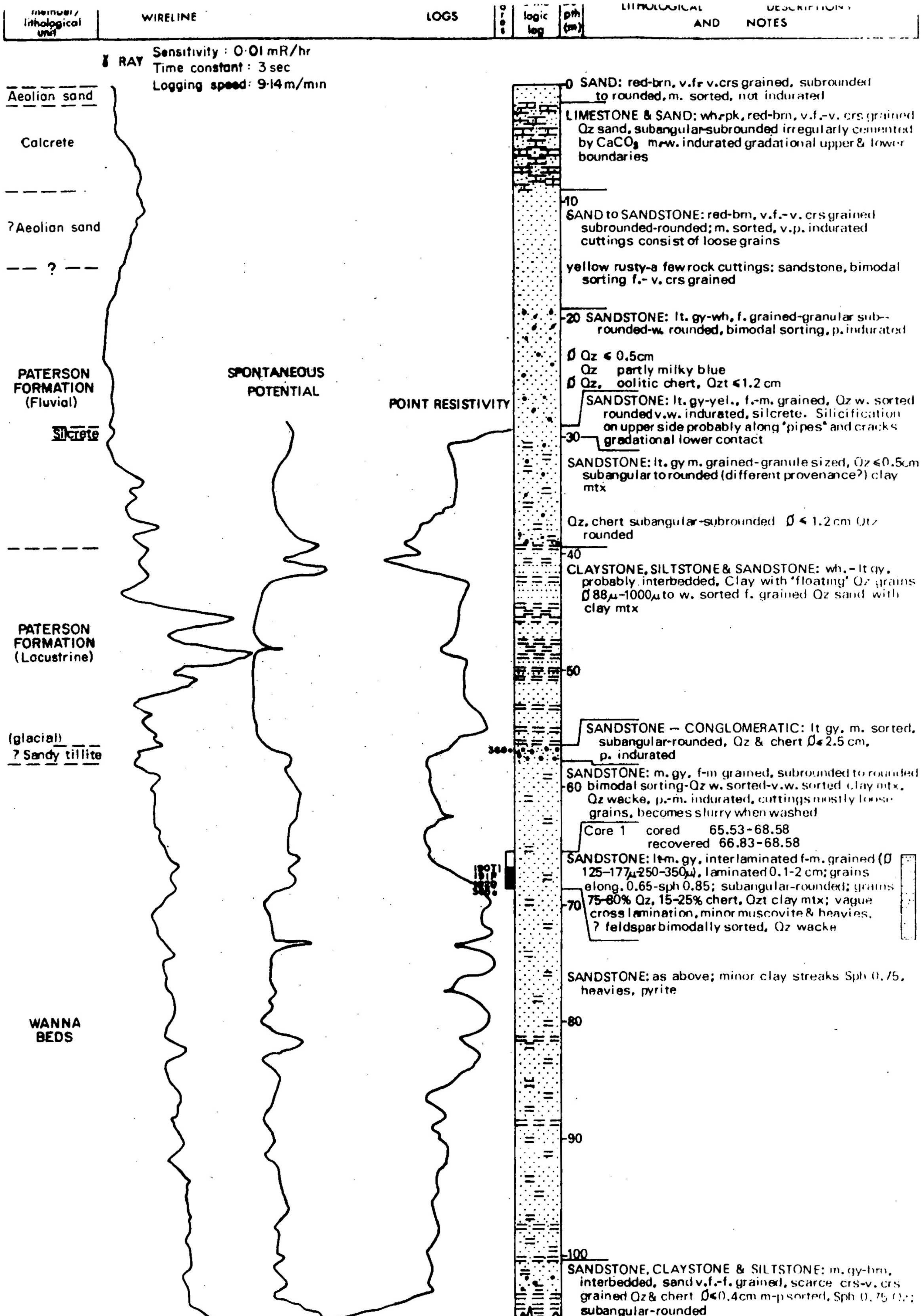

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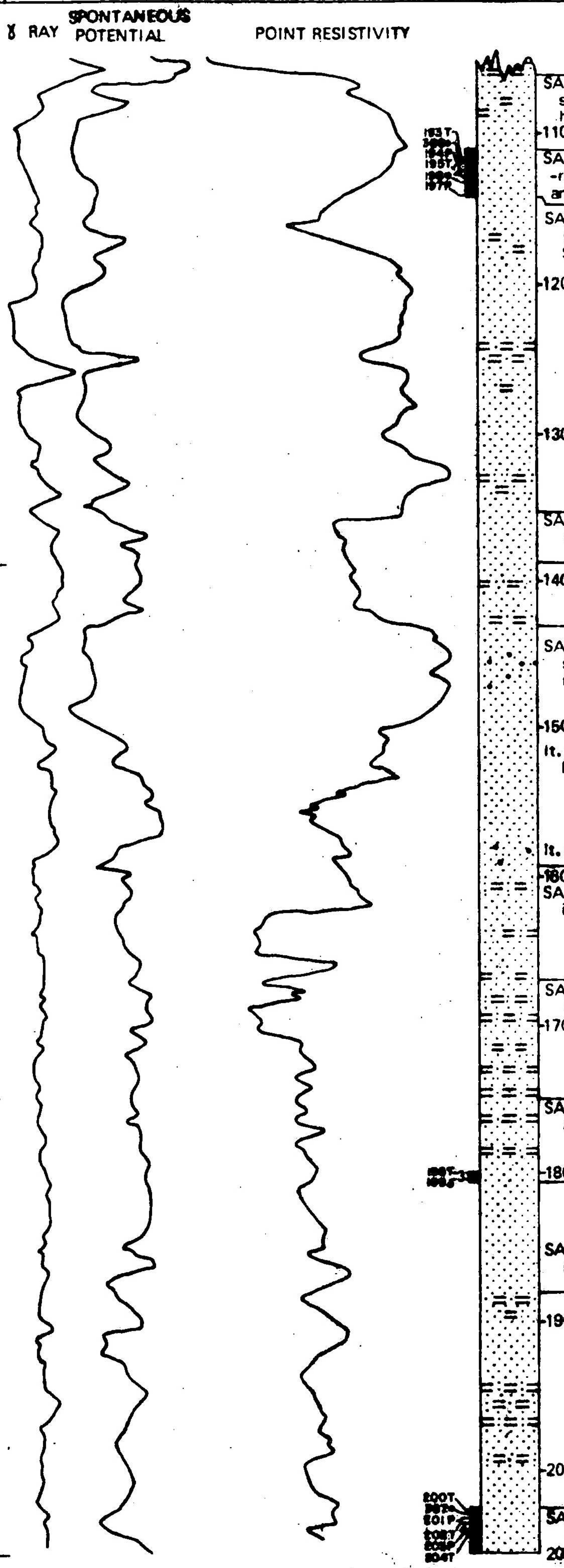
Fig. 6a BMR NEALE 1A & B

M(S)334

Formation/ member/ lithological unit	WIRELINE LOGS	Cores	Litho-logic log	Depth (m)	LITHOLOGICAL DESCRIPTIONS AND NOTES



WANNA BEDS

LENNIS SANDSTONE

SANDSTONE & minor CLAYSTONE: gy-brn, f.-crs grained, subangular- subrounded, minor interbedding of gy-wh. clay; heavies, micas p-w. sorted (bimodal), p. indurated

Core 2 cored 111.25-114.30 100% recovery
SANDSTONE: m. gy, f.-m. grained, w. sorted., subrounded -rounded, heavies, Sph0.75; laminated & crossbedded; angle of dip 30°-40°, m. indurated

SANDSTONE & minor CLAYSTONE: m. gy, f-m. grained, subrounded heavies, rare ?glauconite, feldspar, micas Sph 0.75, m. indurated

SANDSTONE: m. gy-lt. pk, f-m. grained, subangular-subrounded, bimodal sorted, Sph 0.65, heavies,

SANDSTONE & minor CLAYSTONE: lt. gy-lt. red-alternating gy & red. Gy sandstone as above, red sandstone f. grained, subrounded Sph 0.75, heavies, ? glauconite, minor m-crs grained Qz, minor clay interbeds

SANDSTONE: as above, gradual decrease in number of gy sandstone cuttings, scattered granules of Qz, chert m-w indurated

lt. red, f. grained, subangular-subrounded, m. sorted heavies,

lt. red-minor lt. gy, scattered Qz granules Ø≤3mm

SANDSTONE & CLAYSTONE: sandstone as above, interbeds of clay

SANDSTONE & CLAYSTONE: sandstone as above, clay lt. gy, v.p. indurated, plastic; up to 50% clay

SANDSTONE & CLAYSTONE: as above decrease in amount of clay

Core 3 cored 179.83-180.44m 100% recovery
SANDSTONE: red, v.f., f-m grained, subangular- subrounded, Sph 0.65-0.75, laminated 1-5 mm, v.f. & f. sand laminations, m-w sorted. m. grained sand bimodal sorted, heavies,

SANDSTONE: red, v.f.-m. grained, subangular-subrounded, m-w sorted

SANDSTONE & CLAYSTONE: sand red, as above, scattered crs grains Qz, subangular-subrounded; clay interbeds

Core 4 cored 202.69-205.74 100% recovery
SANDSTONE: lt. red, f-m grained, angular-rounded, Sph 0.65 -0.75, bimodal sorted, m.-w. indurated, heavies laminated & crossbedded

205.74 T.D.

Fig. 6b BMR NEALE 1A & 1B

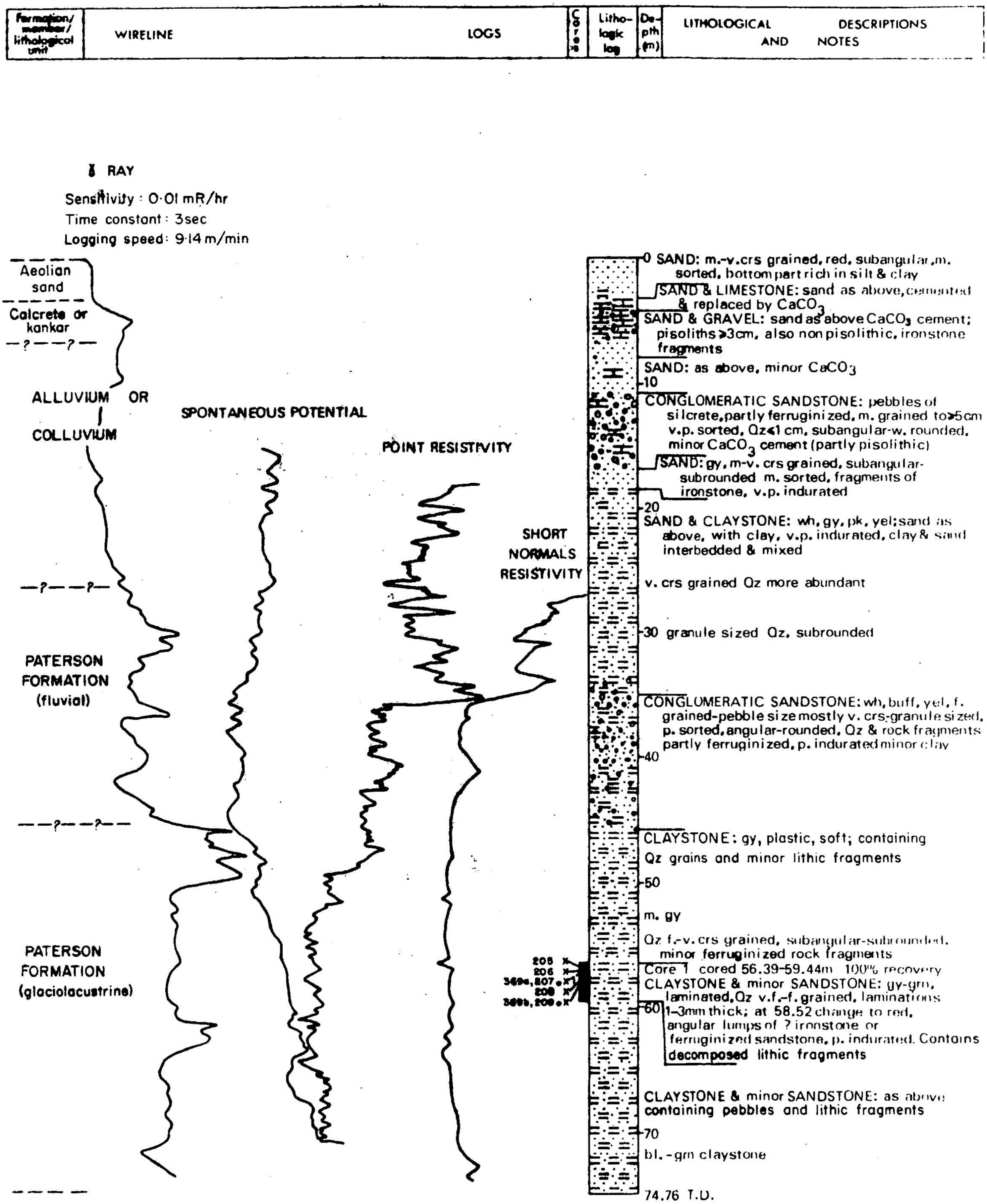


Fig. 7 BMR NEALE 2

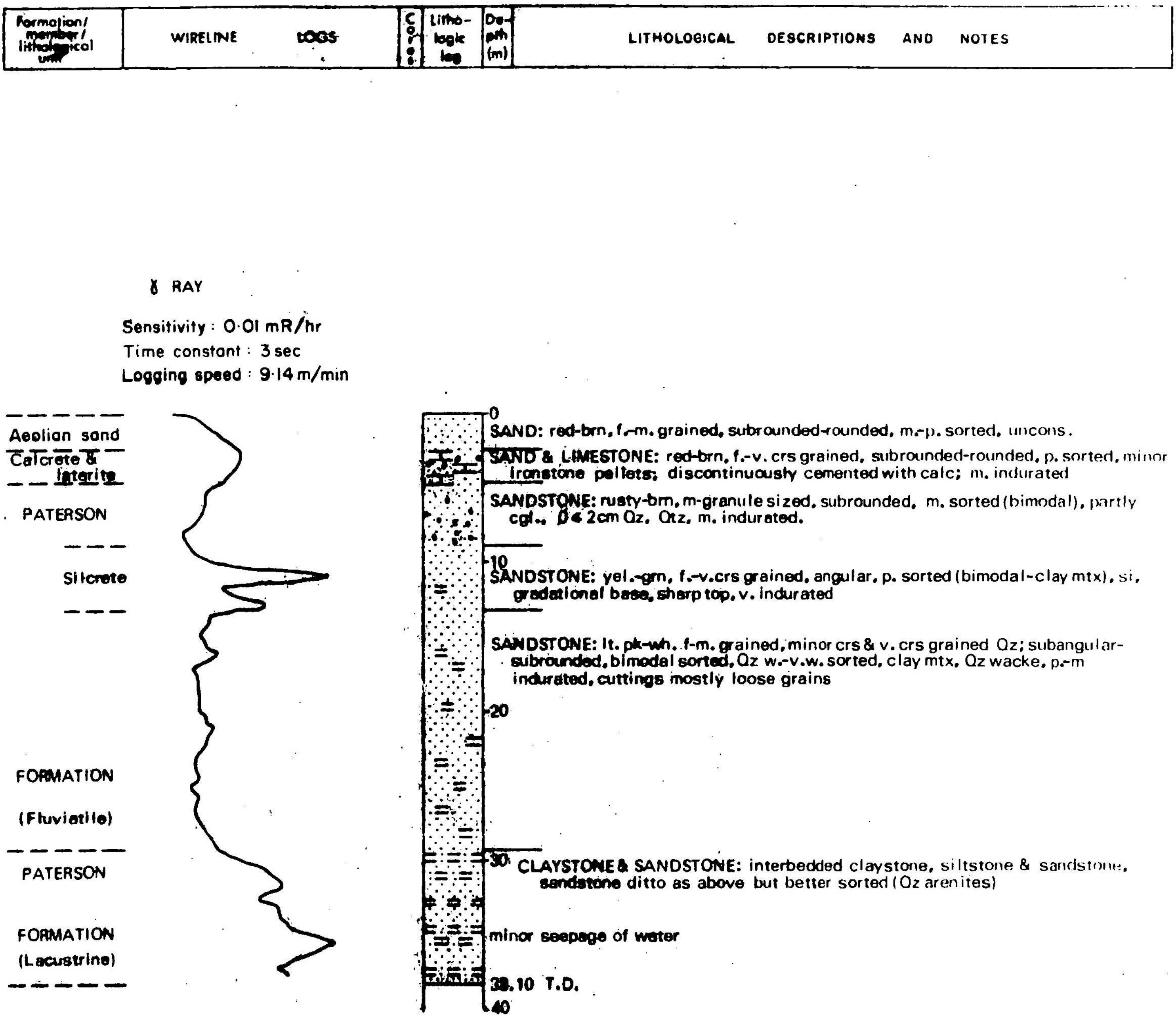


Fig. 8 BMR NEALE 3

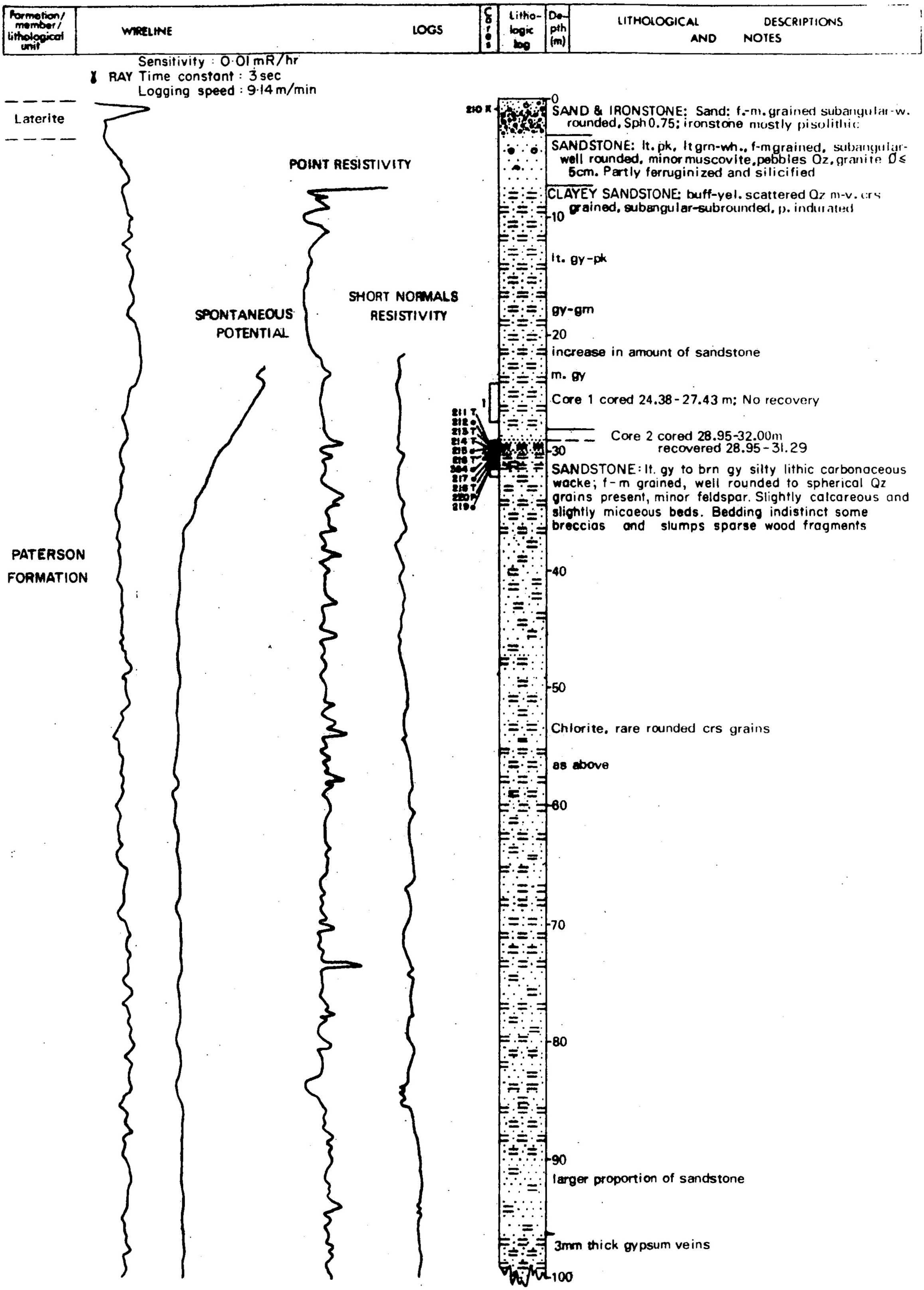


Fig. 9a BMR WANNA 1

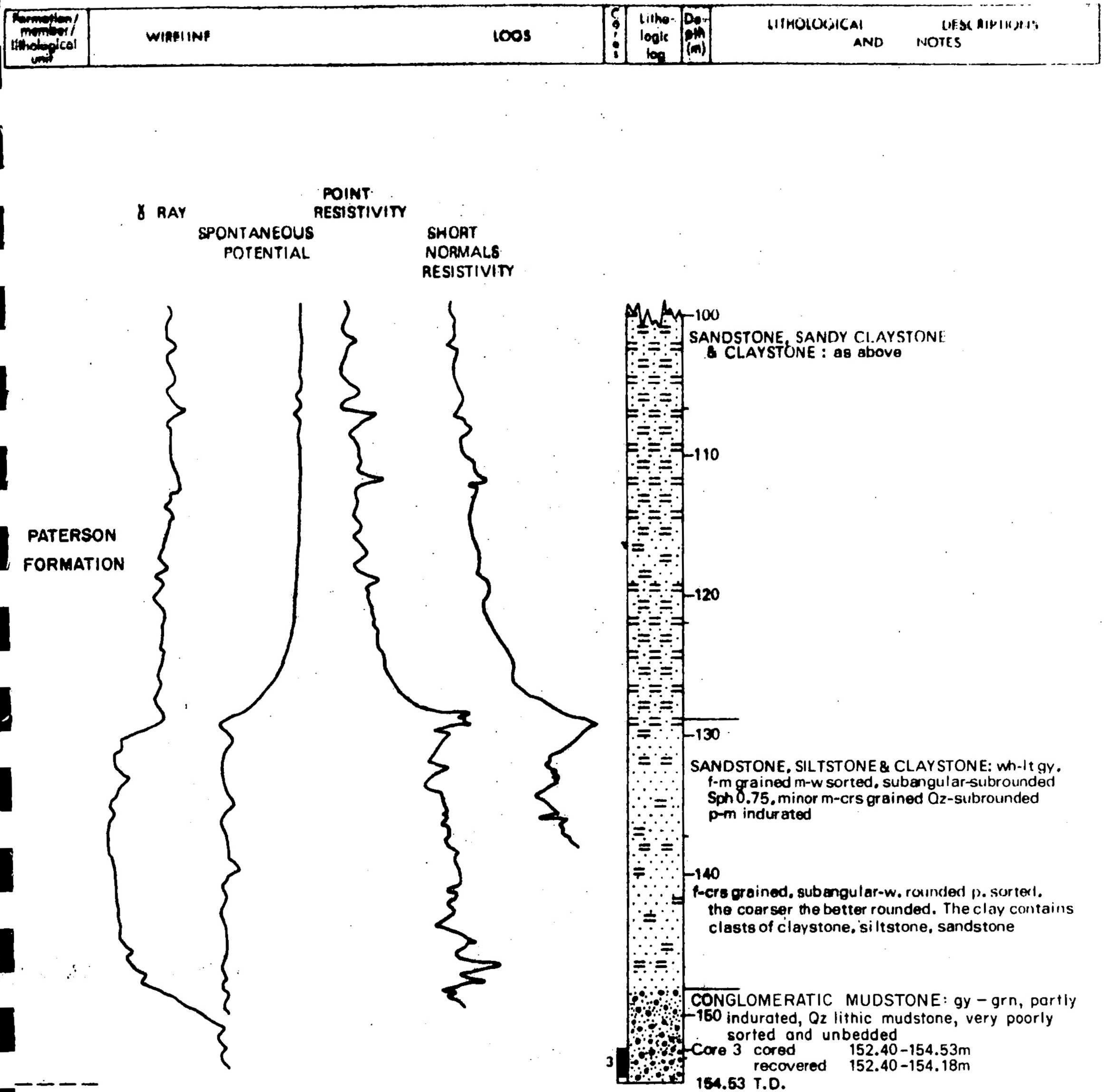


Fig. 9b BMR WANNA 1

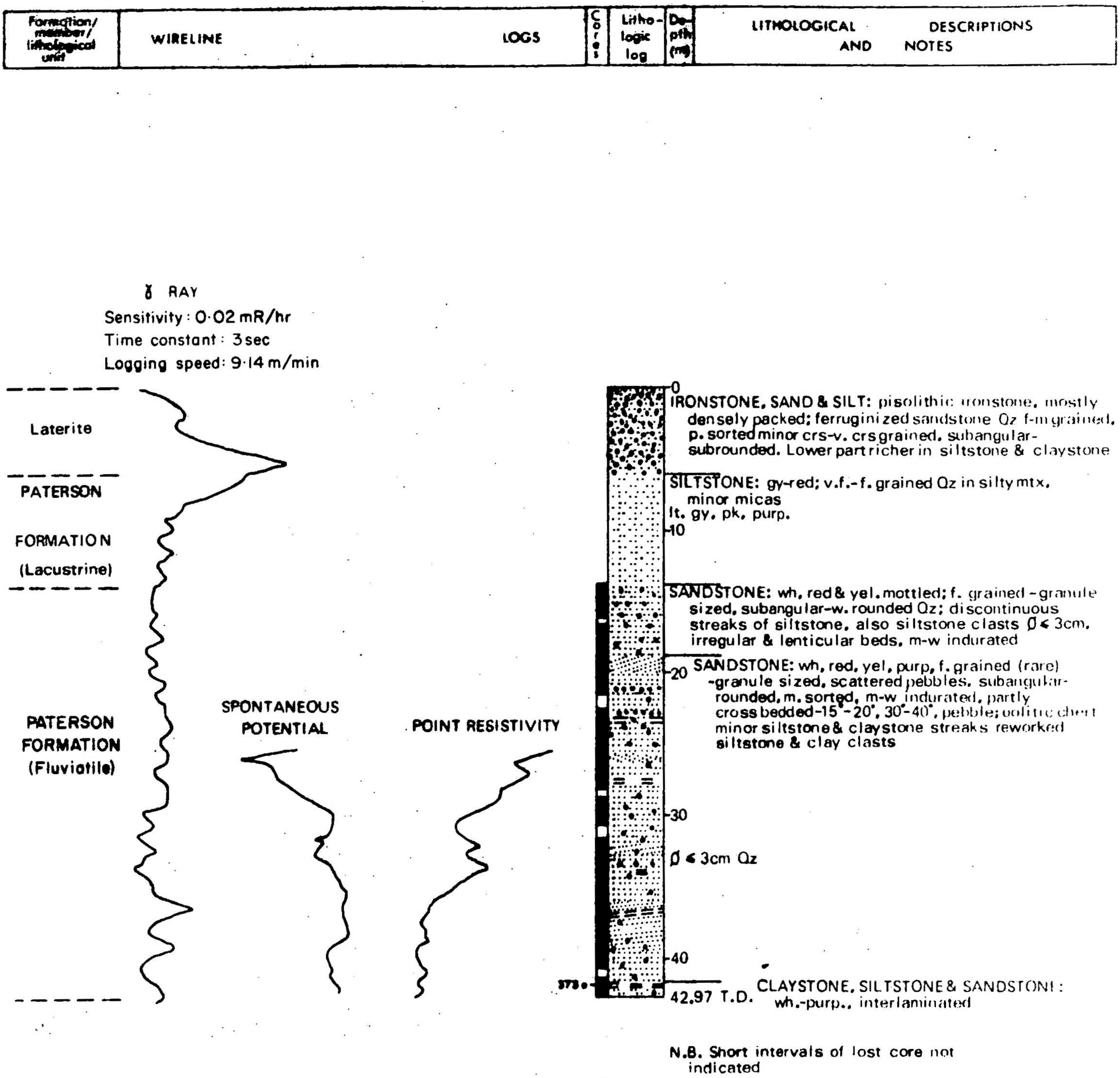


Fig. 10 BMR YOWALGA 4

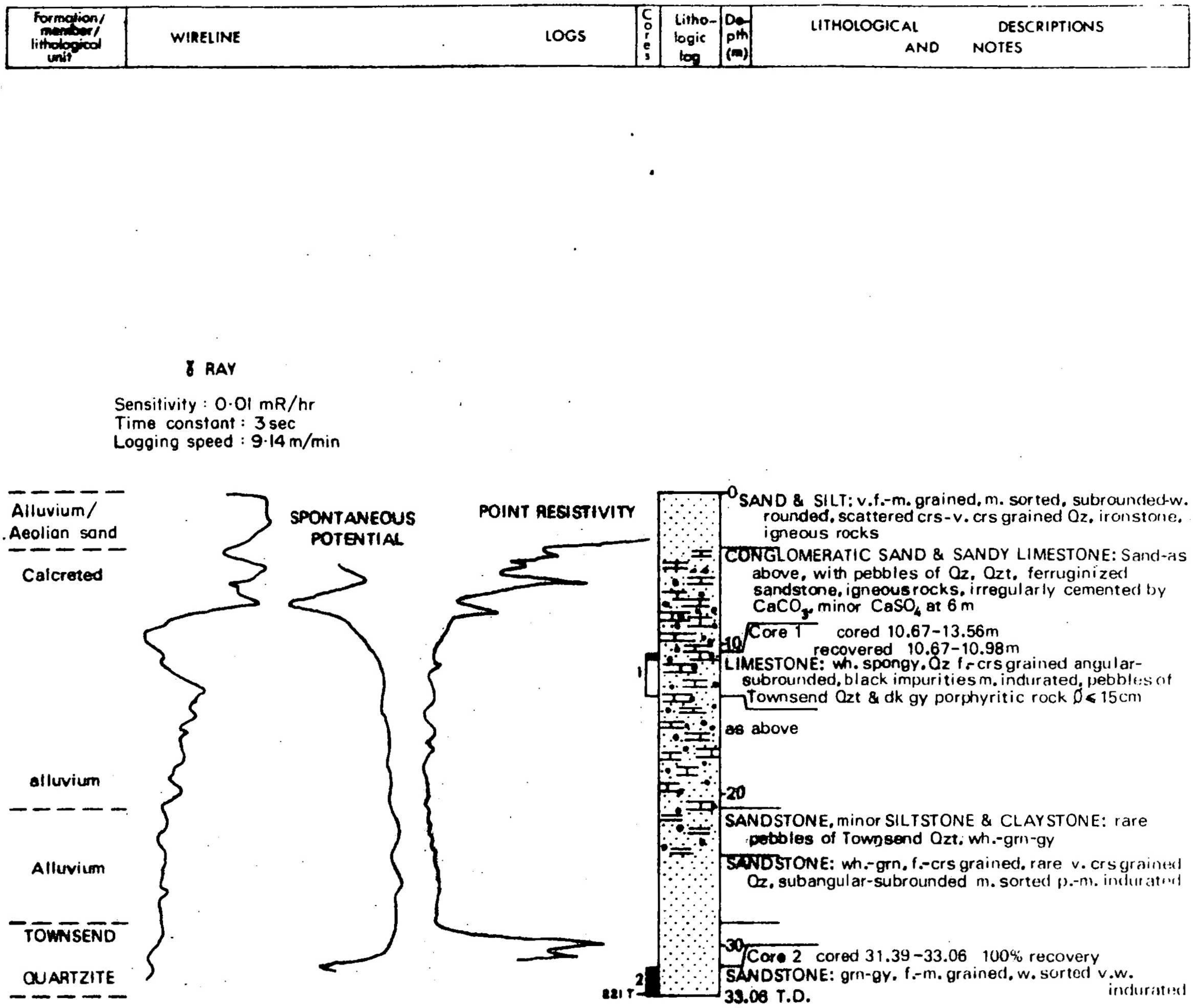
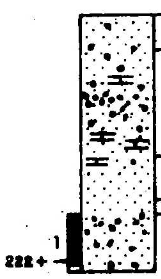


Fig. 11 BMR TALBOT 1

Formation/member/lithological unit	WIRELINE LOGS	Cores	Litho-logic log	Depth (m)	LITHOLOGICAL AND NOTES DESCRIPTIONS

Calcareous alluvium



SAND: f.grained-granule sized, p. sorted, subangular-w. rounded, v. p. indurated

CONGLOMERATIC SANDSTONE: pebbles & granules of:- ironstone, Qz, Qzt, dark, f. grained igneous rocks. Sand as above; v.p. sorted p. indurated subangular-subrounded, minor & irregular cementation with $CaCO_3$

SANDSTONE: gy, v.f.-f. grained, m-p sorted, subangular-subrounded, $CaCO_3$ v.w. indurated

Core 1 cored 10.66 - 13.72 m recovered 10.66 - 13.41m

CONGLOMERATIC SANDSTONE: Sandstone, f.-crs grained, streaks & pockets of v. crs grained to pebble sized gravels, sands m.-w. sorted, subangular-subrounded; pebbles Qz, ferruginized sandstone, basic igneous rocks, Ø ≤ 1.5cm p.-v.w. indurated, minor $CaCO_3$ cement

13.72 T.D.

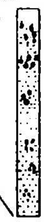


Fig. 12 BMR TALBOT 2

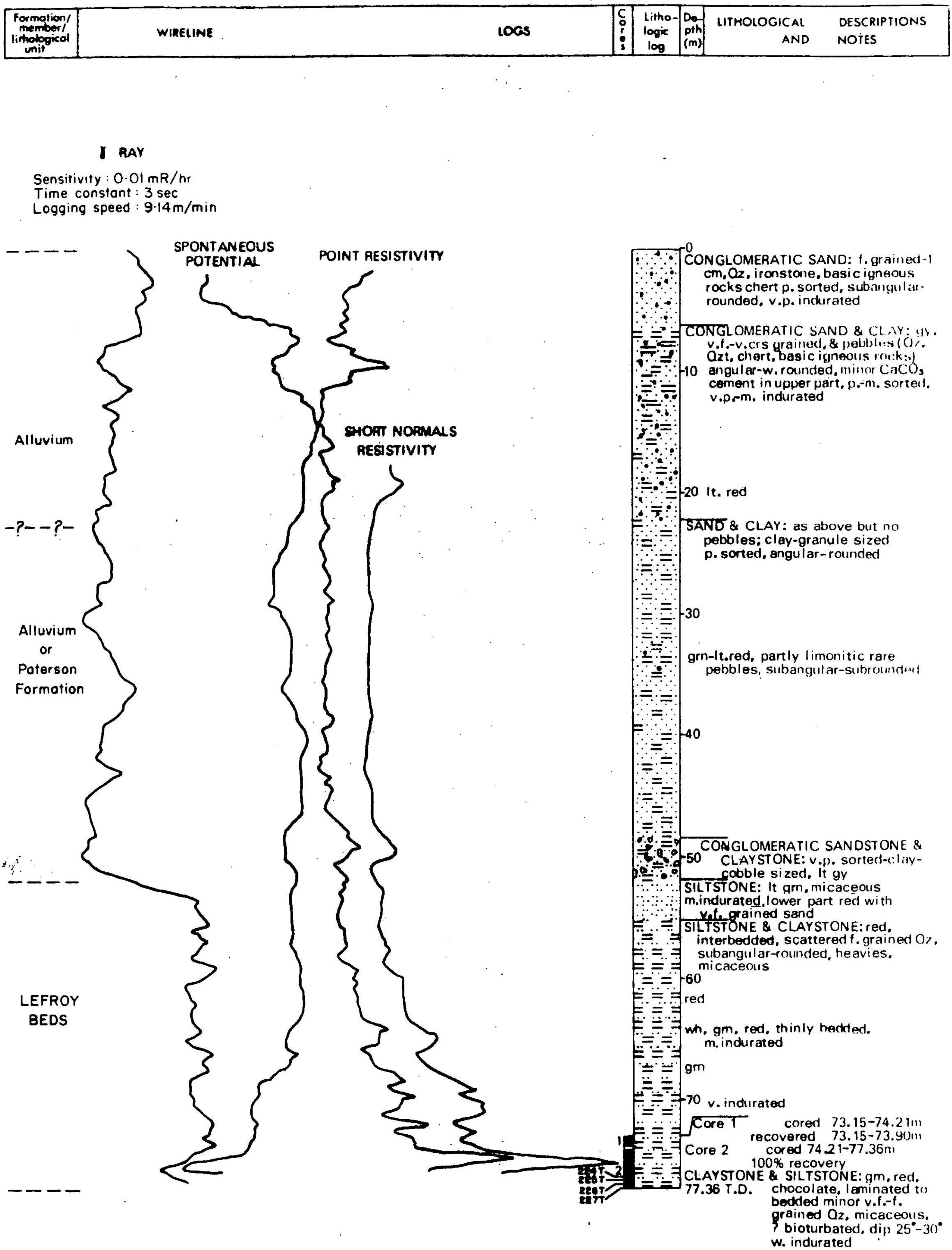


Fig. 13 BMR TALBOT 3

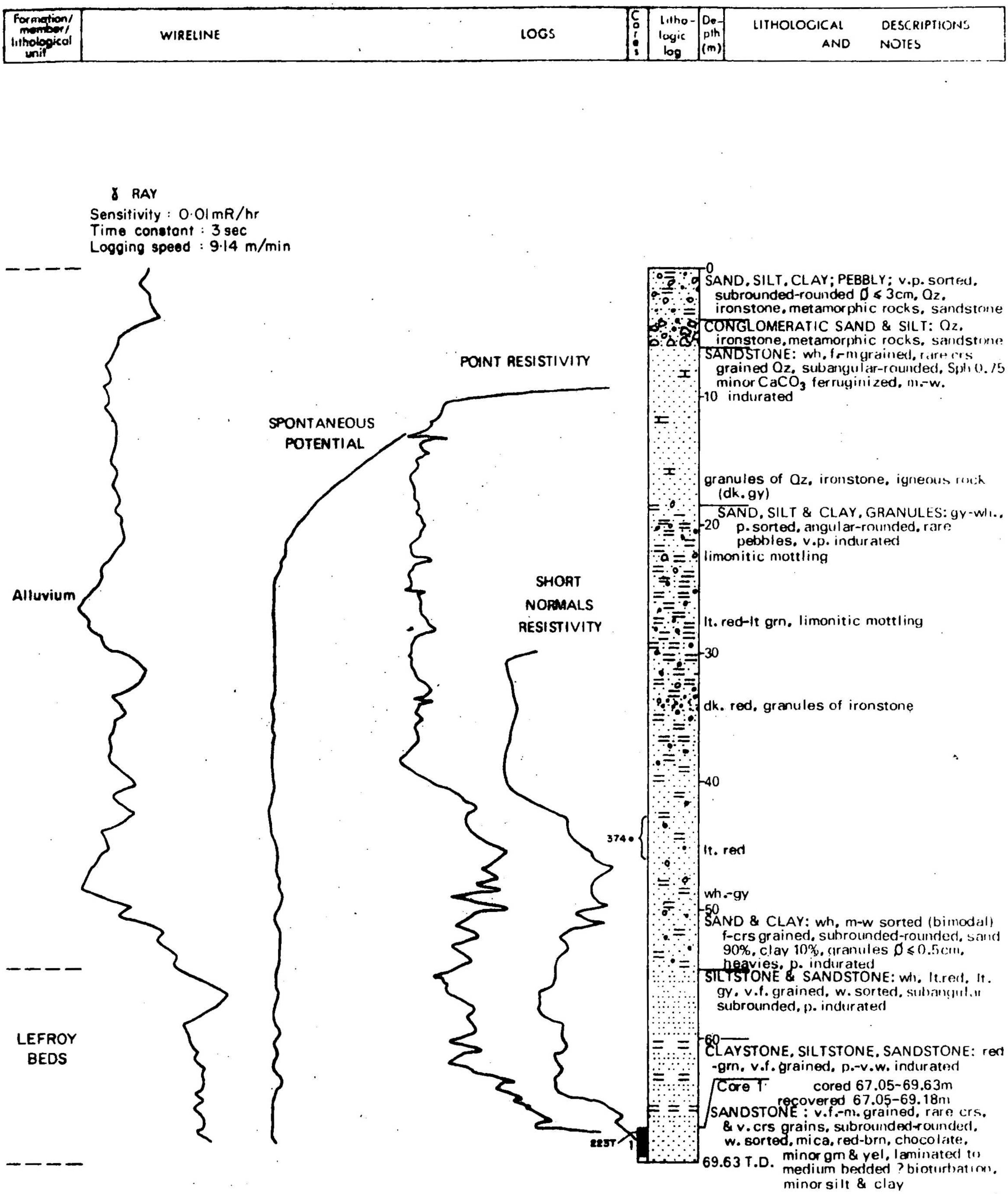


Fig. 14 BMR TALBOT 4

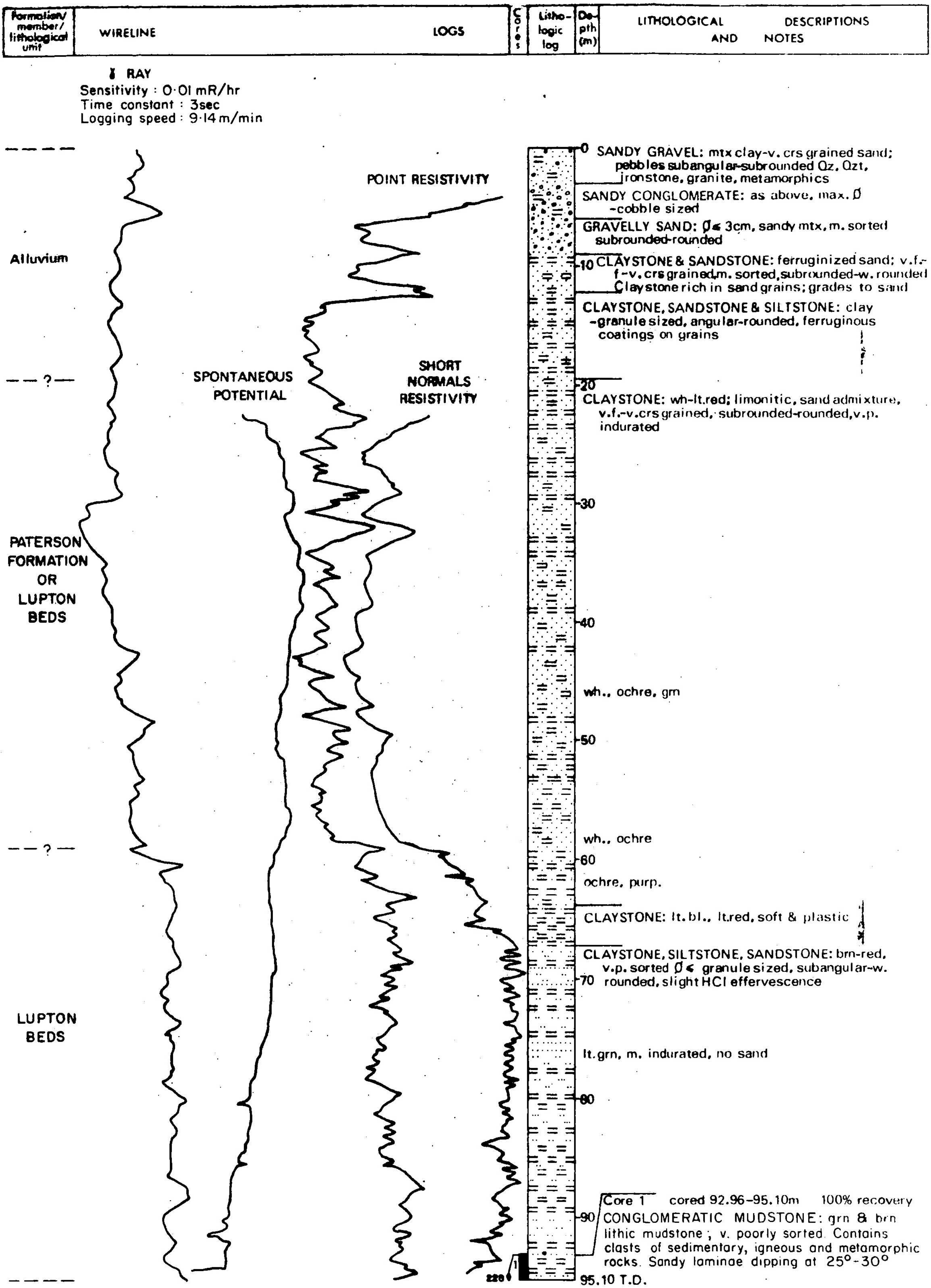


Fig. 15 BMR TALBOT 5

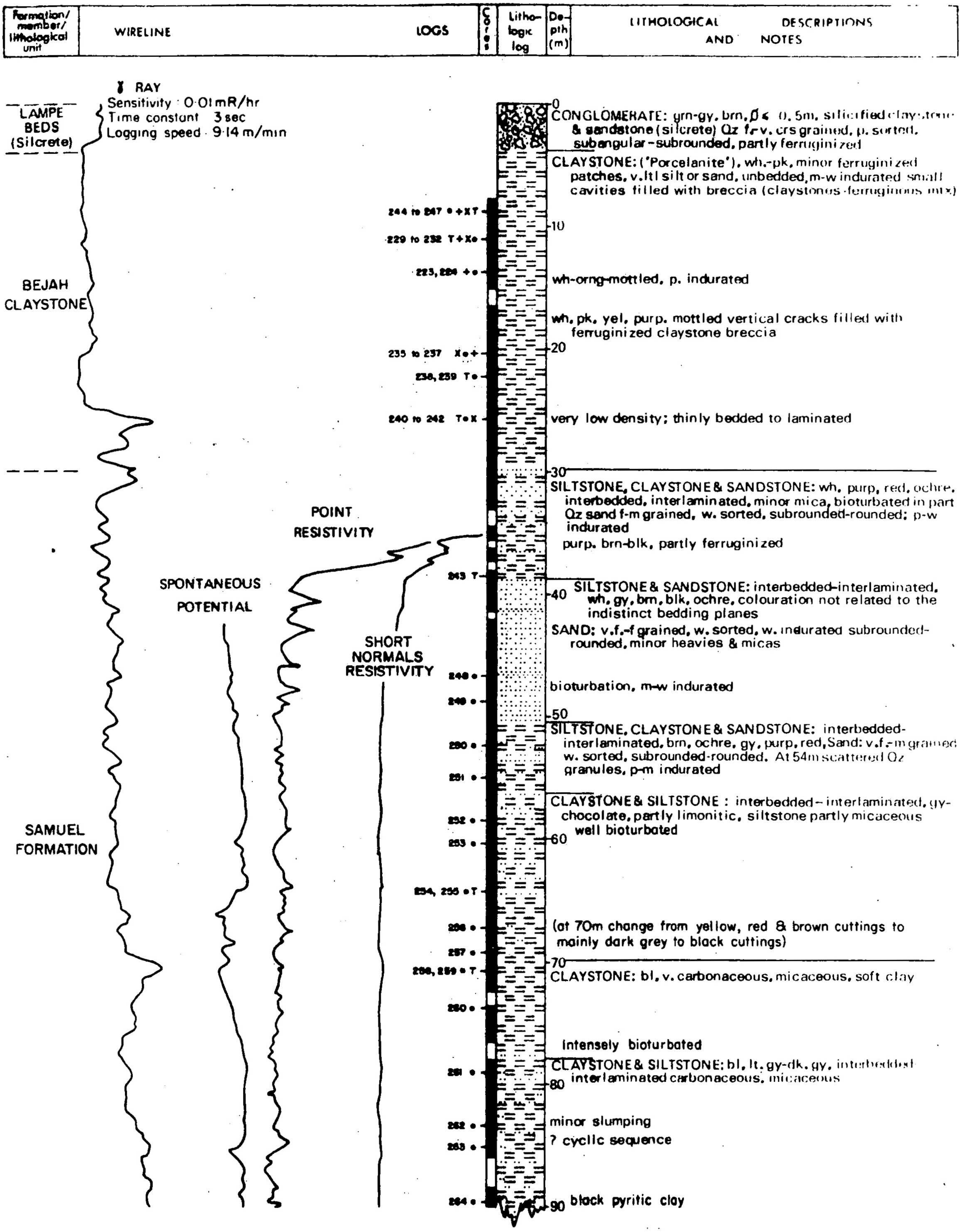
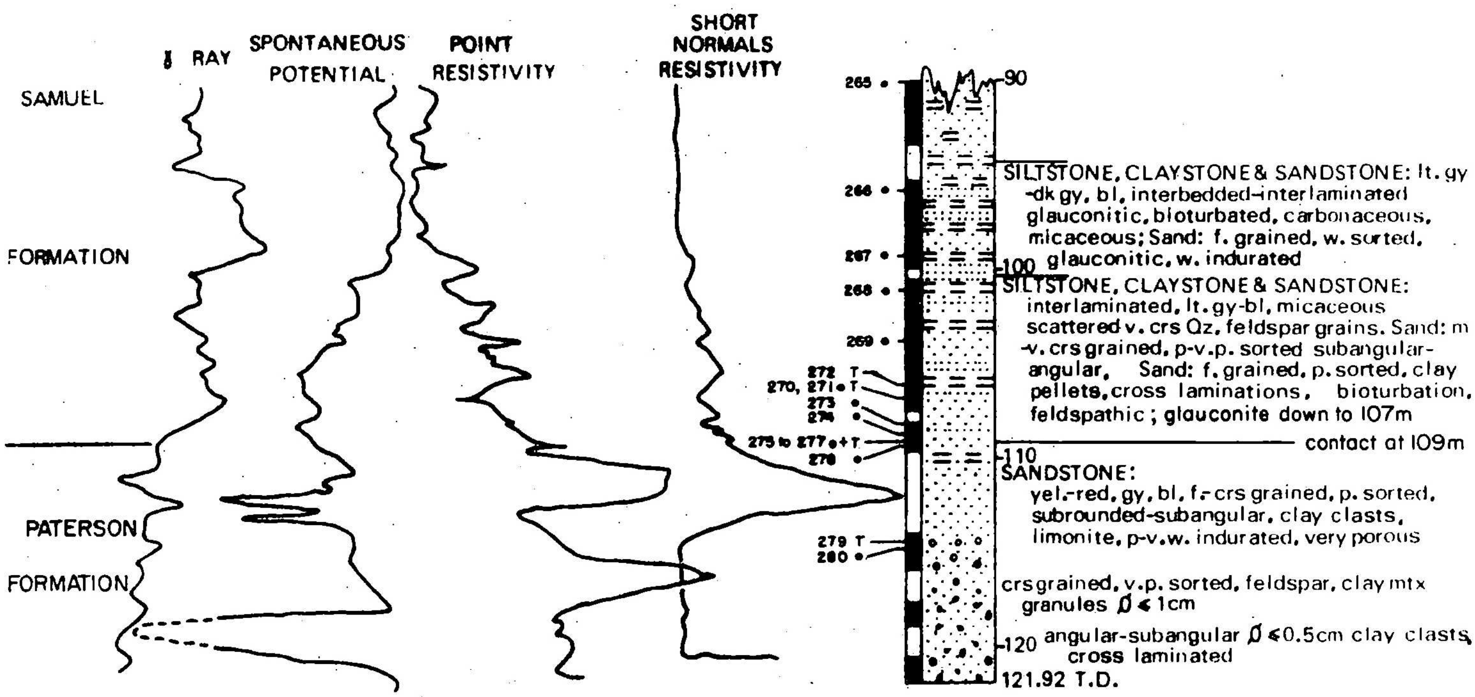


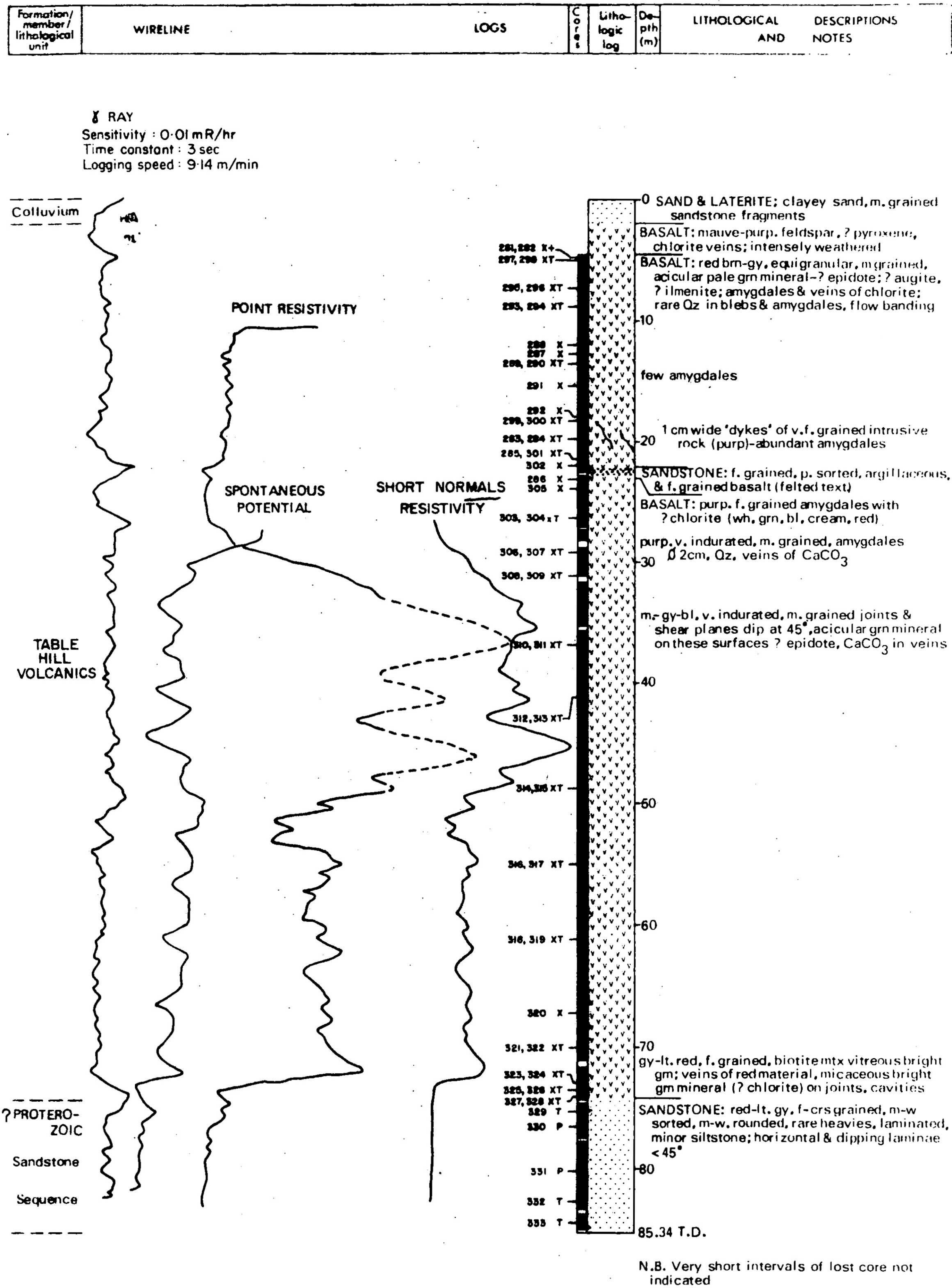
Fig. 16a BMR BROWNE 1

Formation/ member/ lithological unit	WIRELINE LOGS	Cores	Litho-logic log	Depth (m)	LITHOLOGICAL DESCRIPTIONS AND NOTES



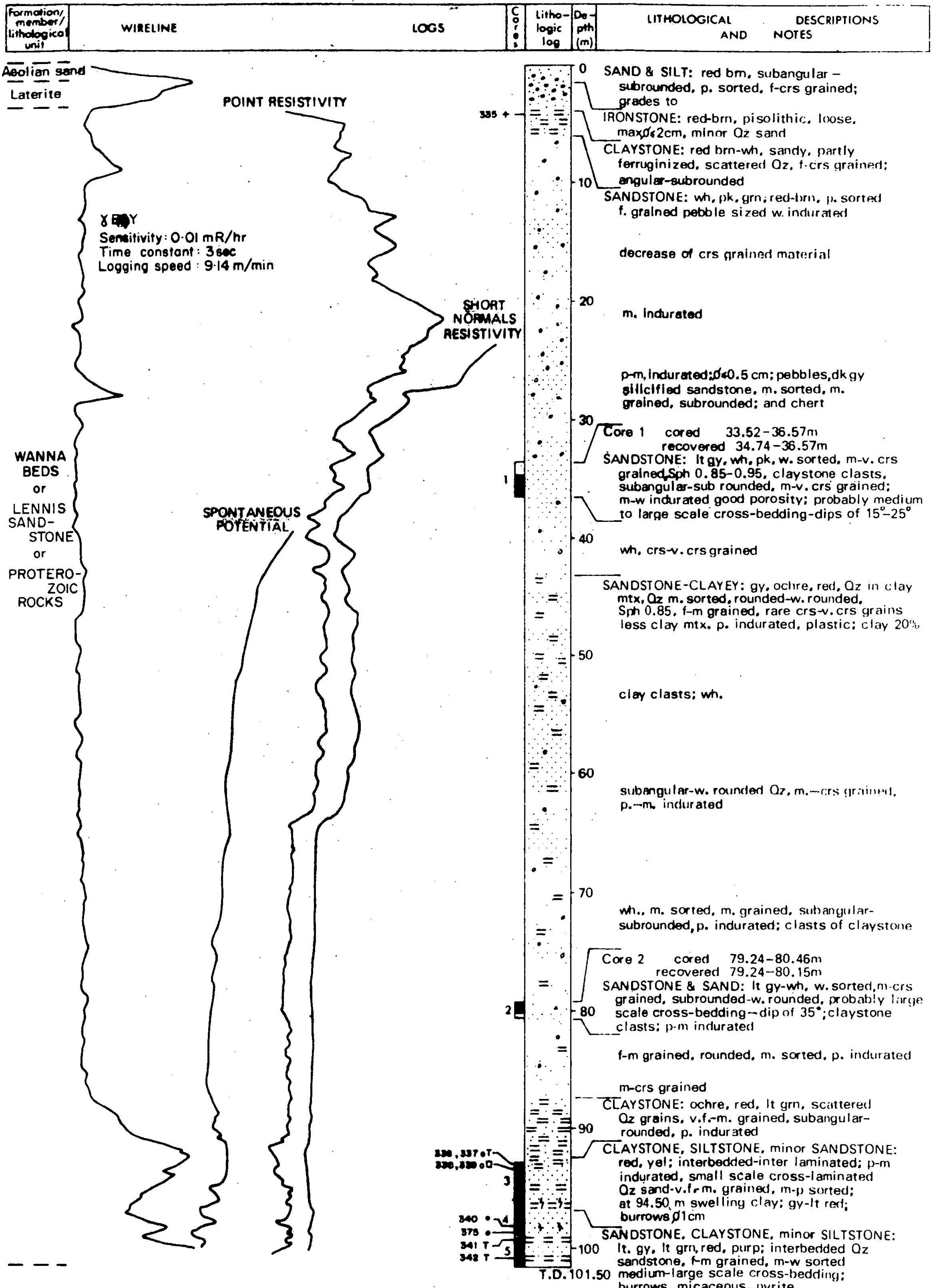
N.B. Very short intervals of lost core are not indicated

Fig. 16b BMR BROWNE 1



N.B. Very short intervals of lost core not indicated

Fig. 17 BMR WESTWOOD 1



Record 1975/49 Fig. 18 BMR WESTWOOD 2 M(S)349

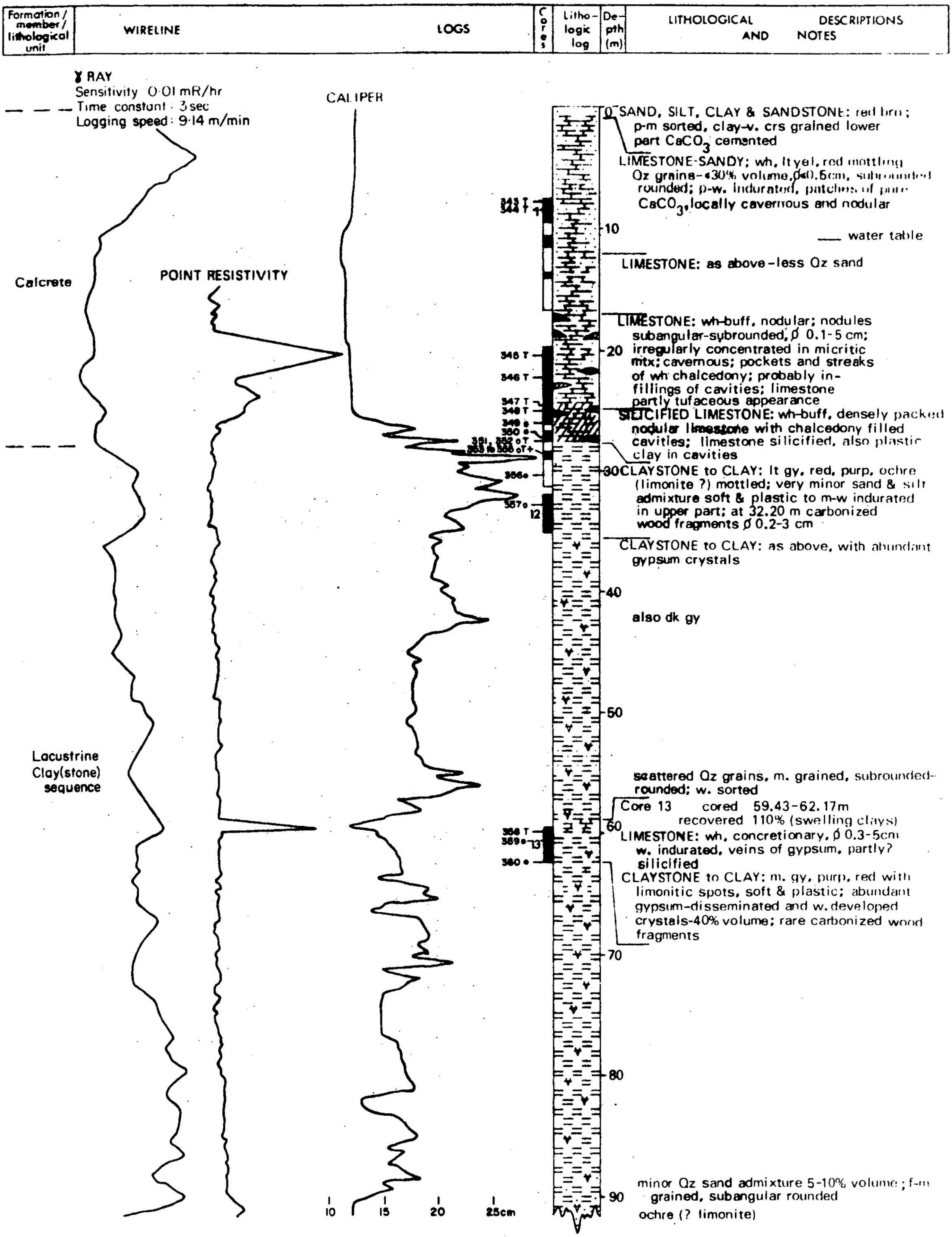


Fig. 19a BMR THROSSELL 1

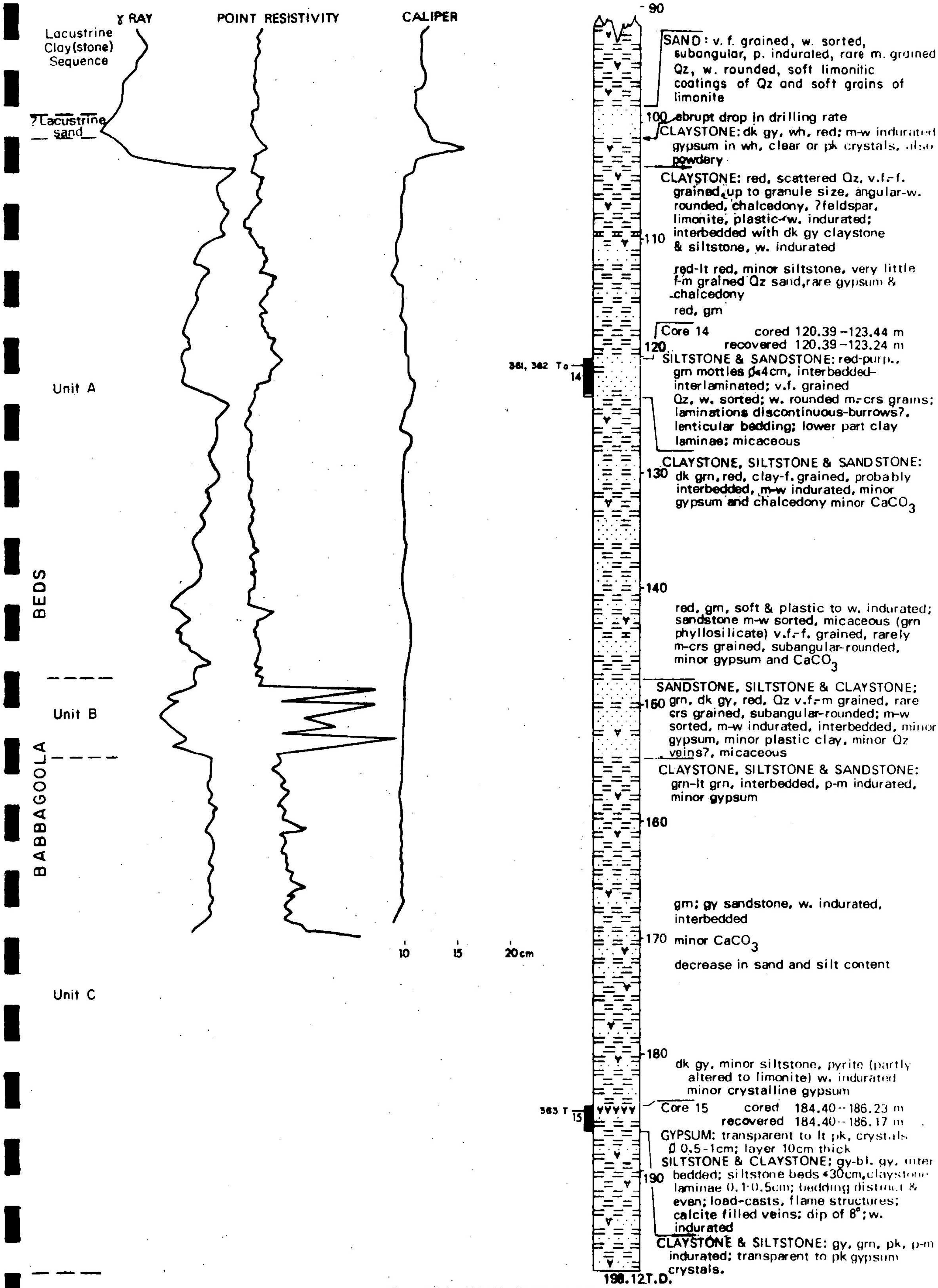


Fig. 19b BMR THROSSELL 1