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1962/168

GEOLOGICAL COMPLETION REPORT, BORES BMR 4 AND BMR 4A, CANNING BASIN, WESTERN AUSTRALIA.

by

L.V. Bastian.

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CONTENTS

APPENDICES:

ILLUSTRATIONS (At back of Record)

S U M M A R Y

Bores BMR 4 and 4A were drilled on Wallal Downs Station in the South-West Canning Basin during 1958. Because BMR 4 had to be abandoned prematurely when artesian water was encountered, the requirements of the programme were completed in BMR 4A, 90 yards to the west; this bore was completed in granitic gneiss at 2228 feet after passing through 73ft. of Quaternary 302 ft. of Lower Cretaceous, 1550 feet of Jurassic, and 297 feet of Triassic and Permian sediments. Equivalents of the middle part of the Permian sequence found in the Fitzroy Trough are absent. No pre-Permian sediments were present.

The results confirmed the geophysical evidence that the sediments thin over a basement high. No oil or petroliferous gas was detected.

I N T R O D U C T I O N

Bores BMR 4 and 4A, in the South West Canning Basin, were the first of five bores drilled in the 1958 Stratigraphic Drilling Programme of the Bureau of Mineral Resources. Only one bore was planned here, but as a result of abandonment of BMR 4 above the target when artesian water was encountered, BMR 4A was drilled alongside to basement.

The original report on these wells by the well site Geologist (L.M.Pulley) was not completed. The present report is based on this after a re-examination of the cores and cuttings made by the author during 1961. Pulley's notes on the lithology were also available.

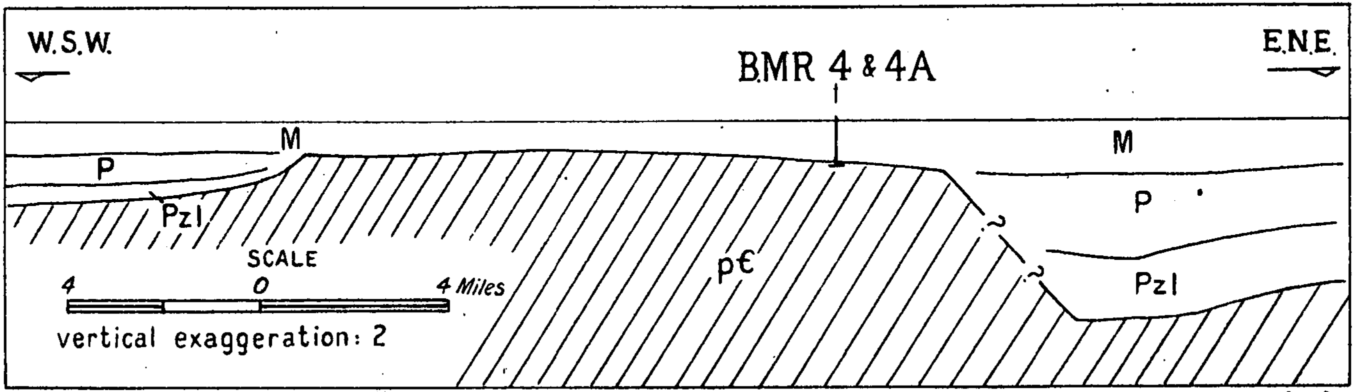
Location and Access (Plates 1 and 2)

Bores BMR 4 and 4A are on Wallal Downs Station, 180 yards west of Coast Well, which is about 8 miles north-east of the homestead. Proximity to this source of water, and maximum elevation - in the hope of completion as a water well for the station - determined the exact location, near the head of a western re-entrant of a group of dunes lying in the recent regression plain. The bores are about 150 yards north of the Great Northern Highway, approximately 160 miles from Port Hedland and 220 miles from Broome.

Personnel and urgently needed supplies were flown to Wallal on the weekly MacRobertson Millar Airlines station flight from Port Hedland. The Flying Doctor radio network based on this town provided a valuable medium for telegraphic communication.

Purpose

Because of the extensive veneer of aeolian sand, knowledge of the geology of the Canning Basin, particularly of sediment thickness and basin configuration, is derived largely from geophysical surveys.



Bureau of Mineral Resources, Geology and Geophysics. Oct 1962 To accompany Record 1962/168 E51/13/4

Fig 1

Gravity and aeromagnetic surveys by the Bureau of Mineral Resources in 1954 and 1956 indicated several basement ridges trending west-north-west, with a thin sedimentary cover. One of these intersects the coast near Wallal where a pronounced gravity high and a sharp magnetic anomaly indicate basement at a depth of 2,000 - 3,600 feet.

(WAPET) The magnitude of the northern scarp of the basement ridge is shown on a seismic refraction profile recorded by West Australian Petroleum Pty.Ltd. (Fig.1). A high velocity refractor identified as basement was recorded at a depth of over 9,000 feet about 6 miles north-east of the proposed bore site. The velocities of the two overlying layers with tops at 4,000 feet and 6,500 feet, are similar to those of Permian and Lower Palaeozoic formations drilled in the northern part of the basin. Only the high velocity refractor was detected on the basement ridge at a depth of between 2,000 and 2,700 feet. Therefore, it seemed probable that the cover over the ridge would consist of the Mesozoic sediments, with the Palaeozoic very thin or absent.

Fig.1 Section through the site of BMR 4 and 4A derived from geophysical profiles. M-Mesozoic; P-Permian; Pzl - Lower Palaeozoic; pC - Precambrian basement.

The potential value of this bore was increased by WAPET's decision to drill an exploratory well to basement on Samphire Marsh, about 30 miles east-north-east of the north flank of the Wallal ridge, thereby revealing the differences of stratigraphy between the thin and thick sections penetrated. This and verification of a possible Palaeozoic calcareous sequence at depth were of great significance for the oil prospects of this region.

BORE HISTORY

DRILL-HOLE DATA

		BMR 4	BMR 4A
Location:	Latitude:	19° 44' 12" S.	19° 44' 12" S.
	Longitude:	120° 44' 28" E.	120° 44' 25" E.
Miscellaneous Data:		180 yds. W. of Coast Well	90 yds. W. of BMR 4
Elevation, Rotary Table:		34'	32'
Elevation Ground:		30'	28'
Date Spudded:		1.4.58	22.4.58
Date Completed:		8.6.58 X	9.5.58.
Total Depth from (R.T.):		1410' (dr.)	2228' (e log) =2224' (dr.)

X Drilling stopped 12/4/58.

Hole Profile:	7 7/8" 0-44' 5 5/8" 44'-T.D.	7 7/8" 0-525' 5 5/8" 525'-T.D.
Casing Profile:	6 5/8" 0-43'	6" 0-522'
Plugs:	Casing Head	
Status:	Abandoned	Artesian water well

Drilling Contractor: Oil Drilling and Exploration Ltd.

Personnel: Toolpusher: A.Madge
Well-site Geologist: J.M.Pulley
e-log operators: L.V.Skattebol (B.M.R.); H.Till (Eastern Services Coy. Inc.)

Samples: Cuttings and cores stored at B.M.R., Canberra; Geological Survey of W.A., and WAPET, Perth.

Drilling History

The bores were drilled under contract by Oil Drilling and Exploration Ltd. The truck-mounted rig, a Failing 2500 Holemaster, and transport consisting of two 10-ton semi-trailers, were supplied by the Commonwealth. The semi-trailers were found to be unsuitable for cross-country transport.

Water supply was provided by a station bore known as Coast Well, 180 yards east of the original site. The large flow from BMR 4 was then used for drilling BMR 4A.

Mechanical defects caused considerable lost time during drilling of BMR 4 and ultimately led to its abandonment at 1,410 feet, well above target depth. This followed influx from an artesian aquifer while both rig motors were out of action. Since the drill-string was out of the hole, conditioning of the mud was not possible, and within a few minutes it flowed at about 40,000 galls. per hour.

Pending the arrival of casing and mud required to control the well, a second bore - BMR 4A - was drilled to basement 90 yards west of BMR 4. This was completed as an artesian water bore for Wallal Downs Station.

Plugging operations were then resumed on BMR.4. This proved difficult because of the high pressure of water flowing from the hole, and the presence of zones of strong loss of circulation above the water sand. After several unsuccessful attempts to set a plug above the aquifer, an inner string of 4 inch casing was run to 893 feet. The annulus was filled with bagging by displacement through a lubricator fitted to the casing head, and then sealed with cement. Finally a 10 foot plug was set at the head of the inner string.

Lithological Logging

Cores and ditch samples were taken at regular intervals in BMR 4 and in the additional section drilled in BMR.4A.

In addition to a systematic coring programme of 10 feet every 100 feet, cores were to be cut at change of formation at the discretion of the well-site geologist. However, except at basement, boundaries were insufficiently marked to be immediately apparent. 2¼ inch-diameter cores were cut with a 10 feet Reed Kor King barrel and 4¾ inch bits. The planned ditch sampling interval of 5 feet was increased to 10 feet in much of the section penetrated because of the high drilling rates and the poor quality of the cuttings.

All samples were tested for traces of natural hydrocarbons with an ultraviolet lamp. Flame tests were carried out after the core barrel was broken.

Drilling Time Logging

A log showing the time for successive 5 feet intervals was kept by drillers. It shows significant correlation with the other logs.

Electric Logs.

Because of its premature abandonment, no logs were run in BMR.4. The whole of BMR 4A was logged in three overlapping runs, details of which are listed in Table 1.

TABLE 1: Electric Logs, BMR 4A

Run	Interval	Logging Unit	Curves
1	600' - surface	Widco 2,000' point electrode	S.P. and Resistivity
2	1510' - 522'		
3	T.D. - 522'	Schlumberger	S.P.; Short and Long Normal, and Lateral Resistivity.

Because of delays in transit of the Bureau's 4,000 feet Widco logger assigned to the programme WAPET provided their Schlumberger unit and crew from the Samphire Marsh No.1 location.

Runs 1 and 2 have been issued with other bore logs as a Bureau record (Dyson and Jackson 1958). In the accompanying explanatory notes, the authors point out the questionable significance of the large deflection in the spontaneous potential curve at 378 feet. This may have been caused by a mechanical fault. The polarity of the S.P. in runs 2 and 3 is reversed because of the salinity of the drilling mud, in which formation water from BMR.4 was used.

Formation Fluids

Hydrocarbons: No sign of oil or petroliferous gas was detected in BMR.4 or 4A. Gas with a strong sulphurous odour, contained in the inner barrel with carbonaceous shaley siltstone cored at 1,900 feet, did not respond to a flame test. The drilling mud had to be reconditioned at several depths below 2145 feet to counteract the effects of gas influx. The mud was severely cut by an odourless, non-inflammable gas during bottom-hole coring.

Water: The artesian flow which forced the abandonment of BMR.4 maintained a rate of approximately 40,000 gallons per hour throughout the month which elapsed before the well was plugged. BMR.4A was completed as a water well with an initial production of approximately 17,500 gallons per hour. A shut-in-pressure of 45 lb./sq.inch was measured after three weeks of undiminished flow. The salt content of the water is low, and it is suitable for domestic, agricultural and pastoral use. An analysis of the soluble-salt content is presented in Appendix F.

The source beds are highly porous Jurassic sandstone intervals below 645 feet. Evidence was obtained during drilling and attempts to mud-off the water in BMR.4, that the top 35 feet of the unit tentatively correlated with the Callawa Formation or Wallal Sandstone* (i.e. 915 - 950 feet) is the major producing interval.

Calcilog

A calcilog was run on all available material by the present author in the laboratory during 1961.

The apparatus is very simple and, in brief, consists of a flask, containing the sample and a small amount of HCl, connected to a measuring cylinder. The sample flask is inverted and, upon contact of HCl and the sample, gas is evolved from any carbonate present, the volume of gas being indicated by displacement of water in the cylinder. Conversion tables then give the percentage of carbonate present. Two readings were taken during each test: the first after three minutes and the second upon completion of reaction, which for consistency was taken as ten minutes. A third reading was taken when the reaction had continued for a much longer period, sometimes for as long as one hour after commencement of reaction. This extended reaction is believed to be mainly the result of reaction on sulphides. The percentage derived from the first reading is said to give an approximation to the calcite percentage, while the difference between that and the second result is said to approximate the percentage of dolomite, which is slower to react.

The results in this work were not particularly useful because of the small amount of carbonate in the section penetrated, and the presence of pyrite in many samples.

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* Wallal Sandstone is used by WAPET geologists, but the term has not been used by B.M.R., as it is probably synonymous with the Callawa Formation. The alternative name may be understood in further references to the Callawa Formation appearing later in this report.

G E O L O G Y

Previous Work

Only Quaternary limestone and sandstone crop out in this part of the coastal fringe of the South-West Canning Basin. Calcarenite, consisting of dune sand cemented by calcite, is found around the bore sites. Geological exploration by Reeves (1949) and the Bureau of Mineral Resources (Traves et al. 1956) revealed outcrops of Jurassic and Lower Cretaceous sandstone and conglomerate (Callawa Formation) about 17 miles south-south-west of the homestead. Almost 1,000 feet of sandstone and siltstone was penetrated below the Cainozoic cover in a bore drilled by WAPET about six miles south of the homestead; tentative correlations were made with Upper Jurassic and Lower Cretaceous formations outcropping along the northern margin of the basin. This information has been reviewed by Veevers and Wells (1961).

Formations

Ditch samples were of limited value in interpretation of most of the section penetrated. Below the Quaternary limestone, there were only two basic rock types - extremely friable and readily caving sandstone which produced samples of loose sand, and siltstone which was incorporated in the drilling mud. Consequently the interpretation, especially of those formations in which sand and silt-stone are intimately associated, is based mainly on the indirect logs. The difficulty of coring the friable sandstone added to this problem.

TABLE 2: Summary of sequence encountered in BMR.4 and 4A

Age	Lithology	Thickness
Recent	Dune sand over calcareous clay.	41'
Pleistocene	Calcarenite	32'
Lower Cretaceous	Sandstone, pebble conglomerate and minor siltstone (Frezier Fm.)	302'
Upper Jurassic to Lower Cretaceous)	Sandy siltstone and argillaceous sandstone (Anketell/Parda Fms.)	538'
Middle-Upper Jurassic	Argillaceous quartz sandstone and quartz sandstone with minor siltstone and shale (Callawa Fm.)	887'
Permian, Triassic and Jurassic	Quartzose and carbonaceous silt-stone and claystone with very fine-grained sandstone.	422'
Lower Proterozoic	Granodioritic gneiss	4'+

T.D. (BMR 4A): 2228'

Recent Dune Sand (2-28 feet): The bores were spudded on one of the clusters of dunes lying on the coastal plain behind the linear dunes parallel to the coastline. They consist of admixtures of quartz and shell sand, probably caused by varying wind directions, the shelly material being contributed by onshore winds and the quartz sand derived from red dunes further inland. Towards the base in BMR.4 the grains are cemented into a firm porous sandstone by clear calcite.

Recent Calcilutite (28-43 feet): This pale grey, silty calcareous clay forms the regression plain on which the dunes stand.

Quaternary Limestone (43-75 feet): This unit consists of cream and pale grey, fine and very fine-grained coquinoid calcarenite, with abundant foraminifera and large shell fragments, and scattered fine to very coarse quartz sand. The rock is porous with little calcite cement. The lower half of the section contains interbeds of calcilutite. The calcilog shows about 80% limestone for this unit as a whole.

The formation contains a Quaternary foraminiferal assemblage (D.J.Belford - pers.comm.) and is correlated with the "Coastal Limestone" which crops out elsewhere along the Western Australian coastline.

Lower Cretaceous Sandstone (Frezier Formation) - (75-377 feet): This uppermost unit of the Mesozoic sequence consists of 302 feet of cross-laminated, poorly sorted quartz sandstone and pebble-conglomerate with subordinate siltstone and shale. The sandstone is composed of subangular to subrounded, fine to very coarse grains of clear quartz set in an abundant matrix of grey, yellow or reddish-brown clay. It is moderately porous and very friable. Cores consist of cross-laminated and mainly coarse-grained argillaceous quartz sandstone, alternating with pebble-conglomerate made up of pebbles of quartz, quartzite and jasper. Occasional laminae and thin beds of grey quartzose and micaceous siltstone occur throughout. The top 20 feet forms the ferruginous zone of a laterite profile and contains scattered limonitic pisolites. A moderate but gradually decreasing percentage of carbonate shown in the calcilog for this interval is believed to be entirely due to cavings from the unit above.

G.M.Pulley considers this unit corresponds with the Broome Sandstone, cropping out on the northern margin of the Canning Basin, and notes that the Broome Sandstone shows progressive thinning and increasing coarseness towards the south-west. Veevers and Wells (1961) prefer to correlate it with the Frezier Formation, which is followed here. Veevers and Wells (ibid.Fig.68) however, regard the Frezier Formation in Wallal 4 as equivalent to the Broome Sandstone in the Broome Town Bore No.2.

Upper Jurassic Siltstone (Anketell/Parda Formation) 377-915 feet: 538 feet of grey quartzose micaceous sandy siltstone with inter-laminated argillaceous quartz sandstone follows. Several sub-units can be recognised:

(1) interbedded quartzose siltstone, reddish-brown ferruginous siltstone and subordinate sandstone, forming the top 23 feet between 377 and 400 feet.

(2) a fairly uniform section of quartzose siltstone, 210 feet thick. There are some beds of grey and brown pyritised siltstone and fine-grained silty sandstone, with carbonised wood fragments between 500 and 560 feet, and claystone believed to be predominant from 560 to 580 feet was marked by slower drilling and poor recovery. Siltstone in core 5 (500-510 feet) shows bedding destroyed by worm burrowing; this structure is probably typical of the section. The small amounts of material available in cuttings samples from this interval gave extended reactions with HCL, due to the pyritic cements; this is plotted as a third curve on the calcilog, depicting the percentage results after one hour reaction.

(3) 192 feet of very argillaceous sandstone and siltstone. Sand is present in all grades, in laminae ranging from sandy siltstone to poorly sorted sandstone with an abundant silt matrix. sands of coarser grain are almost entirely restricted to the top 100 feet, but laminae of fine and very fine grain occur throughout the section. Many nodules 1 to 2 mm. long, in which the silt has been replaced by pyrite, were washed out from this interval by the flow from BMR4, together with large fragments of wood altered to black lignitic coal.

This section is marked by a separation between the short normal and long normal electric logs, indicating porous rock with a filtrate zone and mud cake.

(4) 113 feet of coarse, brownish-grey siltstone and very fine silty sandstone, interbedded with carbonaceous claystone, which increases towards the base. The silt and sand are strongly mottled by worm action, and are essentially the same lithology as in Core 5.

There is no evidence of a major hiatus during deposition of the sequence. Disconformity with the overlying sandstone formation is suggested by oxidation and silicification of siltstone beds near the top of the unit.

Cores 4, 5, 6, 8 and 9 (BMR4) contain abundant plankton of an assemblage which contains many elements from the upper part of the Dingo Claystone of the Carnarvon Basin, of Kimmeridgian age. Comparison with European microfaunas suggests an Upper Jurassic age, but possibly continuing into the Lower Cretaceous (see Appendix B).

The well-site geologist suggested this sequence was equivalent to the Jarlemai Formation (Brunnschweiler 1954 and Guppy et al. 1958) in the Edgar Ranges, and believed that the greater thickness here (538 feet as against 300 feet at Mt.Jarlemai) was not strong evidence against the correlation. However Veevers and Wells (1961) consider the interval 377 feet to approximately 1400 feet is equivalent to the fine-grained Anketell and Parda Formations, outcropping on the southern edge of the Basin, and they note that Parda Formation outcrops as far north as Mt.Phire, 70 miles east-north-east of Wallal.

The present study indicates fairly clearly that the main lithology change is at 915 feet, the sequence beneath being dominantly arenitic down to 1802 feet. Veevers and Wells interpretation however, seems equally as satisfactory if the base of their Anketell/Parda equivalent is placed instead at 915 feet. The thicknesses of this composite fine-grained sequence would then be much closer to those in other sections, which are all of the order of 500 to 700 feet (Veevers and Wells 1961, p.118).

(Callana Formation)- 915-1802 feet:
Jurassic Sandstone/915 feet: This unit consists of 890 feet of argillaceous quartz sandstone and quartz sandstone with minor conglomerate, siltstone and shale. A further 125 feet of Jurassic rocks is present below 1802 feet, but is quite different in lithology. The argillaceous quartz sandstone is grey or salmon-pink, poorly sorted, with fine to very coarse quartz grains set in a clay matrix. This alternates with brownish-grey, better sorted, dominantly medium-grained quartz sandstone, composed of subangular to subrounded, fine to very co grains of clear quartz and, in some beds, minor glauconite; this rock is very porous. For the most part both types are apparently intimately associated, but since both are extremely friable and appear as loose sand in the ditch samples, their distribution can be estimated only very roughly. Quartz sandstone is probably dominant in the water-bearing sand forming the top 40 feet, and a basal subunit consists of 160 feet of quartz sandstone with occasional laminae and thin beds of conglomerate and shale.

Pyrite is common in the upper half, and this mineral and glauconite are mutually exclusive over intervals ranging from 20 to 100 feet or more, probably because of variations in the pH and amount of disturbance of water at the time of deposition. Cores show both horizontal and cross-laminae, and carry in places thin beds of intercalated sandy siltstone, and argillaceous and carbonaceous shale.

At 1650 feet a sharp change in character is shown on all logs, and the interval 1650-1802 feet is apparently very consistent in lithology throughout. Core 3 (BMR 4A) at 1705 feet suggests the main change is improved sorting with a decrease in silty matrix.

A depositional hiatus is suggested by the sharp change of formation at 915 feet at the top of the Jurassic sandstone. However, the plankton assemblage of the overlying unit occurs also in cores from the top 600 feet of this unit and hence no major break is indicated. Only a few species of that assemblage were found below Core 2 (1590 feet). Its upper age limit is unknown, and the age of the base of the formation is fixed only by the Jurassic (?Bajocian-Oxfordian) microflora of its basal siltstone (see Appendix C).

McWhae (in Johnstone 1961 p.15) has used the section from 915 feet to 1927 feet for the type section of the Wallal Sandstone, and noted the possibility of correlating the Wallal Sandstone (a sub-surface unit) with any of these outcropping sandstone formations: Jurgurra, Mudjalla and Callawa Sandstones.

Veevers and Wells (1961) consider that the internal 1400 feet to 1980 feet is equivalent to the Callawa Formation. Although they relate lithologies in BMR 4 with formations known to outcrop close to Wallal, their suggested boundaries do not correspond with the main changes in lithology, which are at 915 feet and 1927 feet as noted by WAPET geologists.

The rather unusual combination of clays and mature quartz sand seen in this unit produces a type of wacke texture, but it is not related to greywacke in origin. The texture is compatible with two conditions likely to have existed at time of deposition: viz. a very shallow basin with a floor above wave base, and a poor circulation away from the main oceanic currents.

Permian-Jurassic Siltstone and Shale (1802-2224 feet):

As a result of the breakdown of silt and clay cuttings into the drilling fluid, the detailed lithology of this basal pelitic section is poorly knowm, but a fairly confident interpretation of the stratigraphy can be made on the basis of the electrical logs and palaeontological work.

Ditch samples from the top 200 feet consist mostly of sand probably caved from the overlying sandstone. No cuttings were recovered from the lower half of the interval. The electric and drilling-time logs show corresponding fluctuations of fairly constant magnitude throughout the section. The S.P. changes, which are reversed, and the apparent resistivities indicate an alternation of non-porous and moderately porous beds. No other distinctive differences are apparent between cores from these zones.

All but the highest core, in which no useful plant microfossils are recorded, contain microspore assemblages which range from Lower Permian to Jurassic (Appendix C). The lithologies and ages of the cored intervals are set out in Table 3. In Table 4 the probable formations represented are shown, and the suggested top of each unit and its thickness.

TABLE 3. Lithologies and Ages of Spore Assemblag s of Cores 4-8, BMR 4A

Depth (top)	Lithology	Age
Core 4 1810	Light grey claystone	?
Core 5 1900	Carbonaceous fissile siltstone with minor very fine sandstone	Jurassic (?Bajocian-Callovian)
Core 6 1988	Grey siltstone and shale with a few sandstone laminae	Lower Triassic
Core 7 2098	Carbonaceous shale with a few sandstone laminae	Upper Permian
Core 8 2169	Grey Quartzose siltstone	Lower Permian (Sakinarian)

TABLE 4: Thicknesses and Suggested Boundaries of Units Between 1802' and 2224', B.M.R. 4A

Age	Unit	Suggested Depth of Top	Thickness
Jurassic	Callawa Fm.	1802'	125'
L.Triassic	Blina Stn.	1927'	83'
U.Permian	Liveringa Fm.	2010'	102'
L.Permian	Grant Fm.	2112'	112'

The portion 1802-1927 feet has generally been taken as a continuation of the Jurassic unit above, but its markedly different lithology deserves mention. As indicated previously, Veevers and Wells (1961 p.121) include rocks down to 1980 feet in the Callawa Formation, which in outcrops may show a finer lithology towards the base, but the sharpest change here seems to be at 1927 feet, which is the depth chosen by McWhae (in Johnstone 1961) for the base of the Wallal Sandstone.

The microfloral assemblage of Core 6(BMR.4A) is almost certainly that of the Blina Shale. Core 7 has an Upper Permian assemblage, probably from the Liveringa Formation, possibly from middle Liveringa (Appendix C). Beneath this, the Lower Liveringa, Noonkanbah Formation, and Poole Sandstone do not appear to be represented. Core 8 contains a spore assemblage comparable to that of the Grant Formation; and has a poorly sorted texture which is characteristic of this formation.

Pre-Cambrian Gneiss (2224-2228 feet): The four feet of basement penetrated in BMR 4A consists of banded grey and green, fine-grained, partly mylonitised, porphyritic biotite granodiorite (Appendix B). Sheared porphyritic granodiorite similar to this occurs in granitic masses in the Lower Proterozoic metamorphics beyond the southern margin of the basin (Traves <u>et. al.</u> 1956.).

Structure

The sedimentary cores show no structural disturbance and the entire sequence is apparently flat-lying.

A cross-section of the structure between Wallal and Samphire Marsh No.1 well, 33 miles east-north-east of the site of BMR 4, using interpretation from the geophysical surveys, is reproduced as Plate 3. As predicted (see fig.2) the thickening of over 4,000 feet of the sedimentary cover between these localities is accounted for almost wholly by the Palaeozoic sequence. About 2,500 feet of Lower Ordovician shale and limestone, and 1,700 feet of Lower Permian Grant Formation, were penetrated at Samphire Marsh (Johnstone, 1961).

The difference on either side of the basement scarp suggests that tectonic movement occurred along this line in the Permian. Ordovician sediments may have never been deposited or may have been removed by uplift and erosion before the Lower Permian sequence was laid down.

No additional evidence on the structure of the ridge - whether flexure or fracture - is apparent.

Oil Prospects of the Region

No oil or petroliferous gas was detected in BMR 4 or BMR 4A (see p. 5). Verification of the geophysical interpretation of the subsurface structure between Wallal and Samphire Marsh No.1 is significant. As noted previously, the high is only one of a series of roughly linear west-north-west trending basement features underlying the sediments of the Canning Basin. Their origin and effects on Palaeozoic sedimentation are probably similar to those demonstrated by these bores.

Although the Mesozoic succession penetrated in BMR 4A contains neither likely source or cap rocks, these may lap against the slopes of the highs elsewhere. The degree to which the thinning of sediments over these features is depositional rather than the result of subsequent erosion, is an important factor in the oil prospects of such areas.

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APPENDIX A.

PETROGRAPHIC DESCRIPTION OF CORE 9, BMR 4A.

by

W.B.DALLWITZ.

Following is a brief description of a rock from the bore BMR 4A at Wallal, Western Australia. The specimen was designated as part of Core 9, from a depth of 2224 to 2228 feet.

The hand specimen represents a grey, closely sheared, gneissic rock containing light grey lenses, rich in feldspar; these lenses are up to 5 cm. long and o.5 cm. thick. Chlorite is developed along some of the stronger shear-planes. Films and isolated grains of pyrite occur along a few of the shear-planes and joints, and a thin film of epidote lies along one crack or joint which is approximately at right angles to the cleavage.

In thin section (T.S.4319) the rock is seen to be made up mainly of altered acid plagioclase (albite-oligoclase) and quartz, with accessory epidote, biotite, chlorite, and pyrite, and rare leucoxene, zircon, and apatite.

The feldspar and quartz occur as more or less anastomosing lenticular streaks. The grain-size of the feldspar is fairly even, and is about 0.1 mm; that of quartz is less even but of about the same order of average size. The plagioclase is sericitized in varying degree,- in some places completely - and epidote is a subordinate product of its alteration. Along narrow planes where shearing appears to have been most intense, the sericite occurs as parallel shreds. Altered feldspar, excluding epidote, makes up about 55 percent of the rock, and quartz about 35. Some epidote has been concentrated into veinlets which run across the quartz-feldspar lenses.

Biotite has been broken up into small shreds, which are admixed with quartz and feldspar. It appears that, along the strongest shear-planes, biotite has been altered later to chlorite by hydrothermal activity; this activity may also have been responsible for the formation of the cross-cutting veinlets of epidote and for the introduction of pyrite.

One long prismatic crystal of zircon has been broken during shearing, and quartz and sericite have moved in to seal the break.

More than one mode of origin can be postulated for this rock, and its naming varied accordingly. It may, for example, be described as a partly mylonitized porphyritic biotite granodiorite, or, more non-commitally, a crushed biotite-biotite-quartz-oligoclase-gneiss.

APPENDIX B.

PRELIMINARY NOTES ON MICROPLANKTON FROM BMR4 & BMR4A (WALLAL), CANNING BASIN, W.A.

by

P.R. Evans

INTRODUCTION

Samples of all suitable cores from BMR 4 and 4A (Wallal) Bores have been examined for their microfloral content. Attention has been directed to the distribution of microplankton rather than of microspores, although a record has been made of certain Upper Mesozoic pteridophytes, key species in eastern Australian stratigraphy, because of their value in subsequent inter-basin correlation. Studies of the microplankton were initiated in 1958, as a result of which comments on the age of the bore section were offered in App. E in Veevers & Wells (1960). The previous observations have now been revised in the light of recent Australian and European publications. The main purpose of this report is to record the data obtained: the significance of this data in regional stratigraphy, particularly in relation to the Jurassic-Cretaceous boundary will be discussed elsewhere (Evans, 1963).

OBSERVATIONS

The species of microplankton and certain microspores observed in core samples from BMR4 and BMR 4A (387-1715 feet) are listed in Table 5. The list does not include the entire microfossil content; many forms await description.

COMMENTS

Hystrichospheres abounded in the Lower Triassic (Balme, Appendix C, ident.) of BMR 4A, core 7, 2098 - 2108 feet. They included forms of Veryhachium and Micrhystridium comparable with those described by de Jekhowsky (1961) from the Permian and Triassic of Europe and Africa. Prominent among them were types referred by de Jekhowsky to Veryhachium reductum (Deunff) and V. irregulare de Jekhowsky. Jansonius (1962) thought that V. reductum (Deunff) de Jekhowsky was identical with Wilsonastrum colonicum Jansonius from the Canadian Triassic. (The distinctions between Veryhachium and Wilsonastrum do not seem to be adequate and the genus Veryhachium is retained here).

No microplankton could be found in BMR4A, core 5, 1900 - 1907 feet.

Microplankton other than hystrichospheres first appeared in BMR4A, core 3, 1705-1715 feet, from which a few specimens of Dingodinium jurassicum Cookson & Eisenack were obtained. Microplankton were consistently abundant and microspores were rare in all samples from BMR4 between cores 4 and 14 (387 - 1408 feet).

The distribution chart illustrates an important change in assemblage between cores 6 and 8 (608 - 803 feet). The lower division defined by this change is characterized by abundant Dingodinium jurassicum, while Dictyopyxis aureolata, Gongyaulax ambigua, G. hyalodermum, Pareodinia aphelia and Pyxidiella pandora range to its top. For the present, core

14 is included in this division as its entire assemblage also occurs at higher levels. However, many species make their first appearance in core 11, so that the differences between core 14 and 11 may be of zonal significance, but equally may be due to a changing environment that progressively favours the entry and growth of these organisms.

The horizons above the change are characterized by abundant Nannoceratopsis pellucida and the first appearance of Scriniodinium dictyotum, S. attadalense, Leptodinium eumorpha and Multiplicisphaeridium torynum.

The two assemblages contain many common elements and there is no reason to suppose than an hiatus occurs between them. They correspond fairly closely to the divisions noted by Cookson & Eisenack (1960) between samples from 350 and 560 - 575 feet in the nearby WAPET Wallal Corehole. Cookson & Eisenack regarded their lower division as Oxfordian - Lower Kimeridgian and the upper as probably Tithonian.

While the lower assemblage in BMR4 (Wallal) contains species that correlate that bore section with the Oxfordian or possibly Kimeridgian forms from the waterbores at Broome and with similarly dated sections of the Dingo Claystone of the North - West Cape (Cookson & Eisenack, 1958), the age of the upper assemblage is uncertain. The presence of Nannoceratopsis pellucida, Gonyaulax jurassica in BMR4, core 4 favours a Jurassic rather than a Cretaceous age for that level. However, as the microplankton from Australian Tithonian or Neocomian localities that could be dated from their macrofaunal content have yet to be described, the range of the upper Wallal assemblage cannot be positively determined. The presence in BMR4, core 4 of Pterospermopsis eurypteris and Cicatricosisporites australiensis, species that have been previously ascribed to the Cretaceous (Cookson & Eisenack, 1958; Balme, 1957) increases the possibility that the upper Wallal assemblage may straddle the Jurassic-Cretaceous boundary. This topic is further pursued by Evans (1963).

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APPENDIX C.

PALYNOLOGICAL REPORTS ON SAMPLES FROM BMR 4A, CANNING BASIN, W.A.

by

B.E. Balme

(University of W.A., Perth)

REPORT NO. GP22 (16.5.58)

Sample 1:

Specimen: Grey Claystone

Depth: Core 4, 1810-1820 feet.

No useful plant microfossils present.

Sample 2:

Specimen: Dark grey shale

Depth: Core 5, 1900-1907 feet.

Assemblage

The microflora from this sample was rich and varied and consisted of spores, pollen grains, fungal remains and fragments of cuticle and wood. The following forms were identified:

Bryophyta

Sphagnites (?) *australis*

Lycopodiales

Lycopodium austroclavatidites

Cingulatisporites caminus

Filicales

Cyathidites australis rimalis

C. minor

Osmundacidites comaumensis

Laevigatisporites neddeni

Ischyosporites cf. *crateris*

Cycadales

Entylissa sp.

Bennettitalean-type cuticles

Pteridospermae or Coniferales

Pityosporites pallidus

Pityosporites spp.

Coniferales

Cheirolepidaceae

Classopollis torosus

Araucariaceae

Araucariacites australis

Inaperturopollenites n. sp.

Podocarpaceae

Microcachryidites antarcticus

Pityosporites ellipticus

? Coniferales

Zonalapollenites segmentatus

Comments

The microflora is certainly Jurassic although it differs somewhat from any assemblage of that age previously examined. Its extraordinarily high content of *Classopollis torosus* is matched only in the pre-Middle Bajocian Cockleshell Gully Formation in the Perth Basin. The absence of *Zonalapollenites dampieri* is also notable as this species is invariably common in Oxfordian and younger sediments in the Canning Basin. Another common type in the present sample (*Inaperturopollenites* sp.) has not been recorded previously.

The presence of *Microcachryidites antarcticus*, *Lycopodium austroclavatidites*, and *Cingulatisporites caminus*, however, suggest that the sample is younger than the Cockleshell Gully Formation. A Middle or Upper (pre-Oxfordian) Jurassic age is, therefore, suggested.

Sample 3:

Specimen: Grey, highly micaceous shale.

Depth: Core 6, 1988-1996 feet.

Assemblage:

Few spores or pollen grains occurred although microplankton were very abundant. Insoluble inorganic debris prevented good concentrations of microfossils. Most of the microfossils were undescribed forms although they have been observed previously in samples from the Fitzroy and Perth Basins.

Spores and Pollen Grains

Lueckisporites cf. *krauseli*

cf. *Cerratriradites* sp.

Punctatisporites n. sp. A

Punctatisporites n. sp. B

Pityosporites n. sp.

Microplankton

Hystrichosphaeridae

Palaeotetradinium hyalodermum

Hystrichosphaeridium spp. (including a variety of spinose, smooth and sekose forms)

Comments

This assemblage looks very similar to those from the Blina Shale in the Fitzroy Basin and the Kockatea Shale in the Perth Basin. Spores are too infrequent here, however, to make the comparison with absolute conviction. All the forms of microplankton found here occur also in the Blina Shale, although some are also found in the Liveringa Formation. *Lueckisporites* cf. *krauseli* is known from the Blina Shale, Erskine Sandstone, Kockatea Shale, Narrabean Group, Hawkesbury Sandstone and from Triassic sediments in a borehole at Springfield, South Australia. None of the other spores listed is a known Upper Permian form.

It is suggested, therefore, that the present sample is of Lower Triassic age. If it is Permian it represents a higher horizon in that System than any samples of definite Permian age that I have examined.

Sample 4:

Specimen: Dark grey shale with silty intercalations.

Depth: Core 7, 2098-2108 feet.

Assemblage:

Spores, pollen grains and other plant fragments were very abundant and, in general, well preserved. The following species were identified:

Group Triletes

Calamospora diversiformis

Acanthotriletes tereteangulatus

A. dentatus

A. ericianus

A. villosus

Granulatisporites trisinus

G. micronodosus

Microreticulatisporites bitriangularis

Group Zonales

Cirratriradites splendens

Cirratriradites n. sp.

Tholosporites egregius

T. parvitholus

Group Monoletes

Laevigatosporites vulgaris

L. scissus

Group Saccites

Sub-Group Monosaccites

Nuskoisporites gondwanensis

N. rotatus

Sub-Group Bisaccites

Pityspsorites sp.

Vestigisporites sp. A

Florinites eremus

F. ovatus

Lueckisporites limpidus

L. cancellatus

L. amplus

L. multistriatus

Group Precolpates

Marsupipollenites triradiatus

M. sinuosus

Comments:

The assemblage is clearly Upper Permian and bears a remarkable similarity to microfloras from the Newcastle Coal Measures in New South Wales. Key species are Tholosporites egregius (known from the Newcastle Coal Measures, the Cygnet Coal Measures in Tasmania, the Indarra Beds at Eradu, the upper coals at Collie and the Liveringa Formation in the Fitzroy Basin) and T. parvitholus, which has been previously found in the Newcastle Coal Measures and the Liveringa Formation. The abundance of Lueckisporites spp. and the presence of Granulatisporites trisinus in association with various species of Acanthotriletes also indicate an Upper Permian age.

The formation from which the sample derives is considered to correlate with part of the Liveringa Formation in the Fitzroy Basin. Similar micro-floras have been obtained from sediments below 2,000 feet in the Derby Town Bore and in cuttings from the upper part of the Myroodah borehole.

Sample 5:

Specimen: Grey sandy siltstone

Depth: Core 8, 2,169-2,179 feet.

Assemblage:

Spores were neither plentiful nor well-preserved and precise identification of many specimens was not possible. The following forms were identified with certainty:

Group Triletes

Apiculatisporites cornutus

Granulatisporites n. sp.

Leiotriletes directus

Punctatisporites gretensis

Group Zonales

Cerratriradites spp.

Group Saccites

Sub-Group Monosaccites

Nuskoisporites gondwanensis

Sub-Group Disaccites

Lueckisporites limpidus

Pityosporites sp.

Group Monocolpates

Entylissa cf. *cymbatus*

Comments

This microflora contains no Upper Permian forms and some positive evidence exists for a Lower Permian age. *Granulatisporites* sp., *Entylissa* cf. *cymbatus*, *Punctatisporites gretensis* and *Apiculatisporites cornutus* are known from the Grant Formation and other units of Sakmarian age in Western Australia. Other forms which occur in the Grant Formation elsewhere are not, however, found in the present sample.

It is suggested that the present assemblage is of Lower Permian age and probably comes from the Grant Formation. There is a possibility, however, that it represents an impoverished Artinskian microflora.

APPENDIX D.

RESULTS OF ANALYSIS OF A WATER SAMPLE FROM BMR 4

by

W.J. Thomas

The results of analysis of a water sample from BMR4, Wallal Downs, Canning Basin, are as follows:-

Total Solids (105°C.): 1023 ppm. (72 grns./gal.)

	ppm.	mille equivalents/litre
Calcium:	47	2.4
Magnesium:	31	2.6
Sodium:	227	10.0
Bicarbonate:	78	1.3
Sulphate:	103	2.1
Chloride:	402	11.3
Nitrate:	not detected	

Sodium Chloride (calculated from ion associations): 445 ppm. (31 grains) pH: 7.3

APPENDIX E.

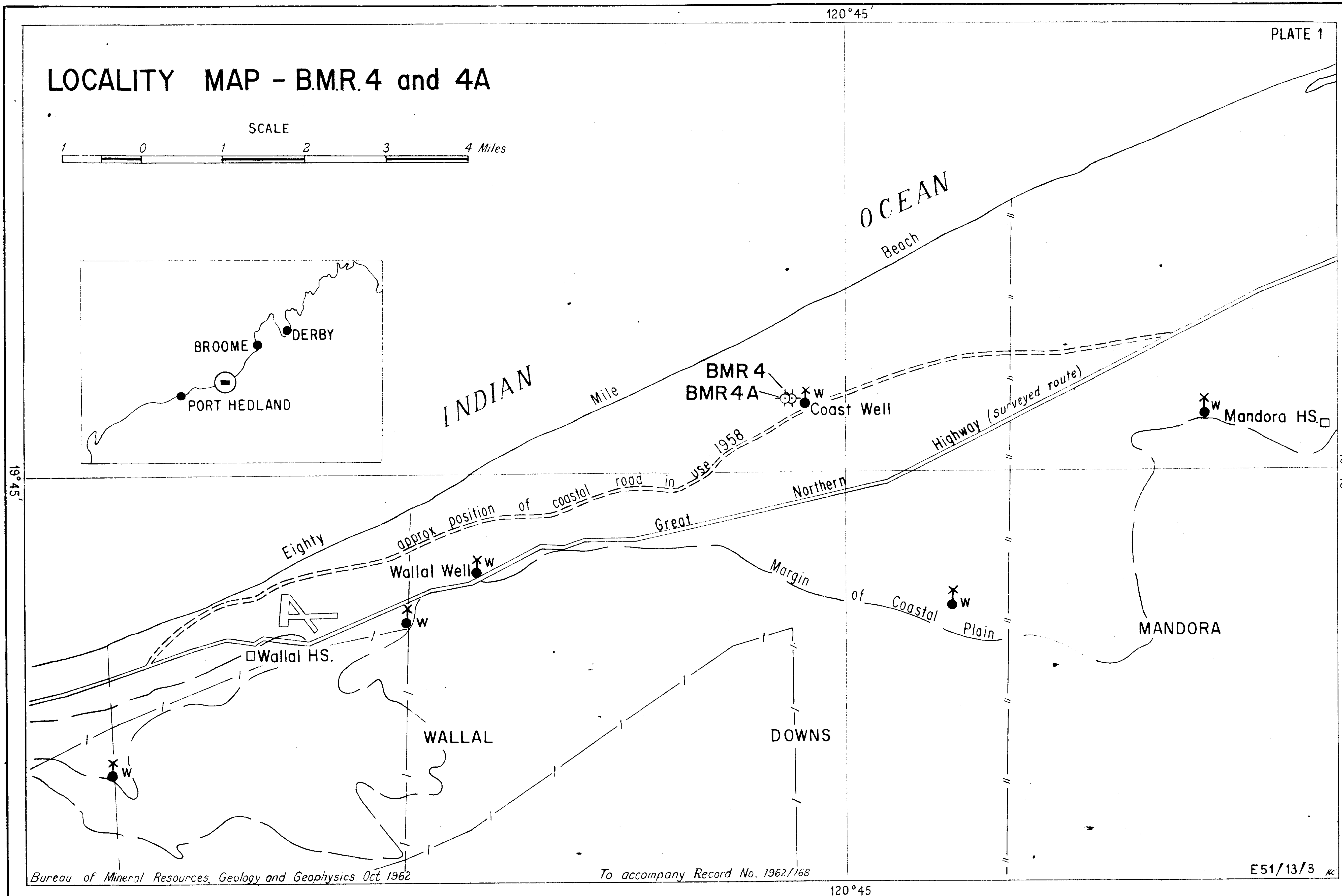
CORE RECORDS

Core No.	Section Cored*	%Recovery	Recovery (ft.).
(BMR4) 1	103-113	30	3
2	195-205	40	4
3	295-305	35	3½
4	397-407	30	3
5	498-508	100	10
6	598-608	95	9½
7	703-713	-	-
8	803-813	100	10
9	886-896	20	2
10	989-999	3	¼
11	1098-1108	1	1 inch
12	1198-1208	-	-
13	1298-1308	-	-
14	1398-1408	85	8½
(BMR4A) 1	1500-1510	7	¾
2	1585-1593	2	2 inches
3	1705-1715	40	4
4	1810-1820	30	3
5	1900-1907	64	4½
6	1988-1996	87	7
7	2098-2108	45	4½
8	2169-2179	50	5
9	2220-2223	83	2½

* Depths in BMR4 have been adjusted to the datum used here - viz. - Rotary Table of BMR4A

PLATE 1

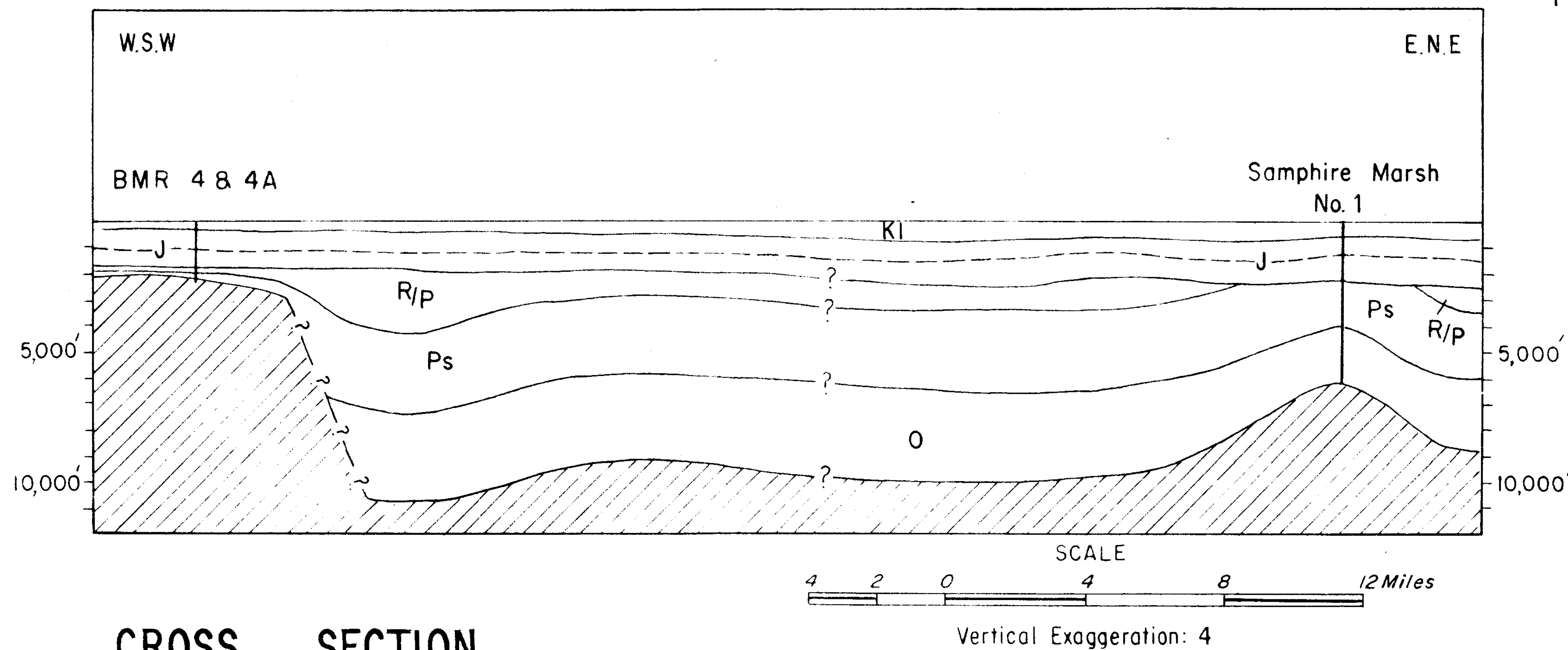
LOCALITY MAP - B.M.R. 4 and 4A



Bureau of Mineral Resources, Geology and Geophysics. Oct 1962

To accompany Record No. 1962/168

E51/13/3

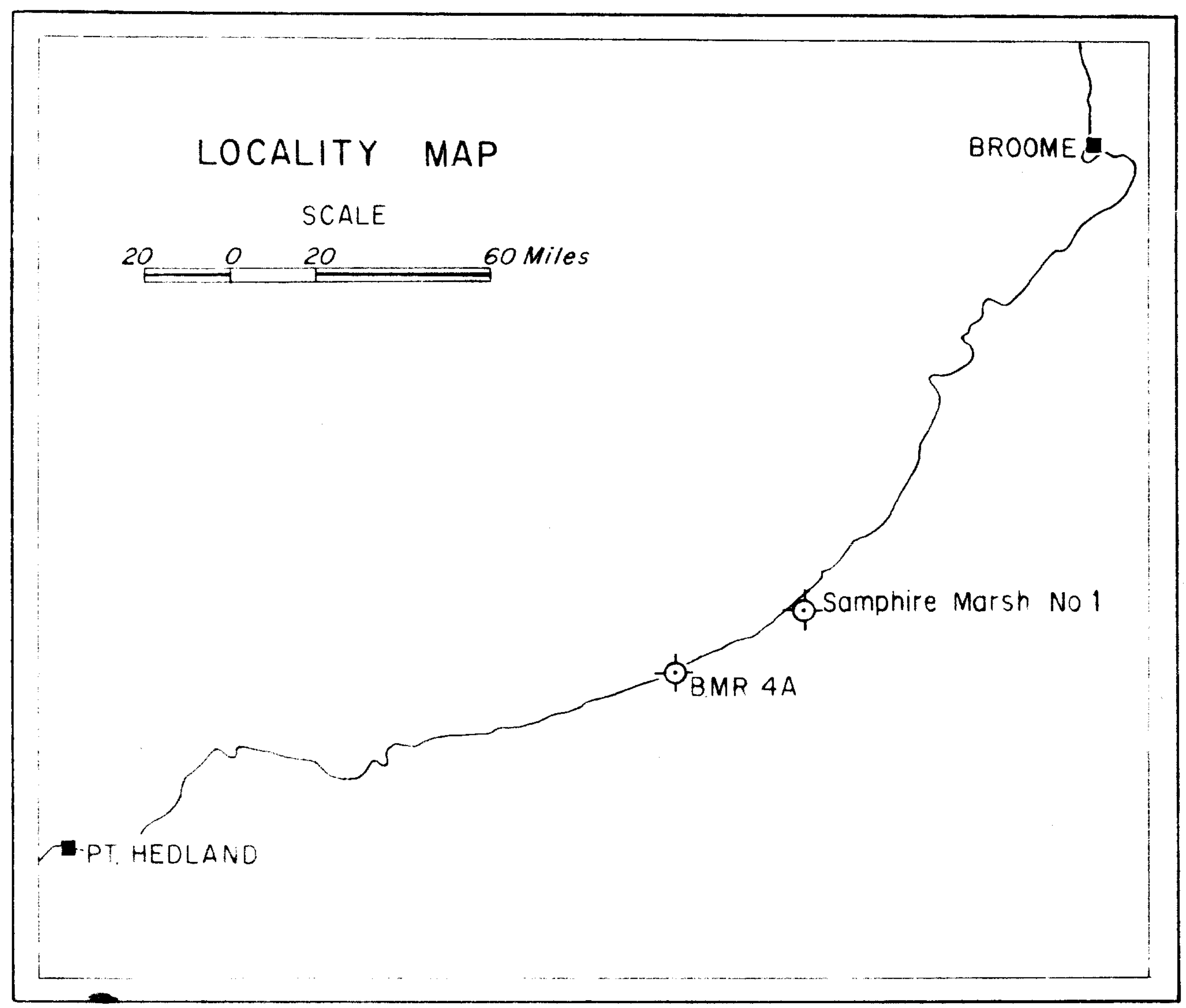


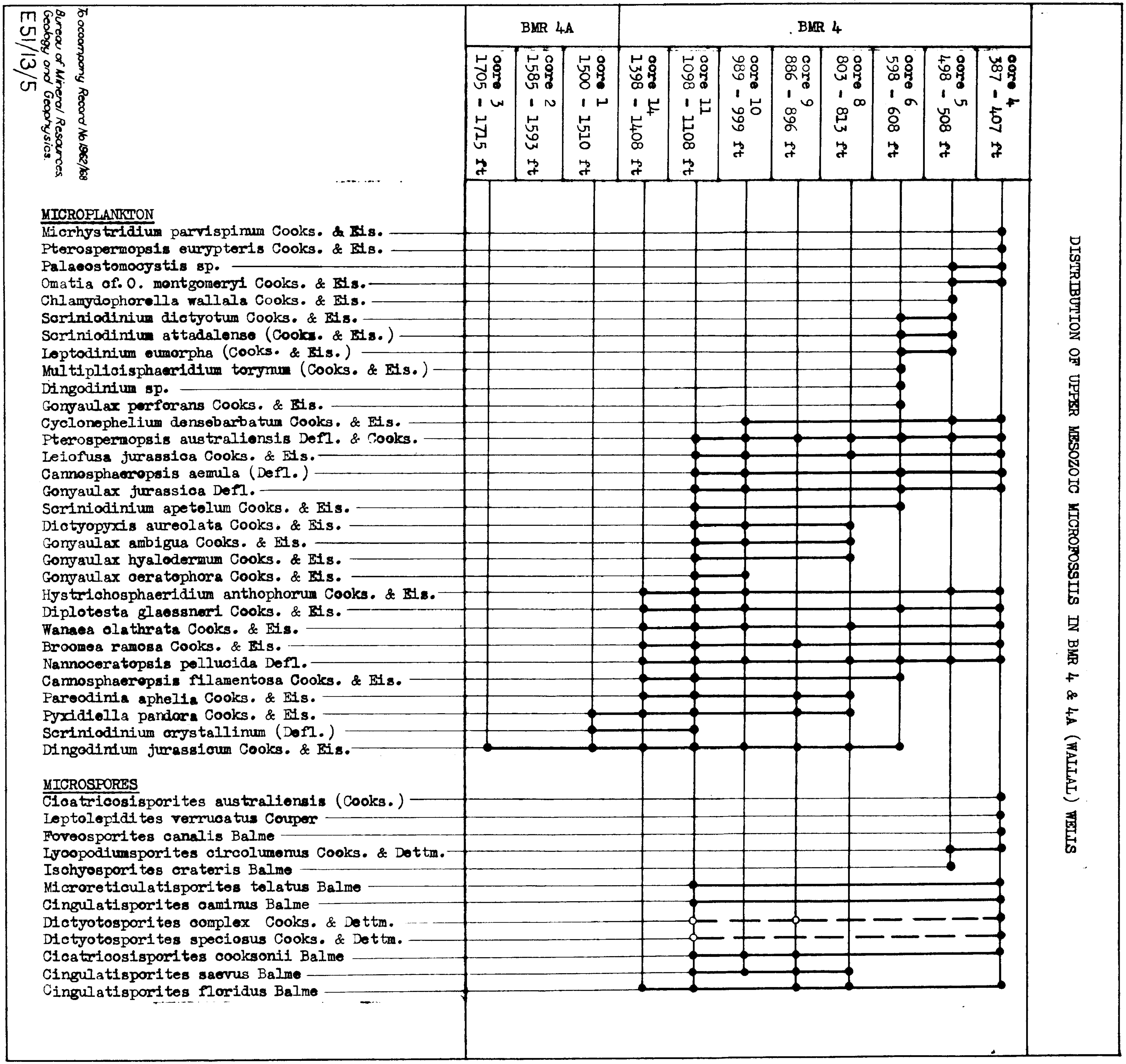
CROSS SECTION

B.M.R 4A—SAMPHIRE MARSH NO.1

REFERENCE

CRETACEOUS	Kl	Frezier Formation or Broome Sandstone
JURASSIC	J	Anketell Fm / Parda Fm. and Callawa Fm.
PERMIAN & TRIASSIC	R/P	Undifferentiated
LOWER PERMIAN	Ps	? Grant Formation
ORDOVICIAN	O	Shale and Limestone
PRECAMBRIAN	(hatched)	Undifferentiated




To accompany Record No. 1962/168
Bureau of Mineral Resources
Geology and Geophysics.
E51/13/5
DISTRIBUTION OF UPPER MESOZOIC MICROFOSSILS IN BMR 4 & 4A (WALLAL) WELLS
BMR 4A
BMR 4
core 3 1705 - 1715 ft
core 2 1585 - 1593 ft
core 1 1500 - 1510 ft
core 14 1398 - 1408 ft
core 11 1098 - 1108 ft
core 10 989 - 999 ft
core 9 886 - 896 ft
core 8 803 - 813 ft
core 6 598 - 608 ft
core 5 498 - 508 ft
core 4 387 - 407 ft
MICROPLANKTON
Micrhystridium parvispinum Cooks. & Eis.
Pterospermopsis eurypteris Cooks. & Eis.
Palaeostomocystis sp.
Omatia cf. O. montgomeryi Cooks. & Eis.
Chlamydophorella wallala Cooks. & Eis.
Scriniodinium dictyotum Cooks. & Eis.
Scriniodinium attadalense (Cooks. & Eis.)
Leptodinium eumorpha (Cooks. & Eis.)
Multiplicisphaeridium torynum (Cooks. & Eis.)
Dingodinium sp.
Gonyaulax perforans Cooks. & Eis.
Cyclonephelium densebarbatum Cooks. & Eis.
Pterospermopsis australiensis Defl. & Cooks.
Leiofusa jurassica Cooks. & Eis.
Cannosphaeropsis aemula (Defl.)
Gonyaulax jurassica Defl.
Scriniodinium apetelum Cooks. & Eis.
Dictyopyxis aureolata Cooks. & Eis.
Gonyaulax ambigua Cooks. & Eis.
Gonyaulax hyalodermum Cooks. & Eis.
Gonyaulax ceratophora Cooks. & Eis.
Hystrichosphaeridium anthophorum Cooks. & Eis.
Diplotesta glaessneri Cooks. & Eis.
Wanaea clathrata Cooks. & Eis.
Broomea ramosa Cooks. & Eis.
Nannoceratopsis pellucida Defl.
Cannosphaeropsis filamentosa Cooks. & Eis.
Pareodinia aphelia Cooks. & Eis.
Pyxidiella pandora Cooks. & Eis.
Scriniodinium crystallinum (Defl.)
Dingodinium jurassicum Cooks. & Eis.
MICROSPORES
Cicatricosisporites australiensis (Cooks.)
Leptolepidites verrucatus Couper
Foveosporites canalis Balme
Lycopodiumsporites circolumenus Cooks. & Dettm.
Ischyosporites crateris Balme
Microreticulatisporites telatus Balme
Cingulatisporites caminus Balme
Dictyotosporites complex Cooks. & Dettm.
Dictyotosporites speciosus Cooks. & Dettm.
Cicatricosisporites cooksonii Balme
Cingulatisporites saevus Balme
Cingulatisporites floridus Balme

B.M.R. 4 and 4A WALLAL

COMPOSITE LOG

STATE WESTERN AUSTRALIA

		BMR 4	BMR 4A
LOCATION	Latitude	19° 44' 12"S	19° 44' 12"S
	Longitude	120° 44' 28"E	120° 44' 25"E
ELEVATION	SURFACE	30ft	28ft
	ROTARY TABLE	34ft	32ft (datum)
DATE SPUDDED		1st April 1958	22nd April 1958
DATE COMPLETED		8th June 1958	9th May 1958
TOTAL DEPTH (from R.T.)		1410'	2228' (e. log) 2224' (driller)
STATUS		Abandoned	Artesian Water Well
HOLE PROFILE		7 7/8" 0-44'	7 7/8" 0-525'
		5 5/8" 44'-T.D.	5 5/8" 525'-T.D.
CASING		6 5/8" 0-43'	6" 0-522'
		4" 0-893'	

DRILLING CONTRACTOR: Oil Drilling and Exploration Ltd

LITHOLOGY BY: J.M. Pulley & L.V. Bastian

BASIN CANNING

ELECTRIC LOG DATA (BMR 4A)

Run	Interval	Logging Unit
1	Surface 600ft	"WIDCO" single electrode
2	522' 1510'	" "
3	522' - T.D.	"SCHLUMBERGER"

RUN 3

MUD NATURE: Clay base

DENSITY: 83lbs/cu.ft

VISCOSITY: 60 S

RESISTIVITY: 1.3ohm-m at 82°F

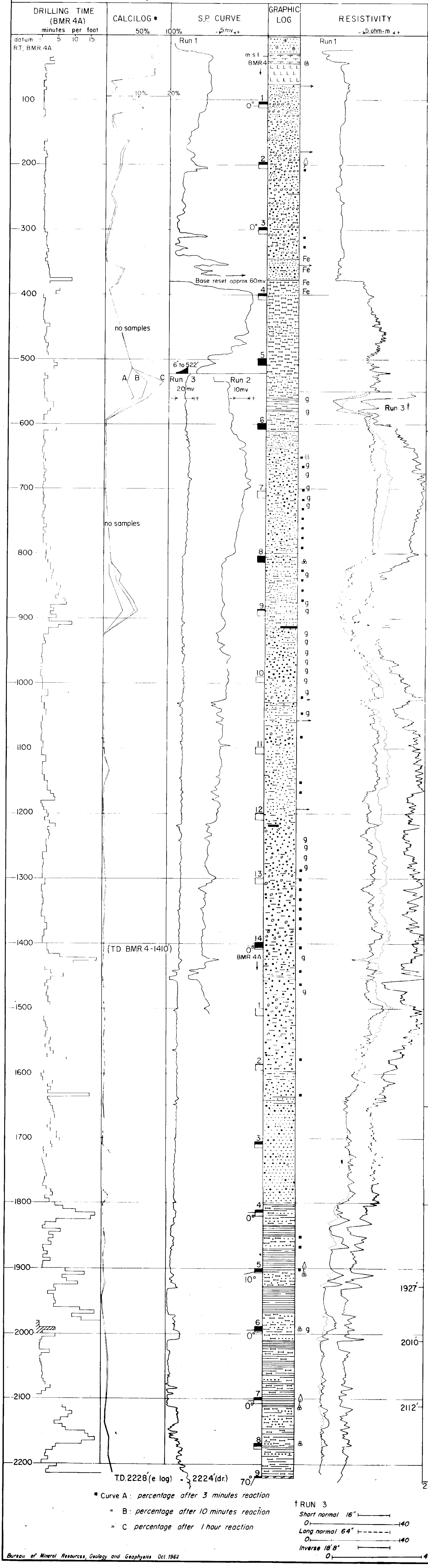
MISCELLANEOUS SYMBOLS

- ▪ PYRITIC
- g GLAUCONITIC
- Fe LIMONITIC
- MARINE FOSSILS
- PLANT FOSSILS
- MICROFOSSILS
- → LOST CIRCULATION ZONE
- CASING SHOE
- 5° CORE INTERVAL SHOWING RECOVERY AND DIP

LOCALITY WALLAL DOWNS

LITHOLOGY

- CONGLOMERATE
- MEDIUM/COARSE GRAINED SANDSTONE
- FINE GRAINED SANDSTONE
- ARGILLACEOUS SANDSTONE
- SILTSTONE
- CLAYSTONE / SHALE
- CALCARENITE
- MARL
- GNEISS
- COAL INTERCALATIONS
- CLAYSTONE INTERCALATIONS
- SANDY



LITHOLOGY	AGE	FORMATION
2'-28' SAND and SANDSTONE: orange, fine-grained quartz and shell fragments; calcite cement in part.	QUATERNARY	
28'-43' MARL: pale grey, sandy.	QUATERNARY	
43'-75' CALCARENITE: grey or cream, fine to very fine-grained; coquinoid, porous, grading to CALCILUTITE.	QUATERNARY	
75'-344' Quartz SANDSTONE: brown or grey, poorly sorted fine to very coarse-grained with kaolinitic matrix; porous, friable; cross-laminate and laminate; intercalated quartz pebble CONGLOMERATE and minor grey quartzose SILTSTONE and SHALE. 78'-90' Limonite pisolites forming pebbles in the conglomerate beds.	LOWER CRETACEOUS	Frezier Formation
344'-377' Quartz SANDSTONE: mainly fine-grained, with coarse beds and minor pebble CONGLOMERATE; glauconitic.	LOWER CRETACEOUS	Frezier Formation
377'-610' SILTSTONE: coarse sandy, grey, micaceous; porous, soft; vague lamination, extensively reworked by worms. 377'-400' Limonitic SILTSTONE: brown sandy silicified, impervious, hard. 525'-560' beds of argillaceous SANDSTONE: very fine-grained with carbonised and pyritised wood. 560'-580' CLAYSTONE dominant.	UPPER JURASSIC	Anketell / Parda Formations
610'-802' Argillaceous quartz SANDSTONE: fine to coarse poorly sorted subrounded, in an abundant silty matrix with pyrite nodules; moderately porous, friable; laminate grading to sandy SILTSTONE. 680'-740' Quartz SANDSTONE with carbonised wood, and SILTSTONE. 740'-802' SILTSTONE increasing.	UPPER JURASSIC	Anketell / Parda Formations
802'-915' SILTSTONE with laminae of very fine-grained quartz SANDSTONE & carbonaceous CLAYSTONE; glauconitic.	UPPER JURASSIC	Anketell / Parda Formations
915'-1650' Quartz SANDSTONE, mostly with abundant argillaceous matrix; poorly sorted fine to coarse-grained subrounded, very porous and very friable; glauconitic with carbonised and pyritised wood fragments; cross laminate; interbeds of pebble CONGLOMERATE and minor coarse SILTSTONE. 1085'-1215' mostly fine and medium-grained. 1215'-1550' mostly medium and coarse-grained silty SANDSTONE with pebble CONGLOMERATE; pyrite nodules and coal fragments. 1550'-1650' increasing proportion of better sorted quartz SANDSTONE. 1630'-1635' pyrite abundant in matrix of SANDSTONE	MIDDLE and UPPER JURASSIC	Callawa Formation
1650'-1802' Quartz SANDSTONE: brownish-grey, mostly medium grained, moderately well sorted, very porous and friable; and minor SILTSTONE.	MIDDLE and UPPER JURASSIC	Callawa Formation
1802'-2224' Quartzose SILTSTONE and CLAYSTONE and carbonaceous SHALE, with laminae of fine-grained argillaceous SANDSTONE; quartz SANDSTONE in some intervals. Core 5: Carbonaceous shaley SILTSTONE with streaks of very fine-grained SANDSTONE.	MIDDLE and UPPER JURASSIC	Callawa Fm?
1927' Core 6: SILTSTONE and SHALE: grey micaceous glauconitic, with thin sandy laminae.	? L. TRIASSIC	Blina Shale
2010' Core 7: Carbonaceous SHALE with laminae of fine and medium-grained argillaceous SANDSTONE.	? U. PERMIAN	"Liveringa Fm"
2112' Core 8: SILTSTONE: grey quartzose micaceous, rather sandy up to medium-grained; non-porous irregular laminae showing slumping.	? L. PERMIAN	Grant Fm
2224-T.D. Biotite-quartz-oligoclase GNEISS: irregularly banded grey and green, fine grained, granular, sheared.	pC	

* Curve A: percentage after 3 minutes reaction
" B: percentage after 10 minutes reaction
" C percentage after 1 hour reaction

† RUN 3
Short normal 16" 0—40
Long normal 64" 0—40
Inverse 18'8" 0—40

Bureau of Mineral Resources, Geology and Geophysics Oct. 1962

To accompany Record No. 1962/168

E51/13/1