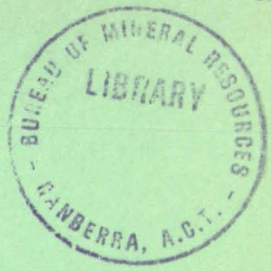

COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

REPORT No. 81

Completion Report, Stratigraphic and Structural Bores BMR 6 and 7, Muderong, Western Australia

BY

W. J. PERRY

Issued under the Authority of the Hon. David Fairbairn, Minister for National Development

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MINISTER: THE HON. DAVID FAIRBAIRN, D.F.C., M.P.

SECRETARY: R. W. BOSWELL.

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

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SUMMARY AND CONCLUSIONS

Two bores with a total footage of 2999 feet were drilled in 1958 in the Middalya area of the Carnarvon Basin to determine whether the structural discordance known as the Middalya Fault is in fact a fault or an unconformity.

Correlation between bore-holes has been made through lithology and the gamma-ray logs, and this information, contrasted with the dips recorded in cores, suggests that a north-trending normal fault downthrown to the east between the two bores is the simplest explanation for the results. Nevertheless, it may also be concluded that the drilling of bores does not necessarily provide a unique solution to a structural problem of this nature.

Useful information about the character of the Byro Group in the subsurface was obtained, including the discovery of residual wax.

INTRODUCTION

The bores at Muderong were intended to provide information on the nature of the structural-stratigraphic discontinuities in the Carnarvon Basin; in particular information was sought on the nature of the contact exposed at the south-western end of 'Big Hill', about half a mile west of Muderong Bore (Fig. 1).

The original programme called for three shallow bores, 800 to 900 feet apart in an east-west line, some two miles north of west of Muderong Tank. The westernmost bore, A, was to be 750 feet deep and about 500 feet east of the inferred position of the contact, which was thought to dip eastwards at a maximum angle of 30°. Bore B was to be 850 feet east of bore A and 1000 feet deep, and bore C 850 feet east of B and 1250 feet deep. The contract also required that ten feet of core be cut in each 100 feet drilled, and that cuttings be sampled at five-foot intervals.

The contractors spudded the central bore, BMR 6, first, on 10th August 1958, and it was completed at 1002 feet on 19th August. Core No. 4 recovered from the interval 296-305 feet showed dips of 30°; cores 100 feet above and below No. 4 had nearly flat dips, and it was concluded that a fault or unconformity had been intersected in Core No. 4. The projection of this inferred contact to the surface, using a 30° dip, intersected the surface east of the western-most bore-site, which consequently was not drilled. The available footage remaining in the contract (2000 feet) was used in the easternmost bore, BMR 7, which was spudded on 21st August and completed on 14th September. For the purpose of the coring programme for BMR 7, it was assumed that the 30° dip encountered in Core 4 of BMR 6 represented an intersection with an unconformity surface - 'angle of rest' unconformity (Condon, 1956) - dipping 30° to the east. The distance between the two bores (929 feet) was measured by tape and the difference in R.T.E., three feet, by Abney Level, and the depth to the inferred unconformity calculated; accordingly in BMR 7 coring was started at 822 feet and continued to 848 feet with the object of coring through the inferred unconformity surface.

The holes were drilled by a Bureau Failing Model 2500 Holemaster unit. Drilling bits were 5 5/8" in diameter, and core bits 4 3/4". The contractors were Oil Drilling and Exploration Ltd.

Electric and gamma ray logs were run by N. Jackson of the Bureau of Mineral Resources Geophysical Branch with a Widco 2000 unit. Mr Jackson also greatly assisted the writer with the routine work at the well-site, and his aid is gratefully acknowledged.

BORE HISTORY

General Data

Bore Name and No.	BMR 6	BMR 7
Location (map reference):	Kennedy Range : 264999 24° 5'55"S., 114°46'20"E.	Kennedy Range : 264999 (929 ft. E. of BMR 6) 24° 5'55"S., 114°46'30"E.

General Data (Continued)

Bore Name and No.	BMR 6	BMR 7
Permit area:	27H	27H
Held by:	West Australian Petroleum Pty Ltd., Perth, W.A.	
District:	North-west	North-west
Area:	Middalya Station	Middalya Station
Total depth:	1002 feet	1997 feet
Date spudded:	10th August 1958	21st August 1958
Date completed:	19th August 1958	14th September 1958
Days actual drilling time:	10	22 1/2
Elevation (ground):	570' $\pm$ 20' estimated from height of gravity stations.	
-RTE:	5' above surface, 3' higher than BMR 7	5' above surface
Status:	abandoned	abandoned, cement plug placed at 437'

Drilling Data

Name and address of drilling contractor:	Oil Drilling and Exploration Ltd, Head Office, 82 Elizabeth Street, Sydney, N.S.W.	
Rig type and rating:	BMR Failing Holemaster 2500.	
Size and make of bits:	8 1/2" Hughes TC-OWS 44' Corebits 5 5/8" Williams 3D 4 3/4 Edeco M Reed H/F Reed 2C Reed S/F TD 1002'	8 1/2" Hughes TC-OWS 23' Corebits 5 5/8" Edeco M Williams 3D 4 3/4 Reed H/F TD 1997' Reed S/F
Drilling mud:	Water-base bentonite mud	Water-base bentonite mud.

Drilling Data (continued)

Bore Name and No.	BMR 6	BMR 7
Water supply and conditions in hole:	Water trucked from Muderong Tank about 1 mile from bores.	Lost circulation particularly in Norton Greywacke, at intervals indicated in composite log.
Plugs:		6 sx. cement at 437' on completion.

Ditch cuttings

Sampled for both bores at 5-foot intervals.

Coring

Original programme - 10 feet of core in each 100 feet drilled. This programme adhered to except in BMR 7 in which extra coring was carried out for geological reasons - see Introduction and composite log.

Side Wall coring: Nil.

Electric logging (by BMR Geophysical Branch)

Self-potential and resistivity logs run with a Widco 2000 unit.
Radioactivity (gamma-ray) log " " " " " "

Drilling-time log: see composite log. Time recorded for each 5 feet penetrated.

Formation tests: Nil.

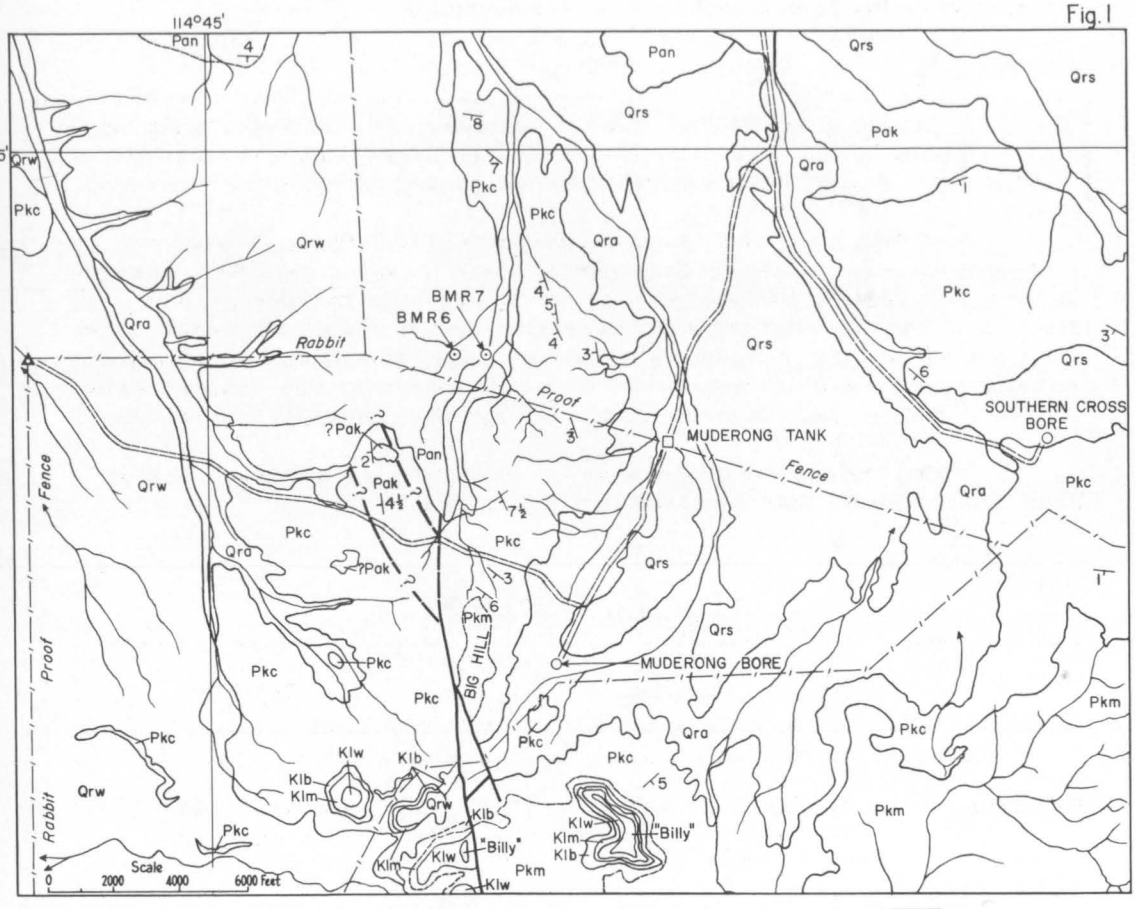
Deviation record taken with a Totco unit at following depths: (indicated in composite log).

BMR 6	BMR 7
302' 0°	200' 1 1/2°
609' 1 1/2°	515' 1°
792' 1°	775' 1°
990' 1 1/2°	999' 1 1/4°
	1400' 1°

No record below 1400 feet - limit of catline.

Temperature records:	Nil	Nil

Fig. 1



Qra	*Alluvium*	Winning Group: Klw	*Windalia Radiolarite*
Qrw	*Wash*	Klm	*Muderong Shale*
Qrs	*Sand*	Klb	*Birdrong Formation*

Kennedy Group: Pkm	*Mungadan Sandstone*	
Pkc	*Coolkilya Greywacke*	
Byro Group: Pak	*Baker Formation*	
Pan	*Norton Greywacke*	

Bureau of Mineral Resources, Geology and Geophysics *June 1964* G50/A1/2 JMF

GEOLOGY

General Statement

The area in which the bores were drilled lies in the north-central part of the Kennedy Range 1:250,000 Sheet area (Condon, 1962). Rocks of the Permian Byro and Kennedy Groups and of the Cretaceous Birdrong Formation and Winning Group were mapped by geologists of the Bureau of Mineral Resources in 1952 (Fig. 1).

Previous Work

Raggatt (1936, p.169) in his account of the geology of the North-West Basin named and described the Middalya Fault along the west side of the Kennedy Range; he regarded it as a normal fault dipping 70° to the west and involving both Cretaceous and Permian rocks.

Condon (1954, p.137) stated that the Middalya Fault dips at 30° to the east; he considered that Permian Coolkilya Greywacke had been thrust up over the Lower Cretaceous Birdrong Formation and Muderong Shale, and that stratigraphical and structural evidence in the Permian rocks indicated that as far as Permian strata were concerned, the downthrown block was to the east. According to Condon, two separate fault planes dipping in opposite directions can be seen five miles east-south-east of Paddy's Outcamp. Movement in late Palaeozoic time on the west-dipping fault caused a relative downthrow of the east block.

The relevant stratigraphy of the area (see Condon, op.cit.) is shown in Table 1, from Thomas & Dickins (1954, p.221) with slight modifications.

TABLE 1. - STRATIGRAPHY

Age	Group	Formation	Thickness (feet) Kennedy Range area	Lithology
Kungurian	Kennedy	Mungadan Sandstone	184	Quartz sandstone
		Coolkilya Greywacke	625	Quartz greywacke
		Baker Formation	210	Siltstone, quartz greywacke
		Norton Greywacke	250	Greywacke, quartz greywacke
	Byro	Wandagee Formation	545	Siltstone, quartz greywacke
		Quinnanie Shale	85	Shale, thin quartz greywacke
Artinskian		Cundlego Formation	700	Quartz greywacke (some calcareous), siltstone

RESULTS OF DRILLING

BMR 7

Formations

Formation boundaries are fairly well-defined in BMR 7, and hence this bore will be considered first. Coolkilya Greywacke was drilled from the surface to 190 feet; it is a grey, very fine-grained quartz greywacke with minor amounts of dark grey siltstone. Below 190 feet the proportion of siltstone increases markedly, and this is clearly shown in the radioactive (gamma-ray) log, which from 190 feet to 500 feet has high positive values; there is also a marked 'break' in the SP log at 193 feet. From 350 to 500 feet, quartz greywacke is virtually absent. The interval 190 to 500 feet is assigned to the Baker Formation. The thickness (310 feet) is greater than that of the section of 210 feet reported by Condon (1954, p.89) about six miles north of the bores. In the bore, microfossils are rare in the Coolkilya Greywacke, but the Baker Formation has a rich fauna.

At 500 feet the lithology changes to quartz greywacke and within a few feet to permeable sandstone, which persists down to 740 feet. The gamma-ray log shows a sharp break at 501 feet and from there downwards is more variable, but shows lower overall radioactivity; there is no break in the SP log, and the SP values increase slowly to a maximum at 555 feet then decrease slowly down to 725 feet. However, a log run on 6th September when the hole was at 1095 feet shows a marked break of 10mv in the positive direction between 495 and 505 feet; otherwise the shape of the SP curve is similar to that of the final log. The sandstone is light grey, micaceous, fine to very fine-grained, with subrounded to subangular grains and clayey matrix, and is regarded as the Norton Greywacke. At the type section 18 miles east-south-east of the bores the Norton Greywacke is medium-grained throughout its 235 feet, but two miles north-north-west of the bores it is a fine to very fine-grained micaceous quartz greywacke. The cores contain no microfossils. Circulation was lost four times in the interval 500 to 740 feet. The thickness of 240 feet is close to the approximate thickness of 250 feet at Paddy's Outcamp recorded by Condon (1954, p.84).

The junction of the Norton Greywacke with the Wandagee Formation is placed at 740 feet, below which the lithology changes to quartz greywacke with interbeds of siltstone. Both the gamma-ray and resistivity logs show a marked positive swing between 740 feet and 755 feet; above and below this swing the gamma-ray log has similar characteristics, but below it has slightly higher average radioactivity. The SP log also shows slightly higher average voltages below 755 feet. There is no swing in the resistivity curve at 740 feet. From 740 to 1020 feet, light grey fine to very fine-grained micaceous quartz greywacke is interlaminated with dark grey to black claystone and siltstone, pyritic in places; quartz greywacke is dominant in the upper part of this interval, but below 920 feet only 30 percent of the cuttings are quartz greywacke. Thin beds of calcareous quartz greywacke are present in places in the formation.

From 1020 to 1215 feet, the dominant lithology is black carbonaceous siltstone which grades into claystone in places, with minor discontinuous laminae of quartz greywacke. The siltstone is pyritic and contains a few slightly phosphatic, grey, calcareous nodules. This lithology is like that of the Quinnanie Shale, and the Wandagee-Quinnanie boundary can be placed at 1020 feet, where there is a 'break' in both the gamma-ray and SP logs. The interval 1020 to 1215 feet is characterized by high values of natural radioactivity comparable in magnitude with those of the Baker Formation.

Placing the base of the Wandagee Formation at 1020 feet and of the Quinnanie Shale at 1215 feet seems justifiable on lithological grounds. However, it means that the thickness of the Wandagee is only 280 feet and that of the Quinnanie 195 feet. This is in striking contrast to the thickness measured in surface sections (Condon, 1954, p.81), though these have not been run close to the bores. At the head of Norton Creek some 20 miles to the east-south-east of the bores, the Wandagee Formation is 650 feet thick, and four and a half miles north of Paddy's Outcamp, that is seven miles north-west of the bores, it is 800 feet thick. Also, at the head of Norton Creek the thickness of shale in the Quinnanie is 85 feet, and five miles north of Paddy's Outcamp it is 125 feet (Condon, 1962).

The reason for the reduced thickness of the Wandagee Formation is not known: part of the section may actually be missing, or lateral variation of lithology is responsible for the different position of the formation boundary. The closest outcropping Wandagee Formation to the bores is three and a half miles to the north, where about 180 feet of the sequence up to the contact with the overlying Norton Greywacke was mapped in 1951. The lithology is thin-bedded to laminated, fine to very fine-grained, micaceous quartz greywacke with small black siltstone lenses in places, interbedded with black gypseous siltstone. Lithology but not unit thickness has been recorded, so that the proportion of siltstone to quartz greywacke is not known, but from the scattered outcrop between observation points 626 and 627 it may be inferred that lutite makes up about half the section. The thickness is estimated by the writer from measured dip and photo distance; the total thickness of the formation, however, cannot be estimated because the lower part is obscured by sand. Strict comparisons between this partial surface section and the sequence in BMR 7 below 750 feet cannot be made, but they appear to be quite similar.

Below 1215 feet the proportion of quartz greywacke to silty claystone increases, and the section comprises interbedded light grey, fine to very fine-grained, quartz greywacke and dark grey to black, pyritic, micaceous siltstone and claystone with a few thin, calcareous, quartz greywacke beds. The sequence from 1215 feet to the total depth of 1997 feet is assigned to the Cundlego Formation.

Structure

The Coolkilya Greywacke is flat-bedded; one piece of core showed probable small-scale cross-stratification.

Cores 2, 3, 4, and 5 were cut in the Baker Formation; these all showed flat bedding or low dips; in Core 5 the dip may go up to 5^{o}, and there is cross-stratification dipping at 10^{o} to 14^{o}. Core 6 is at the base of the Baker Formation and has a dip of 6^{o}; in it G.A. Thomas (pers.comm.) has identified Linoproductus cancriniformis, and J.M. Dickins (pers. comm.) the pelecypod Streblopteria sp. nov.

The Norton Greywacke is represented by Cores 7, 8, and 9. Core 7 shows small-scale cross-stratification over a length of three inches near the bottom; what appears to be true bedding ranges from flat up to 11^{o} within about four inches, and is evidently unreliable. In Core 8 the dip ranges from $3\,1/2^{o}$ to 8^{o}; in Core 9 it ranges from 9^{o} to 16^{o}, but is probably cross-stratification. Foraminifera were not found in these cores.

Cores 10 to 15 inclusive are in the Wandagee Formation. Dips are variable within each core. For example, in Core 10 the dip of the top three inches of fine-grained quartz

greywacke is 4° to 8°; seven inches below this the dip on a calcareous quartz greywacke bed 18 inches thick is 10 1/2°, and in non-calcareous quartz greywacke a few inches below this the dip is 15°. Both these readings could be on foresets. Coring was continuous from 822 to 848 feet, this interval being made up of Cores 11, 12, 13 of a cored length respectively of 10, 10, and 6 feet, and a recovered length of 3 feet, 1 foot 3 inches, and 1 foot 11 inches. Core 11, of laminated, very fine-grained quartz greywacke and siltstone, shows small-scale cross-stratification and minor slump contortion. True bedding is difficult to determine; it apparently ranges from nearly flat to 10°. Core 12 is of similar lithology to Core 11 and has a dip up to 10°. Laminated quartz greywacke and siltstone in Core 13 shows a dip up to 15°, but this is regarded as probable cross-stratification, as siltstone near the base of the core shows wavy but horizontal bedding.

Core 14 comprises interlaminated black siltstone and grey, fine-grained quartz greywacke; it shows small-scale slumping. The dip is from 18° to 20°.

Plate 1, Figure 1 shows a piece from the top of Core 15; bedding is partly destroyed by burrowing organisms, and one burrow can be seen crossing the core from the middle right to the upper left of the photograph. Parts of the core unaffected by burrowing show a dip of 10°. Few foraminifera were found on the upper part of the Wandagee Formation, though ostracods and brachiopod spines are present. Cores 15 to 18, however, all contain foraminifera, which are abundant in Core 16.

From 1020 to 1215 feet the lithology is mainly dark grey carbonaceous siltstone and claystone, and between these depths the gamma-ray log shows the same high radioactivity as that recorded in the Baker Formation. The dip of probable bedding in Core 16 ranges from 12° to 19°, but no bedding was evident in Core 17. A few slightly phosphatic grey calcareous nodules are present in Core 16, and several species of foraminifera and some ostracod and brachiopod fragments were also found.

Core 18 shows small-scale cross-stratification, and evidence of scour and fill, and of slumping; probable worm burrows are present. The bedding dip is up to 5°. Small-scale cross-stratification is common in Core 19 and probable worm burrows are present. Core dip is up to 5°. The interval 1215 feet to total depth, 1997 feet, in which cores 18 to 25 were cut, is assigned to the Cundlego Formation. The lithology is dark grey to black siltstone and silty claystone, interbedded with light grey fine-grained quartz greywacke. Pyrite is common throughout and thin calcareous beds are present in places. Core 20 shows small-scale slumping and cross-stratification in places; the bedding dip ranges from 3° to 10°. Core 21 also shows small-scale cross-stratification and slumping, and the dip ranges from flat up to 5°. Plate 1, Figure 2 illustrates the cross-stratification in laminated fine-grained quartz greywacke and also shows minor flowage at the boundary with the black siltstone near the bottom.

A piece of Core 22 from 1716 feet (Pl. 1, Fig. 3 and Pl. 2, Fig. 1) shows the disturbed bedding at this depth; flowage, contortion, and brecciation are evident. Elsewhere in Core 22 cross-stratification and probable worm burrows are present. The dip of probable bedding is 5°.

Core 23 is flat-bedded; laminae of dark grey siltstone, black carbonaceous claystone, and very fine-grained quartz greywacke are slumped in places, and even where undisturbed most are discontinuous (Pl. 2, Fig. 2); this photograph also shows one of the few calcareous nodules present in this core.

Cores 24 and 25 exhibit the same sort of minor slumping in places as the other cores from the Cundlego Formation. The bedding is horizontal.

BMR 6

Formations

Bore BMR 6 passed from the weathered zone at about 40 feet into pale grey, fine to very fine-grained, micaceous quartz greywacke. In Core 1 it is laminated to thin-bedded (1/4" to 1") and moderately permeable. Fine-grained to very fine-grained quartz greywacke, with minor dark grey sandy siltstone lenses, persists down to 250 feet. Burrowings are present in Core 3 (202-211 feet). The proportion of sandy siltstone in the cuttings decreases from 80 percent at 190 feet to 10 percent at 250 feet. Core 4 (295-303 feet) is coarse siltstone with fine-grained, quartz greywacke lenses, the whole core being much affected by burrowing organisms. A formation boundary is placed at 285 feet, where there is a positive swing in the gamma-ray and SP logs. The sequence from surface to 285 feet has been assigned to the Norton Greywacke, because its lithology is similar to that of the Norton in BMR 7, because of its position in relation to the Wandagee Formation, and because to some extent the gamma-ray log supports this correlation. The ground surface in the vicinity of the bores is almost entirely covered by a scree of silicified sandstone, but there is some evidence that the Norton Greywacke is at the surface in BMR 6. Some 400 feet west of this bore, brown fine-grained micaceous quartz greywacke that may be Norton Greywacke crops out in a creek; also, about 2400 feet north by west from BMR 6 and 100 feet or so higher than the bore collar, is grey gypseous silty claystone that may be referable to the Baker Formation. The BMR 6 sequence is siltier towards the bottom than the Norton Greywacke in BMR 7, but it is still a fine to very fine-grained quartz greywacke. Near Wyera Well five miles north-east of the bores, the Norton Greywacke is thin-bedded, grey and brown, very fine-grained, micaceous quartz greywacke. It is also possible, however, that it is the Coolkilya Greywacke that is represented in BMR 6. Half a mile north-east of the bores the Coolkilya is a very fine-grained micaceous quartz greywacke, with small black siltstone lenses and in places calcareous lenses (Johnstone, 1959, p. 82), so that its lithology is difficult to distinguish from that of the Norton in the vicinity of the bores.

From 285 to 350 feet grey to black siltstone is dominant, with subordinate thin lenses of fine-grained quartz greywacke. From 350 to 390 feet the siltstone is dark grey, hard, and calcareous, and below 390 down to 580 feet the lithology is interbedded dark grey to black soft micaceous, carbonaceous siltstone and subordinate light grey fine-grained micaceous quartz greywacke; a few light grey slightly phosphatic calcareous claystone nodules are present. The interval 285 to 580 feet is regarded as occupied by the Wandagee Formation. The thickness, 295 feet, is 15 feet greater than in BMR 7.

From 580 feet to total depth the lithology is mainly dense firm dark grey to black micaceous siltstone, with minor thin beds of light grey very fine-grained micaceous quartz greywacke. The cores show disseminated pyrite in the siltstone, and the cuttings traces of calcite, and less commonly gypsum. This lithology is somewhat different from that of the Quinnanie Shale in BMR 7 and in outcrop, and although the depth, 745 feet, appears to correlate by gamma-ray log with the base of the Quinnanie (1215 feet) in BMR 7, there is not sufficient contrast in the lithology of the cores and cuttings between 580 and T.D. to establish a formation boundary. Consequently the whole interval is assigned to the Quinnanie Shale, although it may include part of the Wandagee Formation. Small fragments of a black amorphous

substance with a resinous lustre are found in the cuttings, particularly between 700 and 750 feet. A piece of this material examined for West Australian Petroleum Pty Ltd by the Government Analyst, Western Australia, was described as residual wax or ozokerite.

Structure

The dip in Core 1 ranges from flat-bedded to 1 1/2°; Core 2 was not recovered. Steeply-dipping joints and a probable small fault are present in Core 3, and burrowing organisms have been active in places. The attitude of bedding ranges from flat to 5°.

Core 4 contains numerous burrowings and steeply dipping joints, along which there has been a small amount of movement. There is small-scale slumping in places, and poorly developed bedding with dips ranging from 19° to 30°.

Core 5 is mainly siltstone with interlaminations of very fine-grained quartz greywacke; minor slumps and burrowings have destroyed the lamination in places, but elsewhere the dips range from flat to 5°.

The siltstone of Core 6 is also affected by burrowing organisms, but where the bedding can be seen its dip ranges from 2° to 4°.

Burrowings and small-scale slumps have destroyed much of the bedding in Core 7; where the dip can be measured it is horizontal or nearly so.

The dip of the siltstone in Core 8 ranges from horizontal to 5°.

The siltstone of Core 9 is affected by burrowing organisms; the original bedding was probably laminated to very thin, but is now disturbed and contorted. However the bedding is still evident in places and the dip ranges from 3° to 5°.

Core 10 is flat-bedded and the stratification has been affected by burrowings.

A few burrows are present in Core 11 in which the bedding is horizontal; small-scale cross-stratification is present, and small-scale slumping has disturbed the sediments in places.

Environment of Deposition

The character of bedding in the Wandagee and Quinnanie and Cundlego Formations, for example the preservation of fine lamination in some places, and scour and fill, discontinuous laminae, and brecciation in other places, suggests that the environment of deposition was one of intermittent turbulence. Such structures, more or less disturbed by burrowings, have been found in modern sediments on delta-front slopes, and in the sheltered parts of delta platforms (van Straaten, 1959, p.213).

Shepard & Moore (1955, p.1529) in their study of modern sediments of the Central Texas Coast have found that pyrite is common in places in the delta environment. In the bores, pyrite is common, much of it as disseminated grains and blebs in the siltstone, and it is therefore regarded as syngenetic. However in Core 19, BMR 7 (Cundlego Formation) small pyrite nodules are present in the quartz greywacke, particularly along joint surfaces,

and this fact is taken to indicate that some pyrite was formed after consolidation of the sediments and was free to move along the joints.

By analogy with modern sediments it is suggested that the sediments of the Wandagee Formation and below were deposited in the deltaic environment. The Norton Greywacke however, with its generally poor sorting, subangular to subrounded quartz grains and clayey matrix, was probably formed under different conditions, perhaps as a result of a difference in supply of sediment or a change in position of the shore-line. The return to lutite deposition in the Baker Formation may also have been caused by a movement of the shore-line.

Correlation

The absence of definite marker beds in the area makes it necessary to rely largely on the electric and radioactivity logs. Although the logs cannot be matched exactly for more than a few feet, the radioactivity logs afford reasonable correlation, supported to some extent by the SP and resistivity logs and by lithology and microfossils.

Comparison of the gamma-ray logs indicates that the Baker Formation, characterized in BMR 7 with little variation by high values of natural radioactivity between 190 and 500 feet, is absent from BMR 6. Also there is no lutite unit of this thickness in the upper part of BMR 6.

The gamma-ray and resistivity logs in BMR 7 between 518 and 728 feet may be doubtfully correlated with the logs between 68 and 268 feet in BMR 6. This suggests that Norton Greywacke is at the surface in BMR 6. On the other hand there is a possible correlation of the interval 70 to 265 feet in BMR 6 with the interval 80 to 275 feet in BMR 7, in both the radioactivity and the resistivity logs, which suggests that Coolkilya Greywacke occupies the upper part of the bore in BMR 6.

The depth 762 feet in BMR 7 matches reasonably well by gamma-ray log with 335 feet in BMR 6 (Fig. 2) and the interval between 850 and 1220 feet in BMR 7 has the same general form as the interval between 420 and 750 feet in BMR 6. Thus there is little doubt about the correlation of the Wandagee Formation and the Quinnanie Shale. However, it should be pointed out that both radioactivity and resistivity logs can be matched between the intervals 862 to 998 feet in BMR 6 and 790 to 920 feet in BMR 7 (Fig. 3); this would make the whole interval between 285 and 1002 feet Wandagee Formation and give an aggregate thickness for that formation of over 717 feet, which compares favourably with the thickness measured seven miles north-west of the bores.

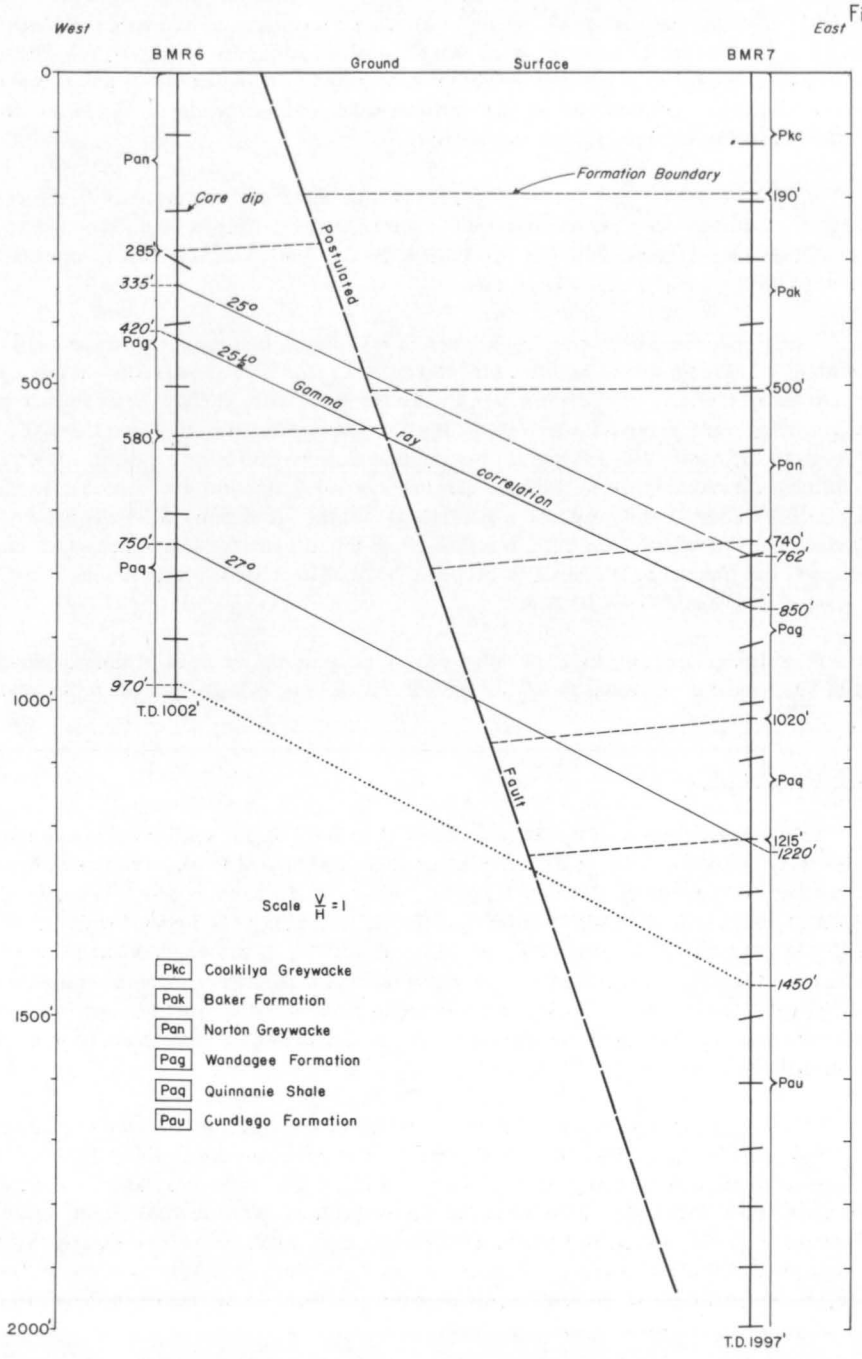
Below 1220 feet in BMR 7 matching is poor; the depth 1450 feet in BMR 7 possibly corresponds to 970 feet in BMR 6.

Two possible interpretations of the structural data are advanced; first, the fault interpretation, and second, the depositional interpretation.

Fault Interpretation

Here Norton Greywacke is regarded as the formation from surface to 285 feet in BMR 6. Referring to Figure 2, it can be seen that the lines joining points correlated by the gamma-ray logs dip at 25 1/2° and 27° respectively. Within the interval so correlated the dips

Fig.2


West
East
BMR6
Ground
Surface
BMR7
0
500'
1000'
1500'
2000'
Pan
Core dip
285'
335'
420'
Pag
580'
750'
Pag
970'
T.D. 1002'
25°
25½°
27°
Gamma
ray
correlation
Postulated
Fault
Formation Boundary
Pkc
190'
Pak
500'
Pan
740'
762'
850'
Pag
1020'
Paq
1215'
1220'
1450'
Pau
T.D. 1997'
Scale V/H = 1
Pkc Coolkilya Greywacke
Pak Baker Formation
Pan Norton Greywacke
Pag Wandagee Formation
Paq Quinnanie Shale
Pau Cundlego Formation
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of bedding in cores from BMR 6 are nowhere higher than 5°. Within the same interval in BMR 7 probable bedding-dips range from 10° to 19°. Whether these figures are true bedding-dips is doubtful. To the writer it seems probable that the whole sequence is only gently dipping, probably about 5°. Slumping is all small-scale and is found in many cores in which there is also cross-stratification; possibly the slumping occurred down foreset slopes at places where instability was caused by changes in current veolcity.

A fault between the bores is postulated because the discrepancy in the dip in Core 4 (BMR 6) of 19° to 30° can be regarded as having been produced by an offshoot of the fault, which is thus considered to be closer to BMR 6 than to BMR 7 at this level; the fault is thus represented as a normal fault dipping east.

The Wandagee Formation is thinner in both bores than might be expected from measurements of surface sections. Assuming that there is a little lateral variation in thickness of the Formation as a whole, the difference in thickness in the bores might be explained by a normal fault dipping east at about 40°, cutting the Wandagee almost in half and throwing the upper part down to the east. It is evident, however, that this explanation is untenable because the bore sections correlate quite well by the gamma-ray logs, and this would not be so if the Formation had been faulted in the manner described. On the other hand if Wandagee Formation continues from 285 feet to T.D. in BMR 6 and the alternative log match is valid, no displacement of the Wandagee Formation between BMR 6 and BMR 7 is necessary, but the Baker and Norton are absent from BMR 6.

If a fault interpretation is adopted to explain the structure, then it must be assumed that for reasons unknown the Wandagee Formation is relatively thin in the area of the bores.

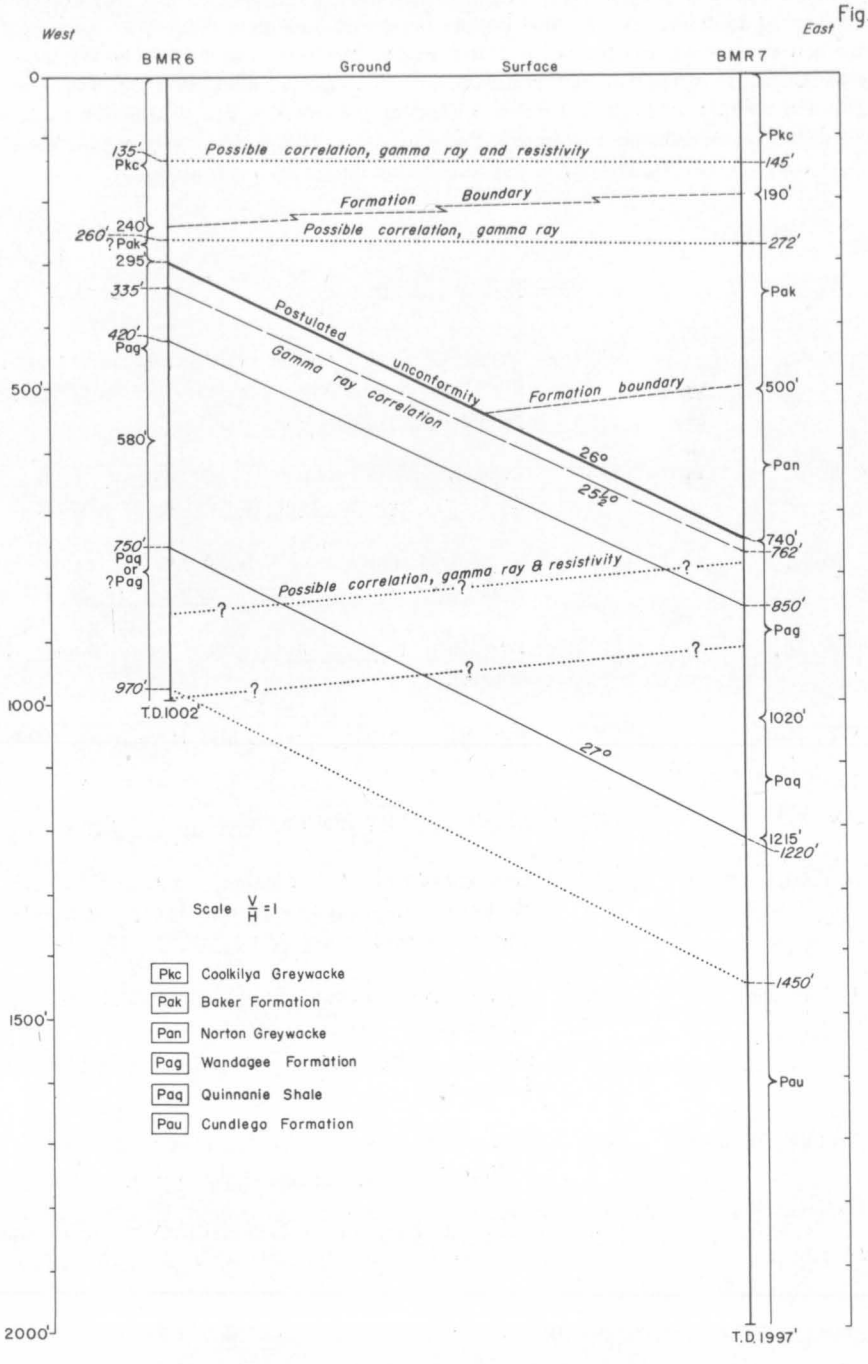
Depositional Interpretation

This interpretation (Fig. 3) postulates that BMR 6 passed through an 'angle of rest' unconformity (Condon, 1956, p.8) in or near Core 4 (295-303 feet). The unconformity surface is thought to dip east at about 30° (Fig. 3); however the gamma-ray 'correlation' of 335 feet (BMR 6) with 762 feet (BMR 7) is fairly reliable, and hence the unconformity surface as a whole dips at a shallower angle than 30°, probably about 26°. If the correlation of 260 feet (BMR 6) with 272 feet (BMR 7) is accepted, it is probable that the Baker Formation is represented in BMR 6 as indicated in Figure 3. The Norton Greywacke wedges out against the unconformity. The unconformity surface truncates the Wandagee Formation in BMR 7, and is responsible for its reduced thickness.

However, it is not clear from this interpretation why the Wandagee is approximately the same thickness in BMR 6, and why the particular sequence in BMR 7 correlates with the sequence in BMR 6, and why, if that is so, in BMR 6 the Quinnanie Shale is coarser-grained whereas the Wandagee Formation is finer-grained than in BMR 7. It would be expected from the angle of rest hypothesis that the sequence in BMR 6 would be stratigraphically higher than that in BMR 7, but from the gamma-ray logs this apparently is not so. There is, therefore, still the difficulty of reconciling the relative positions in the bores of the Wandagee Formation and Quinnanie Shale with the core dips.

The gamma-ray correlations 420 feet (BMR 6) to 850 feet (BMR 7), and 750 feet (BMR 6) to 1220 feet (BMR 7), indicate that if these correlations are valid and if the beds

Fig.3



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between these respective points are continuous, then average dips of 25 1/2° and just over 27° must be assigned to them. As the dips in both bores are less than these (19° maximum) any continuous bed must have a dip greater than these values somewhere between the bores. As the slope of the 'angle of rest' unconformity surface is about 26° then slumping would occur at slopes of this or steeper angles in sediments of similar composition and grain-size such as are found lower in the Wandagee Formation and Quinnanie Shale. Slumping would destroy the continuity of beds and the possibility of correlation by the gamma-ray logs.

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Plate 1

Fig. 1. Bedding partly destroyed by burrowing organisms; worm borrow runs from middle right to upper left. Probable slump brecciation which has produced wisps of one lithology in the other, also can be seen.

Core 15, BMR 7, 992 feet.

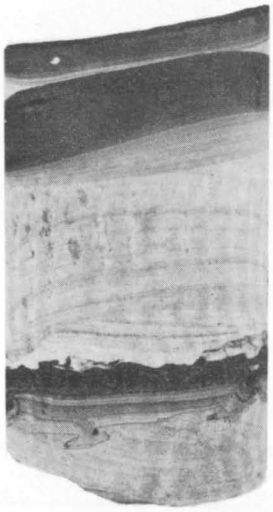


Fig. 3. Probable flowage of material at the base of some fine quartz greywacke layers.

Core 22, BMR 7, 1716 feet.

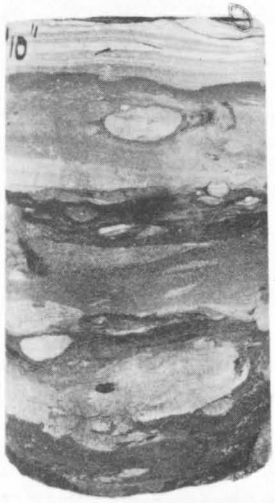


Fig. 2. Cross-stratification in laminated quartz greywacke; slight flowage above black siltstone near bottom of core.

Core 21, BMR 7, 1614 feet.

Plate 2

Fig. 1. Local brecciation of thin layers of quartz greywacke and siltstone.

Core 22, BMR 7, 1717 feet.

Fig. 2. Calcareous nodules(?) in laminated dark grey siltstone and light grey very fine-grained quartz greywacke.

Core 22, BMR 7, 1795 feet.

PLATE I

BORE BMR 6 MUDERONG

STATE: WESTERN AUSTRALIA

BASIN: CARNARVON

AREA: MUDERONG (MIDDALYA STATION)

LOCATION: Latitude 24° 5′ 55″ S.
Longitude 114° 46′ 20″ E.

ELEVATION Ground: 570′±20′ estimated from height of gravity stations.
Rotary Table: 5′ above ground, 3′ higher than B.M.R.7.

DATE SPUDDED: 10th Aug. 1958

COMPLETED 19th Aug 1958

TOTAL DEPTH (From R.T.) 1002 ft.

STATUS: Abandoned.

HOLE PROFILE 5-44 ft: 8½″
44-1002 ft: 5⅝″

CASING: 5-44 ft

PLUGS

LITHOLOGY BY: S.P. Willmott & W.J. Perry

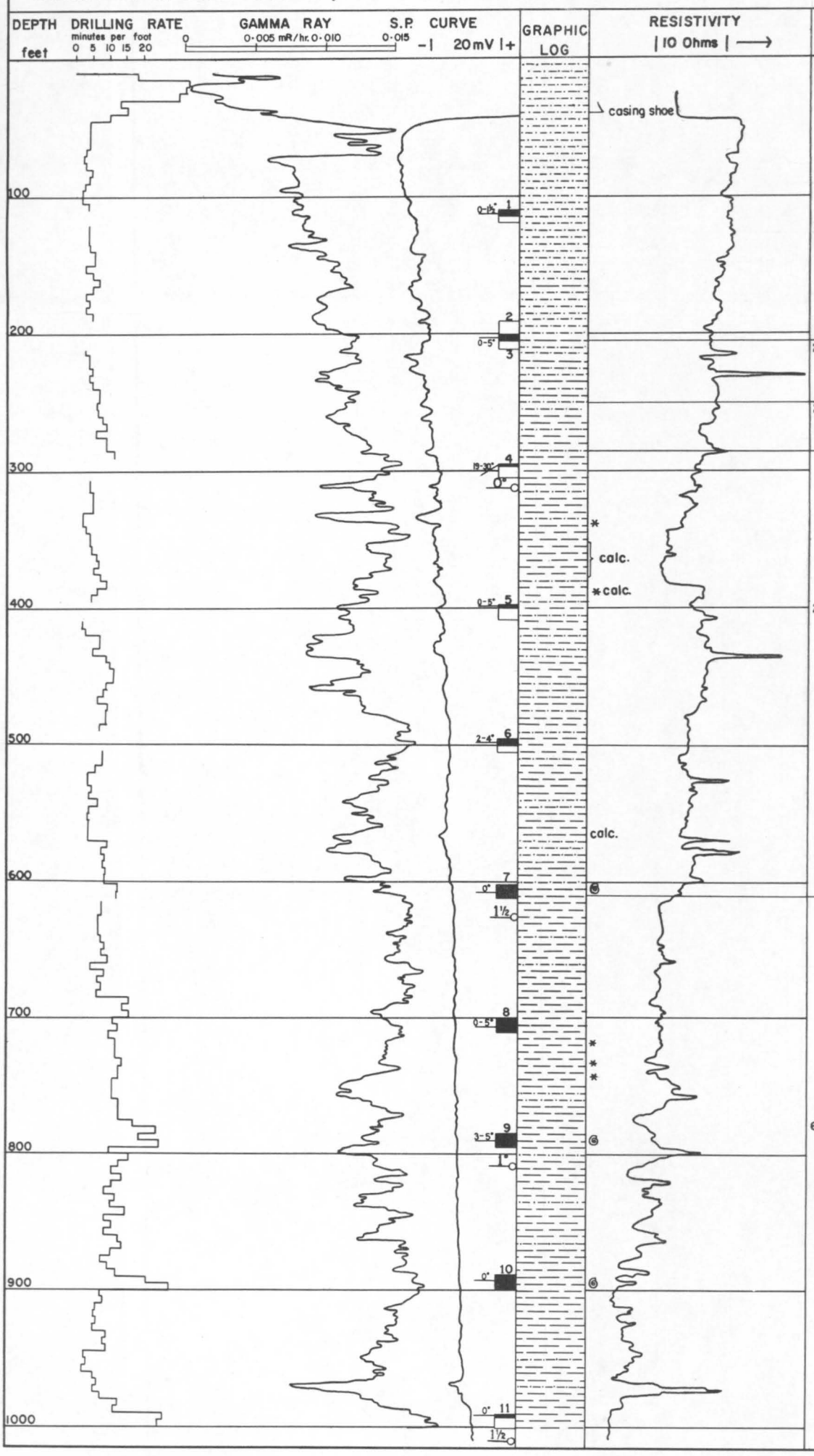
ELECTRIC LOG DATA
DATE: 19th Aug. 1958
INTERVAL LOGGED 1002-45 ft.
MUD - NATURE: Water-base bentonite
DENSITY: 80-90 lbs per cub. ft.
VISCOSITY: 41 S
RESISTIVITY: 1·5 ohm-m at 72°F

OTHER LOGS
DEVIATION
DIP OF CORE 0-5°

(ELECTRIC LOGS PROVISIONAL ONLY)

LITHOLOGY SYMBOLS
QUARTZ GREYWACKE
SILTSTONE

REFERENCE
MACROFOSSILS ⑥
RESIDUAL WAX *
CALCAREOUS calc.



0′-205′	QUARTZ GREYWACKE, fine-grained, micaceous, bedding laminated to 1 inch thick, contorted and irregular in places, with minor SILTSTONE laminae.	
205′-250′	QUARTZ GREYWACKE, fine to very fine-grained, with few lenses and streaks of SILTSTONE, dark grey.	
250′-285′	QUARTZ GREYWACKE, light grey, fine to very fine-grained, with increasing proportion downwards of interbedded SILTSTONE, black, carbonaceous, sandy.	
285′		
350′-390′	SILTSTONE, grey, hard calcareous, pyritic.	
285′-610′	SILTSTONE, dark grey to black, soft micaceous, carbonaceous with subordinate interbedded QUARTZ GREYWACKE, light grey, fine-grained, micaceous, bedding disturbed in places by burrowing organisms; light grey slightly phosphatic calcareous nodules in places.	
580		
610′-1002′	dominantly SILTSTONE, dark grey, carbonaceous, micaceous, pyritic in places, calcareous in part; interlaminated with QUARTZ GREYWACKE, light grey, very fine-grained, calcareous in part.	

FORMATION & AGE

GREYWACKE — NORTON FORMATION — ARTINSKIAN

SHALE — WANDAGEE FORMATION — ARTINSKIAN

QUINNANIE — WANDAGEE FORMATION — ARTINSKIAN

G50/A1/5

BORE BMR 7 MUDERONG

STATE : WESTERN AUSTRALIA
LOCATION : Latitude 24°5'55"S
Longitude 114°46'30"E
ELEVATION : Ground 570±20' estimated from height of gravity station.
Rotary Table 5' above surface.
DATE SPUDDED : 21st. Aug. 1958
COMPLETED : 14th Sept. 1958
TOTAL DEPTH (From R.T.) 1997 ft.
STATUS : Abandoned
HOLE PROFILE :
CASING : 5-23 ft
PLUGS Plug at 437 ft.
LITHOLOGY BY : W.J. Perry

BASIN : CARNARVON
ELECTRIC LOG DATA :
DATE : 14th Sept. 1958
INTERVAL LOGGED :
MUD - NATURE : Water-base bentonite
DENSITY : 73 lbs. per cub. ft.
VISCOSITY : 38 S
RESISTIVITY : 1·5 ohm-m at 72°F
OTHER LOGS :
DEVIATION :
DIP OF CORE : 6°

AREA : MUDERONG (MIDDALYA STATION)
LITHOLOGY - SYMBOLS
QUARTZ GREYWACKE
SILTSTONE
CLAYSTONE
SHALE
REFERENCE
MACROFOSSILS
RESIDUAL WAX
CALCAREOUS calc
LOST CIRCULATION

DEPTH feet | DRILLING RATE 5 10 15 minutes per foot | GAMMA RAY 0 0·005 0·010 0·015 mR/hour | S.P. CURVE −| 20mV |+ | GRAPHIC LOG | RESISTIVITY 0 10 ohm-m 20 30 | LITHOLOGY | FORMATION & AGE

0'-20' SANDSTONE? silicified red-brown and white; derived from surface "billy".

casing shoe

20'-190' QUARTZ GREYWACKE grey, very fine-grained micaceous, quartz grains sub-round to sub-angular and SILTSTONE dark grey to black in wisps and streaks through quartz greywacke; rare small-scale cross-stratification.

190 COOLKILYA GREYWACKE — KUNGURIAN

190'-290' QUARTZ GREYWACKE dark grey, very fine-grained and SILTSTONE very dark to black in streaks through the quartz greywacke; disseminated pyrite common.

290'-350' SILTSTONE dark grey, pyritic micaceous with calcite veins grades into CLAYSTONE or SHALE in places.

350'-500' CLAYSTONE dark grey to black pyritic micaceous with, in places, interlaminated SILTSTONE light grey.

395'-400' SHALE dark grey to black pyritic micaceous.

500 BAKER FORMATION

500'-740' QUARTZ GREYWACKE, light grey, fine-grained to very fine-grained clayey matrix, non-calcareous, grains sub-rounded to sub-angular, sorting moderately good, porosity moderate to high.

740 NORTON GREYWACKE

766'10"-768'4" QUARTZ GREYWACKE light grey fine to very fine-grained micaceous, calcareous.

740'-1020' QUARTZ GREYWACKE light grey fine to very fine-grained micaceous, sorting poor, quartz grains sub-angular to sub-round, clayey cement, in places interlaminated with SILTSTONE and CLAYSTONE dark grey to black soft, pyritic in places, with minor slumping and micro faults.

995'6½"-996'9½" QUARTZ GREYWACKE light, fine-grained calcareous.

1020 WANDAGEE FORMATION — ARTINSKIAN

1020'-1215' CLAYSTONE black silty micaceous, well jointed, with grey calcareous phosphatic nodules in places and minor discontinuous laminae of QUARTZ GREYWACKE light grey fine-grained.

1215 QUINNANIE SHALE

1215'-1235' QUARTZ GREYWACKE light grey, fine-grained.

1235'-1997' CLAYSTONE dark grey to black silty dense micaceous pyritic; in places grades into SILTSTONE grey to dark grey micaceous, interbedded with QUARTZ GREYWACKE light grey, fine to very fine-grained, quartz grains sub-angular to sub-round, sorting poor, pyrite present in disseminated grains, thin calcareous bands in places.

1780'-1802' dominantly CLAYSTONE dark grey, silty micaceous with grey calcareous phosphatic nodules in places grades to SILTSTONE in places with thin interbeds of QUARTZ GREYWACKE light grey very fine-grained micaceous in places calcareous.

1802'-1997' dominantly CLAYSTONE black to dark grey silty, mica in places grading into SILTSTONE dark grey micaceous, minor thin interbeds of QUARTZ GREYWACKE grey to light grey, fine to very fine-grained, sorting poor, clayey matrix, quartz grains sub-angular to sub-round, calcareous in places.

CUNDLEGO FORMATION

partial

calc.

G50/A1/6

APPENDIX

FORAMINIFERA FROM BORES BMR 6 AND 7, MUDERONG, WESTERN AUSTRALIA

by

D.J. BELFORD

Bores BMR 6 and 7 were drilled in 1958. They are located on Middalya Station, 2 miles north by west of Muderong Bore, and 88 miles north-east of Carnarvon.

Eleven cores from bore BMR 6 were examined, between the depths of 110 feet and 1001 feet, and 25 cores from bore BMR 7, between the depths of 110 feet and 1997 feet. Species recorded are listed below, those species common to both bores being marked by an asterisk; further information on the distribution of these species is given by Crespin (1958).

*Flectospira prima Crespin & Belford
*Frondicularia aulax Crespin
*F. parri Crespin
F. woodwardi Howchin
Hemigordius harltoni Cushman & Waters
*Rectoglandulina serocoldensis (Crespin)
*Hyperammina coleyi Parr
*H. elegans (Cushman & Waters)
H. fusta Crespin
H. expansa (Plummer)
H. sp.
*Thuramminoides sphaeroidalis Plummer
*Geinitzina triangularis Chapman & Howchin
*Calcivertella sp. cf. C. palata Crespin
Calcivertella sp.
Calcitornella heathi Cushman & Waters
*Involutina nitida (Parr)
*Pseudohyperammina radiostoma Crespin
Nodosaria conico-densestriata Paalzow
*Giraliarella travesi Crespin
Ammobaculites woolnoughi Crespin & Parr
*Nodosaria raggatti Crespin
N. sp. cf. N. striatella (Paalzow)
N. sp.
Glomospirella nyei Crespin
*Trochammina subobtusa Parr
*Tolypammina undulata Parr
Psammosphaera pusilla Parr
Pelosina ampulla Crespin

Representative specimens of these species are illustrated on Plates 1 and 2. The distribution of species in bores BMR 6 and 7 together with a comparison of the depth ranges of those species common to the two bores is given in Plate 3.

NOTES ON THE ASSEMBLAGES AND CORRELATION BETWEEN THE BORES

It may be seen from Plate 3 that foraminifera occur at three intervals in bore BMR 7, from cores 2-5 inclusive, 15-18 inclusive and 23-25 inclusive, with each separated by an unfossiliferous interval. Foraminifera do not appear with any frequency in bore BMR 6 above core 6, which was taken between the depths of 495 feet and 505 feet.

With the exception of the highest fossiliferous zone in bore BMR 7 the species of foraminifera recorded occur only rarely in each sample, but the restricted levels of their occurrence enable a correlation between the two bores to be made. From Plate 3 it is apparent that the assemblage occurring in bore BMR 7 from cores 2 to 5 inclusive is not represented in bore BMR 6. However, there is good agreement between the assemblage from bore BMR 6 and that of the second fossiliferous zone of bore BMR 7. The most important species for the correlation of these zones are Flectospira prima, Rectoglandulina serocoldensis, Hyperammina coleyi, Involutina nitida, Hyperammina elegans, Nodosaria raggatti and Trochammina subobtusa; this last species is of particular importance as it does not occur in the upper zone of bore BMR 7. Several species are first recorded in bore BMR 6 below 495 feet, propably because of the rarity of their occurrence in the section, while Geinitzina triangularis is recorded above this level. In spite of these irregularities it is possible to recognise a well-defined upper limit in bore BMR 6 at a depth of 495 feet, while the upper limit of the second fossiliferous zone in bore BMR 7 is most clearly defined at 1087 feet.

In the writer's opinion, bore BMR 6 began in the unfossiliferous beds between the first and second fossiliferous zones in bore BMR 7. The assemblage from bore BMR 6 is correlated with that of the second fossiliferous zone in bore BMR 7; the upper limits of these zones are placed at the depths of 495 feet and 1087 feet respectively.

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PLATE 1

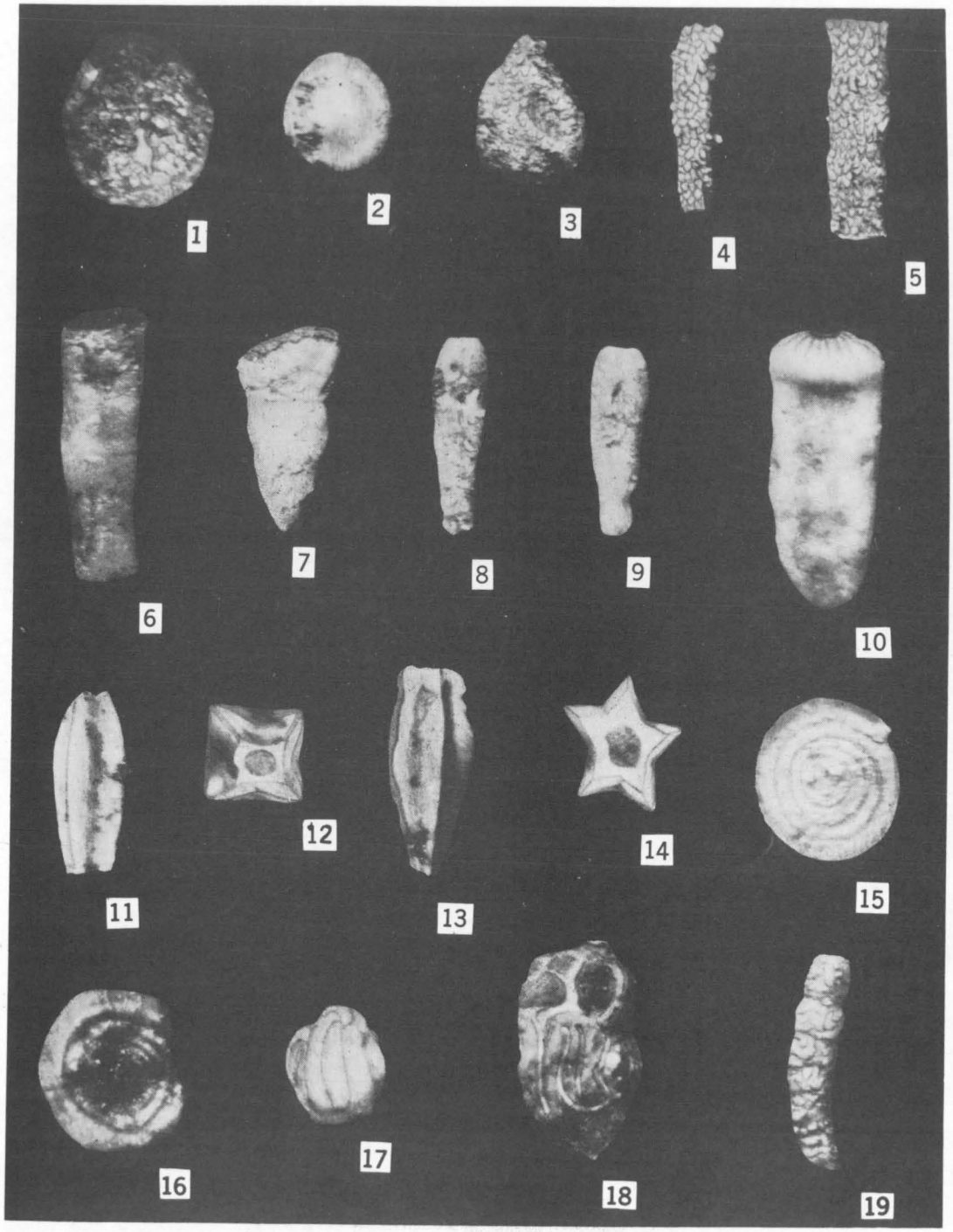


PLATE 1

FIGURE 1. Psammosphaera pusilla Parr.

Figured specimen from bore BMR 7, Core 23, 1793'-1802'. Side view. X54.

FIGURE 2. Thuramminoides sphaeroidalis Plummer.

Figured specimen from bore BMR 6, Core 8, 701'-711'. Side view. X22.

FIGURE 3. Pelosina ampulla Crespin.

Figured specimen from bore BMR 7, Core 23, 1793'-1802'. Side view. X22.

FIGURES 4-5. Hyperammina coleyi Parr.

4. Figured specimen from bore BMR 7, Core 2, 204'-214'. Side view. X22.
5. Figured specimen from bore BMR 6, Core 8, 701'-711'. Side view. X22.

FIGURE 6. Hyperammina elegans (Cushman & Waters).

Figured specimen from bore BMR 7, Core 5, 397'-403'. Side view. X35.

FIGURE 7. Hyperammina expansa (Plummer).

Figured specimen from bore BMR 7, Core 23, 1793'-1802'. Side view. X22.

FIGURES 8-9. Hyperammina fusta Crespin.

Figured specimens from bore BMR 7, Core 16, 1087'-1095'. Side views. X35.

FIGURE 10. Pseudohyperammina radiostoma Crespin.

Figured specimen from bore BMR 7, Core 3, 293'-303'. Side view. X35.

FIGURES 11-14. Giraliarella travesi Crespin.

11-12. Figured specimen from bore BMR 7, Core 5, 397'-403'. 11. Side view, X35; 12, top view, X76.
13-14. Figured specimen from bore BMR 6, Core 8, 701'-711'. 13. Side view, X35; 14, top view, X76.

FIGURES 15-16. Involutina nitida (Parr).

15. Figured specimen from bore BMR 7, Core 5, 397'-403'. Side view. X35.
16. Figured specimen from bore BMR 7, Core 3, 293'-303'. Side view. X52.

FIGURE 17. Glomospirella nyei Crespin.

Figured specimen from bore BMR 7, Core 5, 397'-403'.

FIGURE 18. Tolypammina undulata Parr.

Figured specimen from bore BMR 7, Core 16, 1087'-1095'. X52.

FIGURE 19. Ammobaculites woolnoughi Crespin & Parr.

Figured specimen from bore BMR 7, Core 5, 397'-403'. Side view. X35.

PLATE 2

FIGURES 1-2. Trochammina subobtusa Parr.

Figured specimen from bore BMR 7, Core 16, 1087'-1095'. 1, umbilical view; 2, spiral view. X35.

FIGURE 3. Hemigordius harltoni Cushman & Waters.

Figured specimen from bore BMR 7, Core 5, 397'-403'. Side view. X35.

FIGURES 4-5. Calcitornella heathi Cushman & Waters.

Figured specimen from bore BMR 6, Core 9, 785'-795'. 4, upper view; 5, lower view. X35.

FIGURE 6. Calcivertella sp. cf. C. palata, Crespin.

Figured specimen from bore BMR 7, Core 3, 293'-303', attached to Hyperammina sp. X35.

FIGURES 7-8. Calcivertella sp.

Figured specimen from bore BMR 6, Core 8, 701'-711'. Views from opposite sides. X35.

FIGURES 9-11. Flectospira prima Crespin & Belford.

Figured specimens from bore BMR 7, Core 16, 1087'-1095'. 9, 11, side views; 10, edge view. X54.

FIGURE 12. Nodosaria conico-densestriata Paalzow.

Figured specimen from bore BMR 7, Core 5, 397'-403'. Side view. X35.

FIGURE 13. Nodosaria raggatti Crespin.

Figured specimen from bore BMR 7, Core 16, 1087'-1095'. Side view. X50.

FIGURE 14. Nodosaria sp. cf. N. striatella (Paalzow).

Figured specimen from bore BMR 7, Core 16, 1087'-1095'. X85.

FIGURE 15. Rectoglandulina serocoldensis (Crespin).

Figured specimen from bore BMR 7, Core 2, 204'-214'. Side view. X35.

FIGURE 16. Frondicularia aulax Crespin.

Figured specimen from bore BMR 7, Core 16, 1087'-1095'. Side view. X54.

FIGURE 17. Frondicularia parri Crespin

Figured specimen from bore BMR 7, Core, 3, 293'-303'. Side view. X35.

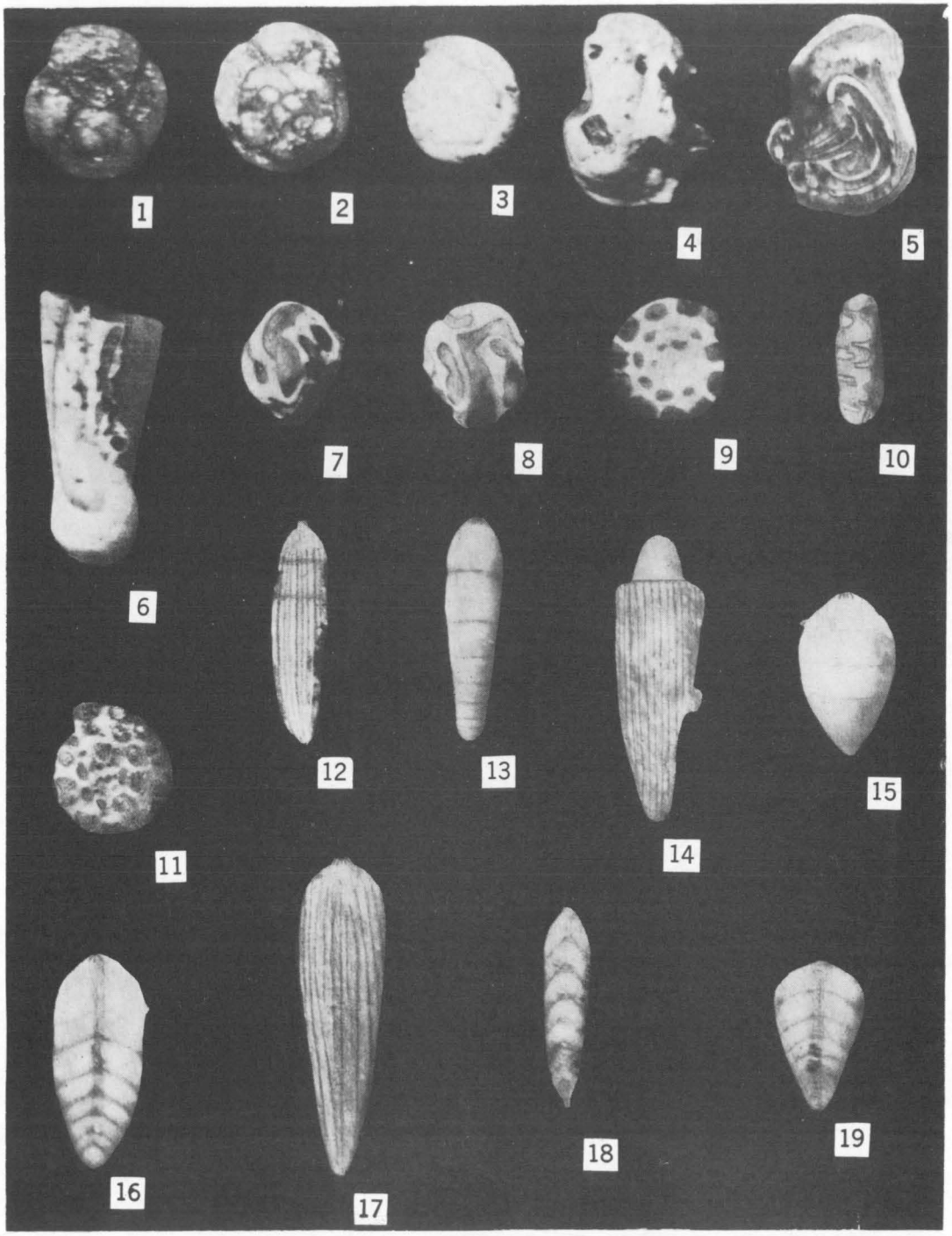
FIGURE 18. Frondicularia woodwardi Howchin.

Figured specimen from bore BMR 7, Core 5, 397'-403'. Side view. X35.

FIGURE 19. Geinitzina triangularis Chapman & Howchin.

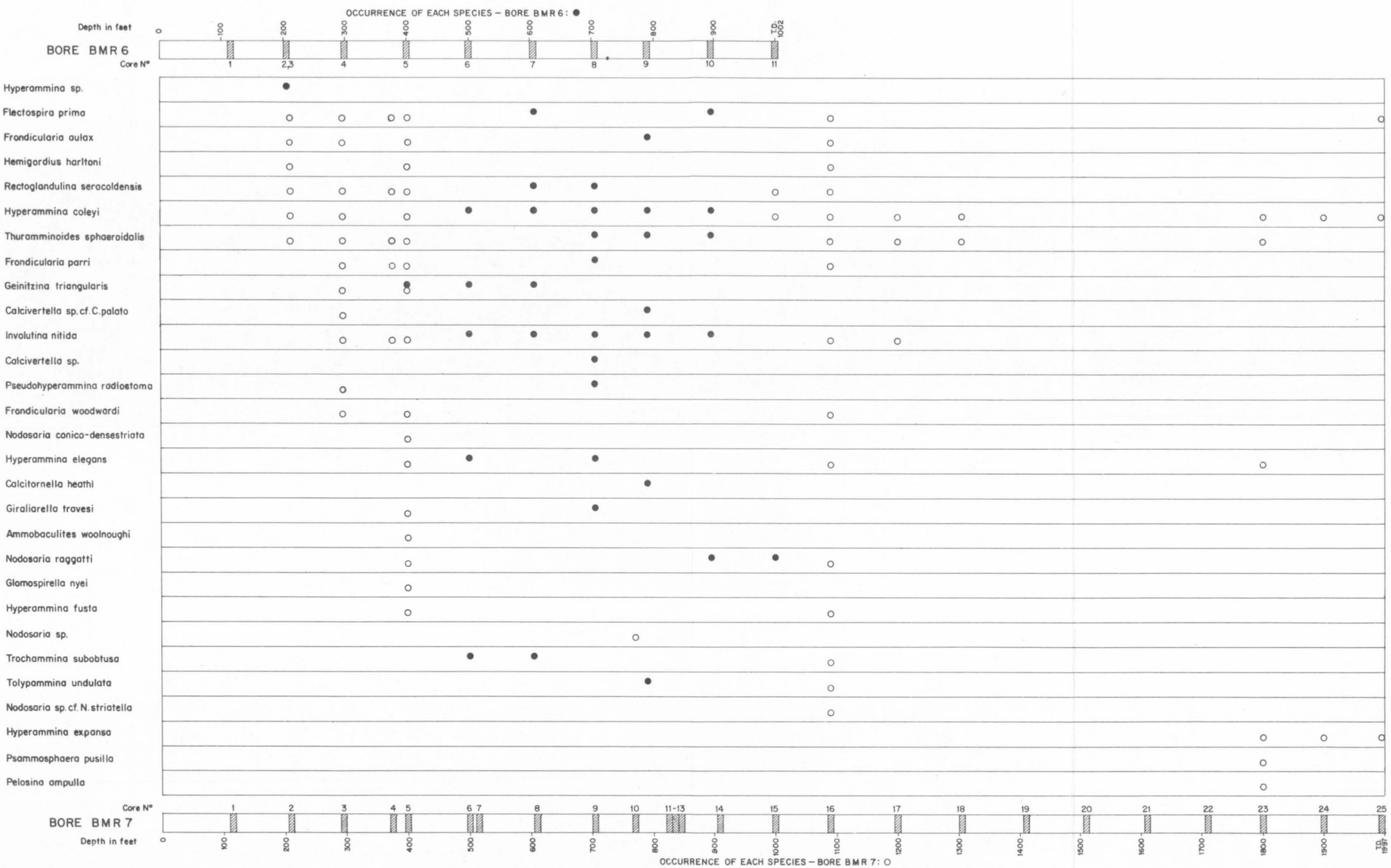
Figured specimen from bore BMR 7, Core 5, 397'-403'. Side view. X35.

PLATE 2



DISTRIBUTION OF FORAMINIFERA

PLATE 3



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