COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

REPORT No. 80

Completion Report BMR 10 and 10A Beagle Ridge Western Australia

BY

R. A. MACTAVISH

Issued under the Authority of the Hon. David Fairbairn
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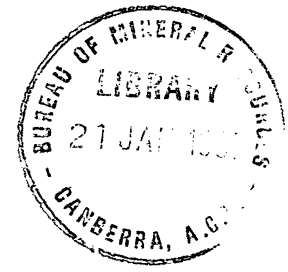

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DEPARTMENT OF NATIONAL DEVELOPMENT

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SUMMARY

BMR 10 and BMR 10A were drilled above the highest accessible (subterranean) part of Beagle Ridge - a subsurface basement ridge which underlies the coast about 150 miles north of Perth, Western Australia. BMR 10A was drilled after BMR 10 had been abandoned owing to mechanical difficulties.

Both wells cut a thin section of about 90 feet of Pleistocene marine calcarenite, below which occurs a thousand feet of coarse-grained Cockleshell Gully Sandstone (Jurassic) containing fossils older than any previously ascribed to that Formation. Below the Jurassic is a thick sequence of marine deltaic sandstone, siltstone, and dark green-grey shale, which yielded the first definite Triassic ammonites recognized in Australia. Three lithological units could be distinguished in the Triassic section and two of these were new. Disconformable under the Triassic is a Permian sequence over 1500 feet thick, of siltstone, sandstone, and shale, with coal beds and limestone. The Permian has been divided into four units, two of which can be correlated with two formations in the Irwin River area.

BMR 10A entered basement, dominantly of metamorphic rocks, at 4794 feet.

Beagle Ridge was apparently a surface feature for most of the Palaeozoic, at least, and was not submerged until the Lower Permian - upper Sakmarian (Artinskian).

INTRODUCTION

As a result of a gravity survey carried out in the Perth Basin by the Bureau of Mineral Resources, Thyer & Everingham (1956) were able to distinguish a basement rise parallel to the coast between Cliff Head and Green Island (see Fig. 1). A subsequent aeromagnetic survey (Newman, 1959) showed that the basement ridge occurred between latitudes 29° 40'S and 30° 30'S and longitudes 114° 50' E and 115° 02'E, and rose to about 4500 feet below the surface. The ridge strikes north and is about ten miles across at its widest part. On the eastern margin, which is very steep, it appears to be bounded by a fault. The name Beagle Ridge was adopted in West Australian Petroleum Pty Ltd's reports because of the proximity of Beagle Island.

BMR 10 was programmed to provide information on the geological history of Beagle Ridge and new information on the stratigraphy of the Perth Basin. The well was sited on the north-east perimeter of Beagle Ridge and reached a depth of 3910 feet before mechanical difficulties necessitated its abandonment. To complete the project, BMR 10A was drilled to a total depth of 4862 feet at a site 150 feet north of BMR 10.

WELL HISTORIES

1. General data

Well name and number:	BMR 10	BMR 10A
Location:	29°49'38"S 114°58'30"E	29°49'36 1/2"S 114°58'30" E
Tenement:	Permit to Explore 27H; area 52,000 square miles; expiry date 22nd October 1960.	
Tenement holder:	West Australian Petroleum Pty Limited.	
District:	Beagle-Logue, Western Australia.	
Total Depth:	3910 feet	4862 feet
Drilling began:	1st August 1959	2nd May 1960
Total depth reached:	6th September 1959	24th June 1960
Well abandoned:	27th October 1959	10th July 1960
Elevation, above mean sea level:	Rotary Table 21 feet Surface 10 feet	26 feet 15 feet
Status:		Abandoned: Cement plugs at 3692 feet, 3640 feet, 3241 feet, 2386 feet, 264 feet, and surface.

2. Drilling data

Contractor:	Oil Drilling and Exploration (W.A.) Pty Ltd.
Drilling Plant:	National Supply Co.

Type:	T-20	
Motors:	General Motors, Series 6-71, 200 b.h.p.	
Mast:	BMR 10	BMR 10A
	Lee C. Moore Cantilever 94 feet, rating 298,000 lb. On 7/9/59 mast collapsed and was replaced by a 136-foot standard derrick from a T-55 rig	Lee C. Moore cantilever 94 feet, rating 290,000 lb.
Pumps:	1. National-Ideal C-150-B; size 7 1/4" x12"	
	Motor: GM series 6-71, 200 b.h.p.	
	2. National-Ideal D-50; size 5" x 10"	
	Motor: Caterpillar D 311	
Blow-out Preventor:	Cameron SS 10", Series (A.P.I.) 900	
Hole size:	17 1/2" surface to 189 feet	surface to 276 feet
	12 1/4" 189 feet to 1650 feet	276 feet to 1620 feet
	8 3/4" 1650 feet to 3910 feet	1620 feet to 4852 feet
	7 7/8" -	4852 feet to 4862 feet
Casing:	13 3/8 x 48 lb/ft Range 2 A.P.I.	
Cemented at:	186 feet	276 feet
	9 5/8 x 40 lb/ft Range 2 A.P.I.	
Cemented at:	1448 feet	1616 feet
Recovered from:	264 feet	120 feet
Plugging back Plugs:		3640-3680 feet, 25 sacks (drilled out firm cement from 3627 to 3640 feet)
		3240-3280 feet, 25 sacks (drilled out firm cement from 3232 to 3240 feet)
		2386-2450 feet 25 sacks.
		264 feet, 25 sacks (at top of 9-5/8" casing)
		Surface (11 feet), 10 sacks (in 13-3/8" casing)

BMR 10

Drilling of BMR 10 was hampered by three main factors:

1. Caving in the 'Coastal Limestone';

2. High porosity in the Cockleshell Gully Sandstone;

3. Poor cementation and resultant caving of the Cockleshell Gully Sandstone.

Possibly factors 1 and 2 caused lost circulation. Because of factor 3 it was impossible to seat the surface casing satisfactorily. Furthermore, the frequent caving in the Cockleshell Gully Sandstone made the bit prone to stick when it was being pulled from the hole. This condition was perhaps aggravated by unsatisfactory drilling mud, whose poor quality could be, in part, attributed to the high salinity of the water with which the mud was made.

The surface casing was cemented at 186 feet without mud returns: owing to failure of the cementing, the lost circulation zones in the Coastal Limestone were not shut off. Consequently lost circulation remained a problem during drilling to 3142 feet, although this might also be attributed in part to the very high permeability of the Cockleshell Gully Sandstone. In order to overcome these difficulties it was decided to cement 9-5/8" casing at about 1660 feet. However, the casing froze at 1448 feet and was cemented at this depth. Later it parted at 1412 feet and the bottom joint of casing and shoe dropped 69 feet to 1517 feet; top of the parted joint was therefore at 1481 feet. The lost joint of casing was sidetracked and the old hole was re-entered below 1600 feet.

The drill pipe became stuck at 3850 feet while pulling out of the hole. During the subsequent fishing operations the 94-foot mast collapsed under a pull of 137,000 lbs and was replaced by a 136-foot Standard derrick. The pipe was freed but stuck again at 1692 feet whilst pulling out. During the fishing operations which followed, drill pipe was recovered to 1380 feet, leaving an 8-3/4" bit, eight 6-1/4" drill collars, two joints of 4-1/2" drill pipe and a safety joint in the hole. It was impossible to wash over below 1481 feet because of the obstructing casing. Therefore the hole was abandoned at T.D. (3910 feet) with the fish still in the hole.

BMR 10A

The drilling fluid used in BMR 10A was a bentonite-water mud without weighting material. Treatment consisted of the addition of caustic soda and myrtan (Quebracho equivalent) for viscosity control, and starch and bentonite for water loss control.

Average properties were :-

Weight	-	76 lb/ft
Viscosity	-	60 sec (Marsh)
Water loss	-	11 cc
Filter Cake	-	2/32 in
pH	-	9
Sand content	-	2%

A 12-1/4" hole was drilled to 276 feet then opened to 17-1/2" to this depth. 13-5/8" casing was run and cemented at 276 feet with 180 sacks of cement mixed to a slurry of 115 lb/ft, and a top plug.

At 1150 feet the bit size was reduced from 12-1/4" to 8-3/4" and the drill collars were changed from 7-3/4" to 6-1/2" O.D. and 8-3/4" hole was drilled to 2300 feet. The hole size was reduced at 1150 feet to see whether the upper sands from the shoe of the 13-3/8" casing to 950 feet would stand up to drilling without being cased off, and to check whether lost circulation zones existed at greater depths. The smaller hole size reduced the volume of cuttings to be lifted as well as allowing for reaming out if difficulties arose.

At 2300 feet it was considered that the danger of bad hole conditions developing was too great and it was decided to run a string of 9-5/8" casing. The 8- 3/4" hole was opened to 12-1/4" from 1150 feet to 1620 feet. A caliper survey was run but the results were inconclusive. Casing (9-5/8" x 40 lb/ft, J-55) was run and cemented at 1616 feet with 269 sacks of construction cement mixed to a slurry of 115 lb/ft ; full returns were received during cementing and displacing.

A temperature survey run 12 hours after cementing indicated that the cement rose to about 1170 feet with some channelling above that point. The calculated rise of the cement was to 700 feet. Drilling continued with an 8-3/4" bit to 4852 feet. Before this depth was reached, two fishing operations had to be undertaken: the first, at 3870 feet, was necessitated by pipe which became stuck when being pulled out of the hole. Diesel oil was spotted around the bit and after 8-1/4 hours the drill pipe worked free. It is interesting to note that the pipe stuck at almost the same depth as in BMR 10, where the bit became stuck at 3850 feet: in both cases in a water-sand zone of high salinity. In addition, there was a sharp rise in the mud water loss opposite this zone and a rise from 2 percent to 4 percent in the sand content. It is possible that the salt water flocculated the water-base bentonite mud to cause the increase in water loss. The second fishing operation was at 4700 feet, where the bit stuck while the wash pipe in the swivel was being replaced. Diesel oil was again spotted around the bit and the drill collars. Ten days were spent in washing over and backing off the drill pipe by the string-shot method before the fish was recovered completely.

The hole was cored with 7-7/8" Hughes hard formation core head from 4852 feet to the final depth of 4862 feet.

Ditch Cuttings

Ditch cuttings were collected at five-foot intervals in BMR 10 from surface to T.D. (3910 feet) and in BMR 10A from 600 feet to 2000 feet and from 3910 feet to 4862 feet. In BMR 10 there were no returns of cutting from 175 feet to 260 feet and 3000 feet to 3142 feet. Below 600 feet in BMR 10 and throughout BMR 10A alternate samples were studied because the rate of drilling prevented a satisfactory examination of every ditch sample.

Washed sample splits were sent to West Australian Petroleum Pty Ltd, and the Geological Survey of Western Australia.

Coring

The coring programme for BMR 10 called for 10 feet of core in every consecutive 100 feet and in BMR 10A for 10 feet of core in every consecutive 100 feet below 3900 feet. Additional cores could be requested by the well-site geologist. 41 cores were cut in BMR 10, and 14 in BMR 10A. They were cut by a Hughes Type 'J' core barrel with 7-7/8" and 8-3/4" hard formation core heads and 8-3/8" soft formation core-heads.

In BMR 10, coring in the Cockleshell Gully Sandstone (101 feet - 1097 feet) was most unsatisfactory; core recovery was only about 12 percent. Additional coring was not attempted as it was unlikely that recovery could have been improved whilst drilling in this formation. Core recovery was less than 50 percent in some cores between cores 11 and 22 inclusive, but the core recovered was regarded as sufficiently representative. An additional core was called for immediately after cores 23 and 34 of the Kockatea Shale in order to obtain more fossil material.

In BMR 10A two cores were cut above 3900 feet at 209 feet - 219 feet (core 1) and 1565 feet - 1585 feet (core 2) to provide drilling information. Core 11 was intended to cover the interval 4681 feet - 4691 feet, but no core was recovered on the attempt, so core 12 was taken at 4691 feet - 4701 feet. Some of the material recovered in core 12 may have been from the interval of core 11.

Details of the coring in the two holes are presented in Appendix A.

Sidewall Coring

Sidewall coring was undertaken in BMR 10A with a Homco sidewall coring tool at the following depths (in feet): 3210, 3220, 3245, 3273, 3626, 3633, 3640, 3723, 4074 (two), 4750, and 4790. There was no recovery from the attempt at 3245 feet.

Description of the sidewall cores are included in Appendix A (ii).

Logging

In BMR 10 a WIDCO 4000-foot logging unit, which recorded a single-point resistivity log and a self-potential log, was used. Two runs were made: the first from 186 feet to 2296 feet, the second from 1230 feet to 1506 feet; in order to locate the fallen joint of casing. The resistivity log was valueless in providing information on the lithology or fluid content encountered because the low resistivity of the drilling fluid (bore water) damped out changing resistance caused by the varying resistivity of the sediments (Jewell, 1959).

The logs in BMR 10A were recorded on a Failing Logmaster unit as shown below:

Electric Logs: Run I (2300 feet to 10 feet) mud resistivity 0.925 ohms at 28°C-S.P. Single Point Resistivity, 16" normal.
Run II (3900 feet to 1400 feet). Mud resistivity 1.467 ohms at 16.6 C-S.P. Single Point Resistivity, 16" normal, 63" normal.
Run III (4525 feet to 3800 feet) Mud resistivity, 1.02 ohms at 34°C - S.P. Single Point Resistivity.
Run IV (4862 feet to 1600 feet) Mud resistivity, 1.65 ohms at 21°C - S.P. Single Point Resistivity, 16" normal, 63" normal.

Gamma Ray Logs: Run I (3900 feet to 50 feet)
Run II (4862 feet to 20 feet)

Caliper Logs: Runs I, II, and III - misrun.
Run IV (4682 feet to surface). In 9-5/8" casing from 1656 feet, log unsatisfactory because of unreliable recordings.

Drilling Time Records

No detailed drilling time records were kept, but the drilling rates ranged from 25 ft/hr to 100 ft/hr in BMR 10 and 7 ft/hr to 20 ft/hr in BMR 10A below 3900 feet.

Formation Tests

No formation tests were conducted in BMR 10. Formation tests were attempted of the zones between 3200 feet to 3230 feet and 3610 feet to 3640 feet in BMR 10A using a Johnston Tester. All attempts to test the zone 3600 feet to 3640 feet and the first attempt to test the zone between 3200 feet and 3230 feet were unsuccessful because the packer could not be seated. This was partly due to the absence of reliable caliper logs.

Details of the mechanically successful test are reported in Appendix F.

Temperature Logs

Temperature logs were run from 1550 feet to 25 feet and from 4525 feet to 25 feet in BMR 10A.

The log 1550-25 feet was run 12 hours after cementing, and its temperature gradient was 1^{o}F in 90 feet.

The log 4525-25 feet was run immediately after pulling out of the hole (about 2 hours after circulation ceased) and its temperature gradient was approximately 1^{o}F in 110 feet. The temperature at 4525 feet was 115^{o}F.

Deviation Surveys

A TOTCO drift indicator was used to conduct deviation surveys. Details of these surveys are shown in Appendix C.

Personnel

Bureau of Mineral Resources staff assigned to BMR 10 and 10A were:- R.A. McTavish, geologist; F. Jewell (BMR 10) and E.N. Jackson (BMR 10A), logging operators; J. Halls (BMR 10) and E. Beever (BMR 10A), drilling supervisors.

S.P. Willmott was the WAPET observer-geologist, and G.J. Netters (BMR 10) and G. Wallace (BMR 10A) were toolpushers for the contractor, Oil Drilling and Exploration (W.A.) Pty Ltd.

GEOLOGY

General Geology and Structure

BMR 10 and 10A were drilled in the Perth Basin, which is a trough of sediments that extends from about latitude 26^{o}S to the southern coast of Western Australia. The Darling Fault Zone, which can be recognized by physiographical, geological, and geophysical means, is the eastern margin of the Basin for most of its length. The western boundary of the Perth Basin is formed by the Dunsborough Fault, south-west of Bunbury (see Fig. 1). It is more difficult to define the northern and western margins of the Basin beyond the outcrop of the Ajana Ridge, but these limits can be taken as those of the northern and western margins of the Coolcalalaya Basin as shown in Konecki, Dickins, & Quinlan (1958, text-fig. 6).

A gravity survey showed the Carnarvon Basin to be continuous with the Coolcalalaya Basin (Konecki et al., 1958). Elsewhere, the Perth Basin extends under the adjacent Continental Shelf.

Faults in the Perth Basin trend northwards generally, but their strikes range from north-north-west to north-north-east.

Geophysical data (Vale, 1956; Thyer & Everingham, 1956; Newman, 1959) have revealed a buried anticline at Gingin, in addition to Beagle Ridge. Thyer & Everingham estimated a maximum thickness of 30,000 feet of unmetamorphosed sediments for the Perth Basin.

McWhae, Playford, Lindner, Glenister, & Balme (1958) described the stratigraphy of the Perth Basin, and summarized the information collected over the last century, including that most recently provided by a regional survey by WAPET. Sediments of uncertain age (late Precambrian to Silurian?), Permian, Triassic, Jurassic, Cretaceous, and Quaternary ages crop out within the Basin. Eocene strata have been found in deep water-bores.

In the Hill River - Cockleshell Gully area, where the wells were drilled, only the extensively faulted Jurassic sediments, Quaternary 'Coastal Limestone', and beach-sand dunes are exposed.

Stratigraphy of BMR 10 and 10A

The units penetrated in BMR 10 and BMR 10A are listed in Table 2. Composite Well Logs are shown in Plates 1, 2, and 3.

The evidence for the section above 3900 feet in BMR 10A is based mainly on the comparison of the S.P. logs of BMR 10 and BMR 10A to 3000 feet (the maximum depth logged in BMR 10) and on the correlation of the ditch cuttings below 3000 feet in BMR 10 with S.P. log between 3000 feet and 3900 feet of BMR 10A. The formation tops in BMR 10A are generally 25 to 30 feet deeper than in BMR 10.

Quaternary

'Coastal Limestone'

The upper part of the 'Coastal Limestone' is white to buff calcarenite, cavernous and massive; it contains rare coarse grains of quartz and dark minerals, and is fossiliferous (foraminifera, pelecypods, gastropods, echinoids). The basal 25 feet of 'Coastal Limestone' is a sandy, pale green-grey, massive, vuggy, recemented limestone, with coarse quartz grains (2.0 mm) disseminated through it.

The 'Coastal Limestone' commonly occurs along the coast of West Australia in a belt up to 10 miles wide; it is also found on offshore islands (e.g. Rottnest, Abrolhos) as much as 50 miles from the coast.

Although the 'Coastal Limestone' elsewhere is aeolian with marine intercalations (e.g. at Minim Cove, Moore River), the section penetrated in BMR 10 and 10A is dominantly marine. The upper part of the formation was deposited in a shallow, well-aerated neritic environment, as indicated by the abundance, variability, and quality of the benthonic fauna. The lower unit is probably the product of a littoral environment.

No detailed age determinations of the 'Coastal Limestone' were attempted, but the age is accepted as Pleistocene (Fairbridge, 1953).

Jurassic

Cockleshell Gully Sandstone *

The Cockleshell Gully Sandstone consists of friable, fine to very coarse-grained, poorly sorted sandstone with thin beds of pelitic sediments. The sandstone is generally grey-white, uneven-grained (the grains range in size from fine (0.2 mm) to conglomerate (7.5 mm)) and very friable, poorly bedded, cross-bedded, and in some parts interlaminated with black carbonaceous, micaceous siltstone. In the upper part of the formation the sandstone matrix is kaolinitic; below 500 feet the sandstone becomes increasingly feldspathic with increasing depth, and angular feldspar grains may constitute up to 10 percent of the rock by volume.

Pelitic sediments were not well represented in ditch cuttings from this formation, possibly because they had been partly absorbed into the drilling fluid. For the 103 feet cored, core recovery was poor (12 percent) and in five cores (50 feet) there was no recovery. Furthermore, the electric log showed little character. Nevertheless, three main pelite types could be recognized. First, a banded red and green shaly siltstone was observed in BMR 10 core 1 (100 feet - 110 feet). Additional thin beds of red, yellow, and brown siltstone were penetrated below 650 feet. Black carbonaceous, micaceous (occasionally pyritic) clayey siltstone with carbonized plant remains first appears at 270 feet and occurs throughout the formation, probably interlaminated as in core 6 of BMR 10 (600 feet - 610 feet). The third pelite type is a massive grey calcareous mudstone; slightly carbonaceous, and bearing rare pyritic nodules (10 mm - 15 mm thick). It was found only in BMR 10 core 5 (500 feet - 510 feet).

The base of the Cockleshell Gully Sandstone cannot easily be established as there is little character in the electric logs; cores near the probable base provide little or no information, and ditch samples are contaminated by cavings. A sharp rise in the S.P. profile is apparent at 952 feet in BMR 10, and is interpreted as a siltstone bed, but there is no indication of this lithology in the cuttings, and it could not be dated. Therefore, the base has been placed arbitrarily immediately above the uppermost siltstone bed that can be dated definitely as Triassic. Such a bed is present in BMR 10 core 11 (1105 feet - 1115 feet) and first appears on the electric log at 1097 feet.

The base of the Cockleshell Gully Sandstone probably does not outcrop anywhere in the Perth Basin. The rock-types of this formation in BMR 10 are not unlike those of the Moonyoonooka Sandstone (Playford, P.E., 1959) of the Chapman Group in the Geraldton area, especially in the feldspathic and kaolinitic sandstones. However, because of their thickness, proximity to the type section, and lithological similarity, they are referred to the Cockleshell Gully Sandstone (McWhae et al., 1958, p.99), in preference to the Moonyoonooka Sandstone, from which they differ most noticeably in the absence of 'Cannonball' ferruginous concretions and coarser grain-size.

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*1. Now known as 'Cockleshell Gully Formation'.

2. Subsequent deep drilling in the Perth Basin has suggested that two lithological units might be distinguished in the interval ascribed to the Cockleshell Gully Sandstone in these wells. The boundary between these units is not well defined, but is taken as 510 feet in BMR 10. From 101 feet to 510 feet is the 'Multicoloured Member' of the Cockleshell Gully Formation. The section between 510 feet and 1097 feet is either Lesueur Sandstone or basal Cockleshell Gully Formation.

TABLE I

Formations in BMR 10 and BMR 10A

Age	Formation	Depth (in feet)		Formation Top (Reduced level) (in feet)		Thickness (in feet)	
		BMR 10	BMR 10A	BMR 10	BMR 10A	BMR 10	BMR 10A
Pleistocene	'Coastal Limestone'	11	11	10	15	90	95
Jurassic	Cockleshell Gully Sandstone	101	106	-80	-80	996	1017
Triassic	Unit 'A'	1097	1123	-1076	-1097	367	363
	Unit 'B'	1462	1486	-1441	-1460	541	517
	*Kockatea Shale	2003	2003	-1982	-197	1287	1231
Permian	Carynginia Formation	?3290	3234	-3269	-3208	298	377
	Irwin River Coal Measures						
	Unit 'A'	3588	3611	-3567	-3585	322	383
	Unit 'B'		3994		-3968		678
	Unit 'D'		4672		-4646		122
		T.D.3910		T.D.-3889			
Precambrian	Basement		4794		-4768		68
		T.D.4862		T.D.-4836			(incomplete)

*The top of the Kockatea Shale in BMR 10A has been raised 27 feet to correspond to the top of a prominent siltstone bed which registers a distinct but small rise in resistivity and marks the top of a series of increased radioactivity recorded on the gamma ray log and overall decrease in S.P.

Balme noted that the microflora of BMR 10, core 5, although of Lower Jurassic age, is older than any previously examined from the Cockleshell Gully Sandstone. There is apparently no break in sedimentation from the Triassic into the Cockleshell Gully Sandstone, which must be thicker here than elsewhere. Between 100 feet and 1097 feet there is no palaeontological evidence.

The age of the Cockleshell Gully Sandstone in these wells is accepted as Lower Jurassic.

Triassic

A Triassic sequence, about 2200 feet thick, was penetrated. Three distinct units have been recognized, of which the upper two were previously unknown; these units have yet to be formally named.[1] Unit 'A' is fine-grained sandstone with minor beds of interlaminated sandstone/siltstone; Unit 'B' is an interbedded sandstone and siltstone formation that is transitional with Unit 'A'; the third unit is a thick sequence of impure sandstone (quartz greywacke and siltstone underlain by fossiliferous shale) that can be correlated with the Kockatea Shale.

Unit 'A'

The sandstone is light grey, kaolinitic or quartzose, moderately sorted, fine-grained, thin-bedded, and cross-bedded. Coarse and medium grains of sand are dominant in the ditch cuttings, but may be regarded as cavings from the overlying Cockleshell Gully Sandstone. Siltstone occurs interlaminated with sandstone; it is dark grey, carbonaceous, micaceous, rarely pyritic, and fissile. Laminae are generally sharply defined and tabular or lenticular, dipping at 5^{o}.

Unit 'A' and Unit 'B' are transitional, but their boundary in BMR 10 has been placed for convenience at the top of the first thick siltstone bed of Unit 'B' at 1462 feet.

Salient features of Unit 'A' are the absence of marine fossils, the fine-grained sandstone/siltstone beds, and the sharp interfaces between sand and siltstone laminae.

Sharp interfaces between sand and siltstone are possible in the process of sedimentation when there is electrolytic flocculation in salt water of the sand/mud mixture, in which the fine sand grains are borne in the mud suspension. The resolution of the water-borne load's system into its components, the sand and sand/mud mixture, and the resultant lamination, is possible after current velocity has fallen below that necessary to transport the sand, which is 'dumped'. Given the same components and a fresh water environment, graded bedding will result.

The absence of marine fossils is striking but by no means surprising. Shepard (1956) has shown that marine organisms (shells, foraminifera, echinoids, ostracods) constitute less than 0.25 percent of the coarse fraction of delta-front platform deposits, but elsewhere they are more common. Hence, it seems that Triassic Unit 'A' is a proximal fluviomarine sediment deposited on a delta-front platform on which sedimentation at least kept pace with subsidence.

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1. Triassic Units 'A' and 'B' together have since been named 'Woodada Formation'.

Because of lack of information on the precise distribution and character of the Triassic and Jurassic of BMR 10 elsewhere in the Perth Basin, and particularly in the Hill River/Cockleshell Gully area, it is impossible to say very much about the deltaic sedimentation from this succession.

Balme examined BMR 10 cores 11 (1105 feet - 1115 feet), 12 (1213 feet - 1223 feet), and 14 (1408 feet - 1418 feet) and compared some features of the microflora in BMR 10, core 14, with beds of the Fitzroy Basin that have been correlated with the Erskine Sandstone. He suggested that BMR 10, core 14, was of Lower to Middle Triassic age, and determined a Middle to Upper Triassic age for BMR 10, cores 11 and 12.

Unit 'B'

Unit 'B', also previously unknown in the Perth Basin, is composed of interbedded fine-grained sandstone and interlaminated siltstone/sandstone with a bed of intraformational shale-breccia in a sandstone at 1800 feet in BMR 10. Typically, the sandstone is light grey, kaolinitic, moderately sorted, fine to medium-grained, massive or well-bedded, thin-bedded, and cross-bedded. Siltstone is interlaminated with sandstone, and is dark grey, carbonaceous, micaceous, in part pyritic, and argillaceous. Laminae dip at 5^{o}.

Lithological properties are similar to those of Unit 'A', but the siltstone/sandstone ratio has increased. It is suggested that Unit 'B' was deposited on a delta-front platform in deeper water than Unit 'A'; possibly a lower part of the section was deposited as proximal fluviomarine sediment at the pro-delta slope.

No data on age determinations of Unit 'B' are available. It is regarded tentatively as being Middle Triassic.

Kockatea Shale

The Kockatea Shale has been defined by McWhae et al., (1958, p.83-84) as follows: 'The name Kockatea Shale is proposed for a sequence of light grey to white, greenish-grey and red shale, with interbedded siltstone and sandstone, exposed in a limited area around the junction of Kockatea Gully and the Greenough River, and encountered in various bores between Geraldton and Tenindewa. Exposures in the type area near the mouth of the Kockatea Gully (28^{o} 33'S, 115^{o} 10'E) are up to 25 feet thick. They consist of light grey shale, mottled pink, yellow and purple, grading into siltstone with thin beds of purple ferruginous shale, and a bed of medium to coarse-grained sandstone at the base of the exposed section'. In BMR 10 this formation consists of dark grey micaceous, carbonaceous, sandy siltstone with thin interbeds of light grey kaolinitic, micaceous, poorly sorted, fine-grained sandstone (quartz greywacke) underlain by a uniform dark green-grey shale with very thin beds and lenticles of light grey silty sandstone and siltstone; rare calcareous beds appear at about 2500 feet and become abundant below 3000 feet.

The shale is dark green-grey, slightly micaceous, silty in part, massive or well-bedded, thin-bedded, and fissile. Bedding planes and planes of fissility dip 5^{o} - 10^{o} (visual estimation). Slump structures and contorted laminae are common high in the formation but rare lower in the sequence. Cross-bedding is also present, and cone-in-cone structure has been noticed in BMR 10 core 27 (2494 feet - 2504 feet). The formation is fossiliferous throughout. Salt water is present in cores but it is uncertain whether this water is connate or secondary.

The fauna of the Kockatea Shale is rich and diverse. It contains fish fragments (maxillae, scales, spines, skin); amphibian or reptilian head; pelecypods (pteriids including cf. Bakevillia, nuculids cf. Claraia, arcomyids, etc.); estheriids; ammonites (including cf. Subinyoites, but generally indeterminable impressions and aptychi); ostracods; serpulids; lingulid brachiopods; bone fragments and xiphosurans. Worm tubes and trails and carbonized wood fragments occur towards the top of the unit. The microflora is poor in spores, but microplankton (hystrichosphaerids) are present throughout the formation. Both palaeontologically (spores and microplankton) and lithologically the section between 2162 feet and 3290 feet in BMR 10 can be referred to the Kockatea Shale.

The quality of the fauna and the microflora, in which the spore content is low, indicate a marine environment of deposition. It is suggested that the Kockatea Shale represents sediment of the foreset beds of the pro-delta slopes and the bottomset beds of the ocean shelf with deltaic influence.

Balme (1963) has suggested a Lower Triassic age for the microflora from the Kockatea Shale. A study of the macrofauna by Dickins & McTavish (1963) showed the presence of Lower Triassic guide fossils Claraia (pteriid pelecypod) and Subinyoites (ophiceratid ammonite). Subinyoites is reported from the Salt Range, India, and is a lower Scythian genus. Also, it was noticed that the fauna is different from and younger than the fauna of the Hardman Member of the Liveringa Formation of Upper Permian, possible Tatarian, age in the Canning Basin. Furthermore, the content of the fauna is close to that of the Blina Shale (Reeves, 1951), which has estheriids, lingulid brachiopods, fish, and amphibian remains.

Therefore, on five criteria age indicated by the microflora; faunal differences from the Upper Liveringa fauna; faunal similarity to the Blina Shale fauna; presence of Claraia; and presence of Subinyoites a Scythian, possibly lower Scythian, age is suggested for the Kockatea Shale. Evidence from Dickins & McTavish (1963) has confirmed an early Scythian (Otoceratan) age for this fauna.

According to McWhae et al. (1958, p.84) the formation is 1091 feet thick in the Geraldton Municipal Bore, more than 1131 feet thick in the Geraldton Racecourse Bore, and 201 feet thick in the 47 1/4 mile-peg Bore. From the above evidence it seems likely that the Kockatea Shale may extend subsurface everywhere below the Jurassic in the northern part of the Perth Basin.

Permian sediments underlie the Kockatea Shale, but the contact is not obvious. The base of the Kockatea Shale is taken as being at 3290 feet on the evidence from the ditch samples.

Permian

The Permian section in BMR 10A is about 1560 feet thick. It can be divided into four units, but the definition of their boundaries is not always easy. The uppermost unit is dominantly a siltstone with marine fossils in its upper half. Below this is a sequence of interbedded carbonaceous siltstone and sandstone that passes gradually into the third unit, which is composed of rapidly alternating sandstone, siltstone, and shale with occasional thin beds of coal. The basal unit consists of interbedded dark coloured siltstone and sandstone, both of which are slightly calcareous and fossiliferous, some claystone, and a thin limestone bed.

Carynginia Formation

The Carynginia Formation is described by Playford & Willmott in McWhae et al. (1958), where it is stated (p. 78): 'it is characterized by micaceous grey siltstone, with interbedded yellow and white fine-grained sandstone and rare beds of fine conglomerate'. In the wells, this formation consists of black, carbonaceous, slightly micaceous, argillaceous siltstone, pyritic in parts, and poorly bedded, with thin lenticles of light grey, silty, fine-grained sandstone. Slumping is common.

Dickins (in Dickins, McTavish, & Balme, 1961) and Appendix D reports 'Chonetes' sp., Strophalosia sp., Permorthotetes'? sp., and Neospirifer sp. as well as a conulariid from the upper part of this unit. Microplankton, spores, and pollen grains are also present. Worm tubes have been observed, and wood fragments occur near the base.

The top of this formation can easily be recognized by the marked change in lithology from the Triassic calcareous shale and siltstone to dominantly carbonaceous siltstone containing Permian fossils. In BMR 10A, the top of the formation is taken as the top of the bed showing the first rise in S.P. below the thick section of Triassic shale, which registers a strikingly uniform S.P. This bed is immediately below the Triassic calcareous bed, which has a high resistivity in contrast to the resistivity of the Carynginia Formation. There is also a sharp change from the carbonaceous siltstone of this formation to the thick sandstone bed which marks the top of the Irwin River Coal Measures in BMR 10A and shows a high S.P. and resistivity, but very low radioactivity on the gamma-ray log.

Lithologically, this formation is most like the Indarra Beds (Playford & Willmott, in McWhae et al., 1958) but the palaeontological evidence, which suggests an Artinskian age, does not support correlation with the Indarra Beds; nor does the disconformity between Permian Unit 'A' and the Triassic, for the Indarra Beds/Kockatea Shale section is apparently conformable. Correlation with the Mingenew Formation (Playford & Willmott, loc. cit.) or Carynginia Formation is more probable. Both these formations have yielded marine fossils, but so far, with the exception of one indeterminate pelecypod, only microfossils-foraminifera (Crespin, 1958) and microplankton (Balme in McWhae et al., 1958) - have been found in the Carynginia Formation. However, a fauna of megafossils has been found in the Mingenew Formation; brachiopods and pelecypods were identified by Dickins (1956).

The fauna of the Carynginia Formation of BMR 10 and BMR 10A is sparse, and correlation based on it, in the light of our present knowledge of brachiopod distribution in the Perth Basin, would be unsound. The presence of megafauna and its composition suggest that, of the Permian megafaunas known from the Perth Basin, that from the Mingenew Formation might be a member in the Carynginia Formation. Alternatively a thin section of Mingenew Formation might be present in the Beagle Ridge wells.

The paucity of its benthonic fauna, the presence of worm-burrows, wood fragments, the uniform silty lithology, the high carbonaceous content, and the presence of small-scale slump structures together indicate that the formation was deposited in a shallow-water marine environment of restricted circulation, perhaps as the bottomset beds of a delta.

However, because it conformably succeeds the Irwin River Coal Measures, because of its lithology, and because of its microflora, the formation is identified with the Carynginia Formation, which is Artinskian. The age of the Carynginia Formation has been considered in some detail in Dickins et al. (1961) and Dickins (Appendix D). An age similar to the Artinskian - most likely the lower-part of the Byro Group has been suggested. The

formation crops out in the Irwin River area, and near Woolaga Creek it is 846 feet thick.

Irwin River Coal Measures

According to Playford & Willmott (in McWhae et al., 1958, p. 7), 'The Irwin River Coal Measures is a sequence of rapidly alternating siltstone and fine to medium-grained sandstone, with lenticular coal beds and carbonaceous clay'. At Beagle Ridge, this formation has been divided into two members on the evidence of lithology and the electrical logs.

Member A*

This unit consists of moderately sorted, very fine to medium-grained, light grey, kaolinitic sandstone and quartz greywacke, which is interbedded with black, carbonaceous shale and fissile siltstone. Rare, very thin beds of moderately sorted, coarse-grained to very coarse-grained sandstone occur near the base.

Slump structures, contorted laminae, and worm burrows have obscured or obliterated much of the bedding. However, the sandstone appears to be thin-bedded and to show cross-bedding in parts and rare graded-bedding. The graded bed in BMR 10, core 41 (3810 feet - 3820 feet) is six inches thick and grades upwards from fine-grained silty sandstone to shaly carbonaceous siltstone. Large ditch cuttings have shown grading between the same rock types but the magnitude and end products of the grading cannot be determined. A bed of intraformational breccia between 3720.5 feet and 3722 feet in BMR 10, core 40 contained pebbles (maximum 7.5 cm) of sandstone in black shaly siltstone. The dip of the bedding is 10^{o} - 15^{o}. Slickensides are present throughout the formation, but maximum vertical displacement is only about 2.5 cm.

Other than worm burrows and occasional pyritized plant fragments, no megafossils have been found in this formation at Beagle Ridge. However, a single specimen of foraminifera, Hyperammina, has been found in BMR 10 core 40 (Belford, pers. comm.) and spores are present (Balme in Willmott, 1959).

A slight hydrocarbon show was present in BMR 10, core 40 (3710 feet to 3722 feet), and light brown oil-staining was observed in an 18-inch bed of porous fine-grained kaolinitic sandstone at 3720 feet. Within a less porous band in this sandstone bed visible intergranular oil giving a bright yellow fluorescence was present. A detailed study of this show is given in Appendix B.

The top of this formation corresponds to the top of the uppermost thick sandstone bed (30 feet) encountered in the Permian section of BMR 10 and BMR 10A. Although the formation is distinct from those above and below it, its base is difficult to distinguish, because of its transitional contact with member 'B'. Therefore the base has been defined arbitrarily to coincide with the base of the bed immediately overlying the first siltstone above the highest coal seam of the Irwin River Coal Measures.

This unit has been included in the Irwin River Coal Measures, but it is possible that part at least might belong in the Carynginia Formation, for it apparently has not been recognized in the surface outcrop. Clarke, Prendergast, Teichert,& Fairbridge (1951) chose

* Comment by J.M. Dickins: In the original unpublished report on BMR 10A the Carynginia Formation of this Report was referred to Permian Unit 'A', and 'Member A of the Irwin River Coal Measures' was identified as Carynginia Formation. This identification was followed in Dickins & MacTavish (1963). As indicated in this section the relationship of this part of the outcrop sequence, particularly in the type area, with that in subsurface remains an unresolved problem. More information from outcrops may clarify the relationship.

the top of the sandstone overlying the uppermost coal seam in the section along the North Branch of the Irwin River, that is, about 20 feet above the top of the seam. In this sense, only Member 'B' should be regarded as Irwin River Coal Measures.

The type section of the Carynginia Formation is too discontinuous for reliable measurements. However, the 846-foot section along Woolaga Creek has less than ten feet of sandstone below the lowermost thick siltstone member. In both sections mentioned the Carynginia Formation and Irwin River Coal Measures are in contact. Between the base of the lowest thick siltstone unit of the Carynginia Formation and the uppermost coal seam of Irwin River Coal Measures in the wells is 400 feet of section not exposed at the surface. This is essentially Member 'A'. It seems to be closer to the Irwin River Coal Measures than the Carynginia Formation. Indeed it seems to differ from the former unit only in the absence of coal and its lower average resistivity.

Member 'A' has therefore been included with the Irwin River Coal Measures because of its closer similarity to that formation. However, it should be realized that its section is additional to that assigned in this well to the Irwin River Coal Measures as defined by Clark et al. (1951). Therefore, it might be desirable at a later date to raise this unit to formation status if it is encountered again.

As pointed out by G. Playford (1959, p. 20), the decision by Johnson, de la Hunty, & Gleeson (1954, p. 49) to include the Carynginia Formation with the Irwin River Coal Measures is untenable, despite their transitional contact. The selection of the boundary between the Irwin River Coal Measures and the overlying Carynginia Formation both in this Report and by Clarke et al. (1951) is arbitrary because of the transitional and apparently conformable contact. However, the formation top in this Report was chosen to coincide with the top of a unit, recognizable on the S.P. log, which includes the youngest coal seam.

For reasons similar to those presented for the interpretations of the environments in which Triassic Units 'A' and 'B' accumulated, it is considered that this member of the Irwin River Coal Measures was deposited in a delto-marine environment. In addition, slump structures, contorted laminae, and intraformational breccia, which may be a result of sub-aqueous gliding, indicate that this environment was on the pre-delta slope, and that this formation represents the foreset beds of a delta.

Member 'B'

Member 'B' comprises a sequence of rapidly alternating sandstone, siltstone, shale, and thin coal beds. As in Member 'A' high-angle slickensides are common, but the maximum displacement appears to be only about 1.5 cm.

This coal-bearing sequence in BMR 10A can be identified readily with the Irwin River Coal Measures because of its age (Artinskian), its rapid changes in lithology, its coal content, and the obvious similarity of its environment of deposition to that suggested for the Irwin River Coal Measures in the Woolaga Creek area (Playford, G., 1959).

The environment of deposition of the Irwin River Coal Measures was considered in some detail by G. Playford (1959), who enumerated several criteria by which he determined it. A few of the criteria (rapid alternation of rock types, presence of well-preserved plant fossils, absence of marine fossils, evidence of worm activity, assumed presence of primary pyrite, and small-scale cross-bedding) are present in the coal measures of Beagle Ridge. Additional supporting evidence from Beagle Ridge is the presence of small-scale cut-and-fill structures. Playford concluded that 'the Irwin River Coal Measures are considered to represent a composite fluviatile and paludal deposit, which possibly accumulated as the topset component of a delta'.

The only megafossils observed in the Irwin River Coal Measures were leaf impressions, and some worm-tubes near the top of the formation (BMR 10, core 4, 4010 feet - 4020 feet).

In BMR 10A, the Irwin River Coal Measures are 1061 feet thick. This formation is known from the Irwin River area, 60-80 miles north-north-east of Beagle Ridge, where the type section on the Irwin River near High Cliff is 217 feet thick. At Woolaga Creek, the formation is about 400 feet thick (Playford, G., 1959). P.E. Playford & Willmott (in McWhae et al., 1958, p.77) have stated, 'The unit is also believed to be present in the Eradu area, where Permian coal seams with associated sandstones are known from bores. Exposures tentatively referred to the Irwin River Coal Measures are also known from the Greenough River in this area. Further palynological work is necessary to confirm this correlation.'

Permian Unit 'D'*

Unit 'D' comprises interbedded dark-coloured siltstone, quartz greywacke, some claystone, and a thin bed of limestone. The siltstone is dark grey to black, carbonaceous, slightly calcareous, poorly bedded, with occasional lighter grey fossiliferous bands. The arenite is dominantly quartz greywacke; it is grey or greenish white, slightly calcareous, and in parts carbonaceous, generally poorly sorted, fine (0.1 mm) to very coarse-grained (1.5 mm), grains usually subangular, but some coarse grains rounded and frosted. Claystone is present in sidewall core SWC 11 (4750 feet), where it is greenish grey, calcareous, and soft. Limestone is prominent only near the base of the formation. It is buff, massive, and fossiliferous. Other thin limestone or calcareous beds can be interpreted in this formation from the resistivity logs, but they are not apparent in the ditch cuttings.

The top of this formation is taken as the top of the first calcareous bed recognizable on the resistivity logs, and its base is the base of the limestone resting unconformably on the metamorphic basement complex.

Fossils are present throughout the formation and include spiriferids and Strophalosia. Worm burrows are present in core 12 (4691 feet - 4701 feet). The fossil evidence implies a marine environment of deposition. The dark highly carbonaceous siltstone suggests that restricted circulation may have dominated conditions during at least part of its deposition.

Although Unit 'D' conforms well with the definition of the Fossil Cliff Formation in that it contains interbedded siltstone and sandstone, with some limestone, and is fossiliferous, its fauna appears to be more akin to that of the High Cliff Formation at Woolaga Creek (Dickins, 1957; and Appendix 'D'). However, fossiliferous material available from BMR 10A is inadequate for definite conclusions concerning its correlation. Each of these formations is commonly thin, so it is possible that both might be present in this unit.

Basement

In BMR 10A a gneissic rock taken as basement was first recognized in core 13 (4803 feet - 4813 feet). The gamma-ray and S.P. logs indicate that basement was first encountered at 4794 feet. The basement complex penetrated to total depth (4862 feet) contained granitic augen gneiss, quartz-feldspar-biotite-garnet schist, and pink and white ?pegmatite.

* On the evidence of the electrical log and lithology of these wells, it would be preferable for the boundary between these units to be selected at 4024 feet. The top at 3994 feet has been selected in accordance with the original definition of this formation by Clarke et al. (1951).

The Precambrian rocks of the southern part of the Greenough Block were discussed by P.E. Playford (1959, p. 104), who reported garnetiferous granite gneiss and granulite. Comparison of the metamorphics of BMR 10A with this suite indicates that the quartz-feldspar-biotite-garnet schist may be similar in composition to the garnet gneiss of the Greenough Block, which is approximately 1.1×10^9 years old, but their textures and grain sizes are, of course, different. Also, the augen gneiss may be similar to the acidic gneiss which grade into granulites in some localities.

With the available evidence, correlation of the basement complex of BMR 10A with part of the Precambrian suite from the Greenough Block is suggested. Also, as basement in BMR 10A is probably composed of part of the 'younger' Precambrian metamorphic complex (1.1×10^9 years) of Western Australia similar to that known from the Greenough Block, it may represent an en-echelon-faulted southern extension of the Greenough Block.

Contributions to Geological Knowledge

Basement at Beagle Ridge which is about 4800 feet below sea level, is composed of a rock suite dominantly of high-grade metamorphics comparable to those from the southern part of the Greenough Block, about 60 to 100 miles north of BMR 10A, and is possible a faulted southern extension of the Greenough Block.

The oldest sediments at Beagle Ridge are of Lower Permian (probably Artinskian) age. Hence it is probable that Beagle Ridge was above sea level during the Palaeozoic up to and including the Sakmarian. The submergence of the ridge in the early Artinskian times may have been affected by melting of the continental ice-caps.

Sediments of Pleistocene, Lower Jurassic, Triassic, and Permian age were penetrated in BMR 10 and BMR 10A. Several interesting points arose concerning the succession.

(a) From the age determined by palynological studies, the Cockleshell Gully Sandstone at Beagle Ridge appears to contain slightly older strata than any previously ascribed to it.

(b) A thick Triassic sequence of marine and deltaic sediments previously unknown from the Perth Basin has been recognized. Although it is unlikely that the entire Triassic is represented in this succession the strata range in age from Lower Triassic (Scythian) to Upper Triassic. This Triassic sequence will probably be found underlying the Jurassic almost everywhere in the Perth Basin. Two new Triassic units and the Kockatea Shale have been distinguished. Evidence from the rich marine fauna, which includes the first definite Triassic ammonites found in Australia, enables a Scythian age determination to be made for the Kockatea Shale.

(c) Upper Permian sediments appear to be absent. Hence there has been a probable hiatus between Artinskian and Lower Triassic which may have been associated with mild tectonic activity. Apart from this hiatus no marked break in sedimentation is apparent until that between the Lower Jurassic and Pleistocene.

(d) Although the Permian succession encountered in BMR 10 and BMR 10A could be associated readily with the Permian of the Irwin River area, precise correlation of the upper and lower limits of the sequence on the basis of the fossil material available is conjectural. The Irwin River Coal Measures at Beagle Ridge are much thicker than those of the Irwin River area and the coal is of a higher rank.

Unfortunately the cores were not oriented, so it is impossible to determine the direction, true magnitude, and subsequently the full significance of their dips. Dips of 5^{o} - 10^{o} in BMR 10 were considered to be primary structures whose attitudes were determined by the slope of the sedimentary environment, with only slight modification by tectonism. Below 4900 feet in BMR 10A dips range from 10^{o} - 20^{o} and increase with depth and it is likely that tectonism played a greater role than in the younger sediments. Alternatively, the uniform decrease in dip upwards may be simply a result of lateral thickening of the units away from the crest of Beagle Ridge.

High-angle slickensides with small vertical displacement in many cores from the Kockatea Shale and Permian sediments of BMR 10 and BMR 10A are more probably a result of compaction of the sediments than of tectonic activity.

During deposition of the Permian and Mesozoic sediments on Beagle Ridge conditions were stable, except for some possible minor tectonism between Artinskian and Lower Triassic times.

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APPENDIX A(i)

CORE RECORDS: BMR 10

Core No.	Section Cored (in feet)	Recovery (in feet)	% Recovery
1	100- 110	3	30
2	205- 215	-	-
3	260- 270	-	-
4	381- 396	1/2	3.3
5	500- 510	1 1/2	15
6	600- 610	1/2	05
7	713- 723	7	70
8	803- 813	-	-
9	893- 903	-	-
10	983- 993	-	-
11	1105-1115	3	30
12	1213-1223	6	60
13	1317-1327	1/4	2.5
14	1408-1418	1 1/2	15
15	1508-1518	6	60
16	1617-1627	2 1/2	25
17	1710-1720	1 1/2	15
18	1800-1810	7 1/4	72.5
19	1891-1901	8	80
20	2011-2021	6	60
21	2103-2113	2	20
22	2131-2141	8 1/2	85
23	2223-2233	1	10
24	2233-2243	6	60
25	2314-2324	10	100
26	2405-2415	8 1/2	85
27	2494-2504	6 1/2	65
28	2614-2624	8	80
29	2707-2712	5	100
30	2802-2812	10	100
31	2902-2912	7 1/4	72.5
32	2993-3003	6	60
33	3105-3115	5	50
34	3193-3203	3	30
35	3203-3213	6 1/2	65
36	3300-3310	5	50
37	3400-3410	10	100
38	3497-3507	7	70
39	3587-3597	9	90
40	3710-3722	12	100
41	3810-3820	7	70

CORE DESCRIPTIONS

Core 1 (100' - 110') Recovered 3 feet.

1 3/4' - Limestone, (calcarenite), light grey-green, massive, recemented, dense, with cavities up to 3 cm; coarse quartz grains (2.0 mm) disseminated throughout.

1 1/4' - Siltstone, green-grey and blood-red, banded, very fine-grained, argillaceous, unfossiliferous.

Core 2 (205' - 215') No recovery.

Core 3 (260' - 270') No recovery.

Core 4 (381' - 396') Recovered 1/2 foot.

1/4' - Sandstone, light grey, kaolinitic, with black carbonaceous laminae, grains uniform, medium-grained (0.3 mm - 0.5 mm, and rarely 2.0 mm), in part micaceous, cross-bedded, friable.

1/4' - Sandstone, light grey, kaolinitic, uneven-grained, grains to 5.0 mm, friable. (Quartz greywacke in character).

Core 5 (500' - 510') Recovered 1 1/2 feet.

3/4' - Sandstone, grey-white, feldspathic, medium to coarse-grained (0.5 mm - 1.0 mm), sorting fair, massive, friable, porosity low.

1/2' - Sandstone, grey, banded, with black carbonaceous laminae about 2.0 mm thick, feldspathic, medium-grained (0.2 mm - 0.5 mm), slightly graded, cross-bedded, friable.

1/4' - Mudstone, grey, calcareous, slightly carbonaceous, massive, with pyrite nodules (Nodules: 60% pyrite, 40% coarse quartz grains of about 1.5 mm).

Core 6 (600' - 610') Recovered 1/2 foot.

1/2' - Sandstone, white, light grey, feldspathic, poorly sorted, medium to coarse-grained (0.5 mm - 1.5 mm, with some grains 5.0 mm), subangular, laminated with black carbonaceous laminae, cross-bedded, friable, porosity low.

Core 7 (713' - 723') Recovered 7 feet.

7' - Alternating sandstone and conglomerate.

Sandstone, grey, slightly calcareous, feldspathic, with occasional dark bands, grains quartz 80% - 90%, feldspar 10% - 20%, sorting fair, coarse-grained (1.0 mm), cross-bedded.

Conglomerate, mottled grey/white, feldspathic, grains quartz 60% - 70%, feldspar 30% - 40%, sorting fair, pebbles 5.0 mm - 7.5 mm, subangular.

Core 8 (803' - 813') No recovery.

Core 9 (893' - 903') No recovery.

Core 10 (983' - 993') No recovery.

Core 11 (1105' - 1115') Recovered 3 feet.

1 3/4' - Interbedded sandstone and siltstone.

Sandstone, light grey, quartzose with traces of feldspar and mica, well-sorted, fine-grained (0.1 mm - 0.2 mm), poorly bedded, dense, porosity low.

Siltstone, dark grey, carbonaceous and micaceous, fissile, with lenticular argillaceous laminae. Dip 5°*.

1/4' - Siltstone, grey-white, quartzose, laminated with dark grey micaceous laminae, cross-bedded. Dip 5°.

1' - Shale, grey, with laminae of white siltstone and a lens of coarse-grained feldspathic sandstone 5 cm x 1 cm x 1 cm. Dip 10°.

Core 12 (1213' - 1223') Recovered 6 feet.

1/2' - Sandstone, light grey, kaolinitic, moderately sorted, fine-grained (0.1 mm - 0.3 mm), rare nodules of pyrite, cross-bedded, laminated, with grey-black micaceous laminae increasing with depth. Dip 5°.

5 1/2' - Interbedded sandstone and shale, medium-bedded.

Sandstone as above.

Shale, grey to dark grey, micaceous, argillaceous, and laminated in part, with laminae of sandstone or siltstone.

Core 13 (1317' - 1327') Recovered 1/4 foot.

1/4' - Sandstone, white, kaolinitic, quartz 60%, well-sorted, fine-grained (0.1 mm - 0.2 mm, very rarely 1.5 mm), occasional grains ferruginized, poorly bedded with interbeds black, micaceous, carbonaceous, in part pyritic, very thin-bedded, porosity low.

Core 14 (1408' - 1418') Recovered 1 1/2 feet.

1/2' - Sandstone, grey, quartzose, with clots 5 mm - 10 mm of pyrite and blue-grey shale, grains well-sorted, fine (0.2 mm), subangular, massive, porosity low.

1' - Shale grey, calcareous, slightly micaceous, massive, with clots of sandstone as above, and pyrite.

Core 15 (1508' - 1518') Recovered 6 feet.

6' - Interlaminated siltstone/sandstone, well-bedded, cross-bedded. Dip 5° - 10°.

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* All dip information was made by visual estimation.

Siltstone, dark grey and black, micaceous, carbonaceous in part, also traces of grey shale, porosity very low.

Sandstone, grey-white, kaolinitic, poorly sorted, fine to medium-grained (0.2 mm - 0.3 mm), porosity low.

Core 16 (1617' - 1627') Recovered 2 1/2 feet.

2 1/2' - Interlaminated siltstone/sandstone. Dip 5°.

Siltstone, dark grey, micaceous, bedded, porosity poor.

Sandstone, in laminae of 2.0 mm, poorly sorted, grey-white, fine-grained, porosity low, and lenticular bed (2.5 cm) of brown massive dolomite.

Core 17 (1710' - 1720') Recovered 1 1/2 feet.

1 1/2' - Interlaminated siltstone/sandstone, well-bedded, cross-bedded. Dip 5°.

Siltstone, dark grey, micaceous, with laminae (1.0 mm) of sandstone as in Core 16.

Core 18 (1800' - 1810') Recovered 7 1/4 feet.

(a) 1/2' - Sandstone, grey, kaolinitic, poorly sorted, medium-grained (0.5 mm), bedded, porosity low, interlaminated with siltstone in 1.0 mm laminae, dark grey, micaceous, and cross-bedded at the base. Dip 10°.

(b) 1 1/2' - Sandstone, grey, kaolinitic, micaceous, poorly sorted, medium-grained (0.5 mm), poorly bedded, porosity low. (Quartz-greywacke in character).

(c) 1 1/4' - Interlaminated sandstone/siltstone as in (a).

(d) 2 1/4' - Sandstone-breccia of dark grey, poorly sorted, gritty to pebbly, massive sandstone with pebbles of brecciated dark green-grey shale (2 mm to 20 mm) as angular blocks and slivers in kaolinitic sandstone matrix, and 3" bed of well-bedded micaceous siltstone. (Probable intraformational breccia).

(e) 1/4' - Interlaminated siltstone/sandstone as in (a), siltstone fraction decreasing towards the base of the bed from 60% to 20%, bedded, cross-bedded. Dip 10°.

(f) 3/4' - Sandstone-breccia as in (d) with pebbles up to 50 mm of dark grey and chocolate brown shale and 2 - 3 cm beds of sandstone as in (a).

(g) 1/4' - Siltstone, dark grey, micaceous, clayey, cross-bedded, and bedded, with sandstone laminae.

Core 19 (1891' - 1901') Recovered 8 feet.

8' - Interlaminated siltstone/sandstone, cross-bedded. Dip 10°.

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Sandstone component ranging through 80% (3 1/3') to 40% - 20% (3/4') to 60% - 80% (4') towards the base. Light grey-brown, kaolinitic, micaceous, slightly pyritic - pyrite as 1 mm grains and rare nodules, poorly sorted, medium-grained, grains subrounded, porosity low.

Siltstone (as lenticular laminae) dark grey, black, micaceous (mica flakes about 1 mm), well-sorted, with traces of carbonaceous material.

Core 20 (2011' - 2021') Recovered 6 feet.

(a) 1/2' - Siltstone, dark grey, micaceous, well-sorted, poorly bedded, porosity low.

(b) 5 1/2' - Shale interbedded with siltstone and sandstone laminae.

Shale, grey-black, micaceous, laminated, with minor blebs of sandstone.

Siltstone, as in (a), cross-bedded, laminated, with laminae of sandstone, grey, micaceous, uneven-grained, fine-grained, porosity low.

Shale 10-20%, Siltstone 70-80%, Sandstone 10%.

Core 21 (2103' - 2113') Recovered 2 feet.

2' - Interlaminated siltstone/sandstone, bedded at the top, then laminae contorted, with snowball swirls in the lower half, the basal 1/4' cross-bedded. Salty taste.

Siltstone, grey-black, micaceous, slightly carbonaceous mica flakes, well-sorted, wood fragments.

Sandstone, grey-white, kaolinitic, very poorly sorted, argillaceous, dominantly very fine-grained (grains up to 1.0 mm). (Quartz-greywacke in character).

Core 22 (2131' - 2141') Recovered 8 1/2 feet.

8 1/2' - Interlaminated siltstone/sandstone, bedded, extensively slumped throughout, reticulated by worm tubes infilled with silty kaolinitic sandstone, fossiliferous - rare lingulid brachiopod. Salty taste.

Siltstone, dark grey and black, micaceous, slightly carbonaceous, coarse-grained in part.

Sandstone, grey to white, kaolinitic, poorly sorted, fine-grained (0.1 mm) grading to siltstone, porosity low. (Quartz-greywacke in character).

Core 23 (2223' - 2233') Recovered 1 foot.

1' - Shale, dark green-grey, slightly micaceous, silty in part, massive, poorly bedded, fissile, fossiliferous - lingulid brachiopod. Dip 5°.

Core 24 (2233' - 2243') Recovered 6 feet.

6' - Shale, dark green-grey, slightly micaceous and carbonaceous, silty in part, with very fine-grained, thin siltstone interbeds, grey white, non-calcareous, slumped in parts, fossiliferous-pelecypods, gastropods, fish maxillae. Dip 5°.

Core 25 (2314' - 2324') Recovered 10 feet.

10' - Shale, dark grey, slightly micaceous, hard, fissile, bedded, with thin interbeds (5 mm) of fine-grained grey siltstone and lenticles in part slumped, and 2.5-cm band of fossiliferous, grey-white, kaolinitic, silty, fine-grained (0.1 mm) sandstone-fossils include pelecypods, gastropods, ganoid fish scales.

Core 26 (2405' - 2415') Recovered 8 1/2 feet.

8 1/2' - Shale, dark grey, slightly micaceous, hard, fissile, bedded, with interbeds and lenses of siltstone becoming shale (grey, massive, soft), occasionally slumped, fossiliferous-indeterminate fossil fragments. Dip 10°.

Core 27 (2494' - 2504') Recovered 6 1/2 feet.

6 1/2' - Shale, dark grey, silty, hard, fissile, well-bedded, with lenticular interbeds of sandstone, grey-white, massive, poorly sorted, fine-grained, argillaceous, porosity low, and rare limestone (especially near the top) grey, massive, interbeds, occasionally pinched out, slumped throughout, cross-bedded, and cone-in-cone structure at 2 1/2', at top 1/2' bed of calcilutite. Dip 10°.

Core 28 (2614' - 2624') Recovered 8 feet.

8' - Shale, dark grey-green, micaceous, silty in part, well-bedded, and fissile, with interbeds of siltstone, grey-white, massive, sandy in part, poor porosity, fossiliferous -pyritized ceratid ammonites, fish, pelecypods. Dip 10°.

Core 29 (2707' - 2712') Recovered 5 feet.

5' - Shale, dark green-grey, slightly micaceous, very fine, in part silty, well-bedded, fissile, with interbeds of siltstone, grey-white, very fine to medium-grained, massive, porosity poor, fossiliferous-indeterminate ammonite, pelecypods. Dip 10°.

Core 30 (2802' - 2812') Recovered 10 feet.

10' - Shale, dark green-grey, slightly micaceous, arenaceous, silty in part, well-bedded, fissile, with interbeds of siltstone, grey-white, very fine to coarse-grained, massive, porosity low, and rare calcilutite lens, fossiliferous-ammonites, pelecypods, Xiphosuran. Dip 10°.

Core 31 (2902' - 2912') Recovered 7 1/4 feet.

7 1/4' - Shale and siltstone as in core 30, and occasional limestone lenses, white, massive, in parts contorted, fossiliferous-ammonites, pelecypods. Dip 10°.

Core 32 (2993' - 3003') Recovered 6 feet.

6' - Shale as in core 31, with siltstone, light brown-grey, massive, hard, in 5 mm interbeds, fossiliferous-ammonites, worm tubes. Dip 10°.

Core 33 (3105' - 3115') Recovered 5 feet.

5' - Shale, as in core 31, with siltstone interbeds as in core 32, and calcilutite, grey-white, massive, soft, in contorted lenticles, fossiliferous—ammonites. Dip 10°.

Core 34 (3193' - 3203') Recovered 3 feet.

3' - Interbedded limestone/shale.

Shale, dark grey and green-brown, massive or laminated, with contorted laminae, fissile, richly fossiliferous-pelecypods, serpulids, fish fragments-and limestone grey-green, massive or laminated, with contorted laminae, tough, fossiliferous.

Core 35 (3203' - 3213') Recovered 6 1/2 feet.

6 1/2' - Interbedded limestone/shale.

Shale brown-grey, calcareous in part, laminated, laminae contorted, fissile, fossiliferous—ammonites, pelecypods, serpulids, fish fragments-and limestone as in core 34.

Core 36 (3300' - 3310') Recovered 5 feet.

5' - Siltstone, grey-black, micaceous, carbonaceous, argillaceous, poorly bedded with minor slumping, calcareous (massive limestone) nodule about 8 cm, and interspersed grey blebs and lenticles of arenaceous siltstone; traces of pyrite, fossiliferous-brachiopods, bryozoa, worm tubes.

Core 37 (3400' - 3410') Recovered 10 feet.

10' - Siltstone, interbedded dark grey and grey-white, with 2.5 cm shelly bed 1/4' from the top. Dark grey beds, micaceous, slightly carbonaceous, and pyritic: grey-white beds, arenaceous, poorly bedded generally, commonly slumped, fossiliferous—worm tubes, brachiopods in bed of 2.5 cm. Dip 10°.

Core 38 (3497' - 3507') Recovered 7 feet.

7' - Shale, black, carbonaceous, slightly micaceous, silty, with trace of pyrite, poorly bedded, with lenticles of arenaceous siltstone, massive, fissile, fossiliferous-wood fragments (pyritized).

Core 39 (3587' - 3597') Recovered 9 feet.

1' - Siltstone, black, carbonaceous, massive, poorly bedded, with trace of slumping near the base.

7' - Sandstone, grey-white, quartzose, feldspathic, well-sorted, fine-grained, porosity low, with flakes of siltstone as above, and 3/4' interbeds at 2' and 5' from the top of the sandstone, with contorted interlaminae of siltstone at 6 1/2'.

1' - Interlaminated shale/sandstone: sandstone as above; shale, black, carbonaceous, massive, hard, brittle. Salty taste.

Core 40 (3710' - 3722') Recovered 12 feet.

6 1/2' - Sandstone, grey-white, micaceous, kaolinitic, even-grained, fine to medium-grained, porosity fair. At 4', interbed of interlaminated and slumped sandstone/shale, sandstone as above; shale, black, carbonaceous, massive, brittle.

1 1/2' - Interlaminated sandstone/shale as above, but sandstone cross-bedded.

1' - Shale, black, carbonaceous, slightly micaceous, massive, with minor lenticles of sandstone, fissile.

1 1/2' - Interlaminated sandstone/shale as above, becoming increasingly sandy, slumped in part, sandstone-oil-stained.

1 1/2' - Breccia (intraformational), sandstone pebbles to 7.5 cm, in a matrix of black, carbonaceous, shaly siltstone.

Core 41 (3810' - 3820') Recovered 7 feet.

7' - Interbedded and interlaminated sandstone/siltstone, in parts slumped or contorted, in the mid-section 1/2' graded bedding from dark grey-black, carbonaceous, clayey siltstone to grey-white, fine-grained, silty sandstone.

Sandstone, typically grey-white, kaolinitic, rare pyrite, moderate sorting, fine to medium-grained, bedded, and cross-bedded; 3/4' from the base is a 1.5-cm bed of sandstone as above, but grain-size very coarse to gritty; siltstone, dark grey-black, very carbonaceous, massive, fissile.

APPENDIX A (ii)

CORE RECORDS: BMR 10A

Core No.	Section cored (in feet)	Recovery (in feet)	Recovery %
1	290- 219	8	80
2	1565-1585	12	60
3	3900-3910	10	100
4	4010-4020	8	80
5	4115-4125	9	90
6	4205-4215	7	70
7	4315-4325	10	100
8	4415-4425	6 1/2	65
9	4515-4525	9 1/2	95
10	4610-4620	10	100
11	4681-4691	-	-
12	4691-4701	4	40
13	4803-4813	3	30
14	4852-4862	4	40
TOTAL	150	101	67.3

Core Specific Gravities

Core No.			S.G.	Lithology
1			2.16	Sandstone
2			2.39	Siltstone
3			2.46	Siltstone/sandstone
4	(a)	(a)	2.49	Carbonaceous shale
	(b)	(b)	2.54	Siltstone/sandstone
5	(a)	(a)	1.29	Coal
	(b)	(b)	2.39	Sandstone
6			2.38	Sandstone
7			2.47	Sandstone
8			2.44	Sandstone
9			2.46	Siltstone/sandstone
10			2.31	Siltstone/sandstone
12			2.53	Calcareous, carbonaceous siltstone
13			2.62	Gneiss
14			2.82	Gneiss

Core 1 (209' - 219') Recovered 8 feet.

5' - Banded red-brown, brown, and light green-grey siltstone, arenaceous, slightly micaceous, massive, soft, with occasional thin (2.5 cm) beds of grey-white, coarse-grained, slightly argillaceous sandstone.

1' - Siltstone, grey, micaceous, argillaceous, massive.

2' - Interlaminated, cross-bedded siltstone/sandstone. Siltstone dark grey-black, micaceous; sandstone grey-white, fine-grained (0.2 mm), argillaceous, friable.

Core 2 (1565' - 1585') Recovered 12 feet.

4' - Interlaminated cross-bedded siltstone/sandstone with some graded bedding. Siltstone, dark green-grey, micaceous, carbonaceous; sandstone (quartz greywacke) grey-white, fine to medium-grained (up to 0.5 mm), fair sorting, argillaceous, friable.

3' - Shale, dark green-grey, and mottled brown and green in parts, massive, carbonaceous, with carbonized plant remains.

5' - Siltstone, dominantly green-black, carbonaceous, micaceous, laminated, with very contorted laminae of sandstone as above, with carbonized plant remains.

Core 3 (3900' - 3910') Recovered 10 feet.

4' - Siltstone, black or dark grey, carbonaceous, micaceous, fissile, containing occasional pyritized plant remains, with very thin interbeds of siltstone grey-white, quartzose, argillaceous. Dissected by talc? slickensides.

2' - Siltstone as above, in contorted laminae, and containing occasional worm-tubes.

4' - Siltstone grading to fine-grained quartz greywacke grey-white, quartzose, interlaminated with siltstone grey-black, carbonaceous, micaceous. Dissected by small faults (vertical displacement about 2.5 cm). Dip 10^{o} - 15^{o}.

Core 4 (4010' - 4020') Recovered 8 feet.

1' - Shale black, carbonaceous, laminated, with occasional lens dark grey, arenaceous siltstone and silty sandstone.

5 1/2' - Iterlaminated siltstone (60%) and sandstone (40%), laminae contorted and lenticular. Siltstone, black, carbonaceous, slightly micaceous; sandstone, light grey, fine to very fine-grained (up to 0.1 mm), as infillings of worm tubes and interlaminae. At 2 1/2' is a 6-inch bed of grey, medium to very coarse-grained and gritty (about 5.0 mm maximum) sandstone.

1 1/2' - Interlaminated sandstone (90%) and siltstone (10%) - siltstone laminae as discontinuous streaks. Sandstone grey-white, arenaceous, fine to medium-grained (0.3 mm maximum); siltstone grey-black, micaceous, carbonaceous. Dissected by high-angle slickensides. Dip 10^{o} - 15^{o}.

Core 5 (4115' - 4125') Recovered 9 feet.

4 1/2' - Interlaminated shale and siltstone. Shale grey-black, carbonaceous, massive, fissile; siltstone, grey-white, arenaceous, cross-bedded, hard, laminae very thin in top 3' then thin-bedded in lower 1 1/2', with contorted shale laminae.

3' - Sandstone with thin interlaminated carbonaceous, silty shale in 3-inch beds at 1' and 1 1/2'. Sandstone (top 1') salmon-pink to buff, quartzose, well-sorted, fine-grained, with occasional blebs of carbonaceous shale. (Bottom 2') grey-white, fair sorting, fine to medium-grained (0.5 mm), grains subangular to subrounded, cross-bedded.

1/2' - Shale as at top of core, with coal, black, vitreous, sub-bituminous, brittle.

1' - Sandstone, grey-white, as above, medium-grained, with interlaminated siltstone, black-grey, carbonaceous, with clots of pyrite (about 1 cm x 0.5 cm). Dip 15^{o} - 20^{o}.

Core 6 (4205' - 4215') Recovered 7 feet.

7' - Sandstone, grey-white, arenaceous well-sorted, fine-grained (0.2 mm), low porosity, laminated with thin (1 - 2 mm) laminae of carbonaceous, micaceous, grey-black siltstone, cross-bedded. Dip 15^{o} - 20^{o}.

Core 7 (4315' - 4325') Recovered 10 feet.

10' - Sandstone, grey-white (speckled), kaolinitic, moderately sorted, medium to coarse-grained (0.4 - 1.0 mm), subangular, poorly bedded with occasional discontinuous laminae and angular grit (7.5 mm) of black carbonaceous siltstone. Fossiliferous leaf impressions. Slickensides. Dip 15^{o} - 20^{o}.

Core 8 (4415' - 4425') Recovered 6 1/2 feet.

6 1/2' - Sandstone, grey-white, arenaceous, slightly micaceous, moderately sorted, medium-grained (0.5 - 0.75 mm), subangular to subrounded, well-bedded with thin beds of interlaminated black carbonaceous siltstone and sandstone as above, cross-bedded, rare pyrite nodules (1.5 cm) in parts. Fossiliferous leaf impressions. Dip 15^{o} - 20^{o}.

Core 9 (4515' - 4525') Recovered 9 1/2 feet.

9 1/2' - Interlaminated sandstone and siltstone with occasional thin interbeds of shale and some graded bedding from sandstone to shale. Sandstone grey-white, arenaceous, moderately sorted, fine-grained, subangular to subrounded, well-bedded, with thin laminae of siltstone and occasional shale, cross-bedded: siltstone grey-black, carbonaceous, micaceous, in laminae (occasionally undulose): shale black, carbonaceous, in laminae and thin beds, with occasional carbonaceous plant remains. High-angle slickensides (vertical displacement 1.0 cm). Dip 15^{o} - 20^{o}.

Core 10 (4610' - 4620') Recovered 10 feet.

10' - Sandstone, grey-white, arenaceous, micaceous in parts, moderately sorted, fine-grained, subangular to subrounded, well-bedded with thin laminae of siltstone, grey-black, carbonaceous, micaceous, fissile, cross-bedded in part, pyritic-pyrite in frequent clots (0.5 - 2.0 cm) and lenses (1 - 7 mm). Slickensides 45^{o}.

Core 11 (4681' - 4691') No recovery.

Core 12 (4691' - 4701') * Recovered 4 feet.

4' - Siltstone, grey-black, carbonaceous, and grey, fine-grained, calcareous sandstone, poorly bedded, with worm-tubes, and fossils in the calcareous bands.

Core 13 (4803' - 4813') Recovered 3 feet.

3' - Gneiss, granulated, coarse-grained, with pink microperthite orthoclase augen up to 4 cm across, augen sheathed by quartz-feldspar (probably plagioclase and orthoclase) and quartz-feldspar-biotite layers of 2 mm grainsize; rock extensively shattered and sheared, especially along biotite layers; feldspar partly kaolinized and biotite chloritized.

Core 14 (4852' - 4862') Recovered 4 feet.

2 1/2' - Schist, finely laminated, fine-grained, garnetiferous quartz-feldspar-biotite schist, grainsize 1 mm, some biotite segregated into layers, mafic layers contain some red garnets and a few small patches of copper pyrites.

1' - Quartz-feldspar rock (pegmatite?), a granular aggregate of very coarse-grained pink feldspar and white quartz, with traces of biotite or chlorite, massive.

1/2' - Schist as above.

Sidewall Core Descriptons

SWC1	3210'	-	Siltstone, white, quartzose, calcareous, carbonaceous, sugary texture, in part sandy (fine-grained 0.1 mm) with thin laminae (1.0 mm) of shale, light grey-green, arenaceous, massive, soft.
SWC2	3220'	-	Siltstone, as at 3210 feet.
SWC3	3245'	-	No return.
SWC4	3273'	-	Sandstone, very light green, quartzose, poorly sorted, fine to medium-grained-dominantly about 0.1 mm, angular to subrounded, matrix approximately 50%, argillaceous, with thin bands of quartz greywacke, grey-white, otherwise as above, matrix 25%.
SWC5	3626'	-	Sandstone, grey-white, quartzose, well-sorted, fine to medium-grained (0.2 - 0.5 mm), angular to subrounded, poorly cemented, soft, moderately porous.
SWC6	3633'	-	Sandstone, as at 3626 feet.
SWC7	3640'	-	Sandstone, as at 3626 feet.
SWC8	3723'	-	Sandstone, light green-grey, very fine-grained, silty (grains dominantly 0.05 mm but ranging from 0.1 mm to less than 0.025 mm), angular grains quartzose, non-calcareous.

* Core 11 from 4681' - 4691' yielded no recovery, but core 12 may represent part of core 11 picked up on the re-run into the hole to cut core 12.

SWC9 - 4074' - Sandstone, grey-white, quartzose, moderately sorted, fine-grained (0.2 mm), grains angular, reticulated with veins of carbonaceous siltstone, interbedded with sandstone, mottled black and white, carbonaceous, medium-grained to coarse-grained (0.5 - 1.0 mm), angular, carbonaceous grains 60% (include woody fragments and coal), quartz grains 40%.

SCW10 - 4074' - Sandstone as in SWC9.

SWC11 - 4750' - Shale, greenish grey, calcareous, massive, soft.

SWC12 - 4790' - Claystone as at 4750' interbedded with sandstone, white, slightly calcareous, moderately sorted, fine-grained, occasional quartz grains to 0.4 mm. Iron - stained in part, subangular, and rare green mineral, low porosity.

A core analysis of a sidewall core from 4074 feet (SWC9) showed a porosity of 33% and a permeability of 432.94 millidarcies at 22 ^{o}C.

CORE ANALYSIS RESULTS - BMR 10 APPENDIX B

Depth in ft. From:- To:-	Lithology	Effective Porosity in % by Vol.		Absolute Permeability in Millidarcies		Avg. density (gms/cc)		Fluid Saturation (% Pore Space)		Acetone Test		Solvent after Extraction		Remarks
		V	H	V	H	Dry Bulk	Grain	Water	Oil	Colour	Precip-itate	Colour	Fluor.	
3710' 0" 3710'11"	Sst. fine-gr. micac. Kaolin partings	20	20	Nil	10	2.18	2.72	6	Nil	Pale Yellow	Trace	Nil	Faint Trace	Abundant carbonaceous material present
3713' 0" 3713' 6"	"	18	21	Nil	Nil	2.25	2.79	9	"	"	"	Trace	"	Carbonaceous shale present, slickensided
3718' 2" 3718' 7"	Sst. as above and shale, carb. slickensided			Too friable to obtain pieces for porosity and permeability					"	Yellow	Nil	"	Trace	70% black carbonaceous shale
3718' 7" 3719' 0"	"				AS ABOVE				"	"	"	"	"	50% black carbonaceous shale
3719' 0" 3719' 0"	"				AS ABOVE				"	"	"	"	"	As above
3719' 0" 3719' 3"	"				AS ABOVE				"	"	"	"	"	As above
3719' 3" 3719' 9"	"	18	22	Nil	316*	2.25	2.83	7	"	Pale Yellow	Trace	"	Fair	70% carbonaceous material, coaly in part
3719' 9" 3720' 0"	"	6	7	Nil	Nil	2.31	2.77	17	"	Yellow	Nil	"	Trace	Brown, carbonaceous partings present
3720' 0" 3720' 6"	Sst. as above interlam. w. carb. shale; slump str.		7			2.41	2.71	4	7	Pale Yellow	Strong	Bright Yellow	Fair	Oil stained patches in Sst.

Notes:

(i) Unless otherwise stated, the porosities and permeabilities were determined on two small plugs (V & H) cut at right angles from the core or sample. Ruska porosimeter were used, with air at 30 p.s.i.g. and dry nitrogen, respectively, as the saturating and flowing media.

(ii) Residual oil and water saturations were determined using Soxhlet type apparatus.

(iii) Acetone test precipitates and fluorescence of solvent after extraction are recorded as: nil, trace, fair, strong or very strong.

* Permeability through vugs and fractures joining very fine-grained sandstone and black shale.

APPENDIX C (i)
DEVIATION RECORDS BMR 10

Depth (in feet)	Deviation (in degrees)	Variation (in degrees)
100	3/4	
200	1/2	- 1/4
550	1/4	- 1/4
777	1/4	-
1009	1/4	-
1150	-	-
1565	3/4	+ 1/2
2161	2 1/2	+ 1 3/4
2280	2 1/2	-
2550	3	+ 1/2
2700	3 1/2	+ 1/2
2843	4	+ 1/2
2887	3 1/4	3/4
3095	3	1/4
3430	3 1/2	+ 1/2
3760	4 1/2	+ 1
4000	3 3/4	3/4
4185	4 1/2	+ 3/4
4310	4	1/2
4490	4	-
4660	4	-
4800	4	-

APPENDIX C (ii)
DEVIATION RECORDS BMR 10A

Depth (in feet)	Deviation (in degrees)	Variation (in degrees)
200	1/2	+ 1/2
600	1/2	-
900	3/4	+ 1/4
1200	3/4	-
1400	3/4	-
1700	3/4	-
2000	3/4	-
2300	1 1/4	+ 1/2
2600	1 1/4	-
2800	2	+ 3/4
3100	2	-
3300	2	-
3790	1 3/4	- 1/4

APPENDIX D

PERMIAN FOSSILS FROM THE BEAGLE RIDGE BORES BMR 10 AND 10A

by

J.M. Dickins

BMR 10

The fossils, consisting of brachiopods and a conulariid, can be identified as follows:

Core 36 (3300 feet to 3310 feet)

Permorthotetes" sp.
Strophalosia sp. A
Neospirifer sp.

Core 37 (3400 feet to 3410 feet)

'*Chonetes*' sp.
Conulariid.

On the basis of further study made since these fossils were reported on in Dickins et al. (1961), it can now be stated that this small fauna is similar to that found in the Mingenew Formation, and the Madeline Formation of the Byro Group, although such a fauna is not necessarily confined to these formations. It is certainly younger than that of the Fossil Cliff Formation and older than the Upper Liveringa beds (Hardman Member) of the Fitzroy Basin. '*Chonetes*' sp. is probably the same species as that occurring in the Mingenew Formation, but at present 'Chonetes' is of little value for detailed correlation since the species are long ranging and the ranges are not known accurately. The most interesting species for correlation is *Neospirifer* sp. It is similar to a species which is known only from the Mingenew Formation, the lower part of the Madeline Formation, and beds of a similar age on the Lyndon River in the northern part of the Carnarvon Basin. Unfortunately, in the bore *Neospirifer* sp. is represented only by a single incomplete specimen which is not sufficient for a reliable comparison. The fauna has only the less specialized forms characteristic of the lower part of the Byro Group, and lacks any of the forms characteristic of the upper part of the Group. It seems likely, according to the marine macrofossils, that these beds are correlatable with the lower part of the Byro Group.

BMR 10A

Identifiable fossils were obtained only from core 12 (4691 feet - 4701 feet). These consisted of brachiopods and can be identified as :-

Strophalosia sp. B
Spiriferidae sp. nov.

Strophalosia sp. B is sparsely spinose and is similar to an undescribed species which occurs in the Callytharra Formation and in the basal part of the One Gum Formation.

Spiriferidae sp. nov. appears to be the same species as that which is abundant in the basal part of the High Cliff Formation at Woolaga Creek (see G. Playford 1959, p.19). Whether this species occurs lower down in the Fossil Cliff Formation is doubtful.

The occurrence of this species here suggests these beds are to be correlated with the High Cliff Sandstone rather than the Fossil Cliff Formation.

APPENDIX E

WATER AND COAL ANALYSES

A water sample from 25 feet in the Coastal Limestone in a water well approximately 50 yards East of BMR 10A was analysed by the Government Chemical Laboratories of Western Australia. They also made an approximate analysis of a coal sample from a 2-inch band between 4115 and 4125 feet in BMR 10A.

The results of the analyses are presented below.

(a) Water analysis:

Reaction,	Neutral
pH	7.6

Mineral Matter	Parts per million
Calcium, Ca	162
Magnesium, Mg	188
Sodium, Na	1510
Potassium, K	26
Bicarbonate, HCO_3	394
Carbonate, CO_3	nil
Sulphate, SO_4	296
Chloride, Cl	2740
Nitrate, NO_3	3
Silica, SiO_2	13
Iron oxide, Fe_2O_3)	1
Aluminium oxide, Al_2O_3)	
Total	5333

Assumed combination on evaporation at N.T.P.	
Calcium carbonate, $CaCO_3$	323
Magnesium carbonate, $MgCO_3$	nil
Sodium carbonate, Na_2CO_3	nil
Calcium sulphate, $CaSO_4$	111
Magnesium sulphate, $MgSO_4$	273
Sodium sulphate, Na_2SO_4	nil
Magnesium chloride, $MgCl_2$	515
Potassium chloride, KCl	50
Sodium chloride, NaCl	3840
Sodium nitrate, $NaNO_3$	4

Hardness calculated as calcium carbonate	
Total hardness	1177
Bicarbonate (temporary) hardness	323
Non-carbonate (permanent) hardness	854
Calcium hardness	404
Magnesium hardness	773

(b) Coal proximate analysis

Proximate analysis	As received	Dry, ash free
	percent	
Moisture	6.4	
Ash	9.5	
Volatile matter	31.8	37.8
Fixed carbon	52.3	
	100.0	
	Btu per lb	
Calorific value	12,460	14,820
	percent, dry basis	
Ash	10.1	
	Colour	
	Off white	

Indications during the analysis suggest that this is a coking coal.

APPENDIX F

Formation Test Report

Well:	BMR 10A	Test No.:	5	Date:	9th July 1960
Object:	To test interval 3200' to 3230'				
Type of Tester:	Johnstone	Type & Size of Packer:		Open-hole 8-3/4£ Choke-NIL	
Well depth:	4862' Pack off at 3175'	Sump at 3234'			
Hole diameter:	8-3/4£	S.G. of Drilling Fluid:		1.15	

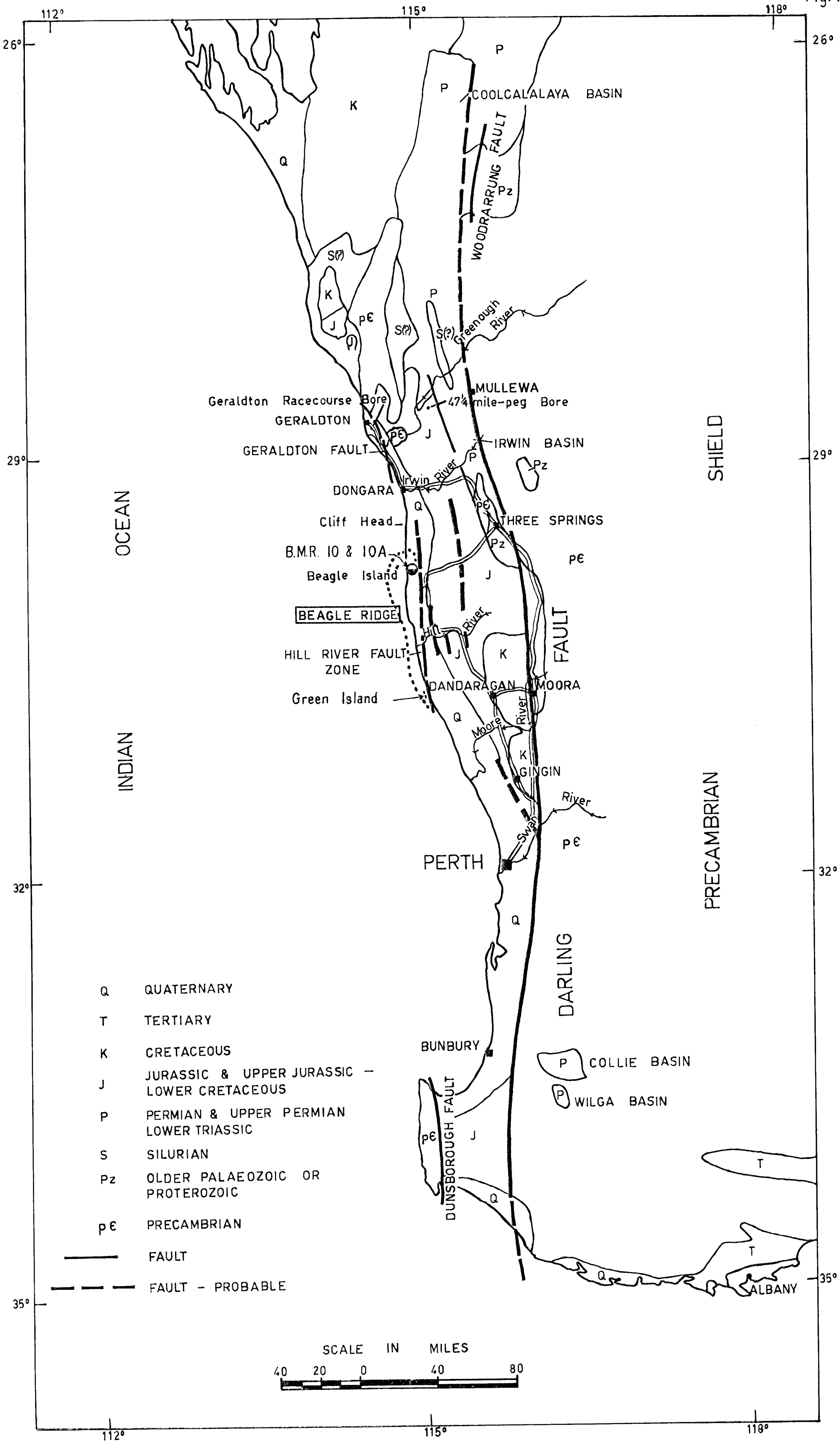
Operation

Started run in at 0500 hrs	Completed run in at 0700 hrs
Packer set at	3175'
Trip valve opened	0700 hrs
Retaining valve closed	0708 hrs
Flow period	0008 hrs
Shut in period	NIL
Unseated packer at	0708 hrs
Fluid level in drill stem at	3' above tester
Nature of fluid	drilling mud
Recorder chart	No. 5 satisfactory
Bottom hole temperature	$101^{o}F$
Bottom hole pressure	1400 p.s.i.

Comments

After tripping valve very slight bubbling observed at surface for half minute. After half minute no flow. Packer unseated after 8 minutes. Recorder chart showed that formation had been opened to atmospheric pressure.

Fig. 1



GEOLOGICAL MAP OF PERTH BASIN

SHOWING POSITION OF BMR 10 & 10A

AUS 1/2

Bureau of Mineral Resources, Geology & Geophysics. July 1961.

PLATE I

B.M.R. 10 BEAGLE RIDGE

COMPOSITE WELL LOG

STATE WESTERN AUSTRALIA
LOCATION Latitude 19°49'18"
Longitude 124°58'30"
ELEVATION (above S.L.) SURFACE 10ft.
ROTARY TABLE (Datum Datum) 21ft (above S.L.)
DATE SPUDDED 1st Aug. 1959
DATE TD REACHED 6th Sept. 1959
DATE OPERATIONS COMPLETED 27th Oct. 1959
TOTAL DEPTH 3910ft (Driller R.T.)
STATUS Abandoned

HOLE PROFILE
17½" 10-189 ft.
12¼" 189-1650 ft.
8½" 1650-3910 ft.

CASING
13⅜" 48lbs API. Cement at 186'
9⅝" 40lbs API. Cement at 1648'
Cut and recovered from 120'
Bottom joint in hole from 1481-1517'

LITHOLOGY BY R.A. Mc Tavish

BASIN PERTH
ELECTRIC LOG DATA
DATE RUN 20th Aug 1959
INTERVAL LOGGED 2996-186 ft
MUD - NATURE Water only
RESISTIVITY 1.3 Ωm at 18°C
OTHER LOGS
DEVIATION

MISCELLANEOUS SYMBOLS
Δ MICROFOSSILS
⊕ MACROFOSSILS
Calc CALCAREOUS
C CARBON
Py PYRITE

CORE INTERVAL AND CORE RECOVERY (IN BLACK)
CORE DIP
CASING SIZE AND DEPTH SET 13⅜" 186'

AREA BEAGLE I. - L. LOGUE
SYMBOLS — LITHOLOGY
CALCARENITE
CALCILUTITE
QUARTZ SANDSTONE
QUARTZ GREYWACKE
SANDY SILTSTONE
SILTSTONE
SHALE
SEDIMENTARY STRUCTURES
BEDDING THIN
LAMINATED
CROSS
CONFORMED
SLUMPED
CAVERNOUS
OIL SHOW ✱ SALT WATER ✱

SELF POTENTIAL 10 mv

GRAPHIC LOG

RESISTANCE 10 ohms

LITHOLOGY

1'-101' CALCARENITE white-buff, cavernous, massive, with occasional coarse grains of quartz and dark minerals: basal 25 feet pale green-grey, massive, recemented, with coarse quartz grains disseminated throughout.

101'-1095' SANDSTONE friable grey-white, uneven-grained, fine-to very coarse-grained, poorly bedded, cross-bedded, kaolinitic and felspathic: minor beds of SILTSTONE black, laminated, carbonaceous, micaceous: banded red and green, very fine-grained at 101 feet, or red, yellow, and brown, shaly below 650 feet, and SHALE grey, calcareous, some pyritic nodules at 510 feet.

1095'-1462' SANDSTONE friable light grey, moderately sorted, fine-grained, thin-bedded and cross-bedded, kaolinitic or quartzose: minor SILTSTONE dark grey, laminated, shaly, fissile, carbonaceous, micaceous, some pyrite.

1462'-2003' Interbedded SANDSTONE light grey, moderately sorted, fine-to medium-grained, massive or well-bedded, thin-bedded and cross-bedded, kaolinitic, and SILTSTONE dark grey, laminated, sandy to shaly, carbonaceous, micaceous: with intra-formational shale BRECCIA in SANDSTONE at 1800 feet.

2003'-2162' Interbedded SILTSTONE dark grey, micaceous, carbonaceous, sandy; and QUARTZ GREYWACKE light grey, poorly sorted, fine-grained, slumped, cross-bedded, kaolinitic, micaceous

2162'-3290' SHALE dark green-grey, massive or well-bedded, thin-bedded, and fissile; and some minor thin beds of light grey silty SANDSTONE and SILTSTONE, slumped, cross-bedded.

3290'-3588' SILTSTONE black, shaly, poorly bedded, slumped, carbonaceous, slightly micaceous; and minor lenticles of SANDSTONE light grey, silty, fine-grained.

3588'-3910' SANDSTONE light-grey, very fine-to medium-grained, thin-bedded, cross-bedded, slumped, kaolinitic; minor SHALE black, fissile, carbonaceous, grading to SILTSTONE: and rare SANDSTONE, well-sorted coarse-grained to gritty near the base.

T.D. 3910

FORMATION				AGE
COASTAL LIMESTONE				PLEISTOCENE
SANDSTONE				JURASSIC
GULLY				
COCKLESHELL				LOWER
TRIASSIC	UNIT "A"	UPPER	TRIASSIC	
TRIASSIC	UNIT "B"	TO		
TRIASSIC	UNIT "C"	MIDDLE		
SHALE				SCYTHIAN
KOCKATEA			TRIASSIC	
		LOWER		
PERMIAN	UNIT "A"			ARTINSKIAN
PERMIAN	UNIT "B"			

Bureau of Mineral Resources Geology & Geophysics June 1961

To Accompany Record No. 1962/30

W.A. Ch-8

BMR 10A BEAGLE RIDGE
COMPOSITE WELL LOG

STATE WESTERN AUSTRALIA

LOCATION Lat. 29°49'36·5" S Long. 114°58'30" E

ELEVATION (above S.L.) Surface 15'
Rotary table (depth datum) 26'

DATE SPUDDED 2 May 1960

DATE T.D. REACHED 24 June 1960

DATE COMPLETED 10 July 1960

TOTAL DEPTH 4862'

STATUS Abandoned

LITHOLOGY BY R.A.Mc.Tavish

BASIN PERTH

AREA BEAGLE I. - L.LOGUE

HOLE PROFILE 17-1/2" 11-276 ft.
12-1/4" 276-1620 ft.
8-3/4" 1620-4852 ft.
7-7/8" 4852-4862 ft.

CASING 13-3/8" 12-276 ft.
9-5/8" 12-1616 ft.

Casing
Depth of deviation reading
Plug

REFERENCE

Limestone
Calcilutite
Sandstone
Quartz Greywacke
Siltstone
Shale
Coal
Basement Complex

Bedded
Laminated
Cross bedded
Contorted laminae
Slumped
Megafossils: Plant, Animal

Zone of mechanically successful drill stem test
Core interval core recovery in black
Dip in unoriented core
Side core by mechanical methods: with recovery, without recovery

arg. - argillaceous
grn. - green
py. - pyrite
bnd. - banded
gry. - grey
sch. - schist
calc. - calcareous
gns. - gneiss
sl. - slightly
carb. - carbonaceous
lt. - light
swc. - sidewall core
c. - coal
mic - micaceous
br. - brown

BIT RECORD

1. REED T-2 12¼"
2. HTC HFCH 7⅞"
1. Reamed 17½" to 276'
REED T-2 12¼"
3. REED T-2 12¼"
4. REED T-2 12¼"
5. REED YT3 8¾"
2 HTC HFCH 7⅞"
6. Reamed 12¼" to 1620'
HTC OSQ2 8¾"
7. SEC S6 8¾"
REED YT3 8¾"

MUD PROPERTIES
Weight (lb./cu.ft.) 65 70 75 80 85 W
Viscosity (cc/sec.) 30 40 50 60 70 V
WL (cc/sec.) 5 10 15 20 25 WL
Sand (% vol) 5 10 15 20 25 S
pH 4 6 8 10 12 pH

DEPTH: 500', 1000', 1500', 2000', 2400'

DEVIATION: 3/4°, 1/2°, 1/4°, 1/4°, 1/4°, 3/4°, 2-1/2°, 2-1/2°

CASING AND CEMENTATION: 264 13⅜ C 275 180; 1616 9⅝ C 269; 2386

TEMPERATURE LOG II °F 75 80 85 90

TEMPERATURE LOG I °F 75 80 85 90

GAMMA RAY Logging speed 40'/min. Time const. 2s. mR/h. 0·01 0·02 0·03 0·04

SELF POTENTIAL 25 mv.

LITHOLOGY: 1 bnd. red br. lt. grn. gry. arg.; 2 carb. sl. mic.

SINGLE POINT 10 ohms

SHORT NORMAL Ohm-metres 0 10 20

LONG NORMAL Ohm-metres 0 5 10

BOTTOM OF CASING

FORMATION: COASTAL LIMESTONE; COCKLESHELL GULLY SANDSTONE; TRIASSIC UNIT "A"; TRIASSIC UNIT "B"; KOCKATEA SHALE

AGE: PLEISTOCENE; LOWER JURASSIC; MIDDLE TO UPPER TRIASSIC; LOWER TRIASSIC (SCYTHIAN)

Bureau of Mineral Resources, Geology and Geophysics October 1964.

H50/A5/3

BMR 10 A BEAGLE RIDGE
COMPOSITE WELL LOG

STATE WESTERN AUSTRALIA

LOCATION Lat. 29°49'36·5" S Long. 114°58'30" E

ELEVATION (above S.L.) Surface 15'
Rotary table (depth datum) 26'

DATE SPUDDED 2 May 1960

DATE T.D. REACHED 24 June 1960

DATE COMPLETED 10 July 1960

TOTAL DEPTH 4862'

STATUS Abandoned

LITHOLOGY BY R.A.Mc.Tavish

BASIN PERTH

AREA BEAGLE I. - L.LOGUE

HOLE PROFILE 17-1/2" 11-276 ft.
12-1/4" 276-1620 ft.
8-3/4" 1620-4852 ft.
7-7/8" 4852-4862 ft.

CASING 13-3/8" 12-276 ft.
9-5/8" 12-1616 ft.

Casing |C
Depth of deviation reading ^
Plug ////////

REFERENCE

Limestone
Calcilutite
Sandstone
Quartz Greywacke
Siltstone
Shale
Coal
Basement Complex

Bedded
Laminated
Cross bedded
Contorted laminae
Slumped
Megofossils — Plant, Animal

Zone of mechanically successful drill stem test (V)
Core interval core recovery in black
Dip in unoriented core
Side core by mechanical methods: 10° 15°
with recovery
without recovery

arg. - argillaceous bnd. - banded calc. - calcareous carb. - carbonaceous c. - coal
grn. - green gry. - grey gns. - gneiss it. - light mic - micaceous
py. - pyrite sch. - schist sl. - slightly swc. - sidewall core br - brown

BIT RECORD

MUD PROPERTIES
Weight (lb./cu.ft.) 65 70 75 80 85 W
Viscosity (cc/sec.) 30 40 50 60 70 V
WL(cc/sec) 5 10 15 20 25 WL
Sand (% vol) 5 10 15 20 25 S
pH 4 6 8 10 12 pH

DEPTH

DEVIATION

CASING & CEMENTATION

TEMPERATURE LOG I °F
90 95 100 105 110

GAMMA RAY
Logging speed 40'/min. Time const.2s
mR/h.
0·02 0·03 0·04

SELF POTENTIAL
25mv

LITHOLOGY

SHORT NORMAL / SINGLE POINT
Ohm/metres 5 Ohms
0 5 10 15 20

LONG NORMAL
Ohm/metres
0 5 10 15 20

FORMATION

AGE

9. REED YT3 8¾"
10. SEC S4 8¾"
11. REED YT3 8¾"
12. REED YT3 8¾"
13. SEC S4 8¾"
14. SEC S4 8¾"
12 REED YT3 8¾"
HTC HFCH 7⅞"
15 SEC S4 8⅜"
16 HTC HFCH 7⅞"
17 REED YT3 8¾"
16 HTC HFCH 7⅞"
17 REED YT3 8¾"
16 HTC HFCH 7⅞"
17 REED YT3 8¾"
18 HTC HFCH 7⅞"
19 HTC OSQ2
18 HTC HFCH 7⅞"
20 REED YT3 8¾"
21 HTC HFCH 7⅞"
22 HTC OWV 8¾"
22 HTC OWV 8¾"
21 HTC HFCH 7⅞"
23 HTC HFCH 7⅞"
24 HTC OWV 8¾"
25 SEC S6 8¾"
26 HTC HFCH 7⅞"
27 SEC M4L 8⅜"
28 HTC HFCH 7⅞"

2500' 3000' 3500 4000 4500 4800

^3° ^3-1/2° ^4° ^3-1/4° ^3° ^3-1/2° ^4-1/2 ^3-3/4° ^4-1/2° ^4° ^4° ^4°

3241 3640 below 3692

swc 1 2 3 4 — calc carb (sl) — REBASE
swc 5 6 7
swc 8
3 10°15° — carb. mic.
4 10°15° — carb.
5 15°20° — carb. pyr.
6 15°20°
7 15°20°
8 15°20° — mic. pyr.
9 15°20° — carb. mic.
10 — pyr.
11 12 — carb. calc.
swc 11 — sl. calc.
swc 12 — calc.
13 — sl. calc.
14 — gns. sch.
T.D. 4862

0 25 50 Change of Scale
0 25 50 75 Change of Scale Ohm/metres

KOCKATEA SHALE — LOWER TRIASSIC (SCYTHIAN)
UNIT "A"
CARYNGINA FORMATION
IRWIN RIVER COAL MEASURES — ARTINSKIAN
UNIT "D"
BASEMENT — pC

Bureau of Mineral Resources, Geology and Geophysics. October 1964

H 50/A 5/4