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RECORDS.

1960/31

COMPLETION REPORT ON BORE BMR 10, BEAGLE RIDGE, WESTERN AUSTRALIA.

by

R.A. McTavish

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SUMMARY

BMR 10 was drilled above the highest accessible part of Beagle Ridge - a subsurface basement ridge indicated by aeromagnetic and gravity surveys conducted by the Bureau of Mineral Resources. Numerous mechanical difficulties arose in the drilling of this well, and it had to be abandoned at a T.D. of 3,910 feet.

A sequence of Pleistocene, Jurassic, Triassic, and Permian sediments was encountered, but basement was not reached. On the evidence available from BMR 10 basement is probably deeper than was expected, but it is impossible to determine how much deeper.

A thin section of about 100 feet of Pleistocene marine calcarenite was penetrated; it overlay about 1,000 feet of coarse-grained Cockleshell Gully Sandstone (Jurassic), older than any previously studied. Below the Jurassic was a thick sequence of marine deltaic siltstone and sandstone, and dark green-grey shale, which yielded the first definite Triassic Ammonites recognized in Australia. Four lithological units could be distinguished in the Triassic section, and three of these were new. Disconformable under the Triassic is a Permian sequence of carbonaceous siltstone overlying sandstone.

A hydrocarbon show (oil-staining with a trace of visible oil) was evident at 3720 feet in the Permian sandstone unit. The hydrocarbon show, and the presence of suitable source, reservoir, and cap rocks have enhanced the prospects for petroleum in the Perth Basin.

INTRODUCTION

As a result of a gravity survey of the Perth Basin by the Bureau of Mineral Resources, Thyer and Everingham (1956) were able to distinguish a basement rise between Green Island and Cliff Head. Subsequently an aeromagnetic survey of the basin was conducted by the Bureau of Mineral Resources; the basement rise was confirmed and a subsurface basement ridge between Latitudes 30°30' South and 29°40' South and Longitudes 114°50' East and 115°02' East and rising to 4,000 feet below the surface was recognised. This ridge has been named Beagle Ridge in West Australian Petroleum Pty. Ltd. reports after Beagle Island (approx. Latitude 29°48' South and Longitude 114°55' East). The ridge is a shallow, north-south subsurface ridge that rises probably to about 4,500 feet below the surface as indicated by aeromagnetic evidence (Newman, 1959, p.5); it is about ten miles across at its widest part. The eastern margin is very steep and probably is bounded by a fault.

BMR 10 was drilled under contract, for the Bureau of Mineral Resources, on the northeast perimeter of Beagle Ridge, and about 40 miles south of Dongara at Latitude 29°49'38" South, Longitude 114°58'30" East. This point is above the highest part of Beagle Ridge accessible on the mainland. Five to ten miles east of the bore the basement is downthrown for several thousands of feet.

It was expected that BMR 10 would yield new information on the stratigraphy of the Perth Basin, and in particular on the geological history of Beagle Ridge. The geological record at Beagle Ridge was particularly important in the light of results obtained from drilling on the Broome Ridge in the Canning Basin where shallow-water Ordovician sediments had been recognized at shallow depth. Also, it was hoped that the ridge might have been a structural or topographic ridge throughout Palaeozoic and Mesozoic sedimentation : if this were were so then the section should have been thinner and more sandy than that in the deeper parts of the basin.

Access to the bore is fair. An excellent paved road (Geraldton Highway) passes through Three Springs; from Three Springs about 85 miles of graded earth roads and tracks that are fair to bad, especially after rain, lead southwest via Eneabba to the wellsite. A second route through Gingin, Dandaragan, and Cockleshell Gully is 90 miles shorter, but it is only passable to light vehicles along the Cockleshell Gully section.

WELL HISTORY

General Data

The general data on the drilling of BMR 10 are presented in Table I, below.

TABLE I

Location:	Beagle Ridge. Latitude 29°49'38" S. Longitude 114°58'30" E. Coordinates - 3,305,550 N., 291,660E. (Logue & Beagle 1-mile map).
Permit Area:	Permit to Explore 27H.
Permit Holder -	West Australian Petroleum Pty. Ltd.
Total Depth:	3910 feet
Date Spudded:	August 1st, 1959.
Date T.D. Reached:	September 6th, 1959.
Date Abandoned:	October 27th, 1959.
Elevation:	Rotary Table - 21 feet above mean sea level Surface - 10 feet above mean sea level

Drilling Data

BMR 10 was drilled under contract to the Bureau of Mineral Resources by Oil Drilling and Exploration (W.A.) Pty. Ltd., Adelaide Terrace, Perth, Western Australia, using their own equipment. A National T-20 rig with an Ideal C-150B7½" x 12" pump, Ideal D-50 5" x 10" pump, and a 94 foot high Lee C. Moore cantilever mast was used. On September 7th, 1959, the mast collapsed and was replaced by a 136 foot high standard derrick from the contractor's T-55 rig.

The well was drilled from the surface to T.D. (3910 feet) using 4½" O.D. x 16.6 lbs/ft. drill-pipe and 6¼" O.D. x 82 lbs/ft. drill collars. Additional hole-size and equipment information is shown in Table II.

TABLE II.

Hole Size:	17½" hole from Surface to 189 feet. 12¼" hole from 189 feet to 1650 feet. 8¾" hole from 1650 feet to 3910 feet.
Casing:	174' - 13⅜ inch x 48 lbs/ft. Range 2 A.P.I. casing cemented at 186' with 200 sacks. 1438' - 9⅝ inch x 40 lbs/ft. Range 2 A.P.I. casing cemented at 1448' with 200 sacks. 9⅝" casing cut and recovered from 120'. Bottom joint of 9⅝" casing loose in hole from 1481' to 1517'.
Casing left in hole:	All the 13⅜" casing and 9⅝" casing below 120 feet.
Fish left in hole:	Top of fish at 1380'; bottom at 1692'. Fish consists of: 1 - T.I.W. Safety Joint 2 - Joints of 4½" API Drill pipe 8 - 6¼" OD x 82 lbs/ft Drill Collars 1 - 8¾" Hughes OSC Rock Bit

Drilling of BMR 10 was hampered by three main factors-

(i) caverns in Coastal Limestone.

(ii) high porosity in the Cockleshell Gully Sandstone.

(iii) poor cementation and resultant caving of the Cockleshell Gully Sandstone.

Possibly, the factors (i) and (ii) caused the lost circulation. Because of factor (iii) it was impossible to get a satisfactory casing seat for the surface casing. Furthermore, with caving frequent in the Cockleshell Gully Sandstone the bit was prone to stick periodically when it was being pulled from the hole. This condition was perhaps aggravated by poor mud, which 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: due to failure of the cement job the lost-circulation zones in the Coastal Limestone were not shut off. Consequently, lost-circulation remained a problem during drilling to 3,142 feet. It is thought, however, that the continued loss of circulation could be also attributed in part to the very high permeability of the Cockleshell Gully Sandstone. In order to overcome these difficulties it was decided to cement 9⅝" 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 3,850 feet while pulling out of the hole on the 6th September. On the 7th September 1959, the 94 foot mast collapsed under a pull of 137,000 lbs. during fishing operations.

The damaged mast was replaced by a 136 foot standard derrick.

Pipe was freed on the 8th October, 1959, but it stuck again at 1692 feet whilst pulling out. During the fishing operations which followed, drill pipe was recovered to 1380 feet, leaving an 8¾" bit, eight (8) 6¼" drill-collars, two (2) joints of 4½" drill-pipe, and a safety joint in the hole. It was impossible to wash over below 1,481 feet because of the obstructing casing. Therefore the hole was abandoned at T.D. (3910 feet) on the 27th October 1959 with the fish still in the hole.

Ditch Cuttings

Ditch samples were collected at five-feet intervals from the surface to T.D. (3910 feet). There were no returns of cuttings from 175 - 260 feet and 3,000 - 3,142 feet. Below 600 feet samples were studied at ten-feet intervals because the fast 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 a 10 foot core in every consecutive 100 feet of hole drilled, with additional cores when required by the well-site geologist. Forty-one (41) cores were cut using a Hughes Type 'J' core barrel with 8¾ inch hard formation core-heads and 8⅝ inch soft formation core-heads.

Coring in the Cockleshell Gully Sandstone (101 feet - 1097 feet) was most unsatisfactory, for core recovery was only about 12%. Nevertheless, additional coring was not requested, because it was unlikely that recovery could be improved whilst drilling in this formation. Sand in this formation caves readily.

Core recovery was less than 50% in some cores between cores 11 and 22 inclusive, but additional coring was not necessary, for the cores recovered were regarded as representative of the full interval cored.

An additional core was called for immediately after cores 23 and 34 of the Kockatea Shale in order to obtain more fossil material; it was not expected that additional lithological information would be added.

A brief record of coring in BMR 10 is shown in Appendix A.

Electric Logging

A WIDCO 4,000 feet logging unit, which gave a Single-point resistivity log and a Self-potential log, was used.

Two runs were made; the first log was run from 2996 feet to 186 feet on the 20th August, 1959. A second log was run from 1230 feet to 1506 feet in order to locate the fallen joint of casing.

Unfortunately the resistance log was valueless in providing information on the lithology or fluid content encountered, and Jewell has stated: "The low resistivity of the drilling fluid (bore water in this instance) has evidently damped out almost entirely the changes in resistance caused by the varying resistivity of the sediments. Resistance measurements opposite the permeable zones are more appropriate to the drilling fluid than to the formations owing to the considerable invasion which took place during drilling, even to the point of frequent loss of circulation."

Drilling Time Logs

No detailed drilling time records were kept, but the drilling rates ranged from 25ft/hr to 100ft/hr.

Formation Tests

No formation tests were conducted.

Deviation Records

A TOTCO drift-indicator was used to conduct deviation surveys. Readings were made at thirteen (13) levels, and the maximum deviation measured with this instrument was 2° at 2860 feet, 3100 feet, and 3300 feet. Details of these surveys are in Appendix B.

Personnel

Bureau of Mineral Resources staff assigned to BMR 10 were: R. McTavish, well-site geologist (Geological Branch); F. Jewell, logger (Geophysical Branch); and J. Halls, drilling supervisor (Petroleum Technology Section).

S.P. Willmott was the WAPET observer-geologist, and J. Netters was toolpusher (drilling foreman) for the contractors, Oil Drilling and Exploration (W.A.) Pty. Ltd.

GEOLOGY

General Geology and Structure

BMR 10 was drilled in the Perth Basin, which is a trough of sediments that extends from about Latitude 26° South to the southern coast of Western Australia. The Darling Fault Zone, which can be recognized by physiographical, geological, and geophysical means, marks the eastern margin of the basin for most of its length.

The western boundary of the Perth Basin is formed by the Dunsborough Fault in the Cape Leeuwin - Cape Naturaliste area.

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 western and northern margins of the Coolcalalaya Basin as shown in text-figure 6 of Konecki, Dickins, and Quinlan (1958), but it must be remembered that a gravity survey showed that the Carnarvon Basin is continuous with the Coolcalalaya Basin (Konecki et al., 1958). Elsewhere, the basin extends onto the adjacent continental shelf.

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

Geophysical data (Vale, 1956; Thyer and Everingham, 1956; and Newman, 1959) have revealed a buried anticline at Gingin and a shallow subsurface basement ridge, Beagle Ridge, between latitudes 30°30' South and 29°40' South. In addition, Thyer and Everingham (1956) have estimated a maximum thickness of about 30,000 feet of unmetamorphosed sediments for the Perth Basin.

The stratigraphy of the Perth Basin that was known after a regional geological survey of the basin by WAPET and other investigations conducted through more than a century has been described in McWhae et al. (1958).

Sediments of uncertain age (Late Precambrian to Silurian?), Permian, Triassic, Jurassic, Cretaceous, and Quaternary age crop out within the basin, and Eocene strata have been found in deep water-bores.

Only the extensively faulted Jurassic sediments, Quaternary 'Coastal Limestone', and beach-sand dunes are exposed in the Hill River-Cockleshell Gully area, in which the well was drilled.

The site of BMR 10 is five to ten miles west of the Hill River Fault Zone, which probably forms the eastern margin of Beagle Ridge, and above the highest accessible part of Beagle Ridge where basement is estimated to be 4,000 feet to 5,000 feet deep.

Stratigraphy of BMR 10

The section penetrated in BMR 10 is listed in Table III, and will be described below.

TABLE III

AGE	FORMATION	Depth	FORMATION TOP Reduced level	Thickness
Pleistocene	Coastal Limestone	11'	10'	90'
Jurassic	Cockleshell Gully Sandstone	101'	-80'	994'
Triassic	Unit 'A'	?1095'	-1074'	367'
	Unit 'B'	1462'	-1441'	541'
	Unit 'C'	2003'	-1982'	159'
	Kockatea Shale	2162'	-2141'	1128'
Permian	Unit 'A'	?3290'	-3269'	298'
	Unit 'B'	3588'	-3567'	322'
	T.D.	3910'	-3889'	

FORMATIONS PENETRATED IN BMR. 10

The well was spudded in Pleistocene sediments and passed through a thin sequence of Coastal Limestone of that age. Then, a thick section of Lower Jurassic Cockleshell Gully Sandstone, older than any previously reported was drilled. About 2300 feet of Triassic sandstone, siltstone, and Kockatea Shale was encountered: it could be divided into four lithologic units, of which the upper three were previously undescribed. Finally, two Permian units were penetrated in the last 620 feet drilled.

Quaternary

Coastal Limestone (11 feet - 101 feet)

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

The Coastal Limestone is widespread along the coast of the Perth Basin in a belt up to 10 miles wide; it is also found on offshore islands (e.g. Rottnest, Abrolhos) as much as fifty (50) miles from the coast.

Although the Coastal Limestone elsewhere is aeolianite with marine intercalations (e.g. at Minim Cove, Moore River, etc.), the section penetrated in BMR 10 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 in BMR 10 were attempted, but the age is accepted as Pleistocene (Fairbridge, 1953).

Jurassic

Cockleshell Gully Sandstone (101 feet - 1095 feet)

This formation 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, grains ranging in size from fine (0.2 mm) to gritty (7.5 mm); it is 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 felspathic with increasing depth, and angular feldspar grains may constitute up to 10% 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%) and in five cores (48 feet) there was no recovery. Furthermore, the electric log showed little character. Nevertheless, three main pelite types could be recognised.

First, a banded red and green, fine-grained and shaly siltstone was observed in core 1 (100 feet - 110 feet). Additional thin beds of red, yellow, and brown siltstones were penetrated below 650 feet. Black, carbonaceous, micaceous, clayey siltstone with carbonized plant remains, and occasionally pyritic, first appears at 270 feet and occurs throughout the formation, probably interlaminated as in core 6 (600 feet - 610 feet). The third pelite type is a massive, grey, calcareous shale, slightly carbonaceous, and bearing rare pyritic nodules (10 mm. - 15 mm.); it was found only in core 5 (500 feet - 510 feet).

It is difficult to establish the base of the Cockleshell Gully Sandstone 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, 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 as Triassic. Such a bed is present in core 11 (1105 feet - 1115 feet) and first appears on the electric log at 1097 feet. Elsewhere in the basin the base of the Cockleshell Gully Sandstone is not exposed.

Although the rock association of the Cockleshell Gully Sandstone in BMR 10 is not unlike that of Moonyoonboka Sandstone (Playford 1959) of the Chapman Group in the Geralton area especially in its feldspathic and kaolinitic sandstones, it has been referred to the Cockleshell Gully Sandstone (McWhae et al, 1958, p.99) because of its thickness, proximity to the type section, and lithological similarity in preference to the Moonyoonooka Sandstone, from which it differs most noticeably in the absence of "Cannonball" ferruginous concretions and coarser grain size.

Balme noted that the microflora of core 5, although of Lower Jurassic age, is older than any previously examined from the Cockleshell Gully Sandstone. Also, there is no break in sedimentation from the Triassic into the Cockleshell Gully Sandstone. Hence it is probable that the thickness must be increased, for the base has been encountered.

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

Triassic

A Triassic sequence about 2,200 feet thick was penetrated. Four distinct units can be recognized, of which the upper three were previously unreported; these units remain unnamed formally in this report. 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'; Unit 'C' is an interbedded impure sandstone (quartz-greywacke) and siltstone; the fourth unit is a thick sequence of fossiliferous shale, that can be correlated with the Kockatea Shale.

Triassic Unit 'A'

(1095 feet - 1462 feet) is a fine-grained sandstone with minor thin beds of interlaminated dark-grey siltstone and sandstone.

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 such grains may be regarded as cavings from the overlying Cockleshell Gully Sandstone. Siltstone occurs interlaminated with sandstone; it is dark-grey; carbonaceous, micaceous, and rarely pyritic; fissile, laminae are generally sharply defined and tabular or lenticular, dipping at 5° (visual estimation).

There is no record of this unit elsewhere in the Perth Basin.

Triassic Unit 'A' and Triassic Unit 'B' are transitional, but their boundary has been placed for convenience at the top of the first thick siltstone bed of Unit 'B' at 1,462 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 can be effected 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. Indeed, Shepard (1956) has shown that marine organisms (Shells, foraminifera, echinoids, ostracods) constitute less than 0.25% 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 has proceeded apace of or slightly quicker than subsidence.

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 apparent from this succession.

Balme examined 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 core 14 with beds of the Fitzroy Basin that have been correlated with the Erskine Sandstone. Consequently, he suggested that core 14 was of Lower to Middle Triassic age, and he determined a Middle to Upper Triassic age for cores 11 and 12.

<u>Triassic Unit 'B'</u> (1,462 feet - 2,003 feet)

This formation is composed of interbedded, fine-grained sandstone and interlaminated siltstone/sandstone with a bed of intraformational shale-breccia in a sandstone at 1800 feet.

The sandstone is typically 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, and in part pyritic; and argillaceous: its laminae dip at 5° (Visual Estimation).

The base of Triassic Unit 'B' could be placed at 2,003 feet where the lithology changes to more silty sediment that shows a marked change (rise) in S.P.

This formation, also, was previously unreported in the Perth Basin either at the surface or subsurface.

Lithologic properties of this unit are similar to those of Triassic Unit 'A', but the siltstone/sandstone ratio has increased. It is suggested that Triassic Unit 'B' was deposited on a delta-front platform in deeper water than Triassic 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 Triassic Unit 'B' are available. It is regarded tentatively as being Middle Triassic in age.

Triassic Unit 'C' (2,003 feet - 2,162 feet)

This unit contains dark grey, micaceous, carbonaceous, sandy siltstone with thin interbeds of light grey, kaolinitic, micaceous, poorly sorted, fine-grained sandstone(quartz greywacke).

Structures include thin-bedding with contorted laminae dipping at 5°, cross-bedding, slump structures, and wormtubes and trails.

This formation has not been distinguished before in the Perth Basin, but it may be present in the top of the Upper Permian - Lower Triassic sequences of the Geraldton Racecourse Bore and the 47¼ mile-peg Bore.

Saltwater is present in cores from this unit, but it is uncertain whether this water is connate or secondary.

Lingulid brachiopods, worm-tubes, and carbonized wood fragments have been found in Triassic Unit 'C'.

The presence of Lingulid brachiopods, worm-tubes, slump-structures and contorted laminae are conspicuous properties of this unit by which it is possible to determine the sedimentary environment of the unit. Most of these features were found together by Van Straaten (1959) in proximal fluviomarine deposits from the foreset beds on the pro-delta slope. Lingulid brachiopods are by no means diagnostic of this environment, but they are common in such a habitat. Hence, sediments of this unit can be regarded as deposits of the above site.

On evidence from the S.P. log the base of Triassic Unit 'C' could be placed at 2,162 feet where the sharp rise in the S.P. log indicates the change from dominantly silty sediments to dark green-grey shale as in core 23 (2,223 feet - 2,233 feet).

No detailed age determinations of this unit are available; Dickins believed that it may be Triassic. By its position in the succession of BMR 10 it is certainly Lower Triassic, especially as it immediately and conformably overlies the Kockatea Shale.

Kockatea Shale (2,162 feet - 3,290 feet)

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 Kockatea Gully (28° 33'S., 115° 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 is 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 2,500 feet and become abundant below 3,100 feet.

The shale is dark green-grey, slightly micaceous, silty in parts, massive or well-bedded, thin-bedded, and fissile. Bedding planes and planes of fissility dip 5° - 10° (V.E.). Rare slump structures and cross-bedding are present, and cone-in-cone structure has been noticed in core 27(2,494 feet - 2,504 feet). The formation is fossiliferous throughout.

Permian sediments underlie the Kockatea Shale, but the contact is not apparent. However, the base of the Kockatea Shale is at 3,290 feet on the evidence from the ditch samples. A rapid change in lithology to carbonaceous, shaly siltstone in Permian Unit 'A' indicates that the contact is disconformable and may even be unconformable.

The fauna of the Kockatea Shale is rich and diverse. It contains fish fragments (maxillae, scales, spines, skin); crocodilian head; pelecypods (pteriids inc. cf. Bakevillia, nuculids cf. Claraia (Pseudomonotis), arcomyids, etc.); estheriids; ammonites (inc. cf. Subinyoites, but generally indet. impressions) and aptychi; ostracods; serpulids; bone fragments, and xiphosurans. The microflora is poor in spores, but microplankton (Hystrichosphaerids) were present throughout the formation. Both palaeontologically (spores and microplankton) and lithologically the section between 2,162 feet and 3,290 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 for deposition of this unit. Cross-bedding, slump structures, and worm-tubes are rare, and the deposit is commonly well-bedded with thin lenticles of sandy siltstone. Structures enumerated above and the silty, clayey deposits are typical of the sediments of the pro-delta slope. 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 has suggested a Lower Triassic - Upper Permian age for the microflora from BMR 10, but he favours a Lower Triassic age for the formation. A study of the macrofauna by Dickins showed the presence of Lower Triassic guide fossils Claraia (pteriid pelecypod) and Subinyoites (ophiceratid ammonite). Also, it was noticed that the fauna is different from and younger than the fauna of the Hardman Member of the Liveringa Formation of Uppermost Permian possibly Tatarian age. Furthermore, the content of the fauna is close to that of the Blina Shale, which has estheriids, lingulid brachiopods, fish, and amphibian remains.

Subinyoites is reported from the Salt Range, India, and is a Lower Scythian genus.

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 proposed for the Kockatea Shale.

The Kockatea Shale is 1,128 feet thick in BMR 10 and according to McWhae et al. (1958, p.84) 1,091 feet thick in the Geraldton Municipal Bore, more than 1,131 feet in the Geraldton Racecourse Bore, and more than 468 feet in the 47¼ 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

Permian sediments were penetrated in BMR 10 from 3,290 feet to 3,910 feet (T.D.). The sequence could be divided readily into an upper carbonaceous siltstone unit and a lower sandstone unit, but neither unit could be correlated definitely with the previously known Permian Beds of the Perth Basin. Also, the boundary between the units is uncertain in the absence of electric logs.

Permian Unit 'A' (3,290 feet - 3,588 feet)

This sequence comprises a 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 and fossils are present.

Chonetids, strophalosia, conularia, bryozoans, and worm-tubes are present in the upper part of this formation, and wood remains have been recognized. Microplankton, spores, and pollen grains are present throughout the formation, and are used to date it.

This deposit probably accumulated in a shallow water, marine deltaic environment as indicated by the paucity of its benthonic fauna, the presence of pyritized wood remains and worm-burrows.

There is a sharp change from the carbonaceous siltstone of this formation to the underlying sandstone unit (Permian Unit 'B'), and the base of Permian Unit 'A' is placed immediately above the sandstone, which first appears in core 39 (3,587 feet - 3,597 feet).

Lithologically this unit is not unlike the Kungurian Indarra Beds and the Artinskian Carynginia Formation of the Perth Basin. Also, marine fossils have been found in the Carynginia Formation; these are microplankton (McWhae et al. 1958), and foraminifera (Crespin, 1958). However, Balme noted features of the microflora that are unusual in pre-Kungurian sediments in Permian Unit 'A'. Nevertheless he suggested an Artinskian age for the formation and correlated it with the Noonkanbah Formation in the Fitzroy Basin on its microflora. The Carynginia Formation is a time-equivalent of part of the Noonkanbah Formation, and broad correlation with Permian Unit 'A' is likely.

Therefore it seems that Permian Unit 'A' is Artinskian in age, and might be identified with the Carynginia Formation.

Permian Unit 'B' (3588 feet - 3910 feet)

This formation contains moderately-sorted, very fine- to medium-grained, light grey, kaolinitic sandstone, which is cross-bedded thin-bedded, and shows slumped or contorted laminae in some beds. Black carbonaceous, fissile shale grading to siltstone is dominant in the thin beds and lenticles, and in some beds there is graded-bedding from silty sandstone to shaly siltstone. Rare beds of moderately sorted, coarse-grained to very coarse-grained sandstone occur near the base of the section penetrated.

The absence of microplankton and other marine fossils in this formation is interesting, in that it is likely that this sediment was deposited in a marine environment. Salt water in core 39 (3587 feet - 3597 feet) tends to support this, although the origin of this water is not certain. Also, it seems that free circulation of these pelagic organisms has been barred so that they have been restricted from the environment of deposition. Likewise, the absence of any benthonic fauna is strange. Nevertheless, in keeping with the picture of a generally marine sedimentary sequence in BMR 10, a marine site of deposition is suggested for this unit. It is considered that sediments were laid down in a shallow-water, well-aerated marine environment.

The only fossils known from this unit are spores and pollen grains, by which Balme was able to date the formation as possible Lower Artinskian. A tentative correlation with the Irwin River Coal Measures is proposed on the basis of the lithological and palaeontological evidence available.

Hydrocarbon Show

A slight hydrocarbon show was present in core 40 (3710 feet - 3722 feet), which is in the lowest unit of BMR 10 and is of Permian age.

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.

Contributions to Geological Knowledge

(i) Unfortunately, BMR 10 was abandoned before basement was encountered; hence, it is difficult to establish whether or not basement is at 4,000 feet to 5,000 feet. However, the stratigraphic position of BMR 10 at 3910 feet indicates that basement may be deeper than previously expected. Although, BMR 10 is about one mile east of the longitudinal axis of Beagle Ridge, it is not so far that thicknesses of sediment will be markedly different from those along the crest of the Ridge.

At 3910 feet in BMR 10 the formation was probable Irwin River Coal Measures equivalent. Below the Irwin River Coal Measures in the Irwin Basin there is a maximum thickness of about 3,500 feet of Permian sediments. Although there is insufficient evidence to determine the rate of change in thickness westwards of the Permian sequence, especially near or on a submarine basement ridge, it is certain that, if this ridge was not exposed during part of the Permian, the Permian section on it would be thinner than that off the ridge. The thinning is indeterminate at present.

Also, it is not impossible that older pre-Permian Palaeozoic sediments could be encountered before basement, because Tumblagooda Sandstone, which crops out in the northern part of the Basin and is of Lower Palaeozoic age, may extend as far south as BMR 10.

Therefore it seems from the above evidence that basement will be deeper than previously estimated but this greater depth is presently indeterminate. However, if there are no rocks between the Permian and basement, and if the Permian sediments in BMR 10 are approximately the same thickness as those of the Irwin River Basin, then the depth to the top of the Nangetty Formation is likely to be about 6,000 ft. and the depth to basement may be as great as 7,500 ft.

(ii) Dips of $5^{\circ} - 10^{\circ}$ were noticed in the cores, and contorted laminae and slump structures were quite frequent. Unfortunately cores were not oriented so that it was difficult to determine the full significance of their dips. It is unlikely that dips are entirely the result of tectonic activity, although it must be remembered that the Hill River Fault Zone is only a few miles to the East of BMR 10. Rather, it is probable that dips are primary structures controlled by the slope of the depositional environment, but tectonism almost certainly had some modifying effect on the attitudes of the strata. This interpretation seems the more reasonable when it is remembered that contorted laminae and slump structures are present in the lower half of BMR 10.

(iii) The Cockleshell Gully Sandstone in BMR 10 was older than any previously known, and its age was determined from palynological studies. Because of the age of this section of the formation it is likely that the thickness of the Cockleshell Gully Sandstone should be increased. Furthermore, the lower limit of the formation should be extended to the base of the Liassic, both on palynological evidence and apparent continuous sedimentation from the Triassic.

(iv) A thick Triassic sequence of marine and deltaic sediments previously unknown from the Perth Basin, was recognized in BMR 10. Probably the entire Triassic is represented in this section. Three new Triassic units have been distinguished, but none has been formally named; a fourth unit, the Kockatea Shale, is also present.

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.

Because of the discovery of the thick Triassic sequence Termier and Termier's predicted Triassic phase of their "Geosynclinal Westralian" is confirmed, but its eastern margin must be moved farther eastwards and onto the Western Australian mainland. This Triassic sequence will probably be found underlying the Jurassic almost everywhere in the Perth Basin.

(v) Upper Permian sediments appear to be absent from BMR 10; hence there has been a probable Artinskian-Lower Triassic hiatus. Apart from this hiatus there is no apparent break in sedimentation until the Liassic-Pleistocene break.

(vi) A hydrocarbon show in the Permian has considerably enhanced the petroleum prospects of the Perth Basin, for both Permian reservoir beds and cap rocks, that have not been eroded for a long period, have been encountered in BMR 10. Also, over 1,000 feet of potential source rock in the Lower Triassic with satisfactory reservoir beds and probable cap-rocks overlying it, considerably strengthen the possibilities for petroleum in the Perth Basin.

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APPENDIX A

CORE RECORD

Core No.	Section Cored	% Recovery	Recovery (ft.)
1	100' - 110'	30	3'
2	205' - 215'	-	-
3	260' - 270'	-	-
4	381' - 396'	02.5	¼'
5	500' - 510'	15	1½'
6	600' - 610'	05	½'
7	713' - 723'	70	7'
8	803' - 813'	-	-
9	893' - 903'	-	-
10	983' - 993'	-	-
11	1105' - 1115'	30	3'
12	1213' - 1223'	60	6'
13	1317' - 1327'	02.5	¼'
14	1408' - 1418'	15	1½'
15	1508' - 1518'	60	6'
16	1617' - 1627'	25	2½'
17	1710' - 1720'	15	1½'
18	1800' - 1810'	72.5	7¼'
19	1891' - 1901'	80	8'
20	2011' - 2021'	60	6'
21	2103' - 2113'	20	2'
22	2131' - 2141'	85	8½'
23	2223' - 2233'	10	1'
24	2233' - 2243'	60	6'
25	2314' - 2324'	100	10'
26	2405' - 2415'	85	8½'
27	2494' - 2504'	65	6½'
28	2604' - 2624'	80	8'
29	2707' - 2712'	50	5'
30	2802' - 2812'	100	10'
31	2902' - 2912'	72.5	7¼'
32	2993' - 3003'	60	6'
33	3105' - 3115'	50	5'
34	3193' - 3203'	30	3'
35	3203' - 3213'	65	6½'
36	3300' - 3310'	50	5'
37	3400' - 3410'	100	10'
38	3497' - 3507'	70	7'
39	3587' - 3597'	90	9'
40	3710' - 3722'	100	12'
41	3810' - 3820'	70	7'

CORE DESCRIPTIONS

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

1¾' - Limestone (Calcarenite) Light grey-green, massive, recemented, dense, with cavities up to 3 cms., coarse quartz grains (2.0 mm.) disseminated throughout.
1¼' - 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 ½'

¼' - Sandstone light grey, kaolinitic, with black carbonaceous laminae, grains uniform, medium-grained (0.3 mm-0.5mm) and rarely 2.0 mm, in part micaceous, cross-bedded, friable.
¼' - Sandstone, light grey, kaolinitic, uneven-grained, grains to 5.0mm, friable. (Quartz greywacke in character)

Core 5 - (500' - 510') Recovered 1½'

¾' - Sandstone, grey-white, felspathic, medium to coarse grained (0.5mm - 1.0mm), sorting fair, massive, friable, porosity low.
½' - Sandstone, grey, banded, with black carbonaceous laminae about 2.0mm thick, felspathic, medium-grained, grains 0.2mm-0.5mm, slightly graded, cross-bedded, friable.
¼' - Mudstone grey, calcareous, slightly carbonaceous, massive, with pyrite nodules (Nodules - 60% pyrite, 40% coarse quartz grains of about 1.5mm).

Core 6 (600' - 610') Recovered ½'

½' - Sandstone, white-grey, felspathic, poorly sorted, medium to coarse-grained (0.5mm - 1.5mm) with some grains 5.0mm, subangular, laminated with black carbonaceous laminae, cross-bedded, friable, porosity low.

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

7' - Alternating sandstone and conglomerate alongbedding planes.
Sandstone, grey, slightly calcareous, felspathic, with occasional dark bands, grains quartz 80% - 90%, feldspar 10% - 20%, sorting fair, coarse-grained (1.0mm), cross-bedded.
Conglomerate mottled grey/white, felspathic, grains quartz 60% - 70%, feldspar 30% - 40%, sorting fair, pebbles 5.0mm - 7.5mm, sub-angular.

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

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

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

Core 11 (1105' - 1115') Recoverd 3'

1¾' - Interbedded sandstone and siltstone.
Sandstone, light grey, quartzose with traces of feldspar and mica, well-sorted, fine-grained (0.1mm - 0.2mm), poorly bedded, dense, porosity low.
Siltstone, dark grey, carbonaceous and micaceous, fissile, with lenticular argillaceous laminae, dip 5° *
¼' - 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 felspathic sandstone 5cms x 1cm, dip 10°.

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

½' - Sandstone, light grey, kaolinitic, moderately sorted, fine-grained (0.1mm - 0.3mm), rare nodules of pyrite, cross-bedded, laminated with grey-black, micaceous laminae increasing with depth, dip 5°.

5½' - 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 ¼'

¼' - Sandstone, white, kaolinitic, quartz 60%, well-sorted, fine-grained (0.1mm - 0.2mm) very rarely (1.5mm), occ. grains ferruginized poorly bedded with interbeds black, micaceous, carbonaceous, in part pyritic, very thin-bedded, porosity low.

Core 14 (1408' - 1418') Recovered 1½'

½' - Sandstone grey, quartzose, with clots 5mm - 10 mm of pyrite and blue-grey shale, grains well-sorted, fine (0.2mm), 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'

6' - Interlaminated Siltstone/ Sandstone, well-bedded, cross-bedded dip 5° - 10°.
Sandstone, grey-white, kaolinitic, poorly sorted, fine-to medium-grained (0.2mm - 0.3mm), porosity low.
Siltstone, dark grey and black, micaceous, carbonaceous in part, also traces of grey shale, porosity very low.

Core 16 (1617' - 1627') Recovered 2½'

2½' - Interlaminated Siltstone/Sandstone, dip 5°.
Siltstone, dark grey, micaceous, bedded, porosity poor.
Sandstone, in laminae of 2.0mm, grey-white, poorly sorted, fine-grained, porosity low, and lenticular bed (2.5cm) of brown massive Dolomite.

CORE 17 (1710' - 1720') Recovered 1½'

1½' - Interlaminated Siltstone/Sandstone well-bedded, cross-bedded, dip 5°.
Siltstone, dark-grey, micaceous, with laminae (1.0mm) of Sandstone as in core 16.

Core 18 (1800' - 1810') Recovered 7¼'

(a) ½' - Sandstone, grey, kaolinitic, poorly sorted, medium - grained (0,5mm), bedded, porosity low, interlaminated with Siltstone in 1.0mm laminae, dark grey, micaceous, and crossbedded at the base, dip 10°

(b) 1½' - Sandstone, grey, kaolinitic, micaceous, poorly sorted, medium-grained (0.5mm), poorly bedded, porosity low. (quartz--greywacke in character).

(c) 1¼' - Interlaminated Sandstone/Siltstone as in (a)

(d) 2¼' - Sandstone - Breccia of dark grey, poorly sorted, gritty to pebbly, massive Sandstone with pebbles of brecciated, dark green-grey Shale (2.0mm to 20mm) as angular blocks and slivers in kaolinitic sandstone matrix, and ¼' bed of well -bedded micaceous Siltstone. (Probable intra-formational breccia).

(e) ¾' - Interlaminated Siltstone/Sandstone as in (a), siltstone fraction decreasing towards the base of the bed from 60% to 20%, bedded, cross-bedded, dip 10°.

* All dip determinations were made by visual estimation.

(f) $\frac{3}{4}$' - Sandstone-Breccia as in (d) with pebbles up to 50mm of dark grey and chocolate brown Shale and 2-3 cm beds of Sandstone as in (a)

(g) $\frac{1}{4}$' - Siltstone, dark grey, micaceous, clayey, cross-bedded, and bedded, with sandstone laminae.

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

8' - Interlaminated Siltstone/Sandstone, cross-bedded, dip 10°. Sandstone component ranging though 80% ($3\frac{1}{4}$')to 40% - 20% ($\frac{3}{4}$') to 60% - 80% (4') towards the base. Light grey-brown, kaolinitic, micaceous, slightly pyritic - pyrite as 1mm grains and rare nodules, poorly sorted, medium-grained, grains sub-rounded, 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'

(a) $\frac{1}{2}$' - Siltstone, dark grey, micaceous, well-sorted, poorly bedded, porosity low.

(b) $5\frac{1}{2}$' - 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'

2' - Interlaminated Siltstone/Sandstone, bedded at the top, then laminae contorted, with snowball swirls in the lower half, the basal $\frac{1}{4}$', 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 1.0mm) - (Quartz-greywacke in character).

Core 22 (2131' - 2141') Recovered $8\frac{1}{2}$'

$8\frac{1}{2}$' - 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-white, kaolinitic, poorly sorted, fine-grained (0.1 mm) grading to siltstone, porosity low. (Quartzgreywacke in character

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

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'

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'

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 (0.1mm) Sandstone - fossils include pelecypods, gastropods, ganoid fish scales.

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Core 26 (2405' - 2415') Recovered 8½'

8½' - Shale, dark grey, slightly micaceous, hard, fissile, bedded, with interbeds and lens of Siltstone becoming Shale (grey, massive, soft), occasionally slumped, dip 10°, fossiliferous - indeterminate fossil fragments.

Core 27 (2494' - 2504') Recovered 6½'

6½' - 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 2½', at top ½' bed of Calcilutite, dip 10°.

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

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

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

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

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

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, dip 10°, Fossiliferous - Ammonites, pelecypods, Xiphosuran.

Core 31 (2902' - 2912') recovered 7¼'

7¼' - Shale and Siltstone as in Core 30, and occasional Limestone, lens, white, massive, in parts contorted, dip 10°, Fossiliferous - Ammonites, pelecypods.

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

6' - Shale,as in core 31, with Siltstone, light brown-grey, massive, hard, in 5 mm interbeds. dip 10°, Fossiliferous - Ammonites, worm tubes.

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

5' - Shale, as in core 31, with Siltstone interbeds as in core 32, and Calcilutite, grey-white, massive, soft, in contorted lenticles, dip 10°, fossiliferous - Ammonites.

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

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 6½'

6½' - 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'

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'

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

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

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'

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

7' - Sandstone, grey-white, quartzose, felspathic, well-sorted, fine-grained, porosity low, with flakes of Siltstone as above, and $\frac{3}{4}$' interbeds at 2' and 5' from the top of the Sandstone, with contorted interlaminae of Siltstone at $6\frac{1}{2}$'.

1' - Interlaminated Shale/Sandstone: Sandstone as above. Shale, black, carbonaceous, massive, hard, brittle. Salty taste.

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

$6\frac{1}{2}$' - 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.

$1\frac{1}{2}$' - Interlaminated Sandstone/Shale as above, but Sandstone cross-bedded.

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

$1\frac{1}{2}$' - Interlaminated Sandstone/Shale as above, becoming increasingly sandy, slumped in part, Sandstone - oil - stained.

$1\frac{1}{2}$' - Breccia (Intraformational) Sandstone pebbles to 7.5 cm, in a matrix of black, carbonaceous, shaly Siltstone.

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

7' - Interbedded and interlaminated Sandstone/Siltstone, in parts slumped or contorted, in the mid-section $\frac{1}{2}$' graded bedding from dark grey-black, carbonaceous, clayey Siltstone to grey-white, fine-grained, silty Sandstone.

Sandstone, typically grey-white, kaolinitic, trace pyritic, moderate sorting, fine to medium-grained, bedded, and cross-bedded, $\frac{3}{4}$' from the base is a 1.5 cm bed Sandstone as above, but grain-size very coarse to gritty. Siltstone, dark grey-black, very carbonaceous, massive, fissile.

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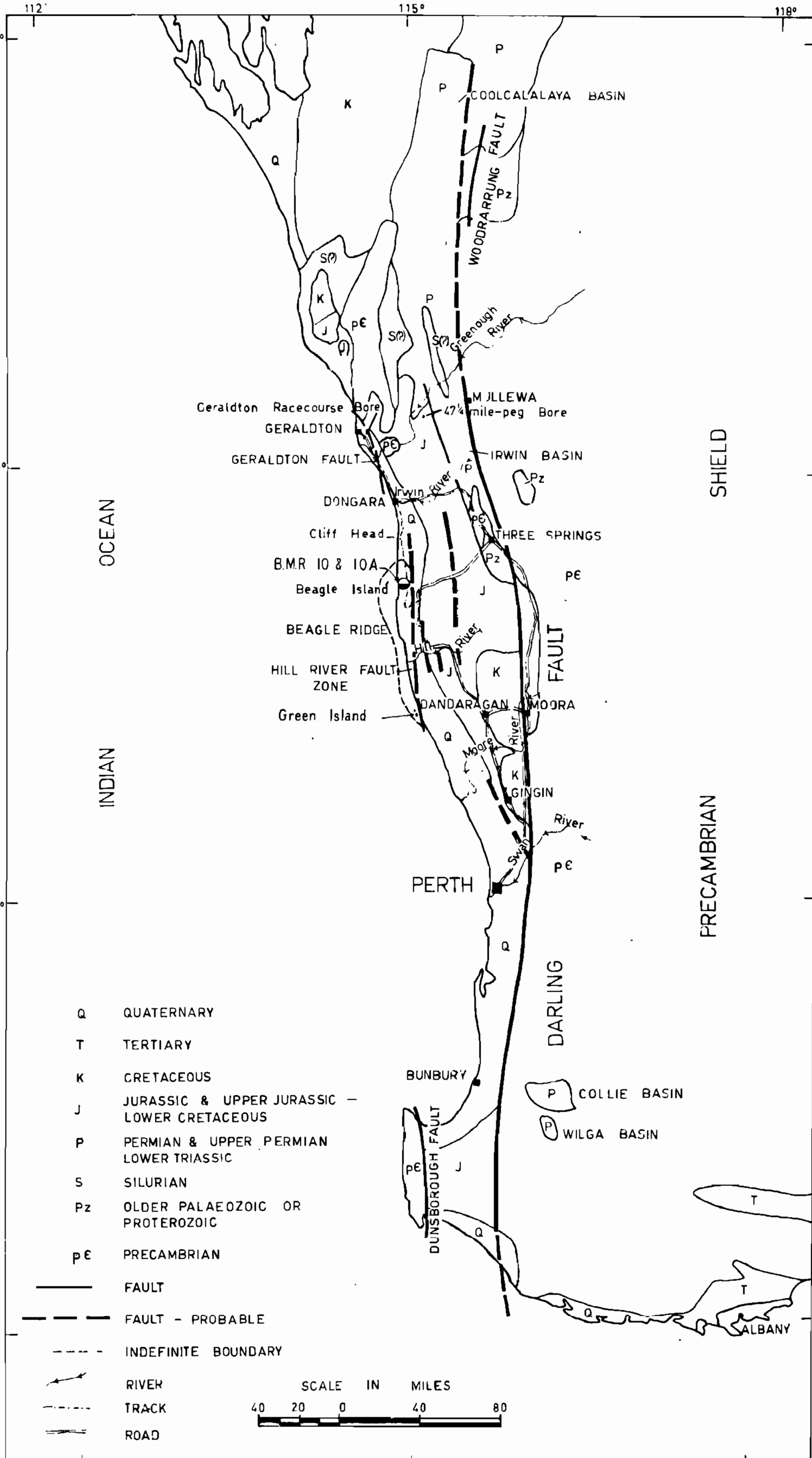
APPENDIX B.

DEVIATION RECORDS

Depth	Deviation (Degrees)	Variation
200 feet	$\frac{1}{2}^\circ$	Inc. $\frac{1}{2}^\circ$
600 feet	$\frac{1}{2}^\circ$	-
900 feet	$\frac{3}{4}^\circ$	Inc. $\frac{1}{4}^\circ$
1200 feet	$\frac{3}{4}^\circ$	-
1400 feet	$\frac{3}{4}^\circ$	-
1700 feet	$\frac{3}{4}^\circ$	-
2000 feet	$\frac{3}{4}^\circ$	-
2300 feet	$1\frac{1}{4}^\circ$	Inc. $\frac{1}{2}^\circ$
2600 feet	$1\frac{1}{4}^\circ$	-
2800 feet	2°	Inc. $\frac{3}{4}^\circ$
3100 feet	2°	-
3300 feet	2°	-
3790 feet	$1\frac{3}{4}^\circ$	Dec. $\frac{1}{4}^\circ$



GEOLOGICAL MAP OF PERTH BASIN SHOWING POSITION OF BMR 10 & 10A

Bureau of Mineral Resources, Geology & Geophysics July 1961. To Accompany Records Nos 1960/31 & 1960/127. AUS 1/2

PLATE 2

B.M.R. 10 BEAGLE RIDGE

COMPOSITE WELL LOG

STATE: WESTERN AUSTRALIA

LOCATION: Latitude 29° 49′ 38″
Longitude 114° 58′ 30″

ELEVATION (above S.L.): SURFACE 10 ft.
ROTARY TABLE (Depth Datum) 21 ft. (above S.L.)

DATE SPUDDED: 1st Aug. 1959

DATE T.D. REACHED: 6th Sept. 1959

DATE OPERATIONS COMPLETED: 27th Oct. 1959

TOTAL DEPTH: 3910 ft (below R.T.)

STATUS: Abandoned

HOLE PROFILE:
17½″ 10–189 ft.
12¼″ 189–1650 ft.
8¾″ 1650–3910 ft.

CASING:
13⅜″ 48 lbs API. Cement at 186′
9⅝″ 40 lbs API. Cement at 1448′
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
MICROFOSSILS
MACROFOSSILS
Calc. CALCAREOUS
C CARBON
Py PYRITE
CORE INTERVAL AND CORE RECOVERY (IN BLACK)
CORE DIP
CASING SIZE AND DEPTH SET

AREA: BEAGLE I. — L. LOGUE

SYMBOLS — LITHOLOGY
CALCARENITE
CALCILUTITE
QUARTZ SANDSTONE
QUARTZ GREYWACKE
SANDY SILTSTONE
SILTSTONE
SHALE

SEDIMENTARY STRUCTURES
BEDDING: THIN, LAMINATED, CROSS, CONTORTED, SLUMPED
CAVERNOUS
OIL SHOW
SALT WATER

Bureau of Mineral Resources, Geology & Geophysics June 1961

To Accompany Record No. 1960/31

W.A. 61-2