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DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

RECORDS 1961 No. 28

BEAGLE RIDGE BMR 10A ELECTRIC BORE LOGGING, W.A. 1960

by

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CONTENTS

ILLUSTRATIONS

ABSTRACT

Bore No. BMR 10A was drilled to basement in 1960 near a previous bore, BMR 10, which had been abandoned at 3910 ft in 1959.

The electric and radiometric logs made by the Bureau of Mineral Resources are used, in conjunction with the ditch sample logs, to define the boundaries of the various rock types, and in particular to locate permeable sandstone beds which might contain petroleum.

A comparison between the logs of BMR 10 and BMR 10A indicates that the strata have a northerly component of dip of about 10 degrees.

Formation water salinities, estimated from the values of self-potential, are high, and are responsible for the low values of resistivity exhibited by the porous sandstone beds. The porosities of these beds, computed from the long-normal resistivities, are low. It is possible that these computed porosity values are erroneously low because of petroleum content of the porous beds.

1. INTRODUCTION

Stratigraphic bore No. BMR 10A was drilled between May and July 1960, to replace bore BMR 10 which had been abandoned at 3900 ft in August 1959 (McTavish, 1960). It is located (Plate 1) approximately 50 yards north of BMR 10 at latitude 29° 49' 38", South, longitude 114° 58' 30" East. The coordinates of the bore are 1,305,600 yd north, 291,660 yd east, on the Dongara 4-mile military sheet. The site is part of the petroleum exploration permit area 27H which is held by West Australian Petroleum Pty. Ltd. BMR 10A struck metamorphic basement rock (gneiss) at approximately 4790 ft.

Logging of the hole was done between 18th May and 27th June 1960 by N.D. Jackson of the Geophysical Branch.

2. EQUIPMENT AND OPERATIONS

A Failing Logmaster was used to run electric logs before and after intermediate casing was set at 1616 ft. Radiometric and temperature logs were made after the casing was set. A caliper log was attempted when the hole was at 2300 ft, but the caliper arms failed to open because the spring mechanism was clogged with debris. Further attempts were also abortive owing to a fault in the electrical circuit of the caliper.

When the first electric logs were run, interference from the drilling rig power supply produced "noise" on the resistivity logs, with the result that these logs could not be made on the most sensitive range of the instrument.

Subsequent electric logs were made with the drilling rig power supply turned off, so that the most sensitive range could be used.

The total logging time was 69 hours.

3. GEOLOGY

The ditch sample log of the bore for depths below 3250 ft is shown graphically on the composite log (Plate 2). The section above this depth is covered by the ditch sample log of bore BMR 10 (McTavish, 1960).

4. INTERPRETATION OF LOGS

In the discussion which follows, depths are referred to the rotary table which was 11 ft above ground level.

Electric Logs (Plate 2)

Single-point resistance and short-normal and long-normal resistivity curves were recorded; the electrode separation was 16 in. for the short-normal resistivity curves and 64 in. for the long-normal resistivity curve. No long-normal curve was recorded on the first run because the electrical circuit of the probe failed to operate.

The logs exhibit the same features as the logs of bore BMR 10 (McTavish, 1960), which was logged to 2996 ft. The logs show that strata in BMR 10A are about 27 ft lower than corresponding strata in BMR 10; this indicates that the strata have a component of dip to the north of approximately 10 degrees. The high salinity of the drilling mud and of the formation water has again led to characterless resistance curves above 2100 ft; the sandstone shows resistances very little different from, and often lower than, those of the shale.

The shale section extends from 2330 ft to 3200 ft. Below 3200 ft the electric log read in conjunction with the ditch sample log indicates the following lithology:

3200 - 3230 ft	cemented sandstone or siltstone (impermeable)
3230 - 3252 ft	sandstone (permeable)
3252 - 3263 ft	siltstone
3263 - 3300 ft	sandy siltstone (permeable)
3300 - 3610 ft	shale and siltstone
3610 - 3640 ft	sandstone (permeable)
3640 - 4787 ft	siltstone with permeable sandstone beds and occasional coal seams

In the last group (3640 - 4787 ft), the resistivity of the siltstone members (which are indicated by the higher level of radioactivity) increases generally with depth, and may be attributed to an increasing calcareous content. This calcareous character of the siltstone is shown by the ditch sample log for the high-resistance section between 4730 and 4780 feet. The permeable sandstone members within this group, which are characterised by negative potentials and low level of radioactivity, have an unusually low resistivity, 10 ohm-metres or less, owing to the low resistivity of the formation water. Occasional coal seams are depicted as thin beds of high resistivity. However, some of the high resistivity peaks (with associated low radioactivity) may be due to cemented sandstone with a low porosity, as for example the resistivity peak between 4163 and 4168 ft.

The salinity of the water contained in the permeable beds can be estimated from the self-potential curve by applying the formula (applicable to clean sandstone) (Martin, 1956, p.20):-

$$\text{S-P. (millivolts)} = -K \log_{10} (R_{mf}/R_W)$$

where R_{mf} = resistivity of the mud filtrate at formation temperature

R_W = resistivity of the formation water

K = $63 + 0.1\ t$

t = formation temperature (in ^{o}F)

S-P. = potential difference between the permeable beds and the shale beds.

R_{mf} has here been taken to be equal to three-quarters of the mud resistivity. For example, the section 1955 to 1980 ft corresponds to a self-potential of 57.5 mV and R_{mf} = 0.95 ohm-metres at 91°F.

Then $57.5 = -72 \log_{10} (0.95/R_W)$.

and R_W = 0.15 ohm-metres.

When corrected for the high salinity of the formation water by the empirical chart of Gondouin, Tixier, and Simard (1956, p.40), R_W becomes 0.17 ohm-metres and corresponds to a salinity of approximately 30,000 p.p.m. equivalent sodium chloride.

The figures for various permeable beds are tabulated below. The self-potential has been corrected for bed thickness from charts prepared by the Schlumberger Well Surveying Corporation, and R_W corrected from the charts of Gondouin _et al_. (_ibid_.)

Depth (ft)	S-P. (mV)	Temp. (°F)	R_{mf} (ohm-metres)	R_W (ohm-metres)	Salinity (p.p.m.)
3610 - 3640	45	104	0.85	0.23	19,000
3715 - 3722	40	105	0.85	0.28	16,000
3850 - 3863	42	106	0.84	0.25	17,000
3910 - 3925	43	106	0.84	0.25	17,000
4360 - 4377	50	112	0.80	0.20	20,000
4473 - 4483	53	115	0.77	0.17	30,000
4611 - 4626	53	117	0.75	0.17	22,000

The water salinity may not in fact vary very much from bed to bed; the differences in computed salinity probably arise from inaccuracies in the correction for bed thickness and from variations in self-potential due to the presence of shale within the sandstone formations.

If the long-normal resistivity R_t is assumed to be the true resistivity (R_o) of the water-saturated bed, then the formation porosities can be calculated; this assumption is not valid for beds less than about 10 ft thick. The formation factor F (= R_o/R_w by definition) is taken as equal to p^{-m}, where p is the porosity and m the cementation factor whose value ranges between 1.3 and 2 or more, depending on the character of the sand. For this report m is taken as 1.8 for a consolidated sandstone (Tixier, 1956, p.4).

Figures for various permeable beds, tabulated below, show that the estimated porosities are low.

Depth (ft)	R_t (ohm-metres)	F	p
3610 - 3640	10.5	46	12%
3715 - 3722	9.0	32	14%
3850 - 3863	7.0	28	16%
3910 - 3925	7.7	31	15%
4360 - 4377	7.3	36	13%
4473 - 4483	7.5	44	12%
4611 - 4626	6.0	35	14%

The short-normal resistivities R_s are effected by mud invasion. Were the invasion deep then the formation factor F would be given by R_s/R_{mf}.

Figures for various permeable beds on the assumption of deep invasion are tabulated below:-

Depth (ft)	R_s (ohm-metres)	F	p
3610 - 3640	15.0	17.6	20%
3715 - 3722	17.5	21	18%
3850 - 3863	11.0	13	24%
3910 - 3925	11.0	13	24%
4360 - 4377	12.0	15	22%
4473 - 4483	9.5	12	25%
4611 - 4626	10.5	14	23%

8

The discrepancies in the two sets of porosity estimates probably arise from the fact that mud invasion has not been extensive enough to validate the assumption that $F = R_s/R_{mf}$.

It is theoretically possible however that the formation factors calculated from the short-normal resistivities are correct and that the formation factors calculated from the long-normal resistivities are high owing to the petroleum content of the formations.

The percentage water saturation of the permeable beds would then be given approximately by the formula (Tixier, 1956, p.7) :-

$$\text{Water saturation} \quad S = (FR_w/R_t)^{\frac{1}{2}}$$

F is calculated from the short-normal resistivities, and R_t is the measured long-normal resistivity which is no longer assumed to be the true resistivity R_o of the water-saturated formation.

The estimated water saturations for the beds considered are:-

3610 - 3640 ft	S	=	62%	(petroleum 38%)
3715 - 3722 ft	S	=	81%	(" 19%)
3850 - 3863 ft	S	=	68%	(" 32%)
3910 - 3925 ft	S	=	65%	(" 35%)
4360 - 4377 ft	S	=	64%	(" 36%)
4473 - 4483 ft	S	=	53%	(" 47%)
4611 - 4626 ft	S	=	63%	(" 37%)

Thus, the estimated petroleum saturation of the various beds is in all cases less than 50 per cent, whereas, for oil or gas production without water, a petroleum saturation of about 80 per cent is required.

A realistic estimate of petroleum content would require an accurate determination either of formation factors from micro-logs, or of porosities from laboratory determinations.

Radiometric Log (Plate 2)

The fluctuations of the radiometric log indicate that the top 1485 ft of strata is not as homogeneous as would appear from the self-potential logs. The positive-going portions of the self-potential logs identify the bands of shale within the sandstone, but there are also many bands of sandstone which, though shaly enough to produce a high gamma-ray count, do not produce positive-going kicks on the self-potential logs.

A change from mainly sandstone to siltstone is indicated at 2003 ft; this depth is evidently the top of what was designated Triassic "C" in BMR 10 (McTavish, 1960). Below this depth, the radioactivity is substantially uniform down to 3610 ft, apart from a low zone which corresponds to the sandstone between 3200 and 3300 ft. The permeable beds between 2273 and 2284 ft have anomalous radioactivity whose cause is unknown.

Below the limestone bed between 4780 and 4787 ft, there is a zone of high radioactivity between 4787 and 4793 ft, which may possibly be the weathered top of the basement gneiss.

Temperature Logs

The temperature log (Plate 3) was taken 12 hours after the intermediate casing (to 1616 ft) was cemented, and shows a large temperature anomaly between 355 ft and 825 ft. This anomaly is difficult to explain except by assuming that the cement has been carried up outside the casing and has solidified between these two depths.

The slight increase in temperature below 1415 ft indicates that a small quantity of cement may have solidified between this depth and the top of the plug at 1550 ft.

The general gradient of the temperature curve is 1°F per 100 ft, which is a reasonable value for the true temperature gradient of the formations.

The temperature log (Plate 2) which was taken to 4525 ft soon after mud circulation had ceased, shows an average temperature gradient of 1°F per 145 ft; the mud column had not attained temperature equilibrium with the formations.

The changes in temperature gradient show some correlation with the formation changes. The substantially sandstone section down to 1350 ft has a practically zero gradient. The interbedded sandstone and shale section between 1350 and 1700 ft has a gradient of 1°F per 90 ft, but the similar section between 1700 and 2003 ft has a zero gradient; the reason for this is unknown. Below 2003 ft the temperature gradient is fairly steady in the siltstone section, though there is an increase in temperature gradient below 4150 ft where the siltstone is carbonaceous.

5. CONCLUSIONS

The succession penetrated by the bore consists mainly of permeable sandstone to a depth of 1485 ft. This is underlain by interbedded siltstone and sandstone to 2177 ft; a change from mainly sandstone to mainly shale and siltstone occurs at 2003 ft.

Shale occurs between 2003 and 3200 ft. This shale was recognised in bore BMR 10 as the Kockatea Shale by McTavish (1960).

Below 3200 ft, siltstone predominates, but there are many permeable sandstone beds of which the thickest occurs between 3610 and 3640 ft. The porosities of the sandstone beds have been estimated from their long-normal resistivities; if the petroleum content of the beds is assumed to be zero, the porosities are low and are between 12 and 16 per cent. The water contained in the permeable beds is saline; the salinity is estimated from the self-potential values and is between 16,000 and 30,000 p.p.m. equivalent sodium chloride.

It is not possible to state whether or not the permeable sandstone beds contain petroleum. However, if there is a petroleum content, it is certainly too low to allow production without water contamination.

Correlation of the electric logs with the electric logs of bore BMR 10 indicates that the strata have a northerly component of dip of about 10 degrees.

The rapid rise of resistivity below 4793 ft corresponds to the non-porous basement gneiss.

6. REFERENCES

GONDOUIN, M., TIXIER, M.P. and SIMARD, G.L., 1956 — An experimental study on the influence of the chemical composition of electrolytes on the S-P. curve. Petroleum Trans. A.I.M.E. Reprint Series No. 1, Well Logging.

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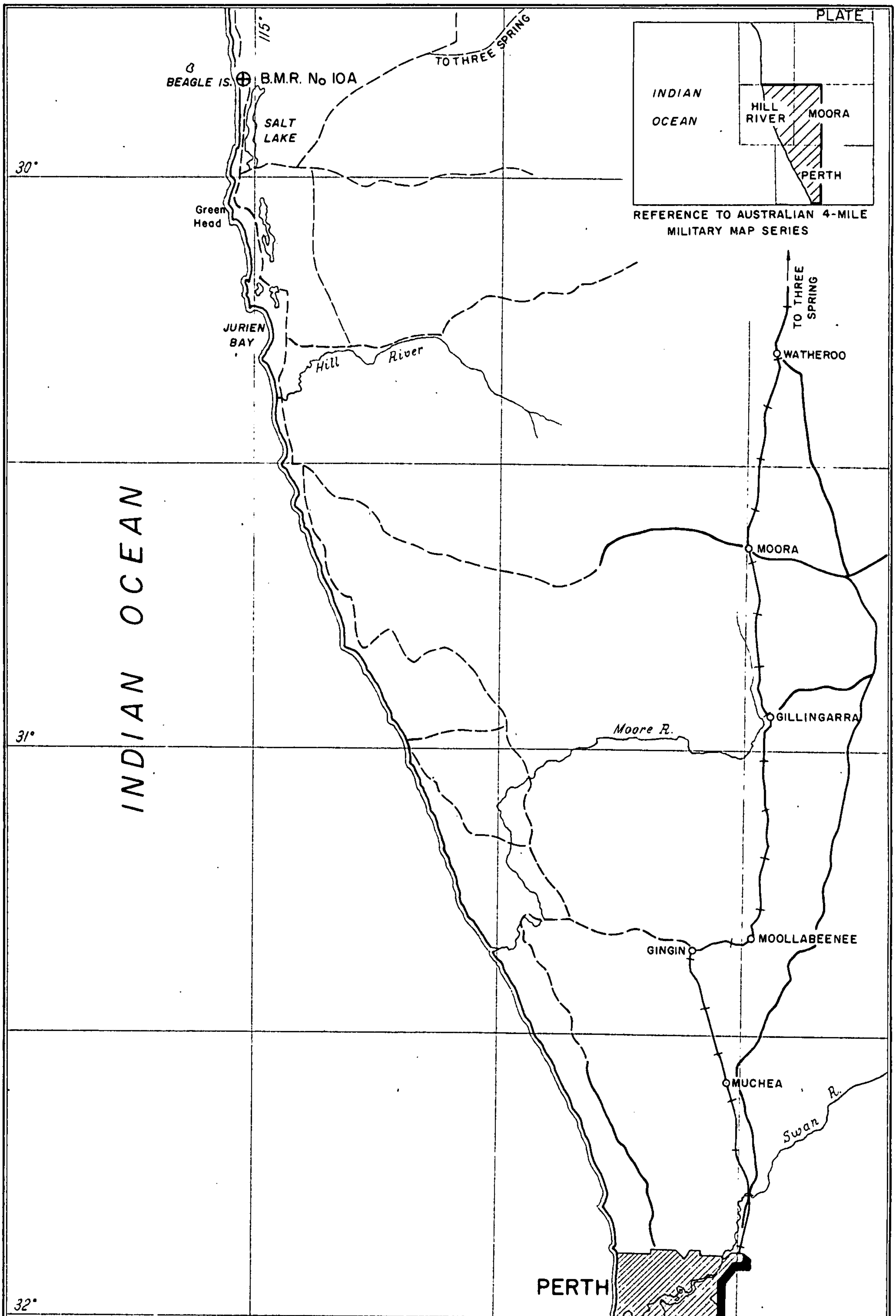

WELL LOGGING, W. AUSTRALIA, 1960

BEAGLE RIDGE SITE
LOCALITY MAP

B.M.R. BORE HOLE No 10 A

SCALE IN MILES

10 0 10 20 30 40 50

Geophysical Section, Bureau of Mineral Resources, Geology and Geophysics. G193-50

To Accompany Records 1961, No 28

BEAGLE RIDGE B.M.R. 10A.

COMPOSITE LOG

LOGGED BY : N. JACKSON
LOGGING EQUIPMENT : FAILING LOGMASTER

STATE : W.A.
BASIN : PERTH BASIN
PETROLEUM TENEMENT : 27H.
LOCATION : LAT. 29° 49' 38" S.
LONG. 114° 58' 30" E.
ELEVATION : GROUND 15 FT. A.S.L.
REF. LEVEL 26 FT. A.S.L.
(ROTARY TABLE)

ELECTRIC LOG DATA				
RUN No.	1	2	3	4
DATE	18/5/60	31/5/60	7/6/60	26/6/60
FIRST READING (FT.)	2300	1600	4525	4845
LAST READING (FT.)	275	3900	2000	1616
MUD TYPE	BENTONITE			
RESISTIVITY (Ωm)	·93 @ 82°F.	1·47 @ 65°C.	1·02 @ 93°F.	1·65 @ 70°C.

LEGEND

- SHALE
- SILTSTONE
- SANDSTONE
- LIMESTONE
- METAMORPHIC BASEMENT (Gneiss)
- COAL

Plate 3

COMPANY	Bureau of Mineral Resources	COORDINATES	E 114°58'30"
AREA	PERTH BASIN	S	29°49'38"
WELL	Beagle Ridge, BMR 10A STATE W.A.	ELEVATION	15 ft. A.S.L.
		D.F.	
		K.B.	
		G.L.	

TEMPERATURE LOG

	Run No. 1	Run No. 2	MUD	Run No. 1	Run No. 2
Date	21st May '60		Nature	Bentonite	
First Reading	1,550 ft.		Density		
Last Reading	25 ft.		Viscosity	@ °F	@ °F
Footage Logged	1,525 ft.		Resistivity	@ °F	@ °F
Bottom (Driller)			Res. BHT	@ °F	@ °F
Casing (From Log)	Cased		pH		
Casing (Driller)			Circ. Temp		
Casing Size	$13\frac{3}{8}$" to 275ft.		B.H. Temp		
~~xxxxx~~	$9\frac{5}{8}$ to 1,616ft.				
Bit Size					
			Logged by	N. Jackson	
			Witnessed by		

REMARKS Depths relative to rotary table, 11 ft. above ground
Temperature log taken 12 hours after cemeting

To Accompany Records 1961, No. 28