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ELECTRICAL LOGGING OF FROME-BROKEN HILL NO.1 BORE, WYAABA, QUEENSLAND

by

D.F. DYSON

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ABSTRACT

Frome-Broken Hill No. 1 bore at Wyaaba, drilled jointly by Associated Australian Oilfields N.L., Associated Freney Oilfields, N.L. and Frome-Broken Hill Co. Pty.Ltd., was logged to a depth of 2,822ft., the total depth of drilling, by self-potential and resistivity methods using the single-electrode technique. The full depth was logged on a scale of one inch equals 50ft. and the section below 2,340ft. was also logged at one inch equals 20ft.

Major formations are clearly indicated and a correlation of the electric log is made with the lithology. In general, the electric log lacks prominent features and some variations may be attributed to the effects of caving. The most important features shown on the log occur within the section between 1,815ft. and 1,894ft. These features are not accounted for conclusively and it is suggested that a packer test may have proved helpful for this and possible future log interpretations in the area.

1. INTRODUCTION.

As the result of an application from Associated Australian Oilfields, N.L., the Geophysical Section of the Bureau conducted a single-electrode electrical log of an exploratory drill hole at Wyaaba, Queensland, on 19th November 1957. The hole was drilled jointly by the Company, Associated Freney Oilfields, N.L. and Frome-Broken Hill Co. Pty Ltd.

The co-ordinates of the bore site are :

Longitude 141° 37' 22.7" East

Latitude 16° 29' 30.1" South

The ground surface elevation at the site is 35.5ft. above S.L. and the drilling platform, from which all measurements were taken, was 40.5ft. above S.L.

The hole was cased to a depth of 169ft. with 8-5/8"- casing and bedrock was encountered between 2758ft. and 2760ft; the hole was terminated at 2822ft. It was necessary to conduct the logging as soon as possible after completion of the drilling because it was expected that the lower section of the hole would cave within a short time after completion.

During transit to Wyaaba the recorder section of the equipment was damaged and temporary repairs were made at Wyaaba. The satisfactory operation of the equipment, except for possible slight sticking of the recording pen, was demonstrated by the similarity of the rerun log (upwards from 2373 ft) to the initial log except for the changes of base line. The results of the 1 inch equals 50ft and the 1 inch equals 20ft logs over the lower section of the hole are at variance; the differences, which are discussed later, may result from the effects of caving in the lower part of the hole.

The hole was logged from the bottom upwards as the probe was difficult to lower at a uniform speed below a depth of 2313ft. due to the caving of the walls.

An initial log of vertical scale one inch equals 50ft. was made over the complete depth of the hole. A re-run to eliminate the changes of base line on the potential log was made from a depth of 2373ft. at which point the hole was blocked. This blockage occurred when running the log on a scale of one inch equals 20ft. over the lower section of the hole immediately after making the initial log. The probe was very tight in the hole between 2373 ft and 2140 ft. and smooth upward movement was interrupted by frequent sticking.

In order to obtain more detail below 2100 ft. logging at 20ft. to an inch was attempted from the bottom but the log was terminated at 2313ft. where the probe jammed and caused a temporary mechanical failure of the winch system.

2. EQUIPMENT

The instrument used was a Widco two-channel logger (Model ZDE), manufactured by the Well Instrument Developing Company, Bellaire, Texas, U.S.A. The instrument uses a single-point electrode and records continuously and simultaneously the variations of self-potential (S.P.) and resistance; the resulting graphs are recorded side by side on a paper chart.

3. METHODS

For information regarding the technique and principles of interpretation, the reader is referred to the appropriate literature (Jakosky, 1950; Schlumberger, 1949; Guyod, 1952; Wiebenga, 1956). Very briefly, the magnitude of the self-potential depends upon the permeability of the formation and the salinity contrast between the pore solutions and the drilling mud. Reference to the self- potential values is in a negative sense, i.e. a high S.P. infers a high negative value. The resistivity depends mainly on the porosity of the formation and the salinity of the pore solutions.

4. DISCUSSION OF RESULTS

Plate 1 is a composite tracing from the two logs at a scale of 1 inch equals 50ft. and Plate 2 is a tracing of the log at a scale of 1 inch equals 20ft. from 2340 ft to the bottom.

In the tracings, a correction is made for the misalignment of the pens which resulted from the damage to the equipment.

The log on a scale of one inch equals 50ft. (Plate 1).

The log is a composite one of the two logs recorded. The S.P. trace consists of that recorded during first run from the bottom of the hole to depth 2373ft. (the depth limit of the second run) and that recorded from 2373 ft. upwards during the second run. The principal difference between the two logs was that the trace of the first run contained several base-line shifts, whereas these were eliminated in the second run. On the resistivity trace, the second run is used upwards from 2100 ft. and the first run below this level, as between 2370 ft. and 2100 ft. (approximately) on the second run variations in the trace not indicated on the first run are attributed to the jamming of the probe by debris in the hole. The only difference between the two resistivity logs above 2100 ft is in the magnitude of minor low- resistivity peaks, mainly between 2035 and 2075 ft. It would appear that these features were not recorded on the first run due to slight sticking of the recording pen.

No correction has been made for cable stretch as no precise marker correlations were available and the sticking of the probe in the lower section of the hole prevented identification of the precise bottoming of the probe. Previous experience has indicated that cable stretch is about 15 inches per 1000 ft.

The drift exhibited by the resistance log is attributed to increasing self- induction during the re-winding of the cable and the drift in the potential curve is attributed to a decrease in porosity at depth caused by the increased compression of the deeper sediments.

Considering the log generally, there are few abrupt changes; this is attributed partially to the low resistivity of the drilling mud (average value about 1.55 ohm- metres), but these variations which occur are definite and have been divided initially into major units correlated with the lithological sequence as revealed by cores and ditch samples. Some of these units are further subdivided on the evidence of minor electrical features.

Surface to 520ft.

This interval is characterised by relatively large variations in S.P. and resistance, the average values of which are relatively high -

(1) The spurious S.P. readings within the casing to 169ft. may be caused by electro-chemical currents due to electrolytic action and should be ignored.

(2) From below the casing to a depth of 420ft., the log shows minor variations in a high average S.P. accompanied by irregular but relatively high resistance. Such a pattern indicates alternating beds of high but variable permeability associated with high but variable perosities and relatively fresh pore solutions. Such a pattern may be expected from alternating layers of unconsolidated clays, muds, sands and gravels as indicated by the logged ditch samples.

(3) Between 420ft. and 520ft. the S.P. and resistance features at 435ft, 465ft. and 512ft. may be caused by a series of beds containing fresh water which have caved to some extent during drilling (this would reduce the high apparent resistivity which would normally be expected from fresh water).

520ft. to 805ft.

Abrupt changes in the general level of the S.P. and resistance values occur at 520ft; these are accompanied by smaller fluctuations from relatively lower average values which persist from 520ft to 805 ft. The S.P. log shows only very small fluctuations throughout this interval and there are no large variations in the resistance log. The character of the legs is consistent with the lithological log which indicates that the section is predominantly mudstone to 740ft. and argillaceous sandstones from 740 to 805ft.

805ft. to 1894ft.

At 805ft. another abrupt lowering of both S.P. and resistance values occurs, lower average values persisting to a depth of 1894ft.

The lower values indicate a greater degree of compaction in this interval than in the sediments immediately above. The 805ft. level on the lithological log is a line of demarcation between beds which are predominantly mudstones above and shales below.

Within this section there are zones in which the resistivity and/or the S.P. differ slightly but significantly from the average.

(1) From 1045ft. to 1125ft. the S.P. value is a little lower than average and the resistance is more variable. This may be caused by water of slightly lower salinity within this zone.

(2) In the zones 1245ft. to 1265ft., 1570ft. to 1605ft., 1615ft. to 1630ft. and 1735ft. to 1750ft., an increase in S.P. value, which usually indicates increased permeability, is accompanied by little or no change in resistance. Such results are difficult to explain but they could be due to minor changes in salinity accompanying changes in porosity.

(3) The sharp feature in the S.P. curve at 1820±5ft. and the less pronounced increase in resistance at the same level may result from a thin permeable layer in which the interstitial solutions are of higher salinity. The increased salinity (with accompanying decrease in resistance) of the pore solutions partially cancels the normal increase in resistance associated with permeable layers (i.e. layers normally of lower porosity).

(4) The zone from approximately 1835ft. to 1850ft. shows a small average increase in both S.P. and resistance values. Such conditions suggest a slightly higher permeability and porosity within this interval than in adjoining sediments. This zone and the overlying zone referred to in (3) above are considered to be the most significant in the log.

(5) From 1855 ft. to a depth of 1894 ft. the sediments are predominantly shale and the S.P. and resistivity values are low with only minor fluctuations.

1894 ft. to 2595 ft.

Another abrupt change in the electrical properties of the sediments is indicated at 1894 ft., at which depth there is a small decrease in both S.P. and resistance. This indicates that sediments above this depth are less compact than those below. The lithological log does not indicate any abrupt change - the sediments are predominantly shale both above and below this change in electrical properties, although siltstone is recorded in several places below 1894 ft.

The S.P. curve from 2000 ft. to 2150 ft. (approximately) and from 2365 ft. to 2595 ft. shows little variation. It is possible that the recording pen, which had been damaged, was sticking slightly and was unable to follow very small changes if these were present.

Only minor variations are shown by the resistivity log between 1894 ft. and 2595 ft., at which depth a further major feature is indicated. The minor features may indicate possible changes in the lithology as follows:-

(1) A progressive decrease in S.P. from 1985 to 2005ft. and no change in resistance indicates a decrease in the permeability of the sediments.

(2) Between 2030 and 2070 ft. a series of sharp low resistivity peaks with no variation in S.P. suggests a zone with several conductive beds. The lithology, as identified by the ditch samples at this depth, indicates that the shale is highly pyritic. Although in other parts of the drill hole the sediments are recognised as being pyritic, less emphasis is placed upon the pyritic nature.

(3) The positive peak on the resistivity curve at 2100ft. followed by a very slight increase in the average resistance to 2165 ft. is accompanied at 2100 ft. by a decrease in S.P., the low S.P. value persisting to 2150 ft. The electrical indication at 2100 ft. is what may be expected from an impermeable resistive bed. Reference to the lithology shows the first identification of siltstone at this point; siltstone, in many instances referred to as "tight", is identified at several levels between 2100 ft. and 2595 ft.

(4) The zone from 2165 ft. to 2190 ft. contains several small positive peaks on the resistivity curve accompanied by corresponding decreases in S.P.; these may indicate a series of impermeable resistive beds - possibly the interbedded siltstone identified in the lithological log.

(5) From 2340 ft to 2365 ft. there is an increase in both S.P. and resistance, representing an increase in permeability and a decrease in porosity. Although no lithological data are available from 2280 ft. to 2370 ft. such an effect may be expected from a more arenaceous sequence of beds underlying impermeable shale from approximately 2305 ft.

(6) Two small features in the S.P. log at 2375 ft. and 2488 ft. respectively are accompanied by small increases in resistance and may be caused by arenaceous beds within predominantly shale beds. The resistance throughout the zone 2365 ft. to 2595 ft. fluctuates more than in the zone immediately above. This indicates a greater variation in porosity of the constituent beds.

2595 ft. to 2765 ft.

There is another decrease in the general level of both S.P. and resistance values at 2595 ft. Between this point and 2765 ft. the electrical logs show a greater variation than in either the overlying or underlying formations. As it was over this section that caving occurred and the effects of changes in hole dimensions contribute to the pattern of the logs, it is not possible to separate the effect due to this from variations in the lithology. The frequent changes in permeability and porosity which are indicated by the logs may be correlated with the lithological log which indicates the zone to be predominantly arenaceous.

2765 ft. to the bottom of the hole.

At 2765 ft., a decrease in the S.P. is followed by a smooth and generally decreasing curve and is accompanied by minor variations in resistance, the average value of which increases gradually with depth from 2765 ft. These electrical characteristics may be expected upon entering a bedrock somewhat weathered in the upper section.

The log on a scale of one inch equals 20 feet.

For this log the sensitivity of the resistance scale was increased from 1 inch equals 10 ohms to 1 inch equals 5 ohms.

Between 2340 ft. and the bottom of the hole this log differs somewhat from the log at one inch equals 50 ft. The more prominent variations in the resistivity log between 2600 ft. and 2720 ft. are in agreement, but the average resistance values above and below these limits are not. The changes in characteristics on the log at one inch equals 50 ft at 2595 ft. and 2765 ft. are not apparent in the log at 1 inch equals 20 feet. The differences between the two logs may be due to changes in the hole size as a result of caving or to the probe following a different path as a result of being fouled by caving material.

Some features of the S.P. curve may be correlated with features on the one inch equals 50 ft. log, e.g. variations at approximately 2485 ft, 2620 ft. and 2640 ft. Effects such as those betwean 2720 ft. and 2760 ft. and above 2465 ft. may be caused by caving material either fouling the electrode or causing it to make contact with the wall of the hole.

Zones in which definite changes in lithological character take place are :-

(i) 2350 ft. to 2362 ft.

(ii) 2617 ft. to 2625 ft.

(iii) 2636 ft. to 2644 ft.

In each zone there is a slight increase in S.P. and a small increase in resistance.

Below 2762 ft., the S.P. decreases and the resistance varies less than in the overlying material; this may represent the top of the bedrock.

Correlation between the electrical log and the lithology.

Table 1 summarises the comparison between major units indicated by the electrical log and the lithology of the sediments as logged by the well site geologist.

TABLE 1.

Units indicated by Electrical Logging.	Lithology of Sediments from cores and ditch samples.
Surface to 520 ft.	Sand, sandstone, kaolinite clay, gravel and mudstone.
520ft. to 805ft.	Mudstone (predominantly 320-740) and Sandstone (predominantly 740-805).
805ft. to 1894ft.	Mainly shale with some sandy shale, sandstone, dolomite, limestone and siltstone.
1894ft. to 2595ft.	Mainly shale and siltstone with a small amount of sandstone.
2595ft. to 2765ft.	Sandstone (some coarse) and conglomerate.
Below 2765ft.	Weathered gabbro or diorite ?

Evidence of oil and/or gas.

No oil or gas was detected during drilling operations and it is reasonable to assume that no substantial quantities of either are present in the formations drilled. However, it is possible that there may be minor quantities, which escaped detection during the drilling, but which might be indicated by the electrical logs.

The interpretation of electrical logs is not a simple procedure, as there are many complicating factors and uncertainties in underground formations which lead to indefinite and ambiguous results. The specific log characteristics from a particular geological section may differ from area to area and precise interpretation is largely a matter of practical experience in the general area and geological section in which the logs are run.

In general, single-point electrode logs (resistance and S.P.) indicate sediments which are permeable and moderately porous, and which may contain significant quantities of oil and/or gas. In those sediments in which the oil and/or gas saturation is high, a high S.P. indicates a permeable formation and a high resistance indicates both the normally lower porosity and the high resistance of the interstitial fluids. If the oil and/or gas saturation is low, the interpretation becomes somewhat ambiguous. This ambiguity may be enhanced by the use of a low-resistance mud, the effect of which would be to reduce the contrast in the recorded electrical properties of the sediments.

In a geological section such as that at Wyaaba, which is predominantly shale with minor sandstone beds, it is only in the sandstone that any appreciable accumulation of oil or gas might occur. The only zones which can be identified as sandstones with possible traces of oil and/or gas are 1835ft. to 1850ft., 2617ft. to 2625ft., and 2636 ft. to 2644ft. The evidence from the core between 2627ft. and 2637ft. makes it most improbable that oil and/or gas occur in the lower two zones.

As this is a new area of operation, and as some uncertainty exists regarding the cause of the features on the log between 1815ft and 1894ft., data from packer tests might have supplied information concerning the interstitial fluid content within this zone. This information would have been useful in the interpretation of logs from any additional holes which may be drilled in the area.

5. CONCLUSIONS

The electrical logging of No.1 bore at Wyaaba was successful in that it was possible to correlate abrupt changes in the electrical properties of the rocks with changes in lithology as recorded by core and ditch sampling; it was not possible, however, to identify any oil and/or gas-bearing sediments.

For the purpose of correlation with logs from other holes which may be drilled in the area, the most important features are the abrupt changes in average S.P. and resistivity which occur at 805ft., 1894ft., 2595ft., and 2765ft.

In other areas, it has been found that similar abrupt changes commonly occur at formation boundaries. As far as is known, no formation changes corresponding to the changes in the average values on the electrical logs have been reported. Nevertheless, there is a strong possibility that such changes will be present throughout the area and that some would provide satisfactory marker horizons for stratigraphic correlations.

6. REFERENCES.

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FROME BROKEN HILL No.1

WYAABA, QUEENSLAND

SELF-POTENTIAL AND SINGLE-POINT RESISTANCE LOGS

WELL SITE CO-ORD	16° 23' [illegible] South, [illegible] East
MUD CELL (SAMPLE FROM MUD PIT)	4 readings were made Average 1.55 Ohm-metres Temp. [illegible]
GROUND ELEVATION	35.5 Feet.
ROTARY TABLE ELEV.	40.5 Feet
HOLE DEPTH	2,822 Feet.
CASING	8.625 inch J55 36 Lbs cemented at 169 Feet

GEOPHYSICIST [signature]

FROME BROKEN HILL No. I

WYAABA, QUEENSLAND

SELF-POTENTIAL AND SINGLE-POINT RESISTANCE LOGS

(BOTTOM SECTION OF WELL)

ATTEMPT WAS MADE TO LOG WELL FROM BOTTOM TO 1,700 FEET AT SCALE OF 20 FEET TO ONE INCH OWING TO JAMMING OF PROBE, LOG WAS NOT COMPLETED.

GEOPHYSICIST