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COMMONWEALTH OF AUSTRALIA
DEPARTMENT OF NATIONAL DEVELOPMENT
BUREAU OF MINERAL RESOURCES,
GEOLOGY AND GEOPHYSICS

RECORDS 1956, No. 3

# ELECTRICAL LOGGING OF No. 3 BORE, ASSOCIATED AUSTRALIAN OILFIELDS, N.L., ROMA, QUEENSLAND

by

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ABSTRACT

Roma Bore No. A.A.O.3, drilled by Associated Australian Oilfields, N.L., was logged to a depth of 3,628 feet in November, 1953, by self-potential and resistivity methods, using the single-electrode technique. The full section was logged on a scale of 100 feet to the inch and the sections from 320 feet to 490 feet and from 3,380 feet to 3,628 feet were also logged on a scale of 20 feet to the inch.

Major formations were clearly defined and good correlation was obtained with logging previously carried out in A.A.O.2. Sandstones, shales, permeable conglomerates and coal seams were indicated with a fair degree of reliability and suitable positions for packer tests were selected.

## 1. INTRODUCTION.

This report describes the electrical logging of the third exploratory bore drilled by Associated Australian Oilfields, N.L. in the area north of Roma. The logging was done by the Geophysical Section of the Bureau at the request of the Company.

The bore, which is referred to as A.A.O. No.3 bore, is situated 800 feet from the old R.B.O. No.4 bore on a bearing N.43°W (magnetic). On the Roma four-mile map of the Australian Survey Corps series, the co-ordinates of A.A.O. No.3 are 163709.

The geophysical party started logging operations on 4th November, 1953, when the bore had reached a depth of 3,380 feet. A log with a vertical scale of 100 feet to the inch was recorded down to this depth. From then on, until the bore reached granite wash overlying the basement, coring was being done continuously and sections of the bore were logged in detail as the drilling progressed. These detailed logs, on a scale of 20 feet to the inch, were recorded for the following purposes:-

(a) Detection and appraisal of potential oil and/or gas beds.

(b) Accurate location of oil and/or gas beds to determine the depths at which to set the packer used in the formation tests.

After completion of the drilling, a log, on a scale of 100 feet to the inch for the full section of 3,628 feet, was recorded for use in correlation with A.A.O. No.2 bore (Wiebenga, 1953), and the lower part of the hole (3,380 - 3,628 ft.) below the Bundamba-Moolayember unconformity was logged on a scale of 20 feet to the inch.

At the Company's request, the section from 320 to 490 feet was also logged on a scale of 20 feet to the inch to investigate the occurrence of coal seams.

The logging was completed on 23rd November, 1953.

## 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 the variations of self-potential (S.P.) and resistance. The S.P. and resistance graphs are recorded simultaneously side by side on a paper chart.

The logger consists essentially of the following components:-

(a) Recorder: Brown "Electronik" recording potentiometer, oscillator, two amplifiers and converters and control panel.

(b) Reel: Cable reel, motor, clutch, gearbox, cable electrode and collector.

(c) Paper drive: Sheave wheel, associated electrical drive by selsyn motors and logging chart.

The cable is powered by an "Onan" winding engine, series C.K. and power for the recorder and selsyn motors is supplied by an "Onan", 120-volt, 400-watt, A.C. generator. Both these units are manufactured by D.W. Onan & Sons Inc., Minneapolis, Minnesota, U.S.A.

The specifications of the model ZDE, "Widco" logger are:-

| | |
|---|---|
| Depth scales: | 20,50 and 100 feet per inch. |
| S.P. scale: | 10,20,50,100 and 200 millivolts per inch, approximately. |
| Resistance scale: | 2.5, 5,10,25,50 and 100 ohms per inch, approximately. |
| Cable: | 4,500 feet, single-conductor stranded steel cable, neoprene covered, tensile strength 2,000 lbs., diameter 0.27 inches, resistance 10 ohms per 1,000 feet. |
| Winding speed: | High, middle and low. The middle speed (normally used in logging) is about 1.5 feet per second. |
| Logging electrode: | Diameter $2\frac{1}{4}$ inches, length 76 inches, weight 70 lbs. |

For further details of the instrument, the reader is referred to the operation manual supplied by the Well Instrument Developing Company.

The winding equipment and generator are firmly mounted in a covered trailer, towed by a Morris, 2-ton, 4 x 4 truck. The recorder unit is mounted in the truck.

Two men are required to operate the logger, preferably a geophysicist to attend to the recorder and an assistant to operate the winding equipment.

## 3. METHODS

### (a) Single-point resistance.

Single-point resistance logging consists of recording the variations in the resistance between the logging electrode, which is raised or lowered in the hole, and the ground electrode situated at the surface, usually in the mud pit. Practically the whole of the resistance in the circuit is in the immediate neighbourhood of the electrodes. As the ground electrode is stationary its resistance may be assumed to be constant during the measurements and the changes of resistance recorded are therefore due to variations in the resistivity of the materials around the moving electrode. Variations are recorded as the logging electrode passes through beds with different resistivities.

The amplitude of the variation is controlled mainly by the bore diameter, the resistivity of the mud, the resistivity of the beds opposite the logging electrode and the thickness of the beds. The recorded variations, due to resistivity differences between neighbouring beds, are not linearly related to those differences. Variations of resistivity in the higher ranges have a smaller effect than similar variations in the lower ranges. The effect of this is to compress the resistance record in the higher ranges and make it impossible to estimate the true resistivity of a bed from the resistance log.

To make a quantitative estimate of the oil or gas saturation of a bed, it is necessary to know the resistivity of the bore solutions, the porosity and the degree of cementation, and the resistivity of the formation. Sometimes the first three quantities can be estimated, but the last, the formation resistivity, cannot be evaluated from the single-point resistance log. This type of log is therefore of no value for quantitative interpretation, but is very useful for correlation between bores.

(b) <u>Self-potential (S.P.)</u>.

The potential graph is obtained by measuring the potential difference between the logging electrode and the ground electrode. As the ground electrode is at a constant potential, variations of potential shown on the record represent the variations of potential in the bore hole.

The potentials in bore holes consist of natural potentials and secondary potentials.

Natural potentials are those which may be present in the ground even when no bore holes exist. They are considered to be contact potentials occurring between dissimilar beds. The dissimilarity may be in the chemical composition of the solid particles constituting the beds or in the nature or concentration of the solutions which the beds contain. Natural potentials cannot be measured in a bore hole unless the hole is dry and the electrodes are brought into close contact with the rock wall.

Secondary potentials arise when the mud column is introduced during the drilling operations, and are considered to be mainly of electro-chemical origin. Laboratory experiments have shown that a flow of current takes place around the common point of contact of shale, sandstone containing salt water, and a fresh water drilling mud, the direction of the current being shale-mud-sandstone-shale. As a consequence of this circuit, the current flowing in the mud column will produce a potential drop opposite the shale-sandstone boundary within the mud column. If the mud column opposite the shale section is regarded as being at zero potential, then the potential in the mud column opposite the sandstone will be negative. Should the mud column be more saline than the pore solution of the sandstone, the current of the electro-chemical circuit will be reversed and the sandstone will be positive with respect to the shale.

Laboratory experiments have shown that the total electromotive force (E) generated by the electro-chemical phenomenon can be represented by the empirical formula (Schlumberger, 1949, 34):-

$$E = k \log_{10} R_m/R_w \quad .......(1)$$

in which $R_m$ = resistivity of the mud

$R_w$ = resistivity of the pore solution within the sandstone

and k is a constant depending on the nature of the sandstone.

For clean sands and a pore solution of sodium-chloride, with E expressed in millivolts, k equals 70. For sands containing a minor amount of clay (unclean sands), k is somewhat lower.

The shape and amplitude of the S.P. peak of an object bed may be influenced by the following factors (Schlumberger, 1949, 37-41):-

(i) The total electro-motive force (static S.P.) involved.

(ii) The thickness of the object bed.

(iii) The resistivity of the bed, of the surrounding formations and of the mud.

(iv) The diameter of the bore hole.

(v) The degree of mud infiltration into the permeable object bed.

(vi) The presence of impervious material such as shale, in the object bed.

(c) Interpretation rules.

(i) Sandstone and conglomerates.

The magnitude of the self-potential depends mainly on the permeability of the formation and on the salinity contrast between the pore solutions and the drilling mud. The resistivity depends mainly on the porosity of the formation and the salinity of the pore solutions. Hence conglomerates and unsorted, coarse sandstones usually, because of their high permeability and low porosity, show high-potentials and high resistivities. They mark the water yielding formations (aquifers). Well-sorted sandstones, often fine-grained, are, because of their lower permeability and higher porosity, characterised by moderate to high self-potentials and moderate resistances. Oil and gas-bearing sandstones are, because of their lower water content, characterised by moderate self-potentials and high resistances.

(ii) Shales.

The self-potential value of shales is customarily used as a zero reference line. Because shales are characterised by high porosities, their resistance is normally the lowest in the section.

(iii) Coals.

High grade, unfractured coal seams have a high resistivity with a low or negligible self-potential. The sharply jagged appearance of the characteristic resistance curve of coal seams is caused by interbedded shales. Shaly, low-grade coals show a low to moderate resistivity. The quality of the coal is generally well indicated by the magnitude of the resistance and the number of shale bands, as indicated by the jagged curve. Fractured, weathered coals show a moderate resistance with a high self-potential.

## 4. RESULTS

(a) Main features of the complete log.

The electrical log and the Company's ditch sample log are shown on Plate 1 at a scale of 100 feet to the inch. Cable stretch was measured and found to be 15 inches per 100 feet. This was taken into account in the depth recordings, and the corrected depths are shown on the electric log.

The resistance log shows a drift which is caused by decreasing self-induction in unwinding the logging cable. The equipment contains a provision for automatic adjustment which can only be set by trial and error.

The electrical log is interpreted as follows:-

Surface - 242 feet.

Mainly shales with some sandstone. Shales are characterised on the electrical log by low resistance and low S.P., sandstones by high resistance and high S.P.

242 - 396 feet.

Mainly sandstones and conglomerates with some shale. The conglomerates show up on the electrical log as high resistances with high S.P. They may be important as shallow water-bearing formations.

394 - 463 feet.

The resistance curve has the typical jagged appearance caused by alternating beds of shales, shaly, coal and coal.

463 - 1,107 feet.

Mainly sandstones and shales in the top part of this section. The irregular resistance and S.P. curves are characteristic of sandstones with varying porosity and permeability, which may be due to thin shale bands or inter-bedded shaly sandstones.

The boundary with the underlying shale section at 1,107 feet is very sharp and represents an excellent electrical marker.

1,107 - 2,288 feet.

Shales and coal measures. The S.P. curve is almost flat. The jagged resistance curve shows many peaks, representing coal seams. The sharp boundary with the underlying sandstones forms an excellent electrical marker.

2,288 - 3,056 feet.

Sandstones with interbedded shales. The electrical log shows high resistance corresponding with high S.P. and low resistances corresponding with low S.P. The boundary with the underlying shales is again well defined and forms a good electrical marker.

3,056 - 3,474 feet.

Shales. The S.P. log is almost flat and the resistance log has very little character. The boundary with the underlying sandstone shale formation is quite distinct and forms a well-defined electrical marker.

3,474 - 3,596 feet.

Sandstones and shaly sands with shale bands. Unusually high relative S.P. values corresponding with relatively high resistance values indicate saline solutions in a poorly sorted sandstone. Low S.P. with low resistance values indicate shale beds within the sandstone. Shaly sandstones form a transition between the two extremes mentioned above.

The electrical logs indicate that the sandstones may contain oil and gas. Cores showed oil traces. Previous geological investigations on wells in the area show that the sandstones just above the basement may be economically important. This section is therefore discussed in greater detail later.

(b) Correlation between A.A.O.2 and A.A.O.3.

The results of the electric logging of A.A.O.3 indicate the value of the technique for correlation purposes.

The following table shows the marker horizons indicated on the logs and the geological description of the marker beds from the electrical logs and the ditch sample logs.

| Depth of marker(ft.) | | Geological description of marker | Level difference from A.A.O.2 to A.A.O.3 (ft.) |
|---|---|---|---|
| A.A.O.2 | A.A.O.3 | | |
| 385± | 386± | Carbonaceous shales and/or coal bands at the bottom of the sandstone within the Blythdale Series of the Upper Walloon. | +2 |
| 1067 | 1107 | Boundary between Upper Walloon and Middle Walloon coal measures at the bottom of the garnet sandstone. | -37 |
| 1466-1485 | 1538-1580 | Zone of alternating coals and shales, within the Middle Walloon coal measures. | Top -69<br>Bottom -92 |
| 1855-2130 | 1885-2162 | Zone of alternating shales and coals with occasional sandstone beds, within the Middle Walloon coal measures. | Top -27<br>Bottom -29 |
| 2260 | 2288 | Unconformity between Lower Walloon coal measures and Bundamba sandstones. (Jurassic - Upper Triassic). | -25 |
| 3094 | 3056 | Unconformity between Bundamba sandstones and Moolayember shales (Upper Triassic - Middle Triassic). | +41 |
| 3469 | 3474 | Top of petroliferous zone (sandstones and shaly sands) within Moolayember Series. | -2 |
| 3597 | 3596 | Top of granite wash above basement. | +4 |

NOTES: 1. Depths are measured from rotary table, which is 4 ft. 6 in. above ground level.

2. Elevation of rotary table at A.A.O.2 = 1087 ft.
" " " " " A.A.O.3 = 1090 ft.

3. No electric log available for A.A.O.2 below 3555 ft.

(c) Discussion of detailed log from 3380 ft. to 3628 ft.

Plate 2 shows the detailed electrical logs of the lower part of the well, together with the geological log based on core samples.

As mentioned under the section on interpretation rules, oil and gas bearing sandstones are characterised by moderate S.P. and high resistance. If the S.P. is very high, it usually means that the pore solution consists of saline water with only insignificant amounts of oil and gas.

In a formation test a so called "packer" is connected to the end of the drill pipe, lowered into the well and set above the formation to be tested. The hydrostatic load of the formation is then removed by opening a valve in the packer. Any gas and liquid in the formation is originally under pressure due to the overlying rock strata. When the valve of the packer is opened the fluids in the formation are released to the atmosphere across a choke in the packer. The differential pressure across the choke is recorded and gives a value for the formation pressure.

The electrical log discloses the most favourable places to set the packer; that is, a shale or impermeable formation above the formation which is to be tested for oil and gas.

Potential oil and/or gas zones indicated by electrical logs were subjected to a formation test where practical. The interesting zones are discussed in the following summary:-

<u>3,475 - 3,484 feet</u>.

Moderate S.P. with moderate resistance. The core log shows a sandstone with a shale cap and shale-conglomerate floor.

Formation test: range 3,469ft-3,501ft, recovery 260ft (260ft in drill pipe of 2⅞ inches diameter equals 6.4 cu.ft) of brackish water with mud and strong oil trace. An electrical log taken after the formation test showed a considerable decrease in the resistance. This indicates that gas and water escaped from the rock during the test and were replaced by mud.

<u>3,487 - 3,492 feet</u>.

Fairly high S.P. with moderate resistance. The core log shows an oil sand with a shale-conglomerate cap and a shale floor. A formation test of the range 3,485-3,501 feet yielded 5 feet of turbid water.

<u>3,503 - 3,509 feet</u>.

Moderate S.P. with moderate resistance. The core log shows sands and shales. A formation test of the range 3,502-3,538 feet yielded 1 foot of drilling mud.

<u>3,534 - 3,538 feet</u>.

Relatively high S.P. with high resistance. The resistance peak is the highest in this sandstone section. This combination of high S.P. and high resistance indicates that this sand has the highest oil/gas saturation within the section between 3,475 and 3,606 feet.

The core samples of this sand indicated a high grade oil sand.

Formation test of the range 3,522-3,538 feet recovered a small quantity of muddy water without any oil or gas.

<u>3,547 - 3,558 feet</u>.

High S.P. with moderate resistance. The core log indicates a poorly sorted sandstone with some gas and oil. The cap and the floor consist of shale and shaly sand.

Formation tests of the ranges 3,541-3,557 feet and 3,543-3,567 feet yielded no fluid.

3,575 - 3,582 feet.

The electrical log indicates several alternate sand and shale bands. This is confirmed by the core log.

No formation test.

3,587 - 3,593 feet.

Very high S.P. with moderate resistance. This indicates a permeable sandstone containing saline water. The core log shows a fine white sandstone. No formation tests.

From 3,606 feet to 3,626 feet the electrical log shows alternate zones of high S.P., low resistance and low S.P., high resistance. This indicates alternate zones of low porosity, low permeability and higher porosity, high permeability. These features are probably characteristic of decomposed granites.

(d) Shallow coal seams - detailed log between 320 and 490 feet.

The electrical logs and ditch sample log on Plate 1 indicate shallow coal deposits between about 400 and 490 feet. Because of the possible economical value of these deposits the company requested a detailed electrical log on a scale of 20 feet to an inch. In electrical logs coal seams and coaly formations show sharp resistance anomalies of large amplitude with only small positive or negative S.P. values. Alternate beds of coal, shaly coal and shale give the resistance curve a jagged appearance.

The electrical logs and the geological interpretation are shown on Plate 3.

The largest thickness of coal indicated by the electrical log is about two feet, between 396 and 398 feet.

The S.P. log shows prominent anomalies, corresponding with high resistances, at 329-343, 381-389 and 403-408 feet. These have been interpreted as permeable, water-bearing conglomerates or coarse sandstones.

## 5. CONCLUSIONS

Electrical well logging (single-point electrode system) is an efficient tool in the geological correlation of wells or bore holes. Sandstones, shales, permeable conglomerates (water zones) and coal seams are indicated with a fair degree of reliability. Unconformities and discontinuities show up well.

Single-point electrode logs (resistance and S.P.) also indicate sandstone formations which may contain oil and/or gas but the interpretation becomes ambiguous with a low gas/oil saturation. However, the electrical logs provide an excellent tool to determine the best position for the packer in a formation test.

Depth measurements with electrical logs can be made with an accuracy of $\pm\frac{1}{2}$ foot.

## 6. REFERENCES

Schlumberger Well Surveying Corporation, 1949 - Review of Schlumberger Well Logging and Auxiliary Methods.

Wiebenga, W.A., 1953 - Electrical Logging of No.2 Bore, Associated Australian Oilfields, N.L., Roma, Queensland. Bur.Min.Res.Geol.andGeophys.,Records 1953, No.65.

PLATE I


## REMARKS

BORE HOLE DIAMETER : 7⅞"
MUD RESISTIVITY : 5·9 OHM METER, t - 91° F.
MUD INFILTRATION : NEGLIGIBLE

GEOLOGICAL DESCRIPTION BY W. D. MOTT

DATE : 24 NOVEMBER 1953.

## LEGEND

| | |
|---|---|
| SANDSTONE | COAL |
| SHALE | LIMESTONE |
| CARB. SANDSTONE | CONGLOMERATE |
| CARB. SH + COALY SH. | |

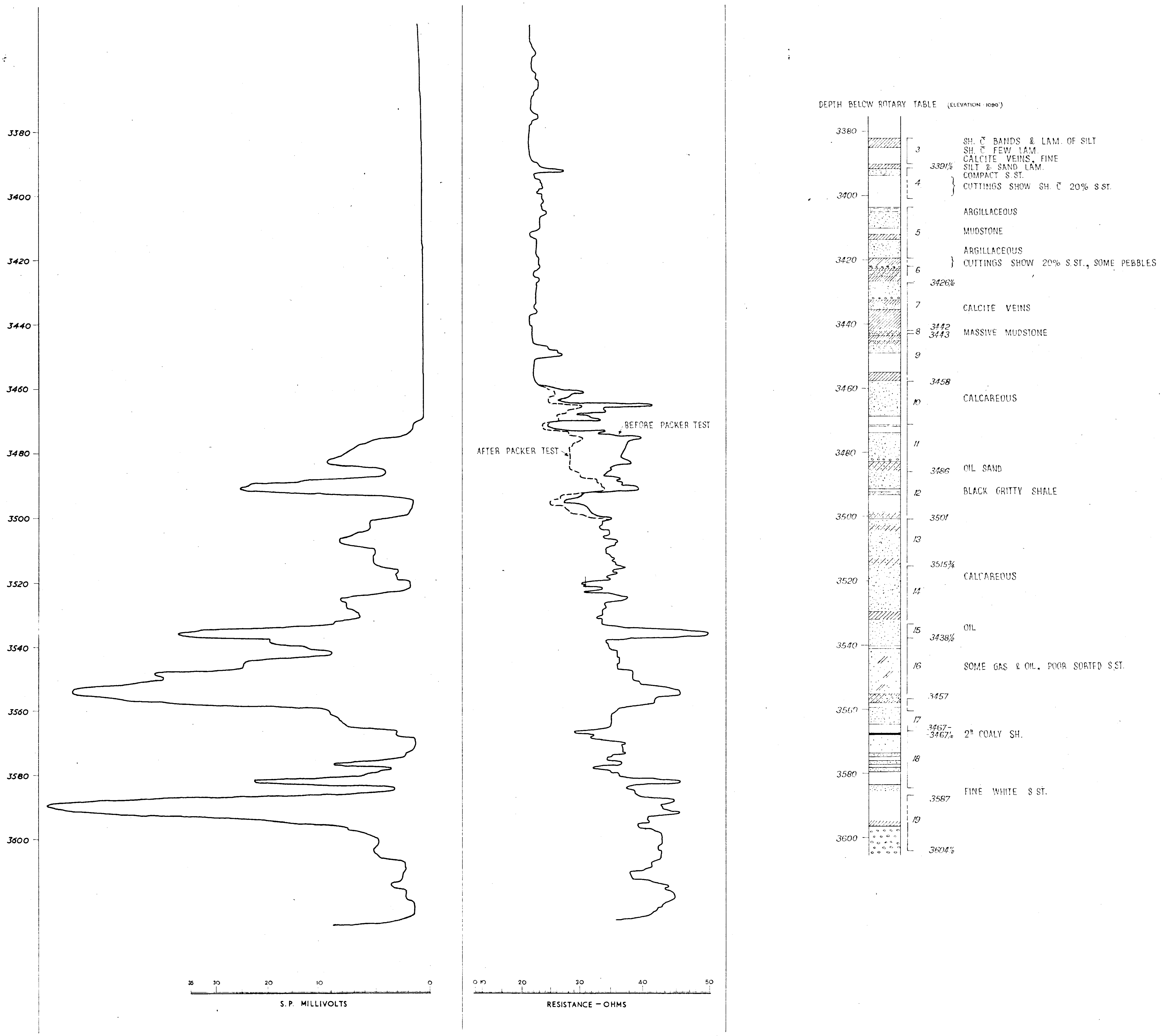
L. Gunson
Geophysicist

VERTICAL SCALE
100 0 100 200 300 FEET

# WELL LOGGING, ROMA

## ASSOCIATED AUSTRALIAN OIL FIELDS N.L. No3 BORE

## SELF POTENTIAL, SINGLE POINT RESISTANCE AND DITCH SAMPLE LOGS




## REMARKS

BORE HOLE DIAMETER : 7⅞"

MUD RESISTIVITY : 5·9 OHM METER AT ± 91° F

GEOLOGY FROM W.D. MOTT

DATE : 24 NOVEMBER 1953.

## LEGEND

- SANDSTONE
- SHALE
- CARB LAMINAE
- LAM. SH., SILT & S.ST.
- S.ST. C̄ SHALE LAM.
- CONGLOMERATE

VERTICAL SCALE

20 0 20 40 60 FEET

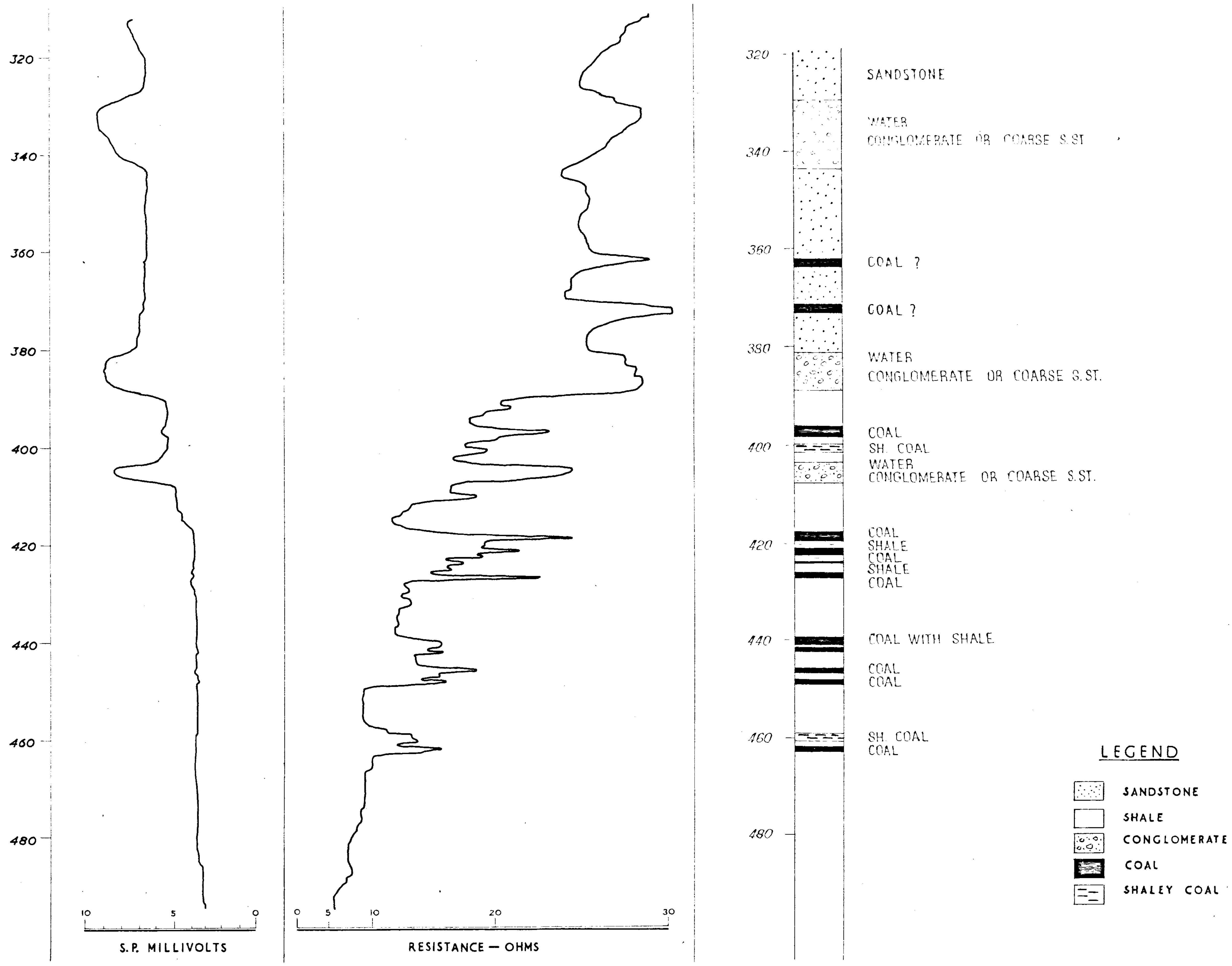
# WELL LOGGING, ROMA

## ASSOCIATED AUSTRALIAN OIL FIELDS N.L. No 3 BORE

## SELF POTENTIAL, SINGLE POINT RESISTANCE AND GEOLOGICAL LOGS OF LOWER PART OF BORE

S. Ginson
GEOPHYSICIST

PLATE 3




## REMARKS

BORE DIAMETER : 7⅞"

PURPOSE OF LOG : TO INVESTIGATE COAL SEAMS WITHIN DEPTH RANGE 320-490'

DATE : 5th NOVEMBER 1953.

VERTICAL SCALE

20 0 20 40 60 FEET

S. Gunson
GEOPHYSICIST

# WELL LOGGING, ROMA

## ASSOCIATED AUSTRALIAN OIL FIELDS N.L. No3 BORE

## SELF POTENTIAL AND RESISTANCE LOGS

## BETWEEN 320 AND 490 FEET

## WITH GEOLOGICAL INTERPRETATION