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COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

# BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS.

RECORDS

RECORDS 1960 No. 88



# TIMBOON No.5 BORE LOGGING SURVEY, VICTORIA 1959

by

F. Jewell

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## ABSTRACT

The electric, gamma-ray and temperature logs of Parish of Timboon Bore No.5 are used to fix the boundaries of the formations traversed. Potential water-producing sands are noted at depths between 2300 ft and 3130 ft, considerably below the calcareous beds in the upper part of the hole. Calculations based on the recorded self-potentials and resistivities indicate that the salinity of the water produced between these depths is probably less that 1000 parts per million equivalent sodium chloride, but may be much greater below 3130ft.

Radioactive sands detected at depths 2053, 2295, and 2315 ft will be useful as marker horizons in other boreholes which may be drilled in the area.

## 1. INTRODUCTION.

In response to a request from the Victorian Mines Department, the Bureau's Failing Logmaster was sent to the Parish of Timboon No. 5 bore on 10th November 1959. It was hoped from the information provided by the self-potential, resistivity, and gamma-ray logs furnished by the logger, to reach conclusions as to the quality of the water obtainable from the various formations traversed, and thus to ascertain the best depths at which perforated casing should be set.

The bore lies within the town of Timboon and roughly a quarter-mile west of the main centre; the town itself is on the road between Camperdown and Port Campbell.

An electric log of the bore-hole was taken to a depth of 3117 ft on November 10th, in an operation lasting 6½ hours; after this the bore was re-conditioned and logging was continued for 8 hours the following day.

After drilling had advanced to a depth of 3500 ft, logs of the new hole were taken on November 15th. In addition a temperature log was made from the surface down to 3085 ft; this was the greatest depth reached by the temperature probe. Neither the electric nor the gamma-ray probe reached bottom, as they were not heavy enough to fall through the thickening mud at great depth, even with the addition of a 15-lb weight to the gamma-ray probe.

A caliper log was attempted but the caliper arms failed to open; the retaining wire had become entangled tightly enough, even after being cut by the unclamping-bullet, to hold the arms together.

Logging in this second phase lasted 16½ hours. The complete operation provided single-point resistance, short-normal and long-normal resistivity, self-potential, gamma-ray, and temperature logs of all but the bottom hundred or so feet of hole on a depth scale 1 in. of chart equal to 50 ft of hole depth. In addition the electric and gamma-ray logs on a scale of 1 in. equal to 20 ft were taken while running down the hole.

On the gamma-ray log, the sensitivity used was such that 1 in. of chart was equivalent to a dose-rate of 0.01 milliröntgens per hour. At the average energy corresponding to the radiation from Uranium (0.8 MeV) this dose-rate would correspond to a gamma-ray flux of approximately 360 quanta per minute per sq.cm.

The 60-cycle generator of the Failing Logger was not used, as it was found that the nearby 50-cycle power-line produced interference which caused slow oscillation of the recorder pens. Power for the recorder was taken instead from the 50-cycle mains. The cause of the occasional "spikes" in the electric logs was not traced but there is a possibility that they are due to contact between the steel braiding of the cable and the casing of the bore.

It was found that cable stretch amounted to about 1 ft per 1000 ft of depth, and the depth counter was adjusted by this amount for the "Up" runs.

The ditch sample log which has been drawn on the electric logs (plates 1 and 2) was obtained from the Mines Department geologist who was working at the site.

## 2. GEOLOGY

The bore lies within the Otway Basin where there is a considerable thickness of Tertiary sediments. These consist mainly of limestone, calcare ous clay, and sandstone. The top of the Anglesian series is thought to lie at a depth of about 1400 ft, and below this the succession includes carbonaceous siltstone and bands of coal down to a depth of about 3400 ft; rocks below about 2900 ft are thought to be of Cretaceous age.

## 3. INTERPRETATION

### Resistivity, Self-potential, and Gamma-ray Logs.

In the following discussion depths are referred to the level of the rotary table which was 9 ft above ground level.

From the measured resistivity of 11.4 ohm-metres, the salinity of the drilling fluid is equivalent to roughly 500 parts per million of sodium chloride. The low salinity ensures that the permeable beds are marked by negative self-potentials compared with the steady value corresponding to the clay. The water contained in the sandstone may not be much more saline than the drilling mud, however, because the variations are generally small. An exception occurs where two sandstone beds lying between 3327 and 3370 ft (plate 2) are marked by strong negative self-potential, an indication that they probably contain brackish water.

The resistivity curves correlate quite well with the sample log; the major lithological units, marked by successively higher and lower resistivity, appear to be as follows:-

| | | |
|---|---|---|
| casing shoe - 120 ft | | marly limestone |
| 120 - 825 ft | | marl |
| 825 - 903 ft | | marl with sandy limestone bands |
| 903 - 997 ft | | marly clay |
| 997 - 1140 ft | | clayey sand with calcareous sandstone bands |
| 1140 - 1185 ft | | marly claystone |
| 1185 - 1402 ft | | silty sand |
| 1402 - 1435 ft | | calcareous siltstone |
| 1435 to bottom | | a succession of thin bands of sand and siltstone |

The calcareous or dolomitic beds (at 1918 ft for instance) are marked by resistivity peaks, though it should be noted that the long-normal curve shows minima opposite high-resistance beds which are thinner than the electrode spacing (63 in.).

The gamma-ray log shows the same general pattern as the S-P. curve, clay and siltstone showing higher radioactivity than the sandstone. The cause of the anomalously high values opposite sand at 2049 - 2057 ft, 2290 - 2303 ft and 2310 - 2328 ft is not known. The corresponding S-P. values indicate that the sands are not shaley; the high radioactivity may therefore be due to some heavy mineral content in the sand.

It is noticeable that below a depth of about 2350 ft, the gamma-ray log appears to distinguish shale from sandstone more definitely than does the S-P. curve. As remarked previously, S-P. variations are small owing to the low salinity of the formation water or perhaps because the sand beds are often too thin for the full self-potentials to be registered.

Resistivity values opposite the sand beds are higher on the short-normal curve than on the long-normal curve, indicating that the result of mud invasion is to increase the resistivity of the sand. This indicates that the resistivity of the mud is higher than that of the formation waters; i.e. the mud is generally less saline than the water.

#### (a) Water Salinity

In the absence of data on the porosity of the sand, estimates of the salinity of the interstitial waters are unreliable. However, they usually give the order of magnitude to be expected.

The value of self-potential (in millivolts) opposite clean sand is usually taken as equal to $-71 \log_{10} 0.75\ Rm/Ra$ where Rm is the mud resistivity and Ra the apparent resistivity of the interstitial water at the same temperature (strictly, 75°F). For saline waters, Ra = Rw the true water resistivity, but in fresh waters such as these, Ra is much less than Rw. Emperical curves relating the true and apparent resistivities have been given by Gondouin (1956).

Considering the sand at 2320 ft, the ~~temperature log~~ shows a temperature of 77°F. At this temperature Rm = 10 ohm-metres, the resistivity of the mud filtrate may be taken as three-quarters of this value. Taking the self-potential as 48 millivolts,

$$48 = 71 \log 7.5/Ra. \qquad \text{or} \qquad Ra = 1.57 \text{ ohm-metres.}$$

According to Gondouin's charts therefore

Rw = 7.6 ohm-metres

corresponding to a salinity of about 650 parts per million equivalent sodium chloride.

Now the formation resistivity equals Rw multiplied by a formation factor F, assuming the formation is water-saturated. Taking the formation resistivity as that value recorded on the long-normal curve, i.e. 29 ohm-metres,

$$29 = 7.6F \qquad \text{or} \qquad F = 3.8$$

(Suppose it had been assumed that the resistivity recorded on the short-normal curve corresponded to a zone completely invaded by the mud filtrate; then taking the short-normal resistivity as 39 ohm-metres, and the mud resistivity as 10 ohm-metres, the formation factor for this zone would be derived from :-

$$39 = 0.75 \times 10F \quad \text{i.e.} \quad F = 5.2\text{)}$$

Use is often made of Archie's empirical formula which relates formation factor and porosity (Archie, 1942):-

$F = P^{-1.8}$ where P equals the porosity fraction.

for this sand $3.8 = P^{-1.8}$

i.e. $P = 0.48$

At 2720 ft, the temperature being 79°F, Rm becomes 9.5 ohm-metres. The recorded self-potential is 44 millivolts.

Therefore $44 = 71 \log 7.1/Ra$ or $Ra = 1.68$ ohm-metres.

giving Rw = 9.4 ohm-metres,
corresponding to a salinity of 500 p.p.m.

The long-normal resistivity is 67 ohm-metres so that F = 7.1

(Or, if the short-normal resistivity of 96 ohm-metres corresponds to mud invasion

$$96 = 0.75 \times 9.5F \text{ (since Rm = 9.5)}$$

Thus $F = 13.5$.)

For a formation factor F = 7.1 the porosity P becomes 0.38. At 2850 ft, the temperature is 80°F and the self-potential 42 millivolts.

We have $42 = 71 \log 7.0/Ra$ or $Ra = 1.8$ ohm-metres.

giving Rw = 12 ohm-metres,

approximately corresponding to a salinity of 400 p.p.m. Gondouin's charts are not reliable where the salinity is so low, but the true resistivity is clearly greater than 10 ohm-metres. The long-normal resistivity is 33 ohm-metres. Therefore F = 33/12 = 2.75. (As the short-normal resistivity is 49 ohm-metres, the assumption as to mud invasion would lead to a factor F = 6.9). For a formation factor F = 2.75, the porosity P is calculated as 0.60. This porosity is unreasonably high. Evidently the sand in question is too thin for the long-normal resistivity to reach its true value.

The routine calculations therefore lead to formation-water resistivities in the range 7 to 12 ohm-metres, corresponding to equivalent sodium chloride concentrations of between 400 and 700 parts per million.

The formation factors calculated from the long-normal resistivities are lower than those derived from the short-normal resistivities on the assumption of mud invasion. It seems likely therefore that the porosities calculated above are too high. Innaccuracies also arise because in Archie's formula the factor taken as 1.8 is not a constant for all sands.

(b) Depths to Producing Zones.

Below the two sand beds at depths 2290-2303 and 2310-2328 ft, there are several thick sands beds (i.e. more than 20 ft thick) which could be brought into production through perforated casing.

They occur at the following depths :-

2398-2444; 2692-2732; 2841-2894; 3025-3050; 3086-3130 ft.

In common with the whole sand section their self-potentials are rather greater than 30 millivolts; i.e., they are permeable and probably free from clayey material. Their formation resistivities reach only moderate values for fresh-water sand, indicating that they are highly porous. Thus, they appear to be clean, well-sorted sand. The formation waters appear to become more saline towards the bottom of the hole, the resistivities falling off very sharply below 3130 ft. In particular, the sands below 3327 ft show very low resistivities and high values of self-potential, indicating the presence of salt water. If the lower sands were to produce saline water, they could be plugged off; for instance, at 3080 ft.

As the well is to be cased to approximately 2270 ft, the sand above this depth will be shut off. It is likely that the zone 2220 to 2257 ft would produce relatively fresh water, but the sandstone above 2000 ft, being largely calcareous according to the sample log, would probably produce hard water.

Temperature Log.

The temperature log shows little detailed character, probably because it was taken too soon (only four hours) after circulation had ceased, to give the maximum distinction between the different types of formation. The lightness of the temperature probe made it necessary to run the log before the mud in the lower part of the hole had become too thick to allow its passage.

The curve shown several changes of temperature gradient from the overall average of 0.415$^{\circ}$F per 100 ft, the principal large-scale changes being approximately as follows:-

| | | |
|---|---|---|
| 200-925 ft | average gradient | 0.5$^{\circ}$F per 100 ft |
| 925-1050 ft | " " | 0.04$^{\circ}$F " " " |
| 1050-1245 ft | " " | 0.26$^{\circ}$F " " " |

(1245-1265 ft sharp rise of 0.6$^{\circ}$)

| | | | |
|---|---|---|---|
| 1265-1875 ft | average gradient | 0.20°F | per 100 ft |
| 1875-2525 ft | " " | 0.45°F | " " " |
| 2525-2820 ft | " " | 0.29°F | " " " |
| 2820-3085 ft | " " | 0.81°F | " " " |

In the absence of a caliper log one can only surmise that the sharp temperature rise at 1245 ft is due to a reduction in hole diameter. (In the history of the well, virtually two holes were drilled. In the first one, which collapsed, the bit diameter was reduced from 12¼in. to 7in. at about 1280 ft. The second hole was drilled through the collapsed first hole). The remaining changes in gradient are presumably due to changes in thermal conductivity. Sand and siltstone are extremely variable in their thermal conductivity, and consequently the changes are difficult to interpret. In general, it is found that the conductivity increases with compaction.

Invasion of the sand by the mud could have the same effect as an increase in hole size; i.e., a cooling due to the proximity of a greater volume of cool mud.

The abnormally low gradient between 925 and 1050 ft might therefore be brought about by mud invasion of the sand shown by the electric log to lie between 997 and 1140 ft.

The formational changes corresponding to the changes in temperature gradient at 1875 ft and 2525 ft are not known. It is possible that further drilling in the area may reveal similar anomalies, however, and allow correlations to be made between bore holes. The increase in gradient at 2820 ft may possibly correspond to the top of the Cretaceous beds.

## 4. CONCLUSIONS

The electric and gamma-ray logs largely confirm the lithology as shown in the sample log, and allow more accurate formation boundaries to be drawn.

Thick water-bearing sand below 2270 ft, the depth to which the well is to be cased off, could be exploited through slotted liners. The sand occurs at the following depths below the rptary table:

2398-2444
2692-2732
2841-2894
3025-3050
3086-3130 ft

Calculations indicate that the water salinity may be very roughly the equivalent of 400 to 700 parts per million sodium chloride.

The sand at depths greater than 3130 ft probably contains water which is more saline and should be cemented off.

Some heavy mineral content may be the cause of the exceptionally high radioactivity of sand occurring at depths 2053, 2295 and 2315 ft. These sand beds will probably be excellent markers on gamma-ray logs taken in any future bore holes to be drilled in the area.

## 5. REFERENCES


ARCHIE, G.E., 1942 The electrical resistivity as an aid in determining some reservoir characteristics. Trans. Amer. Inst. min. (metall.) Engrs., 1942, "Petroleum Development and Technology".

GONDOUIN, M., TIXIER, M.P. and SIMARD, G.L., 1956 An experimental study of the influence of the chemical composition of electrolytes on the S.P. curve. Trans. Amer. Inst. min. (metall.) Engrs. Petroleum Transactions Reprint series No. 1; Well logging.


COMPANY Mines Dept. of Victoria
WELL Timboon No 5
AREA Parish of Timboon
STATE Victoria

| | |
|---|---|
| COORDINATES | ———— |
| ELEVATION | 315 ft. above sea level |

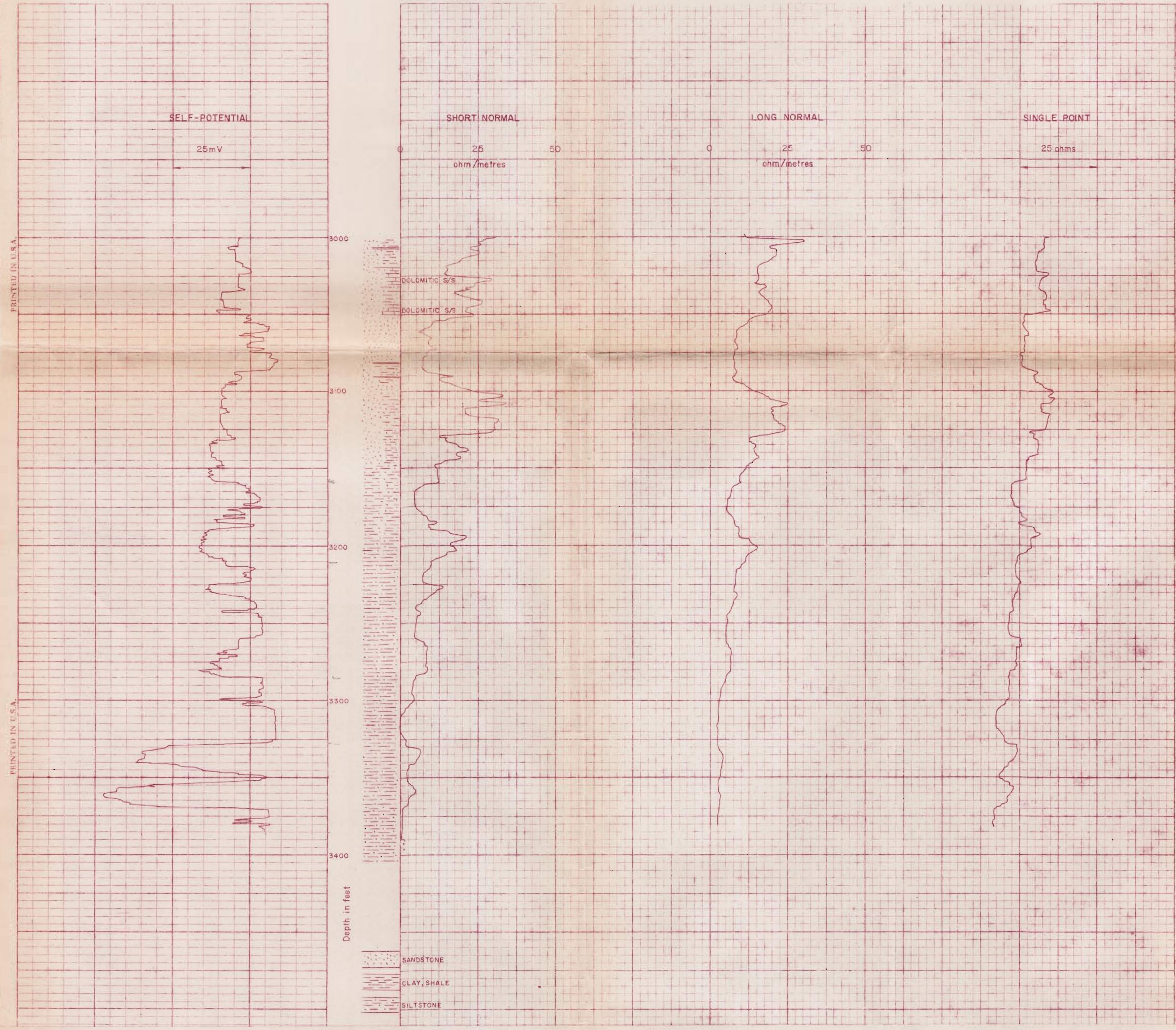
| | |
|---|---|
| Instrument | |
| Logged by | F. Jewell & N. Jackson |

| | Run No 1 |
|---|---|
| Date | 10 - 11 - 1959 |
| First Reading | 67 |
| Last Reading | 3117 |
| Footage Logged | 3050 |
| Bottom (Driller) | 3123 |
| Casing (from Log) | 67 |
| Casing (Drilling) | 66 |
| Casing Size | 12 5/8 I.D. |
| Bit Size: | 12 1/4 ins. to 839 ft. |
| Bit Size: | 9 ins. 839-1127 ft. |
| | 7 5/8 ins 1127-3123 ft. |

| MUD | Run No 1 |
|---|---|
| Nature | Bentonite |
| Density | |
| Viscosity | |
| Resistivity | 11·6 @ 18 °F |
| Res. at BHT | |
| pH | |
| Circ. Temp. | |
| B.H. Temp. | |
| Water Loss | |
| | |

**REMARKS :—** Depths are relative to rotary table, 9 feet above ground.

PLATE 2




COMPANY Mines Dept. of Victoria
AREA Parish of Timboon
WELL Timboon No 5
STATE Victoria

| | |
|---|---|
| COORDINATES | ———— |
| ELEVATION | 315 feet above sea level |

| | |
|---|---|
| Instrument | |
| Logged by | F. Jewell & N. Jackson |

| | Run No 2 |
|---|---|
| Date | 14 - 11 - 1959 |
| First Reading | 3100' |
| Last Reading | 3380' |
| Footage Logged | 280' |
| Bottom (Driller) | 3500' |
| Casing (from Log) | |
| Casing (Drilling) | |
| Casing Size | |
| Bit Size: | $7\frac{5}{8}$" |
| Bit Size: | |

| MUD | Run No 2 |
|---|---|
| Nature | Bentonite |
| Density | |
| Viscosity | |
| Resistivity | 10·4 @ 15 °C |
| Res. at BHT | |
| pH | |
| Circ. Temp. | |
| B.H. Temp. | |
| Water Loss | |

**REMARKS** :— Depths are relative to rotary table, 9 feet above ground.

COMPANY Mines Dept. of Victoria

AREA Parish of Timboon

WELL Timboon No 5

COUNTY ____ STATE Victoria

COORDINATES:
N
S
ELEVATION: 315 feet above s.l.
D.F.
K.B.
G.L.

| | Run No. 1 | Run No. 2 | MUD | Run No. 1 | Run No. 2 |
|---|---|---|---|---|---|
| Date | 14 - 11 - 1959 | | Nature | Bentonite | |
| First Reading | 50' | | Density | | |
| Last Reading | 3130' | | Viscosity | @ °F | @ °F |
| Footage Logged | 3080' | | Resistivity | @ °F | @ °F |
| Bottom (Driller) | [illegible] | | Res. @ BHT | @ °F | @ °F |
| Casing (From Log) | 66' | | pH | | |
| Casing (Driller) | 66' | | Circ. Temp. | | |
| Casing Size | 13 3/8" | | B.H. Temp. | | |
| Bit Size: | 12 1/4" to 839 | | | | |
| Bit Size: | 9" 839 - 1127 | | | | |
| | 7 7/8" to bottom | | | | |
| | | | Logged by | F. Jewell & N. Jackson | |
| | | | Witnessed by | | |

REMARKS Depths are relative to rotary table, 9 ft. above ground.

* Reg. U.S. Pat. Off.

GAMMA - RAY

0.02 milliröntgens/hour/inch

PLATE 4

LOCATION
WELL
COMPANY

COMPANY Mines Dept. of Victoria
AREA Parish of Timboon
WELL Timboon No 5
COUNTY STATE Victoria

COORDINATES:
N
S
ELEVATION: 315 feet above s.l.
D.F.
K.B.
G.L.

| | Run No. 1 | Run No. 2 | MUD | Run No. 1 | Run No. 2 |
|---|---|---|---|---|---|
| Date | 14 - 11 - 1959 | | Nature | Bentonite | |
| First Reading | 50' | | Density | | |
| Last Reading | 3085' | | Viscosity | @ °F | @ °F |
| Footage Logged | 3035' | | Resistivity | @ °F | @ °F |
| Bottom (Driller) | 3500' | | Res. @ BHT | @ °F | @ °F |
| Casing (From Log) | 67' | | pH | | |
| Casing (Driller) | 66' | | Circ. Temp. | | |
| Casing Size | 12 5/8" | | B.H. Temp. | | |
| Bit Size: | 12 1/4" to 839 | | | | |
| Bit Size: | 9" 839-1127 | | | | |
| | 7 7/8" to bottom | | | | |
| | | | Logged by | F. Jewell & N. Jackson | |
| | | | Witnessed by | | |

REMARKS Depths are relative to rotary table, 9 ft. above ground.

* Reg. U.S. Pat. Off.

TEMPERATURE →
5 °F/inch


PLATE 4