COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS.

RECORDS

RECORDS 1960 No. 89

CANBERRA BORE-LOGGING SURVEY, A.C.T. 1958

by

W.A. Wiebenga and N.D. Jackson.

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ABSTRACT

This report describes the electrical (single electrode) and radioactive logging of eight shallow drill-holes near Canberra during November and December 1958.

The logs of eight drill-holes are discussed and interpreted.

It is pointed out that to make logging worthwhile, the holes must be over a certain depth (say 100 ft) before contrasting rock properties can appear as readable features on the logs.

1. INTRODUCTION

This report describes the electrical (single electrode) and radioactive logging of eight shallow drill-holes near Canberra, A.C.T., during November and December 1958. The logging was requested by the Miscellaneous Investigations Group of the Bureau of Mineral Resources, Geology and Geophysics. The following table describes the drill-holes investigated. The first five holes were drilled by the Petroleum Technology Section of the Bureau with a Failing 750 rotary drill.

Name	Co-ordinates or location	Bore size in inches	Depth in feet	Purpose of hole
Belconnen No. 5	Lake George 1-mile sheet 068 528	$6\frac{3}{8}$ to 178 ft $4\frac{3}{4}$ to 200 ft	200	Water investigation
Belconnen No. 6	See above 074 512	$6\frac{5}{8}$ to 64 ft $4\frac{3}{4}$ to 78 ft	78	Water investigation.
Belconnen No. 7	60 ft north of Belconnen No. 6	$6\frac{5}{8}$ to 27 ft $4\frac{3}{4}$ to 57 ft	57	Water investigation.
Belconnen No. 8	60 ft south of Belconnen No. 6	$6\frac{5}{8}$ to 33 ft $4\frac{3}{4}$ to 57 ft	57	Water investigation.
Red Hill No. 1	Block 16, Section 3, Red Hill, Canberra	$6\frac{5}{8}$ to 60 ft $4\frac{3}{4}$ to 102 ft	102	Drainage problem in city.
Pini's Bore	Canberra 1-mile sheet 162 342	Cased to 38 ft casing O.D. 5" logged to 62 ft depth unknown	-	Water investigation.
Lindbeck's bore	Canberra 1-mile sheet 156 275	Uncased old hole 1 ft dia. at top, logged to 54 ft	-	Water investigation.
Woden Weir site D.D.H. No. 3 (Also known as Yarralumla).	Canberra 1-mile sheet 084 403	3" to $61\frac{1}{2}$ ft cased to $14\frac{1}{2}$ ft	$61\frac{1}{2}$ ft	Foundation problem.

The logging was carried out by N.D. Jackson, senior radio technician in co-operation with J. Burton, geologist of the Bureau. The geological information contained in chapter 3 "Discussion of Logs", was obtained from J. Burton. For more geological information the reader is referred to Burton and Wilson (1959).

The logger used was a single-point 2000-ft Widco logger, model XDM. A modification of the Widco logger made it possible to interchange the normal probe so that a gamma ray intensity log also could be obtained.

2. METHODS

Single-point Resistive, Self-Potential (S-P.) and Radioactive (gamma ray) logging techniques were used. Comments on these methods and some aspects of interpreting the logs are given in the Appendix. The ranges used in radioactive logging were 0.0025 and 0.005 mr/hr/in.

3. DISCUSSION OF LOGS

Belconnen No. 5

The resistivity log shows two major discontinuities, at 60 and

160 ft; the S-P. log shows low values between 40 and 56 ft, and relatively sudden increase at 71 ft and 160 ft. The radioactive log shows a remarkable feature of low radioactivity between 52 and 60 ft and a sudden decrease in radioactivity at 160 ft.

The logs suggest the following sequence: -

> A low-permeability zone of clay, mudstone, or shale from 40 to 52 ft, and a low-permeability zone of non-clayey material (say a zone cemented by silica, lime, or hydrated iron oxide) between 52 and 60 ft. The gradual increase in resistivity from 60 to 90 ft suggests a transition from weathered to partly weathered rock. Below 170 ft the logs indicate a rock of low porosity, permeability, and radioactivity; that is, an unweathered silicate rock.

The logs do not indicate any important aquifer. At the best some seepage water may be expected.

The ditch sample log yielded the following approximate figures:

0 to 11 ft	sand and clay
11 to 39 ft	weathered porphyry
39 to 60 ft	brown shale and mudstone
60 to 61 ft	porphyry
61 to 70 ft	brown slate and mudstone
70 to ~~174~~ 169 ft	~~weathered to partly weathered porphyry~~ Black hornfelsed mudstone. Some porphyry at 135 – 138 ft.
~~174~~ 169 to 200 ft	porphyry

A pumping test at first yielded fresh water of 33 ohm-metres resistivity, but after an hour the water resisitivity dropped to 7 ohm-metres. Probably the higher-resisitivity water represents fresh surface water, and the lower-resisitivity water comes from rocks at a lower level where the water in the pores is more saline. During the pumping test the water yield dropped from 450 to 150 gallons per hour in 6 hours.

The ditch sample log and pumping test confirm the findings from the electrical and radioactive logs. It may be noted that the level of radioactivity is much lower in the porphyry than in the shale, mudstone, and slate.

<u>Belconnen No. 6.</u>

As in Belconnen No. 5, the drilling results suggest the presence of weathered and unweathered porphyry.

The resistivity log shows a minor increase in resistivity below 26 ft. The large increase in resisitivity below 55 ft suggests a transition from weathered to unweathered rock.

The S-P. log suggests alternate bands of higher and lower permeability. The increase in S-P. below 67 ft may possibly be caused by oxidation or weathering of minerals in the porphyry.

The radioactive log shows alternate bands of higher and lower radioactivity, probably caused by bands with higher or lower clay content. A large decrease in radioactivity occurs below 60 ft where the unweathered porphyry begins. This suggests that weathering in this locality produces a concentration of radioactive minerals within the weathered zone.

The logging does not indicate important permeable zones which could be classed as aquifers. The logs show that the weathered layer is about 60 ft thick.

Belconnen No. 7.

As in Belconnen No. 5 and 6, the drilling results indicate the presence of weathered and unweathered porphyry.

Below 20 ft the resistivity log shows a general increase in resistivity on which is superimposed a band of still higher resistivity between 26 and 34 ft. The general increase in resistivity to 44 ft represents a transition from weathered to unweathered porphyry. Below 44 ft the rock is unweathered porphyry.

As at Belconnen No. 6, the decrease in radioactivity below 44 ft suggests a concentration of radioactive minerals in the weathered part of the porphyry.

Belconnen No. 8

As in Belconnen No. 5, 6, and 7, the drilling indicates the presence of weathered and unweathered porphyry.

The resistance log indicates alternate bands of high and low resistivity, caused by bands of high and low porosity. The S-P. log is not significant and may be unreliable. The radioactive log shows small anomalies.

The low-resistivity zone at 50 ft coincides with a zone of increased radioactivity, and may be interpreted as a weathered zone. The logs indicate that the bottom of the hole (52ft) is still in weathered porphyry.

The ditch sample and drilling log show alternate bands of weathered and unweathered, or "soft" and "hard" porphyry which confirms the findings of the electrical and radioactive logs.

Red Hill No. 1

This bore was drilled to assist the Department of Works in solving a drainage problem. The formations consist, going from top to bottom, of; clayey soil to a depth of about 6 ft overlying a formation of sandy soil with clay pockets; weathered porphyry; a transition of weathered to unweathered porphyry (inferred); and unweathered porphyry (inferred).

The resistance log shows an increase in resistivity at about 14 ft, indicating the transition from soil into weathered porphyry.

A low-resistivity zone is indicated between 21 and 23 ft at the same place where the S-P. log shows a small increase. This suggests a higher-permeability zone within the weathered porphyry between 21 and 23 ft.

Between 36 and 38 ft a zone of lower resistivity coincides with a zone of lower S-P. suggesting an impermeable zone within the weathered porphyry.

Between 50 and 57 ft a low-resistivity feature coincides with a S-P. feature, suggesting a permeable, weathered zone in porphyry. Below 57 ft the resistivity values become very high, indicating unweathered porphyry.

The radioactive log does not show any clear features which can be related to the electrical logs.

Summarising, the electrical logs indicate relatively impermeable soil to 16 ft; weathered porphyry possibly with zones of higher permeability from 16 to 57 ft; and unweathered porphyry below 57 ft.

Pini's bore

This bore is 2 years old, yields sufficient water for the farm, and is cased to a depth of 38 ft. The logs of the remaining 24 ft lack contrast, and yield no features which can be interpreted. No geological information is available.

Lindbeck's bore

No geological information is available about this bore, which is 8 years old. The bore was logged to a depth of 54 ft.

The resistance and S-P. logs suggest sand or sandy clay from 44 to 53 ft; from the surface to 44 ft. the formations probably consist of clay or mud. The presence of sand between 44 and 53 ft. is confirmed by a minimum on the radioactivity log.

Woden Weir Site, D.D.H. No.3.

This diamond drill hole was drilled to a depth of 62 ft. to investigate the conditions on the Woden Weir site. It was logged to 52 ft. The drilling showed clay, sand, and gravel to a depth of 14 ft., and weathered, more or less fractured porphyry to 52 ft.

The resistance log shows alternate zones of high and low resistivity, coinciding with zones of low and high S-P.

The zones of lower resistivity and higher S-P. can be explained by the presence of permeable fractures in the weathered porphyry.

The steep rise in resistivity from 50 to 52 ft. depth probably indicates the top of the unweathered porphyry.

4. CONCLUSIONS

The survey shows that logging of shallow bores or drill holes may be successfully used to indicate variations of porosity, permeability and radioactivity in near-surface formations. These variations may be translated into geological terms. The transition from weathered to unweathered rock was clearly indicated whenever the holes were deep enough.

The interpretation of logs is largely based on recognising features resulting from "contrasts" in the property being logged. These contrasts do not stand out clearly when logs are run only over short distances, in holes which are shallow. As a practical rule the minimum depth of hole should be 100 ft., and at least 90 per cent of a hole as shallow as this should be logged. If possible, the logged section should include at least 20 ft. of unweathered rock.

The logging of shallow holes also shows that S-P. logs in the weathered section are sometimes difficult to interpret because the weathering process sets up in the drilling liquid an electrochemical current system which cannot be directly correlated with rock features.

5. REFERENCES

BURTON, G.M. & WILSON, E.G., - 1959 Bureau of Mineral Resources experimental water bore drilling, Canberra 1958. Bur. Min. Resour. Aust. Records 1959/53.

APPENDIX - LOGGING METHODS

(a) Single-point resistance logging

In single-point resistance logging, recordings are made of variations in electrical resistance between the logging electrode, at some point down the hole, and the ground electrode, situated at the surface. 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 is assumed to be constant during the measurements, and the recorded changes of resistance are therefore due to the logging electrode passing through beds with different resistivities.

The amplitude and width of the variation is controlled by the nature and thickness of the beds opposite the logging electrode, the drill hole diameter, and the resistivity of the mud. However, the recorded variations due to resistivity differences are not linearly related to these differences; variations in the higher ranges of resistivity have a smaller effect than similar variations in the lower ranges. Therefore the resistivity is compressed in the higher ranges, and it is impossible to estimate the true resistivity from the resistance log.

The resistivity of a rock is inversely proportional to the product of its porosity and the salinity of the pore solutions. Assuming that the salinity of the pore solutions remains about the same over large rock sections, variations in the resistance log will indicate variations in porosity and these can, with certain limitations, be translated into geological terms. For instance, clay and shale, being very porous, are indicated by a low resistance; and unsorted material of low porosity, for instance gravel and unsorted sand, are indicated by a high resistance. Well-sorted sand (often fine grained) is indicated by a medium resistance on the log.

(b) Self-potential (S-P.)

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

The potentials measured in logging arise when the fluid column is introduced during the drilling, 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 fluid; the direction of current flow is from shale to drilling fluid to sandstone and back to 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 drilling fluid column. The potential in the fluid column within the sandstone will be negative with respect to the potential of the fluid within the shale. Should the drilling fluid be more saline than the pore solution in 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

$$E = k \log_{10} Rm/Rw$$

where Rm is the resistivity of the drilling fluid

Rw is the resistivity of the pore solution

k is a constant depending on the nature of the bed in question.

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

The shape and amplitude of the S-P. peak of a bed may be influenced by the following factors: -

1. Total electromotive force (static S-P.) involved
2. thickness of the bed
3. resistivity of the surrounding formation and the drilling fluid
4. diameter of the drill hole
5. the degree of infiltration into the bed, and
6. the permeability of the bed.

Because the S-P. log usually indicates the permeability of formations, it is sometimes called the "permeability log". In practice the S-P. log through shale and clay formations is used as zero reference line, and permeable sands and gravels may be indicated by negative anomalies as high as 100 mV.

In the weathered zone near the surface the S-P. log often shows irregularities, or a drift, caused by electro-chemical reactions of the weathering process.

(c) Radioactive (gamma ray) logging

Radioactive logs show the natural radioactivity of the formations penetrated by the drill. The following is a list of sedimentary rocks in decreasing order of relative radioactive intensity: -

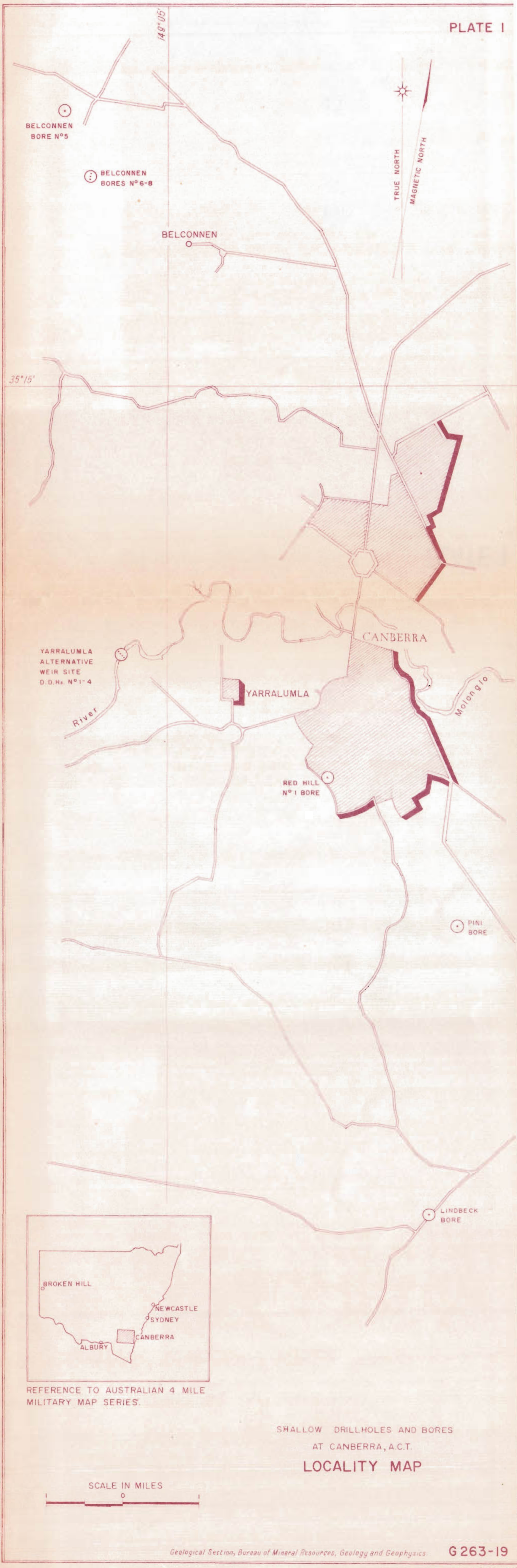
1. Organic clay and shale
2. clay and shale
3. shaley sandstone
4. shaley limestone
5. sandstone
6. limestone
7. dolomite
8. salt
9. coal.

As clay and shale are generally more radioactive than sand or limestone, the radioactive log variations often corresponds to lithological changes in a manner similar to the variations in the S-P. log. In other words, in many places a very good correlation exists between radioactive and S-P. variations. For this reason radioactive logs may often replace S-P. logs where it is difficult or impossible to take S-P. logs; for instance, in cased holes, holes with a saline or oil-based drilling mud, or in empty holes. Radioactive logging may also be used for correlation of old holes, either cased or uncased.

The response of the radioactive probe does not depend only on formation radioactivity. It also varies with the diameter of the hole, the density of the drilling fluid, and the casing thickness. These conditions have to be taken into account in interpretation, and for quantitative interpretation, corrections have to be applied.

The radioactive probe used in the Widco logger is calibrated against a known cobalt source, and the results are expressed in milliröntgen per hour per inch (mr/hr/in.). With this unit a combination of radiation energy and flux is measured.

PLATE I



SHALLOW DRILLHOLES AND BORES
AT CANBERRA, A.C.T.

LOCALITY MAP

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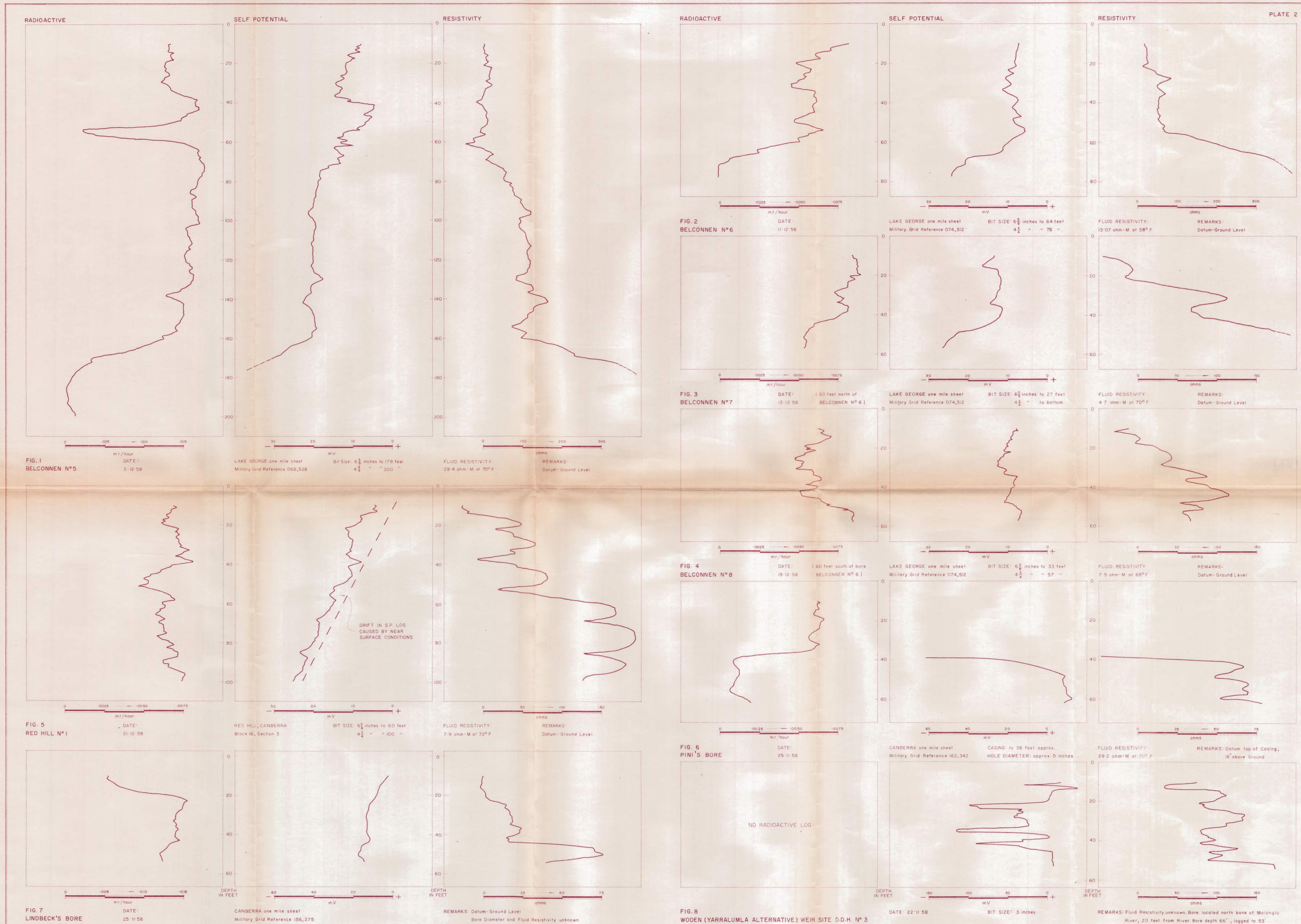
PLATE 2



SHALLOW DRILLHOLES AND BORES

AT CANBERRA, A.C.T.

ELECTRICAL AND RADIOACTIVE LOGS

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