RESULTS OF A GEOPHYSICAL WELL-LOGGING SURVEY, CENTRAL AUSTRALIA, 1986

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1.

TABLE OF CONTENTS Page Number

ABSTRACT

A geophysical well-logging survey was conducted in the southern Northern Territory in July and August 1986 using the BMR's truck-borne digital well-logging system. Of the nine shallow boreholes logged in this period, six were located on the BMR's 1985 Seismic Reflection Traverse, one was located in Alice Springs and two were sited near the Ross Highway to the east of Alice Springs.

The suite of well-logs run at each site included Neutron, Self Potential, Single Point Resistance, Natural Gamma, Short and Long-spaced Density and Caliper. In addition, Hole Deviation and Sonic logs were run at most sites.

The log results were processed in the field to check for data integrity and quality. Log data which failed to meet these standards were rejected and new logs were run.

The Short-spaced and Long-spaced density log data which were acquired in counts per second format were further processed in Canberra using a calibration procedure which allowed the presentation of these data in terms of grams per cubic centimetre.

The results of the logs from each site are presented together with a short discussion of their reliability and specific interpretations of some of their more significant features.

INTRODUCTION

The field survey reported here had 3 specific purposes:

1) To provide detailed information on the lithological and mechanical character of the wall rocks of 6 boreholes drilled along the BMR's 1985 Seismic Reflection Survey traverse for the purpose of evaluating the suitability of these boreholes for *in-situ* stress measurements using the hydraulic fracture technique.
2) To provide estimates of the sonic velocity and *in-situ* density of some of the rock types encountered along the Seismic Reflection Survey traverse with a view to assisting the interpretation of the seismic results.
3) To obtain geophysical well-log data from 2 cored boreholes drilled for the Baas Becking Geobiological laboratory, BMR in the Bitter Springs Formation to the east of Alice Springs in order to facilitate the interpretation of existing well-log data from other uncored boreholes.

The field party comprising myself (as party leader), a BMR Engineering Services Unit technician, Mr H.T. Stone and a fieldhand departed Canberra on 25 June 1986 with 3 vehicles:

The Well-logging truck	ZSV-828
A Mercedes tray top truck	ZBE-687
A Toyota Landcruiser	ZSV-828

together with a kitchen caravan (ZTL-915) and a water trailer (ZTL-998). Full operational details for the survey are included on File 85/130.

Work commenced in the Alice Springs area on 7 July and continued until 18 August when the party departed *en-route* to Canberra. The six week survey was significantly delayed by two periods of heavy unseasonal rain which made travel over the unmade tracks and dirt roads to the west of Alice Springs difficult.

LOGGING OPERATIONS

1. Site Locations

Of the nine boreholes logged during the survey, six were located along the BMR's 1985 Seismic Reflection traverse to the west of Alice Springs (see Figure 1). The six boreholes on this traverse were drilled for use in *in-situ* stress measurements using the hydraulic fracturing technique. These boreholes were drilled in the period March to August 1986. The three southern-most of these boreholes penetrate sediments of the Amadeus Basin while those at the northern end of the traverse intersect acid intrusive granitoid rocks of the Arunta Block.

Of the remaining three boreholes that were logged during the survey, two were drilled for the Baas Becking Geobiological Laboratory, BMR. These boreholes are situated to the east of Alice Springs adjacent to the Ross Highway. Each of these boreholes intersects rocks of the Upper Proterozoic Bitter Springs Formation.

The other borehole to be logged during the course of the survey was the Northern Territory Geological Survey's test borehole at the Power Street compound in Alice Springs. This borehole penetrates an acid igneous granitoid of probable granodioritic composition.

2. Logging Procedures

In general, logging operations at each site followed a similar pattern. The logging truck was firstly positioned over the borehole and then a series of standard calibration procedures were carried out. These calibrations involved:

1) Measuring the background natural gamma radiation level at the site using the gamma detector in the neutron tool. This measurement was always made at a point at least 200 metres distant from the truck and the shielded radiation sources.
2) Re-measuring gamma radiation levels with the detector in the neutron tool after a weak gamma source of known strength (i.e. 200 API units) had been temporarily attached to the neutron tool. The difference between this and the previous measurement allowed the correct operation of the gamma detector to be checked at each site

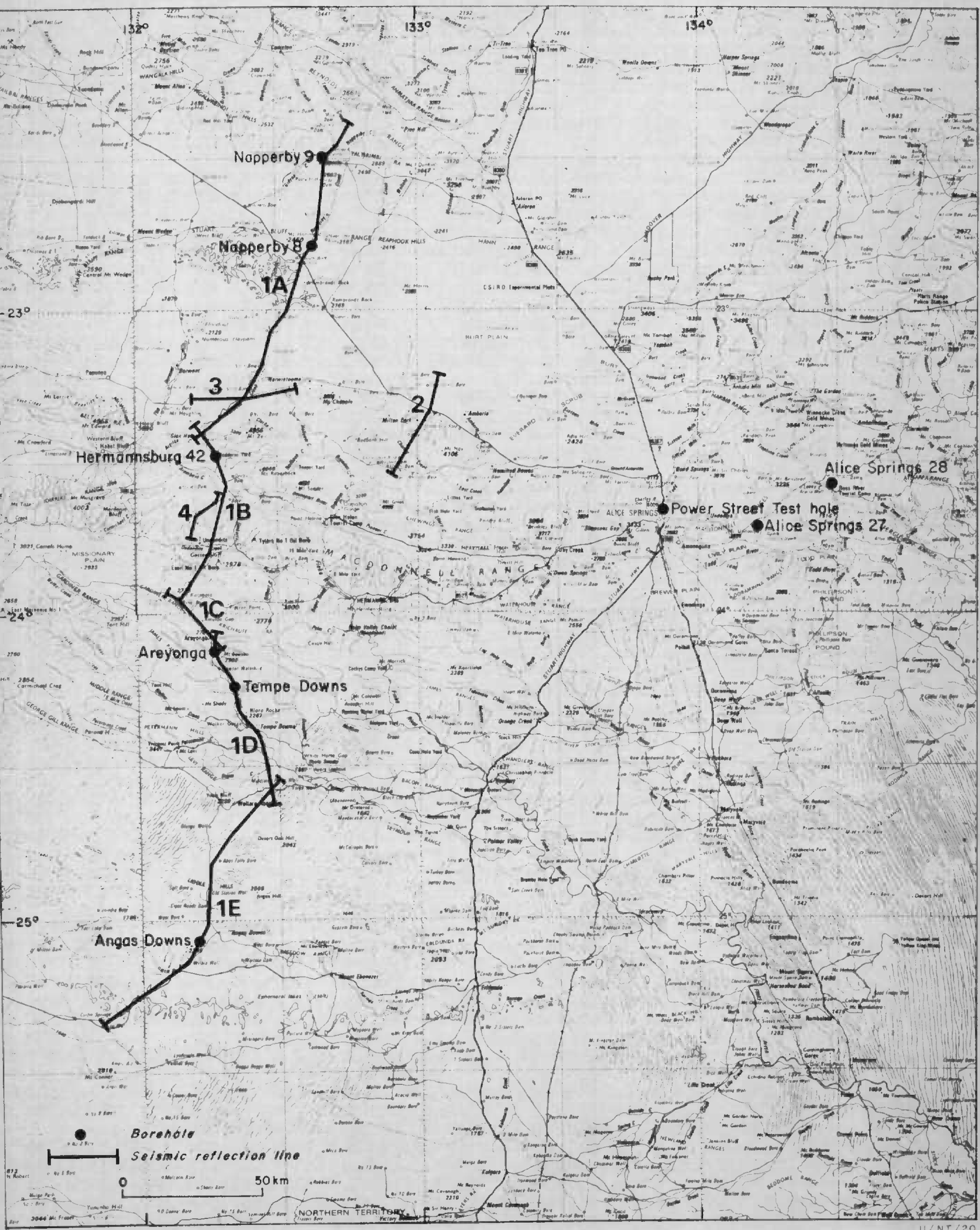


Fig.1 Locality map. Base reduced from 1:1000 000 topographical maps of the region. BMR Traverses and boreholes are marked.

6

independently of differences in background radiation levels.

3) Measuring the strength of the neutron source and verifying correct operation of the neutron detector in the neutron tool. To do this three calibrations were carried out with the neutron tool inserted in the "fish tank". These calibrations involved placing firstly one, then two and finally three slabs of perspex (a neutron absorbing material) in proximity to the source and measuring the flux of neutrons detected by the neutron detector in the tool.
4) Using the Self Potential circuitry in the neutron tool to measure firstly a null voltage and then a signal of 100 mV in order to determine the zero shift and proportionality constant of the circuitry.
5) Using the Single Point Resistance circuitry in the neutron tool to measure the resistance of 4 standard resistors (200, 500, 1000 and 2500 ohm) in order to determine the contemporary circuit response.
6) Measuring the apparent density of a block of perspex and a block of a magnesium-aluminium alloy using the short-spaced and long-spaced detectors in the density tool. These measurements served to check the correct operation of the density tool's detectors and allowed the monitoring of the strength of the tool's gamma source.
7) Measuring the output of the density tool's caliper assembly corresponding to caliper arm openings of 10, 20 and 30 cm.

Once the calibration procedures were complete, a dummy log was run to the bottom of the hole. This run used a dummy tool consisting of an approximately 75 cm length of steel with a cylindrical shape of 4 cm diameter. The purpose of this log run was in each case to determine the current total depth of the hole and to allow an assessment of the condition of the borehole wall to be made before any of the important well-logging tools were committed. This dummy log run was generally run at a speed of 6 metres per minute.

Following the dummy run, a Neutron-tool log was generally run without the Neutron source attached. The purpose of this pass of the hole was primarily to obtain a natural gamma log uncompromised by the emission of gamma rays from the neutron source. This pass also permitted further evaluation of the borehole's integrity without jeopardising the neutron source. This log run and all the others for which log data were acquired, was performed at a speed of 3 metres per minute. This relatively low speed was used to improve the signal to noise ratio of the log data.

After the first pass of the hole with the neutron tool, the source was attached and the tool was run a second time to obtain the neutron log and in the process, a second set of Single Point Resistance (SPR) and Self-Potential (SP) data. After this log was completed, the Density tool was run in order to acquire the Short-spaced and Long-spaced density logs and the Caliper log. Following these logs, the Sonic tool was run in those boreholes which were of sufficiently large diameter. Finally, the Deviation tool was run.

Logging operations generally took from 5 to 7 hours per hole depending upon the depth of the hole that was being logged.

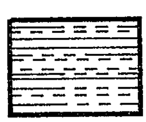
LOGGING RESULTS

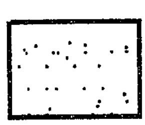
The well-log data acquired at each site were processed and plotted in preliminary form prior to the well-logging truck being moved off each hole. In this way the integrity of the data could be confirmed and its quality could be assessed. On several occasions data did not pass these checks and new logs were run.

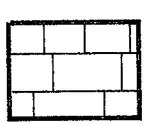
The final plots of the data that are presented here were prepared on return to Canberra. The density log data were also re-processed at this stage from their as-acquired counts per second format to $g\ cm^{-3}$ using the calibration procedures described previously by Chopra and de Bruyn (1987). The density estimates so produced are likely to be accurate to within $\pm 0.05\ g\ cm^{-3}$ for smooth-walled, water-filled boreholes.

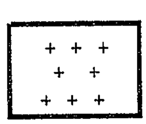
Lithological logs compiled from inspection of core recovered from each of the 8 deeper boreholes have been included with the geophysical well-log data. In the case of the Alice Springs 27 and 28 boreholes, the core log information displayed was extracted from more detailed data provided by P.N. Southgate of BMR.

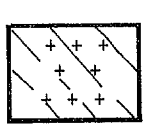
The lithological data are represented by the following symbols.


Shale, Siltstone and Mudstone


Sandstone


Dolomitic Limestone


Granite


Foliated Granite

1. Borehole: Angas Downs

a) Location and Drilling History

This borehole is situated in the north-western corner of the area covered by the 1:250,000 scale Kulgera, Northern Territory sheet at grid reference 532 877. The site is on a low ridge approximately 20 metres west of the seismic reflection traverse and ~200 metres distant from a microwave repeater station on a bearing of 80 degrees magnetic. The surface of the ridge is strewn with rubble composed of an indurated orange-pink medium-grained sandstone. This material is not outcropping but rather is present as "floaters".

This borehole was drilled in the period 5 to 18 April 1986 to a total depth of ~139 metre. The hole was rotary drilled to approximately 50 metre depth and cased to this level with PVC casing. Air-hammering was then used to a depth of ~115 metre followed by coring to the total depth.

b) Geology

The core from this hole consists entirely of finely laminated blue-grey and chocolate-brown shale with some minor sand laminae. The indurated medium-grained sandstone which comprises the surface cover at this site is not represented in the core. This lack of suitable sandstone units in the cored section renders the borehole unusable for hydrofracture measurements.

The lithological character of the core recovered from this hole and the strike of the sediments measured in rocks outcropping a few km to the north-west, suggest that the rocks intersected in the cored section of this borehole may belong either to the Inindia Beds or Winnall Beds of the Upper Proterozoic. In appearance the core is strongly reminiscent of the Pertatataka Formation, a unit that is stratigraphically contemporaneous with the Winnall Beds (Wells et al, 1970; p. 12). The core from this hole was left with the Northern Territory Geological Survey (NTGS) at their Price Street compound.

c) Geophysical Well-logs

General Comments

The borehole was first logged on 18 July 1986 with the dummy tool. This log run bottomed at a depth of 109 metre due to the presence of an obstruction in the hole at this depth. The density tool was then run in the hope that this, the heaviest of the tools, would be able to clear the obstruction. The tool initially would not go down below the 109 metre depth, but by raising and lowering the tool several times the obstruction was eventually dislodged. The tool then reached a depth of 132 metre but would not go down below this point to the total depth, as drilled, of ~139 metre.

After the density log run, the neutron tool was run without the neutron source attached. Problems were experienced in obtaining a good electrical earth in the dry sandy soil cover however which necessitated a second attempt the next day. Unfortunately, this run and the sonic log run which followed it, were unable to access the hole beyond the depth of 109 metre where the original obstruction occurred.

Specific Comments on the Logs

i) Caliper log

The Caliper log shows clear evidence of the three types of drilling used in the generation of this borehole. The upper 49.7 metre of the hole have a generally smooth profile corresponding to the presence of the PVC casing. The air-hammered section down to 115.3 m is characterised by wide variations in hole diameter between 12 and 13.7 cm while that part of the cored section which was available to the Caliper had a smooth tapered section. This tapering of the borehole in the cored section is indicative of rock with a low mechanical strength, a conclusion which is entirely consistent with the friable shale recovered.

ii) Natural Gamma log

This log indicates clearly the presence of two types of wall rock around the borehole. For the most part, the wall rock has a consistent natural gamma ray flux of ~40 counts per second which is consistent with the shale recovered from the cored section of the hole. However from the surface down to a depth of approximately 4.5 m and from ~19 to ~22 m depth, the significantly lower natural gamma signal recorded is consistent with the sandstone observed in sub-outcrop at the surface. The transition between the uppermost sandstone and the underlying shale between 4.5 and 8 metre depth is evidently gradational and characterised by the presence of intercalations of more sandy material as judged by the broadness of the transition in the natural gamma signal and the superimposed "troughs" centred at 5.8 and 7.0 metre. In contrast, the contacts on either side of the sandy layer at 20 m are quite sharp.

There is also a suggestion of a more siliceous layer in the shale at a depth of 64.5 m. Such a layer is also reflected in the Caliper log at this depth as a bar of more resistant rock in the air-hammered section of the hole. Higher mechanical strength in the rock at this depth is also suggested by the sonic log results which indicate a sonic velocity of ~4,500 metres per second.

iii) Short and Long-spaced density logs

Results from these logs are plotted in terms of *in-situ* densities in g cm^{-3} through the application of the calibration equations of Chopra and de Bruyn (1987). Density data are not given for the PVC cased section of the borehole because the density logs are affected by the presence of the PVC. The results of both density logs suggest a gradual decrease in *in-situ* densities up the hole from ~2.7 g cm^{-3} at 132 metre depth to ~2.6 g cm^{-3} at 52 metre depth. This decrease in density may be due to an increasing influence of weathering toward the surface either in the form of increased hydration of the constituent minerals or in the form of increasing numbers of water-filled spaces (e.g. microcracks) in the shale.

iv) The Electric logs (Single Point Resistance and Self Potential)

As remarked above, acquisition of the electric log data was made difficult at this site by problems in obtaining a good electrical earth. The results that were finally obtained, though a little noisy, are however reasonable for shale as judged by comparison with results obtained with the well-logging system elsewhere (see for example. Chopra and de Bruyn, 1987; Appendix C). The results of these logs are not plotted for depths less than 50 metre because of the influence of the PVC casing. The depth to the water table at the time of logging, as indicated by the electric logs was 17.5 metre.

v) Sonic log

The results from the sonic log are largely unusable for the depth interval 79 to 105 metre depth. These data have evidently been compromised by spurious signals generated by the banging of the tool against the borehole walls in the overly large diameter section of the hole. Nevertheless the results from the remainder of the log are apparently of a high quality. These results suggest a gradual decrease in sonic velocity in the shale from ~3,500 metre per second at 110 metre depth in the hole to ~3,000 metre per second at 50 metre depth. This result is in excellent agreement with the density log results and again is indicative of either increased hydration of constituent minerals or of the presence of increased numbers of water-filled openings in the shale toward shallower depths.

vi) Deviation log

The results of the deviation log run in the borehole with the Owl drift tool are given in the following table. A local declination value of 4 degrees east was used to convert the deviation direction from degrees magnetic to degrees from true north.

The results obtained suggest that the 50 metres of rotary drilling resulted in a deviation from vertical of 5.1 degrees, while the air-hammering of the hole from 50 metre to 115.3 metre depth produced a further 12 degrees of deviation. The rapid deviation from vertical during air-hammering, while undoubtedly aggravated by the initial deflection during rotary drilling, may indicate that too large a pull-down force was used.

Depth (metre)	Inclination from Vertical (degrees)	Direction of Deviation (degrees from true North)
5.0	0.1	119
10.0	0.4	326
15.0	0.6	342
20.0	0.8	316
25.0	2.3	8
30.0	3.8	7
35.0	3.8	7
40.0	4.1	20
45.0	4.3	28
50.0	5.1	42
55.0	7.7	52
60.0	9.1	64
65.0	10.1	70
70.0	11.6	74
75.0	12.3	70
80.0	13.2	76
85.0	14.0	79
90.0	15.2	76
95.0	15.9	77
98.0	16.0	80
100.0	16.4	78
109.1	17.4	79
108.5	17.1	76
114.2	17.1	82
119.3	17.1	84
124.0	17.1	86
132.0	16.6	75

BMR ROCK PROPERTIES RESEARCH

COMPUTERISED BOREHOLE LOGGING

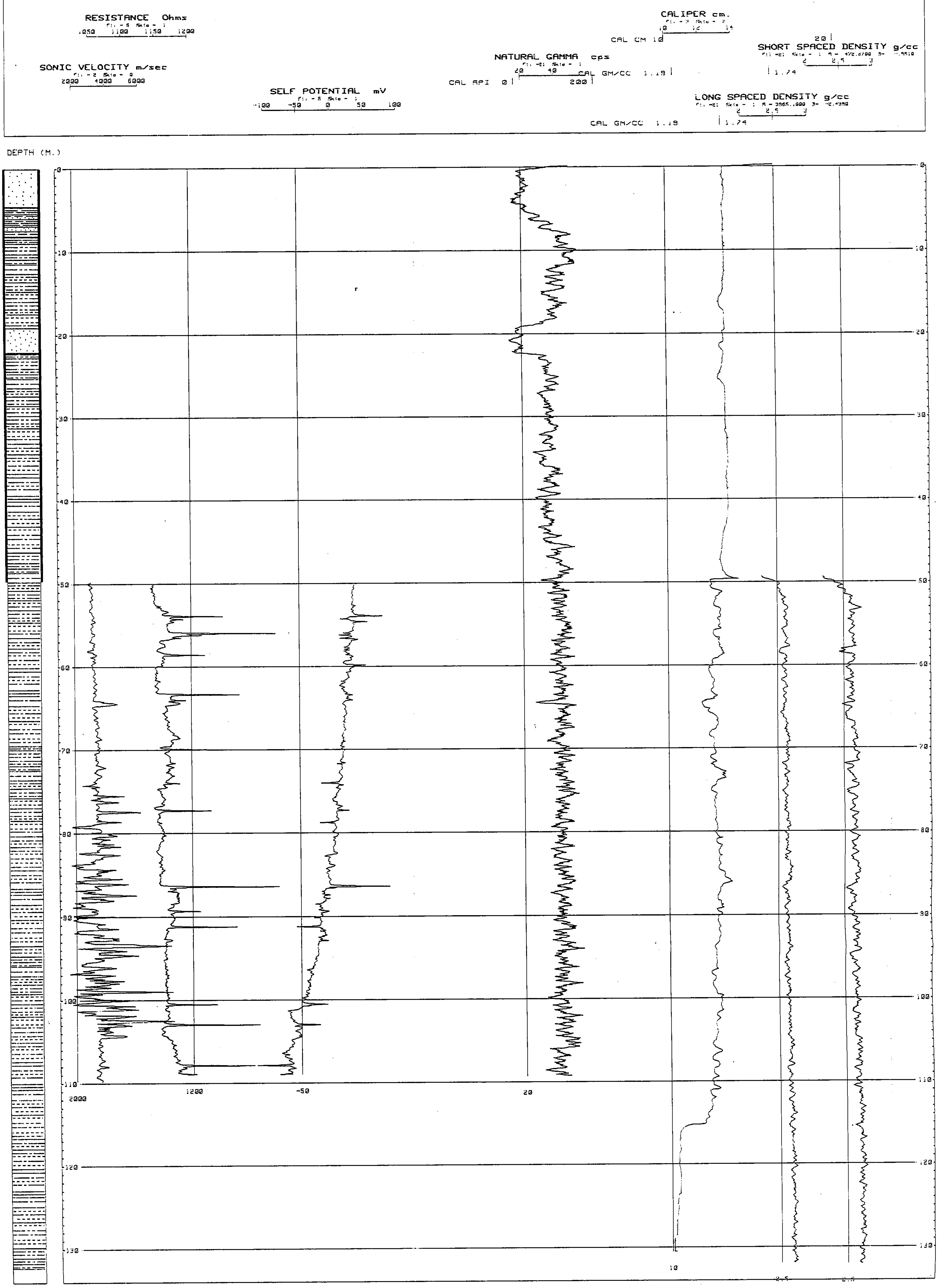
CENTRAL AUST
ANGAS DOWNS

LOGGING SPEEDS:
DENSITY PROBE 3 M/MIN
DATUM ABOVE GROUND LEVEL .20 M.
OPERATOR: : PRAME, TREVOR & IAN
DATA LOG VER: 78586.01
DATA PLOT VER: 78687.31
WATER LEVEL: .7.50 M.

PLOTTING SCALE: . 200

BOREHOLE NO. HYDROFRAC SITE #1

DEPTH LOGGED 130.52 M.
DATE LOGGED 18 07 86
DATE PROCESSED 04 02 87



2. Borehole: Tempe Downs

a) Location and drilling history

This borehole is situated in the north-western corner of the area covered by the 1:250,000 scale Henbury, Northern Territory sheet at grid reference 548 981. The site is approximately 10 metres west of the seismic reflection traverse and east of a north-trending ridge. A deep gully marking the position of a creek lies a few hundred metres to the south. The ground surface at the site is sandy though a few metres to the west the ground is littered with sub-outcropping cobble and boulder-sized pieces of indurated orange sandstone which carry up on to the ridge where the unit outcrops.

This borehole was drilled in the period 24 April to 14 May 1986 to a total depth of 207.7 metre. The hole was rotary drilled to 9.25 metre depth and cased to that level with PVC casing. Air-hammering was then used to a depth of ~110 metre followed by coring to the total depth.

b) Geology

The core from this hole consists of a reddish-coloured medium grained sandstone with a clay matrix. This sandstone has been mapped as the Hermannsburg sandstone, part of the Devonian to Carboniferous Pertnjara Group. In places the rock is quite porous while in others it contains thin layers of interbedded clay. In general the rock is devoid of sedimentary structure other than bedding planes, although there is occasional evidence of cross bedding. This lack of sedimentary structures probably indicates that the rock has been bioturbated (D. Morris, pers. comm.). In places the core contains numerous sub-vertical fractures which are sometimes seen to contain secondary mineralisation. Bedding planes are often distinguished by bleaching of the reddish colouration.

Core recovery during drilling was for the most part good, though this core typically was fragmented into short discrete lengths due to partings along clay interbeds and fractures. The longest piece of unfractured core recovered measured approximately 70 cm in length. It is also noteworthy that drilling operations at this site were beset by problems with lost circulation which probably indicates the presence of zones of high permeability perhaps correlated with locally high fracture densities. The core from this hole was left in the keeping of the Northern Territory Geological Survey (NTGS) at their Price Street compound.

c) Geophysical Well-logs

General Comments

The borehole was logged on 9 August 1986 after performing the calibrations the previous day. The dummy tool was run down the hole and it bottomed at a depth of 77.6 metre. Despite repeated attempts, it was not possible to lower any of the tools below this point to the maximum depth of the drilled hole (207.7 metre). The suite of logs were therefore restricted to the rotary drilled and air-hammered sections of the hole. Problems were encountered in getting the density and sonic tools up past an obstruction at a depth of 15.99 metre. These tools had to be raised and lowered several times to work them through the problem area so in both cases the data acquisition was stopped at this point in the hole. In the case of the density tool, this had the advantage of closing the caliper arm which made the task of tool recovery a little easier.

Specific Comments on the logs

i) Caliper log

The caliper log data for this hole are remarkable in that they indicate hole diameters in the air-hammered section of up to 27 cm. Reference to the caliper data for the other boreholes logged during this survey indicates in contrast that air-hammering usually only produces hole diameters of up to ~13 cm.

These large hole diameters suggest that the rock making up the borehole wall has for the most part a very low mechanical strength and probably a high porosity.

ii) Neutron log

The neutron log data, like most of the other log data, are likely to be seriously compromised by the large borehole size. Since the neutron tool was not eccentred in the hole, the tool was surrounded by a substantial amount of water during the log run. The presence of this water, which is a good neutron absorber, accounts for the low neutron flux measured in this hole. That this is the cause of the anomalous neutron flux is borne out by the observation that the flux increases near the bottom of the log where the hole diameter becomes smaller.

iii) Short-spaced and Long-spaced density

These log data are likely to be the least affected by the large hole diameter since the density tool is eccentred in the hole both by a bow-spring assembly and by the action of the caliper arm. The density estimates obtained from both the short- and long-spaced detectors vary little over the depth interval logged in the hole, though there is perhaps a slight tendency toward decreasing density with decreasing depth. The actual densities obtained of around 2.2 g cm^{-3} are relatively low for a sandstone which again probably reflects the existence of a high porosity.

iv) Electric logs (Single Point Resistance and Self Potential)

The range of SPR values obtained of between 400 and 500 ohms represent relatively low values for a sandstone which is again indicative of a high interconnected porosity. Similarly, the SP values are also relatively low which is consistent with the presence of a clay matrix in the rock, as has been observed in the core recovered from greater depths in the hole. The depth to the water table at the time of logging as indicated by the electric logs was 2.8 metre.

v) Sonic log

The sonic log may also have been compromised to a degree by the large borehole diameters. The recorded sonic velocities probably represent averaged values with the sonic pulses having passed partly through wall-rock and partly through water on their path parallel to the axis of the borehole between the transmitter and the receivers.

However, given that the recorded velocities are still substantially greater than the speed of sound in water at 25°C of 1,496.7 metres per second (Weast, 1981; p.E-47), it might be concluded that the sonic results are still of some value.

The observation of an apparent decrease in sonic velocity with decreasing depth from ~3,000 metre per second at 75 metre to ~2,700 metre per second at 17 metre may reflect an increase in porosity in the wall rock which is consistent both with the inference from the caliper log results of a decrease in mechanical strength and the suggestion of a decrease in rock density from the density logs. Alternatively, the decrease in apparent velocity may be due to the interposing of increased amounts of water in the path of the sonic pulses due to the increasing hole diameter with decreasing depth.

BMR ROCK PROPERTIES RESEARCH

COMPUTERISED BOREHOLE LOGGING

CENTRAL AUSTRALIA
TEMPE DOWNS

LINEAR DENSITY EQUATION IS Counts= A*Dens*EXP(B*Dens)

LOGGING SPEEDS:
DENSITY PROBE 3 M/MIN
NEUTRON PROBE 3 M/MIN
SONIC PROBE 3 M/MIN
DATUM ABOVE GROUND LEVEL .30 M.
OPERATOR: . PRAME, TREVOR & IAN
DATA LOG VER: 78506.01
DATA PLOT VER: 78607.31
WATER LEVEL: 2.15 M.

PLOTTING SCALE: 1:200

BOREHOLE NO. **HYDROFRAC #2**

DEPTH LOGGED 77.45 M..
DATE LOGGED 09 08 86
DATE PROCESSED 16 01 86

RESISTANCE Ohms
Fil = 3 Skip = 3
460 480 500

CALIPER cm.
Fil = 8 Skip = 0
8 12 16 20 24
CAL CM 10 20 30

SONIC VELOCITY m/sec
Fil = 3 Skip = 0
2000 4000

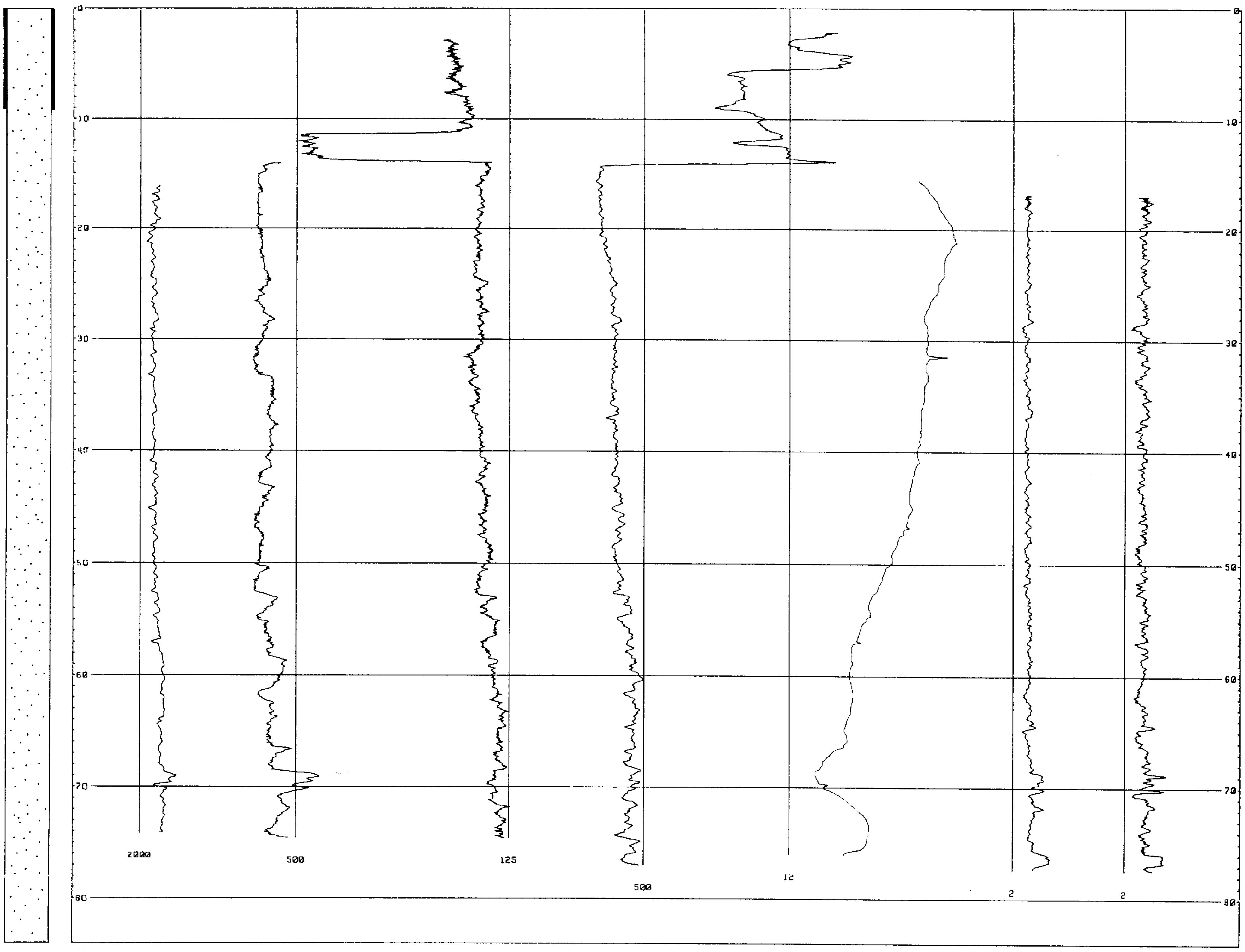
NEUTRON cps
Fil =15 Skip = 1
250 500 750 1000
CAL #1 2 3

SELF POTENTIAL mV
Fil = 3 Skip = 2
75 100 125

SHORT SPACED DENSITY g/cc
Fil =19 Skip = 3 A = 472.6700 B= -.5510
1.5 2 2.5
CAL GM/CC 1.19 1.74

LONG SPACED DENSITY g/cc
Fil =19 Skip = 3 A = 3985.1000 B= -2.4390
1.5 2 2.5
CAL GM/CC 1.19 1.74

DEPTH (M.)



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20

3. Borehole: Areyonga

a) Location and drilling history

This borehole is situated in the north-western corner of the area covered by the 1:250,000 scale Henbury, Northern Territory sheet at grid reference 540 996. The site is approximately 5 metres north of the seismic reflection traverse and a few metres east of a right angle bend in Areyonga Gorge. The ground surface at the site is sandy though a few metres to the north there are low cliffs of medium grained white sandstone.

This borehole was drilled in the period 19 to 30 May 1986 to a total depth of 170.7 metre. The hole was rotary drilled to 2.8 metre depth and cased to that level with PVC casing. Air-hammering was then used to a depth of ~140 metre followed by coring to the total depth. On 30 May the drill stem became stuck in the hole. Eventually, all but the bottom 55 metres of drill pipe were recovered but this left the ~30 metre of cored section of the hole inaccessible to the logging equipment. During the recovery operations, ~400 litres of diesel fuel were emptied into the hole in an attempt to loosen the drill stem.

b) Geology

The core from this hole consists of a white fine to medium-grained sandstone. This sandstone has been mapped as the Mereenie sandstone, a Silurian to Devonian largely aeolian deposit. In places the rock is quite porous while in others it appears well compacted. In general the rock is devoid of sedimentary structure other than bedding planes and cross bedding.

Core recovery during drilling was for the most part good, though this core typically was fragmented into short discrete lengths due to partings along fractures and bedding planes. The longest piece of unfractured core recovered measured approximately 0.5 metre in length. The core from this hole was left in the keeping of the Northern Territory Geological Survey (NTGS) at their Price Street compound.

c) Geophysical Well-logs

General Comments

The borehole was logged on 13 August 1986 after performing the calibrations the previous day. The dummy tool was run down the hole and it bottomed at a depth of 115.47 metre corresponding to the top of the drill pipes lost in the hole. All logging was then restricted to a maximum depth of 111 metres in order to guard against equipment fouling in the drilling relics. The suite of logs were therefore restricted to the rotary drilled and air-hammered sections of the hole.

Specific Comments on the logs

i) Caliper log

The caliper log data for this hole define three zones of differing hole diameter: From the surface down to a depth of ~3 metre the hole has a diameter of ~13 cm corresponding to the rotary drilled section. From ~3 metre depth to ~33 metre depth the hole has an average diameter of approximately 12.5 cm, and from ~33 metre depth to 110 metre the hole has a diameter of 11.5 to 12 cm. Since the latter two zones both lie within that portion of the hole which was air-hammered, it follows that the difference in hole diameter probably reflects a systematic difference in rock strength between these two parts of the hole.

ii) Neutron log

The neutron log data can be separated into two regions with the boundary between them at 38.5 metre depth. At depths above this value the average neutron flux is approximately 2250 counts per second while below it, the average flux is ~1125 cps. The most plausible explanation for this dichotomy is that the top of the layer of remaining diesel fuel in the hole occurs at 38.5 metre depth (A. Spence, pers. comm). Since the results of the electric logs (obtained a few hours later during the neutron tool without source log) suggest a depth to the water table at the time of logging of 51 metres, it follows that the layer of diesel was ~12.5 metre thick. This thickness, when combined with the mean hole diameter of 11.7 cm, suggests that ~134 litres of diesel fuel remained in the hole at the time of logging. Thus ~270 litres of diesel fuel had escaped from the borehole by infiltration into the wall rocks in the 75 day period between the drilling and logging operations.

The magnitude of the neutron flux recorded in the deeper region of the borehole is of the order expected for a sandstone with a moderate porosity.

iii) Short-spaced and Long-spaced density

The density log results can also be divided into two regions with the demarcation at approximately 35 metre depth. This observation implies either a change in lithology at this point, or that the rocks above 35 metre depth are more extensively weathered than those below this depth.

The density estimates obtained in the deeper parts of the hole of around 2.5 g cm^{-3} are consistent with the presence of a sandstone with only low to moderate porosity.

iv) Natural gamma

The natural gamma log is characterised by a near uniform response with a natural gamma signal commensurate with the presence of sandstone. The only features of significance are possible zones of slightly higher shale content at 72.5 and 34.0 metre depth. The peak at ~1.8 metre probably is associated with cement used to fix a steel collar at the surface around the PVC casing.

v) Electric logs (Single Point Resistance and Self Potential)

The SPR data are consistent with a sandstone containing an interconnected porosity. The SP data support the conclusion that a layer with slightly higher shale content occurs at a depth of 72.5 metre. The depth to the water table at the time of logging as indicated by the electric logs was 51 metre.

vi) Sonic log

The sonic log results suggest a decrease in sonic velocity in the rocks of the borehole wall from 4,500 metre per second at 110 metre depth to ~4,000 metre per second at 55 metre depth. This observation probably indicates an increased impact of weathering on the rocks closer to the surface. The spike in the velocity log at 97 metre depth may be due to a zone of fracturing since the density and caliper logs also have corresponding features at this depth.

BMR ROCK PROPERTIES RESEARCH

COMPUTERISED BOREHOLE LOGGING

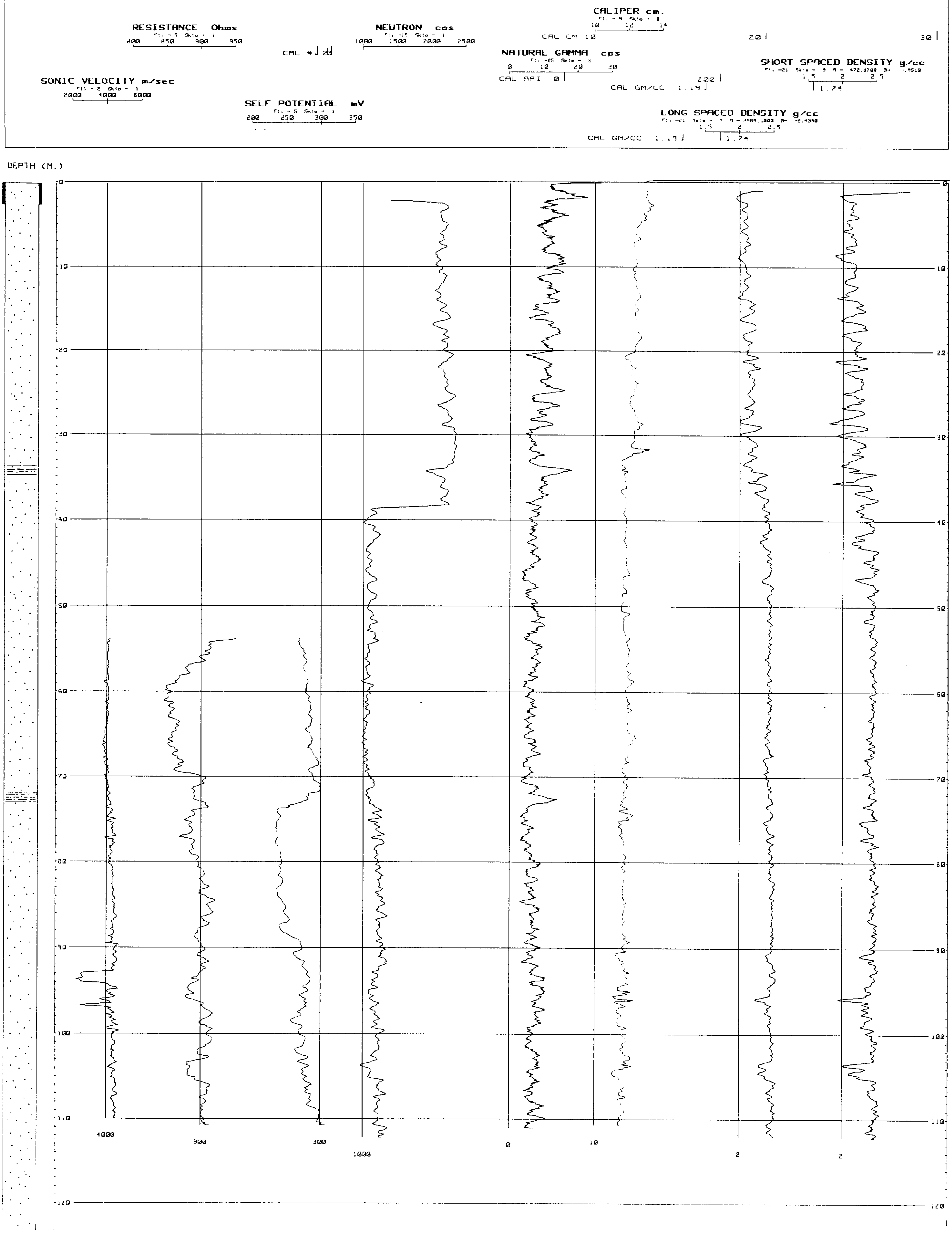
CENTRAL AUSTRALIA
AREYONGA

LOGGING SPEEDS:
NEUTRON PROBE 3 M/MIN
DATUM ABOVE GROUND LEVEL .25 M.
OPERATOR: PRAME, TREVOR & IAN
DATA LOG VER: 78506.01
DATA PLOT VER: 78607.31
WATER LEVEL: 53.80 M.

PLOTTING SCALE: 1:200

BOREHOLE NO. **HYDROFRAC #3**

DEPTH LOGGED 111.06 M.
DATE LOGGED 13 08 86
DATE PROCESSED 27 01 87



4. Borehole: Hermannsburg 42

a) Location and drilling history

This borehole is situated in the western portion of the area covered by the 1:250,000 scale Hermannsburg, Northern Territory sheet at grid reference 543 074. The site is approximately 5 metres west of the seismic reflection traverse on a low east-west trending ridge south of the area known as Madderns Yard. The traverse is now the route of the Amadeus Basin to Darwin natural gas pipeline. The ground surface at the site is sandy with pods of outcropping micro-granite. This borehole was drilled in the period 2 to 19 June 1986 to a total depth of 120.8 metre. The hole was rotary drilled to 7.4 metre depth and cased to that level with PVC casing. Air-hammering was then used to a depth of 78.7 metre followed by coring to the total depth.

b) Geology

The core from this hole consists for the most part of a fresh white micro-granite. Some foliated more melanocratic granitic material also occurs between approximately 100 and 120 metres depth. With the exception of a few epidote-filled fractures the micro-granite is devoid of mechanical discontinuities and as such represents an excellent unit for hydrofracture testing. The foliated granite while also relatively little fractured, would be less suitable for hydrofracturing because the pronounced foliation could influence the induced fracture geometry. Core recovery during drilling at this site was excellent with core typically being retrieved in lengths of a metre or longer.

c) Geophysical Well-logs

General Comments

The borehole was logged on 31 July 1986 after performing the calibrations the previous day. The dummy tool was run down the hole and it bottomed at a depth of 120.65 metre. The suite of logs were then run to this depth.

Specific Comments on the logs

i) Caliper log

The caliper log data for this hole delineate three zones of differing hole diameter produced by the three types of drilling (viz. rotary drilling to ~5.2 metre, air-hammering to ~78.2 metre and coring to the total depth). The air-hammered section of the hole is characteristically variable in diameter with the most notable regions of large diameter being at 16 metre and between 36 and 38.5 metre depth. Prominent constrictions of the hole occur at 39, 49 and 63 metre depth.

ii) Neutron log

The neutron log data show a gradual decrease in recorded neutron flux from the bottom of the hole to the top. Superimposed over this trend are three regions of locally low neutron flux, centred at 37, 69 and 107 metre depth. The feature at 37 metre depth is undoubtedly due to the presence of water- and/or hydrated mineral-filled fractures given the responses of the other logs, in particular the density logs which indicate locally low densities. The 69 and 107 metre depth features however are associated with relatively high densities. Examination of the core from between 103 and 110 metre depth indicates that the low neutron flux observed centred around 107 metre depth is due to the presence of large amounts of hornblende (≥50%) in the rock at this depth. This mineral contains appreciable structurally bound water. The low neutron flux observed near 69 metres presumably is due to a similar locally high hornblende concentration.

The decrease in mean neutron flux from the bottom to the top of the hole points to the presence of progressively more hydrogen in the rocks closer to the surface. This hydrogen may either be present as water in weathering-induced microcracks or as a component in hydrous secondary minerals produced by weathering or it may be present in both forms.

iii) Short-spaced and Long-spaced density

The density log results indicate a gradual decrease in rock density from 2.75 g cm^{-3} at 120 metre depth to 2.55 g cm^{-3} at a depth of 12 metre. This decrease in rock density probably again reflects the increasing role of weathering processes closer to the surface. The rocks in the depth intervals 67-69 and 105-109 metre have mean densities significantly above those of the other rocks in the borehole wall. The rocks in the former depth interval have mean densities of ~2.9 g cm^{-3} while those in the latter depth interval average ~3.0 g cm^{-3}. As mentioned above, inspection of the core taken at 107 metre indicates that the rocks at this level in the hole are rich in hornblende (≥50%), a mafic mineral with a density of between 3.02 and 3.45 g cm^{-3} (Deer et al, 1971; p. 167).

iv) Natural gamma

The natural gamma log delineates two kinds of lithology in the rocks of the borehole wall: rocks with a mean natural gamma flux of ~140 counts per second and rocks with a much lower mean gamma flux of ~30-40 counts per second. Since both types of signal are observed in that part of the hole which was cored, it has been possible to establish that the foliated granite is the lithology responsible for the lower gamma ray emissions, while the micro-granite is responsible for the higher ones. The lithological information included on the well-logs for the air-hammered section of the hole has been inferred on the basis of these natural gamma signatures.

v) Electric logs (Single Point Resistance and Self Potential)

The depth to the water table at the time of logging as indicated by the electric logs was 8.0 metre.

vi) Sonic log

The sonic log results indicate a nearly constant sonic velocity in the rocks of the borehole wall of between 5,400 and 5,600 metre per second with the exception of a short interval of reduced velocity between 36 and 38.5 metre depth. The reduced velocity in this restricted zone is most probably due to local fracturing and increased weathering of these rocks.

vii) Deviation log

The results of the deviation log run in the borehole with the Owl drift tool are given in the following table. A local declination value of 4 degrees east was used to convert the deviation direction from degrees magnetic to degrees from true north.

Depth (metre)	Inclination from Vertical (degrees)	Direction of Deviation (degrees from true North)
5.0	0.5	26
10.0	0.7	355
15.0	0.3	13
20.0	0.2	102
25.0	0.9	116
30.0	1.3	126
35.0	1.2	144
40.0	1.7	145
45.0	2.7	159
50.0	3.2	157
55.0	4.0	152
60.0	4.2	166
65.0	4.4	159
70.0	6.3	173
75.0	6.8	167
80.0	6.9	166
85.0	6.7	165
90.0	6.5	165
95.0	6.5	171
100.0	6.7	172
105.0	6.6	170
110.0	6.7	169
115.0	6.8	165
119.6	6.7	168

The deviation log results obtained suggest that the ~70 metres of air-hammering resulted in a deviation from vertical of only 6.4 degrees which is a good result in such hard rock. The additional ~42 metres of coring added only another 0.4 degrees however which is an even better performance. One conclusion from these observations is that for applications in which boreholes must be drilled close to vertical in hard rocks (e.g. for hydraulic fracturing measurements), air-hammering should not be extensively used.

BMR ROCK PROPERTIES RESEARCH

COMPUTERISED BOREHOLE LOGGING

CENTRAL AUSTRALIA
GLEN HELEN

LOGGING SPEEDS:
SONIC PROBE 3 M/MIN
DATUM ABOVE GROUND LEVEL .22 M.
OPERATOR: : PRANE, TREVOR & IAN
DATA LOG VER: 78506.01
DATA PLOT VER: 78607.31
WATER LEVEL: 0.00 M.

PLOTTING SCALE: 1:200

BOREHOLE NO. #6

DEPTH LOGGED 119.05 M.
DATE LOGGED 31 07 86
DATE PROCESSED 28 01 87

RESISTANCE Ohms — 400 600 800 1000

SONIC VELOCITY m/sec — 2000 4000 6000

NEUTRON cps — 500 1000 1500 2000

CAL #1123

SELF POTENTIAL mV — 50 100 150 200

CALIPER cm. — 6 8 10 12

CAL CM 10

NATURAL GAMMA cps — 0 100 200 300

CAL API 200

CAL GM/CC 1.19

SHORT SPACED DENSITY — 2 2.5 3

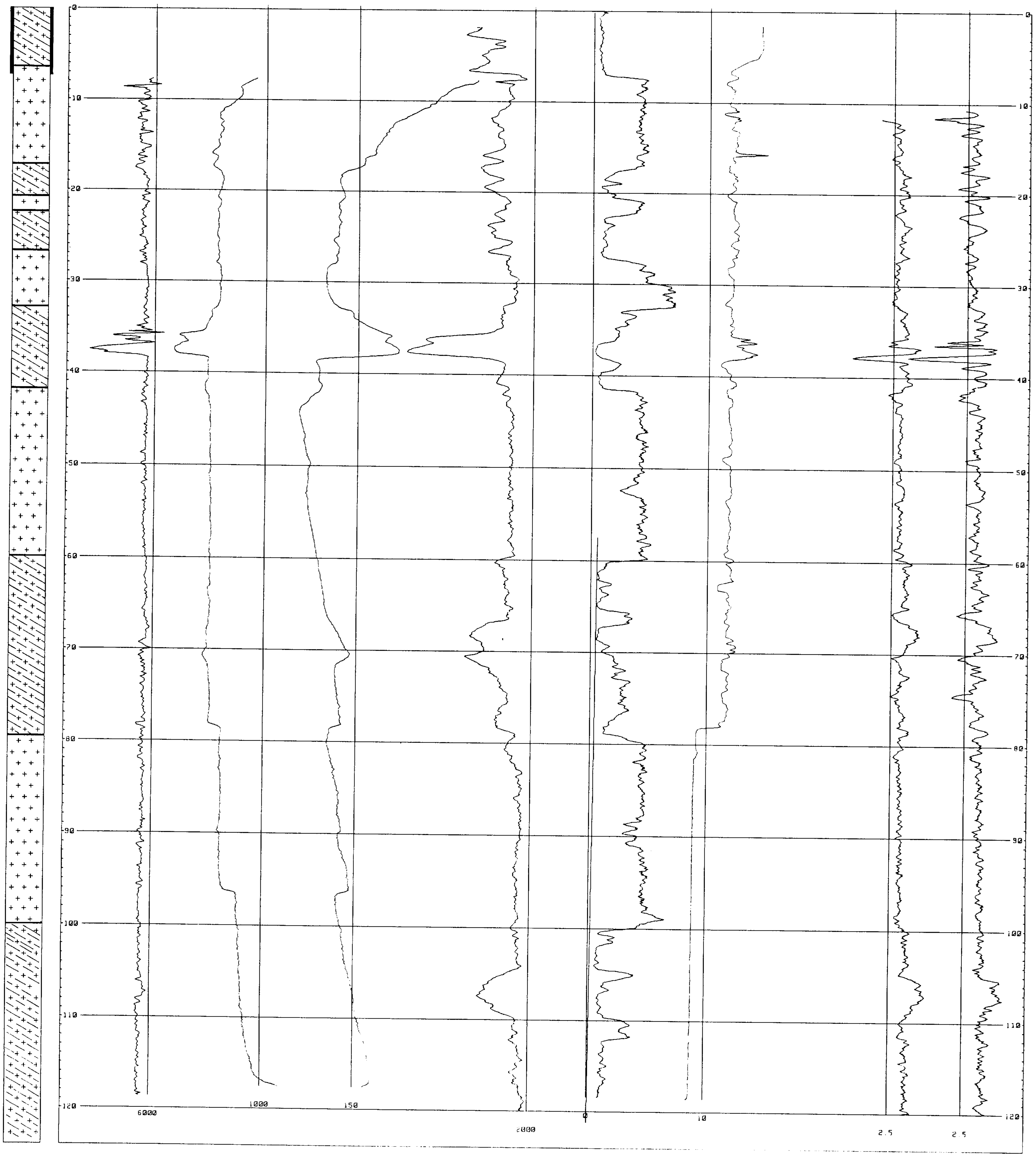
1.74

LONG SPACED DENSITY g/cc — 2 2.5 3

CAL GM/CC 1.19

1.74

DEPTH (M.)



5. Borehole: Napperby 8

a) Location and drilling history

This borehole is situated in the south-central portion of the area covered by the 1:250,000 scale Napperby, Northern Territory sheet at grid reference KQ5581. The site is approximately 10 metres west of the seismic reflection traverse and 10 metres north of the eastern extremity of the ridge marking the western edge of the Stuart Bluff Ranges at Napperby Creek. The ground surface at the site is alluvial sand deposited by the nearby Napperby Creek.

This borehole was drilled in the period 21 June to 8 July, 1986 to a total depth of 157 metre. The hole was rotary drilled to 5.5 metre depth and cased to that level with PVC casing. Air-hammering was then used to a depth of 101.7 metre followed by coring to the total depth.

b) Geology

The core from this hole consists of a fresh pink granite with a grainsize of 1-2 cm. The core contains an appreciable number of closed, epidote-filled fractures many intersecting the core at a high angle. Several opportunities still exist for hydrofracture measurements to be made, however, since the spacing between adjacent fractures in a number of places exceeds 1 metre. Core recovery during drilling at this site was excellent with core typically being retrieved in lengths of a metre or longer.

c) Geophysical Well-logs

General Comments

The borehole was logged on 2 August 1986 after performing the calibrations. The dummy tool was run down the hole and it bottomed at a depth of 150.43 metre which was ~6.5 metre short of the total depth drilled. Despite several attempts to clear the obstruction in the hole, it was not possible to work below this level. The suite of logs was then run to this depth.

Specific Comments on the logs

i) Caliper log

The air-hammered section of this borehole down to a level of ~58 metre is characterised by very large hole diameters (up to 17.5 cm). This observation suggests that the rock down to this level has relatively little mechanical strength which is probably indicative of the substantial impact of weathering, perhaps exacerbated by the proximity of Napperby Creek. Below ~58 metre depth the caliper log data suggest that the rock is mechanically more cohesive and largely free of zones of fracturing except perhaps at 96 metre depth where some enlargement of the hole was recorded.

ii) Neutron log

The neutron log data show a gradual decrease in recorded neutron flux from the bottom of the hole to a depth of ~58 metre. This decrease in mean neutron flux points to the presence of progressively more hydrogen in the rocks closer to the surface. This hydrogen may either be present as water in weathering-induced microcracks or as a component in hydrous secondary minerals produced by weathering or it may be present in both forms.

At shallower depths, the neutron flux observed was substantially reduced in association with the observed enlargement of the hole. Such increases in hole diameter interpose more water between the neutron tool and the rocks of the borehole wall.

The only notable feature on the neutron log below 58 metre depth is a pronounced peak centred at 96 metre. This feature probably marks the presence of a zone of fracturing in the borehole wall.

iii) Short-spaced and Long-spaced density

The density log results indicate a gradual decrease in rock density from 2.65 g cm^{-3} at 150 metre depth to 2.50 g cm^{-3} at a depth of 58 metre. This decrease in rock density probably again reflects the increasing role of weathering processes closer to the surface. The presence of a zone of relatively more weathered granite is suggested at a depth of 96 metre.

The density estimates in the depth interval between 58 metre and the surface are likely to be less reliable than those obtained from the deeper parts of the hole given the wide variations in borehole diameter that occur.

iv) Natural gamma

The natural gamma log data suggest that the rocks below a depth of ~29 metre are much more radioactive than those closer to the surface. Whether this difference is due to a change in lithology or is due to weathering associated leaching effects is unknown since there is no core from this level in the hole.

v) Electric logs (Single Point Resistance and Self Potential)

The depth to the water table at the time of logging as indicated by the electric logs was 13.3 metre. Both electric logs point to the presence of a weathered zone at a depth of 96 metre.

vi) Sonic log

The sonic log results indicate a nearly constant sonic velocity in the rocks of the borehole wall of between 5,400 and 5,600 metre per second in the depth interval from the bottom of the hole to ~58 metre. Velocity estimates at depths above this level are compromised by the large and variable bore diameters. Reductions of velocity at 73.5 and 96 metre depth are suggestive of zones of increased weathering.

vii) Deviation log

The results of the deviation log run in the borehole with the Owl drift tool are given in the following table. A local declination value of 4 degrees east was used to convert the deviation direction from degrees magnetic to degrees from true north.

The results obtained suggest that the ~70 metres of air-hammering resulted in a deviation from vertical of only 7.7 degrees which is a reasonable result in such hard rock. The additional ~49 metres of coring did not add to the amount of hole deviation.

Depth (metre)	Inclination from Vertical (degrees)	Direction of Deviation (degrees from true North)
5.0	0.3	250
10.0	0.4	168
15.0	0.5	114
20.0	0.3	81
25.0	0.5	192
30.0	1.4	240
35.0	3.1	223
40.0	4.1	221
45.0	4.0	222
50.0	5.1	213
55.0	5.8	218
60.0	5.6	209
65.0	6.1	214
70.0	5.8	224
75.0	5.9	221
80.0	7.1	221
85.0	6.7	218
90.0	6.9	218
95.0	7.7	217
100.0	8.0	195
105.0	7.9	236
110.0	7.8	223
115.0	8.0	220
120.0	8.0	221
125.0	7.9	221
130.0	7.7	223
135.0	7.6	224
140.0	7.6	221
145.0	7.4	221
150.0	7.7	223

BMR ROCK PROPERTIES RESEARCH

COMPUTERISED BOREHOLE LOGGING

CENTRAL AUSTRALIA
STUART BLUFF RANGES

LINEAR DENSITY EQUATION IS Counts= A*Dens*EXP(B*Dens)

LOGGING SPEEDS:
DENSITY PROBE 3 M/MIN
NEUTRON PROBE 3 M/MIN
SONIC PROBE 3 M/MIN

PLOTTING SCALE 1:200

DATUM ABOVE GROUND LEVEL .25 M.
CASING DEPTH: 13.3 m.
OPERATOR: [illegible], TREVOR & IAN
DATA LOG VER: 74506.0.
DATA PLOT VER 74607.1.

BOREHOLE NO. HYDROFRAC #7

DEPTH LOGGED 150.77 M.
DATE LOGGED 02 09 86
DATE PROCESSED 28 01 87

RESISTANCE Ohms — 560 640 720

NEUTRON cps — 500 1000 1500 2000 — CAL #1 [illegible]

CALIPER cm. — 6 8 10 12 — CAL CM 10

NATURAL GAMMA cps — 0 100 200 300 — CAL API 000

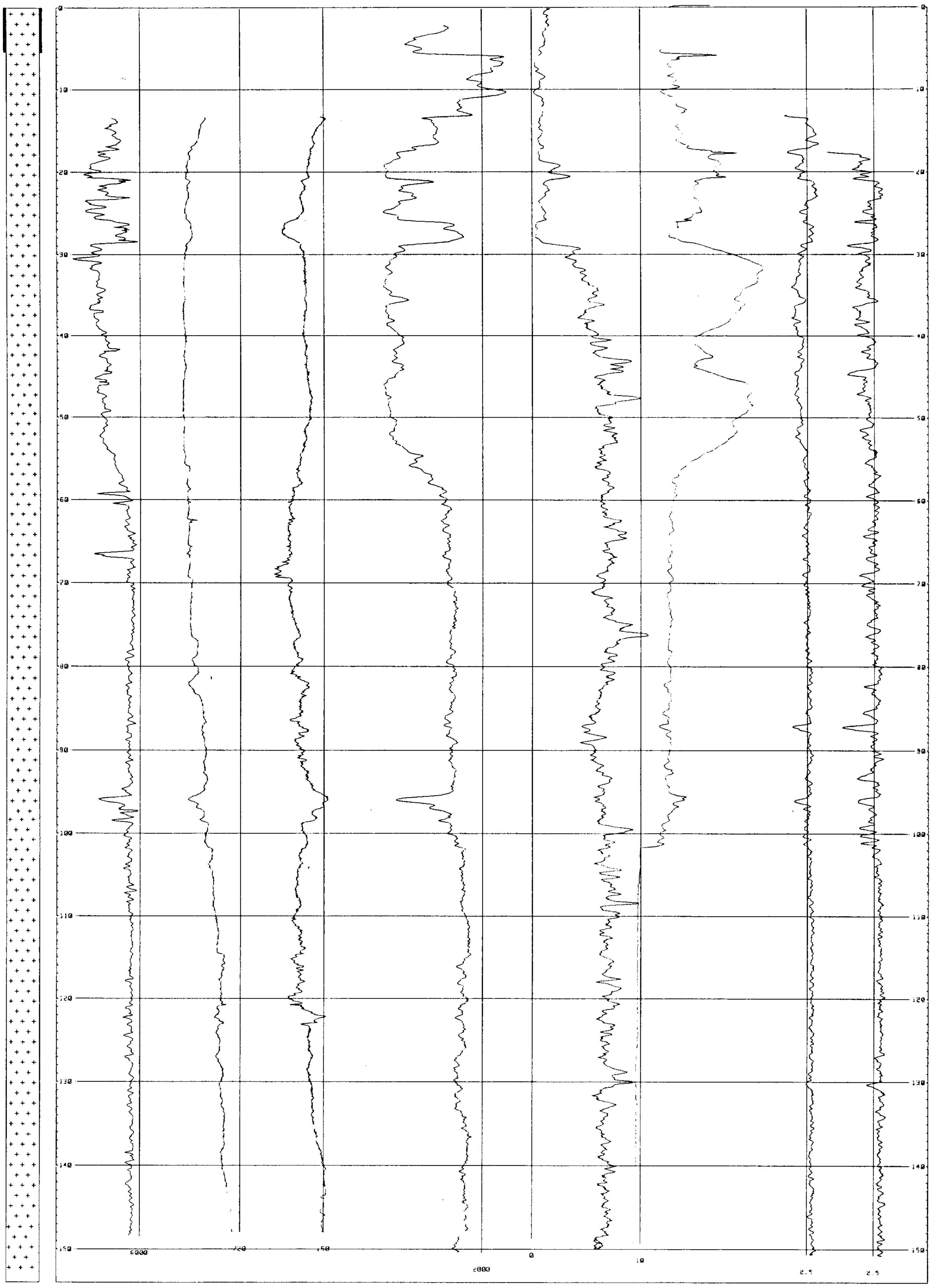
SONIC VELOCITY m/sec — 2000 4000 6000

SELF POTENTIAL mV — 50 100 150 200

SHORT SPACED DENSITY — 2 2.5 3 — CAL GM/CC [illegible] 1.24

LONG SPACED DENSITY g/cc — 2 2.5 3 — CAL GM/CC [illegible] 1.24

DEPTH (M.)



36

R8702710

6. Borehole: Napperby 9

a) Location and drilling history

This borehole is situated in the centre of the area covered by the 1:250,000 scale Napperby, Northern Territory sheet at grid reference KR5912. The site is approximately 100 metres west of the seismic reflection traverse and 20 metres south east of Gidgea bore. The ground surface at the site is sandy and poorly vegetated.

This borehole was drilled in the period 9 July to 1 August, 1986 to a total depth of 149 metre. The hole was rotary drilled to 21.28 metre depth and cased to that level with PVC casing. Air-hammering was then used to a depth of 99.4 metre followed by coring to the total depth.

b) Geology

The core from this hole consists of a fresh white granite with a grainsize of 1-2 cm. The core contains a number of closed, epidote-filled fractures many intersecting the core at a high angle. Several opportunities still exist for hydrofracture measurements to be made, however, since the spacing between adjacent fractures in a number of places exceeds 1 metre. Core recovery during drilling at this site was for the most part good, though some core loss occurred between 120 and 133 metre depth. Core was typically retrieved in lengths of a metre or longer.

c) Geophysical Well-logs

General Comments

The borehole was logged on 4 August 1986 after performing the calibrations. The dummy tool was run down the hole and it bottomed at a depth of 148.67 metre which was approximately the total depth drilled. The suite of logs was then run to this depth.

Specific Comments on the logs

i) Caliper log

The caliper log data for this hole delineate three zones of differing hole diameter produced by the three types of drilling (viz. rotary drilling to ~21.3 metre, air-hammering to ~99.5 metre and coring to the total depth). The cored section is notable for the number of "wash-outs" that occur between 119 and 133 metre depth. These wash-outs represent zones of low mechanical strength probably associated with extensive fracturing of the rock. In all, 12 bags of cement were emptied into the hole by the drillers during the drilling of this section of the hole. This cement was used to fill open cracks around the hole at this level which were responsible for losses of drilling circulation.

ii) Neutron log

The neutron log data show a gradual decrease in recorded neutron flux from the bottom of the hole to a depth of ~22 metre. This decrease in mean neutron flux points to the presence of progressively more hydrogen in the rocks closer to the surface. This hydrogen may either be present as water in weathering-induced microcracks or as a component in hydrous secondary minerals produced by weathering or it may be present in both forms.

At shallower depths, the neutron flux observed was reduced by the absorption of neutrons by the PVC casing.

Numerous peaks in the neutron log trace correspond to the presence of zones of increased fracturing and weathering in the granite.

iii) Short-spaced and Long-spaced density

The density log results indicate a gradual decrease in rock density from 2.60 g cm^{-3} at 148 metre depth to 2.55 g cm^{-3} at a depth of 30 metre. This decrease in rock density probably again reflects the increasing role of weathering processes closer to the surface. The presence of zones of relatively more weathered and/or fractured granite are suggested at depths of 31.2, 37.3, 41.5, 48.8, 49.8, 53.0, 57.5, 64.0, 67.5, 86.8, 88.2, 119.6, 120.8, 123.0, 125.9, 127.5, 130.6, 133.1 and 137.5 metre.

iv) Natural gamma

The natural gamma log data suggest that the rocks below a depth of ~40 metre are slightly more radioactive than those closer to the surface. Whether this difference is due to a change in lithology or is due to weathering associated leaching effects is unknown since there is no core from this level in the hole.

v) Electric logs (Single Point Resistance and Self Potential)

The depth to the water table at the time of logging as indicated by the electric logs was 25.15 metre. Both electric logs point to the presence of numerous weathered zones in the cored section of the hole.

vi) Sonic log

The sonic log results indicate a nearly constant sonic velocity in the rocks of the borehole wall of between 5,400 and 5,500 metre per second in the depth interval from the bottom of the hole to the water table. The numerous local reductions of velocity observed in the hole correlate well with the weathered and/or fractured zones inferred from the density and neutron log results.

vii) Deviation log

The results of the deviation log run in the borehole with the Owl drift tool are given in the following table. A local declination value of 4 degrees east was used to convert the deviation direction from degrees magnetic to degrees from true north.

The results obtained suggest that the ~99 metres of air-hammering resulted in a deviation from vertical of only 2.8 degrees which is an extremely good result in such hard rock. The additional ~49 metres of coring did not add to the amount of hole deviation.

The degree of variability in the direction of hole deviation that is apparent in the data for depths above ~85 metre indicates that the Owl drift tool cannot be expected to produce robust estimates of this quantity for hole deviations from vertical of less than ~2°.

Depth (metre)	Inclination from Vertical (degrees)	Direction of Deviation (degrees from true North)
5.0	0.2	266
10.0	0.2	220
15.0	0.2	186
20.0	0.2	85
25.0	0.3	1
30.0	0.2	277
35.0	0.3	206
40.0	0.2	107
45.0	0.3	65
50.0	0.2	56
55.0	0.3	125
60.0	0.4	109
65.0	0.8	83
70.0	1.3	47
75.0	1.9	20
80.0	2.5	13
85.0	2.7	6
90.0	2.5	359
95.0	2.4	353
100.0	2.8	342
105.0	2.6	345
110.0	2.7	350
115.0	2.6	350
120.0	2.5	349
125.0	2.5	350
130.0	2.5	347
135.0	2.3	345
140.0	1.9	344
145.0	1.7	339

BMR ROCK PROPERTIES RESEARCH

COMPUTERISED BOREHOLE LOGGING

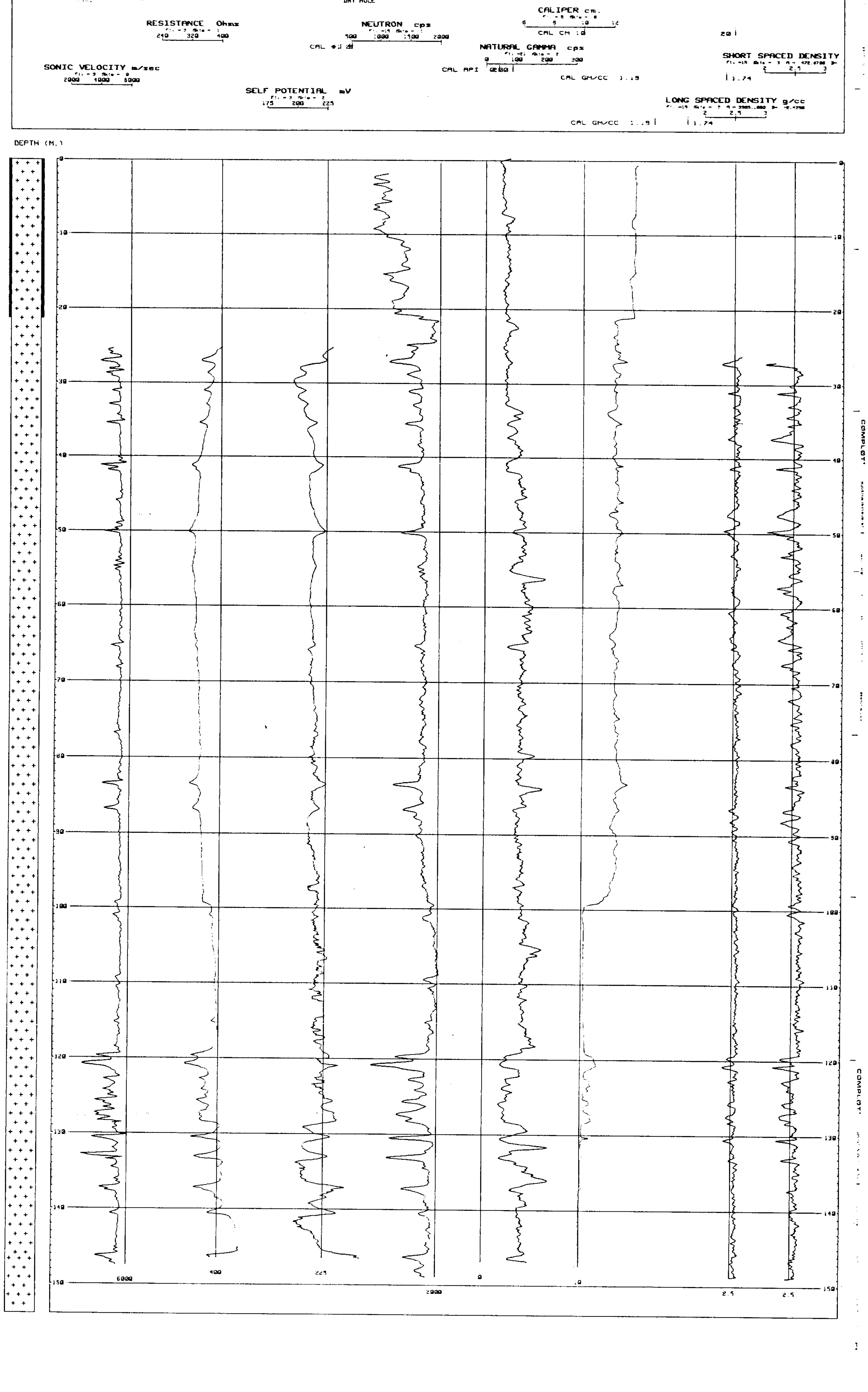
CENTRAL AUSTRALIA
GIDGEA BORE

LOGGING SPEEDS:
NEUTRON PROBE 3 M/MIN
DATUM ABOVE GROUND LEVEL .60 M.
CASING DEPTH: 25.15 M.
OPERATOR: . FRANE, TREVOR & IAN
DATA LOG VER: 78506.01
DATA PLOT VER: 78607.31
DRY HOLE

PLOTTING SCALE: . 200

BOREHOLE NO. HYDROFRAC #8

DEPTH LOGGED 146.81 M.
DATE LOGGED 04 08 86
DATE PROCESSED 28 01 87



R8702712

7. Borehole: Alice Springs 27

a) Location and drilling history

This borehole is situated in the south central portion of the area covered by the 1:250,000 scale Alice Springs, Northern Territory sheet at grid reference MP2079. The site is approximately 500 metres south of the Ross Highway and a few kilometers south-east of Corroboree Rock. The ground surface at the site is sandy and thinly vegetated. This borehole was drilled in May, 1986 to a total depth of 319.5 metre. The hole was cored from the surface, dipping at an initial angle of 15° from vertical in a westerly direction. The hole was drilled with HQ sized equipment to a depth of ~90 metre and then drilled with NQ equipment to the total depth. Approximately 20 metres of HQ drill rods were left in the hole at the bottom of the HQ section.

b) Geology

This hole penetrates approximately 63 metres of the Proterozoic Pertatataka Formation and then ~257 metres of the Bitter Springs Formation. The core recovered includes laminated mudstones, sandstones, conglomerate, dolomitic limestones and Red Beds.

c) Geophysical Well-logs

General Comments

The borehole was logged initially on 12 July with the Neutron tool, the Density tool, the Sonic tool and the Deviation tool. The hole was revisited on 16 August 1986 to obtain another lithological gamma log following problems experienced processing the original data. Secondary calibrations were performed on-site prior to the first logging operations. The dummy tool when run down the hole bottomed at a depth of 207.7 metre which was 102 metre above the bottom of the hole as-drilled. The suite of logs were run to this depth.

Specific Comments on the logs

i) Caliper log

The caliper log data for this hole indicate that the top of the HQ drill pipes left in the hole occurs at a depth of 71.8 metre. The change in hole size from HQ to NQ which occurs some 20 metre deeper in the hole is not resolved by the caliper data. The HQ section of the hole above the drill pipes is characterised by hole sizes that are generally much larger than the nominal HQ size of 9.61 cm. The degree to which this hole diameter varies suggests that the rocks penetrated do not have a high mechanical strength.

ii) Neutron log

The neutron log data show good resolution of the lithological variations recorded in the core taken from this hole. Depth intervals consisting of dolomitic limestone are characterised by a relatively high recorded neutron flux which points to these units being relatively low in hydrogen. This implies a general lack of water-filled pores and fractures and few hydrous constituent minerals in these units. The Red Bed units on the other hand are characterised by a much lower recorded neutron flux which points to the presence of much larger hydrogen concentrations. This hydrogen presumably occurs mainly as structurally bound hydroxyl in clay minerals.

iii) Short-spaced and Long-spaced density

The density log results indicate that the mudstones of the Pertatataka Formation have lower densities than the underlying rocks of the Bitter Springs Formation. The densities of the former rocks show a gradual decrease from 2.7 g cm^{-3} at 60 metre depth to 2.5-2.55 g cm^{-3} at 10 metre depth. This decrease in rock density probably reflects the increasing depredations of weathering closer to the surface. The rocks of the Bitter Springs Formation generally have densities in the range 2.80 to 2.85 g cm^{-3} and there is no evidence of a systematic variation in rock density with depth. All of the density estimates for the Bitter Springs rocks which are lower than 2.80-2.85 g cm^{-3} are erroneous since each is correlated with a wash-out in the hole.

The presence of the steel drill pipe between 71.8 and 93.1 metre depth is well resolved and results in spuriously high estimates of average rock density.

iv) Natural gamma

The natural gamma log data also show excellent resolution of the lithological variations that occur in the wall-rocks of this hole. The Pertatataka Formation's mudstones are characterised by a natural gamma flux of ~60 counts per second (cps), the highest values observed in this borehole. The underlying sandstones and dolomitic limestones are marked by relatively low natural gamma signals of 15 and 10 cps respectively while the Red Beds lithology displays intermediate values of ~30-50 cps.

v) Electric logs (Single Point Resistance and Self Potential)

Both electric logs show good separation of the different lithologies around this borehole. The relatively higher resistance of the dolomitic limestone units again points to a smaller population of water-filled fractures and interconnected pores in this rock type than in the surrounding units. A similar conclusion can be drawn regarding the sandstones and conglomerates at 63 to 72 metre depth.

The depth to the water table at the time of logging as indicated by the electric logs was 40.2 metre.

vi) Sonic log

The sonic log results between 69.5 and ~62.5 metre depth are compromised by noise, perhaps due to banging of the tool in the hole. The data between ~62.5 metre depth and the water table at 40.2 metre suggest a sonic velocity in the Pertatataka Formation's mudstones of between 2,800 and 3,000 metre per second which are fairly low values.

vii) Deviation log

The results of the deviation log run in the borehole with the Owl drift tool are given in the following table. A local declination value of 4 degrees east was used to convert the deviation direction from degrees magnetic to degrees from true north.

Depth (metre)	Inclination from Vertical (degrees)	Direction of Deviation (degrees from true North)
5.0	14.8	229
10.0	15.1	301
15.0	15.4	298
20.0	15.7	292
25.0	15.5	279
30.0	15.6	274
35.0	16.7	296
40.0	16.9	297
45.0	16.7	286
50.0	17.4	279
55.0	17.4	277
60.0	18.8	126*
65.0	18.7	143*
70.0	18.7	157*
75.0	18.4	200*
80.0	18.3	214*
85.0	17.5	218*
90.0	18.5	251*
95.0	18.7	300*
100.0	18.9	297*
105.0	18.1	274
110.0	17.9	273
115.0	18.4	299
120.0	18.8	299
125.0	18.4	282

* these direction estimates are perturbed by the presence of the steel drill pipes between 71.8 and 93.1 metre depth.

Depth (metre)	Inclination from Vertical (degrees)	Direction of Deviation (degrees from true North)
130.0	18.2	286
135.0	18.5	300
140.0	18.4	303
145.0	18.0	292
150.0	17.5	264
155.0	18.3	296
160.0	18.5	301
165.0	18.5	295
170.0	18.4	288
175.0	17.3	244
180.0	18.9	293
185.0	18.4	306
190.0	18.5	302
195.0	18.4	295
200.0	18.0	285
207.0	18.2	297

BMR ROCK PROPERTIES RESEARCH

COMPUTERISED BOREHOLE LOGGING

CENTRAL AUSTRALIA
ALICE SPRINGS

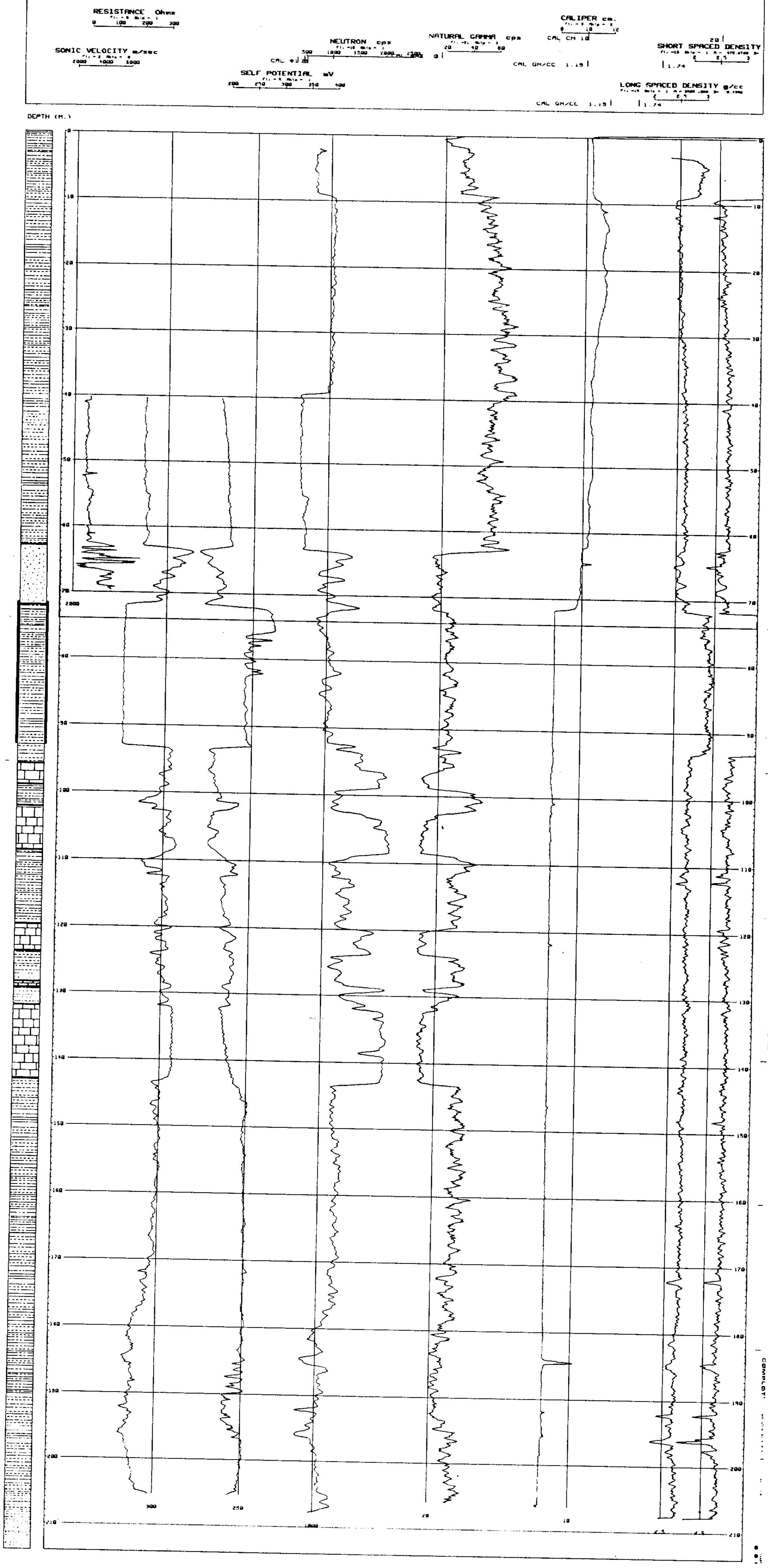
LOGGING SPEEDS
SONIC PROBE 3 M/MIN
DATUM ABOVE GROUND LEVEL .20 M.
OPERATOR : PAMAL, TREVOR & IAN
DATA LOG VER 78906 0.
DATA PLOT VER 76687.1.
WATER LEVEL 40.20 M.

PLOTTING SCALE 1:200

BOREHOLE NO. ALICE SPRINGS 27

DEPTH LOGGED 209.95 M.
DATE LOGGED 12 07 86
DATE PROCESSED 30 01 87

DEPTH (M.)



47

8. Borehole Alice Springs 28

a) Location and drilling history

This borehole is situated in the western portion of the area covered by the 1:250,000 scale Alice Springs, Northern Territory sheet at grid reference MP4692. The site is approximately 150 metres north of the Ross Highway and 3 kilometers west of Ross River Homestead and Tourist Chalet. The ground surface at the site is sandy and thinly vegetated. This borehole was drilled in May-June, 1986 to a total depth of 218 metre. The hole was cored from the surface, dipping at an initial angle of 25° from vertical in a north east direction. The hole was drilled with HQ sized equipment to a depth of 32.63 metre and then drilled with NQ equipment to the total depth. The HQ section of the hole was left lined with steel HQ drill rods.

b) Geology

This hole penetrates sediments of the Bitter Springs Formation. The core recovered is comprised predominantly of siltstones and dolomitic limestones.

c) Geophysical Well-logs

General Comments

The borehole was logged originally on 15 July with the full suite of tools, but a problem with the Digidata tape drive late in the operation corrupted the data. The hole was re-logged on 16 August. The dummy tool when run down the hole bottomed at a depth of 218.6 metre which was the bottom of the hole as-drilled. All logs were run to this depth.

Specific Comments on the logs

i) Caliper log

The caliper log data for this hole indicate that the bottom of the HQ drill pipes left in the hole occurs at a depth of 32.8 metre. Minor wash-outs occur at depths of 46.8, 76.5, 80.8, 81.7 metres and between 204 and 206 metres and 208 and 209 metres.

ii) Neutron log

The neutron log data show good resolution of the lithological variations recorded in the core taken from this hole. Depth intervals consisting of dolomitic limestone are characterised by a relatively high recorded neutron flux which points to these units being relatively low in hydrogen. This implies a general lack of water-filled pores and fractures and few hydrous constituent minerals in these units. The Red Bed units on the other hand are characterised by a much lower recorded neutron flux which points to the presence of much larger hydrogen concentrations. This hydrogen presumably occurs mainly as structurally bound hydroxyl in clay minerals.

iii) Short-spaced and Long-spaced density

The presence of the steel drill pipe between the surface and 32.8 metre depth is well resolved and results in spuriously high estimates of average rock density. Below the bottom of the casing, the rocks of the Bitter Springs Formation generally have densities in the range 2.75 to 2.80 g cm^{-3}. Within this range, there is some evidence of a systematic variation in rock density with depth presumably arising from increasing amounts of weathering closer to the surface. All of the density estimates for the Bitter Springs rocks which are systematically lower than 2.75-2.80 g cm^{-3} are erroneous since each is correlated with a wash-out in the hole.

iv) Natural gamma

The natural gamma log data are unfortunately only available for the bottom 108 metres of the hole due to a malfunction of the Digidata tape unit during data acquisition. The change in lithology at 193 metre depth is well resolved by the natural gamma data with the red siltstones above this level having a signal between 17 and 35 counts per second (cps) and the underlying dolomitic limestones a lower signal averaging ~5 cps.

v) Electric logs (Single Point Resistance and Self Potential)

Both electric logs show poor separation of the different lithologies around this borehole. The most prominent features on the resistance log are areas of decreased resistance associated with wash-outs in the borehole wall. This probably indicates that these wash-outs occur in parts of the hole where there are larger numbers of water-filled fractures and/or interconnected pores.

The depth to the water table at the time of logging, as indicated by the electric logs, was 8.3 metre.

vi) Sonic log

There are no sonic log results for this hole because the diameter of the hole was too small for the tool.

vii) Deviation log

The results of the deviation log run in the borehole with the Owl drift tool are given in the following table. A local declination value of 4 degrees east was used to convert the deviation direction from degrees magnetic to degrees from true north.

Depth (metre)	Inclination from Vertical (degrees)	Direction of Deviation (degrees from true North)
20.0	26.7	-*
30.0	26.1	-*
40.0	28.7	31
50.0	27.5	43
60.0	26.7	39
70.0	27.7	33
80.0	27.9	39
90.0	26.8	40
100.0	27.3	41
110.0	28.2	41
120.0	27.5	39

* no direction information is available because of the presence of the steel casing.

Depth (metre)	Inclination from Vertical (degrees)	Direction of Deviation (degrees from true North)
130.0	28.5	47
140.0	28.5	42
150.0	28.8	31
160.0	28.7	43
170.0	28.2	26
180.0	29.0	46
190.0	29.5	42
200.6	29.7	40
210.5	29.5	40

BMR ROCK PROPERTIES RESEARCH

COMPUTERISED BOREHOLE LOGGING

CENTRAL AUSTRALIA
ALICE SPRINGS

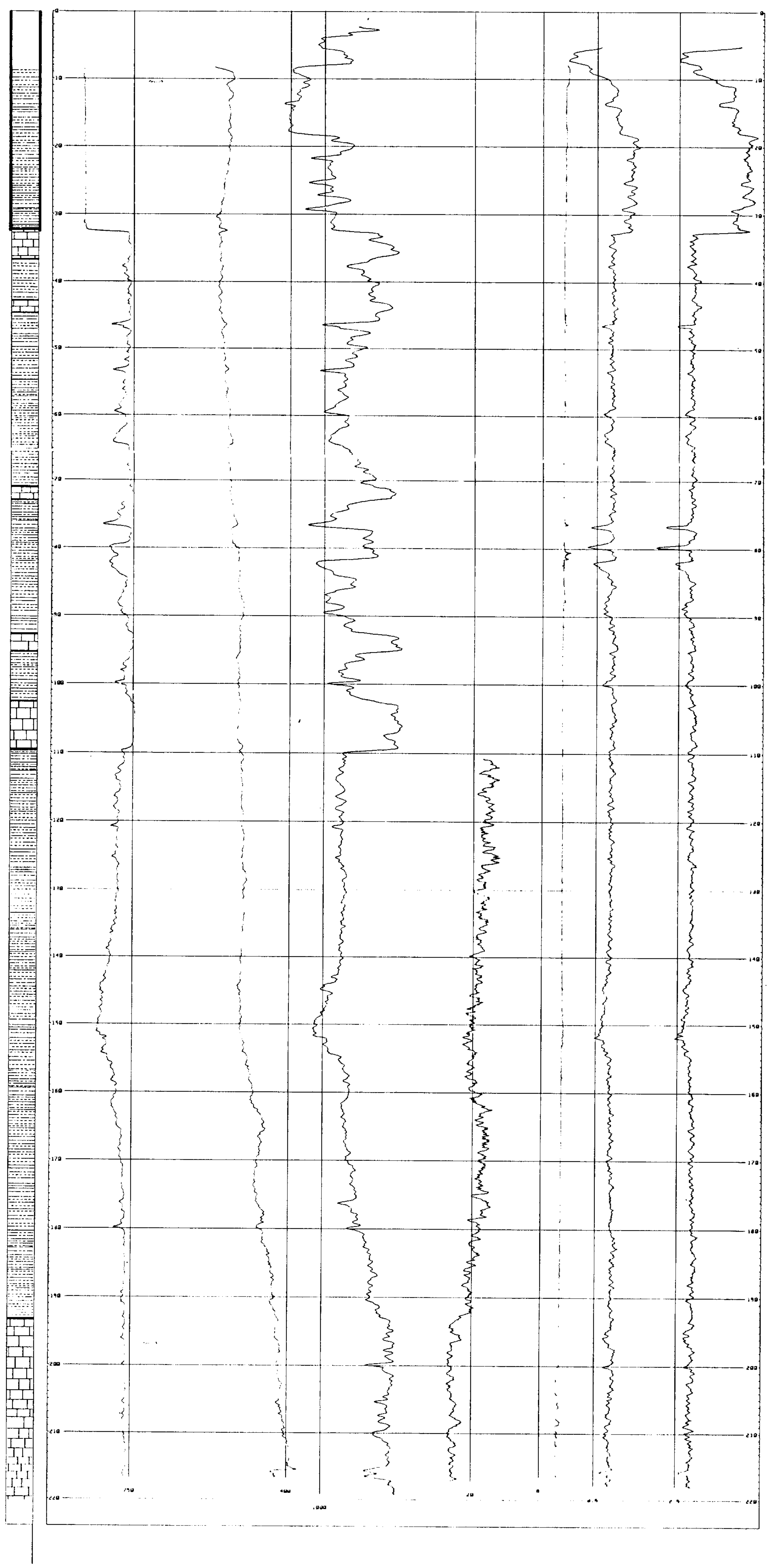
LOGGING SPEEDS
NEUTRON PROBE 3 M/MIN
DATUM ABOVE GROUND LEVEL .04 M.
OPERATOR FRANK TREVOR & IAN
DATA LOG VER 78506 01
DATA PLOT VER 78607 31
WATER LEVEL 4 30 M.

PLOTTING SCALE 1 200

BOREHOLE NO. #28
DEPTH LOGGED 217 18 M.
DATE LOGGED 16 08 86
DATE PROCESSED 04 02 87

RESISTANCE Ohms (300 – 450 – 600 – 750)
NEUTRON cps (500 – 1000 – 1500 – 2000 – 2500) CAL 41 28
SELF POTENTIAL mV (300 – 400 – 500 – 600 – 700)
CALIPER cm. (4 – 6 – 8) CAL CM 10 20
NATURAL GAMMA cps (20 – 40 – 60) CAL API 0 200 CAL GM/CC 1 1.5
SHORT SPACED DENSITY g/cc (2 – 2.5 – 3) 1.74
LONG SPACED DENSITY g/cc (2 – 2.5 – 3) CAL GM/CC 1 1.5 1.74

DEPTH (M.)



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52

9. Borehole: Power Street Test Hole

a) Location and drilling history

This borehole is situated near the south-west corner of the Northern Territory Geological Survey's core store building at the Power Street compound in north Alice Springs. The hole was drilled by the NTGS with HQ sized equipment to a depth of 18 metre and then drilled with NQ equipment to a total depth of ~31 metre. The upper ~12 metre of the hole was left lined with steel HQ drill rods.

b) Geology

This hole penetrates a white igneous rock of granodioritic composition. The core recovered is stored in the NTGS core store.

c) Geophysical Well-logs

General Comments

The borehole was logged on 10 July with the neutron, density, sonic and deviation tools. The dummy tool when run down the hole bottomed at a depth of 31.1 metre which was the bottom of the hole as-drilled. All logs were then run to this depth but due to the presence of the steel casing in the upper part of the hole, data are not reported for the top 10 metres.

Specific Comments on the logs

i) Caliper log

The caliper log data for this hole indicate that the change in hole diameter from HQ to NQ occurs at a depth of 18.0 metre. The bottom of the length of HQ drill pipes left in the hole is not resolved by the caliper tool. Minor wash-outs occur at depths of 12.9 and 17.95 metres.

ii) Neutron log

The two sharp peaks in the neutron log correspond to the wash-outs at 12.9 and 17.95 metre depth. The remaining neutron data suggest a near-uniform wall-rock mineralogy. The average neutron flux measured of ~1700 counts per second is comparable to the values obtained in the much deeper boreholes penetrating granites on the seismic reflection traverse (i.e. boreholes Hermannsburg 42, Napperby 8 and Napperby 9). This site could therefore be a good place to do hydrofracture stress measurements in future.

iii) Short-spaced and Long-spaced density

The presence of the steel drill pipe between the surface and 12.1 metre depth is well resolved and results in estimates of average rock density which are spuriously high. Below the bottom of the casing there is clear evidence of a systematic decrease in rock density with decreasing depth. For example, the average density at 30.5 metre depth is 2.60 g cm^{-3} while at 13.5 metre depth it is 2.55 g cm^{-3}. This variation in rock density is probably due to the increasing depredations of weathering closer to the surface.

iv) Electric logs (Single Point Resistance and Self Potential)

The most prominent features on the resistance log are areas of decreased resistance associated with wash-outs in the borehole wall. This probably indicates that these wash-outs occur in parts of the hole where there are larger numbers of water-filled fractures and/or interconnected pores. The depth to the water table at the time of logging, as indicated by the electric logs, was 8.8 metre.

v) Sonic log

There are no sonic log results for this hole because the diameter of the hole was too small to allow access.

vi) Deviation log

The results of the deviation log run in the borehole with the Owl drift tool are given in the following table. A local declination value of 4 degrees east was used to convert the deviation direction from degrees magnetic to degrees from true north.

Depth (metre)	Inclination from Vertical (degrees)	Direction of Deviation (degrees from true North)
1.0	0.2	-*
2.0	0.3	-*
3.0	0.3	-*
4.0	0.3	-*
5.0	0.3	-*
6.0	0.3	-*
7.0	0.3	-*
8.0	0.4	-*
9.0	0.5	-*
10.0	0.5	-*
11.0	0.4	-*
12.0	0.5	-*
13.0	0.5	39
14.0	0.6	50
15.0	0.6	48
16.0	0.7	52
17.0	0.7	57
18.0	0.7	58
19.0	0.8	58
20.0	0.8	60
21.0	0.8	61
22.0	0.8	61

* no direction information is available because of the presence of the steel casing.

Depth (metre)	Inclination from Vertical (degrees)	Direction of Deviation (degrees from true North)
23.0	0.8	67
24.0	0.9	73
25.0	0.8	71
26.0	0.8	73
27.0	0.9	72
28.0	0.9	71
29.0	0.9	80
30.8	0.9	80

BMR ROCK PROPERTIES RESEARCH

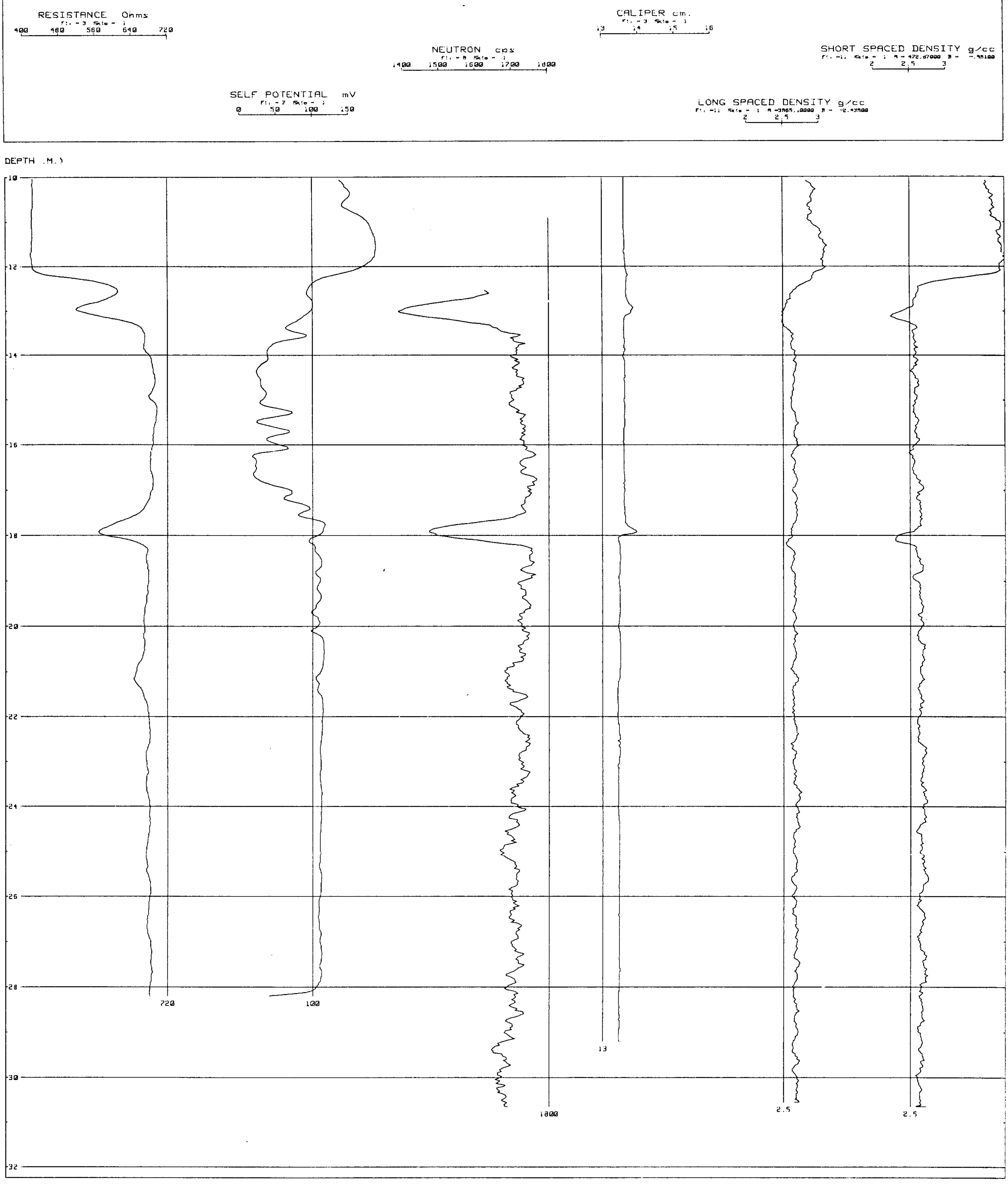
BOREHOLE NO. POWER ST TEST HOLE

CENTRAL AUST
ALICE SPRINGS

EXPANDED SECTIONS :
32 Metres to 10 Metres

DATE PROCESSED : 16 02 87
EXPANDED SCALE PLOT (1:40)

LINEAR DENSITY EQUATION IS Counts= A*Dens*EXP(B*Dens)



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57

CONCLUSIONS

Nine boreholes were geophysically logged in Central Australia in July and August 1986. Five of these boreholes penetrated sediments of the Amadeus Basin while the remaining four intersected granitoids of the Arunta Block.

Specific conclusions that can be drawn from the well-log results include:

1) Of the 6 boreholes drilled along the BMR's 1985 Seismic Reflection Traverse, the 3 southern holes (i.e. Angas Downs, Tempe Downs and Areyonga) are unsuitable for hydrofracture stress measurements. The 3 northern holes in the Arunta Block however do contain sections which could be used for hydrofracturing.

2) The NTGS Power Street Test Hole penetrates a granodiorite which appears to be a good candidate for hydrofracture stress measurements. A new larger diameter borehole (i.e. HQ throughout) would have to be drilled for such work however.

3) The sonic and density log results from the boreholes sited along the Seismic Reflection traverse suggest the following minimum values of *in-situ* V_p and density for rocks free of the effects of weathering.

Lithology	Stratigraphic Unit	Compressional Wave Velocity (m s^{-1})	Density (g cm^{-3})
Shale	Winnall Beds	≥3,500	≥2.7
Sandstone	Hermannsburg Sandstone	≥3,000	≥2.2
Sandstone	Mereenie Sandstone	≥4,000	≥2.5
Granites	Arunta Complex	≥5,400- 5,600	≥2.60- 2.75

4) The lithological variations present in the Bitter Springs Formation east of Alice Springs are well resolved by the well-log data. Of particular importance in this regard are the natural gamma and neutron logs, which allow a clear discrimination of the dolomitic limestones from the surrounding argillaceous sediments.

5) The depth to the water table, as determined from the electric logs, varied widely in the area surveyed. These results can be summarised as follows.

Borehole	**Depth to Water Table (metres below ground surface)**
Angas Downs	17.5
Tempe Downs	2.8
Areyonga	54.0
Hermannsburg 42	8.0
Napperby 8	13.3
Napperby 9	25.15
Alice Springs 27	40.2
Alice Springs 28	8.3
Power Street Test Hole	8.8

6) The depth to which weathering affects the rocks penetrated by the boreholes (as determined from systematic variations in the density &/or sonic &/or neutron log data) is, in all but the case of Alice Springs 27, at least as great as the depths of the holes logged.

7) The deviation log results obtained from the boreholes drilled in granite for this survey suggest that the air-hammering procedures used by the BMR drillers can result in appreciable deviations of the borehole from vertical. Coring operations on the otherhand do not appear to produce significant deflections of the borehole axis. Thus coring, rather than air-hammering, should be used for applications in which boreholes must remain at, or close to vertical in hard rocks.

ACKNOWLEDGEMENTS

I wish to thank Mr Doug Morris of the the NTGS for his assistance with the supervision of the drilling activities between April and July 1986. I also wish to thank Dr R.B. Thompson, Assistant Director of the NTGS, who kindly made the NTGS facilities at Power Street and Price Street, Alice Springs available during the Survey.

The technical assistance afforded by the Electronic Maintenance and Operations Section of the BMR's Engineering Services Unit, both prior to and during the Survey, was instrumental in the success of this project.

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