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Use of geothermal prospecting methods in Tasmania

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Geothermal prospecting techniques have usually been applied to volcanic regions or those places where hot water is circulating near the surface. In such situations there are marked local contrasts between temperatures in normal rocks and those passing hot water, either in pores or fractures. In addition, temperature measurements have usually been made at depths of several metres.

Recently a few workers have examined the possibility of using geothermal methods for prospecting in normal groundwater regions or for structural information by observing temperatures at very shallow depths. Examples of such work are given by Poley and van Steveninck (1970, 1971), Krcmár and Mašín (1970) and Cartwright (1971).

On the basis of such work it appeared that these techniques might be of use in Tasmania for the direct location of aquifers and the indirect location of ores, structures or veins in mineral prospecting. The discussion below is based on test programs in north-eastern Tasmania at Lefroy and Bridport–Waterhouse.

Equipment

Each thermometer probe consists of a thin plastic tube two metres long with a thermistor element at its tip. The thermistor used was type M53 which has a high resistance temperature coefficient and a very large range (<-10°C–100°C). A change in resistance of 100 is equivalent to about 0.4°C at normal temperatures. Each element has been calibrated to better than 0.1°C although much higher precision is possible. In view of the field measurement problems higher precision is not considered justified. The resistance of each element is determined using a simple Wheatstone Bridge circuit capable of measuring across the range 0–10 000 with an accuracy of about 5 . This large range is necessary due to the characteristics of the thermistor used, and the accuracy sufficient to permit improved calibrations of the probes should it be required.

Field technique

The temperature probe is set in the soil at the desired depth by preparing a hole with an auger and then pushing the probe into the soil at the base of the hole. Small diameter augers are preferred as these cause minimal disruption to the thermal environment. A series of readings are made using the following sequence.

A group of holes is drilled to the nominated depth and on completion a probe is placed in each. The time of placement is noted, and when all available probes have been placed the drilling crew either stands by until probes become available again or keep drilling until the placement reading cycle is overhauled. As only fifteen probes are currently available there is often a small break in drilling while temperature stabilisation and observation takes place and the probes are removed. In most circumstances it has been found with the Proline plant used that where holes are more than 1.5 m deep, a fifteen probe cycle can be continuously maintained. Where holes are shallower there will be a time lag. Each probe is left in the ground for at least one hour to enable the temperature of the thermistor element to stabilise at ground temperature. After one hour an observer measures the resistance of each probe and returns it to the planting crew. A crew of three is required for the operation, two on auger operation and one on probe planting and observation. It is possible to obtain 50 to 60 readings per day.

Parasnis (1971) has suggested an alternative field technique. Readings are made at intervals of 1 or 2 minutes for about 10 minutes after setting the probe. A graph of T/ t against t (where T is temperature, t is time) is plotted. From the straight line plot it is possible to deduce the temperature at infinite time and so relate all temperatures to a common point. Several problems have arisen with this method and it is not recommended.

(1) It works well if the probes are seated below the water table. In this situation there are no conductivity problems. In dry conditions there may be thermal shock effects either from the probe case, the heat sink or from the soil itself due to irregular conduction. The latter effect is noted especially in dry sand. The total effect is to disrupt the cooling curve in the first 10 minutes and at least 20 minutes may be needed before the slope of the line can be unambiguously determined.

(2) Plotting and reduction must take place in the field to ensure that sufficient readings are taken. This requires a very efficient and accurate approach to resistance measurement, temperature conversion, reduction and plotting. Although it is possible to complete the necessary conversions and arithmetic in the ten minute interval it is not a process that can be left to a technician or assistant.

(3) Only a maximum of five or six probes may be read per hour which compares unfavourably with fifteen every 1.5 to 2 hours using a continuous run which is back-read at a later time.

This technique may be adequate in bore holes for geothermal gradient measurements, but it is unsatisfactory for surface traversing measurements where time and distance are important economic factors.

Factors influencing temperature or temperature stabilisation

A number of factors may cause variation in the temperature recorded in any given location.

(a) *Diurnal or annual solar variations*. Daily variations are the most significant, producing up to 2.0–2.4°C difference at 1–1.5 m depth. Annual variations have also been found to be nearly 2.5–3°C at this depth, but as the daily rate of change is small it has little effect on a field program of a few days duration. For longer periods, and for short programs undertaken at shallow depth, it is essential to keep a record of all changes at a suitable base point so that survey readings can be suitably adjusted for time and season. Other authors have found depths of 1.5 m adequate to ignore diurnal effects but a review of Figure 1 shows that this may introduce errors in some circumstances, notably in sand.

(b) Soil variations may also produce substantial changes in observed temperature due to conductivity and diffusivity differences. It is possible to differentiate clay, sand and gravel as a result (see also Poley and van Steveninck, 1970). One group of probes sited in a granite area east of Bridport demonstrated how marked the effect of soil composition or nearness to rock may be. In all but two holes a dark clayey loam was found and in the exceptions the probe was set into weathered granite or a coarse sand and gravel. Subsequent deeper drilling showed granite to be present. The temperature differential was 1–1.5°C between these two probes and the others.

(c) The water content of a soil is critical to the observed temperature. It is necessary to either place probes in totally dry soil, or below the water table, or in other situations to be able to estimate the water content. As the latter estimate is difficult it is better to avoid such situations completely. In general dry conditions yield higher temperatures. In some situations it will be necessary to take most readings in either wet or dry conditions and adjust observations in any other state by noting the variation across the water table in one or two places and then allow a gradient factor for any change in depth.

(d) Changes in vegetation may cause temperature variations of up to 3°C in dry conditions (see also Poley and van Steveninck, 1970). In wet conditions tests have shown that there is no change.

(e) Roads, cuttings and hillsides may cause local differences in temperature. Such features are always mentioned in a cautionary fashion in literature pertaining to thermal measurements. However, no evidence is available to show that such caution is justified. One group of probes set at one metre depth on top of an old sand dune showed no trace of edge effects. It is advisable to ensure that all observation points are comparable with respect to points a, b, c and d.

(6) The temperature observed is directly related to the depth of the sensor. At depths, normally in excess of two metres, temperature increases with depth according to the geothermal gradient. Above this level results may be variable (fig. 1).

Temperature stabilisation has been found to require 20 to 45 minutes depending on soil conditions and water content. In water table conditions stabilisation may be very rapid.

Choice of probe placement depth

As shown by Poley and van Steveninck (1971) thermal anomalies persist to depths of as little as 50 mm. Experiments in north-eastern Tasmania have shown that this is so for depths in excess of 300 mm. No tests have been made at shallower depths due to shade effects and other spurious sources of error which very rapidly change the conduction balance near the surface. Low conductivities enhance thermal anomalies and thus dry materials produce sharper anomalies. Dry near-surface materials are also most affected by cloud changes and diurnal effects. Therefore a compromise must be attained between depth, size of temperature variation and anomaly. In most clay soils or loams a depth of one metre is adequate. Figure 1 shows that variations below this depth are generally small. Depths of 1.5 m or greater are to be preferred unless detailed records are made of the temperature changes with time. In sand or other coarse-grained materials greater depths may be advisable.

In general one metre is a suitable compromise between drilling effort, temperature variations and scale of anomaly provided that a base record is made for corrective purposes. Depths less than 500–700 mm cannot be recommended in any circumstances in the Tasmanian summer and may be of little use in winter. This is due to the major near-surface gradient which shows rapid change with time and is hypersensitive to soil composition.

Accuracy of results

Two tests of reproducibility have been undertaken. The first and most obvious was to re-read a traverse a short time after initial observation (same morning or afternoon). This can be done by preparing new holes or by re-reading the probes at one-hour and two-hour intervals. In the former case a variation of up to 0.2°C was noted whilst in the latter the variation was usually less than 0.1°C. The latter variation may have resulted from stabilisation problems or maladjustments of the diurnal correction.

In the second test, probes were placed at the same depth at several locations and the variation in temperature compared. The range of variation was never more than 0.3°C and was normally 0.1–0.2°C.

It appears that a 'noise' level of 0.2°C can be expected in all results and definite anomalies will not be firmly identified unless they exceed 0.4–0.5°C. These results compare very favourably with those of Poley and van Steveninck (1970).

Summary

Trials with the method have shown that the field technique is simple and no major reduction work is required in the office. The equipment is simple and cheap to produce. As sensitive resistance measuring elements are required, great care must be taken with the bridge circuit to ensure that the null point held prior to the reading is matched afterward. Adjustment of the galvanometer may be required from time to time to make this simpler. In all cases the current in the circuit must be reduced as rapidly as possible in order to avoid any heating effects. Such factors probably introduce an error of about 0.05°C.

The method has been tested at Bridport and Lefroy. From the results obtained it has been found possible to locate quartz veins, clay areas and recognise nearness to rock. At the present time no information is available on conductivity values for the materials tested. Its use for structural purposes is not established.

Before undertaking any survey in an area it is necessary to establish what effect vegetation differences will have and the nature of the gradient across the water table for conversion of wet or dry readings. Information on the temperature profile to 2.5 m will also prove invaluable and should be obtained at several places in the area. At least one base station should be established so that the diurnal effect can be assessed and this should be read at intervals of less than two hours.

The method has application with regard to hot water regimes or flowing water systems (Cartwright, 1971). It may also be used to locate limestone cavities or faults passing water (Krcmár and Mašín , 1970). Where water systems are sought, the results obtained will vary according to the season. For example, in summer when the soils are very warm, colder water circulation will be very apparent, whereas in winter when the soils are up to 12°C cooler the water may be slightly warmer. As a result the anomaly pattern will be reversed and in addition, for much of the year there may be no anomaly. Such results will of course depend on the nature, continuity and scale of the feature carrying the water. For the purposes of this discussion only sub-vertical features should be considered. It is therefore necessary to consider all information known about groundwater temperatures and soil temperatures. It may be necessary to repeat some traverses at different times to be sure a null result is not seasonal. Re-reading of a traverse at Lefroy five months later revealed two zones which were previously low to be now high. In this case it is considered that the weathered Mathinna beds, mainly clay, have been affected seasonally whilst the quartz zones, being of lower conductivity when dry, produce higher near-surface anomalies in summer and lower anomalies in winter. When wet the opposite situation may be true.

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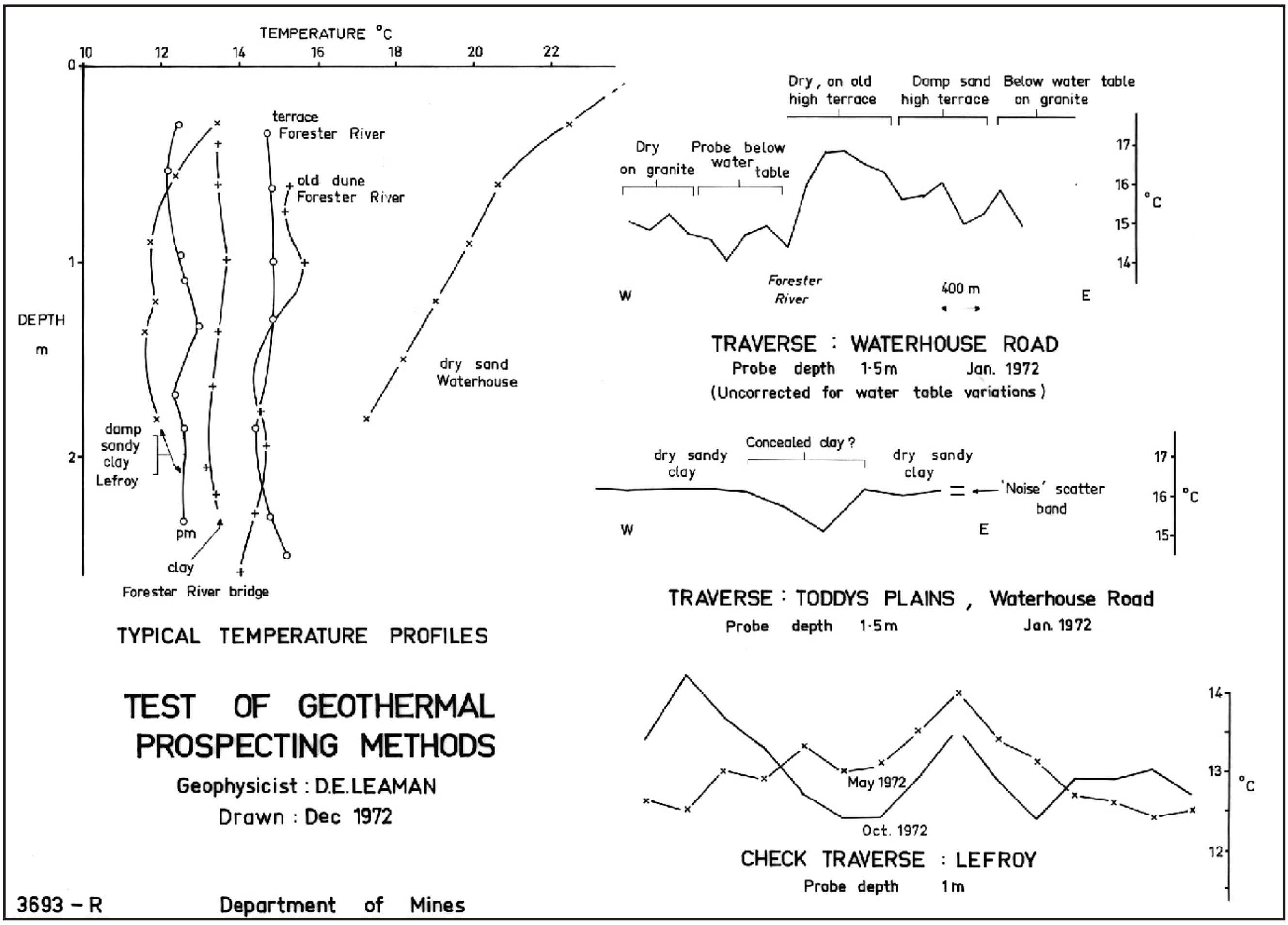
TEMPERATURE °C
10
12
14
16
18
20
22
0
1
2
DEPTH
m
terrace
Forester River
old dune
Forester River
dry sand
Waterhouse
damp
sandy
clay
Lefroy
pm
clay
Forester River bridge
TYPICAL TEMPERATURE PROFILES
TEST OF GEOTHERMAL
PROSPECTING METHODS
Geophysicist : D.E.LEAMAN
Drawn : Dec 1972
3693 – R
Department of Mines
Dry, on old
high terrace
Damp sand
high terrace
Below water table
on granite
Dry
on granite
Probe below
water table
17
16
15
14
°C
W
Forester
River
400 m
E
TRAVERSE : WATERHOUSE ROAD
Probe depth 1·5m Jan. 1972
(Uncorrected for water table variations)
Concealed clay ?
dry sandy
clay
dry sandy
clay
'Noise' scatter
band
W
E
TRAVERSE : TODDYS PLAINS , Waterhouse Road
Probe depth 1·5m Jan. 1972
May 1972
Oct. 1972
CHECK TRAVERSE : LEFROY
Probe depth 1m
14
13
12

Figure 1