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Temperature Measurements in the Pinawa Holes, 1978-1979

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Introduction

Temperature logs of WN-1 and WN-2 were made on 1 December, 1978 and again on 20-21 January, 1979. Our standard borehole logging equipment was used to measure temperature at discrete depths. The accuracy of the system is:

	Absolute	Between two measurements at successive depths
Temperature	$\pm .010^{\circ}C$	.002 K
Depth	± 1.5 m	.3 m

The system is described, including cable stretch and corrections, in Lewis (1975). All depths here will refer to lengths down the hole measured from the top of the casing, and are not corrected for the dip of the hole. Since measurements were made at intervals of 3 or 8 m, the depth at which changes occur within an interval is not known.

The temperature logs are plotted in figures 1 and 2. Generally the temperature decreases from values near the surface down to a temperature reversal near a depth of 65 m. Such temperature reversals are observed everywhere in Eastern Canada and are the results of the climatic change near the turn of the century (Lewis, 1975).

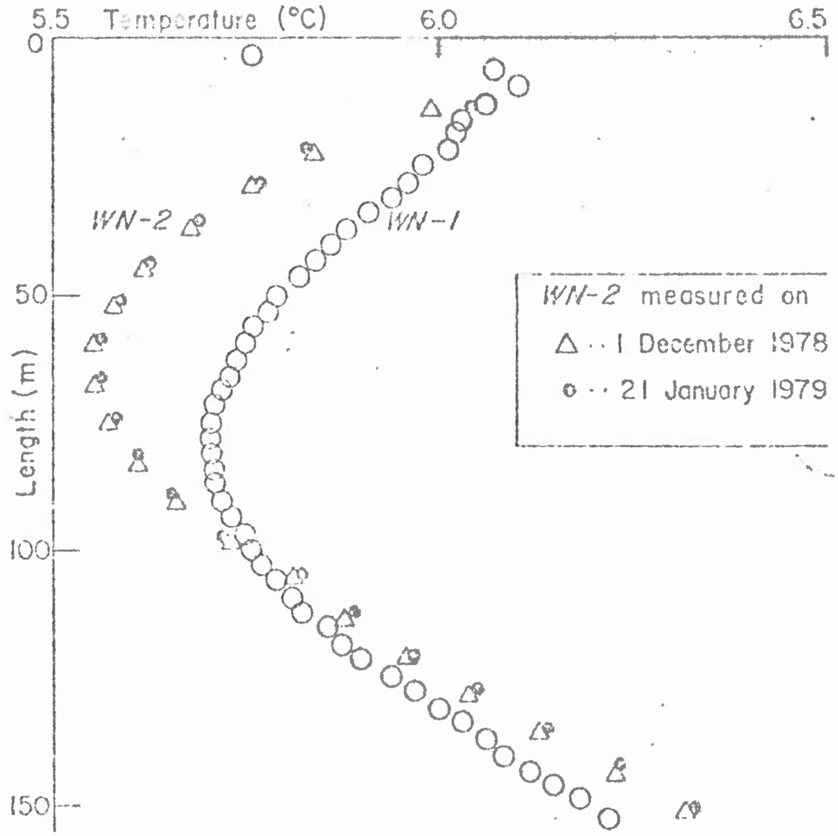

Figure 1: Two complete temperature logs of WN-2 measured at different times, and for comparison the upper part of a temperature log of WN-1.

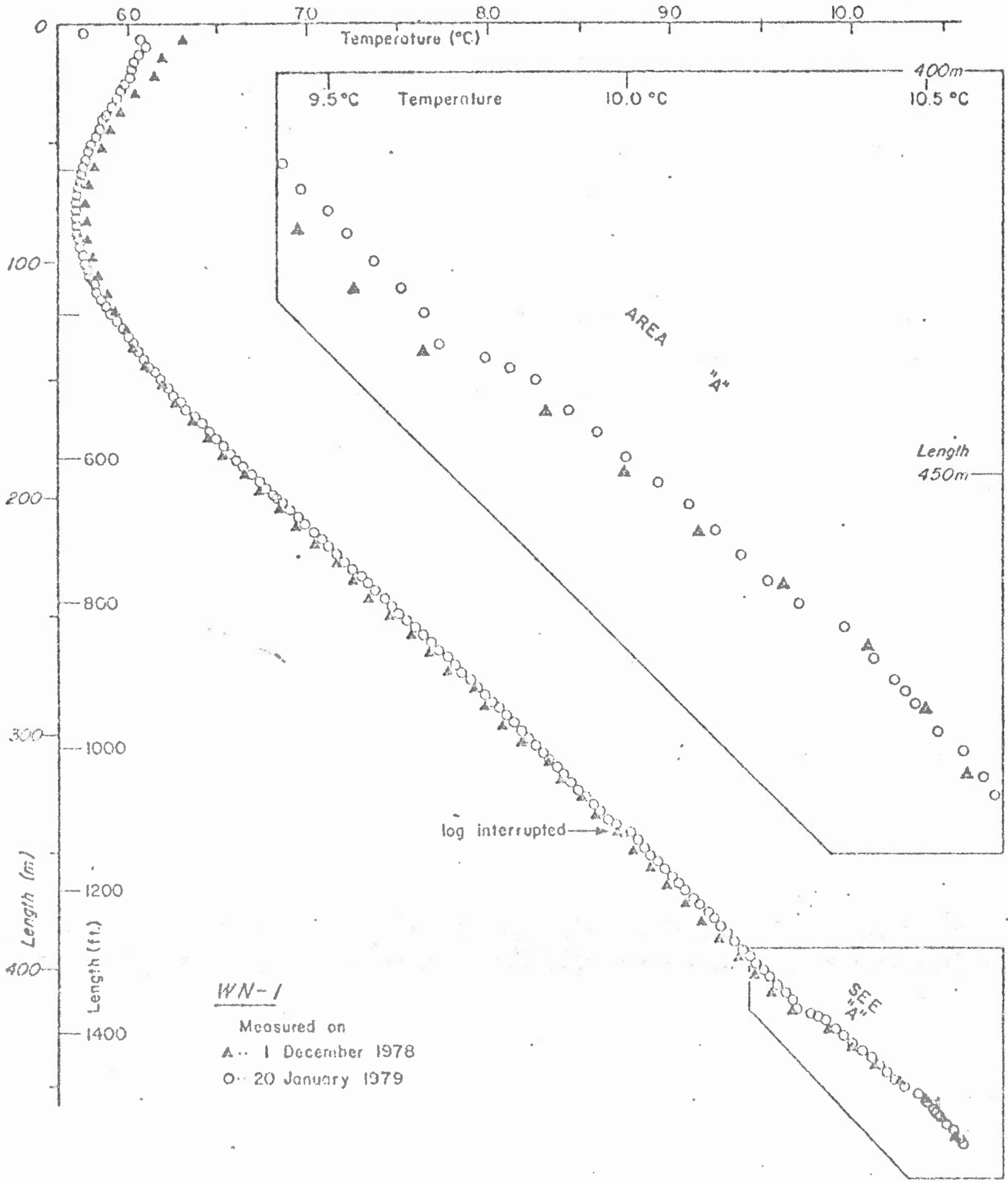

Figure 2: Two temperature logs of WN-1 run 50 days apart.

Figure 1 illustrates that the temperatures measured at the two different times in WN-2 are in good agreement at any particular depth. The upper part of one of the logs of WN-1 is plotted also on this figure for comparison. In WN-1 the temperature at any particular depth above approximately 454 m has significantly changed between the two different times of measurement (see figure 2).

Interpretation

In WN-1 water is flowing from near the surface (approximately 15 m) down to a depth of between 418 m and 454 m. This water flow accounts for:

a. the deeper depth of the temperature reversal in this hole compared to WN-2, and the broader shape,
b. the higher value of the temperature minimum in this hole compared to WN-2,
c. the cooler temperatures above 418 m compared to the extrapolated temperatures from a straight line fitted to temperatures below 454 m and
d. the difference in temperatures between the two logs made 50 days apart: the second log of 20 January has a smaller flow of water starting at a cooler temperature at the top compared to the first log of 1 December, 1978.

We measured quite different temperatures and did not observe the minor change in gradient at 196 m which Scott Keys reports. Since our measurements were made much longer after the hole was completed and after intense logging occurred, the temperature disturbances had had a much longer time to decay.

From 418 to 454 m there appears to be a smaller downward water flow. This observation and interpretation is in agreement with the more saline waters being located below 450 m as shown by the resistivity log, and disagree with Scott Keys' (Tech. Memo No. 53, p. 3) initial interpretation of his temperature log. A slight change, or offset in temperature gradient occurred at approximately 110 m where water was probably entering the hole and joining the downward flow. Between 122 m and 143 m there may be an additional temperature disturbance. A more detailed temperature log and measurement of the conductivity of several borehole cores from these intervals would help an analysis. Grouting off the water inflow near the surface would be most helpful.

Discussion

It is worth noting that water flow into or out of the hole is not associated with any of the larger concentrations of fractures which have been mapped. A single fracture which "may be open to water flow" is mapped between 416 and 417 m by J. Dugal. At 451 m a single fracture is mapped as not open to water flow. Fractures mapped as open to water flow at 110 m and a series from 127 to 134 m may be indirect causes of small temperature gradient anomalies.

Since surface water is flowing down the hole in this instance, resistivity is a good indicator of where the water leaves the holes. If the flow were reversed, there might not be a resistivity change. Accurate temperature measurements are the best way to detect small water flows and an accurate continuous logger is still needed to determine accurately the depths. A series of temperature logs made in the weeks immediately following drilling could be used to locate differences in the decay of the drilling disturbance associated with fault zones.

Using some simplifying assumptions (Birch, 1947), it is possible to calculate the rate of water flow in the hole. For a temperature difference of 0.25 k caused by a constant water flow, the flow is approximately 0.02 l/s, or water moves at a velocity of 0.4 cm/s. Water movements over an order of magnitude smaller can be detected by our equipment. More detailed analysis can be used (eg. Jaeger, 1955).

Finally, it is possible in areas of crystalline rock for water to flow along fractures in quite complicated routes such that one borehole will intercept a flow and a neighbouring one will not intercept a flow (e.g. Lewis and Beck, 1977).

Recommendations

High resolution temperature logs should be made within a day, and again 1 week after the completion of the drilling of holes in the future. No pumping tests should take place until after these initial logs are run. Additional temperature logs should be run a month or more after any circulation has stopped.

Measurements of thermal conductivity should be made on core samples at 30 m intervals down the holes, and at closer spacings where the temperature gradient is not constant.

A high quality continuous temperature logger should be acquired, with a temperature resolution of 1 mK and an accuracy of 0.01 C, and with a depth resolution of 0.5 m.

References

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