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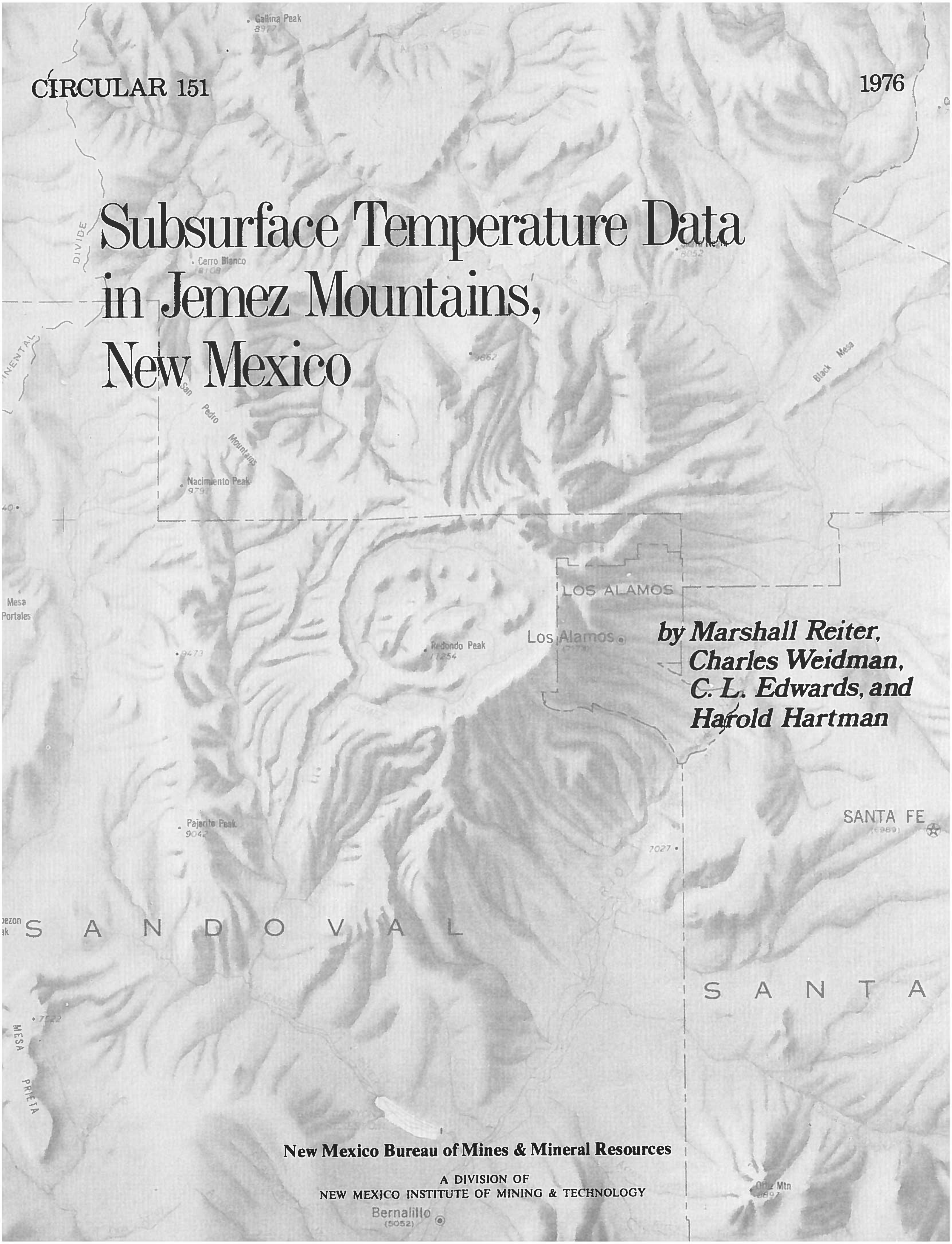

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ABSTRACT

Temperature data taken in 13 drill tests around the Valles Caldera are presented. Seven of these tests were shallow auger holes 30 m), 4 were rotary holes of intermediate depth (140 m to 170 m), and 2 were relatively deep tests (350 m and 730 m). Heat-flow measurements were obtained in the 4 intermediate drill tests whereas only geothermal gradients were measured in the remaining tests. Potential ground-water movement, lack of good thermal conductivity control, and the shallow depth of many of the drill tests makes the heat-flow pattern in the area uncertain. Two trends appear likely: higher heat flows are to the western side of the Valles Caldera (as opposed to the eastern side) and heat flows increase rapidly in approaching the margin of the Valles Caldera from the west. Both observations suggest a relatively shallow heat source located beneath the western part of the Valles Caldera.

INTRODUCTION

Subsurface temperature data are presented for 13 drill tests in the Jemez Mountains, a Tertiary and Quaternary volcanic field in north-central New Mexico associated with Valles Caldera (fig. 1). A geologic map of the Jemez Mountains has been prepared by Smith and others (1970). Bailey and others (1969) and Doell and others (1968) presented data indicating volcanic activity may have begun in the Valles Caldera about 9 m.y.B.P. (Purtyman, 1973). Following a period of quiesence, catastrophic eruptions of ash flows resulted in the formation of the Valles Caldera. The intracaldera domes are dated from 0.4 m.y.B.P. to 1.0 m.y.B.P. (summarized by Purtyman, 1973).

Summers (1965) described hot spring activity in the Jemez Mountains and related the thermal waters to the volcanism of the area. Jiracek (1974) summarized geophysical studies in the Jemez Mountains area. The immensity of the Valles Caldera and its geologic history suggest the probable geothermal potential of the area. Consequently, a series of tests were drilled around the Valles Caldera by the Los Alamos Scientific Laboratory; subsurface temperature measurements were made in these holes by the New Mexico Institute of Mining and Technology in a cooperative effort to study the heat-flow pattern in the Jemez Mountains.

Subsurface temperature gradients were calculated from in situ, equilibrium temperature measurements taken at progressively deeper depths in the drill tests. In situ temperature data were taken by using resistance thermometry; that is, platinum or thermistor sondes in conjunction with Mueller Bridge electronics for surface recording. At 4 locations estimates of the thermal conductivity of the rocks from the holes were obtained by measurements on core and fragment specimens. These conductivity measurements multiplied by the appropriate temperature gradients yield estimates of the heat-flow values at the appropriate drill sites.

The 13 tests measured were drilled around the Valles Caldera near the boundary of the Baca Location No. 1 (fig. 1). Seven of these tests were shallow auger holes 30 m) and were near the eastern, southern and western boundaries of the Valles Caldera. Of the 13 drill tests 4 were rotary holes of intermediate depth (140 m to 170 m) along the western boundary of the Valles Caldera. One hole on the eastern flank of the Jemez Mountains was probed to 350 m. The deepest test (GT-1) in this study penetrated basement rock to the west of the Valles Caldera and was probed to 730 m. Geologic logs are presented for the 4 intermediate depth rotary tests and GT-1 by Purtyman (1973).

Acknowledgments

The drill tests and rock specimens used in the present study were drilled under the sponsorship of the Los Alamos Scientific Laboratory. We gratefully acknowledge the cooperation of Robert Potter, Donald Brown, Morton Smith and William Purtyman of the Los Alamos Scientific Laboratory. Equipment and personnel employed for the thermal measurements were sponsored by the U. S. Bureau of Reclamation Contract 14-06-500-1875, the National Science Foundation Grant GI-32482, and the New Mexico Institute of Mining and Technology. Field and laboratory expenses were sponsored by the Los Alamos Scientific Laboratory. F. W. Trainer (U. S. Geological Survey) and C. A. Swanberg (New Mexico State University) read the manuscript and made many helpful suggestions.

This work was done while the authors were at New Mexico Institute of Mining and Technology. Reiter is presently a geophysicist with New Mexico Bureau of Mines and Mineral Resources and adjunct associate professor of geophysics with New Mexico Institute of Mining and Technology. Weidman is presently a graduate student in physics at University of Arizona, Edwards is employed by the Los Alamos Scientific Laboratories, and Hartman is with Texaco, Inc., Houston.

PRESENTATION OF DATA

Subsurface temperature data for the drill tests are presented in fig. 2. Generally the temperature data taken from deeper holes are considered more reliable than the data taken from shallower holes. Data from deeper holes are more removed from near surface disturbances such as climatic and vegetation changes, topographic relief and water-table fluctuations, while shallower holes are more likely to yield unreliable estimates of undisturbed heat flow as a result of abstraction of heat by ground-water movement.

The intermediate and deeper holes (A, B, C, D, GT-1, and DT5 A) demonstrate interesting temperature profiles. Hole A has 2 similar, linear temperature gradients, from 70 m to 120 m and from 120 m to 170 m. Holes B and C illustrate very high geothermal gradients at intermediate depths, with somewhat lower gradients at shallower and deeper depths. Temperature gradients in hole D are lower than in holes A, B, and C. Holes GT-1 and DT5 A both have thermal gradients that decrease with increasing depth (although GT-1 does show higher temperature gradients than does DT5 A). The decrease in the geothermal gradient at the bottom of hole GT-1 suggests potential ground-water movement near the bottom of the hole. This decrease is probably not compensated by a thermal conductivity increase which would yield an equivalent heat flow as estimated for the top of the hole. The erratic nature of the data between 450 m and 650 m is also suggestive of channeled ground-water movement.

Thermal conductivity measurements were performed on rock samples from holes A, B, C and D. Mean thermal conductivity values multiplied by linear geothermal gradients of corresponding depth intervals yielded estimates of the heat flow, or geothermal flux, in that depth interval (see fig. 1 for sites A, B, C and D). Thermal conductivity measurements were difficult to perform on many of the core samples from holes A, B, C and D because of the friability of the tuff, shale, and clay cores. The large range in porosity of the tuff and the sandstones (4 percent to 42 percent), the probable anisotropy of the shales and clays, and the uphole sloughing of cuttings in the drill tests will cause substantial errors in estimating the thermal conductivity of the fragment samples. In holes A and B the thermal conductivity estimates were made from measurements performed on cuttings samples corrected for porosity. This technique is described by Sass and others (1971a). Porosity estimates are made by comparison with measurements done on similar rock core involving differential weight before and after vacuum flooding. In holes C and D several core-sample conductivity values were averaged with the porosity-corrected fragment values to obtain mean thermal conductivity estimates for certain depth intervals. Core samples were vacuum flooded with distilled water before measurement in an attempt to duplicate an in situ saturated condition for the rock.

In holes A, B, C and D, the heat-flow values calculated for different depth intervals in the same drill hole are generally not in good agreement. In hole A the heat-flow value is 6.7 HFU (1 HFU = 1 heat flow-unit = 1×10^{-6} cal/cm^2 - sec; the world average heat flow is approximately 1.5 HFU, Von Herzen, 1967) in the upper zone and 6.0 HFU in the lower zone. In hole B, the heat-flow values for 3 depth intervals going down the hole are 5.1 HFU, 10.1 HFU and 7.0 HFU. In hole C heat-flow values of 4.7 HFU, 9.9 HFU and 7.8 HFU are estimated; in hole D, the heat-flow values are 4.8 HFU and 3.8 HFU.

The difference between heat-flow values in different depth intervals in these drill holes may imply disturbance of the natural geothermal diffusion gradients in the region, for example, ground-water transport of heat. Alternatively, the difficulty in obtaining accurate thermal conductivity measurements coupled with the probability that the specimens measured are not representative of entire linear gradient sections, leaves open the possibility that the discrepancies in the heat flow are the result of inadequate estimates of thermal conductivity values. Consequently, it is difficult to estimate the heat flow at sites A, B, C and D. If one were to consider heat-flow values for the bottom of holes A, B, C and D they would be 6.0, 7.0, 7.8 and 3.8 HFU respectively. The heat-flow average on each test is 6.4, 7.4, 7.5 and 4.3 HFU respectively. These two approaches give similar qualitative patterns. Values of 5.0 to 5.5 HFU for holes A, B, and C and ~ 3 HFU for hole D were presented by Potter (1973).

The depth of the shallow drill tests and the wide range in character of the near surface material make a comparison of the temperature gradients difficult between the shallow holes. Holes 1 and 3 demonstrate very high geothermal gradients from about 10 m to 20 m and hole 8 from about 10 m to 16 m. In the bottom of holes 3 and 8 a substantial reduction in the geothermal gradients is observed. Drill tests 2 and 9 demonstrate thermal gradients intermediate between the 2 gradients in holes 3 and 8. Hole 5 has a gradient somewhat less in magnitude than the other shallow tests. Hole 4 has an inversed geothermal gradient.

DISCUSSION

With the available data we suggest that geothermal gradients and heat flows are higher west of the Baca Location No. 1 than east. However, this conclusion is based on biased data coverage, the data to the east being less numerous, shallower, and not as widely spaced as the data to the west. Data to the west of the Baca Location No. 1 imply that as one goes westward, away from the location boundary, the geothermal gradients and the heat flows decrease. The data also suggest that as one goes northeastward from hole A to holes B and C the geothermal gradients and the heat flows increase slightly.

The difficulty in obtaining accurate and representative thermal conductivity measurements makes an explanation of the heat-flow variations within a well ambiguous and complicates potential explanations for the heat flow pattern. Apparently as the sites move from the west closer to Valles Caldera the heat flow increases rapidly, implying a relatively shallow heat source in the caldera. In approaching San Antonio Mountain (sites B and C) somewhat higher heat flows are also observed; consequently the resurgent domes within the Valles Caldera may be associated with magmatic heat sources. Higher temperature gradients to the west may suggest that the main magmatic heat source is beneath the western part of the Valles Caldera perhaps associated with Redondo Peak. Alternatively, the heat-flow pattern and the heat-flow variations within the holes may be influenced by the disturbing effects of groundwater movement (Sass, and others 1971b; Reiter and others, 1975). Data from GT-1 may suggest that ground water is abstracting heat.

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Figures follow

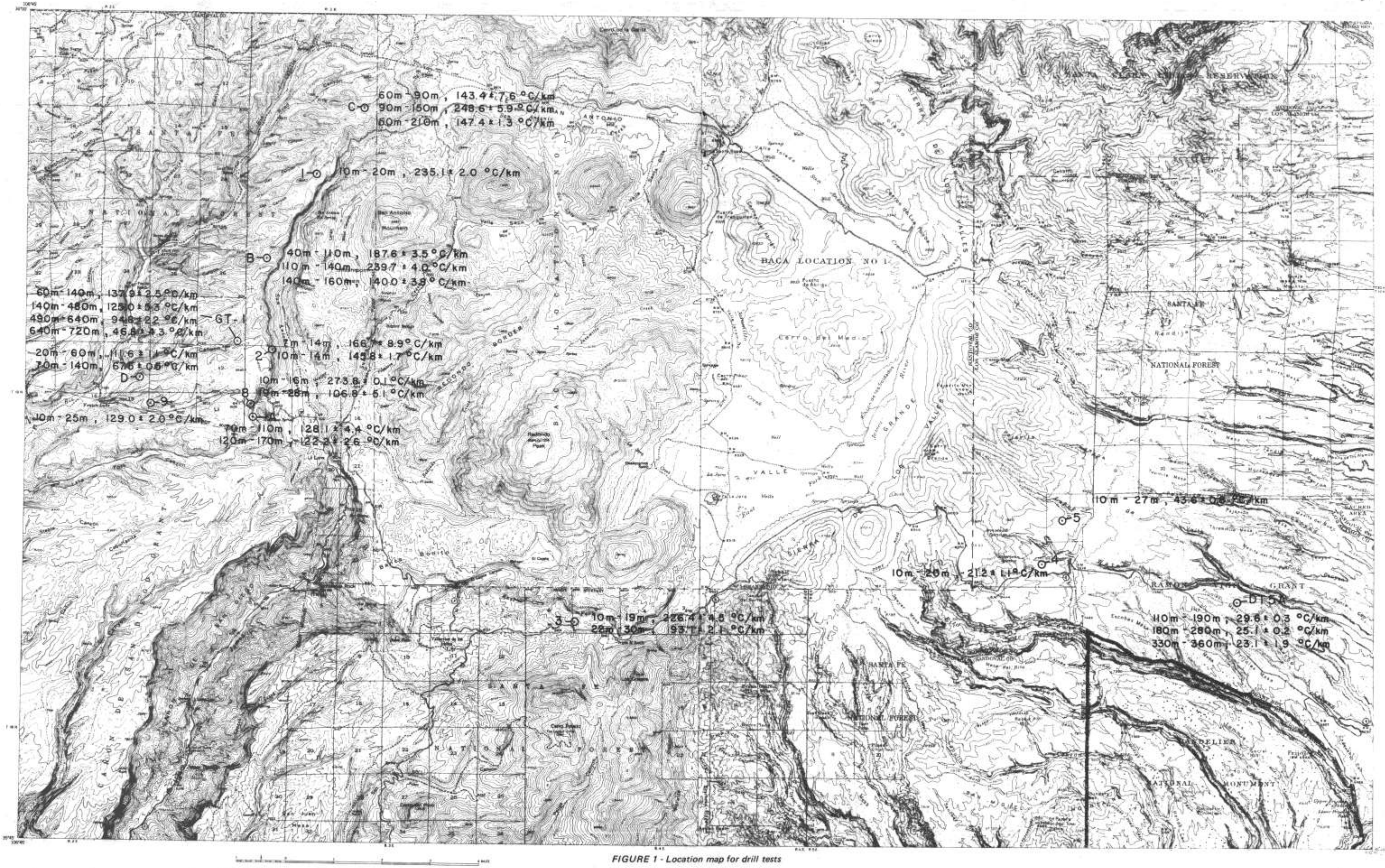

FIGURE 1 - Location map for drill tests

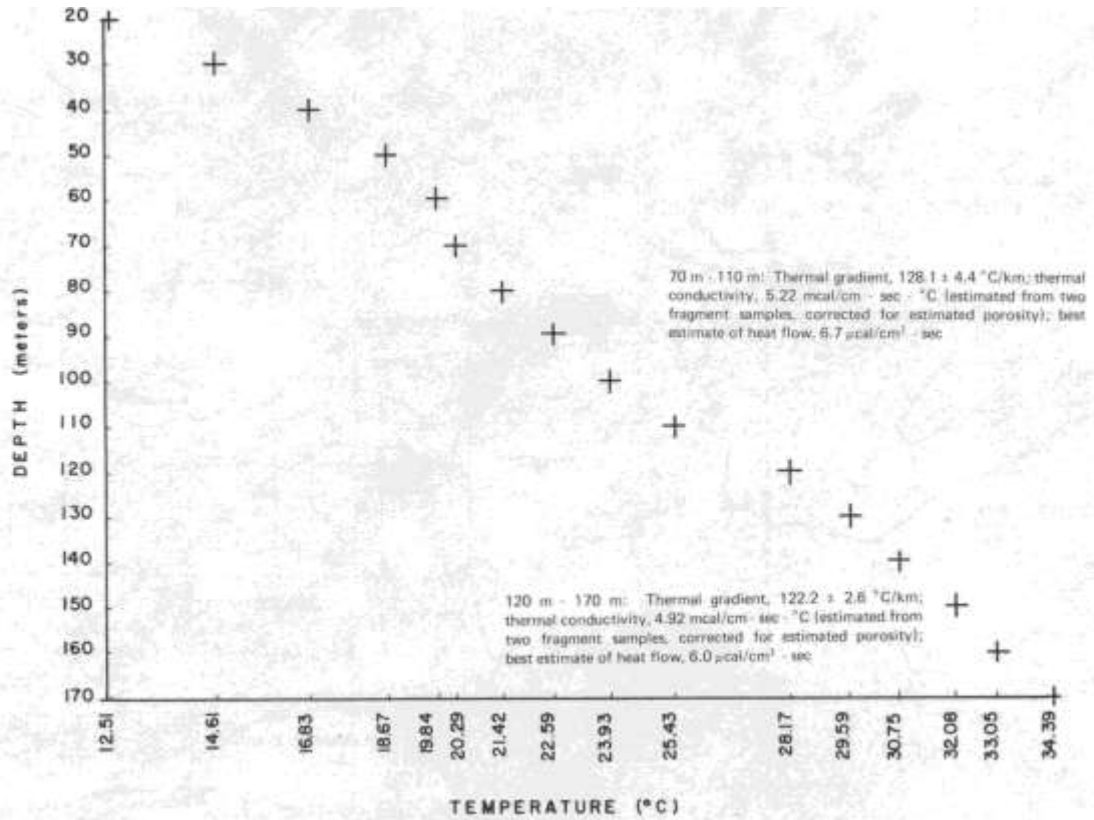

FIGURE 2A — Hole A, temperature vs depth.

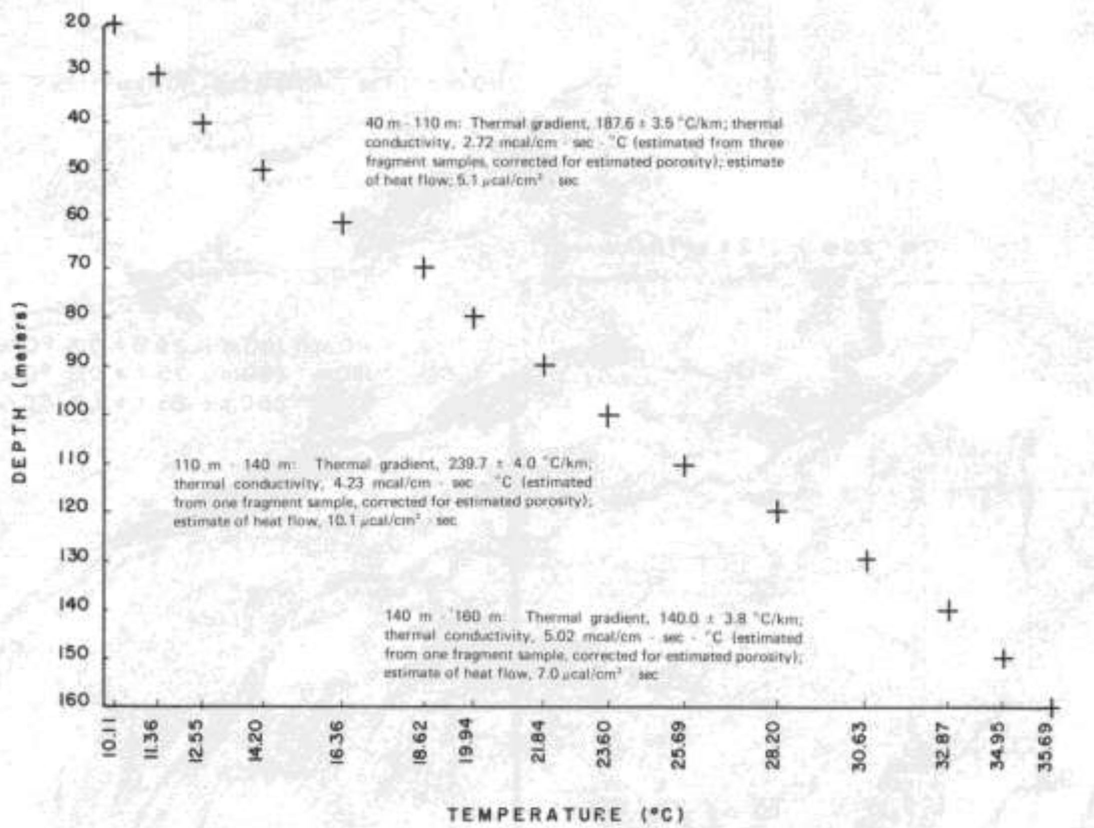

FIGURE 2B — Hole B, temperature vs depth.

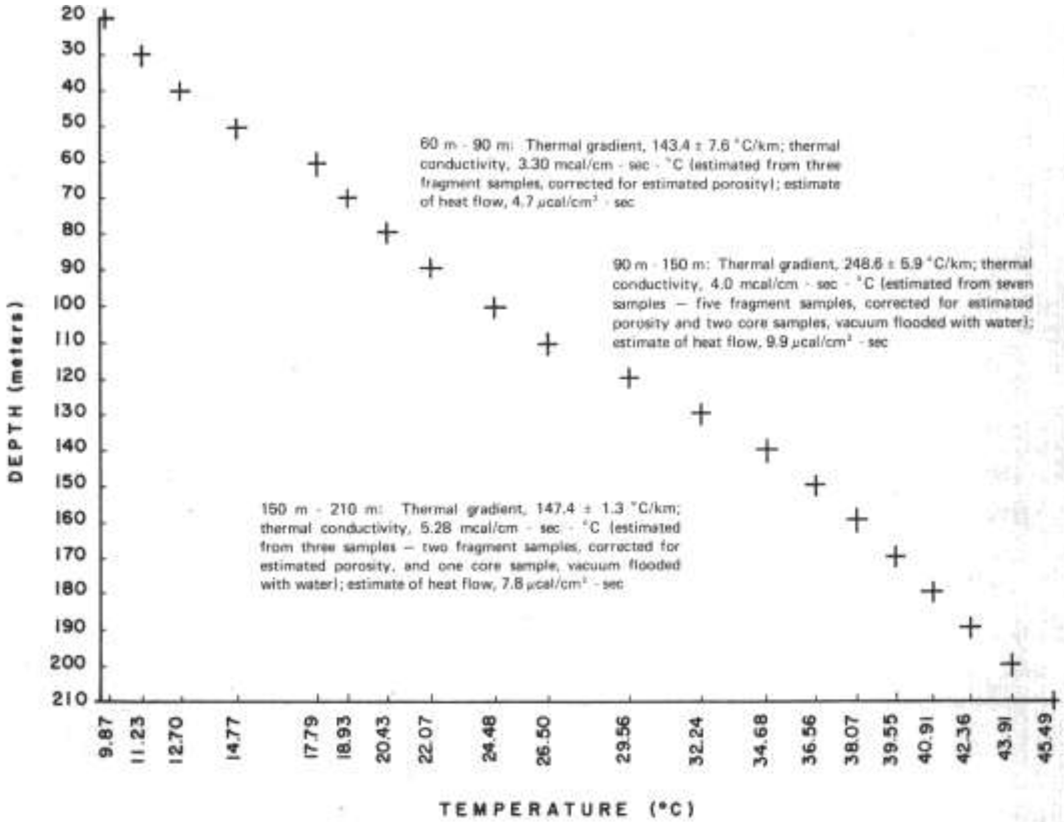

FIGURE 2C — Hole C, temperature vs depth.

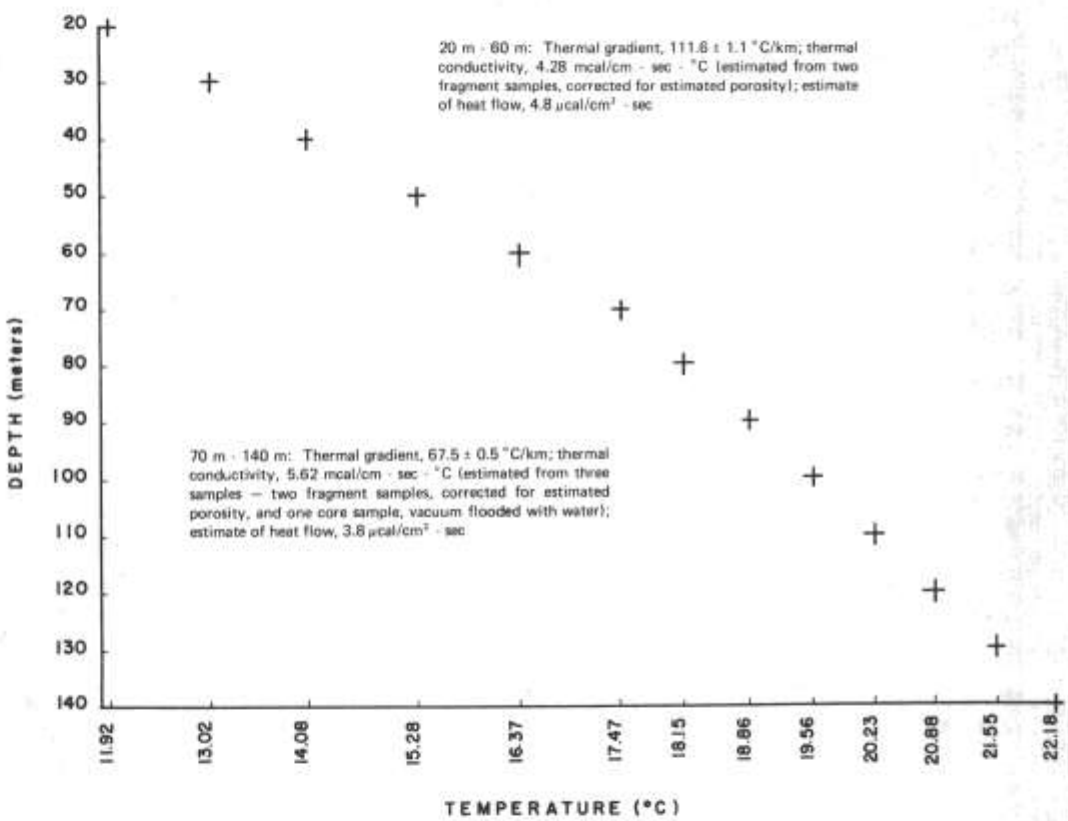

FIGURE 2D — Hole D, temperature vs depth.

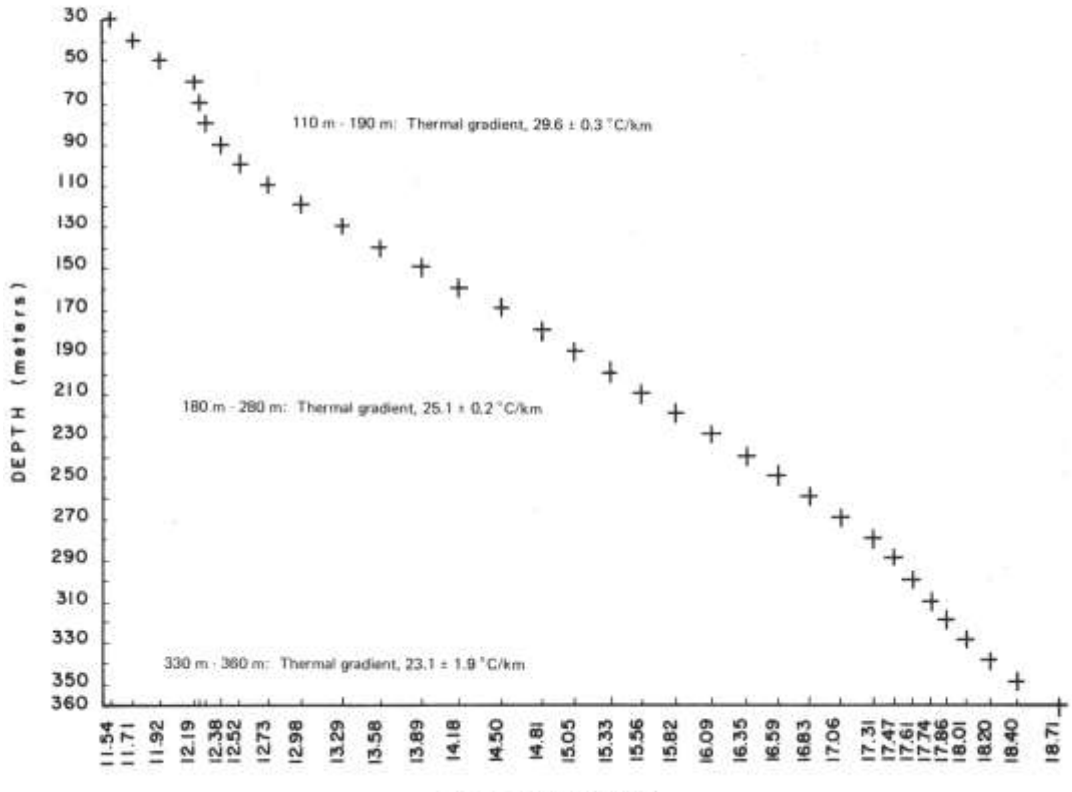

FIGURE 2E — Hole DT5A, temperature vs depth.

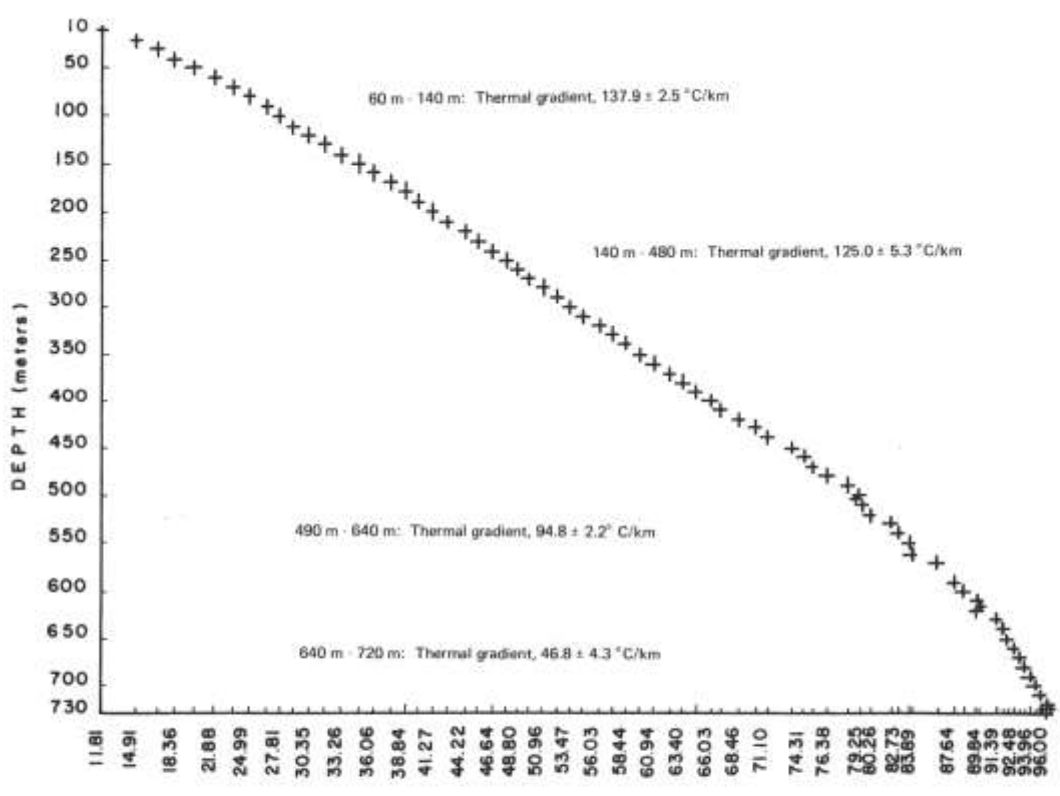

FIGURE 2F - Hole GT-1, temperature vs depth.

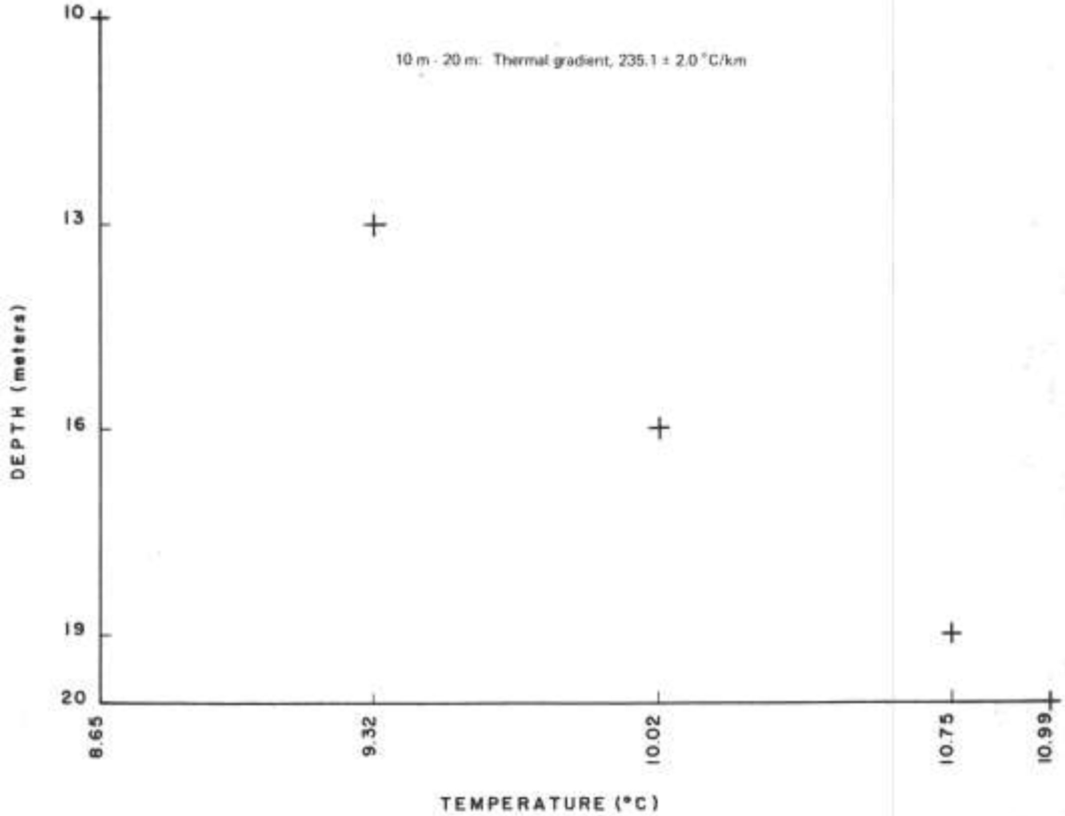

FIGURE 2G— Hole 1, temperature vs depth.

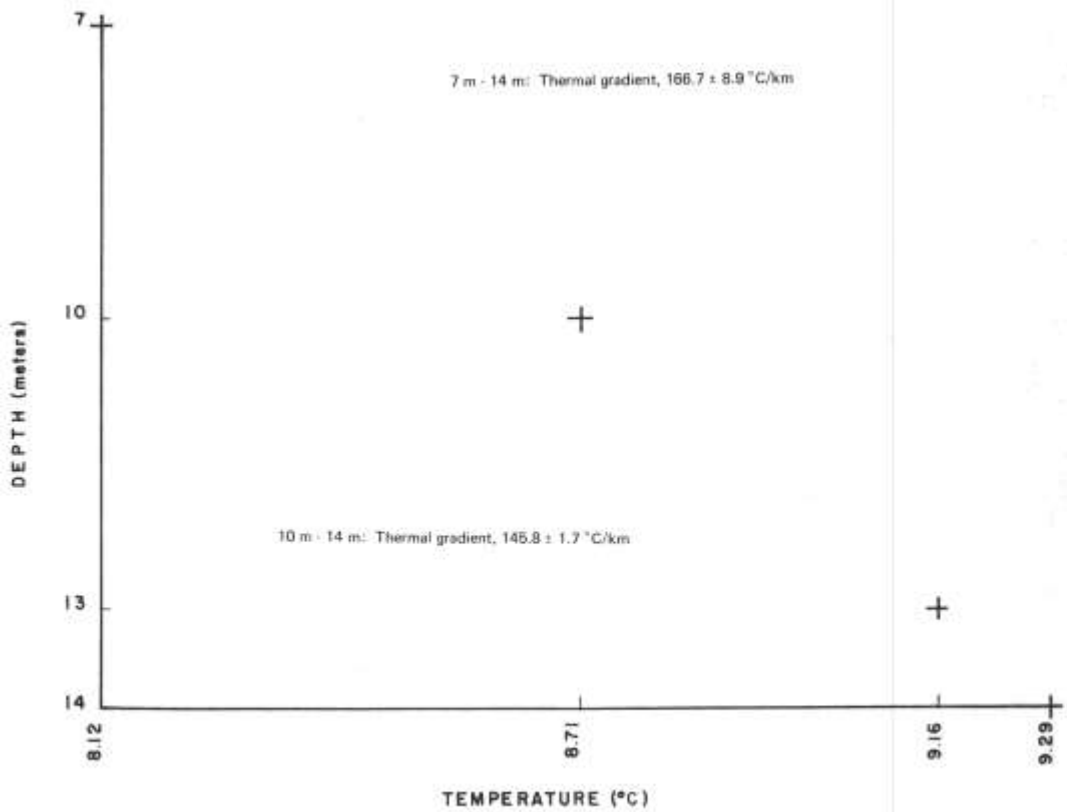

FIGURE 2H — Hole 2, temperature vs depth.

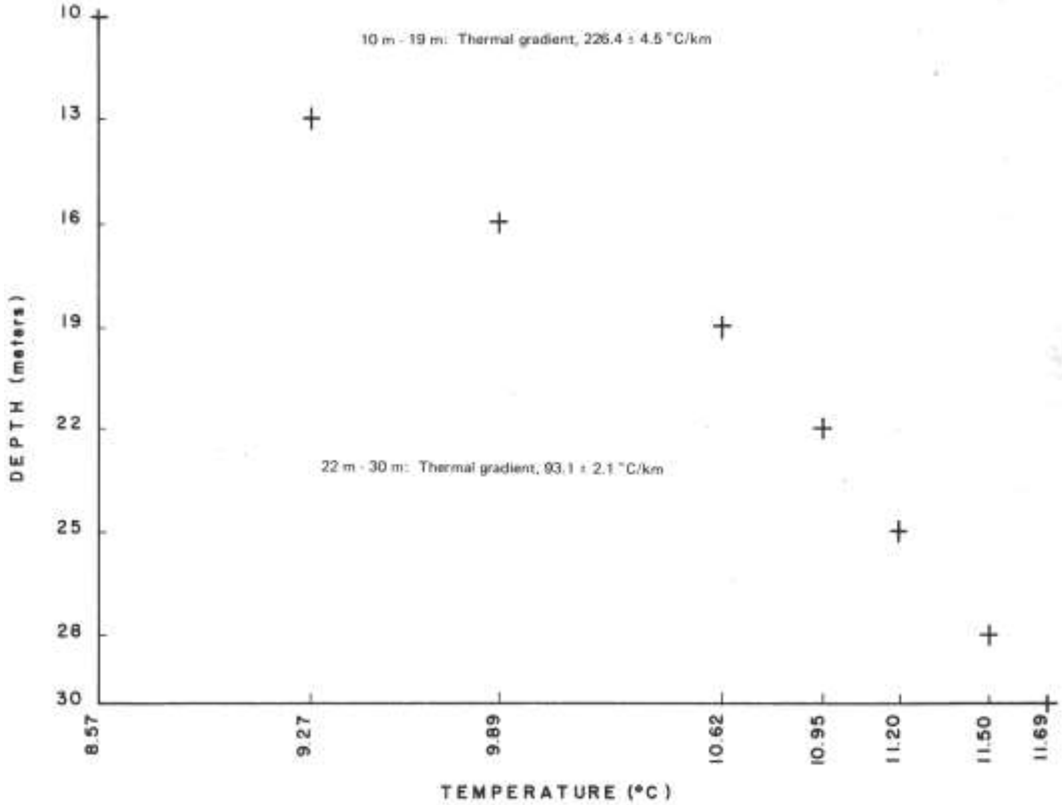

FIGURE 2I—Hole 3, temperature vs depth.

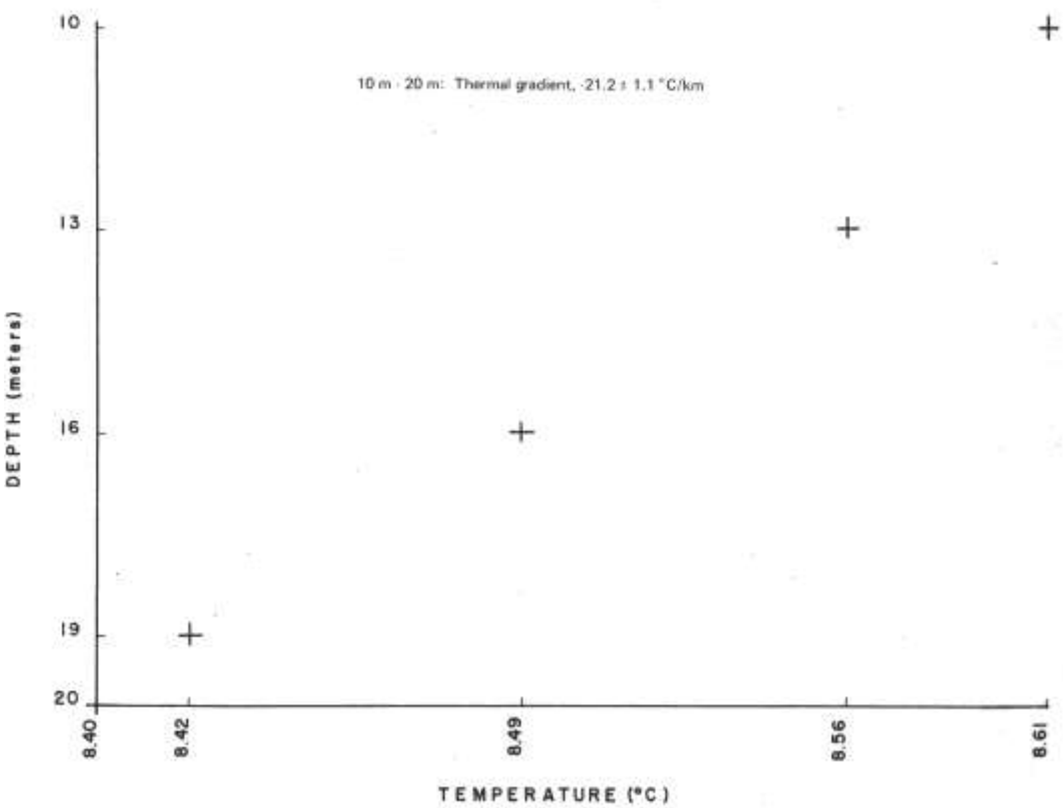

FIGURE 2J — Hole 4, temperature vs depth.

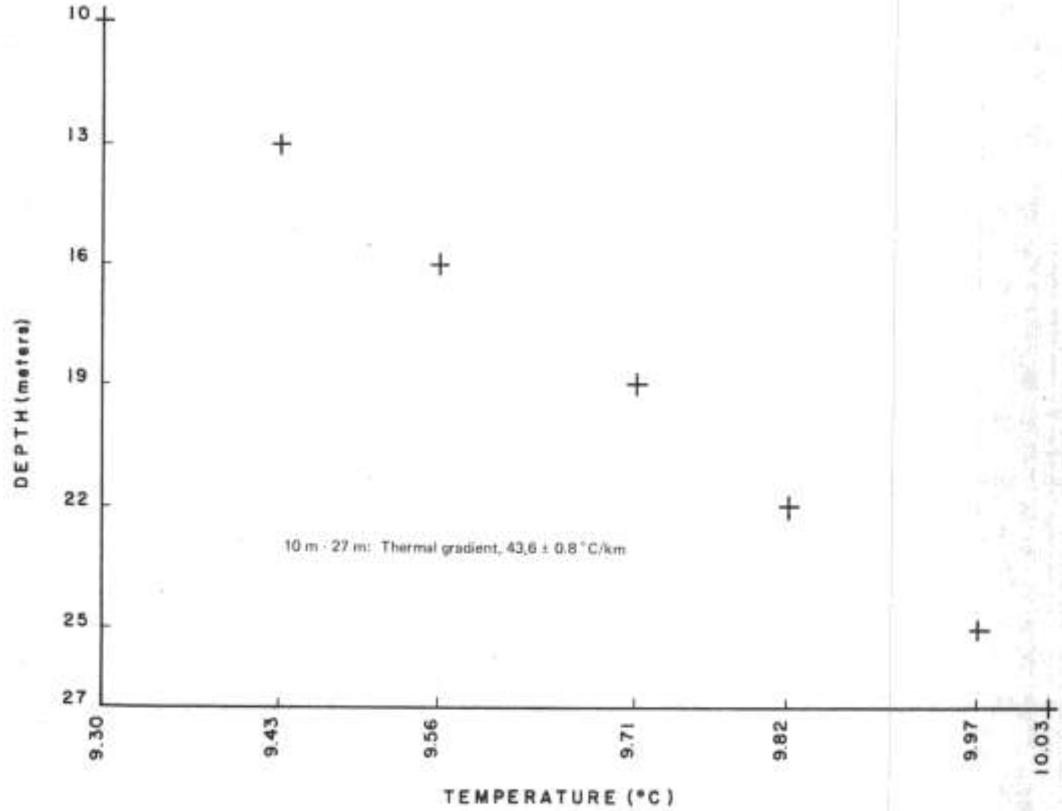

FIGURE 2K — Hole 5, temperature vs depth.

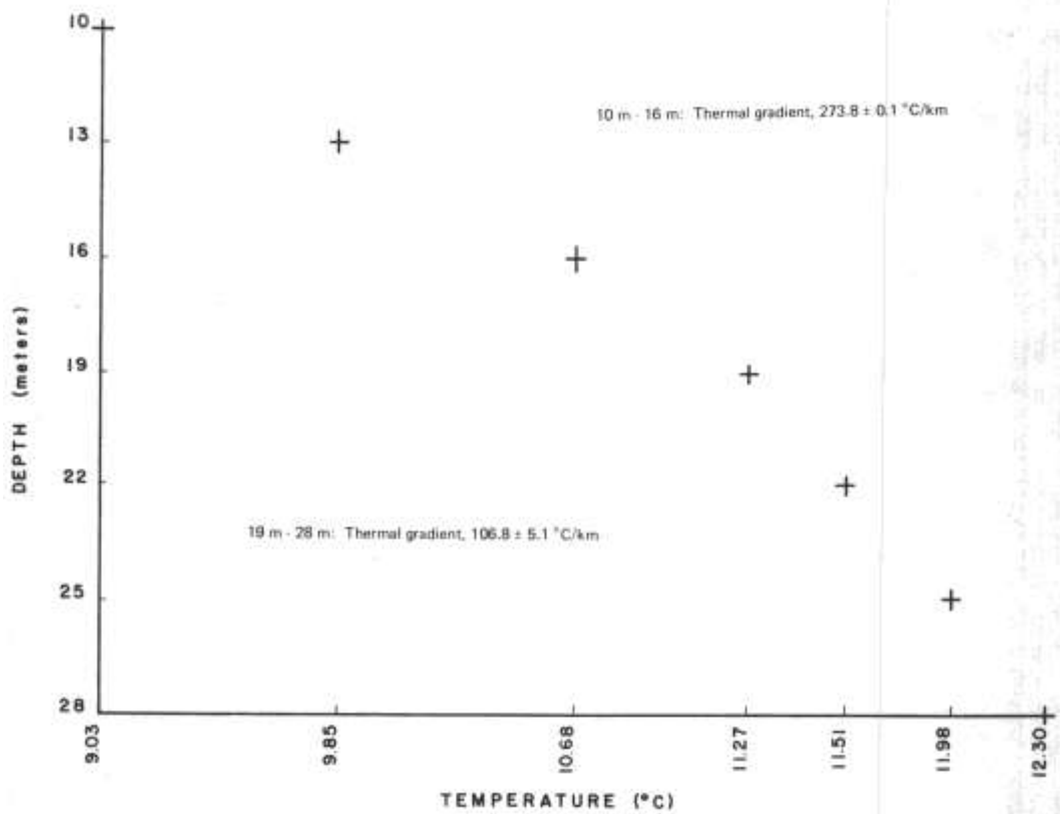

FIGURE 2L — Hole 8, temperature vs depth.

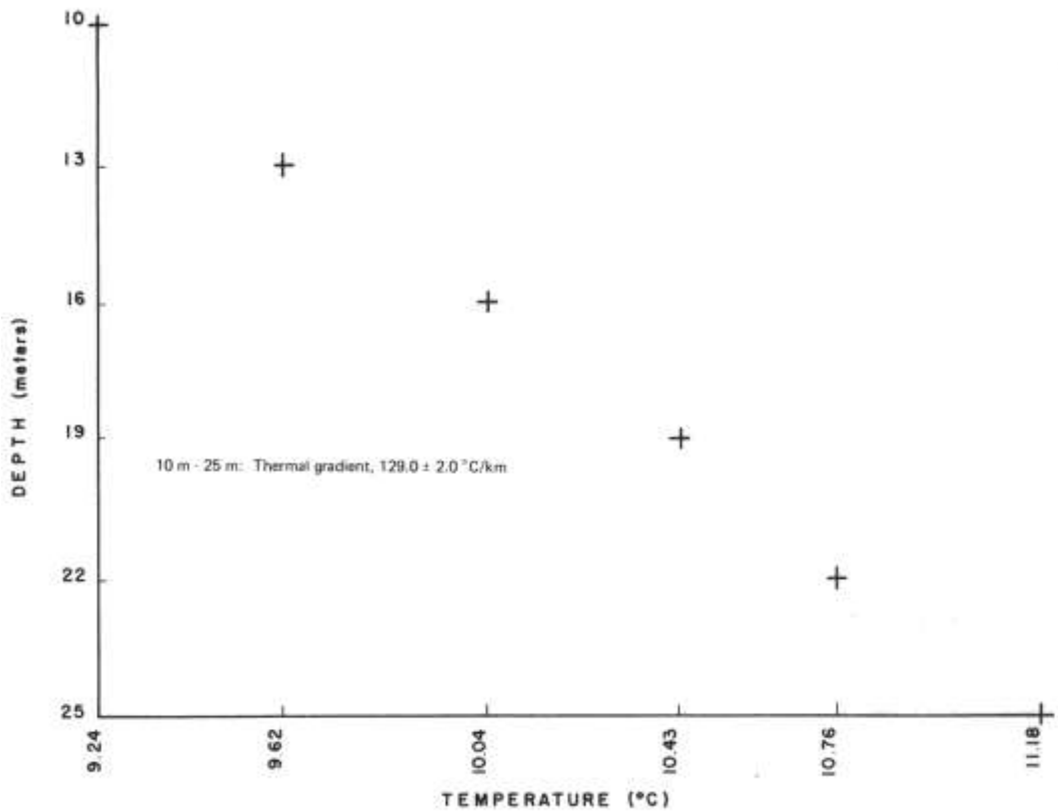

FIGURE 2M — Hole 9, temperature vs depth.

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