SOCORRO PROSPECT AREA

GEOTHERMAL RESOURCE PROSPECT
(SUNEDCO & GULF MINERALS)

GeothermEx
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GEOTHERMAL RESOURCE POTENTIAL OF THE SOCORRO AREA, NEW MEXICO

for

GULF MINERAL RESOURCES COMPANY
DENVER, COLORADO

and

SUNOCO ENERGY DEVELOPMENT COMPANY
DALLAS, TEXAS

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CONCLUSIONS

1. Prior discussions of the geothermal potential of the Socorro area have been based on the premise that magma bodies are present at shallow depth (12 miles and possibly about 2 miles) beneath an Oligocene-age caldera. However, temperature gradient, heat flow, and hydrochemical data fail to identify any strong thermal anomalies in the project area.

2. Analyses of seismic data shows that the widespread magma bodies are at mid-crustal depths (12 miles, or 19 km) and are quite thin (about 3,000 feet or 1 km). If fully molten, these bodies could impose an equilibrium conductive temperature gradient of only 3°F/100 ft (55°C/km). If the magma bodies are very youthful (they are semi-liquid despite their thinness), conductive temperature equilibrium to the surface may not yet be established. That is, the shallow crust may still be warming.

3. Maximum bottom hole temperatures are 90°F (32.0°C) in B40, and 81°F (27.2°C) in A3. Holes B20, B35, U3, U4, and A1B have temperatures in the 77-79°F (25-26°C) range.

4. The highest temperature gradient measured at moderate depth (165-1,391 feet, or 50-424 m) in the Socorro area which may represent equilibrium conditions is 3.1°F/100 ft (55.5°C/km) in B15. Several holes have gradients of 2.2-2.8°F/100 ft (40-50°C/km) below 330 feet (100 m): S2B, NM5, A1B, A6B, B31, B33, S8, S9B. These are close to the predicted equilibrium conductive gradient.

5. The deeper holes, especially B40 and B35, have high gradients (to 7.1°F/100 ft or 128.7°C/km) in their <u>upper</u> portions, but have isothermal or reversed gradients at bottom along with moderate bottom-hole temperatures, demonstrating deep groundwater circulation. High gradients are seen at shallow levels in many shallow (130 feet or 40 m, or less) holes, but the persistence of the high gradients with depth is moot, given the experience of B40 and B35.

6. Regional conductive heat flow probably is closer to 2.0 than to HFU. Higher published estimates probably are erroneous, because they were computed for shallow holes and shallow convective disturbance is likely. Six holes in the project area

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have heat flow greater than 2.0 HFU, but heat transfer by groundwater convection is proven at 4 of these points and is very probable at the other two. Thus, no greater-than-average conductive heat transfer has been demonstrated.

7. Most of the computed heat flow values are subaverage and suggestive of convective disturbances. Those in the La Jencia Creek-Nogal Canyon area are so low (less than 1.0 HFU) that they demonstrate deep cool groundwater circulation.

8. Moderate quantities of cool groundwater move from recharge areas on the flanks of the Magdalena Mountains through the La Jencia Creek and Socorro Canyon areas. In addition, a zone of upwelling cool dilute groundwater has been demonstrated from hydrochemical, temperature-gradient, and heat-flow data in the Strozzi Ranch area west of Socorro Peak.

9. Socorro, Sedillo, and Cook Galleries on the east side of Socorro Peak have mildly thermal water, whose temperature, composition, and calculated reservoir temperatures all are consistent with circulation to only moderate depth in a region of 1.7-2.8°F/100 ft (30-50°C/km) temperature gradient. No strong thermal component is indicated.

10. Only well #367 on the east side of the Socorro Peak block has hydrochemical evidence of a deep, hot circulation (295°F, or 146°C reservoir temperature calculated by Na-K-Ca). SiO_2 geothermometry yields much lower values (not over 165°F or 74°C). A presumptive case for mixing with deep, hot, chlorided water can be made, but with limited confidence.

11. Regional geologic structure and subsurface section remains poorly understood. Presumed Oligocene volcanic cauldrons are not recognizable in surface fault patterns, and impose difficult requirements in geologic cross-sections.

12. Deep aquifers may exist in Paleozoic limestones or more shallowly in any of several Tertiary volcanic-sedimentary units. No single model of subsurface geology, hydrology, thermal regime and hydrogeochemistry is fully convincing. However, a reasonable hypothesis is that cool groundwater recharging to perhaps several thousand feet masks or dilutes the heat rising conductively from a mid-crust magma.

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13. Continued exploration and leaseholding depends upon the assumptions that: (a) a thermal anomaly is present along the east side of Socorro Peak, extending to the west at depth; (b) the anomaly to the west is masked by cool groundwater circulating to an unknown depth; and (c) the anomaly is not too deep to encounter in continued drilling. All 3 assumptions are debatable.

14. It is unlikely that further shallow drilling can resolve these questions. Future gradient holes will have to go to 2,000-2,500 feet in depth, to determine circulation patterns, deep gradients and subsurface geologic section. If fluid samples can be obtained from such deep holes, geochemistry may help in interpreting the groundwater-circulation patterns.

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RECOMMENDATIONS

1. Drill one or two 2,000-2,500-foot holes in the Socorro Peak block to define temperature conditions and deep circulatory system at depth. If feasible, collect fluid samples for comparative geochemical analysis and geothermometry.

2. Because data from an imtermediate-depth hole in the northern Chupadera Mountains showed circulation of only moderate temperature water at depth, no further drilling is recommended there.

3. If further drilling is contemplated, sample selected springs and wells in the Socorro Peak block and Strozzi Ranch area to obtain complete hydrochemical and isotope analyses, which may be used for improved calculation of reservoir temperatures and mixing models.

4. Additional shallow (less than 330 feet or 100 m) temperature-gradient drilling is not warranted at this time.

5. If no further exploration is budgeted or planned, retain those leases that require no performance and that have low annual rentals. Inquire about possible farm-outs based on the recipient drilling several 2,000-2,500 foot holes.

6. Update information on the status of institutional research into the seismology, chemistry and geology of the presumed magmatic bodies before abandoning leases.

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INTRODUCTION

This report provides a regional synthesis of geology, geochemistry, hydrology and geophysical data for the Socorro, New Mexico, area. It is based principally on extensive drill-hole data supplied by, and proprietary to, Gulf Mineral Resources Company and Sunoco Energy Development Co. These temperature-gradient and heat-flow data are integrated with older gradient and heat-flow data, groundwater chemistry, studies of local seismicity, regional and local geologic mapping, and other data. This synthesis yields a revised estimate of the geothermal energy potential for the Socorro area. It should be recalled that attention has been focused on Socorro and vicinity because of reported high heat flow and probable magmatic bodies within the shallow crust.

Some 20 man-days of effort have gone into this study, exclusive of time spent earlier in logging temperature gradients and studying drill-hole cuttings.

GEOLOGY

Regional Setting

The Socorro area lies within the Rio Grande rift, a 400-mile-long north-trending zone of *en echelon* fault-bounded basins, which are characterized by basalt and rhyolite volcanism and thin red crust. The rift has been interpreted by many workers as an intracontinental zone of crustal spreading.

The rift is bordered on the west by the Colorado Plateau and the southern part of the Basin and Range province and on the east by the High Plains. The rift generally is agreed to include Las Cruces, New Mexico on the south and the San Luis Valley in Colorado on the north. However, various authors have proposed different western and eastern boundaries as well as different northern and southern endpoints for the rift, as geological and geophysical models of the region have evolved. For example, Kelley (1952) drew the western boundary of the Rio Grande rift at Socorro along the base of the Socorro Peak block, implying that the rift is much narrower at this latitude than to the north. However, Chapin *et al*. (1978) described the Chupadera Mountains-Socorro Peak-Lemitar Range as an interbasin horst, and placed the boundary of

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the Rio Grande rift at Socorro at least as far west as the flank of the Magdalena Mountains.

It is beyond the scope of this report to discuss regional development of the rift; instead it will concentrate directly on the Socorro area, especially those factors related to possible geothermal resources.

Summary of Stratigraphy

A detailed geologic map of the northern Chupadera Mountains, the Socorro Peak block, and the Polvadera Mountain part of the Lemitar Range is given in plate 1. Less-detailed information covering the east flank of the Magdalena Mountains, as well as the Chupadera-Socorro Peak-Lemitar Mountains, is shown on plate 2. A composite stratigraphic column (figure 1) summarizes the lithology and thickness of the various units.

Precambrian Rocks

Precambrian basement rocks underlie a large part of the Magdalena Mountains in T. 2 and 3 S., R. 3 W. The principal rock types are argillite and schist, which were formed by low-grade regional metamorphism of clay-rich sediments, and a later granitic batholith.

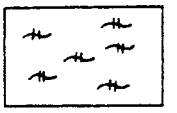
In the Socorro Peak area, Precambrian rock is exposed only in Sec. 4, T. 3 S., R. 1 W. (plate 1). It probably is similar in lithology to extensive outcrops along the east side of Polvadera Mountain in Sec. 31 and 32, T. 1 S., R. 1 W. and in Sec. 5 and 6, T. 2 S., R. 1 W. Here, Precambrian units include mafic and felsic plutonic rocks, gneiss, quartzite, argillite, and schist.

Exposure of Precambrian rocks in the center of the Socorro Peak and Lemitar horsts implies that these areas have undergone profound uplift.

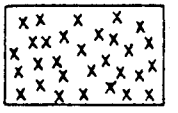
Paleozoic Rocks

Lower Paleozoic rocks are not present in the Socorro area, probably as a combined result of non-deposition and erosion.

EXPLANATION OF SYMBOLS USED IN STRATIGRAPHIC COLUMN


Rhyolite

Tuff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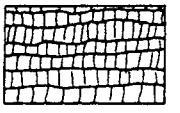
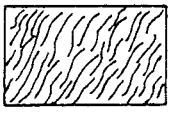
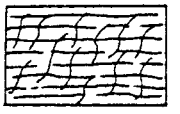

Basalt


Schist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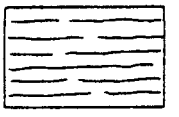
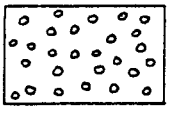
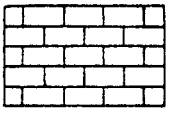
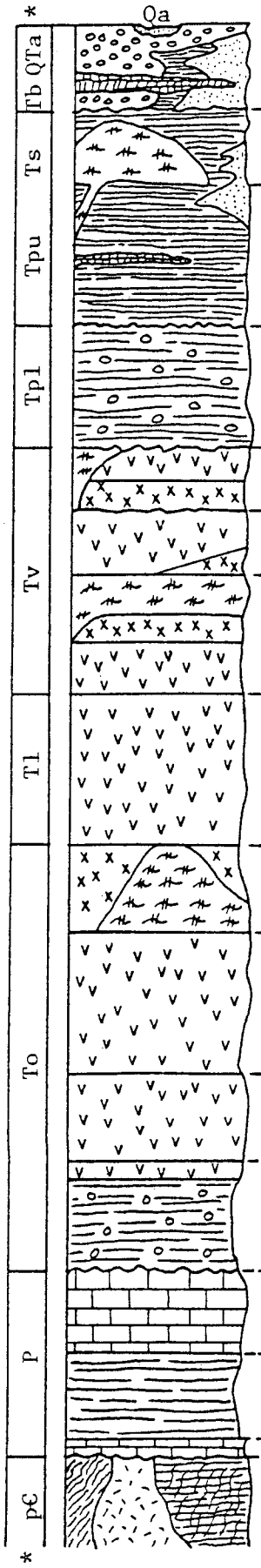

Clay and Shale

Sand


Gravel

Granite


Limestone



Sierra Ladrones Formation: (0-1000'). Piedmont-slope, river-channel, flood-plain deposits, and basalt flows.

Rhyolite of Socorro Peak: 7-10 m.y. (0-800'). Silicic domes, flows, tuffs.

Upper Popotosa Formation: (0-2500'). {Member of Kelly Ranch} Claystones, mudstones, siltstones, sandstones, conglomerates, and basalt flows.

Lower Popotosa Formation: (0-1500'). {Members of Socorro Canyon and Lemitar Mountains.} Mud flow deposits, fanglomerates, and minor lacustrine deposits.

Lavas of Water Canyon Mesa: 20 m.y.(0-600'). Intermediate to silicic lavas and tuffs. Locally present, east flank of Magdalena Mountains.

Tuff of South Canyon: 26 m.y. (0-600'). Ash-flow tuffs. Tongue of basaltic andesite.

Luis Lopes Formation: (0-2000'). Ash-flow tuffs, andesitic lavas, rhyolitic domes and tuffs, minor landslide deposits.

Lemitar Tuff: 27 m.y. (0-400' outflow, 700-2900' cauldron). Ash-flow tuffs; multiple units.

Unit of Six Mile Canyon: (0-200')/ Andesite to basaltic andesite lavas, rhyolite lavas and domes, ash-flow tuffs, laharic breccias. Locally present, east flank of Magdalena Mountains.

A-L Peak Tuff: 32 m.y. (0-700' outflow, 2000'+ cauldron). Ash-flow tuffs, multiple units.

Hell's Mesa Tuff: 32-33 m.y. (0-500' outflow, 3000'+ cauldron). Ash-flow tuffs, multiple units.

Spears Formation: 33-37 m.y. (0-1500'). Conglomerates, mud-flow deposits, lavas, and ash-flow tuffs.

Madera Limestone: (500-1500').

Sandia Formation: (550-650'). Shales, quartzites, and limestone.

Kelly Limestone and Caloso Formation, undivided: (0-90').

Precambrian crystalline basement: Mafic and velsic plutonic rocks, schist, gneiss, argillite, and quartzite.

* Lithologic units shown on Plate 2.

FIGURE 1. Composite stratigraphic column of the Socorro area. Thickness of units not to scale. (Modified from Chapin et al., 1978.)

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Closest exposures of lower Paleozoic rocks are about 40 miles south of the project area.

The oldest Paleozoic units present, the Mississippian Kelly and Caloso Formations undivided, were deposited directly onto eroded surfaces of the Precambrian rocks. In the Kelly mining district on the northeast side of the Magdalena Mountains, the Kelly limestone was very permeable to hydrothermal fluids during stock intrusion and ore deposition. However, this unit is relatively thin (0-90 feet), and it alone could not provide adequate storage for a commercial geothermal system.

The overlying Pennsylvanian Sandia Formation, which is composed of shale with minor quartzite and limestone, acted as an impermeable cap above the Kelly limestone during the ore-forming episode.

At the top of the local Paleozoic section, the Madera Limestone (500-1,500 feet thick) is permeable and is thick enough to be a potential host for geothermal fluids.

Tertiary Rocks

Neither Mesozoic nor lower Tertiary rocks are present in the Socorro area. Such units may have been deposited, but subsequently were removed by erosion. Mesozoic rocks crop out about 10 miles east of the project area.

Oligocene

Volcanic activity began in the Socorro area in early Oligocene time with deposition of the Spears Formation (37-33 m.y.), which is composed largely of volcaniclastic debris but also contains ash-flow tuffs of intermediate composition. The Spears Formation has not been correlated with a specific volcanic center.

According to Chapin *et al*. (1978), a series of nested cauldrons formed in the Socorro-Magdalena region (figure 2) during the period 33-26 m.y. ago (early Oligocene to latest Oligocene). Volcanic units named in figure 1 are correlated with these volcanic centers as follows: The Hells Mesa tuff probably was derived from the North Baldy cauldron. Various members of the A-L Peak tuff were produced from the Mt. Withington, Magdalena, and Sawmill Canyon cauldrons, while the unit of Sixmile Canyon represents infill of the Sawmill Canyon cauldron. The Socorro

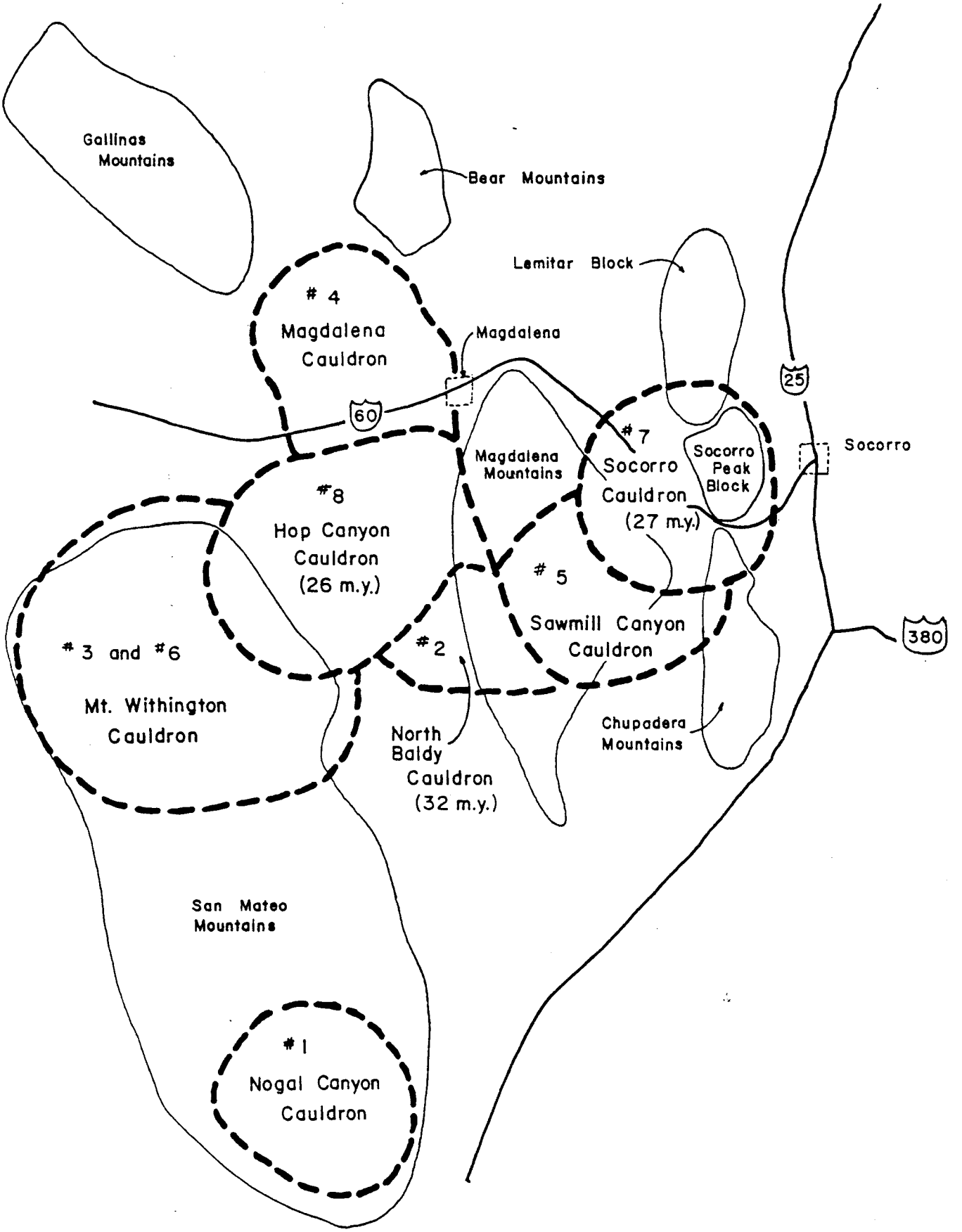

Figure 2. Overlapping and nested cauldrons in the Socorro-Magdalena area. Numbered in sequence from oldest to youngest. (Modified from Chapin et al, 1978)

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cauldron was the source of the Lemitar tuff, and the unit of Luis Lopez represents infilling and resurgent volcanism within the Socorro cauldron. The tuff of South Canyon is a regional unit that was deposited over the Socorro cauldron; its source may have been the Hop Canyon cauldron.

Owing to the differing thickness of caldera-fill and outflow facies of ash-flow units, and the overlapping of calderas, as well as possible post-deposition episodes of erosion, the thickness of volcanic rocks varies greatly between localities.

The great effusion of volcanic units in the Socorro-Magdalena area tapered off at the end of the Oligocene. Some volcanic units, such as the lavas of Water Canyon Mesa, are of Lower Miocene age, but these units are much less voluminous and are relatively restricted in area.

Finally, it should be noted that existence of the several cauldrons and the sequential interrelationship of volcanic units is inferred from indirect evidence of rock type, thickness, particle size, and geophysical parameters. Surface fault patterns do not strongly support cauldron formation.

Miocene

During Miocene time, a broad alluvial basin developed, including the Magdalena area on the west and the present course of the Rio Grande River on the east. The north and south boundaries of the basin are not well known. Thick sediments (at least 3,000 feet) of the Popotosa Formation (Santa Fe Group) accumulated within this basin.

Areas presently standing at high elevation were part of the lowlands receiving sediments, as is inferred from the presence of Popotosa Formation at the crest of the Magdalena Mountains in Sec. 6 and 7, T. 4 S., R. 3 W., (Krewedl, 1974) at an elevation slightly above 10,000 feet. The area presently occupied by the Chupadera-Socorro Peak-Lemitar uplift was persistently a low-lying part of the Popotosa basin, tending to receive the finest-grained sediments (Chapin et al., 1978).

Some lower Miocene volcanic units are known, such as the lavas of Water Canyon Mesa, but these appear to be of local distribution.

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Upper Miocene rhyolitic domes and flows of the Socorro Peak group (7-12 m.y.) are interbedded with the upper Popotosa Formation. These are the youngest silicic volcanic units known in the Socorro area. It appears likely that even if these silicic lava flows are the surface expression of a mid- to shallow-crustal silicic pluton, this episode is too old to serve as a present-day heat source for geothermal fluids.

Pliocene

Between 7 m.y. (youngest Socorro Peak rhyolites extruded) and 4 m.y. (basalts of Sedillo Hill emplaced), the Popotosa basin was broken by uplift. Integration of the ancestral Rio Grande drainage also occurred at this time. Sediments of the Sierra Ladrones Formation accumulated throughout the Pliocene epoch, intercalated with local basalt flows, such as those at Sedillo Hill. This appears to have terminated extrusive volcanism in this region.

Pleistocene and Recent

Minor alluvial sedimentation occurred throughout Quaternary time. However, the cutting of several geomorphic surfaces as a function of aggradation of the Rio Grande River was the most important geologic event.

Structure

As can be seen from plates 1 and 2, faults in the Chupadera Mountains-Socorro Peak-Lemitar Range uplift most commonly trend north-northwest and have normal offset. Northeast-trending faults, possibly somewhat older, are common in the northern Chupadera Mountains. In the eastern part of the Magdalena Mountains, faults show much more curvature than do those to the east, but their general linear trend is north-northwest. A special class of faults in the Socorro Peak block and the Lemitar Range consists of those which originally were normal faults of moderate dip, but which now are nearly flat-lying or have apparent reverse offset as a result of subsequent tilting and rotation. These faults chiefly offset Paleozoic units.

However, there has been movement on the north-northwest-trending faults throughout the project area since mid-Miocene, because upper

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Popotosa Formation and younger units are offset. Many faults have moved in Pleistocene or Holocene time, because they offset unconsolidated alluvium of probable Quaternary age. Some mapped faults, especially those along the east side of the Magdalena Mountains and those east of the Chupadera Mountains, have fresh scarps and offset alluvium at the surface, indicating very recent movement.

These faults appear to be related to breakup of the Popotosa sedimentary basin, upwarping of the Magdalena Mountains and raising of the Chupadera-Socorro Peak-Lemitar uplift. Presumed ring-faults, associated with caldera collapse, are less obvious; and the outline of the Socorro cauldron shown on plate 2 by Chapin et al. has little apparent correlation with mapped faults.

Chapin et al. (1978) proposed a larger-scale structural element in the Socorro area: a transverse shear zone crossing both the Socorro Peak block and the Magdalena Mountains. On the north side of this presumed shear zone, formations are tilted to the west and stepped down to the east by north northwest-trending normal faults; whereas on the south side of the shear zone, formations are tilted to the east and stepped down to the west. Chapin et al. suggested that this transverse shear zone controls the south edge of a postulated present-day deep magma body. They also implied that the zone controlled emplacement of the late Miocene Socorro Peak rhyolites and development of the Oligocene cauldrons, reasoning that this structure must represent a deep-seated structural flaw. Furthermore, they implied that present-day hydrothermal circulation patterns may be strongly influenced by this shear zone.

However, similar zones of reversed fault dip and rotation are found at many places in the western United States including a few geothermal prospects. Notable amongst the latter is the Warner Range of Oregon and California, which exhibits different rotational style to the north and south of Fandango Pass. Various explanations have been proposed, for this phenomenon, including diagonal strike-slip faulting, doming, and regional crustal extension. The significance, cause, and even the existence of such transverse shear zones remains moot. If demonstrated to exist, a magmatic relationship is highly presumptive.

Regionally, the Socorro area lies within the Rio Grande rift zone at its intersection with the Morenci lineament, a northeast-trending zone of mineralization and deep-seated structural grain. Several other lineaments are known in New Mexico and adjacent states, with and without geothermal significance. Structural-mineralized

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belts associated with geothermal systems include the Pioche-Beaver-Tushar belt, which extends through the Roosevelt Hot Springs geothermal system in southwestern Utah. It is moot if a causal relationship exists between such lineaments and present-day hydrothermal systems.

GEOPHYSICS

Geophysical data, particularly evidence from seismic studies, have had a critical influence on the modeling of possible geothermal systems in the Socorro area. Indeed, were it not for strong geophysical evidence of present-day magma bodies at moderate and shallow crustal depths, the Socorro area would not appear much more promising than many other broad areas of crustal extension in the western United States.

In the following sections, seismic and other data will be discussed and integrated with the geologic data.

Seismology and Crustal Deformation

Historical Seismicity

Sanford et al. (1979) summarized available data on instrumentally recorded earthquakes (covering the period 1962-1977) and on non-instrumented reports (covering the period 1849-1962). They found that nearly all felt earthquakes occurred along the Rio Grande rift from Socorro to Albuquerque, and that the greatest proportion (75%) occurred in the 47 mile segment of the rift from Socorro to Belen. A similar spatial pattern was found among instrumentally recorded earthquakes.

Of special interest is an earthquake swarm at Socorro which lasted for 8 month in 1906-1907. The largest shocks were of intensity 7 to 8 (Modified Mercalli Scale) and calculated magnitude 4.4-4.9, or perhaps somewhat higher. Elsewhere, earthquake warms of this type have been correlated with magmatic intrusion at shallow depth.

During a 16-year period (1962-1977) of instrumental data, there has been a low level of seismicity in the Rio Grande rift. The highest magnitude reported was 3.6; and certain large segments

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of the rift (such as from Socorro to Las Cruces) had no events greater than 2.4. This level of activity is no greater than that observed in the neighboring Colorado Plateau and High Plains provinces, which would be expected to have generally low activity. Sanford et al. (1979) suggested that the Rio Grande rift undergoes episodic seismic activity, with the recent instrumental data representing a quiescent, background level of energy release. Certainly, there were fewer earthquakes than would be expected from the previous 100 years of popular report, and smaller earthquakes than might be expected from the prominent recent fault scarps in the Socorro area.

Microseismicity

Much study of instrumental records of microseismic events has been undertaken, especially for events in the Socorro area. Sanford et al. (1979) summarize the results as follows: microearthquake hypocenters are scattered over a 900 square mile (2,300 km^2) area, which is centered roughly over a postulated mid-crustal magma body (discussed below). Activity is somewhat more frequent within the old Socorro cauldron than elsewhere in the Rio Grande rift; but nowhere can recorded hypocenters clearly be correlated with mapped faults.

The focal depths of microearthquakes have been studied using several different techniques; most focal depths are at about 4 miles (7 km) and none are deeper than 8.5 miles (13.5 km). Sanford et al. (1979) attributed the lack of deeper earthquakes to abnormally high temperatures at depth, which inhibits stick-slip movements. However, it should be noted that earthquakes occur at focal depths less than 15 km in many provinces of small crustal thickness.

Midcrustal Magma Body

The most important result of microearthquake studies in the Socorro area is the development of evidence for a widespread mid-crustal zone of very low rigidity, thought by many to be magma body. These data were first presented by Sanford and Long (1965) and Sanford et al. (1973); they have been summarized and integrated with new results by Rinehart et al. (1979).

The magma body was identified from unusual reflections of shear waves generated by microearthquakes. These reflections are

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S to P and S to S reflections off a sharp discontinuity, which is at a depth fo 12.0 miles (19.3 km) at Socorro and dips very slightly (less than 2°) northward. The reflector horizon covers an area of about 665 square miles (1,700 km^2), from Socorro northward at least 35 miles (56 km), although the west, north, and east boundaries of the reflector are not well defined (figure 3).

The reflector horizon probably is a sill-like intrusion which contains at least a partial melt, but which certainly has very low rigidity. This conclusion was reached by Rinehart et al. (1979) because no reasonable combination of contrast in solid rock densities across the reflector horizon could yield the observed reflected waves. Only if the interface were composed of solid rock above and either liquid magma or a partial melt below, would the observed reflections fit theoretical values very well.

That the magma body is relatively thin compared to its lateral extent is shown by very small P-wave residuals for teleseisms, indicating that the magma layer is 2,000-4,000 feet (0.6-1.2 km) thick if it is composed of a full melt (Rinehart et al., 1979).

Shallow Magma Bodies

Chapin et al. (1978) summarized evidence for the existence of small, shallow magma bodies within the project area. The distribution of these bodies is shown in plate 3. Detailed instrumental studies of microearthquakes in the Socorro area have shown that, depending on the instrument array used, SV waves through certain areas are very weak or are absent. This screening of SV waves can be explained if liquid magma or a partial melt is present within the zones illustrated. Calculation of Poisson's ratio for microearthquakes in the same area yields anomalously high values, which can be explained by the same distribution of shallow magma bodies.

Finally, Chapin, et al. (1978) reported that detailed three-dimensional analyses of the distribution of microearthquake hypocenters shows events to occur around, but not within, the postulated shallow magma bodies except at very shallow depths (less than 8,200 feet to 2.5 km). The magma within these shallow zones is thought to be in thin, discontinuous dikes with relatively small total volume. The top of the shallow magma zone may be at about 8,200 feet (2.5 km).

Whether these shallow magma bodies could provide adequate heat to power a significant geothermal convection system is not known.

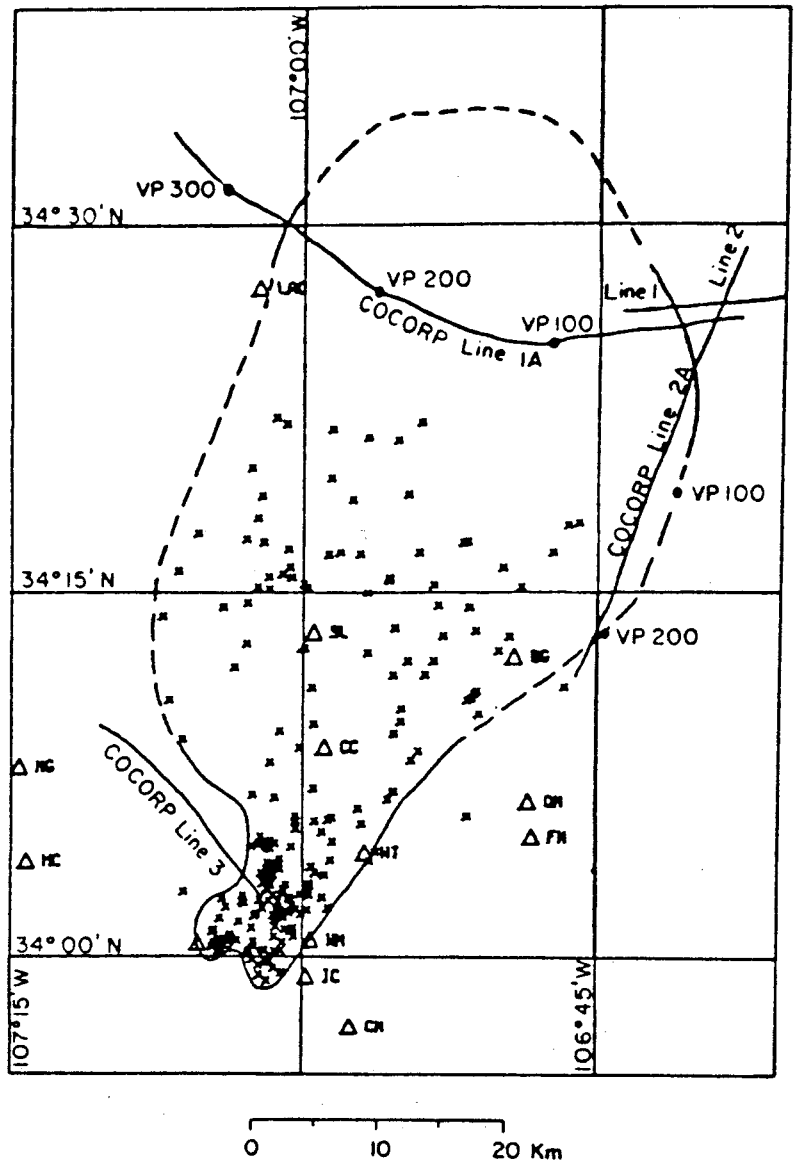

FIGURE 3. Map of well-located reflection points and the outline of the magma body. Also shown are the COCORP lines used to help determine the body's extent. Solid boundaries indicate actual extent while dashed lines indicate a minimum extent. (From Rinehart et al., 1979).

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More fundamentally, whether these shallow magma bodies could remain in the molten state at such shallow depth for more than a brief time interval also remains unknown.

Unpublished Microearthquake Survey

A detailed microearthquake survey was performed during 3 weeks in 1974 in the Socorro area for Gulf Mineral Resources Company. During this time, 58 local events were recorded, whose magnitudes ranged from -1.1 to +1.1. The distribution of best-located events is shown on plate 3 along with calculated focal depths; however, neither position nor depths are known with great accuracy. As can be seen from plate 3, the distribution of events recorded during this brief survey generally corresponds to the pattern observed for longer-term studies.

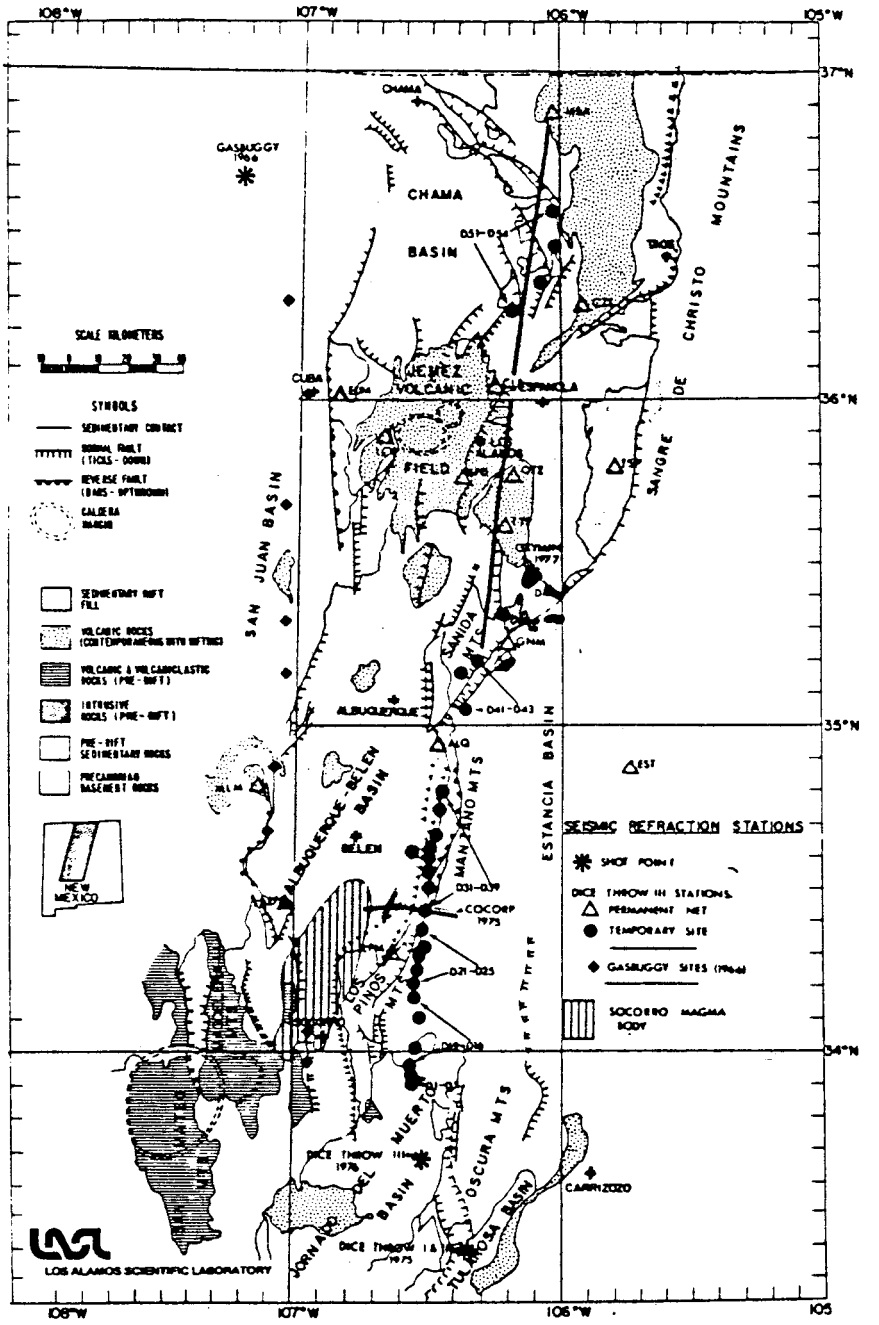
The events located in Sec. 17, 18, 19, and 29, T. 3 S., R. 2 W. may define an active fault which strikes N 10° W., dips about 80° E., and is downdropped to the east. This interpretation is consistent with recent fault scarps mapped nearby. The other events are too poorly located to interpret with confidence.

Reflection and Refraction Surveys

Brown *et al*. (1979) reported the results of several COCORP *Vibroseis* surveys, including a WNW-ESE profile across the Rio Grande rift about 25 miles (40 km) north of Socorro and a NNE-SSW profile along the east side of the rift, the south end of which is about 9 miles (15 km) from Socorro. The locations of parts of these profiles are shown on figure 4.

Brown *et al*. found a strong reflector horizon at 12.5 miles (20 km) depth, corresponding with the location of the postulated Socorro magma body. Detailed interpretation of the reflection data shows that a magma body is consistent with the observed patterns, but is not required by the earth model. If the magma body hypothesis is correct, then the reflection survey results indicate that it is not a simple body but may be layered and/or discontinuous in places.

Olsen et al. (1979) reported the results of a seismic refraction profile that used a chemical explosion as the energy source. The line of profile trends NNE and is located about 15 miles (25 km)



COCORP lines 1 and 2

Segment of seismic refraction profile that overlies a strong mid-crustal reflector

FIGURE 4. Index map of north-central New Mexico showing shotpoints and recording stations for seismic refraction profiles in the vicinity of the Rio Grande rift. (From Olsen et al., 1979).

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east of Socorro (figure 4), far to the east of the Socorro magma body as identified from microearthquake data. However, a strong reflector phase at a depth of about 13 miles (21 km) also was found along this profile. The data show that P-waves are reflected from a major intracrustal layer, which has P-wave velocity of 2,000 ft/sec (6.4 km/sec), compared to velocities of 19,700 ft/sec (6.0 km/sec) in the overlying units, and also has anomalously low shear wave velocities.

East-west dimensions of this intracrustal low-rigidity layer are not known, but its north-south extent is about 68 miles (110 km). It probably is only a few kilometers thick. Olsen et al. (1979) also suggested that this eastern intracrustal low-rigidity layer may have a lower degree of partial melt than the postulated Socorro magma body.

Regional Crustal Structure

Keller et al. (1979) used Rayleigh wave group and phase velocity measurements and also seismic refraction data to establish the thickness of the crust in the Rio Grande rift. They found that it is about 22 miles (35 km) thick, which is substantially less than the neighboring Colorado Plateau (28 miles or 45 km thick) or the southern Great Plains (31 miles or 50 km). The crust within the rift may be slightly thinner in the south, near Las Cruces, than in the north.

If there is any difference in crustal thickness between the Rio Grande rift and the southeastern Basin and Range province, it cannot be resolved from the available data.

Modern Crustal Deformation

That crustal deformation presently is occurring in the Socorro region is shown by analysis of releveling of elevation lines (Reilinger and Oliver, 1976). The maximum offset reported along a south-to-north line in the Rio Grande Valley is 8 inches (20 cm) of uplift at a point 14 miles (23 km) north of Socorro. This offset occurred during the period 1911 to 1951, yielding an average rate of 1 inch per 5 years (0.5 cm/yr).

Lesser amplitudes of uplift exist both north and south of this maximum point. Overall, the zone of uplift extends from 9

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miles (15 km) south of Socorro to 35 miles (55 km) north of Socorro, and is almost directly over the postulated Socorro magma body. Several authors have stated that the observed vertical movements are caused by inflation of the magma body; this remains moot.

It should be noted that there is no east-west profile across the Socorro Peak block, and therefore the degree of modern uplift across the project area is not known.

Gravity and Magnetic Data

The only available published gravity map of the Socorro area is a residual Bouguer gravity map (plate 4). It shows gravity highs over the Lemitar Range and over the Precambrian-Paleozoic outcrop of the Socorro Peak block, with lesser maxima over the northern Chupadera Mountains. Gravity values rise steeply over the east flank of the Magdalena Mountains.

However, interpretation of a residual map is ambiguous because the data have been biased, often to an unknown degree, by assumptions regarding "proper" regional trends. Plate 4 shows the expected pattern of gravity lows over valleys and gravity highs over uplands, but further detailed interpretation is not warranted.

Similarly, plate 5 shows a residual magnetic intensity map, whose significance is difficult to assess. There is great relief in the magnetic contours over the northern Magdalena Mountains, but this may have various, non-thermal causes: dipping, and therefore polarized, volcanic units; widespread magnetite, which Laughlin and Koschmann (1942) stated is a very common alteration product in the Magdalena mining district; or relative percentage of magnetite-rich rocks in surface exposures.

Chapin et al. (1978) suggested that aeromagnetic anomalies are subdued along the "transverse shear zone", and they concluded that this is caused by high subsurface temperatures, with the Curie point isotherm occurring at relatively shallow depths. However, it is not easy to agree that the aeromagnetic contours are markedly different along the transverse shear zone or that any special conclusions regarding depth of the Curie point isotherm are warranted.

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INTERPRETATION OF TEMPERATURE DATA

Subsurface temperature data in the Socorro area are relatively abundant, with 32 proprietary and 17 published data points available to this study.

Temperature

Temperatures observed in drill holes in the Socorro area are not exceptionally high: the maximum is 89.6°F (32.0°C) from 1,392 feet (424 m) in hole B40 (plate 6 and table 1). Elevated temperatures are reported for several other holes, including 81.0°F (27.2°C) at 500 feet (152 m) in A3 and 80.4°F (26.9°C) at 131 feet (40 m) in NM2. Many holes in the northern Chupadera Mountains and along Socorro Canyon have temperatures in the range 75-79°F (24-27°C), and the warmest hole also is located in this area.

Temperatures in drill holes in the Nogal Canyon and northern Chupadera Mountains-Socorro Canyon areas are slightly to moderately higher than temperatures observed for nearby groundwater. However, it is discouraging that even in the deepest holes, temperatures are not as high as the warmest groundwater (92°F or 33.5°C in Socorro and Sedillo Galleries and 103°F or 39.4°C in well #367).

Mean annual air temperature is about 57°F (14°C) at the elevation of Socorro, and decreases by about 3°F per 1,000 feet of elevation (5.5°C per km).

Temperature Gradients

Temperature profiles of most drill holes in the Socorro area are very smooth, with few sharp breaks in gradient or temperature reversals. Many holes have straight-line temperature profiles for intervals longer than 100 m (330 feet). Characteristic temperature gradients for each hole are given in table 1 and shown on plate 6; the temperature profiles are included in Appendix A.

Regional background temperature gradient can be calculated very approximately for the Socorro area: if the postulated regional magma body at 19 km has a temperature of 1,200°F (650°C), corresponding to a granitic composition, then the equilibrium conductive

Table 1. Depths, temperatures, and temperature gradients in the Socorro area, New Mexico

Hole Number	Depth (meters)	Bottom Hole Temperature (°C)	Characteristic Temperature Gradient	
			Interval (meters)	Gradient (°C/km)
B-9	75.9	23.00	9.1- 75.9	71.8
B-15	79.2	22.13	12.2- 79.2	55.5
B-19	115.2	18.77	15.2-115.2	18.6
B-20	73.2	25.70	9.1- 36.6	176.8
			36.6- 73.2	37.9
B-21	116.1	16.72	18.3-116.1	8.5
B-22	18.6	16.12	12.2- 18.6	33.9
B-23	91.4	18.93	9.1- 24.4	53.7
			27.4- 91.4	41.0
B-30	128.0	22.08	27.4-128.0	38.3
B-31	152.4	23.95	9.1- 45.7	20.6
			45.7-152.4	45.4
B-32	137.2	21.55	24.4-137.2	31.6
B-33	150.9	24.89	18.3- 42.7	69.9
			42.7-150.9	42.4
B-35	69.2	25.37	9.1- 61.0	128.7
			64.0- 69.2	-26.7
B-40	424.4	32.02	15.2- 61.0	71.4
			61.0-122.0	23.3
			122.0-167.7	9.1
			167.7-274.4	33.1
			274.4-396.3	19.2
			396.3-424.4	5.9
F-1	97.6	19.84	18.3- 97.6	40.1
F-3	87.2	17.66	12.2- 48.8	47.0
			48.8- 87.2	25.2
F-4	96.0	17.13	12.2- 24.4	55.1
			24.4- 96.0	22.2
U-3	152.4	25.87	15.2- 42.7	41.0
			45.7-140.2	42.1
			140.2-152.4	-10.0

Table 1 (continued)

Hole Number	Depth (meters)	Bottom Hole Temperature (°C)	Characteristic Temperature Gradient Interval (meters)	Gradient (°C/km)
U-4	114.6	25.37	18.3-114.6	45.2
S1B	153.6	22.76	12.2- 67.1	18.8
			67.1-152.4	21.9
S2B	146.3	23.29	18.3-146.3	50.0
S3	150.3	20.09	12.2-150.3	29.0
S4	152.1	20.16	18.3- 85.3	23.4
			85.3-152.1	34.1
S5	153.7	18.16	18.3-153.6	14.5
S7	151.2	20.05	12.2- 88.4	24.5
			88.4-151.2	29.4
S8	146.6	22.61	18.3-146.6	43.7
S9B	152.4	24.16	12.2- 36.6	63.3
			36.6-149.3	44.4
A1B	146.3	25.05	12.2-146.3	49.0
A2B	152.4	23.01	12.2-152.4	31.7
A3	152.4	27.23	12.2- 61.0	95.4
			61.0- 91.4	68.2
			91.4-121.9	41.2
			121.9-152.4	14.0
A4	140.2	20.25	12.2- 42.7	-4.2
			42.7- 97.5	22.5
			97.5-140.2	29.0
A5	151.5	20.15	12.2-103.6	19.8
			103.6-151.5	30.1
A6B	140.2	22.27	12.2-140.2	39.2
NM1	61.0	-	6.0- 31.0	155.9
NM2	40.0	-	11.0- 21.0	240.9
			25.0- 40.0	159.0
NM3	70.0	-	10.0- 20.0	119.0
			35.0- 70.0	35.5

Table 1 (continued)

Hole Number	Depth (meters)	Bottom Hole Temperature (°C)	Characteristic Temperature Gradient	
			Interval (meters)	Gradient (°C/km)
NM4	100.0	-	10.0- 20.0	98.2
			25.0- 35.0	39.2
			40.0- 60.0	19.3
			70.0-100.0	24.3
NM5	110.0	-	10.0- 20.0	83.7
			25.0- 60.0	45.6
			90.0-110.0	50.1
NM6	20.0	19.1	10.0- 20.0	96.2
NM7	20.0	18.4	10.0- 20.0	93.9
NM8	25.0	-	10.0- 20.0	96.9
			20.0- 25.0	44.4
NM9	35.0	-	10.0- 20.0	97.9
			25.0- 35.0	28.0
NM10	30.0	16.2	10.0- 20.0	107.0
			20.0- 30.0	73.0
NM11	80.0	-	30.0- 40.0	44.2
			40.0- 50.0	20.7
			50.0- 80.0	10.2
X1	76.0	-	15.0- 76.0	54.7
X2	70.0	-	35.0- 70.0	35.5
X3	58.0	-	21.0- 58.0	33.8
X4	40.0	-	12.0- 40.0	161.9
X5	31.0	-	12.0- 31.0	168.2
X6	64.0	-	34.0- 64.0	149.5

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temperature gradient would be 1.8°F/100 ft (33°C/km). If the temperature of the magma body is 1,850°F (1,000°C), corresponding to basaltic composition, then the equilibrium temperature gradient would be 2.9°F/100 ft (52°C/km). In this report, the conservative value of 1.7°F/100 ft (30°C/km) is used to represent regional background conductive heat transfer conditions; gradients must exceed 3.0°F/100 ft (54°C/km) to be considered abnormal.

Anomalously high temperature gradients to moderate depths are reported for holes B9, B15, and X6, whose gradients are 4.0, 3.1, and 8.3°F/100 ft (71.8, 55.5, and 149.5°C/km), respectively. These holes range from 210 to 260 feet (64 to 79 m) deep, and the gradients are reported from far below the zone of influence of seasonal variation. Bottom-hole temperatures of B9 and B15 are not high (72-74°F, or 22-23°C); therefore, these results may indicate largely conductive heat transfer conditions. Unfortunately, no heat flow data are available for these holes. No bottom-hole temperature is available for X6, but the setting of this hole leads one to suspect that the very high temperature gradient represents conductive heat transfer over a warm-water aquifer.

Values in excess of 2.75°F/100 ft (50°C/km) are reported for shallow levels (100 feet or 30 m, or less) of many drill holes in the northeast part of the project area; however, these holes terminate at these shallow depths and it is unknown whether high gradients persist.

In the Chupadera Mountains, very high gradients are reported at shallow levels in B35, A3, and B40 (7.1, 5.3, and 3.9°F/100 ft, or 128.7, 95.4, and 71.4°C/km, respectively). That each of these holes is influenced by convective heat transfer is shown by the isothermal or even reversed (-1.5°F/100 ft, or -26.7°C/km at the bottom of B35) temperature profiles at deeper levels.

Most temperature gradients in the Socorro area change very little with depth, and most values are subaverage to only slightly above average. The La Jencia Creek-Socorro Canyon topographic low is characterized by very low temperature gradients to considerable depth (note especially B21, F4, and B19). Of the 18 points which go as deep as 500 ft (150 m), only 2 (A4 and A5) have higher gradients at 500 ft (150 m) than at 330 ft (100 m); 3 points (A3, B40, and U3) have lower values at 500 ft (150 m). The highest gradient reported at either depth is 2.8°F/100 ft (50°C/km) for hole S2B. NM5 also reported 2.8°F/100 ft (50°C/km) for the interval 295-360 ft (90-110 m); and A1B showed 2.7°F/100 ft (49°C/km) over its entire range of depth to 480 ft (146 m).

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Several of the deeper holes show gradients of approximately 2.2-2.5°F/100 ft (40-45°C/km). These are A6B, B31, B33, S8, and S9B. These values may be representative of the regional gradient in diverse rocks of younger sedimentary and volcanic provenance. If such gradients are projected to 10,000 feet (3 km), at which depth holes probably would be in massive crystalline rock (Precambrian basement or Tertiary intrusive), such temperatures would only be 275-300°F (135-150°C). Such temperatures are unattractive for geothermal exploration.

The temperature profile of the deepest hole, B40, is very illuminating. Gradients at the top of the hole are fairly high, but an isothermal zone (78°F or 25.5°C) at 400-550 feet (122-168 m) represents a warm-water aquifer. Lower in the hole, conductive heat transfer conditions are shown by a straight-line temperature profile and moderate gradients, but another deep warm-water aquifer is represented by another isothermal section (90°F or 32.0°C) at 1,300-1,391 feet (396-424 m).

These relations show that deep water circulation is occurring in the northern Chupadera Mountains, and that high near-surface gradients can be caused by very moderate temperatures at depth. Whether low to moderate gradients in the zone to 500 feet (150 m) can be caused by cool groundwater masking or washing out deeper thermal features is discussed in subsequent sections.

Heat Flow

Computations

Calculated heat flow values for 32 holes in the Socorro area, including one 1,391 feet (424 m) deep, are given in table 2 and shown on plate 7. Two published data points also are shown on plate 7. These heat flow computations were made using a range of likely porosities and assuming water-saturated conditions throughtout. The resulting range of heat flow values takes into account the fact that *in situ* porosities in poorly consolidated sedimentary rocks cannot be measured directly, and usually cannot be estimated closely from drill cuttings. Calculations that assume high porosities yield lower heat flow values than do low porosities, because the thermal conductivity of water is 1.381 thermal conductivity units (10^{-3} cal/cm-sec-°C), whereas the measured thermal conductivity of the rock material ranges from 3.32 to 6.39 TCU. For the data of this study, the difference between high and low porosities generally is 0.5 HFU or less.

Table 2. Heat flow in the Socorro area, New Mexico

Hole Number	Depth Interval, meters	Terrain Correction; %	Temperature Gradient °C/km	Thermal Conductivity[1]	Range of porosities estimated for interval; %	Range of computed heat flow, in HFU[2] minimum porosity		maximum porosity	
B9	9- 75	-5	71.8	4.0[3]	20 - 40	2.22		1.80	
B15	12- 79	0	55.5	4.6[3]	20 - 40	2.01		1.58	
B19	15-115	0	18.6	4.8[3]	20 - 40	0.70		0.55	
B20	39- 73	0	37.9	3.9[3]	5 - 20	1.41		1.20	
B21	18-116	0	8.5	5.2[3]	20 - 40	0.34		0.26	
B22	12- 19	0	33.9	4.3[3]	20 - 40	1.17		0.93	
B23	27- 91	0	41.0	4.1[3]	20 - 40	1.36		1.10	
B30	33-125	0	38.3	5.0[3]	5 - 20	1.81		1.48	
B31	46-152	0	45.4	4.7[3]	20 - 40	1.68		1.32	
B32	33-137	0	31.6	5.5[3]	5 - 40[4]	1.63		1.01	
B33	43-137	0	42.4	4.6[3]	20 - 40	1.54		1.21	
B35	24- 61	0	128.7	4.4[3]	5 - 40[4]	5.38		3.59	
B40	168-274	0	33.1	6.0[5]	5 - 20	1.86		1.49	
	274-396	0	19.2	6.0[3]	5 - 40[4]	1.08		0.64	
F1	18- 98	0	40.1	6.2[3]	20 - 40	1.85		1.37	
F3	49- 85	0	25.2	5.1[3]	20 - 40	1.00		0.77	
F4	24- 96	0	22.2	5.5[3]	20 - 40	0.93		0.71	
U3	15-137	0	41.5	4.6[3]	5 - 40[6]	1.81		1.19	
U4	33-113	0	45.2	4.3	5 - 40[6]	1.85		1.24	
S1B	24- 49	-10	19.0	5.34	20 - 40	0.70		0.53	
	91- 98	-5	22.1	3.72	20 - 40	0.64	0.70[7]	0.52	0.56
	134-140	0	22.1	4.36	20 - 40	0.76		0.61	
S2B	49 -79	-5	50.3	5.48	20 - 40	1.99	2.18[7]	1.51	1.62
	79-110	0	50.3	6.39	20 - 40	2.37		1.74	
	140-146	0	50.3	3.79	1 - 10	1.89		1.72	
S3	12- 79	0	29.2	4.67	20 - 40	1.07		0.84	
	79- 85	0	29.2	4.52	20 - 40	1.04	1.09[7]	0.82	0.85
	122-146	0	29.2	5.14	20 - 40	1.15		0.89	
S4	43- 85	0	23.5	5.75	20 - 40	1.02		0.76	
	91-140	0	34.3	5.28	20 - 40	1.38	1.45[7]	1.06	1.10
	140-152	0	34.3	6.01	20 - 40	1.53		1.14	

Table 2 (continued)

Hole Number	Depth Interval, meters	Terrain Correction; %	Temperature Gradient °C/km	Thermal Conductivity[1]	Range of porosities estimated for interval; %	Range of computed heat flow, in HFU[2] minimum porosity	maximum porosity
S5	67- 91	0	14.6	4.12	20 - 40	0.48	0.39
S7	24- 79	0	24.6	5.28	20 - 40	0.99	0.76
	104-152	0	29.5	5.33	20 - 40	1.20	0.92
S8	30-146	0	43.9	4.80	20 - 40	1.64	1.28
S9B	30- 37	-5	63.6	4.31	20 - 40	2.07	1.65
	98-116	0	44.7	5.49	20 - 40	1.86 } 1.90[7]	1.41 } 1.43
	134-146	0	44.7	5.73	20 - 40	1.93	1.45
A1B	37- 91	-5	49.2	4.56	20 - 40	1.68 } 1.62[7]	1.32 } 1.30
	91-146	0	49.2	3.93	20 - 40	1.57	1.27
A2B	24- 30	0	31.9	5.15	20 - 40	1.26 } 1.13[7]	0.97 } 0.89
	98-110	0	31.9	4.34	20 - 40	1.10	0.88
	128-140	0	31.9	3.94	20 - 40	1.02	0.83
A3	37- 61	0	95.9	4.33	20 - 40	3.30	2.63
	61- 91	0	68.5	4.78	20 - 40	2.56	1.99
	91-110	0	41.4	4.12	20 - 40	1.37	1.10
	122-140	0	14.0	3.97	20 - 40	0.45	0.37
A4	55- 98	0	22.6	4.69	20 - 40	0.83	0.65
	110-116	0	29.2	4.06	20 - 40	0.95 } 0.94[7]	0.77 } 0.76
	134-146	0	29.2	3.93	20 - 40	0.93	0.75
A5	37- 55	0	19.9	5.69	20 - 40	0.85	0.64
	134-140	0	30.3	4.61	20 - 40	1.10	0.86
A6B	31- 85	0	39.4	3.32	20 - 40	1.10 } 1.17[7]	0.92 } 0.96
	116-140	0	39.4	3.89	20 - 40	1.24	1.01

[1] 10^{-3} cal/cm-°C-sec

[2] 10^{-6} cal/cm^2-sec

[3] Averaged value for several samples in interval. Lithology of samples not given.

[4] Wide range of porosities used because it is not known which of several widely differing lithologies was used for thermal conductivity measurements.

[5] Assumed value; not measured.

[6] Wide range of porosities used because lithology is not known.

[7] Averaged over segment of constant temperature gradient and similar lithology.

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Topographic factors have been difficult to calculate for this suite of holes. Although most holes are at lower elevations and on gentler slopes than the Socorro Peak upland, these gentler slopes in turn are an upland plateau above the Rio Grande flood plain. The town of Socorro, 4 miles east of Socorro Peak, is at 4,600 feet. The upper reaches of Socorro Canyon near S9B are at about 5,500 feet. Most of the Socorro Peak block is over 6,000 feet in elevation, locally reaching over 7,000 feet. These topographic relations are highlighted on plate 8. The resultant asymmetric topography exhibits over 2,000 feet on the east slope of Socorro Peak, but only 1,200 feet maximum on the western slope.

Therefore, each hole location has both a local and a regional topographic setting, and is affected by both higher-elevation uplands and the deep valley of the Rio Grande. After several attempts, a set of terrain corrections was developed to take both factors into account. Net effect is nearly zero in almost every case. Where there is a terrain correction, it is reduced to zero by 150 m in depth.

Regional Heat Flow

According to Reiter *et al*. (1975), regional background heat flow in the Socorro area under conductive heat transfer conditions may be 2.5 HFU or greater. Their regional heat flow map is given here as figure 5; it shows five control points within the project area. Detailed data on four of these points (table 3) show that calculated heat flow values of 1.9-2.5 HFU are reported for deep holes with relatively well-known rock porosities and thermal conductivities.

However, the fifth control point in the project area is given as greater than 3.0 HFU (figure 5), although no reference is indicated and no detailed supporting data are given. From its position, this point probably represents two heat flow values of 11.7 and 9.6 HFU, which later were reported by Reiter and Smith (1977) for the east side of Socorro Peak (shown on plate 7 as NM1 and NM2).

As is discussed in the section on Water Chemistry, the east side of Socorro Peak is characterized by circulation of moderately warm groundwater. This, plus the relatively shallow depths reported for NM1 and NM2, lead one to suspect that the high heat flows represent only shallow conductive heat transfer above a moderate-temperature convective system.

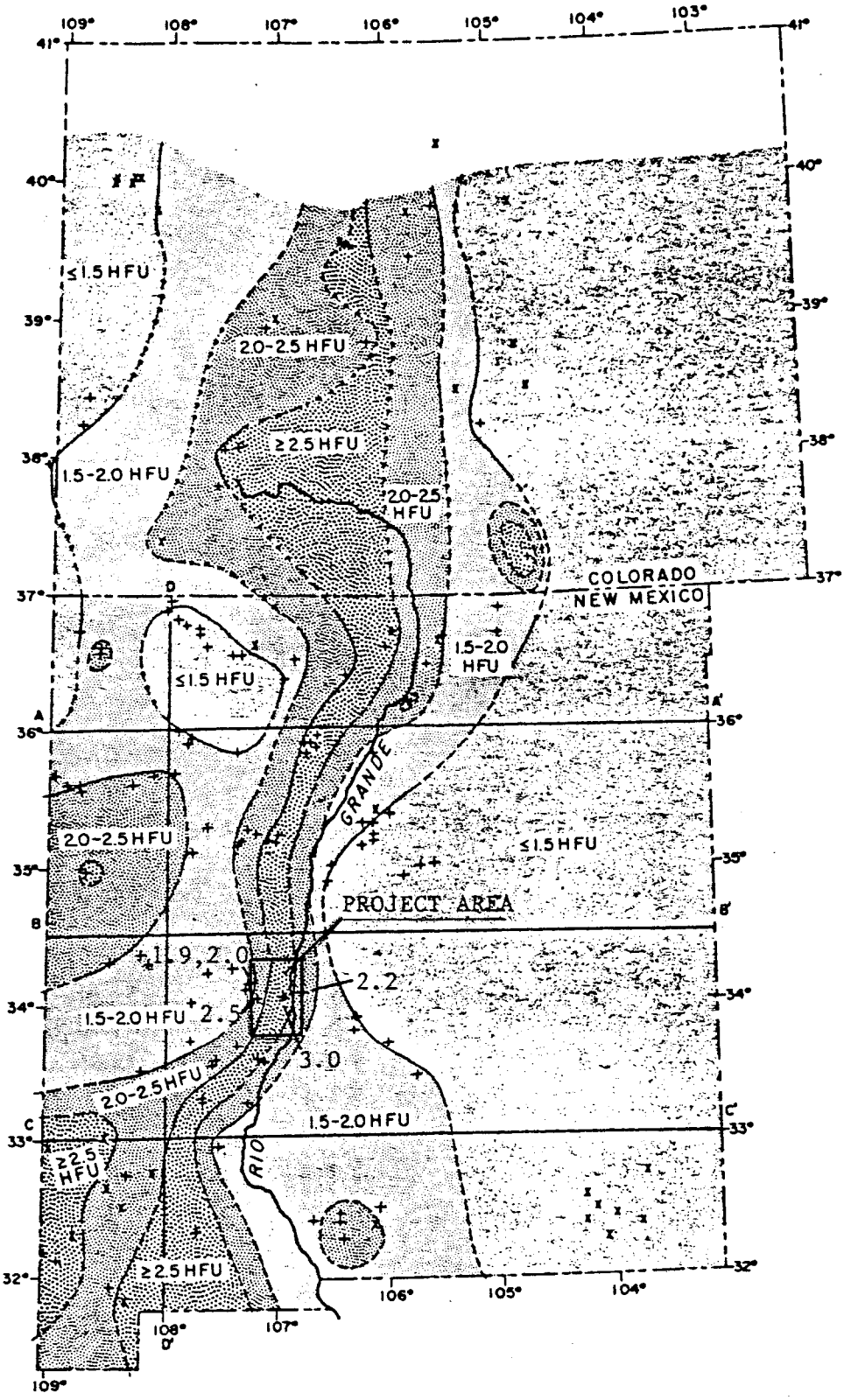

FIGURE 5. Terrestrial heat-flow contour map of New Mexico and southern Colorado. Contour interval, 0.5 HFU. Plus signs indicate control sites measured by New Mexico Institute of Mining and Technology; X's indicate control sites of other investigators. (From Reiter et al., 1975).

Table 3. Heat flow data for control points in the Socorro area, New Mexico (after Reiter *et al.*, 1975)

Locality	North Lat	West Long	Depth Interval (meters)	Temperature Gradient, °C/km	Thermal Conductivity (TCU)	Type of Sample	Calculated Heat Flow	Best Heat Flow Estimate
Chupadera Mesa	34°06'	106°48'	70-130	33.47	6.69	Fragments	2.24	2.20
			130-160	42.61	5.06	Fragments	2.16	
Magdalena/NW	34°09'	107°18'	90-190	43.99	4.31	Core	1.90	1.91
			170-300	40.44	4.73	Core	1.91	
Magdalena/West	34°07'	107°17'	120-180	38.93	5.17	Core	2.01	2.01
North Baldy	34°02'	107°13'	150-210	33.86	5.86	Core	1.98	2.48
			230-280	44.69	6.66	Core	2.98	

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Heat flow values in excess of 2.5 HFU have not been demonstrated for conductive heat transfer conditions in deeper holes in the central part of the Rio Grande rift near Socorro. Instead, background conductive heat flow of 2.0-2.5 HFU seems more likely, and undisturbed values of 1.5-2.0 HFU may be encountered locally.

Discussion

The highest heat flow values reported from the Socorro area are 11.7 and 9.6 HFU from NM1 and NM2, 3.6-5.4 HFU (maximum and minimum porosity values) from B35, 2.6-3.3 HFU from the top of A3, 1.6-2.1 HFU from the top of S9B, and 1.5-1.9 HFU from the top of B40. However, each of these values is disturbed by convective groundwater flow, and does not represent conductive heat transfer conditions. That this is so for A3 and B40 is shown by the decline in heat flow computed for deeper levels (plate 7). Hole B35 has a reversed temperature profile below the interval used in the heat flow computation, which demonstrates groundwater circulation.

Subaverage (less than 2.0 HFU) heat flow values are computed for all other temperature gradient holes in the Socorro area. Many of the values are lower than 1.5 HFU, which cannot represent background conductive heat flow in this region, but rather demonstrates large-scale disturbance by groundwater convection. Most notable are F3, F4, B21, S5, S3, S1B, S7, B22, A5, and B19. These holes are located in an area thought to be affected by groundwater mixing, based on hydrologic and geochemical evidence (see Water Chemistry). That the low heat flows and postulated groundwater movement are not shallow phenomena is shown by the smooth temperature profiles and very low heat flows computed to depths of 280 feet (85 m) or greater, especially in F3, F4, B21, S5, and B19.

Deep circulation of moderate temperature groundwater is demonstrated in B40 in the northern Chupadera Mountains. Here, the bottom-hole temperature is only 90°F (32.0°C) at 1,391 feet (424 m) and the heat flow computed near the bottom of the hole is only 0.6-1.1 HFU.

In summary, regional background heat flow in the Socorro area probably is closer to 2.0 than to 2.5 HFU; and the hypothesis of undisturbed conductive heat flow in excess of 2.5 HFU is unproven. Most of the heat flow values computed for temperature gradient holes in the area are subaverage (1.0-2.0 HFU) and many values are so low

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(less than 1.0 HFU) that they demonstrate large-scale groundwater circulation of moderate temperature, which is in accord with evidence of groundwater mixing developed independently from hydrologic and geochemical data. Six points have computed heat flow greater than 2.0 HFU (maximum 11.7 HFU), but heat transfer by groundwater convection is essentially proven at four of these points and is very likely at the two with the highest computed heat flow. Deep (to 1,391 feet or 424 m) groundwater circulation of moderate temperature (32.0°C) water is observed in the northern Chupadera Mountains from temperature gradient and heat-flow data.

Overall, the heat flow data do not indicate a strong geothermal system in the Socorro area. If a strong heat source exists, it is masked by circulating cool groundwater at moderate depth.

GROUND WATER

A large number of chemical analyses, water temperatures, and determinations of depth to ground water are available for the project area (plate 8). These were compiled from published data (Clark and Summers, 1971; Summers et al., 1972; Summers, 1976) and appear to be relatively complete, in that most springs, windmills, and water wells noted on topographic maps are represented by at least partial data. Because the land on the lower slopes of the Magdalena Mountains and in the La Jencia Creek-Socorro Canyon area is used primarily for grazing, there are not thought to be many unrepresented irrigation or other water wells.

The well depths reported on plate 8 range from 12 m (for #491) to 564 m (for #482), with the average depth about 50 m.

Water levels are shown on plate 8 as elevation relative to sea level, and are assumed to have been measured inside the completed well. In each measurement, it is not known if shallow aquifers were cased off, and the water table is therefore somewhat higher than reported; or if there is much artesian head difference that elevates the measured water surface above the inflow zone. However, the reported water-surface depths made a consistent pattern, so these factors do not appear to be important.

Water-surface measurements were made between 1962 and 1967. Some were made in April, but most were made in June, July, or August, and should represent comparable seasonal recharge-drawdown conditions.

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No long-term changes in groundwater levels are known to affect the area.

Recharge

The amount of water annually available for recharge to the groundwater system in the La Jencia Creek-Socorro Canyon area can be estimated loosely from figures 6 and 7 and data on precipitation given in Summers et al. (1972). Only order-of-magnitude estimates can be made, since available information is insufficient regarding vegetation patterns and evapotranspiration rates.

Arid conditions in the project area are depicted in figure 6, which shows the annual precipitation in the Socorro region generally to be less than 12 in/yr (30.5 cm/yr), except in high mountainous areas. Summers et al. (1972) gave details of the higher precipitation rates for the Magdalena Mountains, with 13.4 in/yr (34 cm/yr) measured at 7,000 feet (2,400 m) and 17.7 in/yr (45 cm/yr) at the crest (10,630 feet or 3,240 m).

Figure 7 shows the surface drainage basin of the project area, including La Jencia Creek above La Jencia Ranch, Nogal Canyon on the west side of the Socorro Peak block, and Socorro Canyon west of Box Canyon in Sec. 31, T. 3 S., R. 1 W. The areas were estimated by graphical techniques to be:

below 7,000 feet (2,100 m) - 264 mi^2 (678 km^2)
7,000-9,000 feet (2,100-2,750 m) = 138 mi^2 (355 km^2)
above 9,000 feet (2,750 m) = 38 mi^2 (98 km^2)

If generous estimates of mean annual precipitation rates are made (12 in/yr below 7,000 feet elevation, 15 in/yr in the zone 7,000-9,000 feet, and 17 in/yr above 9,000 feet), then the total annual precipitation on the La Jencia Creek-Nogal Canyon-Socorro Canyon drainage is 313 x 10^5 acre-ft. If lower precipitation rates are assumed (8, 12, and 15 in/yr respectively), then the total annual precipitation is 2.31 x 10^5 acre-ft.

The fraction of this precipitation which actually reaches the groundwater system is moot. Figure 8 shows that potential evaporation in the Socorro region is several times greater than precipitation, and the lack of perennial streams anywhere in the area except the Rio Grande attests to the general aridity. Also, most of the precipitation at lower elevations results from thunderstorms

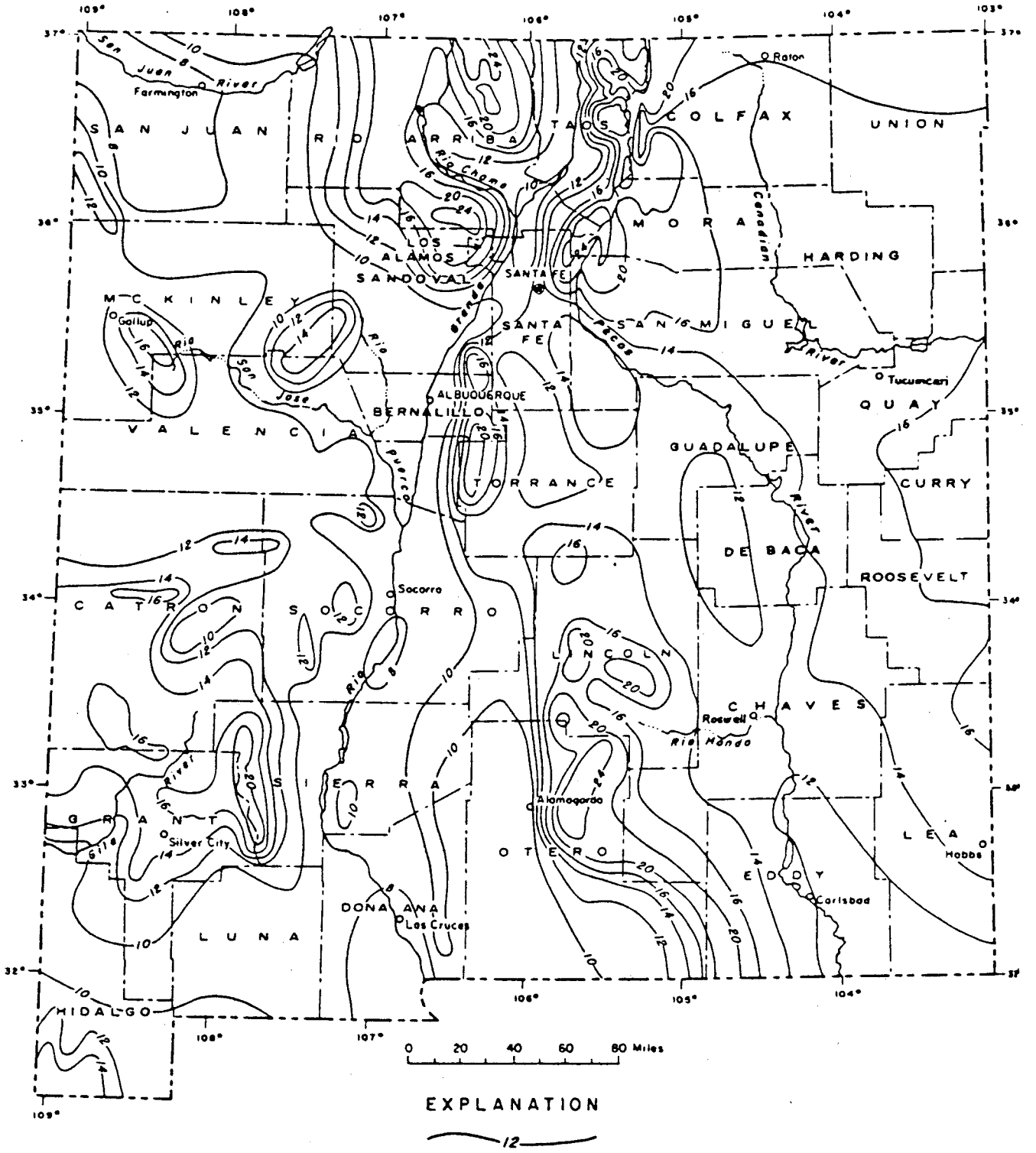


FIGURE 6. Mean annual precipitation, in inches, in New Mexico, 1931-1952.

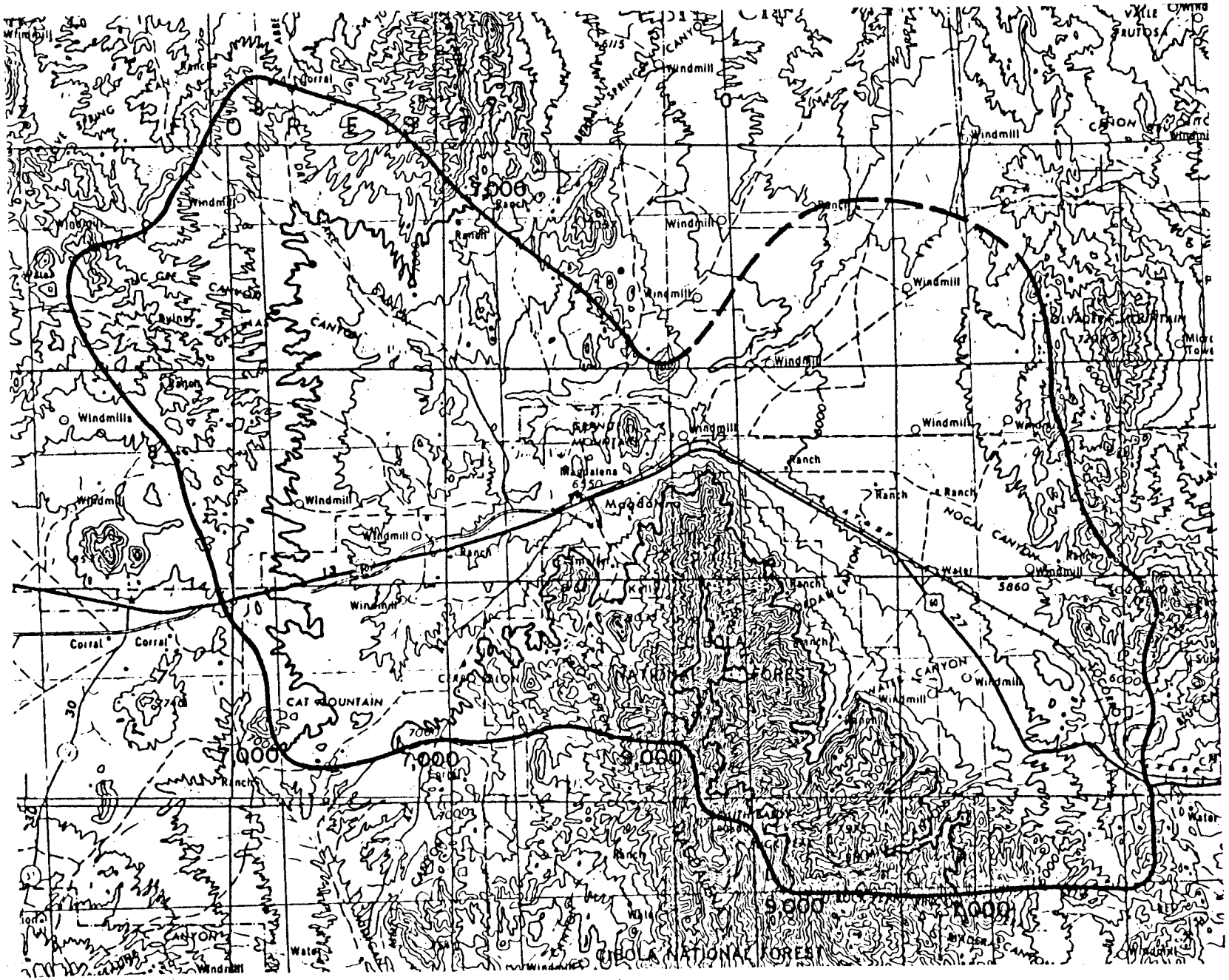
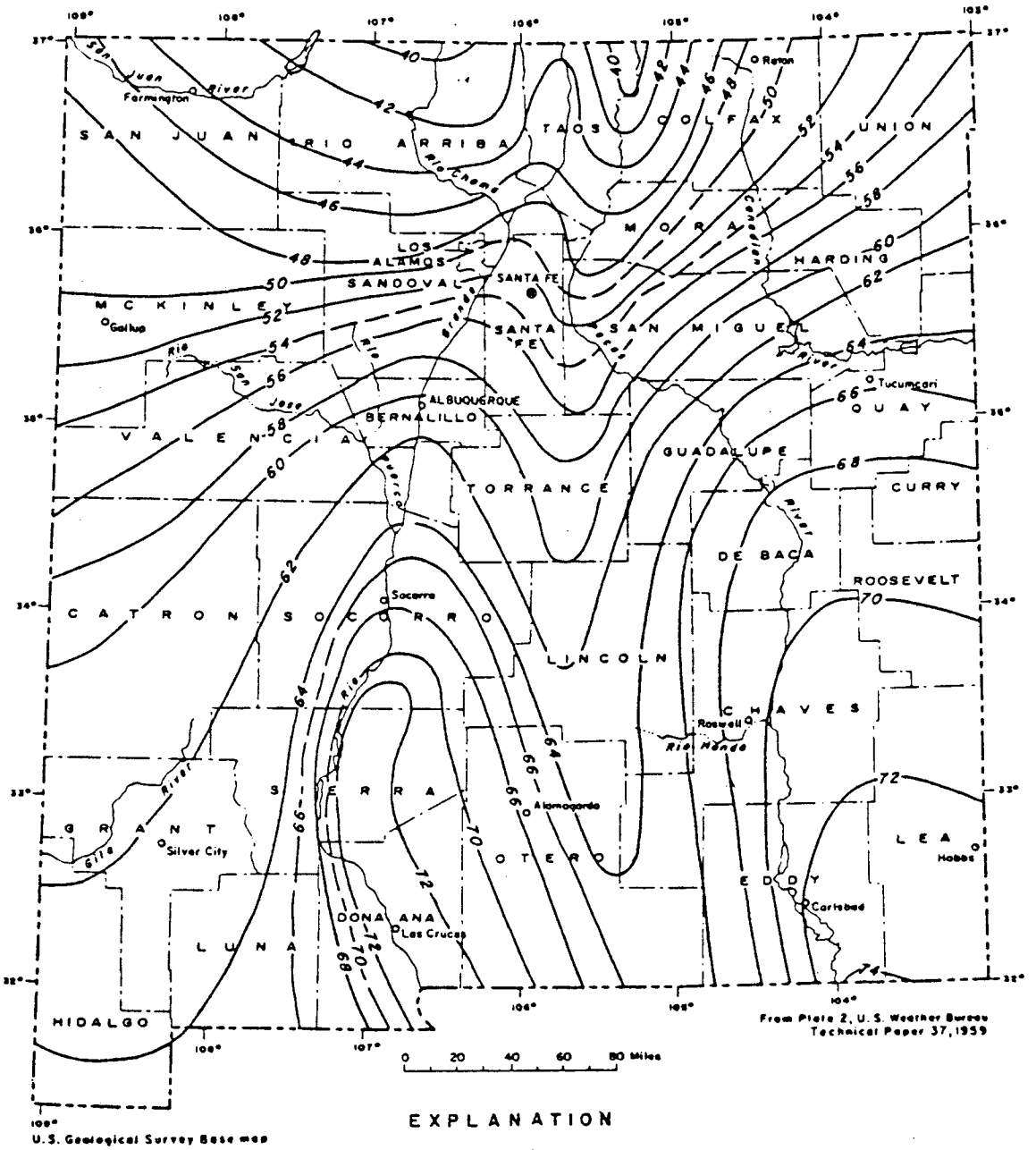


FIGURE 7. Surface drainage areas of La Jencia Creek and Socorro Canyon within the project area.



SEASONAL RESERVOIR EVAPORATION
(Applicable to shallow exposed reservoirs)

Month	Percent of annual	Month	Percent of annual
January	1	July	16
February	1	August	14
March	5	September	12
April	9	October	6
May	14	November	3
June	17	December	2

FIGURE 8. Average annual evaporation, in inches, from shallow reservoirs in New Mexico, 1946-1955.

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during the summer months, when the potential for immediate re-evaporation is greatest. Overall, it seems likely that only 1% to a maximum of 10% of the total precipitation is not immediately re-evaporated, consumed by evapotranspiration, or trapped as soil moisture above the zone of saturation. Under these assumptions, a maximum of 31,000 and a minimum of 2,300 acre-feet of water enters the groundwater system annually. Lacking more precise values, 15,000 acre-feet of annual recharge is assumed, with most of the water entering the west side of the project area.

Recharge is more likely to occur in the Magdalena Mountains and flanking alluvial fans and in the headwaters of La Jencia Creek than at the relatively lower elevations on the east side of the basin.

Direction of Groundwater Movement

In the west part of the project area, the direction of groundwater flow was determined from contours drawn on the measured water-table elevation (plate 8); it appears generally to follow surface-drainage patterns in the Socorro Canyon, Water Canyon-Nogal Canyon, and La Jencia Creek areas. Groundwater from the north and northwest sides of the Magdalena Mountains drains to the northeast, parallel to La Jencia Creek. Along the east flank of the Magdalena Mountains, the water table has a steep slope, falling from 6,300 feet (1,900 m) at the mouths of Garcia Canyon and Water Canyon to an elevation of 5,800 (1,750 m) feet in less than 1.5 miles (2.4 km). Groundwater exits the area at Socorro Canyon and at Nogal Canyon.

The most surprising feature of the water table elevation map is the broad flat area shown in the NE-1/4 of T. 2 S., R. 3 W., the west half of T. 2 S., R. 2 W., and the central part of T. 3 S., R. 2 W. Water table elevations between 5,732 and 5,702 feet (1,748 and 1,738 m) are reported from the north part of 5,726 to 5,720 feet (1,746 and 1,744 m) in the south part, but the location of the groundwater divide is not clearly defined. This flat water table could be caused either by very high transmissivities, leading to quick spreading of ground water throughout the area, or by groundwater rising to shallow levels from deep aquifers and causing a gentle "mound" in the water table.

If the inflections of the water table contours at wells #479 and #200 fairly represent the direction of flow over the flat

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water table, then water at #479 and #462 probably exits the area through Nogal Canyon, whereas water from #464, #463, and #465 probably exits at Socorro Canyon.

On the east side of the project area near the Rio Grande River, few data are available concerning elevation of the water table, but ground water is assumed to drain east toward the Rio Grande.

Water Temperature

The highest temperature reported from the Socorro area is 103°F (39.4°C) from the water well (#367) in Sec. 4, T. 3 S., R. 1 W (plate 8). This marks the north end of a zone of warm water circulation along the east flank of the Socorro Peak block, which also includes Cook Gallery (56°F, or 13.3°C), Socorro Gallery (91°F, or 33.0°C), and Sedillo (Evergreen) Gallery (92°F, or 33.5°C) to the south. These are horizontal infiltration galleries driven westward into the mountain to intercept water that formerly supplied natural springs.

Elsewhere, moderately thermal water is reported from well #233, 84°F (29°C) at 7,000 feet (2,100 m) on the northwest side of the Magdalena Mountains. Mildly thermal water sources are reported to the northeast near Granite Mountain and in the valley between the Magdalena Mountains and the Socorro Peak block, with the warmest being 73°F (23°C) from well #206. Warm springs (maximum 70°F, or 21°C) also are reported near the mouth of La Jencia Creek in T. 1 N., R. 2 E., and a few slightly warm wells occur on the east side of the project area between the Socorro Peak block and the Rio Grande. The warmest is 73°F (23°C) from well #102, 1 mile north of Nogal Arroyo.

Of all these thermal waters, only wells #367 and #233, and Socorro, Sedillo, and Cook's Galleries (springs #33, #34, and #35 on plate 8) are more than 18°F (10°C) above local mean annual air temperature, which ranges from 57.5°F (14.2°C) at Socorro (elevation 4,585 feet, or 1,400 m) to 55.6°F (13.1°C) at Magdalena (elevation 6,538 feet, or 1,993 m). The other apparently thermal waters may represent groundwater circulation to only modest depths in an area of average geothermal gradient, with consequently modest warming.

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Water Chemistry

Published chemical analyses for springs and wells in the Socorro region have been examined. Those samples for which relatively complete data are available are located on plate 8 and summarized on plate 9. Points for which only fragmentary data are available are represented by notations of major ion concentrations.

Tables 4 and 5 list chemical analyses for springs and wells on the east slope of the Magdalena Mountains, the Socorro Peak block, the intervening areas, and the area along the west bank of the Rio Grande. For the west side of the Magdalena Mountains, analyses for spring #56 and well #24 are reported in tables 4 and 5 even though they are outside the project area. No other water sources to the south are thought to have any direct influence on groundwater systems in the project area; they are represented only in summary form on plate 9.

Available chemical analyses are grouped on plate 9 by geographical area and lithology of source rock. These groupings also closely parallel the groupings by water quality, as will be discussed in following sections.

Total Dissolved Solids

Water quality in the project area is good, as is reflected by the fact that most analyzed waters are potable, with total dissolved solids (TDS) less than 500 ppm. The maximum reported value is 2,710 ppm for spring #1 in the La Jencia area, whereas values as low as 75 ppm are reported for the west side of the Magdalena Mountains. Very low TDS values also are reported for the thermal waters of Socorro, Sedillo, and Cook Galleries; in fact the first two have provided all or part of the drinking water for the city of Socorro for more than 100 years.

There is good correlation of TDS by limited geographical areas, as can be seen from plate 9. Very good quality water is found on the west slope of the Magdalena Mountains in an area of Middle Tertiary andesite and rhyolite flows and breccias, where all reported values for TDS are less than 365 ppm, and most are less than 150 ppm. On the east side of the Magdalena Mountains, the Garcia Canyon area, which is underlain by Precambrian granitic and metamorphic rocks, has an average TDS of 325 ppm; and the Water

Table 4. Chemical analyses of springs in the Socorro area, New Mexico

Sample Number	Sample Location	Temperature	concentration in ppm													Na-K-Ca[5]		Quartz C	Quartz A	Chalcedony
			SiO_2	Ca	Mg	Na	K	HCO_3	CO_3	SO_4	Cl	F	B	pH	TDS[1]	β=4/3	β=1/3			
1	1N.2W.7.130	21.1		171.	32.	792.		383		492.	1,032.			7.2	2,710					
2	1N.2W.7.440	19.4		47.	19.	44.		246		56.	22.			7.6	311					
3	1N.2W.8.120	16.1		23.	6.	175.		251		128.	88.			8.0	546					
4	1N.3W.27.440	6.1		50.	12.	39.		198		80.	10.			7.8	290					
5	1S.2W.11.120	9.4		19.	4.	143.		383		32.	14.			8.6	404					
6	1S.2W.11.130	13.9		0.1	-	139.		244		24.	14.			9.0	299					
7	1S.2W.11.130	16.1	21.	1.4	0.1	133.		222	31.	-	16.	1.2		9.3	299[2]					
8	1S.2W.11.130			38.	10.	45.		234		32.	6.			8.4	248					
9	1S.2W.11.130			46.	10.	42.		251		32.	6.			8.5	262					
10	1S.2W.11.130			39.	9.	53.		259		28.	6.			8.5	264					
11	1S.2W.11.140			30.	5.	94.		285		36.	14.			8.5	322					
12	1S.2W.12.140			19.	11.	127.		305		80.	24.			8.6	414					
13	1S.2W.11.420	13.9		37.	7.	84.		300		28.	12.			8.6	318					
24	2S.1W.19.410			50.	12.	67.		308		38.	20.			-	341					
25	2S.1W.30.440	12.8		90.	12.	58.		264		150.	20.			8.1	462					
26	2S.1W.30.440	18.9		89.	11.	62.		268		136.	20.			7.0	452					
27	2S.1W.31.120	13.9		46.	11.	65.		207		104.	16.			8.0	346					
28	2S.1W.31.120	15.0		74.	13.	45.		259		90.	20.			7.8	372					
29	2S.1W.31.140	12.8		60.	16.	47.		254		80.	18.			7.9	348					
30	2S.1W.31.310	16.1		62.	9.	32.		239		40.	16.			7.9	278					
31	2S.2W.35.320			50.	7.	29.		227		10.	14.			8.4	224					
38	3S.1W.06.330			23.	5.	71.		183		48.	24.			8.3	262					
45[3]	3S.3W.10.310	17.2		106.	23.	9.		388		48.	8.			7.8	388					
47	3S.3W.20.420	12.2	19.	97.	18.	17.	2.5	330		78.	6.4	0.2		7.9	403	14	(148)	62	67	29
48	3S.3W.21.340	8.3	22.	59.	6.6	9.0	1.1	213		17.	4.	0.2		7.8	226	0	(134)	67	72	35
49	3S.3W.21.430	10.6	21.	76.	9.5	11.	1.8	269		27.	4.8	0.2		7.5	286	7	(148)	65	71	33
52	3S.3W.27.440	8.9	22.	70.	9.5	10.	1.4	258		23.	3.6	0.2	0.1	8.2	269	3	(140)	67	72	35
53	3S.3W.33.440	7.8	16.	56.	7.2	7.5	1.5	202		19.	2.8	0.1	0.1	-	211	5	(154)	55	62	23
54	3S.3W.34.320		19.	66.	8.4	6.6	1.2	243		21.	2.8	0.2	0.1	7.8	247	x	(146)	62	67	29
56	3S.4W.12.310		35.	21.	2.8	71.		239		8.6	8.2	0.5		8.2	267					

Table 4 (continued)

Sample Number	Sample Location	Temperature	concentration in ppm SiO_2	Ca	Mg	Na	K	HCO_3	CO_3	SO_4	Cl	F	B	pH	TDS[1]	Na-K-Ca[5] β=4/3	Na-K-Ca[5] β=1/3	Quartz C	Quartz A	Chalcedony
60	4S.10W.05.210	17.2		39.	3.	372.		444		476.	42.			8.3	1,154					
Circ. 124																				
03	3S.3W.21.334	10.9		66.	18.	13.	1.8	230		36.	5.			6.7	255	11	(144)			
04	3S.3W.21.442	10.8	22.	69.	18.	12.	1.5	–		30.	6.	0.14		6.9	159[2]	6	(138)	67	72	35
05	3S.3W.21.132	12.5	17.	150.	14.	13.	1.2	260		130.	10.	0.12		7.1	465	x	(121)	57	64	25
06[3]	3S.3W.10.311	19.0	21.	110.	16.	18.	1.3	340		53.	8.	0.08		7.2	397	x	(117)	65	71	33
07	3S.3W.09.341	11.5	17.	100.	13.	11.	1.1	330		28.	9.	2.		7.3	346	x	(124)	57	64	25
08	3S.3W.09.423	14.0	18.	123.	16.	15.	1.1	330		44.	8.	0.		6.9	390	x	(115)	60	65	27
09	3S.3W.05.413	11.0	16.	98.	5.	5.8	1.	210		31.	7.	0.2		7.2	269	x	(139)	55	62	23
17	3S.3W.27.212	16.5	17.	100.	10.	14.	1.8	190		56.	6.	0.02		6.9	300	5	(139)	57	64	25
19	3S.4W.01.432	19.5	8.	9.8	9.8	36.	1.2	180	10.	37.	10.	0.7		8.7	208	39	(112)	32	41	x
33[4]	3S.1W.22.113	33.0		22.0	3.1	52.4	2.73	156.6	0.4	29.5	13.4	0.22		8.35	202	50	(129)			
34[4]	3S.1W.22.131	33.5		18.0	4.9	51.3	4.90	158.6		30.1	12.0	0.29		8.25	201	70	(158)			
35[4]	3S.1W.15.313	13.3	26.	13.	4.0	68.	3.4	158.	3.	42.	14.	0.8		8.4	253	69	(135)	74	78	42

Notes:

[1]Calculated

[2]Major ion not analyzed; calculated value

[3]Spring #45 = Spring #06

[4]From Summers (1976)

[5]Preferred value is underlined. x denotes calculated temperature less than 0°C.

Table 5. Chemical analyses of wells in the Socorro area, New Mexico

Sample Number	Sample Location	Temperature	concentration in ppm SiO_2	Ca	Mg	Na	K	HCO_3	CO_3	SO_4	Cl	F	B	pH	TDS[1]	Na-K-Ca[4] β=4/3	Na-K-Ca[4] β=1/3	Quartz C	Quartz A	Chalcedony
Circ. 115																				
5	1S.1W.14.334	21.1	-	259.	96.	519.	-	264.	-	800.	796.	-	-	7.5	2,602					
8	1S.1W.14.431	21.1	-	110.	31.	181.	-	312.	-	310.	154.	-	-	7.7	942					
11	1S.1W.22.324	21.1	-	171.	49.	264.	-	356.	-	500.	276.	-	-	7.5	1,438					
15	1S.1W.23.331	17.8	-	171.	64.	509.	-	390.	-	780.	472.	-	-	7.7	2,191					
17	1S.1W.23.431	16.7	-	-	-	320.	1.1	351.	-	347.	440.	1.4	0.4	7.8	1,285[2]					
18[3]	2S.4W.01.431	18.0	42.	44.	9.5	33.	1.7	170.	4.	36.	10.	0.7	-	8.7	263	22	(118)	94	96	63
21[3]	1S.1W.25.141	-	28.	75.	10.	93.	-	207.	-	182.	49.	0.4	-	7.4	726					
24	3S.4W.11.321	14.0	46.	50.	5.1	12.	1.5	160.	-	14.	5.	0.15	-	6.7	214	10	(140)	98	99	68
26	1S.1W.26.242	-	53.	154.	43.	202.	-	249.	-	476.	148.	-	-	7.6	1,200					
32	1S.1W.27.434	17.8	-	150.	31.	140.	-	293.	-	420.	92.	-	-	7.6	980					
33	1S.1W.27.442	18.8	-	177.	41.	141.	-	366.	-	420.	128.	-	-	7.3	1,090					
34	1S.1W.27.444	8.8	26.	-	-	110.	-	351.	-	415.	102.	0.3	-	7.6	828					
36	1S.1W.34.422	20.0	-	80.	15.	58.	-	190.	-	152.	52.	-	-	7.8	452					
42	1S.1W.35.142	18.8	-	72.	26.	115.	-	263.	-	248.	44.	-	-	7.8	636					
43	1S.2W.30.121	18.9	-	22.	6.	33.	-	141.	-	18.	12.	-	-	7.9	162					
45	1S.3W.12.131	-	-	42.	-	-	-	-	-	108.	60.	-	-	-	210[2]					
47	1S.3W.33.433	20.0	-	34.	8.	23.	-	156.	-	18.	14.	-	-	7.7	175					
75	2S.1W.02.344	17.8	-	214.	33.	179.	-	430.	-	560.	88.	-	-	7.5	1,289					
81	2S.1W.11.114	21.1	-	121.	26.	85.	-	307.	-	240.	64.	-	-	7.7	690					
96	2S.1W.13.134	17.2	-	179.	42.	117.	-	334.	-	380.	144.	-	-	7.7	1,029					
102	2S.1W.22.141	22.8	-	67.	24.	96.	-	224.	-	240.	28.	-	-	7.5	567					
108	2S.1W.25.123	-	38.	-	-	41.	4.2	192.	-	195.	53.	-	-	7.8	427[2]					
125	2S.1W.35.221	18.9	33.	41.	9.	26.	-	150.	-	48.	16.	-	-	-	248					
130	2S.1W.36.134	20.0	-	38.	11.	45.	-	176.	-	60.	22.	-	-	7.6	264					
147	2S.1W.36.314	22.2	-	40.	12.	46.	-	195.	-	56.	22.	-	-	7.4	274					
190	2S.2W.18.112	20.0	-	34.	8.	32.	-	181.	-	20.	12.	-	-	7.8	196					
192	2S.2W.19.422	17.8	-	30.	9.	24.	-	181.	-	16.	14.	-	-	7.8	184					
195	2S.2W.20.311	-	30.	52.	-	21.	-	172.	-	20.	8.5	0.2	-	7.9	218					
200	2S.2W.34.432	18.9	27.	66.	8.9	16.	1.6	220.	-	16.	20.	-	-	7.6	266	10	(133)	75	79	44
202	2S.2W.35.321	15.0	-	46.	3.	28.	-	190.	-	18.	12.	-	-	8.2	202					

Table 5 (continued)

Sample Number	Sample Location	Temperature	concentration in ppm SiO_2	Ca	Mg	Na	K	HCO_3	CO_3	SO_4	Cl	F	B	pH	TDS[1]	Na-K-Ca[4] β=4/3	Na-K-Ca[4] β=1/3	Quartz C	Quartz A	Chalcedony
203	2S.2W.35.323	15.6	-	59.	9.	20.	-	200.	-	16.	34.	-	-	7.9	238					
206	2S.3W.01.322	22.8	-	26.	7.	35.	-	161.	-	18.	14.	-	-	7.9	180					
208	2S.3W.07.433	21.1	-	67.	15.	-	10.	234.	-	28.	20.	-	-	7.6	257					
209	2S.3W.11.333	20.0	27.	30.	4.1	19.	1.3	132.	-	17.	4.4	-	-	7.9	169	18	(124)	75	79	44
215	2S.3W.24.411	-	-	35.	9.	35.	-	190.	-	20.	14.	-	-	8.3	208					
217	2S.3W.25.133	-	-	34.	11.	25.	-	171.	-	20.	16.	-	-	7.7	192					
218	2S.3W.27.223	22.8	-	44.	10.	18.	-	166.	-	22.	22.	-	-	7.8	199					
221	2S.4W.12.341	17.8	-	64.	19.	-	29.	244.	-	64.	24.	-	-	7.1	322					
227	2S.4W.23.321	-	-	67.	16.	25.	-	229.	-	32.	18.	-	-	7.3	272					
354	3S.1W.02.241	-	-	98.	25.	115.	-	310.	-	292.	32.	-	-	7.6	717					
362	3S.1N.02.441	-	48.	87.	23.	232.	-	358.	-	400.	70.	0.3	-	-	1,039					
367	3S.1W.04.433	39.4	23.	68.	2.1	626.	38.	83.	-	163.	945.	1.1	0.6	7.7	1,908	166	(146)	69	74	37
368	3S.1W.07.314	16.1	-	83.	21.	53.	-	224.	-	152.	48.	-	-	7.4	469					
373	3S.1W.11.212	-	32.	65.	6.	38.	1.7	158.	-	106.	16.	0.6	0.1	7.6	344					
377	3S.1W.11.214	-	35.	115.	13.	69.	3.4	220.	-	228.	53.	0.5	0.2	7.2	627	29	(119)	86	89	55
436	3S.1W.14.234	18.9	39.	-	-	43.	3.1	169.	-	66.	18.	0.7	0.1	-	254[2]					
442	3S.1W.16.323	-	27.	20.	4.6	56.	3.	163.	-	36.	14.	-	-	7.6	242	132	(55)	75	79	44
458	3S.1W.26.311	-	43.	-	-	191.	-	162.	-	-	234.	0.5	-	7.6	550[2]					
459	3S.1W.27.331	-	38.	-	-	61.	3.2	225.	-	113.	23.	0.8	0.1	7.9	352[2]					
462	3S.2W.08.424	17.8	-	61.	8.	40.	-	278.	-	24.	14.	-	-	7.7	286					
465	3S.2W.23.123	17.8	-	50.	7.1	-	-	180.	-	-	-	-	-	7.6	147[2]					
490	3S.3W.23.221	15.0	22.	101.	14.	14.	1.2	338.	-	49.	6.	-	-	7.7	376	x	(121)	67	72	35
497	3S.3W.25.111	-	-	62.	12.	19.	-	229.	5	34.	10.	-	-	8.5	254					
498	3S.3W.26.113	-	-	54.	9.	15.	-	188.	10	20.	8.	-	-	8.7	205					
501	3S.3W.34.332	-	-	65.	10.	10.	-	237.	-	10.	15.	-	-	7.8	228					
552	4S.1W.23.121	-	38.	-	-	82.	-	100.	-	113.	154.	0.2	-	-	437[2]					

Notes:
[1] Calculated
[2] Major ions not analyzed; computed TDS minimum value
[3] From Circular 124
[4] Preferred value is underlined. x denotes calculated temperature less than 0°C.

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Canyon area, which is underlain by volcanic rocks of Oligocene and Miocene age, has lower average TDS (261 ppm). At the north end of the Magdalena Mountains around Granite Mountain average TDS is 324 ppm, which includes one value significantly higher than the other 4 analyses.

Curiously, very low TDS values are reported to the east in the Strozzi Ranch area. The average value for 10 analyses is 188 ppm, and only 2 analyses are above 200 ppm. These are much lower than either average values or the majority of individual water analyses to the west; and they demonstrate that groundwater in the Strozzi Ranch area cannot be direct, undiluted recharge from the Magdalena Mountains, because it is hard to devise a believeable process whereby low concentrations of calcium and bicarbonate ions can be removed from groundwater at low temperatures without abundant development of travertine. Instead, groundwater in the Strozzi Ranch area may represent a mixture of recharge from the Magdalena Mountains with a more dilute component from some other source, as is discussed in a later section.

Numerous analyses are available for water in the Socorro Peak block. Average TDS is 295 ppm, and the lowest value for a complete analysis is 202 ppm (well #202). These higher TDS values, as well as groundwater flow patterns discussed in the section on Direction of Groundwater Movement, makes it unlikely that recharge from the Socorro Peak block causes the low observed TDS in the Strozzi Ranch area.

To the north, a group of springs in the San Lorenzo arroyo area has an average TDS of about 351 ppm. Springs in the La Jencia drainage have very widely differing but higher (290 to 2,710 ppm) TDS.

On the east side of the project area, wells in the Lemitar area produce more mineralized water, with an average TDS value of 994 ppm. Somewhat better-quality water is produced in the vicinity of Socorro between the Socorro Peak block and the Rio Grande, where the average value is 558 ppm, although values as high as 1,154 ppm are reported from this area.

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Composition of Dissolved Solids

Anion Composition

With very few exceptions, bicarbonate ion dominates the anion composition of groundwater in the San Lorenzo and Socorro Peak blocks and all areas to the west. Sulfate ion is commonly 3 to 10 times less abundant (by weight percent) than bicarbonate ion, and chloride ion is insignificant. These relative abundances are very typical of cool groundwater in this region, and in general typify youthful meteoric recharge.

Exceptions to this ranking for the western part of the project area include well #367 on the east side of the Socorro Peak block, where chloride ion dominates and bicarbonate ion is relatively less important. Springs in the La Jencia area have somewhat greater sulfate content, and one anomalous spring (#1) has predominant chloride.

On the east side of the project area, many of the mineralized wells in the Lemitar area have higher sulfate ion content than bicarbonate ion, and one well (#5) has a relatively high proportion of chloride ion. Wells in the Socorro area also tend to have somewhat more abundant sulfate than the groundwater areas to the west. At the south end of the Socorro area, well #522 has dominant chloride. Sulfate may derive from weathering of volcanic rocks or may come from gypsiferous or lacustrine or evaporite beds of any period. Sulfated waters usually represent longer travel- or residence-time underground than do the very dilute bicarbonated waters.

Cation Composition

Calcium is by far the most abundant cation in ground water on the east slope of the Magdalena Mountains and around Granite Mountain. Sodium and magnesium concentrations are about equal, with no strong trends recognizable in these data. Anomalously high potassium contents are shown at wells #332 and #208; however, few potassium analyses are available and the distribution of this ion is not well known.

In the Strozzi Ranch area, calcium is the dominant cation in all samples except #43 and #206, which have somewhat more sodium than calcium. In all the other samples, sodium is the second most abundant cation, and magnesium is much less significant. Similar

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patterns are observed in the La Jencia area, except that sodium predominates in the anomalous water at spring #1 and also at spring #3.

The group of springs in the San Lorenzo area show very similar patterns of cation abundances. Sodium predominates and calcium is second most abundant; the relative proportions of cations are similar for all samples. These relations, along with fairly similar TDS, suggest that the springs produce from a homogeneous water source.

In the Lemitar area, the highly mineralized (TDS greater than 1,000 ppm) waters show both calcium-dominated and sodium-dominated compositions. Magnesium is a minor component in all cases where analyses are given.

In the Socorro area, sodium dominates in all samples except wells #373 and #377, which have higher calcium. In well #459, potassium is listed as the second-most abundant cation but this may be spurious, because calcium and magnesium values were not reported in the analysis.

Whereas abundant calcium and magnesium characterize cool meteoric waters, dominant or abundant sodium and potassium usually are indicative of older, deeper-circulation waters. Chloride also is typical of deeper and older sources, possibly including connate waters in Paleozoic marine sediments and/or metamorphic water derived from Precambrian- to Mesozoic-age rocks.

Comparison Between Different Areas

Relative composition of dissolved solids of ground water in the Socorro area is displayed in plate 10. These diagrams are expressed in percentages of equivalents per liter, rather than weight percent, and show more clearly the chemical characteristics of the water.

Plate 10 shows that the cation and composite plots for waters on the east flank of the Magdalena Mountains (Garcia Canyon and Water Canyon areas) define a distinct field of values that is different from all other groundwaters in the area. The anion composition of the east Magdalena water sources also forms a distinct field, but it is overlapped by the anion composition of samples from the San Lorenzo area.

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The anion and cation compositions of water samples from the Strozzi Ranch area also form coherent fields, which are offset slightly from the east Magdalena water sources, and imply that the observed dissolved-solids compositions could be formed by enrichment of east Magdalena Mountains ground water in chloride and sodium plus potassium. This might come by upwelling of chlorided water from a deeper source, which may be either thermal or non-thermal.

Samples from the Socorro Peak block show scatter in both the anion and cation compositions and in overlap with waters from other areas. However, the composition of water from well #367 clearly is anomalous, being more chlorided than any other sample; its sodium-potassium content is comparable only to spring #60, which lies in the same geographical trend as the warm-water zone on the east side of the Socorro Peak block (plate 9). Cook, Sedillo, and Socorro Galleries and well #442 have closely similar compositions. Well #442 is 1 mile west of Socorro Gallery, but its temperature is not known.

On the east side of the project area, the anion composition of wells in the Lemitar area defines its own broad field, but the cation composition is similar to many other waters.

Water sources in the Granite Mountain, La Jencia, and San Lorenzo areas show much scatter of composition, indicating that several different water types are present in these areas.

Mixing Models

In this section, the groundwater in the Strozzi Ranch area is discussed in more detail, and qualitative limits are set for possible inflow from a deep aquifer.

Five analyses for four springs in Jordan Canyon and Garcia Canyon on the east slope of the Magdalena Mountains are given in table 4 and summarized on plate 9. Averages of TDS and six major ions are shown in table 6 (Composite A); this composition may be taken to represent groundwater recharge from the northeast side of the Magdalena Mountains to the La Jencia drainage area. As can be seen from the water-table contours on plate 8, the recharge moves northeast toward wells #217 and #218, and then probably to the northeast or north.

The calculated TDS of Composite A is 358 ppm, which is 80% higher than that reported for wells #218 or #217, the sample points

Table 6. Major ion and TDS compositions of ground water and calculated mixing components, east Magdalena Mountains and Strozzi Ranch area.

	Ca	Mg	Na	HCO_3+ CO_3	SO_4	Cl	TDS[1]	Water Type
	in ppm							
Composite A[2]	107	15	12	320	41	8	358	Ca>>Mg>Na HCO_3>>SO_4>>Cl
Well #217	34	11	25	171	20	16	192	Ca>Na>Mg HCO_3>>SO_4>Cl
Deep Component at 70% of #217	3	9	31	107	11	19	121	Na>>Mg>Ca HCO_3>>Cl>SO_4
at 80% of #217	16	10	28	134	15	18	150	Na>Mg>Ca HCO_3>>Cl>SO_4
at 90% of #217	26	11	26	154	18	17	174	Na=Ca>Mg HCO_3>>SO_4=Cl
Well #206	26	7	35	161	18	14	180	Na>Ca>>Mg HCO_3>>SO_4>Cl
Deep Component at 80% of #206	6	5	41	121	12	16	136	Na>>Ca>Mg HCO_3>>Cl>SO_4
at 90% of #206	17	6	38	143	15	15	160	Na>Ca>Mg HCO_3>>SO_4>Cl
at 95% of #206	22	7	36	153	17	14	170	Na>Ca>>Mg HCO_3>>SO_4>Cl
Well #43	22	6	33	141	18	12	162	Na>Ca>>Mg HCO_3>>SO_4>Cl
Well #462	61	8	40	278	24	14	285	Ca>Na>>Mg HCO_3>>>SO_4>Cl
Composite B[3]	78	12	12	246	39	6	285	Ca>>Na=Mg HCO_3>>SO_4>>Cl

[1]Calculated

[2]Average of 15 analyses. Note that the TDS value is also an average, not the sum of the averaged major ions.

[3]Average of 14 analyses.

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closest to the Magdalena Mountains. These wells are moderately deep (420 and 280 feet, or 128 and 85 m, respectively) and the water surface in #218 is 347 feet (106 m) below land surface; given the aridity of the area, it is very unlikely that the lower TDS reported here is caused by direct infiltration of precipitation.

Tables 4 and 5 and plate 9 show that groundwater in the Strozzi Ranch area is somewhat enriched in sodium and slightly enriched in chloride relative to groundwater in the Jordan Canyon-Garcia Canyon areas. Such slight changes in relative concentrations can be caused by ion exchange and absorption processes as the groundwater percolates through the alluvial fill; but the decrease in TDS cannot easily be caused by such processes. The low TDS content is caused either by mixing of recharge from the Magdalena Mountains with groundwater of lower TDS, or having the wells in the Strozzi Ranch area tap an unmixed aquifer not associated with present-day recharge.

Table 6 shows the composition and calculated fraction of theoretical mixing components which could produce the observed groundwater composition from Composite A. These calculations are intended only as guidelines, since no provision is made for any change in the composition of Composite A during eastward percolation through the alluvium. Also, no estimate can be made of reservoir temperatures or the fraction of geothermal fluid that might be present, as no silica or potassium analyses are available and thus neither the SiO_2 nor the Na-K-Ca geothermometer can be applied.

It is uncommon for cool or warm groundwater in an alluvial basin in an arid region to have TDS lower than 100 ppm; therefore, this value can be taken as the lower limit of a potential mixing component. The upper limit is the observed TDS at the wells in the Strozzi Ranch area.

Table 6 shows that the observed water composition at well #217 can be explained as a mixture of 70-90% 121-174 ppm water with 10-30% fraction of Composite A. The water composition at well #206 can be explained by 80-95% fraction of 136-170 ppm water with 5-20% fraction of Composite A.

The observed composition at well #43 is so close to the calculated composition of the deep component at well #206 that it may represent this aquifer (TDS = 162 ppm) without admixture of recharge from the Magdalena Mountains or Socorro Peak block.

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Thus, the wells in the Strozzi Ranch area mainly produce water with TDS 150-170 ppm, affected by some mixture with recharge water of higher TDS. The low TDS water is of the sodium-bicarbonate type, as is shown in table 6.

Water at well #462, in the south part of the Strozzi Ranch area, may represent westward groundwater flow without mixing with another water source. At 286 ppm, the TDS of this sample is lower than some analyses of springs and well waters in the Magdalena Mountains, but arithmetic averages of TDS and of the six major ions of all water sources in the Water Canyon surface-drainage basin gives results closely comparable to the composition at #462 (table 6).

Geothermometry

Silica Geothermometer

Generally low values of silica were found in the available analyses (maximum 53 ppm for well #26); and correspondingly low reservoir temperatures are calculated (table 4 and 5); but these should be used with caution because low concentrations of silica may be metastable.

Reservoir temperatures that assume equilibration with quartz show no significant difference between calculations for conductive or adiabatic cooling of the water. Calculations assuming equilibration with chalcedony gave lower results, and calculations assuming equilibration with amorphous silica gave unreasonably low temperatures (less than observed outlet temperature) and are not considered further.

The highest calculated temperatures are 201-210°F (94-99°C) for wells #18 and #24, which are on the northwest side of the Magdalena Mountains. In the Socorro area, one well (#377) has a calculated temperature of about 190°F (88°C).

Many wells, including #367 and #442 in the Socorro Peak block and #200 and #209 in the Strozzi Ranch area, have calculated temperatures in the 167-174°F (75-79°C) range. Of the thermal springs, Cook Gallery and Socorro Gallery also yield reservoir temperatures of 167-174°F (75-79°C).

Alkalai Geothermometer

Because relatively few of the available analyses give potassium values, the Na-K-Ca geothermometer described by Fournier and

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Truesdell (1973) can be applied to only a few data points. Results are given in tables 4 and 5.

The highest computed reservoir temperature is 295°F (146°C) for well #367 on the east side of the Socorro Peak block, which is very much higher than the 156-165°F (69-74°C) computed by the silica geothermometer for this sample. The disagreement may indicate that a thermal component has mixed with cool, dilute water to yield lower silica concentrations and consequently lower calculated reservoir temperatures. However, this is speculative.

Reservoir temperatures calculated by the Na-K-Ca method for Socorro, Sedillo, and Cook Galleries and well #442 are 122-158°F (50-70°C), very close to the results calculated by the silica geothermometer. This close agreement plus their low observed TDS, argues strongly against mixing of a thermal component with dilute groundwater. Instead, the water issuing from these springs apparently last equilibrated at temperatures considerably below 212°F (100°C).

Anomalously low (from less than 0 to 14°C) temperatures are computed by the Na-K-Ca method for springs #47-54 and #04-19 in the Magdalena Mountains. These very low results probably represent disequilibrium conditions, where cool groundwater either does not reside at depth long enough to reach thermally appropriate chemical equilibrium, or obtains excess Ca and/or Na from connate waters or evaporite beds.

Zones of Thermal Water Circulation

Available hydrochemistry and hydrology indicate that the most marked zone of thermal water circulation occurs along the east side of the Socorro Peak block. This includes Sedillo, Socorro, and Cook Galleries, as well as well #367 (plate 8). To the north, data are scanty, but the relatively high temperature gradients reported in holes B15 and B9 may indicate similar warm water circulation. As can be seen from plate 1, NNW-trending faults along the east side of the Socorro Peak block may provide permeable channelways for the thermal water.

Elsewhere, very mildly warm water (90°F, or 32.0°C) is moving at a depth of 1,391 feet (424 m) in hole B40 in the northern Chupadera Mountains. In the southern part of the Socorro Peak block, well #442

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has hydrochemical characteristics similar to the thermal springs one mile east, but its temperature is not known.

Of the available temperature and hydrochemical data, only well #367 in Sec. 4, T. 3 S., R. 1 W. gives any indication of a thermal component in excess of 212°F (100°C). The anomalous TDS and high reservoir temperatures calculated for this well by the Na-K-Ca method indicate the possibility of a deep, hot component in the water. However, single-point anomalies are as questionable and as subject to misinterpretation in hydrochemistry as in any other kind of survey; and without supporting data, it cannot be concluded that a strong hydrothermal anomaly has been demonstrated.

The thermal waters at Socorro, Sedillo, and Cook Galleries are weak features. Their very low TDS, relatively mild temperatures, and low (122-158°F, or 50-70°C) calculated reservoir temperatures, which were derived by both the silica and Na-K-Ca geothermometers, can all be explained by circulation to modest depth in a background temperature-gradient regime of 1.7°F/100 ft (30°C/km).

The source of recharge for the water of Socorro, Sedillo, and Cook Galleries has not been determined clearly. TDS is somewhat lower than in most analyses in the apparent recharge area, the Magdalena Mountains; also the composition of TDS is somewhat different. However, the springs cannot represent water from long-term storage, because tritium (^3H) concentrations in Socorro Spring waters during the period 1957-1959 show sharp increases, apparently representing precipitation contaminated by hydrogen bomb tests no more than 4 years previously (Holmes, 1963). As was discussed in the section on Recharge, the Socorro Peak block apparently contributes little recharge to the groundwater system.

Therefore, the thermal springs at Socorro represent groundwater which has moved relatively quickly from the Magdalena Mountains and been warmed to a maximum of about 158°F (70°C). Surface elevations highlighted on plate 8 show that this path is reasonable.

The zone of deep water upwelling postulated for the Strozzi Ranch area, on the other hand, may represent movement from long-term storage. The water appears to be cool, since subaverage temperature gradients and heat flow are observed in this area. Very slightly warm temperatures for the given elevation are reported for wells #190 and #206 (68-73°F, or 20-23°C), but sampling conditions are unknown and sun-warming of the water or other spurious effects cannot be ruled out.

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DISCUSSION

The Socorro area has been mentioned widely as an attractive geothermal prospect. The principal lines of evidence for supposing the area to have good potential are: seismic evidence for present-day midcrustal and shallow magma bodies, reports of high regional heat flow (greater than 2.5 HFU) based largely on two very high measurements at a single locality, Tertiary rhyolitic and basaltic volcanism and possible caldera formation, thermal springs, and modern faulting and deformation.

However, the proprietary temperature gradient and heat flow data of Gulf Mineral Resource Company and Sunoco Energy Development Co. suggest average to subaverage temperature conditions at depth. When integrated with published data, no potent heat source or strong hydrothermal convection system can be identified. In fact, if such heat sources or convection systems are present, they are weak enough to be effectively masked by moderate volumes of circulating cool groundwater.

The lack of favorable temperature data calls into review the three basic components of a geothermal system: heat source, reservoir, and water as a medium to transport the heat.

Heat Source

Unlike most geothermal prospect areas, the Socorro region has direct evidence of present-day magma in the subsurface. The seismic data unequivocally show a zone of low rigidity, which apparently can only be liquid magma or a zone of partial melt, at a depth of about 12 miles (19 km). However, the immediate project area is not unique in having this magma body, because the well-known low-rigidity zone extends at least 35 miles (56 km) north of Socorro, and another low-rigidity zone at comparable depth recently has been recognized 15 miles (25 km) east of Socorro (Olsen et al., 1979).

That these magma bodies are quite recent seems likely from the fact that they behave as partially or entirely liquid, despite being very thin (average about 3,000 feet, or 1 km) compared to areal extent. Conversely, relatively recent intrusive bodies may be present, which have solidified but still are hot. Such bodies would act rigidly to seismic waves and might not be detected in

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these studies, depending upon assumptions made regarding deep crustal density.

The existence of present-day magma at mid-crustal levels does not guarantee that enough heat is present at shallow crustal levels to drive a significant hydrothermal convection system. First, if the mid-crustal magma bodies have been injected recently, there may be a substantial time lapse (tens of thousands of years) before heat moves by conduction from 12 miles (20 km) to 3 miles (5 km), where large-scale interaction with groundwater could take place.

Second, even if equilibrium conductive heat transfer has been established by earlier intrusions or if the general isotherms at 12 miles (20 km) depth are near 1,800°F (1,000°C), the regional conductive temperature gradient would be about 2.8°F/100 ft (50°C/km). Gradients of this magnitude are not unusual, and unless hydrologic convection is available to transfer the heat to shallow levels, a moderately high temperature gradient like this does not guarantee an attractive target. In such conductive heat transfer conditions, holes would need to be 10,000-13,000 feet (3-4 km) deep to reach temperatures in the 300-400°F (150-200°C) range.

In other geothermal areas, young (less than 1 m.y.) silicic volcanics or very young (less than 0.1 m.y.) basaltic volcanics have been cited as evidence for shallow crustal igneous bodies that may act as heat sources to geothermal systems. In the Socorro area, the youngest known rhyolitic units are 7 m.y. and the youngest basalt unit is 4 m.y. These are much too old to affect the present-day thermal regime.

Small shallow magma bodies postulated to exist in the south part of the Socorro Peak block from microseismic data are thought to contain very small fractions of magma; their influence on hydrothermal circulation is moot.

Water Circulation

In almost every geothermal system discovered to date, the local or regional groundwater area shows distinctive chemical patterns reflecting the influence by a high-temperature regime at depth. This influence may appear also as elevated temperatures of springs and wells and in flow patterns that show upwelling from deep sources.

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Much information has been developed for this report on the flow patterns and chemistry of groundwater in the Socorro area, but no strong thermal component has been identified with assurance. Only well #367 on the east side of the Socorro Peak block with Na-Cl type water, has a good possibility with evidence of having equilibrated chemically at temperatures above 212°F (100°C).

Conversely, of the recognized thermal springs near Socorro, their temperature, composition, and TDS is entirely consistent with modest warming by circulation to moderate depth under a temperature-gradient regime of only 1.7-2.8°F/100 ft (30-50°C/km). This is compatible with the deeper temperature gradient data used in this report. Other authors have suggested that these springs are a priori evidence of a geothermal system; detailed hydrology and hydrochemistry shows this assumption to be unconvincing.

Evidence of deep water circulation was found in the La Jencia Creek-Socorro Canyon area on the west side of the project area; but the hydrochemical, temperature gradient, and heat flow data imply that this circulation is of subaverage temperature, representing rapid flow through porous rocks at depth, without thermal re-equilibration. This tends to discourage further exploration efforts in the area.

Reservoir

Reservoir potentially is present beneath many parts of the Socorro area, especially as the Paleozoic limestones could have both fracture and solution-cavity permeability, and virtually all of the units except the fine-grained Popotosa formation could support fracture permeability.

However, pending determination that significant thermal water is present, the question of reservoir cannot be discussed in detail.

CONTINUED ACTION

It can be expected that various academic or institutional researchers will perform further seismologic and geoelectrical studies of the probable magmatic zone. These studies may help to resolve questions of dimension, exact location, fluid percentage,

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temperature and deep roots of the presumed magmatic bodies. Similarly, there may continue to be hydrologic and/or hydrochemical measurements of particular springs or well waters, in the attempt to identify gases, solutes or isotopes of magmatic origin. Despite the detailed geologic mapping that exists in the Socorro area, a broadly acceptable geologic picture is not yet available.

Briefly, further geologic mapping in the region is needed because identified faults do not agree with the boundaries of presumed Tertiary volcanic cauldrons, and because the resulting cross-sectional structure is contrived and unconvincing. Indeed, decent subsurface geology would require both deep drilling and detailed seismic reflection surveys, both of which are very expensive, and are not likely to occur unless the geothermal prospect is upgraded by work presently underway. Complexity of the subsurface section, and the probability of encountering high-velocity units at variable (and possibly shallow) depth, tends to preclude active seismic profiling at this time. Cost alone would argue against such a study.

The value of shallow gradient drilling accomplished to date is clear. However, further shallow drilling is likely only to add detail to a picture that already is obvious, and not to resolve the deeper regime. Deeper drilling (say to 2,000 or 2,500 feet) will be expensive and complex because of widely varying lithologies and aquifer characteristics at depth, but such drilling offers the only immediate potential for: (a) resolving questions of deep hydrologic flow and temperature, (b) determining deep temperature gradient, and (c) observing deeper geologic structure and stratigraphy. However, there is no assurance that holes even to 2,500 feet will penetrate beneath the principal meteoric-recharge aquifer. That is, holes to 2,500 feet may observe only another portion of the aquifer-aquiclude system represented by alternating isothermal and high-gradient zones.

Costs for such holes, at an average of $40 per foot, might be $80,000 to $100,000, exclusive of permitting, data evaluation and management. The value of data to be obtained must be weighed against other budgetary considerations, and against the less-than-first-class nature of the prospect.

If no deep gradient drilling is done, the project probably will remain in a second-class limbo: not abandoned, because of its apparent magmatic heat source, but not attractive enough to do more than pay yearly rentals. The property under lease might best be handled through a farm-out operation, with the recipient obligated to drill a series of 2,000-2,500 foot gradient holes. As mentioned

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above, the apparent magmatic heat source precludes full abandonment of the prospect at this time.

Should deep gradient (2,000-2,500 feet) holes be considered, it is recommended that at least two be drilled. Reasonable locations for these would be:

a. near S8, in S-1/2 Sec. 11, T. 3 S., R. 2 W.

b. on the east side of the Lemitar Range, in Sec. 18 or 19, T. 2 S., R. 1 W.

Along with this gradient drilling, or immediately preceding it, additional geochemical prospecting would be useful in the Socorro Peak-Strozzi Ranch area. This would have as its aim: obtaining complete chemical analyses for those waters with only partial analyses, obtaining chemical and isotope data for possible magmatic constituents (H_2 and NH_3 gas, isotope ^{34}S), recognition of possible connate-water aquifers (Br/CL ratio), and improved geothermometry (Na-K-Ca, and O_2 isotopes in SO_4 ion).

Cost for such detailed work might run $30,000 complete. It would be warranted only if a decision were made to continue detailed exploration, leading to deep drilling. If a magmatic source were recognized in spring or well waters, a re-interpretation of thermal regime (and possibly of drilling strategy would be called for).

Re-interpretation of structure and subsurface relationships would await results of deep gradient holes. Again, only if magmatic emissions were recognized through hydrochemical surveys would it be advisable to begin remapping of the Socorro-Strozzi Ranch block prior to such drilling. Cost for this would vary with size of map area and required detail.

Should drilling to 2,000-2,500 feet, or further geochemistry, reveal a surprisingly strong anomaly, improvement of existing land positions would become the major objective.

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APPENDIX A

Temperature profiles of gradient holes,

Socorro area, New Mexico.

GTS

FIELD DATA SHEET

TEMPERATURE SURVEY

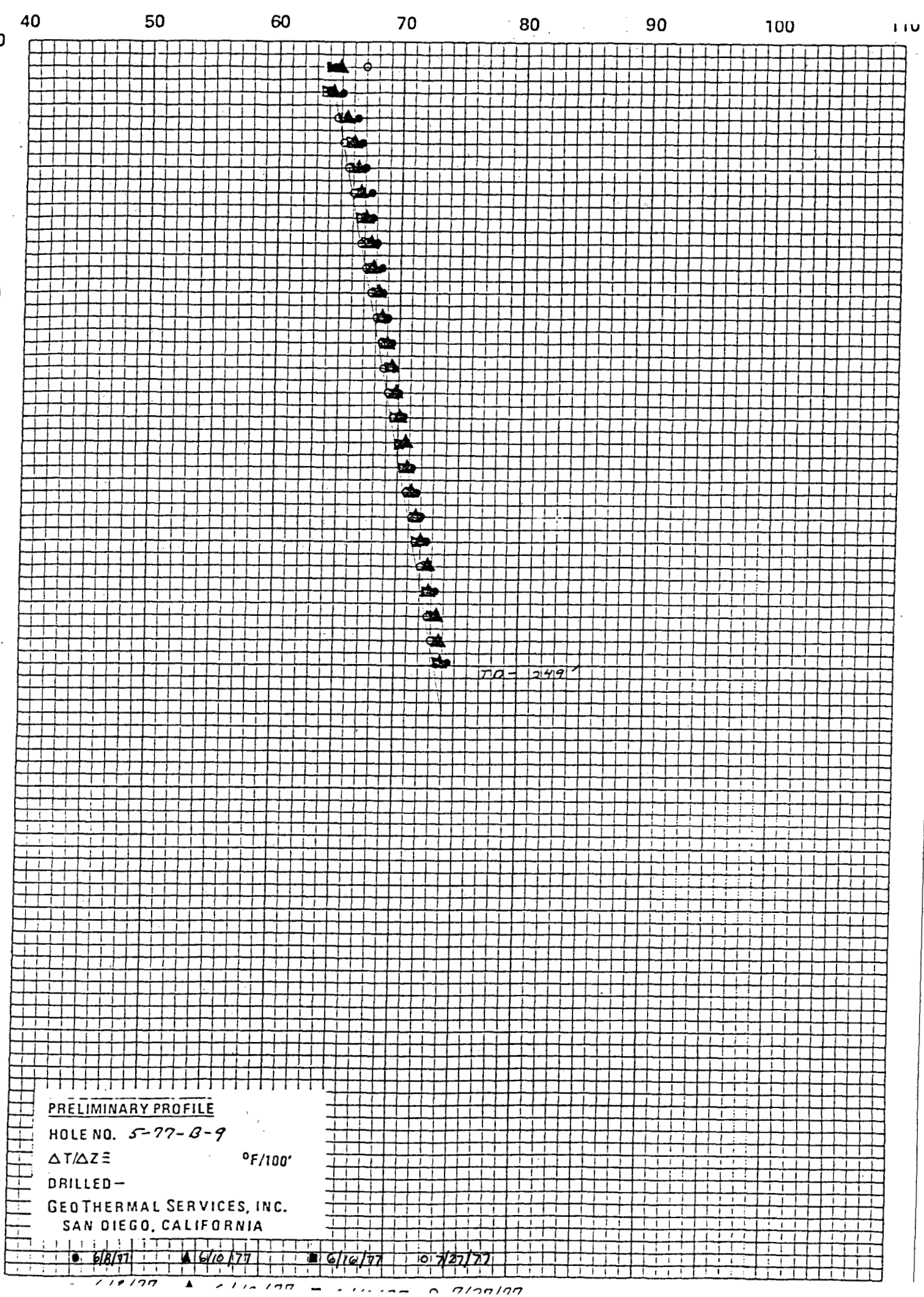
HOLE NUMBER B9 TD 249'

REFERENCE MAP 5-77

REMARKS

HOLE NO. B9
RUN NO. 4 Abandoned
DATE 7-27-77
TIME:
START 2:00 P.M.
END 2:30 P.M.
SENSOR SERIAL NO. 376
OPERATOR Michael R Glascock

FT.	KΩ	°F	FT.	KΩ	°F	FT.	KΩ	°F
10	110.90	67.15	280			550		
20	119.94	64.26	290			560		
30	118.10	64.82	300			570		
40	116.43	65.35	310			580		
50	115.38	65.67	320			590		
60	114.28	66.03	330			600		
70	113.03	66.45	340			610		
80	111.81	66.85	350			620		
90	110.67	67.21	360			630		
100	109.46	67.62	370			640		
110	108.31	68.03	380			650		
120	107.15	68.41	390			660		
130	105.99	68.83	400			670		
140	104.87	69.22	410			680		
150	103.83	69.62	420			690		
160	102.70	70.02	430			700		
170	101.58	70.42	440			710		
180	100.46	70.83	450			720		
190	99.32	71.28	460			730		
200	98.22	71.70	470			740		
210	97.28	72.06	480			750		
220	96.39	72.41	490			760		
230	95.45	72.78	500			770		
240	94.52	73.15	510			780		
~~250~~ 249 T.D.	93.79	73.45	520			790		
260			530			800		
270			540			810		


40
50
60
70
80
90
100
110
0
100
200
300
400
500
TD- 249'
PRELIMINARY PROFILE
HOLE NO. 5-77-B-9
ΔT/ΔZ ≡ °F/100'
DRILLED—
GEOTHERMAL SERVICES, INC.
SAN DIEGO, CALIFORNIA
6/8/77
6/10/77
6/16/77
7/27/77

GTS

FIELD DATA SHEET

TEMPERATURE SURVEY

HOLE NUMBER B15 TD 260'

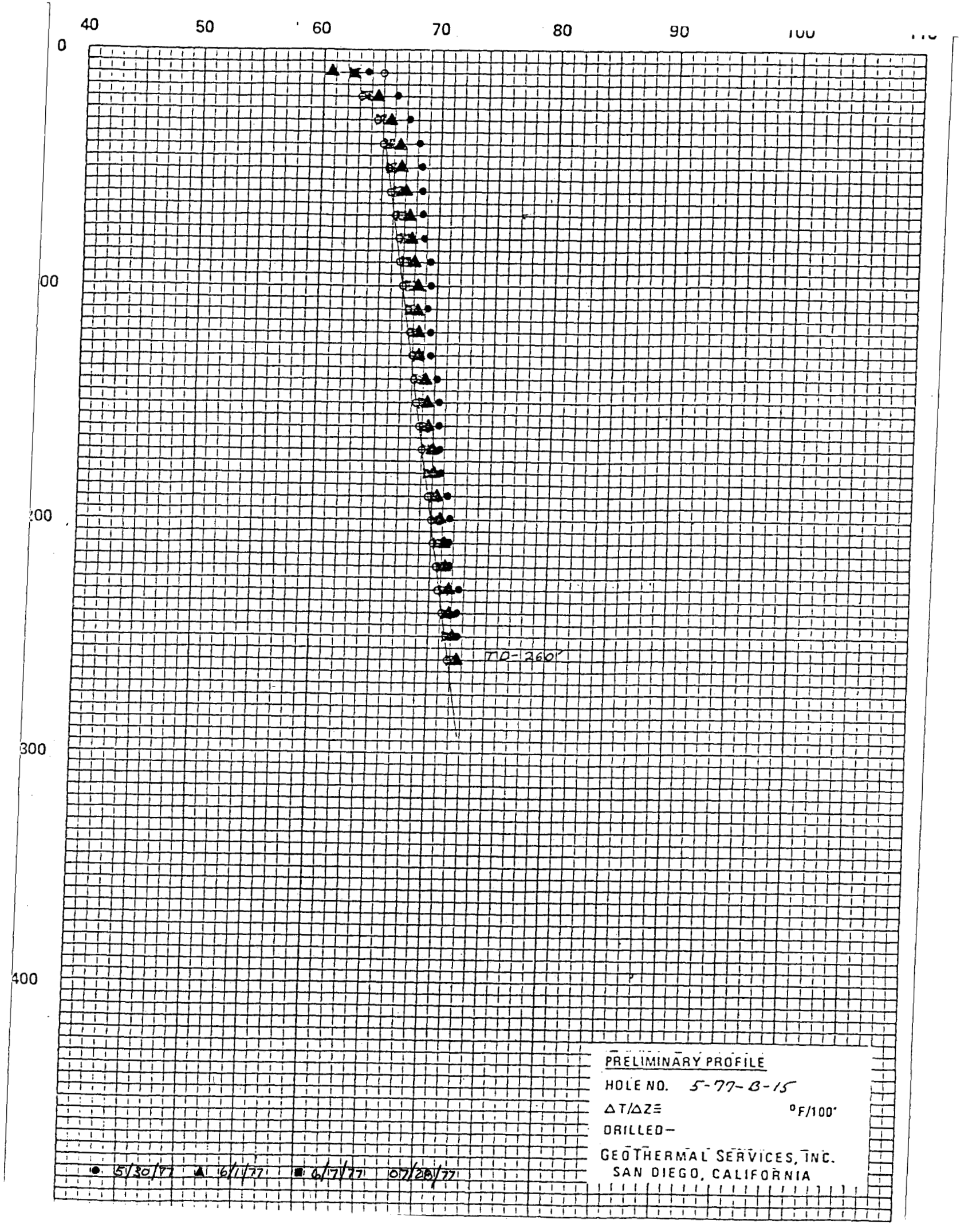
REFERENCE MAP 5-77

REMARKS

HOLE NO. B15
RUN NO. 4 Abandoned
DATE 7-28-77
TIME:
START 10:45 A.M.
END 11:20 A.M.
SENSOR SERIAL NO. 376
OPERATOR Michael R Glascock

FT.	KΩ	°F	FT.	KΩ	°F	FT.	KΩ	°F
10	117.00	65.16	280			550		
20	123.31	63.23	290			560		
30	119.02	64.54	300			570		
40	116.89	65.19	310			580		
50	115.58	65.61	320			590		
60	114.49	65.96	330			600		
70	113.43	66.32	340			610		
80	112.62	66.58	350			620		
90	111.74	66.88	360			630		
100	110.88	67.15	370			640		
110	109.97	67.45	380			650		
120	109.15	67.72	390			660		
130	108.30	68.03	400			670		
140	107.46	68.31	410			680		
150	106.59	68.62	420			690		
160	105.75	68.90	430			700		
170	104.97	69.19	440			710		
180	104.15	69.48	450			720		
190	103.29	69.80	460			730		
200	102.51	70.09	470			740		
210	101.77	70.35	480			750		
220	101.02	70.65	490			760		
230	100.13	70.98	500			770		
240	99.33	71.28	510			780		
250	98.50	71.59	520			790		
260 TD.	97.76	71.88	530			800		
270			540			810		

JANUARY, 1976


40
50
60
70
80
90
100
0
100
200
300
400
TD-260'
PRELIMINARY PROFILE
HOLE NO. 5-77-B-15
ΔT/ΔZ≡ °F/100'
DRILLED—
GEOTHERMAL SERVICES, INC.
SAN DIEGO, CALIFORNIA
● 5/30/77 ▲ 6/1/77 ■ 6/7/77 07/28/77

GTS

FIELD DATA SHEET

TEMPERATURE SURVEY

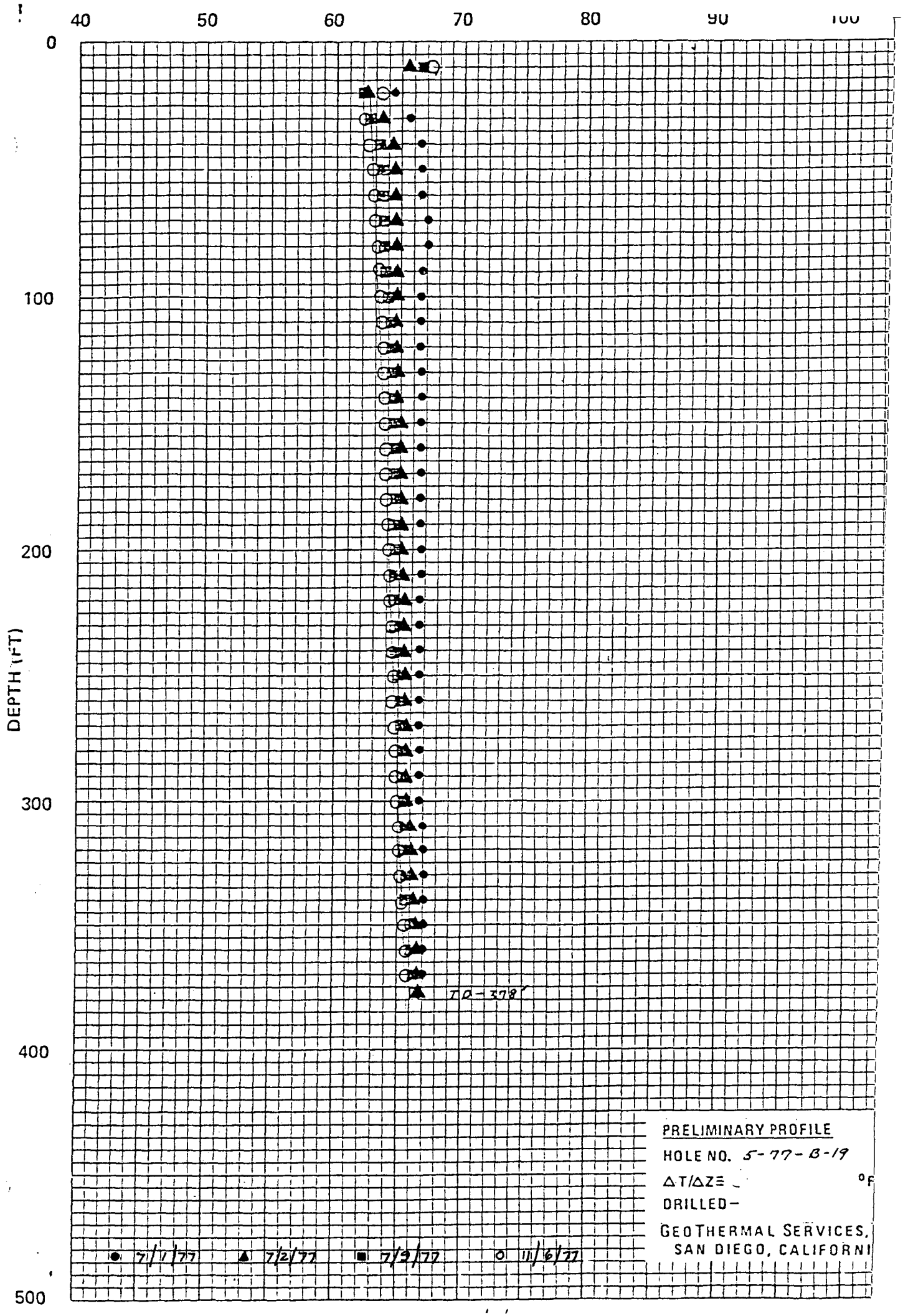
HOLE NUMBER S-77B19 TD 380'

REFERENCE MAP S-77

REMARKS ABANDONMENT SURVEY

HOLE NO. S-77-B19
RUN NO. 4 ABD
DATE 11/6/77
TIME:
START 2:05 PM
END 2:45
SENSOR SERIAL NO. 2
OPERATOR JUDD MUSCAT

FT.	KΩ	°F	FT.	KΩ	°F	FT.	KΩ	°F
10	123.36	67.44	280	132.32	64.85	550		
20	137.24	63.52	290	132.02	64.94	560		
30	141.72	62.35	300	131.87	64.98	570		
40	141.09	62.51	310	131.46	65.08	580		
50	140.05	62.78	320	131.05	65.21	590		
60	139.30	62.96	330	130.60	65.34	600		
70	138.69	63.14	340	130.25	65.43	610		
80	138.22	63.25	350	129.88	65.53	620		
90	137.71	63.39	360	129.44	65.66	630		
100	137.48	63.45	370	128.82	65.84	640		
110	137.14	63.54	380	128.81	65.82	650		
120	136.88	63.61	390			660		
130	136.72	63.64	400			670		
140	136.47	63.72	410			680		
150	136.19	63.79	420			690		
160	135.91	63.86	430			700		
170	135.70	63.91	440			710		
180	135.42	64.00	450			720		
190	135.01	64.09	460			730		
200	134.84	64.17	470			740		
210	134.69	64.20	480			750		
220	134.24	64.33	490			760		
230	134.04	64.38	500			770		
240	133.75	64.45	510			780		
250	133.34	64.56	520			790		
260	132.91	64.67	530			800		
270	132.75	64.72	540			810		


40
50
60
70
80
90
100
0
100
200
300
400
500
DEPTH (FT)
TD-378'
PRELIMINARY PROFILE
HOLE NO. 5-77-B-19
ΔT/ΔZ≡ °F
DRILLED-
GEOTHERMAL SERVICES,
SAN DIEGO, CALIFORNI
7/1/77
7/2/77
7/3/77
11/6/77

GTS

FIELD DATA SHEET
TEMPERATURE SURVEY

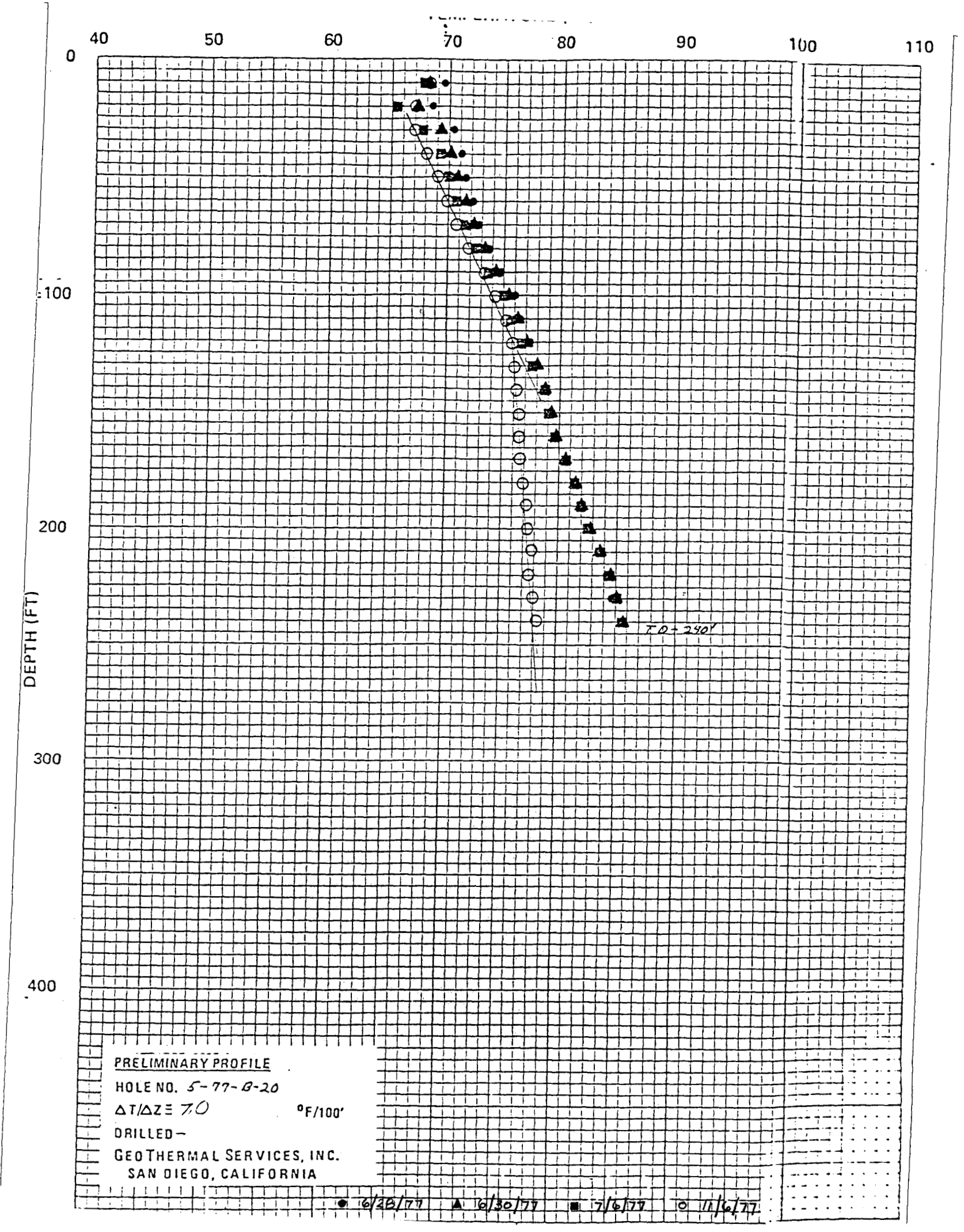
HOLE NUMBER S-77-B20 TD 240'

REFERENCE MAP S-77

REMARKS ABANDONMENT SURVEY
PIPE ONLY 1/2 FULL H_2O

HOLE NO. S-77-B20
RUN NO. 4-ABD
DATE 11/6/77
TIME:
START 11:20
END 11:45
SENSOR SERIAL NO. 2
OPERATOR JUDD MUSKAT

FT.	KΩ	°F	FT.	KΩ	°F	FT.	KΩ	°F
10	120.56	68.29	280			550		
20	124.63	67.06	290			560		
30	124.64	67.06	300			570		
40	121.37	68.04	310			580		
50	118.12	69.04	320			590		
60	115.27	69.96	330			600		
70	112.91	70.74	340			610		
80	109.75	71.80	350			620		
90	105.44	73.31	360			630		
100	102.48	74.39	370			640		
110	99.99	75.31	380			650		
120	98.72	75.81	390			660		
130	98.06	76.06	400			670		
140	97.40	76.32	410			680		
150	96.97	76.50	420			690		
160	96.55	76.64	430			700		
170	96.61	76.64	440			710		
180	95.84	76.95	450			720		
190	94.94	77.31	460			730		
200	94.55	77.45	470			740		
210	93.67	77.81	480			750		
220	94.18	77.61	490			760		
230	93.19	78.01	500			770		
240	92.44	78.31	510			780		
250			520			790		
260			530			800		
270			540			810		


40
50
60
70
80
90
100
110
0
100
200
300
400
DEPTH (FT)
TD = 240'
PRELIMINARY PROFILE
HOLE NO. 5-77-B-20
ΔT/ΔZ ≡ 7.0 °F/100'
DRILLED –
GEOTHERMAL SERVICES, INC.
SAN DIEGO, CALIFORNIA
6/28/77
6/30/77
7/6/77
11/6/77

GTS

FIELD DATA SHEET

TEMPERATURE SURVEY

HOLE NUMBER 5-77-B21 TD 380'

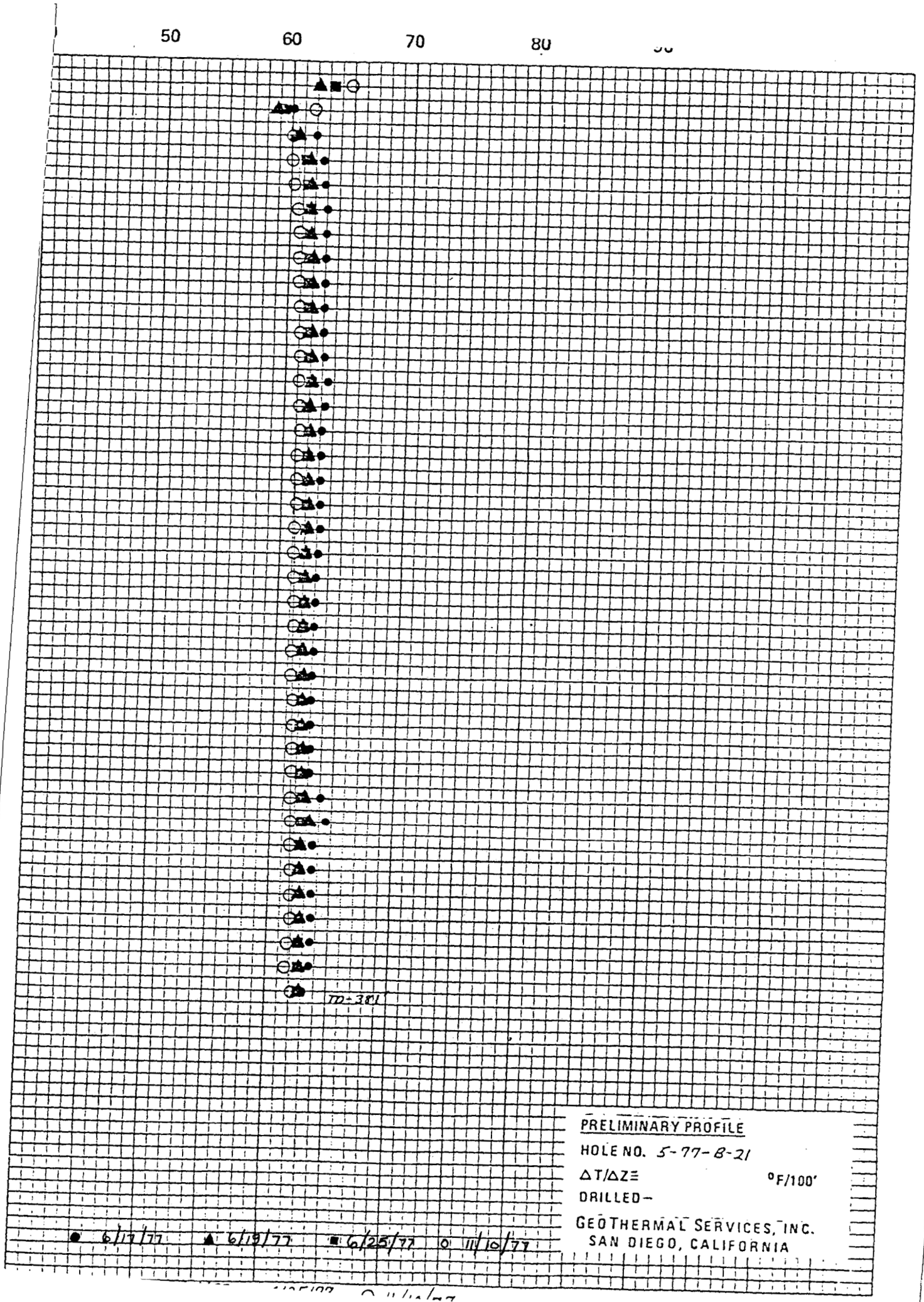
REFERENCE MAP 5-77

REMARKS ABANDONMENT Survey

HOLE NO. 5-77-B21
RUN NO. 4-ABD
DATE 11/10/77
TIME:
START 4:00 PM
END 4:35 PM
SENSOR SERIAL NO. 2
OPERATOR JUDD MUSKAT

FT.	KΩ	°F	FT.	KΩ	°F	FT.	KΩ	°F
10	132.60	64.78	280	144.95	61.52	550		
20	144.01	61.75	290	144.63	61.59	560		
30	150.87	60.06	300	144.37	61.66	570		
40	151.01	60.04	310	144.19	61.72	580		
50	149.53	60.39	320	144.01	61.75	590		
60	148.50	60.64	330	143.85	61.79	600		
70	147.87	60.80	340	143.63	61.86	610		
80	147.61	60.85	350	143.39	61.92	620		
90	147.26	60.94	360	143.91	61.77	630		
100	146.97	61.02	370	144.08	61.74	640		
110	146.75	61.07	380	142.53	62.13	650		
120	146.56	61.12	390			660		
130	146.37	61.16	400			670		
140	146.27	61.20	410			680		
150	145.98	61.27	420			690		
160	146.18	61.21	430			700		
170	146.11	61.23	440			710		
180	145.96	61.27	450			720		
190	146.54	61.12	460			730		
200	146.50	61.12	470			740		
210	145.61	61.36	480			750		
220	145.53	61.38	490			760		
230	145.44	61.39	500			770		
240	145.36	61.41	510			780		
250	145.42	61.39	520			790		
260	145.17	61.47	530			800		
270	145.02	61.50	540			810		

JANUARY, 1976


50
60
70
80
TD-381
PRELIMINARY PROFILE
HOLE NO. 5-77-B-21
ΔT/ΔZ≡ °F/100'
DRILLED–
GEOTHERMAL SERVICES, INC.
SAN DIEGO, CALIFORNIA
● 6/17/77 ▲ 6/19/77 ■ 6/25/77 ○ 11/10/77

FIELD DATA SHEET

TEMPERATURE SURVEY

HOLE NUMBER 5-77-B22 TD 61'

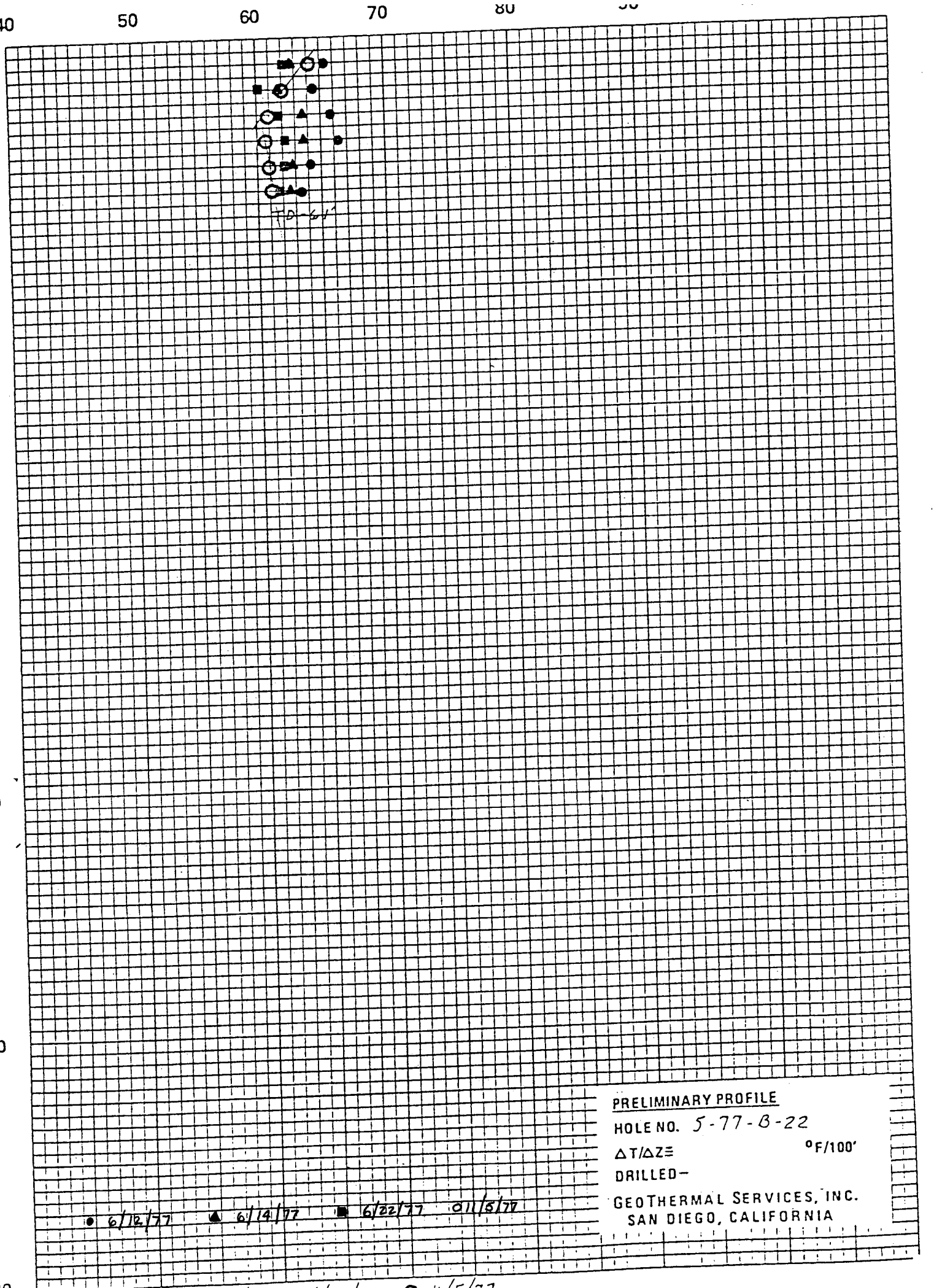
REFERENCE MAP 5-77

REMARKS ABANDONMENT SURVEY

HOLE NO. 5-77-B22
RUN NO. 4-ABD
DATE 11:05
TIME:
START 11:08
END 11:15
SENSOR SERIAL NO. 2
OPERATOR JUDD MUSKAT

FT.	KΩ	°F	FT.	KΩ	°F	FT.	KΩ	°F
10	135.20	64.06	280			550		
20	143.07	61.99	290			560		
30	147.41	60.89	300			570		
40	148.44	60.66	310			580		
50	147.77	60.82	320			590		
~~60~~ 61	146.79	61.05	330			600		
70	TD. 61'		340			610		
80			350			620		
90			360			630		
100			370			640		
110			380			650		
120			390			660		
130			400			670		
140			410			680		
150			420			690		
160			430			700		
170			440			710		
180			450			720		
190			460			730		
200			470			740		
210			480			750		
220			490			760		
230			500			770		
240			510			780		
250			520			790		
260			530			800		
270			540			810		

JANUARY, 1976


40
50
60
70
80
TD-64'
PRELIMINARY PROFILE
HOLE NO. 5-77-B-22
ΔT/ΔZ≡ °F/100'
DRILLED—
GEOTHERMAL SERVICES, INC.
SAN DIEGO, CALIFORNIA
6/12/77
6/14/77
6/22/77
01/5/77

FIELD DATA SHEET

TEMPERATURE SURVEY

HOLE NUMBER 5-77-B23 TD 3001

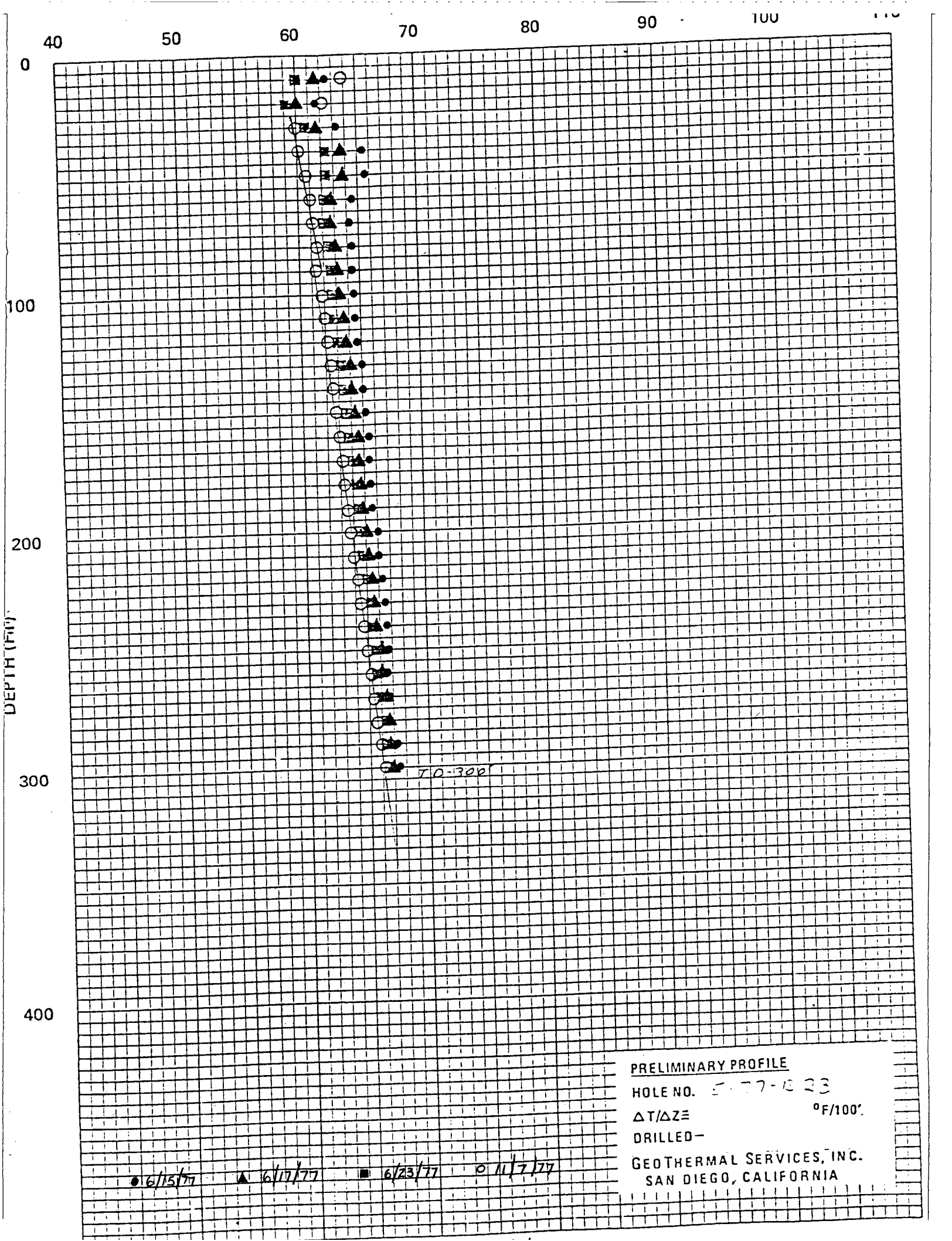
REFERENCE MAP 5-77

REMARKS ABANDONMENT SURVEY

HOLE NO. 5-77-B23
RUN NO. 4-ABD
DATE 11/7/77
TIME:
START 9:25 am
END 9:55 am
SENSOR SERIAL NO. 2
OPERATOR JUDD MUSKAT

FT.	KΩ	°F	FT.	KΩ	°F	FT.	KΩ	°F
10	135.92	63.86	280	129.48	65.64	550		
20	146.15	62.21	290	128.56	65.91	560		
30	151.28	59.97	300	127.84	66.11	570		
40	150.10	60.26	310			580		
50	148.19	60.73	320			590		
60	147.02	61.00	330			600		
70	146.13	61.23	340			610		
80	145.27	61.45	350			620		
90	144.46	61.39	360			630		
100	143.70	61.84	370			640		
110	143.00	62.01	380			650		
120	142.19	62.22	390			660		
130	141.38	62.44	400			670		
140	140.64	62.62	410			680		
150	139.87	62.82	420			690		
160	139.06	63.03	430			700		
170	138.31	63.23	440			710		
180	137.66	63.41	450			720		
190	136.90	63.61	460			730		
200	136.18	63.81	470			740		
210	135.47	63.99	480			750		
220	134.63	64.22	490			760		
230	133.77	64.45	500			770		
240	132.83	64.71	510			780		
250	131.96	64.96	520			790		
260	131.18	65.17	530			800		
270	130.34	65.41	540			810		

JANUARY, 1976


40
50
60
70
80
90
100
0
100
200
300
400
DEPTH (FT)
TD-300'
PRELIMINARY PROFILE
HOLE NO. 5-77-023
ΔT/ΔZ≡ °F/100'
DRILLED–
GEOTHERMAL SERVICES, INC.
SAN DIEGO, CALIFORNIA
6/15/77
6/17/77
6/23/77
11/7/77

GTS

FIELD DATA SHEET

TEMPERATURE SURVEY

HOLE NUMBER: 5-77-F1 TD 320'

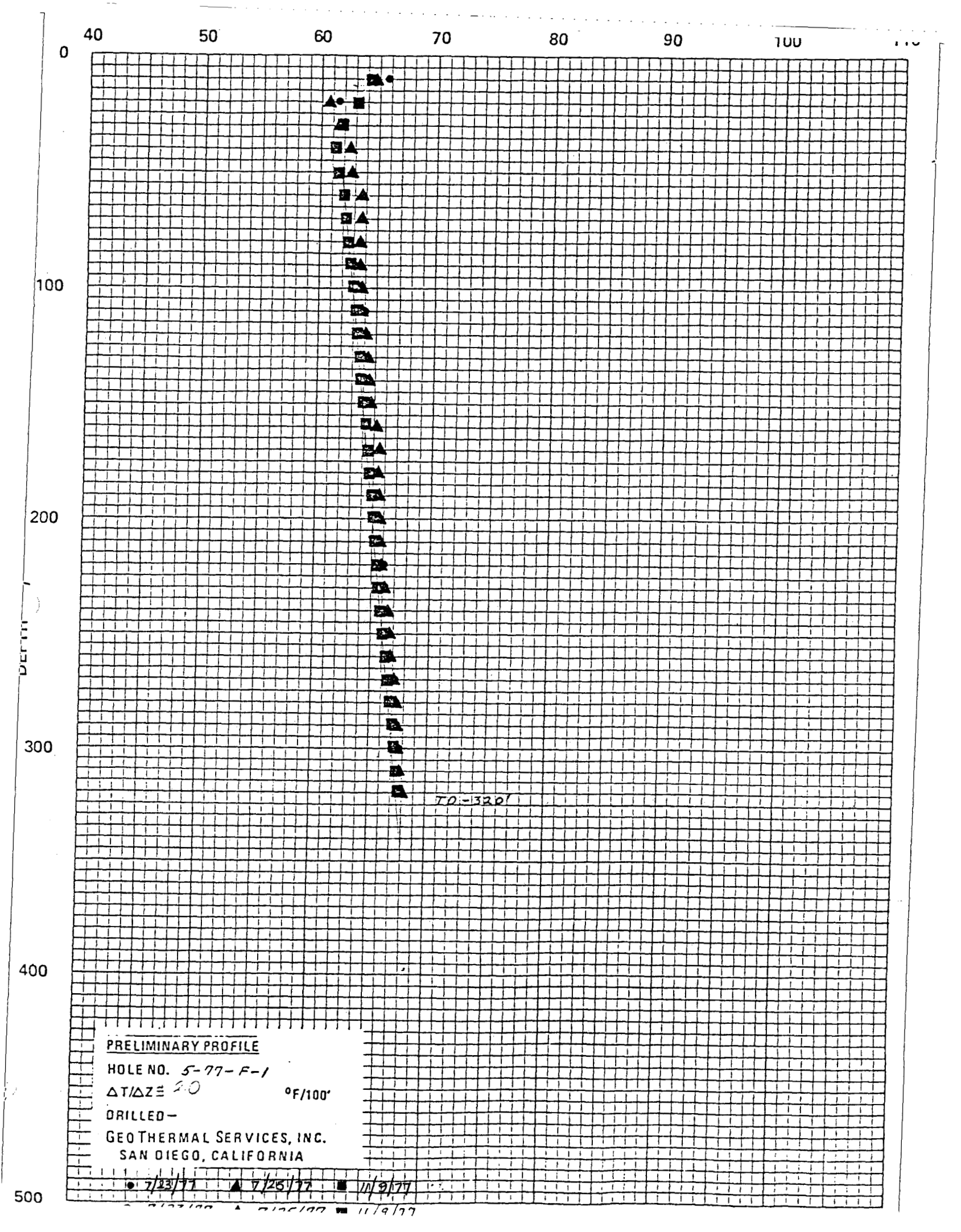
REFERENCE MAP 5-77

REMARKS ABANDONMENT SURVEY

HOLE NO. 5-77-F1
RUN NO. 3-ABD
DATE 11/8/77
TIME:
START 2:50
END 3:20
SENSOR SERIAL NO. 2
OPERATOR JUDD MUSCAT

FT.	KΩ	°F	FT.	KΩ	°F	FT.	KΩ	°F
10	134.14	64.35	280	125.26	66.87	550		
20	138.78	63.10	290	124.58	67.08	560		
30	143.82	61.81	300	123.74	67.32	570		
40	145.61	61.36	310	122.91	67.55	580		
50	144.47	61.65	320	122.33	67.75	590		
60	142.95	62.02	330			600		
70	141.88	62.29	340			610		
80	140.83	62.56	350			620		
90	139.76	62.85	360			630		
100	139.14	63.01	370			640		
110	138.01	63.30	380			650		
120	137.32	63.48	390			660		
130	136.54	63.70	400			670		
140	135.89	63.88	410			680		
150	135.01	64.11	420			690		
160	134.27	64.31	430			700		
170	133.52	64.53	440			710		
180	132.56	64.78	450			720		
190	131.92	64.96	460			730		
200	131.22	65.16	470			740		
210	130.80	65.28	480			750		
220	130.10	65.48	490			760		
230	129.53	65.64	500			770		
240	128.69	65.88	510			780		
250	127.86	66.11	520			790		
260	126.65	66.47	530			800		
270	125.92	66.70	540			810		

JANUARY, 1976


40
50
60
70
80
90
100
0
100
200
300
400
500
TD-320'
PRELIMINARY PROFILE
HOLE NO. 5-77-F-1
ΔT/ΔZ ≡ 2.0 °F/100'
DRILLED-
GEOTHERMAL SERVICES, INC.
SAN DIEGO, CALIFORNIA
7/23/77
7/25/77
11/9/77

FIELD DATA SHEET

TEMPERATURE SURVEY

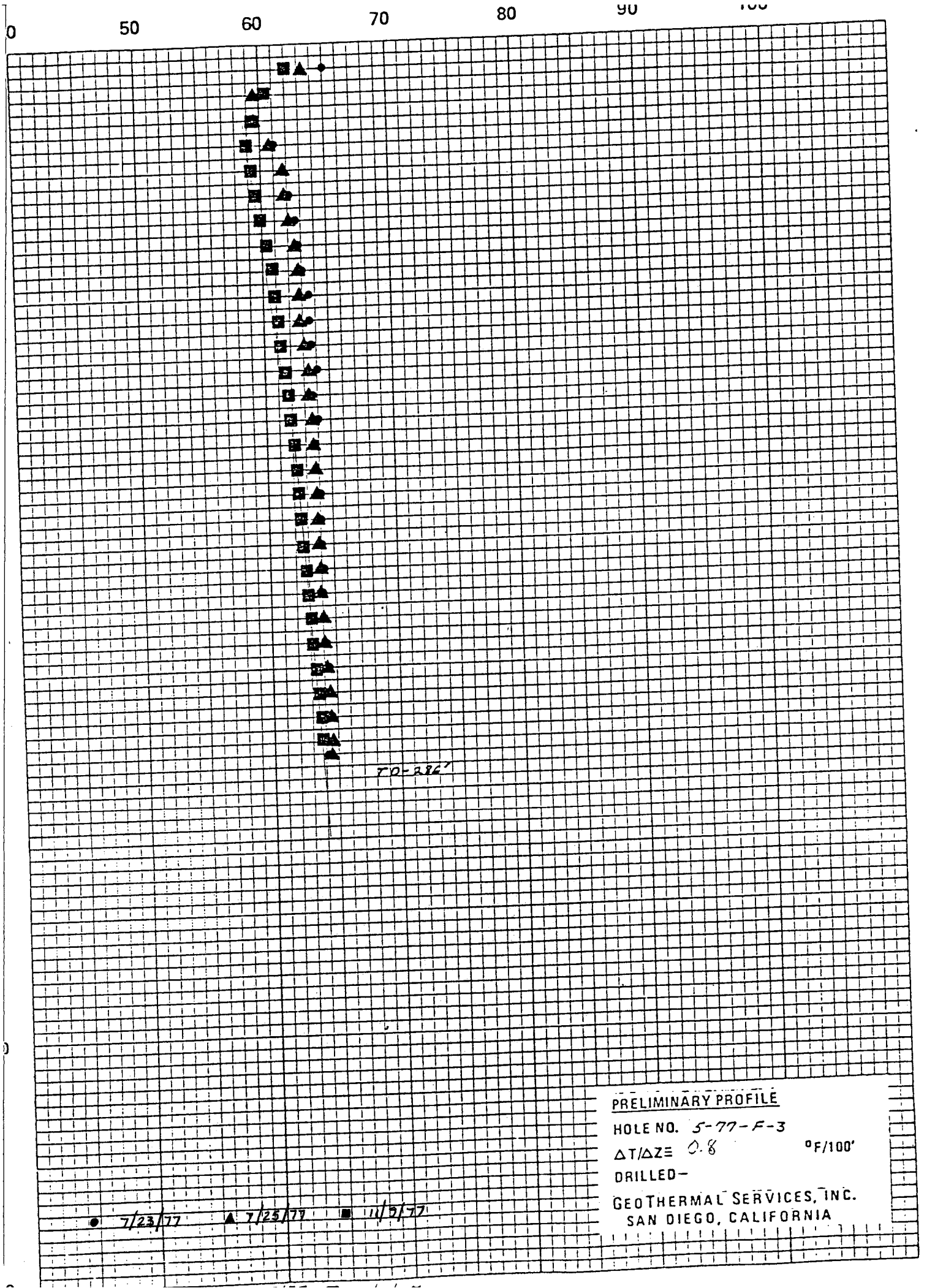
HOLE NUMBER 5-77-F3 TD 286'

REFERENCE MAP 5-77

REMARKS ABANDONMENT SURVEY

HOLE NO. 5-77-F3
RUN NO. 3-ABD
DATE 11/9/77
TIME:
START 1:25
END 1:55
SENSOR SERIAL NO. 2
OPERATOR JUDD MUSKAT

T.	KΩ	°F	FT.	KΩ	°F	FT.	KΩ	°F
0	142.76	62.08	280	136.06	63.82	550		
0	149.23	60.46	~~290~~	135.82	63.82	560		
0	153.31	59.49	300	286' T.D.		570		
0	155.50	58.98	310			580		
0	154.18	59.29	320			590		
0	152.71	59.63	330			600		
0	151.19	59.99	340			610		
0	149.77	60.33	350			620		
0	148.24	60.71	360			630		
0	146.84	60.80	370			640		
10	146.23	61.20	380			650		
20	145.70	61.34	390			660		
30	144.45	61.65	400			670		
40	143.76	61.83	410			680		
50	143.42	61.90	420			690		
60	142.74	62.08	430			700		
70	142.18	62.22	440			710		
80	141.66	62.35	450			720		
90	141.12	62.49	460			730		
00	140.62	62.62	470			740		
10	140.02	62.78	480			750		
20	139.40	62.94	490			760		
30	138.83	63.09	500			770		
40	138.23	63.25	510			780		
50	137.69	63.39	520			790		
60	137.12	63.54	530			800		
70	136.59	63.68	540			810		


0
50
60
70
80
90
TD-286'
PRELIMINARY PROFILE
HOLE NO. 5-77-F-3
ΔT/ΔZ≡ 0.8 °F/100'
DRILLED-
GEOTHERMAL SERVICES, INC.
SAN DIEGO, CALIFORNIA
● 7/23/77
▲ 7/25/77
■ 11/9/77

FIELD DATA SHEET

TEMPERATURE SURVEY

HOLE NUMBER 5-77-F4 TD 315'

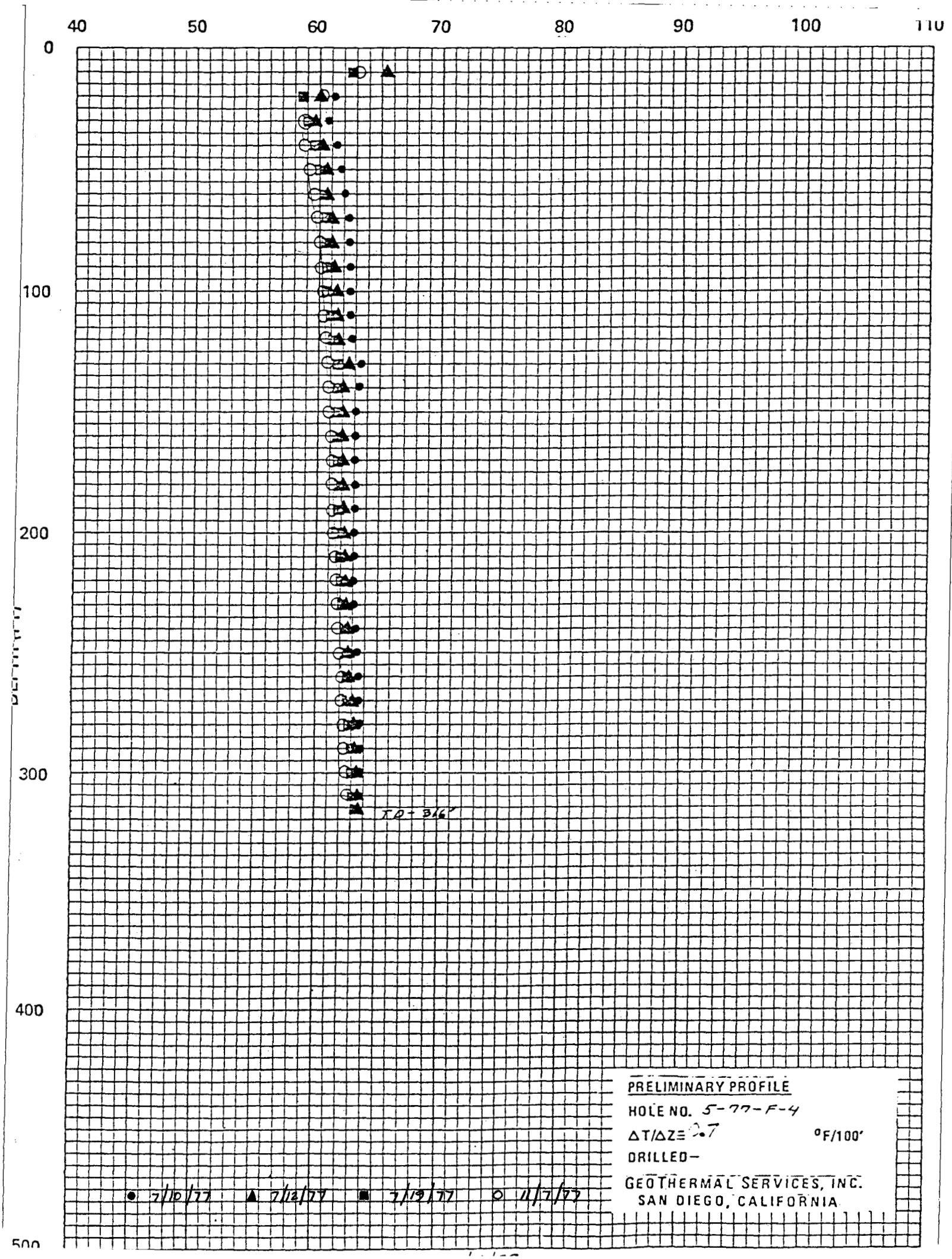
REFERENCE MAP 5-77

REMARKS ABANDONMENT SURVEY

HOLE NO. 5-77-F4
RUN NO. 4-ABD
DATE 11/7/77
TIME:
START 11:50 am
END 12:15
SENSOR SERIAL NO. 2
OPERATOR JUDD MUSKAT

T.	KΩ	°F	FT.	KΩ	°F	FT.	KΩ	°F
	138.21	63.25	280	141.45	62.40	550		
	149.93	60.30	290	140.91	62.53	560		
	155.86	58.89	300	140.41	62.67	570		
	156.25	58.80	310	139.94	62.80	580		
	154.58	59.20	~~320~~	139.70	62.87	590		
	153.08	59.54	330	315 T.D.		600		
	151.91	59.83	340			610		
	151.12	60.01	350			620		
	150.48	60.17	360			630		
	149.84	60.31	370			640		
	149.29	60.46	380			650		
	148.54	60.64	390			660		
	147.85	60.80	400			670		
	147.48	60.89	410			680		
	147.18	60.96	420			690		
	146.78	61.07	430			700		
	146.49	61.14	440			710		
	146.08	61.23	450			720		
	145.64	61.34	460			730		
	145.21	61.45	470			740		
	144.81	61.56	480			750		
	144.37	61.66	490			760		
	143.86	61.79	500			770		
	143.38	61.88	510			780		
	142.98	62.02	520			790		
	142.54	62.13	530			800		
	141.91	62.28	540			810		

JANUARY, 1976


40
50
60
70
80
90
100
110
0
100
200
300
400
500
TD = 316'
PRELIMINARY PROFILE
HOLE NO. 5-77-F-4
ΔT/ΔZ≡ 0.7 °F/100'
DRILLED—
GEOTHERMAL SERVICES, INC.
SAN DIEGO, CALIFORNIA
● 7/10/77
▲ 7/12/77
■ 7/19/77
○ 11/7/77

FIELD DATA SHEET

TEMPERATURE SURVEY

HOLE NUMBER R-30 TD 420'

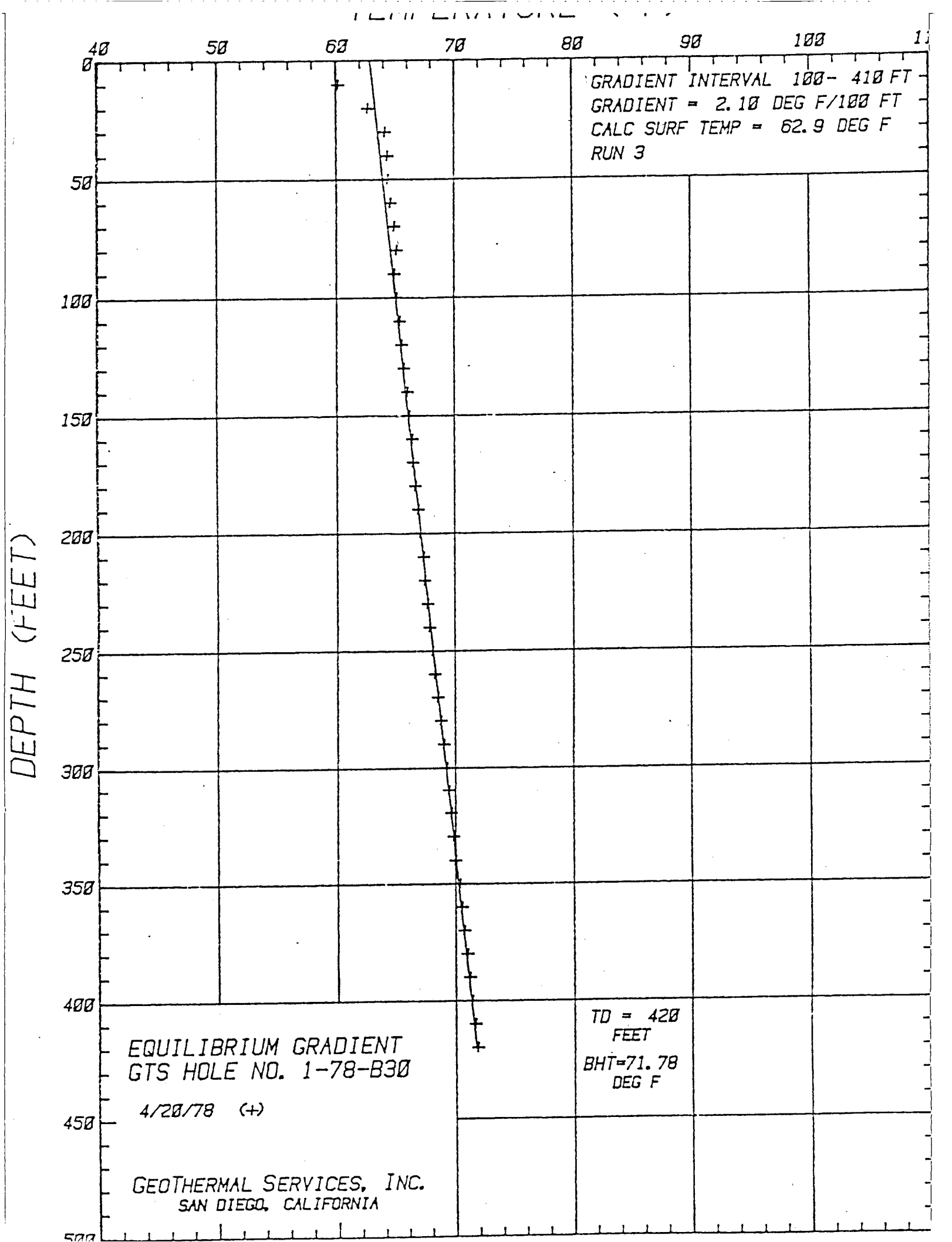
REFERENCE MAP 1-78

REMARKS

HOLE NO. R 30
RUN NO. 3
DATE 4/20/78
TIME:
START 1345
END 1500
SENSOR SERIAL NO. K3267A/[illegible]1477-05
OPERATOR OWEN

FT.	KΩ	°F	FT.	KΩ	°F	FT.	KΩ	°F
10	176.07	60.22	280	139.69	68.74	550		
20	164.68	62.60	290	138.75	68.99	560		
30	158.37	64.09	300	137.84	69.23	570		
40	157.53	64.29	310	137.14	69.42	580		
50	157.25	64.35	320	136.43	69.62	590		
60	156.46	64.54	330	135.78	69.80	600		
70	155.16	64.85	340	135.23	69.94	610		
80	154.27	65.06	350	133.85	70.33	620		
90	155.18	64.84	360	133.24	70.50	630		
100	154.33	65.05	370	132.48	70.72	640		
110	153.24	65.30	380	131.71	70.93	650		
120	152.63	65.44	390	130.99	71.14	660		
130	151.86	65.64	400	130.34	71.33	670		
140	150.65	65.93	410	129.40	71.60	680		
150	149.95	66.10	420	128.81	71.78	690		
160	149.09	66.33	430			700		
170	148.67	66.42	440			710		
180	148.05	66.58	450			720		
190	147.04	66.83	460			730		
200	146.31	67.01	470			740		
210	145.29	67.28	480			750		
220	144.68	67.42	490			760		
230	143.77	67.67	500			770		
240	143.28	67.79	510			780		
250	142.36	68.04	520			790		
260	141.44	68.27	530			800		
270	140.54	68.51	540			810		

JANUARY, 1976


40
50
60
70
80
90
100
0
50
100
150
200
250
300
350
400
450
500
DEPTH (FEET)
GRADIENT INTERVAL 100- 410 FT
GRADIENT = 2.10 DEG F/100 FT
CALC SURF TEMP = 62.9 DEG F
RUN 3
TD = 420 FEET
BHT=71.78 DEG F
EQUILIBRIUM GRADIENT
GTS HOLE NO. 1-78-B30
4/20/78 (+)
GEOTHERMAL SERVICES, INC.
SAN DIEGO, CALIFORNIA

GTS

FIELD DATA SHEET

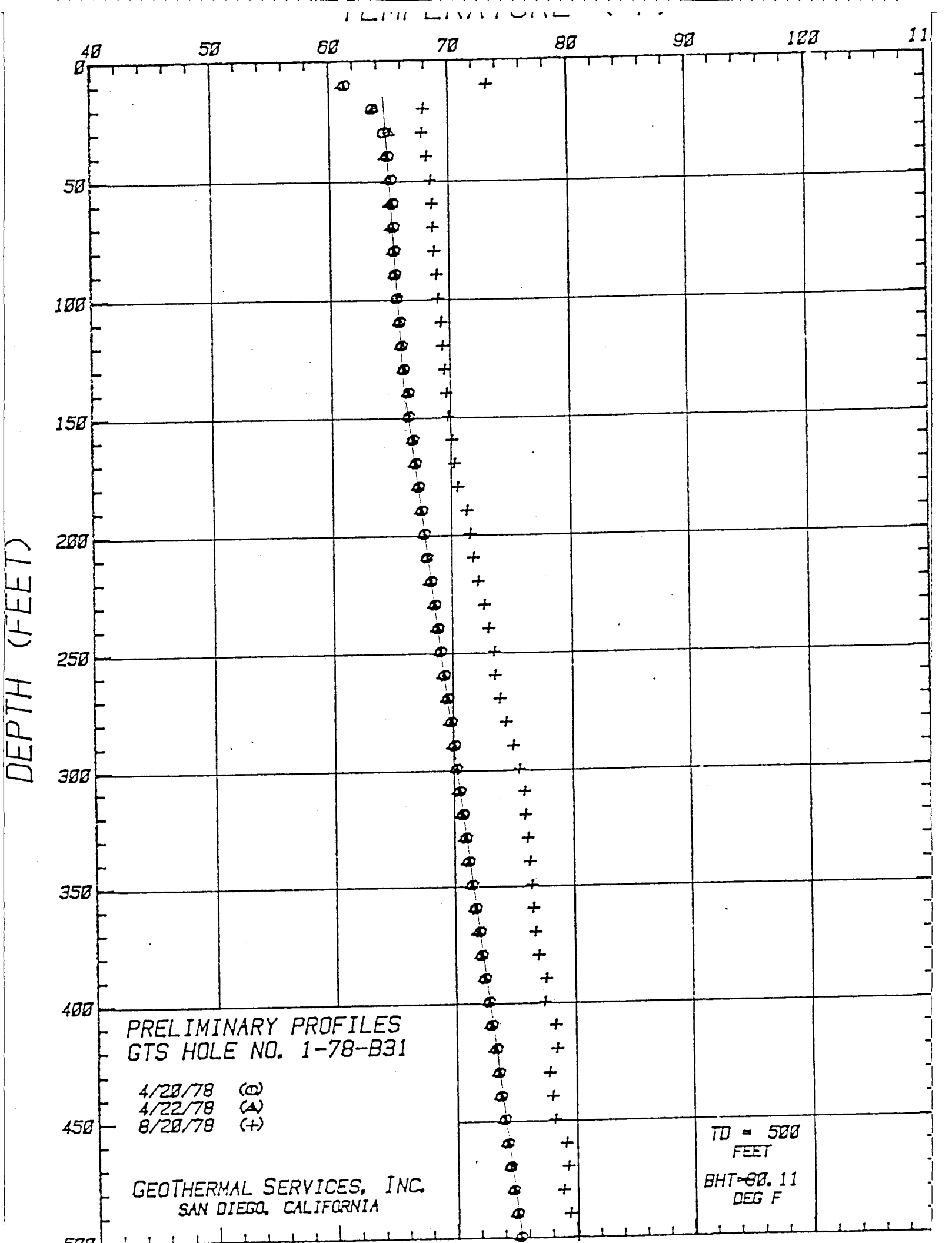
TEMPERATURE SURVEY

HOLE NO. 2-31
RUN NO. 2
DATE 4/22/78
TIME:
START 1430
END 1540
SENSOR SERIAL NO. [illegible]A/0/4477-05
OPERATOR OWEN

HOLE NUMBER 2-31 TD 500'
REFERENCE MAP 1-78
REMARKS Plug at 295', 310'

FT.	KΩ	°F	FT.	KΩ	°F	FT.	KΩ	°F
10	171.98	61.11	280	136.11	69.69	550		
20	159.50	63.82	290	135.14	69.97	560		
30	154.18	65.08	300	134.57	70.13	570		
40	155.89	64.67	310	133.86	70.33	580		
50	155.15	64.85	320	132.84	70.61	590		
60	154.84	64.99	330	132.07	70.83	600		
70	154.00	65.12	340	131.35	71.04	610		
80	153.54	65.23	350	130.32	71.34	620		
90	152.96	65.37	360	129.27	71.64	630		
100	152.06	65.54	370	128.50	71.87	640		
110	151.58	65.71	380	127.67	72.11	650		
120	151.02	65.84	390	126.84	72.36	660		
130	150.53	66.01	400	125.75	72.68	670		
140	149.90	66.36	410	125.13	72.87	680		
150	148.58	66.44	420	124.15	73.17	690		
160	147.56	66.75	430	123.30	73.43	700		
170	146.75	66.90	440	122.69	73.62	710		
180	145.78	67.15	450	121.71	73.92	720		
190	145.03	67.33	460	120.96	74.16	730		
200	144.10	67.58	470	120.08	74.43	740		
210	143.15	67.82	480	119.44	74.64	750		
220	142.01	68.11	490	118.56	74.91	760		
230	140.97	68.40	500	117.80	75.16	770		
240	140.08	68.68	510			780		
250	139.10	68.99	520			790		
260	138.14	69.15	530			800		
270	137.02	69.46	540			810		

JANUARY, 1976


40
50
60
70
80
90
100
0
50
100
150
200
250
300
350
400
450
DEPTH (FEET)
PRELIMINARY PROFILES
GTS HOLE NO. 1-78-B31
4/20/78 (□)
4/22/78 (▲)
8/20/78 (+)
GEOTHERMAL SERVICES, INC.
SAN DIEGO, CALIFORNIA
TD = 500
FEET
BHT=80.11
DEG F

FIELD DATA SHEET

TEMPERATURE SURVEY

HOLE NUMBER 178-32 TD 450

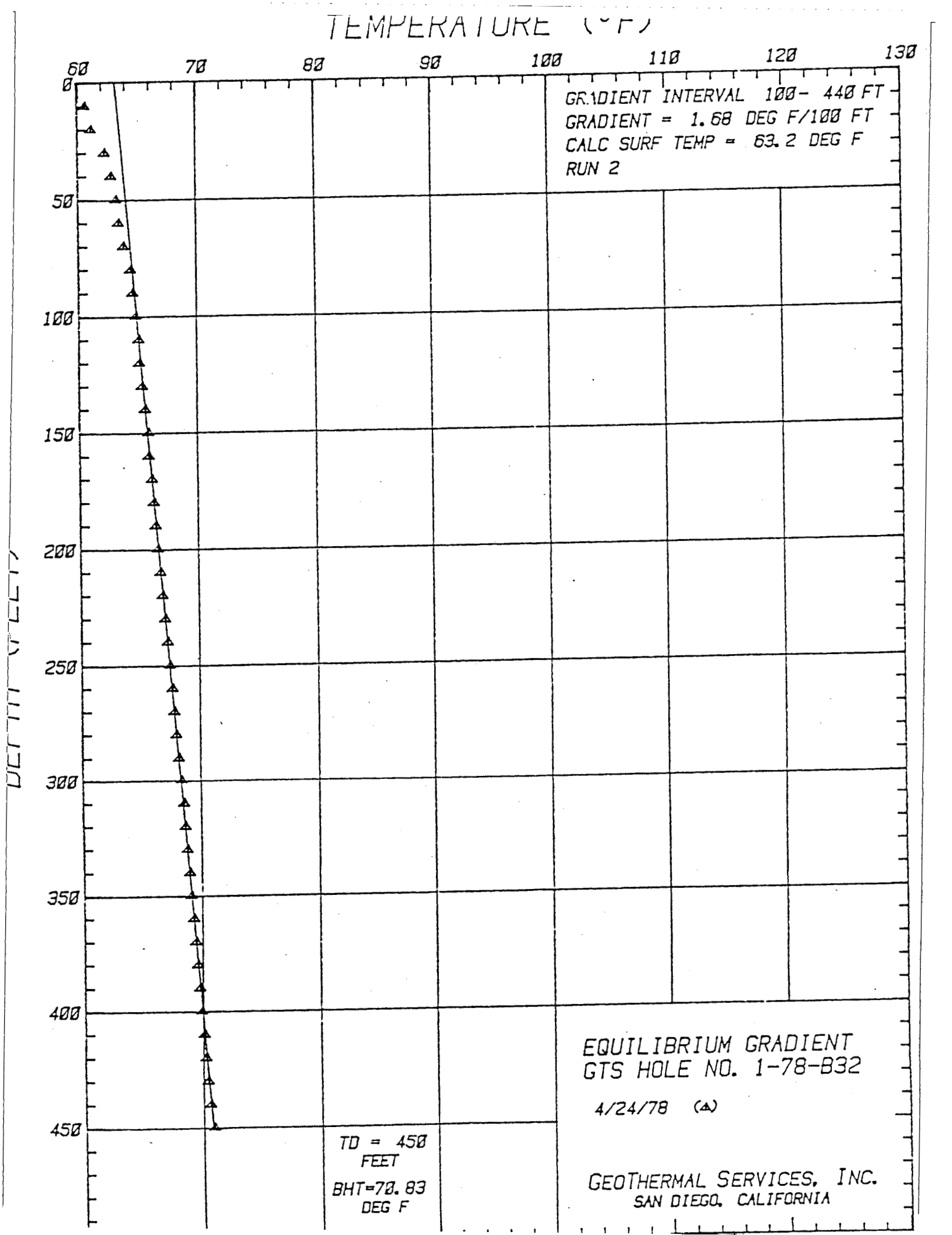
REFERENCE MAP 1-78

REMARKS

HOLE NO. 178-32
RUN NO. 2
DATE 24 APR. 78
TIME:
START 7:52 A
END 8:45A
SENSOR SERIAL NO. 061477-05
OPERATOR WALKER T.

FT.	KΩ	°F	FT.	KΩ	°F	FT.	KΩ	°F
10	174.25	60.60	280	142.81	67.91	550		
20	171.89	61.11	290	142.15	68.09	560		
30	166.60	62.24	300	141.34	68.31	570		
40	164.12	62.80	310	140.66	68.49	580		
50	162.36	63.18	320	140.17	68.61	590		
60	161.40	63.39	330	139.62	68.76	600		
70	159.63	63.81	340	138.95	68.94	610		
80	156.98	64.42	350	138.50	69.06	620		
90	156.44	64.54	360	137.71	69.26	630		
100	155.38	64.80	370	137.24	69.40	640		
110	154.35	65.03	380	136.63	69.57	650		
120	154.02	65.12	390	136.08	69.71	660		
130	153.20	65.32	400	135.52	69.87	670		
140	152.24	65.55	410	134.94	70.03	680		
150	151.20	65.80	420	134.42	70.18	690		
160	151.13	65.82	430	133.83	70.34	700		
170	150.08	66.07	440	133.02	70.57	710		
180	149.62	66.18	~~450~~	132.12	70.83	720		
190	148.89	66.36	460	TD 449		730		
200	148.27	66.52	470			740		
210	147.54	66.70	480			750		
220	146.93	66.86	490			760		
230	146.20	67.05	500			770		
240	145.41	67.24	510			780		
250	144.80	67.41	520			790		
260	143.98	67.60	530			800		
270	143.53	67.73	540			810		

JANUARY, 1976


TEMPERATURE (°F)
60
70
80
90
100
110
120
130
0
50
100
150
200
250
300
350
400
450
DEPTH (FEET)
GRADIENT INTERVAL 100- 440 FT
GRADIENT = 1.68 DEG F/100 FT
CALC SURF TEMP = 63.2 DEG F
RUN 2
TD = 450 FEET
BHT=70.83 DEG F
EQUILIBRIUM GRADIENT
GTS HOLE NO. 1-78-B32
4/24/78 (▲)
GEOTHERMAL SERVICES, INC.
SAN DIEGO, CALIFORNIA

FIELD DATA SHEET

TEMPERATURE SURVEY

HOLE NUMBER 178-33 TD 495

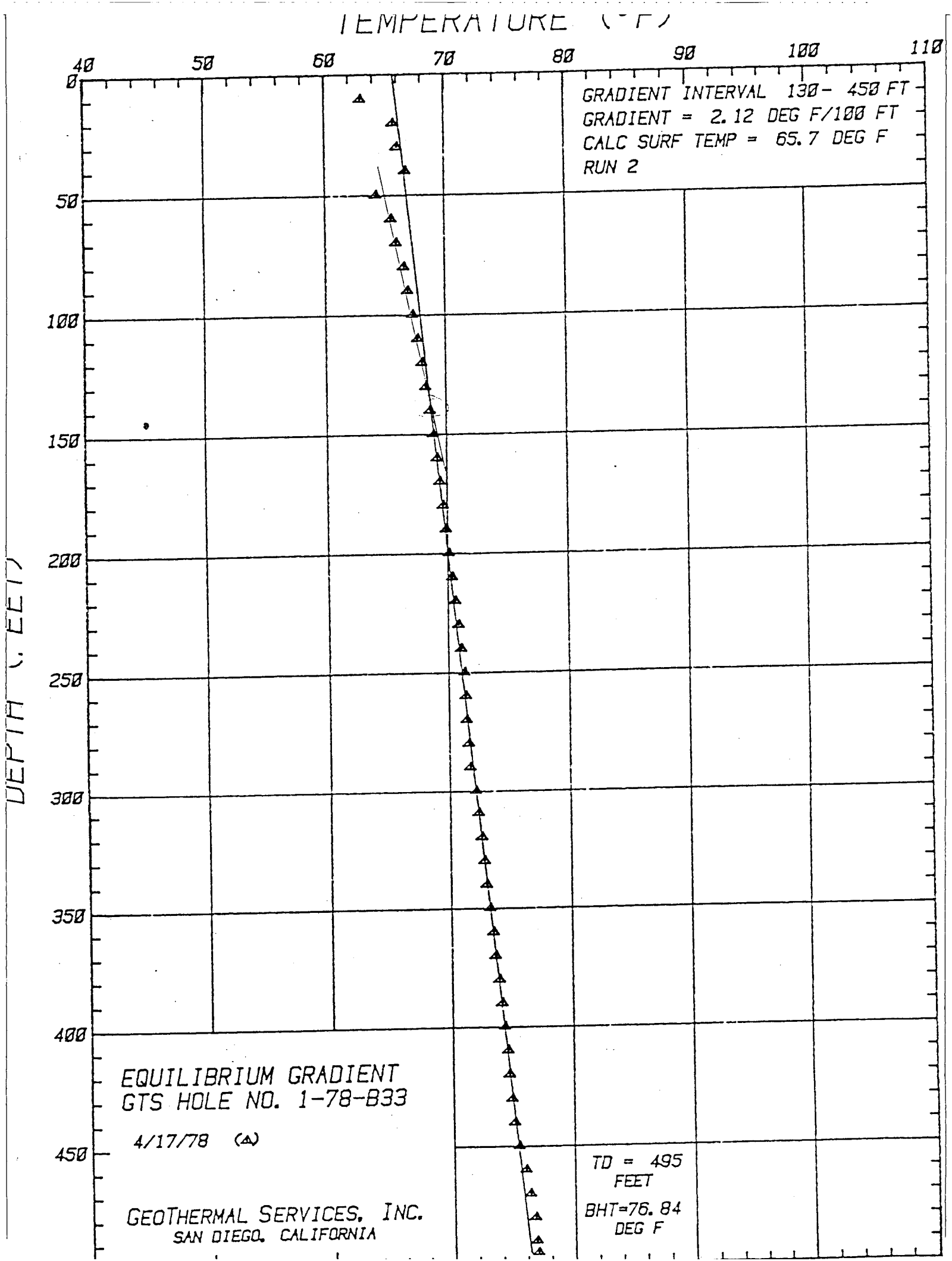
REFERENCE MAP 1-78

REMARKS

HOLE NO. 178-33
RUN NO. 2
DATE 4/17/78
TIME:
START 12:31P
END 1:27
SENSOR SERIAL NO. 061477-05
OPERATOR WALKER T.

FT.	KΩ	°F	FT.	KΩ	°F	FT.	KΩ	°F
10	163.46	63.07	280	129.54	71.56	550		
20	151.70	65.68	290	129.16	71.67	560		
30	150.47	65.98	300	127.23	72.09	570		
40	147.64	66.69	310	127.05	72.30	580		
50	157.69	64.26	320	126.24	72.54	590		
60	152.37	65.52	330	125.58	72.73	600		
70	150.88	65.88	340	125.00	72.91	610		
80	148.30	66.51	350	124.13	73.17	620		
90	147.14	66.81	360	123.47	73.38	630		
100	145.51	67.22	370	122.86	73.56	640		
110	143.98	67.60	380	122.03	73.83	650		
120	142.71	67.95	390	121.39	74.03	660		
130	141.48	68.27	400	120.64	74.26	670		
140	140.20	68.59	410	119.82	74.52	680		
150	139.32	68.83	420	119.49	74.62	690		
160	138.20	69.13	430	118.91	74.80	700		
170	137.38	69.37	440	118.24	75.02	710		
180	136.53	69.58	450	117.21	75.36	720		
190	135.66	69.84	460	115.55	75.90	730		
200	134.84	70.05	470	114.46	76.26	740		
210	134.01	70.29	480	113.37	76.63	750		
220	133.05	70.56	490	113.00	76.75	760		
230	132.21	70.79	~~500~~	112.74	76.84	770		
240	131.44	71.02	510	TD 495'		780		
250	130.61	71.26	520			790		
260	130.33	71.33	530			800		
270	130.18	71.38	540			810		

JANUARY, 1976


TEMPERATURE (°F)
40
50
60
70
80
90
100
110
DEPTH (FEET)
0
50
100
150
200
250
300
350
400
450
GRADIENT INTERVAL 130- 450 FT
GRADIENT = 2.12 DEG F/100 FT
CALC SURF TEMP = 65.7 DEG F
RUN 2
EQUILIBRIUM GRADIENT
GTS HOLE NO. 1-78-B33
4/17/78 (▲)
TD = 495 FEET
BHT=76.84 DEG F
GEOTHERMAL SERVICES, INC.
SAN DIEGO, CALIFORNIA

FIELD DATA SHEET

TEMPERATURE SURVEY

HOLE NUMBER 1-78 B35 TD 227'

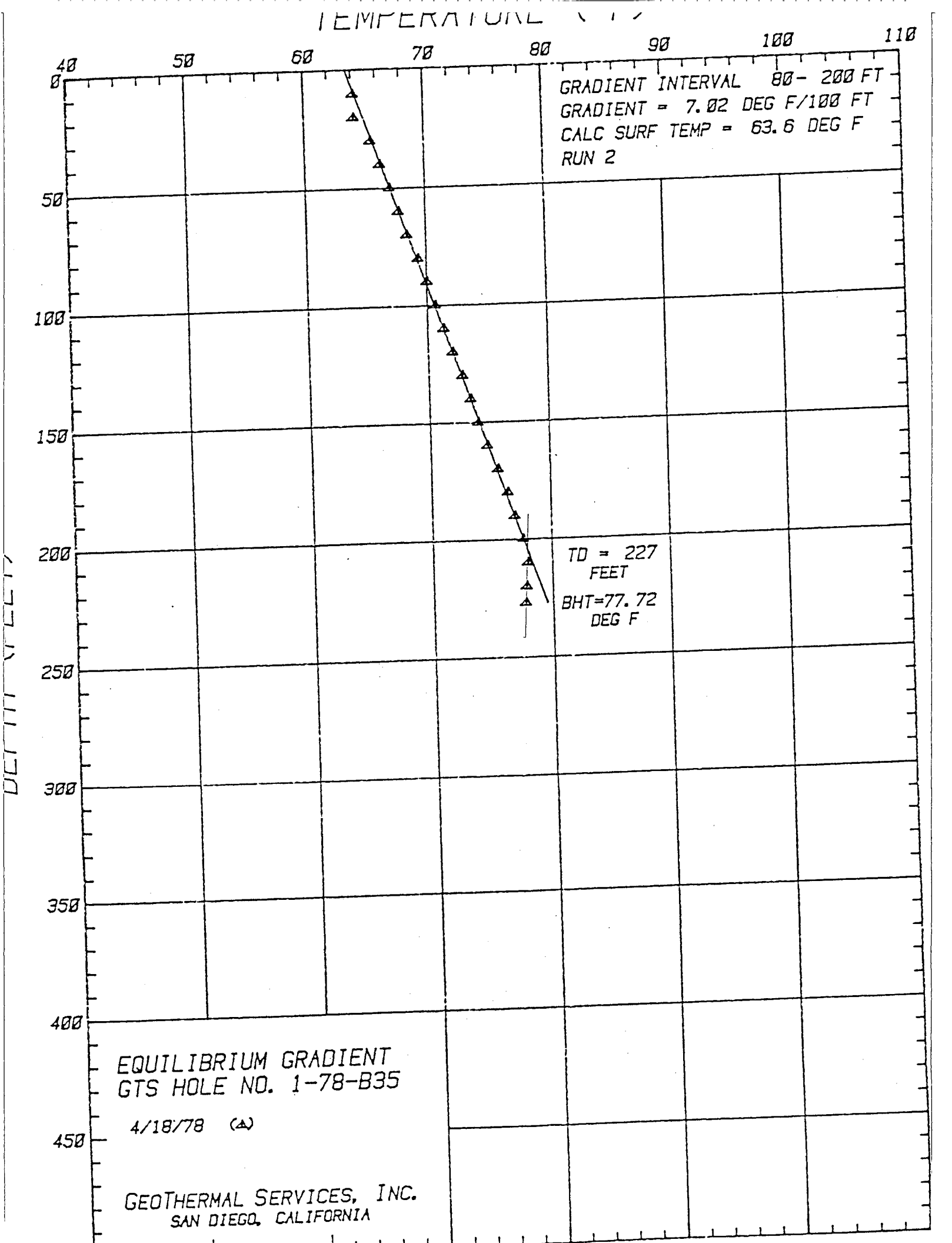
REFERENCE MAP 5-77

REMARKS

HOLE NO. 1-78 B35
RUN NO. 3
DATE 16 AUG. 78
TIME:
START 11:20
END 12:05
SENSOR SERIAL NO. 476
OPERATOR WALKER T.

FT.	KΩ	°F	FT.	KΩ	°F	FT.	KΩ	°F
10	106.57	71.50	280			550		
20	116.22	68.23	290			560		
30	115.32	68.52	300			570		
40	112.20	69.54	310			580		
50	109.28	70.52	320			590		
60	107.14	71.29	330			600		
70	105.23	71.96	340			610		
80	103.32	72.65	350			620		
90	101.44	73.35	360			630		
100	99.57	74.05	370			640		
110	97.72	74.76	380			650		
120	95.95	75.46	390			660		
130	94.24	76.14	400			670		
140	92.64	76.80	410			680		
150	91.28	77.37	420			690		
160	90.14	77.85	430			700		
170	88.47	78.57	440			710		
180	86.68	79.36	450			720		
190	85.28	79.99	460			730		
200	83.10	80.99	470			740		
210	82.83	81.12	480			750		
220	82.48	80.81	490			760		
[illegible]	84.32	80.43	500			770		
240	Total depth	227'	510			780		
250			520			790		
260			530			800		
270			540			810		

JANUARY, 1976


TEMPERATURE
40
50
60
70
80
90
100
110
0
50
100
150
200
250
300
350
400
450
GRADIENT INTERVAL 80- 200 FT
GRADIENT = 7.02 DEG F/100 FT
CALC SURF TEMP = 63.6 DEG F
RUN 2
TD = 227 FEET
BHT=77.72 DEG F
EQUILIBRIUM GRADIENT
GTS HOLE NO. 1-78-B35
4/18/78
GEOTHERMAL SERVICES, INC.
SAN DIEGO, CALIFORNIA

FIELD DATA SHEET

TEMPERATURE SURVEY

HOLE NUMBER B-40 TD 1792

REFERENCE MAP 1-78

REMARKS On multimeter — used 100 scale not 1000

HOLE NO. B40
RUN NO. 5
DATE 9-7-78
TIME:
START 9:44
END 11:41
SENSOR SERIAL NO. 5382
OPERATOR WT

KΩ	°F	FT.	KΩ	°F	FT.	KΩ	°F
	69.07	280			550		78.78
		290			560		
		300		76.70	570		
		310			580		
	69.58	320			590		
		330			600		79.43
		340			610		
		350		77.47	620		
		360			630		
	71.32	370			640		
		380			650		80.07
		390			660		
		400		78.03	670		
		410			680		
	73.28	420			690		
		430			700		81.70
		440			710		
		450		78.06	720		
		460			730		
	75.47	470			740		
		480			750		82.50
		490			760		
		500		78.37	770		
		510			780		
	75.87	520			790		
		530			800		[illegible]
		540			810		

MAY 1978

GTS

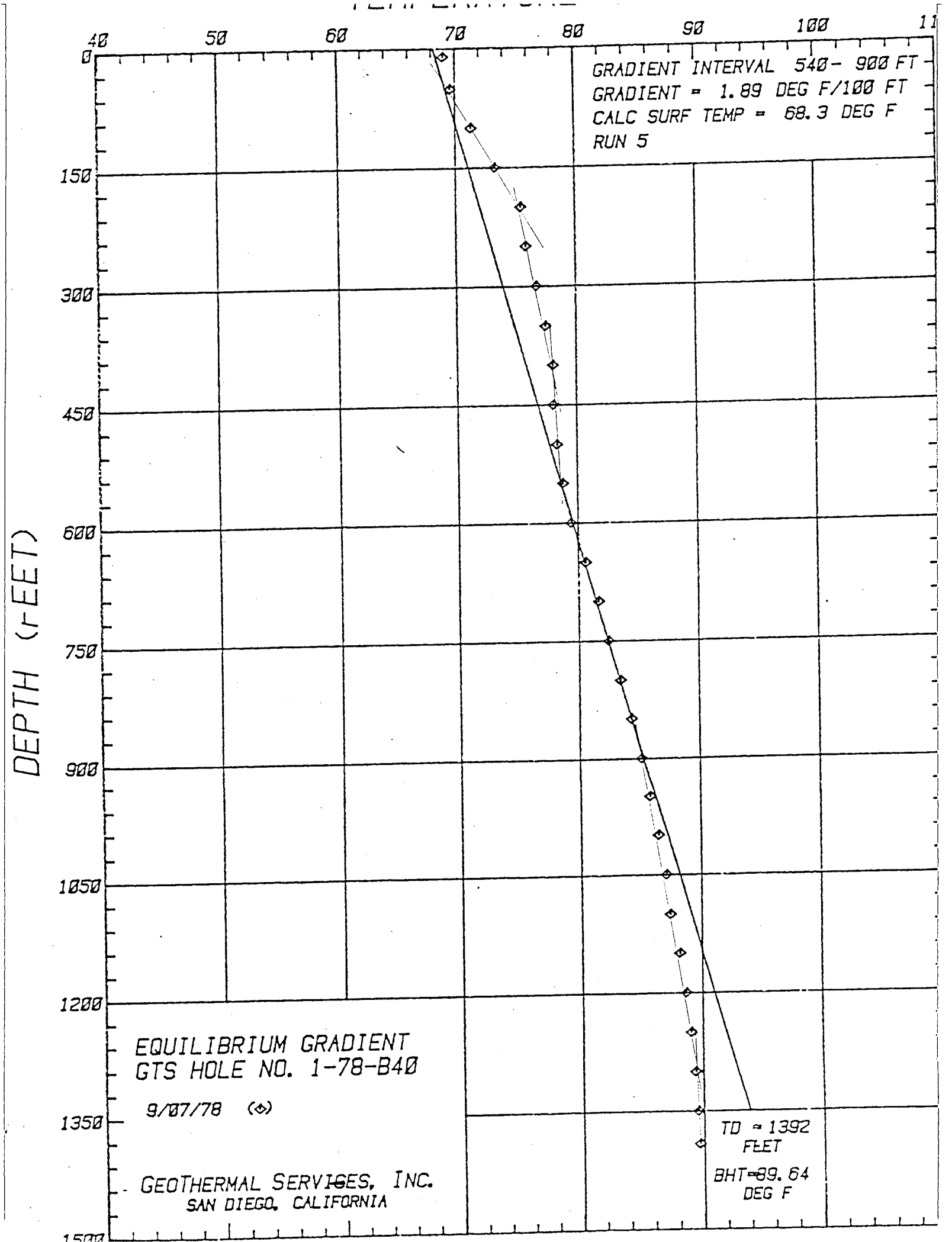
FIELD DATA SHEET
TEMPERATURE SURVEY

HOLE NO. B40
RUN NO. 3
DATE 9-7-78
TIME:
START 9:44
END 11:41

HOLE NUMBER B-40 TD 1392
REFERENCE MAP 1-78
REMARKS On multimeter, used 100 scale not 1000

FT.	KΩ	°F	FT.	KΩ	°F	FT.	KΩ	°F
820			1050		87.05	1280		
830			1060			1290		
840			1070			1300		89.34
850		84.34	1080			1310		
860			1090			1320		
870			1100		87.34	1330		
880			1110			1340		
890			1120			1350		89.53
900		85.13	1130			1360		
910			1140			1370		
920			1150		88.09	1380		
930			1160			1390		
940			1170			1400	1392	89.64
950		85.80	1180			1410		
960			1190			1420		
970			1200		88.59	1430		
980			1210			1440		
990			1220			1450		
1000		86.47	1230			1460		
1010			1240			1470		
1020			1250		89.02	1480		
1030			1260			1490		
1040			1270			1500		

MAY 1978


40
50
60
70
80
90
100
0
150
300
450
600
750
900
1050
1200
1350
1500
DEPTH (FEET)
GRADIENT INTERVAL 540- 900 FT
GRADIENT = 1.89 DEG F/100 FT
CALC SURF TEMP = 68.3 DEG F
RUN 5
EQUILIBRIUM GRADIENT
GTS HOLE NO. 1-78-B40
9/07/78
GEOTHERMAL SERVICES, INC.
SAN DIEGO, CALIFORNIA
TD = 1392 FEET
BHT=89.64 DEG F

FIELD DATA SHEET

2nd TEMPERATURE SURVEY hole 1-78 U3

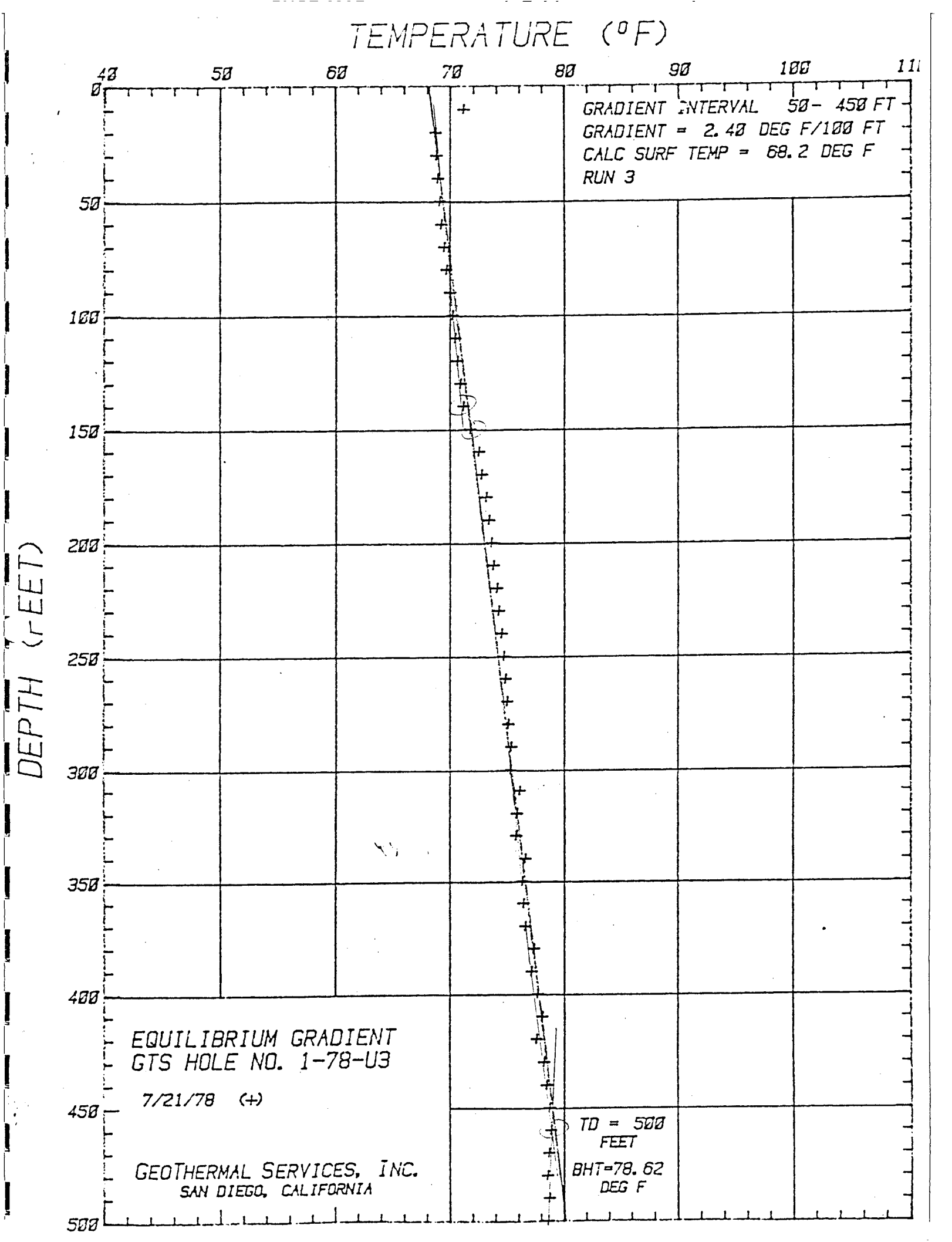
HOLE NUMBER 1-78 U3 TD 500'

REFERENCE MAP 5-77

REMARKS

HOLE NO. 1-78 U3
RUN NO. 3
DATE 21 JULY 78
TIME:
START 1:30 p
END 3:00 p
SENSOR SERIAL NO. 476
OPERATOR WALKER

FT.	KΩ	°F	FT.	KΩ	°F	FT.	KΩ	°F
10	107.50	71.15	280	96.97	75.05	550		
20	114.80	68.69	290	96.38	75.28	560		
30	114.60	68.75	300	96.45	75.26	570		
40	114.10	68.91	310	94.42	76.07	580		
50	113.68	69.05	320	95.09	75.80	590		
60	113.18	69.21	330	95.21	75.75	600		
70	112.50	69.44	340	93.28	76.53	610		
80	111.89	69.64	350	93.91	76.28	620		
90	111.04	69.95	360	93.55	76.42	630		
100	110.33	70.18	370	93.29	76.53	640		
110	109.74	70.39	380	91.45	77.29	650		
120	109.14	70.59	390	91.90	77.11	660		
130	108.34	70.87	400	90.58	77.66	670		
140	107.66	71.08	410	89.66	78.05	680		
150	106.03	71.68	420	90.90	77.53	690		
160	103.90	72.43	430	89.27	78.22	700		
170	103.23	72.69	440	88.70	78.47	710		
180	102.10	73.09	450	88.21	78.68	720		
190	101.39	73.35	460	87.84	78.84	730		
200	100.91	73.54	470	88.29	78.65	740		
210	100.27	73.77	480	88.50	78.56	750		
220	99.50	74.07	490	88.13	78.72	760		
230	99.21	74.18	500	88.35	78.62	770		
240	98.48	74.46	~~510~~	total depth	500'	780		
250	97.94	74.67	520			790		
260	97.67	74.78	530			800		
270	97.27	74.93	540			810		


TEMPERATURE (°F)
40
50
60
70
80
90
100
0
50
100
150
200
250
300
350
400
450
500
DEPTH (FEET)
GRADIENT INTERVAL 50- 450 FT
GRADIENT = 2.40 DEG F/100 FT
CALC SURF TEMP = 68.2 DEG F
RUN 3
EQUILIBRIUM GRADIENT
GTS HOLE NO. 1-78-U3
7/21/78 (+)
TD = 500 FEET
BHT=78.62 DEG F
GEOTHERMAL SERVICES, INC.
SAN DIEGO, CALIFORNIA

GTS

FIELD DATA SHEET
TEMPERATURE SURVEY

HOLE NUMBER 1-78 U4 TD 376'

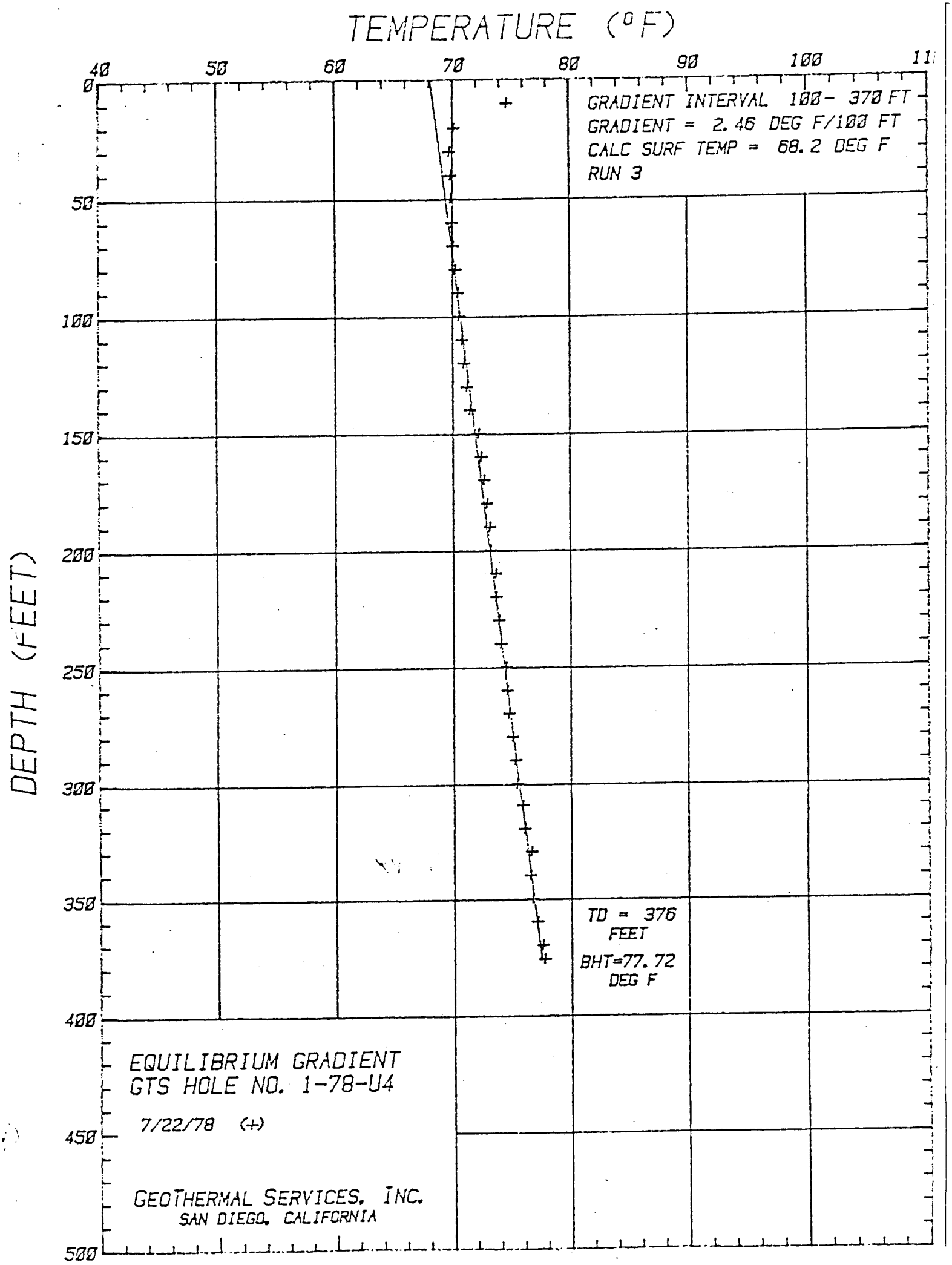
REFERENCE MAP 5-77

REMARKS

HOLE NO. 1-78 U4
RUN NO. 3
DATE 22 JULY 78
TIME:
START 6:10P
END 7:05P
SENSOR SERIAL NO. 476
OPERATOR WALKER T.

FT.	KΩ	°F	FT.	KΩ	°F	FT.	KΩ	°F
10	98.01	74.65	280	97.07	75.01	550		
20	110.50	70.11	290	96.51	75.23	560		
30	111.71	69.71	300	96.08	75.40	570		
40	111.38	69.81	310	94.95	75.86	580		
50	111.49	69.78	320	94.62	75.99	590		
60	111.22	69.88	330	93.16	76.58	600		
70	110.86	69.98	340	93.36	76.50	610		
80	110.15	70.22	350	92.93	76.68	620		
90	109.72	70.39	360	91.93	77.09	630		
100	109.27	70.52	370	90.81	77.56	640		
110	108.61	70.77		90.44	77.72	650		
120	108.21	70.90	390	total depth	376'	660		
130	107.54	71.15	400			670		
140	106.76	71.39	410			680		
150	104.73	72.14	420			690		
160	104.14	72.36	430			700		
170	103.51	72.58	440			710		
180	102.79	72.84	450			720		
190	102.14	73.09	460			730		
200	102.03	73.13	470			740		
210	100.84	73.58	480			750		
220	100.82	73.58	490			760		
230	100.14	73.84	500			770		
240	99.68	74.00	510			780		
250	98.54	74.44	520			790		
260	98.22	74.56	530			800		
270	97.81	74.72	540			810		

JANUARY, 1976


TEMPERATURE (°F)
40
50
60
70
80
90
100
DEPTH (FEET)
0
50
100
150
200
250
300
350
400
450
500
GRADIENT INTERVAL 100- 370 FT
GRADIENT = 2.46 DEG F/100 FT
CALC SURF TEMP = 68.2 DEG F
RUN 3
TD = 376 FEET
BHT=77.72 DEG F
EQUILIBRIUM GRADIENT
GTS HOLE NO. 1-78-U4
7/22/78 (+)
GEOTHERMAL SERVICES, INC.
SAN DIEGO, CALIFORNIA

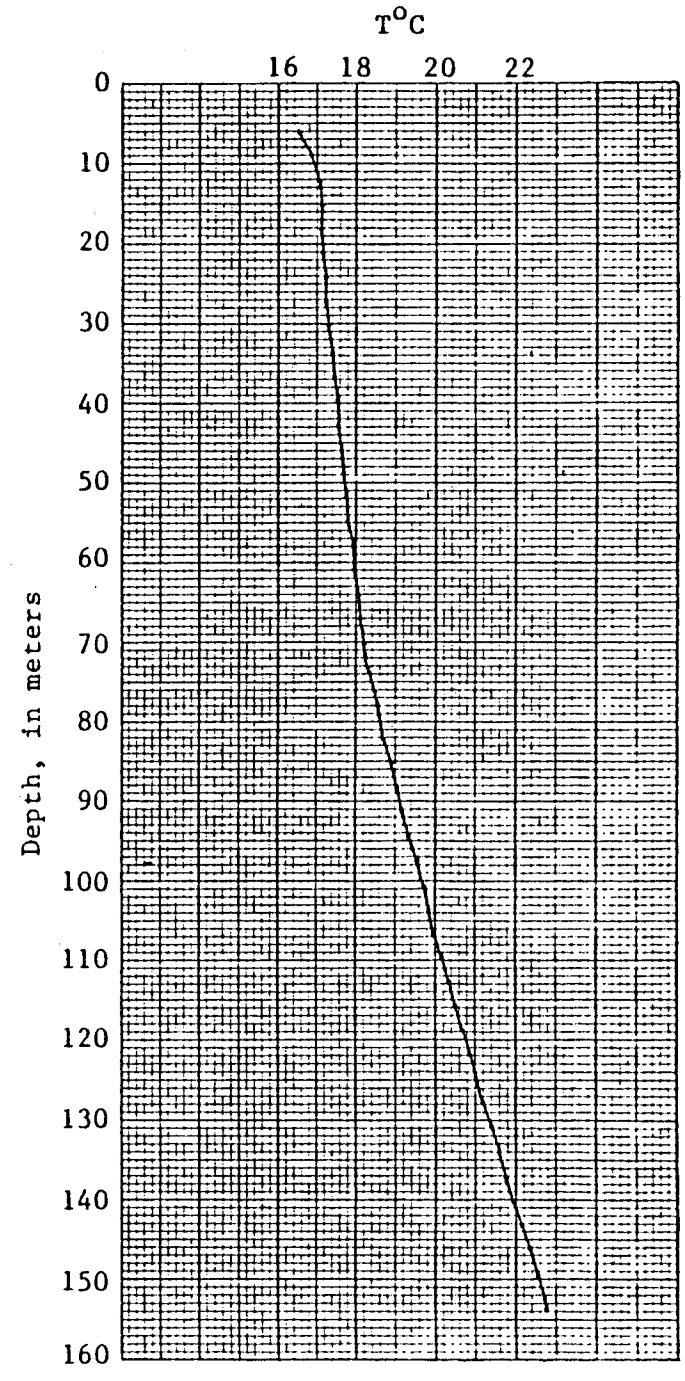
GULF MINERAL RESOURCES COMPANY

T.G. HOLE STROZZI #1B

T. 3 S., R. 2 W., Sec. 1

7/9/79 9:52 PM
Logged by GeothermEx, Inc.

Depth, in feet	Depth, in meters	°F	°C
10	3.0	-----	-----
20	6.1	61.68	16.49
30	9.1	62.31	16.84
40	12.2	62.74	17.08
50	15.2	62.83	17.13
60	18.3	62.83	17.13
70	21.3	62.91	17.17
80	24.4	62.98	17.21
90	27.4	63.05	17.25
100	30.5	63.18	17.32
110	33.5	63.28	17.38
120	36.6	63.41	17.45
130	39.6	63.52	17.51
140	42.7	63.63	17.57
150	45.7	63.75	17.64
160	48.8	63.82	17.68
170	51.8	63.97	17.76
180	54.9	64.06	17.81
190	57.9	64.20	17.89
200	61.0	64.31	17.95
210	64.0	64.47	18.04
220	67.1	64.62	18.12
230	70.1	64.78	18.21
240	73.2	64.98	18.32
250	76.2	65.26	18.48
260	79.2	65.48	18.60
270	82.3	65.70	18.72
280	85.3	65.98	18.88
290	88.4	66.25	19.03
300	91.4	66.52	19.18
310	94.5	66.85	19.36
320	97.5	67.12	19.51
330	100.6	67.44	19.69
340	103.6	67.75	19.86
350	106.7	68.02	20.01
360	109.7	68.32	20.18
370	112.8	68.65	20.36
380	115.8	68.94	20.52
390	118.9	69.22	20.68
400	121.9	69.53	20.85
410	125.0	69.85	21.03
420	128.0	70.16	21.20
430	131.1	70.50	21.39
440	134.1	70.86	21.59
450	137.2	71.19	21.77
460	140.2	71.51	21.95
470	143.3	71.89	22.16
480	146.3	72.18	22.32
490	149.4	72.59	22.55
500	152.4	72.88	22.71
504	153.6	72.97	22.76



GULF MINERAL RESOURCES COMPANY

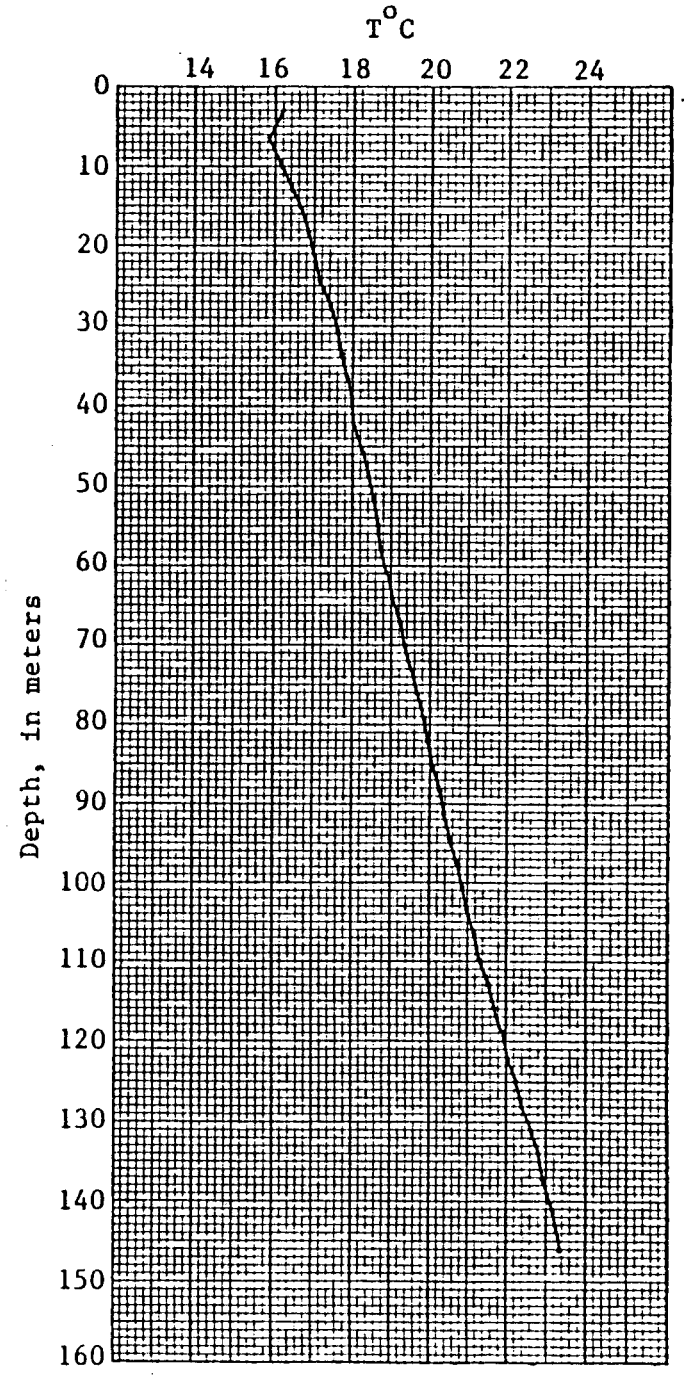
SOCORRO PROSPECT

T.G. HOLE STROZZI #2B

T. 3 S., R. 2 W., Sec. 2

7/9/79 12:31 PM
Logged by GeothermEx, Inc.

Depth, in feet	Depth, in meters	°F	°C	Depth, in feet	Depth, in meters	°F	°C
10	3.0	61.18	16.21	250	76.2	67.35	19.64
20	6.1	60.51	15.84	260	79.2	67.66	19.81
30	9.1	61.02	16.12	270	82.3	67.86	19.92
40	12.2	61.54	16.41	280	85.3	68.13	20.07
50	15.2	61.95	16.64	290	88.4	68.43	20.24
60	18.3	62.31	16.84	300	91.4	68.68	20.38
70	21.3	62.58	16.99	310	94.5	68.92	20.51
80	24.4	62.85	17.14	320	97.5	69.24	20.69
90	27.4	63.32	17.40	330	100.6	69.51	20.84
100	30.5	63.68	17.60	340	103.6	69.82	21.01
110	33.5	63.84	17.69	350	106.7	70.09	21.16
120	36.6	64.18	17.88	360	109.7	70.41	21.34
130	39.6	64.35	17.97	370	112.8	70.77	21.54
140	42.7	64.49	18.05	380	115.8	71.06	21.70
150	45.7	64.89	18.27	390	118.9	71.40	21.89
160	48.8	65.12	18.40	400	121.9	71.73	22.07
170	51.8	65.39	18.55	410	125.0	72.01	22.23
180	54.9	65.61	18.67	420	128.0	72.36	22.42
190	57.9	65.75	18.76	430	131.1	72.64	22.58
200	61.0	66.04	18.91	440	134.1	73.00	22.78
210	64.0	66.29	19.05	450	137.2	73.27	22.93
220	67.1	66.60	19.22	460	140.2	73.56	23.09
230	70.1	66.83	19.35	470	143.3	73.81	23.23
240	73.2	67.06	19.48	480	146.3	73.92	23.29



GULF MINERAL RESOURCES COMPANY

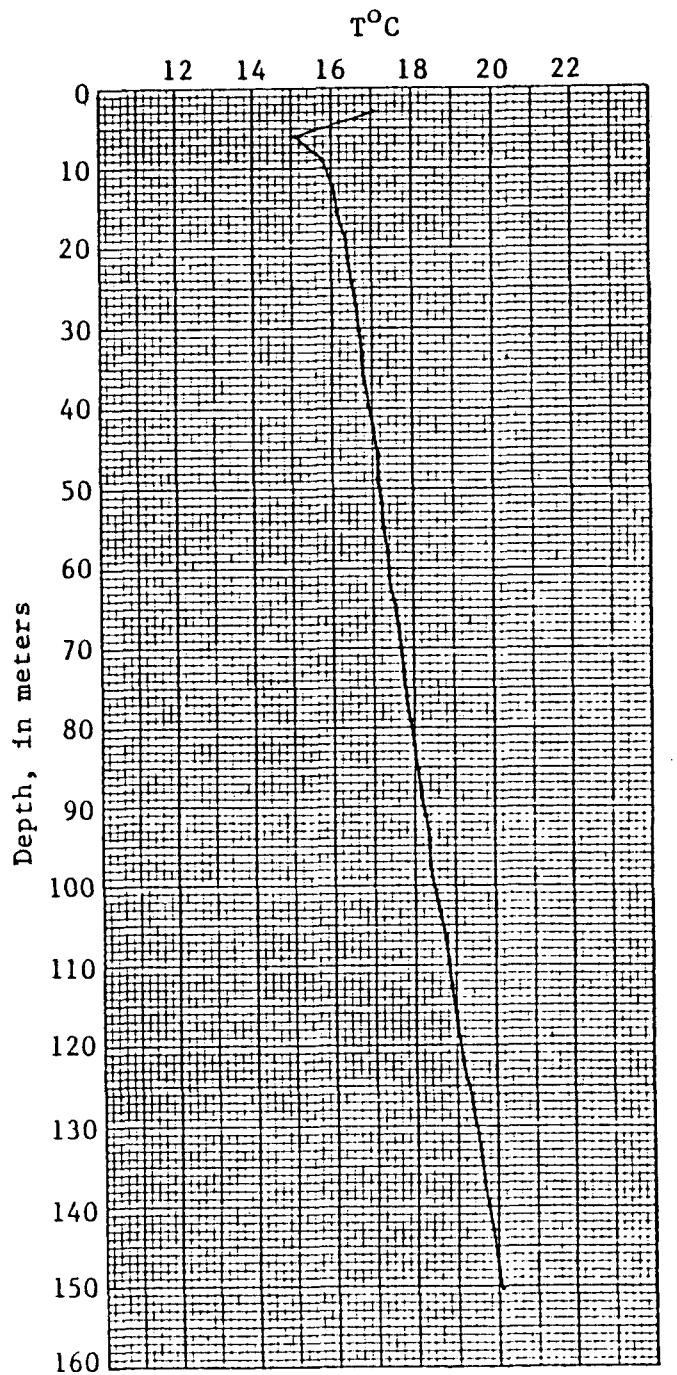
SOCORRO PROSPECT

T.G. HOLE STROZZI #3

T. 3 S., R. 2 W., Sec. 2

7/9/79 2:01 PM
Logged by GeothermEx, Inc.

Depth, in feet	Depth, in meters	°F	°C	Depth, in feet	Depth, in meters	°F	°C
10	3.0	62.69	17.05	260	79.2	64.20	17.89
20	6.1	59.79	15.44	270	82.3	64.35	17.97
30	9.1	60.49	15.83	280	85.3	64.51	18.06
40	12.2	60.93	16.07	290	88.4	64.67	18.15
50	15.2	61.11	16.17	300	91.4	64.85	18.25
60	18.3	61.34	16.30	310	94.5	65.01	18.34
70	21.3	61.50	16.39	320	97.5	65.14	18.41
80	24.4	61.68	16.49	330	100.6	65.30	18.50
90	27.4	61.83	16.57	340	103.6	65.48	18.60
100	30.5	62.01	16.67	350	106.7	65.64	18.69
110	33.5	62.13	16.74	360	109.7	65.80	18.78
120	36.6	62.24	16.80	370	112.8	65.98	18.88
130	39.6	62.37	16.87	380	115.8	66.16	18.98
140	42.7	62.58	16.99	390	118.9	66.34	19.08
150	45.7	62.71	17.06	400	121.9	66.51	19.17
160	48.8	62.83	17.13	410	125.0	66.70	19.28
170	51.8	62.94	17.19	420	128.0	66.85	19.36
180	54.9	63.09	17.27	430	131.1	67.06	19.48
190	57.9	63.21	17.34	440	134.1	67.23	19.57
200	61.0	63.34	17.41	450	137.2	67.39	19.66
210	64.0	63.46	17.48	460	140.2	67.59	19.77
220	67.1	63.63	17.57	470	143.3	67.78	19.88
230	70.1	63.75	17.64	480	146.3	67.95	19.97
240	73.2	63.91	17.73	490	149.4	68.11	20.06
250	76.2	64.04	17.80	493	150.3	68.16	20.09



GULF MINERAL RESOURCES COMPANY

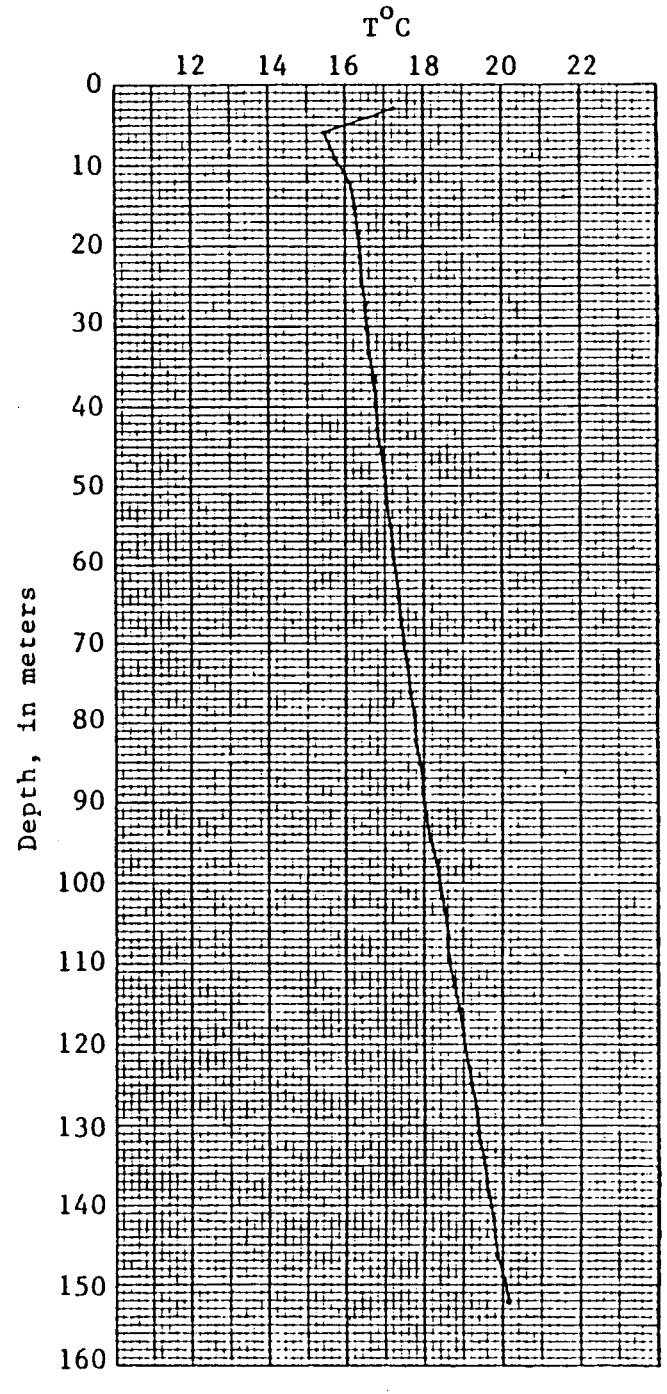
SOCORRO PROSPECT

T.G. HOLE STROZZI #4

T. 2 S., R. 2 W., Sec. 34

7/9/79 3:44 PM
Logged by GeothermEx, Inc.

Depth, in feet	Depth, in meters	°F	°C	Depth, in feet	Depth, in meters	°F	°C
10	3.0	63.05	17.25	260	79.2	63.95	17.75
20	6.1	59.77	15.43	270	82.3	64.06	17.81
30	9.1	60.39	15.77	280	85.3	64.18	17.88
40	12.2	60.96	16.09	290	88.4	64.35	17.97
50	15.2	61.29	16.27	300	91.4	64.49	18.05
60	18.3	61.34	16.30	310	94.5	64.69	18.16
70	21.3	61.45	16.36	320	97.5	64.92	18.29
80	24.4	61.54	16.41	330	100.6	65.08	18.38
90	27.4	61.66	16.48	340	103.6	65.23	18.46
100	30.5	61.75	16.53	350	106.7	65.46	18.59
110	33.5	61.90	16.61	360	109.7	65.59	18.66
120	36.6	62.04	16.69	370	112.8	65.77	18.76
130	39.6	62.15	16.75	380	115.8	66.04	18.91
140	42.7	62.28	16.82	390	118.9	66.22	19.01
150	45.7	62.42	16.90	400	121.9	66.36	19.09
160	48.8	62.58	16.99	410	125.0	66.58	19.21
170	51.8	62.71	17.06	420	128.0	66.76	19.31
180	54.9	62.85	17.14	430	131.1	66.92	19.40
190	57.9	63.00	17.22	440	134.1	67.12	19.51
200	61.0	63.10	17.28	450	137.2	67.32	19.62
210	64.0	63.25	17.36	460	140.2	67.48	19.71
220	67.1	63.37	17.43	470	143.3	67.62	19.79
230	70.1	63.50	17.50	480	146.3	67.77	19.87
240	73.2	63.63	17.57	490	149.4	68.09	20.05
250	76.2	63.77	17.65	499	152.1	68.29	20.16



GULF MINERAL RESOURCES COMPANY

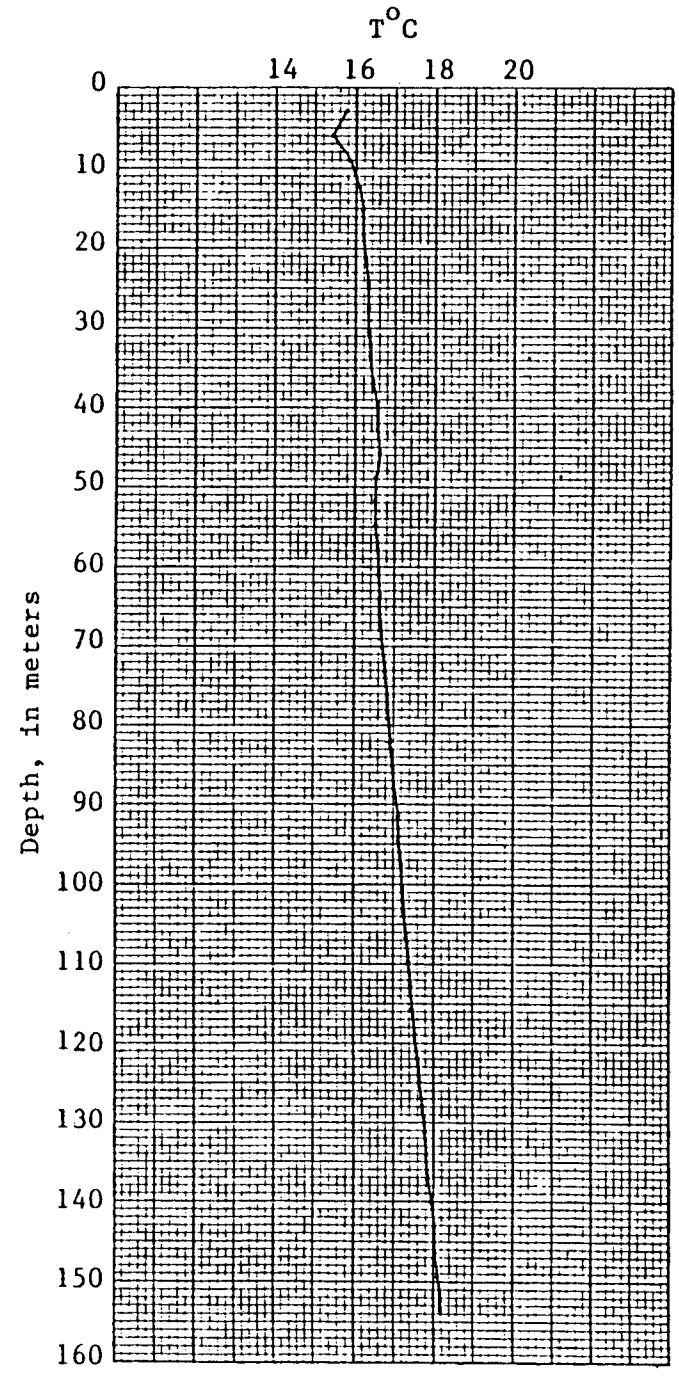
SOCORRO PROSPECT

T.G. HOLE STROZZI #5

T. 3 S., R. 2 W., Sec. 3

7/10/79 12:16 PM
Logged by GeothermEx, Inc.

Depth, in feet	Depth, in meters	°F	°C
10	3.0	60.33	15.74
20	6.1	59.81	15.45
30	9.1	60.53	15.85
40	12.2	60.85	16.03
50	15.2	61.03	16.13
60	18.3	61.12	16.18
70	21.3	61.21	16.23
80	24.4	61.32	16.29
90	27.4	61.36	16.31
100	30.5	61.36	16.31
110	33.5	61.45	16.36
120	36.6	61.61	16.45
130	39.6	61.79	16.55
140	42.7	61.79	16.55
150	45.7	61.86	16.59
160	48.8	61.74	16.52
170	51.8	61.68	16.49
180	54.9	61.72	16.51
190	57.9	61.77	16.54
200	61.0	61.86	16.59
210	64.0	61.93	16.63
220	67.1	62.01	16.67
230	70.1	62.08	16.71
240	73.2	62.17	16.76
250	76.2	62.28	16.82
260	79.2	62.37	16.87
270	82.3	62.47	16.93
280	85.3	62.56	16.98
290	88.4	62.65	17.03
300	91.4	62.76	17.09
310	94.5	62.83	17.13
320	97.5	62.92	17.18
330	100.6	63.01	17.23
340	103.6	63.09	17.27
350	106.7	63.18	17.32
360	109.7	63.27	17.37
370	112.8	63.37	17.43
380	115.8	63.45	17.47
390	118.9	63.55	17.53
400	121.9	63.66	17.59
410	125.0	63.75	17.64
420	128.0	63.84	17.69
430	131.1	63.93	17.74
440	134.1	64.04	17.80
450	137.2	64.15	17.86
460	140.2	64.24	17.91
470	143.3	64.35	17.97
480	146.3	64.45	18.03
490	149.4	64.56	18.09
500	152.4	64.67	18.15
504	153.6	64.69	18.16



GULF MINERAL RESOURCES COMPANY

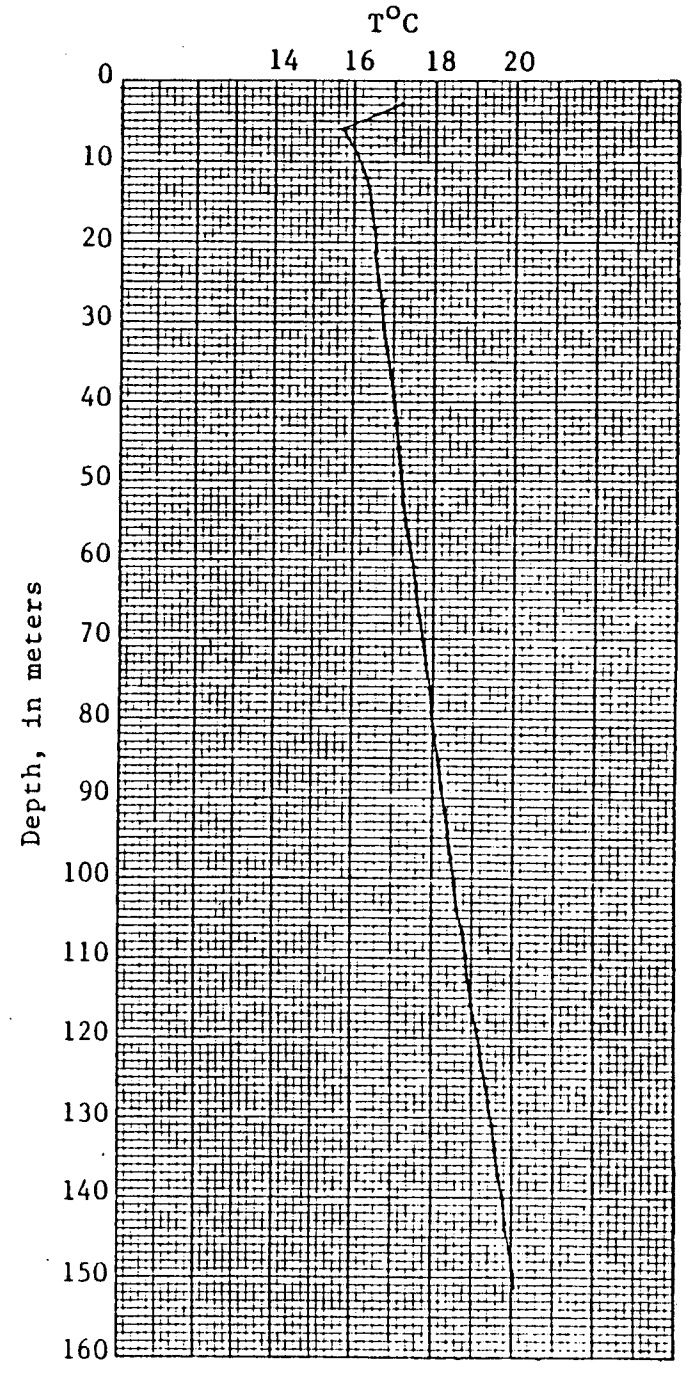
SOCORRO PROSPECT

T.G. HOLE STROZZI #7

T. 3 S., R. 2 W., Sec. 11

7/10/79 1:52 PM
Logged by GeothermEx, Inc.

Depth, in feet	Depth, in meters	°F	°C	Depth, in feet	Depth, in meters	°F	°C
10	3.0	62.87	17.15	260	79.2	64.35	17.97
20	6.1	60.26	15.70	270	82.3	64.47	18.04
30	9.1	60.87	16.04	280	85.3	64.63	18.13
40	12.2	61.38	16.32	290	88.4	64.76	18.20
50	15.2	61.54	16.41	300	91.4	64.92	18.29
60	18.3	61.65	16.47	310	94.5	65.08	18.38
70	21.3	61.74	16.52	320	97.5	65.25	18.47
80	24.4	61.88	16.60	330	100.6	65.39	18.55
90	27.4	62.02	16.68	340	103.6	65.57	18.65
100	30.5	62.11	16.73	350	106.7	65.77	18.76
110	33.5	62.31	16.84	360	109.7	65.91	18.84
120	36.6	62.44	16.91	370	112.8	66.00	18.89
130	39.6	62.56	16.98	380	115.8	66.16	18.98
140	42.7	62.74	17.08	390	118.9	66.38	19.10
150	45.7	62.83	17.13	400	121.9	66.56	19.20
160	48.8	62.94	17.19	410	125.0	66.72	19.29
170	51.8	63.03	17.24	420	128.0	66.88	19.38
180	54.9	63.19	17.33	430	131.1	67.05	19.47
190	57.9	63.34	17.41	440	134.1	67.21	19.56
200	61.0	63.45	17.47	450	137.2	67.41	19.67
210	64.0	63.63	17.57	460	140.2	67.57	19.76
220	67.1	63.73	17.63	470	143.3	67.71	19.84
230	70.1	63.88	17.71	480	146.3	67.89	19.94
240	73.2	64.02	17.79	490	149.4	68.05	20.03
250	76.2	64.18	17.88	496	151.2	68.09	20.05



GULF MINERAL RESOURCES COMPANY

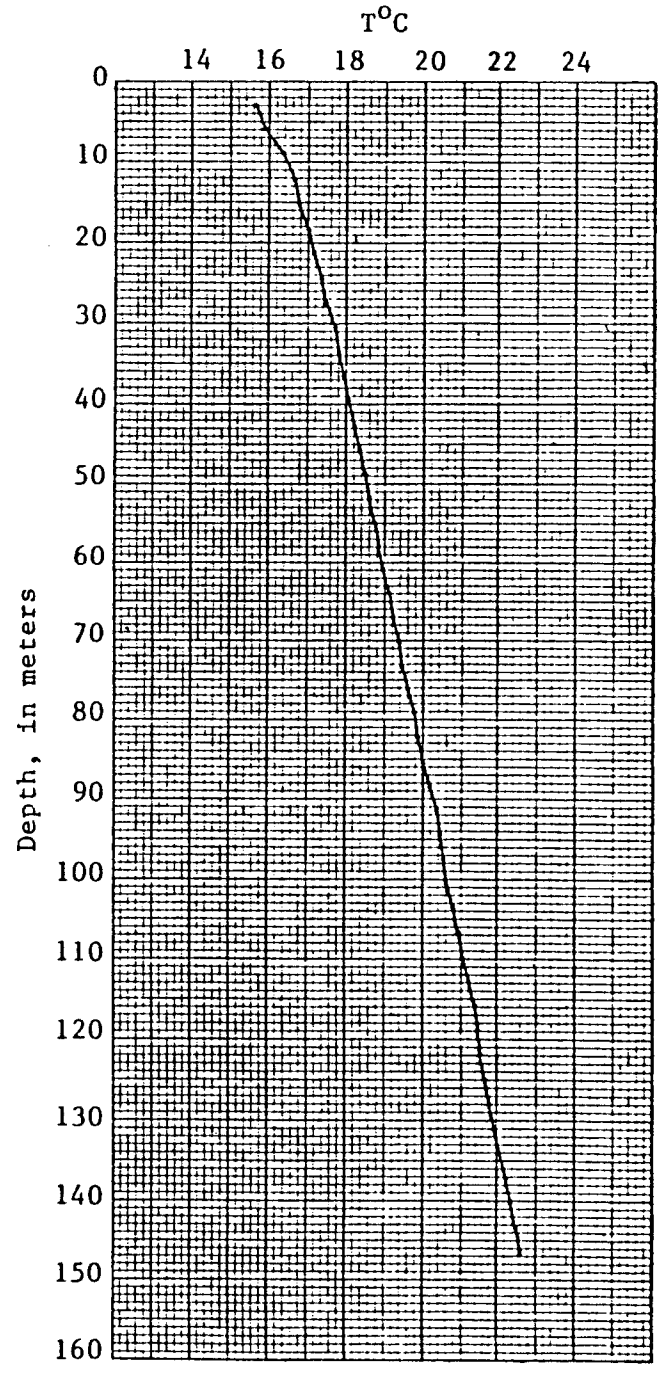
SOCORRO PROSPECT

T.G. HOLE STROZZI #8

T. 3 S., R. 2 W., Sec. 11

7/10/79 3:04 PM
Logged by GeothermEx, Inc.

Depth, in feet	Depth, in meters	°F	°C
10	3.0	60.15	15.64
20	6.1	60.64	15.91
30	9.1	61.41	16.34
40	12.2	61.95	16.64
50	15.2	62.20	16.78
60	18.3	62.56	16.98
70	21.3	62.87	17.15
80	24.4	63.23	17.35
90	27.4	63.52	17.51
100	30.5	63.84	17.69
110	33.5	64.06	17.81
120	36.6	64.29	17.94
130	39.6	64.53	18.07
140	42.7	64.78	18.21
150	45.7	65.01	18.34
160	48.8	65.26	18.48
170	51.8	65.46	18.59
180	54.9	65.66	18.70
190	57.9	65.91	18.84
200	61.0	66.13	18.96
210	64.0	66.36	19.09
220	67.1	66.58	19.21
230	70.1	66.81	19.34
240	73.2	67.03	19.46
250	76.2	67.30	19.61
260	79.2	67.51	19.73
270	82.3	67.77	19.87
280	85.3	67.98	19.99
290	88.4	68.27	20.15
300	91.4	68.61	20.34
310	94.5	68.76	20.42
320	97.5	68.85	20.47
330	100.6	69.12	20.62
340	103.6	69.40	20.78
350	106.7	69.64	20.91
360	109.7	69.85	21.03
370	112.8	70.14	21.19
380	115.8	70.43	21.35
390	118.9	70.61	21.45
400	121.9	70.75	21.53
410	125.0	70.93	21.63
420	128.0	71.24	21.80
430	131.1	71.49	21.94
440	134.1	71.73	22.07
450	137.2	71.98	22.21
460	140.2	72.23	22.35
470	143.3	72.48	22.49
480	146.3	72.66	22.59
481	146.6	72.70	22.61



GULF MINERAL RESOURCES COMPANY

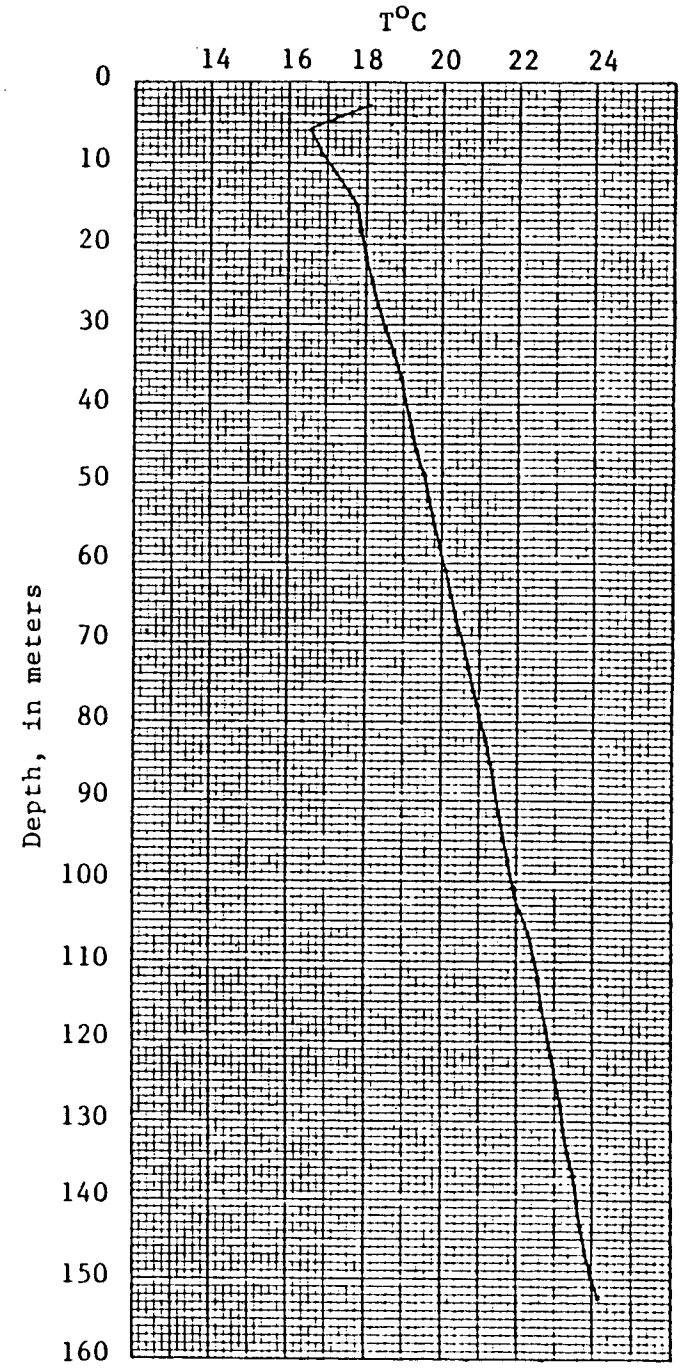
SOCORRO PROSPECT

T.G. HOLE STROZZI #9B

T. 3 S., R. 2 W., Sec. 36

7/11/79 12:46 PM
Logged by GeothermEx, Inc.

Depth, in feet	Depth, in meters	°F	°C	Depth, in feet	Depth, in meters	°F	°C
10	3.0	64.53	18.07	260	79.2	69.80	21.00
20	6.1	61.77	16.54	270	82.3	70.07	21.15
30	9.1	62.44	16.91	280	85.3	70.30	21.28
40	12.2	63.27	17.37	290	88.4	70.48	21.38
50	15.2	63.91	17.73	300	91.4	70.72	21.51
60	18.3	64.15	17.86	310	94.5	70.99	21.66
70	21.3	64.40	18.00	320	97.5	71.13	21.74
80	24.4	64.65	18.14	330	100.6	71.42	21.90
90	27.4	64.96	18.31	340	103.6	71.71	22.06
100	30.5	65.35	18.53	350	106.7	72.10	22.28
110	33.5	65.77	18.76	360	109.7	72.36	22.42
120	36.6	66.06	18.92	370	112.8	72.57	22.54
130	39.6	66.27	19.04	380	115.8	72.75	22.64
140	42.7	66.54	19.19	390	118.9	72.93	22.74
150	45.7	66.83	19.35	400	121.9	73.17	22.87
160	48.8	67.10	19.50	410	125.0	73.40	23.00
170	51.8	67.35	19.64	420	128.0	73.63	23.13
180	54.9	67.64	19.80	430	131.1	73.85	23.25
190	57.9	67.93	19.96	440	134.1	74.05	23.36
200	61.0	68.18	20.10	450	137.2	74.25	23.47
210	64.0	68.45	20.25	460	140.2	74.48	23.60
220	67.1	68.70	20.39	470	143.3	74.66	23.70
230	70.1	69.03	20.57	480	146.3	74.88	23.82
240	73.2	69.24	20.69	490	149.4	75.13	23.96
250	76.2	69.49	20.83	500	152.4	75.49	24.16



GULF MINERAL RESOURCES COMPANY

SOCORRO PROSPECT

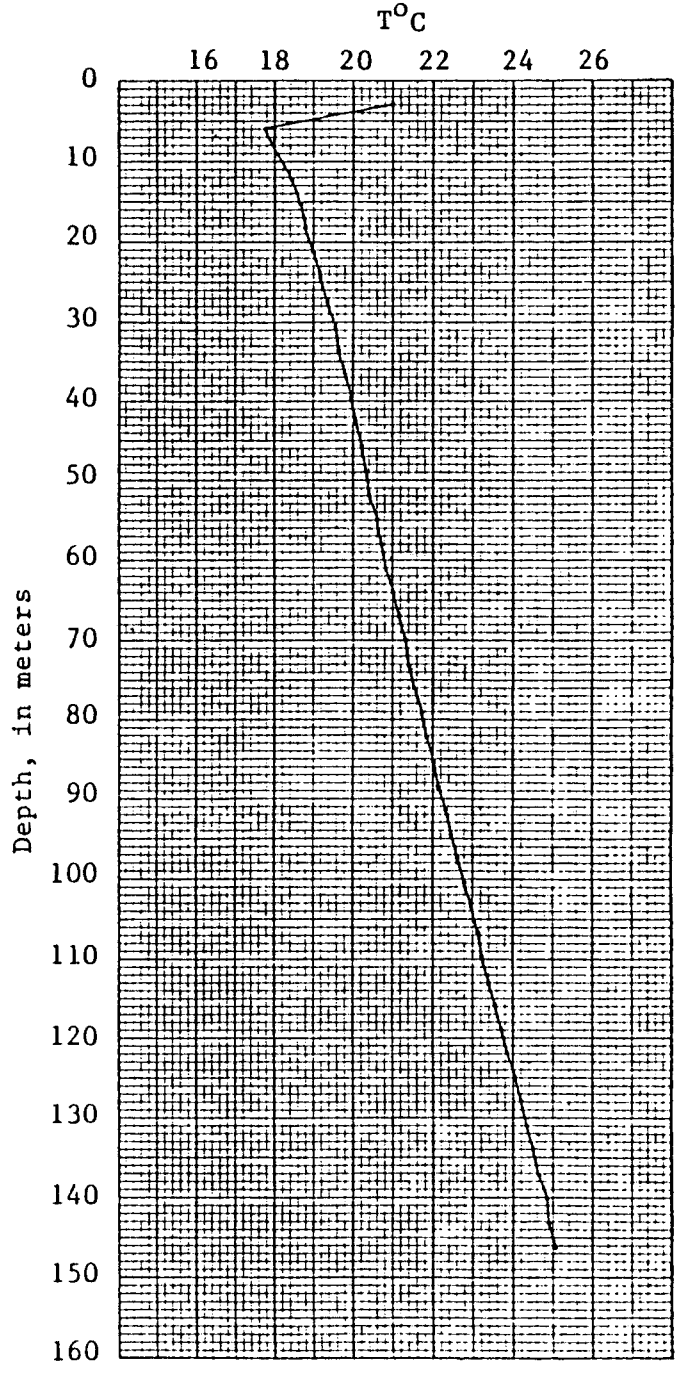
T.G. HOLE ARMIJO #1B

T. 4 S., R. 1 W., Sec. 5

7/11/79 6:06 PM
Logged by GeothermEx, Inc.

Depth, in feet	Depth, in meters	°F	°C	Depth, in feet	Depth, in meters	°F	°C
10	3.0	69.80	21.00	250	76.2	70.77	21.54
20	6.1	63.99	17.77	260	79.2	71.02	21.68
30	9.1	64.53	18.07	270	82.3	71.29	21.83
40	12.2	65.21	18.45	280	85.3	71.56	21.98
50	15.2	65.53	18.63	290	88.4	71.82	22.12
60	18.3	65.80	18.78	300	91.4	72.12	22.29
70	21.3	66.16	18.98	310	94.5	72.39	22.44
80	24.4	66.49	19.16	320	97.5	72.66	22.59
90	27.4	66.85	19.36	330	100.6	72.99	22.77
100	30.5	67.17	19.54	340	103.6	73.29	22.94
110	33.5	67.41	19.67	350	106.7	73.56	23.09
120	36.6	67.62	19.79	360	109.7	73.78	23.21
130	39.6	67.89	19.94	370	112.8	74.10	23.39
140	42.7	68.13	20.07	380	115.8	74.41	23.56
150	45.7	68.38	20.21	390	118.9	74.68	23.71
160	48.8	68.56	20.31	400	121.9	74.95	23.86
170	51.8	68.76	20.42	410	125.0	75.25	24.03
180	54.9	69.06	20.59	420	128.0	75.56	24.20
190	57.9	69.28	20.71	430	131.1	75.79	24.33
200	61.0	69.48	20.82	440	134.1	76.05	24.47
210	64.0	69.76	20.98	450	137.2	76.37	24.65
220	67.1	70.03	21.13	460	140.2	76.71	24.84
230	70.1	70.30	21.28	470	143.3	76.82	24.90
240	73.2	70.48	21.38	480	146.3	77.09	25.05

Note: 10': air-not stable



GULF MINERAL RESOURCES COMPANY

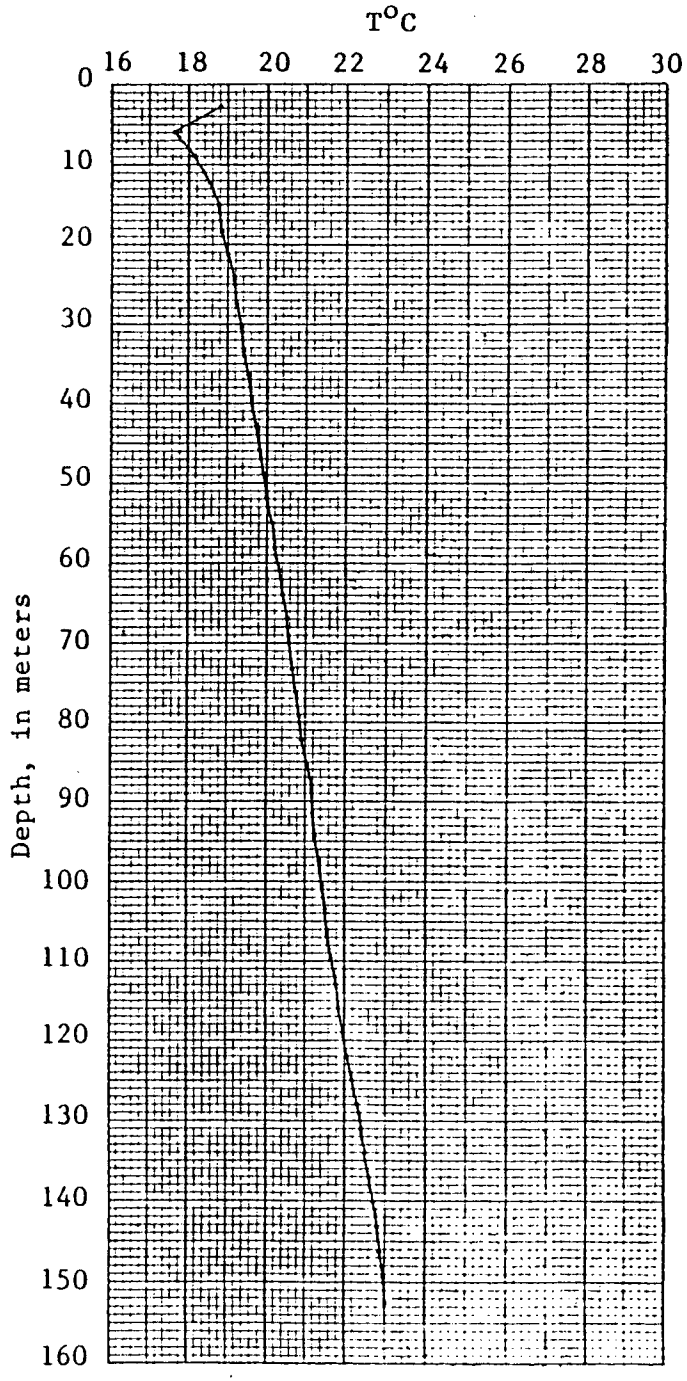
SOCORRO PROSPECT

T.G. HOLE ARMIJO #2B

T. 3 S., R. 1 W., Sec. 32

7/11/79 5:02 PM
Logged by GeothermEx, Inc.

Depth, in feet	Depth, in meters	°F	°C	Depth, in feet	Depth, in meters	°F	°C
10	3.0	65.88	18.82	260	79.2	69.51	20.84
20	6.1	63.81	17.67	270	82.3	69.66	20.92
30	9.1	64.56	18.09	280	85.3	69.91	21.06
40	12.2	65.37	18.54	290	88.4	70.05	21.14
50	15.2	65.75	18.75	300	91.4	70.16	21.20
60	18.3	65.95	18.86	310	94.5	70.27	21.26
70	21.3	66.22	19.01	320	97.5	70.41	21.34
80	24.4	66.45	19.14	330	100.6	70.56	21.42
90	27.4	66.60	19.22	340	103.6	70.70	21.50
100	30.5	66.79	19.33	350	106.7	70.84	21.58
110	33.5	66.96	19.42	360	109.7	70.99	21.66
120	36.6	67.14	19.52	370	112.8	71.15	21.75
130	39.6	67.30	19.61	380	115.8	71.35	21.86
140	42.7	67.53	19.74	390	118.9	71.53	21.96
150	45.7	67.68	19.82	400	121.9	71.73	22.07
160	48.8	67.86	19.92	410	125.0	71.92	22.18
170	51.8	68.02	20.01	420	128.0	72.12	22.29
180	54.9	68.20	20.11	430	131.1	72.28	22.38
190	57.9	68.36	20.20	440	134.1	72.48	22.49
200	61.0	68.50	20.28	450	137.2	72.66	22.59
210	64.0	68.70	20.39	460	140.2	72.84	22.69
220	67.1	68.85	20.47	470	143.3	73.00	22.78
230	70.1	69.01	20.56	480	146.3	73.17	22.87
240	73.2	69.17	20.65	490	149.4	73.33	22.96
250	76.2	69.37	20.76	500	152.4	73.42	23.01



GULF MINERAL RESOURCES COMPANY

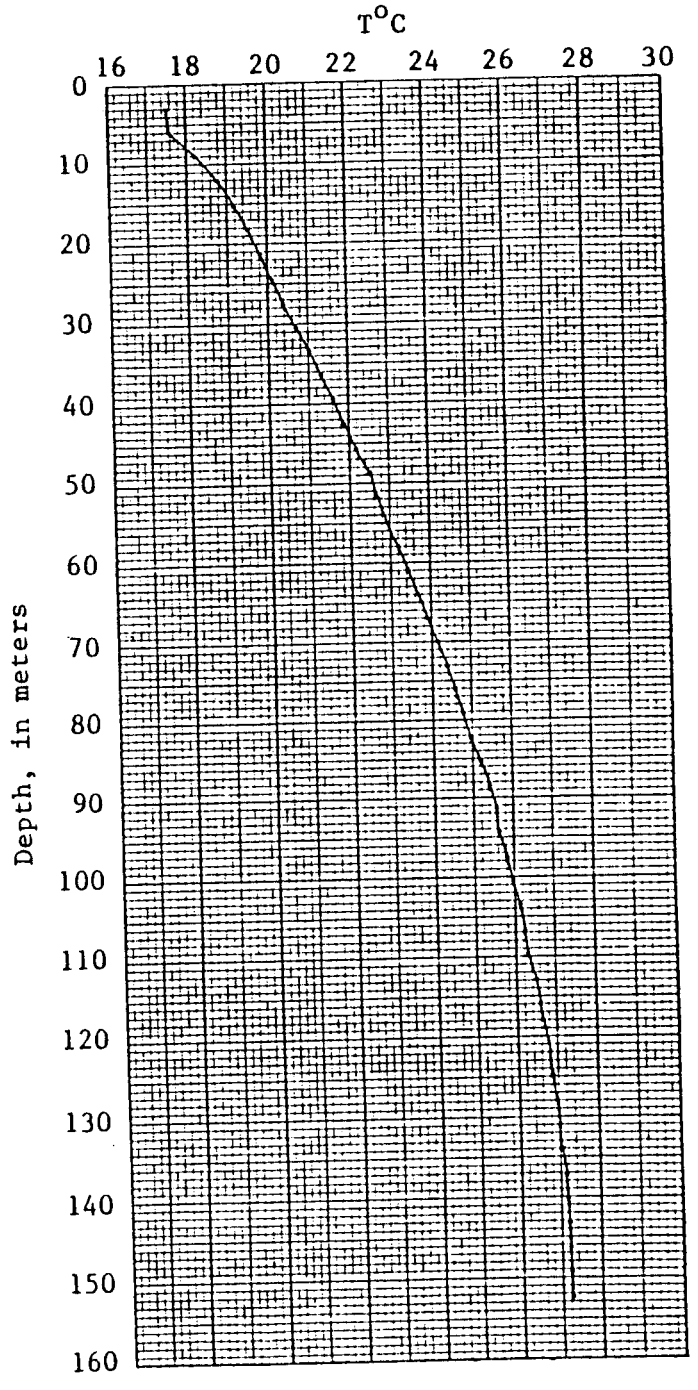
SOCORRO PROSPECT

T.G. HOLE ARMIJO #3

T. 3 S., R. 1 W., Sec. 32

7/11/79 3:29 PM
Logged by GeothermEx, Inc.

Depth, in feet	Depth, in meters	°F	°C
10	3.0	63.50	17.50
20	6.1	63.57	17.54
30	9.1	64.80	18.22
40	12.2	65.80	18.78
50	15.2	66.47	19.15
60	18.3	67.08	19.49
70	21.3	67.62	19.79
80	24.4	68.16	20.09
90	27.4	68.74	20.41
100	30.5	69.24	20.69
110	33.5	69.87	21.04
120	36.6	70.39	21.33
130	39.6	70.92	21.62
140	42.7	71.38	21.88
150	45.7	71.92	22.18
160	48.8	72.43	22.46
170	51.8	72.86	22.70
180	54.9	73.27	22.93
190	57.9	73.76	23.20
200	61.0	74.21	23.45
210	64.0	74.62	23.68
220	67.1	75.02	23.90
230	70.1	75.43	24.13
240	73.2	75.87	24.37
250	76.2	76.23	24.57
260	79.2	76.62	24.79
270	82.3	76.95	24.97
280	85.3	77.36	25.20
290	88.4	77.76	25.42
300	91.4	77.97	25.54
310	94.5	78.19	25.66
320	97.5	78.48	25.82
330	100.6	78.71	25.95
340	103.6	78.96	26.09
350	106.7	79.21	26.23
360	109.7	79.36	26.31
370	112.8	79.65	26.47
380	115.8	79.86	26.59
390	118.9	80.06	26.70
400	121.9	80.24	26.80
410	125.0	80.37	26.87
420	128.0	80.49	26.94
430	131.1	80.62	27.01
440	134.1	80.73	27.07
450	137.2	80.82	27.12
460	140.2	80.89	27.16
470	143.3	80.94	27.19
480	146.3	80.98	27.21
490	149.4	81.00	27.22
500	152.4	81.01	27.23



GULF MINERAL RESOURCES COMPANY

SOCORRO PROSPECT

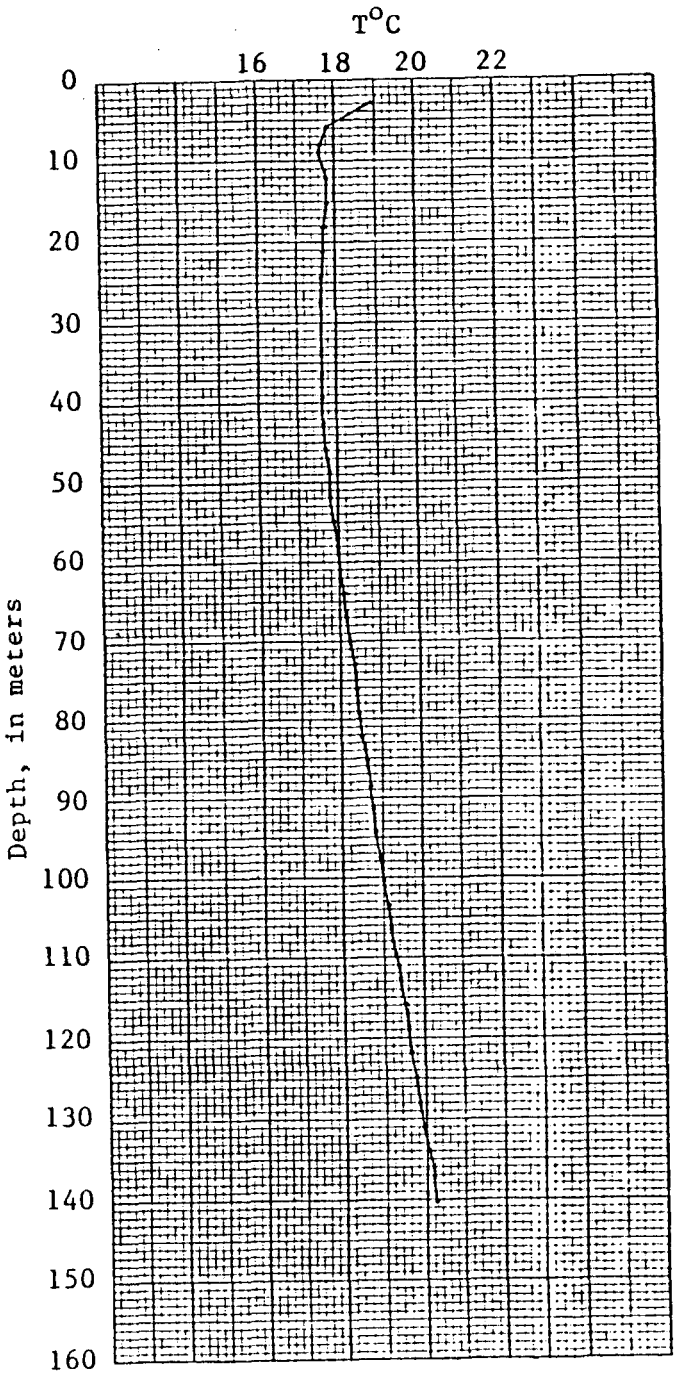
T.G. HOLE ARMIJO #4

T. 3 S., R. 2 W., Sec. 35

7/10/79 8:32 AM
Logged by GeothermEx, Inc.

Depth, in feet	Depth, in meters	°F	°C	Depth, in feet	Depth, in meters	°F	°C
10	3.0	66.02	18.90	240	73.2	64.92	18.29
20	6.1	64.04	17.80	250	76.2	65.07	18.37
30	9.1	63.68	17.60	260	79.2	65.19	18.44
40	12.2	64.04	17.80	270	82.3	65.34	18.52
50	15.2	64.04	17.80	280	85.3	65.48	18.60
60	18.3	63.86	17.70	290	88.4	65.62	18.68
70	21.3	63.82	17.68	300	91.4	65.73	18.74
80	24.4	63.75	17.64	310	94.5	65.89	18.83
90	27.4	63.75	17.64	320	97.5	66.04	18.91
100	30.5	63.75	17.64	330	100.6	66.22	19.01
110	33.5	63.75	17.64	340	103.6	66.40	19.11
120	36.6	63.77	17.65	350	106.7	66.56	19.20
130	39.6	63.79	17.66	360	109.7	66.70	19.28
140	42.7	63.81	17.67	370	112.8	66.88	19.38
150	45.7	63.88	17.71	380	115.8	67.06	19.48
160	48.8	64.04	17.80	390	118.9	67.24	19.58
170	51.8	64.15	17.86	400	121.9	67.41	19.67
180	54.9	64.22	17.90	410	125.0	67.59	19.77
190	57.9	64.31	17.95	420	128.0	67.75	19.86
200	61.0	64.44	18.02	430	131.1	67.93	19.96
210	64.0	64.54	18.08	440	134.1	68.14	20.08
220	67.1	64.65	18.14	450	137.2	68.34	20.19
230	70.1	64.81	18.23	460	140.2	68.45	20.25

Note: 10-90': pipe dry - readings unstable



GULF MINERAL RESOURCES COMPANY

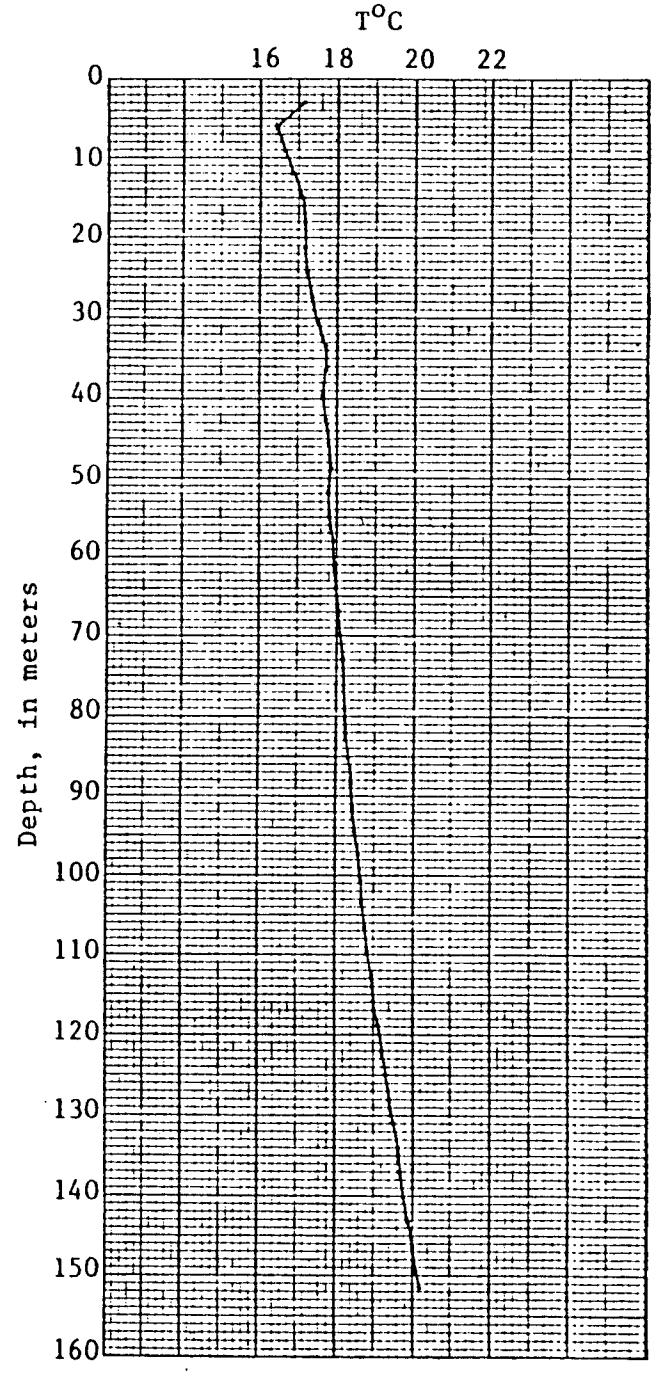
SOCORRO PROSPECT

T.G. HOLE ARMIJO #5

T. 3 S., R. 2 W., Sec. 26

7/11/79 11:27 AM
Logged by GeothermEx, Inc.

Depth, in feet	Depth, in meters	°F	°C	Depth, in feet	Depth, in meters	°F	°C
10	3.0	62.83	17.13	260	79.2	64.80	18.22
20	6.1	61.59	16.44	270	82.3	64.89	18.27
30	9.1	61.95	16.64	280	85.3	64.98	18.32
40	12.2	62.38	16.88	290	88.4	65.08	18.38
50	15.2	62.80	17.11	300	91.4	65.19	18.44
60	18.3	62.91	17.17	310	94.5	65.30	18.50
70	21.3	62.98	17.21	320	97.5	65.44	18.58
80	24.4	63.05	17.25	330	100.6	65.55	18.64
90	27.4	63.21	17.34	340	103.6	65.66	18.70
100	30.5	63.48	17.49	350	106.7	65.79	18.77
110	33.5	63.84	17.69	360	109.7	65.95	18.86
120	36.6	63.84	17.69	370	112.8	66.11	18.95
130	39.6	63.73	17.63	380	115.8	66.25	19.03
140	42.7	63.88	17.71	390	118.9	66.40	19.11
150	45.7	64.02	17.79	400	121.9	66.58	19.21
160	48.8	63.99	17.77	410	125.0	66.74	19.30
170	51.8	64.02	17.79	420	128.0	66.92	19.40
180	54.9	64.08	17.82	430	131.1	67.15	19.53
190	57.9	64.18	17.88	440	134.1	67.32	19.62
200	61.0	64.26	17.92	450	137.2	67.41	19.67
210	64.0	64.35	17.97	460	140.2	67.59	19.77
220	67.1	64.45	18.03	470	143.3	67.78	19.88
230	70.1	64.54	18.08	480	146.3	67.96	19.98
240	73.2	64.63	18.13	490	149.4	68.14	20.08
250	76.2	64.71	18.17	497	151.5	68.27	20.15

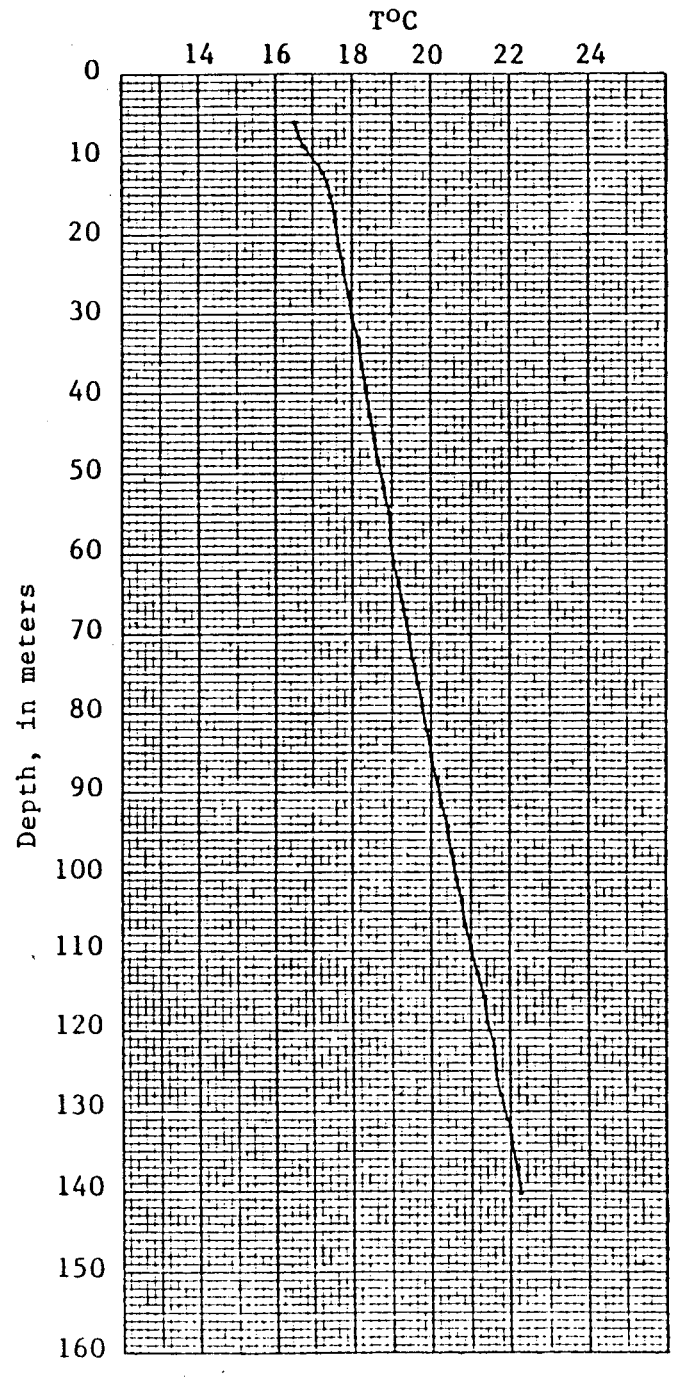


GULF MINERAL RESOURCES COMPANY

SOCORRO PROSPECT

T.G. HOLE ARMIJO #6B

T. 3 S., R. 2 W., Sec. 25

7/10/79 4:51 PM
Logged by GeothermEx, Inc.

Depth, in feet	Depth, in meters	°F	°C	Depth, in feet	Depth, in meters	°F	°C
10	3.0	-----	-----	240	73.2	67.12	19.51
20	6.1	61.74	16.52	250	76.2	67.37	19.65
30	9.1	62.15	16.75	260	79.2	67.53	19.74
40	12.2	63.03	17.24	270	82.3	67.82	19.90
50	15.2	63.41	17.45	280	85.3	68.05	20.03
60	18.3	63.59	17.55	290	88.4	68.22	20.12
70	21.3	63.75	17.64	300	91.4	68.49	20.27
80	24.4	63.99	17.77	310	94.5	68.72	20.40
90	27.4	64.24	17.91	320	97.5	68.90	20.50
100	30.5	64.44	18.02	330	100.6	69.15	20.64
110	33.5	64.65	18.14	340	103.6	69.35	20.75
120	36.6	64.85	18.25	350	106.7	69.57	20.87
130	39.6	64.99	18.33	360	109.7	69.84	21.02
140	42.7	65.17	18.43	370	112.8	70.05	21.14
150	45.7	65.37	18.54	380	115.8	70.30	21.28
160	48.8	65.59	18.66	390	118.9	70.54	21.41
170	51.8	65.75	18.75	400	121.9	70.79	21.55
180	54.9	66.02	18.90	410	125.0	71.01	21.67
190	57.9	66.15	18.97	420	128.0	71.20	21.78
200	61.0	66.27	19.04	430	131.1	71.44	21.91
210	64.0	66.47	19.15	440	134.1	71.65	22.03
220	67.1	66.74	19.30	450	137.2	71.87	22.15
230	70.1	66.97	19.43	460	140.2	72.09	22.27