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INTERPRETATION OF GEOPHYSICAL DATA FROM THE COLADO KGRA, PERSHING COUNTY, NEVADA

by

Claron E. Mackelprang

April 1982

Work performed under contract number DE-AC07-80ID12079

EARTH SCIENCE LABORATORY
University of Utah Research Institute
Salt Lake City, Utah

Prepared for
U.S. Department of Energy
Division of Geothermal Energy

DISCLAIMER

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ABSTRACT

The Colado geothermal area is evidenced by hot water wells in alluvium along the west flank of the West Humboldt Range. The exploration of this geothermal system has progressed into advanced stages with completion of shallow thermal gradient drilling, two intermediate-depth exploration drill holes, one deep exploration drill hole, detailed geologic mapping, dipole-dipole resistivity, gravity, ground magnetics, MT-AMT, TDEM and assorted uncommon electrical resistivity techniques.

A thermal anomaly was outlined by the shallow drilling. Dipole-dipole resistivity and gravity data along with detailed geologic mapping have suggested that this anomaly is structurally controlled. Other geophysical techniques employed do not appear to contribute to an understanding of the geothermal anomaly. The two intermediate-depth exploration holes (IGH-1, IGH-2) and the one deep hole (44x-10) may not have been located in the most favorable portions of the geothermal anomaly. The area having the greatest exploration potential for intermediate-depth drilling appears to be centered on the shallow drill hole 14-22. An intermediate-depth drill hole located near DH14-22 is most likely to encounter one of the conduits that allow thermal waters to rise near the surface.

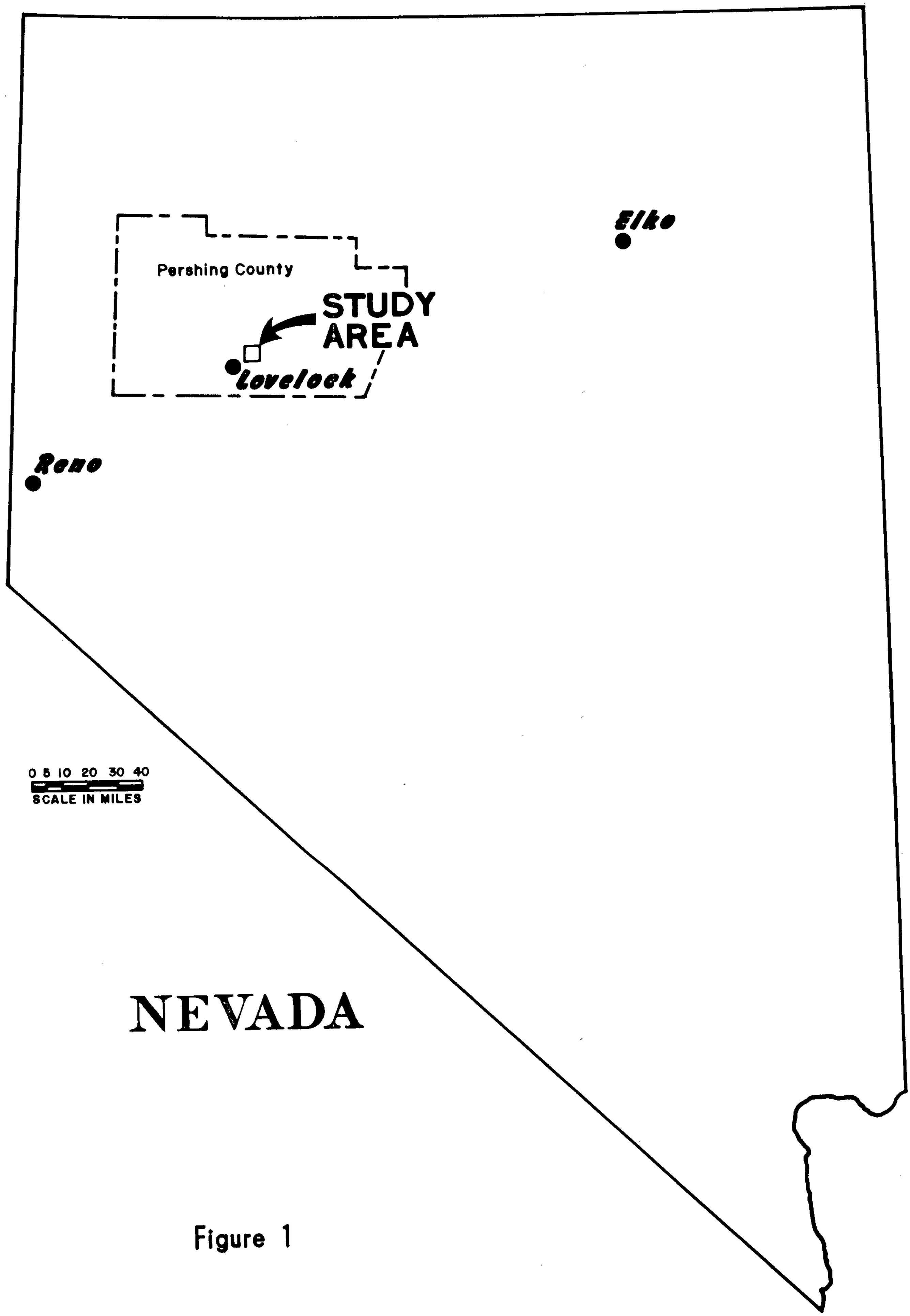
Elko
Pershing County
STUDY
AREA
Lovelock
Reno
0 5 10 20 30 40
SCALE IN MILES
NEVADA

Figure 1

INTRODUCTION

The Colado geothermal area (Figure 1) is located in Pershing County, Nevada approximately 7 miles northeast of the town of Lovelock. Getty Oil Company's interest in the geothermal potential of the area was stimulated when, while drilling on nearby mining claims, they encountered a light flow of steam and thermal waters (Wayne Shaw, personal communication). The main area of geothermal exploration to date is along the western flank of the West Humboldt Range, lying between the railroad sidings of Kodak and Woolsey (Plate I), a distance of about 4.5 miles.

This report presents an evaluation of the geophysical data package which includes the results of a thermal gradient drilling program. The data were submitted by Getty Oil Company to the Earth Science Laboratory, University of Utah Research Institute (ESL/UURI), as part of the data due to the U.S. Department of Energy, Division of Geothermal Energy through Getty's participation in the Industry Coupled Program. Results of a dipole-dipole electrical resistivity survey (Mackelprang, 1980) conducted by the Earth Science Laboratory supporting our evaluation of this data package are also included in this report.

GEOLOGIC SETTING

The Colado geothermal area is indicated by hot water wells in alluvium along the west flank of the West Humboldt Range. To gain a better understanding of the geothermal environment, Sibbett and Bullett (1980) mapped the geology of the West Humboldt Range (Plate I) adjacent to the geothermal area. The following is taken from the abstract of their report.

The West Humboldt Range consists mainly of Triassic to Jurassic slaty shale to quartzite of the Auld Lang Syne Group. Carbonate rocks of the Lovelock Formation have been thrust over the pelitic rocks on the south end of the area. Erosional remnants of Tertiary tuffs and sediments overlay the metasediments in the range.

Several thrust faults are exposed south of Coal Canyon and a structural break in the Mesozoic rocks exists under Coal Canyon. Several low-angle faults occur to the north but their effect, if any, on the geothermal occurrence is not known.

The principal structures are high-angle faults striking north-northwest, northeast and north-south. The horst to graben transition along the range front consists of several step faults following an irregular south-to-north trend. The structural pattern noted along the west edge of the range probably continues to the west under the Quaternary alluvium. The thermal waters are thought to rise along a major fault or fault system to the base of the alluvium.

The surface morphology of the valley has been strongly affected by the Pleistocene Lake Lahontan shore features (Morrison, 1964). Several algal mounds in the southern part of the Colado area remain from Lake Lahontan time. This tufa is a typical lake deposit and has no geothermal significance (Morrison, 1964).

A more detailed geologic description of the Colado geothermal area can be found in the report by Sibbett and Bullett (1980) which is an excellent accompaniment to this report.

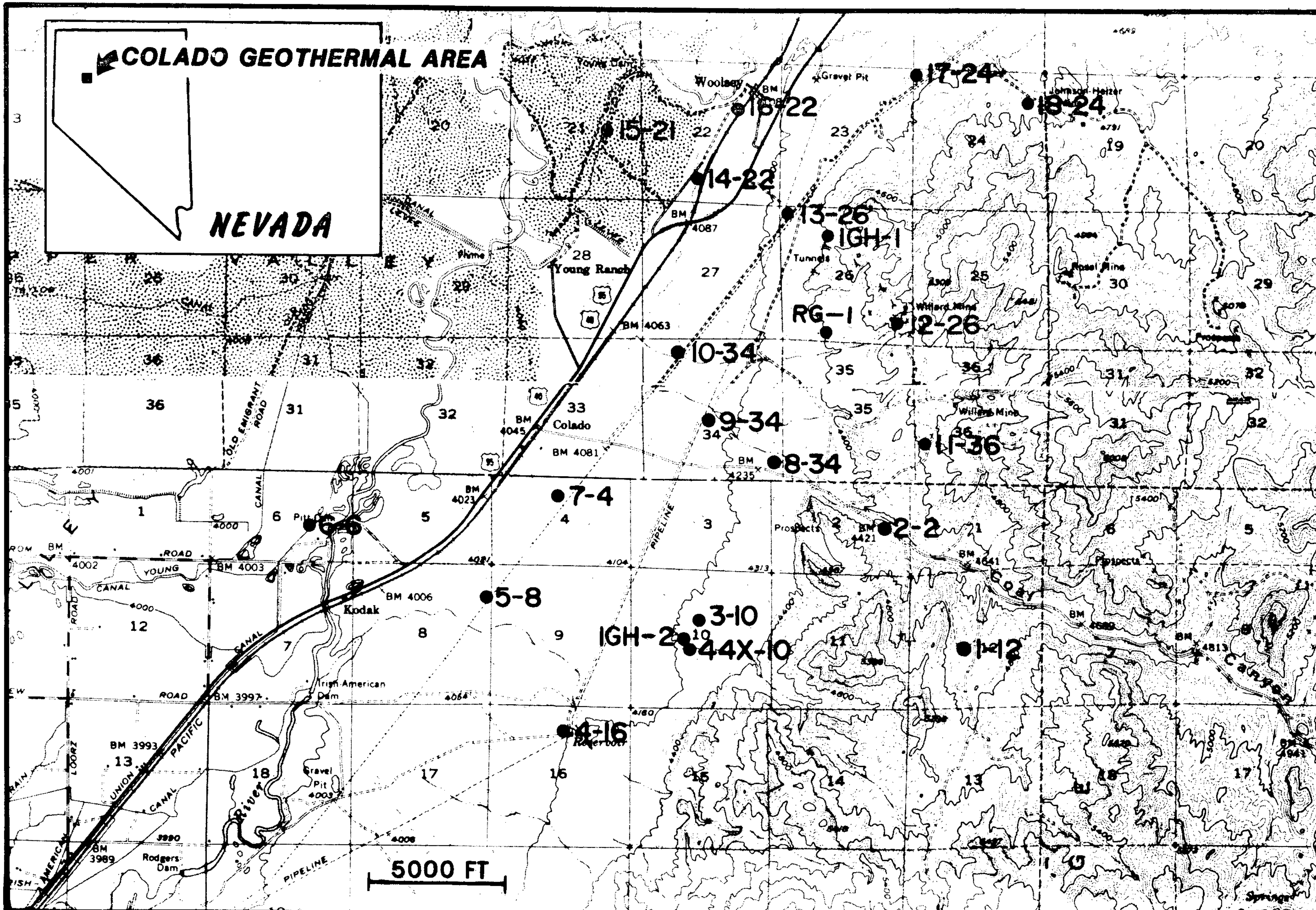

Figure 2
Thermal Gradient Hole Locations
Colado KGRA, Pershing County, Nevada

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THERMAL GRADIENT DRILLING

The Colado geothermal system is a "blind" hot water system in that no surface manifestation exists. Several hot domestic wells have been reported in the Lovelock area and an industrial well in alluvium at Colado has a reported temperature of 66°C (Garside and Schilling, 1979).

Getty Oil was the first company to undertake a serious evaluation of the area's geothermal potential. This began with the temperature logging of two holes, RG-1 and RG-2, drilled for the evaluation of mining claims. The drilling program has progressed through the stage of drilling 18 shallow (<500 feet) thermal gradient holes, two intermediate-depth (1500 feet and 1165 feet) holes, and one deep test well (Colado 44x-10) which was drilled to a depth of 7,965 feet. Figure 2 is a location map for the thermal gradient holes.

Examination of cuttings obtained from the various thermal gradient holes has identified lithologic changes in each hole as discussed in detail by Sibbett and Bullett (1980). Christensen (1980) performed a multielement geochemical analysis of the drill cuttings, and interpretation of the results outlined an area of anomalous geochemistry related to fluid flow and temperature distribution within the Colado geothermal area.

Temperature Logs

Figures 3, 4 and 5 show temperatures in °C recorded in the drill holes at depths of 100 feet, 300 feet and 500 feet respectively. Quite clearly, the highest temperatures are encountered along a northeast-trending zone encompassing drill holes 16-22, 14-22, 13-26, IGH-1, 10-34, 9-34, and 7-4. Fluids encountered in these holes have temperatures 60°C or hotter. It is further evident that the thermal fluids are leaking into valley fill at

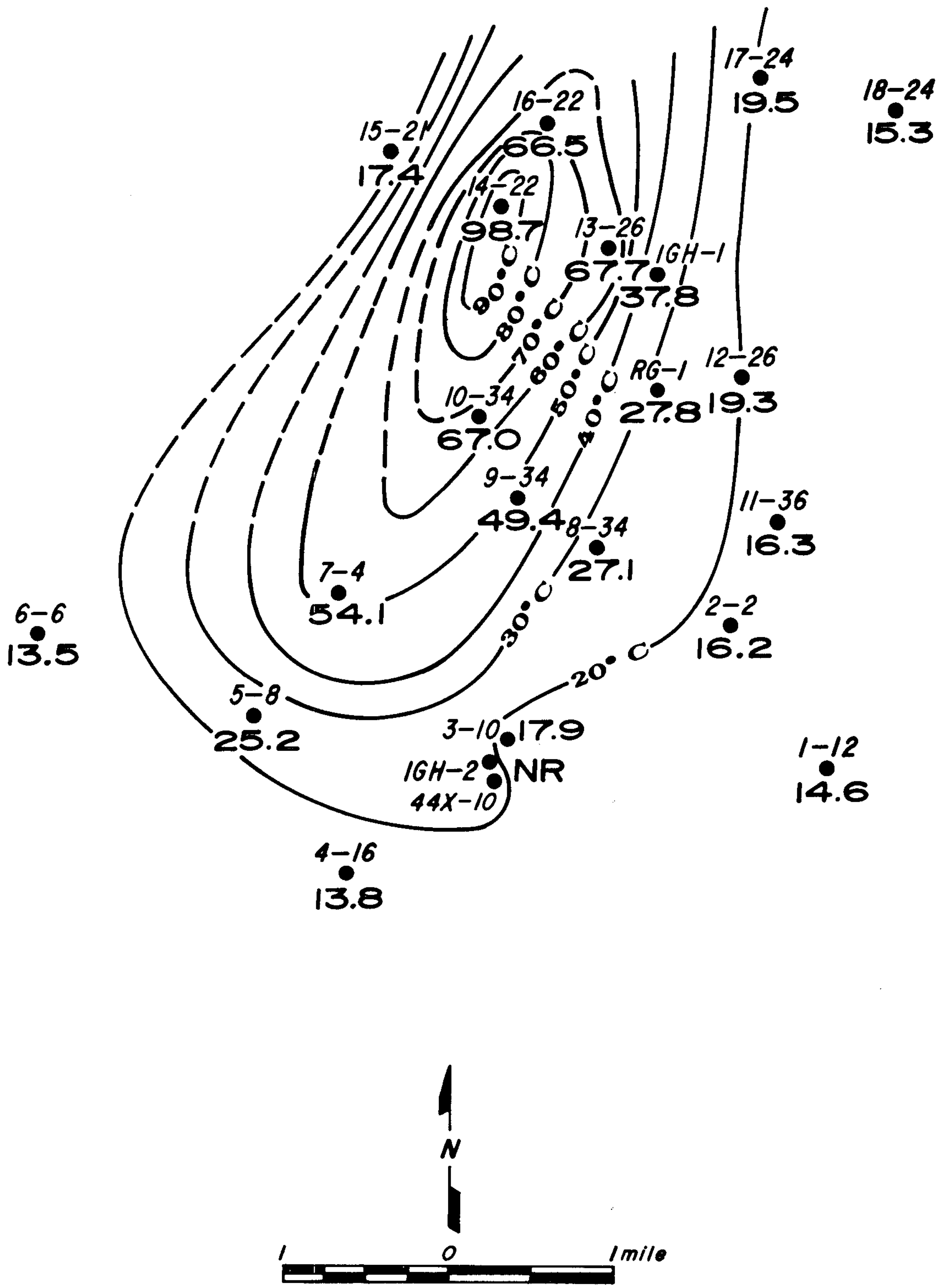


Figure 3
Temperature °C at a Depth of 100 Feet
COLADO KGRA, PERSHING COUNTY, NEVADA

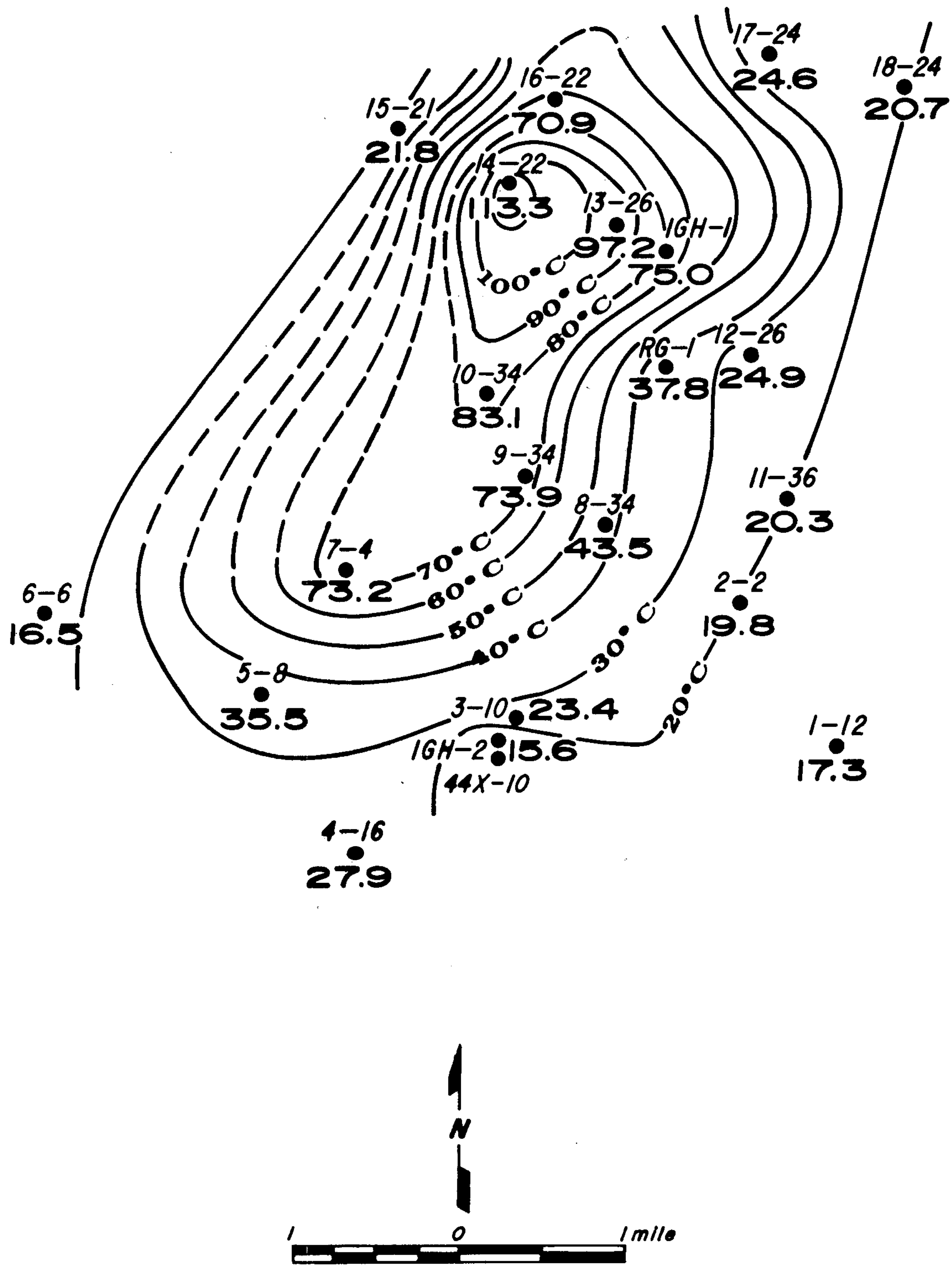


Figure 4
Temperature °C at a Depth of 300 Feet
COLADO KGRA, PERSHING COUNTY, NEVADA

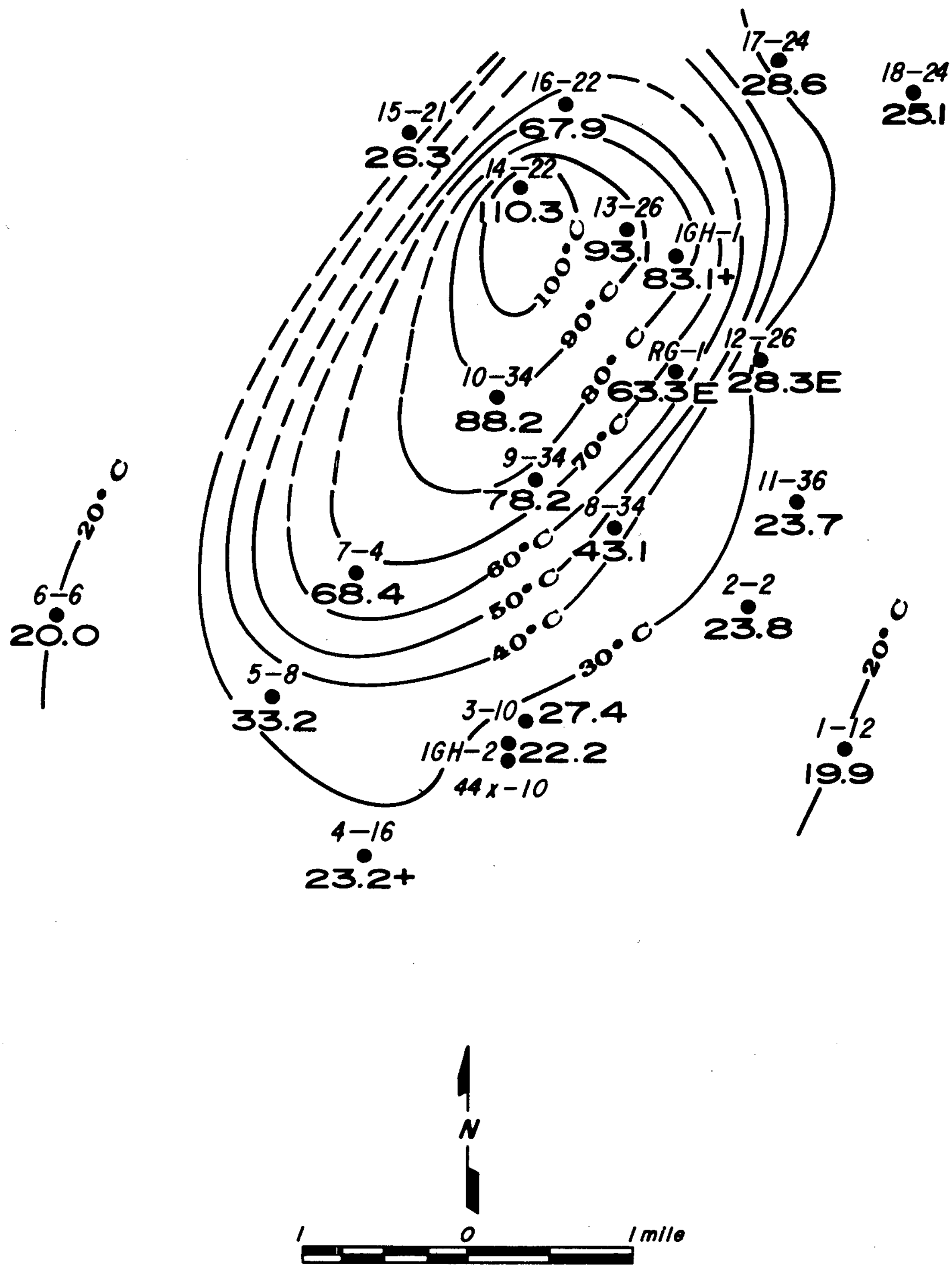


Figure 5

Temperature °C at a Depth of 500 Feet

COLADO KGRA, PERSHING COUNTY, NEVADA

relatively shallow depths. Temperatures are cooler at the greater depth shown by Figure 5, suggesting either a mixing of thermal fluids with ground water or a greater distance between the leaking conduit and the drill hole. The plumbing system for the thermal fluids is very likely fault controlled with the hottest hole, 14-22, probably being located very near one of these structures.

Figures 6 through 9 are plots of recorded temperatures obtained by Getty Oil in the shallow thermal gradient drill holes. These are aligned as profiles north to south across the area of interest. Drill holes 15-21, 17-24 and 18-24 all show increasing temperatures with depth and exhibit thermal gradients of 65.6°C/km, 75.4°C/km and 77.8°C/km respectively. Drill hole 16-22, on the other hand, displays a temperature reversal, but temperatures recover near the bottom of the hole and show a thermal gradient of 19.7°C/km over the final 50 feet. This gradient is about normal for the Basin and Range Province.

Drill holes 11-36 and 12-26 (Figure 7) also show increasing temperature with depth and thermal gradients of 60.7°C/km and 69.6°C/km respectively. Drill holes RG-1 and RG-2, which are the mineral assessment holes, show very high thermal gradients without encountering a temperature maximum. The isothermal interval in the bottom of these holes is interpreted to be due to a closing off or bridging over in the holes. The hottest shallow thermal gradient hole drilled is DH14-22 with a maximum recorded temperature of 113.5°C at a depth of 250 feet. Drill hole 13-26 also shows a high thermal gradient, but both this hole and DH14-22 are exhibiting a temperature reversal in the deeper portion of the holes.

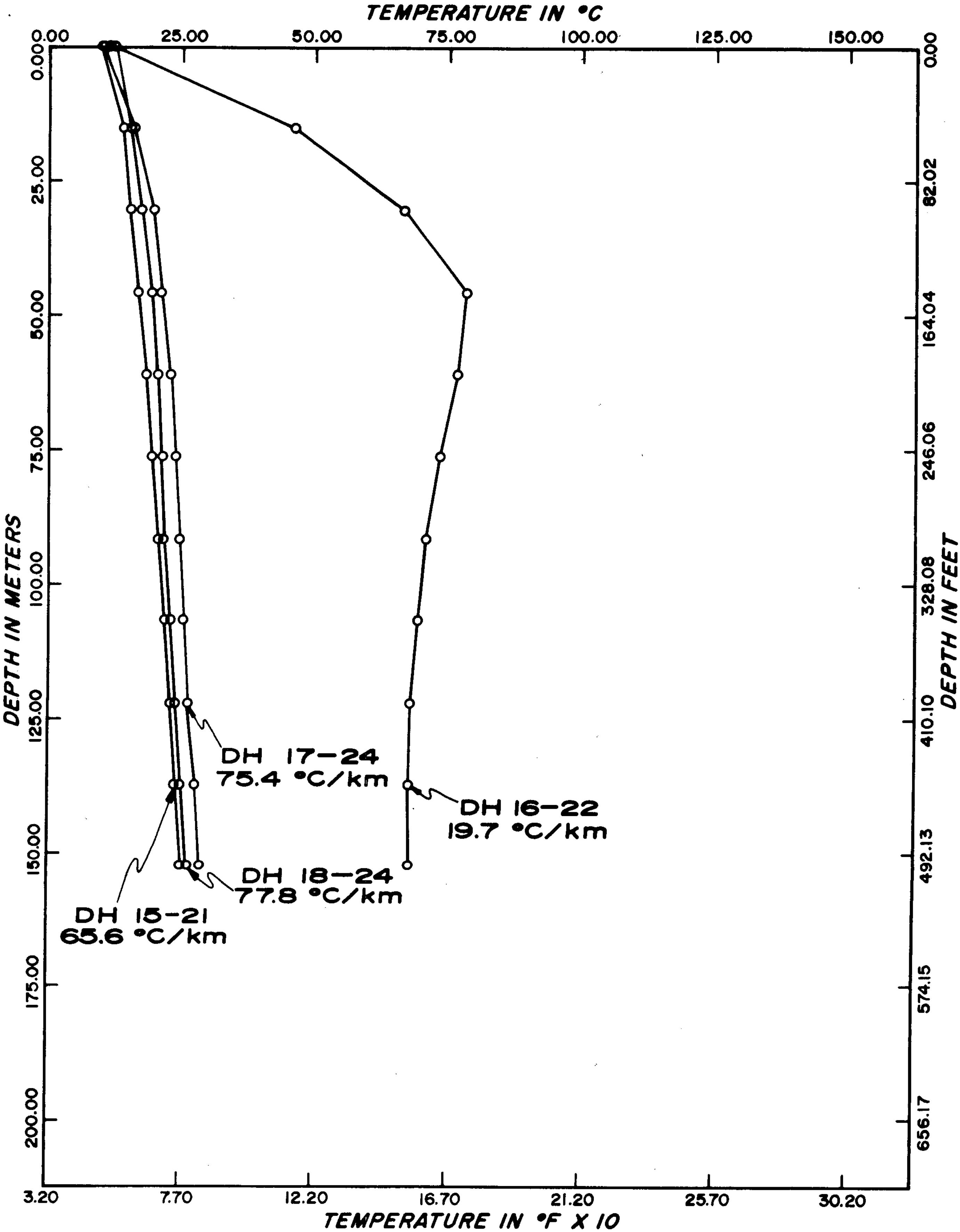


Figure 6
Temperature Logs Profile A

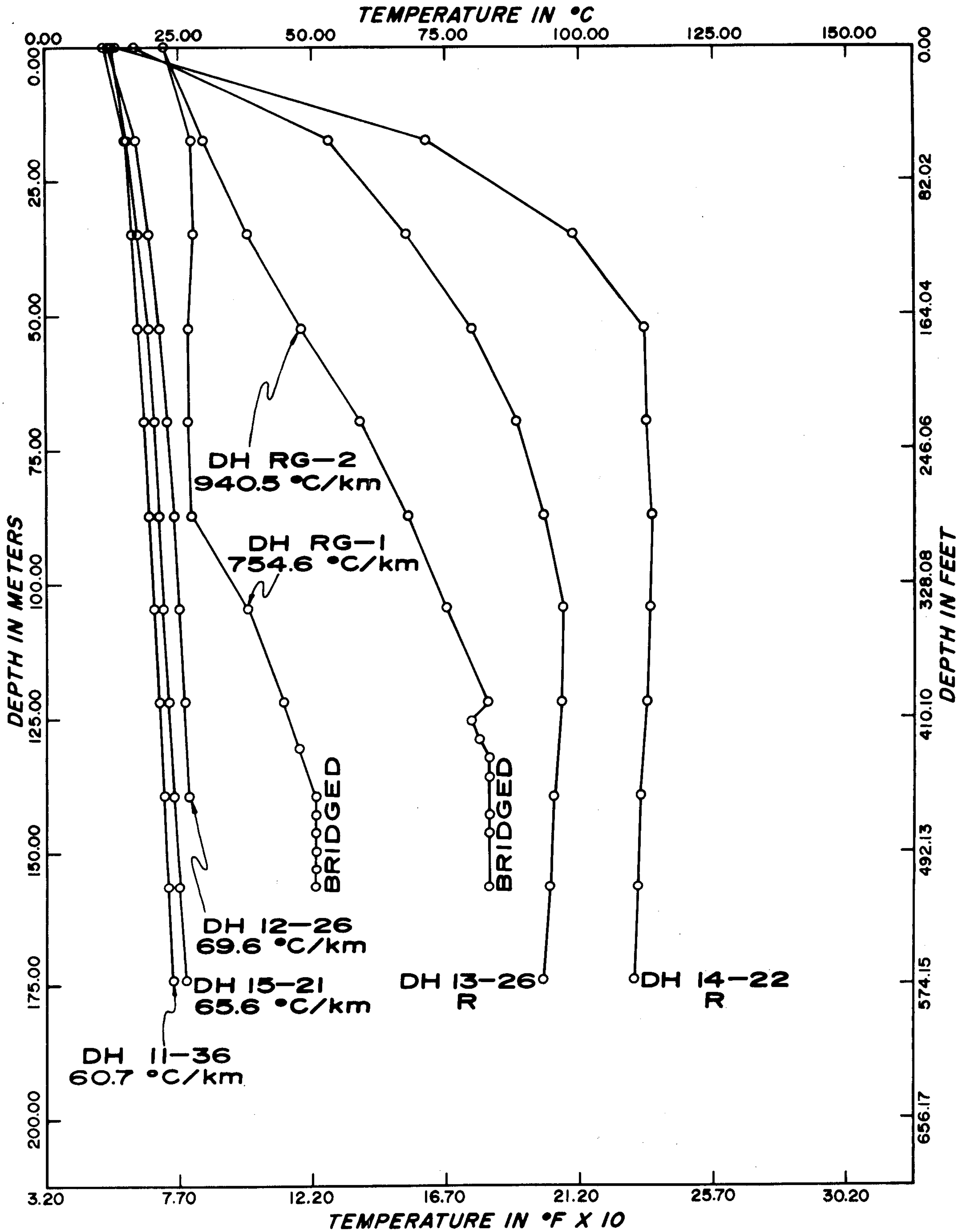


Figure 7

Temperature Logs Profile B

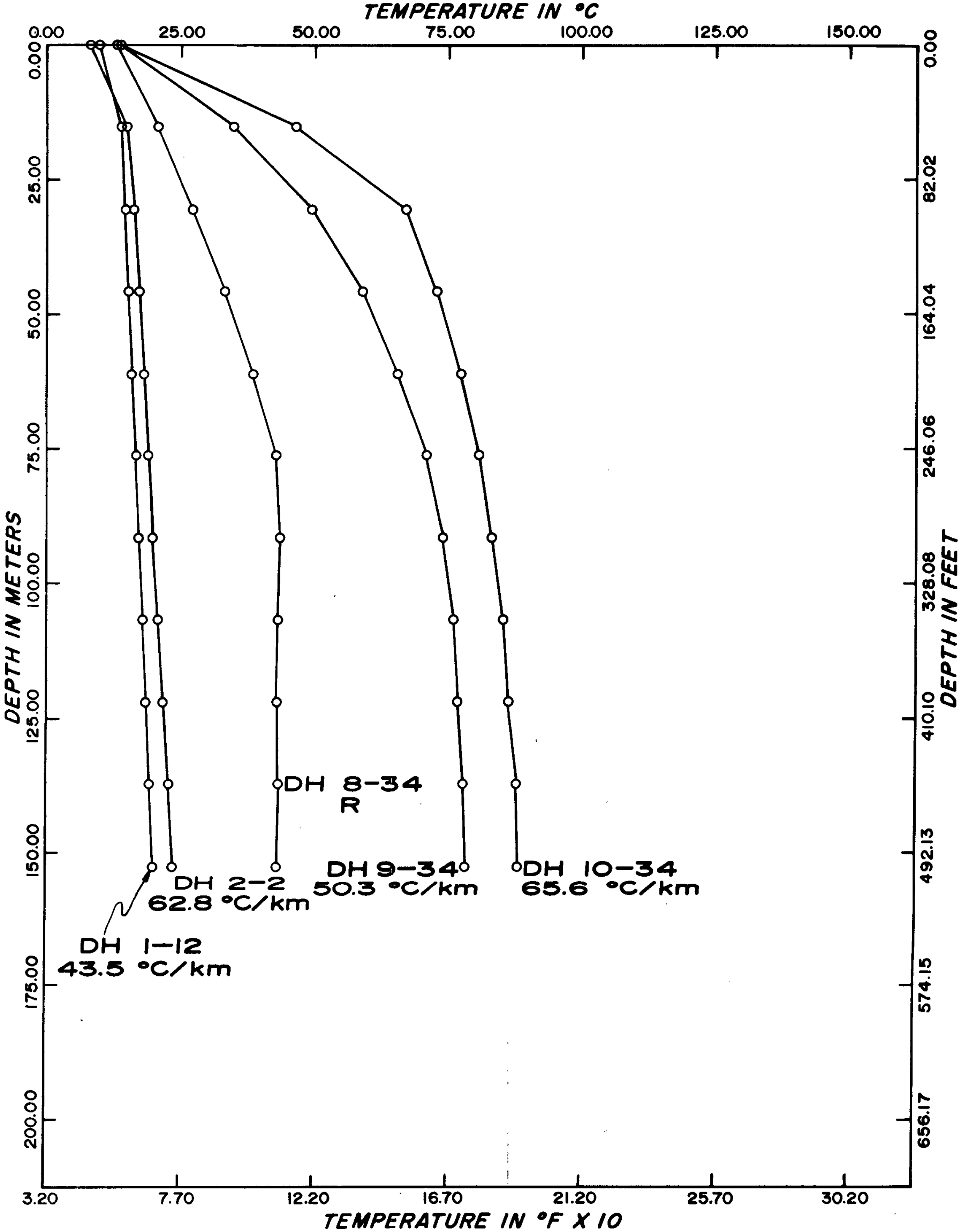


Figure 8
Temperature Logs Profile C

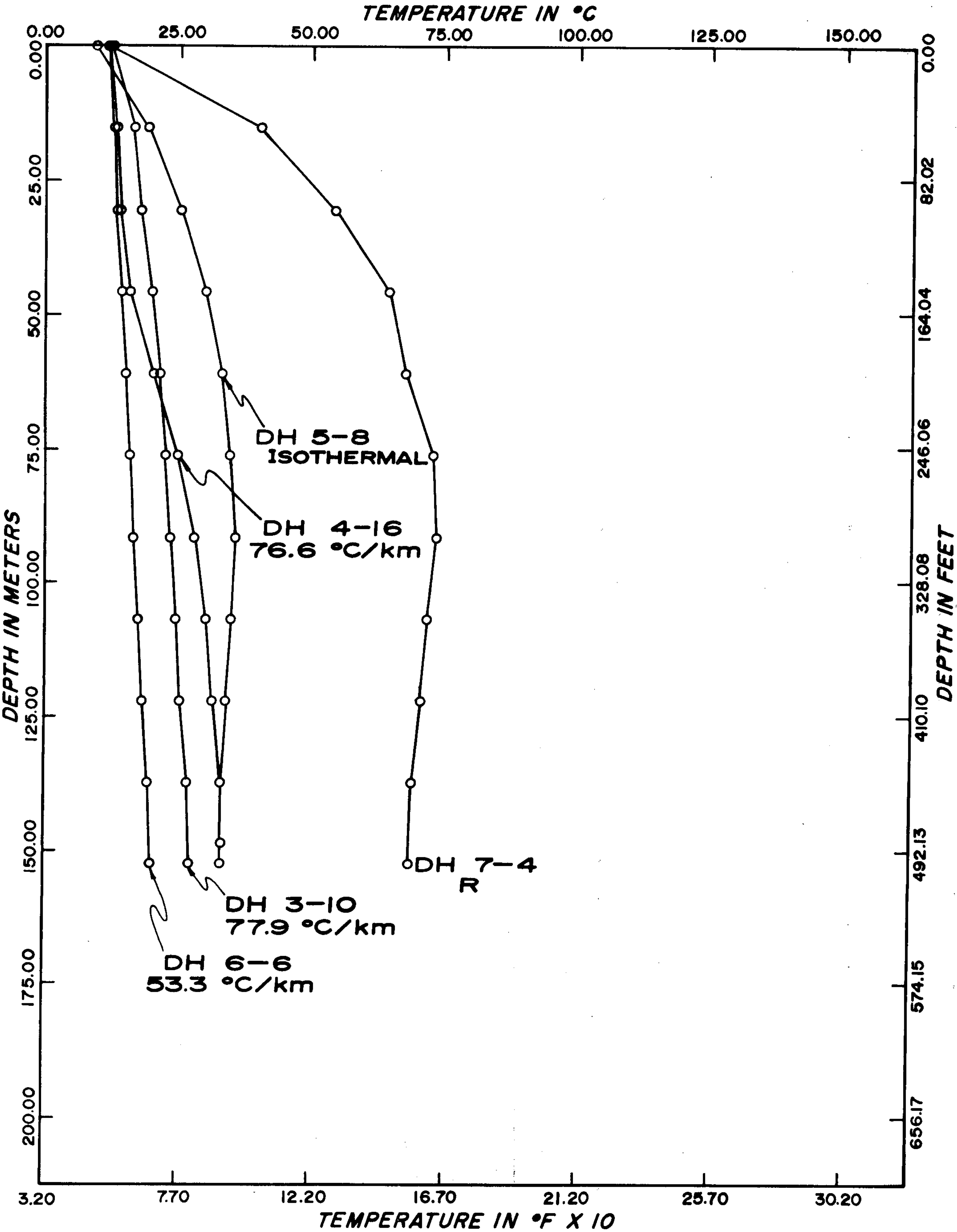


Figure 9

Temperature Logs Profile D

The drill holes shown on Figure 8 show temperatures in DH1-12 and DH2-2 to have gradients about twice the Basin and Range average (20-30°C/km) for the interval between 50 feet and 500 feet. The upper portion of holes 8-34, 9-34 and 10-34 exhibit high gradients but these all decrease to gradients of 50-65°C/km, at least in 9-34 and 10-34. The temperature gradient in hole 8-34 may have reversed at its deepest point.

The remaining holes on Figure 9 are similar to those previously discussed. Thermal gradients roughly double the Basin and Range average occur in DH3-10 and DH6-6 from a depth of 50 feet to total depth. Drill hole 4-16 started out nearly isothermal but picked up about 150 feet with the temperature maximum being at the bottom of the hole. There are, however, indications of a turnover starting to develop. DH5-8 and DH7-4 both started out with higher gradients, but at a depth of 300 feet DH5-8 went isothermal while DH7-4 had a reversal.

WELL LOG DATA FOR DRILL HOLES IGH-1 AND IGH-2

Plate II is a composite of the various logs recorded in the intermediate-depth drill holes. Drill hole IGH-1 was drilled by K. O. Burt Drilling Co., Inc., Springville, Utah, during March 4-18, 1980. Total depth was 1500 feet. Drill hole IGH-2 was drilled by Southwest Drilling and Exploration Inc., Rig #7, during Oct. 30-Nov. 18, 1979, to a total depth of 1165 feet.

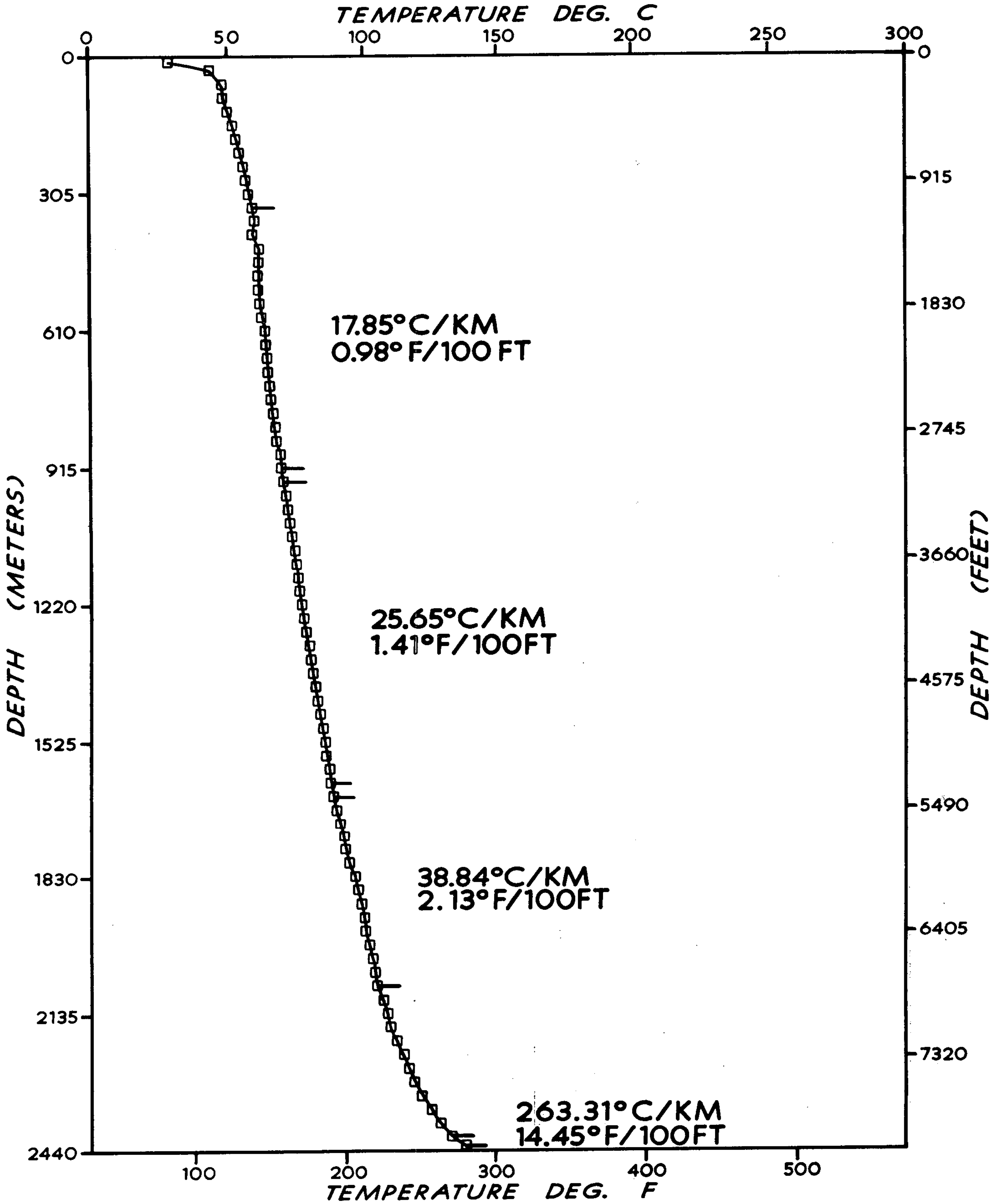
Hole IGH-1 started in argillaceous siltstone, penetrated quartzite and bottomed in a thick sequence of slate or slaty shale. The first characteristic feature in the logs of this hole occurs at a depth of 425 feet, roughly coinciding with the water table. Caliper, porosity (neutron and density) and gamma ray logs show an increase at this depth whereas bulk density, resis--

tivity and spontaneous potential logs show decreases. A possible fault zone is also shown on the lithologic log at this horizon.

The slate or slaty shale layer shown in the 500-540 foot interval is also indicated in the various logs but at a slightly greater depth with all the logs showing increases in their measured parameters. An indication of severe hole enlargement occurs in the 900-1200 foot interval. This interval is evident in the various logs as a general, but irregular, zone of slightly higher porosity and lower bulk density, resistivity, spontaneous potential and gamma ray response. These effects have not, however, been correlated to any diagnostic characteristics of the lithologic log.

Drill hole IGH-2 penetrated approximately 1100 feet of alternating layers of coarse and fine gravel before bottoming in 65 feet of slate or slaty shale. The temperature log was run by United Wireline Surveys, Inc., on January 9, 1980. It shows a pronounced increase in temperature at a depth of 200 feet - the depth to the water table. The temperature gradient below 200 feet to total depth of the hole is a constant 114°C/km (7.2°F/100 ft). The other logs taken in this hole are shown to be very erratic. There is, however, a pronounced increase in hole rugosity, neutron porosity and bulk density along with a decrease in sonic velocity, resistivity and gamma ray response in the depth interval 960-1140 feet. Only the bulk density can not be explained by water-filled open fractures.

Drill hole 44X-10 was recently (1981) completed at an intermediate depth of 7965 feet. This hole was located near drill hole IGH-2. The predominant rocks penetrated were phyllite with intervals of quartz and sericite to the bottom of the hole. The temperature log (Figure 10) showed a fairly normal Basin and Range gradient to a depth of 4600'. The temperature picks up at



May 5, 1981

Figure 10

Temperature Log

Drill Hole 44X-10

5900 feet and continues to increase to total depth of 7965 feet. Thermal gradients are high over this interval with the bottom 65 feet being about 263°C/km. This gradient was obtained from a temperature log taken the day after completion of the drill hole, hence it may be in error because insufficient time had passed for the hole to equilibrate.

SURFACE GEOPHYSICAL DATA

In mid-1977, Getty Oil Company contracted several geophysical surveys of the Colado area to Electrodyne Surveys of Sparks, Nevada. The purpose of these surveys was to delineate structure and anomalous areas within or below alluvial cover that could be related to the geothermal occurrence noted on Getty's mining claims.

Discussion of Data Sets

Several geophysical techniques were applied by Electrodyne Surveys to determine the resistivity structure of the geothermal area. In addition, Electrodyne subcontracted gravity and ground magnetic surveys to Lanton Survey Company of Vallejo, California. Electrodyne's approach was to use what they called "reconnaissance" type surveys, namely MT-AMT soundings, roving Vector Telluric soundings, and in-line Telluric profiling in conjunction with the gravity and ground magnetic data to define the structural make-up and anomalous low apparent resistivity zones. Subsequent areas interpreted by Electrodyne to be of interest were then "detailed" using (DC) galvanic electrical resistivity soundings, parallel electric-field (DC) measurements, time-domain electromagnetic (TDEM) soundings and combined electric-field - TDEM soundings. Two techniques, MT-AMT and a second-derivative map of the gravity data constructed by Electrodyne, form the reference base used by Electrodyne to interpret the data sets from the other surveys. Observations regarding the various techniques and their interpretation by Electrodyne follow.

Gravity Data: This data set obtained by Lanton Survey Company constitutes a regional survey over the general geothermal area. Copies of the field data were obtained from Getty Oil, checked for processing errors and were found to be of good quality. Lanton obtained elevations with transit and stadia and terrain corrections were made at each station through zone D (outer radius of 558'). Our (ESL) revised Bouguer gravity map is shown as Plate III.

Electrodyne computed a second-derivative gravity map from which they interpreted a complex structural picture. Our review, however, suggests that terrain corrections were not computed for an adequate area around each station nor were stations of sufficient areal density to justify a quantitative interpretation based upon the second-derivative technique. Their second-derivative map is therefore thought to be very speculative.

It is possible, however, to present an interpretation based upon the Bouguer gravity data. Gravity data from the Carson Sink Area (Wahl, 1965) show a pronounced low north of Lovelock along the west flank of the West Humboldt Range which has been interpreted as due to 7100 feet of down-faulted Cenozoic sediments. The density contrast between these sediments and the Pre-Tertiary rocks of the range is roughly -0.6 gm/cc. The gravity data obtained by Lanton Survey Company essentially duplicated the gravity low north of Lovelock and gave additional detail along the west flank of the West Humboldt Range (Plate III). These data give strong evidence for faulting along the western flank of the range. South of Coal Canyon the gravity data suggest a NE-SW strike to the bordering structures. A structural break in the Mesozoic rocks follows Coal Canyon (Sibbett and Bullett, 1980). This break apparently forms a hinge line allowing for the deflection of the border faults to the north. This north-trending fault system can be traced in the gravity data across the valley, passing between the range front and DH15-21 and along the eastern side of the gravity high located at the extreme north end of the gravity survey area (C). This northern gravity high is caused by bedrock in the mountain range that forms the western border to the Humboldt River Valley in the Rye Patch area, Rye Patch being located on Highway 40 approximately 15 miles north of Colado. Faulting is present along the eastern side of this northern gravity high and, with little imagination, can be projected south across the valley into the north-trending fault system located just north of Coal Canyon.

The north-trending fault system to the north of Coal Canyon has been open to fluid movement in the past as evidenced by the intense hematite staining in the Tertiary and Mesozoic rocks near this zone. The andesite lava flows nearby have been strongly altered to sericite, calcite, chlorite, quartz, clay and hematite (Sibbett and Bullett, 1980). It is quite possible that the extension of this fault zone to the north beneath the gravel cover is also similarly altered.

Another fault system apparently extends northeast from DH16-22 along the range front and essentially duplicates the trend for the segment south of Coal Canyon. There is evidence in the gravity data that this fault system extends southwest into the vicinity of Colado and is separate from the faulting along the range front south of Coal Canyon. Sibbett (personal communication) notes that the alteration along the NE-SW trending fault segments is considerably less intense as in the intervening area directly north of Coal Canyon. The projected fault intersection in the vicinity of DH14-22 may cause a zone of intense fracturing, increased permeability and fluid movement, and may be the main conduit for hot fluids noted in DH14-22.

Figures 11-13 are computed 2 1/2-dimensional gravity models across the Colado area, their locations being shown on Plate III. A -0.6 gm/cc bedrock-alluvium density contrast was used in computing these models. While non-unique, these models give a good approximation to the thickness of valley fill (<6000 feet) as well as general locations of buried faults which may be the conduits for thermal fluids.

Ground Magnetic Data: Total-field ground magnetic data were acquired during the gravity survey. These stations appear to be located along roads containing buried water lines, powerlines and metal fences. The data presented appear to have strong cultural interferences as a result and are not included in this report.

MT-AMT and Vector Telluric Soundings: Thirty-one MT-AMT and seventeen roving vector telluric soundings were made at Colado by Electrodyne. The data presentation they provided to DOE consists of tabulated apparent resistivities (Tables II-1 and III-1, Vol. II, ESL Open-File Release NV/COL/GOC-1) for the station sites derived from frequencies of 14 Hz and 0.045 Hz. The source data for these results are not available, hence, it is not possible to evaluate the apparent resistivity data presented. The description of the method and acquisition techniques presented in Volume II of Electrodyne's report, however, lends some insight into data quality.

Electrodyne appears to have gathered their field data by measuring the electric field with orthogonal potential electrodes and the magnetic field with a dual-axis fluxgate magnetometer. This magnetometer had a sensitivity of 0.5 gammas, not nearly good enough for quality MT measurements. In the usual case for middle latitudes, the median amplitude value for magnetic variations within the frequency range 0.03 to 0.2 cps is about 0.02 gammas (Yungul, 1966; Campbell, 1959). Based on this rather circumstantial evidence, we belive that the quality of the MT data is suspect.

Typically, it is necessary to know the apparent one-dimensional resistivity at a base site in order to relate the results of telluric soundings at other sites to apparent resistivity. The apparent resistivity at the base site can be determined preferably from a resistivity log in a drill hole or alternatively from a sounding technique such as MT. Due to the low sensitivity of the magnetometer used in the MT soundings and since no resistivity logs were available, none of the necessary requirements for a base site have been met. Hence, the apparent resistivities determined from the telluric surveys at Colado appear to be suspect also.

Telluric Profiling Data: The data acquisition for this technique is similar to roving telluric soundings except that the potential difference is compared between electrodes from a previous site and a new site, placed in-line, using a multichannel receiver. The data should display relative changes in conductance between the two sites. Several discrepancies were noted between contoured apparent resistivity maps (Electrodyne's Plates VII and VIII) and tabulated apparent resistivity values shown in Volume II, Table IV of Electrodyne's report (ESL OFR NV/COL/GOC-1). These discrepancies consists of data omissions, plotting of selected values rather than all values along the profiles, and plotting of values not listed in the table.

Parallel E-Field Electrical Resistivity Data: As Electrodyne states, this technique is relatively unknown. There is no reference to it being used for determination of apparent resistivity either as a general geophysical survey technique or as a method to prospect for geothermal fluids in the U.S. geophysical literature. The Electrodyne description of the technique does not go into sufficient detail to make an analysis of the data possible. One of Electrodyne's profiles was repeated by them with resultant apparent resistivities varying by as much as a factor of 7. Little confidence in the technique appears warranted since better DC and AC surveying methods with well established interpretation procedures are available.

Modified Schlumberger, Equatorial and Monopole Soundings: DC electrical resistivity soundings were also obtained in the Colado area by Electrodyne through the use of long crossed-bipole sources. Supposedly this technique enables both lateral and vertical definition of apparent resistivity through the combined use of modified Schlumberger, equatorial, or monopole soundings at a single site. Apparently, curve matching was used to derive the displayed one-dimensional vertical resistivity sections. With the exception of sites 2.3, 10.1 and 10.2 (ESL OFR NV/COL/GOC-1 Plate X), which used monopole and modified Schlumberger arrays, all soundings are ambiguous regarding the array used. The sounding results were smoothed because the data themselves were highly erratic. In general, the results of this survey are open to conjecture.

Time-Domain EM Data: Because the time-domain EM sounding locations do not coincide with those of the DC electrical resistivity soundings, it is not possible to compare directly apparent resistivity values obtained. It would seem logical to expect at least near-surface apparent resistivities to be similar between the two techniques. The results obtained with DC and TDEM soundings show gross differences in the interpreted apparent resistivity distribution. This appears to result from the use of one-dimensional modeling of the data by Electrodyne, an assumption incompatible with the actual earth conditions. Several good two- and even three-dimensional computer modeling techniques are available which would yield significantly more plausible interpretations, particularly with DC electrical soundings.

DIPOLE-DIPOLE ELECTRICAL RESISTIVITY SURVEY

The Earth Science Laboratory Division, University of Utah Research Institute (ESL/UURI) undertook a dipole-dipole electrical resistivity survey (Mackelprang, 1980) to characterize the electrical resistivity distribution of the resource area in support of the Getty Oil Company geothermal exploration effort. This survey is adequately described in the ESL/UURI report referenced.

A comparison of the dipole-dipole resistivity survey with the Electrodyne resistivity surveys shows the two data sets to have major differences. The dipole-dipole data appear to be more definitive in delineating not only areas of low apparent resistivity but structurally controlled areas as well.

Plate IV is an overlay to Plate I and shows location of resistivity lines and the electrical resistivity distribution at a depth of approximately 1000 feet for each of the five ESL dipole-dipole lines. This plate shows the sharp resistivity contrasts and their locations from which the faulting is inferred. The data source for Plate IV is the computed models shown as Figure A1 through A5 in the report by Mackelprang (1980). There is good correlation with mapped structures within the mountain range. The detection of suballuvial faults away from the mountain front is of particular importance for, while these faults may have been suspected, their location was not known. Although shown as separate faults, several could be part of a single fault zone and it must be understood that the locations of these faults as shown on Plate V are to be considered as close approximations only. They are necessarily subject to the sensitivity of the dipole spacing used as well as the non-uniqueness of the computer modeling technique.

Plate V shows an interpreted schematic of the hydrothermal reservoir based upon resistivity contrasts shown on Plate IV. Areas interpreted to contain gravel saturated with thermal waters as well as areas containing the conduits for these waters have been denoted. Thermal waters encountered in several shallow drill holes support the assumption that the hot fluids may be associated with areas of low apparent resistivity. The evidence of faulting as interpreted from modeling of the dipole-dipole observed apparent resistivity data is therefore particularly significant since these structures may be the conduits for the thermal fluids. Shown also on this Plate are locations of interpreted faults taken from evaluation of the Bouguer gravity data.

SUMMARY

This report presents an interpretation of the geophysical data gathered in the Colado geothermal area. The data package described herein was acquired from several sources. At this point it is felt that additional testing of the geothermal potential in the Colado area will require additional intermediate-depth drilling. Judicious selection of these drill sites can be made through evaluation of the many data sets available, not only in this report but those previously evaluated and released under separate cover. There can be little doubt that the thermal fluids noted in the Colado geothermal area are rising from great depths along structurally controlled conduits. Because drill hole 14-22 is in the center of the thermal anomaly and since structural intersections based on interpretation of gravity and dipole-dipole resistivity data occur near this drill hole, it is concluded that this area provides the greatest potential for intersecting one of these conduits with an intermediate-depth drill hole.

ACKNOWLEDGEMENTS

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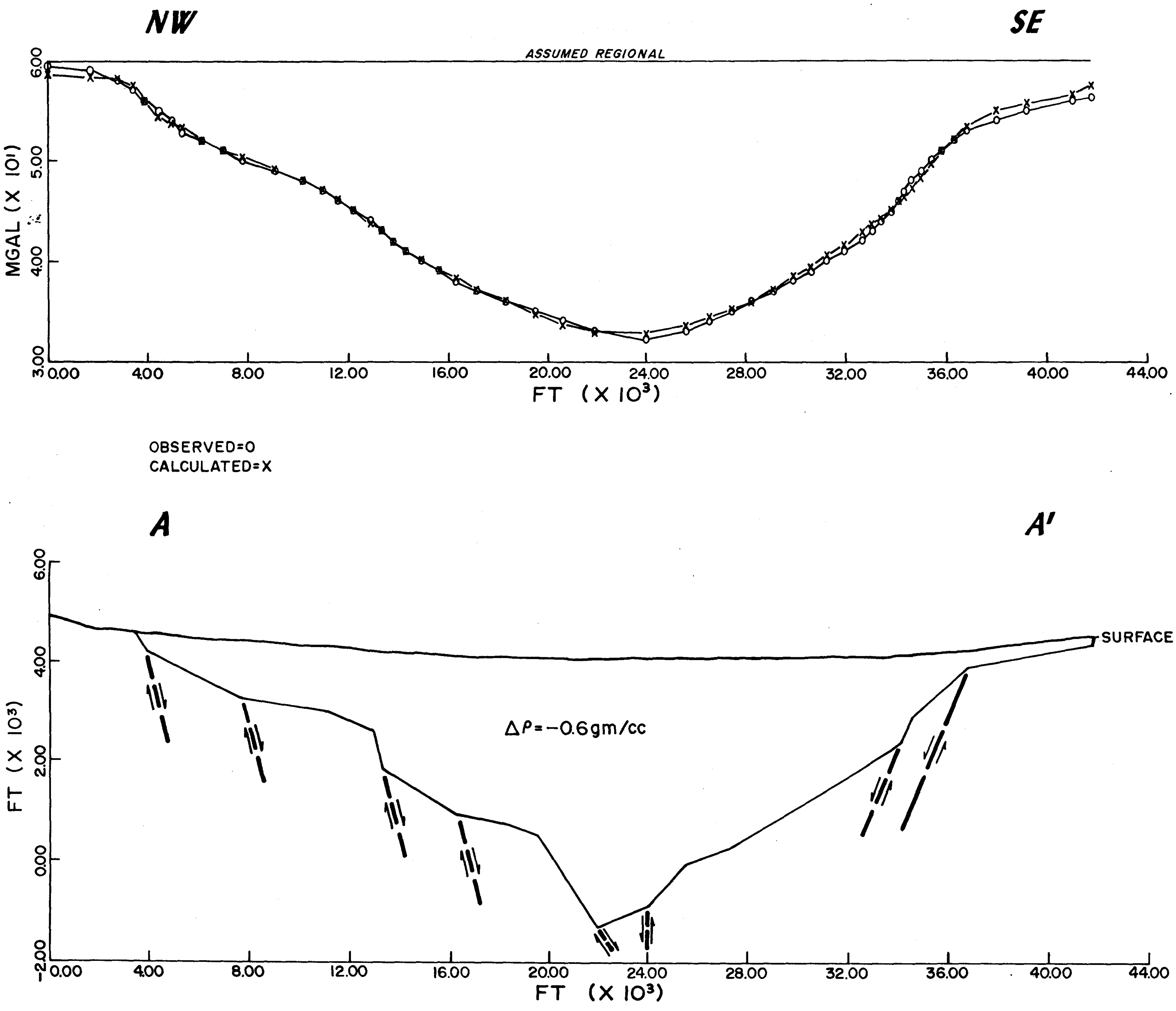

Figure 11
GRAVITY PROFILE A–A'
COLADO KGRA, PERSHING COUNTY, NEVADA

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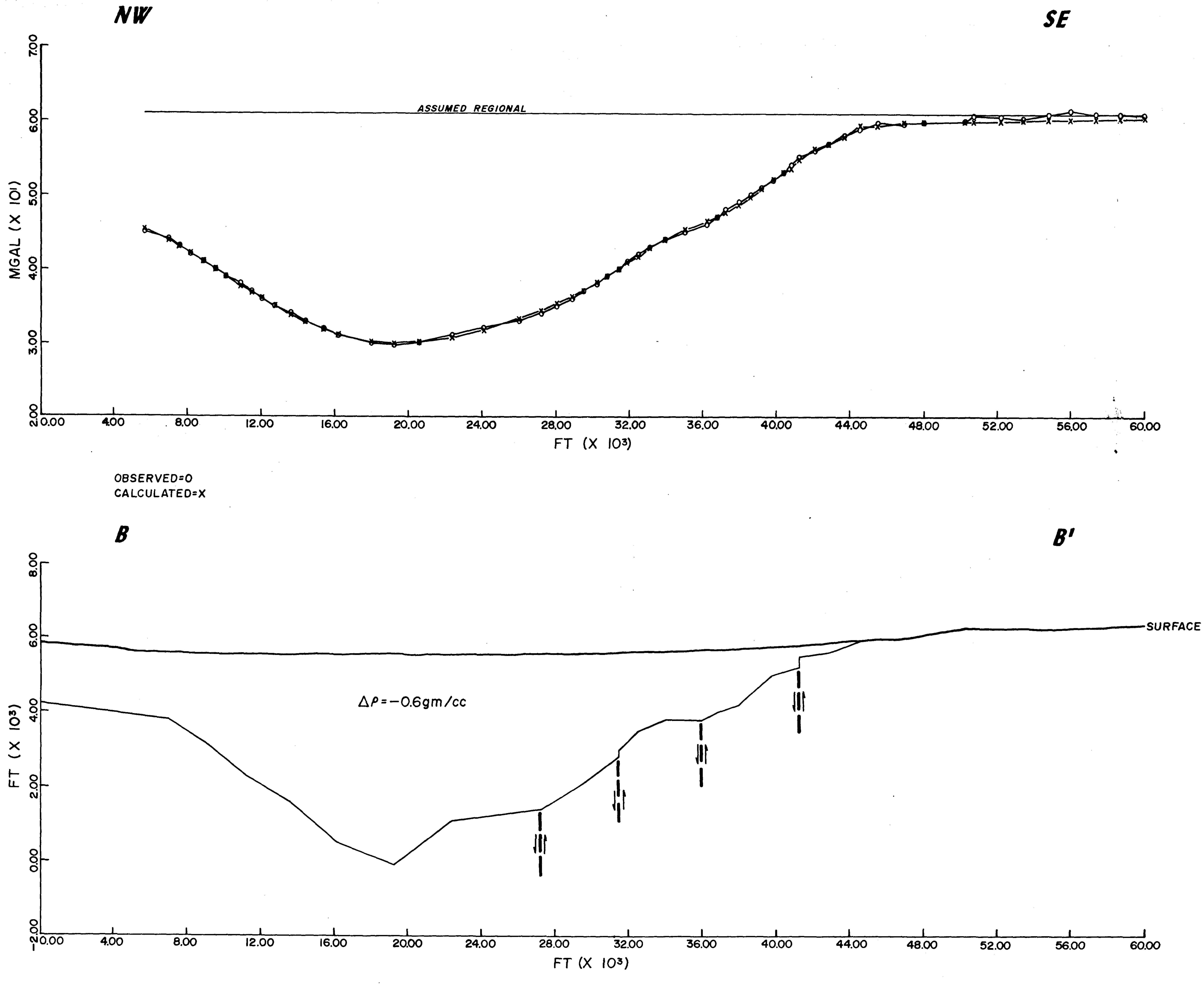


Figure 12

GRAVITY PROFILE B–B'

COLADO KGRA, PERSHING COUNTY, NEVADA

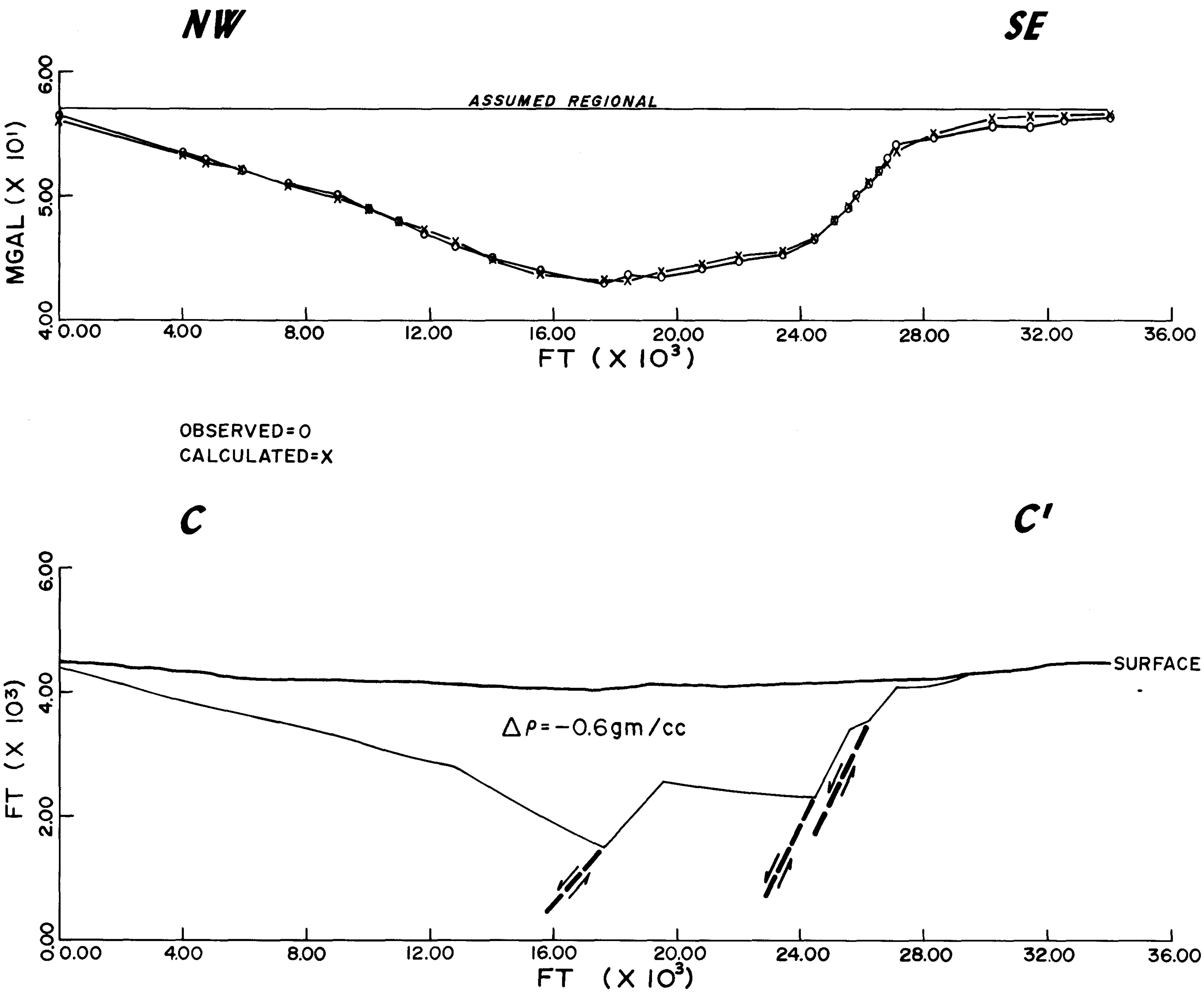
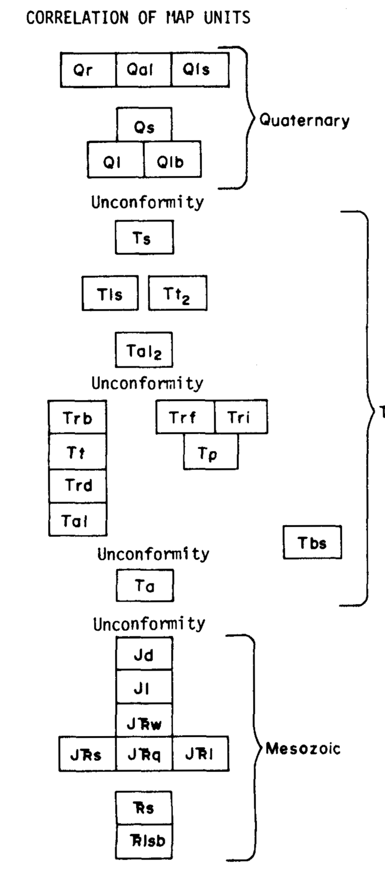


Figure 13

GRAVITY PROFILE C–C'
COLADO KGRA, PERSHING COUNTY, NEVADA

Plate I



DESCRIPTION OF MAP UNITS

Quaternary

Qr	Humboldt River channel and flood plain.
Qls	Landslide deposits.
Qal	Alluvial fans and colluvium.
Qs	Wind-deposited sand and silt, active and inactive, fills valleys in Humboldt Range and reworks Lahontan sediments.
Ql	Lake Lahontan deep water deposits.
Qlb	Lake Lahontan shore deposits, beach and deltas.

Tertiary

Tertiary units north of Coal Canyon

Ts	Tuffaceous mudstone and minor sand and gravel.
Tls	Lacustrine limestone with interbedded clastic sediments.
Tt_2	Pink non-welded ash-flow containing a few altered feldspar phenocrysts, devitrified glass shards, and fine-grained secondary quartz between the shards.
Tal_2	Alluvium, containing cobbles of ash-flow tuff in a clay and silt matrix.
Trb	Rhyolite breccia dikes contain fragments of ash-flow tuff in a glassy matrix and cut Tt.
Tt	White, welded ash-flow tuff, crystal poor with a few quartz phenocrysts.
Trd	Rhyolite sills and dikes, crystal poor, strongly flow banded. Some dikes are feeders to Tt and grade into pyroclastic dikes.
Tal	Coarse conglomerate containing clasts of limestone, quartzite and andesite in a sandy matrix.
Ta	Andesite lava flows which contain small plagioclase and altered mafic phenocrysts. The flows are dark gray to olive.
Tbs	Basalt sill with a diabasic texture. The sill intrudes JTRs but its age is unknown.

Tertiary units south of Coal Canyon.

Trf	Rhyolite lava flow, crystal poor, devitrified.
Tri	Rhyolite intrusive dome or plug, yellowish brown, flow banded felsite.
Tp	Pyroclastic deposits, include perlites, minor ash-flow tuff, and tuff or ash altered to clay.

Triassic and Jurassic

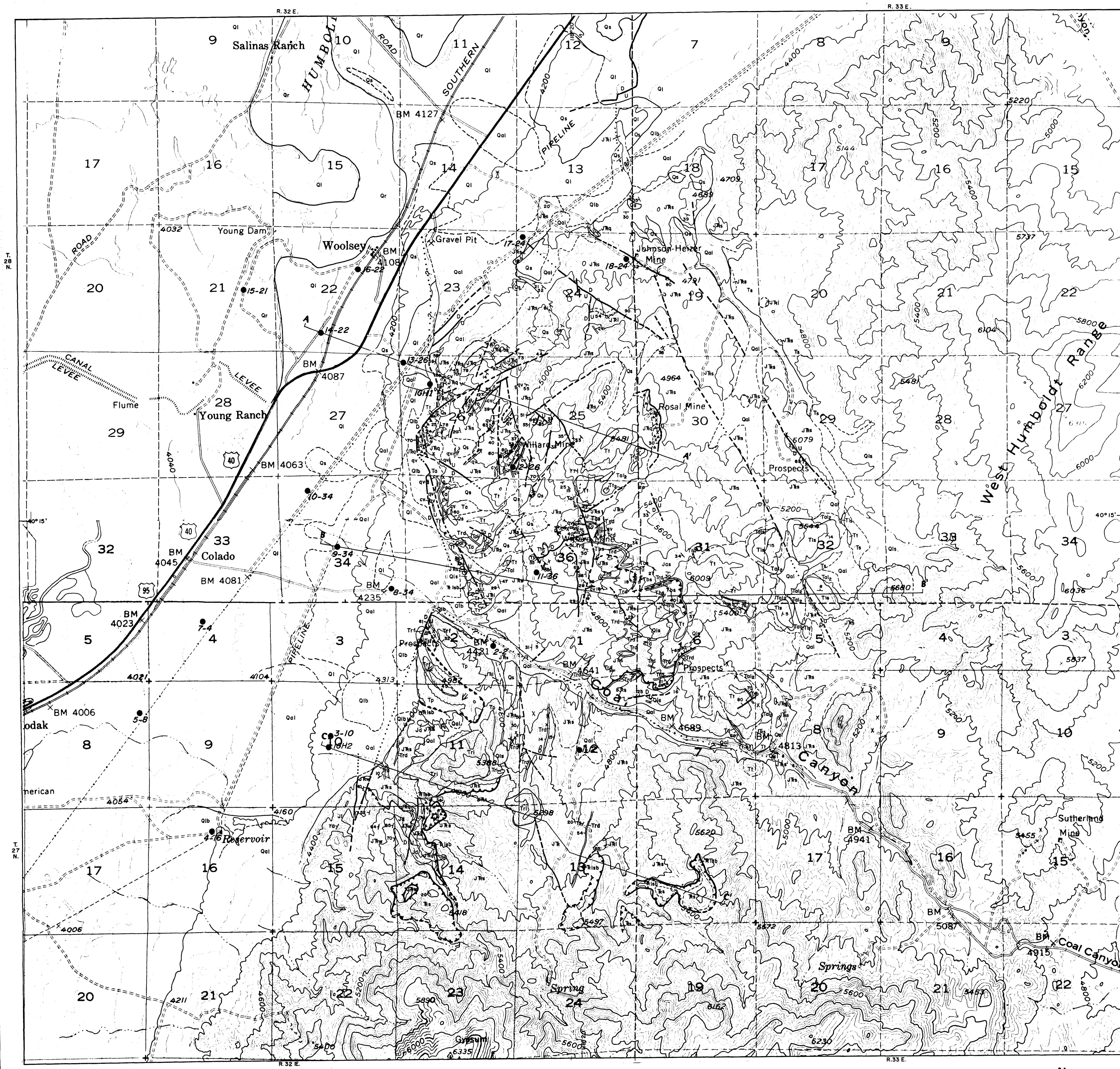
Jd	Diorite, greenish gray and medium-grained. It is tentatively assigned a Jurassic age based on lithologic similarity to age dated rocks to the south (Speed, 1976).
Jl	Lovelock Formation, thick beds of gray limestone with minor shale beds (Speed, 1974).

Auld Lang Syne Group

JTRw	Thick beds of light gray to tan limestone, gray orthoquartzite, and brown mudstone. The 50 to 100 feet thick limestone beds distinguish the sequence from the thin limestone beds in the pelite sequence (JTRs, JTRl, JTRq).
JTRl	Dark gray lenses of limestone within the pelite (JTRs).
JTRq	Orthoquartzite, gray to olive or reddish brown, fine-grained quartzite.
JTRs	Slaty-shale, mudstone and minor siltstone beds. The shale which grades to slate is thinly bedded and weathers tan. The mudstone is medium-to dark-brown and poorly bedded. Thin argillaceous siltstone beds of limited extent are present within the slates.
TRs	Siltstone, clean, well sorted siltstone to very fine sandstone, weathers to yellow and tan tones, occurs only in detached thrust plate. Assigned a Triassic age by Speed (1976).
TRlsb	Limestone solution breccia exposed at the base of thrust sheets. The upper zone is an olive gray collapse breccia. The lower zone contains large blocks of folded gray limestone. The age of the limestone is unknown but it seems to underly the Triassic siltstone.

EXPLANATION OF MAP SYMBOLS

- Contact, dashed where approximate
- Fault, dashed where inferred, dotted where covered
- Thrust fault, dashed where inferred
- Breccia zone
- cv — Calcite vein
- qv — Quartz vein
- 55 — Strike and dip of bedding or compaction foliation
- 15-21 — Thermal gradient hole
- x — Prospect pit
- Adit
- Shaft



SCALE 1:24,000

1/2 0 1 MILE

1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

1 .5 0 1 KILOMETER

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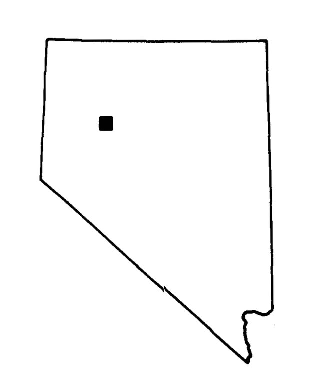
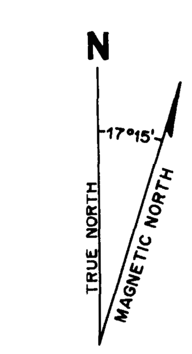
Plate I

GEOLOGY MAP OF THE COLADO AREA PERSHING COUNTY, NEVADA

GEOLOGY BY BRUCE S. SIBBETT, 1980



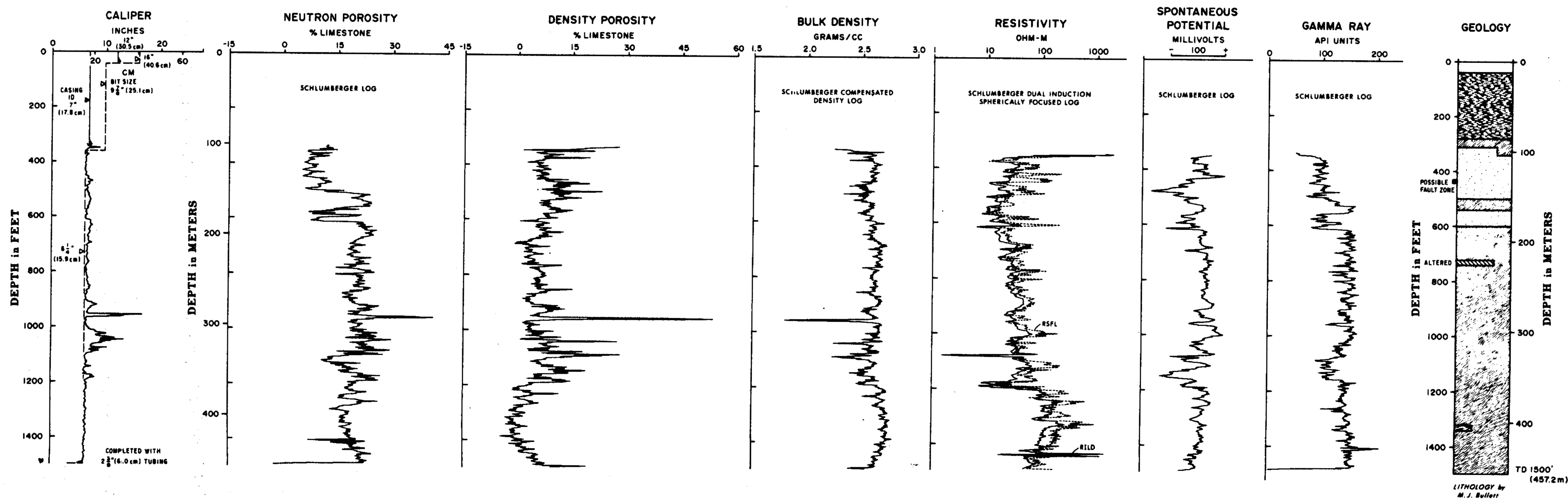


APPROXIMATE MEAN DECLINATION, 1970

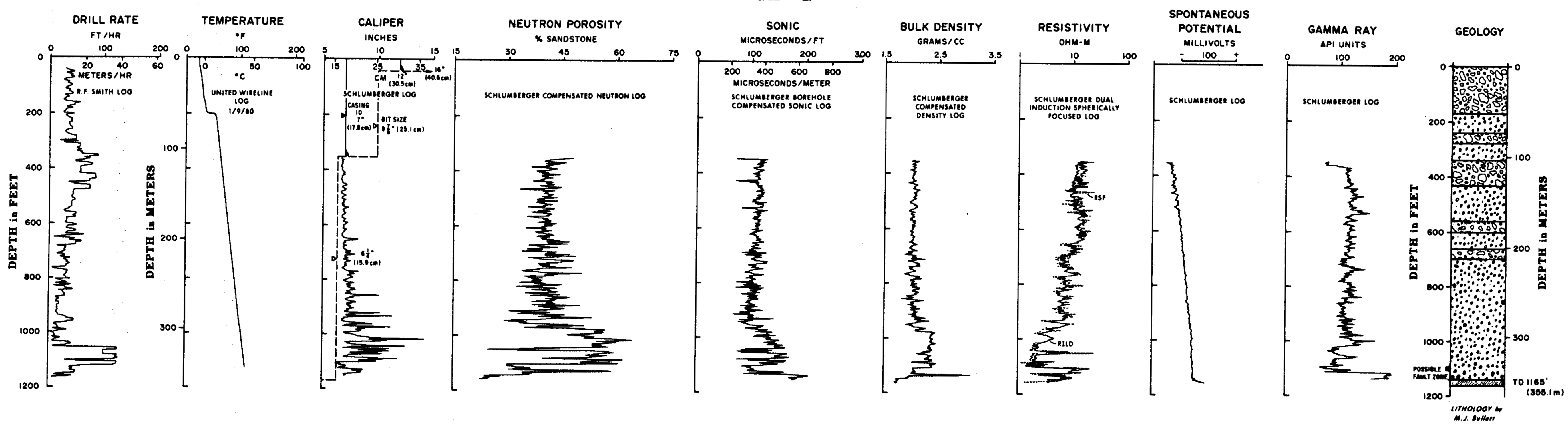
DOE/ID/12079-53

PLATE II

IGH - 1



IGH - 2



EXPLANATION

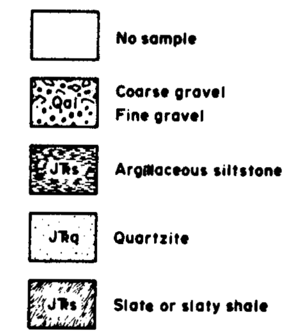


PLATE II

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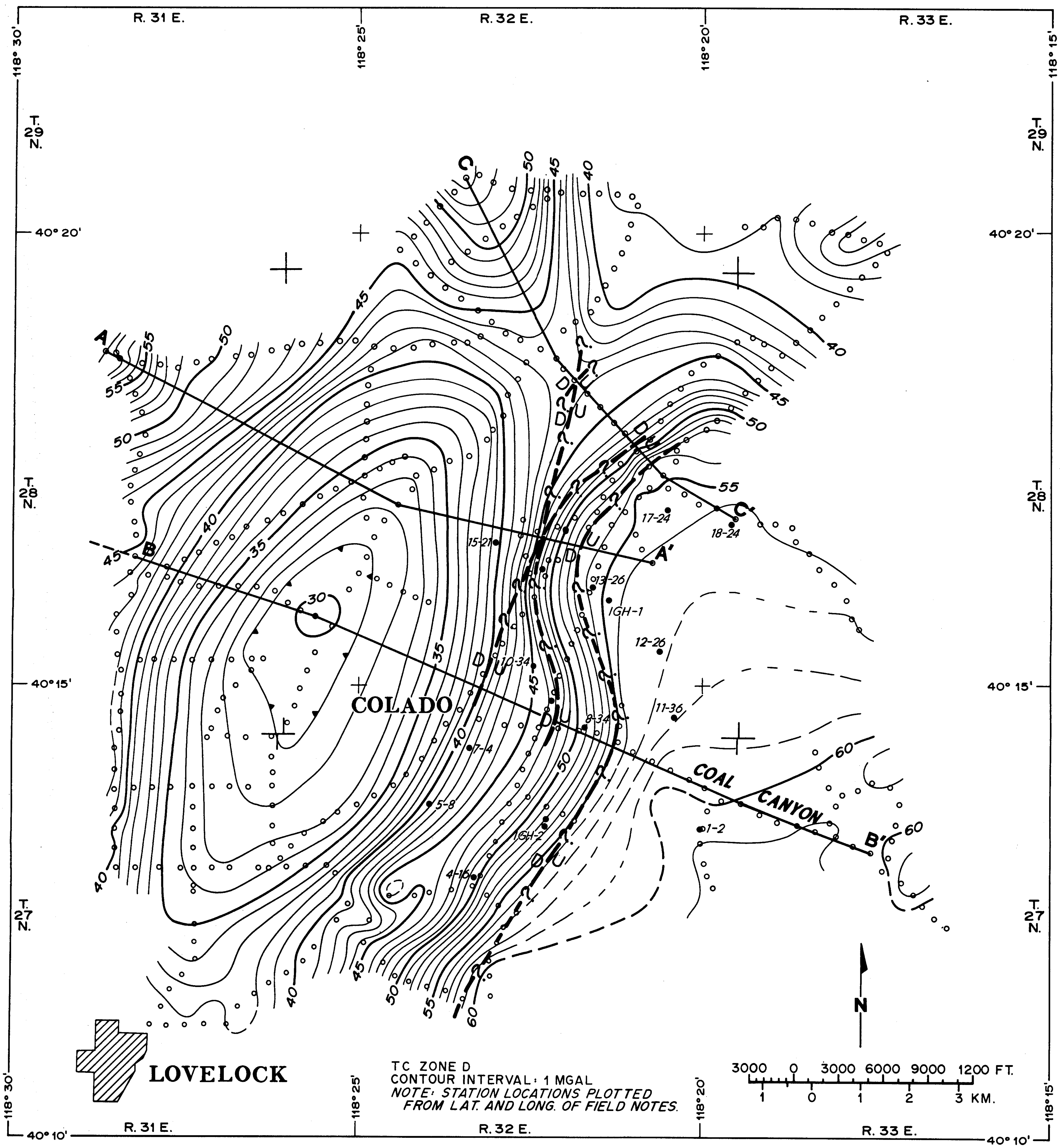
COMPOSITE LOG of GEOTHERMAL WELLS IGH-1 and IGH-2 COLADO KGRA

Pershing County - Nevada

JANUARY, 1981

DOE/ID/12079-58

PLATE III

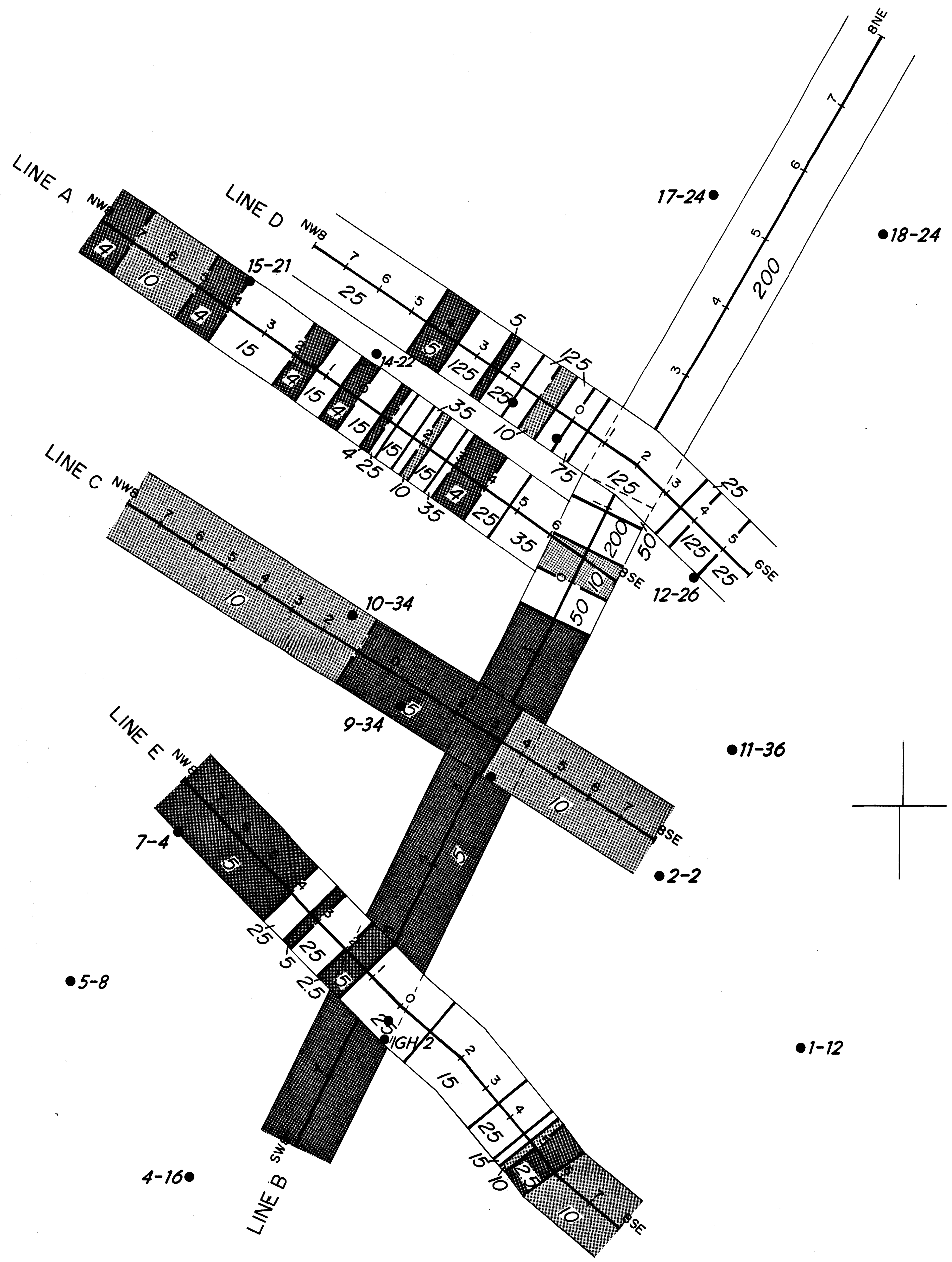


BOUGUER GRAVITY MAP

COLADO KGRA, PERSHING COUNTY, NEVADA

PLATE III

PLATE IV



R. 32 E. R. 33 E.

T. 28 N.

T. 27 N.

40° 15'

118° 21'

EXPLANATION
(OHM-M)
$\rho \leq 5$
$5 \leq \rho \leq 10$
● THERMAL GRADIENT HOLE
7-4

PLATE IV
INTERPRETED
ELECTRICAL RESISTIVITY DISTRIBUTION
at a DEPTH of 1000 FEET

COLADO GEOTHERMAL AREA

PERSHING COUNTY, NEVADA
SCALE 1:24,000

EARTH SCIENCE LABORATORY
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PLATE V

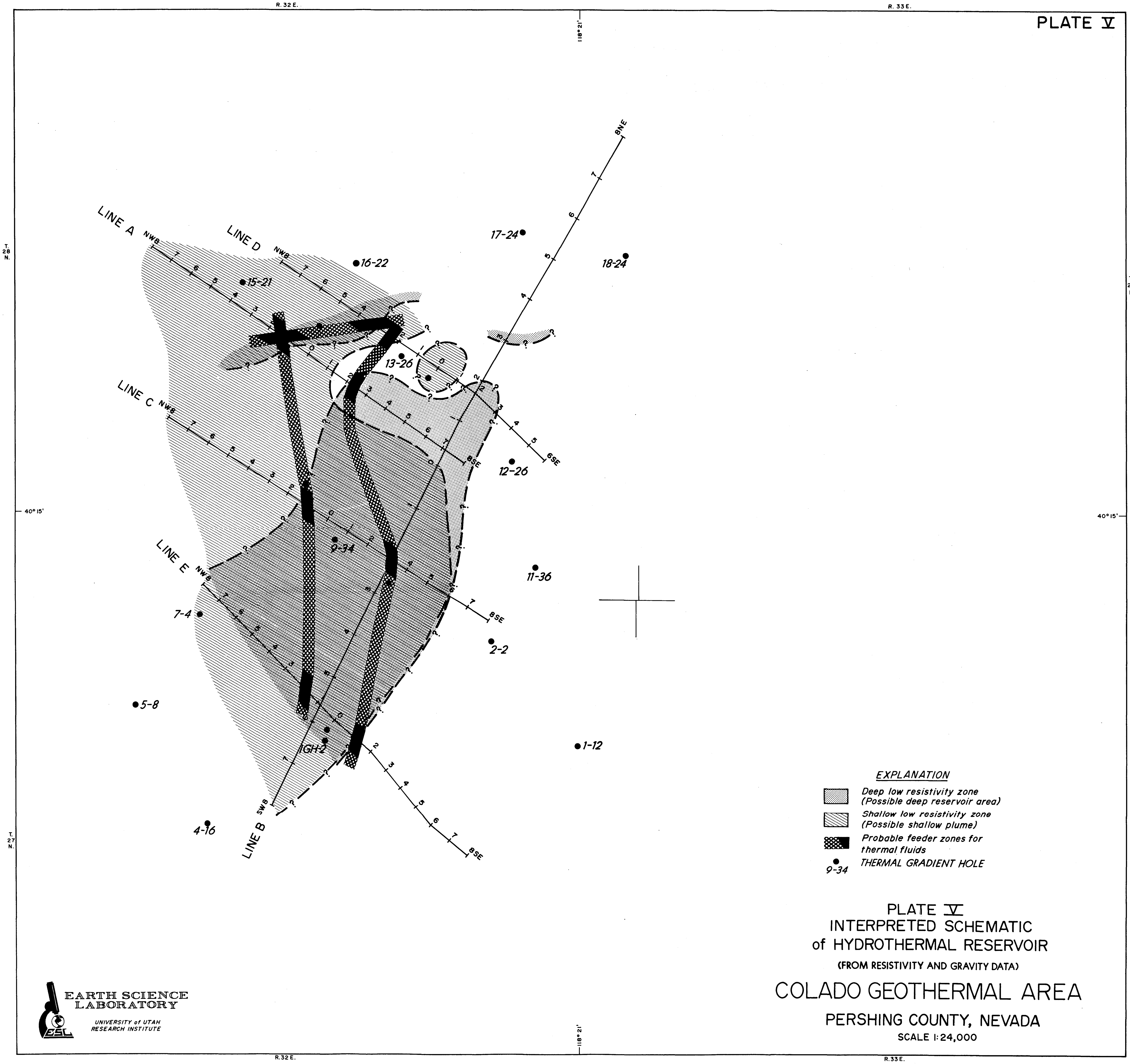

PLATE V
INTERPRETED SCHEMATIC
of HYDROTHERMAL RESERVOIR
(FROM RESISTIVITY AND GRAVITY DATA)

COLADO GEOTHERMAL AREA

PERSHING COUNTY, NEVADA

SCALE 1:24,000