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DOE/ET/27007--1

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# BALTAZOR KGRA AND VICINITY, NEVADA; Geothermal Reservoir Assessment Case Study, Northern Basin and Range Province

FINAL REPORT

1 October 1978 - 31 January 1983

T.C. WRIGHT

Earth Power Production Company
970 East 4800 South
Salt Lake City, Utah 84117

Prepared for the

U.S. DEPARTMENT OF ENERGY
NEVADA OPERATIONS OFFICE
Under Contract DE-AC08-79ET27007

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ABSTRACT

The Baltazor KGRA and McGee/Painted Hills geothermal prospects are located in northern Humboldt County, Nevada along the northwestern margin of the Basin and Range province. Earth Power Production Company (EPPC) began exploration of the prospects in 1977. EPPC continued its program as a Geothermal Reservoir Assessment Case Study funded in part by the U.S. Department of Energy under Contract DE-AC08-79ET27007.

Exploration work other than drilling has included groundwater sampling, a microearthquake study, a geologic literature search and photogeologic mapping, compilation of aeromagnetic and gravity mapping, soil mercury surveying, electrical resistivity and self-potential surveys and detailed hydrothermal alteration mapping.

Exploration drilling included 27 shallow temperature gradient holes, four intermediate-depth gradient wells and one 3703-foot deep test, Baltazor 45-14. The deep test penetrated Miocene rhyolite, andesite, basalt and andesitic basalt flows before excessive hole deviation forced an end to drilling and completion as a deep temperature observation well. A temperature survey two weeks after completion obtained a 119.7°C (247.4°F) reading at survey total depth, 1110m (3640 feet).

## Introduction

The Baltazor Hot Springs KGRA and McGee Mountain/Painted Hills geothermal area are located in northern Humboldt County, Nevada along the northwestern margin of the Basin and Range province (see Figs 1 and 2). The Baltazor prospect contains about 40 sections under lease to subsidiaries and affiliates of Grace Geothermal Corporation. The McGee area contains about 50 sections under lease to the same companies. Earth Power Production Company (EPPC) of Tulsa, Oklahoma is operator.

EPPC began geothermal exploration at Baltazor and McGee in 1977 with a groundwater sampling survey (Klein and Koenig, 1977) and a microearthquake study (Senturion Sciences, 1977). A geologic literature search and photogeologic mapping study (Gardner and Koenig, 1978) followed in 1978 along with a program of shallow gradient hole drilling (EPPC, 1979). An aeromagnetic survey (Scintrex Mineral Surveys, 1972) and gravity maps (Plouff et al., 1976; Peterson and Hoover, 1977) completed the 1978 data base.

EPPC submitted a proposal in May 1978 in response to DOE RFP No. ET-78-R-08-0003 to provide the above existing data and new data as one of the Geothermal Reservoir Assessment Case Studies (Northern Basin and Range Province). DOE awarded a contract to EPPC effective October 1, 1978. New data was to be delivered to DOE in three phases. In Phase I, EPPC drilled and ran temperature surveys in 4 intermediate depth (about 460m=1500 feet) temperature gradient holes in 1979. In Phase II, completed in January, 1983, EPPC drilled one deep exploratory hole, 45-14, in the Baltazor area to a depth of 1129m (3703 feet). EPPC has delivered all technical data including drill cuttings. mud logs and a suite of geophysical logs to DOE for this well.

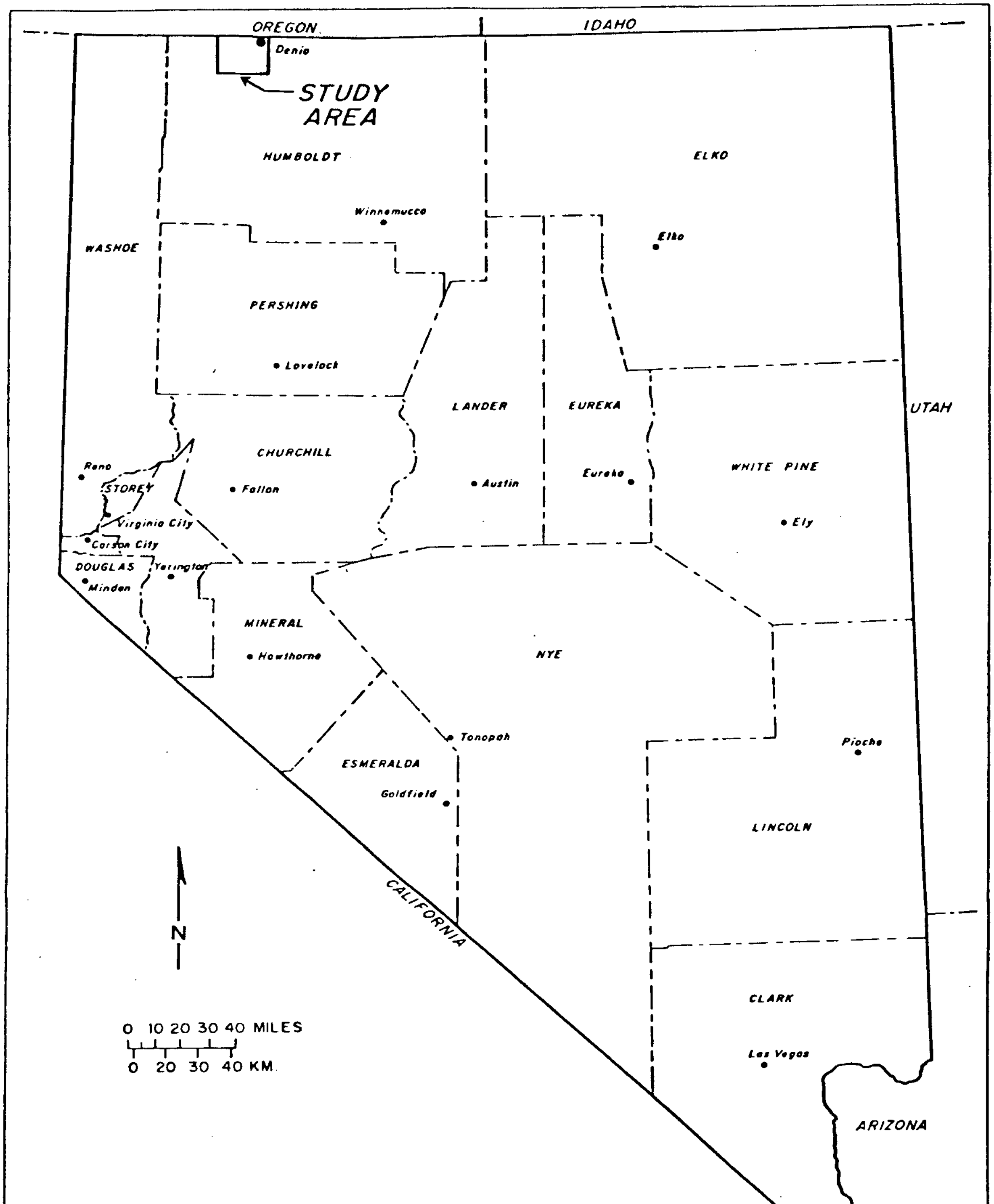



FIGURE I
**INDEX MAP**

(from Edquist, 1981)

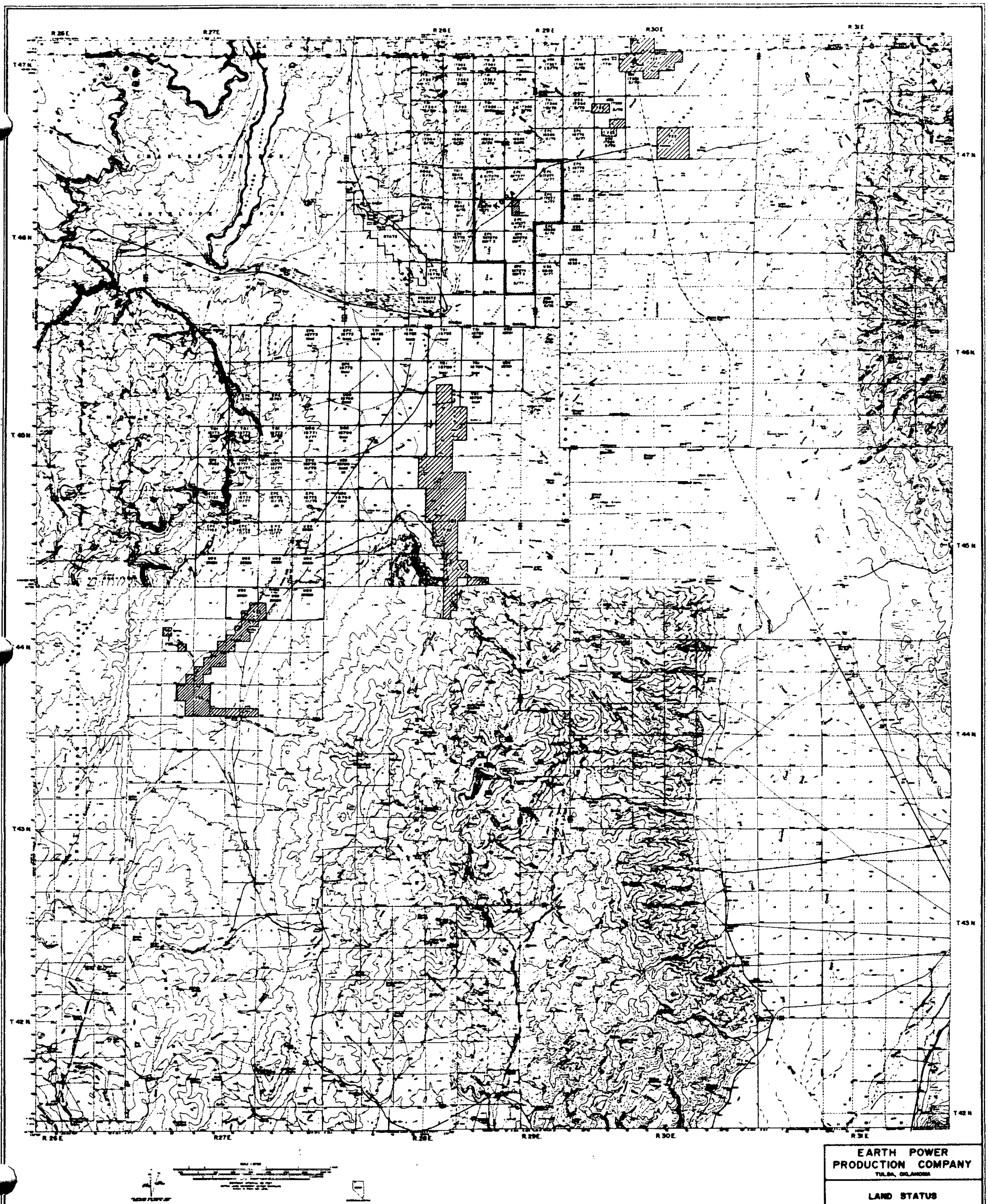

R.26E
R.27E
R.28E
R.29E
R.30E
R.31E
T.47N.
T.46N.
T.45N.
T.44N.
T.43N.
T.42N.
EARTH POWER PRODUCTION COMPANY
TULSA, OKLAHOMA
LAND STATUS
BALTAZOR-McGEE GEOTHERMAL PROSPECTS
HUMBOLDT COUNTY, NEVADA

Figure 2

Steel tubing $2\frac{3}{8}$ inches in diameter was run into the hole to 1110m (3640 feet) and filled with water. A temperature of 119.7°C (247.4°F) was measured at 1110m on February 3, 1983. Phase III, to consist of flow tests, was not performed because no productive zone was encountered.

All of the data delivered to the DOE are on open file with the Earth Science Laboratory, University of Utah Research Institute (ESL/UURI), Salt Lake City (see Appendix A).

Geology

Gardner and Koenig's 1978 literature search and photogeologic mapping study was followed by additional geologic and hydrothermal alteration mapping under a DOE contract with ESL/UURI (Hulen, 1979). The following discussion is based on the latter study.

Plate I (Hulen,1979) is a geologic map of the Baltazor and Painted Hills/McGee areas. Cretaceous diorite and quartz diorite intrude Permian to Triassic eugeosynclinal metasedimentary and metavolcanic rocks in the Baltazor area. A thick sequence of Miocene to Pliocene volcanic and volcanoclastic rocks overlies the Permian to Triassic and intrusive rocks. Only the younger sequence crops out in the McGee area, and only the later part of the sequence has been correlated with rocks in the Baltazor area.

Moderate-to high-angle, north-to northeast-trending Basin and Range faults probably control the ascent of thermal fluids near Baltazor Hot Springs. The hot springs location may be controlled by an intersection with near-vertical, northwest-trending faults, the second prominent fault set in the area. Quaternary landslides dominate the structural geology of the Painted Hills/McGee area.

Baltazor Hot Springs has measured temperatures of 76°C to 98°C (169° to 208°F.; Klein and Koenig, 1977). Near-surface gradients approach 290°C/km (16°F/100 feet). There are no thermal springs in the Painted Hills/McGee area, but near-surface gradients of about 400°C/km (22°F/100 feet) have been measured and warm ground and intermittent fumeroles have been reported (Gardner and Koenig, 1978).

Several different styles and ages of hydrothermal alteration and mineralization are found at Baltazor and McGee. The oldest phenomenon consists of copper-bearing quartz veins emplaced in pre-Tertiary rocks prior to Cenozoic volcanism. Argillizaion, silification, hematization and mercury mineralization are spread throughout the Painted Hills; this alteration is probably pre-Pleistocene. Alteration at Baltazor Hot Springs consists of small calcite-bearing opaline sinter deposits. Siliceous sinter deposits indicate reservoir temperatures of at least 180°C (356°F) in the past at Baltazor. The hot spring is not presently precipitating silica.

No young rhyolitic volcanics are present at Baltazor or McGee. These areas are located within the Battle Mountain zone of high heat flow (Sass et al., 1971). These two facts suggest that the thermal phenonena at Baltazor/McGee are due to deep circulation along faults rather than to a shallow body of silicic magma.

## Geochemistry

GeothermEx, Inc. performed a hydrochemical study of thermal areas in 1977 (Klein and Koenig, 1977). The goals of the survey were "to use integrated hydrologic, hydrochemical, and geologic data to describe the region's water-circulation systems and to predict as closely as possible the temperature and composition of deep thermal fluids, characteristics and location of possible acquifer host rocks, volume of recharge to the deep and shallow systems and potential sustained annual yield."

Twenty-six water samples and three gas samples from hot springs were collected and analyzed. Figures 3 and 4 are maps depicting, respectively, geochemical data and sulfate as a percentage of total dissolved solids. (Full scale plates are available from ESL/UURI as Open-File Report NV/BAL/EPP-7.) Silica and Na-K-Ca geothermometers indicated a maximum surface temperature for Baltazor Hot Springs of about 160°C (320°F). A temperature less than about 135°C (275°F) appeared to be unlikely. While its sub-boiling temperature made it tempting to hypothesize that Baltazor Hot Springs is a mixed water, no cool component could be deduced that would behave consistently with respect to all the major solutes or the Na-K-Ca geothermometer. Baltazor water, therefore, is probably cooled by conduction as it rises from depths of a kilometer or more. High fluoride content points to an acidic igneous reservoir host rock, either Tertiary dacite-rhyolite or Mesozoic granitics, or at shallower depths, basalts.

A well two miles northest of the Painted Hills Mine fumarole in the McGee area produces a cool water very similar to Baltazor Hot Springs. Klein and Koenig postulate this to be a thermal water that rises along the McGee Mountain fault and then flows down to the east within dipping sediments. Probably this water derives from a reservoir in the rocks like those of the Baltazor reservoir at a similar depth.

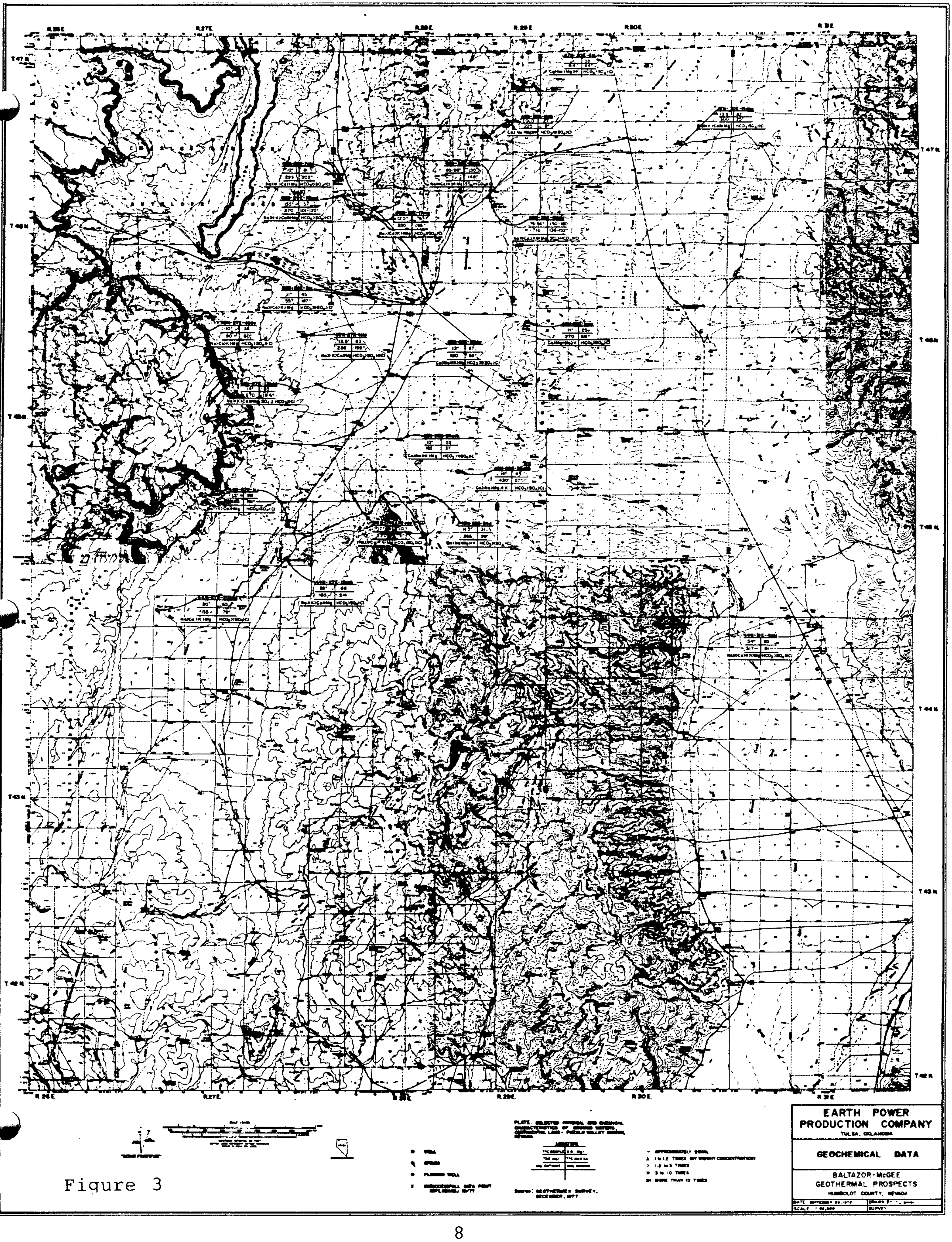
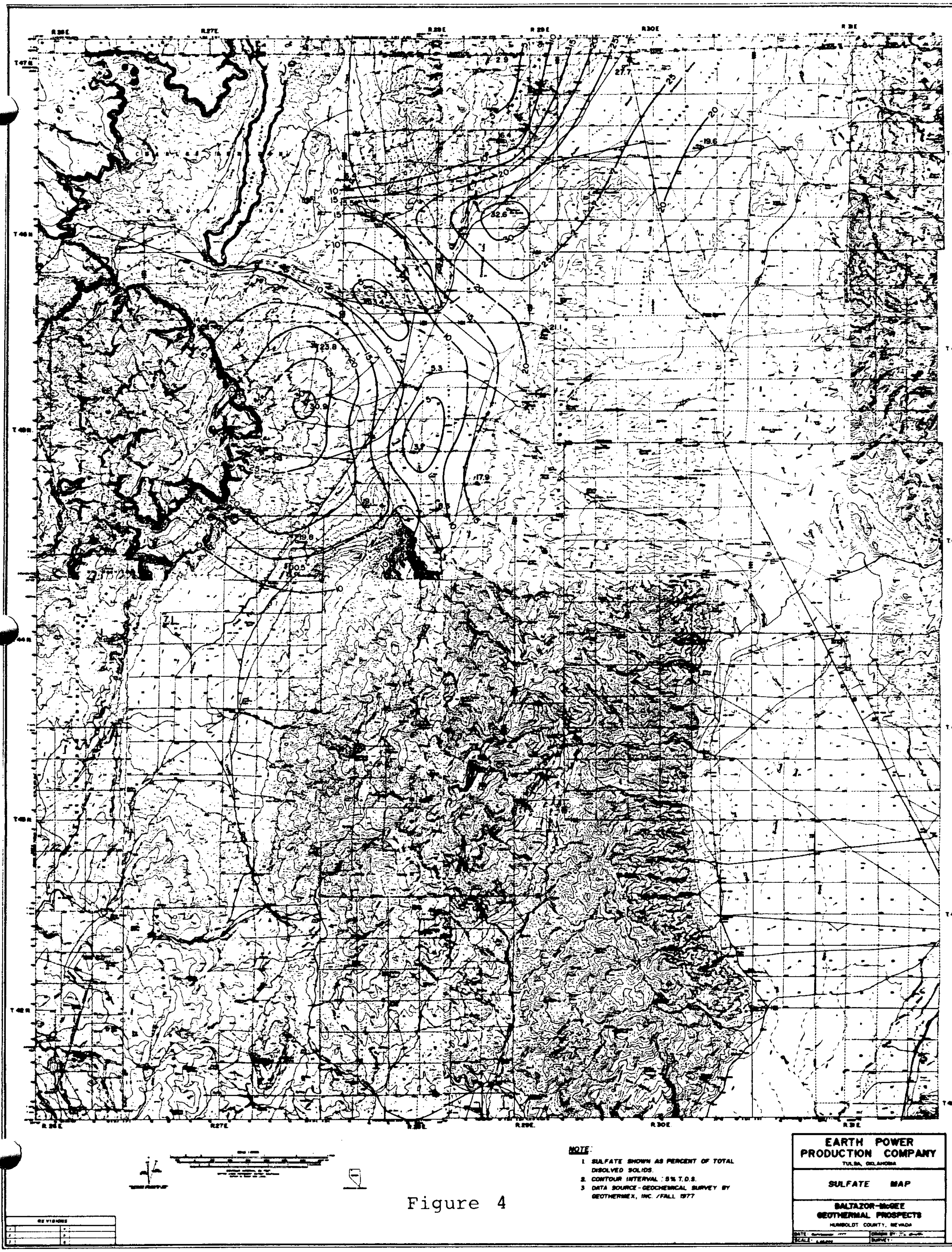

EARTH POWER
PRODUCTION COMPANY
TULSA, OKLAHOMA
GEOCHEMICAL DATA
BALTAZOR-McGEE
GEOTHERMAL PROSPECTS
HUMBOLDT COUNTY, NEVADA
R.27E.
R.28E.
R.29E.
R.30E.
R.31E.
T.47N.
T.46N.
T.45N.
T.44N.
T.43N.
T.42N.

Figure 3


R.26E.
R.27E.
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R.29E.
R.30E.
R.31E.
T.47N.
T.46N.
T.45N.
T.44N.
T.43N.
T.42N.
NOTE:
1. SULFATE SHOWN AS PERCENT OF TOTAL DISOLVED SOLIDS.
2. CONTOUR INTERVAL : 5% T.D.S.
3. DATA SOURCE - GEOCHEMICAL SURVEY BY GEOTHERMEX, INC. /FALL 1977
EARTH POWER PRODUCTION COMPANY
TULSA, OKLAHOMA
SULFATE MAP
BALTAZOR-McGEE GEOTHERMAL PROSPECTS
HUMBOLDT COUNTY, NEVADA
DATE:
DRAWN BY:
SCALE:
SURVEY:
REVISIONS

Figure 4

Soil samples were collected from 14 sections surrounding Baltazor Hot Springs during February, 1980 and analyzed for mercury and arsenic (Blair, 1980). The 171 samples were taken on a grid with 1000-foot centers, 2000-foot centers in the peripheral area. No contour maps or interpretation of the results seems to have been made. The analyses do show two apparent maxima of mercury content: A peak value of 2.8 ppm about 1.3 miles northeast of the later deep test hole, 45-14, along the Pueblo Range front fault; and 1.4 ppm in the N½, Section 22, T. 46 N., R. 28 E. along the west side of the Pueblo Mountains ridgeline.

## Geophysics

Scintrex Mineral Surveys flew aeromagnetic coverage of the Baltazor-McGee area in 1972 at a constant barometric elevation of 2.74km (9000 feet; see Figure 5). Since the survey is regional in scope and contours reflect topography primarily, the survey has not proved very useful for interpretation of the geothermal system (Edquist, 1981).

Senturion Sciences, Inc. deployed two 6-station, 9-km diameter pentagonal seismometer arrays in the Baltazor-McGee area in June and July, 1977 (Senturion Sciences, 1977). The purpose was to define heat sources as indicated by microearthquakes and to determine relative crustal movements. Three microearthquake clusters were detected, the Denio, Thousand Creek and Craine Creek clusters (Figure 6).

First motions for the Denio swarm were compatible with a steeply dipping, north-northeast trending normal fault plane bounding the Pueblo Mountains west of Baltazor Hot Springs. The block on the west side of the fault moved upward relative to the eastern valley. Relative crustal movements could not be deduced from the Thousand Creek and Craine Creek clusters.

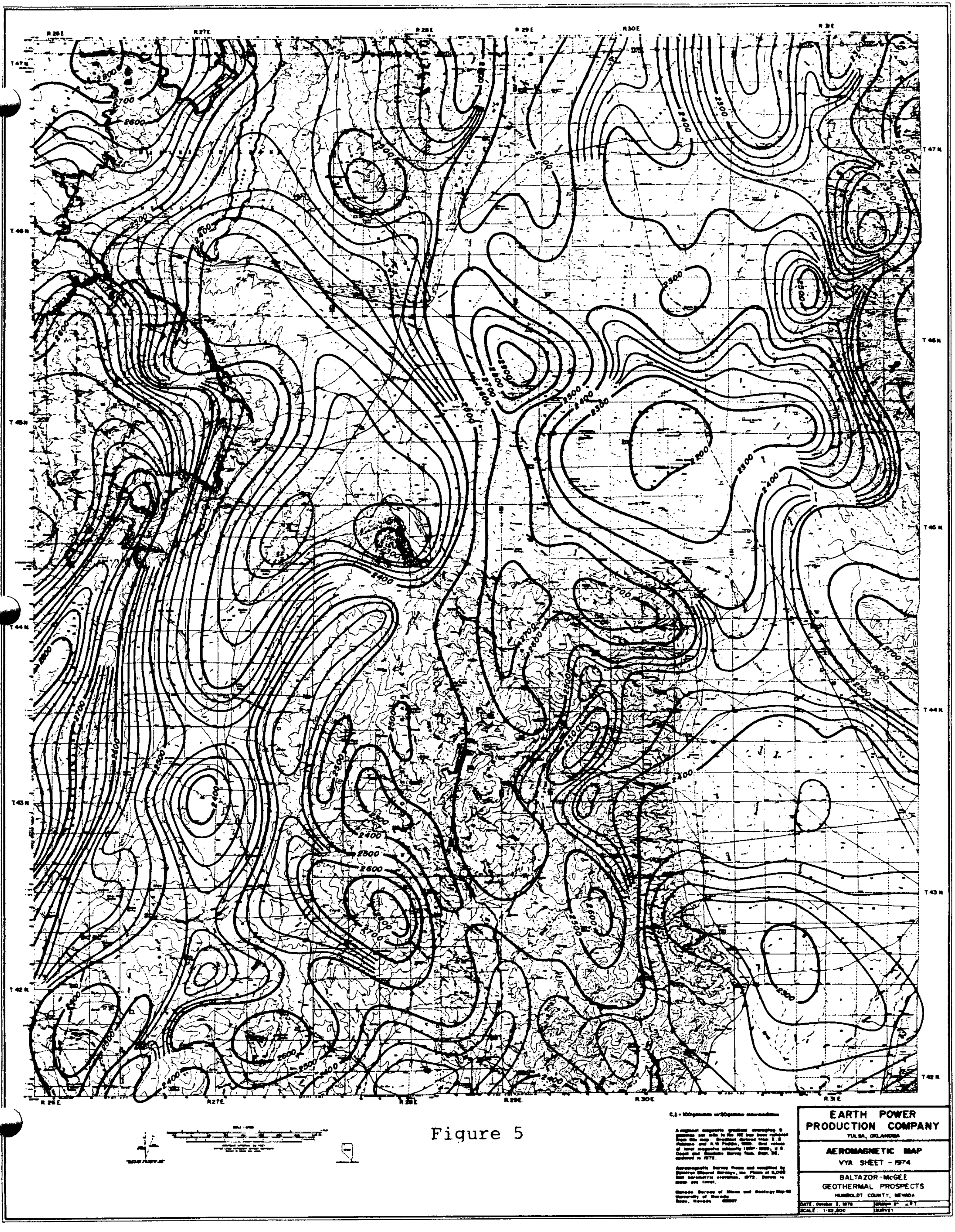

R.26 E
R.27 E
R.28 E
R.29 E
R.30 E
R.31 E
T.47 N.
T.46 N.
T.45 N.
T.44 N.
T.43 N.
T.42 N.
2800
2700
2600
2500
2400
2300
2200
EARTH POWER
PRODUCTION COMPANY
TULSA, OKLAHOMA
AEROMAGNETIC MAP
VYA SHEET - 1974
BALTAZOR-McGEE
GEOTHERMAL PROSPECTS
HUMBOLDT COUNTY, NEVADA
SCALE : 1:62,500
SURVEY

Figure 5

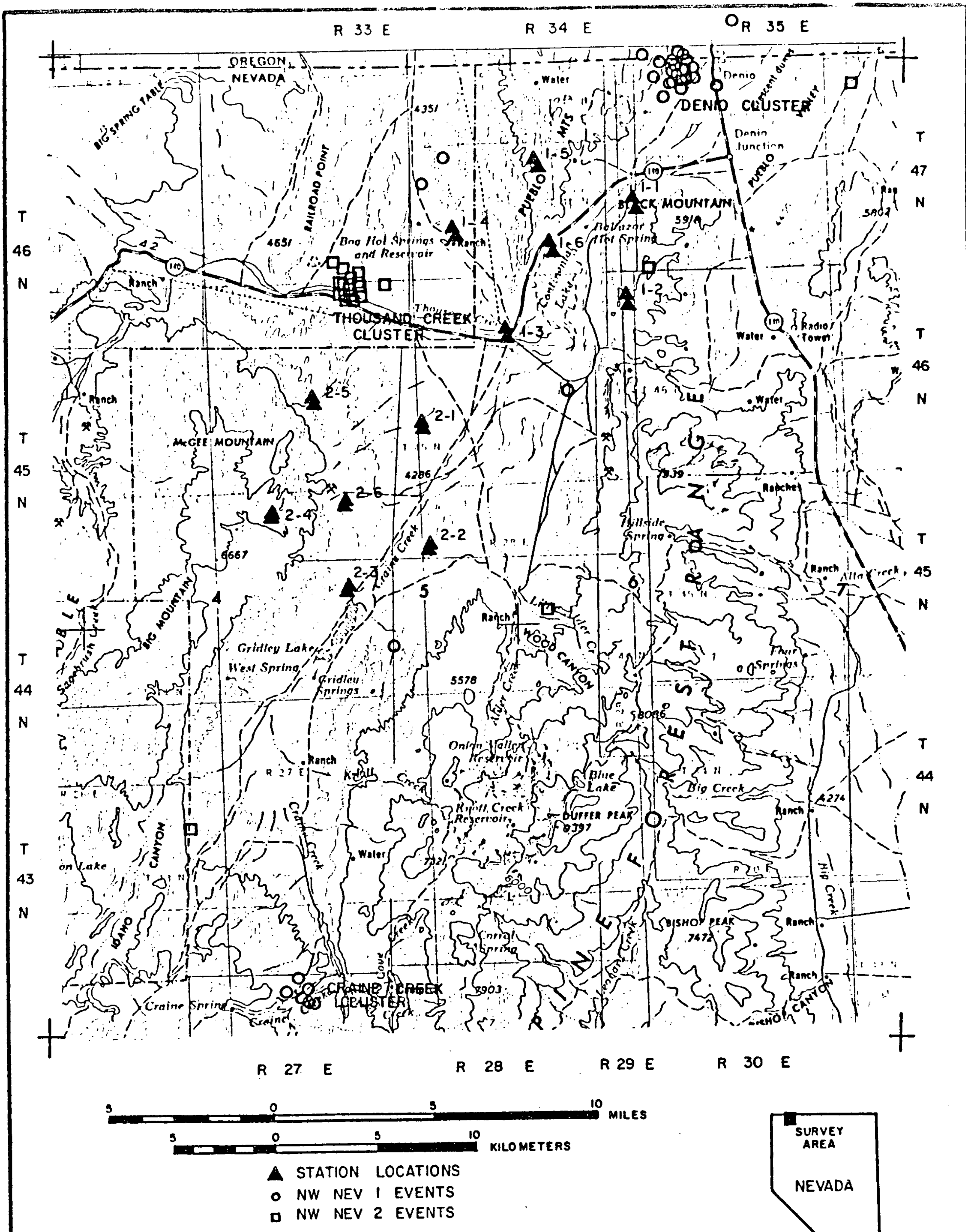



FIGURE 6 NW NEV 1 and 2 station locations and epicenters for microearthquakes detected with both six-station surveys. (from Senturion Sciences, Inc., 1977)

The swarms may have resulted in part from thermal stresses induced by high heat flows; normal tectonic stresses may also have been responsible for the microearthquakes. Vp/Vs ratios for the combined Denio and Thousand Creek data gave an anomalous (low) Poisson's ratio, possibly indicating voids filled with steam.

Edquist (1981) compiled and interpreted gravity, electrical resistivity and self-potential data for the Baltazor and McGee areas under contract to the DOE. Edquist himself collected gravity data from 194 stations and added this to 90 stations collected previously (Peterson and Hoover, 1977; Plouff et al, 1976). About half the data were taken along survey lines (Figure 7 ). Figure 8 is a complete Bouguer gravity anomaly map; Figure 9 is a residual Bouguer gravity anomaly map. Cross section modelling indicates that Baltazor Hot Springs appears to be controlled by recent faults that tap acquifers in the Steens Basalt. Figure 10 is a gravity interpretation map.

Edquist also models and interprets dipole-dipole resistivity and self-potential data collected by Mining Geophysical Surveys, Inc. (1980) on contract to EPPC. Four profiles of resistivity data were collected for a total of 21.8 line-km. About 38 line-km of SP data were collected along eight profiles. Figures 11 and 12 present interpretation of these data for the Baltazor area; Figures 13 and 14 do so for the Painted Hills/McGee area.

## Temperature Gradient Holes

EPPC drilled 27 shallow gradient holes, most to a depth of about 90m (300 feet), during the summer of 1977. The maxi-

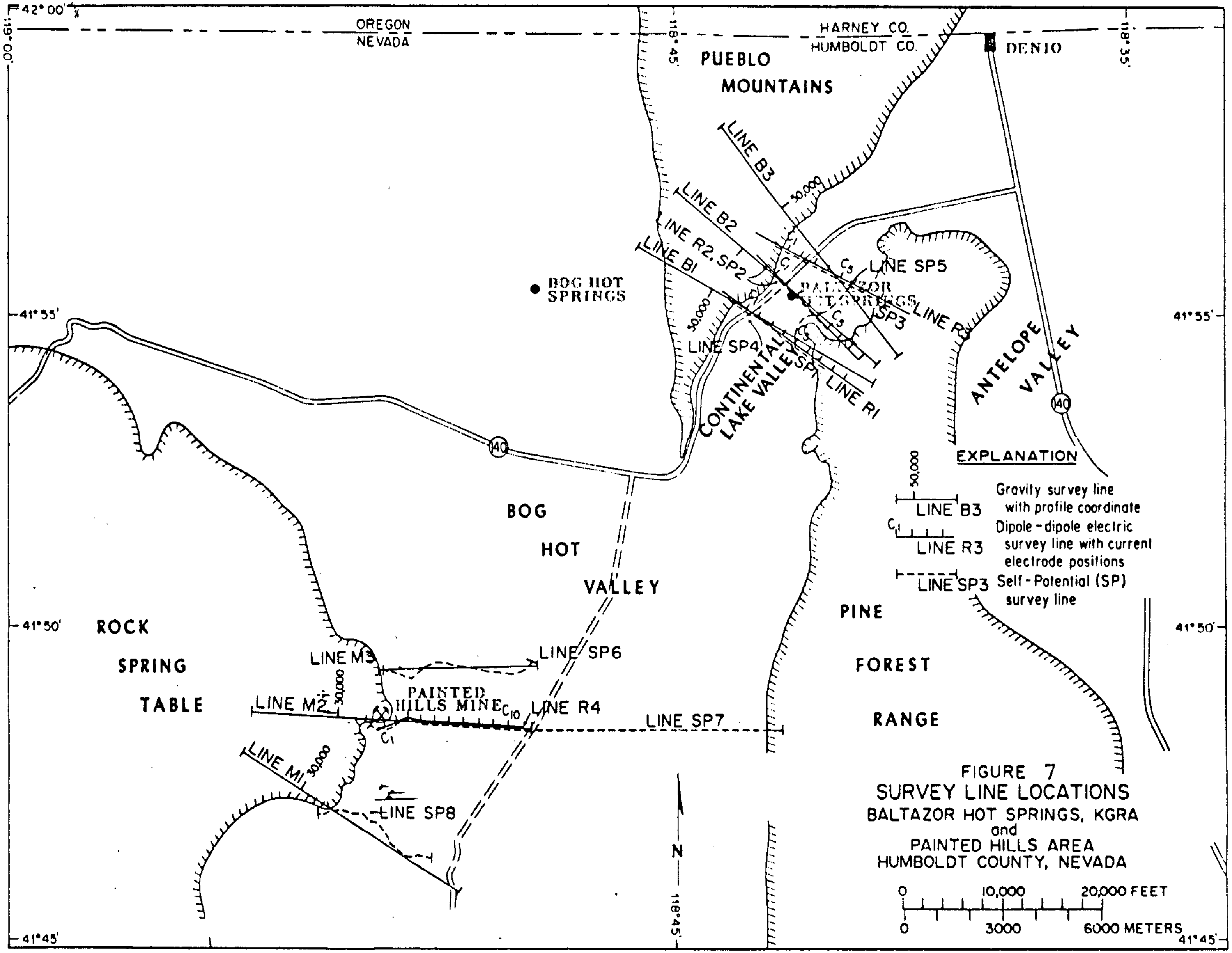



FIGURE 7
SURVEY LINE LOCATIONS
BALTAZOR HOT SPRINGS, KGRA
and
PAINTED HILLS AREA
HUMBOLDT COUNTY, NEVADA

(from Edquist, 1981)

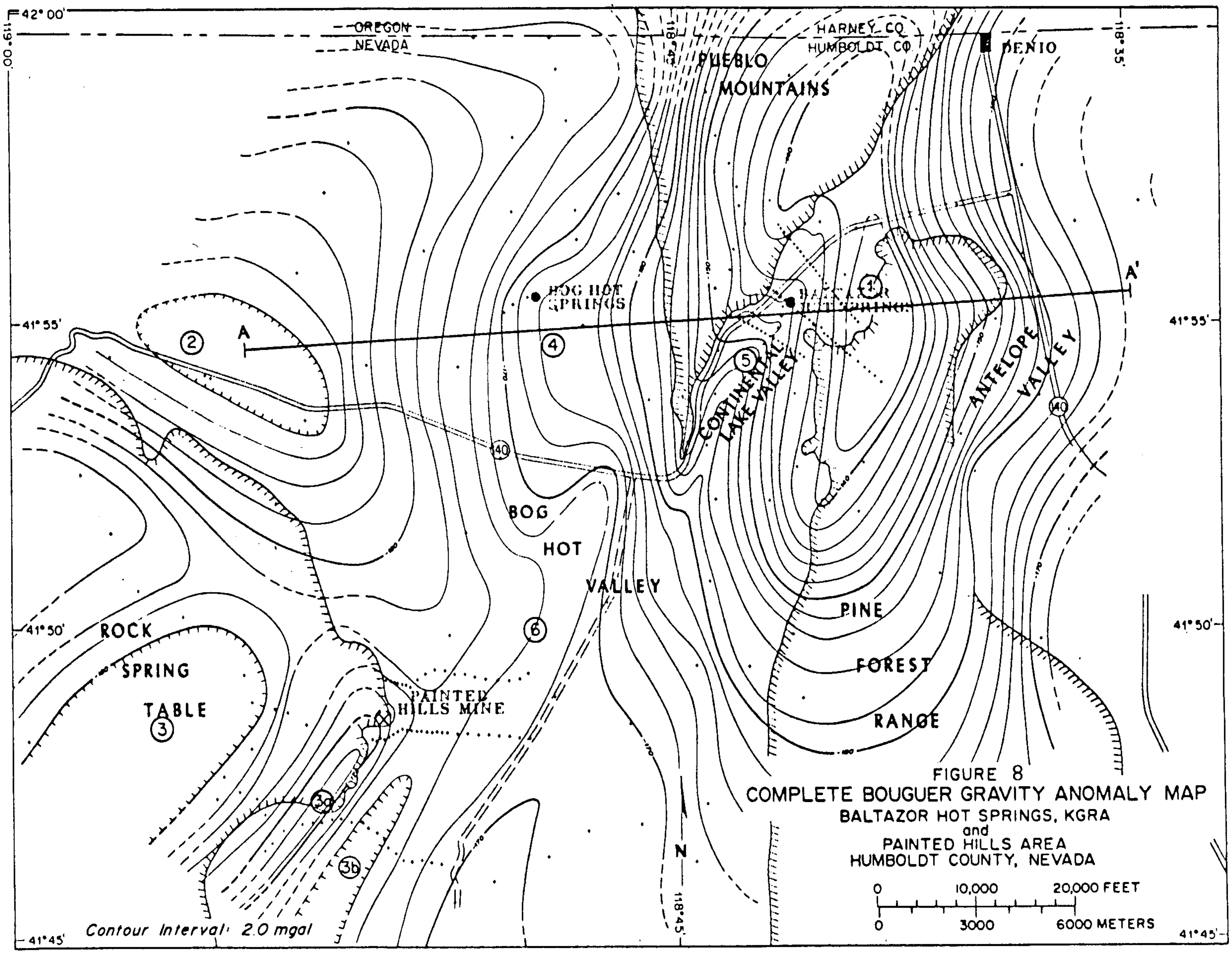



FIGURE 8
COMPLETE BOUGUER GRAVITY ANOMALY MAP
BALTAZOR HOT SPRINGS, KGRA
and
PAINTED HILLS AREA
HUMBOLDT COUNTY, NEVADA

(from Edquist, 1981)

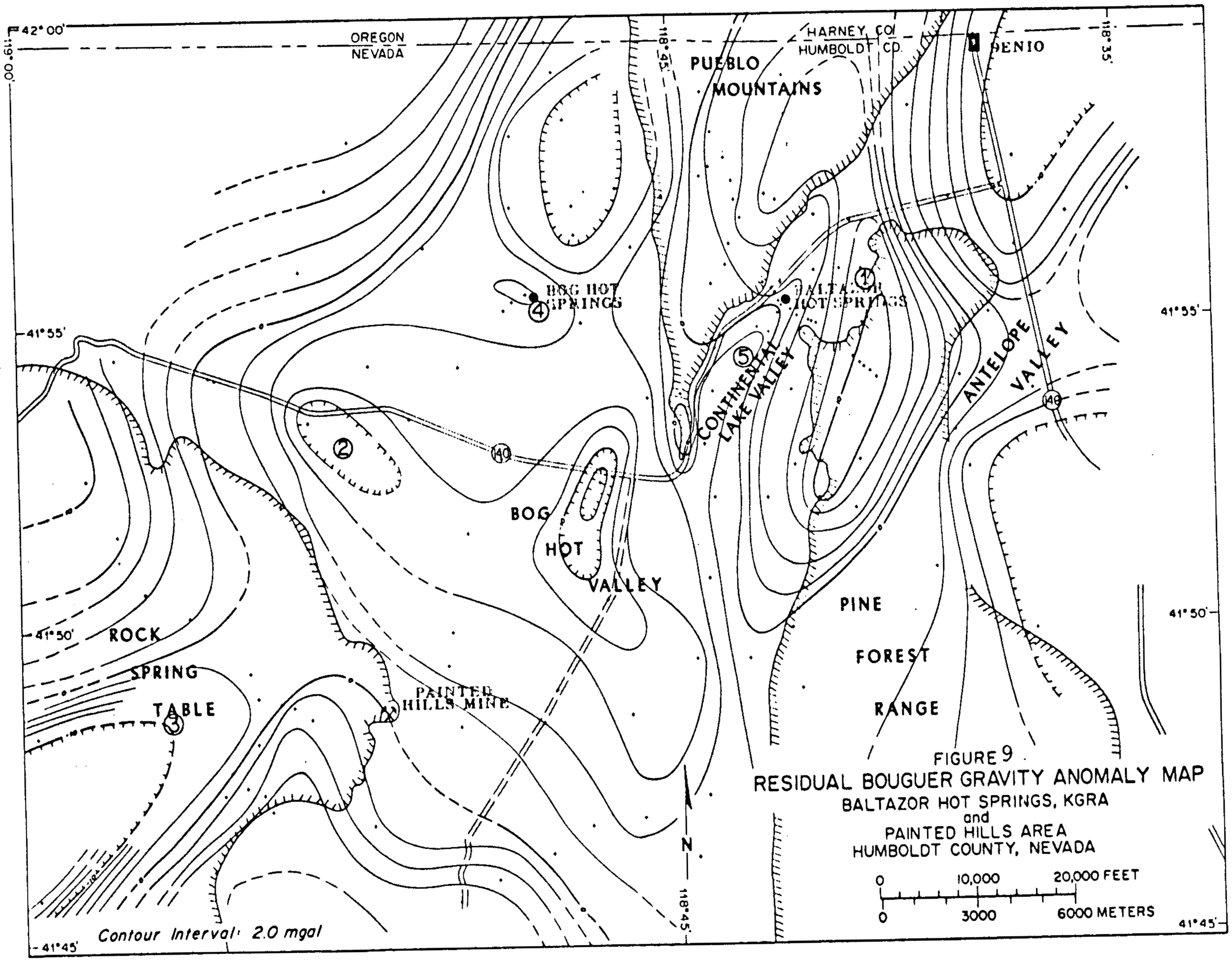



FIGURE 9
RESIDUAL BOUGUER GRAVITY ANOMALY MAP
BALTAZOR HOT SPRINGS, KGRA
and
PAINTED HILLS AREA
HUMBOLDT COUNTY, NEVADA

(from Edquist, 1981)

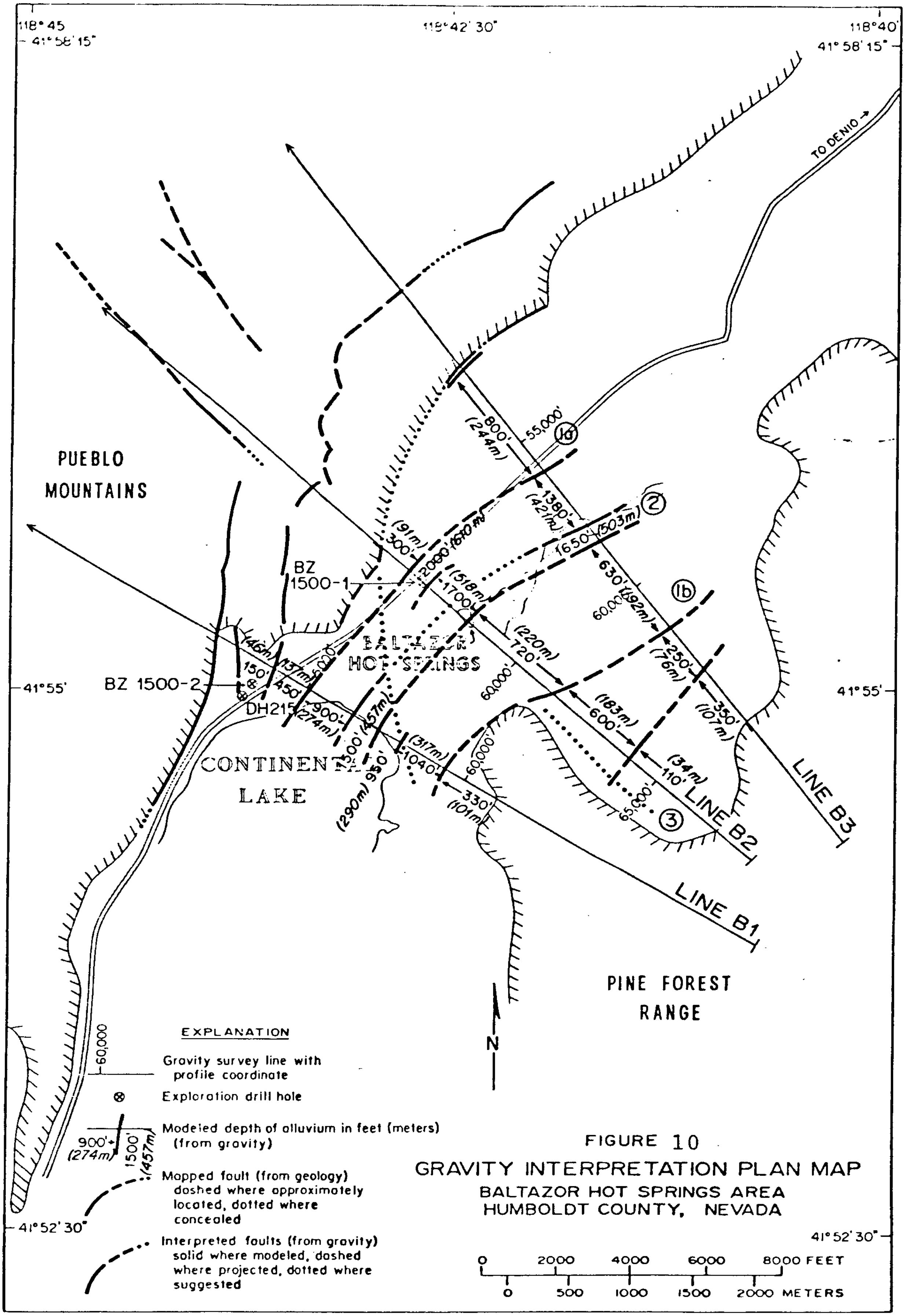



FIGURE 10
GRAVITY INTERPRETATION PLAN MAP
BALTAZOR HOT SPRINGS AREA
HUMBOLDT COUNTY, NEVADA

(from Edquist, 1981)

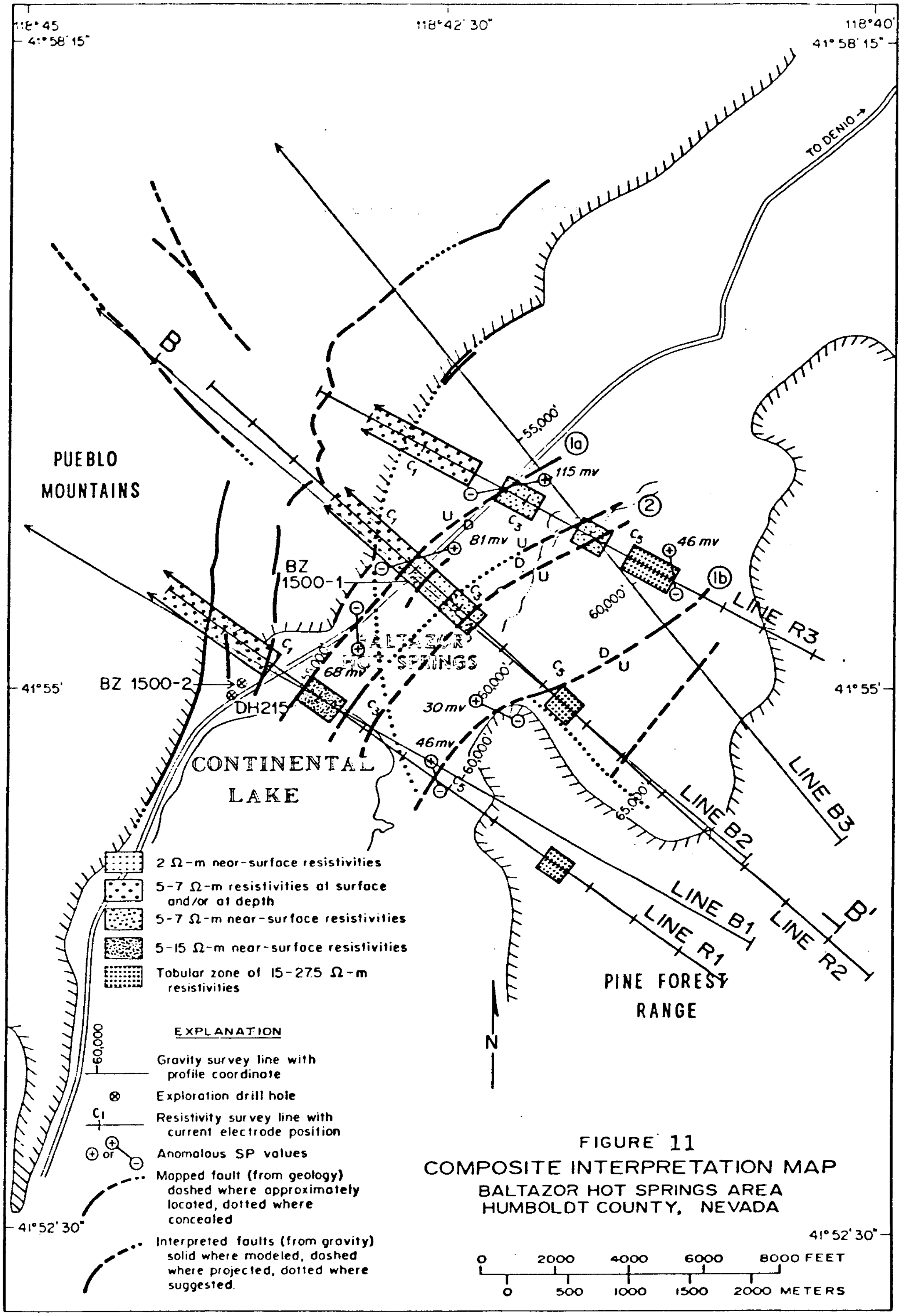



FIGURE 11
COMPOSITE INTERPRETATION MAP
BALTAZOR HOT SPRINGS AREA
HUMBOLDT COUNTY, NEVADA

 (from Edquist, 1981)

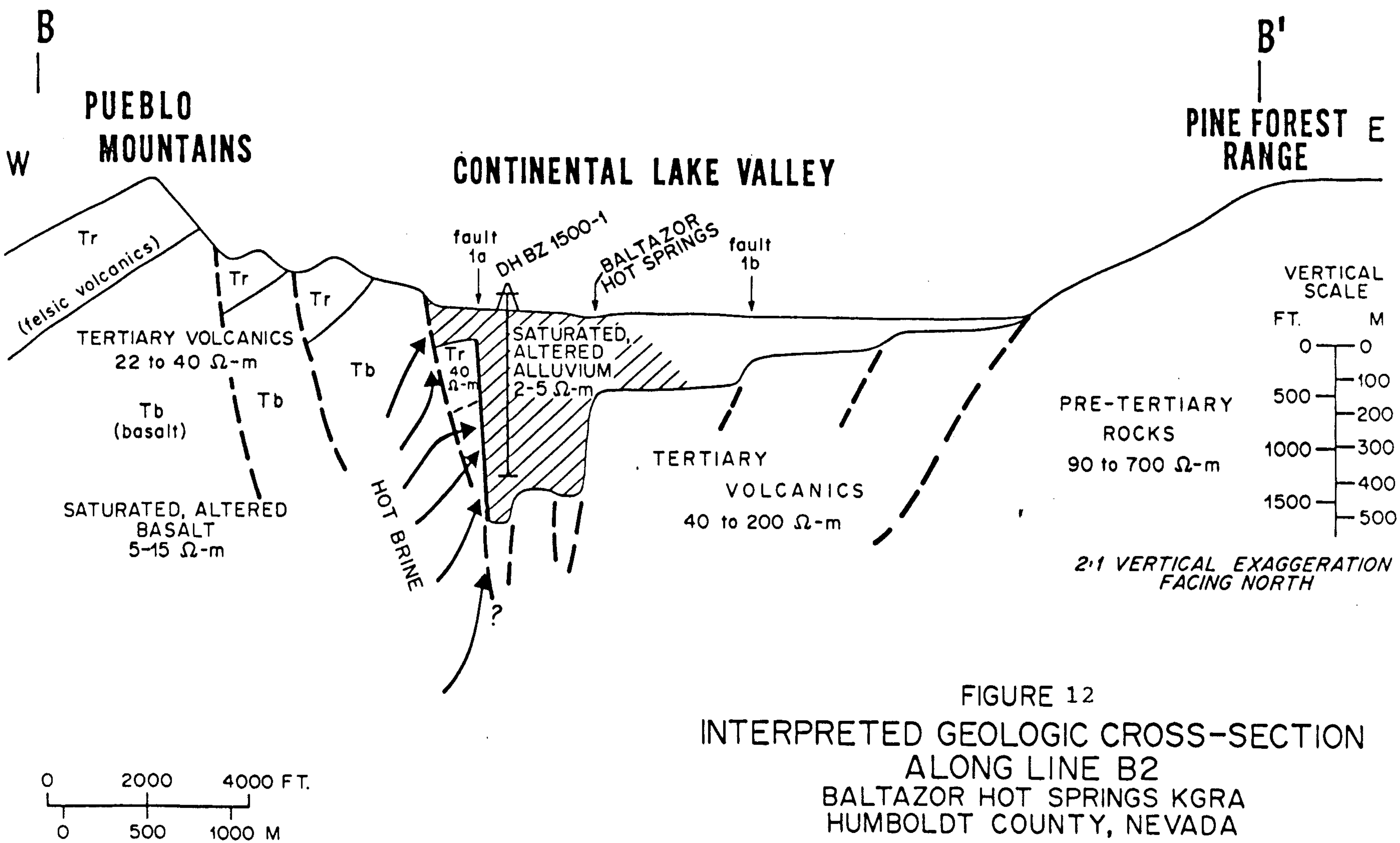



FIGURE 12
INTERPRETED GEOLOGIC CROSS-SECTION ALONG LINE B2
BALTAZOR HOT SPRINGS KGRA
HUMBOLDT COUNTY, NEVADA

(from Edquist, 1981)

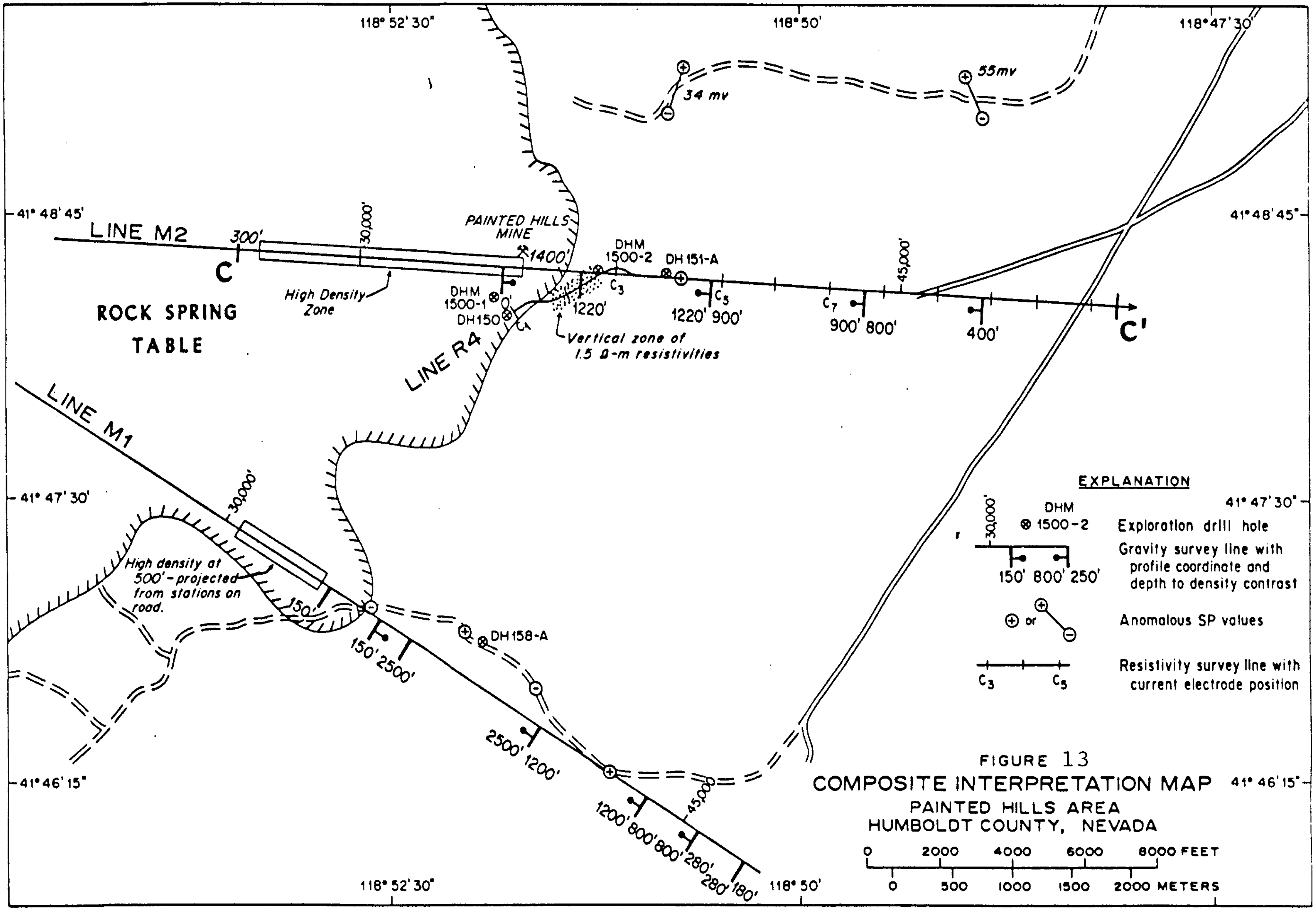



FIGURE 13
COMPOSITE INTERPRETATION MAP
PAINTED HILLS AREA
HUMBOLDT COUNTY, NEVADA

(from Edquist, 1981)

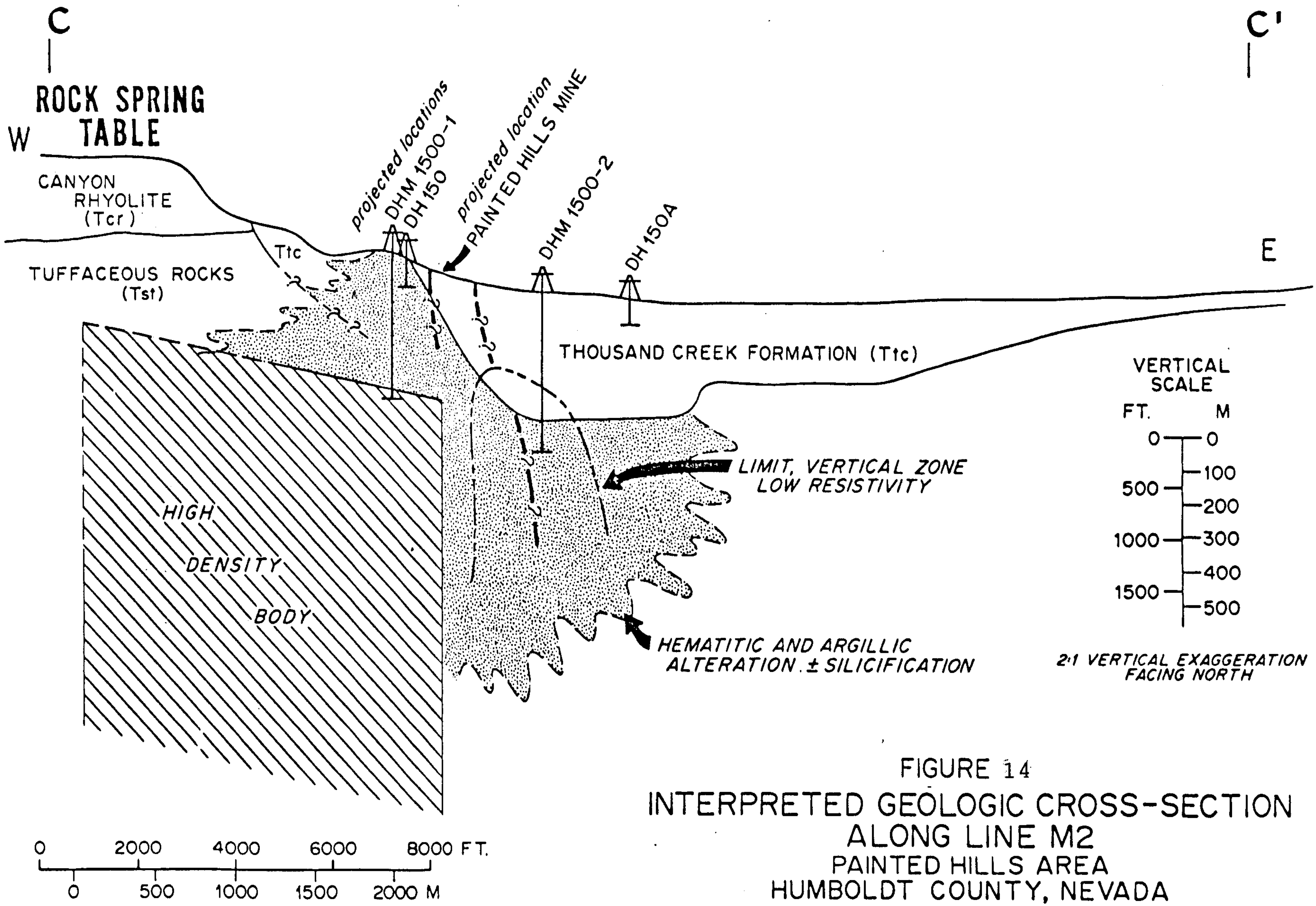



FIGURE 14
INTERPRETED GEOLOGIC CROSS-SECTION ALONG LINE M2
PAINTED HILLS AREA
HUMBOLDT COUNTY, NEVADA
(from Edquist, 1981)

mum gradient measured at Baltazor was 290°C/km (15.9°F/100 feet); the maximum at McGee was about 455°C/km (25°F/100 feet). Figure 15 is a temperature gradient contour map based on these holes.

Four intermediate-depth gradient holes were drilled in 1979 ( see plate I ) . Two intermediate depth holes were drilled near the center of the Baltazor anomaly near the range front fault. Baltazor 1500-1 was drilled about half-way between the hot spring and the range front. This hole went through the hot water aquifer at about 60m (200 feet), cooled to about 82°C (180°F) to 210m (700 feet), then slowly began to warm again with a bottom hole temperature of 90.5°C (195°F) at 467m (1532 feet).

The second intermediate depth hole, Baltazor 1500-2 was drilled about a mile southwest of the first hole at a location very near the range front of the Pueblos. This fault cannot be accurately traced in this area due to the large slump blocks that complicate the surface geology. Presumably, the hole penetrated the main fault zone and entered the foot wall at less than 145m (500 feet) unless this fault is much steeper than thought. The hole encountered a zone of 41°C (105°F) water at 76m (250 feet), then cooled to a low of 37°C (98°F) at 150m (475 feet). From 150m to 380m (475 to 1250 feet), the hole warmed to 57°C (135°F), then began increasing in temperature at a rate of about 200°C/km (11°F/100 feet), to a bottom hole temperature of 68°C (154°F) at 434m (1425 feet).

Two intermediate holes also were drilled in the McGee area. McGee 1500-1 was drilled in the area of warm ground where very high temperatures were measured in shallow holes. This hole heated rapidly to a temperature of 117°C (242°F)

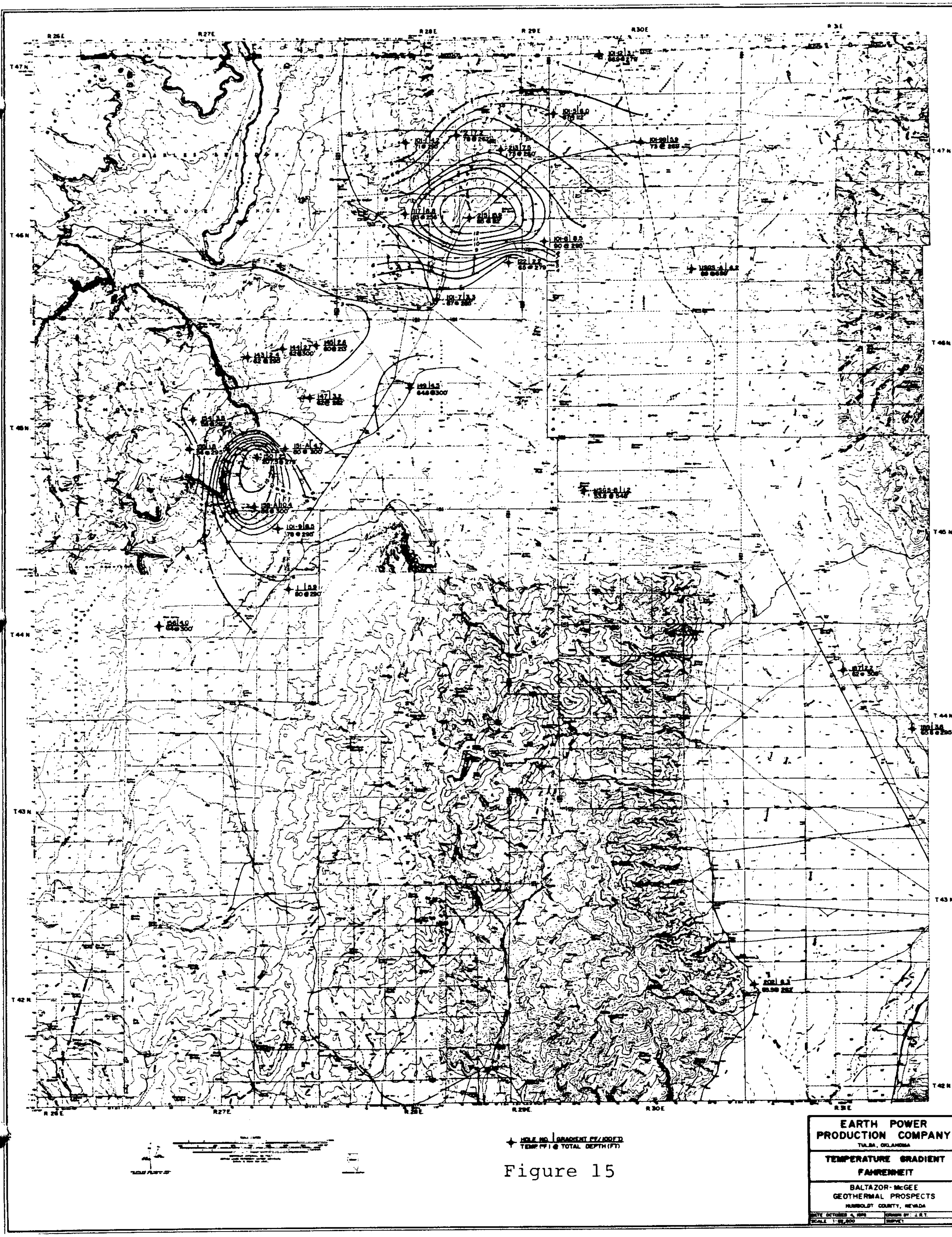

R 26 E
R 27 E
R 28 E
R 29 E
R 30 E
R 31 E
T 47 N
T 46 N
T 45 N
T 44 N
T 43 N
T 42 N
HOLE NO. | GRADIENT °F/100FT
TEMP (°F) @ TOTAL DEPTH (FT)
EARTH POWER PRODUCTION COMPANY
TULSA, OKLAHOMA
TEMPERATURE GRADIENT
FAHRENHEIT
BALTAZOR-McGEE
GEOTHERMAL PROSPECTS
HUMBOLDT COUNTY, NEVADA

Figure 15

at 101m (330 feet), cooled to about 104°C (220°F) at 183m (600 feet), then stayed roughly isothermal to a bottom hole temperature of 103°C (217°F) at 455m (1493 feet). The hole was drilled for the most part wtihout returns but apparently the bulk of the hole was in faulted Miocene sedimentary strata.

McGee 1500-2 was drilled east of the fault system at the foot of the upthrown McGee Mountain block. This hole increased in temperature throughout its depth to a bottom hole temperature of 93°C (200°F) at 509 m (1670 feet). The temperature profile shows a slight break in gradient at about 290m (950 feet), possibly due to a change in thermal conductivity. The gradient at the bottom of the hole is about 110°C/km (6°F/100 feet).

Deep Test Hole

Southwest Drilling and Exploration Rig #111 moved on site September 21, 1982. Baltazor 45-14 was spudded September 24 in the NE¼NE¼SW¼, Section 14, T. 46N., R. 28E. and drilled to 771m (2529 feet) by October 25. Very slow penetration rates and hole deviation problems dictated use of a larger rig. Rig #111 was moved off the hole, which was temporarily shut in.

On December 21, 1982, Calvert Western Rig #5 began moving on site, reamed the hole from 6½ inches to 8½ inches and started making new hole on January 6, 1983. Hole deviation was again severe, culminating in a 24° measurement at 1078m (3537 feet). On January 15, Gearheart-Owens ran a full suite of geophysical logs to a depth of 1100m (3609 feet). (See Table I.) Drilling was continued slowly to a total depth of 1129m (3703 feet), and on January 19, 2 3/8 -inch tubing was set at 1125m (3689 feet) and filled with water in prep-

Table I.
Logging History for Well 45-14
Baltazor KGRA, Nevada

| Date | Type of Log | Logged Interval | Total Depth |
|---|---|---|---|
| 10-01-82 | Dual Induction Laterolog-GO | 39-418' | 419' |
| 10-01-82 | Compensated Neutron-GO | 39-418' | 419' |
| 10/01/82 | Gamma Ray-GO | 39-418' | 419' |
| 10/01/82 | Caliper-GO | 39-418' | 419' |
| 10/01/82 | Borehole Compensated Sonic-GO | 39-409' | 419' |
| 10/01/82 | Integrated Travel Time-GO | 39-409' | 419' |
| 10/01/82 | Temperature-GO | 39-418' | 419' |
| 10/31/82 | Temperature-Southwest | 60-2430' | 2529' |
| 11/25/82 | Temperature-Southwest | 80-1567' | 2529' |
| 1/15/83 | Compensated Neutron-GO | 402-3609' | 3610' |
| 1/15/83 | Gamma Ray-GO | 402-3609' | 3610' |
| 1/15/83 | Caliper-GO | 402-3609' | 3610' |
| 1/15/83 | Borehole Compensated Sonic-GO | 402-3609' | 3610' |
| 1/15/83 | Integrated Travel Time-GO | 402-3609' | 3610' |
| 2/03/83 | Temperature-Southwest | 40-3640' | 3703' |

note: Logs on open file at the ESL/UURI, and reproductions may be obtained from:

Rocky Mountain Well Log Service
P.O. Box 3150
Denver, CO 80201

aration for a final temperature survey. Table II is a complete drilling history for 45-14. Figure 16 is a well completion schematic.

Lost circulation was not the major problem that had been feared. Circulation was lost briefly at 95m (312 feet), 788 (2584 feet; 80 bbl.) and 1082m (3550 feet; 80 bbls.). The major problem was deviation of the hole from vertical, a problem that worsened as drilling proceeded. Weight on the bit was kept relatively low but with little effect. We hypothesize that the hole encountered a range-front fault bordering the east side of the Pueblo Mountains that deflected drilling for most of the depth of 45-14.

Drill cutting samples were collected at 3m (10-foot) intervals; they may be examined at the Geothermal Sample Library, University of Utah Research Insitute, (UURI) Salt Lake City. (Cuttings for 15 shallow gradient holes and 3 intermediate-depth holes also are on file.) Figure 17 is a generalized stratigraphic column for 45-14; detailed mud logs are on open-file at UURI.

Two open-hole temperature surveys, run after the hole was drilled to 771m (2529 feet), are shown in Figure 18. Thermal conductivity measurements on 26 drill cuttings samples permitted calculation of heat flow values for selected intervals (Table III). The gradient value in the 493m to 585m interval (1440 to 1920 feet) of 155°C/km (8.48°F/100 feet) is probably a good approximation to the true conductive gradient. The associated heat flow of 5.3 HFU probably characterizes well the true conductive heat flow (Southwest Drilling and Exploration, 1983a).

Table II.

# DRILLING HISTORY

HOLE NO: 45-14

| DATE | DEPTH | SUMMARY OF OPERATIONS |
|---|---|---|
| 9/21/82 | 0- 0 | Move rig to site. Build road and pad. Dig one mud pit and rig up. |
| 9/22/82 | 0- 0 | Continue to rig up and dig second mud pit. |
| 9/23/82 | 0- 0 | Finish digging mud pits. Haul water and mix mud. Send flat bed truck to pick up casing. |
| 9/24/82 | 0- 36 | Stir up mud pits. Spud hole at 7:30 am with 17 1/2" bit and drill to 36' in alluvial fan deposits. Set 12 1/4" surface casing to 36'. Mix cement and pump down outside of casing. Build and install flowline. |
| 9/25/82 | 36- 190 | Make up 8 3/4" bottom hole assembly and drill to 147'. Trip to check bit. Run in hole with 9 7/8" bit and ream from 36' to 147'. Drill to 190' with 9 7/8" bit. Drilling in alluvial fan deposits to 180', rhyolite to 190'. |
| 9/26/82 | 190- 280 | Drill to 200'. Trip to check bit and adjust rotary table clutch linkage. Drill to 207'. Trip to lay down stabilizer and drill to 280' in rhyolite with 9 7/8" bit. |
| 9/27/82 | 280- 394 | Drill to 312' and encounter lost circulation zone. Loose 1/2 pit of mud. Mix mud and LCM. Regain circulation. Drill to 394' in rhyolite. |
| 9/28/82 | 394- 407 | Mix mud. Drill to 407' in rhyolite. Trip out of hole and make up 12 1/4" hole opener. Ream hole from 36'. |
| 9/29/82 | 407- 421 | Continue to ream hole with 12 1/4" hole opener to 407'. Trip out to lay down hole opener. Clean mud pits and mix mud. Run in hole with 9 7/8" bit and drill to 417'. Trip to lay down stablizer. Run in hole and drill to 421' in rhyolite. |
| 9/30/82 | 421- 442 | Drill to 442' in rhyolite. Trip out of hole. Make up hole opener. Run in hole and ream hole with 12 1/4" opener from 407'. |

| DATE | DEPTH | SUMMARY OF OPERATIONS |
|---|---|---|
| 10/01/82 | 442- 442 | Continue to ream hole with 12 1/4" hole opener to 418'. Pull out of hole. Gearhart logging hole. Run 9 5/8" casing. Unable to get casing past 320'. Pull casing out of hole. |
| 10/02/82 | 442- 442 | Continue to pull casing out of hole. Make up stacked hole opener. Run in hole with 12 1/4" stacked hole opener. Ream to straighten hole from about 280'. |
| 10/03/82 | 442- 442 | Continue to ream hole to straighten down to 403'. Pull out of hole and lay down pipe. Run 9 5/8" casing to 402'. Cement casing; good returns. Wait on cement. |
| 10/04/82 | 442- 442 | Wait on cement. Dig cellar for BOPE. Cut off casing, weld on well head and install BOPE. Test BOPE; passes test. Clean mud pits. Make up 8 3/4" down hole assembly. |
| 10/05/82 | 442- 525 | Run in hole with 8 3/4" bit. Tagged cement at 369'. Condition mud. Drill to formation 428'. Trip to change to 6 3/4" bit and stablizer. Drill in altered rhyolite to 525'. 500' to 520' is vesicular rhyolite and ash tuff. |
| 10/06/82 | 525- 649 | Drill with 6 3/4" bit to 649'. Drilling in vesicular rhyolite to 570', and rhyolite to 610'. Lithology change at 610' to andesite where drilling slows. |
| 10/07/82 | 649- 736 | Drill with 6 3/4" bit to 660'. Trip to change bit and drill to 736' in andesite. |
| 10/08/82 | 736- 750 | Drill to 750'. Pull out of hole to switch from mud to air. Run in hole. Encounter too much water (~200 GPM). Pull out of hole. Switch to mud and ream hole. |
| 10/09/82 | 750- 881 | Continue to ream hole with 6 3/4" bit to 750'. Trip to change bit. Drill to 881'. Lithology change at 870' to basalt. |
| 10/10/82 | 881-1018 | Drill to 940' in basalt, to 970' in ash flow tuff, to 990' in basalt, to 1018' in basalt/clay. Trip out of hole at 990' to clean 6 3/4" bit and put in jets. |
| 10/11/82 | 1018-1228 | Continue to drill with 6 3/4" bit from 1018' to 1228' in basalt. |

| DATE | DEPTH | SUMMARY OF OPERATIONS |
|---|---|---|
| 10/12/82 | 1228-1483 | Drill from 1228' to 1483' with 6 3/4" bit. Drilling in basalt with blue clay. |
| 10/13/82 | 1483-1612 | Drill with 6 3/4" bit to 1490' (still in basalt with blue clay). Thin mud and drill to 1570' in basalt. Trip out of hole to check bit. Clean mud pits and run maintain-ence on rig. Mix mud and run in hole with 6 3/4" bit. Drill to 1612' in basalt. |
| 10/14/82 | 1612-1750 | Drill with 6 3/4" bit to 1750' in basalt. Circulate to clean hole and drop drift tool (bad run). Run in hole and mix mud. |
| 10/15/82 | 1750-1804 | Drop drift tool again (6 deg off). Trip out of hole. Maintainence. Mix mud and run in hole with 6 3/4" bit, drill in basalt to 1804'. Drilling with reduced weight on bit to straighten hole. |
| 10/16/82 | 1804-1872 | Drill with 6 3/4" bit from 1804' to 1872' in basalt with ash/tuff. |
| 10/17/82 | 1872-1913 | Drill with 6 3/4" bit to 1895'. Mix mud and continue down to 1913' in basalt. Drop drift tool (3.25 deg off). Pull out of hole. Run maintainence on rig. |
| 10/18/82 | 1913-1954 | Rig maintainence. Run in hole with new 6 1/2" bit. Drill to 1920'. Mix mud and continue to 1954' in basalt. |
| 10/19/82 | 1954-2038 | Drill to 1994' with 6 1/2" bit. Circulate and drop drift tool (5.75 deg off). Pull out of hole, maintainence, run in hole. Drill ahead to 2038' with 6 1/2" bit in basalt. |
| 10/20/82 | 2038-2132 | Drill ahead to 2132' in basalt with 6 1/2" bit. At 2064' added water to pit to reduce viscosity of mud. Rig maintainence at 2114'. |
| 10/21/82 | 2132-2184 | Drill ahead to 2184' in basalt with 6 1/2" bit. Open 3rd mud pit and mix mud. Pull out of hole - 10 buttons missing from bit. Install new 6 1/2" journel button bit, mix mud and run in hole. Circulate and run wireline deviation survey (3.75 deg off). Pull out of hole - plugged float. Clean mud pump and lines. |
| 10/22/82 | 2184-2268 | Run in hole. Mix and condition mud. Drill with 6 1/2" bit to 2268' in basalt to 2190', to 2268' in andesitic basalt. Water added to mud pits at 2194',2206', and 2254'. |

| DATE | DEPTH | SUMMARY OF OPERATIONS |
| --- | --- | --- |
| 10/23/82 | 2268-2375 | Drill ahead with 6 1/2" bit to 2300' mixing mud at 2294'. Run wireline deviation survey at 2300' (2.25 deg off). Drill ahead to 2375' mixing mud at 2354'. Drilling in andesitic basalt 2268' to 2375'. |
| 10/24/82 | 2375-2462 | Maintainence (repair pump clutch yoke). Drill ahead to 2400'. Circulate and run wireline deviation survey (2.00 deg off). Drill ahead to 2434'. Maintainence (change hoisting line). Drill ahead to 2462', mixing mud at 2454'. Andesitic basalt 2375' to 2462'. |
| 10/25/82 | 2462-2529 | Drill ahead to 2500' with 6 1/2" bit. Circulate and run wireline deviation survey (bad run). Drill ahead to 2513', circulate, and run survey again (5.00 deg off). Drill to 2529' in andesitic basalt. Pull out of hole. |
| 10/26/82 | 2529-2529 | Maintainence (clean and re-install hoist line clutch). Clean mud pits and mix mud. Maintainence (change battery on rig, air line on draw works, and check gear boxes). Run in hole and mix mud. Problems with hoisting line clutch, will not pull pipe. Pull out of hole. |
| 10/27/82 | 2529-2529 | Maintainence on hoisting line clutch. |
| 10/28/82 | 2529-2529 | Make up 8 5/8" hole opener. Run in hole to 475'. Stir mud pits and mix mud. Ream hole from 475' to 758'. |
| 10/29/82 | 2529-2529 | Ream hole with 8 5/8" hole opener from 758' to 796'. |
| 10/30/82 | 2529-2529 | Pull out of hole and lay down pipe. Pick up and load equipment. |
| 10/31/82 | 2529-2529 | Run temperature survey on hole. TD = 2430'. |
| 11/01/82 | 2529-2529 | Rig down. Move rig to Denio Junction. Remove mud from pits. |

| DATE | DEPTH | SUMMARY OF OPERATIONS |
|---|---|---|
| 11/02/82- 12/20/82 | 2529-2529 | Well shut in with BOP installed, waiting on rig. Calvert Western Exploration Co. Franks 400 Series Explorer III "Rocket" moved on hole as follows: |
| 12/21/82 | 2529-2529 | Dig out for cellar and unload truck. |
| 12/22/82 | 2529-2529 | Dig out cellar and for mud pits. |
| 12/23/82 | 2529-2529 | Dig out for mud pits where dozer missed. |
| 12/24/82 | 2529-2529 | Unload trucks and set mud pit. |
| 12/28/82 | 2529-2529 | Rig up and unload trucks. Put derrick on unit. |
| 12/29/82 | 2529-2529 | Rig up -- board in cellar. |
| 12/30/82 | 2529-2529 | Rig up: rework some areas of location; set unit, sub, doghouse, mudpit, mud pump. |
| 12/31/82 | 2525-2529 | Rig up: rework some areas of location with backhoe; set pipe baskets, mudpump, walk and racks. |
| 1/01/83 | 2529-2529 | Rig up. |
| 1/02/83 | 2529-2529 | Rig up: nipple up, weld on Bradden head, mix mud. |
| 1/03/83 | 2529-2529 | Pick up bit and B.H.A. Clean out bridges and condition mud. Ream from 456 to 754 to 8½". Run deviation survey: 9° at 723'. |
| 1/04/83 | 2529-2529 | Reaming 8½" hole to 1560'. Run deviation surveys: 9 3/4° at 824', 9 3/4° at 916', 8¼° at 1008', 8° at 1100', 7 3/4° at 1192", 8¼° at 1284', 8¼° at 1376', 8¼° at 1499'. |
| 1/05/83 | 2529-2529 | Reaming 8½" hole to 2164. Run deviation surveys: 7¼° at 1591', 4¼° at 1990', 3° at 2113'. |
| 1/06/83 | 2529-2540 | Reaming 8½" hole to 2529'. Deviation 2¼° at 2237', 5° at 2391'. Trip out -- I.B.S. 60' off bottom. Change B.H.A., pick up 2 drill collars and trip in. Reaming, drilling new hole to 2540'. |

| DATE | DEPTH | SUMMARY OF OPERATIONS |
| --- | --- | --- |
| 1/07/83 | 2540-2682 | Drilling 8½" hole in andesitic basalt. Deviation 9½° at 2583'. Lost 80 bbls mud at 2584, mix LCM. Deviation 10½° at 2636', 11 3/4° at 2667'. Trip out @ 2655' to change B.H.A., trip in. Drilling to 2682'. |
| 1/08/83 | 2682-2773 | Drilling 8½" hole in andesitic basalt. Deviation 12° at 2696', 11° at 2727', 12¼° at 2758'. |
| 1/09/83 | 2773-2829 | Drilling 8½" hole in andesitic basalt. Deviation 12° at 2789', 12° at 2819. |
| 1/10/83 | 2829-2923 | Drilling 8½" hole in andesitic basalt. Deviation 12° at 2851', 12° at 2881', 12¼° at 2912'. Trip out to change B.H.A., trip in. |
| 1/11/83 | 2923-3081 | Drilling 8½" hole in basalt. Deviation 12½° at 2950', bottom-hole temperature 148°F; deviation 12¼° at 2981', B.H.T. 160°F. |
| 1/12/83 | 3081-3295 | Drilling 8½" hole in basalt and, in 3090-3140' and 3180-3210' intervals, welded tuff. Trip out at 3260' to change bit, trip in. Drilling to 3295'. |
| 1/13/83 | 3295-3551 | Drilling 8½" hole in basalt and, to 3460', welded tuff. Deviation 24° at 3537'. Lost 80 bbls mud at 3550'. Trip out 18 stands drill pipe, circulate mud, add LCM. |
| 1/14/83 | 3551-3588 | Circulate and condition mud. Trip out and lay down B.H.A. and 6 drill collars. Trip in with new 8½" bit and 6 drill collars. Drill basalt to 3588'. |
| 1/15/83 | 3588-3610 | Drilling 8½" hole in basalt to 3610'. Condition hole for logs. Trip out and rig up for logging. Run Gearheart-Owens logs, rig down loggers. |
| 1/16/83 | 3610-3676 | Drilling 8½" hole in basalt. |
| 1/17/83 | 3676-3703 | Drilling 8½" hole in basalt. Condition hole to run tubing. Trip out 30 stands D.P. |

| DATE | DEPTH | SUMMARY OF OPERATIONS |
|---|---|---|
| 1/18/83 | 3703-3703 | Circulate and condition hole for tubing. Trip in 30 stands D.P. to bottom -- no fill. Circulate, trip out and lay down D.P., collars. Break kelly, nipple down. Rig up to run tubing. Run 10 joints 2 3/8" tubing. |
| 1/19/83 | 3703-3703 | Run 116 joints tubing, set at 3689', fill with water. Wash pumps and pits, rig down. |
| 1/20/83 | 3703-3703 | Rig down, move rig to Denio. |
| 1/21/83 | 3703-3703 | Rig down, move rig to Denio. Fence reserve pit. |

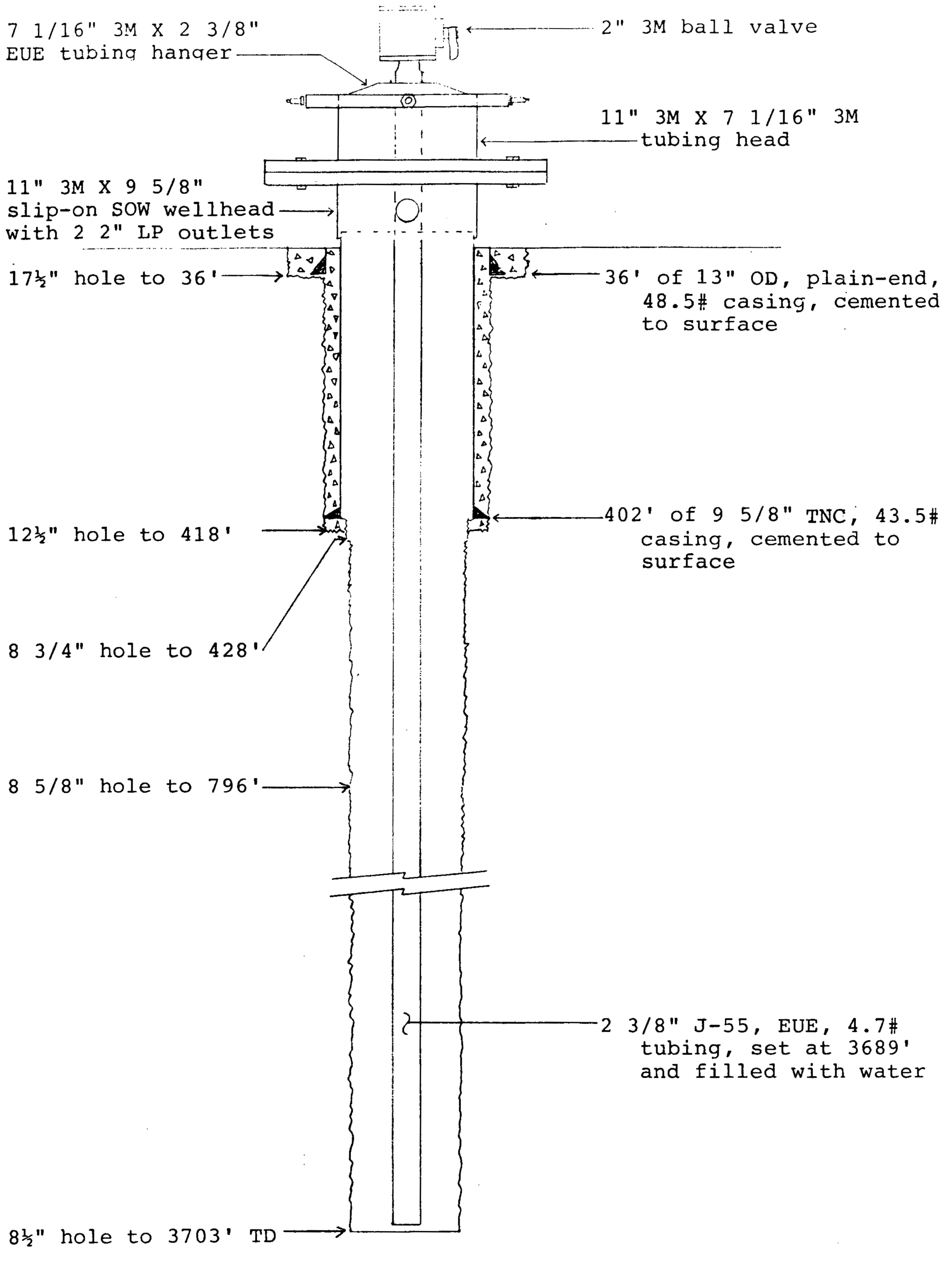
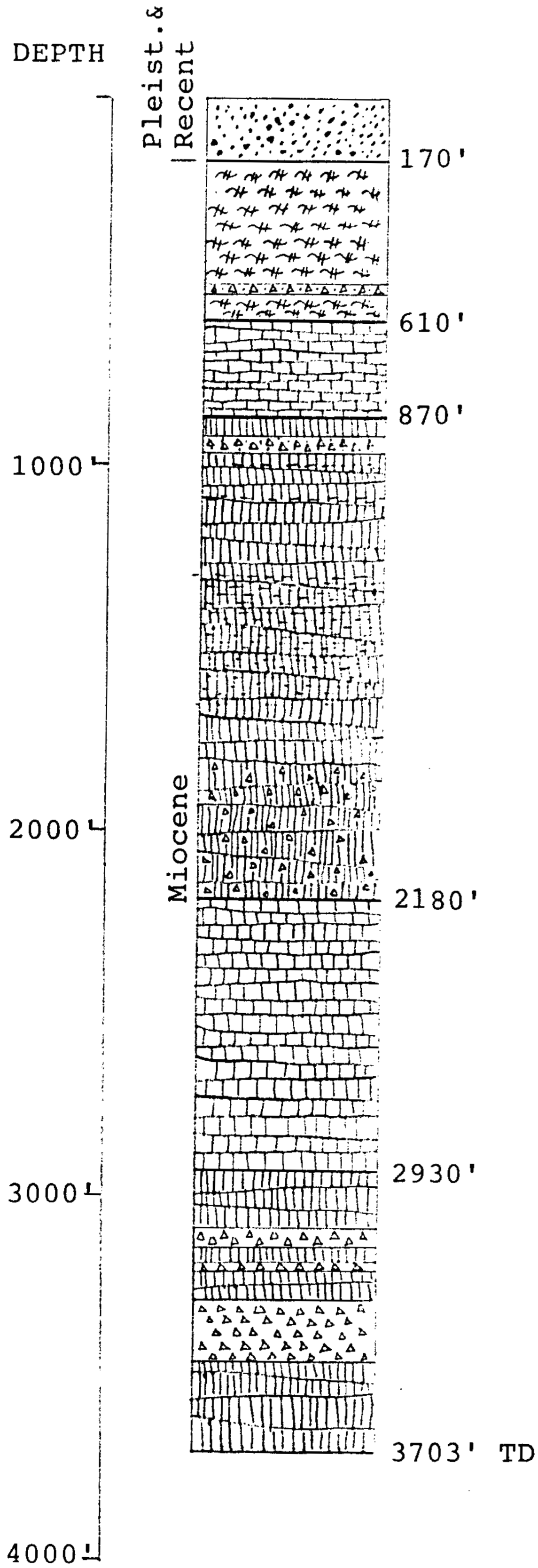



Figure 16. Well Completion Schematic, Baltazor 45-14.




Alluvium/Alluvial fan deposits

Rhyolite flows - purple aphanitic groundmass, sm flow structure, feld., qtz phenocrysts, slight arglztn. 510-530': ves, lt beige-brn ash fall tuff.

Andesite flows - med gray to black groundmass, phenocrysts hb & plag, faulting slick 630-650'.

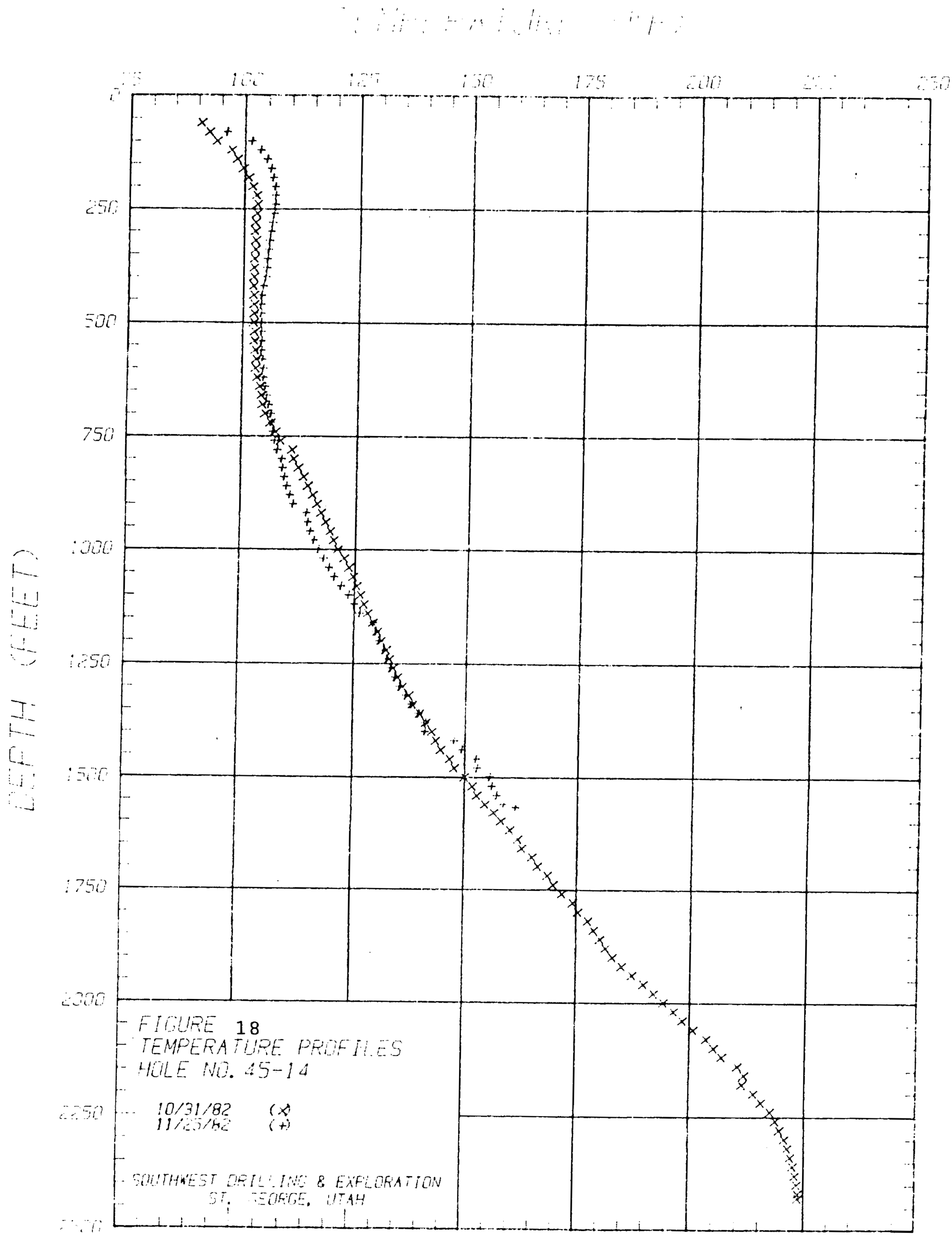
Basalt flows and flow breccias with interbedded tuff and clay horizons- black - gray aphanitic basalt, cryptocrystalline, phenocrysts plag and pyroxene, calcite and qtz veins.
920-970': lt gry-white to brn-white ash tuff, altered to blue to yel-grn clay locally.
1800-2180': white ash tuff (10-15%) with basalt.

Andesitic basalt flows - gray-grn aphanitic groundmass with plag phenocrysts, 5-10% white-tan crystal tuff. Secondary calcite veins and traces qtz fracture filling, sltly altered femag minerals, chloritized 2770-2930'.

Basalt - grn, gry-grn to dark gry, hard, brittle, fine-grned, schistose to phyllitic texture, chloritized, sm white veins qtz and calcite. 3090-3140', 3180-3210', 3290-3460': welded tuff, buff-white, medium-grained, clasts red basalt.

Figure 17. Generalized Stratigraphic Column, 45-14.

Sources: Southwest Drilling and Exploration, 1983a;
ExLog Smith mud logs (on open-file, UURI)




(from Southwest Drilling and Exploration, 1983a)

TABLE III.

HEAT FLOW DATA
BALTAZOR HOT SPRINGS
HOLE NO: 45-14

| RUN NUMBER | TOTAL DEPTH (FEET) | BOTTOM HOLE TEMP (DEG F) | GRADIENT A (DEG F/ 100 FT)* | GRADIENT INTERVAL (FEET) | CALC SURF TEMP (DEG F)** | GRADIENT (DEG F/ 100 FT)+ | THERMAL CONDUCTIVITY (TCU)++ | HEAT FLOW (HFU)} |
|---|---|---|---|---|---|---|---|---|
| 1 | 2430 | 223.77 | 6.9 | 800-1280 | 72.1 | 4.93 | 3.6(6) | 3.2 |
| | | | | 1440-1920 | 22.6 | 8.48 | 3.4(5) | 5.3 |
| | | | | 1920-2120 | -25.7 | 11.00 | 3.5(2) | 7.0 |
| 2 | 1567 | 161.41 | 6.8 | 600- 900 | 90.5 | 2.25 | 4.0(4) | 1.6 |
| | | | | 900-1400 | 56.9 | 6.08 | 3.4(5) | 3.8 |
| | | | | 1420-1567 | 30.8 | 8.26 | 3.1(1) | 4.7 |

* Gradient A = The bottom hole temperature minus an estimated mean annual surface temperature of 55 degF divided by the total depth.
** Extrapolated surface temperature.
\+ Least-squares geothermal gradient calculated over the gradient interval.
++ TCU = mcal/cm-sec-degC. Number of thermal conductivity samples for each interval in parentheses.
} HFU = microcal/sq-cm-sec.

(from Southwest Drilling and Exploration, 1983a)

A final temperature survey was made on February 3, 1983 after the $2^3/8$-inch tubing was set (Figure 19). Gradients over the 493m to 585m and 585m to 646m intervals closely matched those measured earlier. The gradient for the 902m to 1012m interval (2960 to 3320 feet) measured only 25.7°C/km (1.41°F/100 feet). Temperature at the survey total depth of 1110m (3640 feet) was 119.7°C (247.4°F). (Southwest Drilling and Exploration, 1983b). These results are still being evaluated, however, it may be that penetration of the expected range-front fault is responsible for the abruptly lower gradient below about 655m (2150 feet).

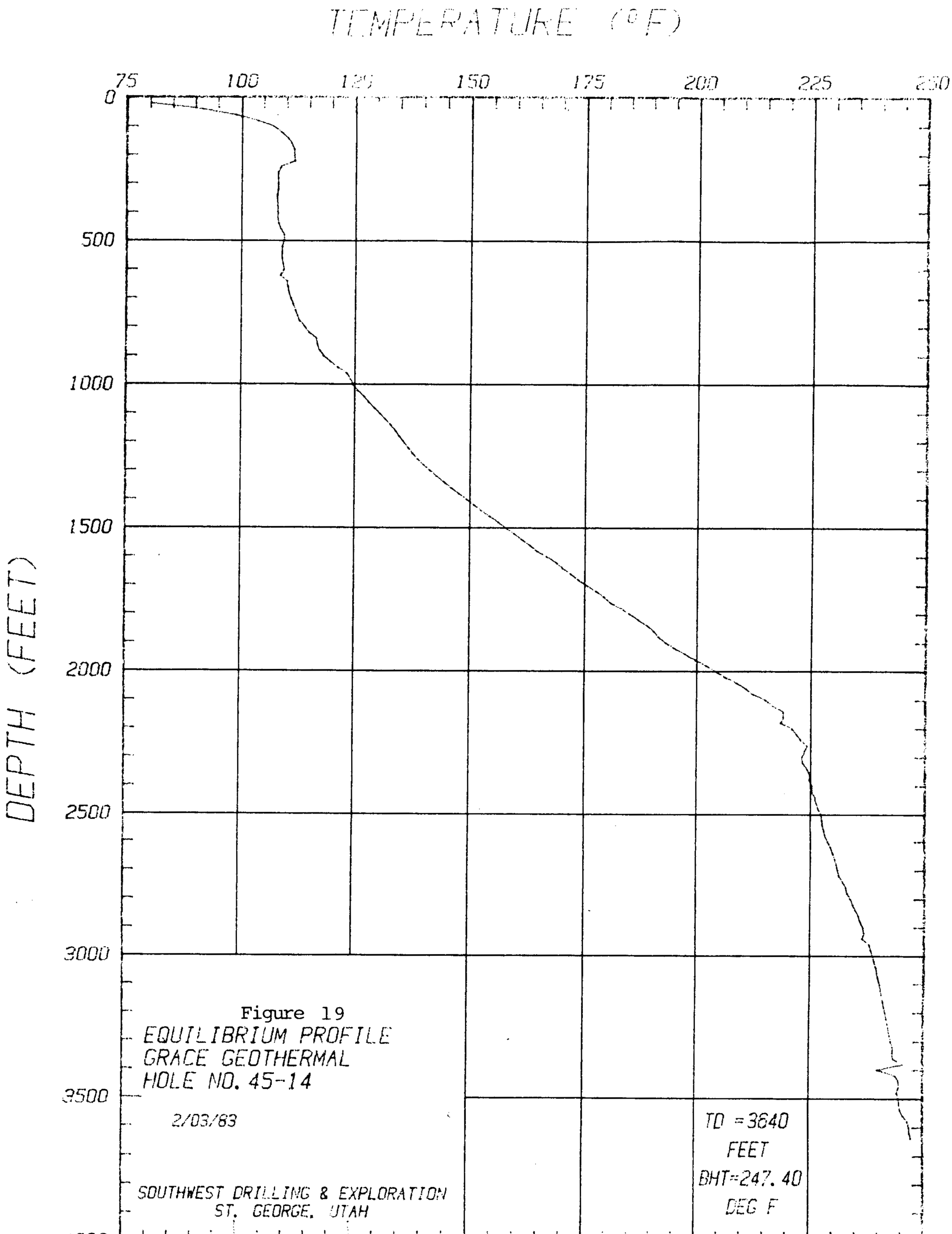



Figure 19
EQUILIBRIUM PROFILE
GRACE GEOTHERMAL
HOLE NO. 45-14

2/03/83

SOUTHWEST DRILLING & EXPLORATION
ST. GEORGE, UTAH

(from Southwest Drilling and Exploration, 1983a)

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Plouff, D., Robbins, S.L., and Holden, K.D., 1976, Principal facts for gravity observations in the Charles Sheldon Antelope Range, Nevada - Oregon: U.S. Geological Survey, OFR, 76-601, 22 p.

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Senturion Sciences, Inc., 1977, Northwestern Nevada microearthquake survey report: Univ. Utah Rsch. Inst., Earth Science Lab., OFR.

Southwest Drilling and Exploration, 1983a, Final report: Grace Geothermal Corp. Baltazor Hot Springs, Nevada Hole No. 45-14: Univ. Utah Rsch. Inst., Earth Science Lab., OFR.

Southwest Drilling and Exploration, 1983b, Temperature survey dated February 3, 1983, Baltazor 45-14: Univ. Utah Rsch. Inst., Earth Science Lab., OFR.

## APPENDIX A. DATA ON OPEN FILE AT UURI

### Open-file Materials

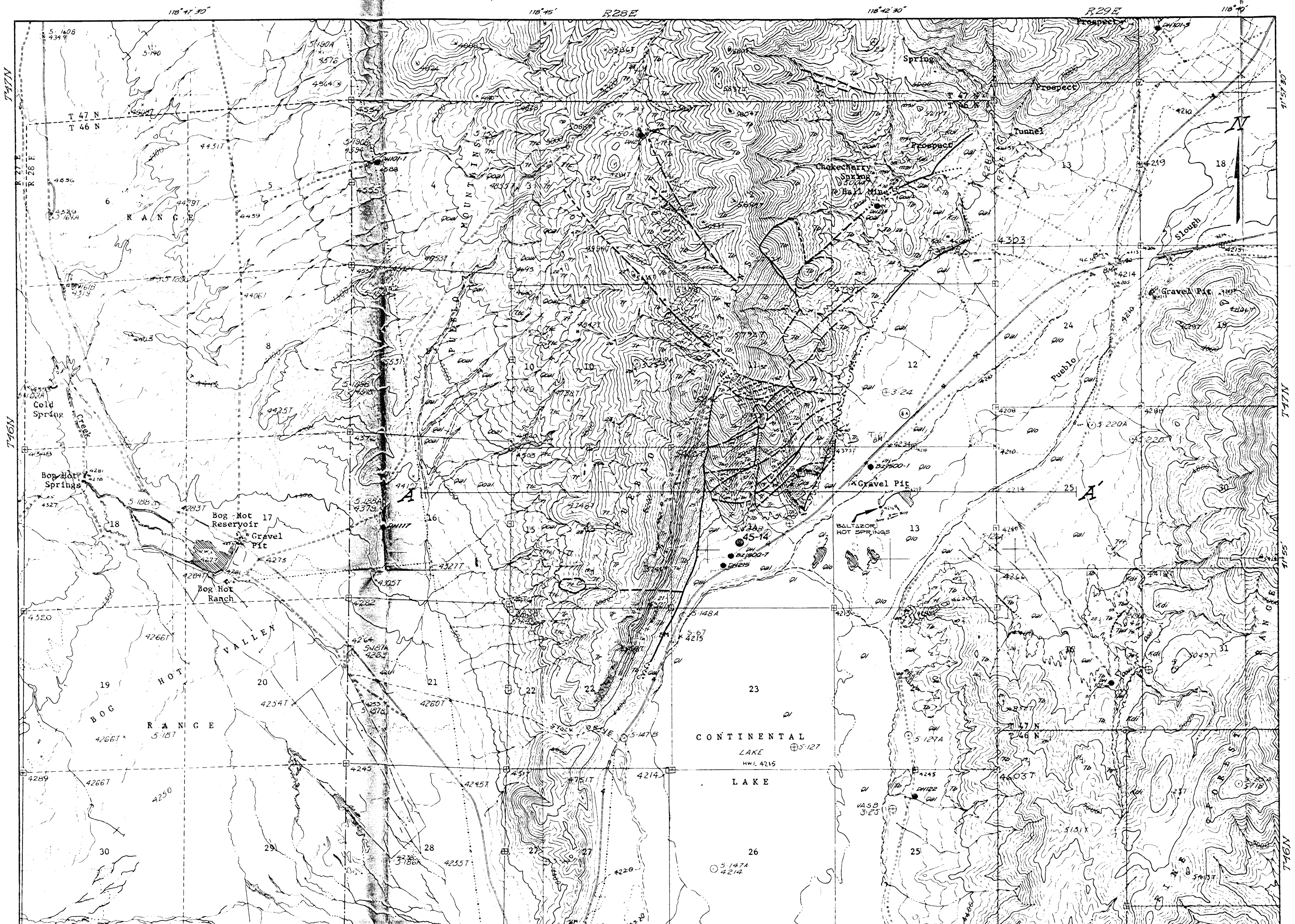
Open-file materials generated under Department of Energy's Industry Coupled Program, and from Earth Science Laboratory research, are available in reproduction at duplicating and handling cost from:

Publications
Earth Science Laboratory
420 Chipeta Way, Suite 120
Salt Lake City, Utah 84108

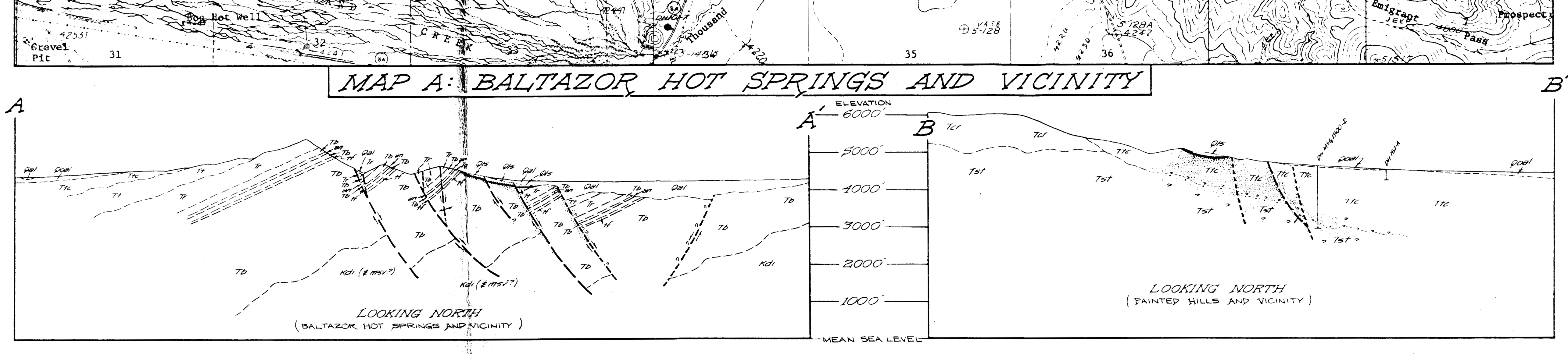
| OFR # | |
|---|---|
| NV/BAL/EPP-1 | Geothermex report: "Geothermal Interpretation of Groundwaters, Continental Lake Region, Humboldt Co., Nevada" (Dec 1977) $2.50 |
| NV/BAL/EPP-2 | Geothermex report: "Photogeologic Interpretation of the Baltazor-McGee Geothermal Prospect, Humboldt Co., Nevada". $1.30 |
| NV/BAL/EPP-3 | Senturion Science Inc. report: "NW Nevada Microearthquake Survey Report for Earth Power Production Corp."; two, 6-station , 9-km diameter seismometer arrays. $6.05 |
| NV/BAL/EPP-4 | 27 shallow thermal gradient holes: temperatures, lithology, temperature gradient map. $2.75 |
| NV/BAL/EPP-5 | Aeromagnetic map, Vya sheet: 1,015 sq mi; scale 1:62,500, flown at 9000 ft by Scintrex Mineral Surveys in 1972. $1.35 |
| NV/BAL/EPP-6 | Gravity map from USGS Open-File 76-601 & 77-67C @ 400 sq mi. $1.35 |
| NV/BAL/EPP-7 | Earth Power Production Co: Geochemical map, geologic cross section, sulfate map, micro-earthquake survey map. $4.35 |
| NV/BAL/EPP-8 | Three deep thermal gradient holes (to 1500 ft): temperature logs, drilling & completion histories, location map. $3.00 |
| NV/BAL/EPP-9 | Dipole-dipole resistivity survey, 10 line miles at a=1500 ft; self-potential survey, 20 line miles at 200 meter stations; by Mining Geophysical Surveys Inc. (Mar 1980). $3.85 |

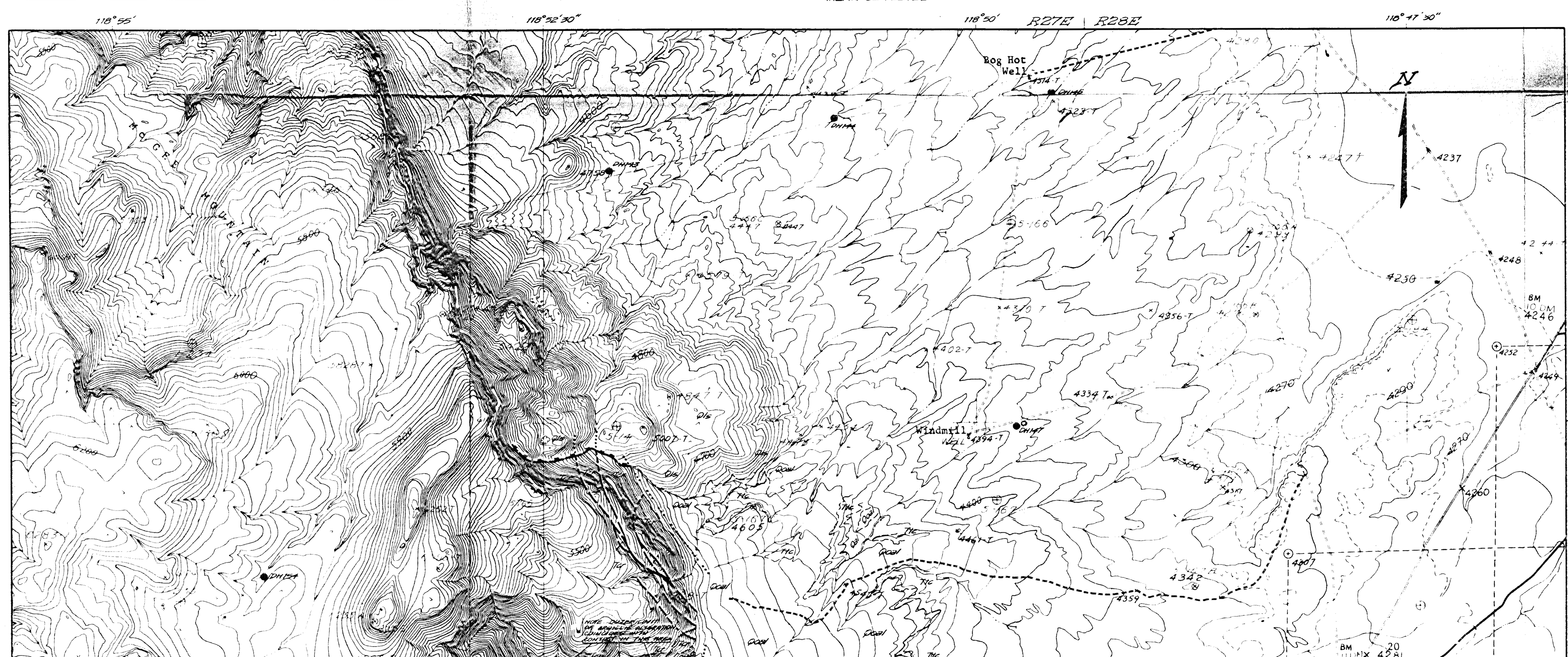
| | | |
|---|---|---|
| NV/BAL/EPP-10 | | Geochemical soil survey (Hg, As) for 173 samples at 1000 ft station spacing covering @ 5 sq mi. $1.25 |
| * | | Driller's logs, 0-2529 feet, Baltazor 45-14. $* |
| * | | Geophysical logs, Gearheart-Owens, 39-418 feet, Baltazor 45-14. $* |
| * | | Temperature surveys dated 10/31/82 and 11/25/82, Baltazor 45-14. $* |
| * | | Drilling history, drilling data log and daily mud logs, 0-2529 feet, Baltazor 45-14. $* |
| * | | Final report, Southwest Exploration,0-2529 feet, Baltazor 45-14. $* |
| * | | Geophysical logs, Gearheart-Owens, 402-3609 feet, Baltazor 45-14. $* |
| * | | Exlog Smith mud logs, 2540-3703 feet, Baltazor 45-14. $* |
| * | | Calvert Western drillers' logs, 0-3703 feet, Baltazor 45-14. $* |
| * | | Temperature survey dated 2/03/83, 0-3640 feet, Baltazor 45-14. $* |

* To be determined by ESL/UURI



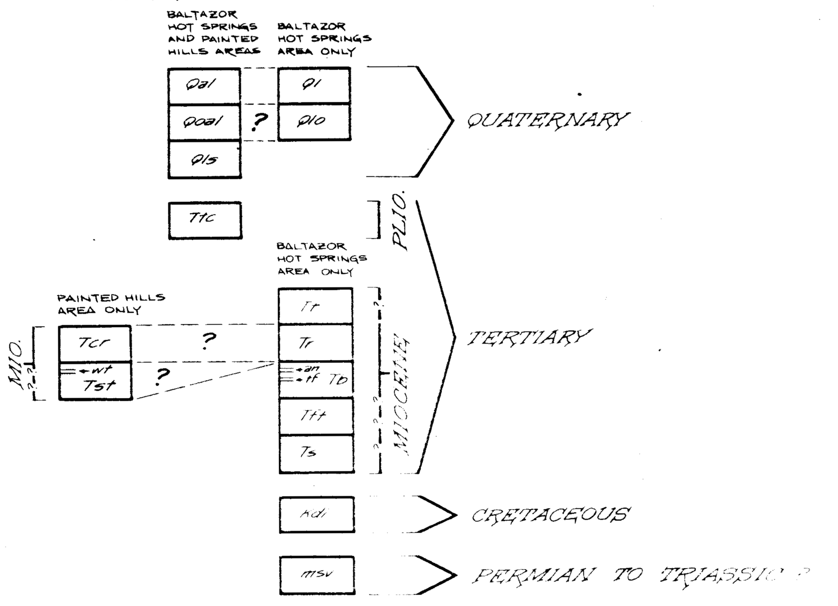

MAP A: BALTAZOR HOT SPRINGS AND VICINITY




MAP B: PAINTED HILLS AND VICINITY

## CORRELATION OF MAPPED UNITS




## DESCRIPTION OF MAPPED UNITS

Qal ALLUVIAL DEPOSITS (QUATERNARY)

Qoal OLDER ALLUVIAL DEPOSITS (QUATERNARY)

Ql LACUSTRINE (PLAYA) DEPOSITS (QUATERNARY)

UNCONSOLIDATED CLAY AND SILT

Qlo OLDER LACUSTRINE (PLAYA) DEPOSITS (QUATERNARY)

UNCONSOLIDATED CLAY AND SILT; PARTIALLY REWORKED [illegible] MINOR FLUVIAL AND AEOLIAN DEPOSITS

Qls LANDSLIDE DEBRIS (QUATERNARY)

CHAOTIC RUBBLE IN WHICH INDIVIDUAL ROCK UNITS CANNOT BE READILY MAPPED

Ttc THOUSAND CREEK FORMATION (PLIOCENE)

LIGHT GRAY TO BUFF, POORLY SORTED, ASH AND PUMICE-RICH SILTSTONE SANDSTONE AND CONGLOMERATE, TUFFACEOUS MUDSTONE, AIR-FALL AND WATER-LAIN TUFF AND PUMICE LAPILLI TUFF AND NON-WELDED VITRIC TO VITRIC-LITHIC ASH-FLOW TUFF; COARSER-GRAINED UNITS PREDOMINATE NEAR PRESENT TOPOGRAPHIC HIGHS; FINE WATER-LAIN TUFFS AND TUFFACEOUS MUDSTONES BECOME PROGRESSIVELY DOMINANT BASINWARD

Tt FELSIC ASH-FLOW TUFF AND TUFFACEOUS SEDIMENTARY SEQUENCE (MIOCENE?)

LIGHT GRAY, REDDISH-GRAY, GRAYISH-BROWN, PINKISH-BROWN AND YELLOWISH-BROWN, NON-WELDED TO DENSELY WELDED, RHYOLITIC TO TRACHYTIC, VITRIC TO VITRIC-CRYSTAL ASH-FLOW TUFFS WITH MINOR INTERBEDDED TUFFACEOUS MUDSTONE, SILTSTONE, SANDSTONE AND CONGLOMERATE; CRYSTALS IN THE TUFFS ACCOUNT FOR <1-20 VOLUME PER CENT AND COMPRISE ANORTHOCLASE, SANIDINE, QUARTZ, BIOTITE, AND MAGNETITE-ILMENITE (TRACE AMOUNTS OF AEGERINE AND RIEBECKITE ARE LOCALLY PRESENT); SEDIMENTARY UNITS CONCENTRATED IN LOWER PORTION OF SEQUENCE.

Tr RHYOLITE OF BALTAZOR HOT SPRINGS AREA (MIOCENE)

LIGHT TO MEDIUM REDDISH-GRAY TO PURPLISH-GRAY RHYOLITE AND RHYOLITE FLOW-BRECCIA, DENSE TO VESICULAR, LOCALLY SPHERULITIC AND LITHOPHYSAL, COMMONLY FLOW-FOLIATED; LESS THAN 1 VOLUME PER CENT PHENOCRYSTS, DOMINANTLY EUHEDRAL SANIDINE WITH MINOR EUHEDRAL QUARTZ; VERY RESISTANT, TYPICALLY FORMING RIDGES AND CAPROCKS.

Tcr CANYON RHYOLITE OF PAINTED HILLS AREA (MIOCENE)

SAME DESCRIPTION AS RHYOLITE OF BALTAZOR HOT SPRINGS (Tr) BUT ALSO INCLUDING LIGHT TO MEDIUM GRAY PERLITE AND DARK GRAY RHYOLITIC VITROPHYRE; AGE RELATION TO RHYOLITE OF BALTAZOR HOT SPRINGS AREA UNKNOWN.

Tst TUFF AND TUFFACEOUS SEDIMENTARY SEQUENCE (MIOCENE?)

LIGHT GRAY, BUFF AND PINK, POORLY SORTED AND POORLY INDURATED VOLCANIC SILTSTONES, SANDSTONES, AND CONGLOMERATES INTERBEDDED WITH VITRIC AIR-FALL TUFFS AND NON-WELDED TO DENSELY WELDED VITRIC ASH-FLOW TUFFS MOST OF THE UNIT IS EASILY ERODED, FORMING SLOPES COVERED WITH TALUS FROM OVERLYING CANYON RHYOLITE (Tcr)

→wt WELDED TUFF MARKER HORIZON: MEDIUM TO DARK BROWNISH-RED DENSELY WELDED FELSIC VITRIC ASH-FLOW TUFF; PROMINENT EUTAXITIC TEXTURE; 5% CRYSTALS, DOMINANTLY SANIDINE WITH MINOR QUARTZ, BIOTITE AND MAGNETITE; INVARIABLY MODERATELY TO INTENSELY SILICIFIED AND HEMATIZED

Tb BASALT SEQUENCE (MIOCENE)

THICK SEQUENCE (ABOUT 2500 FEET IN THE BALTAZOR HOT SPRINGS AREA) OF THIN (AVERAGE LESS THAN 30 FEET), DENSE TO VESICULAR OLIVINE-AUGITE BASALT AND PORPHYRITIC BASALT FLOWS AND FLOW-BRECCIAS; VERY MINOR INTERBEDDED BASALTIC TEPHRA AND THIN (4-30 FEET) FELSIC TO INTERMEDIATE ASH-FLOW TUFFS AND RARE THIN (LESS THAN 5 FEET) VOLCANIC SILTSTONES AND SANDSTONES; BASALTIC UNITS ARE MEDIUM TO DARK GRAY AND COMMONLY WEATHER TO MEDIUM GRAYISH-RED TO GRAYISH-PURPLE; PORPHYRITIC BASALTS CONTAIN TABULAR LABRADORITE PHENOCRYSTS WHICH IN SOME BEDS REACH 4 cm. IN LENGTH; VESICULAR BASALT UNITS COMMONLY CONTAIN CALCITE ± STILBITE-NATROLITE AMYGDULES

→an ANDESITE MARKER HORIZON: DENSE, MEDIUM-GRAY PILOTAXITIC HORNBLENDE ANDESITE; STRONGLY FLOW-FOLIATED IN OUTCROP--FOLIATION LOCALLY HIGHLY CONTORTED; FLOW LAMINAE COMMONLY DISCONTINUOUS, RESEMBLING COMPRESSED PUMICE LAPILLI

→tf ASH-FLOW TUFF MARKER HORIZON: PARTIALLY WELDED (LIGHT GRAY TO PINKISH GRAY) TO DENSELY WELDED (DARK GRAY; VITROPHYRIC) VITRIC TO VITRIC-CRYSTAL DACITE(?) ASH-FLOW TUFF; UP TO 25% CRYSTALS, DOMINANTLY ANDESINE WITH MINOR SANIDINE, AUGITE, HYPERSTHENE, BIOTITE AND MAGNETITE.

Tft FELSIC ASH-FLOW TUFF (MIOCENE?)

VERY LIGHT REDDISH-BROWN, PARTIALLY WELDED TO DENSELY WELDED FELSIC VITRIC TO VITRIC-CRYSTAL ASH-FLOW TUFF; UP TO 10% SANIDINE CRYSTALS, 3% QUARTZ CRYSTALS, AND 5% LITHIC FRAGMENTS.

Ts VOLCANIC SANDSTONE AND SILTSTONE (MIOCENE?)

VERY LIGHT GRAY TO ORANGE- OR BROWNISH-GRAY VOLCANIC SANDSTONE AND SILTSTONE; REDDISH-BROWN BAKED ZONE AT TOP OF UNIT WHERE OVERLAIN BY BASALT (Tb)

Kdi DIORITE AND QUARTZ DIORITE, UNDIVIDED (CRETACEOUS ?)

MEDIUM TO DARK GRAY TO GREENISH-GRAY; GENERALLY MEDIUM-GRAINED BUT MAY BE FINE-GRAINED AT PLUTONIC MARGINS; HYPIDIOMORPHIC-GRANULAR, LOCALLY PORPHYRITIC; LOCALLY FOLIATED; MAJOR ACCESSORY MINERALS INCLUDE BIOTITE, HORNBLENDE, MAGNETITE AND CLINOPYROXENE IN VARIABLE RATIOS; COMMONLY EPIDOTIZED; INCLUDES DARK GREENISH-GRAY ANDESITE PORPHYRY AND LIGHT GRAY TO PINKISH-GRAY APLITE DIKES

msv METASEDIMENTARY AND METAVOLCANIC ROCKS, UNDIVIDED (PERMIAN TO TRIASSIC ?)

LIGHT-COLORED QUARTZ-SERICITE ± CHLORITE SCHIST AND PHYLLITE WITH MINOR METAQUARTZITE, GREENSTONE, MUSCOVITE-GARNET SCHIST, AND FELDSPAR-QUARTZ-BIOTITE GNEISS.

## MAP SYMBOLS

CONTACTS: LONG DASHES WHERE APPROXIMATELY LOCATED; SHORT DASHES WHERE INFERRED

FAULTS: LONG DASHES WHERE APPROXIMATELY LOCATED, SHORT DASHES WHERE INFERRED; DOTTED LINE WHERE CONCEALED; BROKEN DOTTED LINE WHERE INFERRED AND CONCEALED.

BOUNDARY OF LANDSLIDE (Qls); DASHED WHERE APPROXIMATELY LOCATED; ARROWS INDICATE DIRECTION OF MOVEMENT

25 STRIKE AND DIP OF SEDIMENTARY BEDS AND OF INDIVIDUAL BASALT FLOWS IN THE MIOCENE BASALT SEQUENCE (Tb) OF THE BALTAZOR HOT SPRINGS AREA

STRIKE AND DIP OF HORIZONTAL SEDIMENTARY BEDS

50 STRIKE AND DIP OF FLOW FOLIATION IN VOLCANIC FLOW ROCKS AND OF COMPACTION FOLIATION IN ASH-FLOW TUFFS

58 STRIKE AND DIP OF SCHISTOSITY IN METAMORPHIC ROCKS

STRIKE AND DIP OF VERTICAL SCHISTOSITY

DH101-7 THERMAL GRADIENT DRILL HOLE

## SPRING DEPOSITS AND ALTERATION

### BALTAZOR HOT SPRINGS AND VICINITY

sin OPALINE SINTER; LIGHT BROWNISH-GRAY TO MEDIUM GRAY; GENERALLY POROUS INCORPORATES ABUNDANT OPALIZED PLANT DEBRIS; OPEN SPACES MAY BE LINED OR PARTIALLY FILLED WITH WHITE TO LIGHT GRAY CRYPTOCRYSTALLINE CALCITE (CALICHE?)

APPROXIMATE AREA OF PERVASIVE DEVELOPMENT OF CALCITE ± CHALCEDONY VEINS AND VEINLETS, COMMONLY ACCOMPANIED BY WEAK TO MODERATE CLAY-CALCITE ALTERATION OF HOST ROCKS; GOETHITIC TO HEMATITIC JASPEROID OBSERVED IN FLOAT WITHIN THIS ZONE, BUT NOT *IN SITU*.

CHALCEDONY-CALCITE VEIN; WHITE TO LIGHT GRAY; CALCITE IS COARSE- TO VERY COARSE-CRYSTALLINE AND LOCALLY CRUDELY BANDED, CHALCEDONY GENERALLY SHOWS DELICATE BANDING PARALLEL TO CRUDE BANDING IN CALCITE; A FEW ANGULAR CLASTS OF CHALCEDONY ARE IMBEDDED IN THE CALCITE, INDICATING MULTIPLE PERIODS OF CHALCEDONY DEPOSITION

qtz MASSIVE PYRITE- AND CHALCOPYRITE-BEARING QUARTZ; WHITE TO LIGHT GRAY; SULFIDES ARE PARTIALLY OXIDIZED, YIELDING VARIOUS COMBINATIONS OF GOETHITE, PITCH LIMONITE, HEMATITE, MALACHITE, AZURITE, AND CHRYSOCOLLA, PRE-DATES TERTIARY VOLCANISM AND SEDIMENTATION.

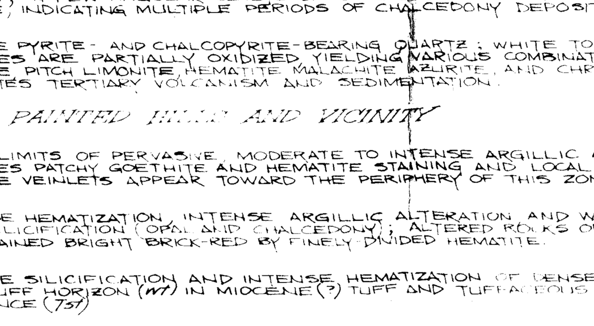
### PAINTED HILLS AND VICINITY

OUTER LIMITS OF PERVASIVE, MODERATE TO INTENSE ARGILLIC ALTERATION; INCLUDES PATCHY GOETHITE AND HEMATITE STAINING AND LOCAL SILICIFICATION; CALCITE VEINLETS APPEAR TOWARD THE PERIPHERY OF THIS ZONE

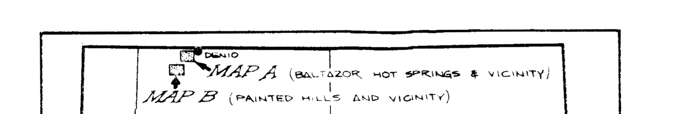
INTENSE HEMATIZATION, INTENSE ARGILLIC ALTERATION AND WEAK TO MODERATE SILICIFICATION (OPAL AND CHALCEDONY); ALTERED ROCKS OF THIS ZONE ARE STAINED BRIGHT BRICK-RED BY FINELY DIVIDED HEMATITE.

INTENSE SILICIFICATION AND INTENSE HEMATIZATION OF DENSELY WELDED ASH-FLOW TUFF HORIZON (wt) IN MIOCENE(?) TUFF AND TUFFACEOUS SEDIMENTARY SEQUENCE (Tst)

ZONE OF PERVASIVE CHALCEDONY ± OPAL VEINS AND VEINLETS IMMEDIATELY EAST AND NORTH OF THE PAINTED HILLS MERCURY PROSPECT; ALSO INCLUDES LOCALLY INTENSE CHALCEDONY-OPAL CEMENTATION OF PUMICE-RICH SANDSTONES AND CONGLOMERATES




INDEX MAP




APPROXIMATE MEAN DECLINATION, 1969

# PLATE I. GEOLOGIC AND HYDROTHERMAL ALTERATION MAPS, BALTAZOR HOT SPRINGS AND PAINTED HILLS THERMAL AREAS HUMBOLDT COUNTY, NEVADA

GEOLOGY BY J. B. HULEN
1979

ESL
EARTH SCIENCE LABORATORY
UNIVERSITY OF UTAH RESEARCH INSTITUTE