GERLACH GEOTHERMAL SYSTEM

GERLACH, NEVADA

GRC FIELD TRIP - OCTOBER 1995

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Introduction

Gerlach is located approximately 80 miles north-northeast of Reno, Nevada in the Black Rock Desert adjacent to the Granite Range, a rugged and steep north-northeast trending group of mountains (Figure 1). Three hot spring complexes exist in the area, with boiling temperatures and chemical geothermometers (~350°F) suggesting a potentially commercial geothermal system.

Geologic Maps

At least two geologic maps have previously been published of the Gerlach area. In 1969 Bonham compiled a map of Washoe County at a 1:250,000 scale. Bonham's map shows the Granite Range to be composed of granodiorite with a fault cutting the top of the mountains. Olmsted and others (1975) published a geologic map that indicated the Granite Range contained both granodiorite and diorite. In addition, they defined a linear trending body of "altered" granodiorite and outcrops of sinter. Olmsted sited a normal fault on the eastern flank of Granite Range and a northwest-southeast trending fault cutting the range. The map also shows numerous lineaments trending both northwest and northeast.

In mid-1994 Mesquite undertook to map the area surrounding Great Boiling Springs in more detail than the prior efforts. Six lithology units were identified which had sufficient character and exposure to warrant mapping (Figure 2). The lithologies mapped are granodiorite, altered granodiorite, arkose, tufa, sinter, and alluvium. The oldest unit is the granodiorite, which had been previously reported to be Cretaceous age. This medium-crystalline plutonic rock is composed of plagioclase, minor orthoclase, quartz, and abundant biotite. Field observations indicate two types granodiorite exist in the Granite Range. The light grey type is relatively fresh looking, while the light brown variety has weathered to a crumbly brown-stained rock.

At several locations north and west of the geologic map (Figure 2) in this report, a dark-grey, fine-grained, diorite with phenocrysts of plagioclase has intruded the granodiorite as dikes. Together the granodiorite and diorite comprise the basement rock in the Gerlach area and constitute the host rock for the geothermal system.

A north-northeast trending zone of the granodiorite has been altered on the eastern flank of the Granite Range. This approximately one mile long zone is exposed north of State Highway 447 to near the western quarter corner of Section 9. The alteration involves massive silicification with abundant red hematite staining. The zone grades from minor fracture-fill alteration on the western boundary to totally silicified, highly brecciated granodiorite on the eastern boundary. At least two periods of brecciation and recementation have occurred over geologic time.

Outcropping to the east of the altered granodiorite is an arkose that grades from conglomerate to coarse sandstone. This arkose is highly silicified and hematite stained adjacent to the altered granodiorite, and becomes quartz-cemented on its eastern edge. The arkose contains little if any biotite.

A crescent-shaped outcrop of brown tufa overlays the altered granodiorite in part. This tufa appears to be shore deposits of Lake Lahontan and has been lightly silicified and iron stained where it overlies the altered granodiorite.

Siliceous sinter occurs north of both Great Boiling Spring and Mud Springs. This sinter is light grey and contains fossil and plant fragments. Texture patterns observed in the sinter indicate it was deposited by flowing hot springs.

The alluvium at Gerlach ranges from conglomeratic fan deposits to clay-rich playa deposits.

Structure

The structural setting of the region reflects a patterns of northeast and northwest trending faults related to Basin and Range tectonism (Figure 2). The major faults have rotated and down-dropped all the lithologic units and appear to have localized the geothermal system along the eastern flank of Granite Range. The north-northeast trending faults have displaced the granodiorite at least 1000 ft down to the east. Limited exposures suggest a dip on these faults from 60° to near vertical.

The three observed northwest trending faults are normal faults associated with the western flank of the Granite Range. These faults are clearly exposed northwest of Gerlach and have down-dropped the Granite Range towards the southwest. The faults cross the Granite Range west of the Gerlach geothermal system in deep, straight canyons that contain highly fractured and sheared granodiorite. In addition, diorite dikes with strikes parallel to the canyon are seen in two of the canyons, confirming that these canyons are fault controlled. Apparent offset in the peaks of Granite Range and the altered granodiorite suggest that a minor amount of right-lateral movement has also occurred along the northwest trending faults.

Hot Springs

Numerous hot springs and mud pots flow thermal water at Great Boiling Spring (Figure 3). The temperatures of the active manifestations range from ±130° to 208°F. In addition, active deposition of sulfur occurs in the area near the 208°F water. This implies that Great Boiling Spring vents from the hottest portion of the Gerlach geothermal system.

Mesquite's mapping shows that all geothermal manifestations at Great Boiling Spring are aligned on the lineament that strikes approximately N25°W. This alignment, which has not been previously reported, projects into the major fault crossing from the western flank of Granite Mountain.

At Ditch Spring, two vents yield hot water at 200°F. These vents occur on trend with the altered granodiorite, and minor amounts of secondary quartz and pyrite are observed near the springs.

At Mud Springs, at least thirteen small hot springs flow water where the maximum temperature is 188°F. The alignment of Mud Springs parallels the strike of the cross faults and occurs adjacent to the altered granodiorite trend.

Geochemistry

The Gerlach hot springs vent a sodium chloride type water with a total dissolved concentration of approximately 4200 mg/l. Similar chloride to boron ratios in the three hot spring complexes indicate a common source for the thermal waters. The low magnesium concentrations suggest a minor groundwater component exists in all three groups of thermal waters. The quartz geothermometer predicts resource temperatures of 319 to 343°F. The Ca-Na-K geothermometer indicates resource temperatures between 349 and 376°F.

Geophysical Surveys

Two sets of ground magnetic and self-potential (SP) surveys have been conducted at Gerlach. A magnetic ridge coincides with the altered granodiorite and the associated north-northeast trending fault (Figure 4). This magnetic high may be caused by the abundant hematite enrichment observed in the secondary mineralization or an iron sulfide mineral at depth. The ridge is broken by northwest striking lows that correspond with the mapped cross-cutting faults.

The SP surveys measured anomalous high-amplitude readings at two locations. These anomalous measurements suggest both north trending and northwest striking structures are conduits of active thermal water flow.

Geothermal Model

The geologic mapping indicates that the Gerlach geothermal resource is structurally controlled. The primary structural control is the north-northeast trending fault that coincides with the altered granodiorite. This fault has brecciated the surrounding granodiorite at least two times. Thermal waters migrating up this fault, informally named the "Thermal Fault," have altered and resilicified the fault gouge. The outcrop of the "Thermal Fault" adjacent to Highway 447 consists of a wide area that is highly silicified and contains numerous silica-filled fractures. Sub-parallel zones with vein-like fractures range from one to three feet in width and are separated by two to ten feet of highly altered arkose. These fracture-filled veins are classic examples of a permeable fault zone transmitting thermal water.

A second potential geothermal-bearing target is the cross-fault that cuts the Granite Range and strikes toward Great Boiling Spring. This fault, informally named "Hot Springs Fault," acts as the conduit for thermal waters being discharged at Great Boiling Spring and the ±15 geothermal manifestations aligned along the fault trend. Limited field evidence suggests that "Hot Springs Fault" dips to the southwest at a high angle.

<u>Drilling</u>

Geothermal companies that have drilled in the Gerlach area include Cordero Mining, Sunedco, U.S. Geological Survey (USGS), Occidental (Oxy), ESI Energy and San Emidio Resources, Inc. Cordero and the USGS drilled gradient holes to 30 meters during the early 1970's. These holes encountered temperatures as high as 227°F and showed the thermal anomaly trending north-northeast.

In 1979, Sunedco drilled a temperature gradient hole to a depth of 125 ft. This hole (TG-1) was located approximately 2000 ft northwest of Great Boiling Springs and in the range-front fault zone (Figure 3). The TG-1 temperature profile is conductive, with a bottomhole temperature of 256°F.

Sunedco then elected to drill an exploration test well. Utilizing geophysical data and constrained by their leasehold, a wildcat well, Holland Ranch 1-15-G was located 1800 ft southeast of Mud Springs. This well was drilled to ±5800 ft, and encountered a maximum temperature of only 197°F near the top of the granodiorite (± 3450 ft) which then decreased with depth to TD.

In the early 1980's, Oxy acquired leases and drilled three temperature observation holes in the Gerlach area. The holes were drilled to ±1000 ft, but partially lost due to fish left in two of them. Hole G-1, located 2 miles north of Ditch Springs, was successfully drilled to 1000 ft and recorded a maximum temperature of only ±90°F. Hole G-3 was located about 1700 ft southeast of Ditch Springs and could only be measured to 757 ft. G-3's temperature profile increased to 217°F at a depth of 300 ft, becoming isothermal before reversing at ±500 ft. The bottomhole temperature was ±190°F, with the gradient again increasing near bottom. The temperature in hole G-4, located on the western flank of Granite Range, was isothermal at 70°F to 363 ft.

Additional Gerlach wells with published temperatures are 76-15, located approximately 4300 ft southeast of Great Boiling Spring, and the Hot Pool Well, located 3000 ft southeast of Great Boiling Spring. Well 76-15 is 200 ft deep and flows 154°F water. The Hot Pool Well yields 186°F water.

In 1993, ESI and its partner, San Emidio Resources, drilled two exploration wells at Gerlach. Well 76-9 (Figure 3) was spudded in granite at a site located 2900 ft northwest of Great Boiling Spring and 600 ft northwest of Sunedco's temperature gradient hole TG-1 (256°F at 125 ft). Well 76-9 penetrated a near surface interval of altered granite, then fresh granite at an average rate of 10 ft per hour. At 273 ft, a total lost circulation zone was encountered. The hole was then drilled blind while losing 200 bbl/hr to 317 ft. Five cement plugs were pumped in this interval. From 317 to ±350 ft, altered granite was drilled at rates up to 80 ft per hour. This high penetration rate continued in fresh granite to 460 ft. From 460 ft to total depth (2297 ft) chloritized granite containing epidote was encountered, which drilled at rates of 10 to 15 ft per hour and exhibited no permeability.

Approximately 25 days after drilling, a temperature profile was measured in Well 76-9. Temperatures increased rapidly from surface to the lost circulation zone at 273 ft. The profile was isothermal at ±265°F between 300 ft and 350 ft, then reversed to ±230°F and only increased slightly to total depth at 2297 ft. The temperatures in the lost circulation zone may not have been equilibrated, considering that several thousand barrels of cold mud and cement were lost in this highly fractured interval.

The rig was then mobilized to the Well 38-10 location, approximately 2700 ft west of the 76-9 site (Figure 3). This well was spudded in alluvium and penetrated granite from ±700 ft to TD at 1900 ft. The well was then redrilled westward to a true vertical depth (TVD) of about 1650 ft. This leg was then plugged back and the wellbore was again directionally drilled westward to a measured depth of 3187 ft (±2800 ft TVD). The bottomhole location of this second redrill is approximately 1200 ft west and 150 ft south of the surface location. The second redrill encountered only relatively fresh granite below the alluvium, except for a single ten foot horizon of calcified dike rock. The lack of significant lost circulation or drilling breaks indicates that permeability was not encountered.

A temperature survey recorded 21 days after drilling showed a gradual temperature increase from the surface to approximately 700 ft where ±190°F was measured in a sandy horizon overlying the granite. The temperature then reversed to ±180°F at 750 ft. Below this the thermal gradient was conductive, with a maximum bottomhole temperature of ±230°F being reached at total depth.

In 1994, San Emidio Resources, Inc. drilled Well 18-10 in an attempt to intersect the "Thermal Fault" at a depth of ±2500 ft. Well 18-10 was spudded in alluvium at a site located 1300 ft northwest of Great Boiling Spring and 900 ft east of the altered granodiorite. The well penetrated clay and arkose to 640 ft, encountering major lost circulation zones at 201 and 368 ft. Granodiorite was then drilled to a total depth of 2868 ft at an average rate of 15 ft per hour. Total lost circulation occurred in the granodiorite at 677 and 2788 ft. The granodiorite was a fresh, biotite-bearing rock, except at the lost circulation zones were secondary minerals including quartz, calcite, edipote, and chlorite had replaced the original minerals. The geologic and drilling data indicate the "Thermal Fault" was first encountered at 2730 ft, with permeable zones intersected at 2780 to 2800, 2827 and 2038 ft.

Approximately 10 days after drilling, a series of temperature profiles were measured. An unstable, sloughing zone at 550 ft continued to bridge-off the hole, requiring numerous cleanouts. Therefore, static temperatures were never measured, but temperature buildup calculations indicate the highest temperature to be less than 300°F.

References

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Olmsted, F. H., Glancy, P. A., Harril, J. R., Rush, F. E., and Van Denburgh, A. S., 1975, Preliminary hydrogeologic appraisal of selected hydrothermal systems in norhtern and central Nevada: U. S. Geol. Survey, OFR-75-56.

FIGURE 1

LOCATION MAP
GERLACH GEOTHERMAL SYSTEM

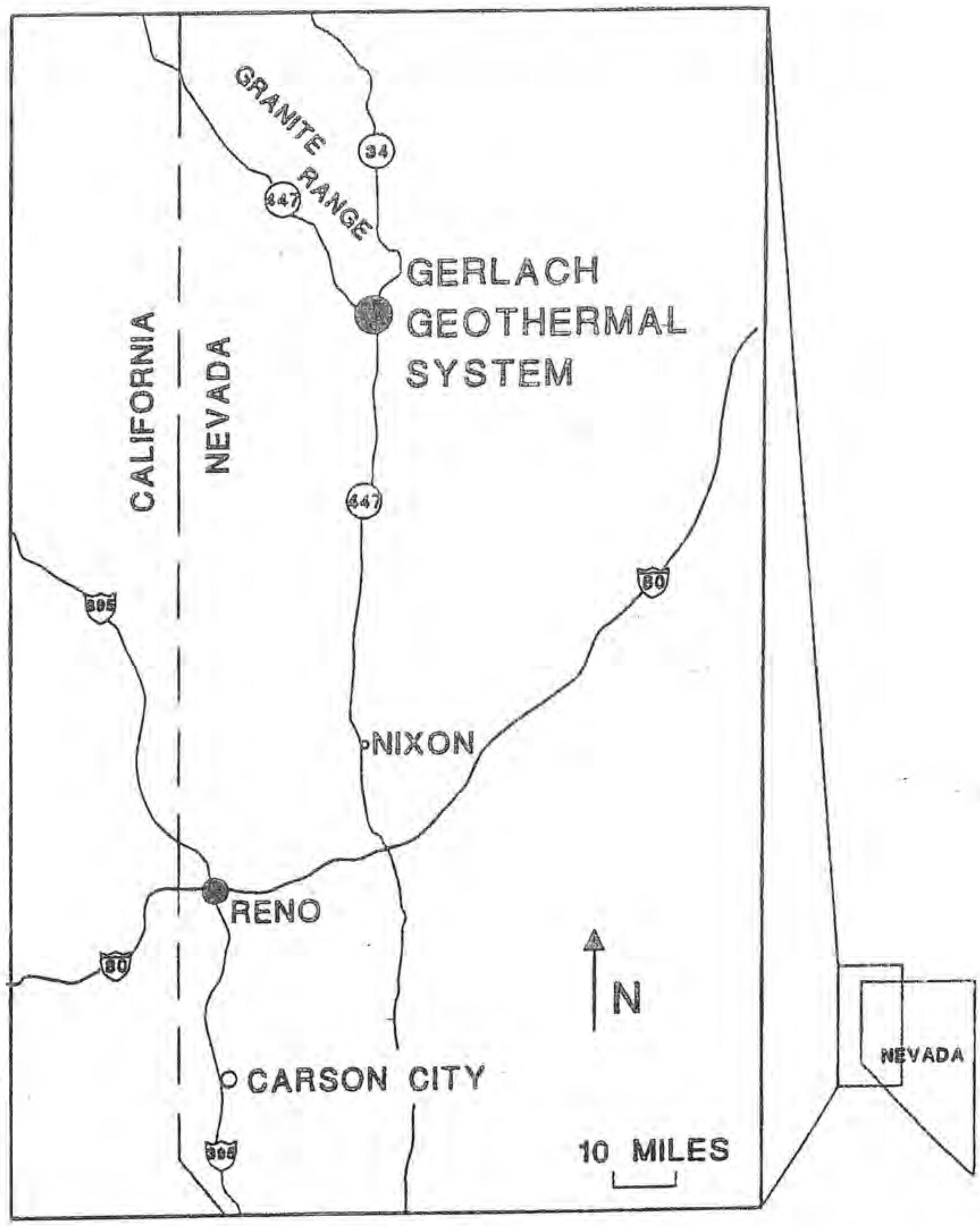

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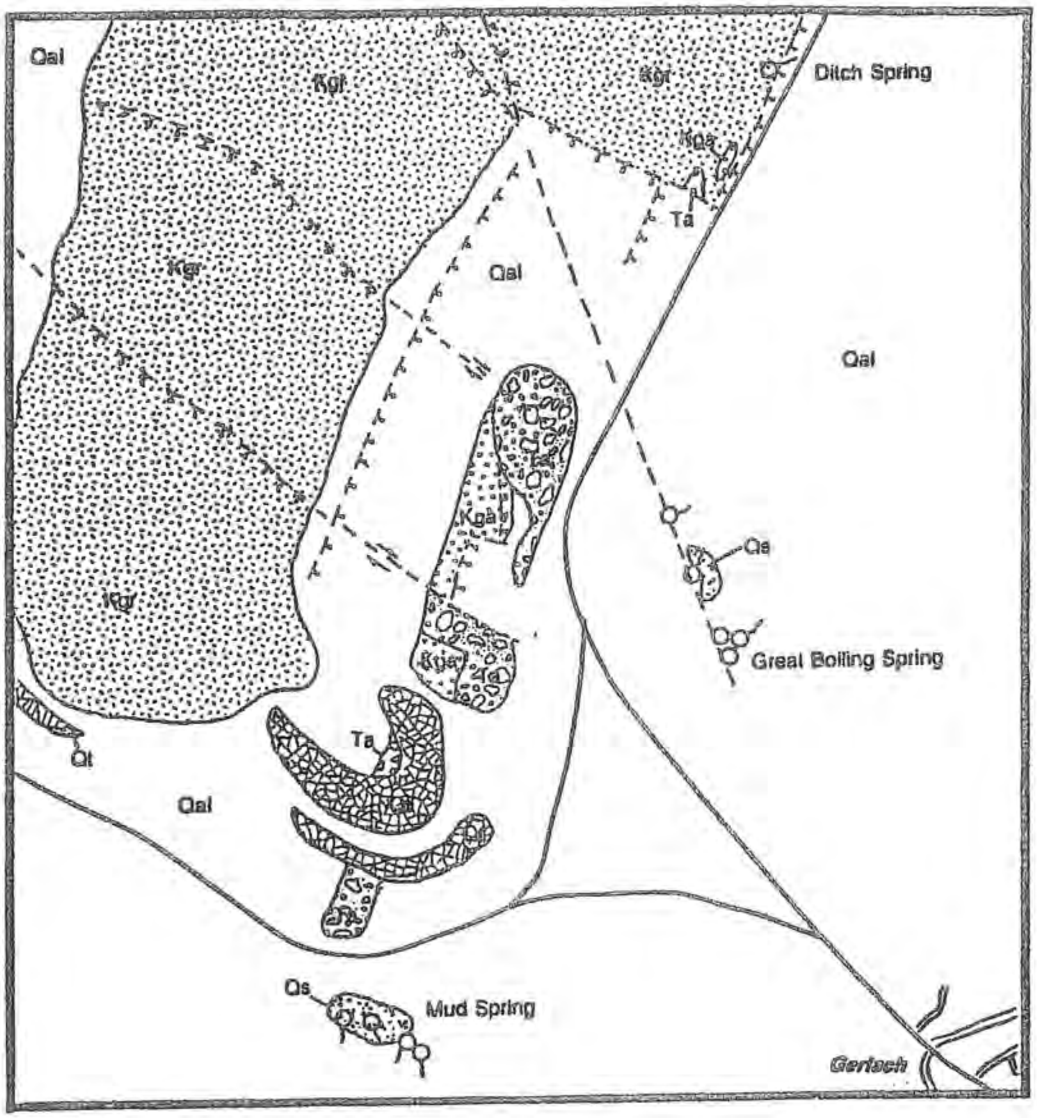
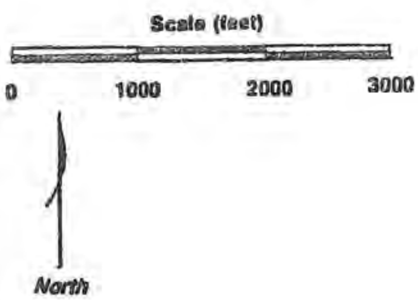
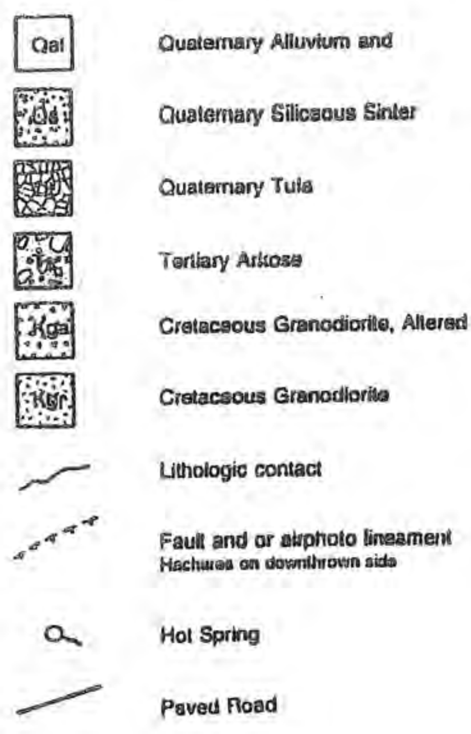
FIGURE 2

Surface Geology
Gerlach Hot Springs
Washoe County, Nevada







Geology by: J. S. Mattick and W. J. Ehni

FIGURE 3

HOT SPRING AND WELL LOCATIONS
GERLACH GEOTHERMAL SYSTEM
WASHOE COUNTY, NV

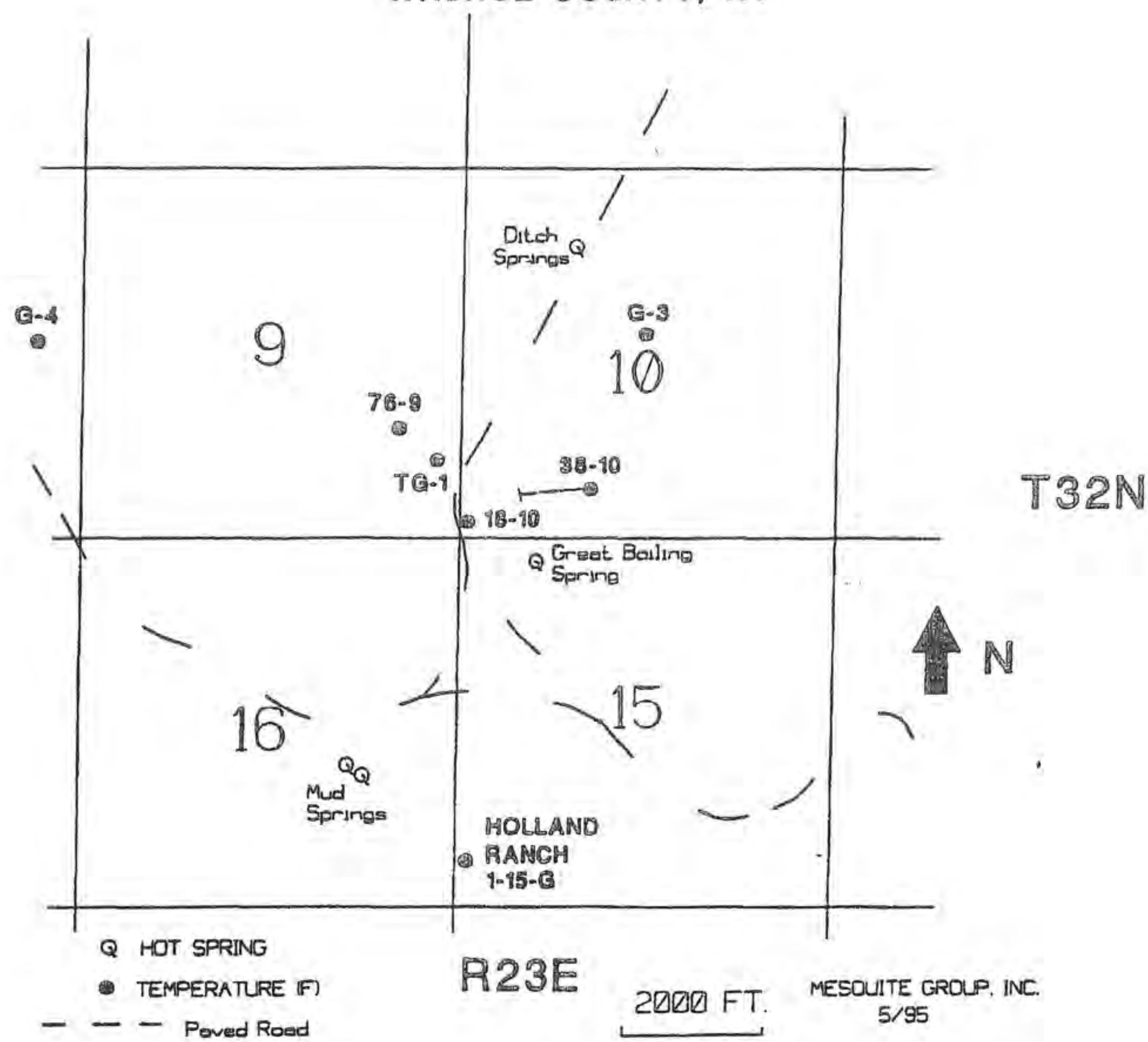
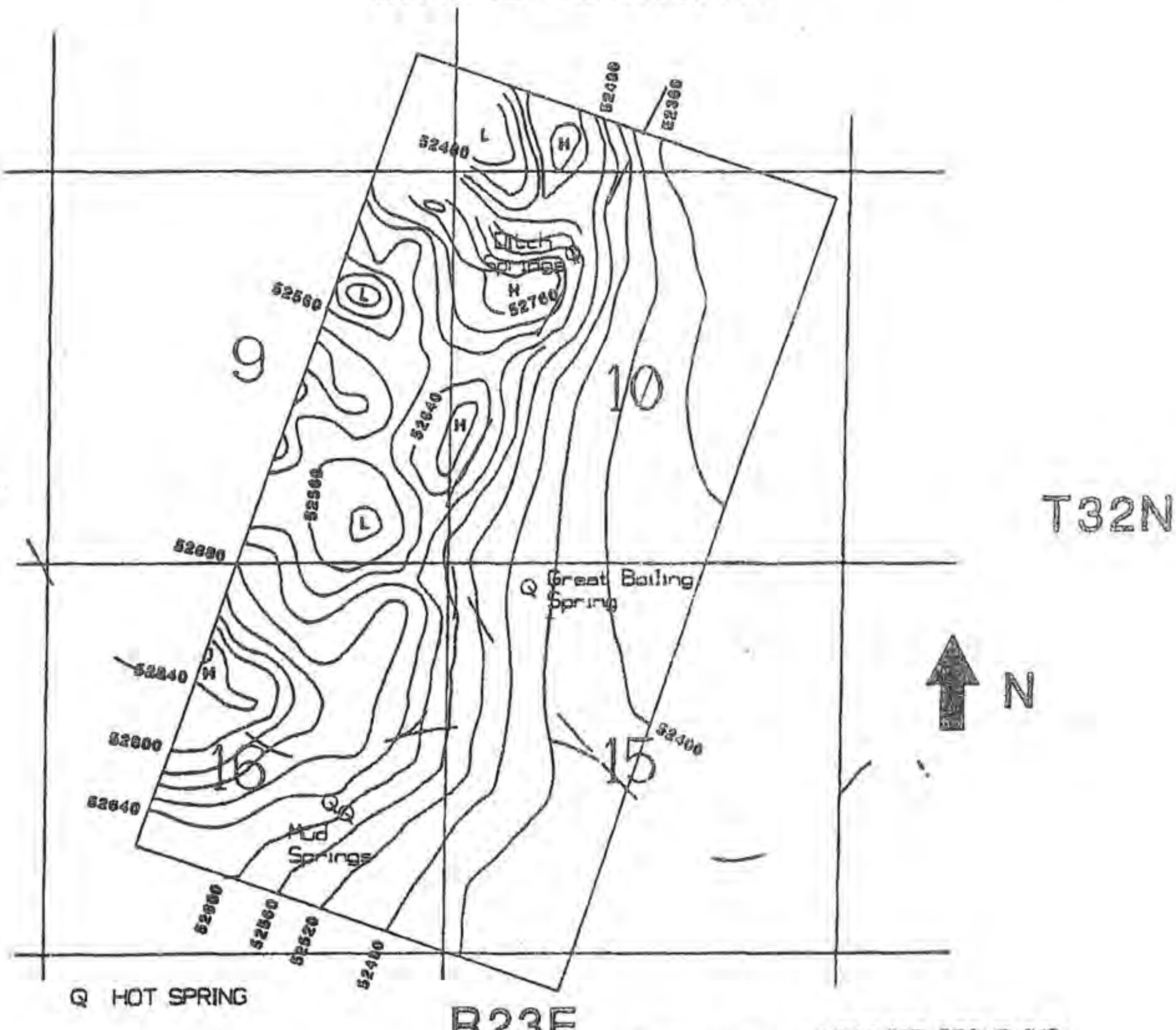


FIGURE 4

GROUND MAGNETIC MAP
GERLACH GEOTHERMAL SYSTEM
WASHOE COUNTY, NV



Q HOT SPRING

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— — — Paved Road

——— MAGNETIC CONTOUR (GAMMAS)

DATA BY EHNI ENTERPRISES, INC.