GEOTHERMAL PROSPECT REPORT
FOR CELEX-NEVADA, INC.
PATUA HOT SPRINGS GEOTHERMAL SYSTEM
LYON AND CHURCHILL COUNTIES, NEVADA

Introduction

The Patua Hot Springs prospect area contains hot springs, fossil hot springs, and hydrothermally altered rocks that indicate a significant geothermal resource may be present. The area is also known as the "Hazen" or "Black Butte" geothermal prospect. This report is intended to characterize the geothermal resource in the Patua Hot Springs area and to provide an opinion as to its suitability for electrical generation development. The work was performed for Celex-Nevada, Inc. which controls the geothermal rights in all odd-numbered sections in the Patua Hot Springs area.

The methodology utilized in this investigation consisted of both office and field work. All available published literature discussing the area was reviewed. Black and white air photos at an approximate scale of 1: 62,500 were studied to locate geological structures and lineaments. These features and the geological literature were then field checked and verified. Numerous corrections and additions were noted during the field work. Original work included detailed mapping of the thermal springs, the hydrothermal alteration, and the surface geology. All of these data are integrated into the conceptual geologic model discussed below.

Geography

The study area is located immediate to the west/northwest of Hazen, Nevada, in the Carson Sink along the Lyon and Churchill Counties boundary. The geothermal system is centered in Section 18, T20N, R26E, with Highway 50 and Southern Pacific Railroad traversing the area. The Hot Springs Mountains to the north are a desolate range of hills with generally subdued topography, while the Carson Sink is an area of alkali flats and playa lakes. Elevations range from over 5300 feet in the mountains to approximately 4000 feet

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in the playa. The climate in the region is arid, with approximately five inches of precipitation per year occurring as rain and snow in the winter months. Vegetation ranges from sparse to thick, depending upon soil and water quality. Sagebrush and saltgrass dominate the flora community.

Geology

The Patua Hot Springs Geothermal System (the Springs) is located in part of the Basin and Range Province adjacent to the Walker Lane right lateral strike-slip fault system. The Hot Springs Mountains to the north and the Virginia Mountains to the south provide the geological boundaries. The Hot Springs Mountains also form part of the northwestern boundary of the Carson Sink depression.

Geological information concerning pre-Tertiary stratigraphy in the area is meager. Evidence from adjacent regions suggests pre-Tertiary rocks consist of metamorphosed sedimentary and volcanic rocks thought to be of Triassic and Jurassic age. These metamorphic rocks have been intruded by mafic and siliceous plutons. The lack of outcrops in the area also limits pre-Tertiary structural interpretation, but neighboring mountains suggest pre-Tertiary folding and faulting was widespread.

The oldest rocks exposed in the southern end of the Hot Springs Mountains and the northern end of the Virginia Mountains are part of the Pliocene Truckee formation (Figure 1), consisting of fluvial and lacustrine sediments and associated volcanic rocks. Axelrod (1956) divided the formation into three members. The lower member consists of basaltic tuff, palagonite tuff, coquina, limestone, water-laid ash, tuff breccia, sandstone, diatomaceous shale, and basalt. The middle member is predominantly thin-bedded to massive, white diatomite with light grey, vitric ash. The upper member consists of limestone interbedded with sandstone, diatomite, and conglomerate.

Overlying the Truckee formation are Tertiary basalts and a welded tuff unit. The welded tuff is a near vent, base surge deposit composed of basalt fragments, volcanic glass and minor lithic fragments. Two separate welded tuff outcrops indicate that two separate vents were located in the area. The basalts are dark grey to black, aphanitic, dense to vesicular flow rocks that contain minor plagioclase and olivine crystals. Tuffs, tuffaceous sandstone, and shale form local interbeds within the basal flows. The basalt flows rest unconformably on Truckee formation rocks and the welded tuff unit throughout the area.

Quaternary alluvium deposits are a general map unit composed mainly of Lake Lahontan sediments, fan deposits, gravels, playa deposits and wind-blown sands. These deposits cover most of the area and are usually younger than 10,000 years old. Within the alluvium are at least nine fossil hot spring deposits. These deposits include jasper, silica sinter, travertine, quartz-cemented sands, jasperoid and minor sulfides. They are further discussed below in the "geothermal manifestations" section.

The geologic structure in the Springs area is dominated by north-northeast trending normal faults and by a series of subparallel northwest striking faults (Figure 1). The normal faults are related to Basin and Range tectonic stresses that began in early Miocene time and continue today. These normal faults have dropped and tilted the rocks into the horst and graben structure of present-day Nevada. Several of the N19°E striking normal faults appear to localize geothermal fluids. Three obvious N19°E striking normal faults traverse the Springs. The northwest trending faults appear to have both a throw and a strike-slip sense of left-lateral motion. The northwest trend is subparallel to the Walker Lane fault system and may be a splay fault of the Walker Lane. Bell and Slemmons (1979) suggest that a series of these secondary left-lateral conjugate fault sets exist adjacent to the Walker Lane.

Geothermal Manifestations

Geothermal manifestations of the area include hot springs, silica sinter, jasper, cinnabar, jasperoid and thermal wells. At least ten groups of hot springs currently vent in the western half of Section 18, T20N, R26E (Figure 2). The surface temperature of the thermal water ranges from boiling (206°F) to 90°F at the minor thermal seeps. The hottest spring flows at an estimated rate of 50 gpm and is accompanied by carbon dioxide degassing. Several of the hot springs are fed by individual vents aligned along fractures trending N19°E. This trend is further highlighted by three alignments of the ten known hot springs. The most westerly N19°E alignment consists of two hot spring groups, both having 154°F surface temperatures. Within these hot springs individual vents align N19°E. The middle N19°E alignment contains five hot springs and is terminated at the north and south by fossil hot spring mounds. The most easterly N19°E alignment is marked by a continuous 3000 foot long exposure of jasper, quartz sinter, and jasperoid fossil hot springs and two minor 90°F hot spring seeps. The largest hot spring appears not to be on a N19°E fault for reasons discussed below in the "geothermal well" section.

Numerous fossil hot spring deposits surround the existing hot springs. These deposits occur in two forms: mounds and jasperoid boulders. The mounds have a base of bedded Lake Lahontan sands and silts that are weakly cemented with quartz. The Lake Lahontan sediments indicate these mounds formed during Lake Lahontan time (6,000 to 10,000 years ago). The large mounds are topped with massive silica sinter. This sinter acts as an erosion resistant layer that accounts for the continued existence of the mounds. Once this layer has been removed, the mounds quickly erode. Between the mounds on the eastern most N19°E alignment, a continuous trend of jasper, opal, and jasperoid cobbles exists. These rocks are colored with iron staining, cinnabar, and iron oxides, and were formed by fossil geothermal waters.

The widespread occurrence of silica sinter and the sparsity of travertine in the area suggests that the resource temperature exceeds 325°F (White, 1970). The contrasting solubilities of quartz, which control quartz concentrations at high temperatures and amorphous quartz, which controls the precipitation of sinter, indicate that subsurface temperatures must exceed 325°F for sinter to form. Travertine deposits are composed of calcite (calcium carbonate), which has a decreasing solubility with increasing temperatures (Blount and Dickson, 1969). This relationship indicates that high subsurface temperature water will not transport calcite in concentrations that allow travertine to form.

Minor cinnabar deposits occur at three locations in the Springs area (Figure 2). Disseminated cinnabar and crystalline cinnabar replace indurated Lake Lahontan clay at the southwestern edge of the northernmost fossil hot spring mound in the main Patua Hot Springs area. Cinnabar coloration is located in the silicified cap rock on the large fossil hot spring mounds. Disseminated cinnabar occurs at several sites along the jasper outcrops. Thermodynamic data suggest source thermal waters must exceed 300°F to allow transportation of dissolved cinnabar (White, 1967). The cinnabar precipitates from the thermal waters when the water cools at the surface.

Geothermal Wells

Within the Patua Hot Springs Geothermal Area, four geothermal wells have reportedly been drilled. In 1961, Magma Power cable tooled three shallow wells (Hazen 1, 2 and 3) at Patua Hot Springs (Garside and Schilling, 1979). Construction and earth workings suggest that one of the three sites was located on the eastern edge of the northernmost fossil hot spring mound in the main Springs area and another site is presently the 206°F hot spring (Figure 2). At both of these sites, neither wellhead equipment nor casing could be located. The third drillsite is located immediately north of the middle fossil hot springs mounds (Figure 2). This well reportedly is 750 feet deep and produced "large quantities" of 275°F water (Garside and Schilling, 1979). The well presently consists of 13⅜-in. casing cut off approximately 18 inches above ground, with an irregular concrete pad poured around the casing. A 12-in. ANSI 400 RF flange is welded on top of the 13⅜-in. casing below the 12-in. flange, with an open 8-in. ANSI 400 RF flange attached to the opposite end. Solid scale blocks the wellbore 8 to 10 feet below ground.

The fourth well (Fernley No. 1) in the area was drilled by Magma Energy, Inc. in the SE¼, SW¼, of Section 24, T20N, R25E, approximately 1.5 miles southwest of the hot springs. The well was drilled in April 1975 to a total depth of 3668 feet. Subsurface temperature, geologic and production data are not available from the well, but it was reportedly "hot."

Geochemistry

One published chemical analysis exists for Patua Hot Springs (Mariner and others, 1975). The reported concentrations (Table 1) show that the thermal water is a NaCl type water, with a total dissolved solids concentration of only 2210 mg/l indicating the water is good quality. Hydrogen and oxygen isotopes indicate the hot spring water is a meteoritic water that has undergone a high temperature rock-water interaction. Silica and alkali geothermometers predict this interaction occurred at 322° and 332°F, respectively.

Table 1

CHEMICAL ANALYSIS OF PATUA HOT SPRINGS, NEVADA

Section 18, T20N, R26E

Temperature 187°F

Chemical	*(mg/l)*	Chemical	*(mg/l)*	Chemical	*(vol. %)*
SiO_2	150	HCO_3	100	CO_2	6
Ca	70	SO_4	400	O_2+A_R	11
Mg	1.5	Cl	820	N_2	81
Na	620	F	4.2	CH_4	2
K	38	Li	1.6		
pH	7.1	B	5.6		

Conceptual Geologic Model

The heat energy for the Patua Hot Springs most likely originates from the shallow mantle. Numerous geophysical studies have outlined a broad region in north central Nevada, named the Battle Mountain High, where the mantle is located at a shallow depth. The occurrence of several nearby geothermal systems already developed (i.e., Brady Hot Springs, Desert Peak, Dixie Valley, Stillwater, Beowawe) in the vicinity support the interpretation of a shallow mantle heat source in the area.

The commercial geothermal systems located in Nevada have predominantly fault/fracture permeability. These systems all appear to occur at or near major fault intersections. This cross-faulting tends to fracture the rock, which greatly increases the localized permeability. The Patua Hot Springs are situated at the intersection of Walker Lane northwest trending faults and N19°E striking Basin-and-Range normal faults. Faults within both of these systems have undergone earthquake induced movement in recent time. The combination of recent movement and cross-faulting appears to have fractured the rocks within the area to a high degree.

The Carson Sink is the major collection basis for three major rivers draining thousands of square miles, including Lake Tahoe and the eastern Sierra Mountains.

Therefore, water for the Patua Hot Springs Geothermal System located at the western edge of the Sink is probably recharged continuously.

A shallow reservoir, located 500 to 1,000 feet below the surface, would be the primary drilling target for this prospect. This shallow reservoir is situated in volcanic and sandstone rocks of the Truckee formation. These rocks appear to be highly fractured by faults. Geothermal water of good quality fills the fractures at temperatures probably in excess of 300°F.

Conclusions

Numerous geological features show that the Patua Hot Springs Geothermal System is an active geothermal resource potentially capable of supporting a binary cycle geothermal power plant. These indicators, which were discussed above may be summarized as follows:

1. Fossil hot spring mounds composed of Lake Lahontan sediments indicate the geothermal system is a mature, moderate temperature system.

2. The alignment of the hot springs and fossil hot springs along the N19°E trend is consistent with that of other major thermal fields in the region (e.g., the Brady Hot Springs and Desert Peak Geothermal Fields), and suggests the geothermal system is active and widespread.

3. The cross-faulting patterns between the north-northeast and the northwest striking faults should provide fracturing and consequent permeability to support the convection recharge required of a commercial geothermal system.

4. The faults located within the Patua Hot Springs area are major faults that penetrate to basement. This potentially provides a large recharge pathway for the geothermal system.

5. The boiling temperature at the Springs is additional evidence that the geothermal resource has a higher subsurface temperature.

6. The occurrence of silica sinter and jasper indicates that the resource temperature exceeds 300°F. This conclusion is supported by the sparsity of travertine deposition.

7. The recent deposition of cinnabar also suggests that the subsurface temperatures exceed 300°F.

8. The geochemistry of the thermal waters at Patua Hot Springs shows the water to be a high quality water that has undergone a moderately hot temperature rock-water interaction. Quartz and alkali geothermometers indicate these interactions occurred at or above 322°F.

9. The previous drilling at the Springs by Magma Power Company is reported to have encountered a shallow geothermal resource. One well, drilled to less than 750 feet, produced a large volume of 275°F water.

10. Geological and geochemical data suggest the Patua Hot Springs resource is similar to that of the Brady Hot Springs Geothermal Field. Both areas have faults transmitting hot fluids from a large basement reservoir into a near surface highly fractured reservoir. Wells drilled in each area encounter the resource at shallow depths and can produce large volumes of hot fluids.

In summary, the Patua Hot Springs Geothermal System has the geological and physical indications of a moderate temperature, active, geothermal resource. Geological data suggest that the resource is widespread. Previous drilling indicates that the geothermal reservoir is capable of yielding high flow rates from shallow depths. Thus, it is reasonable to conclude that this prospect has a high probability of being commercially developable for electrical generation. While its magnitude cannot be quantified with the available data, potential in the 15 to 30 MW_e range is probable by analogy with other fields in the area with similar characteristics.

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FIGURE 2

DETAILED GEOTHERMAL MAP

PATUA HOT SPRINGS, NEVADA
W ½ SECTION 18
T20N R26E

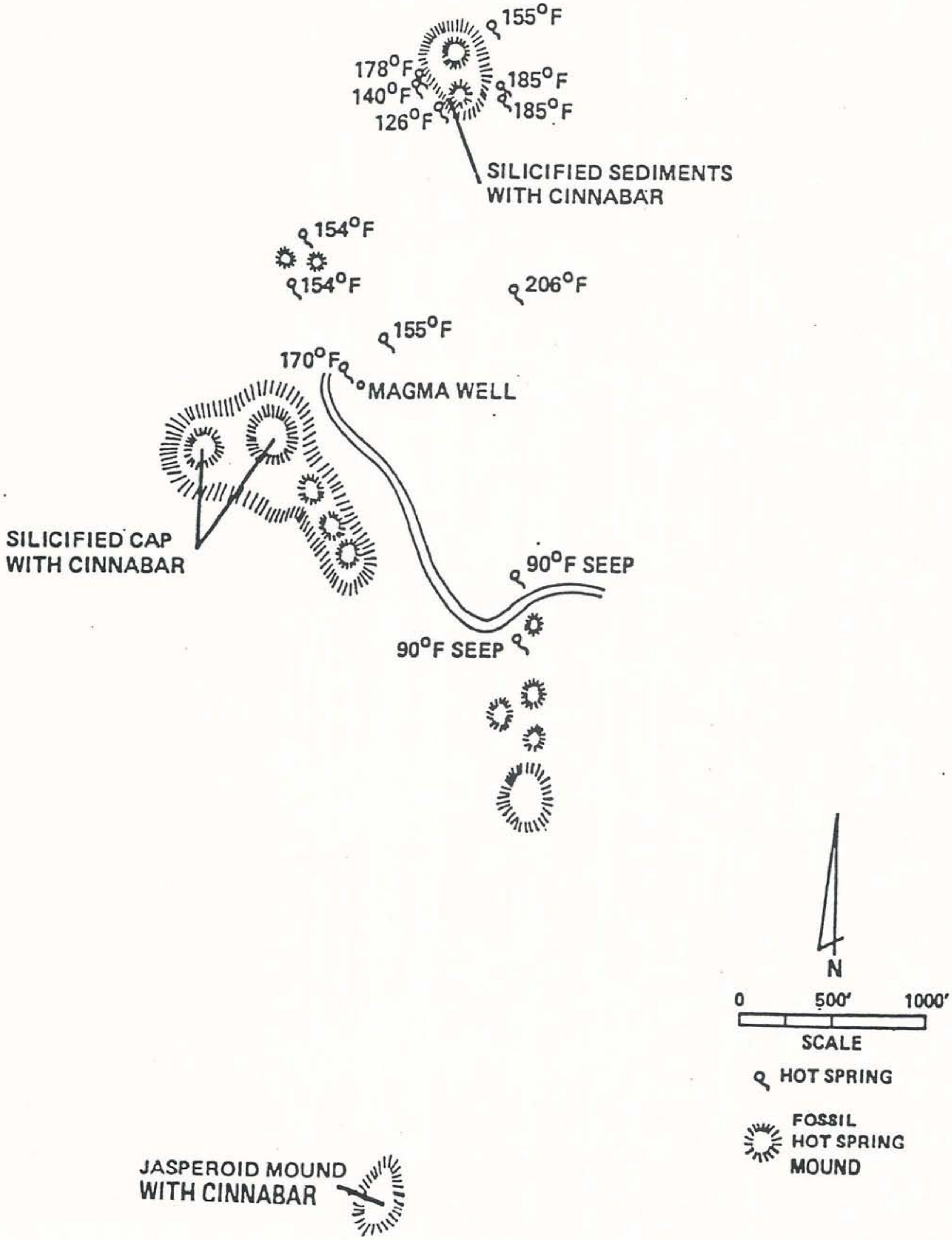
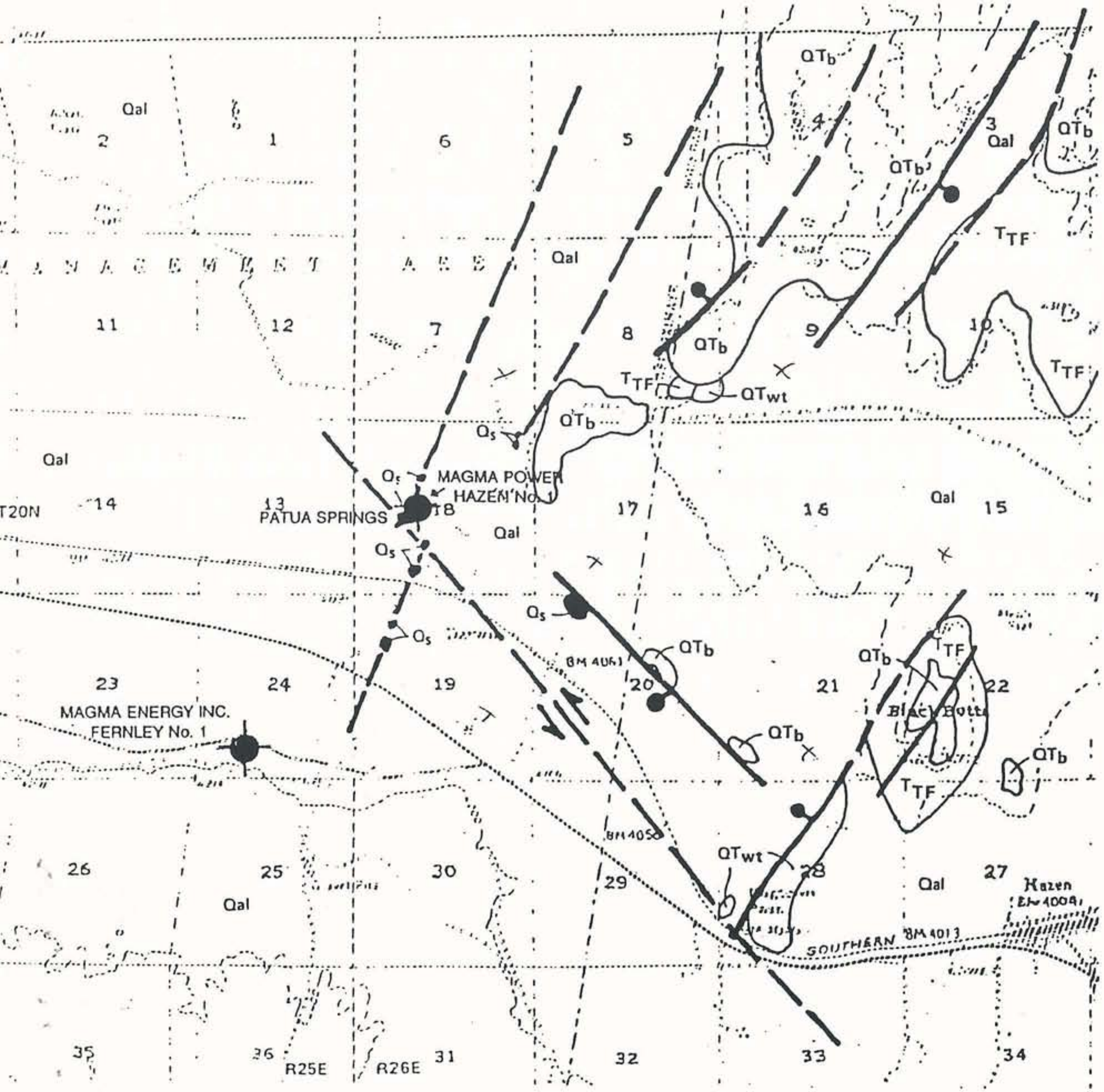


FIGURE 1



GEOLOGICAL MAP
PATUA HOT SPRINGS, NEVADA

QUATERNARY

Qs – Quaternary silica sinter and jasper deposited from fossil hot springs.

Qal – Quaternary alluvium includes Lake Lahontan sediments, pediment gravels, and wind-blown sand.

QTb – Quaternary/Tertiary aphantic, massive to vesicular basalt flows.

QTwt – Quaternary/Tertiary welded tuff composed of basalt lithic fragment and basaltic ground mass glass formed as a near vent base surge deposit.

TERTIARY – Pliocene

TTF – Truckee Formation, undifferentiated limestones, conglomerates, diatomites with vitric ash beds, sandstones, tuffaceous siltstones, basalts, tuffs.

Contact

fault, dashed where approximately located, ball on downthrown side.

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