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A GEOTHERMAL RESOURCE IN LAKE ELSINORE, CALIFORNIA

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ABSTRACT

Lake Elsinore has been designated by the California Energy Commission as one of five Priority I Resource Areas in the State based on physical resource characteristics; excellent economic development factors; an in-place distribution system; and economic and administrative institutions and policies. In 1982, the City of Lake Elsinore developed an Energy Element which places importance on energy conservation and the development of altermative energy sources. The ensuing geothermal assessment program is designed to lead to the successful development and utilization of the geothermal resource by 1990. Resource assessment conducted in Phase I of the study included literature/data review, imagery analysis, field reconnaissance and logging of accessible wells. A cross-cutting structure (Channel fault) between the Glen Ivy and North Elsinore faults appears to control the extent of thermal fluids in the near-surface. Optimal drilling sites are identified for Phase II reservoir analysis and development.

INTRODUCTION

The Lake Elsinore geothermal resource is characterized by the following physical parameters: temperatures above 50°C, shallow well depths (400-500 ft with thermal water being pumped at 150-200 ft depths), low total dissolved solids (TDS = 300-750 ppm), and wells located in the immediate area of potential application. Economic development factors include: abundant industrial and commercial zoned land in the area of the known resource, large labor base, low land prices, a pro-growth community attitude, the potential for direct economic benefits in a community with high unemployment and low median income, and an existing pipeline system in the community center. The City has an Energy Element and Energy Assessment in its new General Plan which identify the geothermal resource and provide policy for utilization, particularly within an established redevelopment project area. The main goal of the assessment and evaluation of the geothermal resource is to lead to its direct use as an economic base for industry and community growth.

PHYSICAL SETTING

Lake Elsinore is located in the northwestern-most extremity of the Peninsular Range province (fig. 1) with the Santa Ana Mountains (Elsinore Mountains) on the southwest side of the lake and the Perris Block (Temescal Mountains) on the northeast. Between the two mountain chains lies the Elsinore fault zone that defines the Elsinore trough in this region.

This geothermal anomaly is one of several fault related features of the Elsinore fault zone. Other thermal anomalies in this zone include Glen Eden, Temecula and Murrieta Hot Springs, Agua Tibia and Agua Caliente Springs and a group of thermal wells at Ocotillo. The Elsinore fault zone extends southward into Mexico as the Laguna Salada fault zone that is associated with the Cerro Prieto geothermal field.

Stratigraphy

The basement complex, or subjacent rocks, include the Bedford Canyon Formation, the Santiago Peak volcanics and the plutonic rocks of the southern California batholith. The Bedford Canyon Formation and the Santiago Peak volcanics consist of a variety of silicified, low-grade metamorphic volcanic and sedimentary rocks. The volcanic rocks range from metamorphosed basalt to rhyolite, but are primarily intermediate in composition and include breccia, agglomerate, tuff and tuff breccia. The Bedford Canyon Formation consists of metamorphosed shale, graywacke, and porcelanite. These metamorphic sequences are intruded by Jurassic-Cretaceous plutons of granodiorite, quartz monzonite, quartz diorite and gabbroic composition. Where exposed in the project area, these intrusives are generally highly weathered diorites and are selectively cut by siliceous dikes and later calcite veins.

The superjacent rocks are limited in extent and include the early Tertiary Martinez and Silverado Formations of fine-grained marine sedimentary sequences of sandstone, limestone, siltstone, clay shale and lignitic coal and the Quaternary fanglomerates, terrace deposits and younger alluvial-colluvial sequences. The marine formations are exposed at the northeast corner of the valley and in the vicinity of North Elsinore. The early Pleistocene Pauba Formation includes non-marine sandstone, conglomerate, siltstone and clay to a maximum thickness beneath Lake Elsinore of approx-

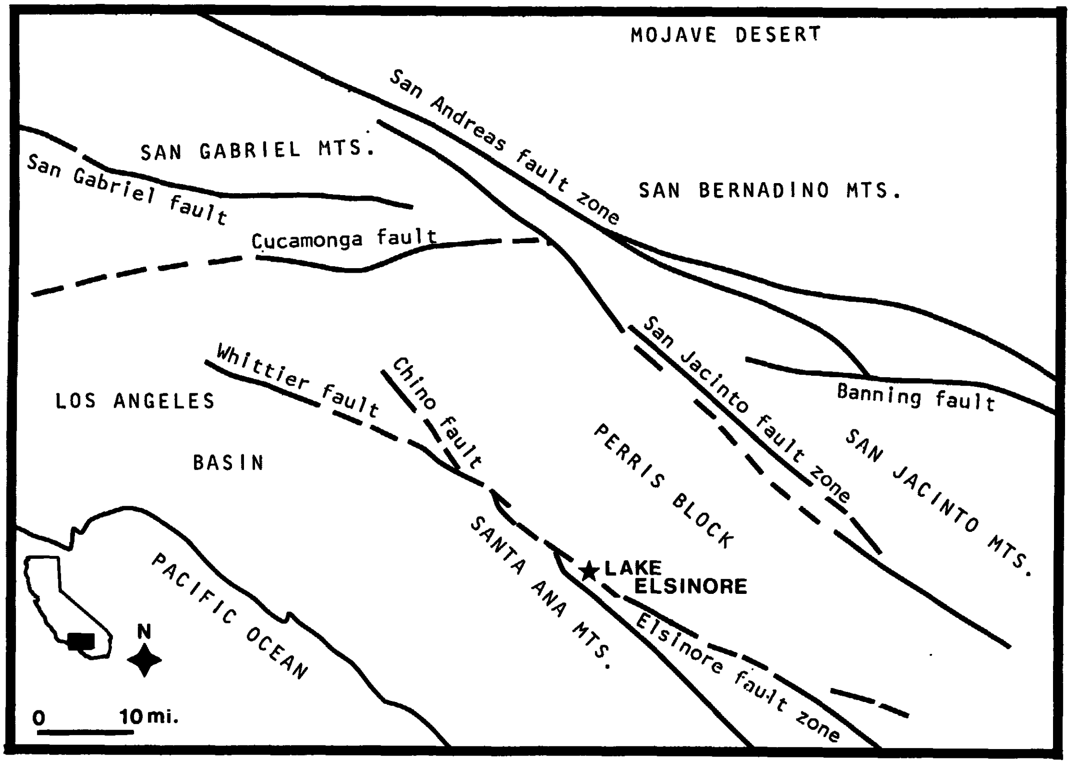

Figure 1. Regional index map of the Lake Elsinore area showing major tectonic blocks and fault zones in this portion of southern California.

imately 660 m (2200 ft). The Quaternary alluvial deposits are present in the Elsinore trough and at North Elsinore and around the lake; these deposits are generally a thin veneer overlying the basement complex.

Structure

The Elsinore fault zone constitutes one of the major tectonic elements of the San Andreas fault system in southern California (fig. 1), being traced from Corona southward into Mexico. The Elsinore fault zone forms a prominent structural boundary between the Santa Ana Mountains and the Perris Block. It is topographically well-marked along most of its length by linearly aligned ridges, swales, sags and fault scarps.

In the Lake Elsinore area (fig. 2), the Elsinore fault zone includes the North Elsinore and Glen Ivy faults within the Perris Block, the Wildomar fault marking the southwest edge of the Perris Block and the Willard fault marking the northeast edge of the Santa Ana Mountains. The Willard and Wildomar faults mark the boundaries of the Elsinore trough. Beneath Lake Elsinore, the valley is a complexly faulted graben formed by movement on a series of parallel, en echelon northwest-trending faults that include the Sedco, Burckhalter and Lake faults (Harding-Lawson Associates, 1978, 1980).

North Elsinore fault is traced by lithologic discontinuities along its strike and by fractures developed in alluvium in North Elsinore during the 1918 San Jacinto earthquake (Engel, 1959, p. 52). The fault plane is nearly vertical and displacements are principally strike-slip.

Glen Ivy fault trends southeastward from the Glen Ivy Hot Springs toward Lucerne and Lake Elsinore. Segments of this fault zone are short and discontinuous, occurring as en echelon zones or intersecting at acute angles. Displacements on this fault are right-oblique, with the southwest side downthrown relative to the northeast side along the trace just north of the City of Lake Elsinore (Clevelin Hills) at the lake margin. The fault is probably vertical to near-vertical with about 300 to 400 ft vertical displacement since the lower Pleistocene in the vicinity of Lucerne. The fault is projected southeastward beneath Lake Elsinore based on geophysical surveys (Harding-Lawson Associates, 1978, 1980). This fault appears to be an effective barrier separating the zone of thermal waters from the principal ground water basin at shallow depths beneath Lake Elsinore.

Wildomar fault zone is marked by prominent alignment of sags, fault-line scarps and displaced

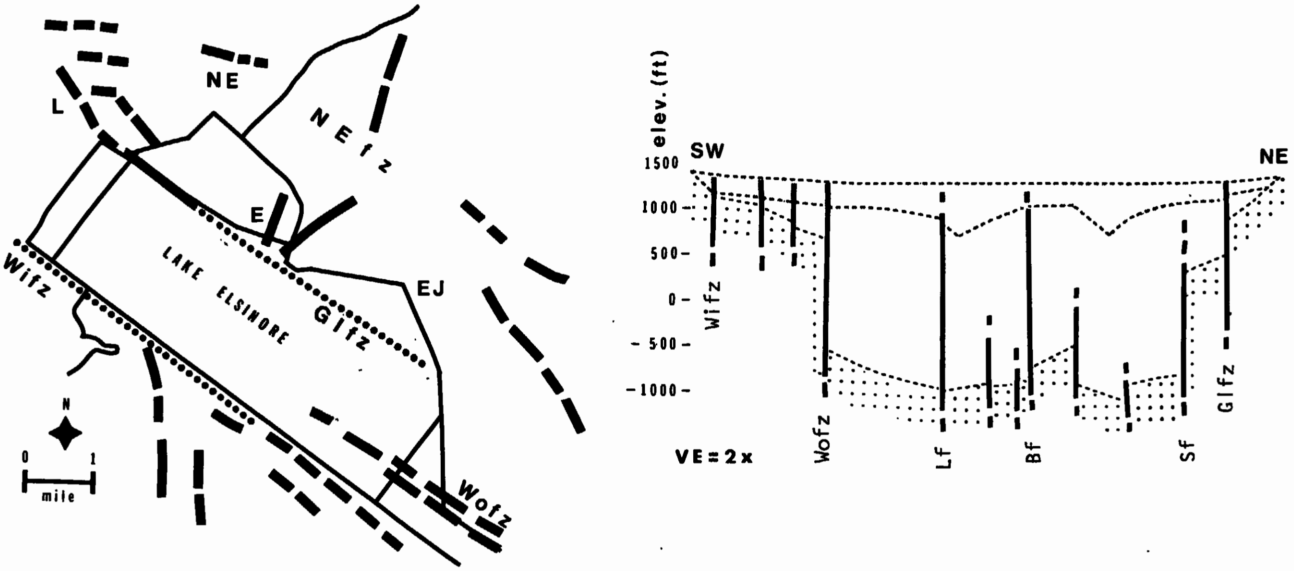

Figure 2. Structural features in the vicinity of Lake Elsinore shown in map view (on left) and in generalized cross-section view (on right). Wifz - Willard fault zone; Wofz - Wildomar fault zone; Lf - Lake fault; Bf - Burckhalter fault; Sf - Sedco fault; Glfz - Glen Ivy fault zone; NEfz - North Elsinore fault zone. L - Lucerne; E - City of Lake Elsinore; EJ - Elsinore Junction. Generalized stratigraphy in cross section includes lake and floodplain deposits (shading), underlying Pauba Formation (no pattern), and underlying basement complex (dotted).

outcrops and deflected stream channels. More than three miles of right-lateral offset is noted in Pleistocene sediments by Kennedy (1977, p. 8). The fault plane is nearly vertical to vertical.

Willard fault zone is composed of a subparallel series of discontinuous northwest-striking, east-dipping high-angle normal faults. This zone marks the boundary of the Santa Ana Mountains with bold linear topographic expression at the bedrock-alluvium contact or is expressed as lithologic discontinuities within the bedrock.

Transverse faults are recognized in this area. For example, the Temescal and Lucerne faults are identified northwest of Lake Elsinore, and within the Santa Ana Mountins, the Stewart and Harris faults trend generally northward. In particular, the Stewart and Harris faults have trends that are essentially on-strike with transverse lineaments identified by imagery analysis in the vicinity of the City of Lake Elsinore and Lakeland Village (fig. 2). These transverse elements are here informally designated the Channel fault zone. Figure 2 illustrates the geometric relationship between the northwest-trending strike-slip faults of the Elsinore fault zone and the graben formed by the Channel fault zone.

Seismicity

Microseismic activity measured 0.5 events per day, increasing southward along the Elsinore fault zone (Langenkamp and Combs, 1974). A magnitude 6 earthquake in 1910 located southwest of the City was reported by Richter (1958). Other activity has generally been of less than magnitude 4.5 (Hileman and others, 1973) along the fault zone between Lake Elsinore and the Agua Tibia Mountains on the southern Riverside County boundary. This segment of the Elsinore fault zone is historically characterized by relatively quiescent activity.

GEOTHERMAL RESOURCE

Historical Development

Early reports (Waring, 1915) describe numerous hot springs issuing in the area now occupied by the downtown portion of the City of Lake Elsinore. A history of once thriving balneological activity, first using the natural hot springs and then shallow wells, began in 1888 when a large bath house was built near the railroad depot. In the early 1890's, a canal was cut passed the springs to divert lake water northward to the citrus groves near Corona; most of the springs ceased to flow and shallow wells were dug to access the hot water. Later known as Elsinore Hot Springs and then as Lakeview Inn Hot Springs, the first bath house has since been included in the Historical Register and now houses an antique shop.

Bundy's Elsinore Hot Springs, later known as Wrenden Hot Springs, included a hotel and guest cottages supplied with warm sulfur water for drinking and bathing. By 1915, the original spring had failed and was replaced by a shallow well.

In 1926, the City of Lake Elsinore drilled two hot wells and constructed a city distribution system (fig. 3) for public consumption and to supply the mineral bath houses. These wells were each 450 ft deep and yielded 42°C (108°F) waters. Because of the high fluoride content (5 mg/l) in the thermal waters, the City constructed a separate (dual) pipeline system to carry hot mineral water in the early 1960's. By 1965 when the pipeline was completed, most of the resort owners, however, had drilled their own wells and few users were available for the pipeline system. This dual pipeline was abandoned only as recently as 1981. The two municipal wells are capable of pumping the thermal water at 500 gpm each.

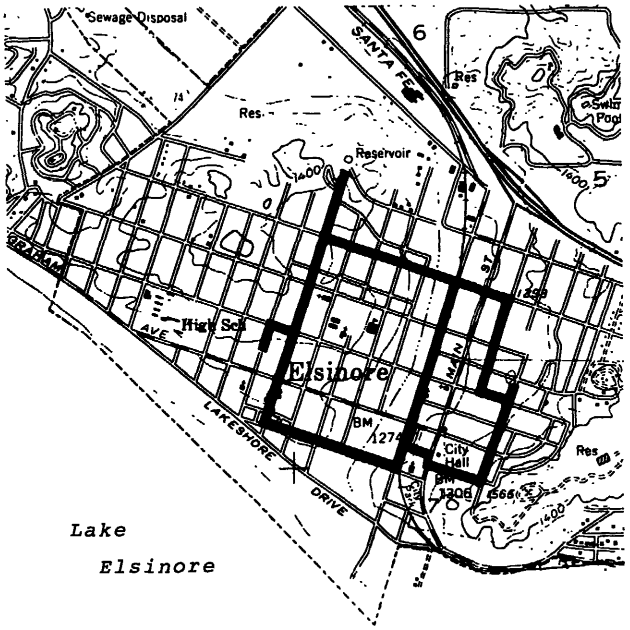

Figure 3. City of Lake Elsinore showing extent of existing dual pipeline distribution system installed in early 1960's.

Approximately eighteen lake-bottom springs have been identified in the northwest end of the lake during geophysical surveys (Harding-Lawson Associates, 1978, 1980). They are associated with faults that cross the lake bed; however, their temperature and water quality are unknown.

Well and Thermal Gradient Data

The main focus of the exploration program in Phase I has been the collection of temperature data from all accessible wells. Although 30 wells were located and 16 subsequently logged, no supporting data such as driller's logs, lithologic logs, completion records, water chemistry or pump test results were available for the majority of the wells. Additionally, most of the wells were unfortunately abandoned with submersible pumps still in place, which limited logging to the depth of the check valve in the discharge line.

Figure 4 shows temperature logs from two wells within the main zone of anomalous temperatures. The hottest well (E-29) shows an irregular gradient averaging 8.5°F/100 ft which projects to far above the mean annual air temperature, reflecting the shallow flow of thermal water in the area. Profile E-26 is from an artesian well (3 gpm), approximately 60 ft horizontally and 6 ft vertically (lower) from E-29. Comparison of the two curves suggests a 115°F aquifer at 60 to 80 ft depth, which may occur at or near the bedrock/alluvium contact. The depressed gradient between 140 and 200 ft in E-29 is probably due to slow vertical movement, with some warming of fluid within the well bore, between the artesian aquifer at 80 ft depth and another aquifer or fracture zone of lower pressure around 150 ft depth. It should be noted that E-29 is one of the few wells in use in the area, and the temperature curve may in part be affected by recent pumping, although the well had not been pumped for over 24 hours prior to logging.

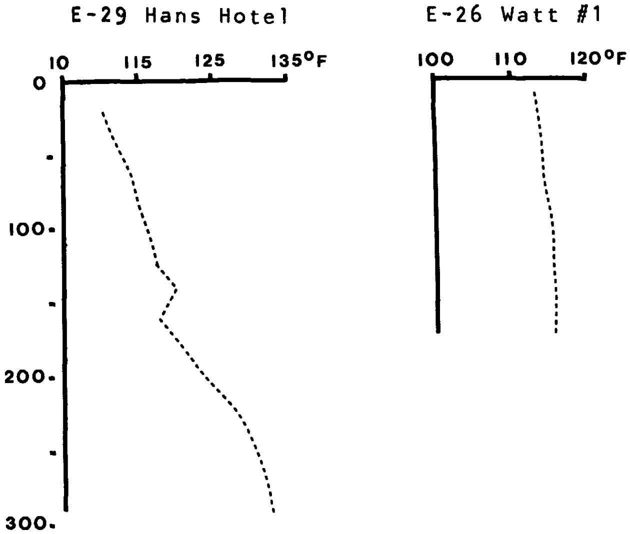

Figure 4. Temperature gradient profiles of well E-29 at Hans Hotel and well E-26, the Watt #1 well. E-29 measured at 20-ft intervals to depth of 290 ft; E-26 measured at 10-ft intervals to 170 ft.

The gradient data from various wells were used to construct a subsurface temperature profile for a vertical section (fig. 5). This profile passes through downtown Lake Elsinore and is parallel to and contained within the Channel fault zone. Well temperatures to both the east and west of this section, particularly the latter, drop off markedly. The most significant temperature distribution feature is the asymmetry of the isotherms to the north of the Watt well, which is near the site of the now defunct Lake Elsinore Hot Springs. This profile suggests that waters cool rapidly to the south from the zone of major upwelling, probably due to mixing with the cold water regime controlled by the lake. To the north lateral flow with conductive cooling may be more important.

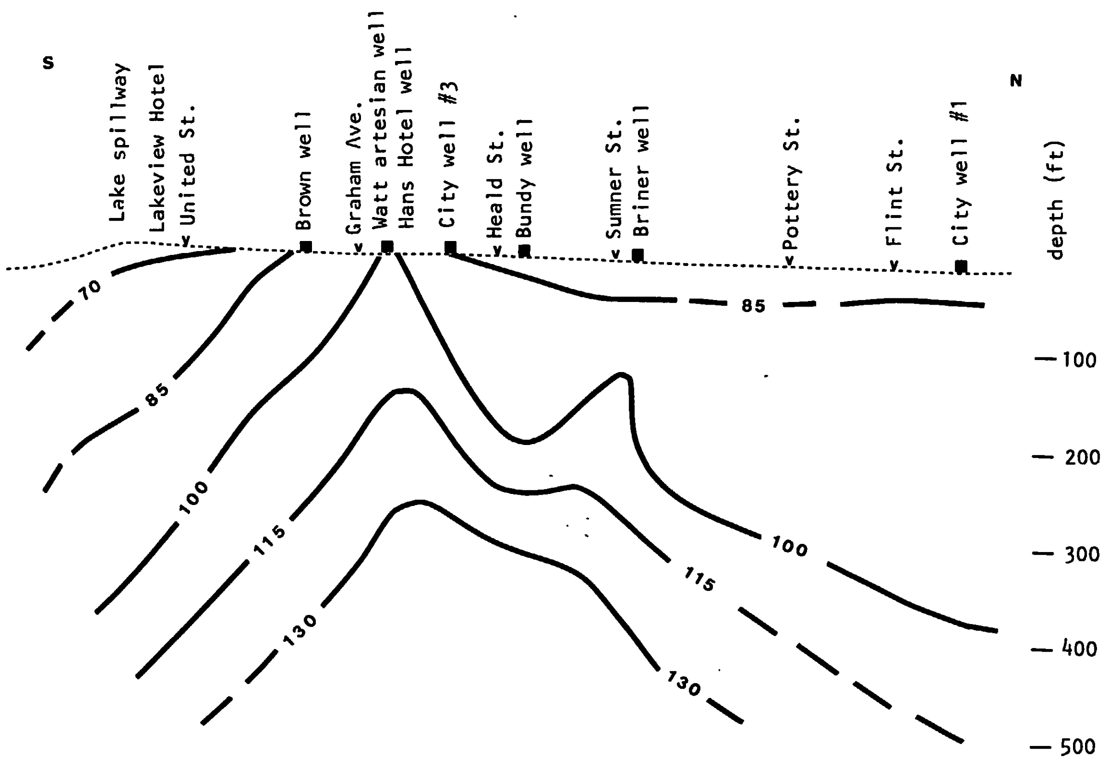

Figure 5. Subsurface temperature profile for a vertical section through downtown Lake Elsinore parallel to Main Street showing locations of wells used as control points to construct the profile.

The geometry of the isotherms probably reflects fracture/fault control with the highest near-surface temperatures occurring in the area of intersection between the lake-bounding Glen Ivy fault and the Channel fault (fig. 3). Zones of lateral flow may be localized by fracturing or contact relationships between different lithologic units. Field reconnaissance identified extensive calcite veining within siliceous dikes cutting the diorite, suggesting fracture permeability controlled by lithology.

Little geochemical data are available; however, the thermal waters are characterized by sodium as the major cation and sulphate, chloride, and bicarbonate variously proportioned, though generally greater than 20% (individually) of the total anions. Fluoride is present in all of the thermal waters in concentrations ranging from 0.3 to 6.0 ppm. Silica values are available for only a few of the waters and range from 32 to 61 ppm. TDS are generally in the range of 250 to 400 mg/l.

The main conclusion to be drawn from the water chemistry is that mixing between thermal and nonthermal waters has occurred extensively and nonuniformly. The relatively high silica values from several wells suggest a substantially hotter fluid exists at depth. The presence of significantly different water types from wells in close proximity is likely due to mixing within a complex hydrologic system involving discontinuous structural and stratigraphic conduits between the surface water regime of the lake, the cold ground water system and the upward moving thermal waters.

CONCEPTUAL GEOTHERMAL SYSTEM MODEL

The deep geothermal reservoir at Lake Elsinore is probably within fractured granodiorite at depth within the Elsinore trough, with the fine-grained sediments within the Pauba Formation possibly acting as a reservoir cap. This area has been shown by geophysical surveys to be extensively cut by high-angle faults (fig. 2). Drilling within the lake bed has revealed relatively high gradients within the upper 1800 ft of basin sediments (average 2°/100 ft).

Thermal waters from depth heated by deep circulation in a zone of high heat flow may be expected to migrate vertically through high permeability pathways such as faults and fault intersections. Within the City of Lake Elsinore, the near-surface occurrence of hot water is localized by the Channel fault, which forms a graben in the narrow zone between the Glen Ivy and North Elsinore faults. The purpose of the present study has been to delineate low risk drill sites for direct use. From this conceptual model, locations near the intersection of the Glen Ivy and Channel faults are priority in order to minimize drilling depths and maximize temperatures. Casing point and well completion decisions will require careful consideration of the complex hydrogeology.

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