GEOLOGY AND HISTORY OF EXPLORATION OF THE GEYSERS FIELD

The Geysers geothermal field is now the largest in the world with installed generating capacity of 522 mw. It is also the first geothermal field discovered in the United States (1922) and is the only steam field generating electric power in the United States. The name "Geysers" is a misnomer as there are no true geysers here, the surface emanations consisting of hot springs and fumaroles.

Location of the Geysers field is about 75 air miles nearly due north of San Francisco, in the northeastern corner of Sonoma County. The southeastern part of the field extends into Lake County. Clear Lake is about 15 miles to the northeast. The Mayacmas Mountains of the northern Coast Ranges trend northwest across the area. The hot springs and fumaroles are spread over an elongated area on the northeast side of Big Sulphur Creek which flows in a northwesterly direction. Access to the area is by two narrow, twisting roads - one from Healdsburg, on Highway 101 about 25 miles away and a northerly road from Cloverdale, also on Highway 101 about 18 miles away.

Records show that a grizzly bear hunter, Bill Elliott, was the first white man to view the spectacular sight of the Geysers in the year 1847. By 1852 a small hotel had been built in the area and became the start of the Geysers Resort. During the 19th century, the Geysers were considered one of the seven wonders of California along with Yosemite, Tahoe, the Golden Gate, etc., and were a "must" for all-of-state visitors to see. A stage coach road was built from San Francisco to service the resort and also service a number of mercury mines that were discovered and developed in this area during the 80's and 90's.

Thermal Activity at the Geysers

The area of hydrothermal alteration, hot springs, and fumaroles in the Geysers area is mainly on the northeast side of Big Sulphur Creek and extends intermittently for over 10 miles paralleling the creek. The main localities are from west to east, the Sulphur Bank area just west of Plants 5 and 6 and which can be seen from Vista Point; Geysers Canyon, the largest area of alteration and originally the most spectacular of the group; the Hot Springs Creek area 1-1/2 miles southeast of Geysers Canyon and Little Geysers which is just outside the east boundary of the map. Still farther east are Castle Rock Hot Springs in Lake County. These areas can be recognized at a distance by their white color and visible steam from the fumaroles which can best be seen early in the morning or late in the afternoon.

Surface Geology

The surface rocks exposed in the Geysers area are primarily of the Franciscan formation consisting of graywacke, interbedded shale, greenstone, and minor chert with intruded, generally concordant bodies of serpentinite, peridotite, and tectonic melanges. In general, these rocks are highly deformed, fractured and sheared, and vary in age from Late Jurassic to Upper Cretaceous. Regional dip is northeasterly. Numerous faults have been mapped, generally following the strike of the Franciscan units, northwest to southeast. Shear zones and tectonic melanges also trend in this direction.

Structurally, the Geysers is situated in a northwest-southeasterly trending Franciscan anticlinorium which forms the central core of the Coast Ranges. Several miles northeast of the Geysers, the Franciscan is in fault contact with the Great Valley sequence of Late Jurassic - Cretaceous age. In the southwest part of the mapped area around Geysers Peak, it is also in fault contact with ophiolite which McLaughlin (1975) believes is correlative with the ophiolite at the base of the Great Valley sequence in the Sacramento Valley 20 miles to the east.

The presently accepted theory of the relationship of the Franciscan to the Great Valley sequence is that they were deposited contemporaneously and that their present juxtaposition is due to underthrusting of the latter by the former along a zone of subduction during Late Cretaceous and Early Tertiary time. Late Tertiary and Quaternary folding and faulting have formed the uplift where Franciscan is now exposed on the surface.

The Franciscan topography is susceptible to landsliding as can be seen on the geologic map. Well sites are carefully selected, excavated and engineered to establish a firm foundation before drilling is begun.

At the north and northeast edge of the map, there are two young Cenozoic volcanic plugs intrusive into the Franciscan. At the most northerly point on the accompanying map is the Caldwell Pines Basalt (TQb) and at the northeast corner is the Cobb Mountains Rhyolite (Qvr). Other volcanics of similar age and younger, the Clear Lake Series of Brice (1953) including obsidian, dacite, andesite, and quartz bearing outcrop northeast of the mapped area. It is believed that the magma body responsible for the Geyser's heat is related to these volcanic rocks.

Subsurface Geology

All wells drilled in the Geysers field start in Franciscan rocks. The steam production is from fractured graywacke which is present in most of the wells drilled in field. Correlations are as difficult in the subsurface as they are on the surface and the structure equally complex. At the present time, we do not believe that structure is the controlling factor in the accumulation.

Exploration and Production History

The idea of drilling holes to utilize the steam was first conceived by a group of Santa Rosa and Healdsburg businessmen led by J. D. Grant. Luther Burbank, the famous horticulturist, was looking for a place where a large hothouse could be built in which he could conduct his plant breeding experiments. As a result, the first well was drilled in the summer of 1921 in Section 13, T11N, R9W with a cable tool outfit. It was completed the following year at a depth of 203'. Steam was encountered below 80' and increased in intensity to total depth. No accurate record of its productivity is available but it had a shut-in pressure of 62 psi. A second well, 50' away from No. 1, was drilled in 1922 to a depth of 318' and completed with the same pressure.

In 1924 and 1925, The Geysers Development Co. took over operations and drilled 5 more wells distributed over an area 550' in length immediately east of Geysers Canyon and north of Big Sulphur Creek and the resort. The deepest hole was 487'. Highest shut-in pressure recorded was 276 psi in Well #6. It was estimated that all the wells together could flow about 150,000# per hour of steam and generate about 7500 kw of electricity. Due to lack of a market, no further drilling was done. One well continued to be utilized to supply steam to the resort.

It was not until 1955 that any further drilling took place at the Geysers. Magma Power Company, headed by B. C. McCabe, obtained a lease from the Geysers Development Company and drilled its first well, Magma #1 to a depth of 817' where it was completed. Steam flow was 157,000# per hour, considerably greater than any of the earlier shallower wells.

The following year another company was formed with new capital to help Magma Power Company develop the lease. This new company, Thermal Power Company, headed by Dan McMillan, became the operator with a 50% interest. In 1957, four successful wells were drilled, the deepest 1414'.

In October 1958, a contract was entered into by The Magma Power and Thermal Power Companies with Pacific Gas and Electric Company whereby the latter would build a 12,500 kw turbine generating plant. This plant was completed and went on production in 1960. In the meantime, Thermal Power, as operator, drilled and completed 8 more wells to justify another 12,500 kw plant in the area. Thermal moved northwesterly about a mile and drilled 19 wells in the Sulphur Bank area during the period from 1961 to 1965. These wells were deeper than the first wells - many bottoming between 2000' and 4000'. Pressures were also greater with several having a shut-in pressure of 480 psi. Flow tests justified the construction of a larger generating plant than the first two and PG&E completed Plant #3 at a capacity of 27,500 kw in 1967.

In 1968, another plant of the same capacity was completed to service the rest of the Sulphur Bank wells. In the meantime, Thermal Power Company filled in the area between Sulphur Bank and shallow area with 6 wells in the Happy Jack area. Productivity ranged from poor to excellent. All were in the 3000' to 4500' depth range and pressures were comparable to the Sulphur Bank area.

In 1966, Union Oil Company, after acquiring a large block of land adjacent and north of Thermal and Magma's leases, drilled Ottoboni #1 which was completed at a depth of 5392'. In 1967, Union and Magma-Thermal entered into an agreement whereby all properties of both parties in this area would be pooled with Union as operator and 50% interest. In the summer of 1967, Union drilled the first well for the new group and up to the present time has completed 71 wells, extending the field northeasterly 2-1/2 miles, to the east 3 miles, and proving up several thousand more acres. These extensions have increased the proven potential of the field to at least 900,000 kw. PG&E in this period built Units 5 through 11, increasing the total electric power production capacity to approximately 500 mw. Total number of Union-Magma-Thermal productive wells in the Geysers field is 110 plus 5 injection wells.

Other operators in the Geysers field include Pacific Energy Corp. who has completed 13 wells south of Big Sulphur Creek in the northwest 1/4 of Section 14, T11N, R9W, and is reported to have a contract with Pacific Gas and Electric Co. for a 50,000 kw plant. Two miles east of Union's most easterly wells, Burmah Oil and Gas Co. has completed 14 wells in the Castle Rock Springs area. Pacific Gas & Electric plans to construct a 130,000 kw plant in this area. Total potentially productive wells in the field by all operators is 137 and total unproductive wells is 9.

Assuming all wells to be part of the same field, total length is over 8 miles and maximum width over 2 miles. A minimum of 6500 acres has been proven productive. Six unproductive wells to the west, north and east would seem to define the economic limits of the field in these directions.

The deepest well in the field, and until recently in the world, was drilled by Union-Magma-Thermal in Section 17, T11N, R8W, and was completed as a producer at a total depth of 9509'. Total depth of completed wells varies greatly. Average total depth of recent wells is between 7000' and 8000'.

Although some of the early wells were drilled with cable tools, modern wells are all drilled with rotary equipment. Union-Magma-Thermal's present practice is to drill through the cool, water bearing surface rocks with mud and run 13-3/8" casing to depths between 1000' and 2000'. The second stage is drilled sometimes with air, sometimes with mud down to the point where steam is expected. Casing of 9-5/8" size is then set and drilling into the steam zone is done with air in 8-1/4" hole.

Well productivity also varies greatly due to the erratic nature of the reservoir. Current wells spacing is roughly on a 40-acre basis. Price of the steam at the Geysers is based on kilowatt hours of electricity. Present price is 6.7 mills per kw/hr. A good steam well producing 100,000# per hr. will generate at 5000 kw capacity.

The Geysers field is now the largest geothermal field in the world. Like the Lardarello field in Italy, the first geothermal discovery in the world, the steam is in a vapor state in the reservoir in contrast to the more common type of geothermal field which contains hot water in the reservoir.

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May 1975

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NOTE: The geologic map of the Geysers area by R. J. McLaughlin is furnished through the courtesy of The United States Geological Survey.