GEOTHERMAL EXPLORATION AT LAS TRES VIRGENES, B.C.S., MEXICO

Aida Lopez Hernandez
Gerardo H. Garcia Estrada
J. Francisco Arellano Guadarrama

Gerencia de Proyectos Geotermoelectricos
Comision Federal de Electricidad
Alejandro Volta 655. 58290, Morelia, Mich., Mexico

Key words: geothermal system, geothermal exploration, Las Tres Virgenes, Mexico

ABSTRACT

The geothermal system of Las Tres Virgenes is related to a Plio-Quaternary volcanic complex, in an active tectonic zone associated with Gulf of California opening. Since 1984, intensive exploration studies were conducted by the Comision Federal de Electricidad of Mexico. This paper summarizes the geological, geophysical and geochemical studies, as well as the exploratory drilling results.

The hydrothermal active zone is related to the most recent igneous activity, between 0.44 Ma and present time. The youngest tectonic structures control the principal permeability zones and hydrothermal activity.

The geoelectrical methods applied, defined an interesting geothermal zone of small size, coincident with the most intensive fumarolic activity and hot soil sites. **A** broader area of secondary interest was delineated, but more detailed studies are required.

Geochemically estimated temperatures agrees well with the 266 "C measured during drill-hole evaluation. Discharged fluids are of acid-sulphate character, having quartz, calcite, chlorite, epidote and clays assemblages.

These results represent the first mexican experience in the evaluation of low permeability reservoirs contained in granitic fracturated rocks. The accumulated knowledge is a valuable guide for the design of future exploratory strategies in some similar areas, reducing the risk of failure and the exploration costs.

1. INTRODUCTION

Las Tres Virgenes geothermal field is located in the eastern coast of the Baja California peninsula, 34 km NW of the city of Santa Rosalia (Fig. 1). The Comision Federal de Electricidad (CFE) of Mexico conducted several exploratory stages, each ending with the drilling of an exploratory well. These stages comprise geological studies (Lira, et al.. 1984; Vargas y Garduiio, 1988; Garduiio and Lopez, 1988; Lopez et al., 1989; Lopez et al., 1993), geohydrology (Vargas, 1988; CFE, 1993), geophysics (Ballina and Herrera, 1984; Bigurra, 1989; Herrera et al., 1989; CICESE-CFE, 1992 and 1993; Garcia, 1993), geochemistry (Quijano, 1984; Gutierrez y Lopez, 1984; Tello, 1988), and petrography (Gutierrez, 1990; Viggiano, 1992), that represent a continuous increase in the knowledge of the zone.

Available results suggest that there exist fluids of meteoric origin interacting with geothermal waters at temperatures over 260 °C, however, the productivity indexes are low because of the low permeability of the rocks hosting the reservoir.

In spite of this limitation, the efforts of the CFE to locate higher permeability zones are justified, because this is a developing region in which the lack of conventional resources, makes the geothermal generation not only the cheapest but the unique viable alternative in the short term.

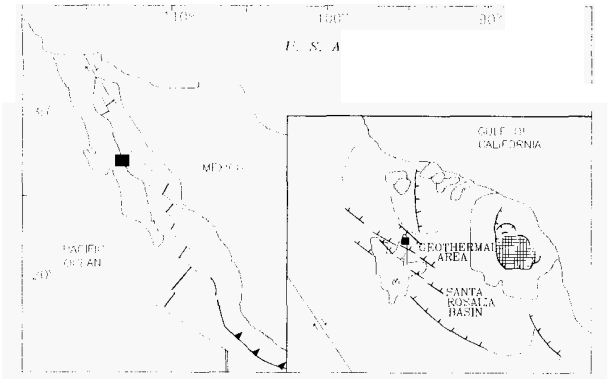


FIG 1.–LOCATION MAP OF LAS TRES VIRGENES, GEOTHERMAL AREA

2. REGIONAL GEOLOGY

Las Tres Virgenes geothermal system (LTV) is located in a Plio-Quaternary depression of NW-SE trend, the Santa Rosalia basin, that constitutes the western limit of a deformation zone related to Gulf of California opening.

The western border of the basin is occupied by a system of big normal faults trending NW-SE. This system originated a series of steps, falling to the NE, that controlled the distribution of the marine sediments deposits (Fig. 2). The intersection of this system with a more recent N-S faulting trend, permitted the magma trapping that gave rise to the formation of three eruptive centers. They are from the oldest to the youngest, La Reforma caldera, the Sierra de Aguajito. and the Las Tres Virgenes complex.

The presently active thermal zone exhibits a clearcut structural control. **It** is located in the northern limit of the youngest volcanic center (Las Tres Virgenes, dated 0.44 Ma)

3. LOCAL SETTING

From a geological and volcanological point of view, the area was described partially by Demant et al., (1981); and Sawlan, (1986). Afterwards, starting at 1984, the CFE conducted several studies with a geothermal approach. Two simplified regional and local geological maps are shown in figures (2 and 3).

The lithologic sequence of the pre- Plio-Quaternary volcanic activity was confirmed with the drilling of two boreholes in the geothermal zone. The oldest lithologic unit, found at 900 - 1000 m depth, is a granodiorite of 91-84 Ma, relatable to the great Baja California batholith. It is overlayed by a volcano-sedimentary sequence known as Comondu Group, having a maximum observed thickness of 750 m. It has an age that spans from the Upper Oligocene to Medium Miocene and was affected by Upper Miocene normal faulting.

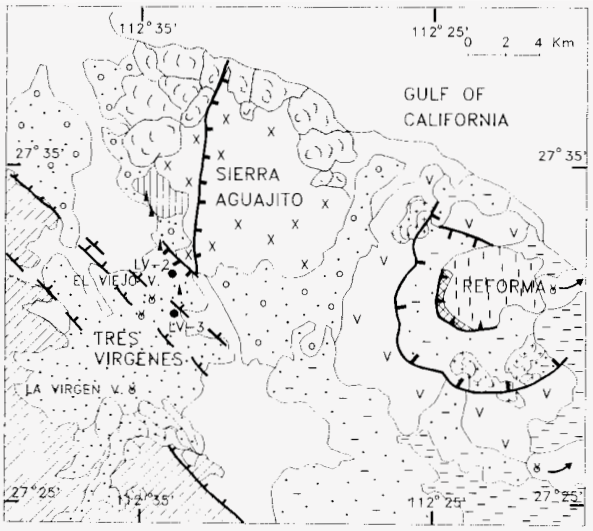


FIG. 2.– SIMPLIFIED GEOLOGY OF THE LAS TRES VIRGENES AREA

COMONDU GROUP; SANTA ROSALIA BASIN DEPOSITS; REFORMA CORE; REFORMA IGNIMBRITE; REFORMA ANDESITE; REFORMA RHYOLITIC DOMES; AGUAJITO DACITE; AGUAJITO ANDESITE; AGUAJITO IGNIMBRITE; AGUAJITO RHYOLITIC DOMES; TRES VIRGENES VOLCANISM; ALLUVIAL DEPOSITS; GRANODIORITE; ALKALIC VOLCANISM; MAIN NORMAL FAULT; CALDERIC COLAPSE; THERMAL MANIFESTATION; VOLCANIC CENTER; RESURGENT DOME; DRILL HOLE.

Overlaying the Comodu Group, there are shallow marine deposits, corresponding to the Santa Rosalia Basin, having a distribution limited to the W by the Main Gulf Escarpment. Its maximum thickness is 300 m (Wilson, 1948), with ages from Upper Miocene to Lower Quaternary age. The upper section of these deposits shows an intercalation of volcanic rocks, that indicates the beginning of the volcanic activity in La Reforma and Aguajito. Field evidences suggest that these volcanic centers acted as volcanic islands (Lopez, et al., 1993). Its outstanding characteristics described in chronological order are the following:

La Reforma is a resurgent calderic structure of 10 km diameter, related to three main pyroclastic events. The magmatism, of bimodal character (basaltic - rhyolitic) has ages from 3.5 to 0.8 Ma (Lopez, et al. 1989).

The Sierra de Aguajito is formed by a great volcanic dacitic edifice of Pliocene age, with a 8 km diameter. Its northern border is crowned by a semicircular lineament of rhyolitic domes, preceded by the emission of a small pyroclastic flow. The eruptive activity elapsed from 0.7 to 0.45 Ma (Lopez, et al. 1993).

The third eruptive center named Las Tres Virgenes, is constituted by three composite volcanoes aligned N-S showing progressively younger ages to the south. The oldest (El Viejo volcano) has an age of 0.44 Ma, and the southern most (Las Tres Virgenes) is still active. The chemical composition of their products is mainly dacitic in the north but shows an increasingly complexity to the south, where products covering the whole range from basaltic to rhyolitic are found.

Chemically, the three volcanic complexes correspond to the calco-alkaline series, excepting an alkaline rich pyroclastic flow and basltic cones at La Reforma, which are marginally peralkaline (Sawlan, 1986).

According to our data, the main thermal activity at present, is related with the Tres Virgenes complex, and a secondary importance zone could be associated with the volcanic activity of Aguajito.

Structurally, this zone was affected to the end of the Miocene by an initially extensive deformational stage, producing a set of Basin and Range-style normal faults and tilted blocks. They were reactivated later by a right-lateral transcurrent movements. During the Quaternary the stress direction was modified. The minimum stress changed from NE-SW to E-W, producing transtensional faulting of N-S direction. The maximum density of faulting at surface is observed around the hydrothermal zone, showing a strong lateral component. The preferential directions are NW-SE, **N-S** and NE-SW (Lopez, et al., 1993).

The main trend that controls the active hydrothermalism is the NW-SE generically named as Las Viboras system (Fig. 3).

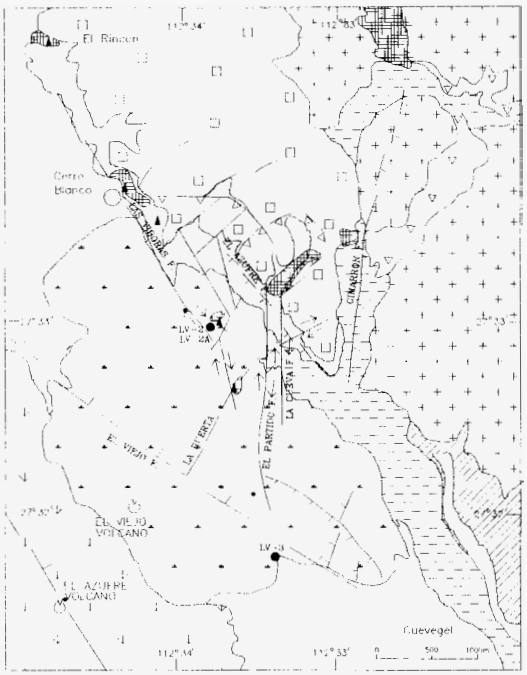


FIG. 3.– LOCAL GEOLOGY OF LAS TRES VIRGENES GEOTHERMAL AREA

Aguajito basal andesite; Aguajito dacite; Basin deposits and Reforma+Aguajito ignimbrites; Aguajito andesite; El Viejo dacite; alluvial fan deposits; El Azufre dacite; Aguajito pyroclastic flow deposits; alluvial deposits; active thermal manifestation area; drill hole; normal fault; infered normal fault; oblique fault; fracture; alteration zone; landslide; volcanic center

4. EXPLORATION METHODS

From the beginning of the exploration in 1984, our knowledge of the zone has increased progressively, thanks to successive studies. The expectatives, based on the ground studies, of finding high temperatures at depth, have been confirmed by the exploratory drilling.

Aside the geological studies described in the previous paragraphs, the preliminary studies included the following:

4.1 Hydrology Studies

The climate in the region is extremely arid, the average annual rain fall is lower than 150 mm/year (Vargas, 1988). The geothermal system is located in the limit of the basins El Azufre, to the NW, El Yaqui, to the SE, and the Coastal Zone to the NE (CFE, 1993). Owing to the low density population in the zone, there are few hydraulic exploitation data to determine the direction of the underground flow. However, it is estimated that the recharge comes from the NE, from the higher levels of the Sierra Aguajito, and the north face of the El Azufre volcano, and flows along the El Azufre canyon, in the limit between Sierra Aguajito and Las Tres Virgenes.

Water samples collected in this zone can be grouped in four sets: calcic-magnesium-sulphate-clorhide;sodium-sulphate: sodium-clorhide and bicarbonate-calcic.

It was concluded that the recharge to the deep aquifer is slow, and to reach its present conditions has taken a long time, because the low precipitations and very high evaporation.

4.2 Radon Detection

A total of 46 stations were analyzed. Located in the most active hydrothermal areas, they established a hierarchical order of the studied areas, according the number of tracks measured in each one. The two most important zones are: Las Viboras and El Rincon, the former, covering the actual location of the LV-2 and LV-2A boreholes, confirms that it is the most permeable zone, allowing the radon to escape to the surface (Gutierrez y Lopez, 1984).

4.3 Geophysics

The CFE has conducted several geophysical projects, including: gravity, magnetics, DC resistivity, magnetotellurics (MT) and recently a passive seismic monitoring.

Gravity Method

This study covered 389 gravity stations, measured in 1984 (Ballina y Herrera, 1984). Recently, a data reinterpretation was conducted (Garcia, 1993), including a two dimensional analysis of the gravity effects of topography. The later study shows the presence of buried regional faults trending NW-SE and NE-SW, in agreement with the geological studies (Lopez et al., 1993).

The thermal manifestations zone is located in the border of a local gravity high, limited by a NW-SE feature that corresponds to the El Azufre fault (Fig. 4). The numerical modeling suggest that the topographic undulations of the granodioritic basement, have not a dominant effect over the Bouguer anomaly map, that in addition seems to have an important isostatic component. However, the gravity anomaly shows a dominant effect of the shallow volcanic masses, effect that is emphasized by the data reduction process.

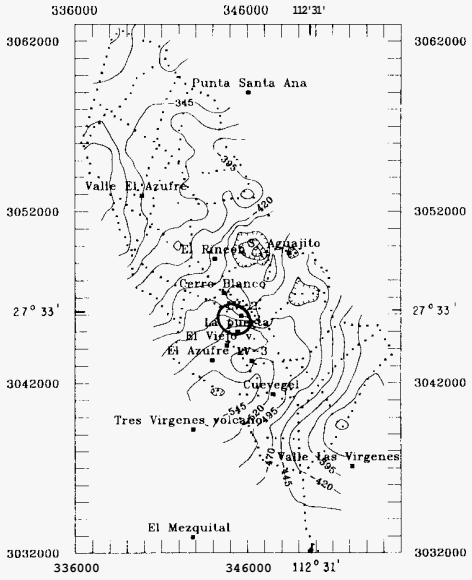


Figure 4.– Bouguer anomaly with density 2.6 g/cm^3 the points indicate the field data location. The contours are given in gravity units. Thermal manifestation zone.

Magnetic method

The magnetic study began with data collection in the same stations of the gravity survey. Generally, there is a clear relation between the magnetic anomalies and the volcanic rocks forming the superficial cover. However data processing let us to identify strong NW-SE and NE-SW trends, that converge in the immediate vicinity of the LV-2 borehole (Fig. *5)* (Garcia, 1993). The most striking high frequency anomalies does not reflect the buried shape of the granodioritic basement, but can be related with fault and fractures in younger units as mapped by geologists.

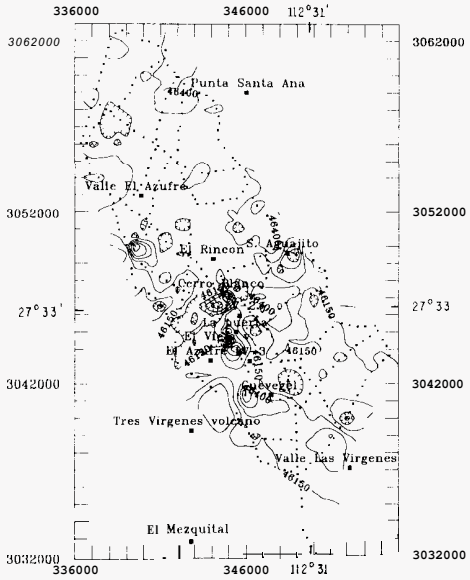


Figure 5 – Total magnetic field in nT (gammas) The points indicate the field data location.

Resistivity Method

This method was used to identify the minimum resistivity zones, that could be related with the presence of the reservoir. This study comprises 62 DC vertical soundings (Schlumberger), covering 120 km^2 in the limit between Sierra Aguajito and Las Tres Virgenes. Their results lets us to identify the three most interesting zones, as the regions surrounded by anomalies with resistivity values lower than 10 ohm-m. They are: Cerro Blanco, Las Viboras-La Puerta and Cuevegel (Fig. ***6)*** (Bigurra, 1989).

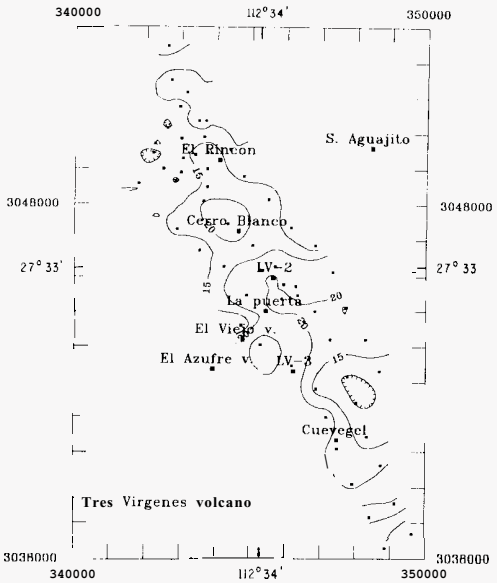


Figure 6. Apparent resistivity, AB/2=2500 m, the points indicate the field data location.

Regionally, minimum resistivities are aligned along the NW-SE El Azufre canyon, between Sierra de Aguajito and Las Tres Virgenes complex, reflecting the regional tectonic control of the hydrothermal altered zones.

Magnetotelluric Method

This study was conducted in order to confirm the interpretation of the DC soundings in relation with the deepest minimum resistivities, because they could be the most promising anomalies (Fig. 7) (CICESE-CFE, 1992). The study covered 20 soundings distributed in an area of 50 km², including the thermal manifestation zones and the location of the LV-2, LV-2A and LV-3 boreholes.

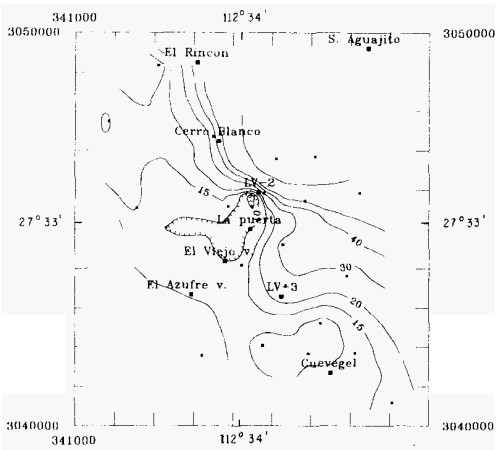


Figure 7.- Magnetotelluric apparent resistivity, mode TM with frequency 0.1 Hz. Contours in Ohm.m. The points indicate the field data.

Results indicate that there are two maximum interest zones, one of them located at Cuevegel, and the second one to the south of LV-2 borehole. Comparison between the MT and DC results, shows that generally, there is a good agreement in the minimum resistivity locations, but their lateral coverage is always smaller in the DC study.

At present, the CFE conducts a more extense MT study, including TDM soundings for the static correction.

Seismic Method

Starting in 1993, CFE conducted **14** months of seismic monitoring of Las Tres Virgenes and surroundings, with a 6 digital stations net (three component Spregnether seismometers). At present 50 % of the information has been analyzed by contract (CICESE-CFE, 1993) and currently a comprehensive interpretation is underway (CSMA). The zone has an intense seismic activity of magmatic and tectonic type, and volcanic tremors. The density of magmatic type events is maximum under the El Azufre volcano, and scarce under the Las Tres Virgenes volcano. The epicentral depths ranges from 3 to 5 km, and the Richter magnitudes are always less than 3.

The grouping of events of tectonic origin, defines two zones in the vertical sense, the shallower is located between 3 and 5 km, and the second between 8 and 12 km depth. Their magnitude ranges from 3 to 5 km in the Richter scale. They are located mainly to the SE of La Virgen volcano, and to the NW and SE of El Azufre volcano, along the La Cuesta fault (Fig. 8).

From the geothermal point of view, the main conclusion is the existence of intense seismic activity, reflecting the presence of a magmatic chamber, that seems to be shallower under the El Azufre volcano and that can he considered as the heat source of the hydrothermal system.

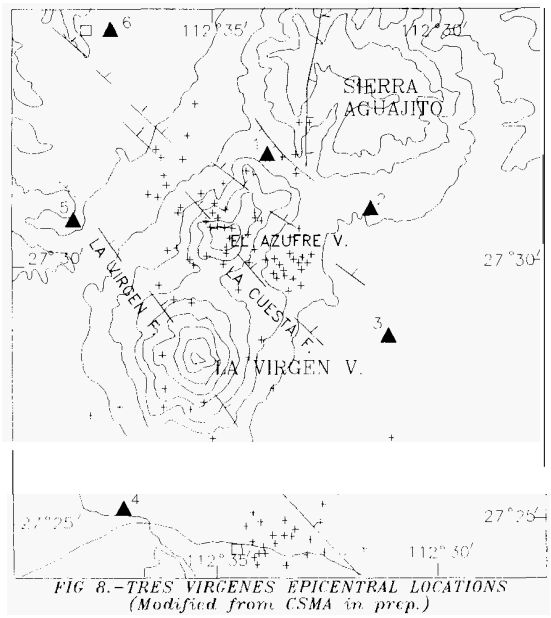


FIG 8.-TRES VIRGENES EPICENTRAL LOCATIONS (Modified from CSMA in prep.)

5. ENVIRONMENTAL STUDIES

The Las Tres Virgenes geothermal zone pertains to the Ecological Reserve of Desierto de Vizcaino, singular region highly protected by the mexican government because its character of ecologic island, due to their environmental factors, and the presence of unique endemic species, and species in danger of extinction as the wild sheep (Antilocapra Americana Peninsularis and Ovis Canadiensis).

Because of the ecological restrictions, and with the aim of preserving its biological wealth, the CFE contracted the execution of a species inventory, in order to control the potential damages to the environment . Additionally a complete strategy to minimize the ecological disturb produced by the exploration and exploitation of the geothermal resources was proposed (CFE, 1990a, 1990b).

6. HYDROTHERMAL SYSTEM

Physically, the known hydrothermal system is located over the oldest volcano of the Las Tres Virgenes complex. The alteration zones can be observed along faults and fractures, trending mainly NW-SE, as well as in the intersections of different structural trends. The higher topographic elevations present fumaroles and steaming grounds, and in the lower levels there are small flow hot springs.

Two main areas of hydrothermal alteration can be identified: El Azufre - Las Viboras, and El Rincon - Agua Agria (Fig. 3). The former presents the most intense alteration zone, still active. At surface the deposits consist of silica and kaolin assemblages produced in a two phase zone with vapor predominance above the clorhide water level, at temperatures between 80 and 200 °C (Viggiano, submitted).

At present three boreholes were drilled: LV-2, LV-2A and LV-3, of 1142m, 1300m and 2150m depth, respectively. The hydrothermal alteration assemblages identified from cuttings include quartz, calcite, chlorite, zeolite, clay minerals, epidote, pyrite, and scarce anhydrite (Gutierrez, 1990). Total alteration does not exceed 50 % of the volume of the rocks. Generally, these minerals are found replacing the primary mineralogy and occasionally filling veins, suggesting that the secondary permeability is low (Viggiano, 1992).

The hydrothermal fluids have an acid-sulphate character. Gas geothermometry suggests the presence at depth of temperatures up to 275 "C (Quijano, 1984). Isotopic analysis show that the fluids

are of meteoric origin, but have interacted with geothermal origin waters (Tello, **1988).**

By the moment, the three boreholes data are not enough to determine the size of the reservoir, however, in the vertical direction, it is possible to confirm that the exploitable fluids are principally hosted in fractured zones of the granodioritic basement and in the base of the Comondu Group as well as in smaller quantity, in lithological contact zones.

7. THERMAL LOGS

There are many thermal logs collected during the drilling of LV-2, LV-2A and LV-3 boreholes (Fig. 9). Their qualitative interpretation suggest that the first two are located in a zone in which the hydrothermalism is shallower, appearing in the lithologic units of marine sediments and the top of the Comondu Group, specially between 300 and 700 m depth. Under these zones, the Comondu Group and the granodioritic basement present a mainly conductive heat transfer, but with small convective portions near the contact.

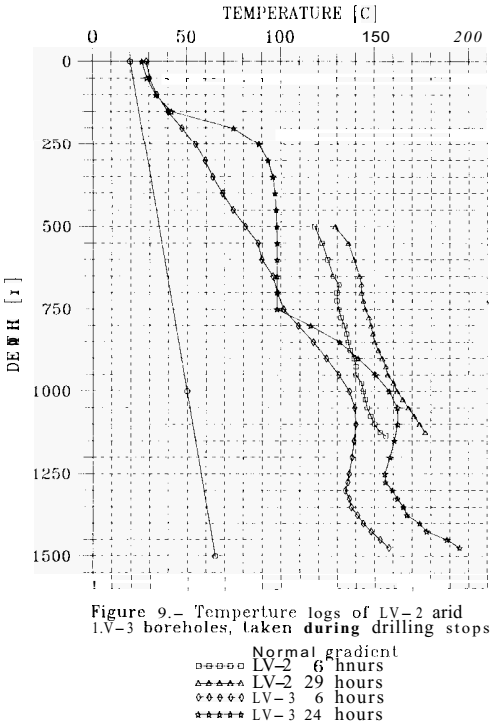


Figure 9.- Temperture logs of LV-2 arid LV-3 boreholes, taken during drilling stops

In comparison with the LV-2, the LV-3 borehole has lower temperatures at the same depths, suggesting that the hydrothermalism is deeper because of the lacking of secondary permeability. This produces the appearance of higher average gradients than in the LV-2. However, near the contact between the Comondu Group and the granodioritic basement, there are strong evidences of convection, that affects a hundred of meters near the contact, and diminishes but does not disappear toward the bottom of the hole.

At the bottom of the LV-3, there is a predominant conductive heat transfer with a thermal gradient of **5** times the world wide average, and temperatures of 266 °C. In the LV-2, the basement does not present evidences of convection in the formation, its gradient is only about 3 times the world average, and the maximum static temperature measured is about 180 "C. Because of these results, at present it is considered that the LV-2 borehole is farthest from the heat source, but the hydrothermalism is more intense because of the existence of higher shallow permeability.

8. CONCLUSIONS

The studies conducted at Las Tres Virgenes geothermal zone demonstrate conditions of temperature, recharge, and permeability, corresponding to a hydrothermal system underground, which has the following general model (Fig. 10).

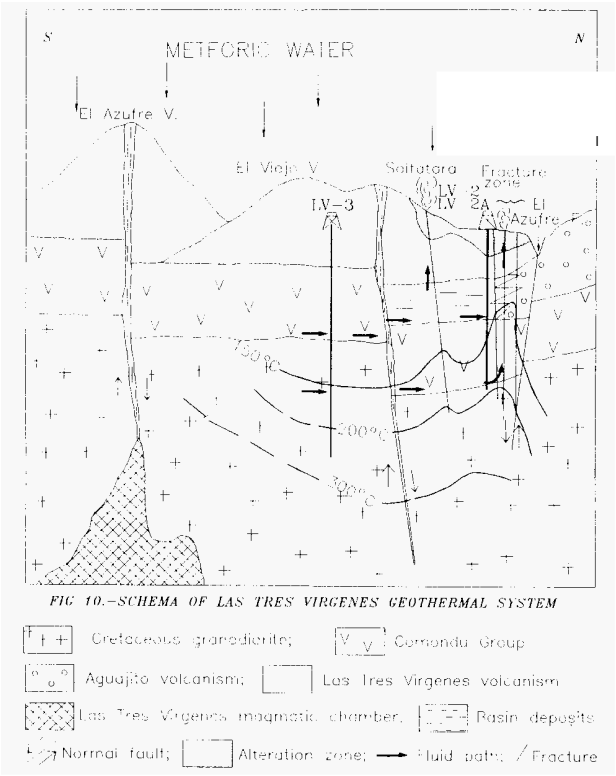


FIG 10.-SCHEMA OF LAS TRES VIRGENES GEOTHERMAL SYSTEM

The heat source is a magmatic chamber that fed the volcanic complex of Las Tres Virgenes. Its top is shallower under the El Azufre volcano where it has a depth of **5** - 6 km under the terrain.

The recharge is scarce, related to the infiltration of meteoric water. The transport fluids are hosted mainly in the fracturing zones near the LV-2 borehole at depths around 1500 m.

According to recent well data, it seems that the fluids at the LV-2 are a lateral discharge coming from a deeper zone under the El Azufre volcano. The fluid movement occurs initially through the lithologic contact between the granodioritic basement and the Comondu Group, afterwards the fluid moves to the north and reach shallower levels because of the existence of faulting in that zone.

Our present knowledge indicates that the geothermal reservoir is of small size and has limited fluid recharge.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the support of Dr. Gerardo Hiriart, Manager of the geothermal branch of the Comision Federal de Electricidad de Mexico, and Ing. Saul Venegas, chief of the Departamento de Exploracion, for the preparation of this paper.

REFERENCES

Ballina L.,H.R. y Herrera B.,F., **(1984).** ***Estudio geofisico de la zona geotermica de Tres Virgenes, B.C.S.,*** Com. Fed. Elec., Mex.,G.P.G., internal report 20184, 28p.

Bigurra P., (1989). *Integracion de estudios geofisicos en la zona geotermica de Las Tres Virgenes, B.C.S.,* CFE. G.P.G. Informe 20-84, internal report, 22pp.

CICESE-CFE, (1992). *Evaluacion con metodos electromagneticos del campo geotermico de Tres Virgenes, B.C.S.,* C.F.E.-G.P.G., internal report:
Contrato: CLS-GPG-3010/92, 23p.

CICESE-CFE, (1993). *Analisis e interpretacion de la informacion sismica digital registrada en el campo geotermico de Tres Virgenes, B.C.S. en el periodo febrero-mayo de 1993.* Contrato No. CLS-GPG-3013/93. Internal report.

CFE, (1993). *Informefinal del sistema hidrogeologico regional de la zona geotermica de Las Tres Virgenes, B.C.S.*, C.F.E.-G.P.G. Contrato: CLS-GPG-3001/92, internal report: OGL/TV/001/93, 82p.

CFE, (1990a). *Caracterizacion de la vegetacion del complejo volcanico de Las Tres Virgenes, B.C.S.,* internal report, G.P.G., 98pp.

CFE, (1990b). *Estudio faunistico de la zona geotermira de Las Tres Virgenes, B.C.S.,* internal report, G.P.G., 43 pp.

CSMA, Assts. Ltd. (in prep.). *Tres Virgenes Earthquake Location Analysis-Summary.* Cornwall, United Kingdom, C:F.E., internal report.

Demant, A., (1981). Plio-quaternary volcanism of Santa Rosalia area, Baja California, Mexico. In: *Geology of northern Mexico and southern Arizona, field guides and papers,* Ortlieb, L. and Roldan, J. (Eds.): 295-307.

Garcia E., G.H., (1993). *Interpretacion magnetometrica y gravimetrira de la zona geotermica de Tres Virgenes, B.C.S.,* C.F.E.-G.P.G., internal report: OGF/TV/001-93, 25p.

Garduño M., V.H. y Lopez H., A., (1988). *Estudio geologico geotermico de la caldera de Aguajito, B.C.S.*, internal report: 26/88, C.F.E., G.P.G. 23 pp.

Gutierrez N., L.C. y Lopez M., A., (1984). *Emanometria de radon en la zona geotermica de Las Tres Virgenes, B.C.S.,* C.F.E.-G.P.G., internal report: 12/84, 12p.

Gutierrez N., L.C.A., (1990). Litologia, mineralogia y geotermometria del pozo LV-2, Las Virgenes, B.C.S., *Geotermia.* Vol. 6 No. 2, p. 185-201.

Herrera B., Alatorre, M.A. y Bigurra P., E., (1989). *Estudio geofisico de Tres Virgenes, B.C.S.,* C.F.E., G.P.G., internal report: GF 2/89. 13 pp.

Lira H.. H., Ramirez S., G., Herrera F., J. y Vargas L., H., (1984). Estudio geologico de la zona geotermica de Las Tres Virgenes, B.C,S., Mexico: in Malpica C., Celis G., S., Guerrero G., J., y Ortlieb, L. (Eds.). *Neotectonics and sea level variations in the Gulf of California area, a symposium. INQUA-UNAM.* 165-178 p.

Lopez H., A., Robin, C., Cantagrel, J.M. y Vincent, P., (1989). *Estudio geoquimico, mineralogico y edades radiometricas de la zona de Las Tres Virgenes, B.C.S. Implicaciones geotermicas.* C.F.E.-G.P.G.,internal report: 5/89, 50p.

Lopez H., A., Casarrubias U., Z. y Leal H. R., (1993). *Estudio geologico regional de la zona geotermica de Las Tres Virgenes, B.C.S.*, C.F.E.-G.P.G., internal report: OGL/BC/002/93, 39p.

Quijano L., J.L., (1984). *Geoquimica de gases de la zona geotermica de Las Tres Virgenes, B.C.S.*, C.F.E.-G.P.G., internal report: 02-84, 4p.

Sawlan, M.G., (1986). *Petrogenesis of Late Cenozoic volcanic rocksform Baja California Sur, Mexico:* PhD thesis, University of California. Santa Cruz, 174p.

Tello H., E., (1988). *Hidrogeoquimica de la zona geotermica de Las Tres Virgenes, B.C.S.,* C.F.E.-G.P.G., internal report: 9/88, 1Ip.

Vargas L., H., (1988). *Estudio geohidrologico de Las Tres Virgenes, B.C.S.,* C.F.E.-G.P.G., internal report: 14/88, 62p.

Vargas L., H. y Garduiio M., V.H., (1988). *Estudio geologico-geotermico de Aguajito, B.C.S.,* C.F.E., G.P.G., internal report: 18-88, 41 pp.

Viggiano G., J.C., (1992). El pozo desviado L-2A, Las tres Virgenes, B.C.S.: Petrologia e interpretacion. *Geotermia,* vol. 8, No. 3, 373-394.

Viggiano G., J.C., (submitted). Evolucion termica del sistema geotermico de Las Tres Virgenes, B.C.S.: un estudio hecho en base a petrografia. *Geotermia.*

Wilson, I. F., (1948). Topografia sepultada, estructuras iniciales y sedimentacion en la region de Santa Rosalia, B.C.S. *Univ. Nal. Auton. Mexico, Inst. Geol. Geof. Geod., Bol.* 53, 78 pp.