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Geothermal and Related Volcanological and Tectonic Research in Mexico

PRESENTATION

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Mexico has a large geothermal potential on the continental mainland as well as offshore. The installed capacity for power generation from high-enthalpy hydrothermal systems amounts at present to 700 MWe. One of the two most important geothermal provinces is associated with the junction of the continental Gulf of California spreading system with the San Andreas transform-fault system. The other is associated with the Trans-Mexican Volcanic Belt (TMVB). The TMVB crosses Mexico approximately between 19° and 21° north latitude. It comprises most of the historic and present-day volcanic activity in Mexico: dacitic-andesitic strato-volcanoes, cinder-cone fields, isolated occurrences of rhyolitic volcanism, and major silicic centers. A large geothermal potential is closely related to this volcanic activity. Indeed the TMVB contains most of the developed or promising hydrothermal areas: Los Humeros, Los Azufres, Araro, Ixtlán de Los Hervores-Los Negritos, La Soledad, La Primavera and El Ceboruco. The well-known geothermal field of Cerro Prieto is located in the Baja California province.

This collection of articles deals mainly with the TMVB geothermal province. We believe that this collection of papers is fairly complete.The broad spectrum of different scientific disciplines and of the concerns of the geothermal community is well represented. Some papers are good examples of cooperation between the Mexican geothermal industry and the academic community. Some are of an interdisciplinary nature, others represent tasks being addressed in the exploration and development of a given geothermal field. Some papers are contributions of Mexican geothermal industry to the knowledge of the geology of the TMVB. Contributions of university and academic research programs to the better understanding of the origin and evolution of the geothermal areas are also included.

In the first paper, Campos-Enríquez surveys geothermy in Mexico, as applied to power generation. He describes the state of the art of the geophysical methods applied to the exploration and development of the geothermal energy in Mexico, as well as the geothermal potential of Mexico. In this introductory paper a brief description is also made of the cooperation between universities and research institutes and the agency responsible for generating and distributing electric power in Mexico (Comisión Federal de Electricidad, CFE).

The second paper, by Urrutia-Fucugauchi, reports preliminary results of a geoelectrical survey conducted in a geothermal system where the heat source may be of a radiogenic nature (heat generated by radioactive decay): the Jantetelco granodioritic intrusives of the Atotonilco-Jonacatepec region. This study represents an effort towards developing other than conventional high-enthalpy geothermal systems. Earlier studies by Campos-Enríquez *et al.* (1991) and Campos-Enríquez *et al.* (1991) had made a first estimation of the heat-dry-rock geothermal energy in the western part of the TMVB. Pioneering work in estimating the geothermal resources located in the sea (Mercado, 1991) is also available.

The two following papers are examples of exploration studies in conventional high-enthalpy geothermal systems (convective hydrothermal type). Both concern the geothermal field associated with the Quaternary rhyolitic caldera of La Primavera, located in the western portion of the TMVB. Maciel-Flores and Rosas-Elguera present the geology, hydrogeology, and fluid chemistry. They discuss the parameters used to establish limits, geometry and main characteristics of the geothermal reservoir and they infer a potential of 100 MWe during a 17 year period.

Alatorre-Zamora and Campos-Enríquez focus on some questions related to development and commercial exploitation of a geothermal field. They infer the subsurface structure of the caldera from gravity data. A geological frame for the hydrogeological conceptual model is presented with some geohydrogeological considerations. The structural information is also useful for selecting sites for reinjection of geothermal brines: an important concern for the protection of the environment, and for understanding the thermodynamics of the geothermal reservoir itself. The inferred structure is an interesting contribution to the question of the origin of calderas (see also Arredondo-Fragoso and Campos-Enríquez, 1992).

The next two papers are further examples of studies conducted in conventional high-enthalpy geothermal systems. They concern the geothermal field of Los Humeros, in the eastern part of the TMVB. Tello-Hinojosa reports results from a geochemical study to estimate the chemical composition of the liquid phase at reservoir conditions and at full discharge. He concludes that well H-1 is producing in a mainly liquid zone, while all other wells may be producing in a two-phase zone as well. Ascencio-Cendejas analizes the effects of the reinjection of geothermal brine. He concludes that reinjection in well H-28 at a rate of 90 ton/h does not affect the thermodynamic state of the reservoir.

Ronquillo reports a case history of seismic tomography to establish suitability of the area for siting a power plant. This study is typical of others conducted in the geothermal industry (see for example, Días-Molinarí, 1987).

The last group of papers are examples of the interaction between the geothermal industry and the academic research community -a trend we wish to commend. The first pair of papers represent contributions by the geothermal industry to the knowledge of the geology of the TMVB. On a local scale, Castillo-Hernández and de La Cruz-Martínez report a structural and volcanological study of the geothermal area of San Pedro Lagunillas Dome (Nayarit State, westernmost portion of the TMVB). A Plio-Quaternary calderic structure was identified. On a regional scale, Garduño-Monroy and Gutiérrez-Negrín present a study concerning the magmatic and tectonic evolution of the Sierra Madre Occidental and the TMVB. They propose the existence of three volcanic hiatus during the last 40 Ma and relate them with the known tectonic evolution of Mexico.

The two following papers represent contributions of the academic research community to the better understanding of geothermal areas. Rosas-Elguera and Urrutia-Fucugauchi report preliminary results of a magneto-stratigraphic study conducted in the volcanic formations of the geothermal zone of Ixtlán de Los Hervores-Los Negritos (Michoacán State). This study is supported by K-Ar radiometric dating. The volcanic activity spans from chron 8 (late Miocene) to the Brunhes chron (Recent). The Reunion normal-polarity subchrons (2.01-2.04 and 2.12-2.14) might be present as well. The other paper, by Urrutia-Fucugauchi and Molina-Garza, reports a study of magnetic properties and petrofabric of Tertiary volcanic rocks in the Arandas-Atotonilco area (Jalisco State, western TMVB).

The last three articles report studies from research fields close related to geothermics: volcanology and tectonics.

The first of these papers by M. Ban and *et al.*, presents a K-Ar dating study of shield volcanoes from the Michoacán-Guanajuato volcanic field. The paper concentrates on the temporal pattern of volcanic activity as recorded by the shield volcanoes in the field. The K-Ar dates cover the range from 0.06 Ma to 2.27 Ma, with those in the north being older than those in the south. In the northern sector, the shield volcanoes and cinder cones display similar age relationship. They suggest that volcanic activity has migrated southwards across the volcanic field during the past 2 Ma.

The two last papers are of a tectonic nature. First Serpa *et al.*, present a geophysical study of the southern sector of the Colima graben, western Mexico. They conclude from ground magnetics and gravity surveys that little or no tectonic extension has affected the area and that features previously interpreted as evidence of regional tension correspond to erosional landforms related to older deformation events. Further, their gravity models do not support the presence of a graben structure in the area around the Colima volcanic complex and towards the Pacific coast.

In the last paper Urrutia-Fucugauchi and Molina report results of a regional gravity study in western Mexico and discuss implications of the gravity models for the crustal and upper mantle structure of the Guerrero terrane. The Guerrero terrane is of a composite nature and represents the largest terrane distinguished in Mexico. They conclude that the crust is of a continental character, with a lower crust of metamorphic or igneous nature. Two-dimensional models are compatible with a low-to-intermediate density layer at the base of the crust which may be related to uplift of the volcanic plateau. This process incorporates a high thermal regime associated with low angle fast subduction of a very young lithospheric plate beneath western Mexico.

Paleomagnetism and magnetotellurics (see for example, Martínez *et al.*, 1984) have made a systematic cooperation between the geothermal industry and the academic research community possible. Paleomagnetic studies have been conducted in several geothermal fields: Los Azufres, Los Humeros, La Primavera, Ixtlán de Los Hervores-Los Negritos. The systematic application of paleomagnetism to the solution of problems in the geothermal industry is unique (Urrutia-Fucugauchi and Campos-Enríquez, submitted). Magnetotellurics has also been used systematically in geothermal exploration, in the frame of cooperative agreements. These studies are being conducted by the Geophysical Institute of the National University and by CICESE (Center for Scientific Research and Postgraduate Studies at Ensenada).

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BIBLIOGRAPHY.

CAMPOS-ENRIQUEZ, J. O., M. A. ARROYO-ESQUIVEL and J. URRUTIA-FUCUGAUCHI, 1991. Basement, Curie isotherm and shallow-crustal structure of the Trans-Mexican Volcanic Belt, from aeromagnetic data, *Tectonophysics, 172*, 77-90.

CAMPOS-ENRIQUEZ, J. O., J. URRUTIA-FUCUGAUCHI and M. A. ARROYO-ESQUIVEL, 1991. Depth estimations to the Curie isotherm from aeromagnetic data and geothermal considerations for the western sector of the Trans-Mexican Volcanic Belt, *Geofís. Int., 28, 5*, 993-1005.

CAMPOS-ENRIQUEZ, J. O. and J. J. ARREDONDO-FRAGOSO, 1992. Gravity study of Los Humeros Caldera complex. Structure and associated geothermal system, *Journal of Volcanology and Geothermal Research, 49*, 69-90.

DIAS-MOLINARI, M., 1987. Evaluación de las propiedades elásticas dinámicas en el área de casa de máquinas y torre de enfriamiento para la central geotermoeléctrica de Los Azufres, Michoacán, *Geotermia, Rev. Mex. de Geoenergía, 3, 1*, 65-75.

GUTIERREZ-NEGRIN, L. C. A., 1991. Desarrollo geotérmico internacional 1985-1990 e índices de productividad, *Geotermia, Rev. Mex. de Geoenergía, 7, 2*, 231-253.

MARTINEZ, M., H. FABRIOL, J. M. ROMO, A. GONZALEZ and R. VEGA, 1984. Levantamiento magnetotélurico en el área de Culiacán, Sinaloa, *Geofís. Int., 23, 4*, 491-534.

MERCADO, S., 1990. Manifestaciones hidrotermales marinas de alta temperatura (350°C) localizadas a 21°N a 2600 m de profundidad en la elevación Este del Pacífico, *Geotermia. Rev. Mex. de Geoenergía, 6, 3*, 225-263.

URRUTIA-FUCUGAUCHI J. and J. O. CAMPOS-ENRIQUEZ (submited), Paleomagnetism and magnetostratigraphy of geothermal fields, Journal of Volcanology and Geothermal Research.