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Geothermal prospects in the Baja California Peninsula

Claudia Arango-Galván[a,*], Rosa María Prol-Ledesma[a], Marco Antonio Torres-Vera[b,1]

[a] Instituto de Geofísica, Universidad Nacional Autónoma de México, 04510 México, DF, México
[b] APEC, I.A.P., Vicente García Torres 46, 04030 México, DF, México

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ABSTRACT

Geothermal resource evaluation was accomplished for the Baja California Peninsula hydrothermal systems. Numerous geothermal areas were identified along the eastern coast of the Peninsula, which are related with the Gulf of California opening process. The western coast presents hydrothermal activity in the northern part related with regional faults like the Agua Blanca Fault nearby Ensenada. The southern part of the Peninsula also has abundant geothermal resources related with local grabens. The heat in place evaluation was accomplished for five geothermal areas where geophysical data were available to estimate the reservoir volume. The minimum calculated potential is more than 400 MWe. There are still more than six geothermal prospects with calculated temperatures above 200 °C that lack reliable information on the reservoir volume and would increase the geothermal potential of the Peninsula. Surface heat loss from the submarine systems reaches more than 6000 MWt.

1. Introduction

Since the early days of geothermal resources exploration in Mexico, the Baja California Peninsula has been identified as a region with high potential (Fig. 1). Currently, this region is a major producer of electricity based on geothermal energy, with two fields generating up to 730 MW (Cerro Prieto and Las Tres Vírgenes; Quijano and Gutiérrez-Negrín, 2005). However, there is an urgent need to identify and assess the region's geothermal areas for future commercial development. The aim of this paper is to review most of the available information on those Baja California Peninsula resources, including the geothermal prospects that presently are not economically viable using today's technology; e.g., the submarine resources. In the future, all these resources may be feasible for commercial exploitation.

In the past, the conventional geothermal studies ignored many areas of the Peninsula that today may be considered for electricity production or for direct utilization using recently developed technologies. Presently, the region's electrical grid is not interconnected with the Mexican national grid, and the fuel used to supply electricity to the local cities and towns is highly expensive. In addition, tourism development has resulted in a significant rise in population and, consequently, to a great increase in energy and water demand. This led to the exploration for new geothermal resources in the Peninsula, as well as to the evaluation of known and new geothermal areas.

There are several reports and papers describing geothermal springs or wells in the Peninsula (e.g., Vidal et al., 1978; Quijano, 1985; Prol-Ledesma and Ortega, 1988; Casarrubias-Unzueta and Leal-Hernandez, 1994; Casarrubias-Unzueta and Romero-Rios, 1997; Portugal et al., 2000; Barragán et al., 2001; Prol-Ledesma et al., 2004; López-Sánchez et al., 2006; Arango-Galván et al., 2011), most are located on the northern coastal areas, while in the southern part of the Peninsula, the geothermal activity occurs in the central part and on the coast (Fig. 1). In addition, more recent exploration work has generated data on new areas (Prol-Ledesma et al., 2010). The presence of hydrothermal manifestations is not restricted to areas with recent volcanic activity; it is also controlled by regional faults that serve as channels for the deep penetration of meteoric water in high heat flow regions, which are related to the intensive tectonism of the region.

The geothermal areas that have been recently explored are Ensenada (Punta Banda) in Baja California Norte (Arango-Galván et al., 2011), and Bahía Concepción and Los Cabos in Baja California Sur (Prol-Ledesma et al., 2004; López-Sánchez et al., 2006). Studies have also been undertaken to unveil the geothermal resources in the Wagner and Consag Basins of the Gulf of California (Fig. 1; Prol-Ledesma et al., 2013); these investigations promote the sustainable exploitation of submarine hydrothermal systems for energy production with the use of new environmentally friendly technologies (Hiriart et al., 2010). Here, we present most of the data available on

* Corresponding author. Tel.: +52 55 56 22 40 27; fax: +52 55 55 50 24 86.
E-mail address: claudiar@geofisica.unam.mx (C. Arango-Galván).
[1] Tel.: +52 55 10 84 14 00; fax: +52 55 10 84 14 04.

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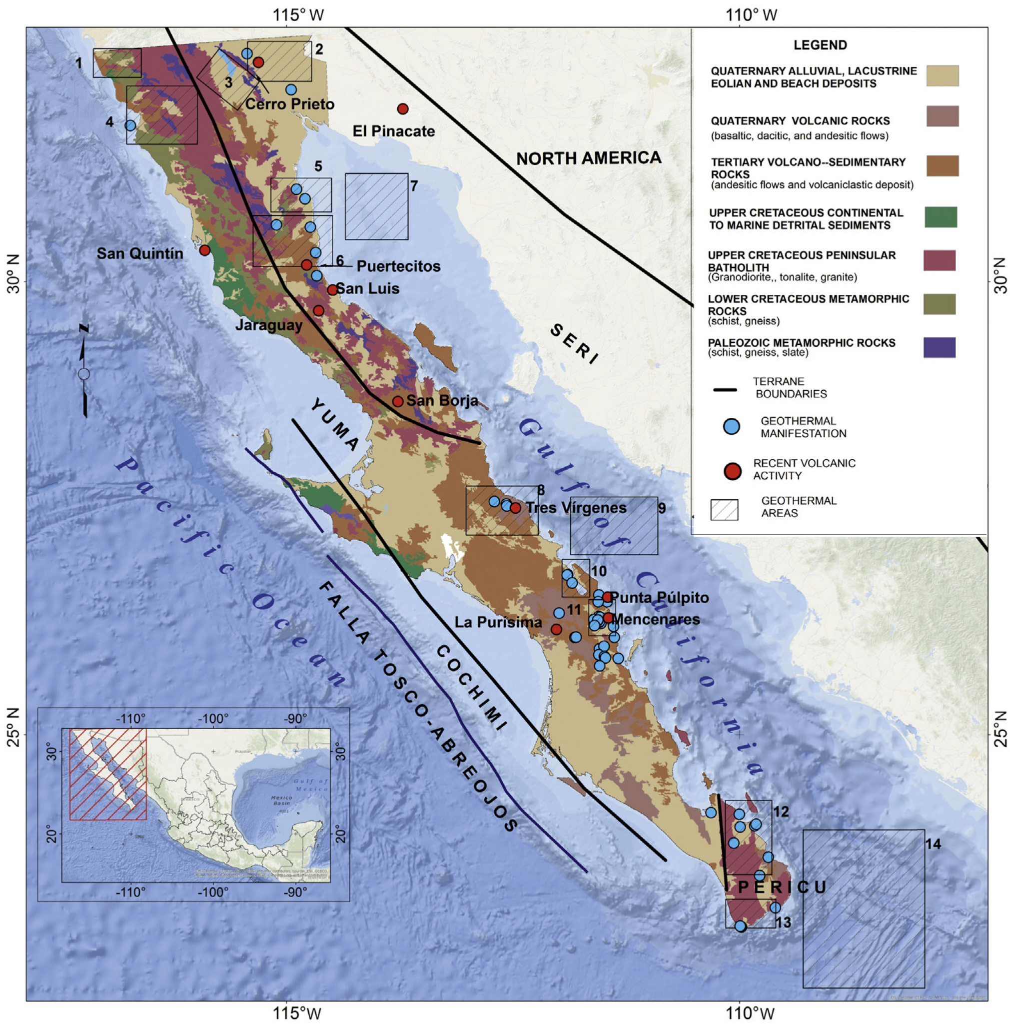

Fig. 1. Baja California Peninsula. Geological map and geothermal areas: (1) Tijuana, (2) Mexicali Valley and Cerro Prieto; (3) Laguna Salada; (4) Ensenada; (5) San Felipe-Punta Estrella; (6) Puertecitos-Valle Chico; (7) Wagner-Consag Basins; (8) Tres Vírgenes; (9) Guaymas Basin; (10) Bahía Concepción; (11) Comondú; (12) LaPaz; (13) Los Cabos; (14) Alarcón Basin. Location of the mapped areas from Vidal et al., 1978; Quijano, 1985; Casarrubias-Unzueta and Leal-Hernandez, 1994; Casarrubias-Unzueta and Romero-Ríos, 1997; Portugal et al., 2000; Barragán et al., 2001; Prol-Ledesma et al., 2004, Báncora-Alsina and Prol-Ledesma, 2006. Geology after Campa and Coney (1983) and Sedlock et al. (1993). Red dots denote areas with recent volcanic activity, after: De Boer (1980), Lynch (1981a,b), Luhr et al. (1995), Martín-Barajas et al. (1995), Paz Moreno and Demant (1999), Calmus et al. (2003), Pallares et al. (2008); López-Hernández et al. (1993, 1995), Umhoefer et al. (2002), Bigioggero et al. (1995), Bellon et al. (2006).

the geothermal resources of the Baja California Peninsula, excluding the two geothermal systems that are already under commercial exploitation; i.e., Cerro Prieto and Las Tres Vírgenes (Fig. 1).

Geochemical data on water samples from hot springs and wells were used to estimate deep temperatures, if partial or total equilibrium was attained and, where available, geophysical surveys were analyzed to evaluate the presence and shape of the geothermal reservoir. The energy capacity of geothermal areas for which geophysical data were available was estimated.

The geothermal areas here described are: Ensenada, Laguna Salada, Mexicali Valley, San Felipe-Punta Estrella-Valle Chico-Puertecitos, Bahía Concepción, San Siquismunde-El Volcán, Agua Caliente, El Centavito and Los Cabos. In addition, estimation of the energy discharge was attempted for active submarine geothermal systems, where heat flow data have been reported; i.e., Wagner-Consag, Guaymas and Alarcón Basins (Fig. 1).

2. Methodology: geothermal resource assessment

There are several methods to estimate the amount of energy that can be extracted from a geothermal field (e.g., Cataldi and Muffler, 1978; Muffler, 1979). Presently, the most widely used is the volumetric-probabilistic method utilized by the U.S. Geological Survey, which evaluates the heat content in the reservoir fluids and rocks (Williams et al., 2008), which requires to know the main reservoir parameters; i.e., temperature, rock specific heat, depth, effective porosity, permeability, fluid circulation model (including the recharge), predominant phase of the geothermal fluid, extraction technique, drilling cost, efficiency of electric energy production, investment cost, energy cost, investment risk and environmental restrictions. However, as we aim to evaluate the regional geothermal potential and not the feasibility of a particular field, the parameters included in the evaluation will be restricted to the following (Garg and Combs, 2010):

Reservoir area (km^2),
Reservoir thickness (m),
Reservoir temperature (°C),
Thermal recovery factor (max. 20%),
Volumetric heat capacity (average 2700 kJ/m^3 K),
Reject temperature (min. 40 °C),
Overall conversion efficiency (45%),
Plant mean life (average 20–30 years),
Load factor (average 90%).