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Shallow submarine and subaerial, low-enthalpy hydrothermal manifestations in Punta Banda, Baja California, Mexico: Geophysical and geochemical characterization

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ABSTRACT

The low-enthalpy geothermal system at Punta Banda (NW Baja California Peninsula, Mexico) has been studied because it might provide heat to future desalination plants in the city of Ensenada. Utilization of subaerial, intertidal and submarine hot springs is evaluated based on geochemical and geophysical data. The results of the geochemical studies show that the geothermal fluids have a major meteoric water component because seawater is not present at the subaerial springs and hot wells. The highest estimated reservoir temperature (140 °C) calculated using a silica geothermometer corresponds to the Agua Caliente intertidal manifestation, a promising area also identified by geophysics. Geothermometric calculations applied to the computed composition of the thermal end member yield a reservoir temperature of 137 °C. Cl/B ratios indicate that the thermal fluids discharged by the intertidal vents and subaerial springs are similar, but they differ from those of submarine vents. Geoelectrical models depict an anomalous conductive trend from the La Jolla well to the Agua Caliente manifestation, suggesting the presence of a fault that allows upflow of hot water from depth. Lastly, integration of geochemical and geophysical data identified the best site for future exploration drilling at Punta Banda.

1. Introduction

The Baja California Peninsula (BCP) in NW Mexico has experienced significant growth in population, principally related to the increase in tourist facilities along the Pacific and Gulf of California coasts, triggering the need for more energy and fresh water.

The most sustainable possibility for increasing the availability of fresh water in the region is the use of renewable energy sources in desalination plants. The abundance of geothermal manifestations along the peninsula provides a reliable energy source for this purpose. The use of geothermal resources for desalination purposes has been studied since the 1970s (Awerbuch et al., 1976; Laird and Tleimat, 1976). Desalination of seawater based on low-temperature (110–130 °C) geothermal resources applying low-temperature multi-effect distillation (LT-MED) was proposed by Ophir (1982). Gutiérrez et al. (2009) have studied using geothermal energy to heat seawater in the production of distilled water along the coast of the BCP.

Geothermal development for electricity production in NW Mexico dates from the 1970s, when the first power plant in the Cerro Prieto geothermal field, located in northern Baja California, came on line. Later on, the Las Tres Vírgenes geothermal field, in the center of the Peninsula, was commissioned. Presently, 10 MWe are being produced at Las Tres Vírgenes and 720 MWe at Cerro Prieto (Gutiérrez-Negrín et al., 2010). About 76% of the total geothermal electricity generated in México comes from Baja California.

Numerous thermal springs and wells (Fig. 1) have been reported along the Peninsula (Barragán et al., 2001; Casarrubias-Unzueta and Leal-Hernández, 1993; Casarrubias-Unzueta and Romero-Ríos, 1997; López-Sánchez et al., 2006; Portugal et al., 2000; Prol-Ledesma et al., 2004; Quijano, 1985; Vidal et al., 1978). However, most of them correspond to low-enthalpy systems and have not been included in the geothermal exploitation plans by the Comisión Federal de Electricidad (CFE; the Mexican National Utility). The distribution of the low-temperature resources in the BCP is controlled by regional faults, which serve as channels for deep penetration of meteoric water and for the upflow of thermal waters, and generally are not closely related to recent volcanism.

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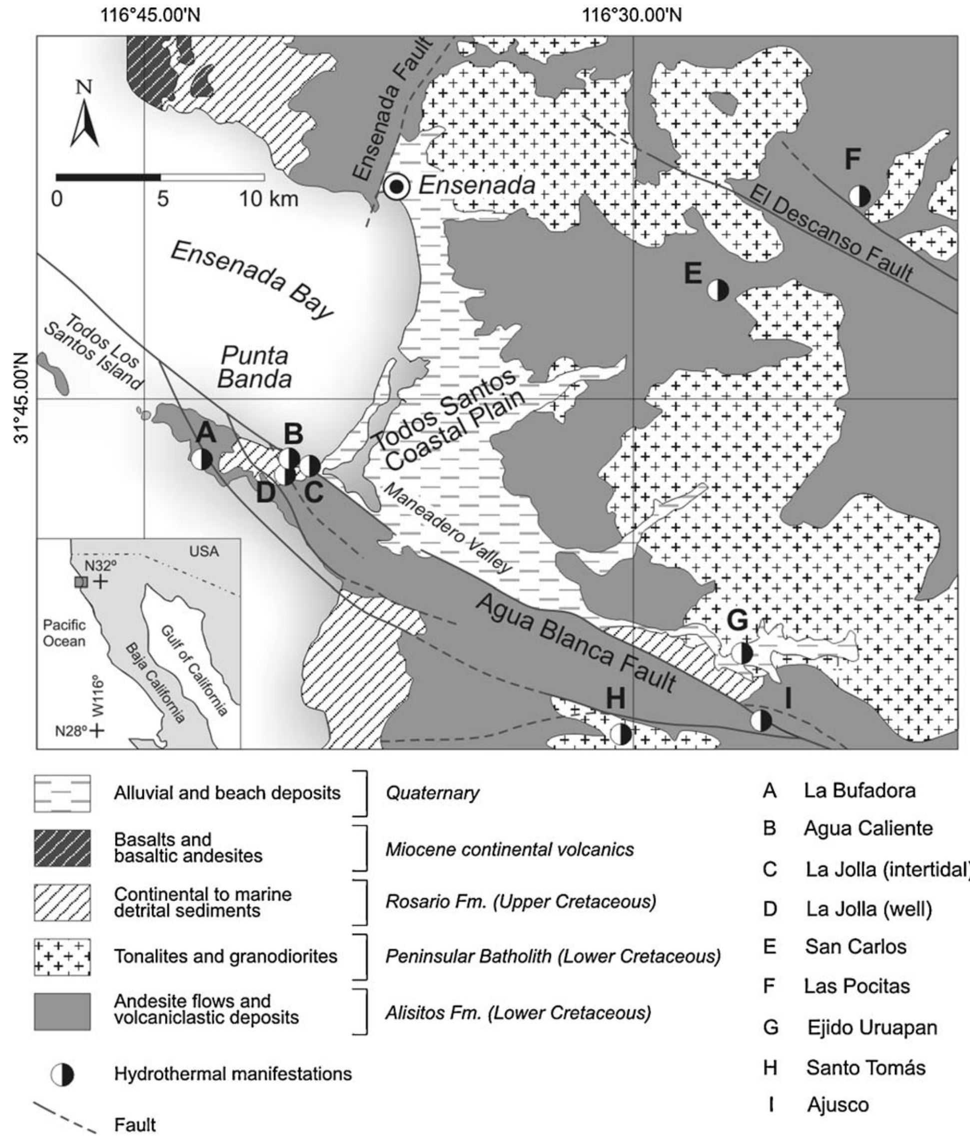

Fig. 1. Map showing the location of the study area and of the low-enthalpy geothermal zones in the Punta Banda Peninsula and surrounding areas. Sites sampled in this study: B (AgCln: Agua Caliente); C (Jll: La Jolla intertidal manifestation); D (Jll: La Jolla thermal well); E (SnC: San Carlos). Geology is after Gastil et al. (1975) and Pérez-Flores et al. (2004).

1.1. Geothermal manifestations in the Ensenada area

Ensenada is the second most populated city in the state of Baja California. It has a desalination plant that is due to be replaced after 2010 (Gobierno de Baja California, 2008), and the geothermal resources of the area could be an option for the new plant.

The geothermal manifestations near the city cluster around the Punta Banda Peninsula and are closely related to the Agua Blanca Fault (Fig. 1). They consist of intertidal (La Jolla and Agua Caliente beaches) and submarine geothermal springs (off La Bufadora). In addition, other manifestations (subaerial) occur onshore, at greater distance (>20 km) from the coast, in Ejido Uruapan, San Carlos, Santo Tomás, Las Pocitas and Ajusco. Onshore in Punta Banda, some water wells attain temperatures as high as 70 °C, similar to those measured at the intertidal springs, whereas in the submarine vents the discharge temperatures are in the 102–109 °C range, and from 40 to 57 °C in the farthest subaerial springs (Ejido Uruapan, San Carlos, Santo Tomás and Ajusco; Vidal and Vidal, 2003; Vidal et al., 1978, 1981, 1982).

The first studies of the submarine vents off Ensenada were performed in the 1970s (Vidal et al., 1978). Since the 1980s, tourist brochures included the intertidal hot springs as a major attraction. Nowadays, urban development (i.e. buildings and roads) has covered all subaerial manifestations in and near the city and only the intertidal and submarine springs, and the water wells are available for measurements and fluid sampling.

The Punta Banda submarine vents were first characterized by Vidal et al. (1978, 1981, 1982) and Vidal and Vidal (2003), whereas CFE personnel performed geological and geochemical studies of thermal wells and subaerial springs (Álvarez-Rosales, 1993; CFE, 1995). Chemical data from these studies are shown in Table 1, and indicate that the waters of the thermal manifestations are Na–Cl and Na–Cl–SO_4 types (Álvarez-Rosales, 1993).

Shallow submarine manifestations off Ensenada occur at 25–30 m depth. Thermal water (PBSHS in Table 1) is enriched in SiO_2, HCO_3, Ca, K, Li, B, Ba, Rb, Fe, Mn, As and Zn with respect to seawater, and the discharged gas is mostly nitrogen and methane in similar proportions (44% N_2, 51% CH_4) (Vidal et al., 1978). The