A NEW NASCENT SPREADING CENTRE AT THE WAGNER BASIN IN THE NORTHERN GULF OF CALIFORNIA: A POSSIBLE GEOTHERMAL RESOURCE?

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SUMMARY - The probable geothermal reserves of Mexico sum up to only 1400 MW; however, they have been estimated on the basis of the high temperature systems and do not include the unconventional geothermal sources. Submarine hydrothermal systems may become in the near future a feasible energy source, especially those that occur at shallow depths. Recently discovered hydrothermal activity in the Wagner Basin may be harnessed to produce electricity using an environmentally friendly system.

1 INTRODUCTION

The geothermal potential in Baja California has been well known since the early stages of exploration for geothermal resources. There are fields that have produced geothermal energy for several years, and the Baja California Peninsula is a major producer of geothermal energy in Mexico with two geothermal plants producing 730 MW: Cerro Prieto and Las Tres Vírgenes (Quijano and Gutiérrez-Negrín, 2005). However, the conventional studies searching for geothermal systems overlooked many areas that contain hydrothermal systems that may be considered for production of base-load electricity or additional energy source for increasingly growing or isolated communities. The Baja California Peninsula is relatively disconnected from the rest of Mexico and the supply of fuel to this region is quite expensive. The occurrence of numerous coastal and submarine hydrothermal systems may be considered as a possible solution to the energy problems in the area (Prol-Ledesma et al., 2008). The Gulf of California hosts several ocean spreading centres, Guaymas being the most studied of them (Einsele et al., 1980)

This work presents information on the gas venting activity at the Wagner and Consag basins and proposes the exploitation of this resource to provide energy to develop the nearby coastal cities.

2 GEOLOGICAL SETTING

The basins were probably formed about 3-2 Myr ago as a result of the shift of tectonic extension from the eastern part of the Gulf of California toward the west (Aragón-Arreola and Martín-Barajas, 2007). The Wagner Basin is connected with another active basin, the Consag Basin that represents a continuation of the main structures to the west of the Wagner Fault; both are the northernmost marine basins within the Gulf of California rift system (Fig. 1). The Wagner Basin trends NNE-SSW along 40 km and is 20 km wide, with a maximum depth of 210 mbsl. The shallow depth of the basin (<210 mbsl) makes easier recording the presence of plumes with the echosounder.

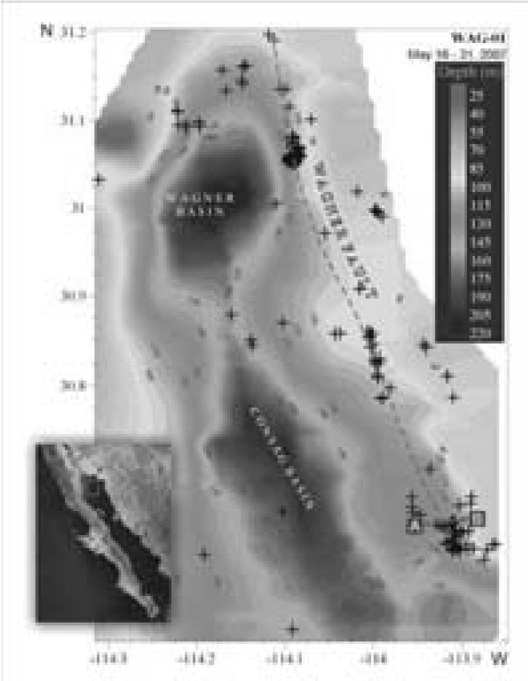

Figure 1: Bathymetry map of the studied area. WB- Wagner Basin, CB-Consag Basin, WF-Wagner Fault. Crosses indicate the location of hydrothermal vents.

A sedimentation rate of 3.3 mm/yr has been estimated for the northern Gulf of California, generating a thick sediment cover that can reach a thickness of up to more than 5 km, according to the wells that have been drilled in the basin (Pérez, 1980). Conductive heat flow was measured by Henyey and Bischoff (1973) in the SW section of the Wagner Basin. The two measurements obtained (75 and 92 mW m-2) indicate that heat flow is lower than expected for an active spreading basin. Microseismic activity is intense in the Upper Gulf of California, especially in the Wagner Basin, where clusters of earthquakes with magnitude 5 to 5.9 and approximately 10 km depth hypocenters occur (Frez and González, 1991). Recent reinterpretation of seismic data by Aragón-Arreola and Martín-Barajas (2007) shows that, presently, the western side of the Northern Gulf of California contains the tectonically active basins, which include the Wagner and Consag Basins; by contrast, the eastern side basins and faults seem to have been inactive since Pliocene.

There is no previous information in the literature about hydrothermal activity in Wagner Basin. Only one project report of the Mexican Electricity Commission describes the presence of bubbles reaching the sea surface and a temperature anomaly at depth, and presents scarce and erratic helium isotopic data with values significantly lower than those obtained for other hydrothermally active areas (Grijalva et al., 1987). However, the deep temperature anomaly is more likely related to the strong tides (more than 6 m high in the Upper Gulf) and currents than to submarine hydrothermalism, since tidal currents transport evaporated sea water (higher salinity and temperature) from the Colorado River delta down to the southern end of the Consag Basin (Lavín et al., 1995). Thus, these anomalies might be misleading when looking for hydrothermal discharges in the sea bottom. No further data were provided to attest the occurrence of hydrothermal activity in the area.

3 METHODOLOGY

During WAG-1 cruise in the O/V “El Puma”, we used two echosounders, KDA TOPAS sub Bottom profiler with one second two-way travel time (TWTT), CTD, turbidity-meter, surface temperature-meter, box corer and dredging in order to carry out an investigation on the occurrence and distribution of hydrothermal plumes in the Wagner and Consag Basins. The simultaneous utilization of echosounders and an acoustic profiler allows the location of gas plumes and the determination of the subseafloor structure beneath them. Temperature of sediment recovered with the dredge was measured by a digital thermometer onboard, immediately after the dredge arrived on deck. pH was determined in the water samples, compared with buffers prepared in artificial seawater. Sediment and water samples were collected as the box corer arrived on deck and sealed to be analysed for dissolved gas by gas chromatography.

4 RESULTS

Bathymetry

The detailed bathymetry of the Wagner and Consag Basins is shown in Figure 1. It shows the steep eastern border of the basin affected by the Wagner Fault. Echosounder profiles were highly relevant in the identification of the hydrothermal plumes, detected as bubble gas flares. Also, bathymetry and profiler data were useful to identify large vertical displacements associated with active faults that disrupted the sedimentary layers (Fig. 2A).

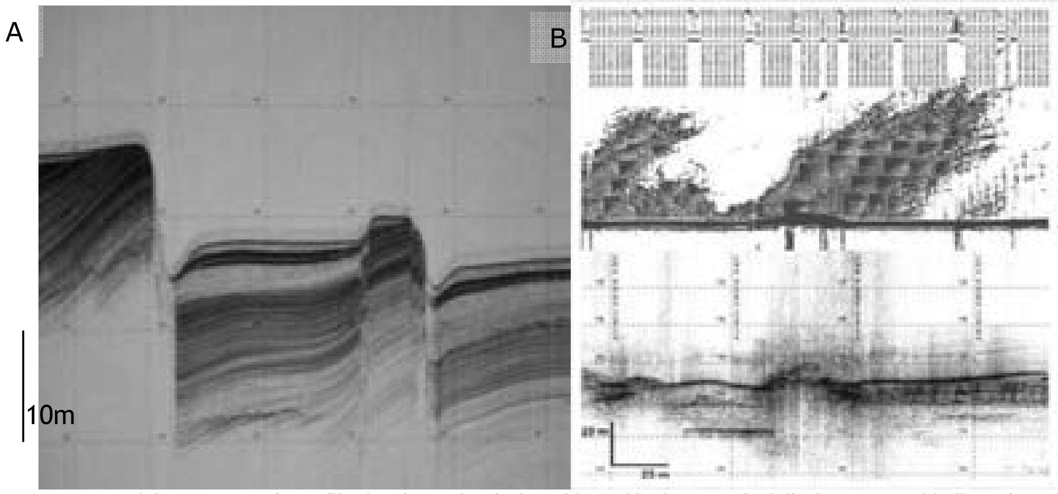

Figure 2: A) TOPAS sub bottom acoustic profile showing active faults evidenced by large vertical displacements with disruption of the sedimentary structures; B) Acoustic profiles of outgassing areas: above - 120 kHz profiles showing gas plumes in the water column; below - TOPAS profile. Scale is approximate.

Acoustic sub-bottom profiles show that all plumes are related to intense disruptions (mostly as syn-sedimentary faults and pockmarks) of the upper sediments (Fig. 2B) due to strong fluid flow. Also, these data show the presence of BSR’s related to high gas concentration in the sediments. Distribution of the observed gas discharge features indicates that the eastern geological structures (e.g. Wagner Fault) are the channelways that allow hydrothermal flow, as most observed plumes are located on those structures (Fig. 1). More than two hundred different sets of plume signals were detected, based on the bottom coverage of the acoustic beam we estimate that there are at least 15,000 individual gas vents along the Wagner fault. Typically each plume was identified simultaneously by both echo sounders and the TOPAS along the same track (Fig. 2B). In the case of some large plumes, bubbles were observed on the sea surface. One of the strongest vents was associated to the presence of a mud diapir (Canet et al., 2008).

Physical and chemical parameters

The turbidity sensor revealed anomalies related to the plumes, being the turbidity related with the occurrence of bubbles and possibly with sediment re-suspension. Higher surface temperature and lower pH values in deep samples are also well correlated with the presence of plumes. Additionally, some of the deepest water samples collected in the plumes have higher Ba and Mn concentrations. CTD profiles show the presence of positive temperature and salinity anomalies near the ocean bottom, but they are due to strong currents that drive the evaporated water from the Colorado River delta to the southern end of the Consag Basin. (Lavín et al., 1995).

The dredges recovered warm sediments with temperatures up to 26°C, which is significantly higher that the bottom ambient water (~15°C). The warm sediment sample was actively degassing when recovered, and the analyses of the water show that the dissolved gas was CO2.

Mineralogy

The retrieved rock samples contained some nodules formed mostly by barite and pyrite, other fragments evidenced the occurrence of intense gas discharge that probably formed channels in the rock. When analyzed in the SEM, abundant deposition of manganese oxide was observed on those channels, also the presence of barite and pyrite was observed in the samples.

5 IMPLICATIONS OF HYDROTHERMAL VENTING ON THE TECTONIC ACTIVITY

The northern Gulf of California represents a different type of evolving ocean basin, characterized by high sedimentation rates, such that oceanic basement is formed not in the usual ophiolite sequence (Einsele et al., 1980). Similar settings have been observed in Guaymas and Okinawa basins, where intense hydrothermal activity occurs in heavily sedimented rifts (Einsele et al., 1980, Glasby and Notsu, 2003). Guaymas Basin is now considered a “nascent spreading centre” (Aragón-Arreola et al., 2005), but it evolved as a half graben similar to Wagner Basin, with a thick sediment cover that masked the magmatic activity at depth. Furthermore, low heat flow values, similar to those measured in the southern border of Wagner Basin, were observed in boreholes (sites 478 and 481 DSDP) located outside of the active rift zones in Guaymas Basin (Einsele et al., 1980). Therefore, the identification of a shallow hydrothermally active area that shares the characteristics of Guaymas and Okinawa basins is a major breakthrough in the study of untypical conditions for the interaction of thermal fluids and sediments.

6 CONCLUSIONS

In summary, the higher temperature of the retrieved sediments, the presence of columns of discharged gas, the disruption of the sedimentary layering and abundance of pockmarks, the occurrence of large vertical displacements related with active geologic structures support the implication of strong hydrothermal activity in the Wagner and Consag Basins and, therefore, intense tectonic activity in the northern section of the Gulf of California.

The future studies of the active areas in the Wagner and Consag Basins will provide a deep insight to the relative motion of the Pacific-North American plates and the characterization of shallow hydrothermal activity in heavily sedimented basins with active oceanic dispersion as shallow proxies of the Guaymas Basin and Okinawa Trough.

Proposals for submersible encapsulated thermal cycle turbines to generate electricity from geothermal energy in the Wagner Basin (Hiriart, 2006) would produce green energy and can help develop this remote area.

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