Near shore submarine hydrothermal activity in Bahia Banderas, western Mexico

F.J. Núñez-Cornú¹, R.M. Prol-Ledesma², A. Cupul-Magaña¹ and C. Suárez-Plascencia¹
¹ CUC, Universidad de Guadalajara, Puerto Vallarta, Jal., México.
² Instituto de Geofísica, UNAM, Cd. Universitaria, México, D.F., México.

Received: June 23, 1999; accepted: December 7, 1999.

RESUMEN
Recientemente se descubrió la existencia de actividad hidrotermal en la zona de Bahía de Banderas. Las implicaciones de esta actividad en el esquema tectónico de la parte central de México apoya la hipótesis de que está ocurriendo actividad tectónica reciente en esta área. Se detectaron tremores en estaciones sismológicas portátiles que fueron instaladas en los alrededores. Se analizaron muestras de las chimeneas formadas por la actividad hidrotermal y se encontró una secuencia de deposición dominada por carbonatos en la primera etapa (calcita y dolomita), seguida por apatita y vetas tardías de barita. También se presentan capas de deposición secuencial de sulfuros y fosfatos que pueden interpretarse como resultado de las variaciones en la fugacidad del azufre.

PALABRAS CLAVE: actividad hidrotermal somera, México, deposición de sulfuros.

ABSTRACT
Shallow submarine hydrothermal activity was detected in the Bahía de Banderas area, Mexico. Volcanic-type tremors were recorded by portable seismological stations onshore. Vent samples suggest a depositional sequence dominated by carbonates in the first stage (calcite and dolomite), followed by apatite and late barite veins. Layers of sequential deposition of sulfides were also observed, and are interpreted as cyclic variations of sulphur fugacity.

KEY WORDS: underwater hydrothermal vents, Mexico, sulfide deposition.

INTRODUCTION
Hydrothermal vents in the ocean are known from deep-sea studies (Scott, 1997); however, few vents have been described at shallow depth (Pichler et al., 1999).

A few years ago local fishermen reported hydrothermal activity close to Punta Mita, in the Bay of Banderas, Mexico. Preliminary exploration identified a 400 m long area of intense hydrothermal activity. The hydrothermal fluids in the discharge centers reach temperatures of up to 87°C and produce hydrothermal deposition of some minerals. However, hydrothermal vents are not well developed, probably due to destruction by recurrent explosive events or by storm erosion.

The occurrence of hydrothermal vents in this area must be related to the tectonic evolution of western Mexico, which has not been clearly explained by seismicity and other parameters like heat flow (Eissler et al., 1984; Luhr et al., 1985; Prol-Ledesma and Juárez, 1986; Ferrari et al., 1994; Ferrari et al., 1997; Kostoglodov and Bandy, 1995; Dañobeitia et al., 1997). Regional tectonics is characterized by the presence of a triple point, where three rift zones have been identified: Tepic-Zacoalco, Chapala and Colima (Allan et al., 1991). The continental part defined by these features is known as the Jalisco Block (Figure 1), which has been interpreted as a distinct geological unit presently being rifted away from the North American plate (Luhr et al., 1985; Allan et al., 1991; Garduño and Tibaldi, 1991; Kostoglodov and Bandy, 1995). The Rivera-Cocos Plate boundary is not well defined, and it has been suggested that it is not a transform boundary but a divergent boundary (Bandy, 1992). Also, the connection between the northwest border of the Jalisco Block and the continent (the Tamayo Fault System) is not well defined. The Bahía de Banderas area may be experiencing strong crustal stresses as a result of the convergence direction of the Rivera Plate (Kostoglodov and Bandy, 1995).

The Punta Mita area, at the northwestern end of the Bay of Banderas, contains three main geologic units: granite, basalt and recent sandstone and conglomerates. Granitic rocks predominate in the area surrounding Bahía de Banderas. The age of some granites has been estimated to be between 90 and 100 Ma (Ferrari et al., 1997). Basaltic rocks in the area of Fisura Las Coronas have not been dated; however, radiometric ages of basalts located north and northeast of the bay range from 0.48 to 3.4 Ma (Lange and Carmichel,
The age of a basalt outcrop at Punta Mita is reported by Gastil et al. (1979) as 10.2 Ma. Photogeologic analysis was carried out on aerial photographs and the seven lineament groups identified in the photographs were correlated with the 1:50,000 geologic map, the results of this analysis are shown in Figure 2a. A basaltic flow in the SW section of the study area is affected by lineaments with directions N42°E, N20°E and N68°E; the latter coincides with the direction of “Fisura de Las Coronas” (N70°E) which is located 800 m offshore. These directions are similar to those reported for grabens and volcanic fields in the Jalisco block, related to NW-SE stretching (Maillol et al., 1997). Therefore, the direction of Fisura Las Coronas coincides with the lineament group, which is also related to recent tectonic and volcanic activity in the Jalisco block.

Dañobeitia et al. (1997) recorded seismic signals at Punta de Mita in the northern part of Bahía de Banderas that looked similar to volcanic or hydrothermal events (Figure 3). These types of signals were also recorded by Núñez-Cornú et al. (1997).

Fishermen reported the occurrence of bubbles in parts of the bay, and noticed that hydrothermal activity had increased in the last year. During our first expedition to study the hydrothermal activity at Fisura Las Coronas, a submarine spring was found southeast of Punta de Mita (Figure 2a) at a water depth of 11 m. No other points with similar activity have been identified elsewhere in the Bay of Banderas. Local sea floor mapping shows a major structural pattern where active vents occur, 70 m of Fisura Las Coronas which trends N70°E (Figure 2b). Photographic, video and spring temperature profiling was carried out along the vent area in September 1997. We observed one large vent growing on the sandy bottom, one large vent in a basaltic rock, and numerous small springs aligned on the sand-gravel bottom. In addition to the mapped sea floor vents at Fisura de Las Coronas, bubbles have been observed on the ocean sur-
Submarine hydrothermal vents, western Mexico.

Fig. 2. a) Structural map of Punta de Mita area and location of submarine vents. Coordinates are UTM. The square denotes the location of Fisura de Las Coronas (After INEGI, 1974). b) Fisura de Las Coronas. Vents A and B are described in the text, and points a, b, c, d, e are minor discharges of geothermal fluid.
Fig. 3. Seismograms of volcanic tremors recorded in portable seismographs installed at station PMJ near “Fisura de Las Coronas” (2 to 6 km). Upper scale is time in seconds. The letter to the left designates the component: Z, N, E, and VR denotes the Z component. Numbers to the left under the seismogram indicate the initial time in seconds; the hour and minute are the last four numbers to the right of the seismogram; the first four numbers indicate the date (year and Julian day). The horizontal number to the right of the seismograms denotes the amplitude.
Submarine hydrothermal vents, western Mexico.

Several samples of vents were collected. The samples are mainly composed of alkaline basalt fragments, detrital crystals and shells cemented by calcite, phosphates, and clays. The detrital crystals are mostly quartz and feldspars. The basalt fragments contain abundant vesicles filled by clays, especially chlorite, and zeolites. The matrix is completely altered to clay; however, most phenocrysts remain unaltered. The samples are covered by fine white layers, and also by sulfide layers a few microns thick (Figure 5). Sulfides are also observed disseminated within the fragments and often fill the vesicles where chlorite occurs. No replacement textures were observed in the disseminated sulfide crystals; we infer that they were deposited directly from the fluid into the cavities. Hand specimens showed typical blue-violet copper sulfide colors on the surface; however, a petrographic examination of polished samples did not show any copper minerals. The most recently collected sample, a basalt fragment, had remained within the chimney and was totally covered by a white layer a few millimeters thick.

Two samples were analyzed for trace elements. One sample was composed only of white layers deposited on the sample surface, and the second sample was a single clean rock fragment without sulfides or white layers. Both samples had low concentrations of copper and zinc, between 0.001 and 0.004 %, and barium between 0.003 and 0.03%. Vanadium ranges from 11 to 52 ppm.

X-ray diffraction analyses were performed on three samples: the white layers and a rock fragment of the first samples collected from the vents, and the white cover of the lastly collected sample. All samples are mostly composed of calcite and minor dolomite; however, the most recent sample shows analcime as the second most abundant mineral. This mineral was not observed in the first samples. The white layer in the first sample was mostly composed of calcite and trace amounts of quartz. The rock fragment contained calcite, quartz, dolomite, feldspars and chlorite. These results agree with the petrographic examination.

SEM analyses were performed on three samples: a polished section of a rock fragment including the sulfide and calcite layers, and two small fragments with a strong blue-violet hue taken from the surface of the chimney fragment. The sulfide and calcite layers (Figure 5) were analyzed with a one-micron spacing; the results show a succession of iron sulfides, calcite, silica and phosphate layers. The fragments yielded up to 14% copper over all the surface; however, single crystals did not show noticeable copper content. Apparently, the copper has been coated recently on the sample; it is probably related to the recent increase in hydrothermal activity.

**DISCUSSION**

According to the results of the analysis of seismic data and magnetic anomalies, Kostoglodov and Bandy (1995) conclude that the greatest amount of extension within the Jalisco Block should be occurring in the Bahía de Banderas area. The occurrence of active hydrothermal vents near the coast in the Punta Mita area (Figure 2a) may be evidence of the recent tectonic activity in this area of the Jalisco Block.

There are several hypotheses about the mineralogical composition of the mounds in the earlier stages of activity of submarine hydrothermal systems; it has been proposed that either sulfides or carbonates are the first minerals to be deposited. The early processes of deposition are documented in this area where no previous hydrothermal activity was reported that could have affected the sea water composition. The collected samples show that simultaneous deposition of carbonates, sulfides and phosphates takes place starting with the first stages of development of the chimneys.

Phosphate anomalies have been reported on low-temperature hydrothermal vents on the flanks of the Juan de Fuca Ridge (Wheat et al., 1997). Copper sulfide deposition at shal-
Fig. 4. Photographs of vents. a) Vent A in September 1997; b) Sources of bubbles; c) Vent A in January 1998.

Fig. 5. Microphotograph of the sampled chimneys that shows layered sulfides.
low depths has been reported in Iceland related to active submarine volcanoes (Scott, 1977); however, in our case, there are no active volcanoes related to the vents. The discharged water and the nearby basaltic flows must be studied to determine whether they may be related to the hydrothermal activity, or whether they may be due to deep circulation of meteoric water. The presence of abundant sulfides in an oxidizing environment implies high sulfur fugacity, possibly related to a shallow magmatic source. Such a source is also suggested by the seismic signals that do not look like typical earthquakes due to faulting.

CONCLUSIONS

Field observations and geochemical studies indicate that the observed hydrothermal activity in the Bay of Banderas is recent. The occurrence of hydrothermal and seismic activity supports the assumption of active tectonics in the Bahía de Banderas area (Kostoglodov and Bandy, 1995). Sulfide and native copper deposition due to shallow hydrothermal activity in the ocean floor provides evidence about the possible formation of some type of exhalative deposits at shallow depths.

ACKNOWLEDGMENTS

We are indebted to R. Lozano-Sta. Cruz and M. Reyes for performing the XRD, XRF and SEM analyses, the CORTES 96 funded by CICYT (ANT94-0182-C02-01/02), Spain; BLOJAL funded by CONACyT(0894PT), LICOJAL funded by CONACyT (4144PT and 32510-T), Mexico. Chemical analyses were supported by the UE contract No CI1*CT94-0075.

BIBLIOGRAPHY


F. J. Núñez-Cornú et al.


F.J. Núñez-Cornú1, R.M. Prol-Ledesma2, A. Cupul-Magaña3 and C. Suárez-Plascencia3

1 SIS VOc, Universidad de Guadalajara, Av. Universidad 203, Puerto Vallarta, Jal., México.
2 Instituto de Geofísica UNAM, Cd. Universitaria, 04510 México, DF., México.