Similarities in the chemistry of shallow submarine hydrothermal vents

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Abstract

Shallow submarine hydrothermal activity has been observed in Western Mexico related to extensional tectonics faults. Hydrothermal vents occur at Punta Banda on the Pacific coast of Baja California, at Bahia Concepcion on the eastern coast of Baja California and in Punta Mita on the Pacific coast of central Mexico.
Submarine discharge of geothermal fluids is located at depths that vary from 5 to 30m. Water and gas discharge at temperatures from 40 to more than 100º C.
The composition of the thermal end-member can be calculated for Mg = 0 using the chemistry data of the water samples. A linear regression of the concentration values vs magnesium content is used to determine the concentration of the end-member thermal water. The chemical composition of the thermal end-member indicates that the water is more dilute than seawater and enriched in Ca, Mn, Ba, I, Cs, B, Li, Rb, Sr and Si.
The results show that the water chemistry is similar in these coastal hydrothermal systems. The thermal water is probably of meteoric origin that penetrates through the extensional faults, and is heated by the high geothermal gradient. The components in the thermal water are contributed by the deep strata.

Key words: Shallow submarine vents, geochemistry, Mexico, isotopic composition.

Introduction

The Pacific margins of Mexico are the location of numerous submarine hydrothermal vents related to the volcanic activity in the East Pacific Rise (EPR). All the studied vents are typical of deep high-temperature systems which are closely associated to recent rifting activity [1,2,3,4]. In addition to the deep vents, shallow coastal hydrothermal activity has been reported in Punta Banda and Bahía Concepción in Baja California [5,6].
Relatively few submarine hydrothermal vents have been described at shallow depths Bay of Plenty, New Zealand, Ambitle and Lihir, Papua New Guinea, and Milos, Greece [8,9,10,11]. The four sites are closely related with recent volcanic activity.
Shallow vents have been reported also in lakes related with continental rift basins in Baringo and Tanganyika Lakes, Kenya and Baikal Lake, Russia, or in crater lakes in Taupo, New Zealand, and Crater Lake, Oregon, [12,13,14,15,16]. The chemical composition of lacustrine hot springs seems to be more similar the continental hydrothermal systems than to the submarine ones.

Shallow submarine vents

The vents in the Bay of Plenty occur at a depth of 200 m with a maximum temperature of 200°C. The gases discharged by the vents are mostly CO_2 but also contain light hydrocarbons formed by cracking of organic matter in the sediments [11]. The shallow Lihir hydrothermal system in Papua New Guinea [10] occurs at depths of 10 to 50 m and the temperatures vary from 60 to 96°C. The gas chemistry is dominated by CO_2 with minor amounts of H_2S, CH_4 and N_2, and suggests a magmatic origin with minor sedimentary contribution. The vent precipitates have anomalous concentrations of As, Cu, Hg, Sb, and Tl. The Ambitle system has diffuse and focused discharge of thermal fluids at temperatures from 89 and 98°C. Water samples show that the thermal fluid is more dilute than seawater and is enriched in HCO_3, B, Si, Li, Mn, Fe, Rb, Cs, Sb, Tl and As. The gas discharged in Ambitle vents is mostly composed by CO2 with minor amounts of CH_4, N_2, H_2S and He.
The hydrothermal system on Milos, Greece, discharges gas and brine from the sea bottom at a depth of 10 m [9]. The brine discharged by the system is enriched in Na, K, Ca, Cl, SiO_2, and dissolved CO_2 and H_2S with respect to seawater. The temperature of the seeps is higher than 90°C and the reservoir temperature was calculated to be above 300°C using the Na/K and Na-K-Ca geothermometers.

Shallow submarine vents in western Mexico

The occurrence of shallow hydrothermal vents in western Mexico is related with the recent extensional tectonic regime (Fig. 1). The hydrothermal activity is restricted to the presence of regional faults that serve as channels for the deep penetration of meteoric water in high heat flow areas. The chemical composition of the vents water is similar in the three cases that have been documented (Table 1) although each has a distinct geological setting.

Fig. 1 Location of the shallow vents in western Mexico. PB – Punta Banda, BC – Bahia Concepcion, PM – Punta Mita.

Table 1. Chemical analyses of the water samples collected in the shallow submarine vents. ND – not determined. Punta Mita and Bahia Concepcion data correspond to the calculated end-member composition from [6,7]Prol-Ledesma et al. (2002) and Prol-Ledesma et al., (2003). Punta Banda data correspond to submarine hot spring water from [5]Vidal et al. (1978).

Sample/Area	mmol/kg				µmol/kg				mmol/kg				
	Ca	**Mg**	**K**	**Na**	**I**	**Mn**	**Cs**	**Ba**	**Cl**	**Br**	**SO_4**	**HCO_3**	**Si**
Seawater	**8.23**	**45.26**	**10.49**	**493.73**	**<0.79**	**<0.02**	**<0.007**	**<0.14**	**535.93**	**0.68**	**26.02**	**2.29**	**<0.03**
Punta Mita	**51.27**	**0.0**	**3.17**	**110.36**	**17.35**	**1.87**	**6.55**	**5.84**	**283.91**	**0.38**	**2.81**	**0.0**	**2.23**
Bahia Concepcion	**44.48**	**0.0**	**13.01**	**230.73**	**5.48**	**165.07**	**12.21**	**8.14**	**380.30**	**0.38**	**4.15**	**10.32**	**7.8**
Punta Banda	**37.92**	**3.29**	**10.0**	**226.2**	**ND**	**15.47**	**ND**	**6.84**	**304.62**	**ND**	**3.65**	**5.69**	**2.6**

Shallow hydrothermal vents along the northern Baja California coast occur at a depth of 40 m and have a temperature of 102°C [5]. The chemistry of the thermal water indicates an enrichment in SiO_2, HCO_3, Ca, K, Li, B, Ba, Rb, Fe, Mn, As and Zn. The gas discharged by the vents is mostly composed of nitrogen and methane; both are present in similar proportions. The location and the chemistry of the vents do not provide any evidence to relate them with a magmatic source, and isotopic data suggest that the vent water is a 1:1 mixture of local meteoric water and "old" seawater [17]. The most abundant minerals are pyrite and gypsum. No other sulfide minerals, with the exception of pyrite, were reported but the metalliferous deposits are highly enriched in As, Hg, Sb, and Tl.

Submarine hydrothermal vents are present also off the southern coast of Punta Mita, in the Bay of Banderas, Mexico. Preliminary exploration identified an area of intense shallow hydrothermal activity off shore from Punta Pantoque, in the Punta Mita area. The area that contains the submarine vents covers an area of 300 m^2 at a depth of about 10m. Water and gas venting occurs in coarse sand along a lineament and consist of both focused and diffuse discharge with a temperature of 85°C. The water is more dilute than seawater and the gas is composed mainly by methane and nitrogen [7]. The Punta Mita hydrothermal system is similar to the Punta Banda vents in the chemistry of the thermal fluid and the hydrothermal minerals. The Punta Mita and the Punta Banda systems seem to be the result of deep circulation of water of meteoric origin, as the discharge water is more dilute than seawater and the gas composition is dominated by nitrogen and methane rather than CO_2. The altered samples and the hydrothermal precipitate are significantly enriched in Sb, As, Ba, Hg, Tl, Cs, Mo.

In the Bahia Concepcion hydrothermal system, fluid venting takes place as submarine diffuse flow at depth that varies from intertidal discharge to 15m depth vents. The gas discharge is episodic and covers an area of more than 1km^2 and the temperature varies from 50°C to 87°C. Additionally to the submarine vents, in Bahia Concepcion there are subaerial springs that discharge on the beach. The subaerial and submarine hydrothermal manifestations in Bahía Concepción discharge water more dilute than seawater and the approximate temperature of equilibrium at depth is about 250°C, as estimated from the quartz and Na-K-Ca geothermometers. The thermal water is enriched in Ca, Mn, Si, Ba, B, As, Hg, I, Fe, Li, HCO_3 and Sr [6]. The hydrothermal system is dominated by mixing of local meteoric water and seawater, as shown by the isotopic composition of the spring water. The major ions and trace elements chemical characteristics of the thermal water are compatible with those observed in deep vents [18]; especially the REE pattern is similar to submarine hydrothermal systems.

In the case of Punta Mita and Bahia Concepcion, several water samples were collected and the calculation of the end-member composition was possible assuming that Mg = 0, according with the results of seawater heating experiments [19]. This calculated end-member composition is shown in Table 1.

Conclusion

The chemical characteristics of the thermal fluids discharged by shallow submarine vents differ from the lacustrine hot springs. Submarine vents composition is controlled by mixing with seawater, even in the case when meteoric water is the main component of the thermal fluid. REE concentration is very low in thermal water from submarine vents, and the pattern that results of REE normalization to chondrite has typical Eu positive anomalies for most submarine shallow vents. The hydrogen and oxygen isotopic composition of the

discharged water is an important feature that provides evidence for the connection with meteoric water. In the case of the shallow submarine vents in Mexico, the three hydrothermal systems have an important contribution from meteoric water. The samples from the vents always fall on a mixing line between meteoric water and seawater.
However, the chemical characteristics of the precipitate of shallow submarine vents show enrichment in such elements as Sb, As, Ba, Hg, which are typical of an epithermal environment. Therefore, the shallow submarine vents discharge water with meteroric water isotopic composition, REE patterns that resemble those observed in deep vents samples, and produce hydrothermal alteration that has mineralogical and chemical characteristics similar to the epithermal systems.

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