

GAS GEOCHEMISTRY EVOLUTION AT THE POAS VOLCANO (COSTA RICA)

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Introduction

The crater summit of Poas Volcano (central Costa Rica) hosts an acid ($pH \approx 0$) crater lake which has changed its morphology from early '50's to early '90's because of geyser-like, small phreato-magmatic and Strombolian volcanic activities (e.g. Malavassi et al., 1994). Presently, the summit area is characterised by the 1953-1955 intra-crater pyroclastic cone, bordering the lake to the south, and by a series of fumarolic fields which have modified both their compositions and positions from February 1998 to February 2000 when a geochemical survey has been carried out in four campaigns (February '98, February '99, December '99 and February '00). The location of the fumarolic vents sampled in this span of time is reported in Fig. 1. During this period of observation a sort of pre-crisis, which could have triggered a geyser-like has been hypothesised by using gas chemistry parameters. A model for such kind of eruptive events, which may evolve in more serious volcanic activity, is proposed, though further observations to validate such a hypothesis are needed.

Sampling technique

Gas samples were collected after the insertion of a titanium tube in the selected fumarole at which quartz-made tubes were connected. Pre-evacuated and weighted thorion-tapped 50 cc vials filled with degassed 20 ml of NaOH 4N and Cd(OH)₂ 0.3N have been used. Gas sampling lasted until the headspace pressure equalised that of the vent. Sulphur species (SO₂, H₂S and S₈⁰) were analysed as SO₄²⁻ by ion-chromatography according to the procedure proposed by Montegrossi et al. (2000). Unreacted gas species (N₂, O₂, H₂, CO, Ar, He, Ne, CH₄ and light hydrocarbons) in the alkaline medium (where CO₂ and HCl were determined by titration and ion-chromatography, respectively) were analysed by gas-chromatography. Condensate samples were analysed for SO₄²⁻ (after complete chemical oxidation of the sulphur species), F⁻, Br⁻, NO₃⁻, etc. Eh has been calculated by main gas species that may take part in oxidation-reduction processes.

Results and discussion

Many are the variables that concur to interfere with the gas composition retrieved at the crater summit of Poas, e.g. rock permeability, thickness of the water table, gas-gas, rock-fluid and water-gas reactions, etc. (e.g. Casertano et al., 1987; Rowe et al., 1992; 1995). During the period the present study was carried out (February 1998-February 2000), the fumarolic manifestations have been modifying both their chemical compositions and their flux, thus impeding to keep at least one of the variables fixed, i.e. a single fumarole vent as a reference point. For instance, the Pared Sur fumarole (PS in Fig. 1) located at about 300 m from the pyroclastic cone has practically

disappeared in December 1999. Contemporaneously, newly formed fumaroles and boiling pools came out from the south-eastern wall of the crater at about 150 m from the lake (Sur-Este, SE, Quebrada Este, QE, and Quebrada Roja, QR, Fig. 1). The Dome fumarole was sampled in two different places due to flux variation in time.

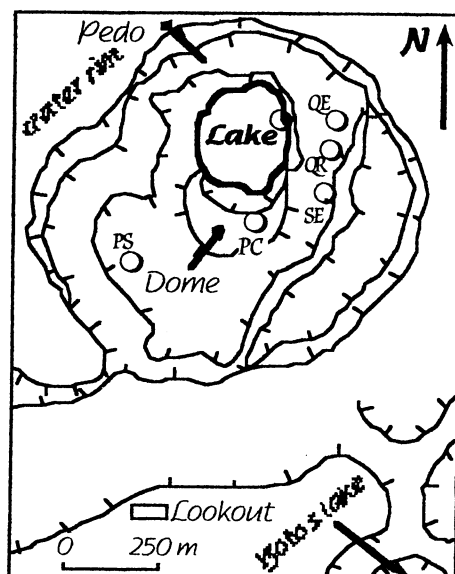


Figure 1. Sampling location of the fumaroles, boiling pools and waters at the Poas crater summit. PS: Pared Sur; PC: Pyroclastic Cone; QE: Quebrada Este; QR: Quebrada Roja; SE: Pared Sur-Este.

The representative gas compositions (in % by vol.) of the Poas fumaroles from February '98 to February '00 are reported in Table 1 whereas SO_4 vs. Cl abundances (in ppm) in the fumarolic condensates (Pared Sur, Pared Este and Dome), Botos and Poas Lakes, and Pedo spring discharge (Fig. 1) are shown in Fig. 2.

The Poas fumaroles have a clear high-temperature signature as testified by the presence of SO_2 , H_2 and CO. However, these gases are affected by interaction with surficial aquifer and modified their composition from February '98 to February '00. No temperature changes were observed for both the fumaroles and the crater lake, the latter also maintaining its chemical composition practically unchanged. On the basis of these chemical variations and field observations, we have tried to reconstruct the fumarolic evolution (Fig. 2).

	H ₂ O	CO ₂	H ₂ S	SO ₂	S	HCl	N ₂	O ₂	Ar	H ₂	CO	CH ₄	Eh
Pared Este	95.570	0.7566	0.1574	3.4463	0.039634	0.0266	0.003356	0.00011	0.000063	0.000176	0.000005	0.00000001	-0.4894
Sur-Este	99.591	0.2125	0.0149	0.1501	0.003964	<0.0001	0.026367	0.00023	0.000093	0.000676	0.000009	0.00002199	-0.5228
Domo '00	99.343	0.0739	0.0861	0.2955	0.001648	0.1430	0.001364	<0.00001	0.000020	0.055652	0.000144	0.00000217	-0.6359
Quebrada roja	97.164	2.4945	0.3256	0.0001	0.001110	<0.0001	0.009411	0.00212	0.000109	0.002916	0.000014	0.00000006	-0.5609
Domo Nov '99	94.778	2.4161	0.0575	2.6408	0.003728	<0.0001	0.097689	<0.00001	0.002016	0.003199	0.000588	0.00000657	-0.5639
Pared Sur Feb'99	97.948	1.8429	0.1883	0.0002	0.000009	<0.0001	0.018800	0.00003	0.000103	0.001315	0.000006	0.00001626	-0.5402
Domo Feb '99	93.991	3.0178	0.0100	2.9458	0.000337	<0.0001	0.036139	<0.00001	0.000146	0.008390	0.000718	0.00000418	-0.5888

Table 1. Gases composition of the fumaroles and boiling pools at the Poas crater summit.

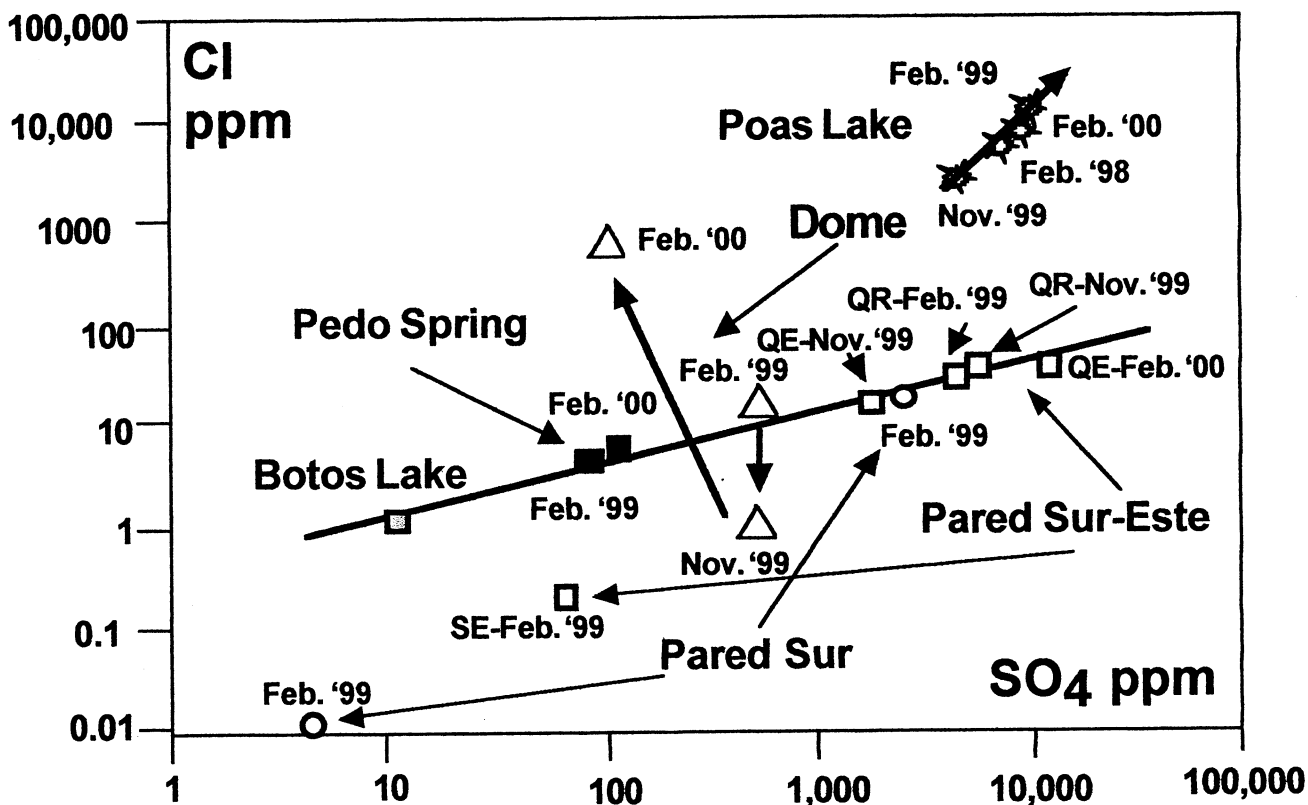


Figure 2. Cl vs. SO_4 diagram for fumarolic condensates, Botos and Poas lakes and Pedo thermal spring discharge. SE: Pared Sur-Este fumarole; QE, QR: Quebrada Este and Quebrada Roja boiling pool, respectively.

- i) In February '98 the fumarole samples from Pared Sur (Fig. 1, Table 1) had a typical high-temperature composition. Between March and November '99, the gas plume sensitively increased its emission as observed by the OVSICORI volcanologists and also supported by the damages in fruit and growing fields as the result of acid rains. However, no evident chemical changes were observed in the fumaroles. The enhanced plume activity may have reflected an interaction (hydrofracturation episodes, as occurred between 1978 and 1990, Rowe et al., 1992) of the surficial aquifer at the Poas crater summit, mainly fed by the Botos Lake (Fig. 2 and Rowe et al., 1995), which entered the magmatic system, located at a relatively shallow depth (Brown et al., 1989). A slight decrease in the Cl content (Dome Feb. '99 and Nov. '99, in Fig. 2) and the slight increase in the calculated Eh values (Table 1) seem to suggest dilution and oxidation processes, respectively, in the Poas fluids as the aquifer interacted with the magma chamber.
- ii) After November '99, the chemical compositions of the fumaroles commenced to change and new fumaroles were identified in the Pared Sur-Este of the Poas crater summit. In February '00, we observed a sharp increase in the Cl content and a clear decrease of the Eh calculated values of the condensates (Dome Feb. '00 in Fig. 2 and Table 1, respectively); thus, suggesting an abrupt release of magmatic fluids to the surface. Simultaneously, the plume declined its activity. The drastic increase in H_2 , CO, CH_4 (and related light hydrocarbons) and H_2S (Table 1), recorded in February '00, is possibly

related to the variation of both the thermal state and redox conditions of the system. The asynchronous behaviour of the plume activity and chemical variation of the fumaroles can be explained as a prompt transmission of the heat to the surface with respect to the kinetics of the chemical reaction chains.

On the basis of the data obtained, we may suggest that chemical variations of the Poas fumaroles from February '98 to February '00, triggered a sort of aborted geyser-like eruption. The energy accumulated in the volcanic system, related to an increased thermal exchange between fluids and magmas (hypothetically due to a partial micro-fracturation of the carapace), did not result in an internal pressure uprising able to overcome the litho- and hydrostatic pressure. However, the accumulated energy was partly released through weakness zones located in the southern-eastern part of the crater summit, e.g. QE fumarole where SO₂ reached 3.44% by vol. (Table 1).

The shallow depth of the magma chamber and presence of the surficial aquifer seem to regulate the volcanic activity at Poas Volcano. Permeability changes due to hydrofracturation favour the vaporisation of water that results in an increase in the internal vapour pressure. As a consequence, the eruptive events may evolve from geyser-like to small phreato-magmatic activity according to the magma/water ratio. In this scenario, gas chemical variations can better trigger modification of the system even if in the absence of seismic phenomena.

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