Fluids Geochemistry from Planchón-Peteroa-Azufre volcanic Complex, Southern Volcanic Zone, Chile

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Abstract. Peteroa is a composite stratovolcano located at the border between Chile and Argentina (35 º 31'W-70 º 14'S-4,107 m a.s.l.) and belongs to the Planchon-Peteroa-Azufre Volcanic Complex. Peteroa presents 4 craters hosting acidic lakes and 3 of them with fumarolic activity. Several thermal springs, occasionally associated with bubbling gases, were recognized in the surrounding of the volcano. Gas geochemistry suggests the presence of a shallow hydrothermal system, constituted by vapor separated from a boiling aquifer at temperatures from 275°C to 340°C, which is affected by input of deep magmatic species (e.g. SO_2, N_2 and ^3He). A mix of hydrothermal and meteoric end members characterizes surrounding thermal springs, although magmatic input cannot be ruled out. Crater lakes have acidic SO_4^{2+} waters, whereas the thermal springs located within the Gendarmería, El Azufre and External valleys, have a HCO_3^--Na^+ and Cl^--Na^+ composition.

Key words: Fluid geochemistry, crater lake, thermal springs, Peteroa.

1 Introduction and geological setting

Planchon-Peteroa-Azufre Volcanic Complex (PPAVC) is a NE-SW volcanic chain located in the border between Chile and Argentina (35º31'W-70°14'S – 4,107 m s.n.m.) and is part of the Southern Andean Volcanic Zone (SAVZ) (Fig. 1). The 4 km wide caldera summit of the currently active Peteroa volcano show 4 main craters (150-500 m diameter) and a scoria cone (150 m diameter, 60 m height) (Naranjo et al., 1999). Acidic lakes are hosted in the 4 craters, 3 of them showing permanent fumarolic activity. An intense thermal activity characterized by presence of thermal springs can be recognized in: the Vergara Valley (N side), External Valley (NE side), Gendarmeria and Los Azufres valleys (E side), SE flank of Azufre volcano and Colorado Valley (SSE side).

Peteroa volcano is the youngest and smallest (<1 km^3) volcano of the PPAVC, and is formed by calc-alkaline lavas and pyroclastic units, mainly corresponding to andesites and Holocene rhyodacitic tuffs. Differently, Azufre and Planchon volcanoes are composed by basaltic to dacitic lava and pyroclastic flows (Tormey et al., 1995). PPAVC is built above an underlying basement consisting in Cretaceous marine and evaporitic sediments, formed mostly of limestone, conglomerates and sandstones, basaltic to rhyolitic lava flows and pyroclastic rocks (Tertiary) and Middle Tertiary granodiorite plutons (e.g. Haller et al., 1985; Naranjo et al., 1999). PPAVC is related genetically to strike-slip faults W–NW trend, where volcanoes are aligned (Tormey et al., 1995).

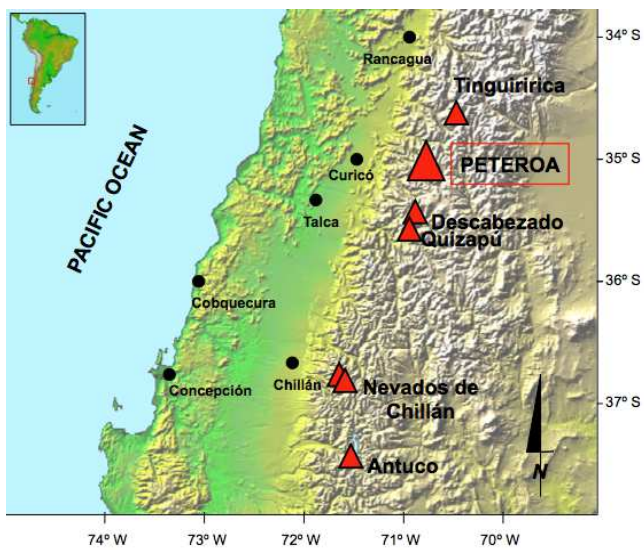

Figure 1. Location map of the study area.

Historical activity of Peteroa volcano includes explosive eruptions in 1762 and 1889–1894 and lava flows in 1837 and 1937. In 1991, the greatest phreatomagmatic eruption of the 20th century occurred. This eruption produced eruptive columns as high as 1,000 and 2,000 m above the crater, being dispersed to E-NE by 80 km approximately. Lahars occurred in the W side of volcano (BGVN, 1991; Gonzalez-Ferrán, 1995; Naranjo et al., 1999). The last eruptive cycle started during September 2010, with sporadic phreatic explosions in October 2010, February, April and May 2011.

This study presents chemical and isotopic data of gas and water from fumaroles, crater lakes and thermal springs related to PPAVC for period 2010-2011. The main aim is to determine the geochemical characteristics of the hydrothermal-magmatic system in the PPAVC.

3 Results

3.1 Gas composition

Gas samples from fumaroles and bubbling pools present temperatures that ranging from 87.7 to 102.1°C, and 24 to 46.2, respectively. Water vapor ranged from 78.19 to 96.15% vol., and from 0.95 to 3.49% vol., for fumaroles and bubbling pools, respectively. Gas composition (excepting water vapour) is dominated by CO_2 (up to 997,000 μmol/mol), and is characterized by presence of SO_2 (up to 0.550 μmol/mol), HCl (up to 0.385 μmol/mol) and HF (up to 0.021 μmol/mol), with the exception of Barros Colorado fumarole and those gas samples collected from the bubbling pools of the surrounding valleys. Significant concentrations of H_2S (up to 35.4 μmol/mol), N_2 (up to 8.14 μmol/mol), CH_4 (up to 1.58 μmol/mol), H_2 (up to 0.384 μmol/mol) and CO (up to 0.015 μmol/mol), where also measured in the fumaroles. Oxygen, Ar and He have concentrations up to 0.64, 0.15 and 0.0078 μmol/mol, respectively. Light hydrocarbons concentrations (ΣC_2–C_7) ranges from 0.0094 to 2.90 μmol/mol. The $\delta^{13}C$-CO_2 values range from -13.21 to -2.02‰ V-PDB. The δD and $\delta^{18}O$ values in water of condensate samples range from -106 to -73‰ and from -14.7 to -3.5‰ V-SMOW, respectively. Helium isotopes composition expressed as R/R_a range between 3.27 and 7.11.

3.2 Water composition

Water samples from bubbling pools and springs have temperature, pH and TDS that range from 2.3 to 77.2°C, 1.49 to 7.92 and 107 to 11,663 mg/L. The concentration of main anions, HCO_3^-, SO_4^{2-} and Cl^-, range from 7 to 1,334 mg/L, 2.1 to 3,288 mg/L and 0.04 to 5,135 mg/L, respectively. The more abundant cations are Na^+ (from 5.3 to 3,674 mg/L), K^+ (from 1.7 to 462 mg/L), Ca^{2+} (from 16 to 674 mg/L) and Mg^{2+} (from 4 to 377 mg/L). Concentrations of NO_3^- are up to 3.64 mg/L, whereas those of F^-, Br^- and Li^+ are up to 39.2, 5.81 and 1.96 mg/L, respectively. The δD and $\delta^{18}O$ values of waters vary from -106 to -74‰ and from -14.7 to -9.5 ‰ V-SMOW, respectively.

4 Discussion

4.1 Gas geochemistry

Gases from Peteroa craters, Colorado Valley and all thermal springs are result of mixing from two end members: i) Hydrothermal and ii) magmatic sources (Fig. 2). In the case of Peteroa craters discharges, the presence of high temperature gas like SO_2, and other acid gases like HCl and HF, suggest input of fluids from a magmatic source. In fact, Peteroa crater fumaroles present high R/Ra ratios, ranging between 6.78 and 7.11. Although Colorado Valley and diverse thermal springs discharges are dominated by input of hydrothermal fluids (Fig. 2), R/Ra ratios suggest contributions of 40 to 46% of magmatic helium (^3He). In fact, N_2/Ar ratios for Colorado Valley discharges (>500) are higher than Air (84), indicating a no atmospheric source for N_2. According to Giggenbach (1996), N_2 in subduction zones is related to sediments released from subducting slab, consequently, N_2 excess can be attributed to a magmatic source. Accordingly, subducted sediments sources originate $\delta^{13}C$-CO_2 composition. Thermal springs discharges are affected by meteoric fluids, scrubbing its original compositions, being especially strong in the farthest springs (e.g. External Valley) (Fig. 2).

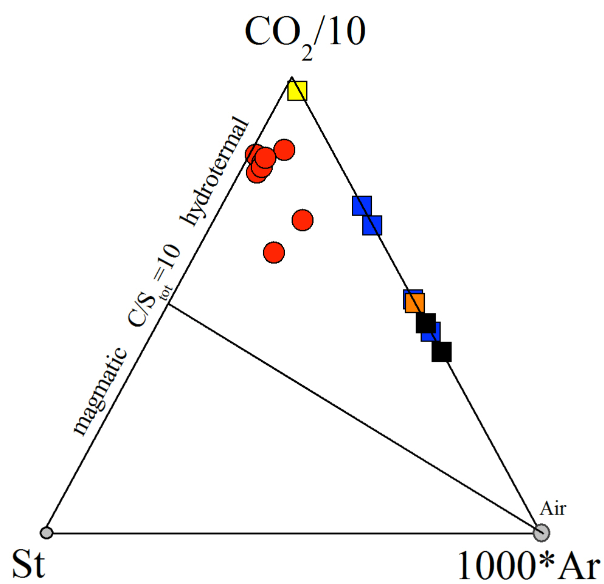

Figure 2. 1000*Ar-CO_2/10-St ternary diagram for PPAVC gases. Red circles: Peteroa crater; Black squares: Gendarmería Valley; Blue squares: Los Azufres Valley; Orange squares: External Valley; Yellow Square: Colorado Valley

4.2 Water geochemistry

Accordingly to Fig. 3, crater lake samples show typical acid SO_4^{2-}-(Cl^-)-Ca^{2+} waters, produced by dissolution of gases like SO_2, H_2S and HCl. Waters from Gendarmería and External valleys correspond to HCO_3-(SO_4^{2-})-Na^+, with relatively high contents of Mg^{2+}. Colorado Valley shows two different water groups, the first corresponding to HCO_3^--Na^+ waters, while the second (Río Colorado Spring) shows a Cl^--Na^+ composition, typical waters fed from geothermal reservoirs. Waters from Vergara Valley have a Cl^--Na^+-(Ca^{2+}) composition and can be attributed to waters from a geothermal reservoir.

The water composition in Peteroa crater condensates is consequence of a mix between "andesitic water" and a meteoric source related to local precipitation (Fig. 4). In the cases of Peteroa crater lakes, Colorado Valley and thermal springs, are dominated by meteoric water.

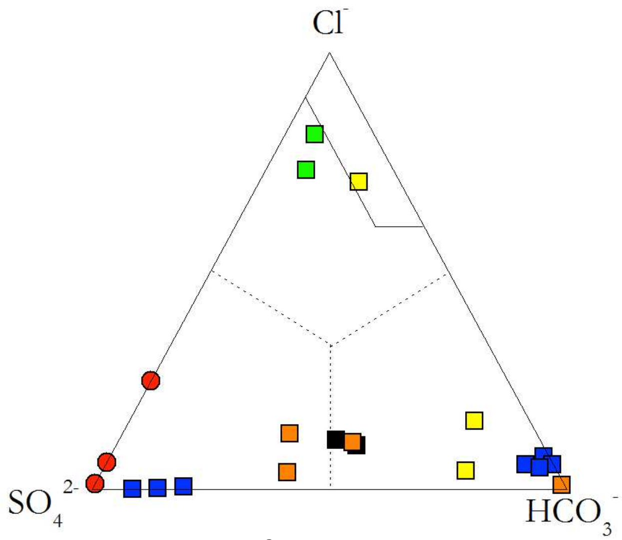

Figure 3. HCO_3^- - Cl^- - SO_4^{2-} ternary diagram for PPAVC waters. Red circles: Peteroa crater lakes; Black squares: Gendarmería Valley; Blue squares: Los Azufres Valley; Orange squares: External Valley; Yellow Square: Colorado Valley; Green squares: Vergara Valley.

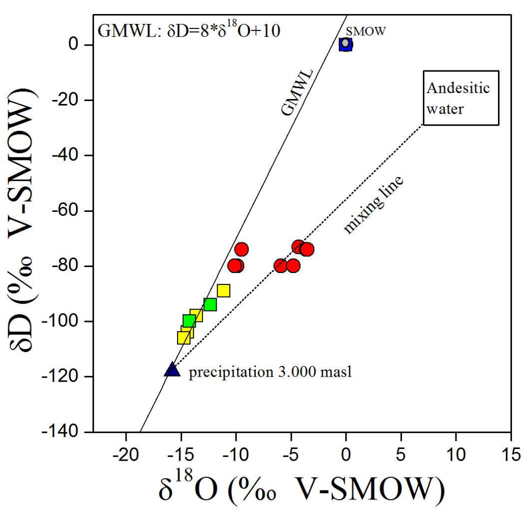

Figure 4. $\delta^{18}O$–δD diagram for fumarolic condensates from PPAVC. Symbols as Fig. 4

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