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Thermo-chemical variations of the hydrothermal fluids in the Berlin geothermal field (El Salvador)

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The liquid-dominated Berlin geothermal field is located about 110 km ESE of San Salvador, on the northern slope of the Berlin-Tecapa volcanic complex. The geothermal reservoir occurs within andesitic to basaltic lavas and tuffs. Measured temperatures in the production zones are in the 280-300˚C range, while in the reinjection zones are 245-250˚C. The reservoir fluids are NaCl waters with total dissolved solids of about 6000-10000 mg/kg and CO_2 partial pressures of 0.049-0.460 MPa. A recent exploration project has been carried out by Enel GreenPower and LaGeo at the southern part of the field. A fluid inclusion studies have been carried out on core-samples from the recently explored area and from the production zone in order to obtain information on the thermo-chemical evolution of the geothermal fluids. In addition, isotopic data on hydrothermal epidote allowed to better constrain the sources of the water that circulated in the geothermal reservoir. The examined samples are mainly composed of volcanic rocks and breccias affected by hydrothermal alteration. The secondary minerals (mostly epidote, chlorite, quartz, adularia, albite, prehnite, calcite) occur either as replacement of primary minerals or within micro-fracture and voids. Fluid inclusions microthermometry has been performed on fluid inclusions found in hydrothermal and igneous quartz, albite, adularia, calcite, anhydrite and prehnite. Most of the observed inclusions are aqueous, two-phase liquid-rich inclusions; rare vapor-rich inclusions also occur in some samples. Fluid inclusion homogenization temperatures range is 191-344˚C; the inclusions with the highest homogenization values at each sampling depths were trapped at or close to boiling condition. A cooling process is recorded by the wide ranges of homogenization temperatures and is also evidenced by the comparison of present-day temperature at the sampling depths and fluid inclusion homogenization temperatures. In particular, a significant temperature decrease (up to 100˚C) occurred from the trapping of hottest fluid in the recently explored area to present-day condition at depths $>$ 1.5 km below the ground level. Apparent salinities of many fluid inclusions are comparable to those of present-day fluids; however there are also fluid inclusions showing higher and lower salinities than present-day fluids. Low values of apparent salinity (down to 0.2 wt. % NaCl equiv.) can be related to the circulation of liquid water formed from steam condensation and/or in part to a decrease of the CO_2 content in the geothermal fluid due to boiling processes. Whereas, the occurrence of inclusions in deep samples showing significantly high salinities (up to 21.2 wt.% NaCl equiv.) can be related to two processes: 1) open system fluid boiling with steam lost, or 2) injection of a high-salinity fluid in the system. The relatively high δD values (up to -42 per mil) of the H_2O in equilibrium with epidote is coherent with the sporadic input of saline fluids of magmatic derivation that mixed with geothermal fluid of meteoric origin in the deep part of the hydrothermal system. On the other hand, prolonged open system boiling processes at the temperatures indicated by fluid inclusions are not compatible with these isotopic values.