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Fluid geochemistry of a deep-seated geothermal resource in the Puna plateau (Jujuy Province, Argentina)

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ABSTRACT

This study focused on the geochemical and isotopic features of thermal fluids discharged from five zones located in the high altitude Puna plateau (Jujuy Province between S 22°20′–23°20′ and W 66°–67°), i.e. Granada, Vilama, Pairique, Coranzulí and Olaroz. Partially mature waters with a Na^+-Cl^- composition were recognized in all the investigated zones, suggesting that a deep hydrothermal reservoir hosted within the Paleozoic crystalline basement represents the main hydrothermal fluid source. The hydrothermal reservoirs are mainly recharged by meteoric water, although based on the $\delta^{18}O$-H_2O and δD-H_2O values, some contribution of andesitic water cannot be completely ruled out. Regional S-oriented faulting systems, which generated a horst and graben tectonics, and NE-, NW- and WE-oriented transverse structures, likely act as preferentially uprising pathways for the deep-originated fluids, as also supported by the Rc/Ra values (up to 1.39) indicating the occurrence of significant amounts of mantle He (up to 16%). Carbon dioxide, the most abundant compound in the gas phase associated with the thermal waters, mostly originated from a crustal source, although the occurrence of CO_2 from a mantle source, contaminated by organic-rich material due to the subduction process, is also possible. Relatively small and cold Na^+-HCO_3^--type aquifers were produced by the interaction between meteoric water and Cretaceous, Palaeogene to Miocene sediments. Dissolution of evaporitic surficial deposits strongly affected the chemistry of the thermal springs in the peripheral zones of the study area. Geothermometry in the Na-K-Ca-Mg system suggested equilibrium temperatures up to 200 °C for the deep aquifer, whereas lower temperatures (from 105 to 155 °C) were inferred by applying the H_2 geothermometer, likely due to re-equilibrium processes during the thermal fluid uprising within relatively shallow Na-HCO_3 aquifers. The great depth of the geothermal resource (possibly > 5000 m b.g.l.) is likely preventing further studies aimed to evaluate possible exploitation, although the occurrence of Li- and Ba-rich deposits associated may attract financial investments, giving a pulse for the development of this remote region.

1. Introduction

The western sector of the Jujuy Province (NW Argentina) is part of northern Puna, a high-altitude plateau (from 3000 to 5000 m a.s.l.) that borders the Central Volcanic Zone (CVZ). Miocene-Pliocene volcanic complexes and extensive ignimbrite plateaus dominate the region that is characterized by arid climate and internally draining basins producing extended salt deposits (*salar*) and ephemeral B- and Li-rich salt lakes. Neogene volcanogenic polymetallic (Ag, Pb, Zn, Sn) sulfide ore deposits (some of them of world class) are also occurring, mostly being exploited by private and governmental companies (Lopez Steinmetz, 2016). Coira (2008) and Pesce (2008) reported the occurrence of several thermal fluids discharges in northern Puna, although little is known about their chemical and isotopic features. Few geochemical data (temperature outlets and concentrations of the main solutes) were produced in the framework of geochemical prospection surveys carried out in the 1970′s and 1990′s by different companies: 1) Aquater Ltd., in collaboration with the Jujuy Mining Direction and Mining Secretary, Hidroproyectos SA, Setec SRL, and Cepic SC; 2) Jujuy Government, in collaboration with CREGEN and Universidad Nacional de Jujuy. According to these preliminary data, the geothermal potential in this area was considered of interest for a possible exploitation. Notwithstanding these promising results, the activity stopped after the drilling of few explorative, unproductive wells at Tuzgle-Tocomar zone (Giordano et al., 2013). The recent renewed interest for geothermal energy (Argentine National Laws n. 26.190/06 and n. 27.191/15), as well as the exploitation of other natural resources such as Li-rich deposits (Lopez Steinmetz, 2016), has intensified investigations in northern Puna aimed to evaluate, by means of geochemical and isotopic tools, the occurrence of

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thermal fluid reservoirs and their suitability for an exploitation in the years to come.

In this paper, original set of chemical and isotopic data of thermal fluid discharges from an area of 8000 km^2 in the Puna plateau, comprised between S 22°20′–23°20′ and W 66°–67° (Fig. 1), are presented. To provide insights into the potential geothermal resource, the main goals are to 1) describe the geochemical and isotopic features of waters and gases, and 2) investigate the primary fluid sources and the secondary processes controlling the fluid chemistry as fluids are discharged to the surface.

2. Geological and volcanological settings

The Puna plateau is located in the back-arc area of CVZ, where the subduction of the Nazca Plate beneath that of South America takes place (Allmendinger et al., 1997 and references therein). A seismic anomaly in the middle crust, between 22°S and 24.5°S, was interpreted as related to the presence of a ~1 km thick sill-like igneous body, namely Altiplano Puna Magmatic Body (APMB) (Chmielowski et al., 1999; Zandt et al., 2003; Ward et al., 2014). As shown in Fig. 1a,b, the outcropping basement formations consist of Ordovician shallow-marine

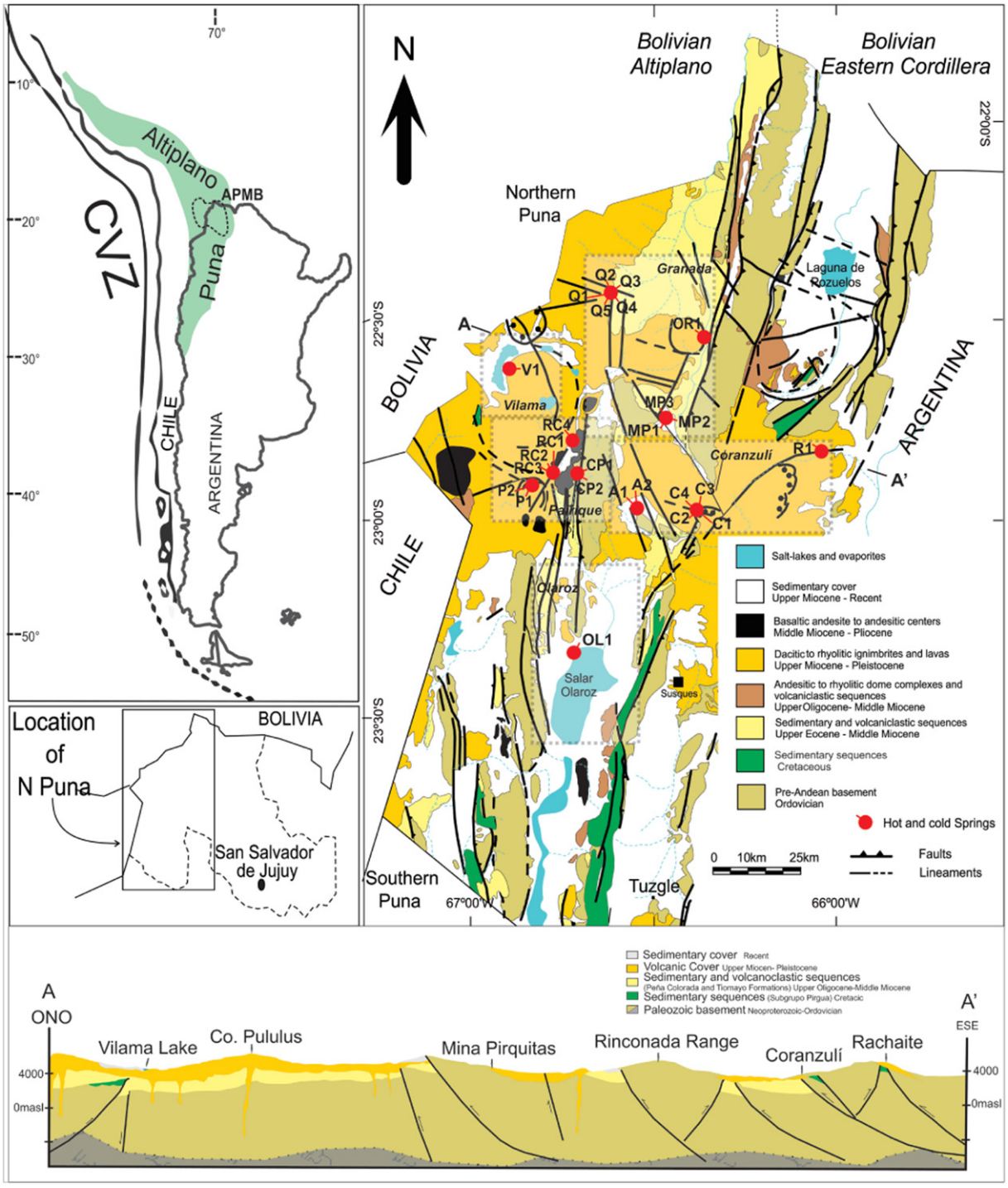

Fig. 1. (a) Geological map of the northern Puna (Argentina) (modified from Caffe et al., 2002) and location of thermal fluid discharges; (b) schematic geological cross-section A–A′ (modified from Coira et al., 2004).