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Sulphate efflorescences at the geyser near Pinchollo, southern Peru

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ABSTRACT

Sulphate mineralization precipitated around a geyser located above the village of Pinchollo, Chivay district and below Hualca Hualca volcano (6025 m a.s.l.) in the Western Cordillera of southern Peru is described. The geyser is one of many manifestations of thermal activity in the Arequipa department. Its age is estimated to be Upper Pleistocene–Holocene, as the discharge point lies at the intersection of a fault system with latitudinal dip-slip fault cutting a volcanic-debris avalanche of probably Pleistocene age. Thermal waters present in the Chivay district are mainly chloride-rich with a neutral pH. They are rich in Li, Sr, and B. The water erupting in the geyser boils at about 85 °C, as it lies at some 4353 m a.s.l.

The minerals examined, of various habits and various yellow, orange and white colours were precipitated on the soil and on plants close to the geyser (location 1), on the walls of a 1 m diameter pothole filled with boiling water (location 1a) and at a distance of some 100 m to the west of the geyser (location 2). All are sulphates. Their chemical composition is fairly simple, consisting of Al, Fe, K, Mg, Ca, S, NH_4 and O, and all display chemical zoning. But the phase composition is more complex. In all locations, alunogene, copiapite, coquimbite, tschermigite and gypsum are present. Close to the geyser (location 1) magnesium-containing sulphates, namely, boussingaultite and pickeringite also occur. Iron sulphates such as mohrite and rozenite precipitate on the walls of the pothole (location 1a). Sulphates containing potassium such as jarosite, alunite and voltaite–voltaite (Mg) dominate among the efflorescences in location 2, where hematite was also noted. Any quartz and kaolinite or illite/mica admixture identified in some samples derives from adjacent soil.

The present geothermal system does not involve the deposition of precious-metal deposits such as those associated with an earlier deep-going epithermal system that scavenged a large volume of rock. Most likely, as the present-day thermal waters do not involve a juvenile-water component, the geyser waters derive from a shallower source.

1. Introduction

Hot springs in the Southern Andes of Peru were investigated in 1996 and 1997 by the Instituto Geológico Minero y Metalúrgico (INGEMMET) to evaluate the possibility of generating electricity and of using hot water for heating and bathing purposes. Present-day geothermal activity there is represented by hot springs, fumaroles and surface precipitates related to active- or dormant-stratovolcanoes. Twelve areas with the highest geothermal potentials in Peru were identified: Puquio, Parinacochas, Cotahuasi, Coropuna, Orcopampa, Cailloma, Chivay, Chachani, Ubinas, Calacoa, Tutupaca and Rio Maure (Steinmüller, 2001). The Chivay geothermal area extends along Rio Colca from Callali to the mouth of Rio Ayo (Fig. 1). Volcanism and thermal activity in Southern Peru is connected with an active subduction zone – the underthrusting of the Nazca Plate under the South American Plate. The process has generated high heat flows since Jurassic times, plutonism and submarine volcanism during the Mesozoic (Aguirre and Offer, 1985) and subaerial volcanic activity in the Cenozoic. Steinmüller (2001) distinguishes two geothermal systems in South Peru. One, deep and long-term, resulted in the leaching of large rock volumes, high precious-metal concentrations in the fluids and the deposition of economic epithermal precious-metal deposits during the Neogene. The second, shallow and short-term, has a lower capacity to mobilize and transport host-rock metals. Fluids generated by this second geothermal system were incapable of forming economic mineralization. Nevertheless, they precipitated a set of minerals which may reflect the chemical composition of the thermal water and indicate its source.

The aim of this study is to describe the surface sulphate efflorescences which precipitated from thermal water in the vicinity of the geyser presently active to the south of Pinchollo village, Chivay

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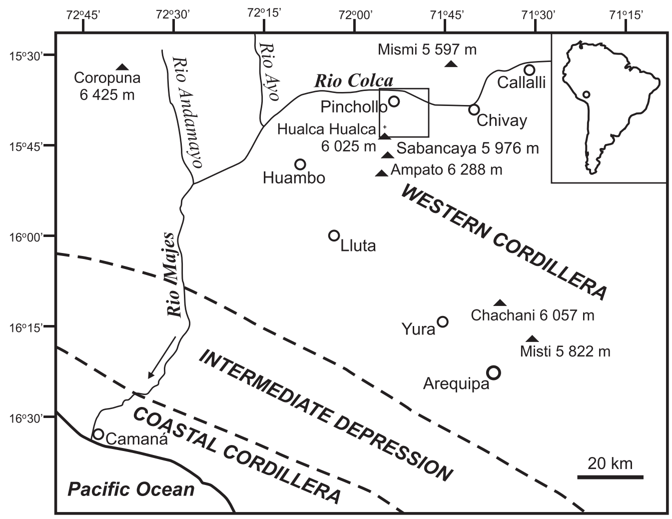

Fig. 1. Geyser location (cross) on the slope of Hualca Hualca volcano in the Western Cordillera, southern Peru. Rectangle shows the area of Fig. 2.

district. Its coordinates are S15°40′448, W71°51′704 and its altitude 4353 m a.s.l. (Figs. 1 and 2). In addition, the study aimed to delineate the geochemical distribution of elements in the environs of the active geyser and to explain of unusual position of the geyser in the Chivay district, far from other thermal manifestations along the Colca river bed.

2. Geological setting

The geyser is one of many manifestations of thermal activity in the Arequipa Department where a belt of huge stratovolcanoes of the Central Volcanic Zone of the Andes surmounts the Western Cordillera and the edge of the Altiplano. One of these is the snow-capped Hualca Hualca stratovolcano (6025 m a.s.l.) bordering the active Sabancaya. They belong to the Pliocene–Quaternary Barroso Group (Fídel et al., 1997). Vast lava fields, and small scoria cones of the Pleistocene–Holocene Andahua Group, evidence persistent input of heat from depth (Gałaś, 2008, 2011).

The Rio Colca flows in a deeply-incised canyon that unveils the crystalline Arequipa Massif and folded Mesozoic sedimentary formations, mostly epicontinental siliciclastics. These are intruded by Late Mesozoic–Paleogene granitoids and covered by a thick sequence of slightly folded Oligocene–Miocene volcanics of the Tacaza Group. Locally, the Barroso and the Andahua volcanics mask the substratum. Both the Tacaza and Barroso volcanics reveal large fields of hydrothermally altered rocks, e.g., at the Hualca Hualca and Mismi stratovolcanoes. Neogene epithermal veins of gold-silver ores are known to the north of the Rio Colca, and Pleistocene(?)–Holocene travertine deposits to the south of the river (Klinck and Palacios, 1985; Paulo, 2008; Paulo and Gałaś, 2005). The Colca Valley between Chivay and Madrigal forms a graben filled with Quaternary volcanic-derived sandy- and silty lacustrine deposits and terraces of river gravels. They are disturbed by Holocene landslides (Kalicki and Kukulak, 2008; Żaba and Małolepszy, 2008; Fig. 2). Farther SW, the erosional regime of the river prevails. Evidence of recent seismic activity and fault tectonism is extensive.

The exposed sequence lacks extensive good aquifers except for the Quaternary fill of the Colca Valley and the Andahua Valley. These are interconnected by the present-day river network and carry cold water. Most of the hot springs in the Colca Valley outpour from fractured Mesozoic formations near the river bed. The Pinchollo geyser is exceptional in that. It appears some 1250 m above the Colca canyon at the distance of almost 9 km from the river bed.

The geyser of Pinchollo, located at the foot of the Hualca Hualca stratovolcano, exploits a fault fissures at the rim of a huge niche which resulted from an avalanche of debris in, probably,

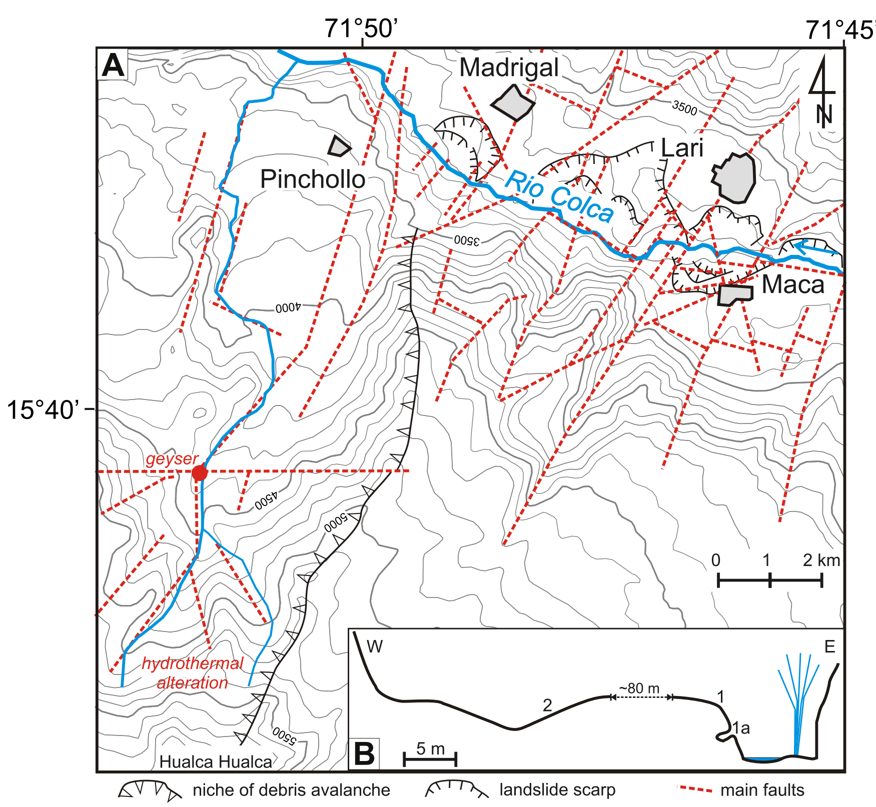

Fig. 2. A) Location of the Pinchollo geyser: S15°40′448 W71°51′704 and its relation to the fault network. B) Sample locations (1, 1a and 2) on the morphological profile at the geyser.