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Mapping patterns of mineral alteration in volcanic terrains using ASTER data and field spectrometry in Southern Peru

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ABSTRACT

Because formation of ore deposits is linked to volcanic and post-volcanic processes, an understanding of alteration style in volcanic regions has important applications in economic geology.

We use ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) data and field spectrometry for mineral mapping in selected Miocene to Quaternary volcanic areas in Southern Peru to better characterize and understand the Tertiary volcanic evolution in this region. Our goal is to characterize volcanic regions near Puquio (Ayacucho) by correlating areas of intense alteration and related ignimbrite outflow sheets. In particular, we spectrally and mineralogically map different types and intensities of alteration based on remote sensing and ground-truth data.

ASTER ratio images, alteration indices and false color composites were used to select ground-training areas for sample collection and field spectrometry. Alteration samples were characterized geochemically, mineralogically and spectrally. Absorption features correlate with chemical properties (e.g. iron content). Hyperspectral data from field spectrometry allow identification of important alteration minerals such as kaolinite and smectite. Alteration mineral assemblages range from silicic to argillic to "zeolite-type". Using a support vector machine classification (SVM) algorithm on ASTER data, we mapped the different types and intensities of alteration, along with unaltered ignimbrite and lava flows with an accuracy of 80%. We propose a preliminary model for the interpretation of alteration settings, discuss the potential eruption sites of the ignimbrites in the region and, propose pH and temperature estimates for the respective classes based on the mineral assemblages identified.

1. Introduction

While the large Miocene to Quaternary silicic ignimbrite fields on the Puna-Altiplano plateau of the southern Central Volcanic Zone (CVZ) are very well studied (e.g. de Silva, 1989, 1991; Kay et al., 2010; Lindsay et al., 2001; Salisbury et al., 2011; Schmitt et al., 2003; Soler et al., 2007), little is known about the ignimbrites and their eruptive centers in the less arid northern CVZ in southern Peru. This is due to their older ages, higher rates of precipitation and resultant, somewhat denser vegetation cover, deep valley incision, and weathering in this area compared to the hyperarid climate and excellent preservation of the southern Altiplano/-Puna ignimbrites and related calderas. Nevertheless, large ignimbrite sheets with estimated volumes that are comparable to Altiplano outflow sheets can be observed, and knowledge about timing, location of eruptive centers, and composition can provide valuable information for the temporal and spatial understanding of the Tertiary evolution of the Andes.

Calderas represent long-lived magmatic systems that may span several millions of years, show prolonged hydrothermal activity, and form mineral deposits related to caldera structures (Rytuba, 1994; Woldegabriel, 1990; Smith and Bailey, 1968; McKee, 1979; Lipman, 1984). Hydrothermal systems are mainly related to post-caldera intrusions and vent complexes along reactivated faults towards the end of a caldera cycle. Our region of interest is located near Puquio (Ayacucho) (Fig. 1). Magmatic activity spans from the eruption of the Nazca ignimbrites >22 Ma (Roperch et al., 2011; Thouret et al., 2007) to the age of deeply glaciated stratovolcanoes (7–9 Ma; Karátson et al., 2012) in the area. Little is known about the location of these calderas and timing of their magmatic

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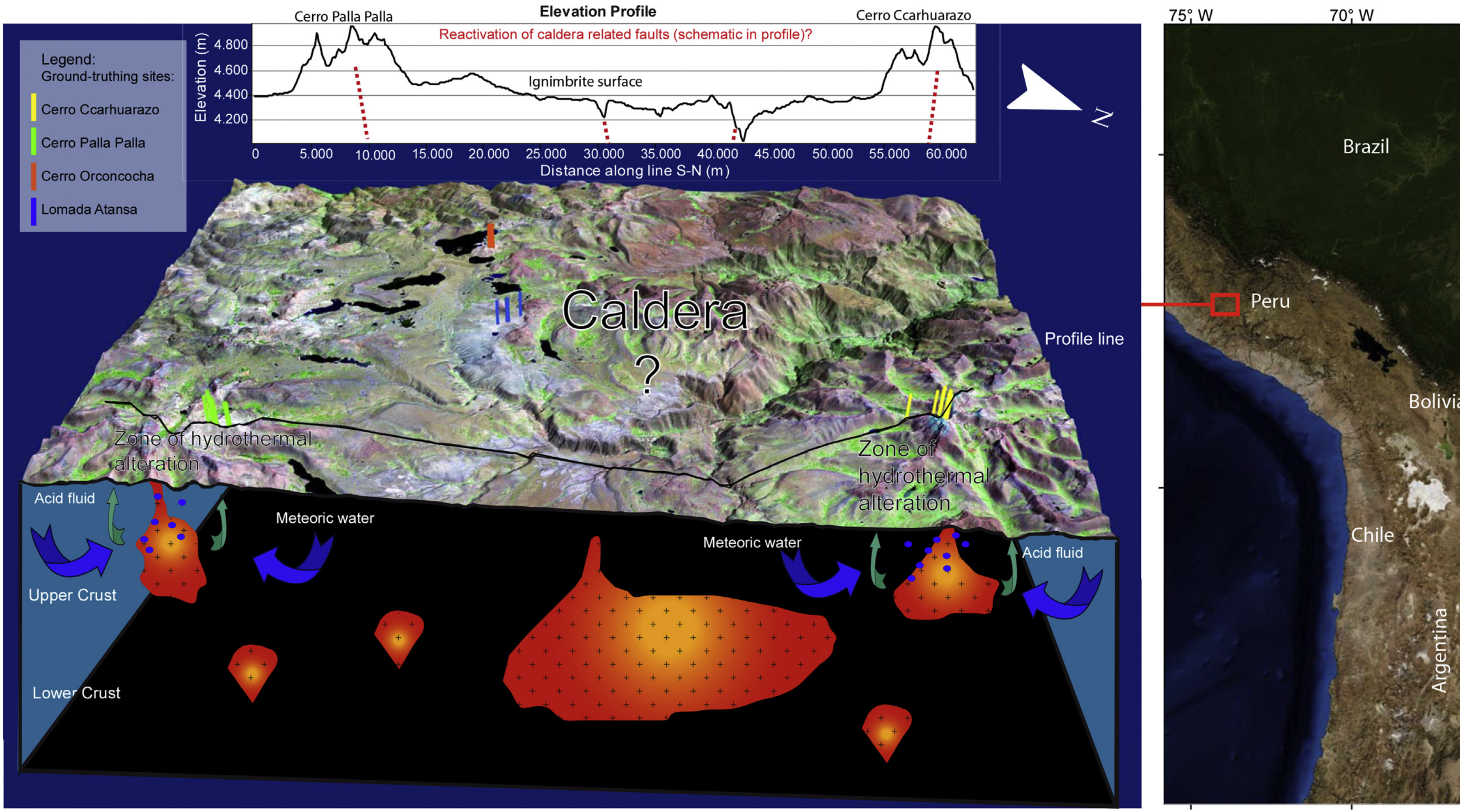

Fig. 1. The area of interest is shown as Landsat (RGB:742) draped on SRTM elevation data ($z = 2$) and an elevation profile through the Cerro Palla Palla, the ignimbrite surface and the Cerro Ccarhuarazo (black line). Ground-truthing sites are shown as 3D features and are also provided as kml file. Underlying the satellite data, a conceptual model is shown: Assuming that the caldera cycle is only part of a larger magmatic episode spanning millions of years, ring fractures of calderas and other tectonic features related with the formation of a caldera can be reactivated and magmatic and hydrothermal activity can continue. Surface processes alter the morphology of the landscape and caldera structures might no longer be visible, but hydrothermal alteration related to reactivated structures can still be detected. The model shows an old magma chamber below the ignimbrite surface and hydrothermal activity close to younger volcanic edifices.