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The magmatic history of the Vetas-California mining district, Santander Massif, Eastern Cordillera, Colombia

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ABSTRACT

The Vetas-California Mining District (VCMD), located in the central part of the Santander Massif (Colombian Eastern Cordillera), based on U–Pb dating of zircons, records the following principal tectonomagmatic events: (1) the Grenville Orogenic event and high grade metamorphism and migmatitization between ~1240 and 957 Ma; (2) early Ordovician calc–alkalic magmatism, which was synchronous with the Caparonensis–Famatinian Orogeny (~477 Ma); (3) middle to late Ordovician post-collisional calc–alkalic magmatism (~466–436 Ma); (4) late Triassic to early Jurassic magmatism between ~204 and 196 Ma, characterized by both S- and I-type calc–alkalic intrusions and; (5) a late Miocene shallowly emplaced intermediate calc–alkaline intrusions (10.9 ± 0.2 and 8.4 ± 0.2 Ma). The presence of even younger igneous rocks is possible, given the widespread magmatic–hydrothermal alteration affecting all rock units in the area.

The igneous rocks from the late Triassic–early Jurassic magmatic episodes are the volumetrically most important igneous rocks in the study area and in the Colombian Eastern Cordillera. They can be divided into three groups based on their field relationships, whole rock geochemistry and geochronology. These are early leucogranites herein termed Alaskites-I (204–199 Ma), Intermediate rocks (199–198 Ma), and late leucogranites, herein referred to as Alaskites-II (198–196 Ma). This Mesozoic magmatism is reflecting subtle changes in the crustal stress in a setting above an oblique subduction of the Panthalassa plate beneath Pangea.

The lower Cretaceous siliciclastic Tambor Formation has detrital zircons of the same age populations as the metamorphic and igneous rocks present in the study area, suggesting that the provenance is related to the erosion of these local rocks during the late Jurassic or early Cretaceous, implying a local supply of sediments to the local depositional basins.

1. Introduction

The northeastern Cordillera of Colombia is a key area to understand the tectonic interactions between the South American, Caribbean and North American plates, and the accreted terranes in northwestern Colombia, in the context of multiple subduction and orogenic events since the Proterozoic (e.g., Cediel et al., 2003; Restrepo et al., 2011). The igneous rocks that are hosted in these tectonic blocks are records of these plate interactions, and unravelling the timing and chemistry of these igneous bodies are crucial in interpreting the nature of such interactions.

In this paper we provide new information on the igneous evolution of the Santander Massif (Fig. 1), with an emphasis on the Mesozoic intrusive evolution. In particular, we evaluate the rocks of the Vetas-California area, which is ~40 km NE of the City of Bucaramanga in the Santander Department, Colombia. The area hosts important porphyry and epithermal style Au and base metal mineralization, which is to a large part, hosted in the Mesozoic igneous rocks. Therefore, an improved understanding of the intrusive history will potentially benefit mineral exploration in the district.

We present nine new U–Pb ages on intrusive rocks and comprehensively discuss these in the context of the previously published age constraints (Goldsmith et al., 1971; Ward et al., 1973; Boinet et al., 1985; Dörr et al., 1995; Royero and Clavijo, 2001; Cordani et al., 2005; Mantilla et al., 2009, 2011, 2012; Restrepo-Pace

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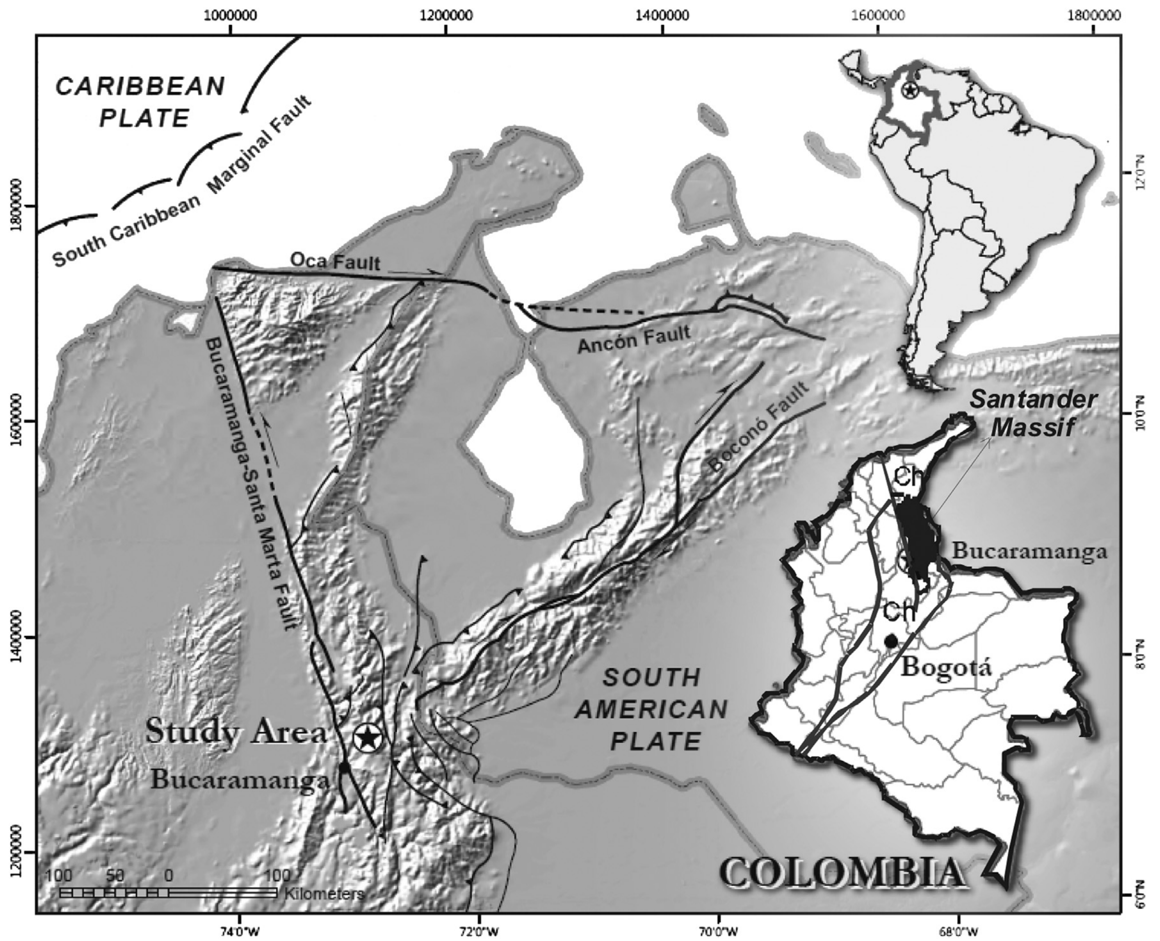

Fig. 1. Location of Vetas-California mining district (Santander Massif, Colombian Eastern Cordillera) with respect to Chibcha terrane (Ch; in the sense of Restrepo et al., 2011) and the triangular Maracaibo tectonic block (Maracaibo Subplate Realm, in the sense of Cediel et al., 2003), bordered by the major NNW striking Santa-Marta Bucaramanga fault and the NE striking Boconó fault.

and Cediel, 2010; Leal-Mejía et al., 2011). In addition, we also obtained ages on detrital zircon grains extracted from Cretaceous sandstone deposited unconformably on the pre-Cretaceous igneous and metamorphic basement and discuss the paleogeographic implications.

2. Background and geological context

2.1. Basement evolution

The Colombian Andean Orogenic System is the result of Paleozoic to the middle Miocene accretion of a series of allochthonous terranes (e.g., Restrepo et al., 2011). Cediel et al. (2003) subdivided the Andean region of Colombia into tectonic realms composed of the Central Continental Subplate Realm, Maracaibo Subplate Realm, Western Tectonic Realm and the Guajira-Falcon Composite Terrane. The study area is located in the Maracaibo Subplate Realm, in the sense of Cediel et al. (2003) and in the Chibcha Terrane, in the sense of Restrepo et al. (2011; Fig. 1). The Maracaibo Subplate Realm comprises the triangular tectonic Maracaibo block between the major NNW striking Santa-Marta Bucaramanga fault (SMBF) and the NE striking Boconó fault (Taboada et al., 1999, 2000). The study area, located in the Vetas-California Mining District (VCMD, Figs. 1 and 2), coincides with the southern tip of the Maracaibo Block in a cornerback position (Tschanz et al., 1974; Van der Hilst and Mann, 1994).

The oldest rocks in the VCMD belong to the Santander Massif (Clavijo, 1994) and comprise at least three principal metamorphic units. The main unit is the Bucaramanga Gneiss (Ward et al., 1973; a.k.a. as Bucaramanga Complex: Clavijo, 1994), which consists of high grade migmatitic paragneisses of early Proterozoic age (García and Ríos, 1999; Ordóñez-Cardona et al., 2006). Peak metamorphism has been dated at 1057 $\pm$ 28 by U–Pb SHRIMP geochronology on zircons, which emphasizes an association with the Grenvillian Orogeny (Cordani et al., 2005). Pressures between 5.5 and 7.2 kbar and temperatures from 660 to 750 °C, have been estimated for the peak metamorphism (Urueña and Zuluaga, 2011). The Bucaramanga Gneiss is overlain by the Silgará Formation; composed mainly of late Proterozoic to early Paleozoic ortho-amphibolites, schists, phyllites, metasiltstones, meta-sandstone, meta-greywackes and minor amounts of marble; and is also part of the metamorphic basement of the Santander Massif (Ward et al., 1973; Schaefer et al., 1998; García and Ríos, 1999; Ríos et al., 2003). This unit is not outcropping in the VCMD but present in the surrounding areas (Ward et al., 1973). Upper amphibolite facies metamorphic conditions (Schäfer et al., 1998) and early-middle Ordovician peak metamorphic ages; likely related to the Caledonian or more specifically to the Caparonensis–Famatinian Orogeny; have also been reported (Forero, 1990; Ríos et al., 2003; Ordóñez-Cardona et al., 2006; Clavijo et al., 2008; Restrepo-Pace and Cediel, 2010).

Meta-diorites, dated at 477 Ma by zircon U–Pb LA-ICPMS, have been documented for the Angostura project area within the VCMD