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Mesoproterozoic crust in the San Lucas Range (Colombia): An insight into the crustal evolution of the northern Andes

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ABSTRACT

The San Lucas Range (SLR) is located at the northernmost end of the Central Cordillera of Colombia and is considered part of the Chibcha Terrane, which is characterized by medium- to high-grade rocks with Late Mesoproterozoic–Early Neoproterozoic metamorphic ages. Granite-gneiss and metamafic rocks, including metamonzogabbro, amphibolite and granulite, crop out in the northern portion of the SLR, with a Lower Jurassic granodioritic batholith intruding all the above-mentioned units. The geochemical features, in terms of major and trace element contents and U–Pb zircon geochronology, suggest protolith crystallization of both felsic and mafic rocks in a post-collisional setting between 1.54 and 1.50 Ga. In addition, positive ε_{Nd} values and initial $^{87}Sr/^{86}Sr$ ratios less than 0.7045 indicate a mantle origin for this bimodal association, with T_{DM} values between 1.7 and 1.5 Ga, suggesting a juvenile character. A correlation between the studied granitic rocks and the A-type Rio Uaupés Granitic Suite in the Rio Negro Province of the Amazonian Craton can be established, thus constraining a provenance from southern latitudes for the Chibcha Terrane, as suggested by earlier models. Metamorphic rims of zircons from both felsic and mafic rocks yielded ages between 1180 and 930 Ma, which are consistent with the ages of related metamorphic terranes in Ecuador, Venezuela, Perú, México and Central America. The latter terranes are regarded as having been part of the northwestern border of Amazonia during its collision with Baltica in the context of the Grenvillian/Sveconorwegian orogeny, which was related to the final assembly of Rodinia.

1. Introduction

The San Lucas Range (SLR) is located at the northernmost end of the Central Cordillera of Colombia and bears special interest as one of its most promising regions for gold and silver mineralization, both hydrothermal and alluvial in nature. It is also one of the key places where the basement of the Chibcha (or Eastern Colombian) Terrane can be observed directly (Restrepo and Toussaint, 1988; Toussaint and Restrepo, 1996; Ordóñez-Carmona et al., 2006). Despite its economic and geoscientific importance, the SLR remains poorly studied mainly due to the difficulties of accessing the area and social issues.

For example, it has been recognized that the unit known as the San Lucas Gneiss is far from being lithologically homogeneous, as it groups several metamorphic rock types having different protoliths (e.g., Feininger et al., 1973). Nevertheless, this heterogeneous character has not yet been represented cartographically, as the unit is currently mapped as a whole entity along its entire extension. Another example of the poor geological understanding of this area is the nature and origin of its gold mineralizations, for which a clear classification and a robust, quantitative data-supported metallogenetic model have yet to be presented.

The research carried out in the SLR during the second half of the 20th century did not consider the geological knowledge of the region beyond petrographic and stratigraphic descriptions of its units, with few or no considerations about their genesis or the geodynamic settings of their formation. During the 1990s and the first decade of the 21st century, the first modern tectonic models for the Colombian Andes, particularly for the eastern and northern flanks of the Central Cordillera, began to be published, stressing the importance of the Grenvillian orogeny on its geological evolution (e.g., Toussaint and Restrepo, 1996; Restrepo-Pace et al., 1997; Ordóñez-Carmona et al., 1999, 2002b, 2006;

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Cordani et al., 2005; Cardona et al., 2010a). This was a major breakthrough because it allowed that portion of the Colombian Andes to be geologically articulated in relation to the rest of the Andean chain, for which a Grenvillian geochronological signature has been recognized in the blocks that constitute its basement (e.g., Fuck et al., 2008; Ramos, 2009, 2010).

At present, it is difficult to unravel the pre-Neoproterozoic geological history of the Colombian cordilleras, and this study constitutes one of the first attempts to assess the origin of some of the units that make up their basement. This work, although not intended to solve all the problems and unknowns related to the regional geology of the SLR, does provide insight into the nature and geodynamic evolution of one small part of the range, namely, its northernmost portion in the municipality of Barranco de Loba, south of the Bolívar department.

2. Geological setting

2.1. Regional framework

The geological evolution of the Colombian territory has been described within the context of terrane accretion models, which state that the western portion of the country consists of a mosaic of allochthonous lithospheric blocks docked to the northwestern border of the Amazonian Craton (INGEOMINAS, 1983; McCourt et al., 1984; Restrepo and Toussaint, 1988). One of those blocks corresponds to the Chibcha Terrane (Fig. 1), with its basement being almost entirely covered by Phanerozoic sedimentary rocks and displaying restricted exposures along the eastern flank of the Central Cordillera, the Quetame and Santander Massifs in the Eastern Cordillera, the Perijá Range, the Sierra Nevada de Santa Marta Massif and the Guajira Peninsula (Toussaint and Restrepo, 1996; Ordóñez-Carmona et al., 2006). A common characteristic linking these provinces is the presence of amphibolite to granulite-facies rocks, which are paraderived metamorphic units that have yielded U–Pb zircon metamorphic ages between 1200 and 890 Ma. These rocks would be the result of the reworking of pre-existent crustal materials as old as 1800 Ma (e.g., Restrepo-Pace et al., 1997; Ordóñez-Carmona et al., 1999, 2002b, 2006; Cordani et al., 2005; Cardona et al., 2006, 2010a). Locally, this basement is unconformably overlain by low-grade metasedimentary rocks displaying Ordovician-Silurian faunas and palynomorphs and unmetamorphosed sedimentary strata ranging from Devonian to Cenozoic in age (e.g., Harrison, 1929; Botero, 1940; Mojica et al., 1988; Grösser and Prössl, 1991; Ward et al., 1973), which allows constraining a low-grade metamorphic event that took place during Late Silurian–Early Devonian times.

Early to Middle Jurassic volcaniclastic rocks that are intermediate to felsic in composition were deposited mainly on the western margin of the Chibcha Terrane. These rocks, as well as the pre-Devonian metamorphic basement, were intruded by quartz-dioritic to monzogranitic batholiths that have yielded ages between 130 and 214 Ma (Feininger et al., 1973; Vesga and Barrero, 1978; Sillitoe et al., 1982; McCourt et al., 1984; Jaramillo et al., 1980; Dörr et al., 1995; Cardona et al., 2006) and host important prospects of Au, Ag, Cu and Mo mineralizations. The Chibcha Terrane is thought to be separated from the Amazonian Craton to the east by the faults of the Guaicáramo system, while the western boundary with the Tahamí Terrane is marked by the Otú-Pericos Fault. The docking of the Chibcha Terrane onto its current position could have taken place during the Late Paleozoic (Restrepo and Toussaint, 1988; Toussaint and Restrepo, 1996).

The SLR is located at the northern end of the Central Cordillera, east of the Otú-Pericos Fault (Fig. 2), thus forming part of the western border of the Chibcha Terrane. Orthoderived quartz-feldspar gneisses, amphibolites and retrograded mafic granulites (Ordóñez-Carmona et al., 2008) grouped into the unit known as the San Lucas Gneiss make up the basement of this region, for which an ID-TIMS $^{207}Pb/^{206}Pb$ age in zircon close to 1150 Ma has been obtained (INGEOMINAS-UIS, 2006), although Ordóñez-Carmona et al. (2009) reported an LA-ICPMS U–Pb age in zircon of ca. 1500 Ma. The San Lucas Gneiss is overlain on its northern portion by volcaniclastic rocks comprising tuffs, volcanic breccias, agglomerates, sandstones and siltstones of the Noreán Formation, for which an Early to Middle Jurassic age has been assigned based on stratigraphic relations to other fossil-bearing rocks farther south (Bogotá and Aluja, 1981). Granodioritic rocks of the Norosí Batholith, which arguably represents the northern extension of the Segovia Batholith in the department of Antioquia (González, 2001), intrude the former units and have yielded crystallization ages between 160 and 200 Ma (INGEOMINAS-UIS, 2006; Mesz, 2008; Ordóñez-Carmona et al., 2009).

2.2. Local geology

Next, field and petrographic descriptions of the units found within the area of study are presented. For geographical and geological references, see Figs. 2 and 3.

2.2.1. Granite-gneiss

This group makes up the bulk of the area of study and comprises medium- to coarse-grained rocks ranging from monzo- to syenogranitic in composition. These rocks are leucocratic and display a compositional banding/foliation that appears as alternating light and dark layers, the former being quartz- and feldspar-rich, while the latter are often enriched in biotite and/or amphibole (Fig. 4A). Locally, the rocks are enriched in potassic feldspar, which imprints a characteristic pinkish color on the rock massifs. In thin section, the mineral paragenesis consists of quartz, microcline, plagioclase, biotite and hornblende, with chlorite commonly replacing the two latter minerals as a result of retrograde reactions in rims and along cleavage planes. Masses of chlorite and/or biotite and hornblende relicts are arranged as narrow strips that give the rock a banded appearance. Opaque minerals commonly consist of magnetite and ilmenite, with small grains of pyrite being rare and apparently derived from hydrothermal alteration along with sericite, clays and epidote. Zircon, allanite and apatite are the most common accessory minerals in these rocks, with titanite associated with chloritized biotite crystals. The texture is mainly relict aphyric, xenoblastic and equigranular, with grain boundaries ranging from lobate to curved. Metamorphic growth is evidenced by poikiloblastic textures of feldspar crystals engulfing small rounded quartz grains. The quartz commonly displays sutured boundaries, polygonization textures, oriented stretched grains, undulose extinction and local micro-graphic and myrmekitic intergrowths.

2.2.2. Metamafic rocks

Rocks from this group display fairly similar mineralogies, but with variable modal proportions and degrees of recrystallization. These rocks are observed to intrude the granite-gneiss, cross-cutting its banded structure (Fig. 4B). Their occurrence is more restricted than that of the granite-gneiss, and their recognition is, in some instances, hindered by migmatization processes that imprint a more leucocratic and, sometimes, even layered aspect that makes it difficult to distinguish between the metamafic and the quartz-feldspathic rocks (Fig. 4C and D).

In outcrop, one of the rock types (petrographically classified as leuco-norite but referred to as metamonzogabbro hereafter; see Section 4.1) displays dark tones that turn somewhat lighter when weathered. In thin section, however, the color index of these rocks barely reaches 30%. The mineral paragenesis consists