Extension-related magmatism during mid-Cretaceous times in the Eastern Cordillera, Colombia

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Abstract

The Eastern Cordillera of Colombia has been subject to lithospheric stretching during the Cretaceous. Scarce magmatic events during that time are represented by small mafic to intermediate dikes and sills. Mid-Cretaceous (?) melts intruded at places of maximum Early Cretaceous extension. Although the timing of emplacement and geodynamic position of the intrusions seem to be similar, strong differences in geochemical and petrological characteristics occur. We suggest a model of a rift-related magmatism in which melt composition reflect derivation from a highly enriched mantle region to the east and a less enriched mantle to the west, the latter melts notably being metasomatized by fluids similar to those resulting from devolatilization of a subducting slab.

Introduction

The Cretaceous of the Eastern Cordillera of Colombia is characterized by its scarcity of magmatic activity (Fig. 1). Only few mafic to intermediate plutonic bodies intruding Cretaceous sediments have been identified in the eastern and western flanks of the cordillera. These sediments have been dated biostratigraphically as Berriasian to Cenomanian in age. The stratigraphic relationship of the intrusions as well as their geodynamic position during the Mid-Cretaceous, permit to assume that these widespread small-sized intrusions record a single partial melting event in different parts of the sub-Andean mantle. The area that today corresponds to the Eastern Cordillera was affected by Early Cretaceous rifting (Campbell and Bürgl, 1965; Fabre, 1983a; Fabre, 1983b; Colletta, et al., 1990; Sarmiento, 2001). Despite the stratigraphic and some major element geochemical investigations (Fabre & Delaloye, 1983; Vásquez et al., 2000; Navarrete et al., 2002) neither the magmatic evolution of these intrusions nor its response to geodynamics are understood. The present work focuses on the geochemical features of five locations, distributed on both flanks of the range.

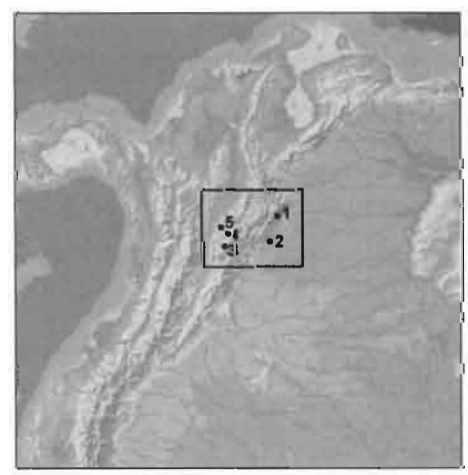

Fig. 1. Location map of the Eastern Cordillera of Colombia. Mafic intrusions: 1: Rodrigoqué; 2: Pajarito; 3: Pacho; 4: La Corona; 5: Cáceres-Puerto Romero.

Geochemistry

Major-element composition and trace-elements abundances were analyzed by XRF-Fluorescence (GeoForschungZentrum Potsdam, Germany). REE concentrations were determined by ICP-OES (Geochemical Laboratory, University of Potsdam) and ICP-MS (GeoForschungZentrum - Dulsky, Potsdam, Germany). The samples from the Eastern Cordillera show SiO_2 concentrations that vary from 44 to 61 wt% in the mafic samples and from 63 to 73 wt% in the intermediate tonalites.

The tonalites are well-exposed in the region of La Corona (Fig. 1), even though there are occurrences in the other locations. The tonalites are mainly composed of plagioclase and quartz. Zircon, tremolite, and rutile have been identified as trace minerals.

The mafic rocks are classified as gabbros and gabbro-diorites after the classification of Middlemost (1994) on the basis of total alkali vs. silica. MgO contents are very different depending on the location. To the west, MgO concentrations are the lowest, ranging from 2 to 11 wt%; whereas to the east, the samples have the highest MgO contents reaching up to 20 wt%. The data indicate that the most primitive mafic melts were emplaced to the east (Pajarito), an interpretation that is in agreement with the high Ni (>150 ppm) and Cr (>200 ppm) concentrations (Wilson, 1993) of these samples. Trace elements suggest a subalkaline affinity for the rocks from Cáceres and Pacho (Fig. 2). Conversely, the rocks from Rodrigoqué, Pajarito, and La Corona exhibit a well-defined alkaline affinity.

In order to evaluate melt-generating and melt-modifying processes in a qualitative or semi-quantitative way, the composition of the mafic rocks is normalized to chondrite (Evensen et al., 1978). Chondrite normalized element concentrations show distinctive patterns for every locality (Fig. 3). The Mid-Cretaceous gabbros of the Eastern Cordillera roughly exhibit an increase in LREE concentration from west to east. Tonalites show slight enrichment in LREE and Eu anomaly as result of plagioclase fractionation.

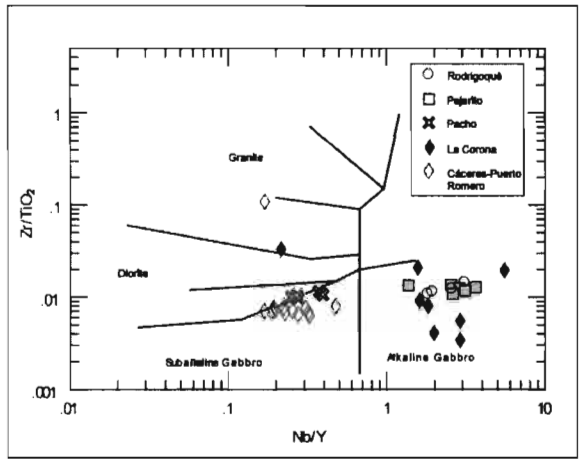

Fig. 2. Discrimination diagram showing two well-differentiated groups. Cáceres and Pacho have subalkaline signature and Rodrigoqué, Pajarito and La Corona belong to the alkaline one.

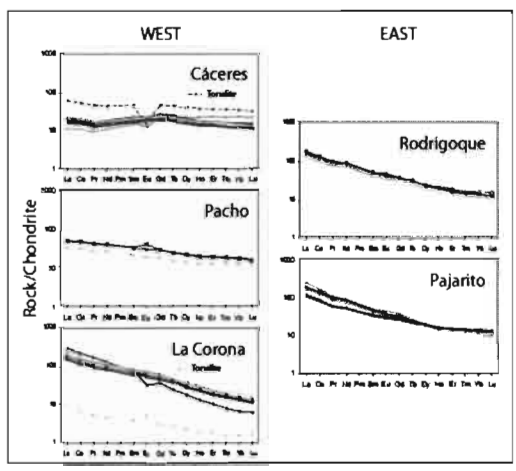

Fig. 3. Rock/Chondrite normalization patterns (after Evensen, 1978). The higher degrees of partial melting are found in the western flank.

Most samples of Cáceres and some of Pacho and La Corona have high concentrations of Ba, suggesting a metasomatized mantle source. Ba-enriched fluids are known from reaction-enhanced release during subduction. High Ba/La values are common for the rocks of Cáceres (22-216) suggesting that sediment contamination may have been affected the mantle source by slab derived fluids or by crustal melts.

Pb-Sr-Nd isotopes

The Pb-Nd-Sr isotopic data show the samples to have high $^{87}Sr/^{86}Sr$ values (Fig. 4) and to follow a trend toward the EMII field. This observation

suggests that these melts became extensively contaminated by continental crust during the ascent. Moreover, the rocks have high Pb/La and Cs/Rb relative to MORB and OIB suggesting that sediments have influenced the melts. Tonalites in La Corona show mantle signatures and an influence of crustal contamination.

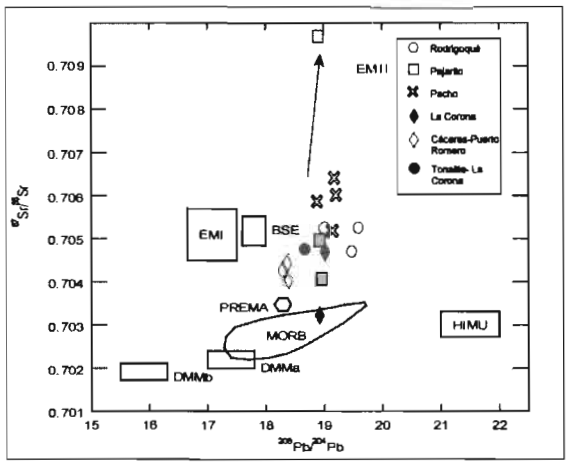

Fig. 4. $^{87}Sr/^{86}Sr$ vs. $^{206}Pb/^{204}Pb$ isotope correlation diagram. The plutonic rocks of the Eastern Cordillera show a trend toward the EMII field.

Evolution of the mafic magmatism in the Eastern Cordillera

During Cretaceous extension, relatively small volumes of mafic alkaline and tholeiitic magmatism affected the area that today corresponds to the Eastern Cordillera. The chemistry of the Mid-Cretaceous magmatism point to a continuous evolution of mantle-derived melts. This magmatism shows a transition from a low to a high degree of partial melting as well as from alkaline to subalkaline affinity (Fig. 2 and 3). The tholeiitic affinity of the samples of Cáceres and Pacho indicate that in this region the stretching of the crust was maximal and magmas sampled the uppermost part of the mantle (Wilson, 1993). The high $^{87}Sr/^{86}Sr$ values indicate that rocks from each location show contamination derived from sediments, seawater and/or metasomatic fluids.

The geochemical and petrological variation of the intrusions leads to the following model: The sub-continental mantle to the west (beneath Cáceres) was metasomatized by fluids derived from an older subducted slab. In this case, the mantle acted as a recorder of past processes, as the devolatilization of the subducted slab was happened prior to melt generation. The maximum stretching took place when the subduction zone was situated far away to the west (Pindell and Tabbutt, 1995).

References

Campbell, C. J., Bürgl, H., 1965. Section through the Eastern Cordillera of Colombia, South America. Geological Society of America Bulletin, 76: 567-589.

Colletta, B., Hebrard, F., Letouzey, J., Werner, P., Rudkiewicz, J. L., 1990. Tectonic and crustal structure of the Eastern Cordillera (Colombia) from a balance cross-section. In: Letouzey, J. (Ed), Petroleum and Tectonics in Mobile Belts. Editions Technip, Paris, pp. 80-100.

Fabre, A., 1983a. La subsidencia de la Cuenca del Cocuy (Cordillera Oriental de Colombia) durante el Cretáceo y el Terciario Inferior. Primera parte: Estudio cuantitativo de la subsidencia. Geología Norandina, 8: 49-61.

Fabre, A., 1983b. La subsidencia de la Cuenca del Cocuy (Cordillera Oriental de Colombia) durante el Cretáceo y el Terciario. Segunda parte: Esquema de evolución tectónica. Geología Norandina, 8: 21-27.

Fabre, A., Delaloye, M., 1983. Intrusiones básicas cretácicas en las sedimentitas de la parte central de la Cordillera Oriental. Geología Norandina, 6: 19-28.

Evensen, N. M., Hamilton, P. J. and O'Nions R. K., 1978. Rare earth abundances in chondritic meteorites. Geochimica et Cosmochimica Acta, 42: 1199-1212.

Middlemost, E. A. K., 1994. Naming materials in the magma/igneous rock system. Earth Science Review, 37: 215-224.

Navarrete, A. T., Moreno, J. M., Concha, A. E., Patarroyo, P., 2002. Interpretación petrogenética del Gabro de Tragarepas al norte de Pacho – Cundinamarca, Colombia. Geología Colombiana, 27: 109-120.

Sarmiento, L. F., 2001. Mesozoic rifting and Cenozoic basin inversion history of the Eastern Cordillera, Colombian Andes. Inferences from tectonic models. Netherlands Research School of Sedimentary Geology (NSG) Publication number: 2002.01.01

Vásquez, M., Concha, A. E., Moreno, J. M., Patarroyo, P. 2000. Caracterización geoquímica y petrografía de los cuerpos intrusivos básicos aflorantes en la region de Cáceres y Puerto Romero, departamentos de Cundinamarca y Boyacá, Colombia. Geología Colombiana, 25: 185-198.

Wilson, M., 1993. Magmatism and the geodynamics of basin formation. Sedimentary Geology, 86: 5-29.