Petrology and geochemistry of Mg-rich basalts from Western Ecuador : remnants of the Late Cretaceous Caribbean plateau ?

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Introduction

Western Ecuador partly consists of Cretaceous oceanic terranes accreted to the Andean continental margin between the late Cretaceous and the late Eocene (Goossens & Rose 1973; Feninger & Bristow 1980; Cosma et al., 1998). Igneous rocks of mafic and ultramafic compositions caught along the Cretaceous and Paleocene sutures are interpreted as remnants of an Early Cretaceous oceanic plateau (Lapierre et al., 1999; Mamberti et al., 1999). However, exposures of picrites and clinopyroxene-rich basalts were recently discovered and studied. New geochemical data show that these mafic lavas are different from the Early Cretaceous rocks but similar to the ≈ 90 Ma basalts from the Caribbean Colombian Oceanic Plateau (CCOP). The aim of this paper is to present the petrology and geochemistry of these picrites and Mg-rich basalts from Ecuador and to compare these rocks with the well studied Cretaceous CCOP crust fragments that outcrop in the Caribbean.

Geological setting

Ecuador is divided into three main geological domains (Fig. 1). The "Oriente" represents the foreland basin of the Andean orogeny. The second domain comprises two cordilleras separated by the inter-Andean valley. The Eastern Cordillera consists of metamorphic material (Litherland et al., 1994) whereas the Western Cordillera is made of oceanic terranes accreted to the Andean margin during the Campanian (85-80 Ma) and the late Paleocene (59-56 Ma; Cosma et al, 1998). The third domain is represented by the coastal zone which consists of Cretaceous basalts and dolerites of oceanic plateau affinity (Piñon Formation; Goossens & Rose, 1973 ; Reynaud et al., 1999) overlain by Late Cretaceous island arc-rocks.
The Western Cordillera includes two distinct assemblages. The Eastern assemblage is composed of (1) 123 Ma ultramafic-maficcumulates (San Juan cumulates, Fig. 1), (2) pillow basalts, dolerites and shallow gabbroic stocks (Merced-Multitud sequence; Fig. 1). The San Juan cumulates likely represent the basalts and dolerites plumbing system. Those rocks are assumed to be likely coeval with the Piñon Formation. The western assemblage is composed of olivine and clinopyroxene (cpx)-rich basalts, which form massive flows interbedded with lapilli and crystal tuffs. These flows show evidence for accumulation of olivine and clinopyroxene (cpx) crystals at their base, while their tops are highly vesicular.
Along the San Juan and Merced-Multitud sections, the eastern and western assemblages are separated by major NNE-trending faults. East of Guaranda (Fig. 1), the cpx-rich basalts are in fault contact with Tertiary rocks. West of Otavalo (Selva Alegre section, Fig. 1), the eastern assemblage is not exposed and the field relations of the cpx-rich basalts with the surrounding units are unclear.

Petrology and geochemistry

The cpx-rich basalts are locally associated with rare picrites. Both lavas are formed by cpx microphenocrysts asssociated or not with olivine pseudomorphs. Cpx has a diopside composition (Wo 44-47, En 47-50) and shows FeO-enriched rims in the Selva Alegre basalts.
Basalts and picrites have high MgO contents (11% to 25%). Picrites are slightly depleted in light rare-earth elements (LREE) relative to heavy (H) REE [0.70 < (La/Yb)n < 0.97] and their REE concentrations do not exceed 3 times chondritic abundances (Fig. 2). The Mg-rich basalts are LREE-enriched [(La/Yb)n = 1.79] and, compared to the picrites, have higher REE abundances (20 times chondrites). Cpx separated from the Guaranda basalts (Fig. 3) are depleted in LREE relative to HREE [0.18 < (La/Yb)n < 0.42] while those isolated from Selva Alegre basalt differ by higher REE abundances and an enrichment in LREE relative to HREE [(La/Yb)n = 1.94]. However, these Selva Alegre cpx show a small depletion in La and Ce relative to Sm and Nd [(La/Sm)n = 0.63].
REE compositions of melts in equilibrium with the cpx were calculated using the partition coefficientsof Hart and Dunn [1993]. The REE patterns of these calculated melts, based on cpx compositions (Fig. 4), are depleted in LREE relative to HREE [0.25 < (La/Yb)n < 0.56]. Since they differ significantly from those of their host rocks, the cpx are not in equilibrium with their host rocks.
Relative to primitive mantle, picrite and Mg-rich basalts display rather flat patterns with Ba and Rb enrichments and a marked depletion in Th (Fig. 5). Both types of lavas display a range of initial 87Sr/86Sr ratios (0.70297 < (87Sr/86Sr)i < 0.70306) while their _Nd(T= 90 Ma) and 206Pb/204Pb ratios are homogeneous. Picrites and Mg-rich basalts from Guaranda have the highest _Nd(T= 90 Ma) (+10.24 < _Nd < + 8.20; Fig. 6) while those from Selva Alegre have significantly lower values (+5.3). All these _Nd fall in the range of Oceanic Island Basalts (OIB). Picrites and basalts have high (206Pb/204Pb)i ratios [19.01 < (206Pb/204Pb)i < 19.59] (Fig. 7).

Comparison of the Mg-rich basalts with the lower Cretaceous Piñón Formation and the 90 Ma Caribbean basalts

Mg-rich basalts and picrites differ significantly from Lower Cretaceous dolerites and basalts from the Piñón Formation for the following reasons : (1) higher MgO contents, (2) larger LREE enrichments, (3) lack of Nb and Ta positive anomalies and (4) significantly lower (206Pb/204Pb)i ratios (17.89 < (206Pb/204Pb)i < 18.58).
Compared to Duarte Mg-rich basalts (Dominican Republic), the Ecuadorian mafic lavas are less LREE enriched and have lower Nb, Ta, Th and TiO_2 abundances. However, Mg-rich lavas from Ecuador and Dominican Republic display some characteristics common to the oceanic plateau basalts of the Nicoya complex (Costa Rica), and to picrites and basalts from the Dumisseau Formation (Haiti; Sen et al,, 1988). They all have Pb isotopic compositions suggesting that they derive from an enriched source, whose composition includes the HIMU component characteristic of the Galápagos hotspot.

Conclusions

Using petrography, major, trace element and isotopic chemistry, we show that the Ecuadorian picrites and Mg-rich basalts display striking similarities with the Upper Cretaceous plateau basalts. The geochemical differences (i.e., lower LREE, Ti, Nb, Ta levels) are probably related to a higher degree of partial melting. The rather large range of _Nd values reflects heterogeneities in the enriched plume source. The Ecuadorian Mg-rich basalts could represent remnants of the Caribbean plateau accreted on the Andean margin sometimes between the end of the Cretaceous and the Paleogene.

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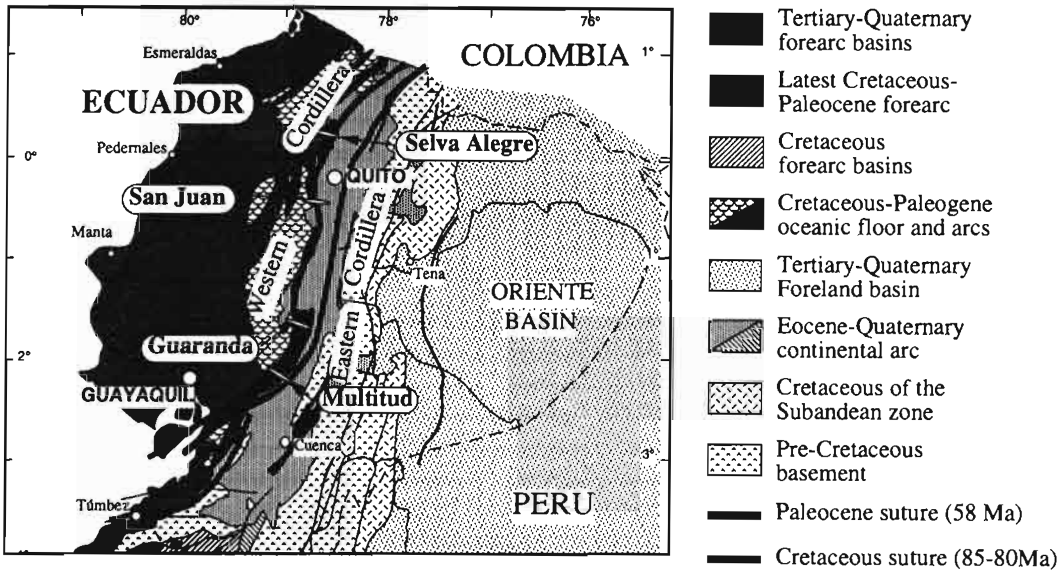

Figure 1: Simplified geological map of Ecuador.

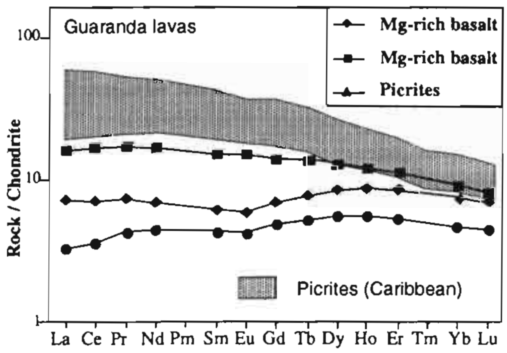

Fig 2 : Chondrite-Normalized rare earth elements patterns of picrites and Mg-rich basalt (chondrite values from Sun & Mac Donough, 1989).

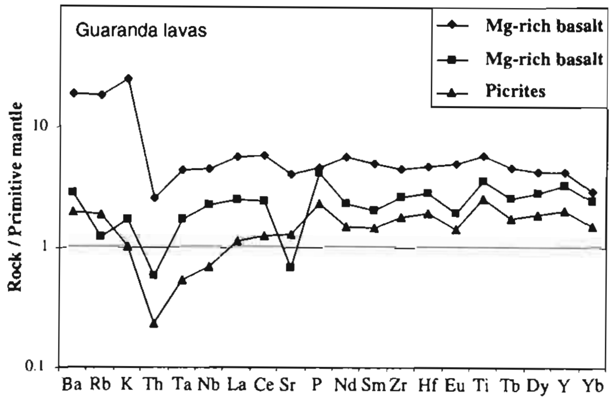

Fig 5 : Primitive mantle-normalized (N) trace element patterns of picrites (primitive mantle values from Sun & Mac Donough, 1989).

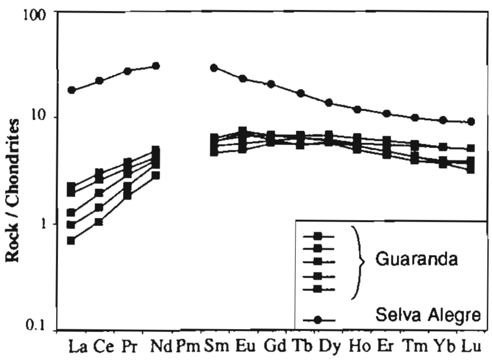

Fig 3 : Chondrite-Normalized rare earth elements patterns of cpx (chondrite values from Sun & Mac Donough, 1989).

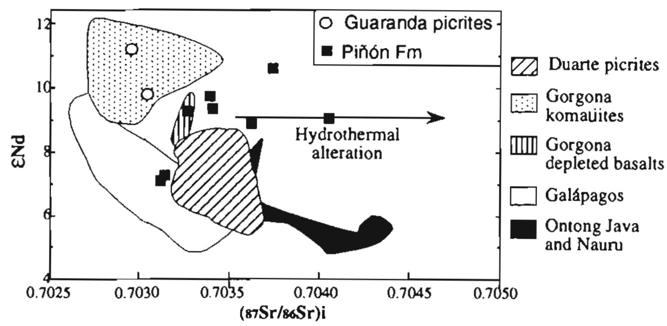

Fig. 6 : εNd-(87Sr/86Sr)i plots for the minerals and host rock from Ecuador.

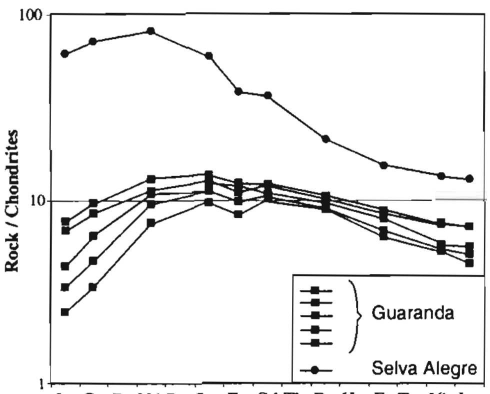

Fig 4 : Rare earth patterns of calculated melts in equilibrium with the clinopyroxenes (chondrite values from Sun & Mac Donough, 1989).

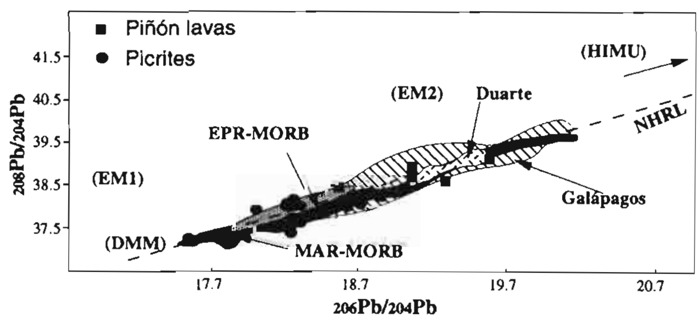

Fig. 7 : 208Pb-204Pb versus 206Pb-204Pb correlation diagrams for minerals and host rocks.