Accreted oceanic fragments below the Western Cordillera of Ecuador

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Introduction

Ecuador is part of the northern Andes. From east to west, it comprises the Oriente basin, the Andean Cordilleras and the Coastal zone (Fig. 1). The Andes of Ecuador consist of two cordilleras separated by the inter-Andean valley. The Western Cordillera and Coastal zone are mainly composed of accreted oceanic terranes of Cretaceous to Eocene age, which consist of crustal fragments of oceanic plateaus, locally overlain by island arcs, that accreted to the passive margin of Ecuador between ~ 80 and 40 Ma (Fig. 2, Jaillard et al. 2000, Mamberti et al. 2004).

From the latest Eocene onwards, a continent-based arc developed first in the Western Cordillera and then, farther east. Since the Oligocene, dextral transpressive kilometer-scale faults crosscut the Western Cordillera and exhumed slices of magmatic and metamorphic rocks, thus sampling the deep levels of the Western Cordillera. The exhumed metamorphic rocks are amphibolites, granulites, and garnet-bearing metasediments. Lherzolites, pyroxenites, harzburgites, as well as gabbros, basalts and radiolarian cherts have been also recognized. The aim of this study is (i) to characterize the protoliths of the exhumed metamorphic and ultramafic rocks, (ii) to determine their thermodynamic evolution and (iii) to characterize the magmatic affinities of the gabbros and basalts.

Petrography, geochemistry

The foliated amphibolites are formed of Mg-rich hornblende + bytownite + magnetite ± quartz. Their major and trace element chemistry is similar to that of oceanic plateau basalts (Fig. 3, flat REE patterns, La/Nb = 0.86, εNd_i = + 5.9, + 2), or of cumulate gabbros of arc affinity (REE patterns, La/Nb = 2.95, εNd_i = +1.8).

The granulites are formed of Ca-rich plagioclase (An_{55-75}) + enstatite + diopside + quartz and share with oceanic plateau basalts similar trace element chemistry (flat REE patterns, La/Nb < 1) and εNd_i values (+7.6).

The garnet bearing meta-sediments are formed of chlorite + quartz + muscovite + garnet. Their REE patterns are enriched in LREE (La/Yb = 4.8) and show marked Eu negative anomaly. These features are similar to those of continent deriving pelites (Bosch et al. 2002).

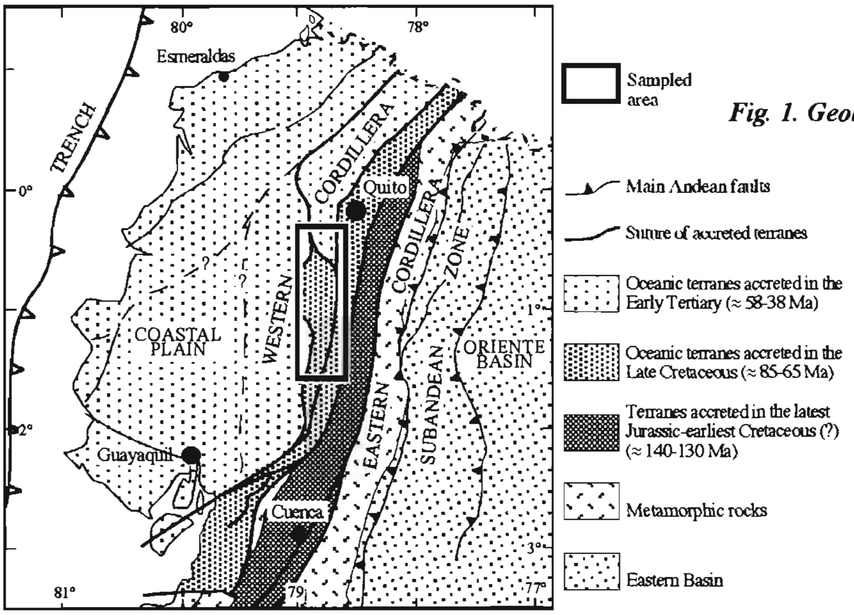

Fig. 1. Geological sketch map of Ecuador.

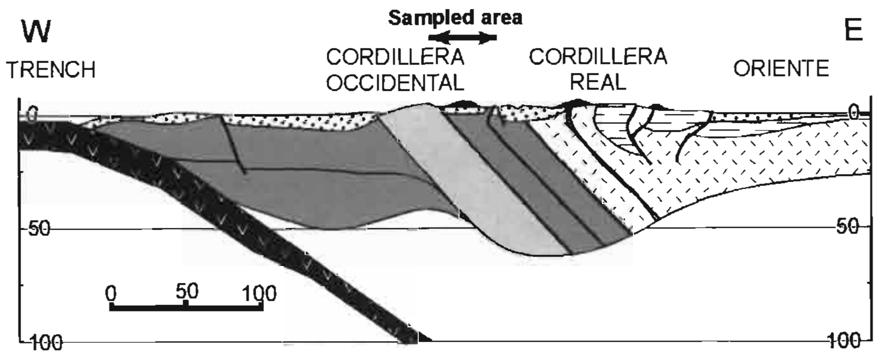

Fig. 2. Crustal scale cross section of the Ecuadorian Andes.

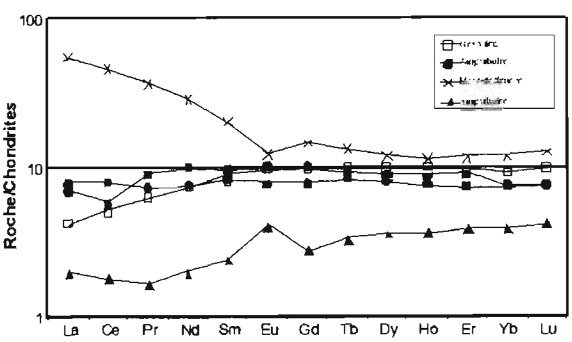

Fig. 3. REE pattern of metamorphic rocks.

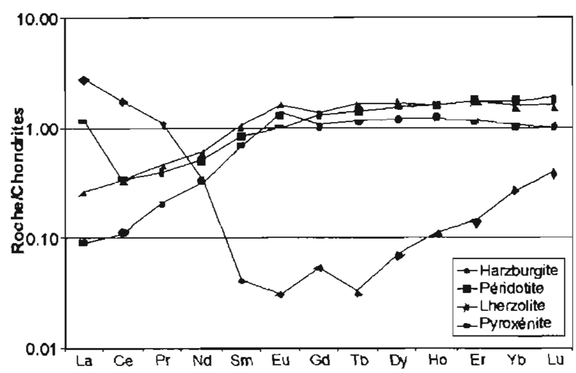

Fig. 4. REE pattern of mantellic rocks.

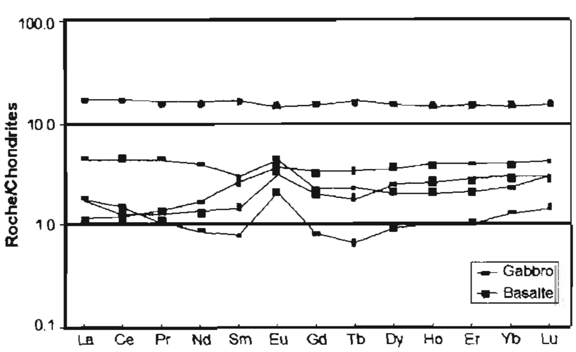

Fig. 5. REE of magmatic rocks.

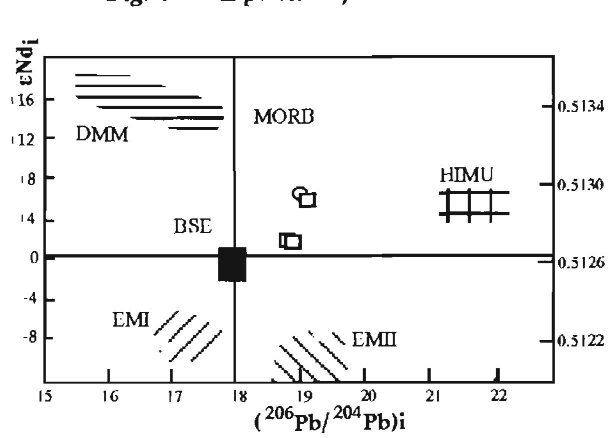

Fig. 6. εNd_i vs $^{206}Pb/^{204}Pb$

The foliated lherzolite and clinopyroxenites consist of serpentinized olivine + cpx + opx ± Ca-plagioclase. The trace element abundances of the ultramafic rocks are very low (0.1 to 1 times the chondritic and primitive mantle values). Lherzolite and clinopyroxenites are LREE-depleted with positive Eu anomalies. However, the εNdi values of the clinopyroxenites (+ 6.2, + 7.04) suggest that these rocks represent deformed cumulates and do not represent depleted mantle rocks. The very low and negative εNdi value (- 2.31) of the lherzolite and the presence of plagioclase suggest that this rock represents a fragment either of continental mantle, or of a depleted mantle contaminated by subduction fluids. The harzburgite displays an U-shaped REE pattern, which is a feature of the depleted mantle.

The basalts (Cpx, plagioclase, Ti-magnetite) show geochemical (flat REE patterns, La/Nb = 0.85) and isotopic (εNd_i = +6.6) characters of oceanic plateau basalts. The gabbros (Ca-rich plagioclase + enstatite + diopside) differ from the basalts by lower REE levels, positive Eu anomalies, Nb and Ta marked negative anomalies, However, the two analysed gabbros differ by their εNd_i values. One sample characterized by a positive εNd_i value of + 6 likely developed in an intra-oceanic pre-accretion environment,while the other sample with negative εNdi (-3.67) could belong to the latest Eocene or younger continent-based island arc.

Figure 6 illustrates the εNd_i – $(^{206}Pb/^{204}Pb)_i$ of some of these exhumed rocks. All the analyzed rocks are aligned between the MORB and EMII fields. This suggests that the amphibolites and one gabbro have been contaminated by the upper continental crust (EMII).

Thermobarometry

Thermometric analysis on mafic granulites (quartz + pl + opx + cpx parageneses) indicate a peak of metamorphism in exces of 800° - 850°C. Temperatures obtained with amphibolites on amphibole – pagioclase thermometer gives similar results. Finally, the deformation mechanisms observed in restitic pyroxenites also suggest that these rocks were deformed in granulitic facies conditions. Such high temperatures were reached at pressure lower than 6-9 kbars consistent with the lack of garnet bearing rocks from various mafic chemistry (Beaudon et al. 2004). Thus, these preliminary data suggest that, during Miocene times, a high geothermal gradient (~40°C km^{-1}) occurred beneath the volcanic arc.

More detailed analyses on amphiboles chemistry (two types of mineral assemblages : Mg-hornblende + labrador $An_{55\text{-}65}$ or tschermakite amphibole + bytownite-anorthite $An_{85\text{-}95}$ for similar sample chemistry) and on garnet-bearing metasediments allow us to constrain the last stage of metamorphic evolution. Especially thermomobarometry using equilibrium between chlorite – quartz and garnet – muscovite – chlorite – plagioclase – quartz coupled with precise textural analyses will be used (Parra et al. 2005, Vidal et al. 2005).

Conclusions

In the Western Cordillera of Ecuador, mafic igneous rocks (basalts, gabbros), ultramafic deformed rocks and metamorphic rocks were exhumed during the Miocene along a transpressive shear zone. The latter are granulites, amphibolites and garnet-bearing metasediments. The mafic igneous and metamorphic rocks exhibit oceanic plateaus or arc affnities, and represent remnants of the oceanic plateaus and associated arcs that accreted the Ecuadorian margin between ~ 80 and 40 My. The ultramafic rocks represent fragments of depleted mantle, deformed cpx-rich cumulate and continental lithospheric mantle or subduction-fluid contaminated mantle. Thus, these rocks likely constitute the root of the Western Cordillera. The metamorphic assemblages indicate a high geothermal gradient related to arc activity, during the Miocene.

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