PETROGENESIS OF THE ECUADORIAN MAGMATIC ARC, A GEOCHEMICAL TRAVERSE ACROSS THE NORTHERN ANDES: PETROLOGY, GEOCHEMISTRY AND ISOTOPIC OBSERVATIONS

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INTRODUCTION

The Andes in Ecuador contains one of the most complete records of igneous activity available for the western margin of South America. They display a strong geochemical and petrological zoning from west to east and provide a good opportunity to test the nature and the effects of subduction, crustal thickness and upper-plate structure on the genesis and evolution of magmatic arcs.

The Ecuadorian Andes lie in two parallel north-striking belts. Besides, several isolated volcanoes lie behind the arc in the subandean zone. There are some fundamental differences in the tectonic setting of the volcanic belts of Ecuador eastward from the trench that could influence cross-strike differences in the magmas from these volcanoes: The Benioff zone drops from about 100Km to 200 Km (?). Successively older and chemically different basement exists. The western (trenchward) belt lies on Cretaceous to Tertiary terranes of oceanic affinity. The eastern volcanic chain lies on strongly metamorphosed Mesozoic. The back-arc volcanoes lie on a thick Phanerozoic sedimentary sequence that overlies the Amazon craton and are not associated with any extensional structures. The crust thickens from 40 to 60 Km between the Western and Eastern Cordilleras, then thins back to 30 Km (Feininger et al., 1983). Besides these complications, the volcanoes from Ecuador lie above the subducting Carnegie ridge.

A study of the entire volcanic chain would obviously be an overwhelming task. Therefore, a few well-suited volcanoes have been selected for detailed study because they are aligned perpendicular to the trench, are representative of their geologic setting and each has had Holocene activity. These volcanoes from west to east are Atacazo from the Western Cordillera, Antisana from the Real or Eastern Cordillera and Sumaco from the back arc basin (Fig. 1). Because this transect is parallel to the convergence of the Nazca and South American plates, variables that are associated with different features of the subducted slab should be eliminated. Instead, this study is focused on the effects of magmatism respect to depth of the subducted slab and the effects of magma production and evolution in different crustal settings.

GEOCHEMICAL CHARACTER

As is typical of most arcs, lavas from the Ecuadorian volcanoes are progressively richer in potassium away from the trench, ranging from medium-K andesites and dacites at Atacazo to high-K andesites and dacites at Antisana to tephriphonolites at Sumaco (Fig. 2).

The absolute concentrations of most of the incompatible trace elements increase inland (Table. 1), so that Sumaco volcano is the richest and Atacazo the poorest in these elements, despite the fact that the lavas are, on average progressively less siliceous. All three volcanoes are characterized by anomalously low concentrations of HFS elements relative to LIL elements, although the size of the anomaly decrease inland from the trench (Fig. 3). The depletion of HFS vs LIL elements is a nearly obiquitous feature of subduction-related lavas and is thought to be inherited from fluids derived from the subducted lithosphere (Hickey et al., 1986). These characteristics are also well displayed on the diagram of LIL/HFS vs. LIL (i.e., Ba/Nb vs. Ba) (Fig. 4). Although the Sumaco lavas are most strongly enriched in all incompatible elements, they have the lowest LIL/HFS ratios (Table. 1), suggesting less slab contribution. In contrast, Antisana and Atacazo volcanoes have progresively lower incompatible element concentrations but higher LIL/HFS ratios, suggesting relatively more slab contributions

Sr isotope ratios range from 0.7042 to 0.7043 at Atacazo, 0.7045 to 0.7047 at Antisana, and 0.7042 to 0.7043 at Sumaco. The slightly higher Sr_{87}/Sr_{86} of Antisana magmas is best explained by assimilation, because of the very thick crust there. Presumably, the cratonic crust beneath Sumaco has the most radiogenic Sr, but the lavas there do not show evidence of extensive assimilation, which is also apparent in the low silica contents of those lavas.

TABLE. 1

Sinthesis of major, trace element abundances and Sr isotopic ratios for volcanoes in study

	ATACAZO Occidental Cord.	ANTISANA Eastern Cordillera	SUMACO Oriente Basin
	(%)	(%)	(%)
SiO2	57.65-66.4	55.64-64.15	43.24-54.22
K2O	0.87-1.26	1.55-3.14	3.96-4.43
Na2O	3.68-4.61	3.72-4.65	6.33-6.93
	(ppm)	(ppm)	(ppm)
Zr	88-129	145-189	396-406
Ba	353-600	611-764	2390-2640
Rb	17-28	38-122	96-125
Sr	335-430	580-885	2542-2624
Y	6-16	12-19	34-49
Nb	1-4	7-12	53-82
La	4.63-10.8	8-21	27-31
Ce	12-18	38-68	183-285
Th	1.07-1.55	6-17	28-30
U	0.5-0.7	1.5-6.4	7.3-10.7
Nd	3.65-11.2	22.9-55.9	86.3-121
Sm	1.4-2.8		13.7-18.5
Eu	0.72-0.83	1.06-2.41	3.65-5.03
Tb	0.21-0.44	0.4-0.78	1.07-1.59
Yb	0.48-1.5	1.03-1.97	3.38-4.67
Lu	0.06-0.22	0.17-0.28	0.5-0.63
Hf	2.25-2.85	3.16-6.05	5.65-6.91
Ta	0.19-0.25	0.42-0.94	2.60-3.54
Ba/Nb	114-223	76-125	31-53
La/Sm	3.3-4.3	1.83-2.08	1.67-1.97
Ba/Sm	214.3-230.7	139.8-150.7	152-187
Sr_{87}/Sr_{86}	0.7042-0.7043	0.7045-0.7047	0.7042-0.7043

CONCLUSIONS

On the basis of the major, trace element evidence and Sr isotope ratios, there are some possible explanations for the systematic compositional trends in the Andes of Ecuador:

- The volcanoes are supplied by similar parental magmas, which undergo different amounts of crustal interaction. Specifically, Sumaco's alkaline magmas may have assimilated more alkali-rich crustal material than the trenchward volcanoes. However, the thickest crust underlies Antisana volcano (60 km). Also, most of the exposed basement in the North Andes zone is siliceous, and Sumaco lavas are notably silica poor, suggesting that this hypothesis is invalid.

- The volcanoes are supplied by similar parental magmas, but they assimilate different kinds of crust. Namely, the terranes underlying the volcanoes are older and have stronger continental affinity away from the trench and younger and of oceanic affinity towards the coast. However, the obvious lack of siliceous contaminants in Sumaco's lavas and the isotopic data suggests this model is not correct either.

- The parental magmas for each volcano come from fundamentally different sources. The magmas of Atacazo and Antisana have both been strongly effected by assimilation in the lower crust, Atacazo less because of the thinner crust and its oceanic affinity. Sumaco is mostly unrelated to the other volcanoes and results from melting of recently enriched alkalis continental lithosphere. This may be related to the depth of the Benioff zone and therefore different pressure conditions in the melting region beneath each volcano. Alternatively, there may be an ancient enriched lithospheric component. In this case.

-Crustal assimilation, although detectable with Sr isotopes, does not strongly alter the major and trace elements in the magmas. Therefore, fundamental differences in the melting regime in the source cause different extents of partial melting. Atacazo magmas (low ITE, high LIL/HFS) result from large input of the slab component and large extent of melting. Sumaco magmas (high ITE contents, low LIL/HFS) result from a small slab contribution and small degree of melting. We presently prefer the latest model, because the Sr isotopes do not correlate with any other geochemical parameters.

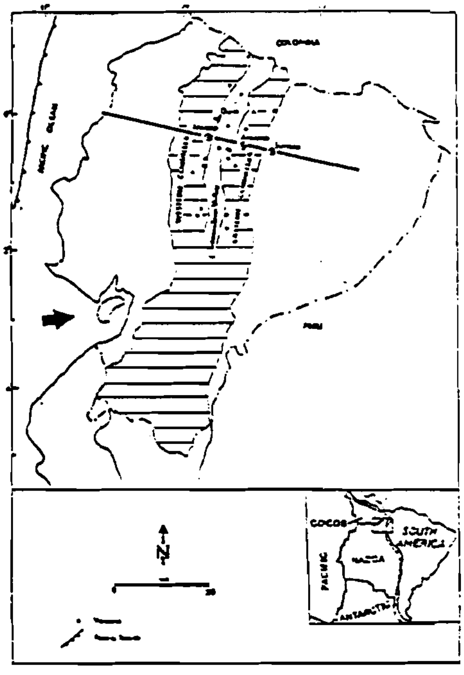

Figure 1. Location of the study area. A petrologic transect of the Ecuadorian Andes

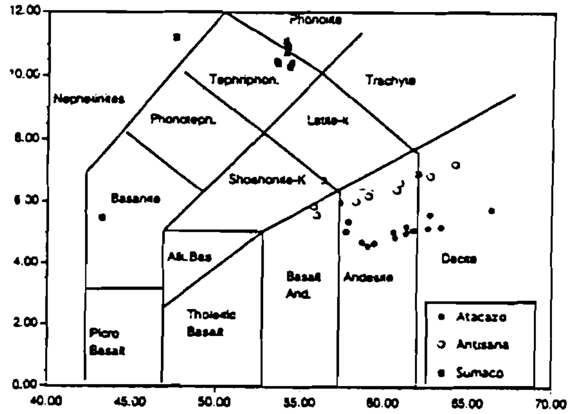

Figure 2 Silica versus total alkalis for lavas from the three volcanic centers. Compositional fields of cal-alkaline and alkaline rocks were taken from Le Maitre(1984), in Wilson (1989)

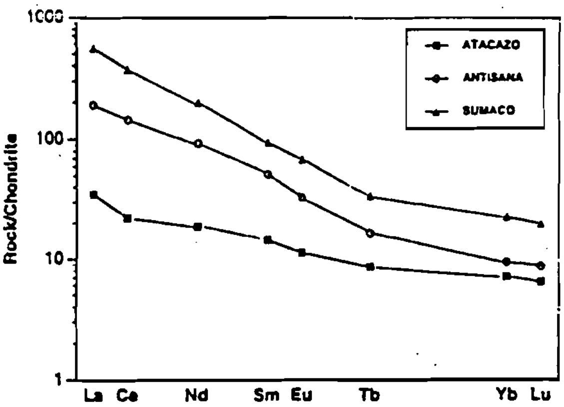

Figure 3 Normalized rare-earth elements of average lavas from Atacazo, Antisana and Sumaco with respect to chondrite values.

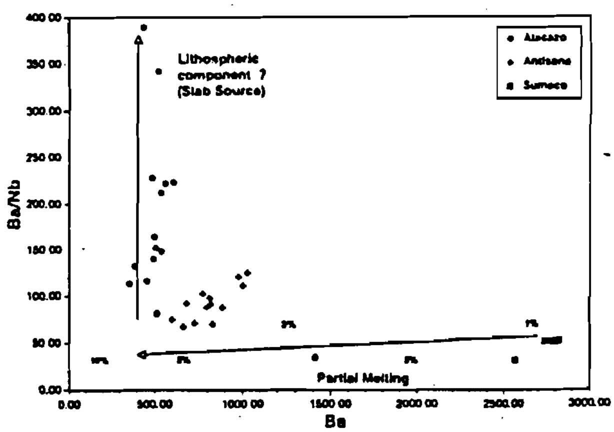

Figure 4. Ba/Nb versus Ba diagram, showing the possible petrogenetic model for the lavas of the Ecuadorian Andes. 1 to 10% partial melting are hypothetical values

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