VOLCANOGENIC EVIDENCES OF THE NORTH ANDEAN TECTONIC SEGMETATION: VOLCANOES SUMACO AND EL REVENTADOR, ECUADORIAN SUBANDEAN ZONE

Roberto BARRAGAN (1) and Patrice BABY(2)

(1) Amerada Hess Corporation, P.O.Box 20316, Libreville, Gabon, Africa
(2) IRD (ex-ORSTOM), Unité de Recherche 104, Université Paul Sabatier, Toulouse III, 38 rue des Trente-Six Ponts, 31400 Toulouse, France.

KEY WORDS: *shoshonites, adakites, partial melting, incompatible elements, HFS, LILE*

INTRODUCTION

The Ecuadorian Andes, characterized by two parallel chains called the Occidental Cordillera (west) and the Cordillera Real (east), present a third volcanic zone consisting of back-arc volcanoes along the northern subandean zone (Napo uplift) (Fig 1). In spite of being developed along the same basement, corresponding to the Phanerozoic sedimentary section of the Amazonian Oriente Basin, these subandean volcanoes show a strong compositional variation :

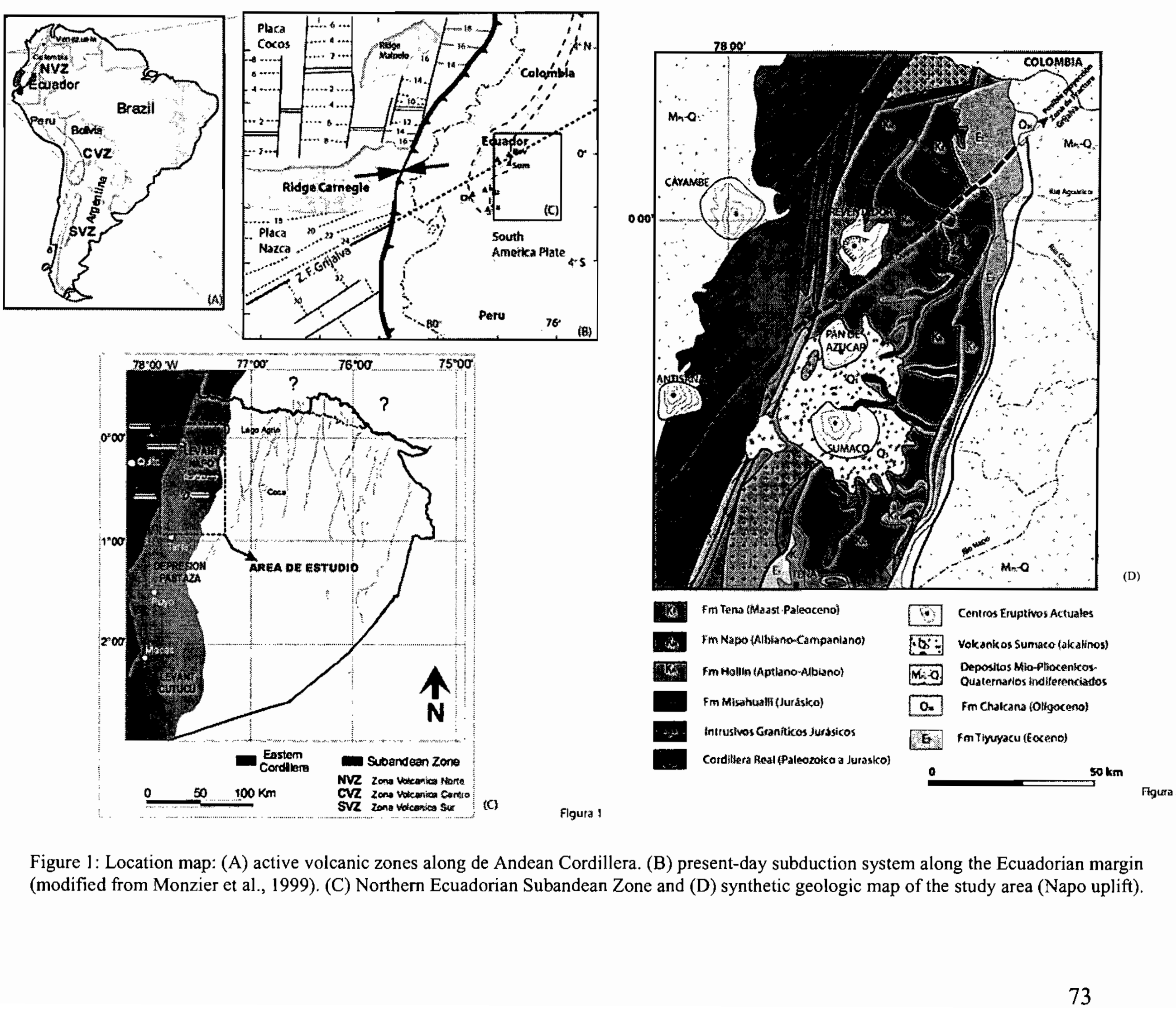

Figure 1: Location map: (A) active volcanic zones along de Andean Cordillera. (B) present-day subduction system along the Ecuadorian margin (modified from Monzier et al., 1999). (C) Northern Ecuadorian Subandean Zone and (D) synthetic geologic map of the study area (Napo uplift).

The Sumaco volcano, located towards the South of the Napo uplift, is characterized by distinct alkaline lavas strongly subsaturated in silica (Fig. 2). They are feldespathoid-bearing phonolites, basanites and tephrites (Barragan, 1998). The alkaline mineral assemblage is reflected in the major elements compositions of the lavas, which shows their shoshonitic affinity. Sumaco's lavas are enriched in all of the incompatible and light-REE elements compared with the rest of volcanoes of the northern Andean zone.

The Reventador volcano, located in the northern part of the subandean Zone and separated just 50 km from Sumaco volcano (Fig. 1), is characterized by a succession of basaltic andesites, andesites and dacites lavas that belong to the medium-high-K calc-alkaline clan (Fig. 2). The lavas of El Reventador are distinguished by high contents in Al_2O_3 (> 18%) and Sr (> 800 ppm), by low values of Y (13-17ppm) and Yb (< 1,57 ppm), in addition to Sr/Y ratios > 47, which suggest a typical adakitic affinity (Defant and Drummond, 1990; 1993).

The $^{87}Sr/^{86}Sr$ and $^{143}Nd/^{144}Nd$ ratios of lavas from volcano Sumaco and El Reventador range from 0,704195-0,704538 and 0,512895-0,512715, within the global range of island arc lavas and similar to the values observed in the Southern Volcanic Zone (Hawkesworth et al., 1993; Davidson et al., 1990) (Fig. 3), suggesting small extents of crustal assimilation.

Trace element abundances in the studied volcanoes and from other Holocene volcanic centers of the present Ecuadorian magmatic arc are plotted normalized to MORB values (Fig. 4). Absolute concentrations of most of the incompatible and REE elements increase strongly towards Sumaco volcano enriched in a 5 to 1 relation with respect to the rest of Ecuadorian Andean volcanoes (Table 1). All of the compared volcanoes are characterized by anomalously low concentration of HFS relative to LIL elements which is a nearly ubiquitous feature of subduction-related lavas and is considered to be inherent from fluids derived from the subducted lithosphere (Hickey et al., 1986). Although the Sumaco's lavas are most strongly enriched in all incompatible elements, they have the lowest LIL/HFS ratios, similar to the observed range in basalts of oceanic islands, suggesting less slab contribution (Barragan et al., 1998) (Fig. 5).

The concentrations of incompatible elements increase towards Sumaco volcano as does the La/Yb ratios, suggesting that magmas of this volcano are the result of progressively lower degrees of partial melting of the mantle wedge associated to normal subduction processes (Hickey et al., 1986). The anomalous adakitic signature observed in El Reventador lavas suggests that a lithospheric tear is present allowing melting of oceanic subducted lithosphere and limiting the distal portions of the aseismic zone that marks the Carnegie Ridge flat slab segment (Gutscher et al., 1999). Although, it has been suggested an affinity of the Sumaco shoshonitic lavas to basalts of high Nb (Bourdon et al., 2001). Nevertheless, this observation is opposite by the high values in the Ba/La (> 20), and La/Nb (> 2) ratios, ruling out any type of relation nor with high Niobium basalts (Reagan and Gill, 1989), nor with respect to the adakitic signature observed in El Reventador lavas.

CONCLUSIONS

The subandean volcanoes, El Reventador and Sumaco, show a strong compositional variation in spite of being developed along the same basement. The systematic variation in the composition is demonstrated to be controlled by the depth of the Benioff zone suggesting that independent subduction zones control the generation of these magmas.Then, it is proposed a volcanogenic limit oriented NE-SW that separates two different volcanic

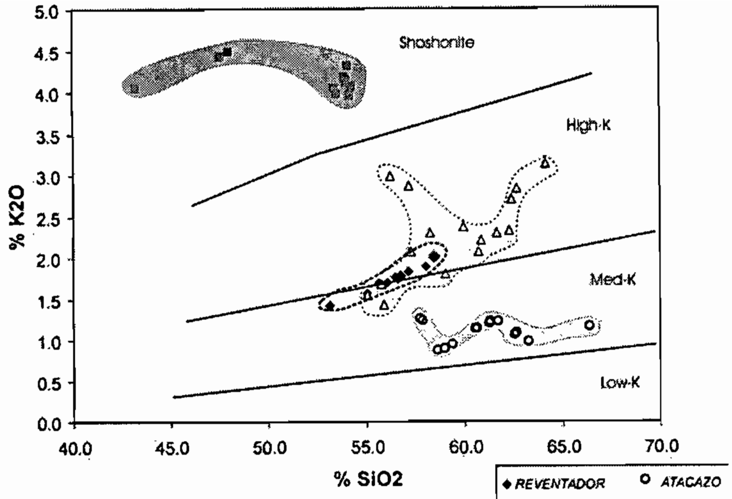

Figure 2: SiO_2 vs. K_2O diagram. Compositional fields from Peccerillo and Taylor, (1976).

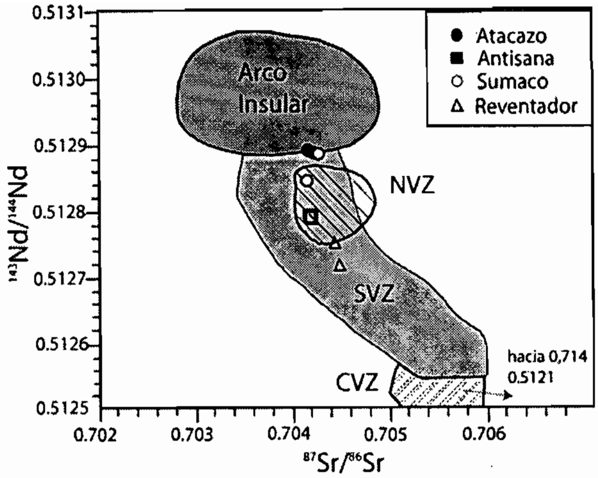

Figure 3 Sr and Nd isotopic ratios for the Sumaco and Reventador volcanoes. Additional compositional fields correspond to the different Andean volcanic zones (modified from Barragan et al., 1998)

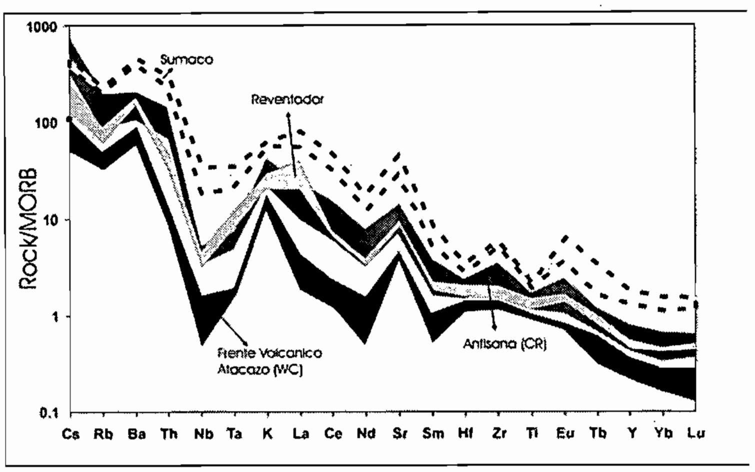

Figure 4: MORB-normalized spider diagram

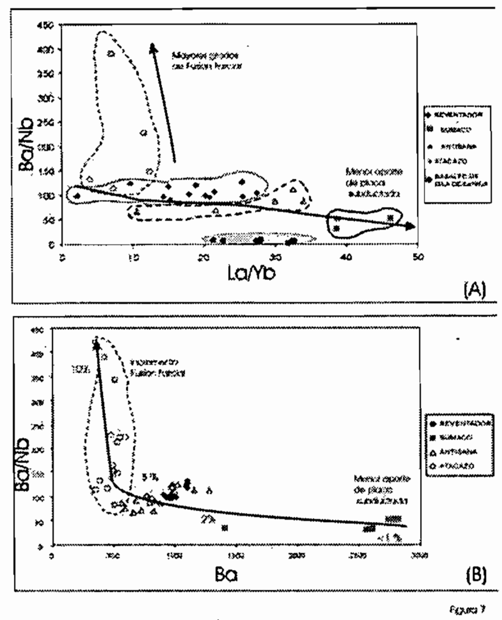

Figure 5: a) LIL/HFS vs. LIL (i.e., Ba/Nb vs. Ba) and (b) Ba/Nb vs. La/Yb. 1 to 10% values are hypothetical

zones or subduction systems. To the north, El Reventador volcano, characterized the distal part of the aseismic zone corresponding to the adakitic trend of the northern Ecuadorian Andes that mark the flat slab subduction of the Carnegie Ridge (Gutschter et al., 1999). To the south, the Sumaco volcano is associated to normal subduction event of the older Oligocene Farallon oceanic crust in the Ecuadorian Andean back-arc. The shoshonitic signature results from low degrees of partial melting and a smaller contribution of the subducted slab. Thus, the volcanogenic limit corresponds to a Tear Zone along the Grijalva fracture zone projected towards the continent previously defined by Hall and Wood (1985) and Gutschter et al. (1999).

ACKNOWLEDGEMENTS : Research supported by INSU grant 99PNSE59 and IRD (Tectonique, érosion et sédimentation dans le bassin de l'Amazone : du Mio-Pliocène à l'Actuel).

REFERENCES

Barragán R., Geist, D., Hall, M., Larson, P., and Kurz, M., 1998. Subduction controls on the compositions of lavas from the Ecuadorian Andes, Earth Planet. Sci. Lett. **154**, 153-166.

Bourdon, E., Eissen, E., Gutscher M., Monzier, M., Robin, C., Samaniego, P., Hall, M., Maury, R., Martin, H., Bassoullet, C., Cotteen, J., 2001. Respuesta magmática a la subducción de una cordillera asísmica: el caso de la margen Ecuatoriana. Cuartas Jornadas en Ciencias de la Tierra, Memorías-Anexos.

Davidson, J., McMillan, N., Moorbath, S., Worner, G., Harmon, R., Lopez-Escobar, L., 1990. The Nevados de Payachata volcanic region (18°S/69°W, N. Chile), II. Evidence fro widespread crustal involvement in Andean Magmatism, Contrib. Mineral. Petrol. **105**, 412-432.

Defant, M., and Drummond, M., 1990. Derivation of some modern arc magmas by melting of young subducted lithosphere. Nature, **347**, 662-665.

Gutscher, M., Malavieille, S., Lallemand, S., and Collot, J., 1999a. Tectonic segmentation of the North Andean margin: impact of the Carnegie Ridge collision, Earth Planet Sci. Lett. **168**, 255-270.

Hall, M., and Wood, C., 1985. Volcano-tectonic segmentation of the northern Andes, Geology, 13, 203-207.

Hawkesworth, C., Gallagher, K., Hergt, J., McDermott, F., 1993. Mantle and Slab contributions in arc magmas. Annu. Rev. Earth. Planet. Sci., **21**, 175-204.

Hickey, R., Frey, F., Gerlach, D., Lopez Escobar , L., 1986. Multiple sources for basaltic ans rocks from the southern volcanic zone of the Andes (34°-41°S): trace element and isotopic evidence for contributions from subducted oceanic crust, mantle and continental crust. Journal of Geophys. Reser., **91**, 5963-5982.

Monzier. M., Robin, C., Hall, M., Cotton, J., Mothes, P., Eissen, J., and Samaniego, P., 1997. Les adakites d'Equateur: modele preliminaie, C. R. Acad. Sci. Paris, **324**, 545-552

Reagan, M., and Gill, J., 1989. Coexisting Calcalkaline and High Niobium Basalts from Turrialba Volcano, Costa Rica. Jour. Geophys. Res., **94**, B4, 4619-4633.

	Volcan Reventador		Volcan Sumaco	
	REV-2	*REV-11*	*3D2*	*GS-8*
SiO2	58.46	55.062	47.56	54.33
TiO2	0.779	0.934	1.29	0.77
FeO*	5.78	7.298	8.99	6.36
MgO	3.41	4.646	2.49	1.68
K2O	2.02	1.575	4.43	4.06
Na2O	4.28	3.888	6.77	6.35
P2O5	0.367	0.366	0.64	0.46
Zr	137	124	441	406
Ni	17	28	4	10
Ba	1107	834	2563	2822
Rb	49	36	125	104
Sr	846	802	4059	2605
Y	13	17	49	35
Nb	8.7	9.2	82	53
$^{87}Sr/^{86}Sr$	0.704538	0.704429	0.704243	0.704195
$^{143}Nd/^{144}Nd$	0.512715	0.512756	0.512893	0.512894
La	32	24	173	138
Ce	52.55	50.57	302	240
Nd	24.64	24.36	121	88.7
Sm	4.98	5.22	18.5	14.4
Eu	1.47	1.64	5.03	3.79
Tb	0.55	0.65	1.59	1.12
Yb	1.26	1.57	4.67	3.67
Lu	0.20	0.25	0.63	0.52
Th	5.13	4.58	27.8	29.8
U	1.60	1.36	7.26	10.1

Table1. Representative Geochemical analyses from Sumaco and Reventador volcanoes

Géodynamique andine
Andean Geodynamics
Geodinámica Andina

Résumés étendus
Extended abstracts
Resúmenes expandidos

Organisateurs **Organizers** **Organizadores**

Institut de recherche pour le développement
Paris

Université Paul Sabatier
Toulouse
France

2002

ISAG

Institut de recherche pour le développement

UNIVERSITE PAUL SABATIER TOULOUSE III

GÉODYNAMIQUE ANDINE
ANDEAN GEODYNAMICS
GEODINAMICA ANDINA

5th International Symposium on Andean Geodynamics

Université Paul Sabatier, Toulouse, France,
16-18 Septembre 2002

Résumés étendus
Extended abstracts
Resúmenes ampliados

Organisateurs / Organizers / Organizadores
Institut de recherche pour le développement
Université Paul Sabatier

IRD
INSTITUT DE RECHERCHE POUR LE DÉVELOPPEMENT
Paris, 2002

ISAG

COMITÉ D'ORGANISATION
COMITE ORGANIZADOR
ORGANIZING COMITTEE

P. Baby (IRD-Toulouse), J. Darrozes (Univ. Paul Sabatier-Toulouse), J. Deramond (Univ. Paul Sabatier-Toulouse), B. Dupré (CNRS-Toulouse), J.-L. Guyot (IRD-Toulouse), G. Hérail (IRD-Toulouse), E. Jaillard (IRD-Quito), A. Lavenu (IRD-Toulouse), H. Miller (Univ. München), T. Monfret (IRD-Géoscience Azur), G. Wörner (Univ. Göttingen)

Comité scientifique et représentants nationaux
Comité Científico y Representantes Nacionales
Scientific Advisory Board and National Representatives

R. Armijo (IPG, Paris), J.-P. Avouac (CEA, Paris), R. Charrier (Univ. Chile, Santiago), J.-Y. Collot (IRD, Géoscience Azur), L. Dorbath (IRD, Strasbourg), S. Flint (Univ. Liverpool), B. France-Lanord (CNRS, Nancy), L. Fontboté (Univ. Genève), Y. Gaudemer (Univ. Paris VII), R. Gaupp (Univ. Jena), F. Hervé (Univ. Chile, Santiago), T.E. Jordan (INSTOC, Cornell), J. Mojica (Univ. Bogotá), O. Oncken (Univ. Potsdam), L. Ortlieb (IRD, Bondy), R.J. Pankhurst (Brit. Antartic Surv.), V. Ramos (Univ. Buenos Aires), P. Ribstein (IRD, Paris), C. Robin (Univ. Clermont-Ferrand), S. Rosas (Univ. Lima), F. Sàbat (Univ. Barcelona), M. Schmitz (FUNVISIS, Caracas), R. Suárez Soruco (YPBF, La Paz), M. Rivadeneira (Petroproducción), W. Winkler (ETH, Zürich).

APPUIS FINANCIERS
FUNDINGS
APPOYO FINANCIERO

L'organisation de l'ISAG 2002 et les bourses accordées à un certain nombre de collègues latino-américains ont été possibles grâce au soutien financier de l'IRD (notamment de la Délégation à l'Information et à la Communication), de la région Midi-Pyrénées, de l'Université Paul Sabatier et de l'Andean Comittee de l'ILP.