

SECOND PARTIAL MELTING STAGE OF A SLAB-MELT METASOMATIZED MANTLE AT SUMACO VOLCANO (NORTHERN VOLCANIC ZONE, ECUADOR)

*Jean-Philippe EISSEN(1,2), Erwan BOURDON(1,3), Bernardo BEATE(4),
Silvana HIDALGO(2) & Joseph COTTEN(5)*

- (1) IRD, UR Processus et aléas volcaniques, Whympet 442 y Coruña, Ap. 17-12-857, Quito, Ecuador (eissen@ird.fr)
(2) Departamento de Geofísica, Escuela Politécnica Nacional, Ap. 17-01-2759; Quito, Ecuador
(3) IRD, UR Processus et aléas volcaniques, Royal Holloway University of London, Egham, Surrey TW20 0EX, UK
(4) Dept. Geología, Petroleo y Minas, Escuela Politécnica Nacional; Ap. 17-01-2759, Quito, Ecuador.
(5) UMR 6538, Université de Bretagne Occidentale, BP 809, 29285 Brest Cedex, France

KEY WORDS: Andes, Northern Volcanic Zone, Ecuador, mantle metasomatism, high-Nb basalts, absarokites.

INTRODUCTION

Sumaco is one of the less known volcanoes of Ecuador, partially because of its remoteness as it is the only recent volcano located in the amazonian forest of the NVZ. However, it has been known for a while that most of its products are understaturated alkaline lavas, with frequently more than 15% of normative nepheline and normative apatite (Colony & Sinclair, 1928). The aim of this contribution is to present the first results obtained on this isolated and peculiar volcano after a recent survey (january 2001) in order better to constrain the petrogenetic process active in the geodynamic setting of Ecuador.

LOCATION AND MORPHOLOGY OF SUMACO VOLCANO

Located some 90 km ESE of Quito, Sumaco volcano rises above the rain forest of the Amazonian province of Ecuador on the eastern foothills of the andean chain. It is the volcano situated the farthest from the trench of all the NVZ, in rear-arc position (Fig. 1). It is at the latitude of Sumaco the the width of the NVZ arc reaches its maximum, with more than 100 km. Sumaco exhibits a regular cone well preserved morphology, suggesting that it may have experienced recent volcanic activity. At least one major avalanche event dissected its northeast flank and its semi-circular scar is still visible in the topography. The summit cone build inside the avalanche scar, is mainly constituted by scorias intercalated with massive lava flows.

Geochemically, they are constituted by K-rich ($0.9 < K_2O\% < 5.3$) undersaturated lavas ranging in composition from basic absarokite to shoshonite ($44 < SiO_2\% < 54$; Fig. 2) with high concentrations in all incompatible elements (Fig. 3). They also present a strong enrichment of LREE over HREE ($La/Yb = 28-50$), unless these later are significantly enriched (*e.g.* $Yb = 2.02-3.9$ ppm) compared to other rocks from the NVZ in Ecuador. On primitive mantle-normalized trace element patterns, a significant positive anomaly in Sr is observed (Fig. 3). But the most remarkable feature of these lavas is their strong enrichment in Nb (21-79 ppm): therefore, these lavas can be designated as high-niobium basalts (HNB ; Defand *et al.*, 1992). Isotopically, these lavas show unradiogenic characteristics with Sr ($^{87}Sr/^{86}Sr \approx 0.7042$), Nd ($^{143}Nd/^{144}Nd > 0.512880$) and Pb isotope data that are virtually the same than those from the adakites from the Western Cordillera (Bourdon, 1999; Bourdon *et al.*, 2002).

DISCUSSION : GEODYNAMIC IMPLICATIONS

The geochemical characteristics of Sumaco absarokites are close to those of HNB found in others arc settings in association with adakites (Saunders *et al.*, 1987; Defand *et al.*, 1992). The close association HNB-adakites has suggested to many authors that HNB could be the partial melting product of a mantle metasomatised by slab melts (Defand *et al.*, 1992). Indeed, slab melts are likely to transport Nb in the mantle, unlike hydrous fluids (Kesson & Ringwood, 1989).

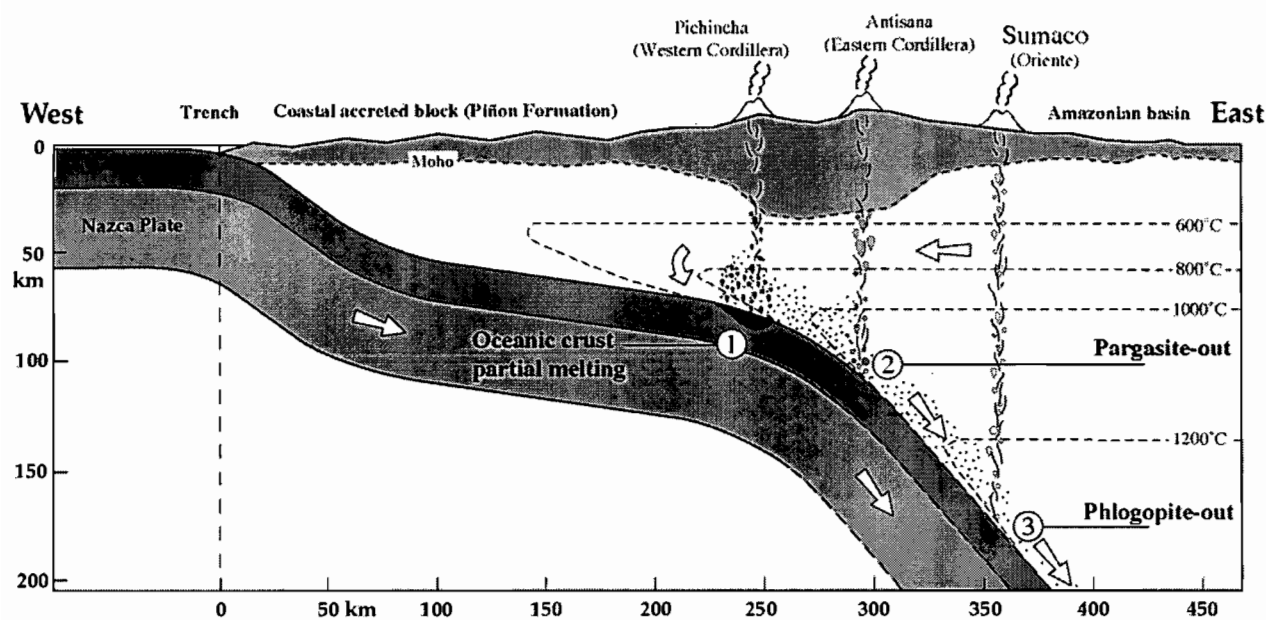


Figure 4: Schematic petrogenetic model in three steps for the NVZ in Ecuador, see the last paragraph (from Bourdon *et al.*, 2002).

Furthermore, Tatsumi & Koyaguchi (1989) experimentally showed that an absarokite with geochemical characteristics close to the most basic basalts of Sumaco was in equilibrium with a phlogopite-rich peridotitic mantle, suggesting that the source of this type of magma is likely to be a metasomatised mantle with significant amounts of phlogopite. Other studies on HNB related to adakites have shown that their low HREE concentrations could be related to a genesis in a garnet-rich mantle, resulting of a metasomatism by slab melts (Defand *et al.*, 1992). But

unlike most HNB, Sumaco basalts display no strong HREE depletions, suggesting that garnet is no longer present in the source. They could, however, be produced by the destabilization of phlogopite (Tatsumi & Koyaguchi, 1989).

But could Sumaco lavas be related to an intracontinental hotspot or an old enriched mantle and not to subduction processes? In the absence of extensional structures in the eastern Andean foothills, the lavas from the Sumaco cannot be related to the partial melting of an adiabatically uplifted mantle. Moreover, the Nb anomalies of the Sumaco lavas are a clear imprint of a "subduction component". Lastly, the exact "match" between the isotopic signature of magma types from the arc front and the Sumaco is an irrefutable proof that their genesis are closely related to one another and thus to the subduction processes (Bourdon *et al.*, 2002).

In our schematic petrogenetic model in three steps (Fig. 4), the magmas of the fore-arc ([1] *e.g.* Pichicnha volcano) are mainly alimented today by adakitic magmas resulting from the direct partial fusion of the oceanic slab, but the adakitic melts are also metasomatising the mantle wedge. Therefore, below the Eastern Cordillera ([2] *e.g.* Antisana volcano), the melts are mainly pseudo-adakites produced by the partial fusion of these metasomatised peridotites. And finally in rear-arc position, ([3] *e.g.* Sumaco volcano), the melts result a deeper, second partial fusion stage at a much lower fusion rate.

REFERENCES

- Barragan R., Geist D., Hall M.L., Larson P. & Kurz M., 1998 - Subduction controls on the composition of lavas from the Ecuadorian Andes. *Earth Planet. Sci. Lett.* 154:153-166.
- Bourdon B., Eissen J.-P., Gutscher M.-A., Monzier M., Hall M.L. & Cotten J., 2002 - Magmatic response to early aseismic ridge subduction: the Ecuadorian margin case (South America). *Earth Planet. Sci. Lett.*, (in press).
- Bourdon E. 1999. Conséquences pétrogénétiques de la subduction d'une ride aiséismique: l'exemple du volcanisme de la marge équatorienne. Université de Bretagne Occidentale, Brest. *PhD Thesis*, 190 p.
- Colony R.J. and Sinclair J.H., 1928 - The lavas of the Sumaco, eastern Ecuador, *American J. Sci.*, 216:299-312.
- Defant M.J., Jackson T.E., Drummond M.S., De Boer J.Z., Bellon H., Feigenson M.D., *et al.*, 1992 - The geochemistry of young volcanism throughout western Panama and southeastern Costa Rica: an overview. *J. Geol. Soc. London*, 149:569-579.
- Gutscher M.-A., Malavieille J., Lallemand S. & Collot J.-Y. 1999 - Tectonic segmentation of the North Andean margin: impact of the Carnegie Ridge collision: *Earth Planet. Sci. Letters*, 168:255-270.
- Iddings J.P., 1895 - Abarokite-shoshonite-banakite series, *J. Geology*, 3:935-959.
- Kesson S.E. & Ringwood A.E., 1989 - Slab-mantle interactions I. Sheared and refertilized garnet peridotite xenoliths - samples of Wadati-Benioff zones? *Chem. Geol.*, 78:83-96.
- Peccerillo P. & Taylor S.R., 1976 - Geochemistry of Eocene calc-alkaline volcanic rocks from the Kastamonu area, Northern Turkey, *Contrib. Mineral. Petrol.* 58:63-81.
- Saunders A.D., Rogers G., Marriner G.F., Terrell D.J. *et al.*, 1987 - Geochemistry of cenozoic volcanic rocks, Baja California, Mexico: Implications for the petrogenesis of post-subduction magmas. *J. Volcan. Geotherm. Res.*, 32:223-245.
- Sun S.-S. & McDonough W.F., 1989 - Chemical and isotopic systematics of oceanic basalts: implications for mantle composition and processes: in *Magmatism in the Ocean Basins*, A.D. Saunders & M.J. Norry, eds., *Geol. Soc. Spec. Pub.*, London, 42: 313-345.
- Tatsumi Y. & Koyaguchi T., 1989 - An abarokite from a phlogopite lherzolite source. *Contrib. Mineral. Petrol.* 102(1):33-40.

Géodynamique andine Andean Geodynamics Geodinámica Andina

Résumés étendus
Extended abstracts
Resúmenes expandidos



5th International Symposium
Toulouse, France
16-18 Sept. 2002

Organisateurs

Organizers

Organizadores

**Institut de recherche
pour le développement
Paris**

**Université Paul Sabatier
Toulouse
France**



**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



COMITÉ D'ORGANISATION
COMITE ORGANIZADOR
ORGANIZING COMMITTEE

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. Antarctic 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 Committee de l'ILP.