ADAKITES FROM ECUADOR: PRELIMINARY DATA

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INTRODUCTION

Adakites are andesites-dacites-rhyolites (but mainly dacites) with peculiar characteristics such as relatively high Al and Na contents, very low Y and Yb contents, and high La/Yb and Sr/Y ratios, that are not associated with parental basalts. They are usually considered to be derived from the partial melting of metamorphosed basalts (amphibolite and eclogite) at high pressure, leaving garnet or amphibole in the residues, thus giving them their unusual geochemical characteristics (Defant and Drummond, 1990; Defant, et al., 1991; Drummond and Defant, 1990; Atherton and Petford, 1993; Defant and Drummond, 1993; Sajona et al., 1993). It is generally accepted that adakitic magmas form where young (<25 Ma), hot oceanic crust is subducted and melts at 23-26 kbar (75-85 km) and 700-775°C (Drummond and Defant, 1990), i.e. near the corner of the mantle wedge. Accordingly, adakitic volcanoes should lie quite close (≈ 80 km) to the trench. However, Atherton and Petford (1993) presented evidence that the partial melting of basaltic material of the lower crust at ≈50 km depths by newly underplated hot magmas (generated in the underlying asthenospheric wedge) should be considered as an additional way to generate adakite, when 1/ subducting oceanic crust is too old and cold, 2/ volcanism is very far from the trench, and 3/ local heat flow is high.

ECUADORIAN ADAKITES

Young oceanic lithosphere (<20 Ma) formed along the Cocos-Nazca spreading axis is being subducted under central and northern Ecuador since at least the early Pliocene with a rate of convergence of ≈ 8 cm/y (Fig. 1). The Benioff plane dips ≈ 25° eastward, attaining ≈130-150 and ≈150-175 km depths under the Quaternary volcanoes of the ecuadorian Western and Eastern Cordilleras, respectively (Winter, 1990). The Eastern Cordillera constitutes the eastern edge of the Andean Block (AB), a wedge between the Nazca (NAZ) and South American (SAM) plates presently affected by an E-W compressive state of stress (Ego et al., 1995). The collision-subduction of the Carnegie Ridge in front of Ecuador (Pennington, 1981) or, more certainly, the oblique NAZ-SAM convergence in the Ecuador-Colombia area (Ego et al., 1995) would explain the northeastward motion of the AB, along the great NE-SW right-lateral transpressive faults of the East Andean Front Fault Zone.

ORSTOM (French Scientific Research Institute for the Development in Cooperation) and the Geophysical Institute of the National Polytecnical School of Quito are collaborating since 1994 in a joint volcanological program which includes studies on several volcanoes of Ecuador, namely Cotacachi, Fuya Fuya, Mojanda, Pululahua, Cayambe, Cotopaxi, Tungurahua, Sangay... (Fig. 2) We present here the first results in geochemistry (see also Robin et al. and Samaniego et al., this volume). To date, all the rocks sampled within the framework of this joint program have SiO_2 contents > 55%; they are mainly medium-K basic andesites to rhyolites, and a few high-K acid andesites to rhyolites (Fig. 3; all values LOI free and recalculated to 100%). For comparison, basaltic rocks clearly predominate in a typical

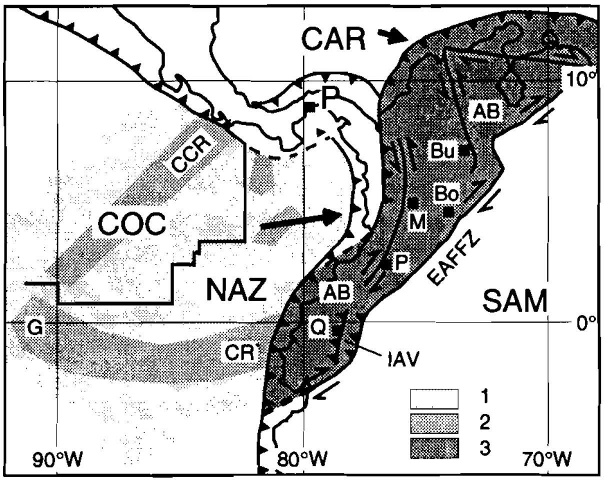

Fig. 1

Geodynamics of the Andean Block.
COC= Cocos Plate;
NAZ= Nazca Plate;
CAR= Caribbean Plate;
1= Galapagos Gore; 2= oceanic ridges:
CCR= Cocos Ridge, CR= Carnegie Ridge; 3= Andean Block (AB);
G= Galapagos Islands.
Large arrows= NAZ and CAR plate convergence with respect to SAM fixed.
IAV= Inter Andean Valley;
EAFFZ= East Andean Front Fault Zone;
Q= Quito, P= Popayan, M= Manizales, Bo= Bogota, Bu= Bucaramanga, P= Panama. After Pennington (1981) and Ego et al. (1993).

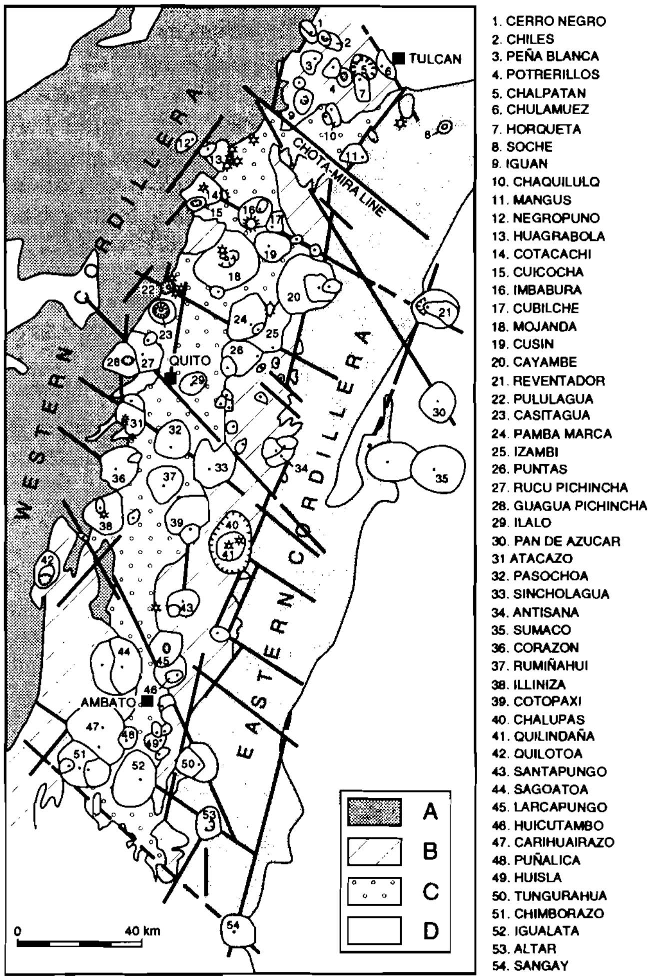

Fig. 2

Quaternary volcanoes and main tectonic lineations of the Ecuadorian Andes from 1° N to 2° S (from Barberi et al., 1988).

A= Western Cordillera: Macuchi Formation and Cretaceous-Eocene clastic deposits;
B= undifferentiated basal volcanic complex (Late Miocene-Quaternary);
C= volcanic and volcano-sedimentary deposits filling the Interandean Depression;
D=Eastern Cordillera: mainly metamorphites.

island-arc, such as the New Hebrides arc (Southwest Pacific; Monzier et al., in prep.). A marked increase of K2O content is also obvious in the volcanic products from the Western Cordillera to the Eastern Cordillera, an observation already noted by Barberi et al. (1988). Another striking difference between the rocks from the two cordilleras is the value of the Ba/La ratio (LILE / HFSE), >49 in the Western Cordillera and <49 in the Eastern Cordillera (Cayambe, Chacana, Cotopaxi, Tungurahua), an observation which may reflect a greater slab contribution in the magmas of the Western Cordillera. Diagrams of Sr/Y vs. Y and La/Yb vs. K2O (Fig. 3) emphasize the very high Sr/Y and La/Yb ratios of recent Cayambe dacites, a characteristic signature of dacitic melts derived from metamorphosed basalts, i. e. adakites. These adakites from Cayambe clearly follow a broad melting trend on the La/Yb vs. K2O diagram, fractionation being only of minor importance. Contrarily, in the Tungurahua suite fractionation is the dominant process. Sr/Y ratios and Y contents of adakites from Cayambe and Mount St Helens (Defant and Drummond, 1993) are very similar. Lastly, it should be stressed that samples from the old part of Cayambe are not adakitic. All samples from Cushnirumi and Fuya Fuya also have a strong adakitic character, whereas only some of the rocks from Cotacachi, Pululahua, Quilotoa, Cotopaxi and Tungurahua volcanoes are adakites. Conversely, all Mojanda samples are calc-alkaline.

PRELIMINARY CONCLUSIONS

At this point of the program, it appear that adakites are common in Ecuador, in both cordilleras. They can appear either during a given period of the history of a single volcano (Cayambe: Samaniego et al., this volume) or simulteanously with calc-alkaline rocks at two close volcanic centers (Fuya Fuya and Mojanda: Robin et al., this volume), which entail some interesting volcanological questions. The question of the basaltic source, i. e. slab or lower crust melting, remains unsolved for the moment, but as ecuadorian adakitic volcanoes (especially Cayambe) lie far from the trench, it is perhaps more reasonable to contemplate a crustal origin than a slab one, even if the subducting crust is young (<20 Ma). Regional crustal modeling and heat flow measurements would be very convenient to solve this question as well as detailed studies on the mode of subduction below Ecuador and the role of the Carnegie Ridge in this process.

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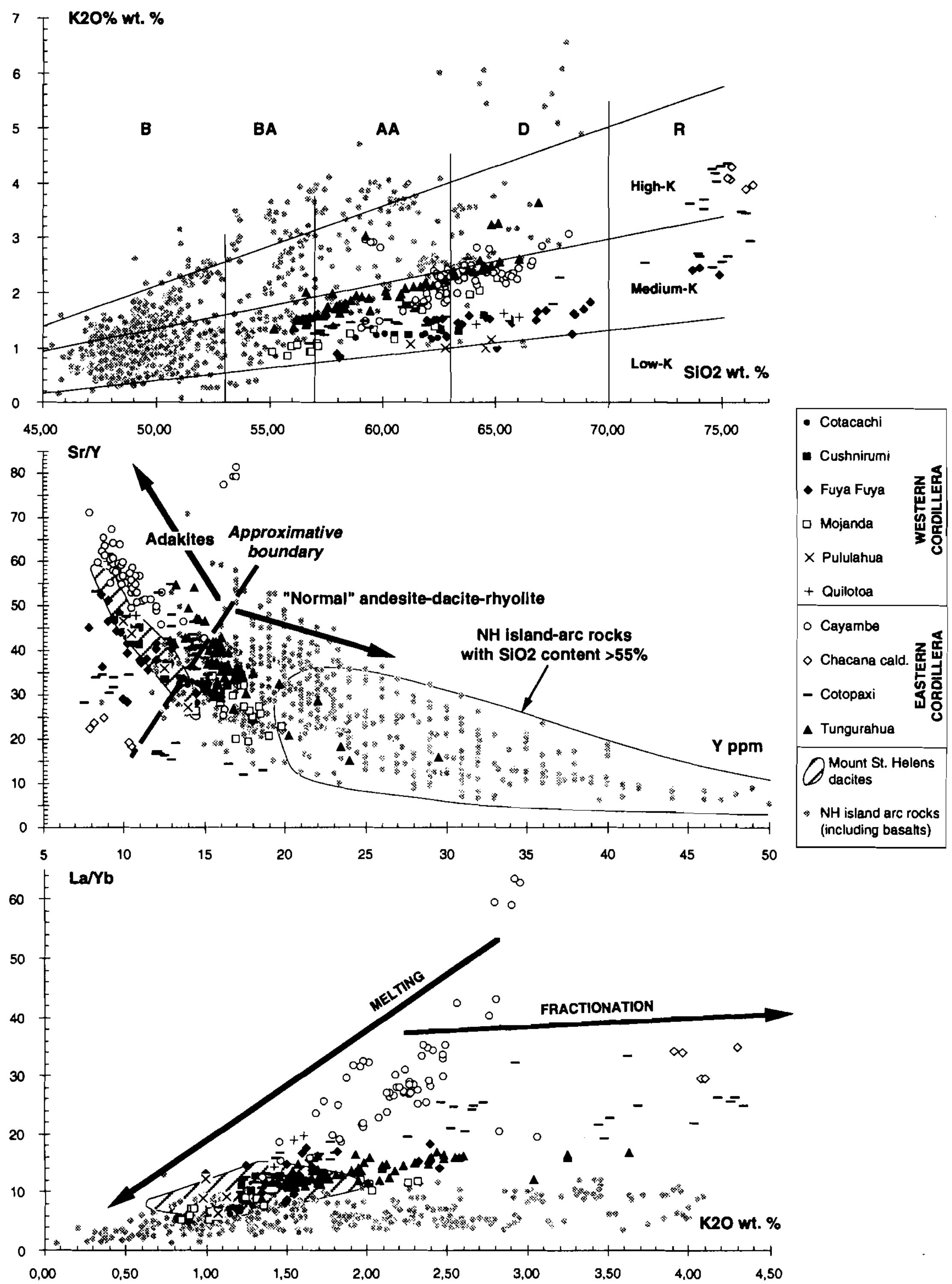

Fig. 3 K2O vs. SiO2, Sr/Y vs. Y and La/Yb vs. K2O diagrams for volcanic rocks from Ecuador. Mount St Helens dacites (Smith and Leeman, 1987) and New Hebrides island arc rocks (Monzier et al., in prep.) are given for comparison. An approximative boundary between adakites and "normal" rocks is also presented, but its exact location is questionable.