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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 A1 and Na contents, very low Y and Yb contents, and high LalYb and SrN 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 40 km depths by newly underplated hot magmas (generated in the underlying asthenospheric wedge) should be considered as an additional way to generate adakite, when 11 subducting oceanic crust is too old and cold, 21 volcanism is very far from the trench, and 31 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 Si02 contents > 55%; they are mainly medium-K basic andesites to rhyolites, and a few high-K acid andesites to rhyolites (Fig. 3; all values L01 free and recalculated to 100%). For comparison, basaltic rocks clearly predominate in a typical

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Fig. 1

Geodynamics of the Andean Block.
COC= Cocos Plate;

NU= Nazca Plate;

CAR= Caribbean Plate;

l= 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 (1 98 1) and

Ego et al. (1993).

Fig. 2

Quaternary volcanoes
and main tectonic lineations

of the Ecuadorian Andes

from l" 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-sedimen-

tary deposits filling the Interandean

Depression ;

D=Eastern Cordillera: mainly

metamorphites.

1. CERRO NEGRO
2. CHILES
3. PEW BLANCA
4. POTRERILLOS
5. CHALPATAN
6. CHULAMUEZ
7. HORWETA
8. SOCHE
I) IGUAN
10. CHAOUILULO
11. UANGUS
12. NEGROPUNO
13. HUAGRABOCA
14. COTACACHI
15. CUICOCHA
16, IMBABURA
17. CUBILCHE
18. MWANDA
19. CUSlN
20. CAYAMBE
21 REVEMADOR
22. PULULAGUA
23. CASrrAGUA
24 PAMBA MARCA
25. IUMBl
28. PUMAS
27. RUCU PlCHlNCHA
28. GUAGUA PlCHlNCHA
29 lUL0
30 PAN DE AZUCAR
31 ATACAZO
32. PASOCHOA
23. SINCHOLAGUA
34. ANTISANA
35. SUMcn
36. CORAZON
37. RUMIAAHUI
38. IUlNlZA
38. COTOPAXI
40 CHALUPAS
41. OUILINOAAA
42. OUILOTOA
U. SANTAPUNGO
44 SAGOATOA
45. LARCAPUNGO
a. HUICWAMBO
47. CARIHUAIRAZO

a. WWLICA 48. HUlSLA
50. TUNGURAHUA
51. CHIMBORAZO
52. IGUALATA
U. ALTAR
54. SANGAY

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island-arc, such as the New Hebrides arc (Southwest Pacific; Monzier et al., in prep.). A marked increase of K20 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 BaLa 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 SrN vs. Y and La/Yb vs. K20 (Fig. 3) emphasize the very high Sr/Y and LdYb 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 LdYb vs. K20 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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B

sitedacite-rhyollte

NH island-arc rocks

9 NH island arc rocks

5 10 15 20 25 30 35 40 45 50

t Wb B

Fig. 3 K20 vs. Si02, SrlY vs. Y and LalYb vs. K20 diagrams for volcanic rocks from Ecuador. Mounl SI Helens dacites (Smith and Leeman. 1987) and New Hebrides island arc rocks (Monzier et al., in prep.) are given for comparison. An approximalive boundary
between adakites and 'normal' rocks is also presented, but its exact location is questionable.