CONTRASTED ERUPTIVE STYLES AND MAGMATIC SUITES (ANDESITIC VS. ADAKITIC) AT MOJANDA VOLCANO, ECUADOR.

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INTRODUCTION

In Ecuador, Mojanda volcano, located 50 km Northeast of Quito, is one of the most voluminous volcanoes in the Interandean Depression which separates the western Cordillera from the Cordillera Real. Very little information (Hall 1977) is available about this edifice which was previously thought to be a single volcano, truncated by a small summit caldera, 2.2 x 2.8 km wide. The volcanic complex consists of two contemporaneous volcanoes. Here, we emphasize the striking differences between these volcanoes, concerning their history, eruptive styles and magmatic characteristics, despite their proximity.

MAIN PHASES OF DEVELOPMENT AND ERUPTIVE STYLES

The Mojanda volcanic complex is 26 km in diameter and rises to a maximum elevation of 4263 m from its base, between 2200 and 3000 m elevation. The orientation and convergence of lava flows and other deposits indicate the existence of two volcanic centres, located only 4 km apart : the Mojanda ss and the Fuya Fuya (Fig. 1).

Mojanda ss centre. This volcano experienced two caldera events. The truncation of a basal, essentially effusive edifice (Mojanda I), observed between 3750 and 4000 m elevation, suggests a former caldera, 5 km in diameter, around the previously recognized small summit caldera. Mojanda I consists of a monotonous series of andesitic and siliceous andesitic lava-flows and breccias (56-63% SiO_2).

Mojanda II : Except for pyroclastic deposits and a series of lavas that flowed to the North, this new cone did not extend over the limits of the caldera. Four volcanic units comprise this cone :

1- Lava flows from Yanaurco (unit MII-1), composed of diopside and olivine basaltic andesites (55-56% SiO_2).

2- Scoria flow deposits (56-58% SiO_2) containing bombs and vitric blocks, found on the SE and N flanks (unit MII-2). These deposits suggest eruptive episodes in an open-conduit regime. Dense juvenile blocks also indicate that andesitic domes emplaced in the summit area were destroyed by strong explosive activity.

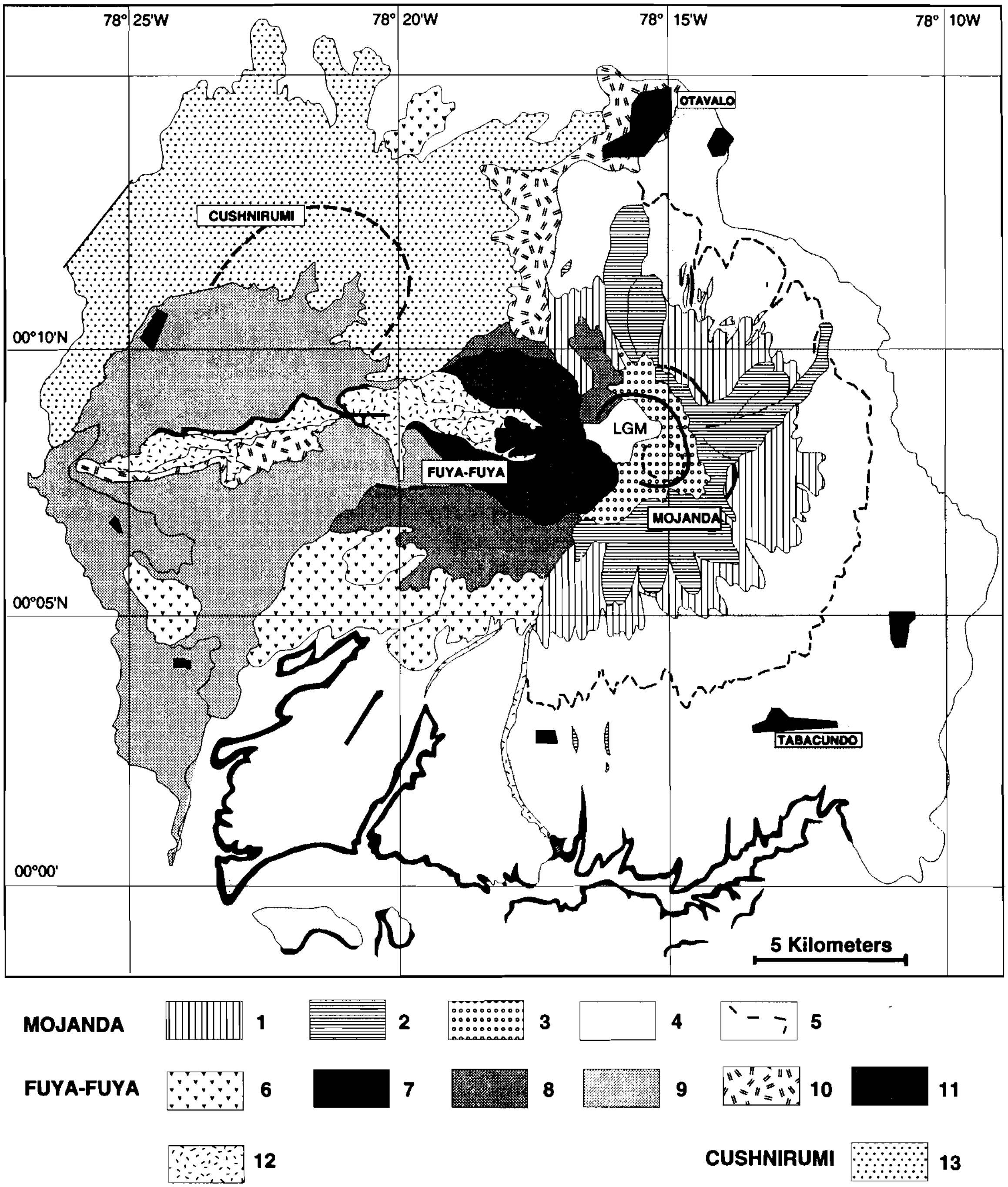

Figure 1. Simplified geological map of the Mojanda volcanic complex. **Mojanda volcanic centre** : 1- Basal edifice (MOJ I, mainly lava flows). 2- Post-caldera edifice (mainly mafic with scoria flows; MOJ II-III). 3- Yanaurcu breccias (MOJ IV). 4- Undifferentiated pyroclastic deposits from Fuya-Fuya and Mojanda (mainly ash and pumice fallout deposits), epiclastic deposits and superficial reworked ashy deposits (Cangahua). 5- Limit of flowage of lavas from MOJ I.
Fuya-Fuya volcanic centre : 6- Basal lavas and domes. 7- Outcrop zones of pyroclastic deposits related to the Plinian and dome activity (especially the thick rhyolite pumice layers R1 and R2, ash and bloc pyroclastic flow deposits and associated lahars). 8- San Bartolo volcanic cone (lava flows). 9- Avalanche deposits. 10- Ahs and pumice flows following the avalanche event. 11- Summit complex ofFuya-Fuya (lava flows and domes). 12- Recent pyroclastic flows related the summit domes.
Cushnirumi : 13- undifferentiated deposits (mainly lava flows) from Cushnirumi. Heavy lines represent the limit of calderas. LGM = Laguna Grande de Mojanda.

3- A 300 m thick unit of basic andesite to andesite breccias forming the upper part of the cone around Laguna de Mojanda (unit MII-3). These breccias, bearing abundant quenched vitric clasts, have hydromagmatic characteristics.

4- A sequence of Plinian and phreatoplinian deposits (ash and lapilli beds) of basaltic andesite and andesite. These products have been ejected during a major eruption or series of eruptions responsible for the formation of the small summit caldera. Mafic dykes which cross the caldera in a N-S orientation are associated with this phase.

Fuya-Fuya volcanic centre. Upon the western flank of Mojanda I, thick andesitic to dacitic lavas and lava domes were extruded, forming the Fuya-Fuya basal edifice. Thick sequences of Plinian and dome collapse deposits are related to this stage of development. The interpretation of numerous sections of pyroclastic deposits on the outer south slopes (block and ash flow deposits, block rich lahars, Plinian ashfalls and extensive pumice fall deposits), clearly indicate that, during this period, the activity of Fuya Fuya was strongly explosive, constantly related to acid magmatism from a gas-rich shallow magma chamber and acid extrusions.

Six major Plinian deposits interbedded with deposits of dome activity and emitted during two long magmatically and volcanically cycles are observed. Each cycle began with a voluminous Plinian eruption resulting in a thick rhyolite pumice deposit (70-71% SiO2), which was followed by episodes of dome construction and collapse, and minor emissions of ash and/or pumice.

The two main rhyolite pumice deposits, R1 and R2, at the base of each sequence, have been recognized as far away as Quito. The lower pumice R1, 4 m thick at 15 km SW of Fuya Fuya centre, is divided into two layers. The lower one is progressively enriched towards the top in andesitic (SiO2 = 60%) juvenile clasts (cauliflower bombs and scoria). Both deposits R1 and R2 represent cataclysmal Plinian eruptions, probably responsible for the opening of large vents in the summit area.

The intermediate construction stage of Fuya-Fuya is represented by the San Bartolo cone, formed by a pile of andesitic and acid andesite lava flows covering the remnants of the summit domes. A large Mount St Helens collapse event was then responsible for the loss of the major volume of this new cone and part of Fuya-Fuya's basal lavas and dome extrusions. The collapse also affected the western flank of the Mojanda II edifice (Fig.1). Voluminous dacitic pyroclastic flows, overlying the avalanche deposits, followed the avalanche event.

During the Late Pleistocene and Holocene, a new complex consisting of viscous lava flows and domes formed in the Fuya-Fuya avalanche caldera. Its eruptive activity is mainly represented by pyroclastic deposits directed to the west by the drainage and prevailing winds. Unglaciated Colangal and Panecillo domes are the last extrusions of this complex.

GEOCHEMISTRY.

48 analyses of major and trace elements have been made other the whole volcanic complex. Both Mojanda and Fuya-Fuya volcanic centres show remarkably distinct chemical characteristics on diagrams using both major as well as trace elements. Both suites lie in the medium-K calc-alkaline field, but the Mojanda series is clearly more K-enriched than the Fuya Fuya series. The Mojanda suite has higher contents of Ti, Fe and Ca, and consequently is less silicic. A discriminant diagram to differentiate the two series is the Sr/Y vs Y diagram. On figure 2, rocks from Fuya-Fuya fit within the adakite field, while the Mojanda suite shows characteristics of the normal continental andesite-dacite calc-alkaline rocks. In this diagram, rocks from Cushnirumi volcano, a third, nearby older volcano, greatly destroyed by an avalanche and dissected by erosion (Fig. 1), also appear as adakites (Monzier et al, this volume).

DISCUSSION AND CONCLUSIONS

Two major closely associated volcanic centres form what was previously considered as Mojanda volcano. Although completely contemporaneous and only 4 km apart, these centres developed different histories and eruptive styles.

At Mojanda, an andesitic basal edifice ended with a caldera collapse. A new cone began with basaltic andesite lava flows, which later turned to andesites with explosive dynamics characterized by magma-water interactions. The volcanic history of this cone ended with the last phreatoplinian eruption

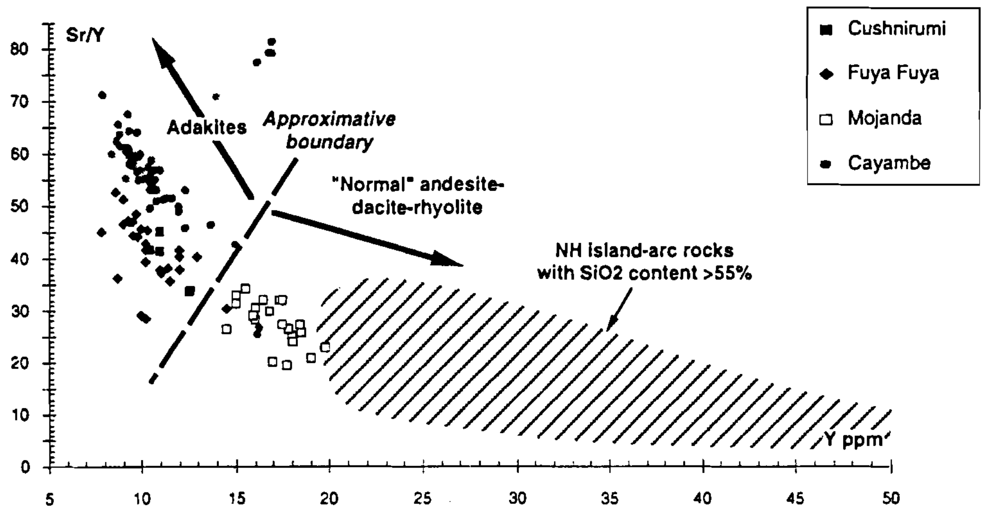

Fig. 2. Sr/Y vs. Y diagram for rocks from Fuya Fuya, Mojanda and Cushnirumi volcanoes, Ecuador. Analyses from Volcan Cayambe (East of Mojanda) are also reported. New Hebrides island arc rocks field is given for comparison. An approximative boundary between adakites and "normal" rocks is presented.

producing the summit caldera. At each evolution stage of Fuya Fuya, explosive activity related to silicic magmas was dominant. Climactic explosive dynamics occurred during two major cycles which began with a cataclysmal rhyolitic Plinian eruption and died out with acid andesite / dacite dome extrusion. Explosive volcanism related to silicic magmas continued during and after a large sector collapse of the volcano. Lastly, the avalanche caldera was occupied by a later dome complex.

These opposite types of development are related to two drastically different magmatic suites and indicate the existence of two magma reservoirs. Although both magmatic suites fall into the medium-K calc-alkaline field in a K2O Vs SiO2 diagram, the Mojanda suite is more K-enriched than the Fuya-Fuya suite which also demonstrates obvious adakitic characteristics. Adakites are andesite-dacite-rhyolite sequences (but mainly dacites) that are not associated with parental basalts, and are considered as being derived from the partial melting of amphibolite or eclogite at high pressure. They are characterized by relatively high contents of Al and Na, very low Y and Yb, and high La/Yb and Sr/Y ratios (Defant and Drummond, 1990; Dummond and Defant, 1990). Below the Mojanda volcanic complex, the slab is ~ 130-150 km deep. At this deph, the P-T conditions exceed those normally proposed for adakitic magma generation (23-26 kbars; 700-775°C). Thus, the presence of the Fuya-Fuya adakites agrees better with a hypothesis that implies their formation by partial melting of newly underplated (magmatic accreted) basaltic material than by a melted slab hypothesis. The simultaneous presence of two distinct magmatic suites at the same place stress an interesting volcanological question. Another question is the possible interaction between both volcanoes, since the juvenile andesitic magma within the R1 deposit from Fuya-Fuya is not adakitic but clearly belongs to the Mojanda series (Fig 2) and thus may have come from the Mojanda magma reservoir. More geochemical studies are in progress in order to answer these questions.

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