STRATIGRAPHY AND GEOCHRONOLOGY OF THE MACUSANI IGNIMBRITE FIELD: CHRONOMETER OF THE MIO-PLIOCENE GEODYNAMIC EVOLUTION OF THE ANDES OF SE PERU

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Résumé

La datation $^{40}Ar/^{39}Ar$ des épanchements ignimbritiques de Macusani (SE Pérou) met en évidence trois épisodes éruptifs majeurs (10±1: 6.7-8; et 4±1 Ma) qui peuvent être correlés a l'ensemble du bassin et dont les caractéristiques pétrochimiques demeurent constantes entre 10 et 6.7 Ma.

Key words: $^{40}Ar/^{39}Ar$ dating, Andes, tectonics, ignimbrites, Peru.

Introduction

The andalusite- and muscovite-phyric rhyolitic tuffs of the Mio-Pliocene Macusani Volcanics, northern Puno Department, SE Peru, have received world-wide attention owing to their extreme contents of lithophile rare elements (*e.g.*, Sn, W, U). This has led to their use as exemplars of quenched, metal-enriched, highly-peraluminous, felsic melts, analogous in many respects to the parental magmas of "two-mica leucogranites", such as are widely associated with lithophile mineralization[1]. The ash-flow tuffs constitute the youngest eruptive system of the Cordillera de Carabaya segment of the Central Andean Inner

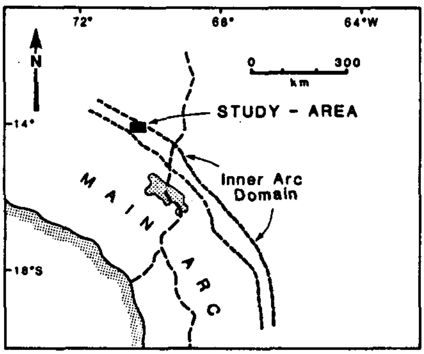

Fig. 1. Location of Study-Area with respect to the Main and Inner Arc Magmatic/Tectonic Domains of the Central Andes (after Clark *et al.*, 1984)

Arc (Fig. 1), an areally-restricted tectono-magmatic domain, broadly cospatial with the *Cordillera Oriental* and characterised by multifarious igneous rocks, some having only tenuous connections to subduction of oceanic lithosphere[2,3]. Stratigraphic and volcanological relationships for the ignimbrites of the main, Macusani, field are herein defined on the basis of 37 $^{40}Ar/^{39}Ar$ step-heating and total-fusion age determinations carried out on high-purity sanidine and biotite separates, and on obsidian.

Stratigraphic and Chronological Relationships

A minimum of 250 km^2 of tuffs accumulated in an asymmetric basin (Fig. 2), whose northern and northeastern limits are defined by faults active during eruption, and by a mountain front uplifted at 39 Ma during the Incaic orogenic cycle[4]. The southern margin of the basin is the site of polyphase magmatic activity, including intrusion of a plug of cordierite-biotite rhyodacite, dated at 19.4 ± 0.3 Ma (Fig. 2), and representative of a mid-Tertiary peraluminous cycle[2,5], petrologically distinct from the succeeding Macusani volcanism[3,6]. In the same area, a plug of muscovite-phyric rhyolite dated at 7.3 ± 0.3 Ma (Fig. 2) represents part of the vent system of the Macusani Volcanics, which flowed broadly northwards from the southern basin margin. Geochronologically-constrained stratigraphic columns are presented for the pyroclastic succession in three areas (Fig. 3). The flows are subdivided into 7 cycles, dated at (1) 10.0 ± 0.5, (2) 7.8-8.0 ± 0.1, (3) 7.5 ± 0.1, (4) 7.3 ± 0.1, (5) 6.8-7.0 ± 0.1, (6) 6.7 ± 0.1 and (7) 4 ± 1 Ma. The Early Pliocene cycle, which includes the macusanite glasses, has not been observed *in situ*, but its detritus overlies both the Chapi and Chilcuno sections (Figs. 2 and 3). At the southern margin, a volcanic flow representative of the oldest cycle has been dated at 9.9 ± 0.8 Ma in the Pampa Orccoyo area (Fig. 2). Variations in aggregate thickness of the tuffs (Chilcuno, 450 m; Chapi, 350 m; Huiquiza, 280 m) reflect the irregular pre-volcanic topography and growth faulting. A widespread unconformity mantled by an epiclastic tuff separates the 4th and 5th cycles (Fig. 3).

The stratigraphic relationships of the uranium mineralization of the field are defined for the first time. The stratiform and stratabound concentrations of polyphase pitchblende (-autunite) veinlet-stockworks[7] are restricted to ignimbritic units of the 2nd, 4th and, particularly, 5th (Chapi, Pinocho and Chilcuno VI: Fig. 2) units. A maximum age of 7.0 ± 0.1 Ma may therefore be assigned to the most important U deposits, although no direct age determinations have been undertaken on the ores.

Geochemical data for the ash-flow tuffs[1] are herein supplemented by analyses of pumice and glass fragments from several units of the succession, carried out employing newly-developed proton-induced X-ray ("PIXE") and gamma-ray ("PIGE") microprobe techniques. Like the whole-

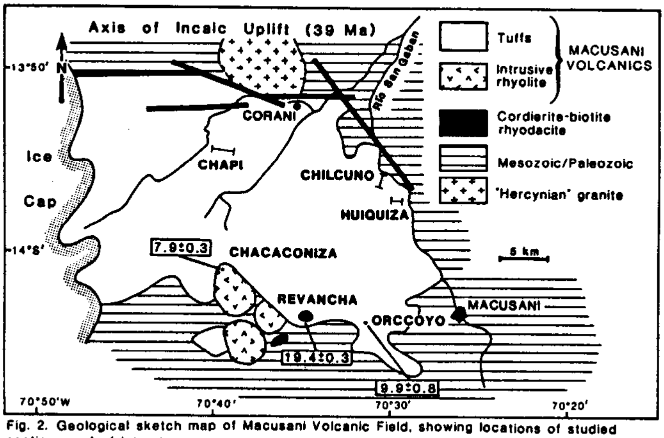

Fig. 2. Geological sketch map of Macusani Volcanic Field, showing locations of studied sections and of intrusive centres

rocks, the fractionated melts represented by the analysed glasses exhibit a striking chemical homogeneity over the interval 10 to 6.8 Ma, but are enriched in Ca and Fe, and depleted in Li, Zn, Ga, Rb and Cs relative to the macusanite obsidian of the terminal eruptions.

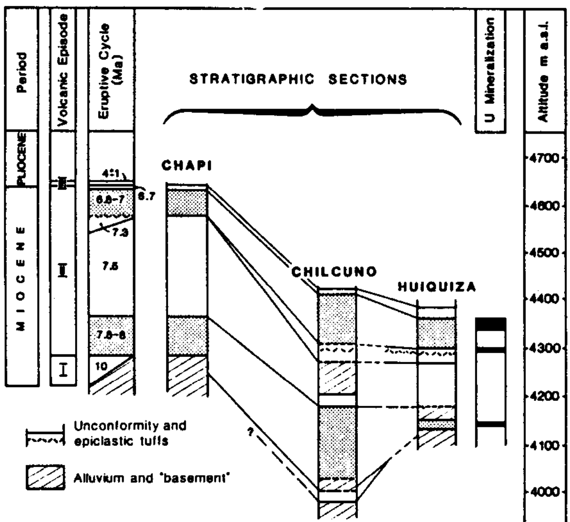

Fig. 3. Stratigraphic correlation chart of the Macusani Volcanics (NB. the 4 ± 1 Ma cycle has not been observed *in situ*)

Conclusions

The ignimbrites of the Macusani Field erupted in three brief episodes, *viz.* 10 ± 1, 6.8 - 8, and 4 ± 1 Ma, of which the second was by far the most voluminous. Two geodynamic models may be advanced to explain the new stratigraphic and geochemical data: both ascribe the lack of chemical evolution of the melts to the repeated partial melting of "pristine" pelitic protoliths, with no significant assimilation or fractional crystallization in the shallow crust, and both assume that "antithetic" subduction of the Brazilian Shield has occurred beneath the Central Andean orogen[8]. In the first model, the Late Miocene (6.8 - 8 Ma) eruptions are interpreted as a protracted response to the "Quechua-3" compressional orogenic event at 8.3 ± 0.7 Ma[9], the successive volcanic cycles reflecting the progressive upward migration of isotherms through a thickened and essentially homogeneous section of metapelites. Alteratively, each pyroclastic cycle may have been triggered by a discrete episode of subduction and crustal shortening; *i.e.*, the distinction of the Late Miocene Quechua-3 orogeny from the Miocene "Quechua-4" event is an oversimplification.

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