LATE OLIGOCENE EARLY MIOCENE ALKALINE MAGMATISM IN THE CENTRAL ALTIPLANO OF BOLIVIA

Michel FORNARI [1], Felix ESPINOZA [2], Eddy BALDELLON [2], Pierre SOLER [1]

(1) ORSTOM, UR 13, 213 rue La Fayette, 75480 Paris cedex 10, France
(2) GEOBOL, Servicio Geológico de Bolivia, La Paz, Bolivia

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INTRODUCTION

The Late Oligocene – Early Miocene basic Tambillo lavas are located in the central Altiplano, between the Miocene to Recent subduction related volcanic arc and the Late Miocene–Pliocene peraluminous ignimbritic fields of Morococala and Los Frailes in the Cordillera Oriental (fig. 1). The Tambillo lavas extend for over 80 km, within a NNW–SSE belt, at the Eastern side of the Salar de Uyuni. Nevertheless, equivalent volcanic formations extend as far north as the Bolivia/Peru border. The petrography, and major and trace element characteristics of the lavas evidence alkaline affinities which suggest particular processes in magma generation.

GEOLOGY AND MINERALOGY

The Tambillo lavas consist mainly of sills, dykes and lava flows; varying from basaltic to andesitic compositions. The hornblendite of Cerro Poke (23.6±1.3Ma) and the andesitic intrusive stock of Yarhui Koya (22.1±0.5Ma) correspond to the same magmatic event.

The sill thickness varies from about 50 cm to 120 m; in the Serrania de Urachata (fig. 2) 15 sills are currently mapped, with a total thickness of 500 m. The sills extend laterally from several kilometers to several tens of kilometers. Each sill shows very homogeneous mineralogy and grain size. Most of the sills are porphyritic; with pyroxene (± 1.5 cm) or plagioclase phenocrysts up to 3 cm.

The dykes strike to the north–east and to the east and rarely to the north. Generally they show finer grain size than the sills; however, sometimes, they contain phenocrysts of

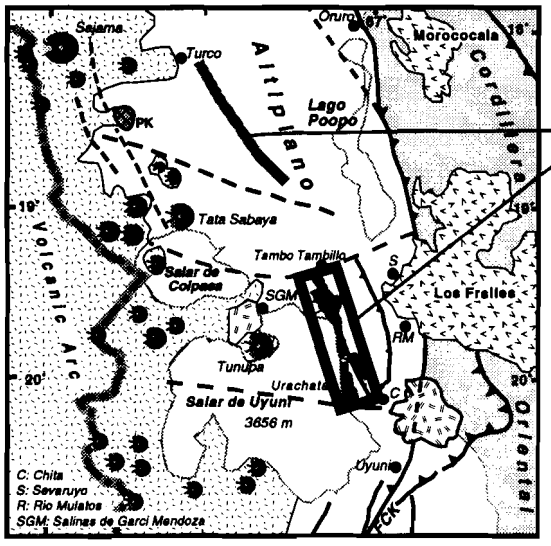

Fig. 1: Location of the studied area

Alkaline lavas

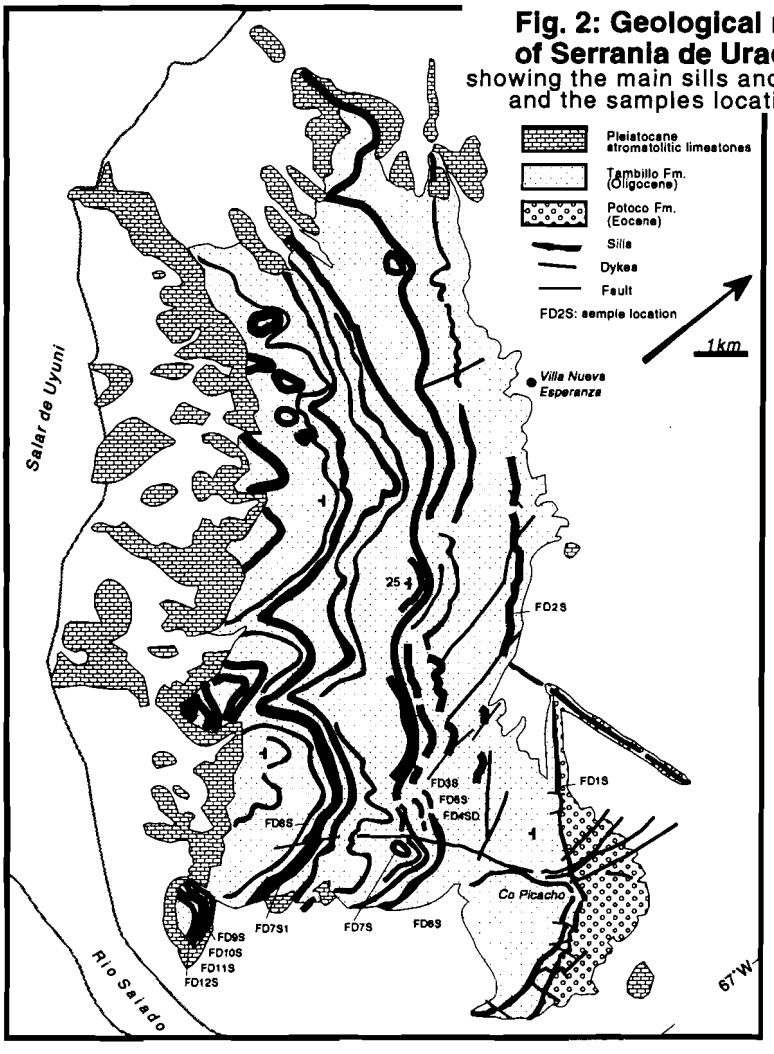

Fig. 2: Geological map of Serrania de Urachata showing the main sills and dykes and the samples location.

pyroxene or biotite up to 1 cm long. Some of the dykes contain millimetric to centrimetric mafic enclaves.
The mineralogy indicates changes with the degree of differentiation; the Tambillo lavas contain abundant olivine in the most basic rocks, augite, calcic plagioclase, opaque minerals, apatite; biotite (phlogopite) and hornblende are more abundant in andesitic lavas. The lavas contains cumulus minerals, which may show resorption borders, evidencing disequilibrium and change during the stages of crystallization.

GEOCHEMISTRY

The rocks are silica undersatured, olivine- and nepheline-normative with high K2O (1.2-6%), TiO2 (0.7-2.25%), P2O5 (0.6-0.9%). The most basic rocks are relatively undifferentiated whereas some sills and dykes define trends with diverse ranges of differentiation, mainly by crystal fractionation.
Incompatible LIL elements rare strongly enriched (up to 1300 ppm of Ba), but the element ratios (e.g., La/Nb, Ba/Nb) and Nb/Y versus Zr/P plot, suggest alkaline affinity rather than subduction related compositions (fig. 3).
The chondrite-normalized patterns of the RRE show enrichment of LREE relative to HREE (La/Lu_N 9-20) with relative flat HREE segment (Sm/Lu_N 2-5) (fig. 4).

DISCUSSION

Most of the samples show comparable patterns in the normalized spidergram which suggests a derivation from basic parent magmas with small degrees of partial melting of a garnet-bearing lherzolitic mantle source. Trace element compositions apparently preclude large amount of crustal contamination.
As indicated by mineral zoning, cumulus phases, and trends in compatible element plots, etc., the Tambillo lavas result from variable degrees of fractional crystallization of relatively homogeneous magmas.
The presence Oligocene alkaline magmatism located eastward of the calc-alkaline arc appears to be related to particular tectonic setting, with transtensional conditions.

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Fig. 3: normalized incompatible element spidergram of Tambillo lavas

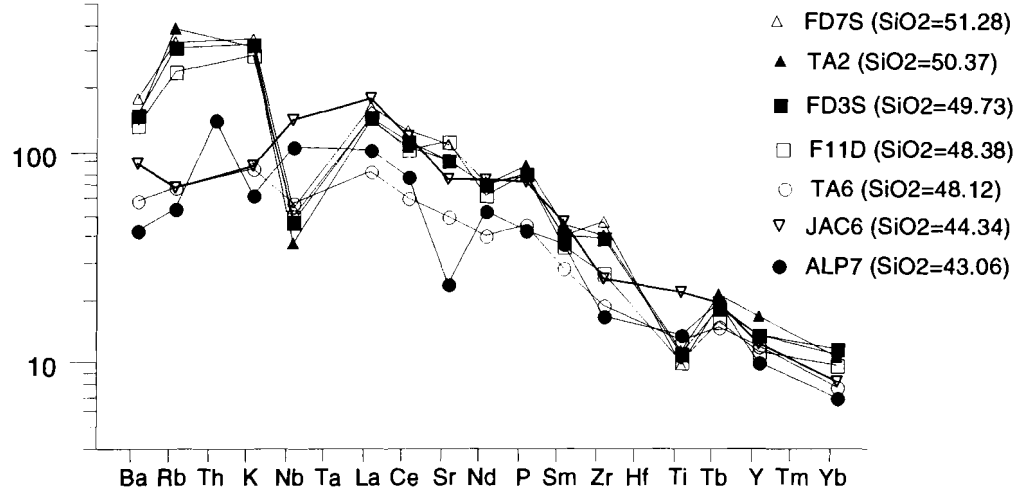

Fig. 4: REE normalized spidergram of Tambillo lavas
(note the similarity between samples)