AR-AR DATING OF LATE OLIGOCENE-EARLY MIOCENE VOLCANISM IN THE ALTIPLANO

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INTRODUCTION

In the Altiplano, the volcanic activity appears to have been very reduced during Eocene and Lower Oligocene when several kms of mainly detrital sediments accumulated. Volcanic activity increased during late Oligocene - early Miocene, forming a succession of outcrops in a SW-NE belt of more than 800 km long located in the Altiplano and oblique to the subduction related magmatism. The aim of this contribution is to present new Ar-Ar data that constrain the time of initiation and the duration of this volcanic activity.

GEOCHRONOLOGICAL RESULTS

^{40}Ar-^{39}Ar laser step-heating age determinations were made on single grains of biotite and sanidine from the crushed rock samples; whole rock fragments were used for basaltic samples lacking of K-rich phenocrysts as separation of suitable minerals was not possible. The laser step-heating experiments were performed following the method described in Féraud (1982) and Ruffet et al. (1991). The criteria used to define a plateau age are: (1) the plateau should include at least 70 % of released ^{39}Ar; (2) there should be at least three successive steps in the plateau; and (3) the integrated age of the plateau should agree with each apparent age of the plateau segment within 2σ error confidence level.

The first occurrences of this volcanic activity are represented by pyroclastic products and also by basic lava flows. In the area of Chivay (Box A in fig. 1), a slightly chloritised biotite from a pyroclastic tuff included in a thick conglomeratic succession, shows a plateau age of 29.66 ± 0.88 Ma (sample 990513-3). In the area of Ayaviri (Box B in fig. 1), pyroclastic levels included in a thick red-beds sequence, were sampled en 2 sites (Sipi Sipi and Co Incanan) located near the limit with of the Eastern Cordillera. They furnish plateau ages on biotite of 28.03 ± 0.15 (sample 990521-4) and 28.03 ± 0.24 Ma (sample 990524-4).

- In the northern part of Laguna Lagunillas (Box C in fig. 1), basalt-andesite lava flows overly unconformably conglomerates of the Puno Formation. A whole-rock sample (sample 981011-3, Pinaya area) yielded a nice plateau age of 29.8 ± 0.06 Ma, accounting 86% of the total ^{39}Ar.

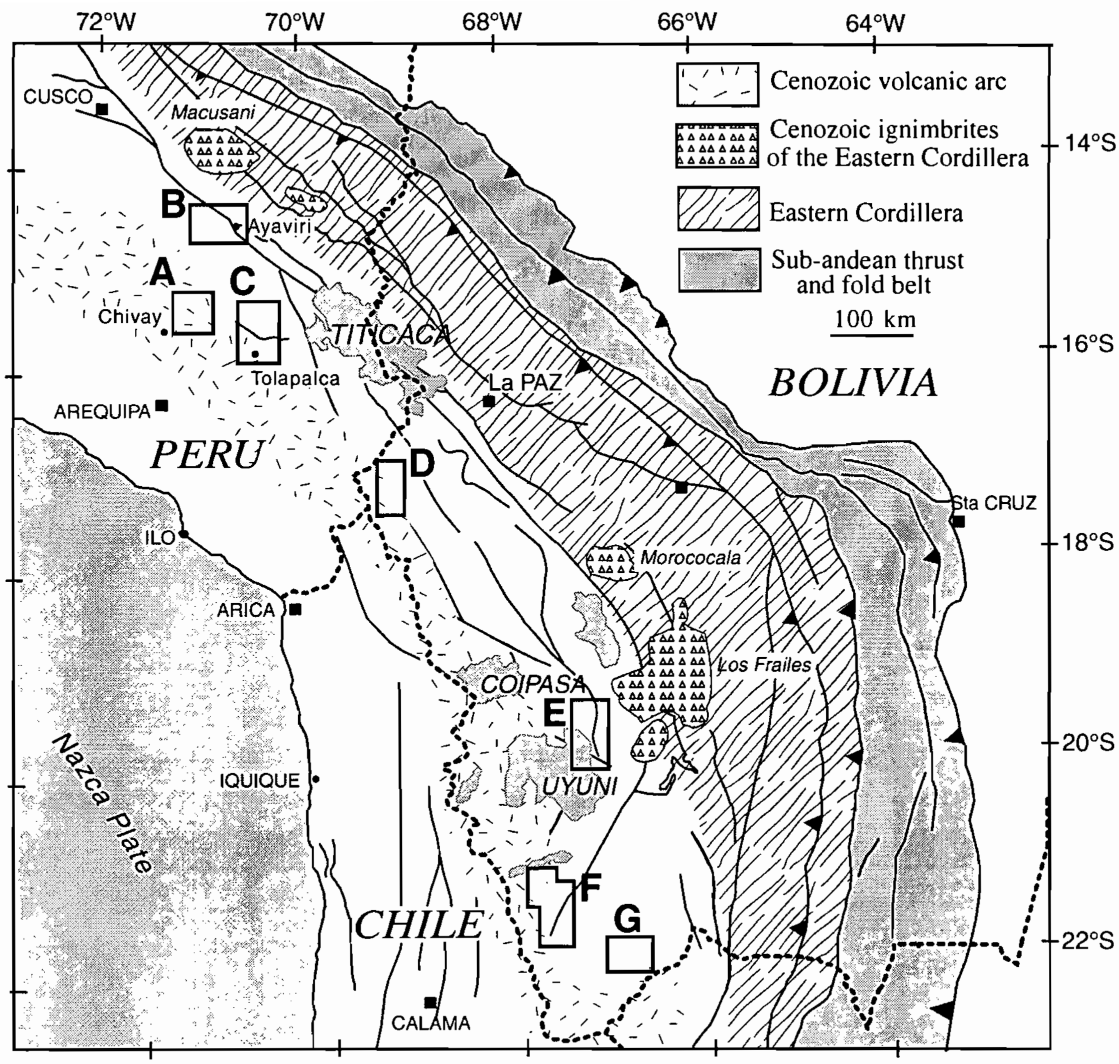

Fig 1: sketch map of the Central Andes showing the location of the sampled area (labeled boxes).

In the same area, basaltic lava flows, sills, dykes and volcanic brecchias form outcrops of several hundred of meters-thick; but they have been strongly altered by hydrothermal circulation and meteorization thus they could not be dated. So we include the sample (970815-1) of a microgabbroic lava from Tolapalca, located at 40 km south of Pinaya. In spite of a disturbed age spectrum due to alteration and ^{39}Ar recoil during irradiation, evidenced by decreasing apparent ages with temperature. Nevertheless, the "mini-plateau" age of 26.50 ± 0.09 Ma, (accounting only for 42% of the total ^{39}Ar released), is probably not far from the true age of the rock. Moreover, biotites from two pyroclastic flows located about 150 m above the basic lava display plateau ages of 24.48 ± 0.11 and 24.09 ± 0.81 Ma (samples 981005-2 and 9981005-1).

These ages are in the same range than the age of 25.23 ± 2.34 Ma (sample 970823-1) from a cluster of plagioclase from a nephelinic lava flow near Ayaviri. The data present a high error because of the low K content of the plagioclase but agree with the 28-25 Ma K/Ar ages of Bonhomme (1985).

In Bolivia similar lavas are identified with different local names from North to South e.g., Abaroa Formation, Tambillo Fm, Julaca Fm., Rondal Fm., but because of the lack of stratigraphic data, the age of the magmatic episode was poorly constrained. These lavas crop out mainly as flows, sills, dykes and small intrusives stocks; ash falls deposits are present in some locations (e.g., Tambillo Fm). A characteristic feature of this volcanism is the presence of thick and extended deposits of flow breccias that indicates the presence of several volcanic centers.

- In the area near the border between Chile, Bolivia and Peru (box D in fig. 1), determinations were made on basic whole-rocks of the Abaroa Fm. The sample ABM1 yielded a plateau age of 27.84 ± 0.05 Ma, accounting for 95% of the total ^{39}Ar released. Three determinations display disturbed spectra with decreasing apparent ages versus temperature. These shapes are due to ^{39}Ar recoil; in that case, we consider that intermediate to high temperature ages may represent geological valid ages; the ages are 27.97 ± 0.13 for sample ABA9 with 47% of the total ^{39}Ar released, 27.34 ± 0.08 for sample ABM2, with 35 % of the total ^{39}Ar released and 27.5 ± 0.2 for sample ABA12 with 30 % of the total ^{39}Ar released.

These dates are much older than the K/Ar determinations (18-13 Ma) of Lavenu et al. (1989) for the Abaroa Fm and also older than the age of 25.2 ± 1.0 Ma for a basalt flow they attributed to the Mauri Formation.

- Near the eastern border of the Salar de Uyuni, outcrops of the Serrania de Urachata (box E in fig 1) contain several hundred meters thick of basic volcanism and some tuffs within detrital sediments (Espinosa, 1995). Several samples of basic lava were analyzed and yielded dates about 23-24 Ma. The basaltic sill from Cerro Chiar Kullu shows a ^{39}Ar-^{40}Ar plateau-age of 24.2 ± 0.4 (sample 95BL18) which is the oldest age from the basic magmatism in this area; the date is in concordance with the K/Ar age of 25.2 ± 0.9 Ma of Hoke et al., (1993) and Khennan et al., (1995). The Chiar Kullu sill is overlain by about 500 m of sandstones and a >100 m-thick basaltic sill with plagioclase phenocrysts up to 3 cm. This sill which forms the Kapora-Tambo Tambillo syncline, shows a whole rock plateau-age of 23.8 ± 0.1 (sample 941112-1). It was probably sampled very close to the sample Rod-91, which yielded a K/Ar date of 23.1 ± 1.2 Ma (Khennan et al., 1995).

The Cerro Picacho (southern part of boxE) shows a section of about 1000 m thick, with more than 15 basaltic levels included in detrital sediments; a lava flow in the basal part of Cerro Picacho section yields a plateau age of 23.45 ± 0.08 Ma (sample FD7S1). An other sample in the top of the same section shows a disturbed age spectrum (^{39}Ar recoil) but contains a "mini-plateau", accounting for 51% of the total ^{39}Ar released with an age of 23.6 ± 0.1 Ma. Morerever a biotite crystal from a basic dyke which cuts several flows and sills provides a plateau-age of 23.5 ± 0.1 Ma (sample 930402-2). Thus it appears that most of the basic lava emplaced very quickly. Above the sequence of basic lava, several hundred meters of conglomeratic levels were deposited (member 2 of the Tambillo formation. They contain thin levels of tuff. The upper part of the Chiar Punta section, which crops out in the border of the Salar of Uyuni contains more than 1000 m of coarse conglomerates. In the lower part of the conglomeratic sequence, a sanidine from a ash-fall horizon above the basaltic sill and lava flows yielded a plateau age of 22.26 ± 0.06 (sample F4).

In the Kapora -Tambo Tambillo syncline, sample 95BL21 was collected from a cineritic level at the base of the Tambillo Formation. The cinerite is located ca. 20 m above the thick porphyric basaltic sill and shows a biotite single grain plateau-age of 25.2 ± 0.3 Ma. Another cineritic level ca. 150 m above 95BL21 displays a plateau-age of 23.6 ± 0.3 Ma (sample 95BL20). Both samples are located in the fine-grained part of the Tambillo formation, which rapidly coarsens upwards. In the eastern flank of the syncline, the conglomeratic upper part of the sequence contains a welded tuff located ca 2500 m above the basaltic horizon. It presents a biotite single grain plateau-age of 16.0 ± 0.2 Ma (sample 95BL22). Presumably the same tuff gave a K/Ar age of 15.8 ± 0.5 Ma, (Hoke et al., 1993, Khennan et al., 1995).

These data permit to calculate low sedimentation rates of about 60 m by million of years for the base of the Tambillo Formation and of about 250 m by million of years for the upper conglomeratic sequence indicating that the area was not affected by an intense tectonic activity at this time although the Member 2 of the Tambillo Formation consists of an up-coarsening sedimentary sequence.

- In the southern part of the Bolivian Altiplano (box F in fig. 1), basic lava flows, sills and dykes occur within detrital sediments in the Serranias de las Minas. Two samples display concordant whole rock plateau-ages of

21.9 ± 0.2 (Khonas, sample 95BL9) and 21.8 ± 0.2 Ma (Suri Puquio, sample EG69). Two age spectra show decreasing apparent ages versus temperature (^{39}Ar recoil) but intermediate to high temperature steps (from 35 to 66% of total ^{39}Ar released) may represent geological valid ages of 21.9 ± 0.2 Ma (sample EG31) and 21.9 ± 0.3 (sample 941115-3). All these dates are in the same range whereas a significantly lower plateau-age of 19.9 ± 0.3 Ma is displayed by the sample 95BL16 (laguna Chuan). Despite the existence of a plateau-age, the age spectrum apparently shows a slight ^{39}Ar recoil effect at low temperature.

A basalt-andesitic dyke near Guadalupe (box E in fig. 1) gave a whole rock plateau-age of 22.18 ± 0.26 (sample S5, Rondal Fm). This age is slightly older than the plateau-age of 21.4 ± 0.1 Ma given by a biotite single crystal from a andesitic sill (sample 910914-1, Rondal lava) and than the plateau-age of 21.1 ± 0.3 from a basic lava flow (sample 3010-4).

Theses lava flows are apparently the first ones that occur in the detrital sedimentary sequence (Baldellon, 1995), and so, the volcanism onset seems to be younger here than in the northern part of the Altiplano.

CONCLUSION

Ar-Ar data evidence magmatic activity in the range of 29-21 Ma; a more subtle difference may exist between the North and the South of the Altiplano (ages between 29 and 25 Ma in Peru, 24.5 and 22.5 Ma in Tambillo area and around 22-21Ma in the Serrania de las Minas - Guadalupe area). The High-K, alkaline affinity of this volcanism indicates a deep origin and may be related to the transtensive tectonic conditions and the reactivation of main fracturation.

The late Oligocene-Early Miocene episode of magmatic activity appears to coincide with an extended period of structural deformation and crustal shortening; it appears also that the onset of volcanism and tectonism followed a period of major plate reorganization in the southeast Pacific following the Farallon plate brake up, with fast plate convergence (Pilger, 1984; Pardo-Casas & Molnar, 1987).

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