

FIELD OBSERVATIONS AND K-Ar DATING OF THE CERRO CHIAR KKOLLU (SOUTHERN ALTIPLANO, BOLIVIA)

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RESUMEN : El cerro Chiar Kkollu, ubicado en el Altiplano Sur de Bolivia, era considerado desde tiempo como un centro volcánico cuaternario alcalino de atrás-arco de la Zona Volcánica Central (CVZ) de los Andes. Era el único ejemplo de un volcanismo de tal naturaleza en esta región. Observaciones de terreno y una datación K-Ar sobre roca total muestran que dicho centro es de edad Oligoceno y pertenece a un conjunto de rocas de afinidad alcalina de edad Oligoceno a Mioceno inferior ampliamente distribuidas en el Altiplano boliviano. Los modelos petrogenéticos propuestos anteriormente por diferentes autores en base a las supuestas relaciones entre el Chiar Kkollu y el volcanismo cuaternario de arco y/o de atrás-arco de la CVZ no tienen ningún sustento geológico.

KEY WORDS : Bolivia, Oligocene, Alkali basalts, Back-arc

INTRODUCTION

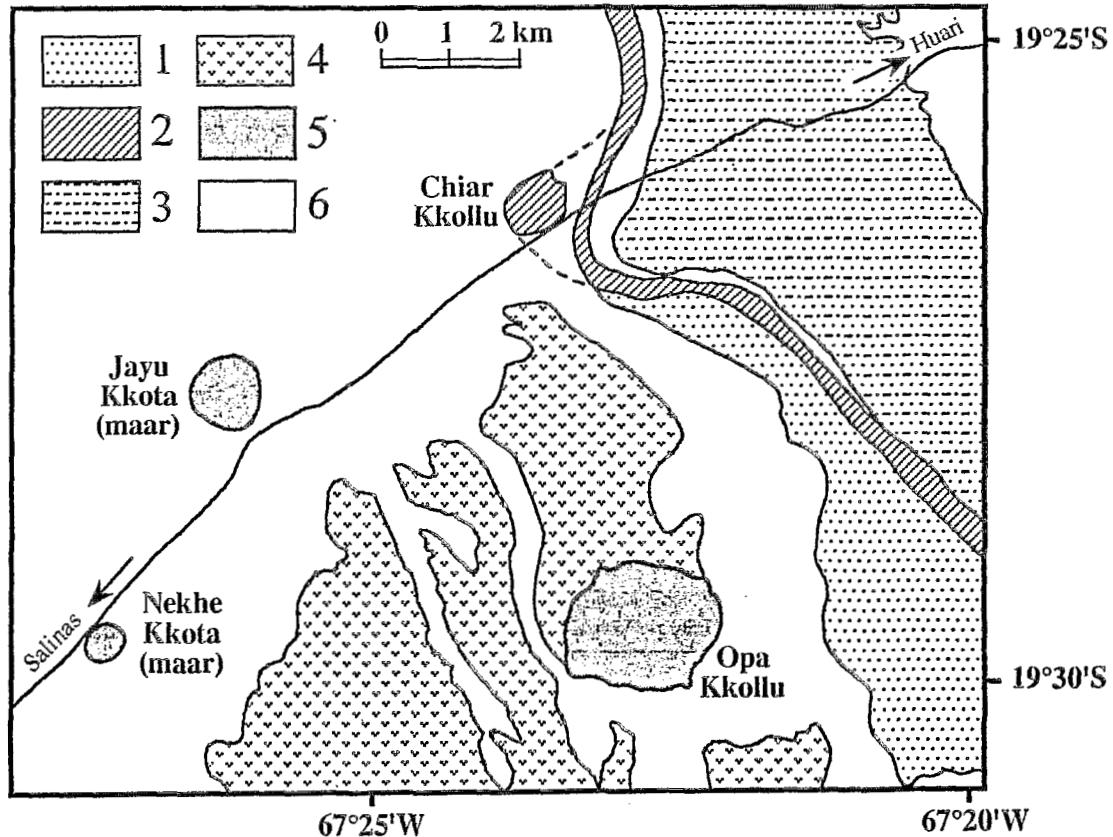
The cerro Chiar Kkollu, in the southern Altiplano of Bolivia, is well known among geoscientists devoted to the recent and present-day volcanic activity of the Central Andes. As a matter of fact, this small volcanic outcrop has long been considered as the unique example of quaternary alkaline back-arc volcanism behind the Central Volcanic Zone in the Bolivian Andes (Thorpe and Francis, 1979; Thorpe et al., 1982), and this "peculiar" volcanic rock has been used by various geochemists (e.g. Thorpe et al., 1984; Rogers, 1985; Rogers and Hawkesworth, 1989; Davidson et al., 1991; Davidson and De Silva, 1992) as a clue for the understanding of the petrogenesis of the modern arc and back-arc magmas of the CVZ.

Our field observations and whole-rock K-Ar dating permit to demonstrate that this apparently peculiar volcanic rock is actually of Oligocene age, and belongs to an alkaline volcanic province of Oligocene-Early Miocene age, which appears to be an important feature of the magmatic and tectonic evolution of the Bolivian orocline.

FIELD, PETROGRAPHIC, AND GEOCHEMICAL OBSERVATIONS

The Cerro Chiar Kkollu (19° 26' S - 67° 23' W - figure) outcrops near Tambo Tambillo along the road between Huari and Salinas de Garcí Mendoza in the southern Altiplano of Bolivia. It is an isolated, roughly circular *mesa*, about 800 metres in diameter, surrounded by Plio-Quaternary continental detritics. Topographically this outcrop is rather similar to some of the Quaternary shoshonitic centers known in the same region (e.g. Davidson et al., 1991; Soler et al., 1992, in prep.), which may explain that it has long been considered as Quaternary in age. However, detailed field observations show that small remnants of metamorphosed red pelites are outcropping over the surface of the cerro Chiar Kkollu. These pelites are quite similar to metamorphosed pelites observed

southeastwards at the contact between alkaline basaltic to micro-gabbroic sills and the Oligocene - Early Miocene continental Potoco and Tambillo sedimentary formations. These sills, known as the "Tambillo lavas", outcrop immediately to the East and Southeast of the cerro Chiar Kollu and dip steeply ($\approx 45^\circ$) towards the NE. These field observations suggest that the cerro Chiar Kollu basalts are not of Quaternary age, and that they rather belong to a folded Late Oligocene - Early Miocene set of alkaline sills.



Geological sketchmap of the Cerro Chiar Kollu area

1 - Eocene-Oligocene Potoco Fm (pelites, red sandstones) ; 2 - Late Oligocene-Early Miocene basalts and micro-gabbros (sills - "Tambillo lavas"); 3 - Early Miocene Tambillo Fm (pelites, red sandstones, conglomerates, tuffs) ; 4 - Late Miocene dacitic ignimbrites; 5 - Quaternary shoshonitic centers; 6 - Plio-quaternary continental detritics.

In addition, as quoted by most authors, the cerro Chiar Kollu basalts display very peculiar petrographical, chemical and isotopic compositions when compared with basic lavas of the modern arc (CVZ - Thorpe et al., 1984; Rogers, 1985; Davidson et al., 1991; Davidson and De Silva, 1992) and of the back-arc (i.e. shoshonites - Davidson et al., 1991; Davidson and De Silva, 1992; Soler et al., 1992, 1993, in prep.) of the Western Cordillera and the Altiplano of Bolivia. In particular, they are characterized by their very primitive feature, their alkaline affinity, their unradiogenic Sr compositions, and the absence of any crustal xenoliths. It should be noted that quite similar petrographical and geochemical features are observed in the "Tambillo lavas".

K-AR DATING

Sample JAC6 from cerro Chiar Kollu has been dated by M.G. Bonhomme at the University of Grenoble following the techniques described in Lavenu et al. (1992). The results are given in the table.

Sample	K ₂ O (%)	⁴⁰ Ar rad (%)	⁴⁰ Ar rad (nl/g)	⁴⁰ K/ ³⁶ Ar (x 1000)	⁴⁰ Ar/ ³⁶ Ar	Age (Ma) (± 1σ)
JAC6	1.05	54.2	0.935	218.1	645.3	27.4 ± 0.8

This 27.4 ± 0.8 Ma whole-rock age may be slightly older than the actual age of emplacement due to a possible excess of argon in the abundant clinopyroxenes of these basalts. It confirms however the interpretation proposed on the basis of field observations. This age is slightly older than ages previously obtained on the Tambillo lavas (22.6 Ma recalculated with new constants Ma; K-Ar age on plagioclase; Evernden et al., 1977; 19.6 ± 2.5 to 23.5 ± 2.6 - IGE-JICA, 1986).

This age fits also with ages obtained on the Rondal Fm (Kussmaul et al., 1975; Fornari et al., this volume), the alkaline basic volcanism of the Tupiza basin (Hérail et al., this volume), and the Abaroa Fm. of the northwestern Altiplano (Lavenu et al., 1989; Jimenez et al., this volume).

Thus the Cerro Chiar Kkollu basalts belong to the Late Oligocene - Early Miocene volcanic episode of alkaline affinity known all over the Bolivian Altiplano (Soler and Jimenez, this volume). They probably derived from the subcontinental lithospheric mantle during a trans-tensional tectonic episode (Soler and Jimenez, this volume) and their composition cannot be used as a clue to model the compositions of the subduction-related, asthenosphere-derived magmas of the modern arc (CVZ) as proposed by several authors (e.g. Thorpe et al., 1984; Rogers, 1985; Rogers and Hawkesworth, 1989; Davidson et al., 1991; Davidson and De Silva, 1992). However their compositions may be used to constrain the petrogenetic models for the back-arc, lithosphere-derived shoshonitic and peralkaline volcanism of the Bolivian Andes (Soler and Jimenez, this volume).

REFERENCES

- DAVIDSON, J.P. & DE SILVA, S.L., 1992 - Volcanic rocks from the Bolivian Altiplano: insights into crustal structure, contamination, and magma genesis in the central Andes. *Geology*, 20, p. 1127-130.
- DAVIDSON, J.P., DE SILVA, S.L., ESCOBAR, A., FEELEY, T. & BOHRSON, W. 1991 - Evaluation of magma sources for central Andean volcanics. 6to Congreso Geológico Chileno, Resúmenes Expandidos, p. 347-349.
- EVERNDEN, J. F., KRIZ, S. J., & CHERRONI M., C., 1977 - Potassium-Argon ages of some Bolivian rocks. *Economic Geology*, 72, p. 1042-1061.
- FORNARI, N., HÉRAIL, G., POZZO, L., & VISCARRA, G., 1991 - Los yacimientos de oro de los Lipez (Bolivia). Tomo I: Estratigrafía y dinámica de emplazamiento de las volcanitas del área de Guadalupe. Mission ORSTOM en Bolivie, La Paz, Rapport n°19, 28 p.
- FORNARI, M., POZZO, L., SOLER, P., BAILLY, L., LEROY, J., & BONHOMME, M.G., 1993 - Miocene volcanic centers in the Southern Altiplano of Bolivia. The Cerro Morokho-Cerro Bonete area (Sur Lipez), this volume.
- HÉRAIL, G., OLLER, J., BABY, P., BLANCO, J., BONHOMME, M. G., & SOLER, P., 1993 - The Tupiza, Nazareño, Estarca basins (Bolivia): strike-slip faulting and thrusting during the Cenozoic evolution of the southern branch of the Bolivian Orocline. This volume.
- IGE(UMSA)-JICA, 1986 - Edades Radiométricas de Bolivia. Publ. especial de la Facultad de Ciencias Geológicas de la UMSA, La Paz, 53 p.
- JIMENEZ CH., N., BARRERA I., L., FLORES B., O., LIZECA B., J.L., MURILLO S., F., HARDYMAN, R. F., TOSDAL, R. M., & WALLACE, A. R., 1993 - Marco geológico de la región de Berenguela. In: Investigación de metales preciosos en los Andes Centrales, Proyecto BID/TC-88-02-32-5, GEOBOL (La Paz), p. 63-74.
- KUSSMAUL, S., JORDAN, L., & PLOSKONKA, E., 1975 - Isotopic ages of Tertiary volcanic rocks of SW-Bolivia. *Geol. Jb. (Hannover)*, B14, p. 111-120.
- LAVENU, A., BONHOMME, M. G., VATIN-PERIGNON, N., & PACHTERE de, P., 1989 - Neogene magmatism in the Bolivian Andes between 16° and 18° S. *Stratigraphy and K-Ar geochronology*. *J. South Amer. Earth Sci.*, 2, 1, p. 35-47.
- LAVENU A., NOBLET, C., BONHOMME, M.G., EGUEZ, A., F. DUGAS, & VIVIER, G., 1992 - New K/Ar age dates of Neogene and Quaternary volcanic rocks from the Ecuadorian Andes: implications for

- the relationships between sedimentation, volcanism, and tectonics, *J. South Amer. Earth Sci.*, 5, 1, p. 1-19.
- ROGERS, G.R., 1985 - A geochemical traverse across the north Chilean Andes. Unpub. Ph. D. thesis, The Open University, Milton Keynes
- ROGERS, G.R. & HAWKESWORTH, C.J., 1989 - A geochemical traverse across the north Chilean Andes: evidence for crust generation from the mantle wedge. *Earth Planet. Sci. Lett.*, 91, p. 271-285.
- SOLER, P., CARLIER, G., FORNARI, M., & HÉRAIL, G., 1992 - An alternative model for the origin and the tectonic significance of the Neogene and Quaternary shoshonitic volcanism of the Andes. *EOS Trans. AGU, Spring Meeting Suppl.*, 73, 14, p. 341.
- SOLER, P., & JIMENEZ CH., N., 1993 - Magmatic constraints upon the evolution of the Bolivian Andes since Late Oligocene times, this volume.
- SOLER, P., CARLIER, G., AITCHESON, S. J., & FORNARI, M., 1993 - Sr, Nd and Pb isotopic constraints upon the origin of the Quaternary shoshonitic lavas and the deep structure of the central Altiplano of Bolivia. *EUG VII, Strasbourg (France), TERRA Abstracts, Abstract Suppl. n°1 to TERRA nova*, vol. 5, p. 584-585.
- SOLER, P., CARLIER, G., & FORNARI, M., in prep. - The shoshonitic province of the southern Altiplano of Bolivia
- THORPE, R.S. & FRANCIS, P.W., 1979 - Variations in Andean andesites compositions and their petrogenetic significance. *Tectonophysics*, 57, p. 53-70.
- THORPE, R.S., FRANCIS, P.W., HAMMILL, M. & BAKER, C.W., 1982 - The Andes. In: *Andesites: Orogenic andesites and related rocks*, R.S. Thorpe, ed., John Wiley & sons, p. 187-205.
- THORPE, R.S., FRANCIS, P.W. & O'CALLAGHAN, L., 1984 - Relative roles of source composition, fractionnal crystallization and crustal contamination in the petrogenesis of Andean volcanic rocks. *Phil. Trans. Roy. Astron. Soc.*, A310, p. 675-692.