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MAGMATISMO NEOGENO EN LOS ANDES BOLIVIANOS ENTRE LOS 16° Y 18° LAT. SUR
Parte 1: Estratigrafía numérica (K-Ar) y Tectónica

NEOGENE MAGMATISM IN THE BOLIVIAN ANDES (BETWEEN 16° AND 18° S)
Part 1: Numerical stratigraphy (K-Ar) and tectonics

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This work results from a study of a profile in central Bolivia, from the Western Cordillera to the Eastern Cordillera, through the Altiplano, between 16° and 18° S. The Andean magmatism was significant at the end of the Paleogene and during the whole Neogene. As well as the study of magmatism, the isotopic dating of numerous stratigraphic formations was carried out so as know better the chronology of tectonic events in that area of the Andes.

NUMERICAL STRATIGRAPHY

Table 1 gives analytical data. Samples are located on Figure 1.

** The Western Cordillera Piedmont*

The Oligo-Miocene age of the Mauri Formation (BO3) is confirmed. The volcano-sedimentary Abaroa Formation was dated from the Oligo-Miocene: that is the equivalent of the Mauri Formation (LA80-2, PH43, LA80-6, LA80-4). The Cerke volcanic Formation which is andesitic, dates from the Pliocene (BO4). This is in agreement with the regional geology. An andesitic flow (LA80-5), which unconformably overlies the Miocene folded sediments of the Abaroa Formation, gave a K/Ar date of 7.6 Ma (upper Miocene).

** The Altiplano*

The ignimbritic tuff overlying the Pliocene sediments of Tirata (W of Curahuara de C.) gave a Pliocene age (BO7). Though it used to be classified until then as Perez ignimbrite (IA, IB, Table 1), it is older and brings about the problem of the dating of the different tuffitic flows that are found in the Western Cordillera Piedmont. They have all been classified as Perez ignimbrite until now.

In the centre of the Altiplano, the dating of a rhyolitic flow confirms the Miocene age of the Turco Formation (LA81-14).

On the eastern edge of the Altiplano, at the bottom of the Eastern Cordillera, the isotopic dating shows the presence of Pliocene sediments (PH48, PH75, LA82-2).

TABLE 1. K-Ar ISOTOPIC DATA OF SOME VOLCANIC FORMATIONS OF BOLIVIA
TABLA 1. EDADES K-Ar DE ALGUNAS FORMACIONES VOLCANICAS DE BOLIVIA

Sample	Mineral (1)	Location	K_2O %	$\frac{^{40}Ar_{rad}}{^{40}Ar_{tot}}$ %	$^{40}Ar_{rad}$ (nl/g).	Age(My)	ref. (2)	S. Lat.	W. Long.	Altitude
BO3	RT	E. Kusima	4,28	58,4	3.488	25,2 ± 1,0	B	17°14'28"	69°14'29"	4060
IO	Pl	Achiri	0,58	66		25,6	A	17°14'	69°08'	
IL	B	C° Hakokota	7,99	75		10,5	A	17°11'	69°10'	
LA80.2	Pl	E. Abaroa	4.30	99.7	2.901	20.8 ± 0.5	B	17°33'14"	69°14'18"	3990
PH43	RT	C° Canasita	3,84	38,2	2,455	17,9 ± 0,7	B	17°44'29"	69°09'33"	4560
LA80.6	Pl	E. Colque Una	0,55	53,7	0,268	15,1 ± 0,8	B	17°50'49"	69°13'07"	4315
"	RT	"	3,35	72,1	1,430	13,2 ± 0,3	B	"	"	"
LA80.4	RT	C° Lupijcala	2,68	69,2	1,172	13,5 ± 0,4	B	17°33'54"	69°13'31"	4060
LA80.5	Pl.	E. Colque Una	0,77	43,6	0,189	7,6 ± 0,8	B	17°52'00"	69°13'20"	4350
BO4	Pl	E. Sacacani	1,015	23,0	0,188	5,7 ± 0,5	B	17°25'05"	69°18'07"	4080
IU	H	Comanche	1,27	51		16,7	A	17°05'	68°35'	
"	"	"	1,79	45		14,6	A	"	"	
LA81.14	Pl	N. Azurita	4,51	90,7	1,701	11,7 ± 0,3	B	18°05'25"	68°09'00"	3920
IK	FK	Turco	11,20	76		9,7	A	18°08'	68°20'	
IJ	FK	Ulloma	10,84	91		9,1	A	17°50'	65°26'	
IS	B	N. Azurita	7,84	97		6,4	A	18°03'	68°10'	
IE	B	Curahuara de C.	7,11	7		5,9	A	17°52'	68°28'	
ID	B	"	9,18	2		5,5	A	17°51'	68°00'	
IC	B	Callapa	9,00	48		5,4	A	17°29'	68°28'	
PH48	Pl	Soledad	2,74	27,7	0,463	5,23 ± 0,29	B	17°41'05"	69°18'57"	3780
"	"	"	"	22,0	0,439	5,0 ± 0,7	B	"	"	"
"	B	"	7,56	31,6	1,123	4,6 ± 0,21	B	"	"	"
PH75	Pl	V. Remedios	5,06	36,9	0,542	3,32 ± 0,22	B	16°46'13"	68°10'51"	3820
"	"	"	"	16.8	0,523	3,2 ± 0,4	B	"	"	"
LA82.2	Pl	Ayo Ayo	1,30	58,0	0,120	2,85 ± 0,39	B	17°07'42"	68°59'00"	3900
BO7	V	E. Tirata	4,66	12,3	0,497	3,30 ± 0,26	B	17°53'04"	68°36'05"	4100
IB	B	Achiri	8,00	25		3,0	A	17°24'	69°24'	
IA	FK	"	10,48	56		2,2	A	"	"	
-	B	La Paz	7,11	22,2		3,27±0,14	E			
LA82.1	Pl	Lac Titicaca	0,87	61,7	0,215	7,6 ± 0,71	B	16°10'21"	68°44'30"	3900
IV	B	Chijini	7,59	54		6,0	A			
PH53a	Pl	Chuquiaguillo	4,70	19,1	0,239	1,58 ± 0,06	B	16°27'05"	68°05'51"	4100
NG2	B	Japo	7,96	42	1,65	6,4 ± 0,13	D			
NG1	B	"	8,63	65	1,75	6,3 ± 0,11	D			
PHM1	RT	C° Huayna Thanka T.	4,72	37,3	0,372	6,4 ± 0,3	B	18°07'16"	66°43'25"	4560
"	Pl	"	2,52	32,1	0,475	5,8 ± 0,3	B	"	"	"
PHM2	Pl	"	2,39	32,6	0,489	6,3 ± 0,3	B	18°06'35"	66°43'17"	4825
"	RT	"	4,36	42,8	0,850	6,0 ± 0,3	B	"	"	"

Constants used (Steiger and Jäger 1977): $\lambda\beta=4.962\times10^{-10}y^{-1}$ $\lambda\varepsilon=0.581\times10^{-10}y^{-1}$; $^{40}K/K=0.01167$ ats.%
(1)whole rock (RT), K.spar (FK), plagioclase (Pl), biotite (B), hornblende (H), vitrophyre (V).
(2) Evernden et al,1966 and1977 (A), M.G. Bonhomme,Grenoble 1984 (B), M.G. Bonhomme,Strasbourg 1982(C); Grant et al, 1977 (D), Clapperton, 1979 (E).
Some samples dated by Evernden, Grant or Clapperton were collected in same place indicated by these authors or in same formation and they were not dated again. The correspondance between samples is in this manner: IO (=PH38),Mauri,member 4, IL (=BO7,PH57),Mauri,member 6; IU (=PH56)Comanche stock; IK (=LA81-14) Turco F , IJ (=PH64) Tofora F ,T Ulloma, IS (=PH71) Umala F.; IE and ID (=PH67) Toba 76 IC (=PH63) Toba 76; IB and IA (=BO7) Perez F., IV (=PH54) Chijini T.; NG1 and NG2 (=PH15) Japo dome.

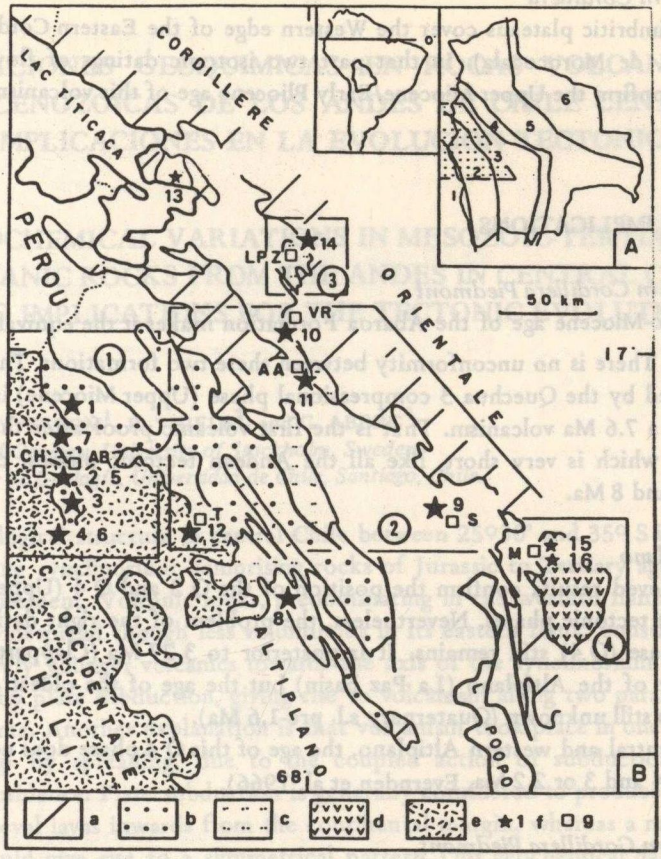

Fig.1. Location map showing studied area (Central Bolivia).
A: Morphostructural zonation. 1. W. Cordillera; 2. Altiplano; 3. E. Cordillera; 4. Sub-Andean zone; 5. Beni-Chaco plain; 6. Brazil Shield. Dotted: studied area (B).
B: Simplified geological map. a. Rocks younger than Miocene; b. Miocene formations; c. Pliocene formation; d. Pliocene volcanic rocks; e. Plio-Quaternary indifferentiated ; f. Situation of analyzed smaples (1: B03,2: LA80-2,3: PH43,4: LA80-6,5: LA80-4,6: LA80—5, 7:BO4, 8:LA81-14, 9:PH48, 10:PH75, 11:LA82-2, 12:BO7, 13:LA82-1, 14:PH53a, 1! :PHM 1, 16: PHM2); g: Principal towns (AA: Ayo Ayo, AB: Abaroa, CH: Charaña, LPZ: La Paz, M: Morococala, S: Soledad, T: Tirata, VR: Villa Remedios); 1 W. Cordillera, 2 Altiplano; 3 La Paz Basin, 4 Meseta of Morococala.

Fig.1. Mapa de ubicación que muestra el área estudiada (Bolivia Central).
A: Zonación morfoestructural: 1. Cordillera occidental; 2. Altiplano; 3. Cordillera oriental; 4. Zona subandina; 5. Llanura Chaco-Beni; 6. Escudo Brasileño; área estudiada en punteado.
B: Mapa Geológico Simplificado: a) Rocas post-mioceno; b) Formaciones del mioceno; c) Formaciones del Plioceno; d) Rocas volcánicas del Plioceno; e)Plio-cuaternario indiferenciado; f) Ubicación de muestras; g) Principales pueblos; 1) Cordillera occidental; 2) Altiplano; 3) Cuenca de la Paz; 4) Meseta de Morococala.

** The Eastern Cordillera Piedmont (La Paz and Titicaca basins)*

In the oldest glacial deposits of the La Paz basin, an iterbedded tuff indicates an Early Quaternary age (PH53a).

South of the Titicaca lake, fluvio-lacustrine sediments (Pliocene?) lie on a volcanic structure, a flow of which gave an upper Miocene age (LA82-1).

** The Eastern Cordillera*

Vast ignimbritic plateaus cover the Western edge of the Eastern Cordillera (Meseta de Los Frailes, de Morococala). In that part two isotopic datings of flows of a volcanic structure, confirm the Upper Miocene/Early Pliocene age of this volcanism.

TECTONIC IMPLICATIONS

** The Western Cordillera Piedmont*

The Oligo-Miocene age of the Abaroa Formation makes it the equivalent of the Mauri Formation. There is no unconformity between these two formations. This Oligo-Miocene series, folded by the Quechua 3 compressional phase (Upper Miocene) is unconformably covered by a 7.6 Ma volcanism. That is the first volcanic proof after the Q 3 phase. So, this phase, which is very short, like all the Andean tectonic phases, could be situated between 7 and 8 Ma.

** The Altiplano*

The achieved results confirm the position of the Q 3 and Q 4 (Upper Pliocene/Early Quaternary) tectonic phases. Nevertheless, the problem of the right dating of the Upper Pliocene phase (Q 4) still remains. It is posterior to 3.27 Ma (Clapperton 1979) in the eastern part of the Altiplano (La Paz basin) but the age of the oldest sediments which fossilize it is still unknown (Quaternary s.l. pre-1.6 Ma).

In the central and western Altiplano, the age of this Q 4 phase does not appear clearly (between 5.4 and 3 or 2.2 Ma, Evernden et al, 1966).

** The Eastern Cordillera Piedmont*

Here, the age of the folded sedimentary Pliocene is older than 3.27 Ma. Near the Titicaca lake, this sediments lie on a volcanic structure (7.6 Ma) as old as the andesitic flow that overlies unconformably the Miocene sediments of the Abaroa Formation. This structure is also thought to be of late Miocene age. The Quechua 3 phase would also be aged between 7 and 8 Ma, like in the Western Cordillera Piedmont.

** The Eastern Cordillera*

The ignimbritic flows dating from the Early Pliocene (about 6.8/5.8 Ma) are not folded. They are equivalent of the flows of the Western Cordillera Piedmont (LA80-5) and of the Titicaca lake (LA82-1), and would come after the Q 3 phase.