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OLIGOCENE MAGMATIC ACTIVITY AND ASSOCIATED MINERALIZATION IN THE POLYMETALLIC BELT OF CENTRAL PERU

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Introduction

Among the most striking characteristics of the Cenozoic evolution of the central Andes are the igneous activity, both effusive and intrusive, and the formation of very numerous associated base metal ore deposits. The most important Pb-Zn-(Ag)-(Cu) metallogenetic province is the polymetallic belt of central Peru (Petersen, 1965; Bellido et al., 1969; Ponzoni, 1982; Soler, 1986; Soler et al., 1986).

Although mineral deposits of Paleogene age are common in southern Peru (e.g., Noble et al., 1984) and in the southern part of the central Andes (e.g., Sillitoe, 1981), they have not heretofore been recognized in the cordillera of central Peru. In this general area, a considerable number of K-Ar determinations of middle and late Miocene have been obtained on intrusive stocks, commonly subvolcanic, which are associated geographically and very probably genetically with these ore deposits, and on alteration and gangue minerals of the actual deposit. North to south, K-Ar radiochronological data from the deposits of Hualgayoc (Borredon, 1982), Antamina (McKee et al., 1979), Raura (D. C. Noble, unpub. data), Cerro de Pasco (Silberman and Noble, 1977), Colquijirca (Vidal et al., 1984), Huaron (Thouvenin, 1984; J. C. Baubron and J. M. Thouvenin, unpub. data), Rio Pallanga (Farrar and Noble, 1976), Morococha (Eyzaguirre et al., 1975), Colqui (Kamilli and Ohmoto, 1977), Yauricocha (Giletti and Day, 1968), Huachocolpa (McKee et al., 1975), Julcani (Noble and Silberman, 1984), and one fission-track determination for Pasto Bueno (Landis and Rye, 1974) gave ages in the range of 15 to 7 m.y. The late Eocene-early Oligocene magmatic belt of central Peru has previously been characterized by the lack of associated mineralization (Noble et al., 1984).

Various volcanic and intrusive rocks were dated at the Institut Dolomieu (Grenoble, France) as part of a research program dealing with the space and time evolution of magmatic and metallogenetic processes along a transect across the central Peruvian Andes. The present communication deals with the part of this new data, which has already been partly published (Soler and Bonhomme, 1988), that refers to metallogenetic aspects; it allows us to conclude that there have been at least two distinct periods of polymetallic mineralization in central Peru during the Oligocene and Miocene epochs.

Data on two polymetallic districts are presented (Fig. 1). The economically important Milpo-Atacocha district, located a few kilometers northeast of Cerro de Pasco near to the eastern edge of the polymetallic belt, is shown to be of middle Oligocene age and the now economically marginal Chungar district, located in the middle part of the belt southwest of Cerro de Pasco near the top of the western cordillera, appears to be of normal middle Miocene age.

K-Ar Geochronologic Data

Analytical procedures

All ages have been obtained by conventional K-Ar methods. The K content of the various samples has been obtained using X-ray fluorescence for $K_2O > 1$ wt percent and using atomic absorption for $K_2O < 1$ wt percent or in cases where only small amounts of a sample were available. The Ar content has been de-

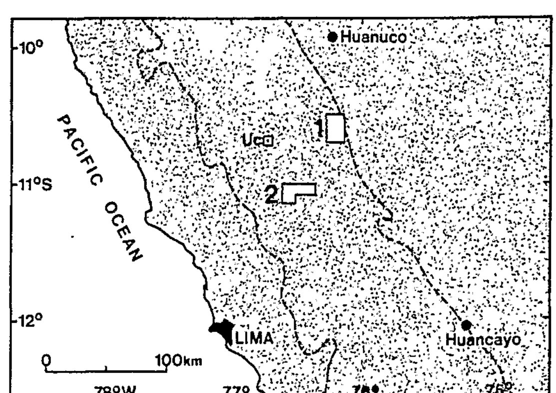

FIG. 1. Map of the northern part of central Peru showing the location of areas referred to in the text and areas covered by Figures 2, 3, and 4. The dashed lines indicate the eastern and western limits of the polymetallic province of central Peru (from Soler et al., 1986). 1 = Cerro de Pasco-Atacocha area (see Fig. 2), 2 = Chungar-Huaron area (see Figs. 3 and 4), Uc = Uchucchacua deposit.

TABLE 1. K-Ar Radiochronologic Data—Milpo-Atacocha Area

Location no. (Fig. 2)	Field number	Location	Analyzed fraction[1]	K_2O (%)	$^{40}Ar_{rad}$ (%)/$^{40}Ar_{total}$	$^{40}Ar_{rad}$ (μl/g)	Age (m.y. ± 1 σ)
Yanamate							
1	CP 66	76° 14′ 02″ W 10° 42′ 23″ S	WR Pl	3.74 1.20	76.9 53.2	1.844 0.509	15.2 ± 0.4 13.1 ± 1.1
Sunkullo							
2	CP 54	76° 08′ 28″ W 10° 39′ 21″ S	Bi Pl	8.48 0.73	92.3 79.8	8.58 0.579	30.9 ± 0.5 24.4 ± 0.9
Mariac							
3	CP 55	76° 07′ 58″ W 10° 40′ 44″ S	Bi Pl	8.59 0.75	92.4 62.3	8.62 0.586	31.1 ± 0.4 24.1 ± 1.9
Milpo-Socorro							
4	MI 15	76° 12′ 24″ W 10° 35′ 42″ S	WR	4.03	82.4	3.65	27.8 ± 0.6
5	MI 106	76° 12′ 31″ W 10° 35′ 25″ S	H Pl	0.91 2.67	37.5 87.9	0.883 2.59	29.8 ± 2.5 29.8 ± 1.4
Atacocha-San Gerardo							
6	AT 43	76° 12′ 55″ W 10° 34′ 37″ S	WR	3.66	76.9	3.49	29.3 ± 0.5
7	AT 47	76° 12′ 55″ W 10° 34′ 28″ S	Pl WR	0.71 2.98	62.3 87.0	0.599 2.60	25.9 ± 1.5 26.3 ± 0.4

[1] Bi = biotite, H = hornblende, Pl = plagioclase, WR = whole rock

termined using isotope dilution of ^{38}Ar in a 6-cm-radius mass spectrometer. The spike was calibrated against the G1-O standard (Odin, 1982). The mean value of this standard measured in Grenoble is 24.92 nl/g as compared to the international value of 24.82 nl/g. All calculations use the constants recommended by Steiger and Jäger (1977).

Most of the samples have been analyzed using various mineral fractions plus whole-rock material. The results are given in Tables 1 and 2.

Milpo-Atacocha district

Milpo and Atacocha are skarn and vein-type base metal deposits emplaced mostly (skarns and veins) in platform limestones of the Late Triassic and Liassic Pucará Group and partly (veins) in sandstones and orthoquartzites of the Neocomian Goyllarizquizga Group (Delgado, 1979; Soler, 1986). The ore deposits appear geometrically associated with a series of small (<1 km in diam) porphyric quartz dioritic to granodioritic stocks, emplaced along a complex system of regional thrust faults (Mégard, 1978).

In this area (Fig. 2), age determinations have been performed for the Atacocha-San Gerardo stock (samples AT 43 and AT 47) and the Milpo-Socorro stock (samples MI 15 and MI 106) which are associated with the ore deposits; for the Sunkullo (sample CP 54) and Mariac (sample CP 55) stocks

TABLE 2. K-Ar Radiochronologic Data—Chungar District

Location no. (Figs. 3 and 4)	Field number	Location	Analyzed fraction[1]	K_2O (%)	$^{40}Ar_{rad}$ (%)/$^{40}Ar_{total}$	$^{40}Ar_{rad}$ (μl/g)	Age (Ma ± 1 σ)
Chalhuacocha							
8	CH 28	76° 33′ 25″ W 11° 03′ 00″ S	Bi	8.20	71.1	2.67	10.0 ± 0.3
Chungar							
9	CU 40	76° 31′ 54″ W 11° 06′ 57″ S	WR	1.93	56.6	1.57	25.1 ± 1.6
10	CU 31	76° 32′ 22″ W 11° 07′ 09″ S	Bi Pl	7.65 2.94	78.1 61.1	3.29 1.21	13.3 ± 0.3 12.7 ± 0.6
11	CU 56	76° 32′ 15″ W 11° 07′ 24″ S	Bi	7.78	76.5	3.40	13.5 ± 0.3
12	CU 57	76° 32′ 05″ W 11° 07′ 15″ S	Bi	8.91	81.7	3.87	13.4 ± 0.3

[1] Bi = biotite, Pl = plagioclase, WR = whole rock

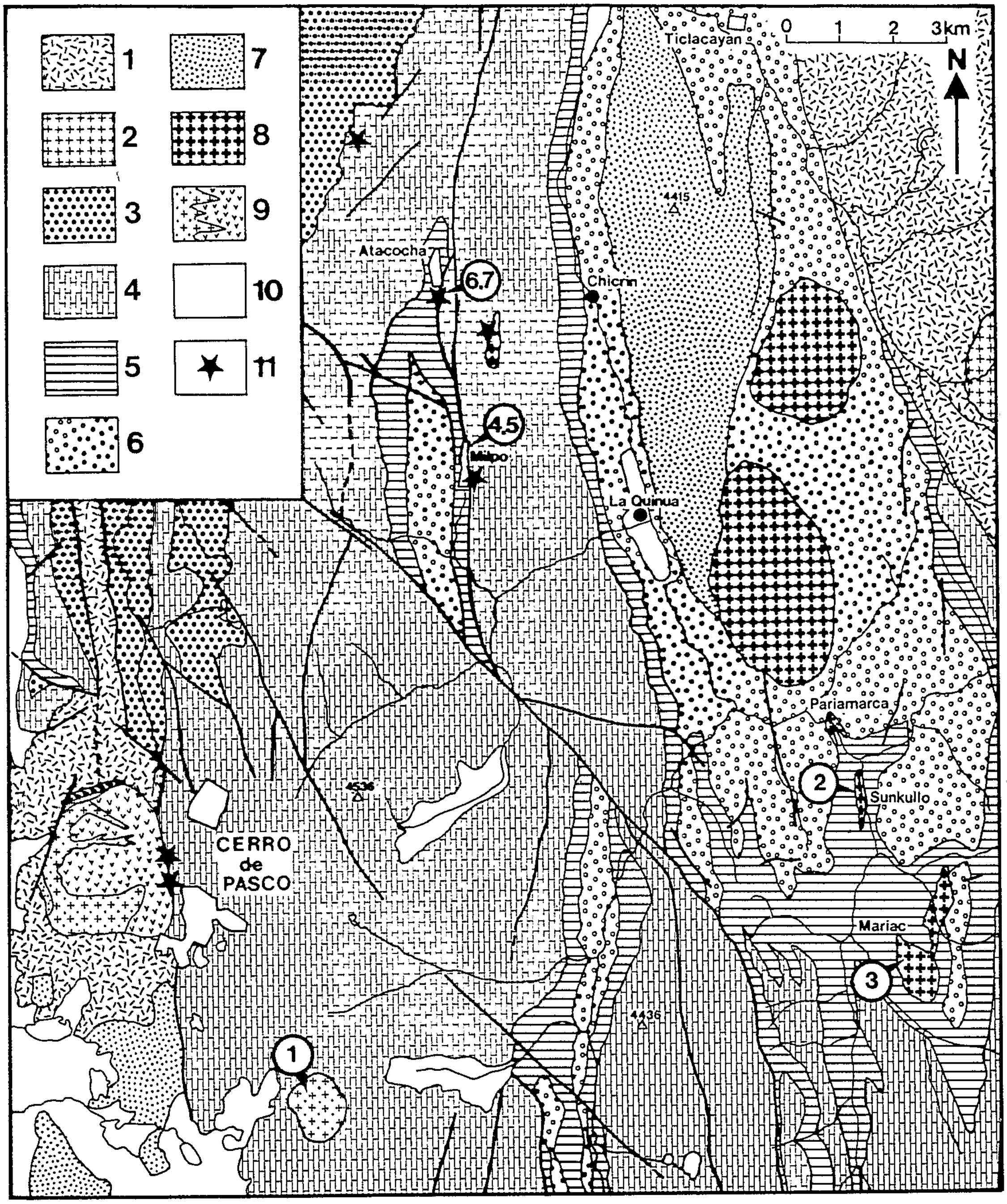

FIG. 2. Geologic map of the Cerro de Pasco-Atacocha area (compiled from Mégard, 1978, and unpub. data; Delgado, 1979; Soler, unpub. data), with location of samples 1 to 7. Definition of patterns: 1 = lower Paleozoic, 2 = Eo-Hercynian granite (Soler and Bonhomme, unpub. data), 3 = Mitu Group, 4 = Upper Triassic and Liassic Pucara Group (limestones), 5 = Neocomian Goyllarizquizga Group (sandstones and orthoquartzites), 6 = Middle to Upper Cretaceous sedimentary formations, 7 = uppermost Cretaceous and Paleogene red beds, 8 = Oligocene intrusive rocks, 9 = Miocene intrusive rocks, 10 = Quaternary deposits, and 11 = polymetallic ore deposits.

which are located about 12 km east of Cerro de Pasco; and for the Yanamate (sample CP 66) stock which is located about 4 km southeast of Cerro de Pasco. The data are presented in Table 1.

The Yanamate granodioritic porphyric stock gives slightly discordant plagioclase-whole-rock ages. The plagioclase phenocrysts are partly sericitized, so that the age of 15.2 m.y. has to be considered as a minimum age for the emplacement of this stock; it appears to be approximately contemporaneous with the Cerro de Pasco intrusions (Silberman and Noble, 1977) and slightly younger than the Marcapunta stock at Colquijirca (Vidal et al., 1984).

The Sunkullo and Mariac granodioritic porphyric stocks gave discordant ages on biotite and plagioclase. The plagioclase age probably corresponds to a partial reset; the plagioclase phenocrysts are slightly sericitized, but the biotite appears unaltered. Cobbing et al. (1981) obtained an age of 29.5 m.y. on plagioclase for the Quinua stock located several kilometers to the north in the same belt (Fig. 2). The K_2O content of the material dated by Wilson (2.06%) indicates an imperfect separation of the plagioclase; the obtained age is intermediate between the ages we obtained on biotite and plagioclase. Thus the data set appears to be internally coherent and an age of 31.0 ± 0.5 m.y. may be considered as a good approximation for the age of emplacement of the stocks of the Ticlacayan-Mariac belt.

The ages obtained for the intrusions associated with the Milpo and Atacocha deposits are discordant and scattered between 25.9 ± 1.5 and 29.8 ± 2.5 m.y. The dated porphyric quartz diorites and granodiorites show a clear alteration of the plagioclase (sericitization and carbonation), so that the plagioclase and whole-rock ages have to be considered as minimum ages. However, sample MI 106 gives ages of 29.8 ± 2.5 m.y. on hornblende and 29.8 ± 1.4 m.y. on plagioclase; we may assume an age about 30 m.y. for the emplacement of the Milpo-Atacocha stocks. Moreover, the similarity of the petrographic and chemical features of the stocks of the Milpo-Atacocha district and those of

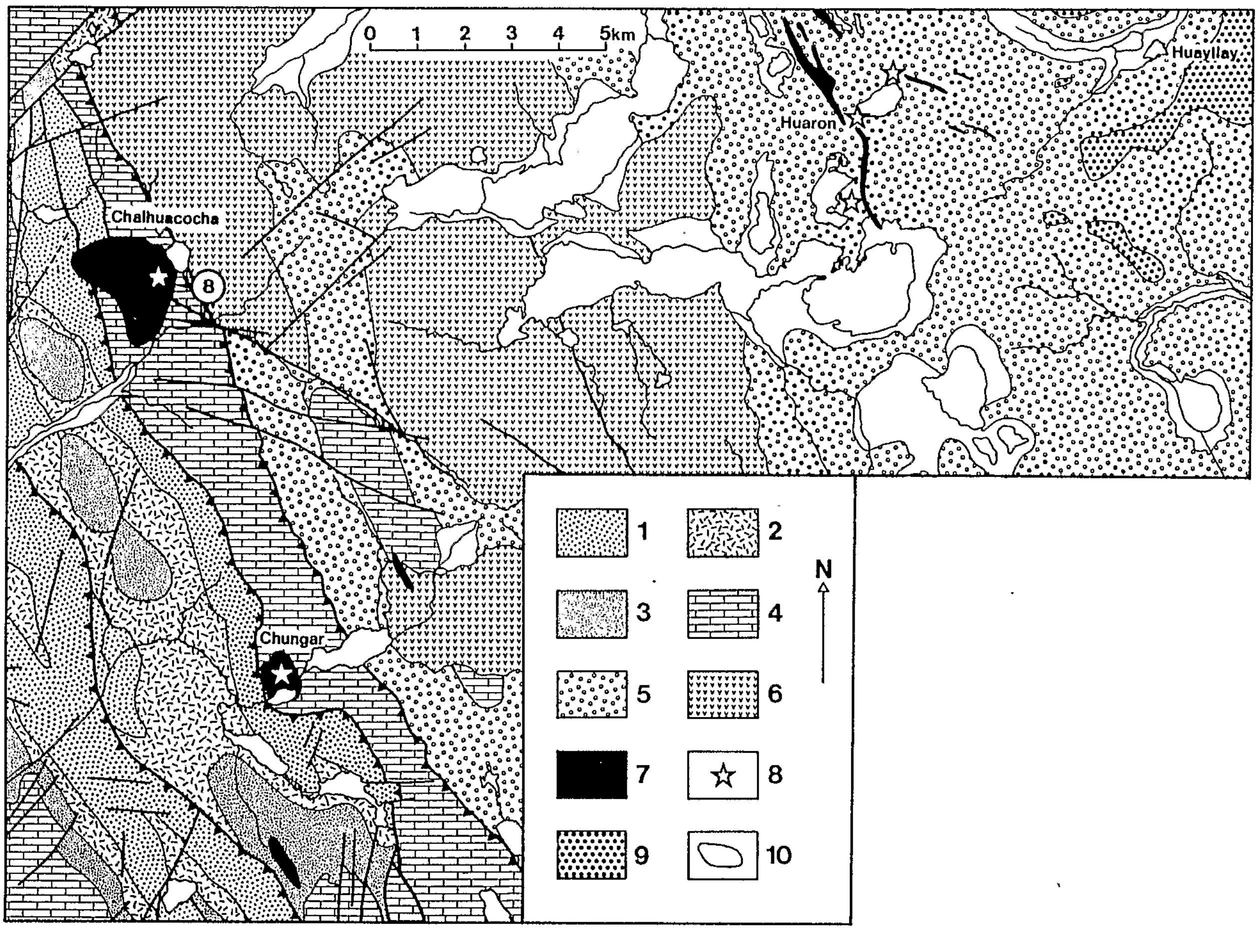

FIG. 3. Geologic map of the Chungar-Huaron area (compiled from Cobbing, 1973, and Thouvenin, 1984), with location of sample 8. Definition of patterns: 1 = Chimú and Santa Formations, 2 = Carhuaz Formation, 3 = Farrat, Pariahuanca, Chulec, and Pariatambo Formations, 4 = Jumasha and Celendín Formations, 5 = Upper Cretaceous and Paleogene red beds, 6 = post-Incaic Calipuy volcanic rocks, 7 = Miocene intrusive rocks, 8 = polymetallic ore deposits and occurrences, 9 = Pliocene ignimbrites (Bosque de Piedra), and 10 = lakes and Quaternary deposits.

the Ticlacayan-Mariac belt allows us to propose that all these stocks belong to a single Oligocene magmatic ensemble, emplaced about 31 m.y. ago.

Chungar district

The Chungar skarn-type base metal deposit is associated both spatially and genetically with a granitic stock (1,300 m NS-750 m EW), which is emplaced in Turonian platform limestones of the Jumasha Formation along an important regional thrust fault. Ore consists mostly of sphalerite, galena, chalcopyrite, and pyrrhotite in an andradite-garnet skarn gangue, which was developed in the western contact of the stock and in roof pendants.

In this area (Fig. 3), age determinations have been performed on three igneous bodies: (1) the granite associated with the Chungar ore deposit (samples CU 31, CU 56, and CU 57; Fig. 4); (2) the Chalhuacocha granodiorite located about 8 km north of Chungar (Fig. 3), with which the polymetallic prospect of Don Miguel (*similar to Chungar*) is associated (sample CH 28); and (3) an andesitic sill (sample CU 40), intrusive into the Jumasha Formation near the eastern contact of the Chungar granite (Fig. 4). The results are given in Table 2.

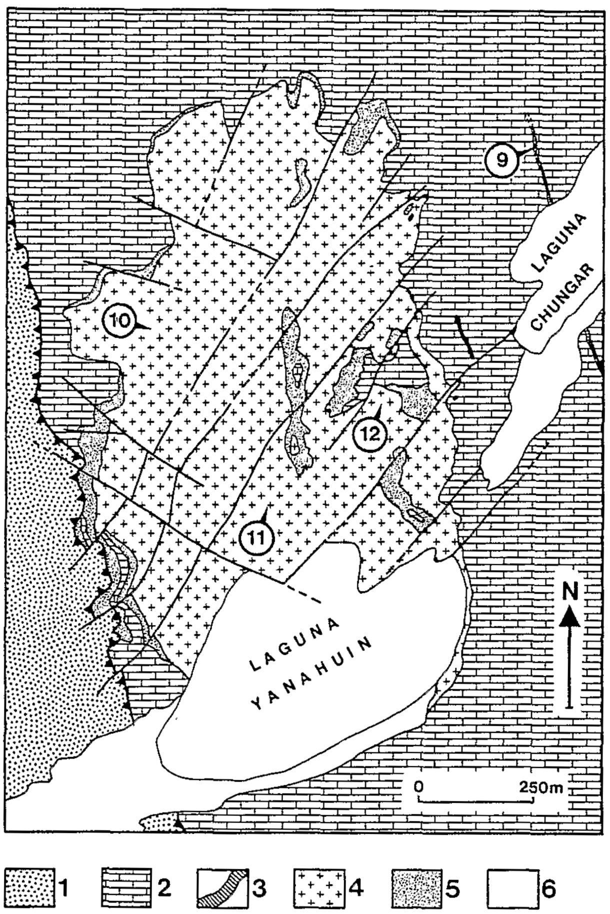

FIG. 4. Geologic map of the Chungar granite (Cia. Minera Chungar, unpub. data; Soler, unpub. data), with location of samples 9 to 12. Definition of patterns: 1 = Chimú Formation (sandstones and orthoquartzites), 2 = Jumasha Formation (limestones), 3 = Oligocene sills, 4 = Miocene intrusive rocks, 5 = Skarn and ore, 6 = lakes and Quaternary deposits.

Sample CU 31 of the Chungar granite gives concordant biotite-plagioclase ages of about 13.0 m.y. Both additional samples give biotite K-Ar ages in agreement with this concordant age. Both biotite and plagioclase appear completely unaltered and this age (13.0 ± 0.5 m.y.) can be regarded as the age of emplacement of the Chungar granite.

The Chalhuacocha granodiorite gives a biotite age of 10.0 ± 0.3 m.y.; the analyzed biotite shows no alteration and this age may be considered as a good approximation for the age of emplacement of this stock, which appears to be slightly younger than the Chungar granite. Both the Chungar and Chalhuacocha stocks were emplaced along the same thrust fault, probably linked with the "Incaic" tectonic phase (Noble et al., 1979).

Thouvenin (1984) gives an age of 10.3 ± 0.2 m.y. for the second stage of ore formation at Huaron which is located in the same general area (Fig. 3), and J. C. Baubron and J. M. Thouvenin (unpub. data; Thouvenin, writ. commun., 1985) have obtained K-Ar ages of 15.6 ± 1 m.y. on plagioclase for the unaltered part of the Huaron stock and of 13.2 ± 0.7 m.y. on chlorite for the first stage of the alteration of the stock.

The CU 40 andesitic sill, which belongs to an intrusive ensemble recognized from Oyon (Romani, 1982) about 50 km to the north and stretching to the latitude of Chungar (Soler, in prep.), gives an age of 25.1 ± 1.6 m.y. on whole rock; this has to be regarded as a minimum age for the emplacement of this sill. Conceivably, this age corresponds to a partial reset due to a weak alteration (carbonation) of the rock and to the low-grade metamorphic episode of Miocene age, the existence of which has been recently demonstrated (Soler, 1987) in the western cordillera of central Peru.

Conclusions

The present K-Ar data for the Chungar granite, the Chalhuacocha granodiorite, and the Yanamate porphyric granodiorite confirm the importance of the medium to late Miocene magmatic episode in the western cordillera and high plateaus of central Peru; the Chungar ore deposit and the Don Miguel prospect are two more polymetallic occurrences associated with this magmatic episode.

The early and middle Miocene magmatic arc is identified from the medium elevations of the Pacific slope of the western cordillera—the Rupay lacolith near Cajatambo (Soler and Bonhomme, 1988) and the East Churin stock in the Huaura River valley (Cobbing et al., 1981)—to the Amazonian slope of the eastern cordillera, where various alkaline stocks have been identified in the Oxapampa area (Soler, unpub. data). Preliminary dating on three of these stocks has given ages in the range of 21.0 ± 1.0 to 12.8 ± 0.6 m.y. by K-Ar on plagioclase and whole-rock material (Soler and Bonhomme, in prep.).

The data obtained for the andesitic sill near Chungar and for the porphyric intrusions of the Milpo-Atacocha district and the Ticlacayan-Mariac belt are important from two points of view.

First they confirm and even increase the volumetric importance of the middle Oligocene magmatic episode in central Peru. The middle Oligocene magmatic arc is identified from the medium Pacific slope of the western cordillera—i.e., from the West Churin and Paccho Tingo stocks in the Huaura River valley (Cobbing et al., 1981; Soler, 1987)—to at least the limit between the high plateaus and the eastern cordillera (Ticlacayan-Mariac belt). The hypothesis of an eastward extension of this arc in the eastern cordillera cannot be disregarded, but the chronology of magmatic activity in this area is still poorly documented.

Second, they demonstrate that the middle Oligocene magmatic episode actually plays a metallogenetic role in the central Peruvian polymetallic belt; this fact is totally new. The only previous indication of possible ore formation during Oligocene times was an age of 25 m.y. obtained by D. C. Noble (unpub. data, quoted *in* Romani, 1982) on the small dacitic porphyry stock associated with the Uchucchacua ore deposit, located about 50 km north-northwest of Chungar at the crest of the western cordillera (Fig. 1). This single age was considered to be equivocal by Noble, who pointed out the possibility of excess radiogenic argon which might have been extracted from the underlying Precambrian basement. Our data suggest that no excess argon is present and that the age obtained by Noble, considering both the hydrothermal alteration and the Miocene regional metamorphism (Soler, 1987), is a minimum age for the emplacement of this stock. Consequently, the Uchucchacua stock appears to belong to the same magmatic episode as the sills of the Chungar area and the stocks of the Milpo-Atacocha district and the Ticlacayan-Mariac belt. Thus, middle Oligocene metallogenetic igneous activity is documented from the crest of the western cordillera at Uchucchacua to the eastern part of the high plateaus at Milpo-Atacocha.

This metallogenetic igneous activity appears to be slightly younger than that associated with the Cu-Fe skarn deposits at Tintaya and Chalcobamba (Noble et al., 1984) which belong to the Andahuaylas-Yauri copper province (Bellido et al., 1969; Santa Cruz et al., 1979) of the south-central segment of the Peruvian Andes (Soler et al., 1986).

June 22, December 21, 1987

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