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TRES FUENTES DE PB, PARA LOS DEPOSITOS DE METALES PRECIOSOS OLIGOCENOS Y MIOCENOS, EN LA CORDILLERA ANDINA OCCIDENTAL, SUR DEL PERU, OESTE DE BOLIVIA Y NORTE DE CHILE

THREE PB SOURCES FOR OLIGOCENE AND MIOCENE PRECIOUS METAL DEPOSITS OF THE WESTERN ANDEAN CORDILLERA, SOUTHERN PERU, WESTERN BOLIVIA AND NORTHERN CHILE

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A variety of precious metal deposits characterize the western part of the Andean cordillera in southern Peru, western Bolivia, and northern Chile. Deposits in this transect include polymetallic vein deposits in southern Peru (Orcopampa, Arcata, Cailloma; Lat. 15°-16°S), quartz-adularia and quartz-alunite deposits in western Bolivia and northern Chile (La Española prospect, Choquelimpie; Lat. 17°-18°30' S), and quartz-alunite and gold-rich porphyry deposits in north-central Chile (Maricunga and El Indio belts; between Lat. 26°-28°S). All deposits are associated with Oligocene and Miocene calc-alkaline volcanic, or intrusive, rocks erupted from, or emplaced in, strato-volcanos along the main arc.

Pb isotopic compositions from sulfides and whole rocks indicate that three major crustal sources contributed Pb to these deposits. The source regions include (1) old nonradiogenic and high μ ($^{238}U/^{204}Pb$) lithosphere with high time-averaged Th/U > 4; (2) high-μ lithosphere with time-averaged Th/U ~4; and (3) lower-μ lithosphere with time-averaged Th/U ~4.

The nonradiogenic lithospheric source is characterized by retarded $^{206}Pb/^{204}Pb$ compositions that are mostly less than 18.2. Thorogenic ($^{208}Pb/^{204}Pb$ versus $^{206}Pb/^{204}Pb$) and uranogenic ($^{207}Pb/^{204}Pb$ versus $^{206}Pb/^{204}Pb$) Pb isotopic compositions lie above the average crustal growth curve of Stacey and Kramers (1975) (Fig. 1). The elevated $^{208}Pb/^{204}Pb$ ratios demonstrate that Th/U greater than 4 dominate this lithosphere, indicating the presence of granulitic rocks, or lower-crustal type Pb reservoirs, where U is depleted with respect to Th. This lower-crustal-like source is present in two adjoining areas. One area is underlain by the Early Proterozoic Arequipa massif in southern Perú, and is characterized by ~2.0 Ga rocks, $^{206}Pb/^{204}Pb$ between 16.0 and 17.1, and $^{208}Pb/^{204}Pb$ between 37.0 and 41.0 (Barreiro and Clark, 1984). The second area underlies western Bolivia and northern Chile where most $^{206}Pb/^{204}Pb$ ratios are between 17.0 and 18.2, $^{208}Pb/^{204}Pb$ between 37.2 and 41.2, uranogenic Pb isotopic compositions that scatter about 1.75-Ga reference isochrons, and Late Proterozoic (1.1 tó 1.25 Ga) U-Pb zircon ages (Damm et al., 1990; Tosdal et al., 1993).

The high-μ source is characterized by elevated $^{207}Pb/^{204}Pb$ with respect to a given $^{206}Pb/^{204}Pb$ ($^{206}Pb/^{204}Pb$=18.5-19.9; $^{207}Pb/^{204}Pb$=15.63-15.72) such that most of the uranogenic Pb isotopic compositions lie above and along the extension of the average crustal growth curve, and scatter about Late Proterozoic (~1.0 Ga) reference isochrons (Fig. 1B). Thorogenic Pb isotopic compositions scatter about the average crustal growth curve (Fig. 1A). These characteristics indicate that the source had high μ values, typical of upper-crustal environments, but average crustal Th/U. Carboniferous, Permian, and Triassic plutonic rocks in north-central Chile, representative of the leading edge of Gondwana, have these Pb isotopic characteristics, and are a product of this source region. Very limited data suggests that this source region also influenced Pb isotopic compositions of some early Paleozoic granitoids in northern Chile and Paleozoic and early Mesozoic granitoids and associated ore deposits in southeast Peru (Pichavant, et al. 1988; Kontack et al., 1991). Furthermore, the isotopic compositions for sulfide-Pb province IIIa of MacFarlane et al. (1990), located in the Cordillera Oriental of Bolivia and northern Argentina, overlap the Pb isotopic compositions for the high-μ source in the north-central Chile, suggesting the involvement of this lithosphere in the generation of the magmatic rocks and their associated ore deposits.

The third source is characterized by lower μ values and average crustal Th/U~4 (Fig. 1). Uranogenic Pb isotopic compositions derived principally from this source generally lie along or below the average crustal growth curve ($^{206}Pb/^{204}Pb<18.7$; $^{207}Pb/^{204}Pb<15.62$) (Fig. 1B). This source is widely recognized in Cenozoic magmas in the Central Andes (e.g. Mukasa, 1986; Davidson et al, 1988), and has been interpreted as sub-continental lithosphere that has been fluxed or enriched by material emanating from the subducting slab or as a MASH zone at the crust-mantle boundary. This source represents the least radiogenic isotopic compositions recognized in Oligocene and Miocene precious metal deposits. This source dominates the Pb isotopic compositions of ore deposits that are present in province I of MacFarlane et al. (1990) located along the coast of the Central Andes.

Present-day Pb isotopic compositions of the Oligocene and Miocene precious metal deposits and their host volcanic

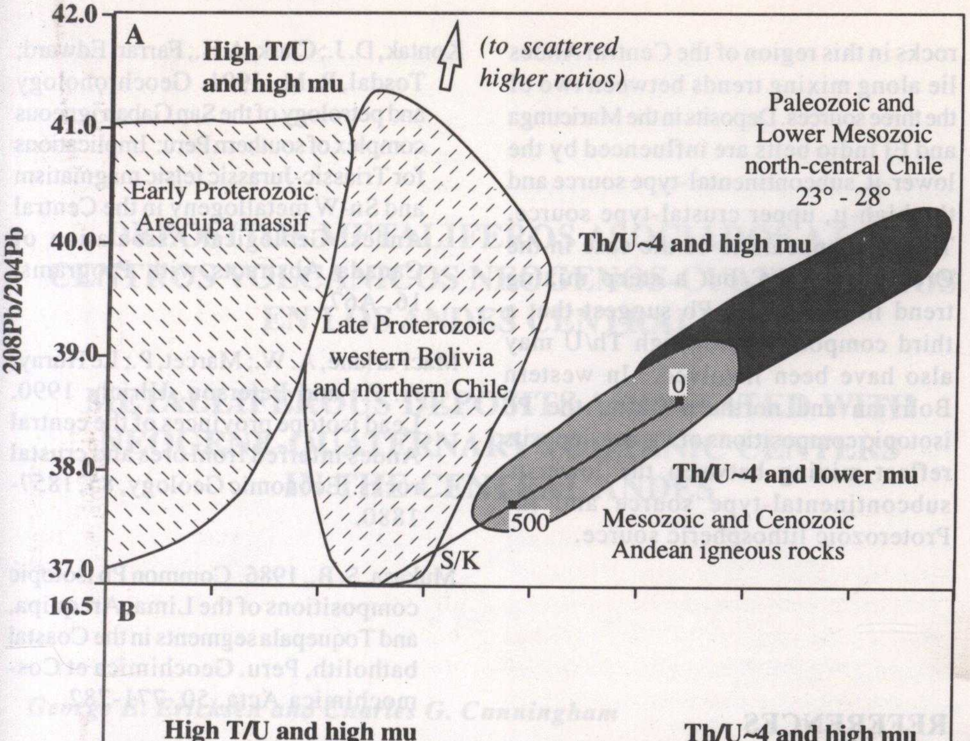

Fig. 1: Summary of (A) thorogenic and (B) uranogenic Pb isotope variations diagrams showing broad fields outlining major Pb sources in Oligocene and Miocene precious metal deposits in southern Peru, western Bolivia, and northern and north-central Chile. Only end-member compositions were used to define the fields; isotopic compositions that exhibit evidence for mixing between two fields are not included. Fields modified from: Early Proterozoic Arequipa massif from Barreiro and Clark (1984); Late Proterozoic in western Bolivia and northern Chile and Paleozoic and early Mesozoic in north-central Chile from Tosdal et al (1993) and unpublished data; Mesozoic and Cenozoic Andean igneous rocks from Davidson et al. (1990); Mukasa (1986), MacFarlane et al (1990), Tosdal et al (1993) and references listed therein. S/K - average crustal growth curve of Stacey and Kramers (1975).

rocks in this region of the Central Andes lie along mixing trends between two of the three sources. Deposits in the Maricunga and El Indio belts are influenced by the lower-μ, subcontinental-type source and the high-μ, upper crustal-type source. This also appears to be the case in the Orcopampa area, but a steep mixing trend in thorogenic Pb suggest that a third component with high Th/U may also have been involved. In western Bolivian and northern Chile, the Pb isotopic compositions of the ore deposits reflect mixing between the lower-μ, subcontinental-type source and the Proterozoic lithospheric source.

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