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MIDDLE PROTEROZOIC CRYSTALLINE BASEMENT IN THE CENTRAL ANDES, WESTERN BOLIVIA AND NORTHERN CHILE: A U-Pb AND Pb ISOTOPIC PERSPECTIVE

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Middle Proterozoic crystalline rocks underlie the western parts of the Andean cordillera in northern Chile and western Bolivia. These Middle Proterozoic rocks are southeast of the Early Proterozoic Arequipa massif (~2000 Ma) in southern Perú. Both Proterozoic terranes form the Arequipa-Antofalla craton[1]. Although exposed only in isolated fault-blocks or known from petroleum exploration drill holes[2, 3], crystalline clasts in Tertiary sedimentary and tuffaceous rocks in the western altiplano[4] and Pb isotopic compositions in Quaternary volcanic rocks[5] attest to the widespread presence of old rocks as far south as 21° S. Because recycled Proterozoic rocks contained in Cenozoic rocks are widespread, they provide a mechanism to better understand the basement to the Andean cordillera.

U-Pb geochronology

Near Berenguela (~17° S) in Bolivia, crystalline clasts in the Oligocene and Miocene Mauri Formation include pebbles to boulders of gneiss and undeformed granitic rocks[6] derived from a western source which is now buried beneath Neogene and Quaternary volcanic rocks. Upper amphibolite- or granulite-facies metamorphic mineral assemblages characterize most of the gneissic clasts (green amphibole-biotite-plagioclase in mafic gneisses and garnet-biotite-perthite-quartz-plagioclase in quartzofeldspathic rocks; garnets are as large as 1 cm in diameter). Protoliths are dominantly igneous, ranging in composition from basaltic to granitic. Two petrologically similar augen gneiss clasts have crystallization ages of 1171±20 Ma and 1158±12 Ma (U-Pb on zircon) and Devonian lower intercept ages. Other gneissic clasts have uncertain protoliths. Zircons from a quartzofeldspathic gneiss clast (Fe-oxide-quartz-perthite-plagioclase) have an upper intercept age of 1100±17 Ma. A migmatitic garnetiferous gneiss clast (biotite-garnet-plagioclase-perthite-quartz) has U-Pb isotopic data from zircon that scatter about a chord with a poorly defined upper intercept age of 1098±48 Ma. Early Cretaceous lower intercept ages characterize both gneisses. The high metamorphic grade of the migmatitic gneiss suggests that the 1098±48 Ma age may approximate the time of metamorphism of a Middle Proterozoic terrane. These U-Pb ages are consistent with U-Pb zircon ages and Rb-Sr and Sm-Nd model ages for other basement occurrences in northern Chile and western Bolivia[2, 3, 7].

Pb isotopic geochemistry

The Middle Proterozoic rocks from the Berenguela area have Pb isotopic compositions on whole rocks that are less radiogenic than average crust (present day ratios of 19 samples - $^{208}Pb/^{204}Pb$ = 37.68-41.05; $^{207}Pb/^{204}Pb$=15.54-15.67; $^{206}Pb/^{204}Pb$ = 17.12-18.24; five samples are more radiogenic). Their Pb isotopic compositions are characterized by high time-averaged Th/U and high $^{207}Pb/^{204}Pb$ lying above the average crustal growth curve[8] (Fig. 1). Pelitic schists from the Middle Proterozoic Belen Schist in northern Chile (~18°22' S) have similar Pb isotopic compositions, but they also

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extend to less radiogenic values where they overlap the field for the Early Proterozoic Arequipa massif[9]. Orthogneiss of uncertain age intruding the schist also have nonradiogenic Pbisotopic compositions. As a package, the Middle Proterozoic rocks are more radiogenic (higher $^{206}Pb/^{204}Pb$) than the adjoining Early Proterozoic Arequipa massif[9], located to the northwest, which is also characterized by high time-averaged Th/U and high $^{207}Pb/^{204}Pb$ values. Correcting the Pb isotopic compositions of Middle Proterozoic rocks for 1.1 Ga of growth, based upon present-day U, Th, and Pb compositions, still maintains the distinction between the two crystalline terranes in the Arequipa-Antofalla craton. Clearly, the Middle Proterozoic rocks are not simply reworked Arequipa massif. The age-corrected data for the Middle Proterozoic rocks also forms an elongate field which scatters about an isochron suggesting an earliest Proterozoic or latest Archean model age (~2.4-2.5 Ga). This old model age coupled with $^{207}Pb/^{204}Pb$ values higher than the crustal average is characteristic of Early and Middle Proterozoic rocks of the Arequipa-Antofalla craton, and furthermore indicates long-term involvement of old continental crust in their genesis. Recycling of old crust, or its derivatives, has continued in the Phanerozoic[5, 9-11].

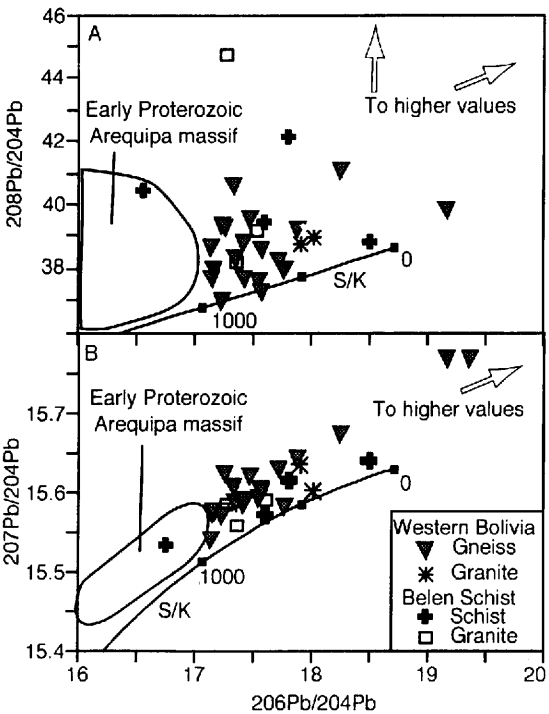

FIG. 1. Present-day (**A**) thorogenic ($^{208}Pb/^{204}Pb$ versus $^{206}Pb/^{204}Pb$) and (**B**) uranogenic ($^{207}Pb/^{204}Pb$ versus $^{206}Pb/^{204}Pb$) Pb for Middle Proterozoic gneiss clasts from western Bolivia and for gneiss and schist from the Belen Schist, northern Chile. Also shown are the present-day fields for the Early Proterozoic gneiss in the Arequipa massif, southern Perú[9]. The average crustal growth curve[8] is shown for reference, and each tick represent 500 m.y.

Tectonic associations

The high $^{207}Pb/^{204}Pb$ isotopic compositions of the Proterozoic Arequipa-Antofalla craton are similar to high $^{207}Pb/^{204}Pb$ isotopic compositions characteristic of Early and Middle Proterozoic rocks in the southwestern part of the Amazon craton, western Brazil[12, 13] (Fig. 2), located some 500 km northeast of the Andean frontal fold and thrust belt. The Pb isotopic compositions are consistent with parauthochthonous models for the Arequipa-Antofalla craton[1, 14] in which the rocks originated as part of the Amazon craton. Conversely, the Pb isotopic compositions for the Arequipa-Antofalla craton are inconsistent with allochthonous models for these rocks[15] as there is no Pb isotopic reason to derive these rocks from elsewhere and accrete them to the Amazon craton. In addition, Pb isotopic compositions for Middle Proterozoic rocks in the Arequipa-Antofalla craton are different from rocks of similar age in the Precordillera terrane of central Argentina (Fig. 2). The latter crystalline rocks are characterized by crustal average Th/U and $^{207}Pb/^{204}Pb$ values lower than the average crust model[16, 17]. The dramatic isotopic differences between Middle Proterozoic rocks suggest that a fundamental boundary lies between them. This boundary must pass obliquely across the Andean and Gondwana orogens north of the Precordillera terrane (~29°S), Argentina, and south of 21° S[5]. It might represent a Grenville suture zone or an Early Paleozoic Taconic-

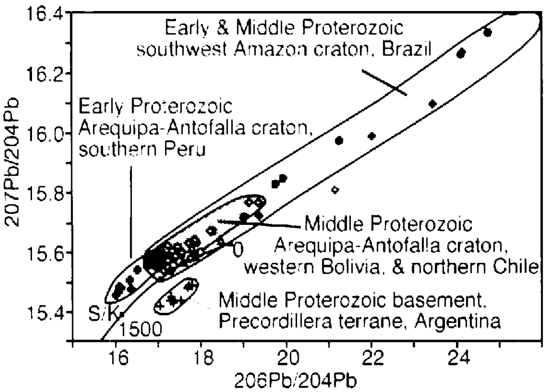

FIG. 2. Comparison of present-day uranogenic Pb isotopic compositions for Early and Middle Proterozoic rocks in the Arequipa-Antofalla craton (Fig. 1B). Early Proterozoic gneiss and Middle Proterozoic rapakivi granites of the southwestern Amazon craton, Brazil[12, 13], and Middle Proterozoic xenoliths in Miocene volcanic rocks overlying the Precordillera terrane of central Argentina[16]. The average crustal growth curve[8] is shown for reference, and each tick represents 500 m.y.

Famatinian terrane boundary[14]. Because younger cover rocks obscure its exact location, mapping of the boundary in the intervening region must rely on isotopic analysis of the scattered Proterozoic or Proterozoic(?) rocks and by using Phanerozoic magmas as probes of the crustal structure.

This is a contribution to IGCP #345, Andean lithospheric evolution; and to IGCP #342, Age and isotopes of South America ores.

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