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Lead Isotope Constraints on the Origin of Nonsulfide Zinc and Sulfide Zinc-Lead Deposits in the Flinders Ranges, South Australia

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Abstract

Hypogene nonsulfide zinc deposits represent a mode of zinc enrichment in the Earth's crust that until recently has largely been overlooked relative to supergene nonsulfide zinc and sulfide zinc-lead deposits. The Flinders Ranges, a deformed and uplifted portion of the northern Adelaide geosyncline in South Australia, host numerous prominent examples of hypogene nonsulfide zinc mineralization and thus provide an excellent setting in which to investigate the origin of this deposit type. The Flinders Ranges also host numerous syngenetic and Mississippi Valley-type sulfide zinc-lead deposits, allowing a possible genetic relationship between sulfide and nonsulfide mineralization to be examined. In the present study, lead isotope compositions of zinc and lead minerals from nonsulfide zinc and sulfide zinc-lead deposits from throughout the Flinders Ranges were analyzed to investigate these issues.

All the lead isotope compositions measured are anomalous with respect to the Holmes-Houtermans and Stacey-Kramers models. Compositions range from 18.332 to 21.125 for $^{206}Pb/^{204}Pb$, from 15.729 to 16.022 for $^{207}Pb/^{204}Pb$, and from 38.264 to 40.967 for $^{208}Pb/^{204}Pb$. The anomalous, highly radiogenic lead isotope compositions probably reflect input from the highly uranium and thorium enriched basement rocks in the region. The data also form a linear trend in both $^{207}Pb/^{204}Pb$ versus $^{206}Pb/^{204}Pb$ and $^{208}Pb/^{204}Pb$ versus $^{206}Pb/^{204}Pb$ space, indicating that the data either define an isochron from one of multiple possible stages of lead evolution, or that the deposits all contain varying mixtures of the same two end-member leads, in either case implying that the deposits are genetically related. For a mixing scenario, the present data provide little further constraint on the origin of a hypothetical less radiogenic end member. However, further constraints on the origin of the more radiogenic end member can be obtained by considering the slope of the regression line through the data. Based on an instantaneous model of lead growth, the maximum age of formation of the more radiogenic lead component would be between 910 and 1036 Ma. These ages fall within a period of tectonic quiescence in the region but allow for the possibility that the lead may be associated with a younger event, such as the 850 to 600 Ma rifting event that led to the opening of the Adelaide geosyncline. Based on a continuous model of lead growth, the more radiogenic lead component could have evolved in a source with an age between 1313 and 1523 Ma before it was sequestered in the mineral deposits at about 435 Ma. These 1313 to 1523 Ma dates correspond with the age of much of the younger igneous rocks (e.g., the Hiltaba Suite granites) in the Gawler craton that flank the Adelaide geosyncline on the west and may comprise part of the basement of the Adelaide geosyncline.

The lead isotope data also show a strong regional pattern consisting of two distinct centers of radiogenic lead, one located in the southeast corner of the study area and a second, broader zone lying near the west-central part of the study area. This pattern may in part be a function of depth to the basement, in which the more radiogenic lead occurs in deposits located near the edges of the basin, where sediment thicknesses are lower, although heterogeneity in basement composition and proximity to sources of less radiogenic lead may also have affected the pattern. Finally, the lead isotope compositions also show some correlation with deposit size, in which the largest deposits in the Flinders Ranges also contain the most radiogenic lead.

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