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Recycling of early continents: the story from lead isotopes

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When plate tectonics, the formation and recycling of plates into the mantle, began on Earth is still an unresolved question. Modern-style steep subduction is well known, but how to track the initiation of the plate tectonics? One approach is to study the radiogenic lead isotope composition of the mantle, which can be done indirectly by determining isotope compositions of mantle-derived rocks. Uranium decays to lead, the isotopes of which are especially sensitive indicators of crustal contribution. Compared with the mantle, U-rich upper crust produces more and U-depleted lower crust less radiogenic lead. Within time, distinctive crustal isotope signatures are developed. Recycling of isotopically different lead affects the isotope signature of the mantle, and may be inherited into mantle-derived rocks.

A time-fixed common lead model tested with 700 analyses of 2.7 $\pm$ 0.1 Ga granitoids from different Archean cratons shows that the lead isotope compositions of mantle-derived granitoids are in accordance with the age frame of their surrounding blocks. For example, the most radiogenic compositions are found in the Slave Province that includes the 4.0 Ga Acasta gneisses. The differences in Pb isotope compositions can be explained by sediment recycling at different-aged continetal margins. Recycling of crustal Pb through subduction-related processes gave rise to more radiogenic Pb isotope compositions in the mantle wedge.

The inherited lead isotope signatures in these granitoids tell the story of crustal evolution. Increasingly radiogenic mantle sources may have generated by crustal recycling during accretion of island arcs and protocontinents into young (<3.2 Ga) continental margins. The extreme high- and low-radiogenic sources can be explained by recycling at old (>3.2 Ga) continental margins encompassing fragments of Early Archean protocrust. Crustal lead isotope signatures in the ca. 2.7 Ga mantle-derived granitoids indicate that plate tectonic processes involving crustal recycling into the mantle operated in the Neoarchean.