Evidence from Early Cretaceous basalts for storage of unradiogenic lead in recycled lower crust: solution to the lead paradox

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The mantle sampled by most basalts and the upper continental crust (i.e. the accessible Earth) have more radiogenic lead isotope compositions than the bulk silicate Earth, and thus the Earth is imbalanced in Pb isotopes, giving rise to the so-called the first 'Pb paradox'. The straight way to resolve this paradox is to find, at least, a compensatory reservoir with unradiogenic lead. The present-day preserved lower continental crust, in addition to the core and/or ancient refractory mantle domains, has been proposed as an important potential candidate. Unfortunately, it appears to have insufficient unradiogenic Pb or/and mass to balance the radiogenic accessible Earth. Recently, foundered lower crust in the mantle has been considered as a hidden reservoir with sufficient unradiogenic Pb, yet direct evidence of this hypothesis has been scare.

Here we report unradiogenic Pb isotope compositions in three suites of Early Cretaceous primitive basalts (MgO ≥ 10 wt%) from the eastern block of the North China craton. The primitive nature, tight ranges of Sr, Nd and Pb isotope ratios and high Pb contents suggest that unradiogenic Pb ratios of these basalts inherited from the mantle sources but not crustal contamination. Whole-rock and mineral geochemical features demonstrate that these Early Cretaceous basalts were derived from pyroxene/garnet-rich mantle sources generated by interaction between Si-rich melt from foundered Archaean lower crust of the North China craton and peridotite. We propose that their unradiogenic Pb in the mantle sources initially originated from foundered Archaean lower crust, which is evidenced by unradiogenic Pb composition of the low-Mg# green clinopyroxene cores that crystallized from Si-rich melt of foundered Archaean lower crust. Our data provide confirmatory evidence for storage of unradiogenic Pb in foundered Archaean lower crust within the deep mantle. Furthermore, our mass balance calculation suggest that global foundered lower over geological times, together with modern preserved lower continental crust, could account for the missing unradiogenic Pb reservoir in the Earth