# The formation and evolution of continental lithospheric mantle

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Beginning with the broad conceptual models of Boyd (e.g. Boyd and McCallister, 1976) and Jordan (1978), the distinct compositional and physical properties of mantle beneath continents, particularly beneath ancient cratons, was tied both to the mechanism of generation and the long-term survival of continental crust. Decades of study of mantle xenoliths and the improved spatial resolution provided by dense seismic deployments have confirmed at least the gross properties predicted by Boyd and Jordan – that the continental mantle is depleted in magmaphile elements and that this depletion provides a buoyancy and strength to the lithospheric mantle that contribute to its survival beneath the crust. Arguably, the most important recent development in studies of the continental lithosphere is an improving ability to detangle the many events that have modified the composition of the lithospheric mantle, with the result that continental lithosphere evolution often is revealed as involving numerous events occurring over many million to billions of years. Rather than a stagnent residue of a single large-volume melting event, the history of cratonic lithosphere can include any or all of: 1) initial melt extraction at low pressure (< 100 km depth) possibly at an ocean ridge setting, 2) melt extraction steps that may have occurred in a suprasubduction zone setting through fluid-fluxing, 3) advective thickening during collision between cratonic fragments, 4) 'winnowing' of more fertile and dense components through delamination, and 5) refertilization through melt addition that ultimately can lead to complete lithosphere removal. While cratonic lithosphere definitely shares some similar characteristics, the differences between different cratons are becoming more obvious. The high-Si content characteristic of Kaapvaal peridotites is not a common feature of other cratonic peridotite suites. The Slave Craton displays strong compositional variability imaged both petrologically and geophysically. These differences provide insight into the many processes that created, and destroyed, continental lithospheric mantle over Earth history.

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# The consequences of isotopic variability in the early solar nebula

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Isotope abundance anomalies in a large fraction of the periodic table have now been found at the whole rock scale in meteorites, particularly in carbonaceous chondrites. Of these, only oxygen and chromium isotope variations have proven systematic enough to serve as a classification tool, clearly distinguishing different meteorite classes from one another and from the terrestrial planets. These classification schemes do not always agree – ureilites have C-chondrite like oxygen, but HED-like Cr – which perhaps will eventually reveal information both about the causes of the isotope variation and the conditions in the solar nebula that led to the preservation of isotopically distinct reservoirs. The isotopic variability in early solar system materials has important consequences for planetary formation models. For example, while carbonaceous chondrites are the closest meteorite class to 'solar' in composition, and for that reason are commonly used to model the bulk composition of a planet, they show many isotopic differences both between different groups of C-chondrites and compared to the terrestrial planets and other classes of chondrites. C-chondrites clearly sample a different, and variable, mixture of nucleosynthetic components than do other chondrite classes or the terrestrial planets. Although other interpretations are possible, differences in $^{142}$Nd/$^{144}$Nd between Earth and all chondrites so far measured raise the possibility that the Earth may not be strictly chondritic even in refractory lithophile element relative abundances. Another important consequence of the isotope variability is its effect on the short-lived radioactive systems that are now routinely used for determining the precise chronology of a wide range of early solar system events. Cosmogenic complications to $^{53}$Mn-$^{53}$Cr, $^{146}$Sm-$^{142}$Nd and $^{182}$Hf-$^{182}$W dating are now better appreciated than they were in initial studies of these systems, but accurate correction is not always easy as it depends on details of the irradiation history of each sample. Nucleosynthetic anomalies are present in Cr, Nd, Sm, W and U in carbonaceous chondrites and their components. The effect of these on $^{53}$Mn-$^{53}$Cr, $^{146}$Sm-$^{142}$Nd, and $^{182}$Hf-$^{182}$W dating appears to be minimal, but the recently discovered U isotope variability may have important consequences for U-Pb dating of primitive solar system materials.