SCLM age, composition and evolution

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The composition of the subcontinental lithospheric mantle (SCLM) varies broadly with the age of the last major tectonothermal event in the overlying crust. Archean SCLM is distinctively different from younger mantle; it is highly depleted, commonly is strongly stratified, and contains rock types that are essentially absent in younger SCLM. Its formation reflects processes that do not operate today. Phanerozoic terrains are generally underlain by fertile mantle, and most Proterozoic SCLM is intermediate between these two extremes. This secular evolution in SCLM composition implies quasi-contemporaneous formation (or modification) of the crust and its underlying mantle root.

Trace-element and isotopic studies show that most "typical" Archean xenoliths have experienced repeated metasomatism; the introduction of cpx and garnet produces a progression from dunite/harzburgite through “depleted" lherzolite to "fertile" lherzolite, mirroring the secular evolution of the SCLM as a whole. Similar refertilisation processes can be observed in peridotite massifs (eg Western Norway), where the dominant Archean protoliths are highly magnesian dunite/harzburgites, poorly represented in the published xenolith record. Si-enrichment (high opx/olivine), rather than being typical of Archean SCLM, is essentially restricted to the SW Kaapvaal Craton. Since "typical" Archean xenoliths are metasomatic products, rather than melt residues, their compositions should not be used for melt-modelling exercises. The results of such exercises, which imply a shallow origin for these suites and have been used to support "lithosphere stacking" models for SCLM formation, are not meaningful.

Accumulating Hf-isotope data on crustal zircons show that much Proterozoic crust, especially in cratonic areas, has Archean protoliths, suggesting that the underlying SCLM also is originally Archean. Seismic tomography shows high-Vs roots, which require depleted compositions and low geotherms, under many of these areas; clearly juvenile Proterozoic belts (eg SW Scandinavia) do not have such roots. These observations suggest that much of the observed secular evolution in SCLM composition reflects progressive reworking of buoyant Archean SCLM, rather than secular changes in the mechanisms of SCLM production.

In situ Re-Os data from sulfides in massif peridotites and SCLM xenoliths give older depletion ages than most whole-rock analyses, but none >3.9 Ga have yet been found; there appear to be no samples of Hadean SCLM. The Archean may represent a specific tectonic regime that formed an interlude between the Hadean and a more modern Earth. The "pristine" Archean dunites/harzburgites are best modelled as restites/cumulates from high-degree melting at 3-6 GPa, supporting models of SCLM generation in ascending plumes/mantle overturns. This process may have died out well before 2.5 Ga, as Earth cooled. This uniquely Archean regime may have coexisted with a more modern plate-tectonic regime, which produced weakly depleted residues similar to Phanerozoic SCLM. This "modern" SCLM would be inherently unstable and easily recycled. SCLM mapping suggests that ≥50% of existing continental crust is underlain by relict Archon SCLM, modified to varying degrees. This implies a much larger volume of originally Archean crust than currently accepted, and hence very high early crustal growth rates.