Archean Lithospheric mantle: its formation, composition and today's remnants

O'Reilly, S.Y.* & Griffin, W.L.
GEMOC, Earth and Planetary Sciences, Macquarie University, Sydney, Australia (*sue.oreilly@mq.edu.au)

Archean subcontinental lithospheric mantle (SCLM) is distinctive in its highly depleted composition, commonly strong stratification, and the presence of rock types absent in younger SCLM. Was the Archean mantle formed in a different way in a distinctive tectonic regime? What is the composition of original Archean mantle and how much persists today?

The "typical" Archean mantle composition used in geochemical/geophysical modelling is depleted garnet lherzolite, derived mainly from peridotite xenoliths in kimberlites from the SW Kaapvaal Craton, and a few from Siberia. However, most such "typical" Archean xenoliths have experienced repeated metasomatism, leading to a progression from dunite/harzburgite through "depleted" lherzolite to "fertile" lherzolite, mirroring the secular evolution of the SCLM. Similar refertilisation processes can be studied *in situ* in peridotite massifs (eg Western Norway, Lherz), showing the lherzolites to be the product of melt infiltration into magnesian dunite/harzburgite protoliths. The most depleted rocks are poorly represented in the published xenolith record; the bias partly reflects the collecting of rocks useful for P-T studies, but also has a geological basis. High-resolution seismic tomography of Archean cratons shows high-Vs volumes surrounded and dissected by zones of lower Vs. The low-Vs parts can be modelled using the "typical" garnet lherzolite compositions, while the higher-Vs volumes require much more depleted rocks. In detail, kimberlites avoid the high-Vs volumes to preferentially follow older zones of fluid passage and metasomatism, hence biasing our "mantle sample" toward the metasomatic products. Seismic tomography suggests that this material still underlies the bulk of Archean cratons to depths of 150-200 km, but is poorly sampled by kimberlites. Relict Archean mantle is also imaged as buoyant high Vp blobs in oceanic regions, a likely source for reported "recycled" geochemical signatures in some ocean island basalts and providing evidence of mechanisms of continental breakup

Hf-isotope data on zircons show that much Proterozoic crust, especially in cratonic areas, has Archean protoliths, suggesting that the underlying SCLM also was originally Archean. Seismic tomography shows high-Vs roots, requiring depleted compositions and low geotherms, under many of these areas; clearly juvenile Proterozoic belts (eg SW Scandinavia) do not have such roots. Re-Os isotopic data for the underlying mantle record similar events, indicating a linked tectonic history. 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. Seismic tomography suggests that $\geq$50% of existing continental crust is underlain by relict Archean 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.

Melt-modelling exercises that treat "typical" Archean peridotites as simple residues are invalid, and cannot be used to support "lithosphere stacking" models for SCLM formation. The "primitive" Archean dunites/harzburgites are best modelled as restites/cumulates from high-degree melting at 3-6 GPa, in ascending plumes/mantle overturns. 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, easily recycled and lost to the modern record.