The composition of sub-continental lithospheric mantle: garnet-based estimates

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Data from xenoliths, garnet concentrates and peridotite massifs demonstrate secular evolution in the composition of subcontinental lithospheric mantle (SCLM), related to the last major tectonothermal event in the overlying crust. The garnet data show that subcalcic (cpx-free) harzburgites are restricted to Archaean mantle, and that the dominant lherzolites become progressively less depleted (in terms of major-element composition) from Archaean through Proterozoic to Phanerozoic time. This broad correlation of SCLM composition with crustal age implies quasi-contemporaneous formation of crustal volumes and their underlying SCLM, and crust-mantle coupling over periods measured in aeons.

In most xenolith suites, concentrations of major- and minor elements are well-correlated with Al_2O_3 contents, while in garnet peridotites there is a good correlation between the Cr_2O_3 content of the garnet and the Al_2O_3 content of the host rock. Algorithms relating garnet composition to bulk-rock composition allow calculation of mean SCLM compositions from garnet concentrates; this procedure gives good agreement with aveages or medians of large xenolith suites of both Archaean and Phanerozoic age (Table 1).

Application of this approach to garnet concentrates (>13,000 analyses) from 28 regions of different crustal age yields estimates of mean composition ('Gnt-SCLM') for SCLM of Archaean, Proterozoic and Phanerozoic age (Table 2). Proterozoic Gnt-SCLM is similar to averages of orogenic peridotite massifs and xenolith suites of known Proterozoic age. Phanerozoic Gnt-SCLM and garnet peridotite xenoliths are similar to Zabargad Island peridotites, but less depleted than the average of spinel peridotite xenolith suites from extensional regions with Phanerozoic crust; these suites may include relict older SCLM. Even if the spinel peridotite data are used as an estimate of mean Phanerozoic SCLM,

TABLE 1. Comparison of mean mantle compositions calculated from garnets, with median compositions of xenolith suites (after Griffin *et al.*, 1998)

	Kaapvaal <90MA Gnt. Lherz. Calc. from Gnts	Kaapvaal Lherz. Xens Median	Kaapvaal <90MA Gnt. Harz. Calc. from Gnts	Kaapvaal Harz. Xens Median	Vitim Gnt. Lherz. Calc. from Gnts	Vitim Lherz. Xens Median
SiO_2	46.0	46.6	45.7	45.9	44.5	44.5
TiO_2	0.07	0.06	0.04	0.05	0.15	0.16
Al_2O_3	1.7	1.4	0.9	1.2	3.7	4.0
Cr_2O_3	0.40	0.35	0.26	0.27	0.40	0.37
FeO	6.8	6.6	6.3	6.4	8.0	8.0
MnO	0.12	0.11	0.11	0.09	0.13	0.10
MgO	43.5	43.5	45.8	45.2	39.3	39.3
CaO	1.0	1.0	0.5	0.5	3.3	3.2
Na_2O	0.12	0.10	0.06	0.09	0.26	0.32
NiO	0.27	0.28	0.30	0.27	0.25	0.25

TABLE 2. Calculated mean compositions for Archaean, Proterozoic and Phanerozoic SCLM (after Griffin *et al.*, 1998)

	Archaean Gnt SCLM	Proterozoic Gnt SCLM	Proterozoic xens, massifs	Phanerozoic Gnt SCLM	Phanerozoic spinel perid.	Prim. Mantle (McD. &Sun)
SiO_2	45.7	44.7	44.6	44.5	44.4	45.0
TiO_2	0.04	0.09	0.07	0.14	0.09	0.2
Al_2O_3	0.99	2.1	1.9	3.5	2.6	4.5
Cr_2O_3	0.28	0.42	0.40	0.40	0.40	0.38
FeO	6.4	7.9	7.9	8.0	8.2	8.1
MnO	0.11	0.13	0.12	0.13	0.13	0.14
MgO	45.5	42.4	42.6	39.8	41.1	37.8
CaO	0.59	1.9	1.7	3.1	2.5	3.6
Na_2O	0.07	0.15	0.12	0.24	0.18	0.36
NiO	0.30	0.29	0.26	0.26	0.27	0.25
mg#	92.7	90.6	90.6	89.9	89.9	89.3
Mg/Si	1.49	1.42	1.42	1.33	1.38	1.25
Ca/Al	0.55	0.80	0.80	0.82	0.85	0.73
Cr/Cr+Al	0.43	0.30	0.30	0.17	0.18	0.05
Fe/Al	4.66	2.64	2.64	1.66	2.23	1.30

these data demonstrate the secular evolution of SCLM composition toward lower degrees of depletion, as measured by Al, Ca, Na, mg#, cr#, Mg.Si and Fe/Al, from Archaean through Proterozoic time to the present (Table 2).

Depletion in Cr and a strong Cr-Al correlation in Archaean xenolith suites indicate that Cr behaved incompatibly during generation of Archaean mantle. Most Archaean SCLM probably was derived by high-degree melting at depths = 150 km, with no Cr-Al phase present on the liquidus. Observed variations in olivine/orthopyroxene ratios may reflect both sorting of olivine and high-*T* opx, and variable degrees of melt interaction leading to more olivine-rich rocks. Comparison of SCLM xenolith suites with peridotites from convergent-margin settings and ocean basins suggests that accretion of subducted oceanic or sub-arc mantle is not a major process in the production of Proterozoic or Phanerozoic SCLM. We propose that most Proterozoic and Phanerozoic SCLM has been generated in extensional environments; typical Phanerozoic SCLM has experienced = 10% melt extraction.

References

Griffin, W.L., O'Reilly, S.Y. and Ryan, C.G. (1998) In: Y. Fei (ed.) *Mantle Petrology: Field Observations and High-pressure Experimentation* (in press).