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Redox state of cratonic and off-craton lithospheric mantle: new Mossbauer data from garnet and spinel peridotites

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We present new data on redox and thermal state of lithospheric mantle beneath the Siberian craton and PR-PZ mobile belts between the Siberian and North China cratons based on studies of garnet- and spinel-facies peridotite xenoliths from the Udachnaya kimberlite and the areas of Cenozoic basaltic volcanism in Russia (Vitim east of Lake Baikal) and SE Mongolia (Dariganga). The redox conditions are estimated using $Fe^{3+}/\Sigma Fe$ ratios in spinel and garnet obtained by Mössbauer spectroscopy for over 70 new samples together with published data for 24 Vitim peridotites (Ionov and Wood 1992; Luth et al. 1990).

Beneath the Siberian craton, fO_2 decreases by several orders of magnitude with depth, from +1 to -4 log units below the FMQ buffer, i.e. the base of the lithosphere at ~220 km is strongly reduced, as earlier inferred for the Kaapvaal and Slave cratons. In addition, there is strong lateral redox heterogeneity due to partial melting and metasomatism. The redox state of deep off-craton mantle is poorly known because garnet-peridotite xenoliths are very rare in alkali basalts. The T (780-1150°C) and fO_2 (-1.9 to -3.0 $\Delta \log fO_2$(FMQ)) ranges of our garnet peridotites from Vitim and Dariganga overlap those of coarse garnet and spinel cratonic peridotites worldwide, but the off-craton rocks equilibrated at much lower pressures (1.8-2.5 GPa). Because of a higher geothermal gradient, the deepest off-craton garnet peridotites are more reduced (by 0.5-2.0 $\Delta \log fO_2$(FMQ)) than shallow cratonic garnet peridotites at the same depth. The shallow spinel-facies mantle beneath Vitim is more oxidized than deep garnet peridotites (average -0.1 vs. -2.5 $\Delta \log fO_2$(FMQ)). Importantly, fO_2 estimates for garnet-spinel Vitim peridotites from spinel-based oxybarometers are 1.5-3.2 $\Delta \log fO_2$(FMQ) lower than garnet-based values. The gar-spl rocks are out of chemical and phase equilibrium because lithospheric heating by recent volcanism was not fully compensated by slow cation diffusion. The spinel-based fO_2 may be erroneous (e.g. they yield unrealistic C-O-H fluid compositions) while garnet-based fO_2 refer to conditions before the heating.

Oxygen fugacity controls speciation of C-O-H fluids coexisting with mantle rocks. The "water maximum" conditions (>80% H_2O) beneath the Vitim and Dariganga regions exist in a more shallow and narrow depth range (60-85 km) than in the central Siberian and other cratons (100-170 km). In general, uppermost spinel peridotites coexist with CO_2-rich fluids and the region near the base of the lithospheric mantle (~90 km) at 2.5 GPa and 1150°C has fO_2 of -3.0 log units below FMQ, with dominant CH_4 and H_2O and minor H_2 in the fluid. If fO_2 continues to decrease with depth at the same rates, metallic iron (controlled by the IW buffer) may be stable below -4 $\Delta \log fO_2$(FMQ) at 1250°C and ≤3GPa, i.e. ≥100 km, in off-craton mantle, and at -5 $\Delta \log fO_2$ (FMQ), 1450°C and ≥8GPa (≥250 km) in cratonic mantle.