Redox events in cratonic mantle underneath Obnazhennaya kimberlite, Yakutia – chemical records in pyroxenites

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EGU2020-18688
https://doi.org/10.5194/egusphere-egu2020-18688
Carbon in mantle rocks

$f_O^2$ controls:
- speciation within C–H–O–S system
- stability of C-bearing phases (Dia, Gr, carbonates, carbides, volatile-bearing fluid and melt)
- C mobility in silicate mantle

Source of carbon
Subduction of carbonaceous sediments
Deep mantle origin
Kimberlitic and carbonatitic melts

Graphite inclusion in Dia (Mikhailenko et al., 2016)
Graphite inclusions in Grt (Nikolenko et al., 2017)
Carbonate inclusions in Dia (Sobolev et al., 2009)
Interstitial carbonates (Sharygin et al., 2018)
Sample location and petrography

Studied sample Ob90/13:

Grt websterite (Cpx+Grt+Opx)

Oxides (Rt, Ilm)
Sulfides (Po, Pn)
Graphite
Secondary — Srp, Phl, carbonates

Optical photo made in reflected light
Inclusions in rock-forming minerals

- Grt
- Amp
- Srp

Secondary inclusions

Graph showing Raman intensity vs. wavenumber (cm⁻¹) with peaks at 154, 282, 711, and 1086 cm⁻¹ for Ob90/13 Calcite in Cpx.
Major elements in rock-forming silicates

Green field — Obnazhennaya pyroxenite mantle xenoliths with exsolutions in silicates (Solovyeva et al., 1994; Kuligin, 1997; Taylor et al., 2003; Alifirova et al., 2012)

Grey field – peridotite and pyroxenite mantle rocks with exsolutions in Grt and Pyx worldwide (Haggerty & Sautter, 1990; Schmickler et al., 2004; Song et al., 2005; Spengler et al., 2006).
Rare earth elements in rock-forming silicates

REE abundances in Grt, Cpx & Opx normalised to C1 carbonaceous chondrite (Sun and McDonough, 1989).

Mineral REE data for Grt-bearing websterites from Siberian craton. Figure is from Spengler & Alifirova (2019)

REE abundances in Grt, Cpx & Opx normalised to C1 carbonaceous chondrite (Sun and McDonough, 1989).
Graphite mineralogy and carbon isotope composition

Graphite forms flattened hexagonal crystals (up to 3 mm in size)
Association with Ti-oxides and Fe-Ni-sulfides

$\delta^{13}C$ $-8.5$ (‰ PDB)

«Mantle range» C isotopes & mantle source for carbon

Summary of $\delta^{13}C$ of whole rock mantle xenoliths and separated minerals. Figure is from Deines (2002), the references to data are therein.
**P‒T estimates for Obnazhennaya mantle xenoliths**

\[ T = 910 \, ^\circ C, \, P = 3.5 \, GPa \]

Geothermometer - Taylor (1998)  
Geobarometer - Nickel & Green (1985)

Obnazhennaya geotherm, based on equations of McKenzie et al. (2005), is from Howarth et al. (2014).

Graphite-diamond transition line is after Kennedy & Kennedy (1976). Pargasite stability line is according to Niida & Green (1999). CMAS phase relationships are from Gasparik (2014). Isentope for \( T_p = 1315 \, ^\circ C \) is from McKenzie et al. (2005).

Solidi are from experiments:  
Dry peridotite solidus (Gudfinnsson, Presnall, 1996).  
Solidus in alkali-bearing peridotite + CO₂ + H₂O system (Wallace, Green, 1988).  
K-carbonatite solidus (Litasov et al. 2013).
A possible sequence of redox freezing and redox melting events driven by oxidation state contrasts

Carbonatitic redox freezing and redox melting caused by redox capacity changes in Earth’s mantle. Figure is from Rohrbach & Schmidt (2011)
Concluding remarks

• High-T Mg-rich magmas (similar to AEK komatiites) from which garnet websterite is supposed to crystallize had a deep Grt-bearing depleted mantle source with low oxygen fugacity.

• Subsequent metasomatism of the reduced websterite by oxidising C-O-H fluids caused graphite precipitation through redox freezing.

Thank you for watching display!