

Direct constraints on redox conditions in the early Archean (>3.85 Ga) mantle from peridotites

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The complex and likely significant role of the mantle in the chemical evolution of the atmosphere, hydrosphere and lithosphere, is being increasingly recognised, with for example, some studies linking the development of an oxygen rich atmosphere directly to changes in mantle redox chemistry (e.g. 1, 2). To define conditions in the early (>3800 Ma) mantle, we measured major and trace element concentrations, including the redox sensitive element V (e.g. 3), from rare, well-preserved, temporally and geographically distinct suites of spinel peridotites from early Archean terranes of southwest Greenland. The sample ages are determined by U-Pb zircon dating of cross cutting and/or intrusive tonalites, and include ≥ 3.81 Ga (4) and recently identified ≥ 3.85 Ga peridotites. The chemical affinities of these samples e.g. Si-Al-Mg proportions, ol/opx ratios and mineral compositions, are more similar to modern abyssal peridotites than to cratonic mid-Archean lithospheric mantle represented by xenoliths from southern Africa and Siberia; the peridotites are interpreted as early Archean lithospheric mantle that was trapped within ancient sialic crust during its formation.

Trace element compositions determined by solution ICP-MS are compared with suites of post-Archean peridotites of known tectonic setting, measured by identical methods, thus eliminating problems of interlaboratory bias and enabling a relative fO_2 resolution between sample suites of better than 0.5 log units. The 3.81 Ga and 3.85 Ga peridotites are indistinguishable from modern peridotites on V-MgO and V-Al₂O₃ arrays, indicating melt extraction in the early Archean mantle at oxygen fugacities between FMQ-3 and FMQ, i.e. identical to the present day. All early Archean peridotites fall within 0.5 log units of average post Archean mantle spinel peridotites. Thus, the V systematics of these peridotites provide no evidence for evolving redox conditions in the mantle from ≥ 3.85 Ga to the present day and suggest the composition of volcanic gases was similar throughout Earth history. The data require the change from a highly reducing upper mantle (in equilibrium with metallic Fe) to an oxidised mantle must have occurred within 700 myr of core formation, i.e. ≥ 3.85 Ga.

References:

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Model of magmatic fluid evolution of active volcano-hydrothermal systems (by the example of volcano Ebeko, Paramushir, Russia).

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The purpose of the work was the construction of physical-chemical model of a fluid evolution from the magmatic chamber to fumaroles. "Petrofluid" [Sharapov, etc., 2000] and "Selector – win" [Karpov, etc., 2002] software were used for physical and thermodynamical modelling accordingly.

The physical model describes dynamics of magmatic chamber boiling and edge of temperature/pressure change above the magmatic chamber. There is shown, at shallow (1-1.5 km) depth chambers the greatest influence have the size of the chamber, structure of a cross-section. Melt composition, practically, does not influence on distribution of temperature and pressure in a cross-section.

Results received with help of "Petrofluid", were used for construction of thermodynamic model. The special attention was given to the zones of phase change – boiling, condensation and unloading on the surface. The presence of a zone of secondary boiling is determined. Difference in composition of discharged fluid is the reason of secondary boiling zone migration. Secondary boiling leads to separation of CO₂ from the fluid, so the residual solution becomes hyperacid. The residual solution at mixture with neutral subterranean/superficial waters (pH=6-7) forms solutions with pH=1.8.

The model was constructed and verified on the basis of own field materials on composition of rocks, gases, thermal solutions of volcano Ebeko.

Work is executed with support of the RFBR, grant _ 03-05-64324.