

## Geophysical constraints on the water content in the lunar mantle and its implications for the origin of the Moon

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Although the Moon was considered to be “dry”, recent measurements of hydrogen content in some of the lunar samples showed a substantial amount of water comparable to the water content in the Earth's asthenosphere. However, the interpretation of these observations in terms of the distribution of water in the lunar interior is difficult because the composition of these rocks reflects a complicated history involving melting and crystallization. In this study, I analyze geophysically inferred properties to obtain constraints on the distribution of water (and temperature) in the lunar interior. The electrical conductivity inferred from electromagnetic induction observations and the geodetically or geophysically inferred  $Q$  are interpreted in terms of laboratory data and the theoretical models on the influence of water (hydrogen) on these properties. Both electrical conductivity and  $Q$  are controlled by defect-related processes that are sensitive to the water (hydrogen) content and temperature but less sensitive to the major element chemistry. After a correction for the influence of the major element chemistry constrained by geophysical observations and geochemical considerations, I estimate the temperature-water content combinations that are consistent with the geophysically inferred electrical conductivity and  $Q$ . I conclude that the lunar interior is cooler than Earth (at the same depth) but the water content of the lunar mantle is similar to that of Earth's asthenosphere. A possible model is presented to explain the not-so-dry Moon where a small degree of water loss during the Moon formation is attributed to the role of liquid phases that play an important role in the Moon forming environment.

## Four types of olivine from orangeites of Kostomuksha-Lentiïro area (Russia, Finland)

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Mineral characteristics of alkaline ultramafic rocks of the Kostomuksha-Lentiïro area suggest their orangeitic rather than lamproitic nature. The orangeites are divided into three types by their macrocryst assemblages: Ol-Phl-Cpx, Ol-Phl and Phl-Carb. The Ol-Phl-Cpx orangeites of Lentiïro contain four generations of unaltered olivine that vary in composition and origin.

Olivine I is large (3-2 mm) typically rounded zoned macrocrysts. Core composition is Fo 92 with the highest content of NiO (0.33-0.37 wt. %) and the lowest CaO (0.03-0.04 wt. %). This olivine is interpreted as a xenocryst derived from depleted mantle peridotite.

Olivine IIa is represented by euhedral and subhedral phenocrysts (commonly 0.15-0.3 mm). Olivine IIa and rims of olivine I and III have the same composition - Fo 88-89 with high content of CaO (0.10-0.42 wt. %), and moderate contents of NiO (0.14-0.35 wt. %) and MnO (up to 0.07-0.21 wt. %), which is consistent with fractional crystallization trend of olivine from orangeites. This olivine crystallized from orangeitic melt at 950-960°C (content of Ca and Al [1]).

Olivine IIb is observed as microphenocryst in a groundmass (< 0.1 mm). It is Fo 86-87 with the highest content of CaO (1.19-1.40 wt. %). This olivine is the product of late-stage crystallization of evolved kimberlitic melt.

Olivine III forms medium size (commonly 1.0-1.5 mm) rounded zoned "tablet"-shaped crystals [2]. Core of olivine III is Fo 82-83 with the lower content of CaO (0.03-0.05 wt. %), NiO (0.12-0.17 wt. %) and high MnO (up to 0.40 wt. %). This generation is interpreted to represent either early stage crystallization of megacryst assemblage [3] or a product of metasomatic interaction between mantle peridotite and protokimberlitic melt [2].

[1] De Hoog J.C.M., Gall L., Cornell D.H. Trace-element geochemistry of mantle olivine and application to mantle petrogenesis and geothermobarometry // *Chem. Geol.* 2010. V. 270. P. 196–215. [2] Arndt N.T., Guitreau M., Boullier A.M., et al. Olivine and the origin of kimberlite // *J. of Petrology.* 2010. V.51. P. 573-602. [3] Moore A.E. The case for a cognate, polybaric origin for kimberlitic olivines // *Lithos.* 2012. Vol. 128-131. P. 1-10.