Origin of upper mantle eclogites from the Catoca pipe (N.-E. Angola)

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The abstract studies mineralogical, petrological and geochemical evidences on genesis and alteration of mantle eclogites xenolths (21 samples) from Catoca kimberlite pipe (Kasai Craton, N.-E. Angola). Three types of eclogite have been distinguished: high-alumina (high-Al_2O_3), low-magnesian (low-MgO) and high-magnesian (high-MgO) eclogites. Eclogites of each group are characterized by its own unique set of features. High-Al_2O_3 eclogites consist of high-Na omphacite (Jd 51-67) and garnet (Prp30-33 Alm28-29 Grs37-41). There are small quantities of kyanite in each sample (up to 15 vol.%). Low-MgO eclogites are bimineralic, composition of garnet: Prp35-53 Alm28-45 Grs16-28; composition of omphacite: Jd 32-57. High-MgO eclogites are also bimineralic and consist of minerals with a high MgO content, composition of garnet: Prp68-70 Alm21-23 Grs5-8; composition of omphacite: Jd 19-25. Rutile is the most common accessory mineral. High-Al_2O_3 and low-MgO eclogites have a granoblastic texture. High-MgO eclogites have mainly porphyroblastic-like texture combined with either banded or implicitly shale and massive structure.

We used almost all known tools of classical thermobarometry to estimate the PT-parameters of mantle eclogites. In the case of low-MgO some of high-Al_2O_3 eclogites geothermometers (Ellis, Green, 1979; Powell, 1985; Ai, 1994; Krogh, 2000; Nakamura, 2006, 2009) have shown a good agreement in the range of 1000-1200°C at pressures of 40-50 kbar. PT-parameters of high-Al_2O_3 and high-MgO eclogites vary in the significant range 900-1360°C, 35-60 kbar. Thus, to compare all samples together we have choosen the same for all groups of eclogites set of tools. The equilibration temperatures of the eclogite xenoliths were evaluated using a garnet-clinopyroxene geothermometer (Nakamura, 2006). To calculate the pressure of the xenoliths, a geotherm with the heat flow capacity of $40 mW/m^2$ was chosen (Hasterok, Chapman, 2011). The relevance of the selection is based on the indirect mineralogical and geochemical criteria (Mg# and Mg/Si in the reconstracted bulk rock, Cr contents in rock-forming minerals). The choice of the geotherm accounted for the fact that almost all of the current estimates of P and T parameters for the mantle beneath ancient Archaean cratons (including Kasai Craton) are close to it. In addition, the Catoca unaltered garnet lherzolite xenolith points lie on the geotherm with the heat flow capacity of $40 mW/m^2$.

Different groups of the eclogites represent different levels (with insignificant overlaps) of the Kasai Craton lithospheric mantle. The upper part of the mantle profile 110-170 km (P=35-50 kb, T=900-1200°C) is represented by high-Al_2O_3 and low-MgO eclogites. High-MgO eclogites were taken from depths corresponding to an area of diamond stability: 170-210 km, P=52-60 kb, T=1220-1360°C. The lower boundary of the lithospheric mantle beneath the Kasai Craton according to global seismic tomography is estimated at the depth of 300–400km (O'Reilly et al., 2009; Begg et al., 2009). Thus, our data shows that mantle eclogites from the Catoca pipe represent only about 2/3-1/2 of the lithospheric mantle (110-210 km).

Origin of mantle eclogites, geochemical evidences.

High-Al_2O_3 eclogites. REE_N patterns (Fig. 1), Y, Zr, Li contents and Zr/Sm, Zr/Hf, La/Sm ratios (Fig. 2b) and other geochemical markers of reconstructed whole rock of high-Al_2O_3 eclogites reveal greatest similarity with ophiolitic gabbro and modern oceanic gabbro. Weak Eu-peak together with an increased concentration of Sr in garnets are also an indicator of a plagioclase-bearing protolith.

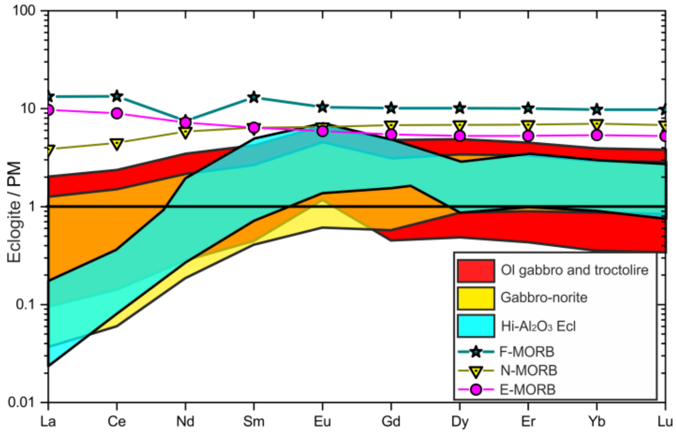

Fig. 1. Rare Earth element patterns of the reconstructed bulk composition of high-Al_2O_3 eclogites and hypothetical protolith (gabbro and troctolite, gabbro-norite, F-MORB, N-MORB, E-MORB).

Low-MgO eclogites. REE_N patterns, Y, Zr, Li contents, Zr/Sm, Zr/Hf, La/Sm ratios as well as other geochemical markers and depleted $LREE_N$ of the reconstructed whole rock of lo-MgO eclogites may indicate that these eclogites were formed during transformation of N-MORB (possible with a boninite component) restite. The geochemical modelling results of melting at 1100-1200°C, 30-40 kbar support the introduced assumption. According with the geochemical modelling results a melting degree of eclogitic protolith/eclogites could reach 25-50%. Figure 2 demonstrates the similarity of the compositions of restites and mantle eclogites in relation to key indicators Zr/Sm, Zr/Hf, La/Lu.

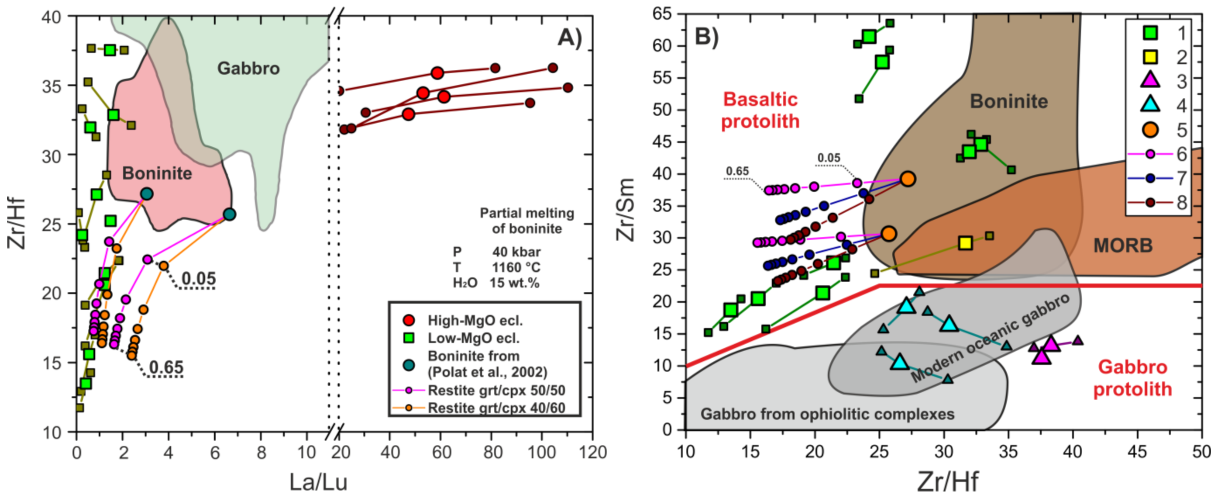

Fig. 2. A) The Zr/Hf vs. La/Lu diagram for the reconstructed bulk compositions of mantle eclogites. Signs on the trend of partial melting of boninites (orange and purple lines) indicates restit. The degree of partial melting increases from 0.05 to 0.65 in increments of 0.1. B) The Zr/Sm vs. Zr/Hf diagram for the reconstructed bulk compositions of mantle eclogites. 1 – Low-MgO eclogites, 2 – altered low-MgO eclogite, 3 and 4 - High-Al_2O_3 eclogites, 5 – boninites, 6-8 – Trends of partial melting of boninites (6 – 40grt/60cpx, 7 – 50grt/50cpx, 8 – 60grt/40cpx) with the degree of partial melting from 0.05 to 0.65.

Values of $^{187}Sr/^{186}Sr$ (0.7056-0.7071, n=4), positive ε_{Nd} (1.8-2.6, n=9), high values of $^{187}Re/^{188}Os$ (80 and 135) and $^{187}Os/^{188}Os$ (1.311 and 1.9709), high radiogenic ^{187}Os isotopic composition (γOs=129 and 147) in single eclogites support their subduction origin.

High-MgO eclogites. A large body of mineralogical and geochemical data shows that at least part of high-MgO eclogites could be recrystallized at mantle conditions. Clinopyroxene and garnet from high-MgO eclogites are enriched in Ba, Sr, LREE and other trace elements relative to the counterpart minerals from a peridotite and other eclogite types from the Catoca pipe. Some samples contain fine grained garnet as well as rare coarse grains (~ 5mm). Proto-cores were found in some coarse grains. Chemical composition of the proto-core garnet (major and trace elements) appreciably differs from the recrystallized fine grained garnet. Comparison of the different garnet composition (unaltered and altered garnet from low-MgO eclogite, proto-cores and recrystallized fine grained garnet from high-MgO eclogite and unaltered garnet from fresh peridotite xenolith) is shown in the figure 3.

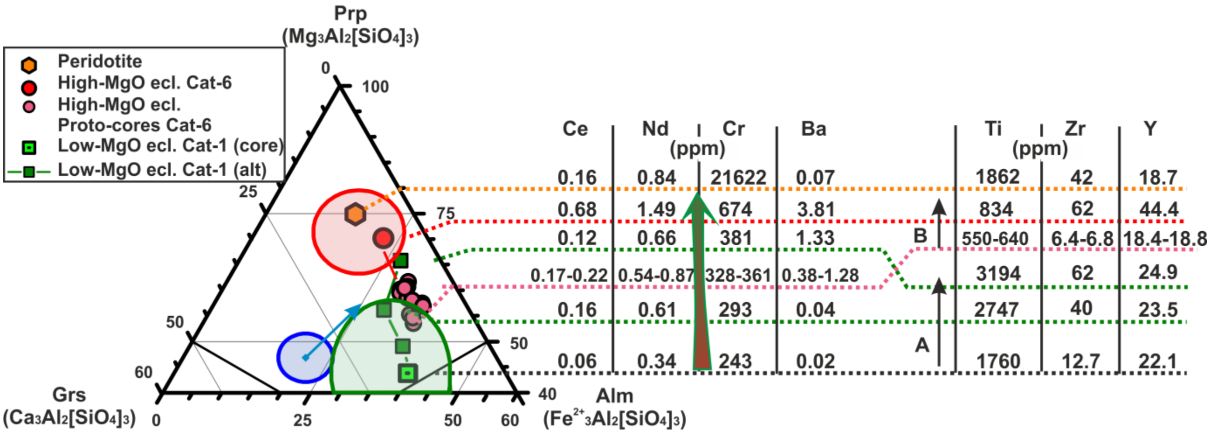

Fig. 3. Comparison of chemical composition of garnet proto-cores from high-MgO eclogite with differen type of garnet from mantle xenoliths from Catoca pipe. Red area shows compositions of garnets from high-MgO eclogites and peridotite; Green area shows compositions of garnets from low-MgO eclogites; Blue area shows the composition of garnets from high-Al_2O_3 eclogites.

As shown by our study, processes of recrystallization of the mantle eclogites and specific "metasomatic" processes leading to a high-niobium rutile formation have already appeared. The average Nb_2O_5 content 7-11 wt.% in the rutiles from the high-MgO eclogites was determined. There are some areas (no more than 10–15 microns) with composition of Nb_2O_5 up to 20–25 wt.% and Ta_2O_5 up to 4 wt.% within the rims of the rutile grains (Korolev et al., 2014).

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