Origin of coarse-granular and equigranular eclogites from V. Grib kimberlite pipe, Arkhangelsk region, NW Russia

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Introduction

The 372 Ma V. Grib kimberlite pipe (Shevchenko et al., 2004) is located in the central part of Arkhangelsk Diamondiferous Province (ADP) in 135 km NE of the Arkhangelsk city and in 35 km NE of the Lomonosov diamond deposit. As observed from the garnet xenocrysts study from the heavy mineral concentrate (Shchukina et al., 2016), eclogites comprise 10 – 12 % of the mantle population of V. Grib pipe kimberlite. V. Grib pipe eclogite xenoliths could be divided into two main groups based on the textural varieties and mineral composition: coarse-granular (CG) and equigranular (EG) zircon-bearing eclogites. Herein, we present the results of the first comprehensive study of the eclogite xenoliths from the diamondiferous V. Grib kimberlite pipe. This study aims to define the protolith for each of the eclogite samples based on the isotopic, major- and trace-element data.

Analytical Results

CG eclogites are distinguished by large (0.5 – 1.3 cm) fractured bright orange garnet and partly altered dark-green clinopyroxene grains with accessory phases + Phl ± Ilm ± Ru. EG eclogites are composed of minerals (Gar + Cpx + Ilm + Ru + Zr) with a grain size of < 0.2 cm. Al^{VI}/Al^{IV} ratios > 2 in the clinopyroxenes for all eclogites indicates their equilibration at high-pressure conditions (Aoki and Shiba, 1973). CG eclogites are divided into A, B and C groups according to Taylor and Neal (1989) classification. The average Na_2O_{cpx} content increase in the following sequence (wt. %): EG (2.1), Group A (2.4), Group B (4.0), Group C (7.3). The average MgO_{grt} and MgO_{WR} contents increase in the following sequence (wt. %): EG (6.1 and 9.0), Group C (10.8 and 9.6), Group B (12.5 and 11.5), Group A (18.3 and 17.2). P-T estimations indicate that xenoliths were taken by kimberlites

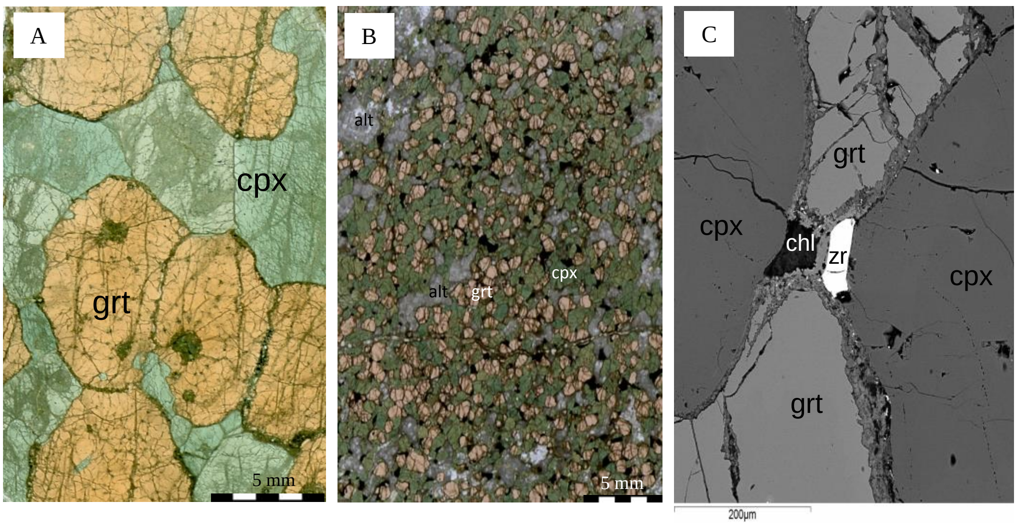

Figure 1. Photos of thin sections of coarse-granular (A) and equigranular (B, C) eclogites from the V. Grib kimberlite pipe. Cpx – clinopyroxene, grt – garnet, zr – zircon, chl – chlorite, alt – altered.

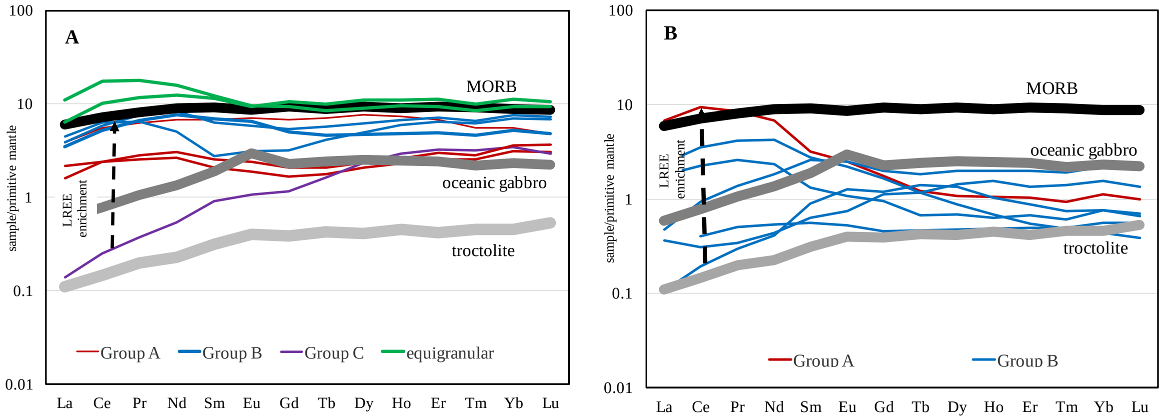

Figure 2. PM-normalized (McDonough & Sun, 1995) reconstructed whole-rock REE profiles of V.Grib pipe CG and EG eclogites. A – eclogites with upper-crustle protholits, B – eclogites with low-crustal protholits. MORB (Le Roux et al., 2002), gabbro and troctolite (Godard et al., 2009).

from the depth of graphite stability field of lithospheric mantle section in case of EG eclogites (~ 120 km) and from diamond stability field in case of CG eclogites (~130 – 240 km). We considered that protoliths for all studied eclogites are of oceanic affinities and remnants of different layers of the oceanic crust. CG eclogites with higher WR HREE predominantly represent upper-oceanic crustal protoliths whereas protoliths for CG eclogites with lower WR HREE could be of gabbro-troctolite series of the lower oceanic crust (fig. 2). High-MgO eclogites of Group A could represent MgO-rich portions in oceanic crustal rocks: picritic/MgO basaltic portions in the upper oceanic crust and/or troctolite/peridotite portion in the lower oceanic crust. EG eclogites retained the geochemical characteristics of MORB and could be the relicts of the oceanic crust which did not undergo partial melting, i.e. products of recrystallization as a result of the evolution of the P–T parameters. However, CG and EG eclogites have different history that is evidenced from the age determination: by Sr and Nd isotope composition of garnet and clinopyroxene for six of CG eclogites samples and by U-Pb and Lu-Hf zircon (19 grains) age for one of EG eclogites. Similarities in Nd isotope composition and 2-point Sm-Nd isochron ages suggest the similar history of CG suite of eclogites: they were taken from the deep levels of lithospheric mantle that were heated by pre-kimberlite thermal event (396 ± 24 Ma) that leads to re-equilibration of Sm-Nd isotope system between garnet and clinopyroxene. Nd DM model age calculated from reconstructed whole-rock composition gives the ranges of age 2.8 Ga, 2.0, 1.8 and 1.2 Ga. Sr isotope composition of clinopyroxenes gives an isochron age of 2.84 Ga. The age of the most of zircons from V. Grib pipe EG eclogite ranges within 1.8–1.9 Ga and the age of 1.2 Ga was obtained from the rim in one zircon grain. $\varepsilon Hf_{(T)}$ values varies from -1.90 to +1.16. Hafnium DM model ages are in range of 2.26 – 2.36 Ga. The calculated two-stage crustal extraction age is 0.23 – 0.32 Ga older than DM model age.

Discussion and conclusions

Archean age obtained from CG eclogites correspond to the age of subduction-related Salma eclogites that outcrops in the Meso-Neoarchaean Belomorian eclogite province of Kola peninsula. The main subduction event and eclogite-facies metamorphism of the Salma association occurred within the time interval from ~2.87 to ~2.82 Ga (Mints et al., 2014). Late Archean age (2.7 Ga) was also obtained from the V.Grib pipe granulitic zircons that corresponds to major events recorded in upper-crustal rocks of the north-eastern Baltic Shield (Koreshkova et al., 2014). Nevertheless, three of V. Grib pipe CG eclogites samples have Proterozoic Sm/Nd DM model ages of 2.0, 1.8 and 1.2 Ga that correspond to the age of the most of V. Grib pipe EG eclogites zircons. The ages of 2.72 – 2.70 Ga, ~ 2.4 Ga and 1.9 Ga were also obtained from the Salma and Gridino eclogites assemblage of the Belomorian province and indicated the periods of post-eclogite history with mantle plumes invoked (Mints et al, 2014). And, the 1.7 Ga is regarded as the time of exhumation of the Belomorian province eclogite assemblage to mid-to-lower crust under the erosion or younger thermal event (Mints et al, 2014). The Proterozoic ages were also established for the tonalite–trondhjemite–granodiorite (TTG) orthogneiss and granitoids (1.8–2.0 Ga) representing the lower crust in the area of V. Grib kimberlite pipe (Samsonov et al., 2009) as well as for some granulitic zircons from V. Grib pipe (1.8 – 1.9 Ga; Koreshkova et al., 2014). The age range of 1.8 – 1.9 Ga corresponds to the period of the formation of the orogenic zones upon collision in many cratons worldwide (e.g. Akitkan orogen in Siberia, Russia; Wopmay in NW Canada), including the time of collision of the Karelian and Kola Cratons (Zhao et al., 2002). Data obtained from V. Grib pipe CG and EG eclogites can indicate two major subducted events in the lithospheric mantle of the ADP region: 1) the Archean (2.8 Ga) subduction corresponds to the time of formation of the Meso-Neoarchen Belomorian eclogite province in the northeastern Fennoscandian Shiled as well as to crustal rock formation of the north-eastern Baltic Shield; 2) the Proterozoic (1.8 – 1.9 Ga) subduction that corresponds to the time of collision of the Karelian and Kola Cratons.

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