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Regularities and mechanism of formation of the mantle lithosphere structure beneath the Siberian Craton in comparison with other cratons

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A B S T R A C T

Regularities of the mantle structure beneath the Siberian Craton were determined using the monomineral thermobarometry and common Opx-Gar methods. Samples were taken from 80 pipes from the Siberian Craton and in comparison 70 pipes from worldwide kimberlites. The largest pipes contain several dunite layers in the lower part of lithospheric mantle which are responsible for the diamond grade. The lithospheric mantle consists of two major parts divided at a depth of 4.0 GPa by a pyroxenite layer. Major intervals determined for the mantle beneath Udachnaya and Mir are: 1) 8.0–6.5 GPa harzburgites, eclogites and dunitic veins; 2) 6.5–5.5 GPa sheared peridotites, low-Cr pyroxenites, dunites; 3)in 5.5–4.0 GPa interval there are 4–6 layers of harzburgitic paleoslabs; 4) 4.0–3.5 GPa the pyroxenites lens; 5) upper layered Sp-Gar peridotite sequence including a trap of basaltic and other silicate melt cumulates at 3.0–2.0 GPa. The lithospheric mantle beneath seven different tectonic terrains in Siberia is characterized by TRE geochemistry and major elements of peridotitic clinopyroxenes. The mantle in Magan terrain contains more fertile peridotites in the South (Mir pipe) than in North (Alakit) which were metasomatized by subduction-related melts producing Phl and Cpx about 500–800 Ma ago. Daldyn terrain is essentially harzburgitic in the west part (abyssal peridotite) but in the east in Upper Muna (East Daldyn terrain) the mantle is more differentiated and in general more oxidized. The Markha terrain (Nakyn) contains depleted but partly refertilized harzburgites, subducted pelitic material and abundant eclogites. Circum-Anabar mantle is ultradepleted in the lower part but in the upper regions it has been fertilized by fluid-rich melts very enriched in incompatible elements. The P-Fe# diagrams (and other components) reveal different structure of mantle columns in each terrain. They are subvertical for the mantle sampled by Devonian pipes. Beneath Mesozoic pipes the mantle has been affected by melt percolation caused by the Siberian Superplume which created continuous Fe-enrichment in the upper part. The models of continent growth and evolution are briefly discussed. In general the geothermal regime and mantle heating is negatively correlated with the thickness of lithosphere. The sheared peridotites under Udachnaya and other kimberlite pipe are likely to have formed after the intrusion of protokimberlite volatile rich (hydrous) melts and hydraulic fracturing. This mechanism is responsible for the origin of asthenospheric lenses. Progressive melting especially in the pervasive zones may be responsible for the creation of 3-4 upper asthenospheric lens near mostly before 4.0 GPa which may be accompanied by mantle diapirism. Such a lens is the trap for the kimberlites in Siberia in Mesozoic time and in rifted intracontinental areas and margins.

1. Introduction

Archean and early Proterozoic cratons are the oldest preserved bodies of the Earth's lithosphere and contain abundant records of the its ancient history (Sobolev et al., 1973, 1975, 1984, 1997, 2003, 2004, 2009; Boyd et al., 1983, 1997, 2004; Pearson, 1998; Rudnick et al.,

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1998; Griffin et al., 1999a, 1999b; Rudnick and Nyblade, 1999; Griffin et al., 2002, 2003, 2005; Wittig et al., 2008; Griffin et al., 2009a, 2009b; Murgulov et al., 2011; Polat et al., 2011; Zhai and Santosh, 2011). Xenoliths in kimberlites yield abundant information about the structure and development of cratonic keels (e.g., Tang et al., 2012). Here we present new information for the subcratonic lithospheric mantle (SCLM) beneath the Siberian Craton and make a comparison with some examples of similar reconstruction of SCLM according to deep seated inclusions in kimberlites worldwide. These shed light on the structure, composition and evolution of mantle at the time of intrusion of the kimberlite magmas. This new information allows us to address more questions concerning the processes of continent growth, evolution and modification from the positions of petrology, geophysics and geodynamics. Locations of the Siberian kimberlite pipes were described in numerous papers (Sobolev et al., 1973, 1975, 1984, 1997, 2003, 2004, 2009; Kostrovitsky et al., 2007; Ashchepkov et al., 2010a) are shown on Fig. 1.

2. Data set

About 30,000 analyses from kimberlite concentrates and xenoliths were used for the reconstructions from published data as well as newly generated results. Most of the analyses were carried out at the Institute of Geology and Mineralogy Siberian Division RAS. Some of them were published (Ashchepkov et al., 2010a) and a large database of mineral compositions from EPMA methods were described in previous papers (Lavrent'ev and Usova, 1994; Sobolev et al., 2009; Ashchepkov et al., 2011). Several new data were gathered on xenoliths from Udachnaya (110 xenoliths) and some Alakit pipes (30) using Cameca 100SX housed at the University of Vienna (Ashchepkov et al., 2012a). The analytical methods are described in previous publications (Ntaflos et al., 2007). About 200 mineral associations from peridotite xenoliths from Udachnaya pipe were carried out recently in the IGM SD RAS (Ashchepkov et al., 2010b) (>2500 analyses). We also used the data for mantle xenoliths and xenocrysts from Mir, Aykhal, Amakinskaya, Taezhnaya, Aerogeophysicheskaya, Khardakn, Djanga, Maiskaya (Tolstov et al., 2009) and Manchary (Smelov et al., 2010) pipes, for xenocrysts from three pipes from Kharamai fields and also data for the placers from southern and northern parts of Siberian Craton (>6300 EMPA analyses). New data were also obtained for the xenocrysts from Sloan and Kelsey Lake-1 pipes (Ashchepkov et al., 2012b) pipes and for Catoca pipe (Ashchepkov et al., in press). New diagrams for large pipes were constructed using the data for diamond inclusions (Logvinova et al., 2005; Pokhilenko, 2006; Ashchepkov et al., 2010d). The data set of trace elements (TRE) (~900) ICP MS analyses are taken from the reports of joint research programs with the ALROSA Company (Ashchepkov et al., 2008). Large data sets for the Yakutian xenoliths from dissertations (Ovchinnikov, 1991; Kuligin, 1997; Malygina, 2002; Alymova, 2006; Pokhilenko, 2006) were also included in the data set.

3. Variations of major element chemistry

Variations of clinopyroxene (Cpx) analyses (>5000) are shown in Fig. 2 in comparison with diamond inclusions and diamond associations (Sobolev et al., 1984, 1997, 2003, 2004, 2009; Logvinova et al., 2005, 2008). Each of the seven kimberlite regions reveals their own set of individual features. The highest variations are found for clinopyroxenes from most studied Daldyn region. In Malo-Botuobinsky pipes, the mantle sequences are the richest in eclogites responsible for high diamond grade. Peridotitic Cpx from Alakit show the highest Na and Cr

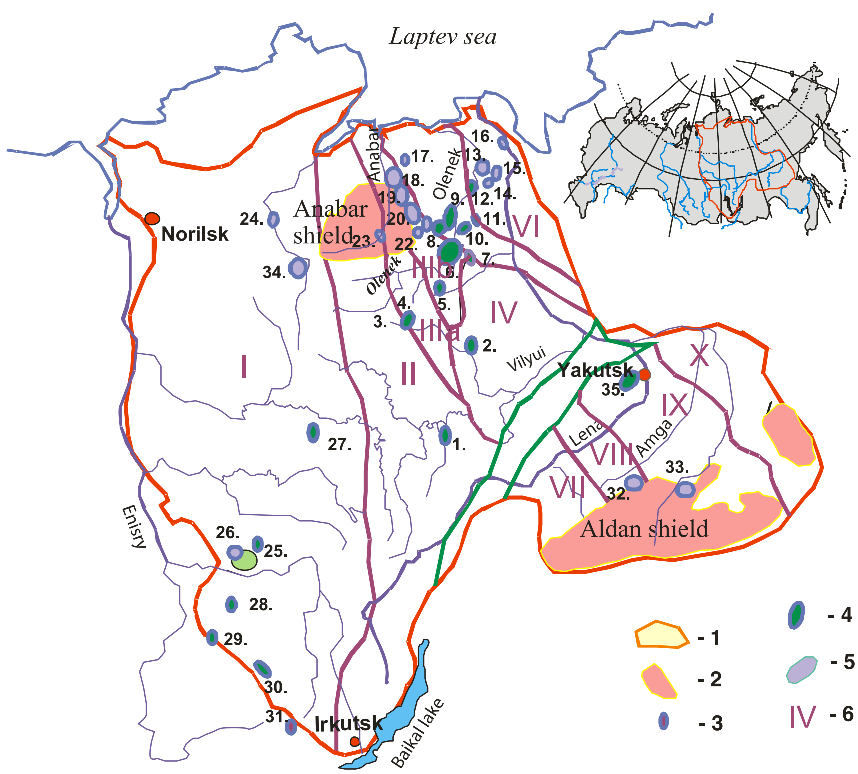

Fig. 1. Location of the kimberlite and carbonatite fields in Siberian platform. 1. Siberian platform. 2. Shields. 3. Precambrian kimberlites. 4. Paleozoic kimberlites. 5. Mesozoic kimberlites. 6. Tectonic terrains. Fields: 1. – Malo-Botuobinskoe, 2. – Nakyn; 3. – Alakit-Markha, 4. – Daldyn, 5. – Upper Muna, 6. – Chomurdakh, 7. – Severnei, 8. – West Ukukit, 9. – East Ukukit, 10. – Ust-Seligir, 11.– Upper Motorchun, 12. – Merchimden, 13. – Kuoyka, 14 – Upper Molodo, 15. – Toluop, 16. – Khorbusuonka, 17. – Ebelyakh, 18. – Staraya Rechka, 19. – Ary-Mastakh, 20. – Dyuken, 21. – Luchakan, 22. – Kuranakh, 23. – Middle Koupnamka, 24. – Middle Kotui, 25. – Chadobets, 26. – Taichikun-Nemba, 27. – Tychan, 28. – Muro-Kova, 29. – Tumanshet, 30. – Belaya Zima, 31. – Ingashi, 32. – Chompolo, 33. – Tobuk-Khatystyr, 34. – Kharamai. 35. –Manchary. The terrains classification (following Galdkochub et al., 2008) is: I—Tungus; II—Magan; IIIa—West Daldyn; IIIb—East Daldyn; IV—Markha; V—Hapchan; VI—Birekte; VII–XII—Aldan–Stanovoy province: VII—Olekma, VIII—Central Aldan, IX—East Aldan, X—Batomga, XI.