Gondwana Research 28 (2015) 106–120

Contents lists available at ScienceDirect

Gondwana Research

journal homepage: www.elsevier.com/locate/gr

Diamondiferous subcontinental lithospheric mantle of the northeastern Siberian Craton: Evidence from mineral inclusions in alluvial diamonds

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ARTICLE INFO

Article history:
Received 12 December 2013
Received in revised form 8 March 2014
Accepted 19 March 2014
Available online 18 April 2014

Handling Editor: J.G Meert

Keywords:
Subcontinental lithoshperic mantle
Diamond
Peridotite
Eclogite
Siberian craton

ABSTRACT

Headless placer diamond deposits occur in Cenozoic alluvium within the Paleoproterozoic Khapchan fold belt of the Olenek province in the northeastern part of the Siberian Platform, yet the known kimberlite pipes from this region are low-grade or non-diamondiferous. To characterise the subcontinental diamondiferous lithospheric mantle of this region, the mineral inclusions in 265 diamonds were exposed and analysed. Inclusions of the eclogite suite are predominant (>72%): garnet, omphacitic clinopyroxene, coesite, K-feldspar, rutile and corundum. The garnet and Cpx inclusions are within the range of eclogitic inclusions worldwide. Diamonds of the peridotitic contain olivine, Cr-pyrope garnet, ortopyroxene and chromite. The olivines have Fo contents between 89.7 and 93.8 mol. % (average – 92.4). Majoritic garnets of both peridotitic and eclogitic parageneses were identified in four diamonds. Most eclogitic diamonds display positive Eu anomalies. High-Ca garnets are LREE-depleted, show strong positive Eu (up to 4.25) and Sr anomalies and have HREE contents lower than those of the lowand intermediate-Ca garnets. The presence of majorite inclusions indicates that some of the diamonds may have sublithospheric origins.

Although diamonds with peridotitic-suite garnets constitute a minor percentage of the volume, the composition of these diamonds indicates a depleted composition for the peridotitic mantle. Diamonds of harzburgitic paragenesis compose 57% of the peridotitic suite, which is close to the world average. For an assumed pressure of 5 GPa, eclogitic garnet and clinopyroxene gave temperatures in the range of 1028–1290 °C. The composition of mineral inclusions of the peridotitic suite and the equilibrium temperatures of the eclogitic suite suggest that the lithospheric mantle of the Olenek province had a composition and thermal regime that was similar to those of the Archean cratonic mantle at the time the diamonds were brought to the surface.

1. Introduction

Syngenetic mineral inclusions in diamonds reflect the compositional features of their host rocks, and therefore, diamonds provide information regarding the composition and early stages of the evolution of the diamondiferous mantle beneath cratons (Haggerty, 1995; Schulze, 1995; Stachel et al., 1998; Shirey et al., 2003). The mineral inclusions in diamond represent two contrasting suites: (1) peridotitic (lherzolitic, harzburgitic and verhrlitic parageneses (P-type)) and (2) eclogitic (E-type (e.g., Meyer and Boyd, 1972; Sobolev, 1974; Prinz et al., 1975). The garnet inclusions of P-type paragenesis are mainly harzburgitic garnets, which are Ca-depleted relative to lherzolitic garnets (Gurney and Switzer, 1973; Sobolev, 1974; Sobolev et al., 1978; Gurney, 1984; Sobolev et al., 1997; Stachel and Harris, 2008). The trace-element compositions of these garnets reflect the processes of the metasomatic modification of the mantle in the early stages of its evolution (Sobolev et al., 1997; Stachel et al., 1998; Wang et al., 2000; Leost et al., 2003; Promprated et al., 2004; Stachel et al., 2004; Donnelly et al., 2007; Schulze et al., 2008; Sobolev et al., 2008). The low-Ca harzburgitic garnets in diamond inclusions and harzburgitic garnet nodules have been dated as Paleoarchean (Richardson and Harris, 1997; Richardson et al., 2004; Westerlund et al., 2006; Shirey and Richardson, 2011), whereas inclusions of lherzolitic and eclogitic parageneses have been dated as Mesoarchean and Proterozoic (Richardson, 1986; Richardson et al., 1999, 2004; Stachel and Harris, 2008; Shirey and Richardson, 2011). As shown in several studies (Griffin et al., 1999a,b; O'Reilly et al., 2001) the composition of subcontinental lithospheric mantle is strongly correlated with the tectonothermal age of the crust. Archean lithospheric mantle is characterized by high proportions of subcalcic harzburgites. The evolution of the composition of Archean peridotitic subcontinental lithosphere mantle has involved a decrease in the proportion of

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http://dx.doi.org/10.1016/j.gr.2014.03.018
1342-937X/

harzburgitic garnets and an increase in the proportion of lherzolitic garnets through time (Griffin et al., 1999a; O'Reilly et al., 2001; Griffin et al., 2003).

At present, the xenoliths and inclusions in diamonds have been most intensively studied in the kimberlites of South Africa, and these studies have recognised this trend in the evolution of the subcontinental mantle. In the model that was proposed by Shirey et al. (2002), the harzburgitic diamonds beneath the Kaapvaal and Limpopo cratons formed ca 3.3–3.2 Ga ago in the strongly depleted keel of the early cratonic core. The Mesoarchean generation of eclogitic diamonds (2.9 Ga) correlated with the beginning of subduction and accretion events. The Proterozoic generation of eclogitic and lherzolitic diamonds was related to tectonic and magmatic events along the margins of the Kalahari Craton. Shirey et al. (2003) reported a correlation between the composition of inclusions in the diamonds from the kimberlite pipes in the Kaapvaal and Zimbabwe cratons and the seismic structure of the lithosphere. The mantle lithosphere, with low-velocity P-waves, correlated well with an increasing abundance of eclogitic diamonds, a greater range in the Sm-Nd age of silicate inclusions, a lighter C isotope composition of diamonds and a high average N content. Shirey et al. (2003) inferred that the modification of the lithosphere mantle of cratons and the formation of diamonds are related processes. An analysis of inclusions in diamonds also revealed a marked difference in the structure of the diamondiferous mantle of the Kaapvaal (South Africa) and Slave (Canada) cratons (Shirey et al., 2003; Stachel et al., 2003; Donnelly et al., 2007; Stachel and Harris, 2008; Aulbach et al., 2009a; Deines et al., 2009). Comparison of peridotitic inclusions indicates that the diamondiferous mantle of the Slave Craton is less depleted that that beneath the Kaapvaal Craton.

The Siberian Craton hosts more than 1100 kimberlite pipes. After having examined the pyropes and chromites from Paleozoic and Mesozoic kimberlite pipes of the Yakutian diamondiferous province, some critical implications were derived regarding the modification of the lithosphere mantle in the northeastern part of the Yakutian diamondiferous province (Griffin et al., 1999b). This evidence suggests that the lithosphere is considerably thinner beneath the northern part of the Siberian Platform, i.e., in the Olenek tectonic province (Rosen et al., 1994) (Fig. 1), and the predominant kimberlite magmatism is of Mesozoic age, much younger than the fields of Devonian kimberlites further south (the Anabar tectonic province according to Rosen et al., 2006). It was presumed that the process of mantle modification proceeded

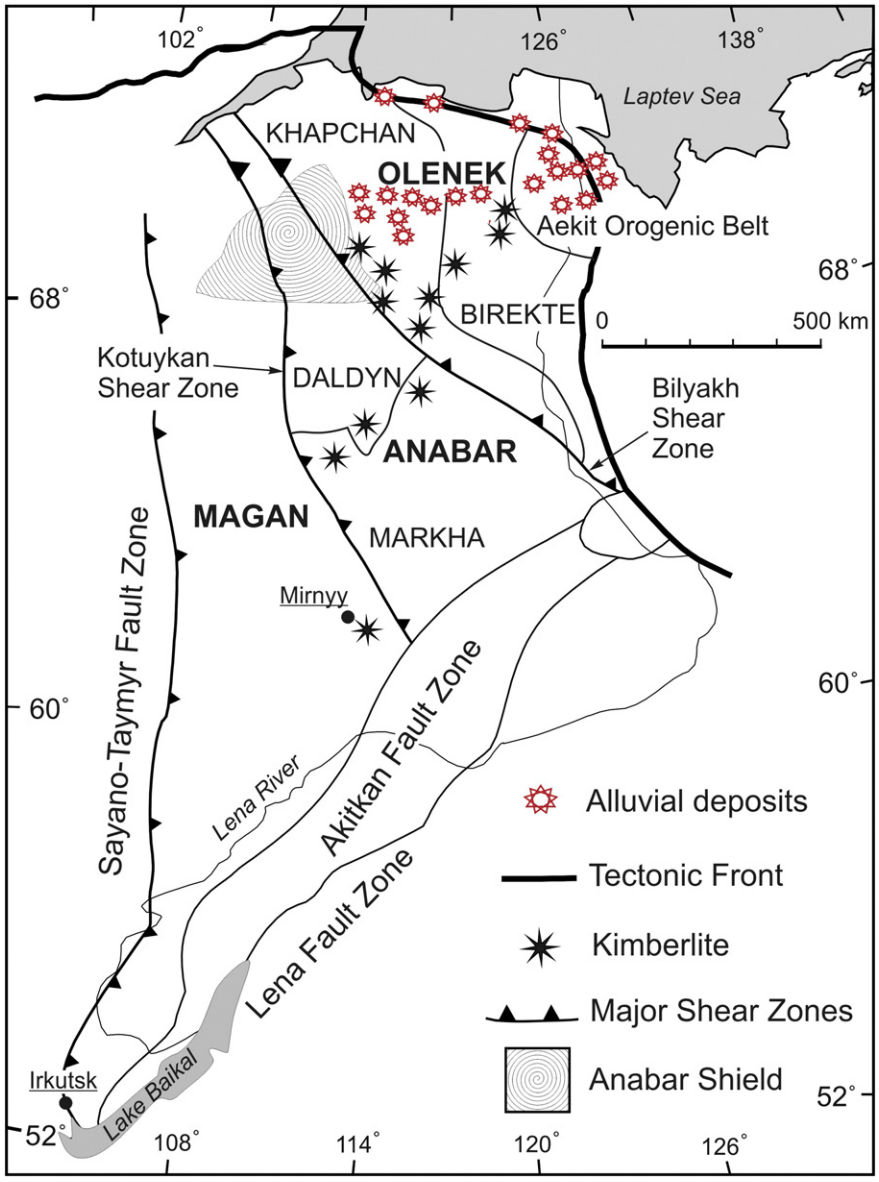

Fig. 1. Location of diamondiferous alluvial placers in the northeastern Siberian Platform. Terrane map of the eastern part of the Siberian Platform showing where the major kimberlite trends are reproduced from (Griffin et al., 1999b).