Thermobarometry of Inclusions: Implications to the Structure of Lithospheric Mantle and Evolution in Time and Diamond Formation

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Thermobarometric calculations for mineral diamond inclusions and associations (DIA) provide a systematic comparison of PTXFO2 conditions for different cratons worldwide, using a database of 4440 mineral EPMA analyses (Ashchepkov et al., 2021). Comparison by minerals shows that the PT estimates for clinopyroxenes (Fig. 1A) (Nimis, Taylor, 2000; Ashchepkov et al., 2017) and orthopyroxenes from peridotites and eclogites are representing mainly the middle part of the sub-lithospheric mantle while garnets gives more high-pressure estimates for peridotites (Fig. 1B) and eclogites and reflect the processes of the differentiation during migration of partial melts. This produces the trends of joint decreasing Mg' and pressures. The PT conditions for the chromites (Ashchepkov et al., 2010) (Fig. 1C) reflect conditions just above the lithosphere-asthenosphere boundary formed due to interaction with hydrous plume protokimberlite melts.

There are significant differences between the Archean diamond inclusions and those found in diamonds from Archeab Proterozoic, Devonian and Mesozoic and other later kimberlites. Those from Wawa province found in Archean lamprophyres (De Stefano et al., 2006) are, on average, more enriched in and Ca (pyropes) and reveal lower temperature conditions than those in younger kimberlites in the Superior and Slave cratons (Aulbach et al., 2018) (Fig. 2) showing complex high-temperature geotherms due to later plumes influences.

The Proterozoic kimberlites from the Kaapvaal are much higher temperature but this is probably due to the influence of the Bushveld superplume (Korolev et al., 2018) which also caused extensive removal of all the ultra -depleted dunitic garnets. The eclogitic inclusions are very high-temperature and also seem to be mainly re-melted. This is less pronounced for the Mesozoic pipes (Field et al., 2008). Those from the Roberts Victor pipe known by eclogite xenoliths show less influence of the plume melts and as reported and keep their primary subduction features but also they are relatively high temperatures compared to DIA from the other Mesozoic pipes in South Africa (Stachel and Luth, 2015). In general, the Proterozoic kimberlites contain more eclogitic inclusions of various types. The study of the eclogitic diamonds gives information about the subduction formation of the ancient crust

Beneath all cratons, the cold branch of the mantle geotherm (35–32 mWm−2) relates to the sub-Ca garnets and rarely omphacitic diamond inclusions, referring to major continental growth events in Archean. High-temperature plume-related geotherms are common in Proterozoic kimberlites (Korolev et al., 2018) (Fig. 3) such as Premier, Mesozoic–Roberts Victor etc. and are common in Slave and Siberian cratons. For the Mesozoic pipes in Kaapvaal, the heating is less pronounced (Figs. 3a, b). In the mobile belts: Limpopo, Magondi, Ural Ural, Khapchan belts and in the marginal parts of cratons like Kimberly Australia pyroxenitic and eclogitic pyroxenes and garnets prevail (Sobolev et al., 1976; Ashchepkov et al., 2021). The pyropes in the mobile belts are more Fe- and Ca-rich, in central parts of cratons, the peridotitic associations with sub-Ca pyropes prevail. The accretionary complexes like Khapchan and Magondi belts a thick eclogite-pyroxenite lens is highly diamondiferous.

The PT conditions estimated for the different terranes in Yakutia (Siberia) are quite variable (Sobolev et al., 1976; Logvinova et al., 2005). The age of the diamonds vary from Archean to Paleozoic time (Pearson and Shirey, 1999). The late Archean Early Proterozoic granulite-orthogneiss Daldyn and Alakit terranes marking ancient suture zones differ mainly in the amount of pyroxenitic pyropes which are abundant in the East Daldyn (Alakit) terrane They all demonstrate the folded structure of the mantle structure (Ashchepkov et al., 2013). beneath the Anabar and Aldan shields, dunite cores are more roughly layered (3–4 units) The suture and accretion terranes concentrate mainly on mafic eclogites and basic pyroxenites.

One could also find the PT arrays regarded as the advective geotherms which mark the interaction with the ascending protokimberlitic melts This boundar show the abundance of the pyroxenitic and fe- enriched associations. Commonly the protokimberlite magmas create Ti-rich associations which are not so frequent among the DIA and their are mainly composed of the megacrystic association . Very often large well-shaped diamonds of type II determined as megacrysts (Moore, 2009). There are also geochemical evidences for the crys-

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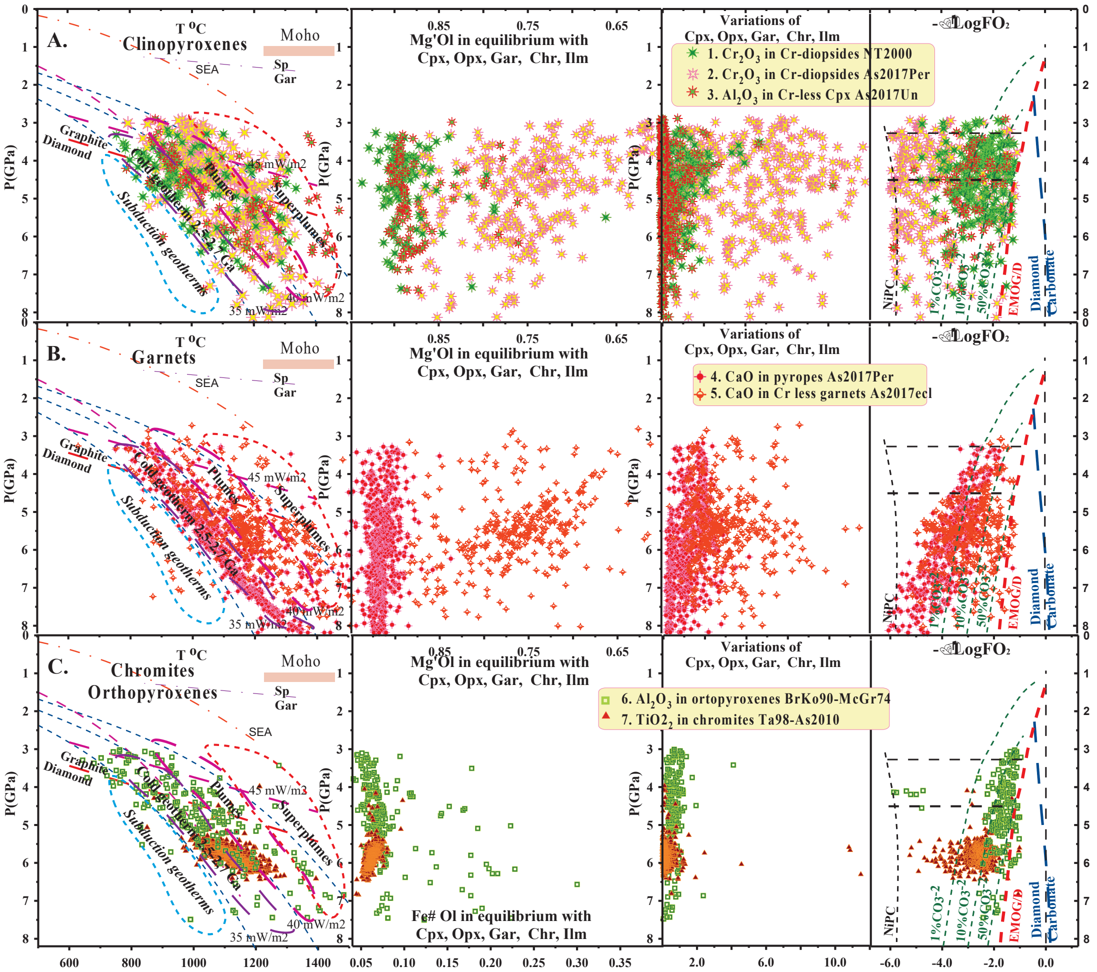

Fig. 1. PTXFO2 diagram for DIA for A. Cr-diopside Cpx Pressure estimates (1–Nimis, Taylor, 2000; 2, 3, 4, 5–Ashchepkov et al., 2017; 6–McGregor, 1974; 7–Ashchepkov et al., 2010).

The lines on the oxidation states are from (Sragno et al., 2013).

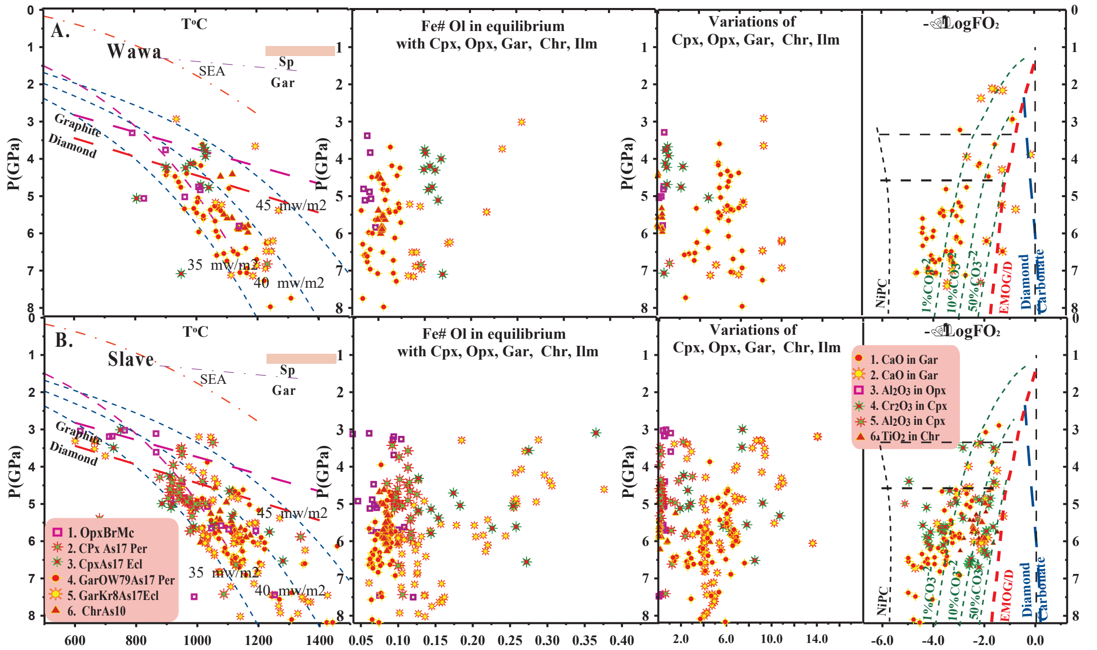

Fig. 2. PTXFO2 diagram for DIA from A. Archean lamprophyres Wawa province, Superior, B. for DIA from the Mesozoic pipes from Slave craton, Canada. The signs see (Ashchepkov et al., 2017).

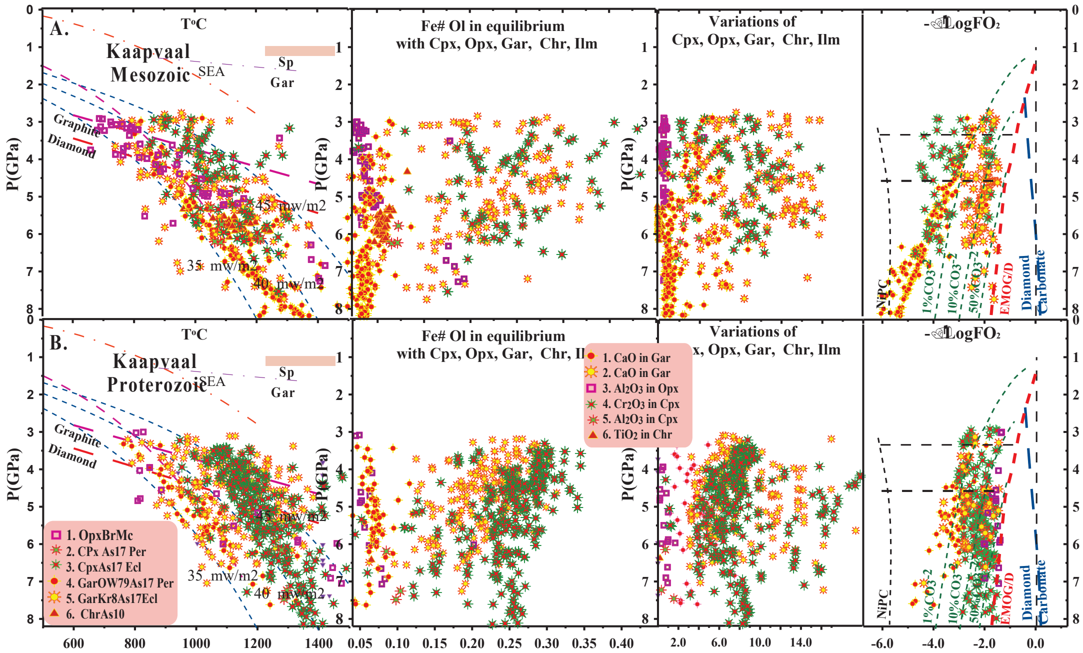

Fig. 3. PTXFO2 diagram for DIA from A. from Mesozoic kimberlites and B. Proterozoic kimberlites Kaapvaal craton, S. Africa. The signs see (Ashchepkov et al., 2017).

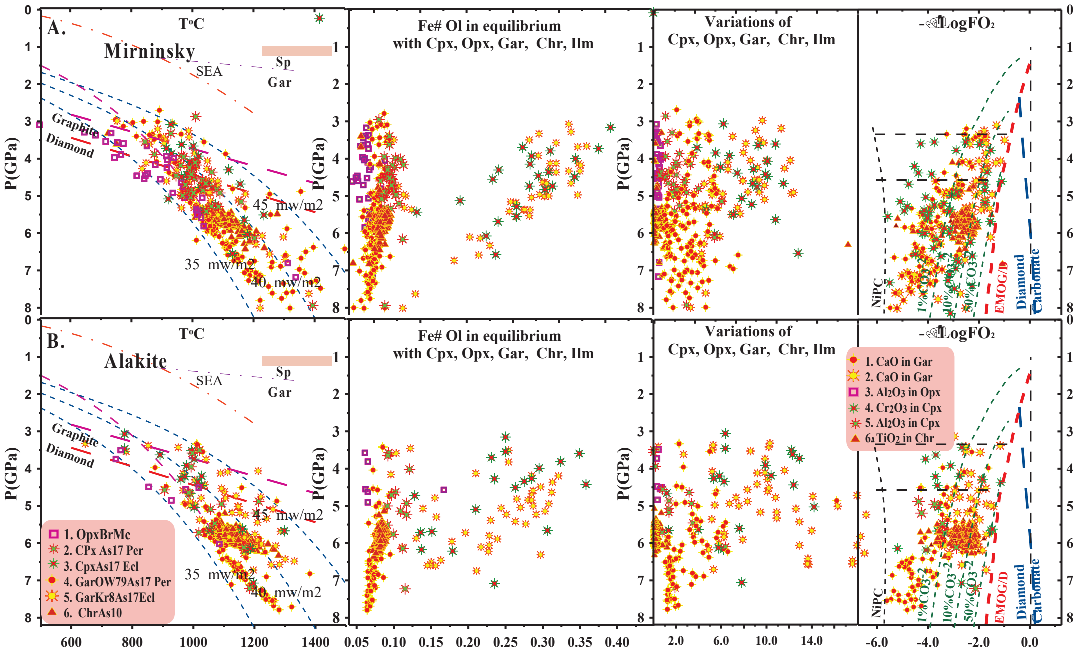

Fig. 4. PTXFO2 diagram for DIA from A. kimberlite of Mirninsky field and B. Alakite field. The signs see (Ashchepkov et al., 2017).

tallization of diamonds from protokimberlites.

There are many evidences that the diamonds were created at the vicinity of the magmatic systems and chambers and mechanically capture minerals from the mag-matic-fluid mush of different associations. The magmatic systems cold increase the pres-sure around the magmatic system due to the hydraulic effect transferring it from the depth. Hydrous conditions and extra fluid pressure could expand the diamond sta-bility field to lower pressure.

Commonly the peridotitic inclusions are lower temperature than pyroxenitic and ec-logitic ones due to a greater degree of reaction to plume influences of later inclusions. Pressures above the diamond stability field could result from the expansion of the diamond stability field at fluid and volatile influence. Another possibility is in in-creasing pressures transferring from depth due to the hydraulic effect. The kimberlites in off-craton settings and mobile belts show also higher temperature conditions and prevailing pyroxenitic and eclogitic assemblages. There

are essential difference in compositions of garnets from mantle sub-terrains such as Alakit and Daldyn (and other examples) containing continental arc and abyssal oceanic material, respectively.

Key words: diamond inclusions, craton, garnet, clinopyrogene, orthopyroxene, geothermal regime, manle lithosphere

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Igor V. ASHCHEPKOV, male, born in 1957 in Khabarovsk city, Russia. Graduated in 1975 from mathematical class Sch11 in Novokuznetsk city. In 1975, he entered and in 1980 graduated from Novosibirsk State University. In 1980–1989, he worked at the Geological Institute SB RAS in Ulan-Ude. In 1986, PHD “Deep xenoliths of alkaline basalts of the Vitim Plateau”. In 1989–2021, he worked at the N.V. Sobolev’s Institute of Geology and Mineralogy of the SB RAS. From 1994 to 2021, he led the 7th grats of the Russian Foundation for Basic Research. From 2002–2008, he led 3 contractual works with ALROSA. From 2012 to 2021, leed covener of sessions in General Assembly of European Geoscience Union. He was the responsible editor of special issues of Geoscience Frontiers (2017, N8) and in 2020-2021–Minerals.