Microdiamonds from UHP Metamorphic rocks of the Kokchetav Massif, Northern Kazakhstan : FTIR spectroscopy, C & N Isotopes and Morphology

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Introduction

The Kokchetav Massif (Northern Kazaksthan) is one of the few places in the world where ultrahigh-pressure (UHP) metamorphic rocks of crustal origin contain microdiamonds. The genesis of these microdiamonds continues to be controversial.

The present paper reports for the first time integrated data on C and N isotopes, morphology, nitrogen content and aggregation state of alluvial and *in situ*-found diamonds from garnet-clinopyroxenites and a garnet-clinopyroxene-dolomite rock. They support *in situ*-formation and place the genesis of the Kokchetav diamonds within the broad framework of plate tectonics.

Samples and methods

Microdiamonds from two different types of metamorphic rocks of the Kokchetav Massif were isolated from ca. 200 g rock using the thermochemical extraction method. Alluvial diamonds from the northern part of the Kokchetav Massif were also examined for comparison purposes.

- FTIR analyses

Individual spectra of nine diamond crystals from garnet-clinopyroxenite K76-94 and five from garnet-clinopyroxenite 2-4 were examined. All analysed crystals are yellow, translucent cuboids with complex morphology. The size of the crystals ranges from 80 to 139 µm. In addition three diamonds from a garnet-clinopyroxene-dolomite rock K92-99 were studied. The cuboids included in this rock are pale yellowish with a size of 50 µm. Alluvial diamonds have a cubo-octahedral morphology and are significantly bigger (from 202 to 320 µm). In order to examine the homogeneity of the diamonds at least two spectra of each crystal, examined in the frame of this study, were collected.

- Combustion

Three diamond samples from garnet-clinopyroxenite 2-4 and three from garnet-clinopyroxene-dolomite rock K92-99 were analysed. The samples have a weight ranging in the order of 0,2 to 2,5 mg. The experimental combustion procedure used for $\delta^{13}C$, $\delta^{15}N$ and N content measurements is that described by Boyd *et al.* (1995).

Results

It appears that diamond samples from garnet-clinopyroxenites are more yellowish than diamonds from garnet-clinopyroxene-dolomite rocks. FTIR analyses demonstrate that diamonds from garnet-clinopyroxenites have a very high nitrogen content (from 1150 to 2930 $\pm$20% at. ppm N) and are all of type Ib-IaA. Because of their smaller size, the N content and aggregation state of diamonds from dolomite rock are unreliable.

A correlation between N content and colour of the diamonds, is confirmed by combustion. Indeed, using this method, diamonds from garnet-clinopyroxenite 2-4 provide average concentrations of 2500 at.ppm N while diamonds from garnet-clinopyroxene-dolomite rock only bear 800 at.ppm N. Compared to diamonds from garnet-clinopyroxenites FTIR demonstrates that alluvial diamonds contain a relatively high nitrogen content (up to 3770 at. ppm) and that their aggregation state varies a lot (from 41 in sample T-86-4 to 81%IaA in sample T-86-3).

Diamonds from garnet-clinopyroxenites are characterized by water (OH and H_2O absorptions) and carbonate inclusions; alluvial diamonds on the contrary do not contain any carbonate inclusions and no or only minor amounts of water. IR absorption spectra of diamonds from dolomite-bearing rock K92-99 are very noisy although clear OH-absorptions can be recognized.

Both diamonds from garnet-clinopyroxenites and alluvial diamonds show a variable N content and aggregation state, even within single crystals. This heterogeneity and the absence of clear correlation between the N content and aggregation suggest that T-t estimations based on aggregation state have to be used carefully.

Diamond samples from clinopyroxenite and dolomitic rock do not vary more than 1‰ in their $\delta^{13}C$ and plot near to -10.5‰. These results differ from those reported by Pechnikov *et al.* (1993). $\delta^{15}N$-values of microdiamonds from a garnet-clinopyroxenite have $\delta^{15}N$-values of about +5‰ while diamonds from a garnet-clinopyroxene-dolomite rock are characterized by $\delta^{15}N$-values of about +10‰.

Morphology and diamond growth

All investigated microdiamonds from the Kokchetav Massif testify to growth in the diamond stability field. Their morphological variety reflects changing growth conditions. Aggregates, cuboids, cubo-octahedrons, octahedrons, macles, skeletal and re-entrant crystals are well represented among the diamonds of the Kokchetav Massif. However, a relationship between the diamond morphology and the nature of the host rock has been observed: cuboids dominate the diamond population of garnet-clinopyroxenites and garnet-clinopyroxene-dolomite rocks while cubo-octahedrons typify biotite-gneisses.

X-ray topography studies (Martovitskiy *et al.*, 1987; Shatsky *et al.*, 1997) highlighted that most microdiamonds have a core surrounded by a fibrous textured-margin. The fibres characterize rapid growth and because of their fragile character are believed to have formed in a fluid. This was confirmed by FTIR. The presence of water and carbonate inclusions in the diamond supports growth from a fluid phase. Most probably the inclusions originate in the fluid that is trapped between the fibres.

Origin of N and C

Despite of a similar morphology, diamonds from clinopyroxenite and dolomite-bearing rock can be distinguished by their contents and isotopes of N. Diamonds from clinopyroxenite have $\delta^{15}N$-values of about +5‰ while diamonds from the second rock type contain $\delta^{15}N$-values of about +10‰. The diamond population of each rock type is diagnostic and suggests a rather restricted mobility of the fluid phase, favouring a metasedimentary origin.

The $\delta^{13}C$ value of -10.2‰ is not indicative of the carbon source. Because of the high positive $\delta^{15}N$-values, it is however likely that the carbon and nitrogen source of the diamonds is the metasedimentary material. More detailed investigations are needed to enforce (or not) this idea.

About the diamond origin

The analytical results show that diamonds from different metamorphic rocks can be discriminated using nitrogen data. The presumption is that diamonds from other UHP metamorphic rocks will also bear distinctive characteristics.

In addition to arguments given by Sobolev and Shatsky (1990), new evidence for the *in situ*-formation of the microdiamonds is given in this study :(i) relationship between morphology of the diamond and composition of the host rock, (ii) correlation between nitrogen content and composition of the host rock, (iii) all FTIR analysed diamonds are of type Ib-IaA, (iv) $\delta^{15}N$ values provided by diamonds from different rock types are different.

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