A COMPARISON OF THE MICRODIAMONDS FROM KIMBERLITE AND LAMPROITE OF SIBERIA AND AUSTRALIA

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Introduction Physical properties for around 2500 microdiamonds have been examined from six Siberian kimberlite and seven Australian kimberlite and lamproite hosts (Table 1). All of the microdiamonds have dimensions under 0.5mm. Chips and broken crystals were excluded during the initial sampling. The microdiamonds are described with respect to both primary and secondary features, including external morphology, colour, surface features, nitrogen abundance, degree of aggregation and relative hydrogen content. The classification scheme followed is that described by Otter et al. (1994).

Table 1 Siberian and Australian microdiamond hosts

Siberian kimberlites	Aikhal Mir Sputnik Sytykanskaya Udachnaya Yubeleinaya
Australian kimberlites	Aries Emu 2 Excalibur
Australian lamproites	Argyle dyke Ellendale 4 Walgidee Hills
Australian (unknown)	Coanjula

Analytical methods Microdiamond form and colour were inspected using a stereo microscope and reflected light. Surface textures were examined using a high resolution scanning electron microscope (HRSEM) at the Centre for Microscopy and Microanalysis, The University of Western Australia. Low electron beam voltage (3keV) and magnifications up to 50 000 times were utilised. Infra-red spectra were collected using an optical microscope attached to a Bruker FT-IR spectrometer over the range 4000 to 650cm^{-1} at University College London.

External morphology External morphology indicates the nature and history of the source region in which the microdiamonds crystallised and resided (McCallum et al., 1994). To define the morphology; external form, crystal regularity, and resorption of each microdiamond has been described.

The proportions of external forms vary substantially between hosts, though with Siberian and Australian microdiamonds the octahedra is the predominant primary form. Only a small proportion (<10%) of octahedra appear to be equidimensional or nearly equidimensional. The remaining portion are distorted to varying degrees. Single crystals dominate all microdiamond suites, but aggregates are abundant in the Yubeleinaya (>15%) and Excalibur (>20%) pipes. Twinned crystals were recognised in each suite, but are significant only within the Emu 2 pipe (46% macles), Argyle dyke (25% macles) and Aries pipe (>15% interpenetrant twins). Each of the Siberian and Australian pipes show distinct differences in the proportions of cubic and irregular forms. Cuboids are present in each Siberian microdiamond fraction, and are significant forms in the Udachnaya (19%), Sytykanskaya (15%) and Yubeleinaya (8%) hosts. Other Siberian pipes have less than 4% cuboids. Of the Australian microdiamonds, cuboids were only observed in the Coanjula, Emu 2 and Excalibur suites. At Coanjula (host unknown) the suite is dominated (>70%) by opaque, fibrous cubes. Cubo-octahedra are present only in small numbers, and rarely exceed a few percent of the microdiamond suites. Cubo-octahedra are significant only within the Excalibur pipe, where they make up 23% of the microdiamond suite.

The degree of resorption evident in each suite varies. Dodecahedra are abundant, reaching 40%, in the Sytykanskaya and Mir pipes and 25% in the Udachnaya pipe. In contrast, dodecahedra make up less than 2% of the microdiamond suite from the Emu 2 and Walgidee Hills pipes. Dodecahedra of microdiamond size may be the resorption product of a larger diamond fraction, without a distinct genetic relationship to octahedra of similar or smaller size. Few microdiamonds show non-uniform resorption, believed to result from partial shielding by xenoliths during the resorption process. Isolated examples were observed in the Sytykanskaya and Yubeleinaya microdiamond suites.

Colour Microdiamond colour in many cases is difficult to distinguish, but can be an indicator of impurities and post-growth deformation (McCallum et al., 1994). The dominant colours from all the studied microdiamonds are colourless, yellow and brown. Green and pink microdiamonds are uncommon. The proportions of each of these colours varies not only between hosts, but also between microdiamond form.

Predominant in all suites are colourless microdiamonds. A higher proportion of dodecahedra and cubic forms are coloured. These trends in colour have been observed for macrodiamonds and have been suggested to be controlled by nitrogen aggregation and plastic deformation (Otter et al., 1994). No clear correlation emerges, however, when deformation is compared to microdiamond colour. Surface features indicative of deformation (most frequently lamination lines) do not appear more prevalent in coloured microdiamonds. The proportion of resorbed forms on which such textures are evident may effect this observation.

Surface features Surface features reflect the post-growth history of the microdiamonds, most of which have been ascribed to deformation, resorption and late-stage processes. A wide range of textures reported by Robinson (1979) are found on Siberian and Australian microdiamonds. Triangular growth platelets, trigons, lamination lines, knob-like asperities, ribbing and shield-shaped and serrate laminae are well developed on many of the crystals. Corrosion sculpture, heavy frosting and etch channels are late-stage features found frequently on microdiamonds hosted by lamproitic rock (Hall and Smith, 1984). A higher proportion of Argyle dyke, Ellendale 4 and Walgidee Hills microdiamonds show these characteristics when compared to microdiamonds recovered from kimberlitic hosts.

Nitrogen content and aggregation state Fourier transform infra-red spectroscopy (FT-IR) can be used to determine the amount and types of nitrogen defects within the microdiamond lattice. Nitrogen defects are divided according to how the nitrogen is substituted within the lattice and the degree to which it is aggregated (Evans and Harris, 1989).

The proportion of microdiamonds containing negligible amounts of nitrogen (type II) varies substantially between hosts. Over 95% of Aries microdiamonds are classified as type II, compared to 26% of the Yubeleinaya and 6% of the Sputnik microdiamond suite. Type I (nitrogen containing) microdiamonds from both Siberia and Australia contain nitrogen predominantly aggregated in the A form, with the exception of the Argyle microdiamond suite where over 80% are aggregated in the B form. With minor exception all cubic forms have nitrogen aggregated in the pure IaA form, suggestive of short residence times and/or low temperatures in the source region. Microdiamonds containing singly substituted nitrogen (type Ib) are present in the Excalibur suite.

For each of the studied microdiamond suites there is a wide range in total nitrogen content and aggregation state. The majority of microdiamond suites have nitrogen contents ranging from 20 to 2200ppm. Based on these values and corresponding aggregation states, estimates of the resident times and temperature of the source region can be made (Taylor et al., 1990). Each microdiamond suite reveals a broad time-temperature distribution which suggests the growth histories for microdiamonds differ even within hosts.

Within a single host, cuboids and cubo-octahedra show a relatively restricted range in nitrogen content and a slight enrichment in nitrogen over other morphologies. Significant differences between the nitrogen contents of octahedra, dodecahedra, macles and aggregates were not detected. Mean nitrogen content was compared for colourless and all coloured microdiamonds, regardless of form. Slight differences were found between coloured and colourless microdiamonds, the later depleted in nitrogen, though significant overlap in exists. Between pipes, the range in nitrogen content for different morphologies and colours differ.

FT-IR spectra have also been used to resolve the relative hydrogen content of microdiamonds. The types of defects hydrogen assumes and the defects that result in infra-red absorption are unknown, thus hydrogen content is yet to be quantified and can only be used as a relative comparison. Siberian and Australian microdiamonds, on average, show low to medium relative hydrogen content. An exception to this is the Excalibur pipe. The microdiamonds from this source are unique in their high to extreme levels of hydrogen. Relative hydrogen content shows a positive correlation with nitrogen content. Over 40% of microdiamonds displaying very high to extreme hydrogen level are cubo-octahedra.

Discussion The following comments can be made for Siberian and Australian microdiamonds

1. Octahedra are the predominant primary form, regardless of the host rocks and their localities.
2. The proportions of dodecahedra vary, and may be the resorption product of larger diamonds.
3. Colourless microdiamonds predominate, with dodecahedra and cuboids comprising the bulk of coloured stones.
4. Coloured microdiamonds, on average, show slightly higher nitrogen content than colourless microdiamonds.
5. A higher proportion of microdiamonds from lamproitic hosts relative to kimberlite hosts are heavily frosted and contain etch channels.
6. A wide diversity of nitrogen contents exists within suites with a corresponding range of time-temperature relationships. This may be attributable to an inhomogeneous source region, more than one microdiamond growth event, or a number of sources being involved for a single host.

Many of these trends may relate to variations in the physio-chemical conditions of the growth environments. The wide variety of physical features found within individual microdiamond suites make comparison between hosts and between regions difficult. It appears that multiple microdiamond populations are likely to be present in a single host, and no one distinguishing characteristic can be used to clearly separate the microdiamonds from the kimberlite and lamproite hosts of Australia and Siberia.

Additional studies on inclusion content, internal structure and carbon isotope composition of the microdiamonds are planned.

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