CHARACTERISTICS OF MICRODIAMONDS FROM ULTRAMAFIC MASSIFS IN TIBET: AUTHENTIC OPHIOLITIC DIAMONDS OR CONTAMINATION?

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Introduction: Microdiamonds and some other highly reduced minerals such as moissanite (α-SiC), Ni-Fe alloys, platinoid metals, and Cr^{2+}-bearing chromites have been reported from heavy mineral concentrates derived from the Donqaio and Luobusa ultramafic massifs in Tibet (Bai et al., 1993). Bai et al.'s hypothesis is that the diamonds formed by high pressure metamorphism and reduction of subducted oceanic crust which was subsequently rapidly emplaced into the crust under relatively cool conditions such that the diamonds were preserved. In order to evaluate the authenticity of these diamond occurrences and the validity of the hypothesis, a total of 12 microdiamonds from the Luobusa massif and 16 microdiamonds from the Donqaio massif were examined in this study using various techniques including infrared (IR) microspectroscopy. In addition, inclusions were analysed from a Donqaio diamond and the oxygen stoichiometry of chromite grains were investigated by electron microprobe analysis. Carbon isotope analyses of the microdiamonds are in progress.

Physical properties: Diamond samples from Luobusa comprise broken fragments of colourless diamond ranging in size from 400 μm to 180 μm. Original surface characteristics (including grooves and frosting) are preserved on the faces of some diamonds suggesting the fragments were derived from resorbed stones probably of original dodecahedral or rounded morphology. The Donqaio microdiamonds differ considerably from the Luobusa specimens examined here. They consist of yellow-green to pale yellow and almost colourless, sharp-edged cubo-octahedra and octahedra of 225 μm to 70 μm size. The cubo-octahedra resemble quite closely synthetic type Ib diamonds although octahedra are not common in synthetic tool stones. Some of the cubo-octahedra contain dark inclusions and one specimen was an intergrowth of two cubo-octahedral crystals. The faces of some stones show fine pitting and many of the stones have broken corners that possibly are the result of mechanical damage occurring during sample recovery, but such damage is also common on diamonds broken from drill bits. Because of similarities between the Donqaio microdiamonds and synthetic stones, a collection of synthetic diamonds of Chinese manufacture were examined for comparison. The Chinese synthetics contained a wider variety of morphologies than are found in batches obtained from other sources, and in particular contained a number of pale, sharp-edged octahedra similar to some Donqaio microdiamonds. In fact all the morphological and colour types seen in the Donqaio microdiamonds could be recovered from the Chinese synthetics.

IR spectra: IR spectra indicate the Luobusa fragments examined here are type IaAB natural diamonds. They were probably derived from several diamonds that had slightly different thermal histories. Total nitrogen contents range from ~20 atomic ppm up to ~700 atomic ppm and aggregation states are high, up to 80%. These aggregation states are too high for diamonds thought to have had only a short mantle residence time in cool subducted oceanic crust, but are similar to many diamonds from kimberlite sources that have had long-term histories in the mantle at temperatures >1150°C. IR spectra of the Donqaio microdiamonds indicate they are essentially type Ib stones with a small amount of nitrogen in the IaA form and low nitrogen contents in the range 80-250 atomic ppm. No hydogen defect peaks at 3107 cm-1, which would have indicated a natural origin, were found. These spectral characteristics are similar to synthetic diamonds, including those of Chinese manufacture, and are unlike most natural Ib-IaA diamonds which have higher nitrogen contents and contain hydrogen defects.

Inclusions: One of the larger Donqaio microdiamonds (WCDA2), containing dark inclusions, was sectioned and the inclusions analysed by energy dispersive microprobe analysis. The inclusions were found to be Fe-Ni alloys with Fe:Ni in the ratio of about 3:1. They are of similar composition to the metal inclusions (usually Fe-Ni and Fe-Ni-Co alloys) found in synthetic diamonds.

Chromite Analyses: Over 200 chromite grains from chromitites and peridotites were analysed with a Cameca SX-50 microprobe analyser. Some grains were selected for oxygen analysis in order to verify the presence of Cr^{2+} as inferred by Bai et al. (1993) from Mössbauer studies. The chromites were found to be relatively uniform in composition with mostly 2.5 to 3.5wt% Fe_2O_3 calculated on the basis of stoichiometry. Oxygen analyses indicate the chromites are stoichiometric within the analysed wt% Fe_2O_3 range, and there is no evidence for the presence of Cr^{2+}.

Conclusions: Green and yellow-green cubo-octahedral and octahedral micro-diamonds from the Donqaio massif examined in this study, and similar stones reported from the Luobusa massif by Bai et al. (1993), are consistent with synthetic contamination introduced at some stage during the sampling or concentration of heavy minerals from these ultramafic bodies. A remote possibility is that the microdiamonds were formed by a natural-process-analogue of the synthetic process, but this would require contact between graphite and Fe-Ni alloys at high pressures (>5.5 GPa) and temperatures (>1450°C) for a short duration (a matter of a few hours at peak temperature because of the low aggregation state of the diamonds). Although Fe-Ni alloys have been reported from the Tibetan ultramafic massifs (and other ultramafic bodies worldwide), such alloys are formed during low-pressure serpentinization reactions and it is therefore difficult to see how they could come into contact with graphite at high P,T.

On the other hand, the colourless Luobusa microdiamond fragments examined here are derived from genuine natural diamonds. However, the high aggregation state of these diamonds is inconsistent with their formation in "cool" subducted oceanic crust. It is likely that they are contaminants derived from a more conventional diamond source. Because sedimentary rocks and alluvial material were evidently put through the heavy mineral concentration plant in addition to ultramafic rocks, these diamonds could be derived from recent alluvium or perhaps from an unrecognised tectonic slice of Precambrian sedimentary rock containing diamonds reworked from an ancient kimberlite. Diamonds having such a source are known from northern Burma and there are probably similar occurrences in other parts of the India-Eurasia collisional zone.

The low inferred primary oxidation state of the Tibetan ophiolites has not been confirmed in this study. The presence of some reduced phases is probably related to low pressure serpentinization reactions.

In conclusion, none of the microdiamonds from the Tibetan ultramafic massifs have yet been proved to be genuine examples of ophiolitic diamond. Further sampling of these bodies, under controlled conditions, will be required to confirm the presence of diamond.

References:

Bai W-J, Zhou M-F, and Robinson P.T. (1993) Possibly diamond-bearing mantle peridotites and podiform chromitites in the Luobusa and Donqaio ophiolites, Tibet. Canadian Journal of Earth Sciences, 30, 1650-1659.