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Cathodoluminescence investigations on the Popigai, Ries, and Lappajärvi impact diamonds

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ABSTRACT

Twenty impact diamond samples from the Popigai, Ries, and Lappajärvi astroblemes were analysed using cathodoluminescence (CL) at room temperature (RT). Five of the samples were further investigated at liquid nitrogen temperature (LNT). Cathodoluminescence images allowed for the discrimination of diamond from graphite, thus contributing to a better understanding of the reciprocal relationships between these carbon polymorphs and their overall textural features.

Cathodoluminescence spectral measurements of the diamonds revealed emission bands and peaks located at 1.8 eV (688 nm), 2.23 eV (556 nm), 2.32 eV (534 nm), 2.39 eV (519 nm), 2.49 eV (498 nm), and 2.8–2.9 eV (443–427 nm). The bands at 2.8–2.9 eV and at 1.8 eV, observed at RT, were related respectively to vibronic levels (involved in electronic transitions), located at dislocation defects and to dislocations. Regarding the other lines, which were only visible at LNT, there may be a relationship between the peaks at 2.32 eV, 2.23 eV, and 2.39 eV, and the content of amorphous carbon phases.

Some spectral features may be considered a possible signature of impact diamonds. In particular, the band at 1.8 eV, which is uncommon in terrestrial natural diamonds, and the peaks at 2.23 eV and 2.32 eV, are present in all the samples studied.

INTRODUCTION

The relationship between diamond and pressure has been well known since the carbon phase-diagram was established; however, in nature almost all diamonds are related to persistent high-pressure conditions in the mantle, where they originated. Consequently, most of our knowledge about them derives from studies of this typical kind of diamond.

Impact diamonds represent another important type. Such diamonds constitute mineralogical evidence of shock metamorphism and give unique information about impact processes. Nevertheless, in spite of their importance and the progress that has been made in their study, some genetic aspects of impact diamonds are still not completely clear. The cathodoluminescence (CL) technique is effective in studying diamonds, but very few impact diamonds from terrestrial impactites (rocks being affected by impacts resulting from collisions of planetary bodies) have been studied by this method (Val'ter et al. 1992).

The first discovery of impact diamond was made in 1888, in the Novo Urei, Russia, ureilite (Yerofeev and Lachinov 1888). Soon after this, Foote (1891) found diamonds in fragments of the Canyon Diablo, Arizona, iron meteorite. But it was only in the 1950s that Nininger (1956) considered a shock origin for the diamonds of the Canyon Diablo meteorite. Later, his hypothesis was confirmed by Lipschutz and Anders (1961), who established that these diamonds were of impact origin. At the same time, De Carli and Jamieson (1961) reported the first shock synthesis of diamond. After these studies, knowledge about the formation of diamonds by shock pressure and impact processes rapidly increased and many impact diamonds were found in meteorites (Vdovykin 1967, 1970).

It was only in the 1970s that Masaitis discovered the first occurrence of impact diamonds in the rocks of a terrestrial meteoritic crater, at the Popigai astrobleme in Russia (Masaitis et al. 1972). Other Russian scientists soon made further important contributions to this subject by discovering and describing high-pressure polymorphs of carbon in the impact glass of the Ries crater, Germany (Rost et al. 1978). A few years later, impact diamond discoveries were also made at other sites. These include the Kara (Ezersky 1982) and Puchezh-Katunski (Marakushev et al. 1993) impact structures of Russia; the Obolon, Il'intsy, Terny, and Zapadny craters of the Ukraine (Gurov et al. 1995; Val'ter et al. 1992; Val'ter and Er'omenko 1996); and the Lappajärvi astrobleme (Masaitis et al. 1998a) in Finland. Occurrences of impact diamonds have also been reported recently from the suevitic breccias of the Onaping Formation (Sudbury, Canada impact structure: Masaitis et al. 1999), the "catastrophic layer" of the 1908 Tunguska impact event (Kvasnitsa et al. 1979) and the Yanis-jarvi impact structure (Vishnevsky and Pal'chik 2002), both in Russia.

In addition to in situ findings in the impactites of terrestrial meteorite craters, redeposited impact diamonds are also known to occur in unconsolidated Cenozoic sediments. Around the Popigai crater, for example, some of them were disseminated to form strewn fields (Vishnevsky et al. 1997). Strewn fields also occur around the Chicxulub crater. At Arroyo El Mumbral,

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