Compositional layering in a highly diamondiferous eclogite xenolith and its implications for diamond genesis

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Diamond is a well-known and extensively studied accessory mineral in the Earth’s mantle. It has been widely accepted that natural diamonds in kimberlitic magma are brought from the deep mantle (>150 km) to the surface as xenocrysts. This relationship is firmly supported by the common presence of peridotitic and eclogitic silicate inclusions within diamonds together with the complementary occurrence of diamondiferous peridotite and eclogite xenoliths from worldwide kimberlite locations. However, the nature of diamond formation in these host rocks remains contentious, in part because of the relative rarity of diamondiferous samples that are large enough for comprehensive study. Recent advances in the understanding of diamond formation within eclogitic hosts have been made from systematic studies of diamondiferous eclogites from Yakutia, applying high-resolution X-ray computed tomography (HRXCT) techniques to investigate the spatial and textural relationships between diamonds and other minerals. In these studies, eclogitic diamonds always occurred in proximity to clinopyroxene but never fully enclosed within fresh garnet or clinopyroxene. These lines of evidence, together with other evidence from diamonds and their inclusions, have led to suggestions of the metasomatic formation of eclogitic diamonds, post-dating the formation of the host eclogites. However, this is in apparent conflict with previous studies of two diamondiferous eclogites (HRV247 and RV124) from the Roberts Victor kimberlite, South Africa. These southern African eclogites display systematic changes in diamond (and graphite) abundance within a single nodule that are closely associated with compositional layering in silicates, defined by mineral and modal chemistry. The origin of layering has been attributed to igneous fractionation processes, either in high-pressure (mantle) or low-pressure (crustal) environments. The close association of silicate layering with diamond abundance can be used to imply the syngenetic formation of diamonds with silicates within the host eclogites.

In this study, we report a third example of compositionally layered diamondiferous eclogite (RVSA71) discovered in a new collection from the Roberts Victor Mine. In our preliminary investigation, 94 crystals of diamond ranging in size from 0.5 to 2 mm in maximum dimension have been recovered from 160 g of a clinopyroxene-rich part of the specimen, yielding a diamond grade of approximately 8400 carats per metric ton. This high concentration of diamond, the relatively large size of the xenolith host (15 x 12 x 8 cm) together with its compositional layering shown by modal variations of garnet, clinopyroxene and diamond, provide a rare opportunity to test whether the diamond formation was contemporaneous with or post-dated the formation of the host eclogite. We will address this issue based on the results of (1) 3D mapping of the rock using the HRXCT technique, (2) major element analyses of garnet and clinopyroxene across the layering by the electron microprobe, (3) analysis of the nitrogen content and aggregation state of the diamonds by Fourier Transform Infrared spectroscopy (FTIR), and (4) Carbon isotope analyses of the diamonds by the conventional combustion technique.

Keywords: diamond, eclogite xenolith, X-ray CT, FTIR, Carbon isotope

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