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# Diamond Genesis in the World's Largest Diamondiferous Eclogite, Part I: X-ray Tomography and Xenolith Dissection

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**Introduction**

Textural analyses of primary silicate minerals and diamonds in diamondiferous eclogites offer important information about the origin of diamonds in the Earth's mantle. Three-dimensional, high-resolution computed X-ray tomography (HRCXT) provides a non-destructive, *in-situ* method to study the internal textures of rocks (Carlson and Denison 1992, Rowe et al., 1997). The 2005 discovery of the world's largest diamondiferous eclogite (8.8 kg) at the Udachnaya kimberlite pipe, Siberia, offered a rare opportunity to study the crystallization of diamond and compare findings to previous studies conducted on smaller xenoliths (Taylor et al. 2000, 2005; Anand et al. 2004; Taylor and Anand, 2004). In this study, we report results obtained on a ½ kg chunk (UDE 2005, ~10 x 7 x 4.5 cm) of this eclogite (Fig. 1). In an accompanying report (Liu et al., this volume), we report on the internal texture of diamonds, their carbon isotopes, and the compositions of their inclusions.

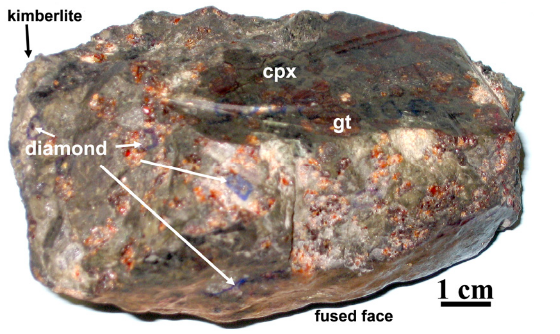


**Figure 1**. A ½ kg portion (UDE 2005) of the world's largest diamondiferous eclogite.

**Methods**

Three-dimensional HRCXT data were determined at the University of Texas, Austin using the method as described in Taylor et al. (2000) and Anand et al. (2004). Because the xenolith is unprecedently large, a smaller portion, UDE2005, of this xenolith was used for the HRCXT technique. Even with this smaller size, higher voltages were utilized (100 and 180 KeV) to enhance the silicate versus diamond contrasts, as well as to minimize beam hardening and ring effects.

Based on the HRCXT, a detailed dissection (pull-apart) of the xenolith was planned and conducted in order to recover its diamonds, as well as to examine their settings in the host minerals. The nature and physical properties of minerals in direct contact with the diamonds were especially noted.

Primary garnet, clinopyroxene, and sulfide minerals were analyzed using a Cameca SX50 electron microprobe at the University of Tennessee. Ananlytical conditions included an accelerating voltage of 15 keV, a beam current of 20 nA for silicates and 10 nA for sulfides, beam size of 1-5 µm for silicates, and 10 µm for sulfides.

**Results**

The HRCXT technique produced 2D slices of UDE 2005 from which a 3D model of the rock was reconstructed from these slices. In spite of the difficulties caused by the sample size, HRCXT successfully revealed >100 macro-diamonds (1–5 mm) and two clusters of diamonds (Fig. 2). None of the diamonds visible in HRCXT are located inside primary minerals. *These diamonds are always interstitial to the primary garnet and omphacite (inside alteration veins).* Indeed, multiple diamonds appear to form lineations along structurally weak zones, which appear to have had increased permeability for fluid migration (e.g., alteration veins) throughout the sample.

All extracted diamonds (0.3-5 mm) are associated with secondary alteration products, as previously found in other diamondiferous eclogites (e.g., Taylor et al., 2000, 2005; Anand et al. 2004). Diamonds (<1 mm), unseen in the HRCXT, are often found in close proximity to larger diamonds. Intergrowths of two or more diamonds are common.

Two significant small clusters (5-10 mm) were recovered from deep inside the eclogite, in association, albeit not contact, with entirely fresh garnet. One

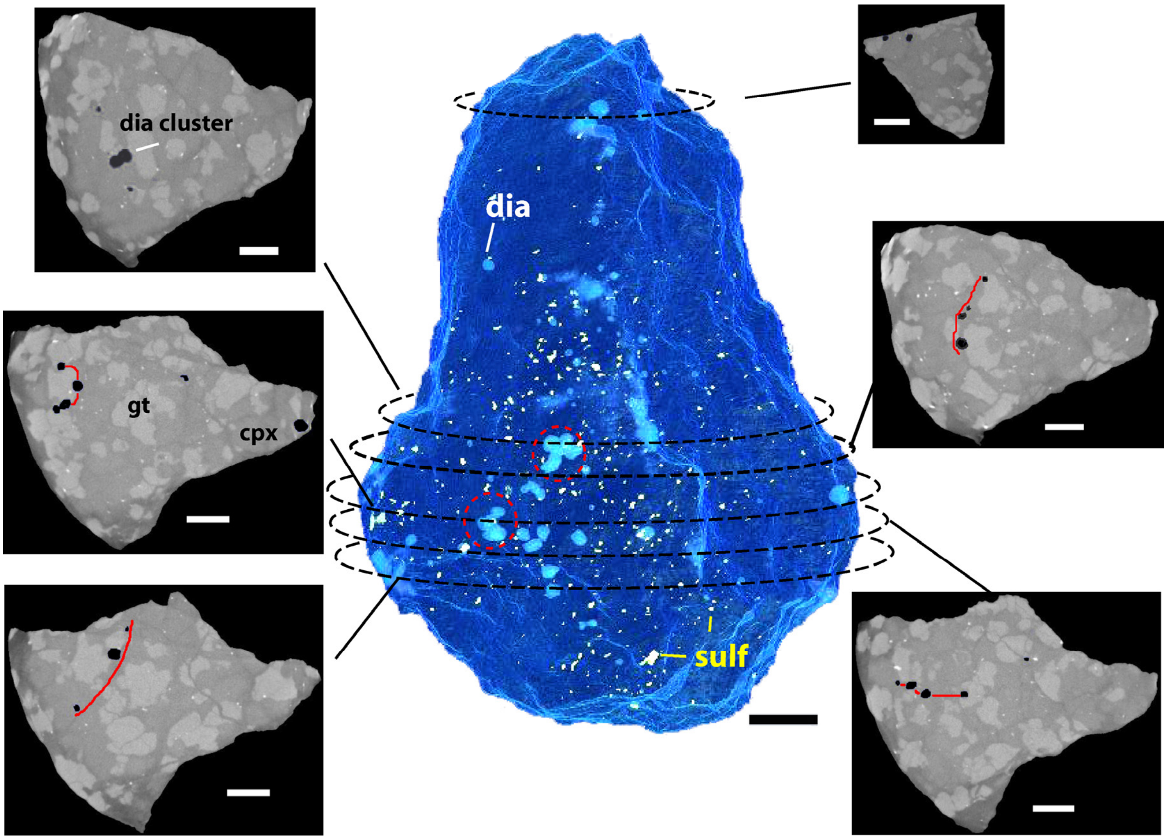


Figure 2. Center: a 3D model of UDE 2005 based on HRCXT. Light blue grains are diamonds, and yellow specs are sulfide minerals. Garnet and clinopyroxene crystals were rendered invisible to improve the clarity. Red circles outline the diamond clusters found with dodectahedral morphology (Figure 3). Figures on left and right of the central image are 2-D X-ray slices obtained originally by the HRCXT technique from the level outlined by the dashed girdle around the eclogite. In these slices, diamond appears black, garnet as light gray, clinopyroxene as dark gray, and sulfide as white. Alteration veins can be readily distinguished from the primary minerals. Lineation of multiple diamonds appear in two slices on the lower left and two on the lower right. All scale bars are 1 cm.

cluster was shown in Figure 3. The diamonds in these clusters have been extensively resorbed, displaying dodecahedral morphology. *This is the first documentation of dodecahedral diamonds from inside an eclogite xenolith*. This is additional evidence for metasomatic fluids penetrating the eclogite, probably depositing diamonds, some resorbing, exactly what we see in the stratigraphy of diamonds (Liu et al., this volume).

Primary minerals show features consistent with metasomatically induced partial-melting event(s) (Spetsius and Taylor, 2002; Misra et al., 2004). Clinopyroxenes in the host eclogite are typically omphacitic and display compositional variation among different grains (5.0 to 6.6 wt% $Na_2O$, Fig. 4). In alteration veins, clinopyroxenes contain higher CaO (~16-18 wt%) and lower $Na_2O$ (2-3.9 wt%). Garnet in the host eclogite are near the boundary of Group A and B (Fig. 4), with endmember compositions of pyrope ~36% and almandine ~35%, similar to many Udachnaya eclogite xenoliths. Compositions of these primary minerals (Fig. 4) suggest that UDE 2005 is a Group B eclogite, typical for diamondiferous eclogitic xenoliths found in the Udachnaya kimberlite pipe (Sobolev et al., 1994). All garnet grains in the eclogite contain kelyphitic rims (~0.1 mm thick). Omphacite is surrounded by a 'spongy texture' of secondary pyroxenes in optical continuity (Taylor and Neal, 1989), which have lower $Na_2O$ and $Al_2O_3$ and higher CaO contents, and with an interstitial K-rich glass (Fig. 5a). Sulfide minerals (pyrrhotite with pentlandite and minor chalcopyrite exsolution, Fig. 5b) show no clear association with diamonds.

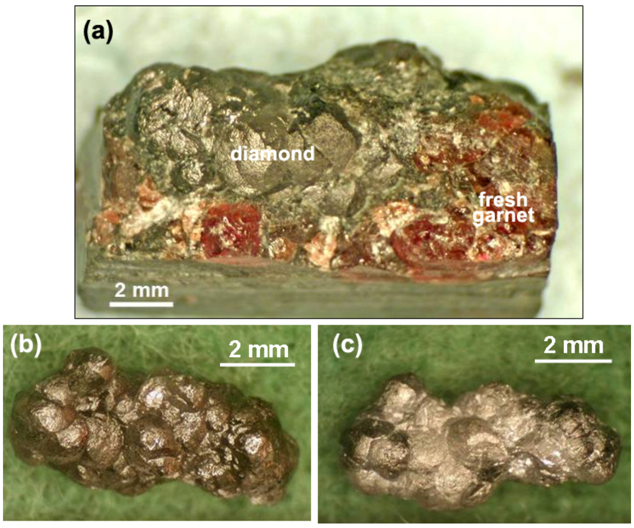


Figure 3. Resorbed and coated multi-crystalline diamond aggregates. (a) shows the diamond cluster before extraction; (b) and (c) are this same diamond cluster after dissolving silicates in HF. Individual diamonds display dodecahedral morphology.

## Concluding Remarks

Textural observations, made possible by HRCX Tomography and subsequent dissections, suggest that diamonds in the world's largest diamondiferous eclogite (8.8 kg) from Udachnaya occur along metasomatically induced alteration zones. This conclusion concurs with findings from studies of other diamondiferous eclogites (e.g., Taylor et al., 2000, 2005; Anand et al. 2004). In this gigantic diamondiferous eclogite, evidence also indicates multiple metasomatic events that occurred after the formation of the primary silicates of the host eclogite – *i.e., they are not synchronous with eclogite formation*. It is becoming increasingly evident that in eclogites, diamonds are *never* in contact with primary minerals (garnets; omphacites) and have an origin that completely post-dates the formation of their host eclogites.

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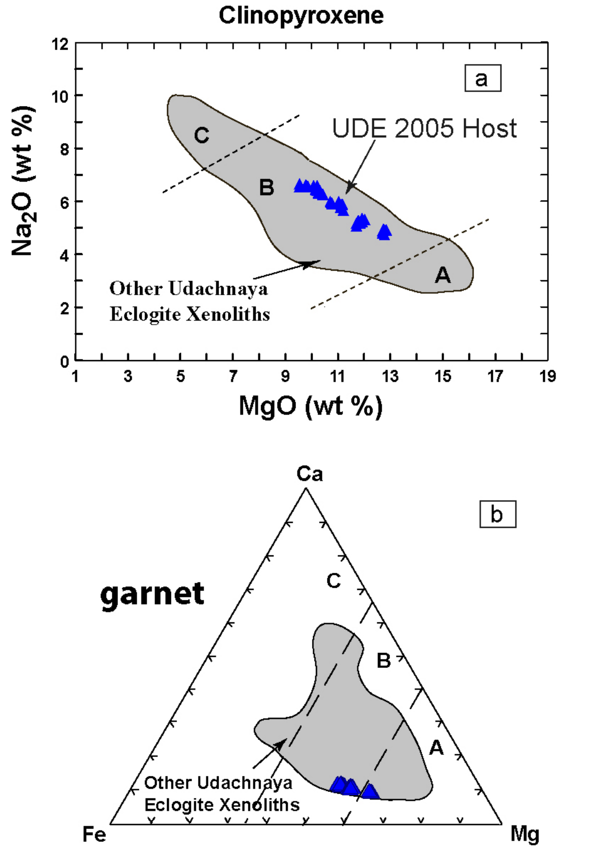


**Figure 4**. Compositions of host minerals (filled triangles) in UDE 2005. Gray fields outline clinopyroxene and garnet in eclogite xenoliths from Udachnaya (Taylor and Anand, 2004).

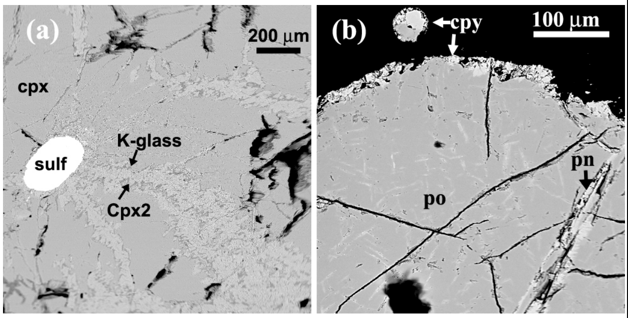


**Figure 5**. SEM images of pyroxene (a) and sulfide (b) in UDE 2005. In (a) primary omphacite (cpx) was altered to a calcium-rich pyroxene (Cpx2) with interstitial K-glass. In (b) sulfide mineral shows intergrowth of pyrrohtite (po) and pentlandite (pn) with calcopyrite rims (cpy).