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Microdiamond and Moissanite Inclusions in Garnets from Pohorje Mountains, Eastern Alps, Slovenia

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Natural microdiamonds and moissanite (SiC) can form during the orogenic events under ultrahigh-pressure metamorphic conditions (UHP), when parts of Earth's crust are subducted to extreme depths. So far, such processes were identified only in few places on the Earth, and therefore, represent unique opportunity to study the evolution of the Earth's deep interior. An important discovery of microdiamonds and moissanite was reported from Pohorje (Slovenia), where they occurred as single or polyphase inclusions in garnets. Metasedimentary rocks from Pohorje are predominantly gneisses representing parts of the Austroalpine metamorphic units of the E-Alps. During Cretaceous orogeny (ca. 95–92 Ma) continental crustal rocks were subducted to the mantle depths (below 100 km) and metamorphosed at pressures exceeding 3.5 GPa and temperatures 800–850 °C.

Microstructural and phase analysis of the inclusions as well as detailed elemental analysis of host garnets were carried out combining several analytical techniques: optical microscope in plane polarized transmitted light, electron probe microanalysis (EPMA) with wavelength-dispersive x-ray spectrometry (WDS) and field-emission scanning microscope (FEG-SEM) with energy-dispersive x-ray spectroscopy (EDS). Micro-Raman analysis revealed sharp, first order diamond bands sometimes accompanied by graphite bands implying that transformation of diamond back to graphite occurred. To study the chemical and crystallographic relationship between microdiamonds and co-inclusions, advanced techniques of transmission electron microscopy (TEM) were applied, which included high-angle annular dark-field scanning transmission electron microscopy (HAADF-STEM), combined with EDS and electron energy-loss spectroscopy (EELS). To prepare electron transparent TEM lamellae selectively a dual-beam Focused Ion Beam/SEM (FIB/SEM) was employed.

Detailed study of TEM lamellae, which was cross-sectioned from the highly faceted inclusion body located within the host garnet crystal matrix, revealed rich and rather complex internal structure. Namely, the negative crystal facets of the main inclusion body were typically decorated with up to 1 μm thick amorphous layer, reflecting the general garnet composition with slight variations in Fe/Ca content. Within these layers, ELNES analysis revealed the presence of a 28–30 nm thick layer of amorphous carbon. The very last section of this layer corresponds to composition of SiO_2. Within the inclusion, besides diamond and moissanite alumosilicate mineral with pronounced layered structure, iron sulfides and chlorine were identified under TEM and CO_2 and CH4 using Raman. Moissanite is found as single crystal or composed from numerous highly textured nano-crystals with the average size of 10 nm. Moissanite inclusions were found embedded inside the amorphous crust implying that moissanite crystalized well before the deposition of the amorphous layer.

From the microstructural, crystallographic and chemical observations so far we can deduce, that polyphase inclusions in diamond bearing garnets from Pohorje most probably crystallized from reduced supercritical fluids. Based on layered interface structure of the host mineral multiphase process of crystallization is possible. The presence of microdiamonds and moissanite in rocks from Pohorje demonstrates that these parts of the E-Alps were the most deeply subducted parts of the Austroalpine units of the Alps, and were subsequently exhumed back to the surface without complete breakdown of UHP mineral phases, allowing an opportunity to study them in-situ.