

Diamond in Almahata Sitta Ureilite

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Almahata Sitta, originating from asteroid 2008 TC₃, is the first meteorite that was observed and its trajectory was determined before the fall [1]. Almahata Sitta 2008 TC₃ is a polymict asteroid, consists mainly of coarse-grained and fine-grained ureilite with less abundant chondritic fragments [2-3]. The ureilitic fragments contain carbonaceous materials such as graphite and diamond. There are three major models as a diamond formation mechanism in ureilite; i.e., 1) formation from a fluid or melt in the deep interior of an ureilite parent-body [e.g., 4], 2) formation through chemical vapor deposition (CVD)[e.g., 5] and 3) shock-induced transformation of graphite at the moment of planetesimal collision [e.g., 6]. We found a huge single diamond crystal from one of Almahata Sitta coarse-grained ureilite samples. Here, we report the occurrence and nature of the unique diamond in the Almahata Sitta coarse-grained ureilite, and discuss its possible formation mechanism.

The coarse-grained ureilite, Almahata Sitta MS-170 consists mainly of olivine (Fa₁₈₋₂₁) and low-Ca pyroxene, with less abundant troilite, kamacite, magnetite, schreibersite (Fe₃P) and diamond-graphite assemblages. Most diamond-graphite assemblages exist between the olivine grains. The olivine grain adjacent to the diamond-graphite assemblages usually shows a reduction texture; i.e., olivine dissociates into enstatite and kamacite. Because of its hardness, diamond appears above the polished surface, easily seen under an optical microscope and SEM. The main diamond Raman band stays within narrow range (1333.5 cm⁻¹, sigma = 1.7, n = 53), implying that the diamond is well-crystallized. High-magnification BSE images show that many diamonds have hexahedron- or octahedron-like habits, which corresponds to idiomorphic {001} or {111} diamond, respectively, although not always idiomorphic. TEM images and EBSD analysis show that most diamonds are single crystals because several diamond fragments have similar crystallographic orientations. One of the biggest single crystal diamond we found is ~100 microm or more in a dimension. We could not find a specific crystallographic orientation between graphite and diamond. The isotope distribution images obtained with a NanoSIMS show heterogeneous nitrogen abundance and delta¹³C among individual diamond grains and even within the grains. Almahata Sitta is a less shocked ureilite (S0). The idiomorphic huge single diamond was not formed from graphite through martensitic phase transformation mechanism under high-pressure and -temperature condition induced by a dynamic event. Nitrogen sector zoning texture implies that the diamond grew very slowly. It is likely that the diamond was formed by chemical vapor deposition (CVD) process or formed from a C-H-O fluid at the deep interior of an ureilite parent-body. Nonetheless, some deformation textures were observed by TEM in the diamonds, which is due to a later dynamic event after primary diamond formation.

References:

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