

Invited Lecture

Early carbon minerals in the solar system – structures, genesis, and planetological significanceF. Langenhorst^{1,2}

¹*Institute of Geosciences, Friedrich-Schiller-University Jena, Lessingstr. 14, D-07743 Jena, Germany;* ²*Hawai'i Institute of Geophysics and Planetology, University of Hawai'i at Mānoa, 1680 East-West Road, Honolulu, HI 96822*

Falko.Langenhorst@uni-jena.de

The element carbon shows a remarkable chemical versatility and occurs in minerals in variable bonding environments with coordination numbers from 2- to 4-fold and valence states from -4 and +4. This enabled the carbon mineralogy to be already quite diverse in the early solar system. Early carbon minerals are pure carbon phases (graphite, diamond, lonsdaleite), carbides (moissanite, SiC; cohenite, FeC₃; haxonite, (Fe,Ni)₂₃C₆; khamrabaevite, TiC), and carbonates (calcite, CaCO₃; dolomite, MgCa(CO₃)₂; breunnerite, (Mg,Fe,Mn)CO₃ etc.) [1-4]. The genesis of these minerals is also very diverse, as they occur in different types of meteorites (e.g., iron meteorites, chondrites) and in the context of various processes, such as early condensation from solar nebulae, cosmic collisions between celestial bodies, core-mantle differentiation in planetesimals, and aqueous alteration in a cometary environment.

Most crystal structures of early carbon minerals are relatively simple with the prototype graphite, diamond, and calcite structures. The carbides possess, however, crystal structures with more complexity. The cohenite structure accommodates iron in regular trigonal prisms as coordination polyhedra and displays variable lattice parameters, potentially related to different quenching rates. The haxonite structure contains 116 atoms in the cubic unit cell, in which the metal atoms have a rich variety of atomic coordination numbers, ranging from 12 to 16. The dolomite structure has also some complexity, as the cation ordering results in superstructures.

These crystal structures of early carbon minerals are however imperfect and contain various typical defect microstructures related to their incipient formation and further processing in the early solar system. For example, the imperfect growth of diamonds by condensation from a solar nebula results in the formation of interconnected stacking faults on {111} planes [2]. At the faults the stacking sequence changes locally from cubic (3C) to hexagonal (2H) stacking, with the latter being a kind of a hexagonal lonsdaleite monolayer [3]. Similar stacking faults resulting from imperfect growth during condensation are also observed in moissanite, while cohenite and haxonite may develop planar defects during slow cooling and exsolution from the nickel iron phases kamacite and taenite [1] or by reaction of iron with carbonaceous matter [4]. The carbonates form in the process of early aqueous alteration by precipitation from cold aqueous solutions. They show chemical zoning and modulation structures that may be related to cation ordering and fine-scale exsolution.

The presentation will address these structural peculiarities of early carbon minerals in the light of their formation processes. It will emphasize the importance of crystal chemistry and structural defects to decipher the early cosmic processes that prevailed during the formation of solar systems.

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