

HYDROTHERMAL SYNTHESIS OF CUBANITE: IMPLICATIONS FOR FLUIDS ON COMET 81P/WILD 2 & THE CI-CHONDRITE PARENT BODY

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Introduction: The low-temperature form of CuFe_2S_3 , cubanite, has been identified in the CI-chondrite and Stardust collections [1]. We report the first synthesis of cubanite under hydrothermal conditions relevant to the CI-chondrite parent body.

An aqueous system can be described by the interplay between pH, temperature, oxygen and sulfur fugacities (f_{O_2} , f_{S_2}). These four variables are interrelated; the specification of three of them de facto determines the fourth [2]. Temperatures of 50-150°C, pH of 7-10 and $\log f_{\text{O}_2} > 10^{-55} - 10^{-70}$ on the CI-chondrite parent body have been predicted from oxygen isotope measurements [3] and modeling of hydrous asteroids [4]. The presence of cubanite confers a temperature maximum, as it undergoes an irreversible phase transition at 210°C [5-6].

Methods: We form Cu-Fe sulfides by controlling temperature, pH and f_{O_2} . Experiments are run at 100, 150 and 200°C over the pH range 7-10. Oxygen fugacity is held at the iron-magnetite and quartz-fayalite-magnetite buffers.

Compositions of the experimental products are obtained via EMPA on the Cameca SX-50 at LPL. Crystal structure is determined using FIB-TEM techniques at JSC on the FEI Quanta 3D 600 dual-beam FIB and the JEOL 2500SE 200kV FE-STEM.

Results & Discussion: Cubanite forms under aqueous conditions, in the presence of iron and magnetite, at a pH of 9 and temperatures of 150 and 200°C. While only a minor sulfide constituent at 150°C, it is the chief product at 200°C with an average composition (at.%) of $\text{Cu}_{15.7}\text{Fe}_{33.6}\text{S}_{50.7}$.

Two FIB sections were prepared, each containing numerous cubanite grains. Measurements of SAED patterns obtained at multiple orientations from individual grains are consistent with cubanite [5]. TEM analyses reveal extensive twinning. The experimentally produced cubanite, like the CI-chondrite cubanite [1], has a superstructure, likely based on cation ordering. There are superstructure reflections present along both a^* and c^* .

The successful synthesis of cubanite, under aqueous conditions, aids in refining the parameters (T, pH, f_{O_2} and f_{S_2}) of the time-varying low-temperature fluids which existed on the CI-chondrite parent body.

References: [1] Berger E. L. et al. 2011. *Geochimica et Cosmochimica Acta* 75:3501-3513. [2] Barnes H. L. and Kullerud G. 1961. *Economic Geology* 56:648-688. [3] Clayton R. N. and Mayeda T. K. 1999. *Geochimica et Cosmochimica Acta* 63:2089-2104. [4] Zolensky M. E. et al. 1989. *Icarus* 78:411-425. [5] Fleet M. E. 1971. *Zeitschrift fur Kristallographie* 132:276-287. [6] Cabri L. J. et al. 1973. *Canadian Mineralogist* 12:33-38.

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