

DISCOVERY OF METEORITIC DMISTEINBERGITE (HEXAGONAL $\text{CaAl}_2\text{Si}_2\text{O}_8$) IN THE ALLENDE TYPE B FUN CAI *STP-1*: A NEW REFRACTORY MINERAL. Chi Ma¹, Alexander N. Krot², and Martin Bizzarro³; ¹California Institute of Technology, Pasadena, CA 91125, USA, chi@gps.caltech.edu; ²University of Hawai'i at Manoa, Honolulu, HI 96822, USA; ³Centre for Star and Planet Formation and Natural History Museum of Denmark, University of Copenhagen, DK-1350 Copenhagen, Denmark.

Introduction: We identified dmisteinbergite, $\text{CaAl}_2\text{Si}_2\text{O}_8$ with $P6_3/mcm$ structure, in the recently discovered coarse-grained, igneous Type B FUN (fractionation and unidentified nuclear effects) Ca,Al-rich inclusion (CAI) *STP-1* from the Allende CV3 chondrite [1]. Electron probe microanalysis (EPMA), scanning electron microscopy (SEM), and electron backscatter diffraction (EBSD) were used to characterize its chemical composition and structure. Dmisteinbergite was previously only found in burned coal dumps from Chelyabinsk Coal Basin, Ural Mountains, Russia [2], and in a pseudotachylyte from Italian Alps [3]. Synthetic hexagonal $\text{CaAl}_2\text{Si}_2\text{O}_8$ is well known [4]. Dmisteinbergite is trimorphous with anorthite (triclinic) and svyatoslavite (monoclinic). We report here the first occurrence of dmisteinbergite in a meteorite as a new refractory mineral in a CAI and consider its origin and implication for the formation of *STP-1*.

Mineralogy and petrology of the host CAI: *STP-1* is a coarse-grained igneous CAI composed of pure $\text{CaAl}_2\text{Si}_2\text{O}_8$ (mostly dmisteinbergite and rare anorthite), gehlenitic melilite (Åk_{6-28}), and igneously-zoned Al,Ti-diopside ($\text{Al}_2\text{O}_3 = 17.7\text{--}28.5$ wt.%, $\text{TiO}_2 = 0.03\text{--}8.7$ wt.%), all poikilitically enclosing euhedral compositionally pure spinel grains (Fig. 1). Lath-shaped hibonite grains and spinel-hibonite intergrowths occur in the outermost portion of the inclusion (Figs. 1, 2). The hibonite grains have low contents of MgO (0.2–1.7 wt.%) and TiO_2 (0.09–3.2 wt.%). No multi-layered Wark-Lovering rim sequence is observed around *STP-1*. The CAI experienced only a small degree of secondary alteration resulted in replacement of melilite by nepheline, sodalite, Fe-bearing Al-rich, Ti-poor pyroxene ($\text{FeO}, 2.5\text{--}6.3$ wt.%, $\text{Al}_2\text{O}_3, 5.1\text{--}16.2$ wt.%, $\text{TiO}_2, 0.10\text{--}0.27$ wt.%), and Na-bearing plagioclase (0.35–0.89 wt.% Na_2O), and enrichment of spinel in FeO (up to 19.5 wt.%) in its peripheral portion. In addition, melilite crystals are crosscut by thin veins of grossular, Al-diopside, and Na-bearing plagioclase.

Appearance, chemistry and crystallography of dmisteinbergite: Dmisteinbergite occurs as irregular single crystals (100–600 μm in size) with perfect cleavage {001} lines on the section plane (Figs. 2–4). Euhedral anorthite was observed in one dmisteinbergite crystal (Figs. 3, 4). Dmisteinbergite and anorthite show no evidence for replacement by secondary minerals. Some of the cleavage planes in dmisteinbergite, however, are filled by secondary grossular (Figs. 2, 4).

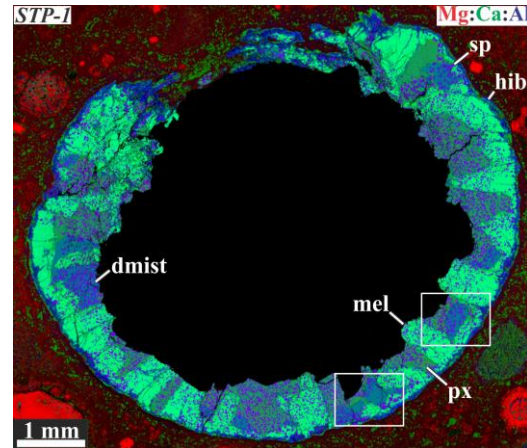


Fig. 1. Combined elemental map in Mg (red), Ca (green), and Al (blue) $K\alpha$ x-rays of the Allende FUN CAI *STP-1*. The central part of the CAI is missing. Regions outlined are shown in Figs. 2 and 3. dmist = dmisteinbergite; hib = hibonite; mel = melilite; px = Al,Ti-diopside; sp = spinel.

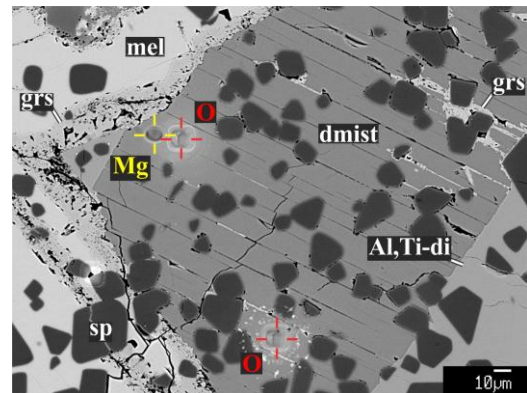


Fig. 2. Backscatter electron (BSE) image showing dmisteinbergite and coexisting minerals in *STP-1*.

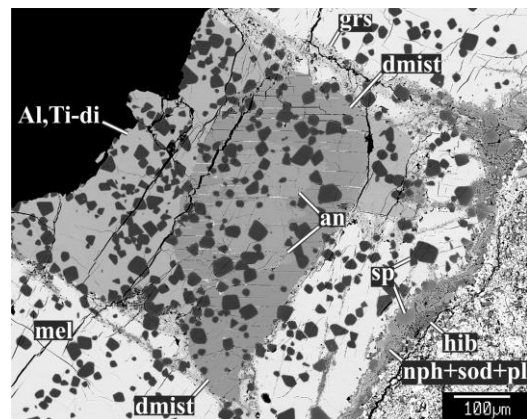


Fig. 3. BSE image showing primary melilite, Al,Ti-diopside, spinel, dmisteinbergite, and anorthite, and secondary grossular, nepheline, and sodalite.

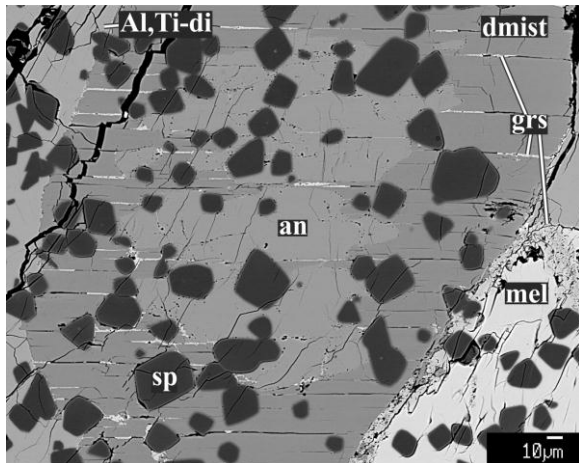


Fig. 4. BSE image showing dmisteinbergite enclosing anorthite. Some cleavage planes in dmisteinbergite are filled by secondary grossular.

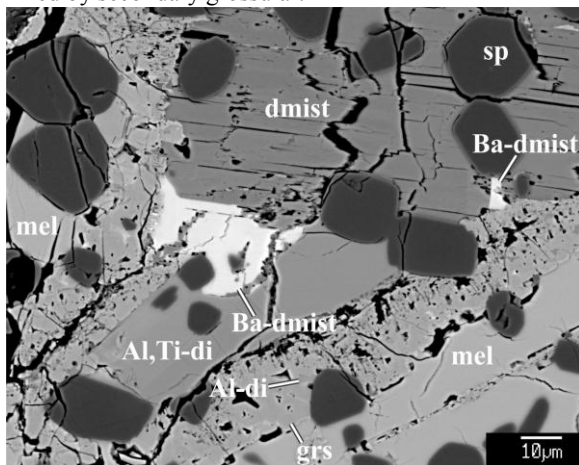


Fig. 5. BSE image showing dmisteinbergite, Ba-rich dmisteinbergite, melilite, spinel, and Al,Ti-diopside in *STP-1*. Melilite is partly replaced by grossular (grs) and Ti-free Al-diopside (Al-di).

Dmisteinbergite is colorless and transparent, with a chemical composition of (wt%) SiO₂ 42.6, Al₂O₃ 36.9, CaO 20.2, MgO 0.05, sum 99.8, and empirical formula of Ca_{1.01}Al_{1.96}Si_{2.02}O₈. One dmisteinbergite grain has two Ba-rich domains with a chemical composition of (wt%) SiO₂ 38.2, Al₂O₃ 35.3, CaO 13.5, MgO 0.13, BaO 11.4, Na₂O 0.21, sum 98.7, and empirical formula of (Ca_{0.74}Ba_{0.27})Al_{1.93}Si_{2.05}O₈ (Fig. 5).

EBSD patterns of dmisteinbergite were obtained, which can only be indexed using the hexagonal CaAl₂Si₂O₈ structure and this yields a best fit based on synthetic CaAl₂Si₂O₈ [5] (Fig. 6). The Allende dmisteinbergite has Space Group: *P6₃/mcm*, showing *a* = 5.10 Å, *c* = 14.72 Å, and *Z* = 2.

Origin of dmisteinbergite: Dmisteinbergite in *STP-1* could have crystallized from a silicate melt at high temperature (~1200–1400°C) via rapid cooling.

Prior to its crystallization, the melt experienced evaporation at low total pressure that resulted in mass-dependent fractionation of oxygen and magnesium isotopes [1]. Dmisteinbergite is metastable and partly transformed to anorthite, possibly during subsequent reheating. The CAI experienced relatively minor secondary alteration on the Allende parent asteroid that resulted in formation of grossular, Al-diopside, Na-bearing plagioclase, nepheline, and sodalite.

Dmisteinbergite is a new member of refractory silicates, joining the refractory silicates melilite, Al,Ti-diopside, anorthite, davisite, grossmanite, kushiroite, eringaite, and thortveitite.

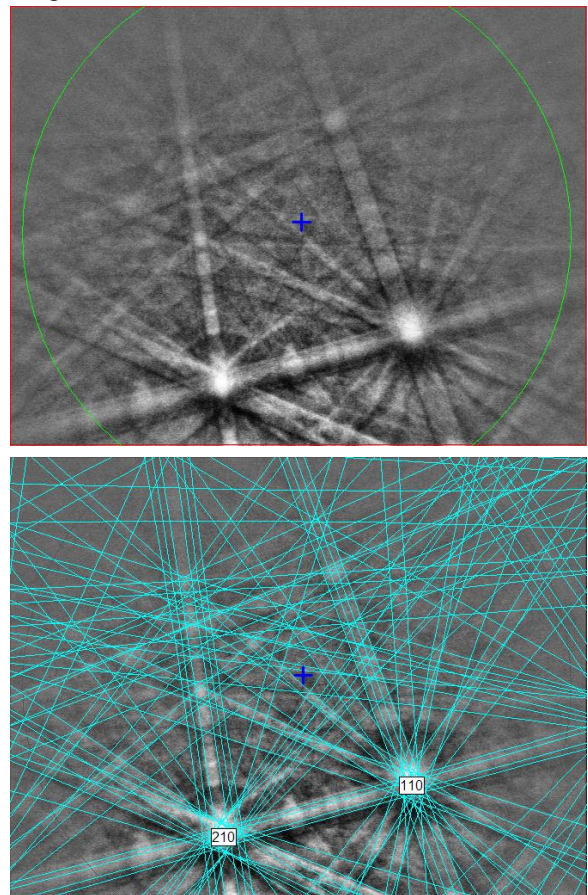


Fig. 6. (top) EBSD pattern of one dmisteinbergite crystal from Allende; (bottom) the same pattern indexed with the *P6₃/mcm* structure of synthetic CaAl₂Si₂O₈.

References: [1] Holst J. C. et al. 2012. *Meteoritics & Planetary Science*, #5223. [2] Chesnokov B. V. et al. 1990. *Zap. Vses. Mineral. Obshch.* 119:43. [3] Nestola F. et al. 2010. *American Mineralogist* 95:405. [4] Abe T. et al. 1991. *Physics & Chemistry of Minerals* 17:473. [5] Takeuchi Y. and Donnay G. 1959. *Acta Crystallographica* 12:465.