

## **Majindeite, $\text{Mg}_2\text{Mo}_3\text{O}_8$ , a new mineral from the Allende meteorite and a witness to post-crystallization oxidation of a Ca-Al-rich refractory inclusion**

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### **ABSTRACT**

Majindeite (IMA 2012-079),  $\text{Mg}_2\text{Mo}_3\text{O}_8$ , is a new mineral, occurring as submicrometer-sized crystals with Ni-Fe and Ru-Os-Ir alloys,  $\pm$  apatite and Nb-oxide. The observed assemblages are partially or wholly enclosed by  $\text{MgAl}_2\text{O}_4$  spinel in a Type B1 Ca-Al-rich inclusion, *ACM-2*, from the Allende CV3 carbonaceous chondrite. The type majindeite has an empirical formula of  $(\text{Mg}_{1.57}\text{Fe}_{0.43})\text{Mo}_{3.00}\text{O}_8$ , and a nolanite-type *P6<sub>3</sub>mc* structure with  $a = 5.778 \text{ \AA}$ ,  $c = 9.904 \text{ \AA}$ ,  $V = 286.35 \text{ \AA}^3$ , and  $Z = 2$ , leading to a calculated density of  $5.54 \text{ g/cm}^3$ .

Majindeite likely formed during the subsolidus oxidation of Mo-rich precursor phase(s) included in Fe-Ni rich alloys in a system that was open to O, Mg, and Ca, which were derived externally and introduced via cracks, subgrain boundaries, and/or surfaces exposed at the exterior of the spinel. If magnetite existed in the phase assemblage, it was lost due to Fe volatilization prior to the formation of majindeite. The immediate precursor to majindeite was likely kamiokite. Majindeite formed during an oxidation event contemporaneous with or postdating the formation of grossular-rich veins in melilite.

Kamiokite, the Fe-rich analog of majindeite, also occurs in *ACM-2* but only within phase assemblages that contain magnetite and which are entirely enclosed in melilite  $\pm$  alteration products. Here, grossular-rich veins are not observed and the coexisting awaruites are more Fe-rich than those observed with majindeite. As with majindeite, the precursors for kamiokite grains were also likely to have been Mo-rich alloys, but the Mo-oxide remained magnetite-saturated throughout the alteration process and therefore remained Fe-rich.

**Keywords:** Majindeite,  $\text{Mg}_2\text{Mo}_3\text{O}_8$ , new mineral, kamiokite group, Allende meteorite, CV3 carbonaceous chondrite, EBSD, Ca-Al-rich inclusions