POLYHEDRAL SERPENTINE GRAINS IN CM CHONDRITES. Thomas J. Zega[1], Laurence A. J. Garvie[2], István Dódony[2], Rhonda M. Stroud[1], and Peter R. Buseck[2,3]. [1]Naval Research Laboratory, Code 6360, 4555 Overlook Avenue SW, Washington, D.C. 20375. [2]Department of Geological Sciences and [3]Department of Chemistry and Biochemistry, Arizona State University, Tempe, AZ 85287-1404. (tzega@nrl.navy.mil).

Introduction: CM chondrites are primitive rocks that experienced aqueous alteration in the early solar system. Their matrices and fine-grained rims (FGRs) sustained the effects of alteration, and the minerals within them hold clues to the aqueous reactions. Sheet silicates are an important product of alteration, and those of the serpentine group are abundant in the CM2 chondrites. Here we expand on our previous efforts to characterize the structure and chemistry of serpentines in CM chondrites [1-3] and report results on a polyhedral form that is structurally similar to polygonal serpentine.

Polygonal serpentine consists of tetrahedral (T) sheets joined to M^{2+}-centered octahedral (O) sheets (where M^{2+} is primarily Mg^{2+} and Fe^{2+}), which give rise to a 1:1 (TO) layered structure with a 0.7-nm layer periodicity. The structure is similar to chrysotile in that it consists of concentric lizardite layers wrapped around the fiber axis. However, unlike the rolled-up chrysotile, the tetrahedral sheets of the lizardite layers are periodically inverted and kinked, producing sectors. The relative angles between sectors result in 15- and 30-sided polygons in terrestrial samples, e.g., [4-6].

Samples and Analytical Methods: We examined several grains from the FGRs and matrices of the Mighei and Cold Bokkeveld CM chondrites. Samples were prepared by either extracting areas of interest from petrographic thin section and ion milling them to electron transparency (see [1] for details) or gently disaggregating and dispersing cm-sized chips onto lacey carbon transmission electron microscope (TEM) grids (see [3] for a description). TEM data were acquired using a 400 keV JEOL 4000EX TEM and 200 keV JEOL 2010F. High-resolution secondary-electron images were acquired with a Hitachi S-4700 field-emission-gun scanning electron microscope (FEG-SEM).

Results: TEM images show that the polyhedral material occurs both isolated and in combination with other polyhedral grains, serpentine nanotubes, a chrysotile-like phase, and cronstedtite. The absolute abundance is difficult to estimate, but the polyhedral material is relatively less abundant than other serpentine-group minerals such as cronstedtite and the chrysotile-like phase. Some grains have nearly complete polygonal cross sections (Fig. 1a), whereas others appear to be intergrown or partially formed (Fig. 1b). Measurements on the high-resolution TEM images indicate that the angles between sectors range from 13.5º to 27.5º. Grain diameters range from tens to hundreds of nano-

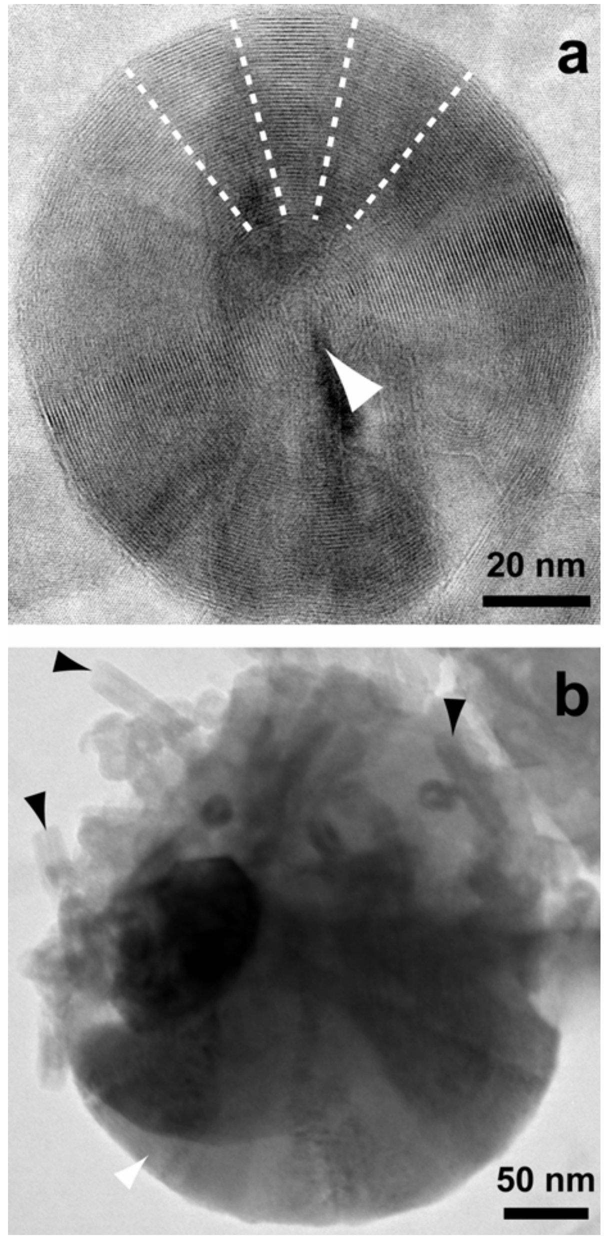

Figure 1 TEM images of the polyhedral material from the Mighei CM chondrite. (**a**) Sectors (dashed lines) occur around the fiber axis (arrowhead). (**b**) Partially formed grain. Serpentine nanotubes (black arrowheads) occur with the polyhedral material (white arrowhead).

meters, and the FEG-SEM images show that the grains have a spherical to sub-spherical morphology (Fig. 2). Many grains are rich in Mg with up to 2 at% Fe [1].

Discussion: Terrestrial polygonal serpentines contain either 15 or 30 sectors with angles of 24º±3º and 12º±3º between them, respectively [4]. Chisholm [7] suggested that a grain in off-axis orientation or one with an incomplete structure could explain the ±3º deviation in terrestrial samples. Although we do observe grains in off-axis orientation and those with incomplete structures, the angles that we measure in some of them deviate beyond those reported for the terrestrial samples. For example, the angles between two adjacent sectors from a disordered grain in Cold Bokkeveld measure 14º and 22º. We hypothesize that the composition partly contributes to the measured deviations. The Fe in these chondritic grains probably substitutes in Mg sites and contributes to the disorder and measured deviations.

TEM images reveal that the polyhedral material is among the coarsest-grained sheet silicates in the CM chondrites that we have analyzed and compositional measurements indicate that it is the richest in Mg [1-3]. In our report on serpentine nanotubes [3] we suggested a possible reaction sequence for CM chondrites that parallels bulk compositional trends [9] and previous mineralogic observations [10]. This sequence, in order of increasing Mg concentration, consists of cronstedtite, serpentine nanotubes, a chrysotile-like phase, and polygonal serpentine. We propose that there is a correlation between the composition and grain size of the polyhedral material in CM chondrites.

The coarse-grained polyhedral material appears to be a stable end-member serpentine product in the alteration sequence. This observation is surprising given the level of brecciation that many CM chondrites have sustained and the compactness of the grains in some FGRs and matrices as evident from SEM images [1,11]. If supported by additional observations, then the presence of the polyhedral material is an indicator of intensive aqueous alteration and also perhaps the lack of extensive regolith gardening that could have fragmented such grains.

The morphology of the polyhedral material is intriguing. Plate-like, layered, and tubular serpentine are common in terrestrial environments [6] and were also observed in the CM chondrites [1-3, 12-15]. To our knowledge, spherical and sub-spherical forms of serpentine have not been reported, and perhaps this morphology is unique to the CM chondrites, e.g., growth in a porous, strain-free or low-gravity environment.

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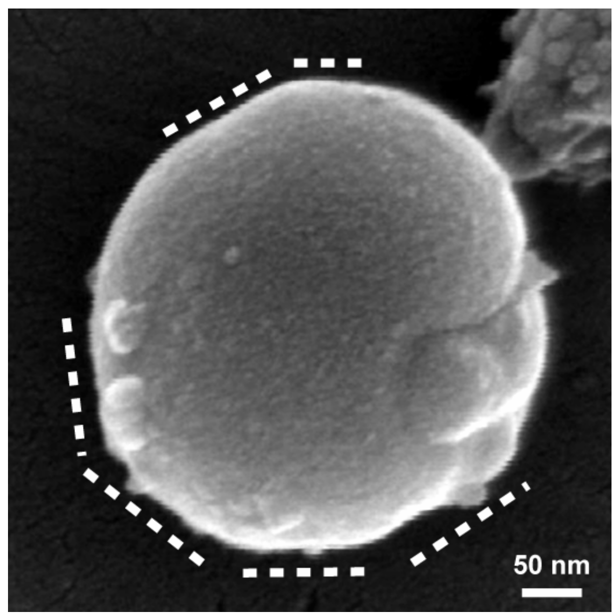

Figure 2 Secondary-electron FEG-SEM image of a polyhedral grain from the Cold Bokkeveld CM chondrite. The sectors (outlined by dashed lines) are visible on the exterior of the grain.