MAGNETITE IN CARBONACEOUS CHONDRITES Xin Hua and Peter R. Buseck, Depts. of Geology and Chemistry & Biochemistry, Arizona State University, Tempe, AZ 85287-1404, USA.

INTRODUCTION: Magnetite (Fe_3O_4) occurs in many carbonaceous chondrites (CCs) and has long attracted the attention of meteorite researchers (Jedwab, 1971; Kerridge et al., 1979; Tomeoka et al., 1989; Löhn and El Goresy, 1992; Weisberg et al., 1993). However, its origin is unresolved; suggestions range from condensates from the solar nebular (Jedwab, 1971) to products from aqueous alteration on the meteorite parent body (Kerridge et al., 1979). The report of possible evidence of former life in ancient Martian meteorite ALH84001 suggested an additional and highly intriguing origin for certain meteoritic magnetite, namely as magnetosomes from bacteria (McKay et al., 1996). However, a recent publication reports TEM evidence of spiral defects running through some of the the magnetite in ALHA84001(Bradley et al., 1996), which they interpret as evidence for a high-temperature origin. These studies provide special interest to the occurrence of magnetite in meteorites. Using scanning electron microscopy (SEM), we studied magnetite from the Orgueil (CI), Murchison (CM), and Kaba and Mokoia (CVs) meteorites and obtained images at a nm-scale. We also did EMPA measurements to determine the compositions of the magnetite and surrounding minerals.

OBSERVATIONS: We observed several morphological types of magnetite in CC matrices: 1) relatively isolated spherules up to 30 µm in diameter, 2) framboidal clusters with individual crystals roughly 200 nm in diameter, and 3) plaquettes that appear like identical stacked discs. The plaquette and framboidal magnetites occur in clusters within voids in the matrix. In some cases uniformly sized framboidal grains are enclosed within larger spheres, and different spheres contain different-sized framboids. The smallest framboids are arranged in close-packed configurations (Fig. 1). All three types can occur together, either in veinlets or embedded in the fine-grained inclusions that appear darker in back-scattered electron images than their surrounding matrix. These veinlets and inclusions also contain hydrated carbonates, hydrated sulfates, or both.

Using SEM with a field-emission-gun, we obtained high-resolution images of the magnetite. The smaller framboids tend to cluster, but they can also occur on the stacked discs or sticking between adjacent discs. Some of the framboidal grains are perfect trapezohedral crystals (Fig. 2). The spacing between adjacent discs is constant (~250 nm); there is the suggestion that they grew by a spiral mechanism (Fig. 3). We also observed a sphere consisting of radiating needle-shaped crystals, with magnetite framboids sitting on the surface of the sphere. Some areas show chains of round craters from which the magnetite framboids were apparently displaced (Fig. 4).

EMPA data show that all these types of magnetite contain no detectable elements other than iron and oxygen, which occur in approximate stoichiometric proportions. The neighboring carbonates and sulfates have low totals (from 50 to 90 wt %) and were damaged by the electron beam, suggesting they are hydrated.

DISCUSSION: Even as a result of this relatively cursory examination of a few meteorites, it is evident that a rich variety of magnetite morphologies occurs. It remains to be determined what type, if any, of genetic information can be gleaned from this richness. This work was done several years prior to the report of evidence of possible life in ALHA84001, and so we did not emphasize crystals in the smallest size range, comparable to the single-domain magnetite reported by McKay et al. We do not wish to suggest that the forms illustrated and discussed here necessarily have any relation to a biogenic origin, but we believe – and intend to test – whether similar or other types of distinctive features can be found in magnetites from bacteria.

REFERENCES: (1) Jedwab (1971) Icarus 15, 319-340, (2) Kerridge et al. (1979) Science 205, 395-397, (3) Tomeoka et al. (1989) Proceedings NIPR Symposium on Antarctic Meteorites 2, 36-54, (4) Löhn and Goresy (1992) Meteoritics 27, 252, (5) Weisberg et al. (1993) GCA 57, 1567-1586, (6) McKay et al. (1996) Science 273, 924-930, (7) Bradley et al. (1996) GCA 60.

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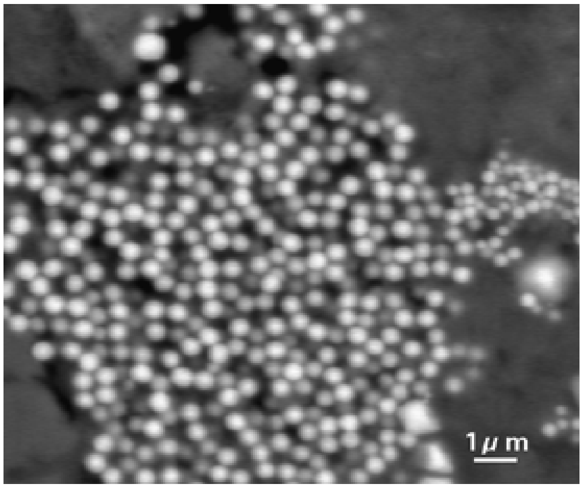

Fig. 1

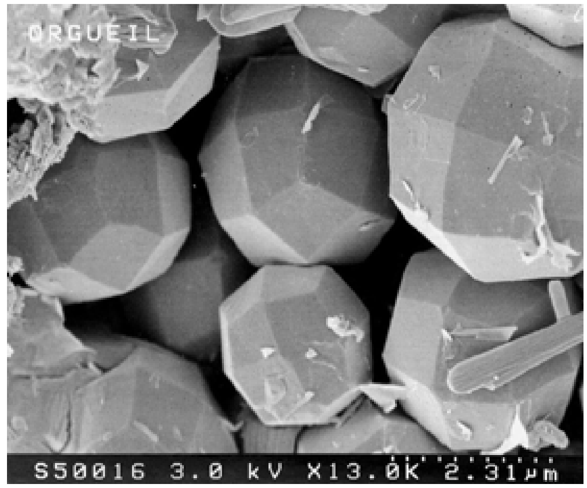

Fig. 2

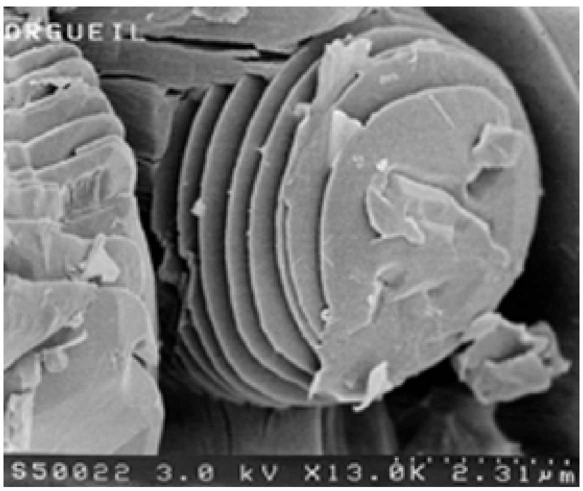

Fig. 3

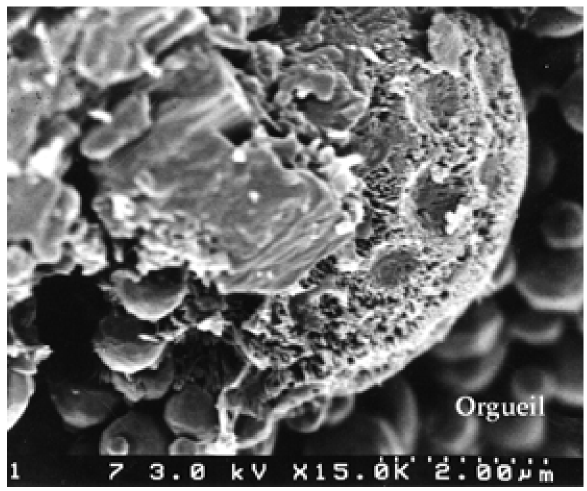

Fig. 4