HIGH RESOLUTION ELECTRON MICROSCOPY OF CARBONACEOUS MATERIAL FROM CI, CM, CV, AND H CHONDRITES. Gregory R. Lumpkin, Department of Geology, University of New Mexico, Albuquerque, NM 87131.

INTRODUCTION. Carbonaceous material is a major carrier of planetary and anomalous noble gases in several classes of meteorites (1,2). As a result, it is of interest to examine the microstructures and degree of graphitization of the carbonaceous matter. Such information is valuable for postulating possible origins, thermal histories, and noble gas trapping sites within meteoritic carbon. This paper summarizes the results of combined high resolution TEM (HRTEM) and electron diffraction work on Orgueil, Cold Bokkeveld, Murchison, Allende, and Dimmitt.

EXPERIMENTAL METHODS. Acid residues of five meteorites were dispersed in methanol and deposited on holey carbon grids. Samples were studied with a JEOL 2000FX TEM operated at 200 keV. High resolution images were taken at 410,000 or 500,000X and enlarged photographically by another 5X. Electron diffraction patterns were calibrated using a polycrystalline gold standard.

RESULTS. Low resolution TEM work on Orgueil, Cold Bokkeveld, and Allende (3,4,5) has been extended to include Murchison and Dimmitt. On this basis carbonaceous matter can be broadly classified as: 1) Irregular clumps with amorphous to moderately developed turbostratic structure. 2) Carbon grains with a circular to subcircular morphology and a poorly developed turbostratic structure. 3) Circular to polygonal carbon black-like particles and aggregates with well developed turbostratic structure and concentric microstructures. 4) Polycrystalline sheets of partially ordered graphite. 5) Hexagonal crystals of highly ordered graphite. Results for each meteorite are given below.

<u>Orgueil CI1</u>. Most of the carbonaceous matter occurs as irregular clumps with d(002) = 3.8Å. HRTEM images show that this material has an amorphous to poorly developed turbostratic structure. Maximum crystallite dimensions are L(a) = 30Å and L(c) = 15Å. Circular grains have a poorly developed, tangled ribbon microstructure with d(002) = 3.6Å. They constitute about 10% of the total amount of carbonaceous material. Very rare carbon black-like particles and polycrystalline sheets were observed. The carbon black-like particles have the characteristic concentric microstructure and d(002) = 3.42Å.

<u>Cold Bokkeveld CM2</u>. Carbonaceous material closely resembles that from Orgueil. Irregular carbonaceous clumps having d(002) = 3.7Å are predominant. The structure consists of amorphous material plus poorly developed turbostratic crystallites as revealed by HRTEM. Circular grains are similar in abundance and microstructure to those from Orgueil. Carbon black-like aggregates are a rare component of Cold Bokkeveld carbonaceous matter. They have a concentric microstructure, d(002) = 3.43Å, and maximum crystallite dimensions of L(a) = 250Å and L(c) = 100Å.

<u>Murchison CM2</u>. Carbonaceous material differs from Orgueil and Cold Bokkeveld in having a higher proportion of turbostratic crystallites within the irregular clumps. This results in a lower d(002) value of 3.57Å and

larger maximum crystallite dimensions of L(a) = 50Å and L(c) = 20Å. Circular grains are comparable to those in Orgueil and Cold Bokkeveld. A rare component having d(002) = 3.38Å was also observed. HRTEM shows that the microstructure is transitional between carbon black-like aggregates and polycrystalline sheets. Crystallite dimensions approach L(a) = 500Å and L(c) = 200Å. Edge dislocations and kinks are common.

Allende CV3. Most of the Allende carbon consists of irregular clumps of material having d(002) = 3.50Å. HRTEM images reveal a tangled ribbon microstructure with little or no amorphous carbon, consistent with previous work (6,7). Crystallite dimensions are on the order of L(a) = 150Å and L(c) = 30Å. A small amount of circular grains were observed. They also have a tangled ribbon microstructure with d(002) = 3.55Å. The crystallites tend to be smaller than those noted above. Another minor carbon component is polycrystalline, partially ordered graphite having d(002) = 3.40Å. Maximum crystallite dimensions of this material approach L(a) = 400Å and L(c) = 100Å. Rare carbon black-like particles with a concentric microstructure were also observed, similar to those found in an earlier HRTEM study (6).

Dimmitt H3,4. Two types of carbon were found in the acid residue of Dimmitt. The major form occurs as polycrystalline sheets of partially ordered graphite with d(002) = 3.38Å. Estimated crystallite dimensions from (002), (100), and (110) diffraction rings are L(a) = 360Å and L(c) = 80Å. These are in general agreement with (002) and (100) dark field images. Lattice fringes were only seen in HRTEM images taken at the curled edges of the sheets. Edges consist of 10-30 sp^2 hybridized layer planes with occasional edge dislocations and kinks. A minor carbon component is represented by micrometer sized graphite single crystals which give hexagonal [001] diffraction patterns. The crystals are presumably very highly ordered.

SUMMARY. CI and CM meteorite carbonaceous matter consists predominantly of irregular clumps having both amorphous and poorly developed turbostratic structures. Both meteorite classes contain a minor amount of circular grains which have an incipient tangled ribbon microstructure. Carbon black-like particles and aggregates, and polycrystalline sheets are rare. CV (Allende) carbon consists mainly of irregular clumps which have a tangled ribbon microstructure. Circular grains are also present and have a similar microstructure. Polycrystalline graphite is a minor component and carbon black-like particles are rare. The H chondrite Dimmitt contains polycrystalline graphite plus minor, micrometer sized, hexagonal single crystals of graphite.

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