BIOGENIC MARTIAN MAGNETITE CRYSTALS? A COMPARISON OF PRISMATIC MAGNETITE CRYSTALS IN THE ALLAN HILLS 84001 CARBONATE GLOBULES WITH THOSE FROM MAGNETOTACTIC BACTERIA STRAIN MV-1. K. L. Thomas-Keprta[1], S. J. Clemett[1], D. A. Bazylinski[2], J. L. Kirschvink[3], D. S. McKay[4], S. J. Wentworth[1], H. Vali[5] and E. K. Gibson[4], [1]Lockheed Martin, Mail Code C-23, NASA Johnson Space Center, Houston, TX, 77058, USA (kthomas@ems.jsc.nasa.gov), [2]Iowa State University, Ames, IA 50011, USA, [3]California Institute of Technology, Pasadena, CA 91125, USA, [4]NASA Johnson Space Center, Mail Code SN, Houston, TX 77058, USA, [5]McGill University, Quebec H3A2A7, Canada.

McKay et al. [1] suggested that the fine-grained magnetite (Fe_3O_4) located within Fe-rich rims surrounding the carbonate globules in the Martian meteorite ALH84001 might be the fossil remains of Martian micro-organisms. This work is an extension of previous studies [e.g., 2] that showed magnetite particles (594) extracted from the ALH84001 carbonate globules can be grouped into three distinct subpopulations: *irregular* (389; cuboidal, teardrop, and other irregular forms), *prismatic* (164; euhedral to slightly elongated crystals that have hexagonal cross-sections when viewed along the elongation axis [111 direction] and appear approximately rectangular when viewed along the other two perpendicular axes), and *whisker-like* (41; distinct from the other two groups).

As a possible terrestrial analog for the ALH84001 elongated prisms, we compared these magnetites with those produced by the terrestrial magnetotactic bacteria strain MV-1. By TEM again, we examined 206 magnetites recovered from strain MV-1 cells. Natural (Darwinian) selection in terrestrial magnetotactic bacteria appears to have resulted in the formation of intracellular magnetite crystals having the physical and chemical properties that optimize their magnetic moment. Here we describe six properties of magnetite produced by magnetotactic bacteria, properties that, collectively, are not observed in any known population of inorganic magnetites. These properties are: (1) sizes in the superparamagnetic to single-domain range and restricted anisotropic width/length (W/L) ratios, (2) chemical purity, (3) lack of defects except for occasional twinning, (4) alignment in chains, (5) unusual crystal morphologies, and (6) elongation along [111] axis. These criteria can be used to distinguish one of the modes of origin for magnetites from samples with complex or unknown histories. Of the ALH84001 magnetites that we have examined, the elongated prismatic magnetite particles (~27% of the total) are indistinguishable from the MV-1 magnetites in five of these six characteristics.

Chemistry(criterion 2). The prismatic ALH84001 magnetites do not appear to contain any transition elements and are chemically pure at levels >few hundred ppm in contrast to ALH84001 irregular and whisker-like crystals which commonly contained Al and/or Cr. The MV-1 biogenic magnetites were composed only of Fe and O with no Al or Cr.

Morphology (Criteria 3,5,6). Like MV-1, TEM images of individual ALH84001 prismatic magnetites show a high degree of crystal perfection, are elongated along the [111] axis, and display an unusual morphology, which is technically described as hexaoctahedral (eight {111} octahedral faces and six {110} hexagonal faces). Particles with this morphology have approximately hexagonal or cubic image projections at different angles of tilt. Faceted ends are present on each end and are rotationally offset from the facets at the other end by $\pi/3$ radians.

Size Distribution and W/L Ratios (Criterion 1). We have used rigorous mathematical modeling to compare ALH84001 and MV-1 prismatic magnetites in order to correct for geometric distortions that occur when a three-dimensional (3-D) object is projected onto a two-dimensional (2-D) image plane using TEM. The martian prismatic magnetites appear to be statistically indistinguishable from those of MV-1. Prismatic (hexaoctahedral) magnetite crystals in ALH84001, like the biogenic MV-1 magnetites have a restricted size range (superparamagnetic to single-domain) and size distribution that violates a log-normal distribution.

Summary: The similarity between the Martian prismatic magnetites and those from the terrestrial bacteria strain MV-1 is striking. The ALH84001 elongated prisms (hexaoctahedral) display five of the six criteria required for their interpretation as biogenic. We note that the ALH84001 irregular and whisker magnetites display only one or two of these criteria and thus likely formed by inorganic processes. Given the complexity of the ALH84001 meteorite, we believe that more than one process was responsible for the presence of magnetite in the carbonate globules. Therefore, many processes contributed to what is now observed. One of these processes produced magnetite in ALH84001, that in a terrestrial context, would be defined as biogenic.

Mathematical equations will be furnished upon request and at the conference.

References: [1] McKay D. S. et al. (1996) *Science, 273*, 924. [2] Thomas-Keprta K. L. et al. (2000) in press.