EXPERIMENTAL SHOCK DECOMPOSITION OF SIDERITE TO MAGNETITE. M. S. Bell[1], Golden, D.C. [2], and Zolensky, M.E.[3]; [1]University of Houston/Lockheed Martin, Houston, TX 77058, mary.sue.bell1@jsc.nasa.gov , [2] Hernandez Engineering Inc., Houston, TX, [3]NASA Johnson Space Center, KT, Houston, TX 77058

Introduction: The debate about fossil life on Mars includes the origin of magnetites of specific sizes and habits in the siderite-rich portions of the carbonate spheres in ALH 84001 [1,2]. Specifically [2] were able to demonstrate that inorganic synthesis of these compositionally zoned spheres from aqueous solutions of variable ion-concentrations is possible. They further demonstrated the formation of magnetite from siderite upon heating at 550°C under a Mars-like CO_2-rich atmosphere according to $3FeC0_3 = Fe_30_4 + 2CO_2 + CO$ [3] and they postulated that the carbonates in ALH 84001 were heated to these temperatures by some shock event.

The average shock pressure for ALH 84001, substantially based on the refractive index of diaplectic feldspar glasses [3,4,5] is some 35-40 GPa and associated temperatures are some 300-400°C [4]. However, some of the feldspar is melted [5], requiring local deviations from this average as high as 45-50 GPa. Indeed, [5] observes the carbonates in ALH 84001 to be melted locally, requiring pressures in excess of 60 GPa and temperatures > 600°C. Combining these shock studies with the above inorganic synthesis of zoned carbonates it seems possible to produce the ALH 84001 magnetites by the shock-induced decomposition of siderite.

We are testing this hypothesis experimentally by exposing siderite to experimental shocks. As reported earlier by [6] we produced intimately mixed zones of spinel-structure Fe- and Mg-oxides, based on preliminary transmission electron microscope (TEM) analyses. We have now concentrated magnetic separates from this mix for more detailed identification and characterization of the shock products.

Analytical Methods: Target disks of a naturally occurring siderite (Red Lake, Nova Scotia, Canada: (Mg ~ 13%, Fe ~ 87% with trace Cr and S) were sliced from a single core and encased in W-alloy holders (W=90%, Ni=6%, Cu=4%) to avoid any contribution of Fe from the sample holder to the reaction products. Magnetic susceptibility of our natural siderite was determined as ~8 x 10^{-7} m^3/kg (mid-range for published values, 4-12 x 10^{-7} m^3/kg). This corresponds to < 1.6 ppt of some possible combination of paramagnetic, ferromagnetic, and or diamagnetic minerals in the starting material and is three orders of magnitude less than values for crustal rocks with low magnetic susceptibility [7]. Electron microprobe mapping and back-scattered image surveys of polished siderite starting material sections revealed no localized iron enrichments on the micron scale. Also unshocked powdered siderite was dissolved in acetic acid and the residue was determined to be hematite using Transmission Electron Microscopy (TEM). Also, no magnetite was detected in powdered starting material by Mössbauer spectroscopy.

The samples were shocked at pressures up to 49 GPa at the Johnson Space Center according to the methods of [8,9]. Matrials were extracted from a 49 GPa experiment by hand magnet to be processed in two different ways: 1) an aliquot was immersed in distilled water, sonicated for 5 seconds, and floated onto carbon substrates on copper grids for TEM examination. 2) The other aliquot was treated with acetic acid to dissolve carbonates according to the methods of Golden et al. [3] and also floated onto carbon substrates on copper grids for TEM examination, including bright field, dark field, and SAED (selected area electron diffraction). A JEOL 2000FX

ScanningTEM was operated at 200kV and equipped with NORAN System Six Energy Dispersive X-ray Spectroscopy (EDS). SAED patterns were acquired to identify phases present as the EDS beam size is too large to resolve individual objects in the 50 – 100nm size range.

Results and Conclusions: Magnetite, identified by characteristic d-spacings in SAED patterns from extensive areas, was found in closed system siderite shock experiments at 49 GPa. We believe this magnetite is produced in the shock experiment as no magnetite was detected in the starting material. Another oxide phase, possibly periclase (MgO), was detected but is as yet unverified. Magnetites in the experimental shock product encompass the same range of sizes (10-50nm) and shapes (equant to slightly elongated, euhedral to anhedral) found in ALH84001 (Figure 1). TEM examination of the magnetites before and after the acetic acid treatments indicates that the acid extraction technique did not alter the size and shape of the magnetite crystals.

Devolatilization of the ALH84001 carbonates occurred. Langenhorst et al. [5] found bubbles or channels in ALH84001 carbonates which they interpret to represent shock-induced degassing structures. Brearley [11] describes the presence of magnetites associated with voids in ALH84001 carbonate which could be evidence of CO_2 loss.

Only a few things are known about ALH84001 unequivocally: it was formed at depth on a body other than Earth [12] (probably Mars) and it contains evidence of shock metamorphism requiring 35-40 GPa [4,5]. Impact shock metamorphism, could provide the thermal input to convert siderite to magnetite. In light of these details, a likely mechanism for magnetite formation in ALH84001 is shock devolatilization of iron carbonate.

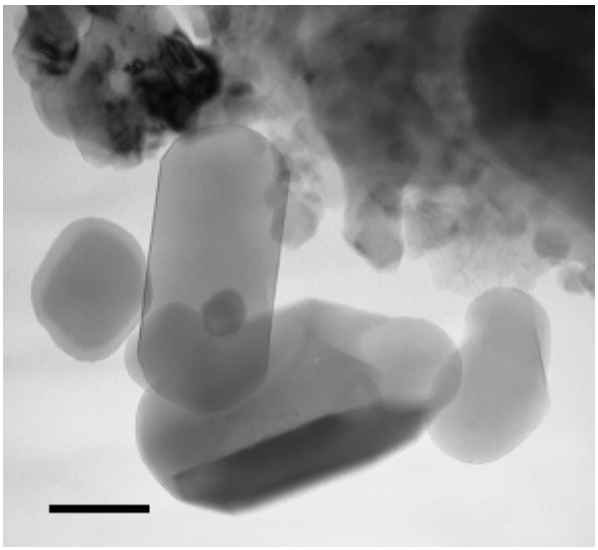

Figure 1. TEM bright-field image of euhedral equant and elongated magnetite produced by experimental shock metamorphism of siderite. Scale bar is 50 nm.

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