

MAGNETITE AND CARBONATE TEXTURES IN ALH84001: EXPERIMENTAL INSIGHTS.

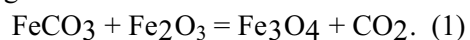
Andrea M. Koziol, Dept. of Geology, University of Dayton, Dayton, OH 45469-2364 USA; koziol@notes.udayton.edu

Introduction: Siderite (FeCO_3) occurs in a number of terrestrial occurrences, usually as a solid-solution component in Fe-Mg carbonates [1, 2]. Its stability is controlled in part by O_2 and CO_2 fugacity. The carbonate globules found in Martian meteorite ALH84001 and the ensuing discussions about their formation have increased interest in iron carbonate minerals. These globules are magnesite-siderite ($\text{MgCO}_3\text{-FeCO}_3$) solid solutions with variable Ca and Mn content [3, 4].

Small magnetite grains occur both in the core and rim of these globules. These grains have been variously interpreted as magnetosomes of biological origin [5, 6], vapor-phase condensation [7], or a by-product of siderite decarbonation due to a later reheating event [8]. The magnetite grains appear to be closely associated with small voids, seen by [5] and [8] using TEM analysis. Thomas-Kepra et al. [9] have recently published a careful study in which they characterize the morphology of magnetite grains from ALH84001. They divide the grains into several sub-groups in an attempt to distinguish modes of origin. A close comparison of one of the subgroups is made to magnetites produced by the terrestrial magnetotactic bacteria strain MV-1. The bacteria produce chemically pure magnetite. A reasonable question is, would magnetite produced inorganically from a magnesium-iron carbonate have minor or trace amounts of Mg?

My research involves producing synthetic magnetite in equilibrium with siderite, hematite (Fe_2O_3) and CO_2 . Recently, I have performed similar experiments with synthetic siderite-magnesite solid solutions. I would like to report here the results of my experiments.

Experimental method: The reaction investigated is:



Experiments on reaction (1) were made in a piston-cylinder apparatus, using procedure similar to those described in [10]. Some experiments were performed in the University of Dayton High Pressure laboratory, which has recently come online. Crystalline starting materials plus silver oxalate ($\text{Ag}_2\text{C}_2\text{O}_4$) as a source of CO_2 were sealed in platinum capsules. Oxygen fugacity was controlled along the hematite-magnetite buffer.

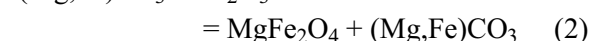
Magnetite + CO_2 stability was indicated by a CO_2 yield at least 20% larger than expected from $\text{Ag}_2\text{C}_2\text{O}_4$ decomposition and significant growth in magnetite as shown by powder XRD scan of the solid charge. Conversely, siderite + hematite stability was shown by a 20% reduction in CO_2 yield and significant growth of siderite by powder XRD.

In a later set of experiments, a synthetic carbonate of composition 60% siderite, 40% magnesite was equilibrated with hematite, magnetite, and CO_2 in similar experiments. Synthesis of the carbonate is described in [11].

Results: *End-member siderite.* Experiments on reaction (1) involving pure siderite are shown in figure 1. In most experiments X-ray analysis confirmed the weight-loss data. No new phases were detected in the experimental charges.

Fe-Mg carbonate. Siderite₆₀magnesite₄₀ carbonate was equilibrated in this assemblage at 11 kilobars pressure and 660 deg C for several days, conditions at which carbonate should have broken down and magnetite formed. However, there was no apparent reaction detected by the methods described above. X-ray diffraction analysis and SEM imaging revealed that no hematite remained in the experimental charge.

Discussion: An earlier abstract [12] hypothesized that magnesioferrite (MgFe_2O_4) (Fe is ferric) formed during these experiments by the reaction:



where the carbonate becomes more Fe-rich during the experiment. Magnesioferrite spinel would be indistinguishable from magnetite in an XRD scan. However, EDS analysis during later SEM imaging revealed that no magnesioferrite was present.

Previous investigations of siderite's thermal decomposition have been performed at room pressure and reducing conditions, or in a near-vacuum [13, 14]. Pure siderite decomposes to magnetite, and Fe-Mg carbonates decarbonate to form a magnesio-wüstite phase.

Figure 2 is a backscatter electron image of a portion of the solid solution experimental products. This charge was a slightly sintered powder. Bright grains are magnetite; dark gray grains are

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the solid solution carbonate phase. No hematite is visible. Two grain sizes of magnetite are apparent. There appears to be some differential shading in the magnetite grains but no magnesium is present, according to EDS.

It is still unclear why hematite is not stable at these conditions, as the hematite/magnetite buffer assemblage was still present in the outer capsule. Further SEM and TEM work is in progress to examine the fine scale texture of these experimental products. Hopefully, a comparison to the work of [9] can be made.

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Figure 1: Pressure-temperature diagram showing experimental determination of the reaction siderite + hematite = magnetite + CO₂. Open symbols: siderite + hematite stable. Filled symbols: magnetite + CO₂ stable. Also shown is the calculated curve using the dataset of Holland and Powell [15].

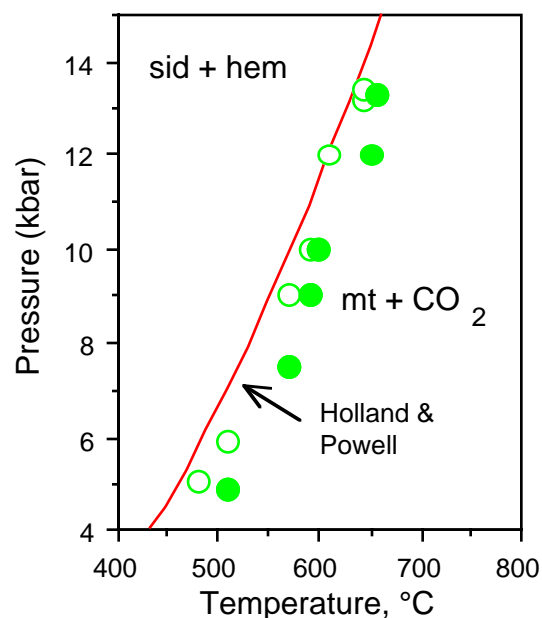


Figure 2. (Below) Backscatter electron image of experimental product (described in text) obtained on a JEOL JSM 840A in conjunction with an Oxford ISIS energy dispersive X-ray detection system. Scale bar is 10 microns long. Bright phase: magnetite. Dark gray phase: Fe-Mg carbonate. Accelerating voltage: 15 KV.

