

## HEMATITE FORMED FROM PYROXENE ON MARS BY METEORITIC IMPACT;

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### INTRODUCTION

In earlier work [1,2], we showed using Mössbauer data that the mineralogy of iron-bearing phases in impact melt rocks from Manicouagan Crater (Quebec, Canada) is to a first approximation hematite and pyroxene. The visible and near-IR reflectivity data for these impact melt rocks show a continuous trend in band position from ~850 to ~1000 nm, which corresponds to the positions for the hematite and pyroxene endmembers, respectively. The oxidation is thought to occur shortly after the impact when oxidizing vapors and/or solutions reacted with the impact melt which was below its solidus temperature but still relatively hot [3]. The reflectance data have important implications for Mars because band positions which occur between the ~850 and 1000 nm bands observed for Mars [e.g., 4] can be attributed to hematite-pyroxene assemblages and not necessarily to a different ferric mineralogy.

Because oxidation of impact melt rocks at Manicouagan is thought to occur subsolidus, precursors for the hematite include oxides such as magnetite and ilmenite and silicates such as pyroxene and olivine. To determine if the Manicouagan impact-melt rocks are related to each other by simple thermal subsolidus oxidation, we calcined in air a relatively unoxidized Manicouagan impact-melt rock (MAN-74-608A). Previous work has shown that np-Hm (nanophase hematite) particles can be derived by calcination of iron-bearing silicates [e.g., 5].

### RESULTS AND DISCUSSION

Reflectivity spectra for unheated and heated impact-melt samples are shown in Figure 1. The original, unheated impact-melt rock shows absorption features centered near 970 and 1900 nm which result from ferrous iron and are diagnostic of pyroxene. No features diagnostic of ferric iron, except perhaps for a very weak feature near 500 nm, are seen in the spectrum. Upon heating, the spectrum of this sample shows a remarkable evolution from ferrous- to ferric-dominated character. At 400°C, the 970 and 1900 nm features are essentially unchanged, but the visible color of the sample is substantially reddened. This reddening is caused by ferrous to ferric conversion in the sample and the resulting spectral effects of the very strong ferric absorption edge near 550 nm. By 500°C, there has been enough ferrous to ferric conversion to begin to see evidence for the  $Fe^{3+}$  crystal field transition bands near 660 nm and 860 nm and the distinct absorption edge at 550 nm. These spectral features are characteristic of crystalline hematite [6]. At 800°C, the ferric features are even stronger and the entire spectrum short of 1600 nm appears reddened because of an increase in reflectivity at the longest wavelengths. Evidence for the 1900 nm pyroxene feature has vanished but there is still a strong indication of pyroxene near 970 nm. Finally, at 1000°C all evidence for  $Fe^{2+}$  absorption features is gone and the spectrum looks like that of a typical hematite. As shown in Figure 2, the changes in iron mineralogy with calcination from a ferrous, pyroxene dominated assemblage to a ferric, hematite dominated assemblage are also observed in the Mössbauer spectra.

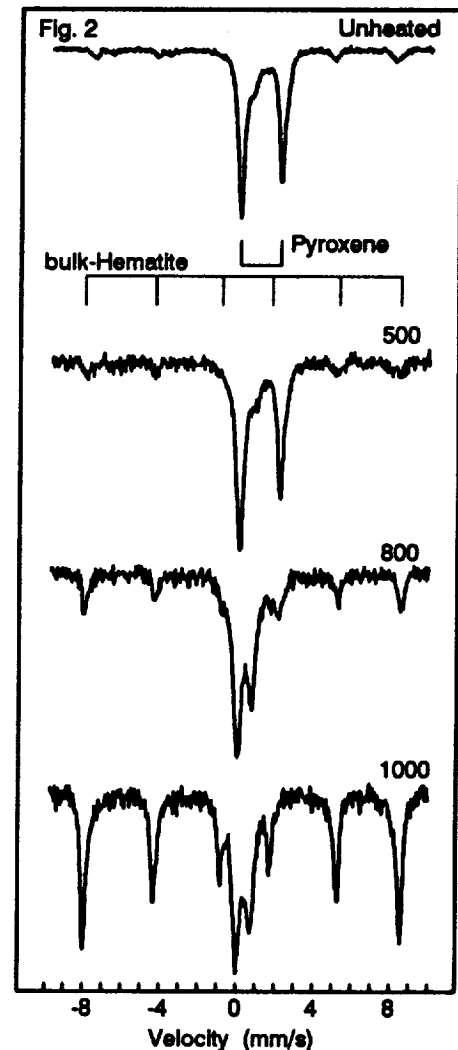
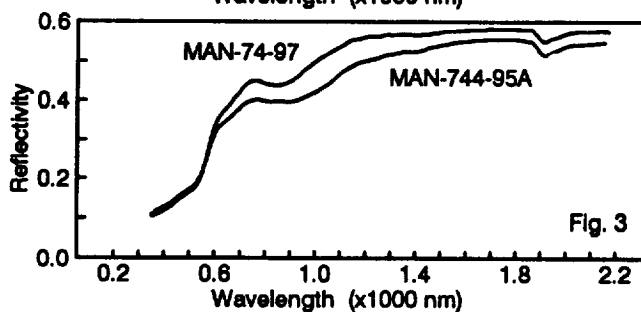
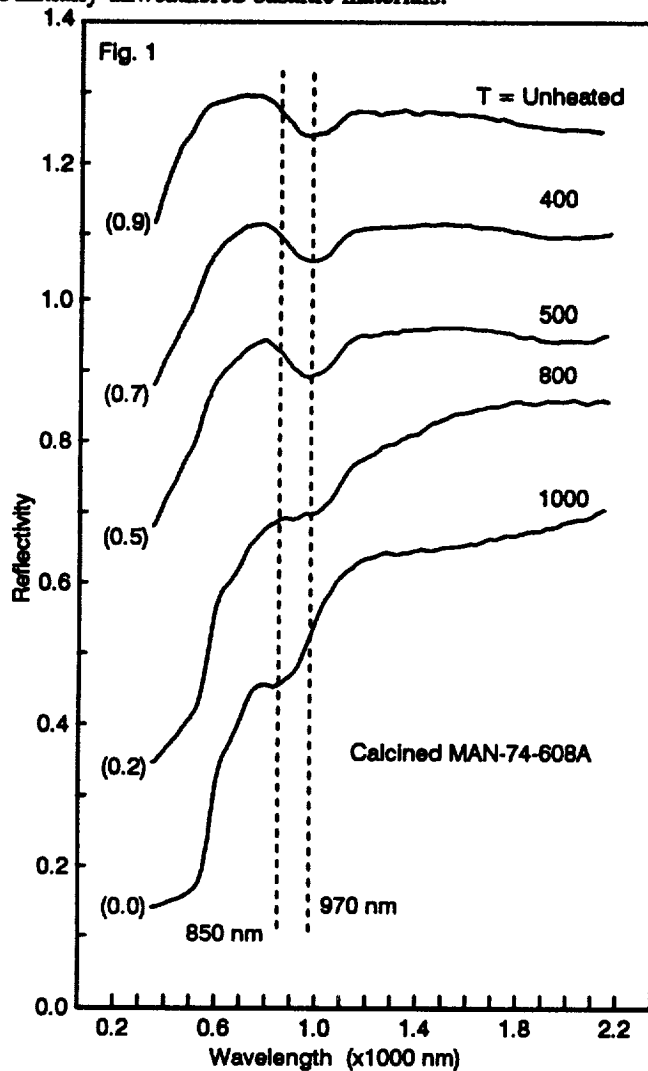
Figure 3 shows reflectivity spectra for two highly oxidized samples of impact-melt rock from Manicouagan. They are very similar to the 800 and 1000°C samples, and demonstrate that the oxidized Manicouagan rocks can be derived from the relatively unoxidized ones by simple thermal oxidation.

The calcination experiments have important implications for the interpretation of Mars reflectance spectra. Recent analyses of Phobos-2 ISM spectra of Mars [4] have revealed a class of surface materials exhibiting spectra with absorption band centers transitional between the 860 nm and 980 nm endmember wavelengths observed for most classical bright and dark regions, respectively. [4] favor the interpretation of these spectra as indicating the presence of an additional ferric oxyhydroxide phase (such as goethite or ferrihydrite). We advocate here and previously [1,2] an alternate hypothesis: that the band center wavelengths may be transitional because the spectra represent intimate assemblages of hematite and pyroxene analogous to the Manicouagan impact-melt rocks. Impacts have obviously been an important surface modification and alteration

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process throughout Martian history. For example, [7] has calculated an equivalent global impact-melt layer of 521 m.

An additional likely mechanism for producing mixed hematite-pyroxene spectral signatures from Mars comes from spectroscopic evidence for both hematite and pyroxene occurring alone in specific regions of the Martian surface [4,8]. At the ISM spatial resolution of ~22 km, it is not unreasonable to expect some degree of sub-pixel areal mixing of hematite-dominated and pyroxene-dominated regions on the surface. The Manicouagan samples and our calcination experiments show that these two mineralogies can both be present as a mineral assemblage in oxidized impact-melt rocks. Both the areal mixing and oxidation mechanisms probably take place, although only the latter provides a way (meteoritic impact in an oxidizing environment) of producing hematite from initially unweathered basaltic materials.



References: [1] Morris *et al.*, *LPSC24*, 1015, 1993; [2] Morris *et al.*, *MSATT*, LPI Tech. Rept. 93-06, 30-32, 1993; [3] Floran *et al.*, *JGR*, 83, 2737, 1978; [4] Murchie *et al.*, *Icarus*, 105, 454, 1993; [5] Straub *et al.*, *JGR*, 96, 18830, 1991; [6] Morris *et al.*, *JGR*, 90, 3126, 1985; [7] Clifford, *JGR*, 98, 10973, 1993 [8] Mustard *et al.*, *JGR*, 98, 3387, 1993.