SPECTRAL AND GEOCHEMICAL CHARACTERISTICS OF LAKE SUPERIOR TYPE BANDED IRON FORMATION: ANALOG TO THE MARTIAN HEMATITE OUTCROPS. Alicia Fallacaro[1] and Wendy M. Calvin[1], [1]University of Nevada, Reno.

Introduction: The Thermal Emission Spectrometer (TES) onboard Mars Global Surveyor discovered grey, crystalline hematite based on its fundamental oxide vibrational features at 300, 450, and 525cm^{-1} at Sinus Meridiani (SM), Aram Chaos (AC), and various small outcrops within the Valles Marineris (VM) [1]. One of the proposed formation mechanisms for the grey, crystalline hematite is through precipitation of ferric oxides in iron rich waters as in terrestrial banded iron formation (BIF) [1]. Subsequent burial metamorphism would crystallize the deposit.

Archean earth banded iron formation was first suggested as a possible terrestrial analog for early Mars based on the hypothesis that dark regions on Mars could be chemically altered, containing ferrous clay alteration minerals similar to those in BIF [2]. A recent study of the Mariner 6 and 7 spectra shows increased hydration signatures in the SM and AC hematite regions further supporting an aqueous formation mechanism [3]. Due to the lack of a volcanic source and subsequent volcanic features surrounding the Martian hematite regions, and the increased hydration signatures, a sedimentary, aqueous depositional environment is the preferred interpretation for this research, and thus terrestrial BIF is chosen as an appropriate analog.

Terrestrial BIF: *James (1954)* [4] has defined iron formation as being a chemical sedimentary rock, typically thin banded and/or finely laminated, containing at least 15% iron of sedimentary origin and commonly but not necessarily containing layers of chert. Iron formation consists of four facies: sulfide, carbonate, silicate, and oxide. Their occurrence is controlled by the Eh/pH levels within the depositional environment. A reducing environment precipitates iron sulfide (pyrite), intermediate conditions precipitate iron carbonate (siderite) and iron silicates such as chamosite and stilpnomelane, and an oxidizing environment precipitates iron oxide (hematite). In the Lake Superior BIF, the iron oxide magnetite accompanies the carbonate, silicate, and oxide facies as it is a combination of ferrous (Fe^{2+}) and ferric (Fe^{3+}) iron and precipitates in intermediate to oxidizing conditions. Lake Superior Type BIF differs from other types of BIF due to its sedimentary (rather than volcanic) origin [5].

Samples from the oxide, carbonate, and silicate facies have been collected from Lake Superior Type BIF in northern Michigan from the Marquette and Gogebic iron districts. They have been measured for reflectance in the VNIR/SWIR (0.4 to 2.5 μm) and emittance in the TIR (5 to 50 μm). Geochemical analyses including thin section analysis, X-ray diffraction (XRD), and scanning electron microscopy (SEM) were also performed on the samples to attain more detailed compositional information and to corroborate mineralogy identified with spectroscopy. The minerals composing the separate BIF facies are possible auxiliary minerals to the hematite deposits on Mars. Data collected in this study can be directly compared to data gathered by the Mars Exploration Rover Opportunity (MER-B) at the Meridiani Planum landing site to determine whether or not a banded iron formation like process has occurred. This is significant because it requires the stability of a large body of water for an extended period of time at some point in Mars' history.

Oxide facies. The oxide samples occur in two distinct forms of grey, crystalline hematite along with chert and minor magnetite. The hematite exists as distinct, thin bands alternating with chert bands in typical BIF structure (figure 1), and in a more metamorphosed state as bulk, crystalline hematite with a schistose texture. The schistose samples are also associated with accessory metamorphic minerals.

Figure 1. Photographs of banded oxide sample at the two orientations measured for emission spectra.

The banded oxide samples are dominated by hematite features in the VNIR/SWIR. The emission spectra vary with a hematite versus a banded (cross sectional) face. The banded faces are dominated by quartz features, and the hematite face is dominated by oxide features with weak to non-existent quartz features (figure 2). The schistose samples have much weaker hematite features in the VNIR/SWIR consistent with coarser grained hematite. However, the oxide emission features in the schistose samples are two to three times stronger than in the banded samples.

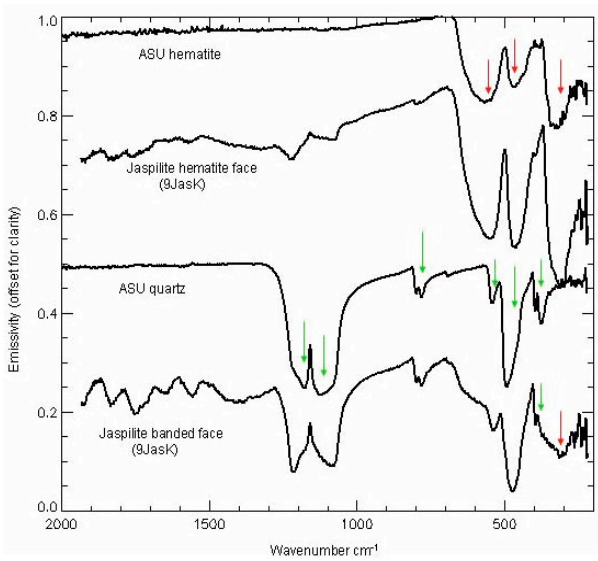

Figure 2. Banded oxide emission spectra measured at two orientations. The red arrows denote hematite features and the green arrows denote quartz features.

Carbonate facies. The carbonate samples generally consist of banded quartz and siderite with minor amounts of magnetite and chlorite. Carbonate sample spectra vary with weathered versus fresh surfaces in reflectance and emittance. In reflectance, the weathered surfaces show evidence of ferric iron, while the fresh surfaces show only ferrous iron associated with the mineral siderite. However, neither the fresh nor weathered surfaces exhibit carbonate features around 2.35 μm. This could be due to the very fine grain size, or the presence of opaques scattered throughout the sample.

In emittance, the weathered surfaces show weak to non-existent carbonate features, and quartz features. The fresh surfaces show much stronger carbonate bands in addition to the quartz bands (figure 3).

Silicate facies. There are two silicate samples; one is silicate iron formation and the other is a Precambrian greenstone from the underlying basement rock. In reflectance the weathered greenstone and the silicate iron formation show ferric iron features consistent with chlorite. The greenstone also has features around 2.3 μm that are consistent with chlorite.

In emittance, the silicate BIF has a feature at 1060 cm^{-1} that closely resembles amesite, a Mg endmember serpentine, as well as quartz features at the longer wavelengths. The greenstone is a weathered basalt and can be modeled with plagioclase, chlorite, and some quartz.

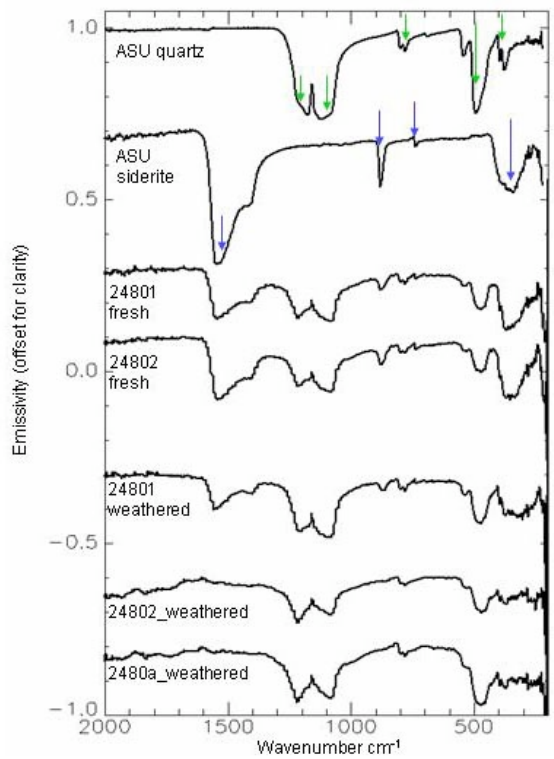

Figure 3. Emission spectra of weathered and fresh surfaces of carbonate facies BIF. Green arrows are denoting quartz features and blue arrows call out carbonate features.

Detecting BIF on Mars: Current and future missions to Mars will be further investigating the surface composition of Mars, with special interest in the hematite regions. MER-B "Opportunity", lands at Meridiani Planum on 1/24/04 to analyze the hematite deposit. CRISM (Compact Reconnaissance Imaging Spectrometer for Mars) is a hyperspectral instrument scheduled for launch in 2005 on the Mars Reconnaissance Orbiter (MRO).

MER B is equipped with six instruments capable of imaging, and assessing geochemistry on the surface of Mars at a spatial resolution comparable to holding a hand sample. Several compositional and textural diagnostic characteristics of BIF should be identifiable with this payload.

The hyperspectral nature of the CRISM instr ument should easily detect spectral differences in iron mineralogy associated with BIF in the VNIR/SWIR region from 0.4 to 4.0 μm.

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