

**THE EFFECTS OF COMPOSITION AND STRUCTURE OF MAGNETITES ON THEIR SPECTRAL PROPERTIES.** Tesia Rhind<sup>1</sup>, Edward Cloutis<sup>2</sup>, and Stanley A. Mertzman<sup>2</sup>. <sup>1</sup> Department of Geography, University of Winnipeg, 515 Portage Avenue, Winnipeg, MB, Canada R3B 2E9 ([tesiacoil@hotmail.com](mailto:tesiacoil@hotmail.com)). <sup>2</sup> Department of Geosciences, Franklin and Marshall College, Lancaster, PA, USA 17604-3003.

**Introduction:** Magnetite is found on the Earth in environments ranging from igneous and metamorphic rocks to diverse sedimentary environments. It is also common in aqueously altered meteorites (CI1 and CM2 chondrites). Magnetite has also been identified in the ALH84001 martian meteorite, and there is an ongoing debate regarding its origins. Magnetite can be formed via biotic and abiotic processes, and has been found intracellularly in multiple lineages of life [1].

Magnetite has an inverse cubic spinel structure with one tetrahedral site occupied by  $\text{Fe}^{3+}$  ions and two octahedral sites randomly occupied by equal amounts of  $\text{Fe}^{2+}$  and  $\text{Fe}^{3+}$  ions [2]. The chemical composition of magnetite can be quite complex due to the substitution of iron by other cations, for example:  $\text{Fe}^{2+}$  may be replaced by magnesium, manganese, zinc, nickel or titanium, and  $\text{Fe}^{3+}$  may be replaced by aluminum, titanium, vanadium, or chromium [3]. The presence of magnesium and titanium in nature play a role in determining the stability of magnetites.

As part of an on-going investigation we have found measurable differences in reflectance spectra of a suite of magnetites. Our goal is to understand the interplay between mineral structure data from XRD analysis and chemical variation from XRF analysis (including  $\text{Fe}^{2+}$  via wet chemistry) and their effect on magnetite reflectance spectra.

**Experimental Procedure:** All magnetite samples were hand crushed and dry sieved to <45 $\mu\text{m}$  particle size. Reflectance spectra were acquired both at the RELAB spectrometer facility at Brown University and at the University of Winnipeg HOSERLab with an ASD Field Spec Pro HR spectrometer (0.35-2.5  $\mu\text{m}$ ) with a 50 watt QTH light source and a viewing geometry of  $i=0^\circ$  and  $e=15^\circ$ . Spectra were measured relative to a calibrated Spectralon® standard.

X-ray diffraction analysis involved acquiring continuous scan data from  $5^\circ$  to  $80^\circ$   $2\theta$  on a Bruker D8 Advance with a DaVinci automated powder diffractometer. A Bragg-Brentano goniometer with a theta-theta setup was equipped with a  $2.5^\circ$  incident Soller slit, 1.0 mm divergence slit, a 2.0 mm scatter slit, a 0.2 mm receiving slit, a curved secondary graphite monochromator, and a scintillation counter collecting at an increment of  $0.02^\circ$  and integration time of 10 seconds per step. The line focus Co X-ray tube was operated at 40 kV and 40 mA, using a take-off angle of  $6^\circ$ . Sample compositions were determined using X-ray fluores-

cence, while ferrous/ferric iron abundances were determined by wet chemical methods [4].

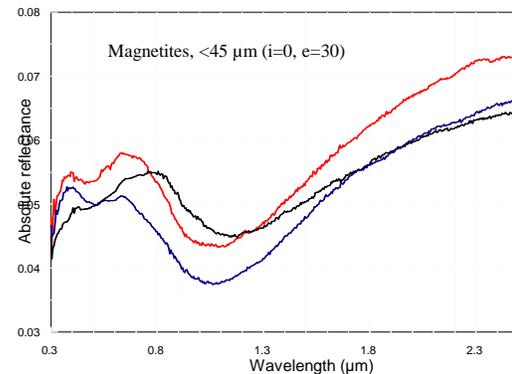


Figure 1: Magnetite reflectance spectra (<45  $\mu\text{m}$  grain size): red: MAG102; black: MAG103; blue: MAG104 (measured at RELAB).

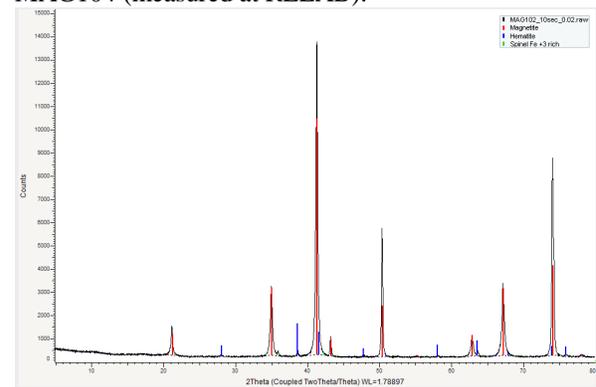


Figure 2: MAG102 X ray diffractogram  $5^\circ$  to  $80^\circ$ , integration time 10 second.

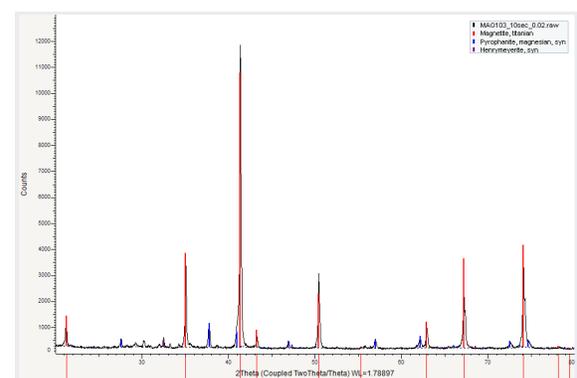


Figure 3: MAG103 X ray diffractogram  $5^\circ$  to  $80^\circ$ , integration time 10 second.

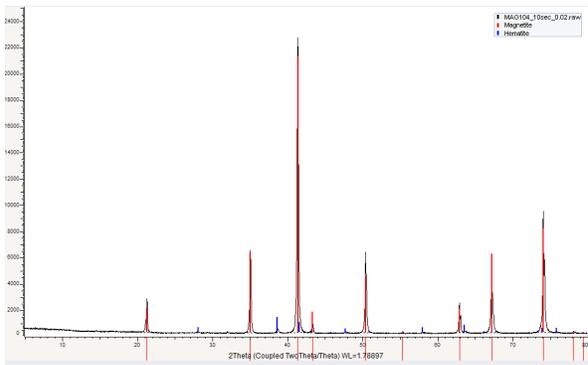


Figure 4: MAG104 X-ray diffractogram 5° to 80°, integration time 10 seconds.

Wt. %	MAG102	MAG103	MAG104
TiO <sub>2</sub>	0.04	7.28	0.01
FeO	88.546	88.941	92.36
MgO	0.61	<0.01	0.13
Other	7.384	3.149	0.53

Table 1: Selected elemental abundances in some of the magnetite samples.

**Results:** Reflectance spectra comparing three magnetite samples can be seen in Figure 1. MAG102 and MAG104 exhibit a "typical" magnetite spectrum with major absorption bands near 0.5 and 1  $\mu\text{m}$ , but MAG103 does not and the band we would have expected to fall at 1  $\mu\text{m}$  is located at a longer wavelength. This shift is characteristic of several magnetites analyzed in this study. When analyzed with the XRD, MAG 102 (fig. 2) and MAG104 (fig. 4) appears to be relatively pure magnetite with a bit of hematite, while MAG103 (fig. 3) contains appreciable titanium.

**Discussion:** In the majority of the magnetites we analyzed (e.g., MAG 102 and MAG104 in Fig.1) the strongest absorption feature occurs near 1000 nm. This can be attributed to spin-allowed crystal field transitions in the octahedrally coordinated Fe<sup>2+</sup> [5]. The weaker absorption feature near 500 nm is generally attributed to Fe<sup>2+</sup> - Fe<sup>3+</sup> charge transfers [5]. The cause of the 1000 nm band shift in some of the magnetites is unknown, but we postulate that it is possible for the band minimum to change due various cation substitutions.

**Conclusion and Future Work:** There are differences in some of the features in the magnetite spectra that we have analyzed, including shifts in band minima positions, depths, and spectral slopes. We believe that there are multiple mechanisms to explain these variations, and we are continuing our investigation of possible causes, including examining both structural and

compositional explanations. We are also exploring how particle size affects magnetites spectral properties.

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**References:** [1] R.U. Onyenwoke and J. Wiegel (1997) *Magnetite: Structure, properties and applications* [2] Bruno Siberchicot (2013) *Journal of Magnetism and Magnetic Minerals* 335, 86-89 [3] G.A. Waychunas (1991) *Oxide Minerals: Petrologic and magnetic significance*, 25, 24-33 [4] S.A Merztman (2000) *Oregon Geology*, 62, 99-122. [5] R.G Strens and B.J Wood (1979) *Mineralogical Magazine*, 43, 347-354.