Magnetic Properties of Zagami and Nakhla.

D.P. Agerkvist, L. Vistisen, M.B. Madsen and J.M. Knudsen Niels Bohr Institute for Astronomy, Physics and Geophysics, Blegdamsvej 17, DK-2100 Copenhagen Ø, Denmark.

Both Zagami and Nakhla contain a small amount of a ferrimagnetic mineral, titanomagnetite. Does the magnetic phase in the Martian dust also contain titanium?

Introduction: In coming missions to Mars (US Pathfinder 1996, Russian Rover 1996) efforts will be made to study the strongly magnetic (ferrimagnetic) phase known to exists in the Martian soil [1,2].

Most SNC meteorites are known to contain titanomagnetite. If the SNC meteorites really are Martian rocks, we may thus assume that the rocks of Mars contain titanomagnetite. The magnetic phase in the red soils of Mars may or may not have been inherited directly from the titanomagnetite in the Martian surface basalts.

We have therefore initiated an investigation of the magnetic properties of the meteorites Zagami and Nakhla. Preliminary results from the study of the magnetization as function of an applied field will be presented and mössbauer spectra included.

Experimental: On two small samples of the meteorites Zagami (0.0278 g) and Nakhla (0.0126 g) we have measured the hysteresis loops up to 1.6 T at room temperature. The measurements were performed in an Vibrating Sample Magnetometer (VSM). The curves are shown on the figure.

It is important to note that the magnetization given in the figure is the magnetization of the bulk sample of the respective meteorites. No separation of magnetic phase has been attempted. Contrary to this, the mössbauer spectra also shown on the figure correspond to a rather careful separation of the magnetic phase.

Results and Discussion: Both magnetization curves shown in the figure consist of a magnetically ordered (ferrimagnetic) phase, and a paramagnetic component. The paramagnetic component in Zagami is mainly due to pyroxene, in Nakhla to a mixture of pyroxene and olivine. The interesting aspect from our point of view is the hysteresis loop present for both Zagami and Nakhla. (There is an asymmetry in both loops. The reason for this has not been found, but it is probably due to a systematic error in the VSM). The ferrimagnetic curve is most significant in Nakhla. In Zagami the ferrimagnetic phase only causes a small bending of the line corresponding to the paramagnetic phase. The results of magnetization measurements on the bulk samples are consistent with the results of mössbauer spectra of the magnetic separates from the two meteorites. The magnetite in Zagami contains so much Ti ($Fe_{3-x}Ti_xO_4$, $x \sim 0.7$) that it is close to being paramagnetic at room temperature. The sample from Nakhla shows a hyperfine splitting corresponding to a Ti content of $x \leq 0.1$.

Conclusion: From the magnetic properties experiment on the Viking landers it was estimated that the spontaneous magnetization σ of the Martian soil is in the range 1

Am^2/kg soil $\leq \sigma \leq 7$ Am^2/kg soil. The magnetization of Nakhla and Zagami is evidently substantial lower. If the Martian soil formed by direct communition from basaltic rocks with a composition as Nakhla and Zagami, the soil would not stick to both permanent magnets brought by the Viking landers.

However, by chemical weathering of similar terrestrial rocks the magnetic phase may basically survive and be concentrated in the weathering products [3]. In this case the magnetic phase still contains titanium as found in the underlying rocks. On the other hand, if the iron has been completely dissolved in abundant liquid water, the magnetic phase may have formed via precipitation of Fe(III)-compounds (e. g. γ-FeOOH). In this case the magnetic phase will not contain Ti. A basic problem in the future exploration of the magnetic phase on Mars will though be to investigate - by means of X-ray fluorescence - if the Ti ions in the soil of Mars correlate with the magnetic phase.

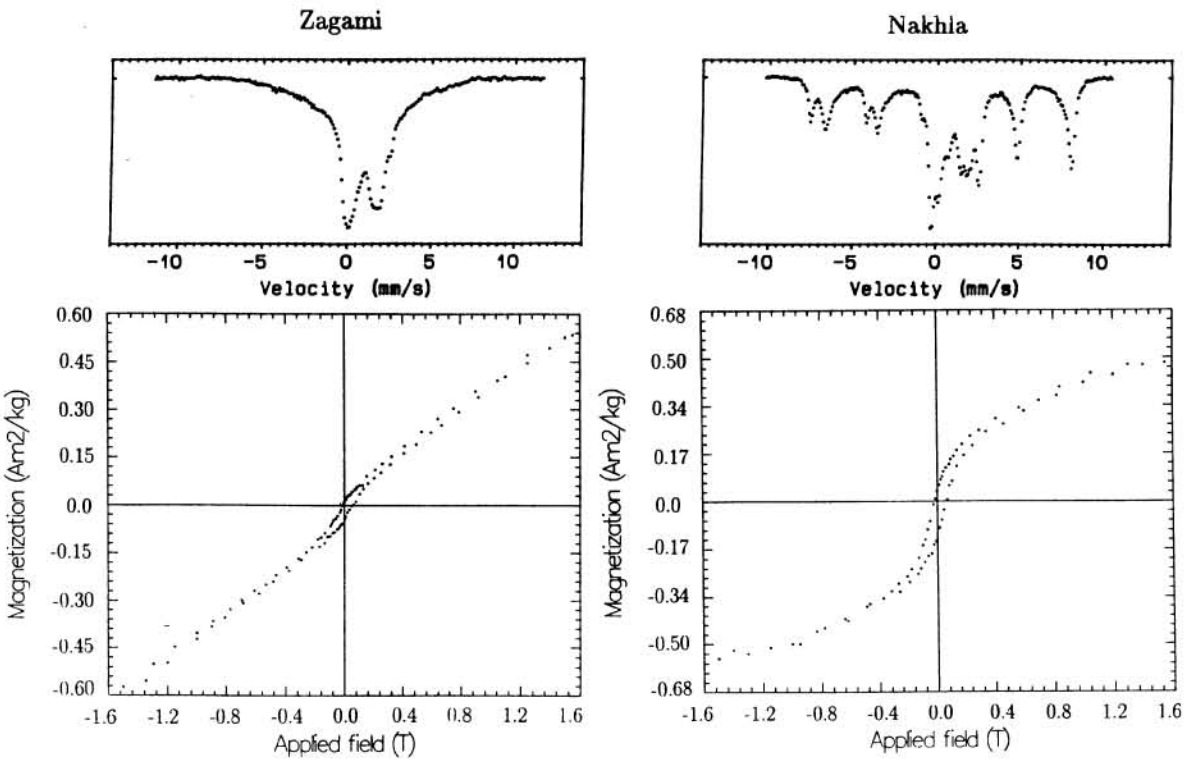

Figure 1: Magnetization as a function of applied field and mössbauer spectra for Zagami and Nakhla, room temperature

Acknowledgements: The Novo Nordisk Foundation and the Danish Natural Science Research Council are gratefully acknowledged for support.

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