EXPERIMENTAL RHEOLOGY OF PLANETARY ICES: TRIAXIAL DEFORMATION TESTS ON $MgSO_4 \cdot 11H_2O$ (MERIDIANIITE). P. M. Grindrod,[1] A. D. Fortes,[1] I. G. Wood,[1] P. R. Sammonds,[1] D. P. Dobson,[1] C. A. Middleton,[1] and L. Vočadlo,[1] [1]Centre for Planetary Sciences, Department of Earth Sciences, University College London, Gower Street, London WC1E 6BT, United Kingdom (p.grindrod@ucl.ac.uk).

Introduction: The hydrated sulfate salt meridianiite ($MgSO_4 \cdot 11H_2O$) may be the most likely source of liquid on Mars, especially in low latitudes where ice is less common or even absent in the regolith [1]. Stability studies in the $MgSO_4$-H_2O system show that there could be cycling between different phases during the course of a martian day (Figure 1), although sluggish hydration reactions and metastability in this system mean that, at present, it is difficult to predict accurately the phase transitions under martian conditions [2]. On the basis of their presence in chondritic meteorites, hydrated sulfate salts, including meridianiite, have been suggested to be major rock-forming minerals in the mantles of large icy moons [3].

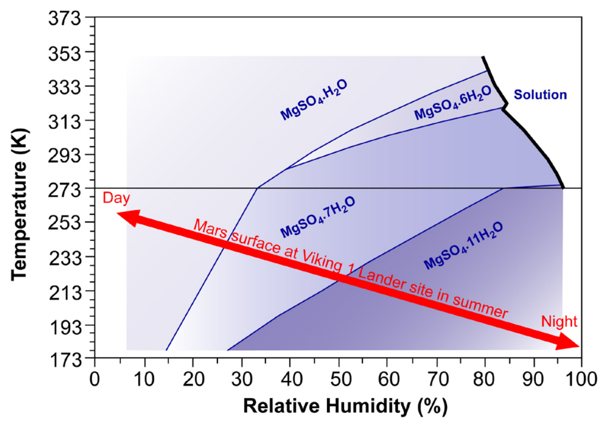

Figure 1. Phase relations for the $MgSO_4$-H_2O system at 0.1 MPa (after [1]). The red line indicates the conditions at the Viking Lander 1 site in summer.

Mono- and poly-hydrated sulfates have been identified from orbit in several different places on Mars, in outcrops several kilometers thick in the walls of Valles Marineris for example [e.g., 4], and inferred *in situ* at the Opportunity landing site in Meridiani [e.g. 5,6]. The Near Infrared Mapping Spectrometer (NIMS) instrument aboard the Galileo space-craft has also found evidence for hydrated salts on the jovian satellites [7,8].

This work forms part of our ongoing cross-disciplinary research program into planetary ices and hydrates (see contributions by Fortes *et al.*, Brand *et al.*, and Middleton *et al.*, this volume). Here we address the importance of rheology of hydrated phases in understanding the water budget of Mars and convection in icy satellites, focusing on meridianiite deformation.

Sample Preparation: Meridianiite poses experimental challenges for deformation tests [e.g., 9]. For this study, we prepare stoichiometric solutions (37.78 wt. % $MgSO_4$) at ~100°C, which are placed in Perspex sample tubes of 25 mm diameter. These tubes are dipped in liquid nitrogen, thus flash-freezing the solutions. This method successfully avoids the formation of metastable epsomite near the eutectic composition [e.g. 10]. No attempt has been made to control the grain size of the samples in this study. However, preliminary SEM analysis of the surface of a used indium jacket suggests that the mean grain size obtained by rapid quenching is very fine, typically <5 μm (Fig. 2).

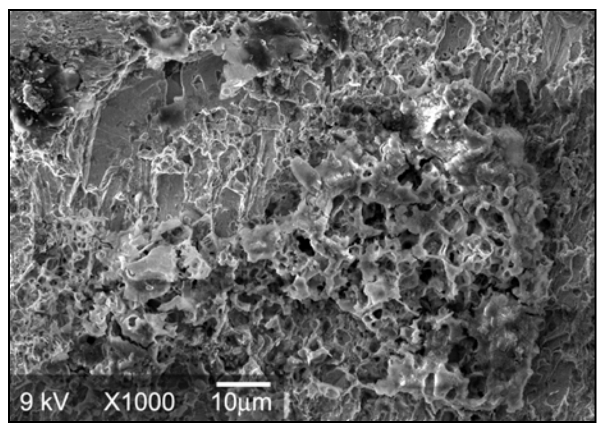

Figure 2. SEM image of the inside of an indium jacket used in one of the deformation tests. Raised material near centre-right is dehydrated meridianiite (probably epsomite), showing crystal molds of the original material.

Experimental Methods and results: We use a typical triaxial deformation cell in our experiments, described in more detail in [11], the only significant difference being the use of a balanced ram. Here we report the results of our tests carried out on 25 mm diameter samples under confining pressure of 50 MPa, and at a temperature of 263 K (Figure 3). Our preliminary results show that meridianiite is considerably weaker than other sulfate hydrates (e.g., epsomite and mirabilite), with a rheology at 263 K similar to low-pressure water ice. Further deformation experiments on meridianiite, and other sulfate hydrates, are required under different conditions to corroborate our findings, although they appear to match well with other preliminary results [e.g., 12,13]. If meridianiite has a similar rheology to water ice, the behaviour of which is quite well-known under planetary conditions, then it may have important implications for studies of martian permafrost, and icy satellite interiors, which we discuss below.

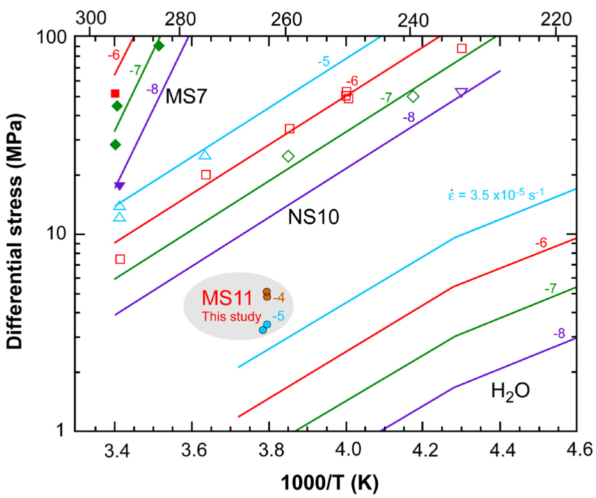

Figure 3. Arrhenius plot showing the strength of meridianiite (MS11) from this study, compared with epsomite (MS7), mirabilite (NS10) and water ice (after [9]). Note the relative weakness of MS11, whose behaviour at the stoichiometric composition is closer to water ice than epsomite (MS7), or even mirabilite (NS10).

Discussion: The rheological properties of meridianiite have an impact on models of the mechanical stability of 'permafrost' in the martian regolith - with consequences for putative martian glaciers and the origin of gullies - as well as the stability to convection of ice/hydrate shells in the outer solar system. Our preliminary results indicate that meridianiite behaves much more like water-ice than other sulfate hydrates, which may be consistent with the molecular architecture (more non cation-coordinated water molecules than epsomite and mirabilite), but further work is necessary to quantify the effects of temperature and grain size on the creep behaviour.

References: [1] Chou I.-M. and Seal R.S. (2007): *JGR*, **112**, E11004. [2] Vaniman D.T. and Chipera S.J. (2006): *Am. Mineral*, **91**, 1628-1642. [3] Kargel, J. S. (1991): *Icarus* **94**, 368-390. [4] Bibring J.-P. *et al* (2007): *Science*, **317**, 1206-1210. [5] Squyres S.W. *et al* (2007): *Science*, **306**, 1731-1733. [6] Peterson R.C. and Wang R. (2006): *Geology*, **34**, 967-960. [7] Dalton *et al.* (2005): *Icarus* **177**, 472-490. [8] Orlando *et al.* (2005): *Icarus* **177**, 528-533. [9] Durham W. B. *et al*. (2005): *JGR*, **110**, E12010. [10] Hogenboom D. L. *et al.* (1995): *Icarus*, **115**, 258-277. [11] Grindrod P. M. *et al*. (2008): *LPSC* **39**, #1199. [12] McCarthy C. *et al.* (2006): *LPSC*, **37**, #2467. [13] McCarthy C. *et al.* (2007): *LPSC*, **38**, #2429.