THERMAL DEMAGNETIZATION OF SHOCK REMANENT MAGNETIZATION IN EXTRATERRESTRIAL MATERIALS. S.M. Tikoo[1], J. Gattacceca[1,2], B.P. Weiss[1], C.R. Suavet[1], [1]Department of Earth, Atmospheric and Planetary Sciences, Massachusetts Institute of Technology, 77 Massachusetts Avenue, Cambridge, MA 02139, smtikoo@mit.edu, [2]CEREGE, CNRS/University of Aix-Marseille 3, BP80, 13545 Aix-en-Provence Cedex 4, France.

Introduction: The ubiquity of impact events in the solar system underscores the need to understand the effects of these impacts on geological samples. Within the context of paleomagnetism, shock remanent magnetization (SRM) may be acquired as an impact shock wave passes through a rock in the presence of an ambient field. SRM is acquired instantaneously and therefore is capable of recording transient magnetic fields like those which might be produced by impact-generated plasmas, as well as longer-lived core dynamo fields [1,2]. On the other hand, in the absence of an ambient field, shock can demagnetize rocks [3]. Therefore, an understanding of shock magnetization and demagnetization processes is important for interpreting the natural remanent magnetization (NRM) of lunar rocks and meteorites, as well as determining the nature of magnetic anomalies associated with planetary impact cratering (e.g., [4]).

The alternating field (AF) demagnetization behaviors of SRM and its hydrostatic analog, pressure remanent magnetization (PRM), have been explored in numerous studies (e.g., [2,5-7]). However, the thermal demagnetization behavior of SRM has not been well-constrained, except for preliminary analyses of lunar materials by refs. [6,7]. It is important to have an understanding of the thermal demagnetization behavior of SRM in order to determine whether or not thermal demagnetization is an appropriate mechanism for identification and efficient removal of SRM overprints from samples. Here we compare the AF and thermal demagnetization behavior of SRM in two ordinary chondrites. We also discuss potential caveats for the use of thermal demagnetization and Thellier paleointensity methods on samples with SRM overprints.

Samples and Methods: In this study we induced PRM as a proxy for SRM in several types of meteorites and lunar rocks (e.g., [1, 8]). Here we present results for two Fe-Ni-bearing ordinary chondrites: the H5 chondrite NWA 6490 (weathering grade W1) and the L5 chondrite NWA 7629 (also W1). Following ref. [6], subsamples ranging between 33-350 mg in mass were hydrostatically pressurized up to 1.8 GPa using a non-magnetic piston cylinder pressure cell. A solenoidal coil surrounding the pressure cell is connected to a stabilized DC power supply. The magnetic field produced by the coil was calibrated using a gaussmeter. All samples were AF demagnetized to at least 150 mT prior to PRM acquisition.

Following extraction from the cell, we measured the magnetic moment of the samples, which were then subsequently stepwise demagnetized using either alternating field (AF) or thermal demagnetization techniques in an effort to compare demagnetization results from both methods. Samples were thermally demagnetized in a controlled oxygen fugacity atmosphere using a calibrated H_2-CO_2 mixture following the methods of ref. [9].

Results: The demagnetization behaviors of the two meteorites were similar. Therefore, we will focus herein on the results for sample NWA 6490.

AF demagnetization. Using AF demagnetization, the PRM component (acquired at 1.8 GPa in a 500 µT field) of NWA 6490 was removed completely by 7.5 mT, with ~85% of the moment removed by the first AF demagnetization step at 1.5 mT (Fig. 1a). The blocking of PRM in the low coercivity (LC) fraction of magnetic grains is consistent with prior PRM studies of Fe-Ni-bearing materials [6]. At higher AF levels, the magnetic signal exhibited noisy demagnetization (Fig. 1b). This behavior is likely due to a combination of spurious anhysteretic remanence (ARM noise) acquired during AF applications and magnetic anisotropy that is frequently observed in multidomain metal-bearing lunar rocks and meteorites [10].

Thermal demagnetization. Controlled-atmosphere thermal demagnetization was conducted on three subsamples of NWA 6490. Two subsamples were given PRMs in 500 µT DC fields at pressures of 1.8 GPa and 0.9 GPa, respectively. The third subsample was given a saturation isothermal remanent magnetization (sIRM). Samples were stepwise thermally demagnetized until the PRM was fully removed. The 1.8 GPa and 0.9 GPa subsamples were fully demagnetized by ~550°C (Figs. 1c, 2). This blocking temperature range for PRM in Fe-Ni-bearing samples is similar to that observed for shocked lunar soil [7]. The sIRM of the third subsample persisted to at least 750°C, consistent with the kamacite Curie temperature. Our preliminary results suggest that the 0.9 GPa PRM was removed more quickly at lower blocking temperatures than the 1.8 GPa PRM, which in turn was more easily removed than the sIRM (i.e., 60% of the 0.9 GPa PRM was removed by 210°C, versus 270°C and 400°C for the 1.8

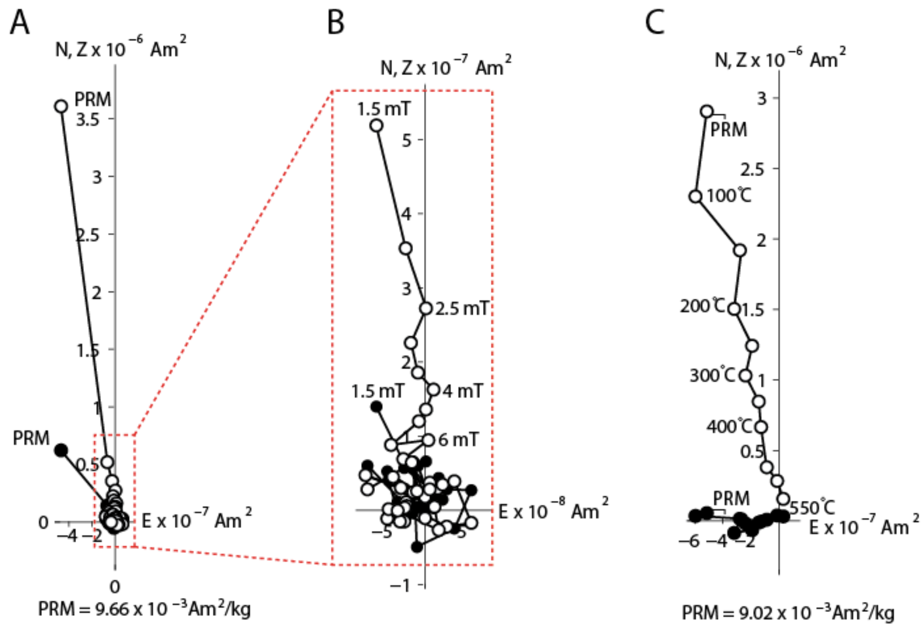

Fig. 1. Two-dimensional projection of the magnetization vectors of NWA 6490 during AF and thermal demagnetization of 1.8 GPa, 500 μT PRM. Solid (open) symbols represent end points of magnetization projected onto the horizontal N-E (vertical Z-E) planes. (A) Complete AF demagnetization of PRM up to 20 mT. (B) Magnification of data shown in A, with AC fields ranging from 1.5 mT to 20 mT. (C) Thermal demagnetization of 1.8 GPa, 500 μT PRM up to 550°C.

GPa PRM and sIRM, respectively). Since ~97% of the sIRM was demagnetized by 550°C rather than the kamacite Curie temperature (760°C), we infer that the samples were either altered during heating or some magnetization was carried by taenite or tetrataenite.

Discussion and Conclusions: Our AF demagnetiation results confirm the observation that PRM occupies the very low-coercivity fraction of geological samples (in this case, < 7 mT). Our preliminary thermal demagnetization results hint at a potential relationship between pressure level and blocking temperature spectrum, with higher pressures preferentially occupying higher blocking temperatures. A similar observation was made by ref. [6].

Our demagnetization results show that PRM is removed much more easily from our samples by AF methods than thermal demagnetization, where PRM may persist to unblocking temperatures of > 500°C. This is because AF demagnetization more efficiently targets the low coercivity magnetic grains that PRM and SRM reside in. Therefore, conducting thermal demagnetization and Thellier paleointensity experiments alone on samples with low pressure SRM overprints on a dynamo-field induced TRM will yield inaccurate interpretations because the SRM will not be properly removed from these samples using thermal demagnetization. Therefore, our results suggest that AF-based demagnetization and paleointensity methods can in some cases be superior techniques for assessing the remanent magnetization preserved in samples with SRM overprints. Ideally, a combination of both AF and thermal demagnetization techniques should be implemented in paleomagnetic analyses in cases where SRM overprints are likely to occur.

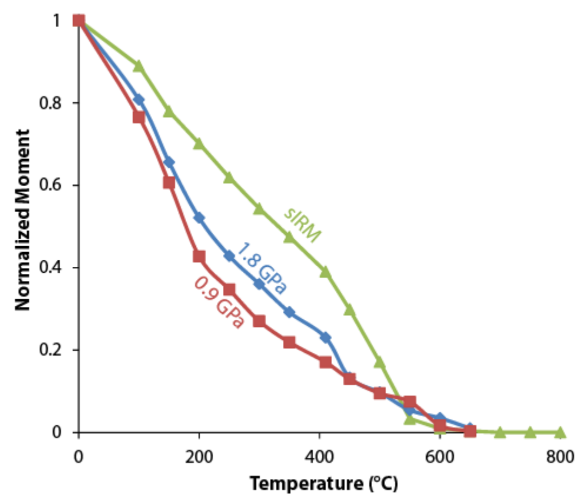

Fig. 2. Thermal demagnetization of NWA 6490 subsamples given a 1.8 GPa PRM, a 0.9 GPa PRM, and a sIRM, respectively. Shown here is normalized moment vs. demagnetization temperature step.

References. [1] Nagata T. (1971) *Pure Appl. Geophys, 89*, 159-177. [2] Gattacceca J. et al. (2010) *Phys. Earth. Planet. Int., 182*, 42-49. [3] Bezaeva N. S. et al. (2010) *Phys. Earth Planet Int., 179*, 7-20. [4] Weiss B. P. et al. (2010) *Space Sci. Rev. 152*, 341-390. [5] Gattacceca J. et al. (2008) *Phys. Earth Planet Int., 166*, 1-10. [6] Gattacceca J. et al. (2010) *Earth Planet Sci. Lett., 299*, 42-53. [7] Cisowski S. et al. (1973) *PLSC IV*, 3003-3017. [8] Carporzen L. et al. (2011) *Proc. Natl. Acad. Sci. USA., 108*, 6386-6389. [9] Suavet C. et al. (2012) *EOS Trans. AGU Fall Meeting.*, Abstract #GP51A-1305. [10] Tikoo S. M. et al. (2012) *Earth Planet. Sci. Lett., 337-338,* 93-103.