PALEOMAGNETIC STUDIES OF RETURNED SAMPLES FROM MARS. B. P. Weiss[1] and the Returned Sample Science Board (D. W. Beaty[2], H. Y. McSween[3], B. L. Carrier[2], A. D. Czaja[4], Y. S. Goreva[2], E Hausrath[5], C. D. K. Herd[6], M. Humayun[7], F. M. McCubbin[8], S. M. McLennan[9], L. M. Pratt[10], M. A. Sephton[11], A. Steele[12]), [1]Department of Earth, Atmospheric and Planetary Sciences, Massachusetts Institute of Technology, 54-814, 77 Massachusetts Avenue, Cambridge, MA 02139, bpweiss@mit.edu, [2]Jet Propulsion Laboratory, Pasadena, CA, [3]University of Tennessee, Knoxville, TN, [4]University of Cincinnati, Cincinnati, OH, [5]Universitiy of Nevada, Los Vegas, NV, [6]University of Alberta, Edmonton, Canada, [7]Florida State University, Tallahassee, FL, [8]NASA Johnson Space Center, Houston, [9]Stony Brook University, Stony Brook, NY, [10]Indiana University, Bloomington, IN, [11]Imperial College, London, U.K., [12]Carnegie Institution, Washington, DC.

Introduction: The red planet is a magnetic planet. Mars' iron-rich surface is strongly magnetized, likely dating back to the Noachian epoch when the surface may have been habitable. Paleomagnetic measurements of returned samples could transform our understanding of the Martian dynamo and its connection to climatic and planetary thermal evolution and provide powerful constraints on the preservation state of biosignatures in the samples.

Although Mars presently does not have a core dynamo magnetic field, but the discoveries of intense magnetic anomalies in the ancient southern cratered terrane by the Mars Global Surveyor mission [1] and remanent magnetization in Martian meteorite ALH 84001 [2] provide strong evidence for a Martian dynamo during the Noachian epoch. The time of origin and subsequent decline of this field are poorly constrained but have critical implications for planetary thermal and tectonic history [3] and the evolution of the Martian atmosphere and climate [4].

Science from paleomagnetic studies: When magnetic minerals crystallize, cool, or are aqueously deposited in the presence of a magnetic field, they will magnetize in the direction of the local magnetic field with an intensity that scales with the field intensity. As a result, paleomagnetic studies of rocks yield two main pieces of information: the paleointensity and the paleodirection of past fields.

Because the original orientations in which all Martian meteorites and returned samples acquired their magnetizations are unknown, all paleomagnetic studies on Martian samples to date have only been able to infer the field paleointensity. By comparison, paleomagnetic studies of returned, oriented samples afford: (a) the first opportunity to infer the paleodirection of Martian paleofields; (b) geologic context; (c) the opportunity to obtain semicontinuous time sequences of paleomagnetic measurements; and (d) measurements of samples unaffected by shock processing associated with planetary ejection of meteorites.

A recent community-based study [5] produced a ranked list of key science objectives that could be achieved using paleomagnetic studies of returned Mars samples and that are linked to the leading Mars science objectives identified by the End-to-End International Science Analysis Group (E2E-iSAG) [6]. The top 6 objectives identified were:

1) Determine the intensity of the Martian dynamo
2) Characterize the dynamo reversal frequency and conduct magnetostratigraphy
3) Constrain the effects of heating, aqueous alteration, and radiolysis on the samples
4) Test the hypotheses that Mars experienced plate tectonics and/or true polar wander and constrain the tectonic and deformational history of the landing site
5) Determine the major mineral carriers of Martian crustal magnetization
6) Constrain sediment sourcing, fluid flow, and the depositional environment using environmental magnetism studies.

Sampling and curation strategy. The ideal targets for paleomagnetic studies are oriented samples acquired from bedrock with well-defined paleohorizontal indicators and lacking complex metamorphic, aqueous alteration, and shock histories. Samples should ideally be acquired from a time spanning the estimate lifetime of the Martian dynamo (pre-Noachian to Noachian Periods) During and following sampling, key sample quality criteria for ensuring the success of the magnetism science objectives are: (a) no exposure to fields >200 μT, (b) no exposure to temperatures >100 °C, (c) no exposure to pressures > 0.1 GPa, and (d) samples absolutely oriented with respect to bedrock with a half-cone uncertainty angle of <5°. On Earth, samples should be stored in a magnetically-shielded environment to prevent remagnetization in the Earth's field. Our recent tests of the Mars 2020 testbed drill indicate that all criteria are likely to be met, with the possible exception that some cores may experience unconstrained azimuthal rotations.

References: [1] Acuña M.H. et al. (2008) in *The Martian Surface: Composition, Mineralogy, and Physical Properties*, ed. by J.F. Bell (Cambridge University Press, Cambridge) 242–262. [2] Weiss, B. P., et al. (2008) *GRL*, 35, L23207. [3] Stevenson, D. J. (2001), *Nature*, 412, 237-244. [4] Jakosky, B. M., and Phillips, R. J. (2001), *Nature*, 412, 237-244. [5] Weiss, B. P. et al. (2014) unpublished white paper. [6] MEPAG E2E-iSAG (2011) Final report, http://mepag.jpl.nasa.gov/reports/.