SINGLE CRYSTAL PALEOINTENSITY ANALYSES OF OLIVINE-DIOGENITES: IMPLICATIONS FOR A PAST VESTAN DYNAMO.

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Introduction: Pioneering studies of meteorites [e.g. 1-3] and recent investigations [4-5] have presented paleomagnetic data suggesting some parent bodies had dynamos. In addition, modeling suggests bodies >80 km in radius could be in the regime of supercritical magnetic Reynolds numbers where large scale dynamo action is possible [5-6]. With this background, meteorites of the Howardite-Eucrite-Diogenite (HED) group of anchondrites, linked to the differentiated asteroid 4 Vesta, represent promising targets for magnetic investigation.

Prior studies of HED meteorites have yielded contrasting results. Cisowski [7] reported low paleofields (1-5 μT) from two unbrecciated eucrites, whereas Morden [8] reported paleointensities of up to 37 μT from Thellier analyses of the brecciated Millbillillie eucrite; the latter were interpreted as indicative of a past dynamo. The age of the Millbillillie magnetization might be approximately 3.55 Ga [9] when the meteorite was heated by impact. Fu and Weiss [10-11] have recently reported a study of fusion crust of the Millibillie eucrite, supporting the conclusion that the meteorite preserves an ancient magnetization, but with very low (2-3 μT) paleointensity values.

Olivine-Diogenites: Olivine-rich peridotite meteorites linked to Vesta have been called olivine-diogenites or harzburgites [12]. Here we investigate Northwest Africa (NWA) 5480, which is approximately 57 vol% olivine and 42 vol% orthopyroxene, with olivine found in bands that have been interpreted as magmatic flow within the Vestan mantle [13-14].

Methods: We have developed a new approach for the determination of past magnetic field intensity using single silicate crystals [12]. The silicate host is not of magnetic interest, but such crystals often contain minute nm-sized magnetic inclusions with ideal single to pseudo-single domain behavior (with magnetic domain state testable by measuring magnetic hysteresis properties). Measurements of remanent magnetization have shown that silicate crystals are less susceptible to alteration as compared to bulk rock samples. Based on experience studying the magnetization of terrestrial silicate minerals with magnetic inclusions [13-14] and olivine from pallasite meteorites [15], we have conducted initial studies of olivine from NWA 5480 to evaluate the potential of olivine-diogenites as paleomagnetic recorders.

Olivine grains 1-2 mm in size were separated for analyses. We specifically exclude grains with large visible inclusions as these may be multidomain magnetic minerals which relax on relatively short timescales. Instruments used for rock magnetic measurements include a Princeton Measurements Alternating Gradient Force Magnetometer. Samples were demagnetized by alternating field demagnetization to address magnetic contamination during collection and subsequent handling. Instruments used for remanence measurements include two high resolution 3-component 2G DC SQUID magnetometers housed in a magnetically-shielded room at the University of Rochester. A Synrad CO_2 laser (with FLIR and Mikron IR pyrometers for temperature control) was used to heat olivine crystal subsamples on minute timescales in field free space and in the presence of applied fields [12-14]. A 60 μT field was used for Thellier-Coe [15] paleointensity experiments.

Findings: Magnetic hysteresis measurements suggest that olivine hosts single to pseudo-single domain magnetic inclusions suitable for paleointensity analyses. Thermal demagnetization reveals removal of several scattered magnetizations at low unblocking temperatures, followed by stable decay at higher temperatures (Figure 1).

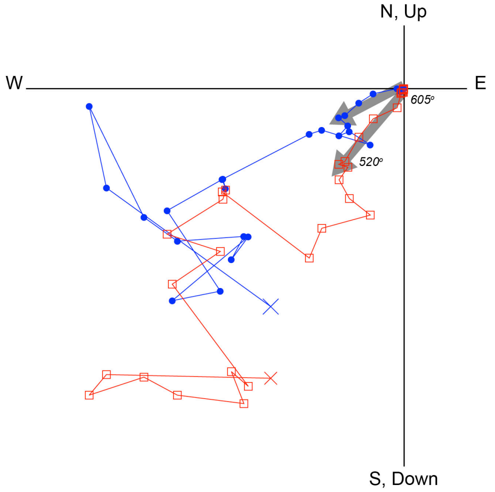

Figure 1. Orthogonal vector plot of thermal demagnetization of an unoriented olivine crystal from NWA 5480. All values shown are in degrees Celsius. Red is

magnetic inclination, blue is declination. Stable decay (grey arrows) is defined at temperatures > 520 °C.

The component unblocked at high temperatures is a candidate for recording an ancient magnetization. We apply the Thellier-Coe [16] paleointensity approach in the high unblocking temperature interval where the stable magnetization is recorded (Figure 2). These measurements involve first demagnetizing the natural remanent magnetization (NRM) over a fixed temperature interval, followed by reheating the sample over the same temperature range in the presence of a known field, imparting a partial thermal remanent magnetization (TRM). The slope of the NRM/TRM data constrain the paleofield value. These data suggest a field of approximately 36 μT.

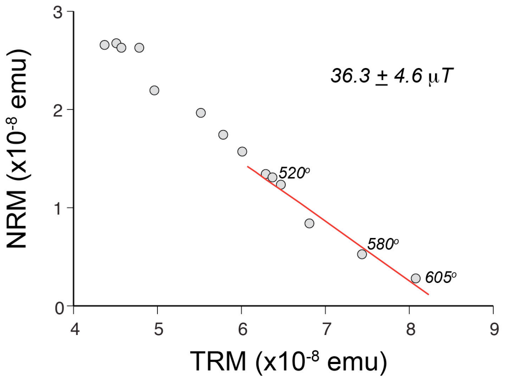

Figure 2. Natural remanent magnetization (NRM) versus thermal remanent magnetization (TRM) Thellier-Coe [16] paleointensity data measured on an olivine crystal from the olivine diogenite NWA 5480. Labeled points are degrees Celsius (compare with Figure 1). These define a slope suggesting a paleofield of approximately 36 μT.

Discussion: On the basis of our rock magnetic analyses to date, olivine from olivine-diogenites appears to be suitable for paleointensity analyses. The preliminary field value, if confirmed, implies a Vestan dynamo because alternative primary magnetic sources would have imparted much weaker fields. Consistency tests are needed to further address potential magnetic contamination during meteorite collection. In addition, definition of the nature and composition of the magnetic inclusion carriers is needed. These studies are in progress, as are single crystal paleointensity analyses of other HED meteorites.

References: [1] Fuller, M. (1974) *Rev. Geophys. Space Phys. 12,* 23-70. [2] Sugiura N. and Strangway, D.W. (1987) In *Meteorites and the Early Solar System,* p. 595-615 Univ. Arizona Press, Tucson. [3] Cisowski, S.M. (1987) In *Geomagnetism, vol. 2*, p. 525-560, Academic Press, N.Y. [4] Weiss, B.P. et al. (2008) *Science, 322,* 713-716 [5] Weiss, B.P et al., (2010) *Space Sci. Rev., 152*, 341-390. [6] Nimmo, F. (2009) *Geophys. Res. Lett., 36,* L10201. [7] Cisowski, S.M. (1991) *Earth Planet Sci. Lett., 107*, 173-181. [8] Morden, S.J. (1992) *Meteoritics 27*, 560-567. [9] Yamaguchi, A. et al. (1994) *Meteoritics 29*, 237-245. [10] Fu, R. and Weiss B.P. (2011) EPSC, Abstract 1646. [11] Fu, R. and Weiss B.P. (2011) AGU abstract P21E-08. [12] Beck A. and McSween, H.Y. Jr. (2010) *Meteoritics & Planet. Sci.* 45, 850-872. [13] Irving, A.J. et al. (2009), LPSC Abstract 2466. [14] Tkalcec, B.J. (2010), LPSC Abstract 5191. [12] Tarduno J.A. (2006) *Rev. Geophys., 44,* RG1002. [13] Tarduno J.A. et al. (2007) *Nature, 446,* 657-660. [14] Tarduno J.A. et al. (2010) *Science, 327*, 1238-1240. [15] Tarduno J.A. et al. (2010) LPSC Abstract 2150. [16] Coe, R.S. (1967) *J. Geomag. Geoelectr. 19*, 157-179.