PALEOMAGNETISM OF THE SPRINGWATER PALLASITE: FURTHER EVIDENCE FOR A DYNAMO IN THE MAIN GROUP PALLASITE PARENT BODY. J. A. Tarduno[1,2], R. D. Cottrell[1], [1]Department of Earth & Environmental Sciences, University of Rochester, Rochester, NY 14627 (john@earth.rochester.edu) [2]Department of Physics & Astronomy, University of Rochester, Rochester, NY 14627

Introduction: The origin of pallasites, meteorites with roughly equal amounts of FeNi metal and olivine, has been a long-standing paradox because the seemingly improbable mixture is expected to have separated into distinct layers by density [1-3]. Although alternative models have been proposed [4-7], an origin for pallasites near a parent body core-mantle boundary is commonly assumed. Recently we reported evidence for a dynamo in the main group pallasite parent body on the basis of paleomagnetic investigations of the Imilac and Esquel pallasites [8]. Magnetization in a dynamo field indicates that these pallasites could not have formed near a core-mantle boundary (where temperatures would have been too high). We used these observations, together with cooling rate data [7] and thermal modeling to suggest that some pallasites formed when liquid FeNi from the core of an impactor was injected into the shallow mantle of a ~200-kilometer-radius protoplanet. Here we discuss new paleointensity data from the Springwater pallasite which further constrain the formation of pallasite meteorites and their parent bodies.

The major mineralogy of pallasites includes kamacite (αFeNi), taenite (γFeNi) and olivine ($\{Fe,Mg\}_2SiO_4$) with minor troilite (FeS), schreibersite ($\{Fe,Ni\}_3P$) and chromite ($FeCr_2O_4$). Olivine ranges from Fa_{11} to Fa_{20}, and often occurs as large yellow or green crystals. The olivine crystals are often cm-sized and are either angular or rounded [1-2]. When etched, the metal often shows a Widmanstätten structure. There are over 30 known pallasite falls with most assigned to a "main group". The main group pallasites have isotopic ratios that are well grouped along the terrestrial mass fractionation line. The Imilac and Esquel main group pallasites are generally classified as having angular olivine e.g. [2], whereas the Springwater pallasite, also classified in the main group [3], has rounded olivine.

Methods: We have developed a new approach for the determination of past geomagnetic field intensity using single silicate crystals separated from terrestrial rocks [9-11]. The silicate host is not of magnetic interest, but such crystals (e.g. ~1 mm in size) 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 in nature and in the laboratory as compared to bulk rock samples. Based on this experience studying the magnetization of terrestrial silicate minerals with magnetic inclusions, we applied this approach to olivine from the Imilac and Esquel pallasites [8], and we follow that approach for analyses of the Springwater pallasite. By focusing on olivine crystals, we avoid the problems of magnetic instability of the massive metal [12-13] that surrounds the olivine. Importantly, for paleomagnetic (paleointensity) analyses, we select only olivine subsamples that are clear, lacking visible inclusions. This is a typical criterion used in the selection of crystals for terrestrial studies—the lack of visible inclusions helps to exclude larger unstable multidomain magnetic carriers [9], whereas smaller submicron magnetic inclusions can carry magnetizations stable on timescales of billions-of-years (hence bearing on parent body processes).

We characterize magnetic inclusions within olivine samples using rock magnetic/paleomagnetic measurements and SEM, TEM and MFM analyses. Instruments used for rock magnetic/paleomagnetic measurements, the focus here, include a Princeton Measurements Alternating Gradient Force Magnetometer with P1-probes for magnetic hysteresis measurements, and two high resolution 3-component 2G DC SQUID magnetometers 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 [10-11].

We typically demagnetize the natural remanent magnetization (NRM) of olivine subsamples first by stepwise alternating field techniques (to ~10 mT) to check for (and remove) any magnetic contamination, and then proceed with thermal demagnetization with the CO_2 laser. Paleointensity is examined using two techniques: the classical Thellier method and through the demagnetization of a Total Thermal Remanent Magnetization (Total TRM) [8].

Findings: Relative to olivine from the Imilac and Esquel pallasites, Springwater pallasite samples examined to date contains a smaller number of olivine crystals lacking visible inclusions or evidence of alteration. However, stepwise thermal demagnetization data of select samples meeting our selection criteria show stable demagnetization behavior. After the removal of a series of complex magnetizations at low unblocking temperatures (less than approximately 200 °C), a linear component of magnetization is defined which trends to the origin of orthogonal vector plots of the remanence (Figure 1). Demagnetization of a Total TRM, when compared to the NRM demagnetization, suggests magnetization in strong fields, of ~100 μT. This preliminary value is comparable to values obtained from the Esquel and Imilac pallasite meteorites.

Discussion: Lugmair and Shukolyukov [14] report ^{53}Mn-^{53}Cr systematics on the Springwater pallasite, suggesting an age of ~4557 Ma. This provides an upper bound (i.e. oldest age) on the time of metal olivine mixing. The acquisition of the magnetic remanence will be later, at temperatures less than approximately 500 °C, as inferred from our thermal demagnetization experiments. In an early K-Ar study, Megrue [15] reported an age of ~ 4.3 Ga for the Springwater pallasite. This age is consistent with age estimates from other pallasites (Marjalahti, Omolon, Bragin) based on fission track analyses [16]. The temperature for removal of tracks is 450-500 °C; thus, these ages could be close to the time of acquisition of the magnetization. But this depends critically on the accuracy of the fission track age model. Nevertheless, these ages provide a lower bound (i.e. youngest age) on the time of metal-olivine mixing, and are consistent with our previously reported parent body thermal modeling results [8]. Hence, paleointensity data of the Springwater pallasite, together with the available age constraints, further supports the present of a dynamo in the main group pallasite parent body that was active during slow cooling of the pallasite olivine.

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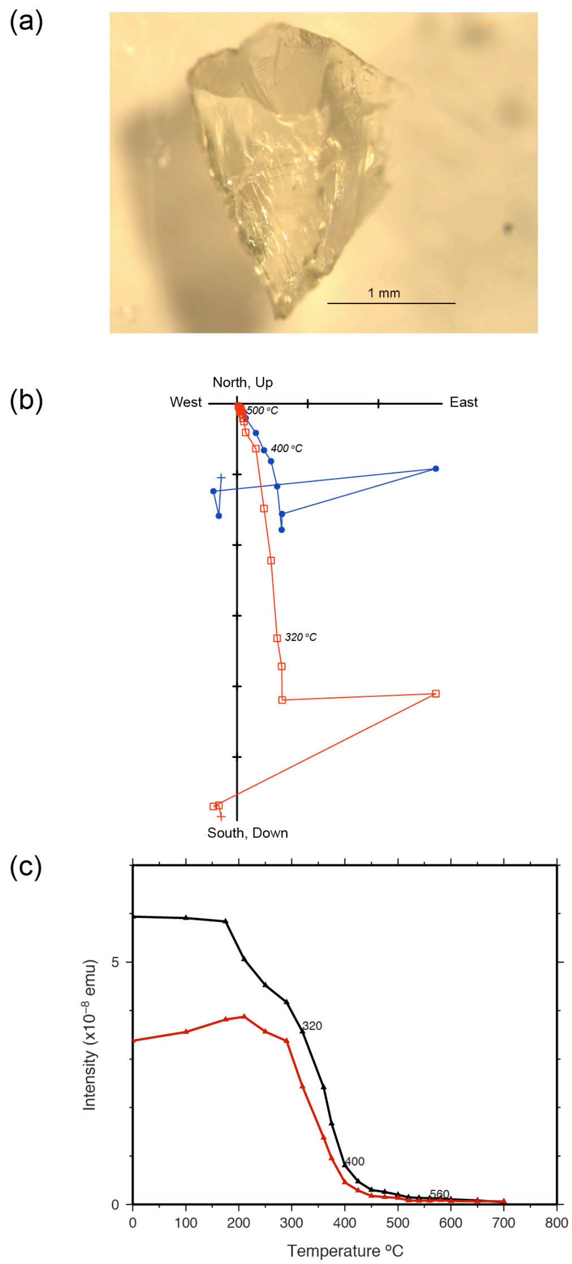

Figure 1: Thermal Demagnetization and paleointensity data from a Springwater pallasite olivine subsample. (a) Olivine subsample analyzed. (b) Orthogonal vector plot of demagnetization of the natural remanent magnetization. Red is relative inclination, Blue relative declination (sample is unoriented). (c) Thermal demagnetization of the natural remanent magnetization (black) plotted with the thermal demagnetization of a Total Thermal Remanent Magnetization [8] in a 60 μT field (red). Comparison of these curves suggests paleofields of ~100 μT.