MAGNETISM ON THE ANGRITE PARENT BODY. B. P. Weiss[1], E. A. Lima[1], and M. E. Zucolotto[2], [1]Department of Earth, Atmospheric, and Planetary Sciences, Massachusetts Institute of Technology 54-814, 77 Massachusetts Ave., Cambridge, MA 02139, USA, bpweiss@mit.edu, [2]Museu Nacional, Quinta da Boa Vista, Sao Cristovao, 20940040, Rio de Janeiro, RJ, Brasil

Introduction: Angrites are thought to be the oldest known pristine samples of a differentiated body and are among the oldest known solar system materials of any kind. They therefore should have recorded the earliest stages of planetary evolution and solar system magnetic fields. Such a record could potentially be used to infer the intensity of early stellar and disk fields and the first stages of core formation.

Knowledge of the paleointensity of the early solar and disk fields is critical for identifying the process that was responsible for momentum and mass transfer within the protoplanetary disk. One of the few known feasible mechanisms for this is magnetorotational instabilities [1], which would be associated with a disk dynamo and may be responsible for the formation of the first solar system solids [2]. Alternatively, the discovery of an internally generated field on the APB would likely demand the presence of a convecting metallic core. Hints of an early core on the APB have previously come from observed siderophile depletions [3] and Mn/Cr [4] and Hf/W [5] isotopic data. Such a discovery would critically test the hypothesis that angrites are direct melts of undifferentiated nebular accretions rather than partial melts [6, 7].

Here we present the first paleomagnetic investigation of angrites. We have thus far analyzed 6 of the 11 known angrites: D'Orbigny, LEW 86010, Angra dos Reis, NWA 1670, NWA 2999, and NWA 4801.

D'Orbigny: We acquired samples ranging from the fusion crust to the meteorite's center (15 cm deep) in order to identify any preterrestrial remanence. Alternating field (AF) demagnetization, rock magnetic and paleointensity studies of mutually oriented subsamples revealed that much of the exterior ~1 cm of the meteorite has been completely remagnetized by the collector's magnet. Samples at 4-cm depth had two components of a magnetization: a nonunidirectional, near saturation, low coercivity magnet component (MC) from the collector's magnet and a high coercivity (HC) (~10-50 mT) stable, unidirectional component ~90° away from the local MC direction. Samples at ~>8-cm depth had no or only weak MC overprint (Fig. 1A). Paleointensity experiments (following [8, 9]) on HC components from 6 samples gave paleofield values of 24 ± 2 μT (anhysteretic remanent magnetization (ARM) method) and 14 ± 6 μT (REM' method) (2-σ uncertainties) (Fig. 1B). Our laboratory magnetic viscosity experiments imply that most of the HC component cannot be a viscous remanent magnetization (VRM) acquired after landing on Earth. It also cannot be a secondary crystallization remanent magnetization acquired during weathering because primary pyrrhotite, titanomagnetite and iron-nickel are the dominant ferromagnetic minerals in the meteorite. D'Orbigny's great antiquity (Pb/Pb age of 4564.48 ± 0.24 Ma [10], within the uncertainty of its (U-Th)/He age [11]), nearly instantaneous (10-50°C/h) initial cooling rate [12], and lack of metamorphic, metasomatic, and shock features [3] strongly suggest that this is in fact a truly ancient thermoremanent record. *We conclude that there was a magnetic field of order 10 μT (20% of the Earth today) on the angrite parent body at 4564.48 ± 0.24 Ma.*

LEW 86010: Although LEW 86010 formed only ~6 M.y. after D'Orbigny [10], its (U-Th)/He age of 3700 ± 700 Ma suggests that its magnetic record was reset well after this early epoch [13]. In fact, with the exception of LEW 87051, LEW 86010 is the only angrite known to have a (U-Th)/He that is not within the uncertainty of its formation age [11]. This makes LEW 86010 a unique sample for determining the late (~3.7 Ga) history of magnetism on the APB.

Our analyses of two LEW 86010 samples reveal a magnetic record totally different from that of D'Orbigny. Two samples with fusion crust (,25 and ,29) retain a stable magnetization. However, the unbaked interior of ,29 has a moment per unit mass >>20 times weaker than the unmelted, baked exterior. The interior natural remanent magnetization in both samples is very unstable, varying by up to 50° in direction and a factor of 1.4 in intensity over a period of several minutes during careful handling in the MIT magnetically shielded clean laboratory. During AF demagnetization, both samples have no remanent magnetization blocked above ~5 mT that exceeds the ARM noise level of our AF equipment. The magnetization up to 5 mT has ARM and REM' paleointensities characteristic of viscous remanent magnetization (VRM) acquired after landing on Earth. Two week long laboratory VRM acquisition experiments indicate that the moment of at least ,25 could be easily explained as entirely contamination by the Earth's field. Using Student's *t*-test, we find that the paleointensity values derived from the >5 mT coercivity component from both samples are indistinguishable from 0.

The presence of strong natural remanence carried by low coercivity grains and zero natural remanence carried by high coercivity grains is a record distinct from that of virtually every previous sample studied in paleomagnetism. This despite the fact that our rock magnetic analyses indicate that LEW 86010 holds stable ARM and isothermal remanent magnetization with coercivities exceeding 900 mT. *We believe that the simplest interpretation of these data is that there was no or only a weak magnetic field on the APB at 3700 ± 700 Ma.*

Angra dos Reis, NWA 1670, NWA 2999 and NWA 4801: Although as yet incomplete, our analyses to date indicate that some subsamples of these meteorites have been at least partially to fully overprinted by collectors' magnets. Other subsamples likely retain preterrestrial records.

Implications: D'Orbigny contains by far the oldest magnetic record of any planetary rock yet studied. Our paleomagnetic data indicate that magnetic fields of order ~10-20 µT existed on the APB at 4565 Ma but had decayed sometime within the next 200-1600 My. The origin of these paleofields could have been external or internal to the APB. Postulated external fields at this time include a solar field (if the APB were within a few tenths of an AU of the T Tauri sun) or a disk dynamo. An internal field source would most likely be a dynamo (presumably from a convecting metallic core) or crustal remanence. But a crustal field is not favored by the lack of remanence in LEW 86010.

The key to deciding between an external field and an internal dynamo will be paleomagnetic measurements of the angrites with the youngest formation ages (which range up to ~10 M.y. after calcium aluminum inclusions). Given that any early solar fields should have decayed by this time, the identification of primary remanent magnetization in these angrites would strongly indicate that the field was of internal origin.

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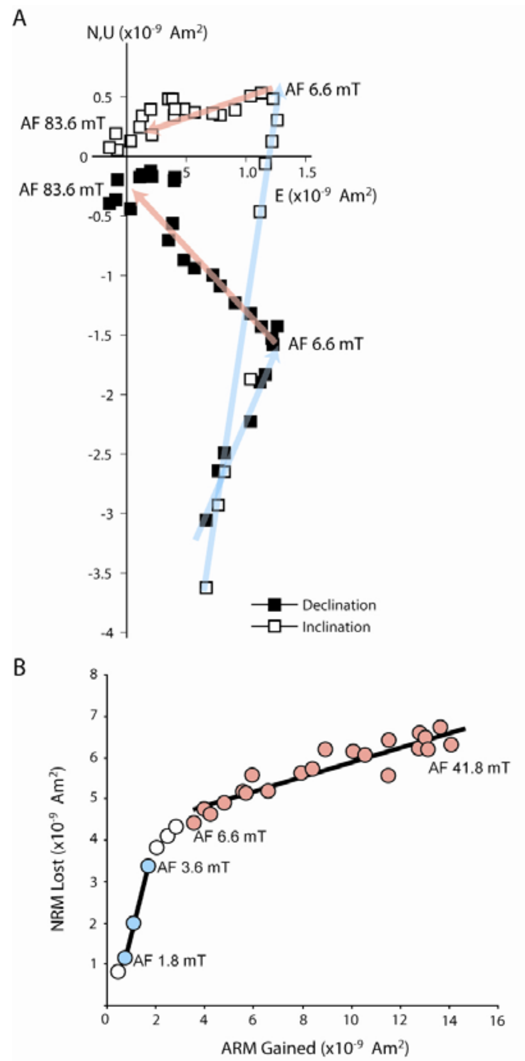

Fig. 1. Paleomagnetism of D'Orbigny subsample DORBF1, taken from ~8 cm deep into the meteorite. (A) Evolution of the magnetic moment during three axis alternating field (AF) demagnetization as projected onto the N-S-E-W (black squares) and U-D-E-W planes (white squares). Measurements above 7.2 mT were averaged over 3-5 AF steps to reduce ARM noise. Two components are visible: a low coercivity component up to 6.6 mT (blue arrow) and a a high coercivity component extending to >50 mT (red arrow). (B) ARM paleointensity of DORBF1. The low coercivity component (blue symbols) was acquired in a field of 150-350 µT (presumably weak IRM overprint) while the high coercivity (HC) component was acquired in a field of 26 ± 5 µT (red symbols) (uncertainties are 95% confidence interval).