METEORITES AS MAGNETIC PROBES: RECENT RESULTS. Aviva Brecher, Dept. of Earth and Planetary Sciences, MIT, Cambridge, MA 02139 USA

The search for clues to ancient nebular or proto-planetary magnetic fields was recently focused on the most likely meteoritic carriers of such records: a) the carbonaceous chondrites (1) and the ureilites (2) for extended nebular magnetic fields; and b) the achondrites, particularly the rarer, igneous unbrecciated types, for probing the presence of fields associated with early parent-body differentiation (3). The aim of studies undertaken was to isolate a primordial component of the natural remanent magnetization (NRM) and attempt its laboratory simulation to make inferences about the mode of acquisition and required paleofield strength.

Samples

Two mutually oriented samples of Ibitira, which is an unbrecciates vesicular eucrite (4), were obtained from Dr. K. Keil, U.N.M. Prof. T. Nagata at N.I.P.R. made available two Antarctic Yamato meteorites: YM74013, an unbrecciated diogenite and YM74662, a primitive carbonaceous (C2) chondrite (5). The meteorite Working Group (MWG) provided samples of the Allan Hills meteorites ALHA77257,21 (a ureilite) and ALHA77256,15 (a monomict breccia diogenite). Two other Antarctic meteorites were too corroded or crusty to permit useful studies (ALHA77003,24 and ALHA77214).

Results and Discussion

Ibitira is a primitive representative of a vesicular basaltic flow on a eucrite parent body, whose age is 4.52±.25 AE (6), which contains < 2% wt. of Ni-Fe metal, of very low Ni(< 1% Ni), present as rounded ∿.1mm grains (4). The two samples studied had weak and inhomogeneous NRM, not directly coincident, of 3.2 and 7×10^{-6} emu/g. One sample has an irregular AF demagnetization curve, with marked directional scatter in some pinning plane; the other has a very hard, directionally stable, single-component NRM Their saturation magnetization is more similar in both (2.36 and 2.96 $\times10^{-4}$emu/g) with identical coercivity spectra, similar to that of NRM. The IRM_S/NRM ratios (74 and 43) permit a paleofield estimate by the Fuller method of .1 to 1 oe, which is extremely strong for a small parent body. However, until heating experiments can be carried out, this estimate is dubious, since lack of uniformity in magnetization level and characteristics seem to prevail on scales of a few cm.

Diogenite 74013 is another unbrecciated achondrite, likely to record upon cooling an ambient magnetic field. Two large and mutually oriented samples had NRM's of 4 and 7×10^{-6}emu/g. Their relative NRM directions differed by ∿40° in both declination and inclination. In zero field storage tests of 24 hrs. to 1 week, as much as 45% of NRM was lost by viscous decay, with a large directional change. AF cleaning to 400 õe of the less stable moment, brought the NRM's in near coincidence. One sample had a hard, stable component of NRM above 50 õe, of probably primary origin, which was well reproduced by an ARM (.5 oe, 400 õe) in both intensity and coercivity. This lends support to Nagata's (5) approach to paleofield determination. However, additional thermal modeling experiments, intended to simulate conditions on the parent bodies, led to complexities. Heating to 800°C in Argon and cooling in zero-field, a strong moment (TRM_o = 10 NRM) and extremely hard, was obtained. The true TRM (800°C, .5oe) was however, 730 times stronger than NRM, but only slightly harder and more coherent than TRM_o. Comparison of ARM before and after heating showed a 300x increase in ARM due to heating, indicative of severe thermal alteration. Hence the Shaw method and VanZijl method are not applicable, although the latter yields .64 - 1.33 oe paleointensities (ave. .71 oe). Moreover, a fictitious field of .95 oe may be obtained for zero-field cooling, by comparison of TRM_o with TRM(2). However, the ARM low-temperature method is also invalid, since the correction factor TRM /ARM, assumed to be ∿1, is in the present case ∿600! Hence, experimental problems of thermal degradation preclude reliable paleofield estimates.

The Diogenite ALHA 77256,15 is also weakly magnetized (5×10^{-6} emu/g). The IRM_S/NRM = 144 value places it in the .01 - .1 paleofield range in the Fuller plot. However, the NRM is directionally scattered, and shows irregular intensity changes. The NRM, up to 100 õe cleaning fields, is lined up with the observed axis stringers of metal grains. The ratio ARM/NRM ≃ 24, and the softer ARM coercivity spectrum (40% of NRM survive 100 õe, but only 10% of ARM), prove ARM to be a poor analog to NRM. Heating was not permitted, but further modeling is not warranted, since a useful NRM component is clearly absent (7).

The ureilite ALHA77257,21 sample had an NRM of 2.76×10^{-3} emu/g, far below the range of ref 2, by a factor of 10; the IRM_S/NRM = 57, is, however, in the high range of previously reported values, closest to the highly shock-demagnetized and metal enriched Goalpara to which the IRM_S coercivity is also similar. No useful NRM component was found, suggesting severe shock-disturbance and no magnetic resetting. Hence no modeling needs to be undertaken.

The carbonaceous (C2) chondrite YM74662, kindly made available by NIPR, was studied in detail. Two large samples (M_A=3.7g) and M_B=2g) were cut, whose measured moments were 3.7×10^{-3} emu/g and $.49 \times 10^{-3}$ emu/g, respectively. (A) was subjected to 5 low-temperature (liquid N_2) cycles in null-field in order to clean any possibly secondary remanance residing in multi-domain coarse magnetite. No loss of NRM was observed, indicating an extremely stable NRM of S-D character. Indeed, subsequent AF cleaning to 1000 õe removed only 50% of the NRM, with excellent directional clustering persisting. Two component convergence plots confirmed the presence of a single-component NRM, of probably primary origin. (A) was then given an ARM (1 oe, 1000 õe), whose intensity was x3 NRM, but whose AF coercivity spectrum was much softer than that of NRM, with only 1% surviving 800 oe AF cleaning. (B) was cleaned to 400 õe, thus removing 10% of its NRM, then thermally cleaned in Argon to 200°C, which removed an additional 20% of NRM. Thermal cleaning to 300°C left only 10% of NRM present, suggesting that this CC carries a low-T PTRM type of remanence, which is not modeled well isothermally by ARM A PTRM (300°C, loe) was imparted to (B), whose intensity was only

∿40% of the NRM, hence suggesting that some high-coercivity and highly magnetic carriers were lost in heating. This supports the observation (by M. Funaki) of a loss of 1 order of magnitude in thermal demagnetization of 74662 in N_2 gas, between 200 and 300°C. Indeed, the AF coercivity spectrum of this PTRM closely matches that of the softer ARM, being only ∿30% harder in the range 300-600 $\tilde{o}$e but still considerably softer than the NRM and less coherent directionally. A post-heating ARM (twice as strong as NRM, closely matched in coercivity the ARM prior to heating; this positive Shaw-test allows a reliable paleointensity to be extracted by the VanZijl method, except that no linear-regression is observed for the VanZijl plot, above 200$\tilde{o}$e. (The low slope to 200$\tilde{o}$e yields a low paleofield of .08oe, which is unacceptable.) However, an ARM vs. TRM f-factor of 1.63 = ARM/TRM is obtained, allowing the ARM method to be used. For the high coercivity part of the NRM, a 1.2oe paleofield becomes - after correction - closer to .7oe, in agreement with Nagata's estimate of .93oe (5). The low-coercivity portions of ARM vs. NRM lead to a <.1oe requirement for the range 0 → 400$\tilde{o}$e, in agreement with the Van Zijl linear segment. This problem of two distinct paleofield estimates for a single component NRM was noted previously (1).

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