MORE EVIDENCE FOR A PARTIALLY DIFFERENTIATED CV PARENT BODY FROM THE METEORITE KABA. J. Gattacceca[1,2], B. P. Weiss[2], M. Gounelle[3], E. A. Lima[2], and P. Rochette[1], [1]CNRS, Aix-Marseille Université, CEREGE UM34, 13545 Aix-en-Provence, France, gattacceca@cerege.fr, [2]Department of Earth, Atmospheric, and Planetary Sciences, Massachusetts Institute of Technology, 77 Massachusetts Avenue, Cambridge, MA 02139, USA, [3]MNHN, UMR7202, Laboratoire de Minéralogie et Cosmochimie du Muséum, 61 rue Buffon, 75005 Paris, France.

Introduction: Undifferentiated meteorites have long been regarded as samples from undifferentiated asteroids. However, this view has been recently challenged as evidence has emerged for partially differentiated asteroids in which an outer unmelted and variably metamorphosed layer overlays a differentiated body [1,2]. This idea is based on thermal modeling [1] and paleomagnetic evidence [2] indicating that the parent body of CV chondrites had a magnetic field generated by a dynamo, implying that it had an advecting molten core. This has profound implications for our understanding of asteroid accretion, differentiation, and the links between spectroscopic properties of asteroid surfaces and their true nature. To further test this hypothesis, we conducted a detailed paleomagnetic study of another CV chondrite: the Kaba meteorite.

Kaba meteorite fell in 1857, and is classified as type 3.1 in Bali-type oxidized CV sub-group [3]. As such it is more aqueously altered but less thermally metamorphosed than Allende. Moreover, it contains abundant magnetite [4] and shows no petrographic evidence for shock [5], making it a potentially high fidelity recorder of ancient magnetism on the CV parent body.

Samples and methods: We obtained four non-oriented bulk samples of Kaba devoid of fusion crust. Three samples were cut into mutually-oriented pieces, including sub-samples that consist exclusively of matrix material or chondrule material. A variety of magnetic properties were measured: natural and artificial remanences and their behavior upon thermal and alternating field demagnetization, hysteresis parameters...

Intrinsinc magnetic properties: Magnetic susceptibility and saturation magnetization are homogeneous down to very small scales (~1 mg) indicating fine-scale dispersion of ferromagnetic minerals in the meteorite. Hysteresis properties indicate an overall pseudo-single domain behavior.

Low-temperature magnetic measurements show a Verwey transition at 120 K indicating the presence of pure magnetite. Thermal demagnetization of saturation remanent magnetization (SIRM) show a major inflexion at 580°C, confirming that magnetite is the main magnetic mineral as previously established [4]. A minor inflexion at 300°C reveals the presence of ferromagnetic sulfides. The dominance of magnetite is confirmed by a S_{-300mT} ratio of 1.00. The saturation magnetization indicate a magnetite content of 11.4 wt.%.

Paleomagnetism: We demagnetized 25 subsamples with masses ranging from a few mg to about 50 mg using alternating field (AF) in most cases and/or thermal for a few samples. In all samples, a large fraction of the natural remanent magnetization (NRM) is a low coercivity (blocked below 10 mT) or low-temperature (blocked below 100°C) component of magnetization that is likely a viscous remanent magnetization (VRM) acquired during residence of the meteorite in the Earth's field since its fall in 1857. The intensity of the magnetization erased below 100°C is in agreement with the expected values derived from our VRM acquisition experiments.

All single-chondrule samples show erratic demagnetization from which no high-coercivity (HC) component of magnetization can be isolated (Fig. 1). Conversely, matrix-rich samples show a stable HC magnetization blocked from above 10 mT and up to 100 mT (Fig. 1). Bulk samples with masses above 2 mg also show a stable HC magnetization above 10 mT, or high-temperature (HT) magnetization above 100°C and up to at least 260°C (work in progress).

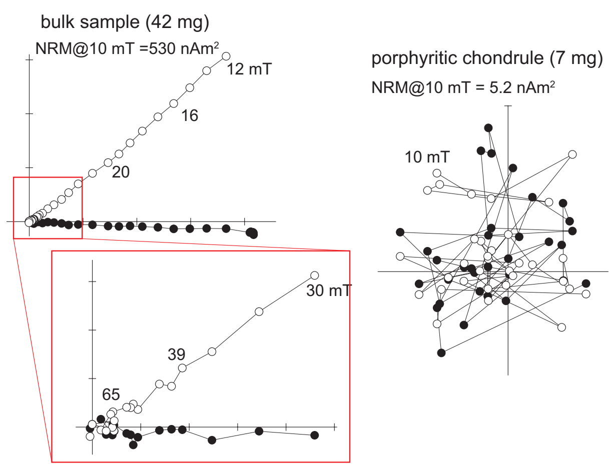

Figure 1. Orthogonal projection of AF demagnetization data for two samples of Kaba meteorite. Open and solid symbols are projections of the magnetization vector onto two perpendicular planes. AF demagnetization level is labeled in mT for selected steps.

When mutually-oriented bulk or matrix samples were measured, they show clustered directions for the

HC/HT component (Fig. 2). Therefore the remanent magnetization was acquired after accretion of Kaba parent body. Because the VRM acquired on Earth could be isolated using AF or thermal demagnetization, it is very likely that the HC/HT component of magnetization in Kaba predates the meteorite fall on Earth and was acquired on the parent body. Moreover, thermal demagnetization shows that the NRM is unblocked up to at least 260°C (work in progress) indicating that it is stable over the age of the solar system [6].

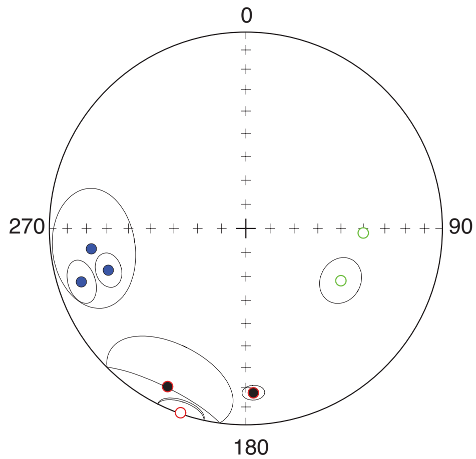

Figure 2. Equal area stereographic projection of high-coercivity and high-temperature components of magnetization for three groups of mutually-oriented samples. Each group comes from one parent sample, but the three parent samples were not mutually oriented.

Several magnetization mechanisms may account for the acquisition of the observed HC/HT magnetization: thermoremanent magnetization (TRM), partial TRM (pTRM), shock remanent magnetization (SRM), isothermal remanent magnetization (IRM), chemical remanent magnetization (CRM). An IRM is ruled out by NRM/IRM values lower than 10^{-2} along the AF range of stability of the NRM [7] as well as the high coercivity (100 mT) of the HC component. The coercivity spectra of NRM and TRM are widely different, indicating that the NRM is not a TRM. A SRM is ruled out because it would require a magnetizing field of several hundred µT, which is above any reasonable estimate that can be made for impact generated transient magnetic fields [8]. The two only plausible hypotheses are that the HC magnetization is a pTRM or a CRM. Upper estimates for the temperature suffered by Kaba during parent body metamorphism are estimated between 200 and 370°C [9,10], which fit well our preliminary maximum blocking temperature of the NRM. Assuming the NRM is is a CRM, and a comparable efficiency for TRM and CRM, a paleointensity estimate of about 25 µT can be computed for the HC magnetization using normalization by saturation IRM [7]. Assuming the NRM is a pTRM aquired at 260°C, normalization of the HT magnetization by a laboratory 260°C pTRM gives a similar estimate. Both estimates are corrected for the fact that chondrules contribute to the laboratory TRM and SIRM but do not contribute to the NRM.

Magnetizing field: Even though the exact nature of the magnetization (CRM or pTRM) cannot be determined yet, these two magnetization processes require a steady magnetic field on the parent body for a period of time that excludes transient impact-generated fields [8] or magnetic fields generated by magneto-rotational instability-driven turbulence in the protoplanetary disk [11]. A remanent crustal field is ruled out by the strong paleointensity that would require unrealistic high crustal magnetization. The magnetite in Kaba was formed by aqueous alteration on the parent body [12]. If the magnetization is indeed a CRM, it was acquired during of after crystallization of magnetite in Kaba, dated at 4.558 Ga by I-Xe ([13] using Shallowater reference age of [14]). This is 10 Myr after the formation of the solar system [15] when fields of solar and nebular origin have already decayed [16,17].

Conclusion: The only possibility that seems to account for a stable (in time and spatially relative to the parent body) magnetic field with a minimum intensity of about 25 µT is an internally generated magnetic field. This implies that the parent body of Kaba had an advecting molten core about 10 Myr after the formation of the solar system. This is a confirmation of previous results on Allende meteorite that the CV parent body was partially differentiated, with an outer chondritic shell overlying a differentiated interior.

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