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AN IMPACT ORIGIN FOR THE FOLIATION OF ORDINARY CHONDRITES. J. Gattacceca[1], P. Rochette[1], M. Denise[2], G. Consolmagno[3], and L. Folco[4], [1]Université Aix-Marseille III, CEREGE, BP80, 13545 Aix-en-Provence, France (gattacceca@cerege.fr), [2]MNHN, Paris, France, [3]Specola Vaticana, Vatican City State, [4]Museo Nazionale Antartide, Siena, Italy.

Introduction: A large number of observations and measurements of the anisotropy of their magnetic susceptibility (AMS) [e.g., 1] reveal the existence of foliation in almost all chondrites, and lineation in some of them (Fig. 1).

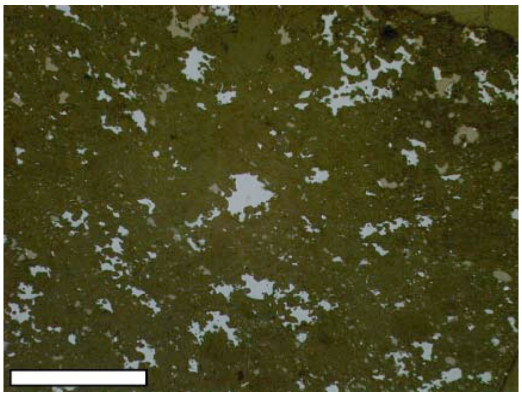

Figure 1: Reflected light image of the Hainaut H chondrite showing elongated and oriented metallic FeNi grains.

Explanations proposed in literature include accretional sedimentation, metamorphism, lithostatic compaction and hypervelocity impacts, but the former two can be confidently ruled out [2]. Impacts and lithostatic compaction remain as the two most plausible explanations. However, no definitive conclusion can be reached, mostly because of the limited dataset in former studies with respect to the number of potential parameters (group, petrologic type, shock stage, weathering).

In this work, we present a large dataset of AMS measurements, mostly on ordinary chondrites, in order to elucidate the origin of chondrite foliation. This anisotropy database contains 259 different chondrites, as well as 35 achondrites (HED and SNC).

AMS significance and limitations: We performed AMS measurements on meteorites with known petrologic type and shock stage. E and H chondrites were discarded due to (shape) self demagnetization effects. For L and LL ordinary chondrites, we show that the magnetic susceptibility axes are identical to ±10° to the preferred orientation of the metallic FeNi grains determined by image analysis. This indicates that the AMS in ordinary chondrites is controlled by the orientation of metallic grains.

It has been already shown that the foliation and lineation are coherent in direction over a given chondrite sample [e.g., 1, 3-4]. We tested the consistency of the degree of AMS (i.e. the fabric intensity) in a given meteorite by measuring 22 different samples of the Knyahinya ordinary chondrite with mass ranging from less than 1 g to 50 g. AMS degree is fairly constant down to the 1 g scale, which indicates that, like bulk susceptibility [5], AMS is an intrinsic physical property of a given chondrite.

AMS database: We used shock stages defined following the petrographic classification scheme proposed by [6-7]. We focused our work on L chondrites whose magnetic susceptibility is low enough to avoid strong shape anisotropy. Moreover the metallic grains in L chondrites (kamacite, taenite) have bcc and fcc structures, ensuring that the grain shape effect dominates over the magnetocrystalline effect.

Foliation and impact on L ordinary chondrites: The database contains AMS measurements for 117 L chondrites (57 falls) with known shock stage. Magnetic anisotropy is high for L chondrites, peaking at 1.40 (Fig. 2), and is much higher than in most terrestrial rocks.

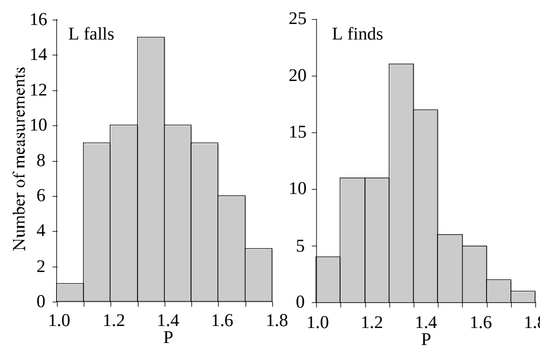

Figure 2: Histogram of degrees of AMS for L chondrite falls (66 data) and finds (76 data).

The susceptibility ellipsoid is generally oblate, in agreement with uniaxial compaction, but a significant lineation is present in most samples. For falls, anisotropy increases with shock stage (Fig. 3).

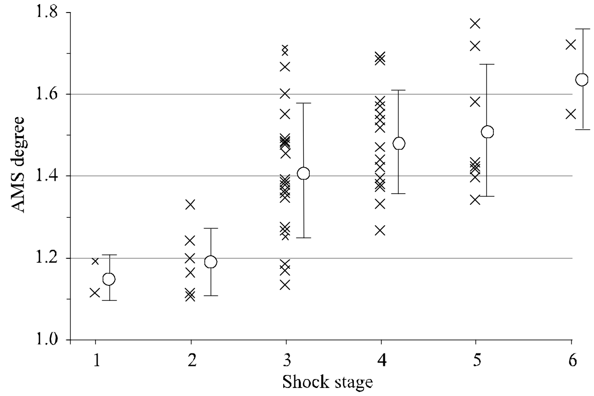

Figure 3: Degree of AMS vs. shock stage plot for L chondrite falls (57 data). Crosses: individual data (small crosses = L/LL), circles: mean values with standard deviations.

Therefore it can be concluded that hypervelocity impacts rather than overburden compaction are responsible for the foliation of L chondrites, confirming hypotheses in a number of previous works [2, 8-9]. It is noteworthy that the results from L finds do not show the clear correlation observed for L falls, with some quite large inconsistencies. This indicates that AMS in metal-bearing meteorites is very sensitive to weathering.

Our data also indicate that, despite a rather wide scatter, porosity and degree of AMS are inversely related (Fig. 4). This implies that porosity and shock stage are positively related, consistent with previous observations [10]. Deformation resulting from dynamic uniaxial compaction of an originally loose porous material during impacts is therefore the most plausible mechanism for the formation of foliation in L chondrites.

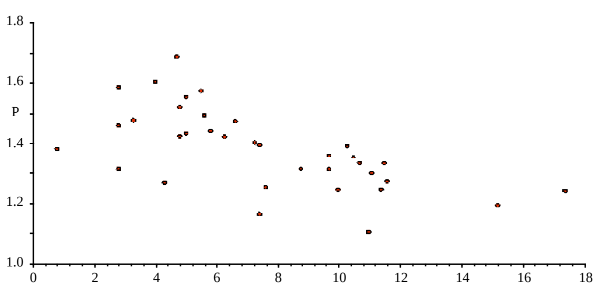

Figure 4: Degree of AMS (P) vs. porosity plot for L chondrite falls

Other meteorites: Our AMS database also contains measurements on other chondrites (37 LL with know shock stage, 17 C chondrites, and the first 8 measurements on R chondrites) and on achondrites (14 SNC, 20 HED).

Chondrites. Results for LL chondrites are consistent with those for L chondrites but data are scarce for shock stages S1, S4, S5 and S6. Moreover the scatter is higher, probably because of the presence of the highly anisotropic mineral tetrataenite. The limited dataset for C chondrites is also consistent with an impact related foliation. Rumuruti chondrites yielded surprising results with a low magnetic anisotropy (P=1.04, s.d.=0.02) that contrasts with the high deformability and high intrinsic anisotropy of their main magnetic mineral (pyrrhotite) and their shock stage (S2 in most cases). This may indicate that pyrrhotite crystallized after the major impacts on the Rumuruti parent body.

Achondrites. The weak magnetic anisotropy of SNCs (P=1.05, s.d.=0.04) indicates that uniaxial stress during impact produced limited or null shock fabric, in agreement with the low initial porosity and high compressive strength of SNC unbrecciated target material. HED meteorites provided very scattered results that probably reflect their small-scale heterogeneity and the significant contribution of paramagnetic minerals to their magnetic susceptibility. Therefore, the limited dataset for HED achondrites do not provide any insight into their complex shock history.

References: [1] Weaving B. (1961) *GCA*, *26*, 451-455. [2] Sneyd D.S. et al. (1988) *Meteoritics*, *23*, 139-149. [3] Cain P.M. et al. (1986) *EPSL*, *77*, 165-175. [4] Gattacceca J. et al. (2003) *PEPI*, *140*, 343-358. [5] Rochette et al. (2003) *MAPS*, *38*, 251-268. [6] Stöffler D. et al. (1991) *GCA*, *55*, 3845-3867. [7] Scott E.R.D. et al. (1992) *GCA*, *56*, 4281-4293. [8] Hamano Y. and Yomogida K. (1982) *Mem. Natl. Inst. Polar. Res.*, *25*, 281-290. [9] Sugiura N. and Strangway D.W. (1983) *GRL*, *10*, 83-86. [10] Consolmagno G.J. et al. (1998) *MAPS*, *33*, 1221-1229.