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Compaction of ordinary chondrites by hypervelocity impacts

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A large number of observations reveal the existence of foliation in almost all chondrites. In this work, we present a large dataset of measurements of anisotropy of magnetic susceptibility (AMS), mostly on ordinary chondrites, in order to elucidate the origin of chondrite foliation. This anisotropy database contains 259 different chondrites (mostly L and LL), as well as 36 achondrites (HED and SNC).

We performed AMS measurements on meteorites with known petrologic type and shock stage. For L and LL ordinary chondrites, we show the AMS is controlled by the orientation of metallic grains. AMS degree is fairly constant down to the 1 g scale, which indicates that, like bulk susceptibility, AMS is an intrinsic physical property of a given chondrite.

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. The susceptibility ellipsoid is generally oblate, in agreement with uniaxial compaction, but a significant lineation is present in most samples. For falls, anisotropy clearly increases with shock stage. Therefore it can be concluded that hypervelocity impacts are responsible for the foliation of L chondrites, confirming hypotheses in a number of previous works. 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. This implies that porosity and shock stage are positively related, consistent with previous observations. 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.

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 (15 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.