MAGNETIC FABRIC FORMATION BY OBLIQUE IMPACT IN PUŁTUSK H CHONDRITE.

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Introduction: The magnetic fabric of meteorites is a good proxy of their petrofabric and it was likely created by impact events [1, 2]. It has been shown that meteorites have well defined foliation and that the degree of foliation is related to the shock stage, suggesting impact and shock compression as main fabric-forming processes [3]. The presence of magnetic lineation has received less attention and, when observed, it was believed to be the intersection type related to the multiple impact events [1, 4].

The Pułtusk H chondrite displays presence of both magnetic foliation and lineation. Here we describe its fabric and put it together with the structural deformational record in order to reveal details of the impact process which could form it.

Methods: Low-field (378 μT, 920 Hz) measurements of anisotropy of magnetic susceptibility (AMS) were performed with KLY2 Agico aparatus at CEREGE (Aix-en-Provence, France). Isometric subsamples were prepared with a wire saw [3]. AMS measurements were performed to define the susceptibility ellipsoid (with eigen values $K_1 \geq K_2 \geq K_3$). Both, the degree and shape of anisotropy parameters were calculated according to [5]. Petrofabric analysis and microstructural analysis were done by high resolution X-ray tomography, optical microscopy and electron microprobe measurements.

Petrofabric: Pułtusk is a brecciated meteorite of H4-H5 type with some lithified H3 fragments. It is cut by darkened zones rich in CM material. Impact melt clasts are also present, although rare. Shock stage of meteorite was defined as S2-S3 [6, 7].

Darkened, cataclastic zones are formed by crushed and/or sometimes dynamically recrystallized silicate grains. Some zones have geometry of pseudotachylite with well-developed generation plane rich in dendritic troilite and strongly recrystallized silicates. Along with pseudotachylitic veins, striated surfaces occur parallel to the vein generation plane as well as parallel shear bands and microfaults with ~200 – 400 μm of displacement.

Impact melt is characterised by unmixed metal and troilite melt forming strongly elongated globules with axes ratio of 1.2 – 4.7 for ~4 μm and the largest bodies, respectively.

The measurements done on tomographic recontruction show that metallic grain size decreases significantly in cataclased and impact melt fragments compared to the host rock. At the same time, large, irregular metal nodules appear in these deformed zones what suggests that metal was involved in process of melting, grain size reduction and recrystallization [8].

Magnetic fabric: Bulk magnetic susceptibility of the Pułtusk samples that were prepared for this study (with masses ranging from 257 to 482 mg) is in the range of $\log\chi$ = 4.76 – 5.60 (with χ in 10^{-9} m^3/kg). For the host rock, cataclased rock and relict clasts inside impact melt the values are very similar: $\log\chi$ = 5.13 to 5.27, and typical for H chondrite [9]. The lowest values are related to impact melt samples. It suggests that melt segregation accompanied imact melting but not cataclasis.

Cataclased rock: Sub-samples representing darkened, cataclastic part of the meteorite differ from the surrounding host rock in their higher degree of the AMS ($P=K_1/K_3$= 1.45 – 1.51) and the degree of straining (unit shear e_s = 0.25 – 0.29). Pseudotachylite-like parts are even more strained than irregular cataclastic parts intermingled with discrete clasts (P=1.66, e_s = 0.35). Magnetic susceptibility ellipsoid of the zones and surrounding rock is generally oblate but magnetic lineation is also evidenced. $F=K_2/K_3$ and $L=K_1/K_2$ parameters put on the Flynn/Ramsay diagram (fig. 1A) are located near the diagonal, in the field of plane strain deformation (L=S). Pseudotachylite-like zones are more foliated (SL), however lineation is still distinct. For all the measurements, the intermediate K_2 axis relative value is close to 1: 0.97 – 1.04, while stretching along K_1 (1.10 – 1.20) is compensated by shortening along K_3 (0.73 – 0.78) axes directions.

There is no directional difference between orientation of AMS ellipsoid axes of cataclased parts and surrounding host rock. For the samples containing pseudotachylitic geometry the K_3 axes show good directional grouping whereas K_1 and K_2 axes are scattered on the great circle (fig. 1B). For the cataclased samples with discrete chondritic clasts, directional grouping is very well expressed for all the axes (fig. 1D), and not surprisingly these samples show the best developed lineation.

Magnetic foliation is parallel to the pseudotachylitic veins generation plane, microfaults in the host rock and striated surfaces. Lineation direction is consistent with the slickeniside striations (fig. 1C).

Impact melt rock: The melt fragments as well as chondritic relicts are highly anisotropic, highly strained and show strong foliation development and oblate shape of AMS ellipsoid (P = 1.93 – 2.16, e_s = 0.45 – 0.51; F=1.44 – 1.93, L = 1.12; fig. 1A). Magnetic lineation is not developed. Orientation of the principal AMS axes is random, related to flow-texture.

Discussion: Oblate fabric of impact melt samples of Pułtusk is in agreement with shock compression impact formation [1,2,3,4]. In contrast, cataclased samples show distinct magnetic lineation overprinted on the foliation (fig. 1A) what is hardly expected to be formed by impact, compresional regime.

Orientation of the magnetic fabric is coherent through the brecciated, cataclased Pułtusk samples and it was suggested earlier that impact induced foliation forms in brecciated chondrites in a ductile deformational pulse occurring after the overall brecciation [2]. Cataclastic samples of Pułtusk are, however, more strained and more anisotropic than the surrounding host rock. Because of inhomogeneous shearing record in Pułtusk (microfaults, brittle brecciation, cataclasis and pseudotachylite formation [6]), it seems that brittle brecciation of silicates and formation of the cataclastic zones could have been simultaneous with the ductile deformation of metallic grains in the whole rock.

When rock was sheared and brecciated, the strongest deformation occurred in cataclastic zones. Metallic grains, as the most ductile, were deformed in whole rock, dynamically recrystallized and formed magnetic fabric. Deformed by simple shearing they formed folition and lineation at the same time as noncoaxial deformation causes flattening in one direction and elongation in perpendicular. It is also evidenced by the absence of high longitudinal changes in K_2 AMS direction in Pułtusk samples i.e. transport direction along shear plane. Also, the consistent spatial arrangement of magnetic fabric and shear-related petrofabric is usual for highly strained, sheared rocks. Interestingly, in Pułtusk we can observe the inclined metallic grains on the boundaries of the pseudotachylitic veins, near generation plane. That is also in agreement with rotation of foliation during the deformational pulse. Shearing and high strain-rate deformation was most likely related to oblique collision, as shock record in Pułtusk is not very strong [8, 10].

Conclusion: Magnetic fabric and petrofabric of the Pułtusk chondrite are impact related. However their formation was related mainly to inhomogeneous, noncoaxial strain. Shearing caused formation of cataclastic zones and brittle fractures as well as brecciation of the meteorite. Simultaneous, noncoaxial ductile deformation of metalic grains caused formation of foliation and lineation. Processes occurred most likely due to high strain-rate oblique impact.

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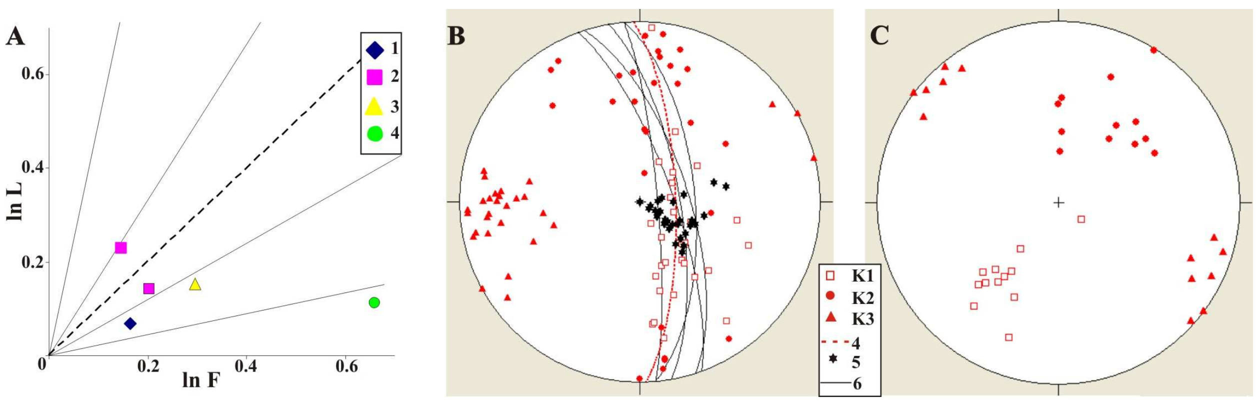

Fig. 1. AMS results and petrofabric oreintation for Pułtusk meteorite. A. Flynn/Ramsay diagram: 1 – host rock, 2 – cataclastic zones, 3 – pseudotachylite-like zones, 4 – impact melt rock. B. Orientation of ellipsoid axes (K_1, K_2, K_3), folaition plane (4), sliceknsides (5) and pseudotachylie generation planes (6) in pseudotachylitic sample C. AMS axes orientation for cataclased, well lineated sample.