Magnetic fabric in brittle faults and ductile shear-zones: Examples from cataclasites from the Iberian Peninsula

Marcos Marcén¹, Antonio Casas-Sainz¹, Teresa Román-Berdiel¹, Belén Oliva-Urcia², Ruth Soto³, Cristina García-Lasanta⁴, Pablo Calvin⁵, Andrés Gil-Imaz¹, and Luca Aldega⁶

¹Geotransfer, Dpto. Ciencias de la Tierra, Instituto de Investigación en Ciencias Ambientales (IUCA), Universidad de Zaragoza, Spain
²Departamento de Geología y Geoquímica, Universidad Autonoma de Madrid, Spain
³Instituto Geológico y Minero de España, Oficina de Proyectos de Zaragoza, Spain
⁴Geology Department, Western Washington University, EE.UU
⁵Departamento de Física, Universidad de Burgos, Spain
⁶Dipartimento di Scienze della Terra, Università Roma 1 la Sapienza, Italy

Shear zones, or their counterparts in near-surface conditions, the brittle fault zones, constitute crustal-scale, narrow, planar domains where deformation is strongly localized. The variation with depth of deformation conditions (P-T), rheology and strain rates entails a wide range of fault rock types, characterized by different petrofabrics and classically grouped into mylonitic (fault rocks undergoing crystalline plasticity) and cataclasitic (fault rocks undergoing frictional deformation) series. Magnetic fabric methods (most frequently anisotropy of magnetic susceptibility, AMS) have been established as a useful tool to determine fault rock petrofabrics in shear/fault zones, being interpreted as kinematic indicators with a considerable degree of success. However, mylonites and cataclasites show remarkable differences in magnetic carriers, shape and orientation of the fabric ellipsoid. Here, we present a study of ten brittle fault zones (one of them at the plastic-brittle transition) located in various locations in the Iberian Plate, with an aim to interpret patterns of AMS in cataclasites.

Reviewing AMS studies dealing with SC mylonites, three fundamental features can be drawn: i) the presence of composite magnetic fabrics with shape and lattice-preferred orientations, ii) the fabric is carried predominately by ferromagnetic minerals and iii) surprisingly in composite fabrics, the absolute predominance of magnetic lineations parallel to (shear) transport direction (88% of the reviewed sites), independently of fabrics being defined by paramagnetic or ferromagnetic carriers. Based on our study, magnetic fabrics in cataclasites: i) are mainly carried by paramagnetic minerals and ii) show a strong variability in magnetic lineation orientations, which in relation with SC deformational structures, are either parallel to transport direction (44% of sites) or parallel to the intersection lineation between shear (C) and foliation (S) planes (41%). Furthermore, changes between the two end-members can be frequently observed in the same fault zone. Sub-fabric determinations (LT-AMS; AIRM and AARM) also indicate that the type of magnetic lineation cannot be consistently related with a specific mineralogy (i.e. paramagnetic vs ferromagnetic minerals).
The wide range of deformation conditions and fault rocks covered in our study allowed us to analyse the factors that control these different magnetic lineation orientations, especially in brittle contexts. Plastic deformation results into a mineral stretching parallel to transport direction which can be directly correlated with the development of transport-parallel magnetic lineation. In brittle fault zones, the degree of shear deformation can be directly correlated with the type of magnetic lineation. The fault cores, where strain and slip are localized, show a predominance of transport-parallel magnetic lineations, most probably related with the development of lineated petrofabrics. Furthermore, the minor development of shear-related petrofabrics enhance the frequency of intersection-parallel magnetic lineations, also contributing the presence of inherited, host rock petrofabrics in the fault rocks.