Anisotropy of magnetic susceptibility: the influence of metamorphism on magnetic mineralogy and magnetic fabric - limiting factors for quantitative strain analysis.

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The relationships between the anisotropy of magnetic susceptibility (AMS), macroscopic structural features, preferred orientation of minerals, and finite strain were investigated in a section of increasing metamorphism in the Helvetic zone of the Central Alps. The study is restricted to pelitic material of the Upper Triassic Quartenschiefer formation which can be traced from the unmetamophosed state in the Swiss Jura Mountains to medium grade metamorphic areas south of the Lukmanier region. The orientation of the AMS ellipsoid was found to agree well with the foliation (normal to k_{min}, principal susceptibilities: $k_{max} \geq k_{int} \geq k_{min}$) and the stretching lineation (parallel k_{max}, fig. 1). The behavior of isothermal remanent magnetization (IRM) and demagnetization curves reveals that the transition from hematite to magnetite as the magnetic carrier occurs near the stilpnomelane-out isograd, although hematite is thermically stable up to 550°C (fig. 2).

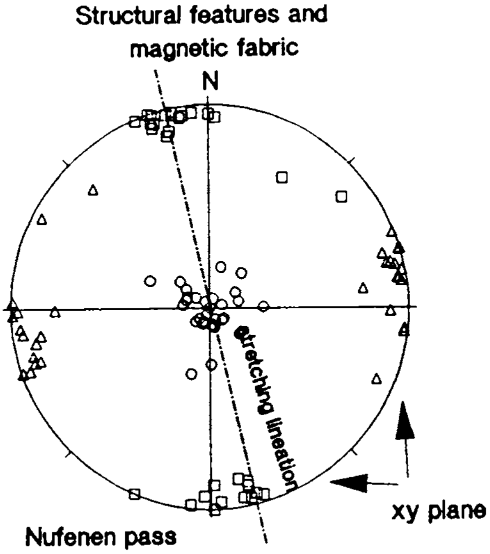


Fig. 1: Tilt corrected AMS and structural data from a low grade metamorphosed site.

Form and magnitude of the susceptibility quadric can not be compared over the metamorphic isograds (fig. 3, 4). Reduction of ferromagnetic minerals, changes in grain size, and metamorphic mineral growth affect the AMS, masking and overprinting the strain induced magnetic fabric. However, the principal directions of the susceptibility tensor remain remarkably constant in an approximate N-S orientation for k_{max} throughout the investigated profile.

The degree of anisotropy ($P = k_{max}/k_{min}$) in the narrow zone of sedimentary rocks between Aar and Gotthard massif (Urseren-Garvera zone) is extremely high, reaching values up to $P = 9.5$. Alpine thrusting and tectonic reduction affected these rocks squeezed between the two basement massifs. The results are high strains and hence high susceptibility anisotropy.

In the Lukmanier region the classical fold test, applied to principal AMS axes, proves that magnetic fabric is related to a steeply plunging N-S oriented stretching lineation combined with a penetrative axial plane cleavage ("Phase B" of Chadwick 1968) and was not affected by later nonpenetrative folding around an E-W axis (Chadwick's "Phase V").

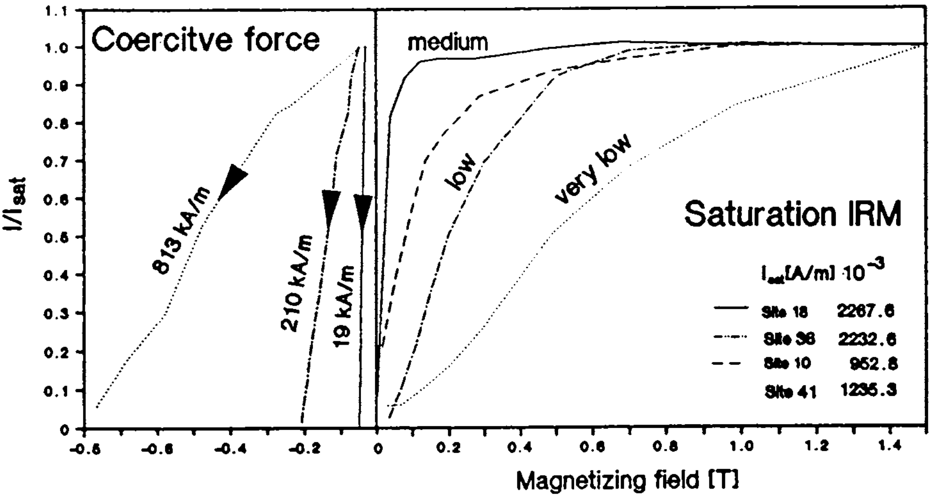


Fig. 2: Acquisition curves of isothermal remanent magnetization. Four representative specimens from different metamorphic grades are presented. Determination of remanent acquisition coercitive force is illustrated on left side.

The calculation of the maximum degree of anisotropy surface ("perfect aligned model", Borradaile 1987) can be used to distinguish between magnetic fabrics which originate from differences in mineralogical composition and those which originate from preferred orientation of minerals.

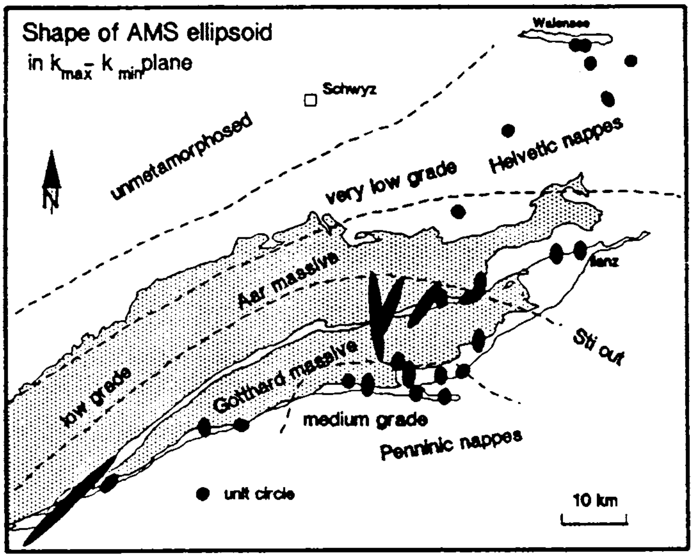


Fig. 3: Geological sketch map, site locations, and shapes of AMS ellipsoids. Stippled areas indicate pre-hercynian helvetic basement.

The maxima of density distributions of illite (001) and (020) X-ray goniometry pole figures show marked parallelism with the principal susceptibility directions (fig. 5). (001) reflexes coincide well with the direction of k_{min}. This is to be expected, since minimum susceptibility of mica is normal to the crystallographic basal plane. Maximum susceptibility of the investigated specimens are parallel to the maximum of (020) poles. Though AMS is caused only subordinately by illite, a distinct correlation between illite fabric, magnetic fabric, and macroscopic fabric is detected. March strains as evaluated from illite orientation data and principal susceptibilities exhibit no quantitative correlation. Nevertheless, the oblate shape of both strain and AMS ellipsoids is similar indicating a strain regime in the field of flattening. Magnitudes of ellipsoid axes, however, are not taken as a quantitative estimate of finite strain.

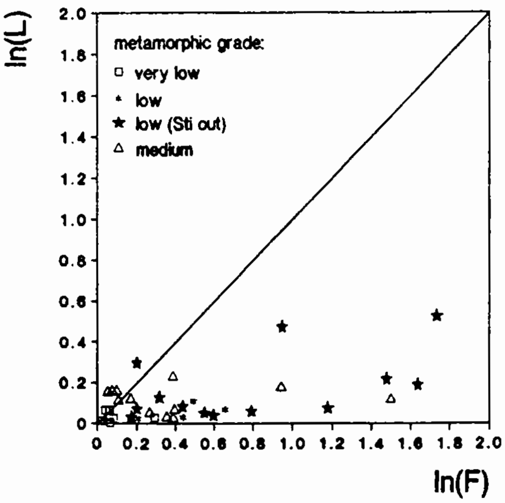
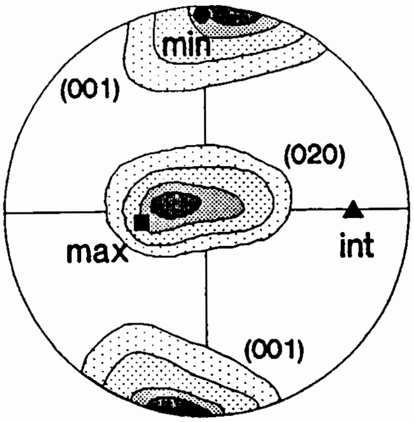


Fig. 4: Ellipsoid shapes in Flinn type diagram. Each point represents the site mean value of between 6 and 30 specimens, a total of 805 specimens. A relationship between metamorphism and AMS shape does not exist.



Contour levels (001): 1.00 - 2.00 - 4.00 - 6.00
Contour levels (020): 1.00 - 1.50 - 2.00 - 2.25

Fig. 5: Comparison between preferred orientation of illite (001) and (020) poles and orientation of principal susceptibility axes of the same specimens. All data are in specimen coordinates. Orientation of fiducial line: 195/71.

Literature:

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