

Microstructures and LPO as indicators of strain partition in metamorphic tectonites: the example of the Eclogite Micaschists Complex (Sesia-Lanzo Zone, Austroalpine domain, Western Alps, Italy)

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ABSTRACT

We studied microstructures and lattice preferred orientation (LPO) of the Eclogite Micaschists Complex (EMC) metapelites and metabasites. The EMC belongs to the Sesia-Lanzo Zone of the Austroalpine domain of the Western Alps (Italy). The Sesia-Lanzo Zone is a fragment of the Adria plate continental lithosphere, involved in the alpine subduction. The alpine imprint on the Sesia-Lanzo rocks is characterised by penetrative superimposed foliations, developed under eclogite facies conditions and marked by millimetre- to centimetre-size aggregates.

The microstructural analysis revealed a multi-stage evolution: i) pre-S1 mm-thin aggregate of quartz, white mica and rutile as inclusions within S1 garnet porphyroblasts; ii) S1 millimetre foliation defined by white mica and garnet; iii) D2 folding produces an axial planar foliation S2 marked by white mica, rutile, glaucophane, omphacite and locally aggregates of garnet; iv) D3 is associated with the reactivation of S2 and the growth of chlorite and green biotite or produces shear planes cutting the S2 foliation and marked by re-crystallized quartz and white mica.

LPO analysis was carried out using original diffraction data collected at the Institut Laue-Langevin (Grenoble) and processed using the Maud software package (Material Analysis Using Diffraction). Only quartz and white mica was studied by texture analysis since other mineral components constitute less than 20% in volume cannot be quantitatively detected by diffraction.

White mica LPO are characterized by (001) pole to planes distributions close to a cluster at high angle to S2 while poles to (010) and (100) describe girdle close to the S2 foliation.

Quartz distributions describe girdle of (100) and (110) poles close to the foliation plane with maxima close to the macroscopic lineation; (001) and (011) poles to planes describe two clusters close to the normal to the S2 foliation.

Several samples, even still displaying broadly same LPO features are also characterised by LPO of quartz more close to a single crystal distribution, likely indicating an important contribution of a static re-crystallization.

LPO may be used as additional tool to infer various scale strain partitioning where mesoscopic evidence are lacking.

KEY WORDS: Alps, LPO, microstructure, Sesia, subduction.

INTRODUCTION

The heterogeneous distribution of mesoscopic fabrics, as foliation and lineations, in metamorphic tectonites has been described in various tectonic contexts (Bell & Rubenach,

1983). It has also been shown that strain partitioning may be related or linked with metamorphic reaction progress (Salvi et al. 2010). The quantitative assessment of these parameters has important meanings when basement units are studied and their tectono-metamorphic evolution is reconstructed. Quantitative definition of metamorphic transformation is commonly accomplished by mineral-chemical investigation and quantitative petrographic modelling (Rebay et al., 2012). Less obvious is the quantification of fabrics evolution, commonly accomplished by qualitative optical analysis or quantitative 2D image analysis (Heilbronner & Herwegh, 1997).

This contribution describes a possible tool to quantify the degree of fabric evolution in metamorphic rocks. The method

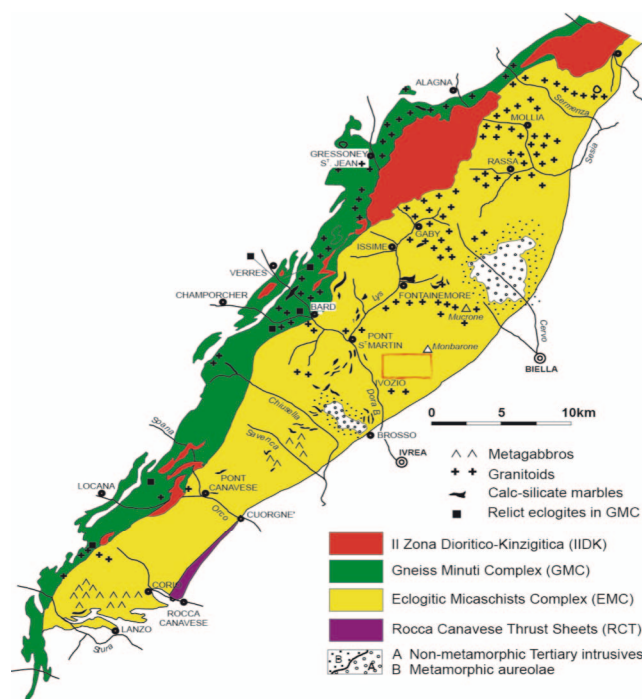


Fig. 1 – Tectonic sketch of the Sesia-Lanzo Zone. Red box indicates the sample source area.

uses data from neutron diffraction collected on relatively large samples ($\approx 1\text{cm}^3$) and describes the quantitative 3D lattice preferred orientation (LPO) of rock forming minerals.

The studied samples were sampled in the Eclogitic Micaschists complex and preserve a well defined eclogite facies mylonitic foliation (fig. 2).

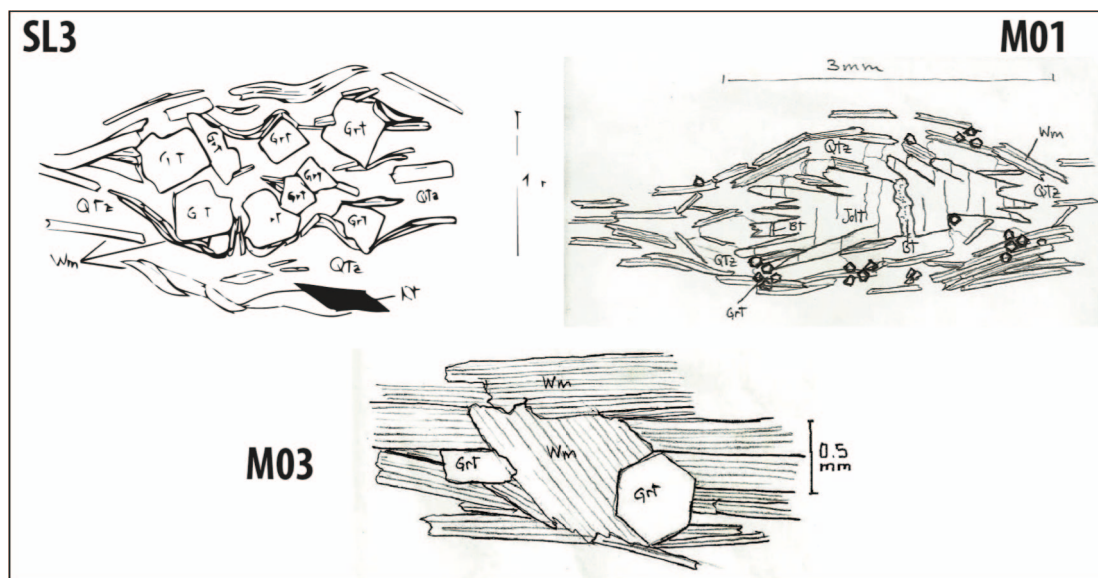


Fig. 2 –Sketches of the microstructural features of the samples SL3, M01 and M03. The dominant fabric is a foliation marked by SPO of phengitic white mica and quartz. Garnet also occur as sub-idiomorphic grains with rational boundaries. M01 also displays mm-thick jadeite grains wrapped within the foliation.

GEOLOGICAL SETTING

The Sesia-Lanzo Zone (fig. 1) is a large portion of pre-alpine continental crust that underwent high pressure metamorphism during the alpine subduction and exhumation phases (Zucali & Spalla, 2011). It is constituted by four main tectono-metamorphic units, distinguished on the basis of their lithostratigraphy, structural features and metamorphic evolution (Spalla et al. 2005; Zucali & Spalla, 2011). The Eclogitic Micaschists Complex define the most important one in terms of the area extent (fig. 1) and it is constituted by pre-alpine metapelite, metabasite and marble and Permian intrusive (Delleani et al., 2013; Zucali, 2011), deeply transformed during the alpine eclogite facies evolution; the Gneiss Minuti Complex, that records a high-pressure low temperature metamorphism of alpine age but this is commonly found as relict within a more pervasive green-schists facies metamorphic imprint and fabric; the IIDK, constitutes a relict of the pre-alpine continental crust that mostly escaped the alpine high-pressure re-equilibration; the Rocca Canavese Thrust Sheet experienced a high pressure imprint, under eclogite facies conditions but it is pervasively replaced by the blue schist imprint which is associated with a penetrative, km-scale, mylonitic foliation (Zucali et al., 2012b) that combines fragment of rocks with contrasting provenience, as mantle-derived gabbro and seppentinite and crustal orthogneiss.

METHOD

LPO data were collected using neutron diffraction techniques. Quantitative texture analysis using neutron diffraction allows for the investigation of volumes of rock on the order of 1cm^3 in a short time (few hours) thanks to the penetration of neutrons in matter and the high flux available at the nuclear reactor at the ILL (Tartarotti et al., 2011; Zucali et al., 2012a). Lattice planes are investigated in the sample space and represented as pole figures. Pole figures (PF) represent the directional distributions of the lattice plane normal (hkl) relative to sample coordinates. PF representation (fig. 3) uses equal-area projections of the orientation sphere and displays pole densities in multiples of a random distribution (m.r.d.) (Wenk, 2006). Quantitative analysis of diffraction data has been carried out using the Maud software (Lutterotti et al., 1999), and data are represented using the BearTex software package (Wenk et al., 1998).

A monochromatic radiation is used with a Cu (111) monochromator with a wavelength λ of 1.46\AA , a flux of $6 \times 10^6\text{ n} \cdot \text{cm}^{-2} \cdot \text{s}^{-1}$ and a maximum beam size of $2 \times 5\text{ cm}^2$. The diffracted intensities are measured by rotating the sample around two axes with a texture goniometer and a step interval of 5° . A position sensitive detector with an angular range of $120 \times 30^\circ$ is used to simultaneously acquire diffracting lattice planes at different Bragg's angles. PFs (fig. 3) correspond to the direction normal to the labelled planes.

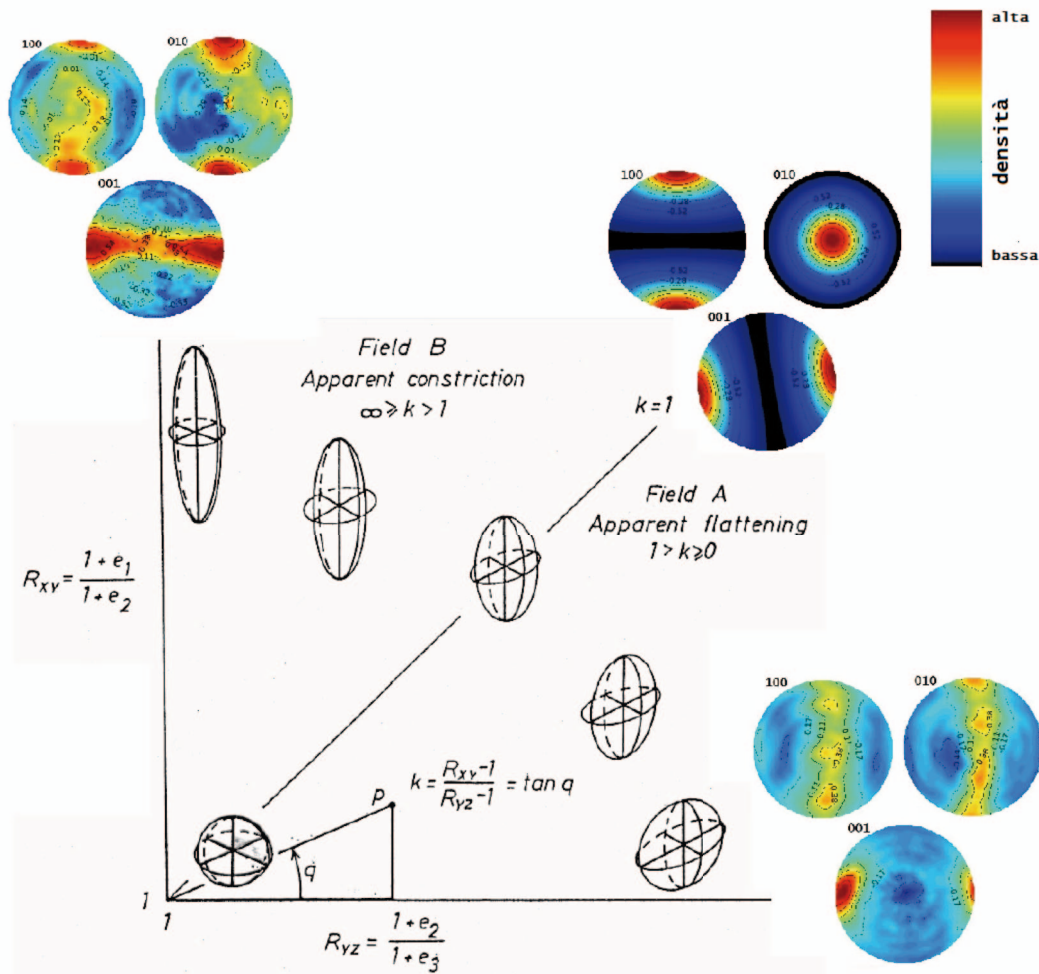


Fig. 3 – Flinn-like diagram showing the relations between phengite LPO and strain fields. M01 and M03 samples are characterized by oblate strain ellipsoid (lower – right image) whereas SL3 sample produce a prolate ellipsoid (higher left image).

RESULTS

MICROSTRUCTURAL FEATURES

Three samples of micaschists were analysed, m01, m03 and sl3 (fig. 3). They are all characterized by a eclogite facies foliation marked by shape preferred orientation of phengitic white mica, quartz and, in various percentages garnet, omphacite and glaucophane. More in details, **sl3** is constituted by quartz (55 vol%), phengite (25 vol%), garnet (8-10 vol%), amphibole (8-10 vol%), chlorite (<5 vol%), rutile (< 5 vol%) and opaque (< 5 vol%). Main constituents of the **m01** sample are quartz (35 vol%), phengitic mica (30-35 vol%), glaucophane (<10 vol%), jadeite (<10 vol%) and garnet (5-10 vol%). **M03** main constituents are phengitic mica (60-65 vol%), garnet (10-15 vol%), quartz (10-15 vol%) and pyroxene (<10 vol%).

Phengitic mica shows a well developed shape preferred orientation in all samples, whereas quartz may produce thin continuous layers or small lenses. Garnet grains are commonly well formed and their grain boundaries are in equilibrium with

mica and jadeite; this relations are used to suggest the eclogite facies as metamorphic conditions for the foliation development.

Lattice Preferred Orientations

Quantitative Lattice Preferred Orientation analysis (LPO) has been performed only on mineral phases with a minimum amount of 20 vol%. Lower contents may be detected by neutron diffraction but the intensities are too low to be used for the reconstruction of the Orientation Distribution Function (ODF).

In the studied samples only phengitic mica and quartz have been studied quantitatively. The resulting features are summarized in figure 3. In particular, Figure 3 shows the reconstructed LPO for phengitic white mica. The results are particularly clear and well defined in terms of preferred orientation directions and density (or probability) of distributions of the pole to lattice planes. The reconstructed LPO are displayed in a Flinn-like diagram where the strain state may be inferred from the orientation of the strain tensor. M01 ad M03 sample are clearly characterized by a oblate

ellipsoid, typical for flattening strain field, whereas SL3 sample is described by a strongly prolate ellipsoid, characteristic of a constrictional strain field (fig. 3).

White mica is characterized by two distinct LPO distribution: in M01 and M03 the (001) poles to planes describe a cluster distribution normal to the foliation plane (XY plane) and close to the Z mesoscopic fabric direction. Conversely, SL3 describes the (001) distribution as girdle parallel to the YZ plane, normal to the X shape-lineation direction. Quartz LPO distributions are also different: SL3 and M01 describe a thick girdle of the (110) poles to plane directions along a plane at 10-15 degrees to the XY plane. M03 quartz LPO instead is similar to those of single crystal, suggesting a crystallization under static conditions, whereas white mica LPO is typical for dynamic growth.

DISCUSSION AND CONCLUSIONS

The described microstructural and lattice features are clearly characteristic of a strongly partitioned strain during the eclogite facies deformational event that produced the dominant foliation. Because the described samples were collected in the same area, of about 2 km², it is possible to suggest a strain partitioning at the same scale and confirming the reliability of the method for identifying strain partitioning in metamorphic tectonites.

This method may be used as strain marker in terranes where the protolith of tectonites (or mylonites) was not necessarily an isotropic rock and, consequently, no strain markers are available.

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