RESIDUAL STRAINS AND CRYSTALLOGRAPHIC TEXTURES IN NATURAL QUARTZITES : TOWARDS AN UNDERSTANDING OF THE THERMOMECHANICAL HISTORY OF ROCKS

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Quartzites are nearly monomineral polycrystalline quartz-rich rocks, very common in the upper crust of the earth, and which have generally supported a complex deformation path at medium or high temperature. They show a great variety of microstructures (grain shapes, sizes and arrangement) and preferential crystallographic orientations (textures) of the quartz grains, and contain also small contents (a few percent) of a brittle second phase (e.g. feldspath or epidote mineral). Both the microstructure and the texture of quartz grains contain informations on the history of the rock deformation.

Due to the difficulty in conducting deformation tests, numerical simulations of the texture have been performed with the experimental residual elastic strain tensor.

The crystallographic texture and the complete residual elastic strain tensor in the quartz phase have been measured by neutron diffraction at the LLB on several quartzite samples, collected in Spain (betic zone) [1] and Turkey.

In order to precise the deformation mechanisms during geological processes, a large set of samples has been collected for many years, and the microstructures as well as the textures have been characterized and discussed.

Two main texture components (*) (plus a random fraction), determined either by the harmonic method or by discrete and component methods, have been clearly identified in all the samples: {-1 2 -1 0}<-1 0 1 0> and {-1 1 0 -1}<-1 -1 2 0>. These components have been further examined with the features of the various types of microstructures, and linked with specific proportions of grains considered respectively deformed and recrystallized. This result is in agreement with the textures of deformed and annealed hexagonal titanium and zirconium alloys.

On figures. 1b and 2 are shown repectively the texture and microstructure of two areas, B (recrystallized) and A (deformed), of a stretched quartzite vein (Fig. 1a), collected in a shear undulation in Turkey.

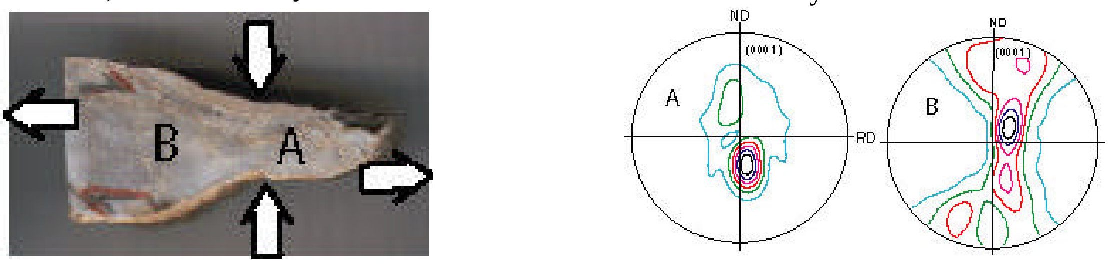

Figure 1. a) Macroscopic sample b) Pole figures (neutron diffraction)
(RD is the lineation direction and ND is the normal to the foliation plane)

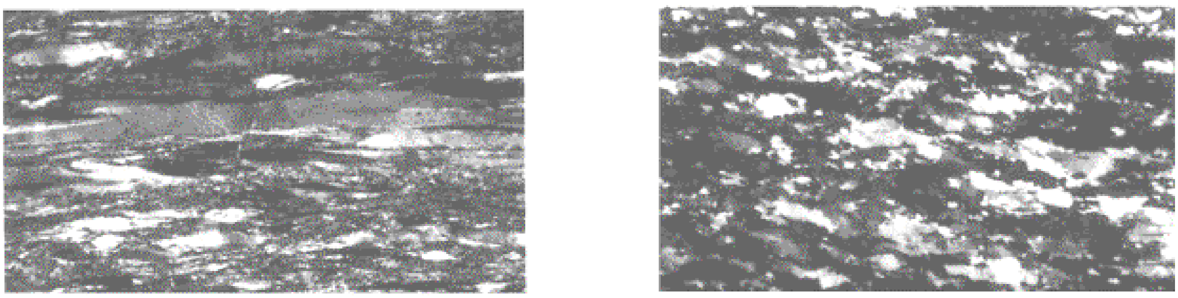

Figure 2. Microstructure of samples A (left) and B (right)

The measured residual elastic strain tensors are given below for the A and B samples depicted in Fig. 1a:

Sample **A:** $[e]=\begin{bmatrix}-88 & -7 & -7\\ -7 & 110 & -30\\ -7 & -30 & 17\end{bmatrix}\text{x}10^{-6}$ Sample **B:** $[e]=\begin{bmatrix}-38 & -28 & -14\\ -28 & -6 & -7\\ -14 & -7 & 12\end{bmatrix}\text{x}10^{-6}$, error $\leq$ 20 x10^{-6}

The largely recrystallized samples (e.g. sample B) do not show significant residual strains. In the samples containing a strong proportion of non-recrystallized deformed grains (e.g. sample A), the experimental strain values are very low in comparison to those generally measured in deformed metal samples; however, they are significant and allow one to perform texture simulations using a VPSC model (see below). Local measurements show some heterogeneity of the sample deformation. In some cases, the measured strains appear associated to the presence of brittle second phase grains.

A numerical simulation of the deformation texture, based on a visco-plastic self-consistent (VPSC) modelisation applied to anisotropic polycrystals *[2]*, has been performed. The calculation assumes a single-phased material, with an isotropic initial texture, with well-known slip systems and critical shear stresses. However, one does not know anything *a priori* about the plastic strain tensor to apply.

The main hypothesis made here is that the measured residual (elastic) strain tensor, which likely results from the accommodation of plastic incompatibilities between the quartz matrix and the precipitates (brittle secondary phases), is a memory of the plastic strain tensor undergone by the material during its history. Applying this plastic strain tensor (derived from the measured residual elastic strain tensor by reversing the sign of the trace components and setting the trace to zero) to the quartz crystallites in the VPSC model, one obtains simulated pole figures (corresponding to the deformation textures) consistent with those measured by neutron diffraction (compare Fig. 3 to Fig. 1b left).

Usually, modelisation of rock textures is made assuming *a priori* models for the strain tensor. In the present work, this is the first time that a complete "realistic" strain tensor is experimentally determined, and allows to reproduce the experimental pole figures.

In future, this work should be extended by the study of natural quartzites deformed in laboratory conditions, in order to confirm the correspondance of the residual elastic strain tensor with the slip system and the plastic strain intensity deduced from macro and microstructures observed *in situ*.

$$\begin{bmatrix}0.8 & 0.0 & 0.0\\ & -1.0 & 0.3\\ & & 0.2\end{bmatrix}_{e}=1.0$$

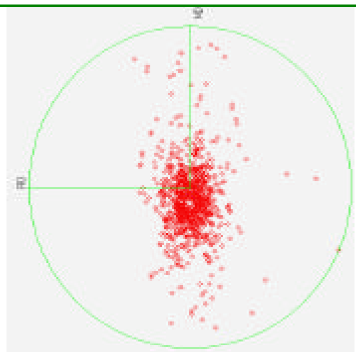

Figure 3. VPSC simulation of the deformation texture of quartzite with a complete strain tensor derived from residual elastic strain tensor measurements. Comparison of the {0001} pole figure of a typical deformed sample (sample A of Figure 1, characterized by the {-1 2 -1 0}<-1 0 1 0> texture component) with the simulated one.

(*) The texture components of rhombohedral structure quartz grains are identified by their crystallographic plane { } and direction < > preferentially parallel to the macroscopic shear plane ("foliation plane") and direction ("lineation direction") of the rock, deduced from the morphology of the grains and other markers of the deformation.

References

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