Influence of Initial Grain Size on Microstructural Stability and Rheology of a Dynamically Recrystallized Polycrystalline: Marble as a Case Study

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The relative nucleus density model (Sakai and Jonas, 1984) of dynamically recrystallized grain size was applied on experimentally and naturally deformed marbles that underwent dynamic recrystallization. The model shows that a relationship between initial grain size (D_0) and stable dynamically recrystallized grain size (D_S) for a given value of temperature corrected strain rate (Z) is critical for the operation of the different microstructural mechanisms of dynamic recrystallization. A new microstructural mechanism map (MMM) for experimentally and naturally deformed marbles (based on previously reported data) was defined in log grain size-log Z space and shows two distinct regions of grain refinement and grain coarsening. The boundary between these two regions is characterised by an equation for stable dynamically recrystallized grain size that is proposed in this work. The new MMM map was also used to trace microstructural changes in naturally deformed marbles that underwent dynamic recrystallization at different strain rate / temperature conditions.

Presented examples of naturally deformed marbles showed that the ratio of $2D_S/D_0$ controls mechanism of dynamic recrystallization and can be correlated to the degree of reworking of inherited microstructure. If the value of $2D_S/D_0$ is around 1, complete recrystallization occurs. A development of fine- and coarse-grained shear zones is expected for the values of $2D_S/D_0$ below and above 1, respectively.

The example of highly deformed marbles of the Lower Moravian Nappe in the eastern margin of Bohemian Massif shows that in case of $2D_S/D_0=1$ complete reworking of original microstructure occur. It is interesting, that this marble forming a continuous layer hundred metres thick, was preferentially used as tectonic lubricant for overthrusted orthogneiss body rather than micaschists, even when it shows microstructure indicative for dislocation creep mechanism (Ulrich et al., 2002). This suggests that the critical volume proportion of newly formed grains can be reached much faster in case of $2D_S/D_0=1$, in order to switch from LBF to IWL microstructure (Handy, 1994).

A critical strain is another important aspect that influences shear zone formation, which varies with the flow stress in the same way as Zener-Hollomon parameter Z (Rutter, 1999). Avoiding shear zone formation in case of our exceptional natural example of marble from the Lower Nappe (Ulrich et al., 2002) suggests that three main conditions of Rutter (1999) were not satisfied.

a) the amplified strain rate in the weakened shear zone was not sufficiently great to accommodate the imposed far-field displacement rate than would be required for uniform deformation of the entire marble body,
b) strains in the low-strain domains between shear zones became so high that rock matrix in the low strain domains itself enters dynamic recrystallization,
c) the original microstructure that enters dynamic recrystallization did not show local strain heterogeneities in order to form shear zones.

These conclusions of Rutter (1999) rewritten in order to explain given natural observation must be regarded in broad geological context. In other words, strain imposed by thick orthogneiss sheet on underlying marble of the Lower Nappe at temperatures around 400 °C is supposed to be much bigger than that imposed by e.g. metasediments. It seems in this special case when none of conditions of Rutter (1999) is satisfied and $2D_S/D_0=1$, that a degree of weakening caused by dynamic recrystallization is probably sufficient to produce significant strain localisation. Thus dislocation creep itself can be very important and effective mechanism of energy dissipation in deformed rocks.

References

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