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Assessing the role of grain boundary sliding in naturally deformed low-grade limestones (southern Apennines, Italy) based on finite strain and microscopy (optical, SEM and TEM) analyses

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Grain boundary sliding (GBS) is a fundamental deformation mechanism during in ductile deformation of fine-grained rocks. The first aim of this study is to estimate the occurrence of GBS, rarely observed directly, comparing rock bulk strain with finite strain measured from grains where markers are available and to quantify the amount of GBS with respect the rock strain. The second goal is to analyze ductile microstructures by means of optical and electronic (SEM and TEM) microscopy, in order to unravel subsidiary intra-granular mechanisms acting together with GBS. Samples are low to highly deformed oncoidal packstones from the southern Apennines (Italy). These rocks have been deformed, at very low-grade conditions, in a ductile (*ca.* 50 m thick) shear zone. Classical methods of strain analysis have been applied on polished slabs and SEM images in order to evaluate bulk and grain strains, respectively. In all samples the granulometry, measured by image analysis on SEM images, falls in the micrite field. A shape fabric defined by flattened oncoids characterizes moderately deformed packstones. Large grains (d = 20-500 microns) are elongate and show curved twins of thickness ranging between 2 and 22 microns, twins in twins and patchy twins, undulose extinction and subgrains. Small-recrystallized grains surround the larger ones and also occur along twins. The highly deformed limestones show microstructures dominated by small grains with very elongated large grains parallel to the foliation and exhibit undulose extinction, subgrains and dynamically recrystallized grains in bands oblique to the main foliation. Very low to highly deformed samples were examined in TEM with the objective of characterizing the defect microstructures

related to ductile deformation. Intracrystalline deformation is seen as glide dislocations that are most prominent in the low strain samples, occurring in both large grains from oncoidal and micritic matrix grains. At larger bulk strains, micrometre-scale matrix grains are largely quasi-equant and contain dislocation substructures. Large grains develop dislocation arrays (subwalls) leading to subgrain rotation and dynamic recrystallization. At very high strains, large grains are mostly recrystallized with recrystallized grains approaching the initial micrite grain size.

These limestones are deformed by a mixed-mode deformation process expressed as the combination of inter- and intra-crystalline mechanisms. Dislocation-mediated strain is reflected in individual grains as an increase in aspect ratio is association with formation of dislocation networks that define subgrains. The largest primary grains exhibit twinning and grain-size reduction by dynamic recrystallization. The similarity of grain size distribution in protolith and highly deformed samples precludes dynamic recrystallization as a volumetrically important process in establishing grain size. Despite the twins in large grains, there is distinct paucity of twins throughout the samples, an observation that suggests stresses were not sufficiently high for twinning to be enabled throughout the rock. Furthermore, the calculated grain strain is always less than bulk strain, hence most of the deformation must be accommodated by inter-crystalline mechanisms. According to these observations, the most important intergranular deformation mechanism has been grain boundary sliding accommodated by dislocation processes.