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Mechanical and microstructural development of Carrara marble with pre-existing deformation history in torsion experiments

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The deformation behaviour of Carrara marble has been studied mostly by performing deformation experiments on initially undeformed samples. In this study, torsion experiments on Carrara marble with a pre-existing deformation history have been conducted and analysed in terms of both mechanical and microstructural development. Torsion experiments have been conducted to deform initially deformed Carrara marble samples until a bulk shear strain of gamma 1 or 2.6 was reached. For Carrara marble experiments typically yielding is followed by strain hardening until a peak stress is reached around a shear strain gamma = 1 , after which a weakening phase occurs. Weakening gradually develops into a steady-state creep. During hardening, a shear microstructure and CPO develops; afterwards dynamic recrystallization becomes increasingly effective resulting in pervasively recrystallized microstructure and recrystallization CPO at gamma 5 and higher.

Starting material of the new experiments are sandwich samples consisting of three equally sized segments: a top segment previously deformed counter clockwise, an undeformed centre segment and a previously clockwise deformed segment in the bottom. Shear strain of the deformed bottom and top segments are equal in magnitude but opposite in sense and correspond with the shear strain of the actual experiments (e.g. sample of the gamma 1 experiment, consists of initially gamma 1 deformed top and bottom segments). All torsion experiments were conducted using a Paterson type internally heated gas-medium deformation apparatus equipped with a torsion actuator, under temperature and pressure conditions of 1000K and 300 MPa, respectively. Angular displacement rates during the experiments correspond to a strain rate of 3.0x10-4 s-1 at the outer cylinder periphery. The second deformation event imposed on the sandwich sample is always counter clockwise (or dextral).

The sandwich experiment to gamma 1 shows a weakly developed strain partitioning between the three segments. Most strain is accommodated in the initially undeformed centre segment, whereas the top segment appears least deformed during this experiment. For the higher strain experiment (gamma 2.6), strain partitioning is enhanced and reversed, i.e. maximum and minimum strains are accommodated by the top and centre segment respectively. This strain partitioning can be explained by the strength evolution of Carrara marble with shear strain. For Carrara marble at gamma 1, deformation is harder than undeformed, due to hardening of the material caused by shearing microstructure. At higher strain, Carrara marble starts recrystallizing instead of shearing, weakening the material. Therefore, for the gamma 2.6 experiment deformation is easier in the initially deformed segments than in the undeformed segment. Consequently, strain partitioning can be an onset for strain localization.

The observed microstructures reflect the finite strain (pre-existing plus added) in the sample segments of same sense of shear, which are shear microstructures for 0+1 and 1+1, and recrystallization microstructures for 0+2.6, and 2.6 + 2.6. For the segments of reversed sense of shear, the segment 1-1 appears like undeformed with respect to grain shape, but contains larger amounts of intragranular defects; the segment 2.6-2.6 is mostly recrystallized to a fine grained matrix with some ‘un-stretched’ clasts embedded. Similarly, the CPO in segments 0+1 and 1+1 resembles shear textures, while segments 0+2.6, 2.6+2.6 and 2.6-2.6 show recrystallization CPO. In segment 1-1, the pre-existing shear CPO is nearly annihilated by the second deformation in reversed sense.