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Natural deformation of ultra-fine-grained (UFG) and nanostructured limestone

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Ultra-fine-grained rocks (grain size < 5 μm) comprise a volumetrically limited, but phenomenologically significant fraction of crustal and mantle lithologies. In extreme cases, grain sizes can approach that of nanostructured materials (a few hundred nanometers) for which mechanical responses are not always as predicted by extrapolation from 'normal' microcrystalline material. Central to this behaviour is the ratio of grain boundary to bulk grain volumes that influences a host of parameters including stress distribution within the polycrystal, dislocation generation and organization and diffusion kinetics. Micritic (lithographic) limestone serves as an example of the complexity of mechanical response than can occur in UFG lithologies. Preservation of the syndeformational grain size in such units is moot unless homologous temperatures are sufficiently low or other textural or kinetic factors sufficiently suppress grain coarsening. The common occurrence of platformal carbonates, including micrites, in upper crustal deformation regimes allows microstructural characterization to be undertaken with the reasonable expectation that thermally induced adjustments of fabric are minimal. For sub-greenschist conditions at temperatures below 523K (250°C), deformation occurs below depths of 7-12 km at maximum lithostatic pressures of 180-300 MPa. Transitions in deformation modes under these conditions are abrupt in both space and time; under roughly the same conditions, micritic exhibits extreme fracture toughness and brittle response, distributed shearing and folding, and localized ductile flow. Refinement of the controls on these responses is a core motivation of this research. In aid of the latter, characterization of microstructures in UFG limestones, both protoliths and tectonites, by analytical transmission electron microscopy has been utilized to establish evidence for specific deformation processes during natural deformation for comparison with experimentally constrained behaviour.