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Results from deformation experiments performed at a range of temperatures and pressures in the ENGIN-X neutron beamline at RAL

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Conventional deformation experiments designed to investigate the mechanical properties of polycrystalline materials are generally restricted to measurements of whole-sample properties. However, when comparing the experimental measurements with theoretical analyses, it is frequently essential to be able to determine how the deformation is being accommodated at the grain-scale within the sample as the experiment is progressing. In principle, information bearing on the latter can be obtained by post-experiment analysis of the microstructures of several different samples of the material of interest, each deformed to a different strain. However, this introduces the effects of sample and experimental set-up variability into the dataset and, moreover, is restricted to problems where the deformation involves microstructural changes which are both permanent and measurable.

The penetrating nature of neutrons offers an alternative and more experimentally efficient way of addressing this matter. By performing deformation experiments in the neutron beam-line and collecting neutron diffraction patterns at several different applied loads, the lattice parameters of all the crystalline phases present in the sample may be determined as a function of load. From this it is straightforward to calculate the changes in elastic strain (and stress if the elastic properties are known) experienced by each phase during the course of an experiment, as well as the variation in that strain with lattice direction, the latter of which allows inferences to be made about grain-scale accommodation mechanisms. We have conducted a number of experiments to explore the potential of this approach for investigating the mechanical behaviour of geological materials. These have focused on:

(1) examining the influence of LPOs and mineral phase spatial distribution on elastic property anisotropy in polymineralic materials;

(2) examining changes in strain partititioning between the phases during plastic yielding of polymineralic materials;

(3) monitoring the progress of stress-induced crystallographic / phase transformations during deformation.

Our early experiments were performed at room temperature and pressure. The results of some of these experiments, particularly those in which we monitored changes in strain partitioning between the phases during the plastic yielding of calcite+halite aggregates of different compositions, will be discussed to illustrate the experimental practicalities and the nature of the results which can be obtained using this approach.

For the approach to be generally applicable for investigating the mechanical behaviour of geological materials, it is important to have the capability of performing the experiments at elevated temperatures and confining pressures in order to suppress cataclasis in the samples. To this end, more recently we have (a) performed room pressure experiments at elevated temperatures to examine the pre-yield behaviour of calcitic aggregates and the onset of mechanical twinning, and (b) have designed and commissioned a pressure vessel which allows room temperature experiments at confining pressures of up to 250 MPa. The results of these experiments will be described to show that performing experiments at elevated temperature or pressure does not lead to a significant diminishment in the quality of the measurements obtained. Our next experimental challenge is the design of an apparatus which allows the application of elevated temperatures and pressures simultaneously.