Volume changes during diagenesis and metamorphism: where are they?

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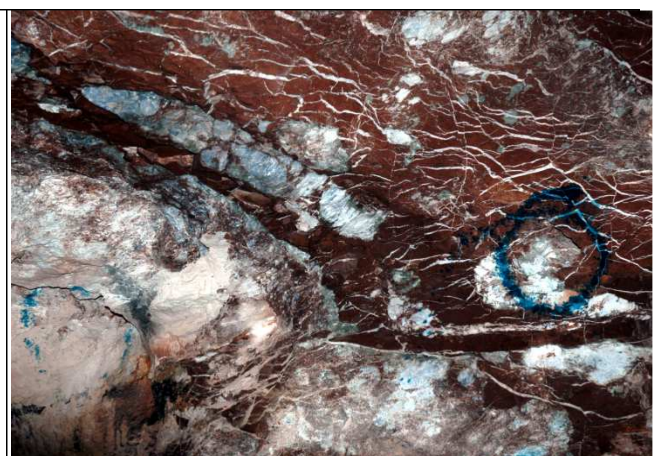
<u>Is this a CASE studentship?</u> YES

<u>If so, please state intended CASE partner:</u> British Gypsum (part of St Gobain)

Introduction: It is undeniable that in general metamorphic and diagenetic reactions involve both net and solid volume changes. For example olivine becomes serpentinised with an increase in volume on addition of water; anhydrite becomes gypsum with a 60% volume increase. Rocks do show cracking related to new mineral growth in some instances but on the whole the volume changes that must occur leave no obvious trace. Various explanations have been proposed, including some which call upon open system behaviour. In other words the excess volume is conveniently carried away by fluid movement. If this is the general situation then most of metamorphism and diagenesis is open system not just with regard to fluids but to (dissolved) solids too. That is not part of conventional metamorphic thinking, in which we assume systems are isochemical with respect to non-volatile chemicals until proved otherwise. Understanding volume change therefore has major significance for elucidating metamorphic and diagenetic processes. A combination of physical processes (including deformation) and chemical processes (including reaction kinetics and long range transport) must be considered. The anhydrite to gypsum transformation is simple yet is predicted to have a substantial volume change – it is an ideal focus for studying the general problem of volume change during reaction in the Earth.

	
Fig. 1. Banded anhydrite (grey) replaced by gypsum (white) without any apparent disturbance of banding despite volume change	Fig. 2 – Evaporite to shale contact on a face in Faulds mine, UK. On the left a diapir structure is visible.

Project Summary: The retrogression of anhydrite to gypsum is a relatively simple reaction and is predicted to have a spectacular 60% volume increase (if $CaSO_4$ is immobile). This makes it an ideal reaction to understand how the volume increase occurs. Evaporitic rocks underlie approximately 25% of the continental areas with gypsum and anhydrite (its dehydration product) as the principal components [1]. They are very soft minerals relative to other rocks types. Thus they accommodate large displacements in fold and thrust belts, such as the Northern Apennines in Italy and the Betics of Southern Spain. This weakness also gives rise to engineering problems [2]. Deformation may result from applied stresses and also from the actual reaction of gypsum to anhydrite and back, in engineering settings causing foundations and tunnels to warp or disintegrate altogether. These interactions of deformation and reaction are not understood.

The project will involve field studies of gypsum-anhydrite relationships in Tuscany and the UK. In Tuscany there are inspiring natural and quarried localities where anhydrite is variably converted back to gypsum. Gypsum replaces deformed anhydrite, with the anhydrite foliation allowing the shape change to be tracked; veins contain 30cm crystals of gypsum, testament to at least some open system behaviour. In the UK, Faulds Mine contains diapirs where anhydrite is converted back to gypsum, indicating a likely link between volume change and deformation (Fig. 2). Having characterised field relationships, the student will use microstructural methods to investigate grain-scale relationships between gypsum and anhydrite. In particular we have pioneered the use of Electron Backscatter Diffraction in the Earth Sciences and this technique allows detailed microstructural maps, including lattice preferred orientations, to be collected automatically. Vital clues to how minerals deform are provided in the microstructures, in particular lattice preferred orientations (LPOs). There are very few LPO studies on gypsum and anhydrite, in part because efficient techniques for measuring LPOs have only recently been devised - by us [3-5]; [6]. Optical microscopy and XRD (to determine bulk proportions of the target minerals) will be followed by in-depth investigation via EBSD mapping which can reveal not just the overall LPO but also the details of intracrystalline deformation, dislocation slip systems operating [7] etc.

The student will receive training in the EBSD, optical microscopy and XRD techniques and will be part of a stimulating multidisciplinary environment within the Microstructure and Rock Deformation Research Group. The University of Liverpool provide a certified Postgraduate training programme for general research and other professional skills.

The results of the project will enhance our understanding of the effects of volume change during diagenesis and metamorphism and the ductile deformation behaviour of evaporitic horizons including diapirism.

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