

New holes for old? Dolomite formation and porosity development in sediments

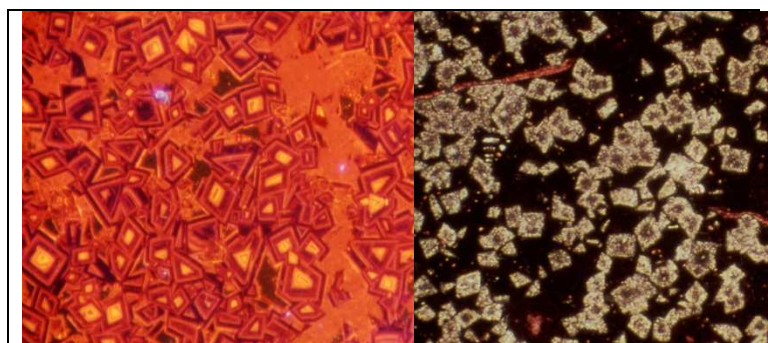
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Is this a CASE studentship? YES

If so, please state intended CASE partner: Cambridge Carbonates

Introduction: Dolomites, formed by the replacement of limestones, commonly act as anomalously porous hosts for hydrocarbon, mineral and water resources. It is often asserted that dolomitisation results in porosity generation. Calcite is less dense than dolomite and if CO₃ is conserved then a 12% volume reduction is required, argued to result in a commensurate increase in porosity. In many dolomites,



CL image of zoned dolomite crystal fabric suggests that dolomitisation involves flux of redox sensitive elements, most likely Mn and Fe) as well as magnesium. Field of view ~1mm.

Thin section photomicrograph of partially dolomitised limestone provides evidence of volume-for-volume replacement in this example. Field of view ~1mm.

though, porosity appears to be unchanged or inherited from precursor limestone, with further modification only by infilling cements and/or compaction. Textures in partially dolomitised limestones (pictured) support such replacement on a local volume-for-volume basis and show that the dolomitisation reaction, in itself, does not involve bulk porosity changes to the sediment. Whilst reaction mass balances may range from mole for mole to volume for volume, with a range of intermediates, “It is not clear how Nature ‘chooses’ one reaction stoichiometry over another” (Machel, 2004). This has important implications for the understanding and therefore prediction of reservoir quality and performance. The “choice” remains to be explained in terms of the kinetics of

diagenetic processes.

Project Summary

The aim of this work is to link grain- and pore-scale physical and chemical processes to better understand porosity evolution during dolomitisation, and the implications for distribution of reservoir quality. The research potentially impacts on the ability to estimate hydrocarbon reserves and to evaluate reservoir performance, and the approach developed will have general applicability to other diagenetic and metamorphic replacement phenomena. We will focus on dolomitisation “fronts”, regions where the spatial variations in the degree of dolomitisation are manifest. Spatial variations are a proxy for the temporal evolution during dolomitisation. There are three themes that will run in parallel.

Theme 1 is field/core-based investigation of dolomite geometry, to give essential background to guide sampling strategy and to give larger scale context to results. At Paldiski, Estonia, for example, it is possible to map the 3D geometry of decimetre-scale coarsely crystalline dolomite bodies and sample across replacement fronts that are parallel to or cross-cut lithological units in the host limestone. The experience gained in this first study will then be used to study economically-important subsurface dolomite reservoir rocks.

Theme 2 is lab-based investigation. The student will carry out detailed textural analysis including cathodoluminescence (CL), UV and electron microscopy including Electron Backscatter Diffraction (EBSD) to characterize intracrystalline distortions if present (these influence chemical behaviour); and collect elemental profiles and matched high resolution stable isotopic data across dolomitisation fronts. This will be done in the LIFER laboratory at Liverpool and via the NERC Ion Probe facility – to test inheritance versus external exchange of ions. For example in the “mole for mole” hypothesis, it might be that C is conserved, including its isotope ratios.

Theme 3 is modelling of small-scale physical and chemical behaviour. Using equilibrium and kinetic concepts the student will test the relative importance of diffusion, interface, and longer range transport mechanisms. Clarification of these small-scale processes is critical to the development of larger scale models for porosity development.

The student will receive training in a range of sampling, analytical (stable isotope; electron microprobe; CL; EBSD) and numerical techniques that are widely used in academic and industrial environments. The student will benefit from working within an active interdisciplinary research environment, based at the University of Liverpool with frequent interaction with Manchester and CASE partner Cambridge Carbonates.

Supervision Team: John Wheeler has worked on the link between isotope behaviour and crystal structure (MacDonald et al., 2013) and has experience of understanding kinetic phenomena from metamorphic studies (Llana-Funez et al., 2012). Jim Marshall and Steve Crowley have wide experience in petrological and geochemical studies of diagenetic and other processes (Machent et al., 2012; Shelton et al., 2011) working within and with the hydrocarbon industry. Cathy Hollis is an expert in dolomitisation processes (Hollis and Walkden, 2012) and has worked on examples from the UK and the Middle East and Benoit Vincent specialises in carbonate studies (Breesch et al., 2006) and has worked with many of the world's leading oil and gas companies.

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