Basin-Scale Mineral and Fluid Processes at a Platform Margin, Lower Carboniferous, UK

A Thesis submitted to the University of Manchester for the degree of Doctor of Philosophy (PhD) in the Faculty of Science and Engineering

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Late diagenetic, fault-controlled dolomitisation has received much interest as it is an important host for MVT-mineralisation and hydrocarbons, and an excellent proxy for fluid flow and reaction in carbonate systems. The source of fluids of sufficient volume and the correct chemistry to explain the volume of dolostone is much debated. Recent work has shown how seawater convection along deep-seated crustal lineaments is focused in zones of structural complexity. Since dolomitisation is favoured where there is a precursor high magnesium calcite or dolostone, it is possible that such a process is a critical precursor to the formation of these late diagenetic dolostones from evolved brines during extension and transpression. In the Pennine Basin and North Wales, UK, late diagenetic fault/fracture controlled dolostones developed on the margins of Mississippian carbonate platforms that grew on the rotated footwalls of normal faults and a basement of Lower Palaeozoic metasediments. Conceptual models for their formation focus on expulsion of fluids from Serphukovian-Bashkirian sediments within adjacent hanging wall basins, by compactional dewatering or rupture of overpressured compartments and seismic pumping. This project aims to determine the source, composition and drive mechanism of fluids that formed a large (~60km$^2$), non-stratabound dolostone body exposed within the Viséan sediments on the southern margin of the Derbyshire Platform, through a combined regional sedimentological, diagenetic and structural framework using multiscale, interdisciplinary techniques. Techniques include field observation, transmitted light and CL analysis, bulk major and trace element analysis including rare earth elements, stable isotope (oxygen/carbon), and strontium isotope analysis. The Derbyshire Platform underwent burial, several episodes of fluid-flow, and multiple phases of diagenetic overprinting. The products of fluid circulation in this area consist of dolomitisation and Mississippi Valley-type (MVT) mineralisation, affecting the carbonates of the Lower Carboniferous (Viséan) succession.

Dolomitisation on the Derbyshire Platform is aligned to deep-seated basement faults and extrusive, intraformational volcanic beds, and five dolostone phases have been identified. These are present as matrix replacive and cement phases that are spatially and temporally related to deep seated structural lineaments. It is proposed that stratabound, early post-rift dolomitisation resulted from the geothermal convection of a mixed meteoric-seawater that interacted with the Viséan extrusive and intrusive volcanics on the Derbyshire Platform, providing additional magnesium for dolomitisation. This previously undescribed model of dolomitisation is key to explaining the anomalously large
quantity of dolomitisation observed on the Derbyshire Platform and has implications to other carbonate platforms where dolomitisation is interpreted as fault-controlled.

Subsequent phases of dolomitisation are fault-controlled, with each phase becoming increasingly confined to fractures. Timing of dolomitisation is interpreted to be a Carboniferous event, with later mineralisation also being of late Carboniferous in age, with basin de-watering on to the platform via faults/fracture systems and the development of pockets of overpressuring. Illite-smectite clay transformations within Viséan basinal sediments provided the necessary magnesium required within select fault/fracture systems. Consequently, burial calcite cements and MVT mineralisation was precipitated within fractures and dissolution-enhanced secondary porosity, with fluids derived from the overlying Namurian succession which also acted as the seal.

This project provides a step-change in our ability to predict the location of late diagenetic fault/fracture controlled dolomitisation in rift basins by demonstrating the importance of dolomitisation by mixed meteoric-seawater on platform margins to the localisation of late diagenetic dolostone bodies. It also highlights the complex interplay between basin kinematics, host rock permeability and timing of fluid supply through episodic fault reactivation, connecting platforms to basin compartments, which ultimately controlled the positioning of dolostone geobodies on platform margins. This has implications to the exploration of both minerals and hydrocarbon within dolostone hosts, and will inform studies of fluid transfer and reaction in carbonate systems.
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