Fault-Fracture Diagenesis of Lower Carboniferous Carbonate Platforms, UK-Potential Analogues for Giant Carbonate Reservoirs of the Caspian Region?*

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Abstract

Relatively little data has been published on the diagenetic overprint of the giant carbonate oilfields of the Caspian Region, even though it has been widely recognized that both early and late diagenetic processes play an important role in controlling reservoir quality (eg. Jones and Xiao, 2006). In order to better predict and visualize the control of diagenetic processes on porosity and permeability, well studied and accessible analogues are required. Since the diagenetic evolution of the Lower Carboniferous (Visean) carbonate platforms of the UK have been widely investigated and documented, they potentially provide valuable data on the mechanisms and timing of porosity modification within a time-equivalent tectono-stratigraphic context.

This study concentrates upon the diagenetic evolution of the Derbyshire and North Wales Platforms using integrated field, petrographical and geochemical characterization. The platforms record widespread evidence of cementation within the marine and meteoric environment. In particular, a well-developed cement stratigraphy developed in response to tectonically and glacio-eustatically controlled sea level fluctuations. Cementation from aquifer-derived porewaters occluded much of the matrix macropore network in the shallow burial environment, and therefore late burial diagenetic processes are dominated by fault-fracture controlled fluid migration and circulation. The burial diagenesis of the Derbyshire and North Wales platforms is dominated by pervasive cementation of faults and fractures by calcite. This calcite is coeval with hydrocarbon emplacement and Mississippi Valley-type (fluorite, barite, galena) mineralization. Locally, these phases are preceded by fault/fracture related dolomitization. Although there is some indication of solution-leaching beneath aquitards to form metre-scale ‘pipes’, the burial environment was largely one of porosity degradation. A diagenetic model will be presented that relates the distribution of burial diagenetic carbonate cements and mineralization to post-rift basinal subsidence and inversion, with the onset of the Variscan Orogeny. The diagenetic evolution of the platforms will be compared and the application of the data and models to the Caspian region evaluated, including an assessment of the likely diagenetic controls on porosity and permeability in the subsurface.

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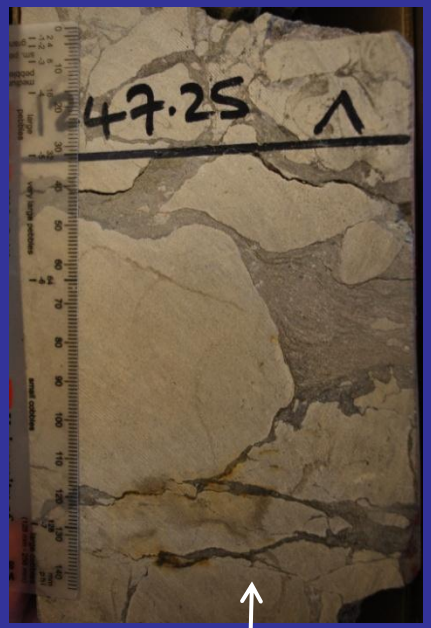
Rationale

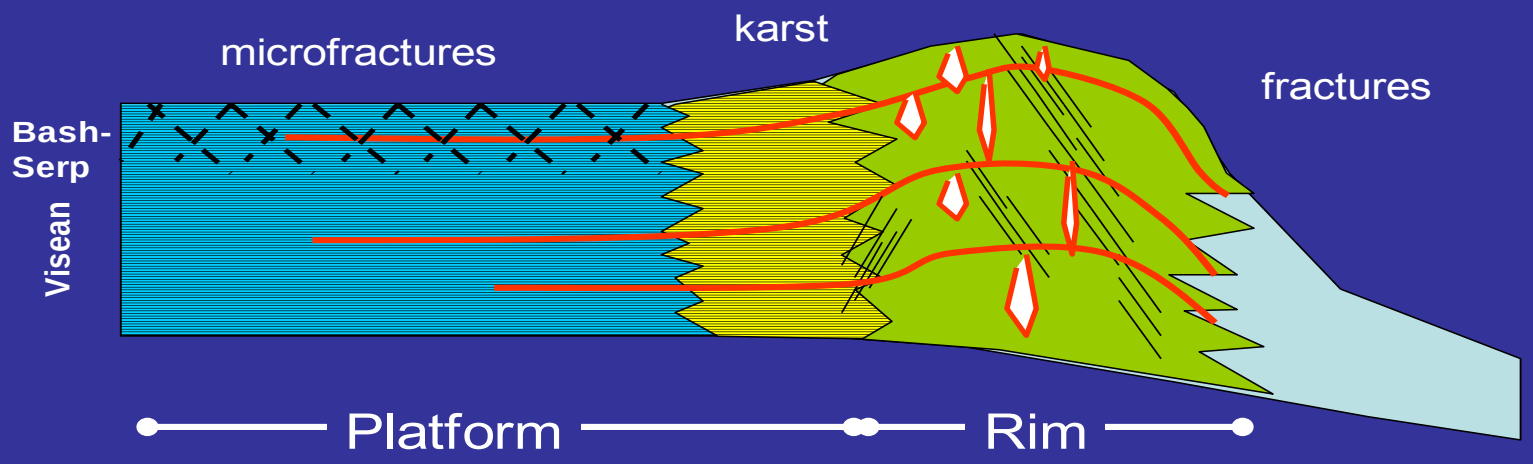
- Diagenesis results from a series of processes that develop in response to the availability of fluids and reactants within a given tectono-stratigraphic framework
- The resultant porosity/permeability architecture develops in response to these post-depositional events
- Analogues provide an opportunity to map the distribution/geometry of diagenetic products



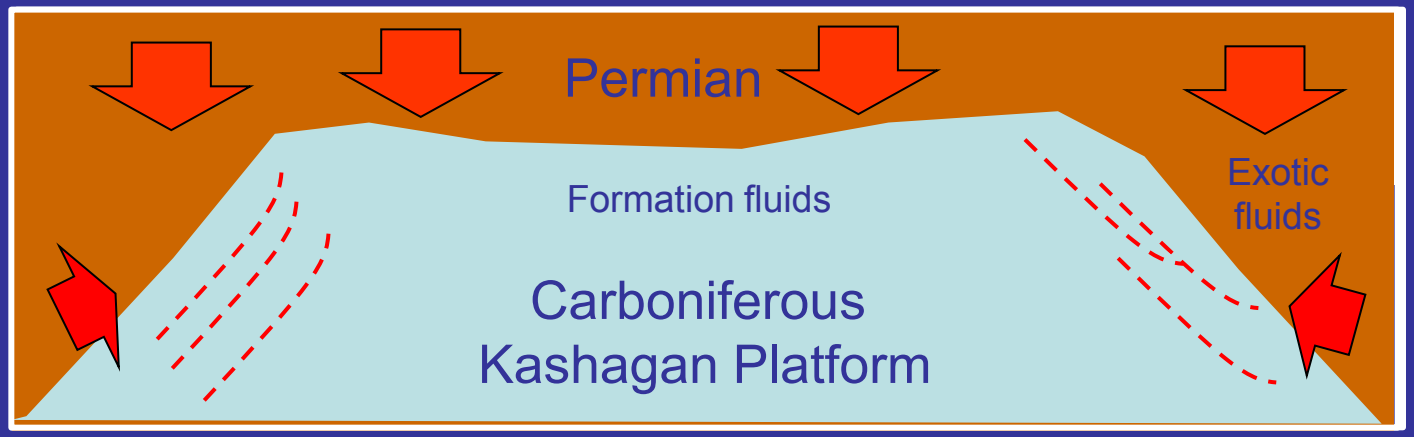
Karst
Nettleham-2

Vuggy dolomite
Somerton-1

Kashagan Platform

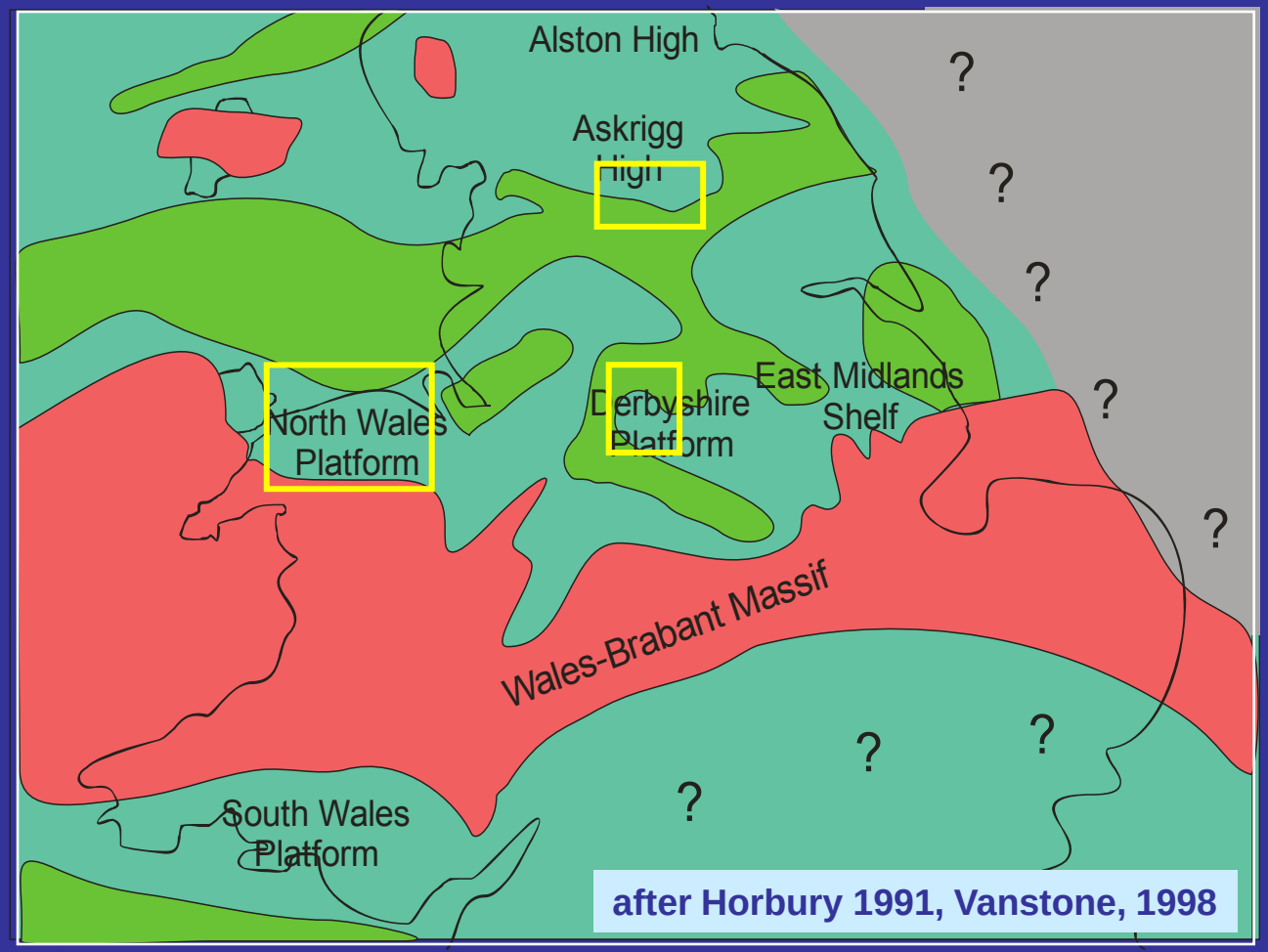


Francesconi *et al.*, 2009



Ronchi et al, 2010

Lower Carboniferous, UK



Carbonate platform

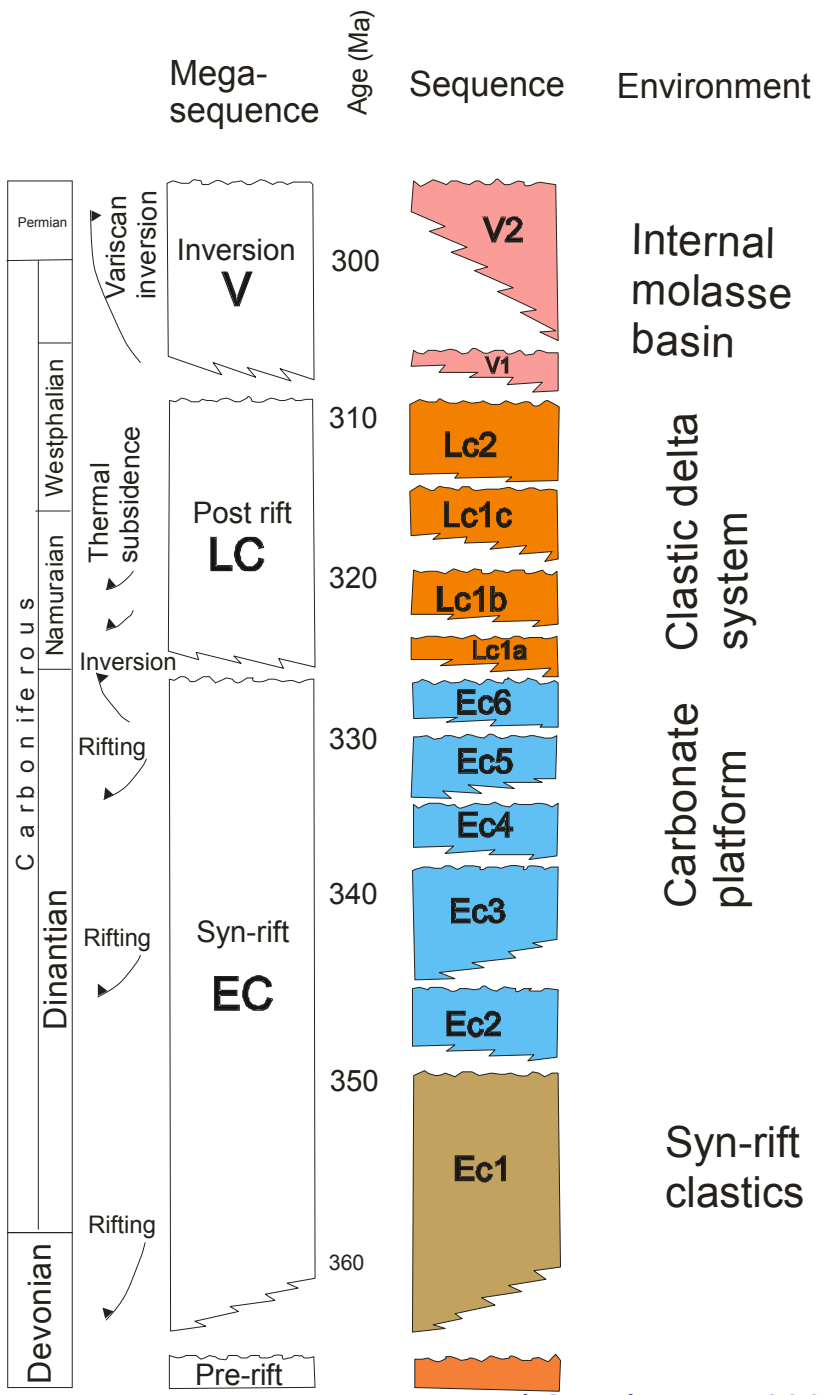
Basin

Land

- Detailed tectono-stratigraphic and sedimentological framework
- Basin evolution and play fairway analysis in place
- Established mineralogical model (hosts F-rich MVT deposits)
- Small, accessible outcrops

Stratigraphic framework

- Dinantian ~ Visean
- Lower Dinantian ramp-limestone, dolomite and evaporites
- Upper Dinantian rimmed shelf dominated by marine limestones with interbedded volcanics
- Basins filled by fine grained mudstones in Dinantian-Namurian
- Topographic infill and burial beneath fluvio-deltaics in Late Carboniferous



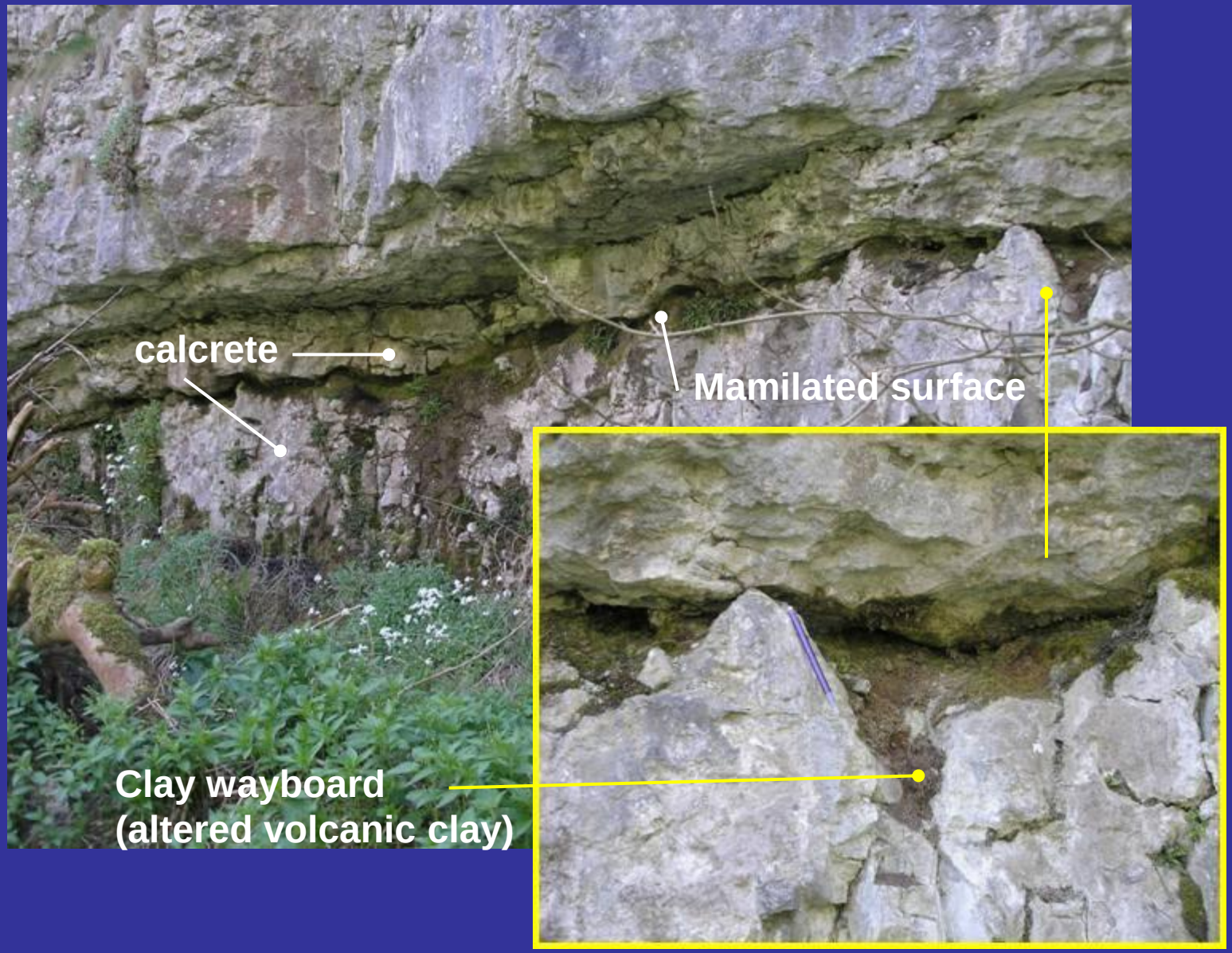
Fraser and Gawthorpe, 1990

Platform margin geometry

Platform interior

- Stacked metre-scale upward-shallowing cycles
- Platform interior dominated by shallow water skeletal (crinoidal) packstone
- Locally, oolitic grainstone shoals on platform margin

Karstification

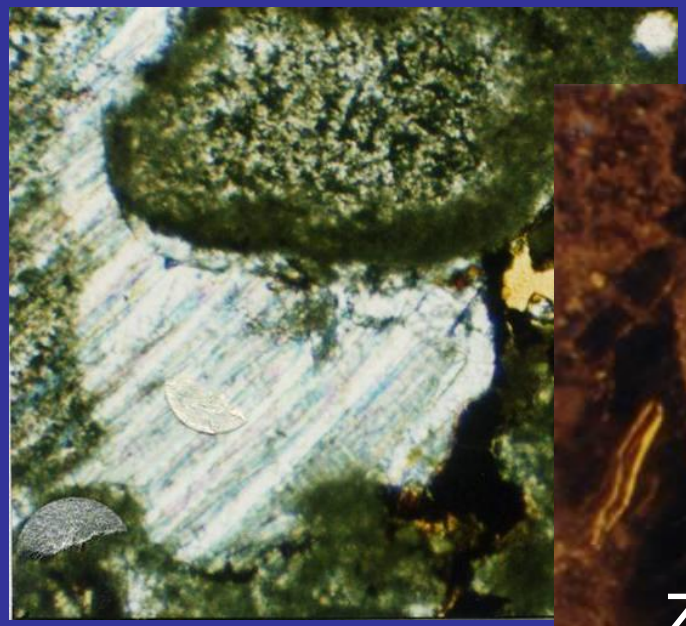


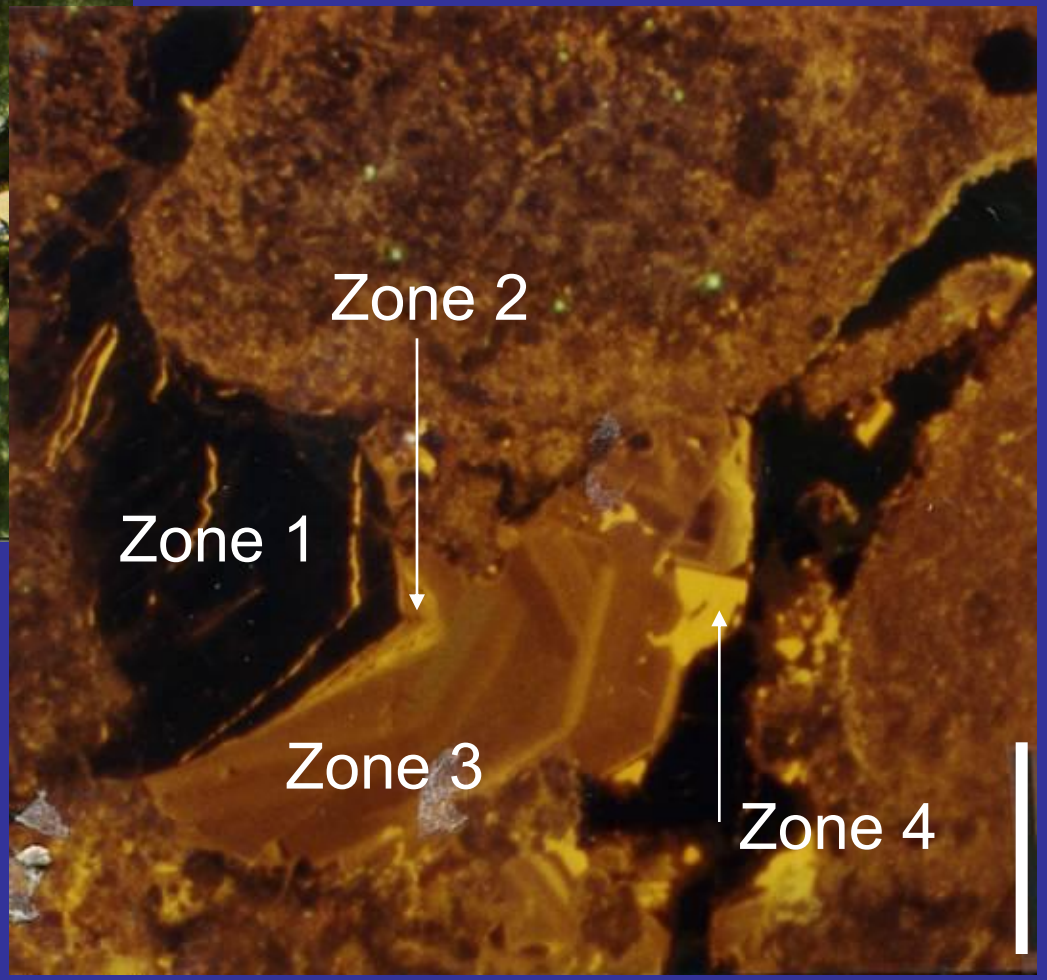
Solution pipes: collapsed palaeokarst?

Clast of laminated pst/gst

Vuggy porosity on cave margins

Matrix cement paragenesis





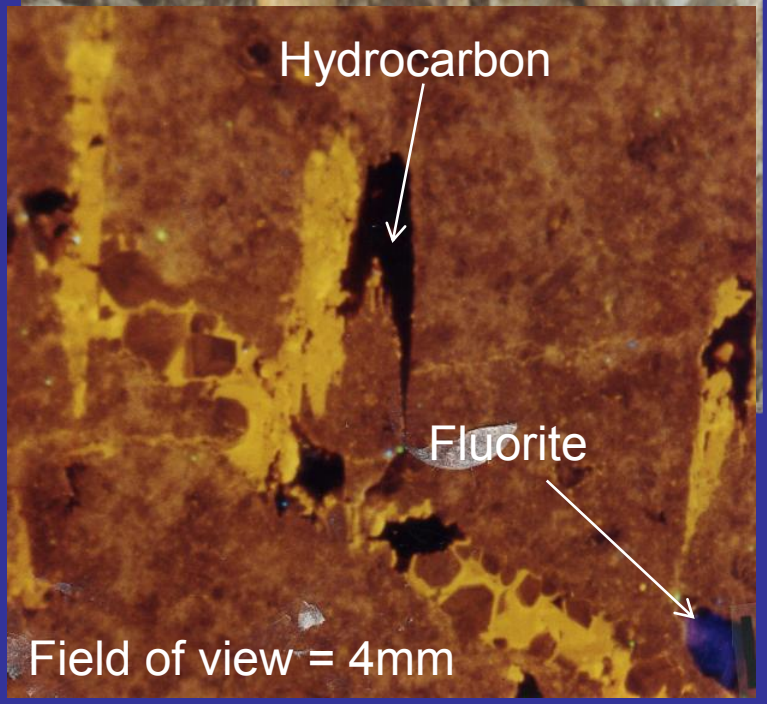
Zone 1-2 meteoric
Zone 3: shallow burial
Zone 4: deep burial

Meteoric cements fill primary and secondary macropores

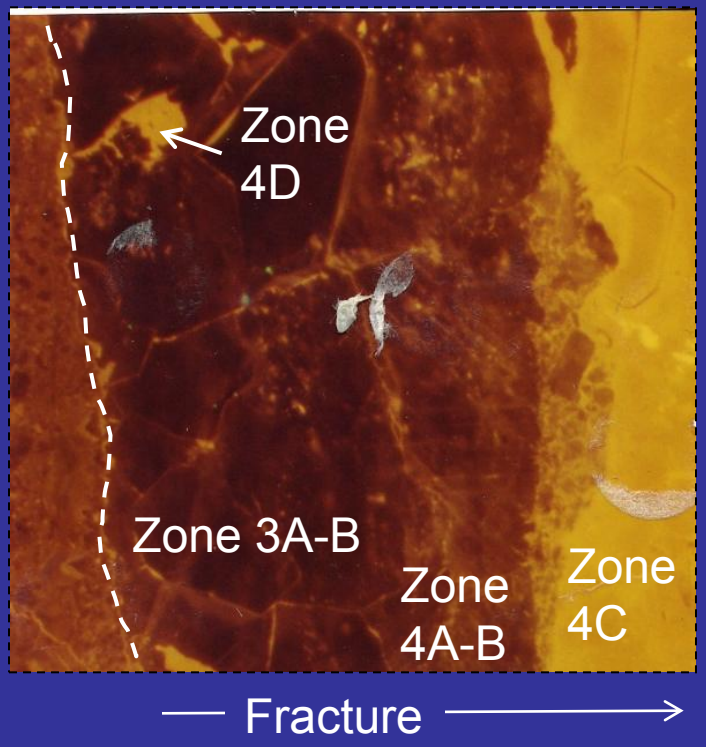
Walkden and Williams, 1991

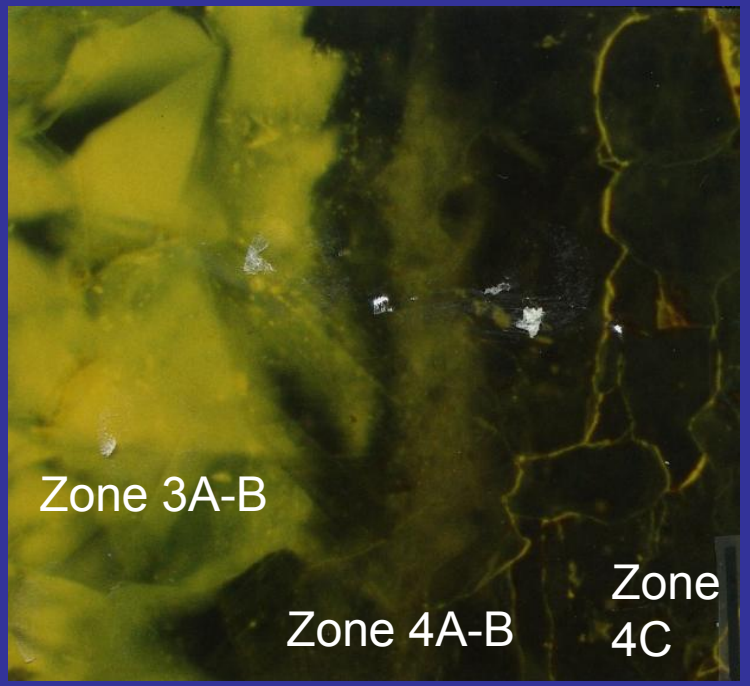
Dolomitisation

Fault and fracture related diagenesis



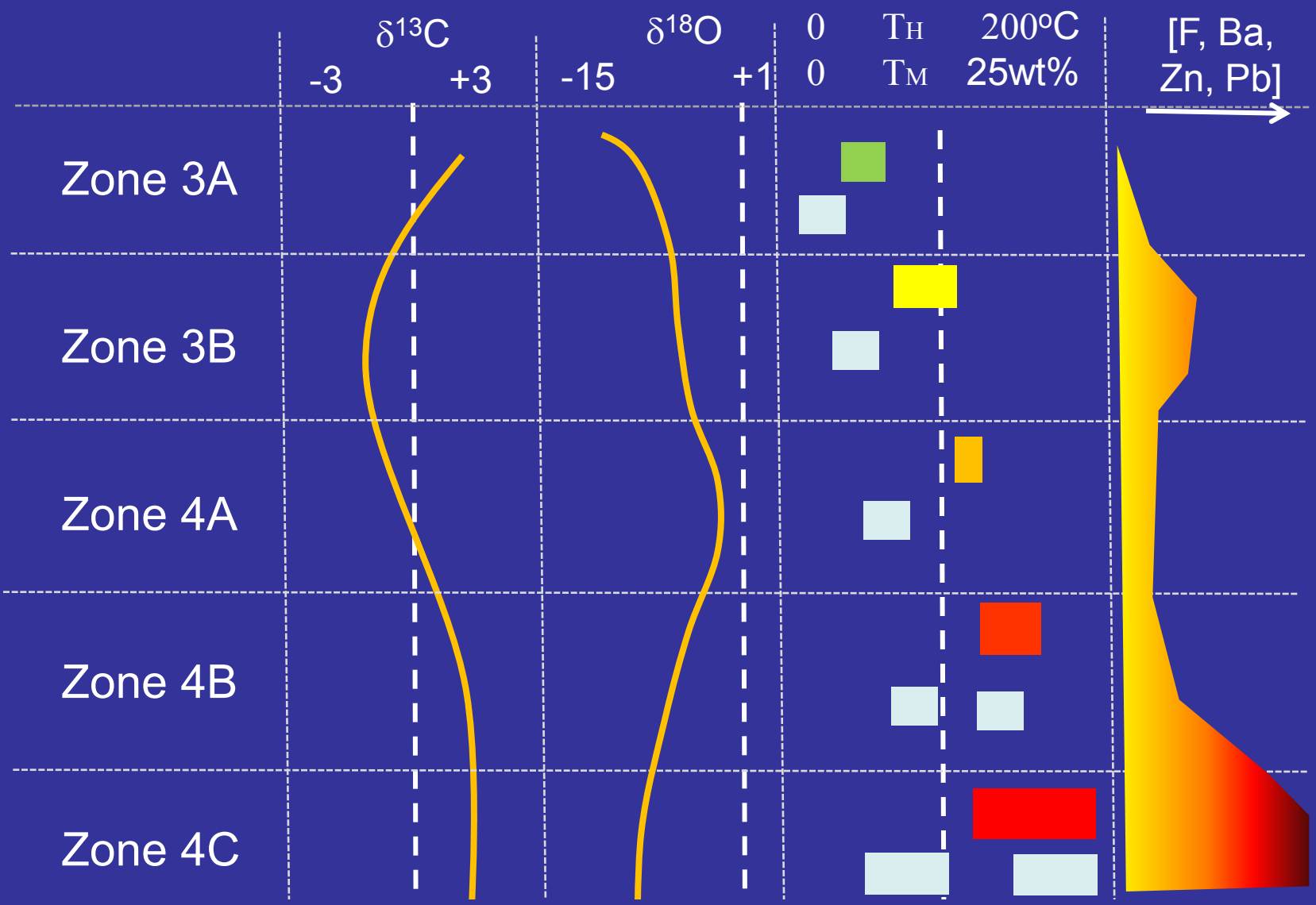
Fracture paragenesis, Derbyshire Platform



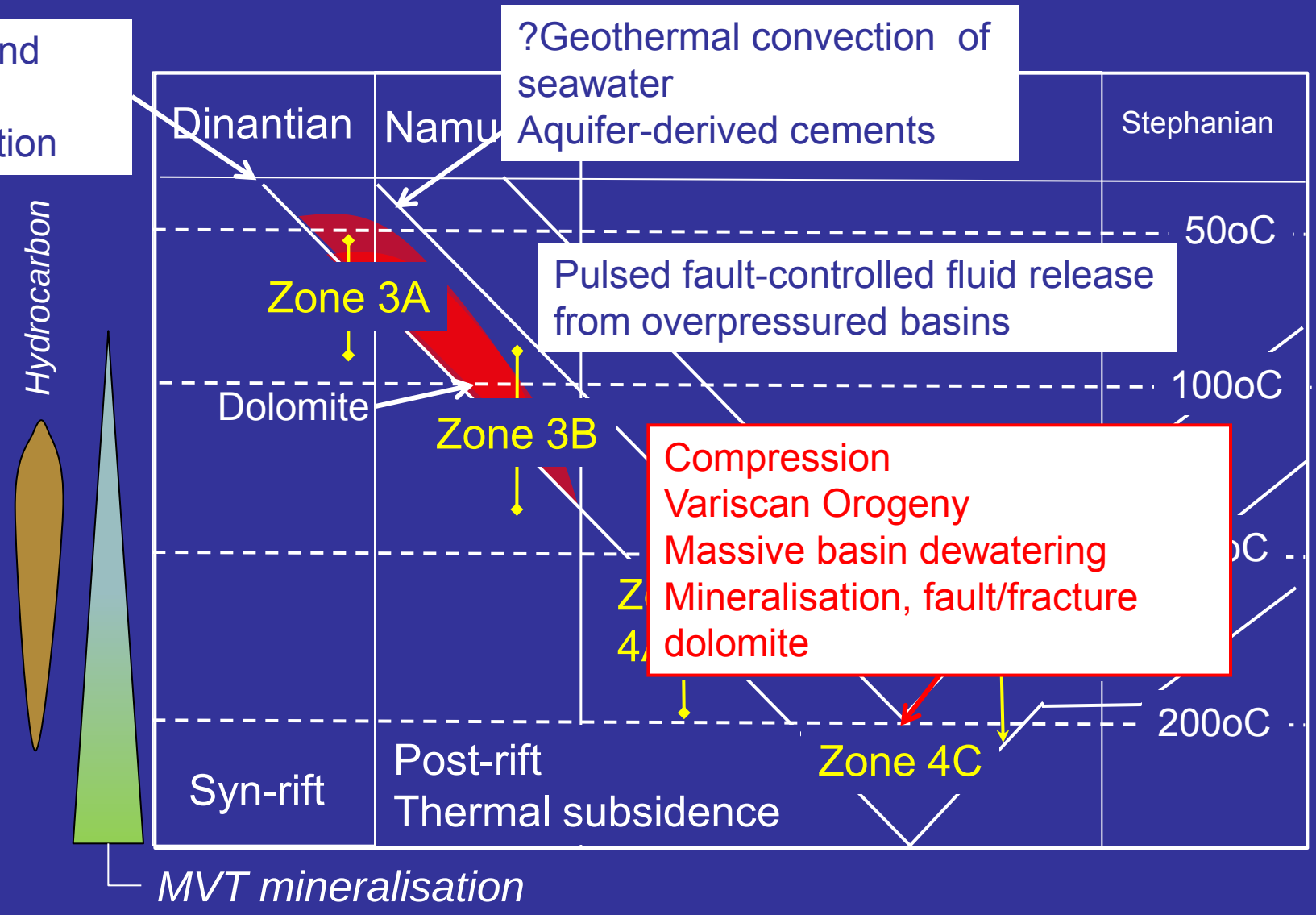


Zone 3A: fluid inclusions
Zone 3B: hydrocarbon & fluid inclusions; fluorite
Zone 4A: hydrocarbon & fluid inc; fluorite, baryte, galena, spahlerite
Zone 4B: hydrocarbon & fluid inc; fluorite, baryte, galena, spahlerite
Zone 4C: hydrocarbon & fluid inc; fluorite, baryte, galena, spahlerite
Zone 4D: fluid inclusions

Cement geochemistry



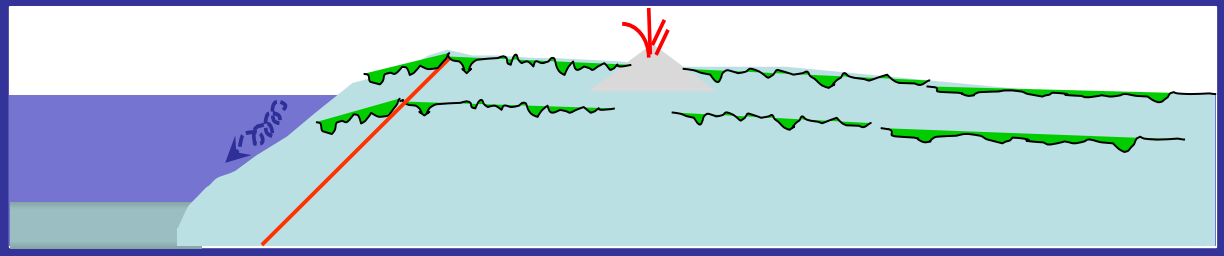
Burial history and structural evolution



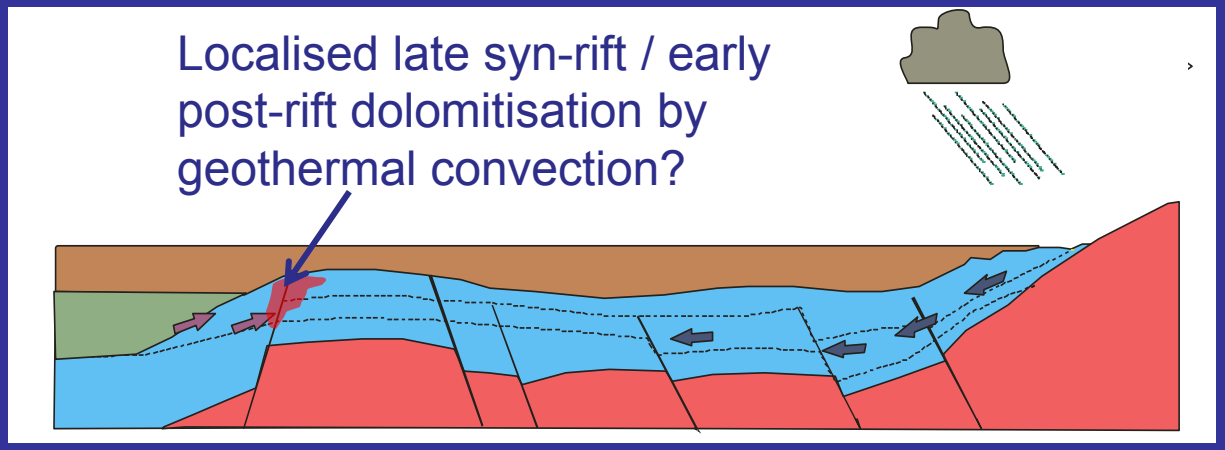
Burial history curve for Edale Basin (Geothermal gradient= 50^0C km^{-1} ; Jones and Plant, 1989)

Diagenesis and basin evolution

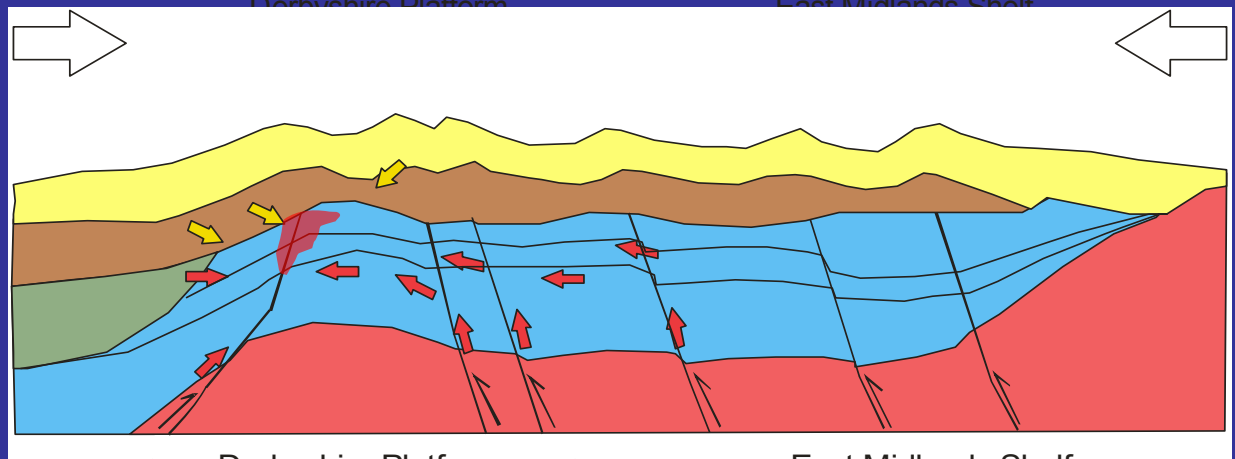
Syn rift
Meteoric diagenesis



Post rift sag
Topographic flow
Dolomitisation: geothermal?



Inversion
Fault-controlled basin dewatering: mineralisation



Application to subsurface

- The Lower Carboniferous of Northern England and Wales provides the opportunity to explore the relationship between diagenesis and hydrocarbon emplacement within a syn- and post-rift regime
- Field, petrographical and geochemical data have been used to map fluid source, composition and migration pathways
- A complex, multiphase paragenesis that reflects the tectono-stratigraphic evolution of the region is developed. Future work will test these models by forward (reactive transport) modelling
- Geometrical data on dolomite distribution and collapsed palaeo-caverns as well as mechanical stratigraphical data is readily accessible

Acknowledgements

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