Introduction

West of Britain represents arguably the last frontier area of hydrocarbon exploration in the UK territorial waters, but remains a challenging area to operate due to the aerially extensive lava and intrusive sequences present in numerous basins at this margin. The learnings from these basins in terms of hydrocarbon exploration can be applied to many other volcanic effected basins worldwide, including the Australian Margin.

This talk focus on both our current state of understanding and future challenges associated with intrusive and extrusive volcanic rocks in prospective sedimentary basins.

Intra-Basaltic Plays – A Future?

In 2004, a major oil and gas discovery was made within the Palaeocene–Eocene lavas of the Faroe-Shetland Basin in the form of the Rosebank Field (Fig. 1). The reservoir intervals are unusual in that they are a series of intra-basaltic fluvial clastic sequences, separated by basalt lava flows, hyaloclastite and volcaniclastic sediments (Fig. 2), giving rise to a new hydrocarbon play concept.

However, at the time of writing, the Rosebank Field has been the only intra-basalt play with commercial quantities of hydrocarbons discovered in this region. Despite several wells targeting the play, and the identification of a major intra-lava incised drainage system running parallel to the Rosebank Field (see Schofield and Jolley, 2013), the play fairway and distribution of potential good quality intra-basaltic reservoirs remains poorly defined. Intra-basaltic sequences represent some of the most complicated sedimentary systems present in the geological record, and a major challenge in the FSB lies in understanding where and how ‘clean’ sand was inputted and distributed through the FSB lava fields.

Fig 1 - Schematic geological cross-section through the Faroe-Shetland Basin (From Schofield and Jolley; modified from Gallagher and Dromgoole, 2007). The intra-basaltic Rosebank field is located in lava sequences above the Corona Ridge.
Igneous Intrusions – Faroe-Shetland Sill Complex (FSSC)

Igneous Compartmentalization – “Box Work, Side and Top Seals’
Interconnected, low-permeability sheet intrusions (e.g. sills and dykes) can compartmentalise significant volumes of source and reservoir rock (Fig. 3). Detailed mapping of intrusive systems in the Faroe-Shetland Basin, has revealed these systems often consist of complex, interconnected networks of sills that cover large vertical and lateral distances. Furthermore, the propensity for sills in these systems to exploit and intrude along ductile shale horizons (Thomson and Schofield, 2008) raises the possibility of compartmentalisation of reservoirs (and indeed source rocks) by sills and dykes in basins containing high densities of intrusives. The creation of isolated compartments sealed by low-permeability igneous bodies, and/or formation of side or top seals (Fig. 3) would clearly impact migration pathways and migration efficiency, and may result in differential lateral pressures in reservoir bodies by creation of pressure cages, although ‘broken-bridge’ structures between distinct lobes in sheet intrusions may offer fluid pathways through laterally-continuous intrusions (Schofield et al, 2012).

Fig. 2 - Well correlation through five wells from SW to NE in the Faroe-Shetland Basin, showing lava field stratigraphy and Colsay reservoir sequences. (From Schofield and Jolley, 2013)

Fig 3 – A sill intrusion compartmentalizing sedimentary sequences in East Greenland. (Photo courtesy of John Howell)
Fluid flushing of Reservoirs Sequences by Hydrothermal Fluids

Igneous related hydrothermal circulation systems that can be highly mineralising and thus detrimental to reservoir quality (Holford et al. 2012). Hydrothermal fluids generated with igneous intrusions can be highly mineralising and thus degrade the quality of potential reservoirs through the temperature-controlled cementation of minerals such as quartz. Fluid inclusion data from several volcanically-influenced basins along the northwest European Atlantic margin, including the Faroe-Shetland Basin, contain evidence for high temperature (>200°C) and short lived (<0.1 to 1 Myr) hot fluid pulses that have precipitated quartz cements in potential reservoir sandstones (Parnell, 2010). Such hot fluid pulses have been attributed to hydrothermal activity related to sill intrusion at deep basinal levels (Parnell, 2010).

Hydrocarbon Migration – HC migration through Fractured Conduits

The Faroe-Shetland Basin contains an extensive suite of igneous intrusions (the Faroe-Shetland Sill Complex or FSSC) which forms a laterally and vertically extensive sheet complex that transgresses basin stratigraphy. Recent work has suggested that areas of FSSC may have played a key role in the migration of hydrocarbons through the sedimentary fill (Fig. 4), by acting as fractured migration conduits (Rateau et al. 2013; Schofield et al. 2015). In particular, the Laggan-Tormore fields have a close spatial relationship with the tips of intrusions, with the down-dip extent of the Tormore sands can be seen clearly intersecting with sills. The same relationship can be seen in other areas of the basin, in particular in Quad 204, where a VpVs anomaly in T36 Vaila stratigraphic trap can be seen to correspond with the edge of the sill complex in the area. Although we have tantalizing evidence of direct interaction between the sill complex and petroleum system, our knowledge is still lacking. Currently, a key issue is trying to understand when an intrusion may be acting as a permeable conduit, or conversely acting in a sealing capacity to form a “barrier or baffle” to HC migration in the subsurface. Therefore key future work is needed to understand associated fracture systems and how intrusive structure (e.g. broken bridges) control the migration or sealing ability of sheet intrusions in the subsurface.

![Fig. 4](image.png)

Fig. 4 – (From Rateau et al. 2013) Showing concept of HC migration through a fractured sill in the subsurface.

Conclusions

As hydrocarbon exploration moves to more challenging basins, it is clear the need exists for us to fully understand the role in which intrusive and extrusive volcanism plays in hydrocarbon systems. This is particularly the case West of Britain, where to fully exploit and unblock what is a viable petroleum system, we
need to understand the role in which volcanics systems have played and interacted in the basin and not treat them in isolation away from the petroleum system.

References


Parnell, J, 2010, Potential of palaeofluid analysis for understanding oil charge history, Geofluids, 10, 73–82.


