Understanding Zechstein Carbonate Reservoirs in NW Europe

Introduction

Historically, Zechstein carbonate plays in NW Europe have had varying production success. Zechstein reservoirs account for some of the earliest hydrocarbon discoveries in the North Sea. Zechstein carbonates are also a current focus for exploration, for example in the area of the Mid North Sea High. Understanding the connectivity of the carbonates is critical in explaining the production history of fields and in applying these insights to future ventures.

To improve understanding of key factors affecting performance of Zechstein reservoirs we have carried out an extensive multi-disciplinary study involving integration and interpretation of new and legacy data from outcrops and sub-surface. World class Zechstein carbonate outcrops in NE England have been examined in conjunction with cored wells, published articles and production data (located in Fig 1.) to improve understanding of connectivity within Zechstein carbonates.

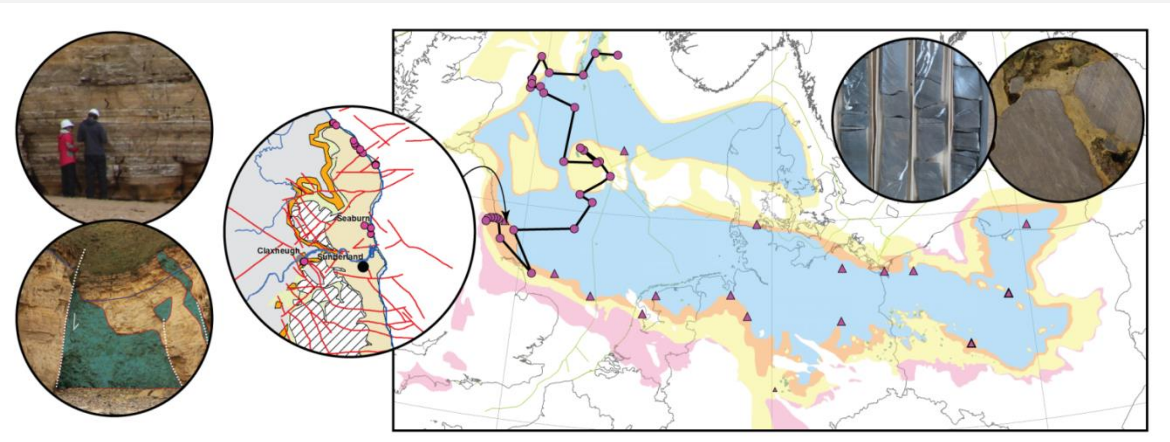

Fig 1. Palaeogeographic map for the Z2 (after Slowakiewicz et al., 2015) showing location of field fracture studies in northeast England (inset map), sequence stratigraphic articles reviewed (triangles) and correlation panel (black path). Blue represents basin, orange represents slope, yellow represents platform, pink represents sabkha and salina, white are highs.

This study brings new insight into several factors that affect Zechstein carbonate reservoirs, including

- The characterisation of fractures, which have been extensively documented through lidar, photogrammetric and field measurements, and analysed within their structural, stratigraphic and diagenetic context to allow prediction of fracture behaviour within the reservoir
- A revised basin-wide sequence stratigraphic framework, which allows application of the derived mechanical understanding in both the Northern and Southern Permian Basins.

The diagenetic effects in carbonate-evaporite systems, the processes and impact of brecciation associated with collapse following evaporite dissolution have also been studied. In addition, three fields which produce(d) from Zechstein reservoirs were studied to understand the production history in terms of connected volumes, water breakthrough, pressure support, and, in terms of applying the learnings from the other components of this study.

The findings have implications for both exploration and production. Play based exploration, testing of prospects and development of fields can all be informed from application of either, or both, of the resulting conceptual and numerical models.

Issues

Zechstein carbonates within the Southern Permian Basin, from the southern North Sea to Poland, have been widely studied, although peer-reviewed literature from different sub-basins includes sequence stratigraphic interpretations that are inconsistent across the whole basin. In the Northern Permian Basin, the central and northern North Sea are relatively under-studied, and there are still divergent opinions on facies assignation in cored wells (e.g. Ardmore and Auk fields designated as shallow-water facies by Trewin et al., 2003, and deep-water facies by Taylor, 1998).

Diagenesis in carbonate-evaporite systems is complex and can variously lead either to permeability reduction or enhancement: effects include lateral and vertical variation between limestone and dolomite, complex history of cementation, evaporite-filled fractures, and enigmatic diagenetic fabrics. Although diagenesis typically follows a particular path, prediction of porosity-permeability properties are difficult.

Another common challenge in most Zechstein carbonate reservoirs is that fracture permeability is significant for production. This can also be associated with early water production, a relatively common occurrence for Zechstein carbonate reservoirs. Sometimes fracture permeability is higher or lower than anticipated, with significant impact for well (and field) productivity. Understanding the mechanical stratigraphy, in particular identifying any units which have pronounced fracture properties (either a tendency to retard fractures and act as a mechanical barrier, or units with a tendency to be highly fractured) will be useful in optimising development.

Brecciation is also common in Zechstein carbonate reservoirs, though is not encountered in every field. There are multiple causes of brecciation, including debris flows, karst, or collapse following evaporite removal. The significance of brecciation for fluid flow is dependent upon breccia body shape, degree of cementation, timing, and lateral and vertical extent. Understanding the cause of brecciation and any implications for breccia body permeability and extent can be beneficial.

The important influence of reservoir properties is illustrated by a comparison of the Ardmore, Auk and Dalen fields. Ardmore (once known as Argyll, now active as Alma) and Auk lie within the UK Central North Sea, have comparable Zechstein stratigraphy and both are in Quad 30 (ca. 40 km apart). Both fields have strong aquifer drive and Zechstein wells in both have a similar range of cumulative oil production volumes, with pressure depletion over the life of the fields. Whereas on Ardmore the spatial position of a well within the field has an impact on produced volumes, the volumes produced from Auk wells do not have a systematic spatial relationship. The Dalen field in the Drenthe province, onshore Netherlands, is very different from Ardmore and Auk. There is little evidence of aquifer support, only one well shows significant water production; production rates are relatively low and there is no evidence of pressure depletion. Understanding the connectivity of the carbonates is critical in explaining the observed differences.

This presentation will focus on insights into the mechanical behaviour of the different carbonate units, brecciation caused through collapse following evaporite dissolution, and evaluation of these insights through comparison with production data.

References

Peryt, T.M., Geluk, M.C., Mathiesen, A., Paul, J. & Smith, K. 2010 Zechstein. In: Petroleum Geological Atlas of the Southern Permian Basin Area. Eds: Doornenbal, J.C. & Stevenson, A.G. EAGE Publications, 123-147.

Slowakiewicz, M., Tucker, M.E., Perri, E. & Pancost, R.D. 2015 Nearshore euxinia in the photic zone of an ancient sea. Palaeogeography, Palaeoclimatology, Palaeoecology 426, 242–259.

Taylor, J.C.M. 1998 Upper Permian-Zechstein. In: Petroleum Geology of the North Sea (4th Ed.). Ed: Glennie, K.W. Blackwell Sciences, Oxford, 174–212.

Trewin, N.H. and Bramwell, M.G., 1991 The Auk Field, Block 30/16, UK North Sea. Geological Society, London, Memoirs, 14(1), 227-236.