ABSTRACTS

ONSHORE AND OFFSHORE GEOLOGY – THE VITAL LINK

Saturday 21 September 2013,
Collingwood College,
Durham University

The Geologists' Association Two-Day Meeting, 21–22 September 2013
Collingwood College, Durham University

Onshore and Offshore Geology – the vital link

Programme and Abstracts

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Onshore and Offshore Geology – the vital link

Geologists' Association Two-Day Meeting

Collingwood College, Durham University

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Foreword

This booklet accompanied the fourth Annual Geologists' Association Meeting. This series of meetings was inaugurated in September 2010 by a one-day meeting at Burlington House entitled 'Warm Climates in the Geological Record: Linking the Past and Present'. The second meeting, in September 2011, was at the University of Worcester and its theme was 'Geoconservation for Science and Society: An Agenda for the 21st Century', its output published recently as a special issue in the *Proceedings* . A second day was added in the form of a field excursion, a feature that was retained for the third meeting , in October 2012, and this present meeting. The 2012 meeting was in Exeter, on the theme of 'Rivers through geological time'. It was convened jointly with the Devonshire Association, which was celebration its 150th anniversary, in the Royal Albert Memorial Museum Exeter.

A next meeting in this series is already being planned for September 2014 and will be based in Leicester, on the theme of 'Palaeo for the people (fossils in the service of mankind)'. It will follow a similar format to the second, third and fourth meetings, with combined conferences and field trip components. This series has come about in conjunction with Elsevier taking over publication of the *Proceedings of the Geologists' Association*, making use of generous sponsorship from that company and linked to themed issues in the journal. This present meeting also benefits from the support of the BP, Shell, the Department of Energy and Climate Change and the UK Onshore Geophysical Library.

In May 2014 the GA will team up with the Geological Society and the Society of Antiquaries to host a meeting at Burlington House entitled 'Puddingstone and related silcretes in the Anglo-Paris Basin'. This will take a similar form to the present meeting, with a day of lectures and posters and field excursions to Hertfordshire and the Paris Basin.

Rory Mortimore, President of the Geologists' Association

Friday 21 September – Arrival and early registration. Reception in Grey College

Proceedings of the Geologists' Association on the Marine Devonian and the Wealden

Onshore and Offshore Geology – the vital link

Saturday 21st September - conference

Time	Speaker	Title
0900-0945	Professor John Underhill, University of Edinburgh	Introductory keynote address
0945-1015	Dr Rachel Jamieson University of Edinburgh	Role of onshore-offshore, surface-subsurface mapping in unravelling the structural evolution of the Flamborough Head Disturbance
1015-1045	Peter McPhee, Durham University	Controls on Triassic subsidence in the Solway Basin, northern England
1045-1115	Dr Bethan Davies Aberystwyth University	The Quaternary Glaciations of the western North Sea Basin: implications for ice-sheet dynamics
1115-1145	Coffee Break	
1145-1215	Dr Haydon Bailey	Chalk micropalaeontology and nannopalaeontology - how understanding offshore sections increases our understanding of the onshore sections.
1215-1245	Dr Stephen Stukins, Natural History Museum	Using onshore palynology to inform offshore exploration
1245-1315	Professor Malcolm Hart	The Holocene separation of Jersey from France: the microfossil evidence
1315-1415	Lunch	
1415-1500	Professor Paul Younger, University of Glasgow	Chloride waters of Great Britain revisited: what can offshore brines now tell us about onshore geothermal brines?
1500-1530	Dr Rick Smith FWS Consultants Ltd	Polyhalite prospecting, deep below North Yorkshire
1530-1600	Professor David Manning, Newcastle University	NE link to how will minerals feed the world in 2050
1600-1615	Break	
1615-1645	Professor Cynthia Burek, University of Chester	The importance of Marine Geoconservation for sustainable development
1645-1715	Vicky Wanstall	Geological Characterisation of onshore and offshore sites
1715	Professor Rory Mortimore	Closing address

Chalk micropalaeontology and nannopalaeontology - how understanding offshore sections increases our understanding of the onshore sections

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Onshore Chalk locations suitable for systematic micropalaeontological collecting are few in England, being restricted predominantly to sections on the south coast and quarry faces, frequently with limited stratigraphic coverage. The south coastal sections only range stratigraphically as high as the Lower Campanian (*G. quadrata* Zone) chalk and any stratigraphically younger chalk has to be collected from sporadic, disparate, chalk pits, occasional boreholes and glacially moved coastal blocks across East Anglia. Many of the chalk pits have been backfilled and lost over the last thirty years preventing new research analyses.

The microfaunal succession established from the these onshore sections has provided the principal tool for comparison with offshore wells, although it's been clear to micropalaeontologists involved in the offshore industry that the foraminifera described from onshore sections, frequently dominated by benthonic species, were not well represented in offshore wells. In these the microfaunal associations were mainly represented by long-ranging planktonic foraminifera, associated with largely undescribed radiolarian taxa. The development of nannofossil studies from North Sea Chalks over the last twenty five years has provided a rich tool for the stratigraphic calibration of other microfossil groups.

Present day Upper Cretaceous zonal schemes used throughout the offshore hydrocarbon exploration and production industry are reviewed in the light of recent studies of the chalk microfauna and nannoflora analysed from the 42/28b-12 well, located on the Tolmount gas field off the Yorkshire coast. Micropalaeontological results from this well provide a unique dataset combining the benthonic foraminifera previously known well only from onshore sections, the long-ranging planktonic lineages, plus the radiolarian assemblages recorded from offshore (Central Graben) wells. These occur together with diverse nannofloral assemblages, proving a stratigraphic succession ranging from Turonian to Late Campanian age.

The calibration of these data indicates that the onshore sections are incomplete, with physical gaps between sections in addition to stratigraphic gaps or hiatuses within them. Whilst the onshore sections provide the initial stepping off point to the offshore, the offshore sections in being more stratigraphically complete provide the necessary insight into the punctuated onshore sections. Only by utilising the two datasets, both offshore and onshore, does a more comprehensive understanding of the controls on Chalk deposition across the North Sea Basin begin to emerge.

*Denotes speaker (haydon@network-stratigraphic.co.uk)

The importance of Marine Geoconservation for sustainable development

Professor Cynthia Burek

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As the United Nations Decade of Education for Sustainable Development draws to a close in 2015, it behoves us to look at the importance of recent legislation in relation to what Sustainable Development means to people. Has the decade actually educated people about the true meaning of this abstract phrase? Added to this we have another difficult concept for most people - how to conserve rocks or Geoconservation? Add to this the marine sphere that is normally out of sight and therefore out of mind for most people and dealt with, with difficulty by the planning authorities and we are onto a BIG looser. How can we put over three difficult concepts? This talk will examine the definitions of each and how well they fit together.

In 2009 the Marine and Coastal Access Act was passed by the English and Welsh Government and the following year the Scottish Parliament passed its own Act. At present there is no passed leislation for Northern Ireland. The process adopted for this implementation of the Act will be examined in light of both geoconservation and sustainable development - both relatively recent terms.
The idea of geoconservation did not really fully mature until it had a history highlighted by a conference in 2007. The term Sustainable development has been around since Gro Brundtland and her committee in the late 1980s. It remains to be seen if these three concepts can be melded together.

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Geological Characterisation of onshore and offshore sites: bringing early understanding and value to engineering projects

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Early, sound engineering geological characterisation is essential for geotechnical engineering projects. It can provide many benefits by optimising both the cost and programme time of ground investigations and geotechnical design. A thorough understanding of the geology, geomorphology and anthropogenic processes is necessary for the successful characterisation of sites for the geotechnical engineering design of onshore and offshore projects, and the communication of complex geological models to non-specialists.

This presentation will describe how information used for engineering geological characterisation differs between onshore and offshore sites. The differences in scale, rate of change and natural processes between offshore and onshore sites can affect what information is used. Information about geological formations onshore may not be applicable offshore and, conversely information gathered using offshore techniques may provide a bigger picture of a geological formation onshore.
The presentation will illustrate how early geological characterisation can help close collaboration to develop between the engineering geologist and geotechnical engineer, and enable delivery of added value to the client by using geological and geomorphological models that evolve throughout the project.

The Quaternary dynamics of the western North Sea Basin: implications for ice sheet dynamics

Bethan J. Davies[1†], David H. Roberts[2], David R. Bridgland[2] & Colm Ó Cofaigh[2]

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The North Sea Basin is infilled with thick sequences of Quaternary sedimentary strata that thicken eastwards, which provide detailed information on glacial-interglacial cycles throughout the Quaternary. Borehole, swath bathymetry and seismostratigraphical data allow detailed inferences to be made on Quaternary ice sheet provenance, flow, thermal regime and processes. These ice sheets were marine-based, and the dynamics of these marine ice sheets could be used as an analogue for understanding present-day marine ice sheet processes in West Antarctica. However, source regions, ice-flow pathways and ice sheet limits in the central North Sea throughout the Quaternary are poorly understood. We analysed Middle to Late Pleistocene formations to determine genesis and provenance, using micromorphological, palynological, and sedimentary petrological techniques. The Elsterian Swarte Bank Formation is a subglacial till with palynomorphs from the Moray Firth and NE North Sea and heavy minerals from the Scottish highlands. The Late Saalian Fisher Formation (central and northern North Sea), is interpreted as a subglacial till with glaciomarine sediments further south, with a provenance signature from the Midland Valley of Scotland, the Eocene in the North Sea Basin, the Grampian Highlands and NE Scotland. The Late Weichselian (Dimlington Stadial) Bolders Bank Formation is a subglacial till originating from the Midland Valley, Grampian Highlands, Southern Uplands and NE Scotland. Together, these data provide substantial new evidence for a subglacial origin for the Swarte Bank, Fisher and Bolders Bank formations. The results demonstrate repeated glaciation of the North Sea Basin throughout the Mid- to Late Pleistocene, with similar ice-flow pathways that originated in northern Scotland. There is no evidence for the presence of Fennoscandian ice in the western North Sea Basin, supporting recent onshore work in County Durham and north Norfolk that the eastern margin of the Fennoscandian Ice Sheet did not reach eastern England during the Pleistocene.

The Holocene separation of Jersey from France: the microfossil evidence

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The island of Jersey receives most of its electrical power from France by way of two submarine cables. These are now nearing a time when replacement must be considered and a new cable is now planned. More than fifty marine boreholes have been drilled into the seabed between France and the east coast of Jersey and these are being used to plan the route of the new cable by consultants. Aside from rare, mainly terrestrial, Pleistocene and Holocene sediments, Jersey is formed of Precambrian to Devonian 'basement' and the off-shore area, at low tide, is dominated by E–W trending rock platforms including, to the north, Les Ecréhou and, to the south, Les Minquiers and the Isles Chausey. The Baie du Mont-St-Michel, in which Jersey sits, is macrotidal with an exceptionally large tidal range and the planned cable must be buried within the very limited sediment cover. The sediment succession of the post-Last Glacial Maximum is only present between Grouville, on the east coast of Jersey, and the immediately adjacent coastline of France.

The cores, which are now stored on Jersey, provide a complete record of this Holocene sedimentary record and core OVC-18 is being used as a reference because it contains a near-complete record of the transition from woodland, with peats and plant beds, to inter-tidal mud flats and, eventually, marine sediments with abundant marine fossils and highly significant occurrences of the calcareous alga known as maërl. This core, therefore, contains a near-complete record of Holocene sea level rise through to the invasion of the slipper limpet, Crepidula, in 1962. Many of the samples contain well-preserved assemblages of foraminifera and ostracods that can be used to identify a range of sub-environments through to fully marine. Below the terrestrial sediments in core OVC-18 is a thickness of carbonate-rich, marine sands that may be of Eocene age or derived from pre-existing Eocene sediments off-shore Jersey or an the Cotentin Peninsula.

Role of onshore-offshore, surface-subsurface mapping in unravelling the structural evolution of the Flamborough Head Disturbance

Rachel J. Jamieson & John R. Underhill

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Flamborough Head is a major promontory formed of resistant Chalk cliffs lying on the North Yorkshire coast that juts eastwards into the Southern North Sea (SNS). It has long been known that it is the site of spectacular but enigmatic zone of structural deformation, termed the Flamborough Head Disturbance (FHD), characterised by W-E striking fault arrays and complex folding. Whilst the variable normal and reverse fault offsets displayed in the coastal exposures has led some to presume that the structures resulted from strike-slip deformation, others have suggested that contractional deformation dominates and uncertainty as to the genesis of the structures remains. The integration of subsurface database from offshore waters of the SNS with well-calibrated seismic data and fieldwork in neighbouring onshore areas allows the true nature of the FHD to be deduced. The results demonstrate that the development and evolution of the complex zone of deformation is primarily the result of structural inversion of the Cleveland Basin against the Market Weighton High, a rigid granite-cored footwall buttress. In addition, seismic interpretation also highlights the important role that Upper Permian (Zechstein) and Triassic evaporite horizons had in controlling the stratigraphic geometries and structural styles during Jurassic (syn-rift) extension, Cretaceous (post-rift) subsidence and the subsequent phase of Cenozoic basin inversion.

How minerals will feed the world in 2050

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By 2050, the world's population will have reached 9 billion. To feed that many people, soils will have to work much harder than they do at present. Importantly, all fertiliser materials ultimately have a geological source: nitrogen (N) fertilisers depend on fossil fuels for their production, and both phosphate (P) and potassium (K) are derived from mined rocks. Irrespective of the success of new biological techniques in plant breeding and genetic modification, the bottom line is that soils need to be able to supply the mineral nutrients that plants require, and these are exported from the soil with every crop that is sold.

A number of studies have determined the global offtake of N, P and K from soils as a consequence of crop production (e.g. Sheldrick et al., 2002); although N and P are roughly in balance, K is being removed from soils at a rate that far exceeds inputs. On the basis of offtake studies, world mine production of K needs to double to replace the amount that agriculture removes from soils.

Against this background, it is clear that new potash mining ventures are required. In the developed world, the supply of potash from conventional sources will continue for decades to come. However, in developing countries the high price of potash means that novel unconventional sources are being considered (Manning, 2010). K silicate minerals, such as feldspar and nepheline, have the potential to provide an adequate source of K for communities that cannot afford conventional fertiliser. However, it is not the total K content of these materials that controls their ability to supply plant nutrients, but the rate at which they dissolve.

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Controls on Triassic subsidence in the Solway Basin, northern England

Peter McPhee

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The Solway basin is part of an extensive corridor of Permo-Triassic rifting in the Irish Sea, and is strongly oblique to contemporary structural trends in adjacent basins. In this study, a detailed reappraisal of seismic data has shed new light on the role that basement fabrics have played in oblique evolution of the basin. The Ramsay-Whitehaven ridge divides the structurally complex East Irish Sea Basin (EISB) from the Solway and is found to be a significant and long lived anisotropy that has facilitated stress transfer at the northward termination of the EISB. The structure has prevented major faulting in the EISB from propagating into the Solway basin. The oblique basin trend is found to be the results of: 1) Late Jurassic reactivation of border faults, down-warp and preservation of Solway sediments; 2) basement faulting, which has controlled the evolution of Early Permian extension and 3) bounding granites.

Decompaction and back-stripping analysis was conducted for wells from across the province. These define rapid subsidence following Early Permian rifting. The endorheic basin setting allowed deposition to keep pace with subsidence. Depositional loading caused rapid and prolonged subsidence. Syn-rift subsidence was accelerated by rapid thermal re-equilibration, where much of the heat loss was lateral in this narrow rift setting.

The search for onshore analogues for the offshore Chalk of the North Sea

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In two major areas of the offshore industry, foundations for windmills and reservoir characterisation, identification of suitable onshore analogues in the Chalk would be invaluable. These are two contrasting engineering environments. The one at shallow depth requires examples of near surface weathering illustrating both glacial and periglacial Quaternary processes as well as lithology and structure. The second setting at depth in the North Sea requires examples of the range of lithologies and detailed structure in terms of a possible mechanical stratigraphy and the impact both lithology and structure have on material and mass porosity and permeability.

In addition to the general ground conditions, there is a need to locate onshore experimental sites where conditions similar to the offshore exist so that, for example, full-scale pile testing can be performed to determine longevity of offshore installations such as windmills. Similarly, interpretation of geophysical borehole logs and seismic sections in both shallow and deep environments benefit from examples found in onshore field sections.

The coastal Chalk cliffs and quarries of England from Yorkshire to Sussex and the French coast of Upper Normandy all provide partial analogues. There is no single field section that contains all the answers. An ideal onshore analogue will combine the hard, high density, glacially eroded chalks of the Yorkshire coast, with the soft, high porosity, part glacially and part periglacially weathered chalks of Norfolk, southern England and the Paris Basin. Other key aspects include the presence of palaeovalleys and faults so that the extent of weathering and damage zones can be measured and related to features seen in seismic sections. Field sections showing such features are illustrated. It is essential that these field sections are conserved for future studies as they provide the vital link to the offshore.

Polyhalite prospecting, deep below North Yorkshire

Dr F.W. Smith and Dr J.P.L. Dearlove[1]

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Britain's only high grade potash resources lie in the Zechstein Basin, and extend onshore for just a short distance in northeast England. Sylvite has been mined from the Z3 cycle since the 1970s. Exploration of the deeper Z2 cycle deposits in recent years has identified a world class polyhalite resource. The mineral, whose existence has been known since the 1930s, is consistent, thick and high grade. Its distribution around the NW margin of the Southern North Sea Basin, is demonstrated from recent exploration and legacy boreholes, and is described. Theories about its mode of formation (generally by replacement of anhydrite) are discussed. The Z2 cycle Fordon Evaporites show considerable changes across the basin margin ramp, and three depositional zones can be distinguished – the Shelf, the Transition Zone, and the Basin. Polyhalite is present in each, and exploration has identified significant, potentially mineable resource at depths >1,500 m below surface.

Underground mining faces several unusual challenges, including its situation within the North York Moors National Park. A combination of seismic imaging, core drilling, laboratory studies, and geological modelling has helped unravel the complex history of the deposit, and identify mineable resources. An understanding of the hydrogeology of the proposed mine site area, including the deep saline aquifer within the Sherwood Sandstone Group, has been advanced through recent work and will be discussed.

[1] Presenter

Using onshore palynology to inform offshore exploration

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Models created from outcrop studies and applied to subsurface exploration are commonplace. Discussed here is a method of palaeoecological analysis which can be applied to terrestrial and marine palynomorphs in the application of stratigraphy and understanding of depositional facies analysis. Multivariate analysis has been applied to palynological assemblages from two distinct sedimentary successions to produce and substantiate a technique to firstly, describe floral palaeoecologies and secondly, to relate the assemblages to depositional environment.

An outcrop study of the Middle Jurassic, marginal marine, Lajas Formation, Argentina, provided an established sedimentological framework in order to integrate the palynological analysis with depositional facies. Correspondence analysis, performed on the exclusively allochthonous, terrestrial palynomorph assemblages, concluded ecological groupings characteristic of a number of floral palaeoecologies from coastal/deltaic, river margins and floodplains, to higher altitude arid forests. The relationship between ecological groupings throughout the section informs us of a dynamic terrestrial ecosystem and also forms evidence for the drivers of floral succession. A relationship between the palaeoecologies and depositional environments is also observed and discussed leading to a conclusion that the observed assemblages are a result of transportation processes prior and during deposition.

The process used in generating this paleoecological model is transferable into other depositional settings and time intervals. An example is given from the subsurface Palaeogene of the Faroe-Shetland Basin. Here, the findings have aided the understanding of the sedimentary architecture and stratigraphy of hydrocarbon prospectivity.

Chloride waters of Great Britain revisited: what can offshore brines now tell us about onshore geothermal brines?

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Curiosity has surrounded anomalously saline shallow groundwaters in the UK ever since the Victorian fad for supposedly healthy spa springs. It was only with a classic paper by William Anderson in 1945 that systematic investigation of such waters finally entered the scientific era. When that work was published, there were insufficient data available to support a comparative assessment of the affinities of individual brine springs. This began to change as deep mining proceeded beneath the North Sea encountering prolific Na-Cl brines. Despite being under the sea, marine water was never detected in the mines. Brine formed by dissolution of halite in the overlying Permian (Zechstein) were found locally in abundance. More enigmatic are apparently native "strata water" in the Carboniferous. Quite what the ultimate source of the "strata water" is remains subject to debate, though much light has been shed on this topic by the systematic investigation of formation waters in North Sea hydrocarbon reservoirs. The most recent recruit to the catalogue of saline groundwaters are the geothermal brines of north-east England, which have recently been encountered during exploratory drilling. Though data are as yet sparse these appear to differ from other waters in their isotopic signatures. The total dissolved solids load encountered in the Weardale Granite exceeds that previously seen in otherwise similar Cornish and Lake District granite waters by a factor greater two, and yet the isotopic signature is distinctly meteoric. Quite why this should be so remains open to debate. These investigations are of more than pure curiosity value, as different possible origins imply different total volumes of water in storage, with implications for geothermal resource quantification and management.

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Offshore continuation of Quaternary fluvial archives: evidence from the southern North Sea and the English Channel

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It has been realised in recent years that the different widths of offshore continental shelves has an important effect on onshore fluvial records and, in particular, on how river systems will have responded to Quaternary sea-level fluctuations. Text-book views of rivers being profoundly affected by sea-level (base-level) fluctuations, with these being primary influences on terrace formation, are applicable only to regions of fairly narrow shelf, it being agreed that such influences are unlikely to be felt more than a few tens (<200) km inland. The seaways separating Britain from the European continent consist entirely of shelf, which means that rivers entering the sea in the region of SE England and the Strait of Dover do so at a considerable distance from the shelf-break. Offshore research using seismic profiling and other techniques has revealed the submerged valleys along which these various rivers flowed during the last sea-level lowstand, during Marine Isotope Stage (MIS) 2. Such data record a particularly well-developed channel system extending offshore from the Thames, with tributary confluences and submerged terraces, seemingly heading towards a confluence with the Rhine. The latter river extends offshore in a subsiding area, so instead of having terraces its valley immediately off the Netherlands is developed above a stack of its own sediments. Turning towards the Strait of Dover, through which it flowed during MIS 2, the palaeo-Rhine soon leaves the subsiding axial area of the southern North Sea and heads into an area that has been uplifting, which causes a gentle north-eastward (i.e., upstream) modern-day gradient. The well-known idea that the routing of the Rhine–Thames system through the Dover Strait was brought about by glacial lake overflow remains current, although evidence for repeated cold-stage lake formation is lacking and a single overflow event during MIS 12 seems most plausible. This means that the submerged geomorphology of the English Channel probably owes little to this notable event and that most of the fluvial valley-floor features detected owe their formation to the very large high-discharge Rhine–Seine river system that drained into the SW Approaches during MIS 2. The poster will depict the various offshore palaeochannels that have been reconstructed, as well as longitudinal profiles of the rivers systems concerned, interpretative palaeodrainage maps and palaeoflow calculations.

Curlew C: Shell U.K.'s only Chalk Oilfield

Stephen Drake

Lead Geologist, Shell U.K.

Curlew C is Shell's first development of a Chalk field in the UKCNS; discovered in 1993 by well 29/7-5. The reservoir comprises the Palaeocene Ekofisk and Upper Cretaceous Tor Formations in a 4-way dip closed inversion structure related to salt movement, composed of alternating allocthonous and autochthonous units. Average Chalk porosities are 12-27% and effective permeability ranges from 8-84mD. Both the Tor and Ekofisk were tested separately at rates between 2000-5000 b/d of light 40 degree API oil following acid fracture. The key subsurface uncertainties are (a) porosity distribution (where is the net pay?); (b) fracture distribution and interplay with faults and (c) the fracture to matrix permeability and drive mechanism. The field is presently produced by a single NE-SW orientated (parallel to Shmin), 5000ft horizontal well drilled to intersect as many open fractures as possible, assumed to be aligned with the regional max stress direction of NW-SE, and to target low acoustic impedance (high porosity) slump units within the Tor. The FMI image log was used to assess fracture distribution along the borehole to aid the completion strategy. Production commenced in 20018 via the Curlew FPSO facility 6 km to the East.

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