Petroleum Geoscience Research Forum

11-12 November 2008

The Petroleum Group would like to thank BP and ConocoPhillips for their support of this event:

Monday 10 November	
10:00 - 16:00	Core Workshop Drilling Centre Tour
18:00 – 22:00	Conference Icebreaker: Zeste Lounge, King's Hall

Tuesday 11 November	
08:30	Registration + coffee
09:00	Welcome and opening: Mads Huuse (University of Aberdeen)
09:10	Stuart Harker (AAPG and Circle Oil) KEYNOTE: Tales from an ex-ELF
Session 1 (Chair: Chris Jackson) Tectono-stratigraphy	
09:50	D J Moy (Durham) The tectono-stratigraphic evolution of the NW Vøring Basin, offshoreNorway: the role of two transfer zones in rift and passive margin segmentation
10:10	Rob Butler (Aberdeen) Structural interpretation of seismic data and the Virtual Seismic Atlas
10:30	Rachel Kieft (Imperial) Structural controls on facies variability within the syn-rift Hugin Formation, Block 15/3 Norwegian South Viking Graben
10:50	Sophie Leleu (Aberdeen) North Atlantic Triassic Rift Basin Fills: Controls on the Evolution From Fluvial to Playa Stage
11:10	Tea / Coffee
Session 2 (Chair: Rob Butler) Geochemistry, Diagenesis, Fluid Flow	
11:40	Joe Macquaker (Memorial, Newfoundland) KEYNOTE: Source rocks and sequence stratigraphy: Dispelling myths about the optimal environments of source rock deposition
12:20	Z Al-Aisri (Newcastle) Controls on subsurface biodegradation in the East Ghaba Basin of North Oman
12:40	Duncan Chedburn (Mærsk Oil) Seismic characteristics of shallow seismic anomalies and their relationship to fluid flow, West Africa

13:00	Ulf Böker (Newcastle) Multi-scale Controls on Natural Gas Leakage and Migration in the Nile Delta Fan, offshore Egypt
13:20	Lunch *(Lunch will be provided)*
Session 3 (Chair: Stuart Archer) Carbonates	
14:20	Jon Hill (Edinburgh) Modelling shallow marine carbonate depositional systems
14:40	Joyce Neilson (Aberdeen) The relationship between petroleum, exotic cements and reservoir quality in carbonates: a review
15:00	Nicholas Thibault (Copenhagen) How synchronous are calcareous nannofossil events across latitudes in the Latest Cretaceous?
15:20	Delphine Desmares (Aberdeen) Test microevolution in planktonic foraminiferal index species in response to environmental changes during the Cenomanian-Turonian interval in the US Western Interior Basin: Consequences for high resolution biostratigraphic correlations
15:40	Tea / Coffee
Session 4: Keynote, posters and wine	
16:10	Andrew Hurst (University of Aberdeen / Northlight Geoscience) KEYNOTE: Commercialisation of Intellectual Property Derived From Academic Research
16:50	Bruce A Tocher (StatoilHydro) KEYNOTE: The Role and Value of External Research to StatoilHydro's Exploration Goals
17:30	Poster session and wine reception
20:00	End of Day 1

Wednesday 12 November	
08:30	Registration + coffee
09:00	Roy Davies (Rocksource) KEYNOTE: Perspectives on working for a small start-up / new entrant company on the UKCS and NCS
Session 5 (Chair: Mads Huuse) Geophysics	
09:40	Magda Szuman (Aberdeen) The use of seismic attributes and spectral decomposition in interpretation of forward models of Mass Transport Complexes
10:00	Julien Moreau (Aberdeen) 3D seismic interpretation and visualization of glaciogenic structures in the North Sea
10:20	Uisdean Nicholson (Aberdeen) Deltaic evolution in a strike-slip setting: impacts of a changing tectonic regime on petroleum habitat
10:40	Tim Reston (University of Birmingham) The formation of magma-poor rifted margins
11:00	Tea / Coffee
11:30	Richard Davies (Durham) KEYNOTE: The East Java Mud Volcano: What Caused Indonesia's Worst Ongoing Environmental Disaster?
Session 6 (Chair: Joyce Neilson) Reservoir Geology	
12:10	Orji Akaa (Aberdeen) Mesozoic-Cenozoic evolution of the Niger Delta: implications for reservoir quality
12:30	Joseph Harwood (Newcastle) Quartz cementation in the North Sea basin: A high precision SIMS investigation
12:50	Ewa Szarawarska (Aberdeen) North Sea Giant Sand Injectites: Petroleum Significance And Numerical Modelling
13:10	Close – End of Day 2

Dedicated Posters
Døssing, Anders (Copenhagen) Fylla Structural Complex offshore SW Greenland: A Structural and Tectonic Study based on Seismic, Magnetic and Gravity Data
Anderskou, Kresten (Copenhagen) The sedimentology of redeposited chalk
Townend, Edward (IKON) Generating synthetic borehole geophysical data from down-well geological observations; initial results from a 1D study
Jennifer Martin (Durham) Characterising Fractured Basement using the Lewisian Complex: Implications for Petroleum Potential in the Clair Field

Tuesday 11 November

KEYNOTE:

Tales from an "Ex-ELF"

Stuart D Harker, VP Geology Circle Oil PLC, AAPG Advisory Council European Region Representative

This brief broadside is based on my academic and professional experiences of the last four decades, from which suggestions are made to improve the cooperation between industry and university. My own batchelors-masters-doctorate experience spanned eight years before someone finally offered me a job. The political infighting that I had seen at university initially deterred me from maintaining academic ties and I enjoyed spreading my newly formed exploration wings at Texaco in Calgary. Following a two year secondment in Saudi Arabia, I returned to Canada to experience the Trudeau government enforce the National Energy Policy, which curtailed much foreign investment and I took Uncle Sam's silver to join Occidental in California. After four years in global exploration I was so successful that I got posted to the production department in Aberdeen.

It was in Aberdeen that I became an ELF, when that "Essence, Liquides et Fluides" company took over Oxy UK in 1991. But more significantly, it was the place where I became re-enthused with academia, becoming part of the industry-university steering group in finding focus and funding for research projects, as well as providing data for and supervising masters and doctoral projects. A transfer to Paris HQ put a hold on this, though the Pau-ELF research centre became my academic contact. Total merged with ELF in 2000 and I was transferred back to Aberdeen, rejoining university activity by participating in their Drylands project and teaching on their MSc in Hydrocarbon Enterprise. In 2004 I was offered early retirement and thus became an "Ex-ELF". Although I no longer teach, I maintain active contact with several UK universities in support of post graduate work.

When it comes to research, there are two basic categories: Industry Focussed and "Blue Sky". There is a need for industry to support both. Oil and gas companies commonly provide postgraduate projects with ideas, datasets and financial support; let's keep this aspect going, as it's helpful in the short and medium term for the students, the universities and the companies. However, "Blue Sky" is where significant breakthroughs for the future can be made, but funding is in short supply. Innovative ideas need the necessary financial support and there is a need for strong academic and industry advocates to achieve this. Another way in which cooperation can be improved is for companies to allow motivated professionals to take a sabbatical of one or two years to teach and do research in universities. A programme like this already exists in the USA.

Industry to date has had precious little input into the structure of university course content. This should be rectified if progress in producing prospective quality geoscientists is valued. More on this topic will be covered in the presentation, with particular emphasis on the need to eradicate the current trend to cartographically challenged "Nintendo" interpreters. Industry-University steering groups should be established and maintained with a cross section of experience levels to ensure success. After all, the future of a company's success lies in the hands of its competent employees.

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The tectono-stratigraphic evolution of the NW Vøring Basin, offshore Norway: the role of two transfer zones in rift and passive margin segmentation

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The NE Atlantic margin initiated ca. 54 Ma during continental break-up between Norway and Greenland. The precursor rifts have a mainly NE-SW orientation, but regional potential field anomalies highlight a series of NW-SE trending lineaments – commonly referred to as "transfer zones" – along the length of the margin. Previous authors have suggested that some transfer zones may have originated due to reactivation of basement structures, but the structure of these lineaments is unclear. An improved understanding of the nature and tectonic significance of these "transfer zones" is of practical interest to the hydrocarbon industry, given their likely role in controlling the structural segmentation of basinal depocentres at a variety of scales. The aim of this study is to constrain the impact of two NW-SE trending lineaments on the tectono-stratigraphic evolution of a segmented rift system in the NW Vøring Basin.

The NW Vøring Basin is characterised by two NE-SW trending structural highs – the Gjallar Ridge and Nyk High – that formed during Late Cretaceous-Paleocene rifting. The Gjallar Ridge and Nyk High are offset in an apparent dextral sense across the NW-SE trending Rym Accommodation Zone (RAZ). Previous analyses of 2D seismic data suggested that the RAZ accommodated sinistral strike-slip movements during Late Maastrichtian-Paleocene rifting. New interpretations of 3D seismic data from the region have not, however, found conclusive evidence for strike-slip. Rather, the RAZ is believed to have developed as a low-relief accommodation zone during Cretaceous rifting. We speculate that the location and nature of the RAZ may have been controlled by a Caledonian lower crustal body beneath the Gjallar Ridge.

Regional uplift during the Late Maastrichtian-Early Paleocene caused large scale erosion of the Gjallar Ridge and Nyk High, and the subsequent removal of large amounts of syn-tectonic strata. Evidence for renewed rifting during the Paleocene is confined to areas of the Nyk High and RAZ, and is also postulated to have occurred in the region to the NW of the Gjallar Ridge. The preservation of late Paleocene lavas within the RAZ is consistent with focused flow of sub-aerial igneous material, and possibly sediment, along this structure. The RAZ is believed to have acted as a conduit, during the successive rift events for both distal and locally sourced sands, deposited within structurally complex, E-W striking half grabens to the south.

A second NW-SE trending lineament – here termed the Gleipne Saddle – intersects and apparently offsets the Gjallar Ridge in a sinistral sense. Despite a much less distinct structural expression than the RAZ it is also likely to have formed as a low relief accommodation zone in the region. Again, the Gleipne Saddle appears to have had an important impact on syn-rift sedimentation during the Maastrichtian. Here, sedimentation outpaced normal fault movements during deposition of marine fans, which appear to have been sourced distally from the NW and locally from the exposed Gjallar Ridge. The Gleipne Saddle is associated with a distinct Bouguer gravity low and shallowing of the lower crustal body, again implying a crustal-scale control on the development of this accommodation zone.

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Structural interpretation of seismic data and the Virtual Seismic Atlas

Rob Butler, University of Aberdeen

Abstract to be circulated at conference.

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Structural controls on facies variability within the syn-rift Hugin Formation, Block 15/3 Norwegian South Viking Graben

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Sedimentological and sequence-stratigraphic analysis within rift basins is complicated due to syn-depositional fault development. Localised uplift and subsidence due to normal faulting can impact facies distributions by modifying basin-floor topography and sediment transport pathways. When sediment supply to the basin is low, sea-floor topography may develop across active faults, leading to localisation of depocentres and restriction of certain facies to these topographic lows. When sediment supply matches the rate of accommodation generation, topography does not develop and the same spatial restriction of certain facies may not occur. This makes facies prediction problematic in such settings, but conversely an understanding of facies character and architecture can provide important insights into the timing of structural development.

This study focuses on the shallow-marine, Middle Jurassic Hugin Formation where it forms an economically important reservoir within Norwegian Block 15/3 in the South Viking Graben. The formation was deposited during the southerly transgression of the Brent Delta system and was coincident with the earliest phase of extension and normal faulting in the region related to the Upper Jurassic rift event.

The Hugin Formation within the study area comprises five stacked parasequences separated by flooding surfaces. These parasequence typically consist of restricted marine, bioclastic claystones grading upwards into muddy and sandy bay-fill deposits, which are locally truncated by sand-rich tidal channels, thought to be connected to the fluvial feeder system to the basin. Along-strike facies variability is seen with muddy bay-fill deposits passing into sandy bay-fill deposits and coals. These bay-fill deposits are missing entirely from the distal sections of some parasequences, with much thicker (up to 40 m) sandstones sharply overlying the restricted marine claystones. These sandstones are interpreted as tidal inlet deposits associated with a barrier system that developed to the west of the sudy area.

Seismic mapping and well correlations both show the Hugin Formation thickening from east to west across the study area as a result of initial rift-related movement on the graben-bounding fault to the west. Further minor thickness changes are superimposed on this trend, highlighting the subtle influence of smaller, antithetic faults and halokinesis during Hugin deposition. In some cases, facies variability highlighted in the well correlations corresponds to these thickness changes, suggesting that structural development was the dominant control. However fault-parallel facies variability also occurs over comparatively short distances (2-4 km).

It is possible to correlate parasequences of the Hugin Formation within Block 15/3, indicating that sediment supply and structurally controlled subsidence were approximately in balance. However, some facies are focussed within syn-depositional depocentres, indicating that evolving structures may have influenced facies architecture at intra-parasequence scales, although proximity to sediment transport pathways into the basin is also important. In this area, a robust sedimentological model integrated with structural mapping provides the best basis for reservoir prediction.

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North Atlantic Triassic Rift Basin Fills: Controls on the Evolution From Fluvial to Playa Stage

Sophie Leleu and Adrian J. Hartley

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The continental deposits of Triassic rift basins developed along the Central and North Atlantic margins display a similar sedimentological evolution. Classically, two phases of sedimentation can be recognised: 1) a lower sand-prone phase characterised by fluvial deposits including alluvial fan and fluvio-aeolian deposits and 2) an upper fine-grained phase which is mud-prone unit and may include evaporites which record deposition in playa/ lacustrine dominated environments. Triassic basins that display this sedimentological evolution include those of the UK, Ireland, Portugal, Newfoundland and the North American Newark Group Basins. The lower fluvial succession contains important sandstone reservoir intervals in the UK/Ireland sandstones (Sherwood Sandstones).

Although the sedimentological evolution of these basins is similar, the timing and duration of the phases of fluvial and playa deposition vary from one to another. Characterising the transition between the fluvial and playa dominated episodes of basin development is important in terms of understanding what the controls are on this widespread architectural signal within Triassic continental basins.

This work presents a detailed description of a section from the Minas Sub-Basin (Fundy Basin, Nova Scotia) where the transition from the fluvial to the playa/ lacustrine stage is exposed. The fluvial phase is represented by the Wolfville Formation the upper part of which (250 m of vertical section) occurs beneath the lacustrine/playa phase represented by the Blomidon Formation. The transitional section shows well organized and repetitive alternations of fluvial/ephemeral fluvial/playa-lacustrine deposits with increased preservation of aeolian sediments in the upper part of the succession. These observations suggest a gradual evolution from the fluvial to playa stage that likely reflects a long term climatic change onto which smaller-scale climatic cycles are superimposed and which strongly influences the resultant depositional architecture. This transition is directly analogous to the Corrib Field reservoir in the Slyne Basin, west of Ireland (Schmid et al., 2006), where the upper Sherwood Sandstone reservoir is developed just below the contact with the Mercia Mudstone.

Despite a possible climatic control on sedimentary succession, the diachronous nature of the transition in different north Atlantic basins suggests that other major controls rule continental Triassic basin evolution, such as drainage basin evolution or fault array development related to rift basin re-organisation.

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KEYNOTE:

Source rocks and sequence stratigraphy: Dispelling myths about the optimal environments of source rock deposition

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Organic-rich fissile mudstones ("black shales"), deposited on ancient marine continental shelves, are commonly interpreted as having been deposited in low energy environments under conditions of bottom water anoxia associated with times of reduced clastic dilution. In these settings sedimentary detritus is typically interpreted as having been delivered to the sediment water interface as hemipelagic rain below zones of high primary production and in settings where the bottom waters were persistently anoxic. Fabrics and component variability revealed by recent advances in microscopy, coupled with high-resolution stratigraphic sampling suggest this view is rather simplistic, even in the most organic-rich successions.

In order to investigate the fundamental controls on sediment delivery and the conditions at and close to the sediment water interface during source rock formation, selected, Mesozoic aged, organic-rich siliciclastic mudstones (e.g., Kimmeridge Clay, and Cleveland Ironstone Formations) have been investigated utilizing high resolution stratigraphic techniques combined with geochemical, optical and electron optical methods.

Analyses of these successions reveals that individual genetic beds are commonly very thin (<10 mm), upward-fine, and have bioturbated tops. Moreover, they show that much of the sediment has been pelleted and organized into organo-mineralic aggregates. They also demonstrate that agglutinated foraminifera maybe abundant, and starved ripple laminae, intraclasts horizons, concretionary cements and shell pavements are present at some levels. Finally, bioturbation in these units is common and comprises a variety of diminutive trace (<1.0 mm) fossil taxa including *Chondrites* isp., *Paleophycus* isp., *Planolites* isp*., Phycosiphon* isp., and a diverse assemblage of burrows of uncertain origin.

Together these data indicate that during deposition of these organic-rich rocks: a) conditions at the sediment water interface were predominantly oxic / dysoxic; b) hemipelagic sediment was delivered as marine snow, c) the sediment was regularly reworked by currents (particularly storms) and d) at least episodically there was sufficient energy at the sediment water interface to rework the sediment forming intraclasts and concentrate the shell debris into pavements. These data also indicate that the significance of long term bottom water anoxia as a pre-requisite for enhanced organic matter interpretation has been overestimated, genetic thin-beds have commonly been misinterpreted as lamina, the benthic faunal communities were restricted because of the existence of an unfavourable substrate rather than bottom water anoxia and outer shelf environments, during deposition of these sediment were much more dynamic than most researchers believe. Finally, they show that source rocks do not just form associated with condensed sections, rather they form in settings where clastic dilution did not significantly dilute the organic components, rates of sedimentation were fast enough to bury the organic matter, and significant amounts of organic matter were being produce

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Controls on subsurface biodegradation in the East Ghaba Basin of North Oman

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The East Ghaba Basin of North Oman has biodegraded oil occurring amidst non-degraded oil in both clastic and carbonate reservoirs. Given the economic implications of biodegraded, heavy oil, understanding the controls on biodegradation is a key to future exploration and production in the area. To understand and explain regional controls on biodegradation and to help predict biodegradation risk, 22 oils from a number of fields were analysed. In-reservoir biodegradation was also investigated in carbonate reservoirs using core samples from 4 wells in the area.

Bulk compositions in the oils varied significantly in the older clastic reservoir (45%-60% saturates) and younger carbonate reservoir (27%-62%). Little or no variation was seen in the saturate fraction in most of the wells except two where the saturate fraction decreased with depth towards the oil-water contact. This indicates relatively recent biodegradation of oil at the oil-water contact (1) as prolonged biodegradation without fresh charge tends to homogenise saturates – depth trends.

Oil gas chromatograms indicate a wide range of fluid types, ranging from fresh oils, to heavily biodegraded oils, to mixtures of biodegraded oil with fresh oil. Surprisingly, these variations did not correspond with the saturate fraction in that some oils were severely “biodegraded” but had a high saturate fraction as well as some “fresh” oils with a low saturate fraction. Again this indicative of mixing of biodegraded and fresh oils as well as possible mixing of different oil types with different initial saturated hydrocarbon contents. Biomarkers and bulk carbon isotope analysis suggest that the oils are sourced either from the Huqf or the Q, or are mixtures of the two oil types (3) (reference Huqf Q here).

In the clastic reservoir the degraded oils (Peters and Moldowan (PM) rank 4-5) are on the flank of the basin whilst the non-degraded oils (PM 0) are located deeper within the basin. However, the deeper reservoirs are only buried to 60-70°C, suggesting that the oils are still in the biodegradation window (2). Better quality oil could therefore be dependent on accessibility to new/recent/late charge. In the younger carbonate reservoir better quality oils are also dependent on accessibility to fresh charge as the extent of biodegradation was neither depth nor temperature related. In addition fresher oils (PM 0-1) in both reservoirs are located close to the Maradi Fault Zone (a major regional fault that has been active through geological time to date) compared to biodegraded oils (PM 4). This could suggest that the Maradi Fault Zone acts as a conduit for new charge to these fields.

References

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Seismic characteristics of shallow seismic anomalies and their relationship to fluid flow, West Africa

D., Chedburn, L., Clausen, L., Seidler., M., Huuse

Shallow seismic anomalies are common in West Africa, and studies have shown many of them to be related to fluid flow from deeper reservoirs. Therefore it is important to be able to recognise them and their relationship to fluid flow using seismic data. The results from a study using a 2D seismic database from West Africa is used to illustrate these fluid flow features in detail. Pockmarks can be identified as they truncate underlying strata, have an onlapping infill, and are seen to be circular in plan view at the seabed, so are erosive in nature, due to gas venting. These are the most abundant fluid flow feature in the study, and their relationship to underlying features helps to indicate a shallow (biogenic or dewatering) or deep (thermogenic) source for the gas. Many pockmarks are found where the sediment column is thick, but appear unrelated to anything below and are likely to be related dewatering or shallow sourced gas. These pockmarks are only found in the top 250ms of the section, suggesting specific conditions for shallow gas release or dewatering exist and have only been reached recently in this area. The location of other pockmarks seems to be controlled by underlying features including faults, salt and sedimentary features, so seem most likely to have a deep thermogenic fluid component, as they can act as conduits for flow from depth. Vertically stacked pockmarks can be seen above some of these underlying features, suggesting a continual pathway for fluid flow exists, but as individual pockmarks are seen above faults, it suggests that faults only act as temporary conduits to flow, possibly only around periods of fault slip. Bottom Simulating Reflections (BSR) are another type of shallow seismic anomaly observable in this study and they indicate an area with gas hydrates in the shallow sediment column, and free gas below. In this area pockmarks can be seen above the gas hydrate column, and are seen to connect downwards to the free gas zone. At the seabed these pockmarks coalesce into long linear troughs or furrows, which indicates a long laterally continuous weakness in the poorly permeable gas hydrate exists, possibly structurally or ocean current controlled. The presence of gas hydrate is dependant on pressure, temperature, as well as water and gas availability, and therefore the level of the BSR can be used to calculate a geothermal gradient of 42°C/km in that area. If the source of the free gas can be discerned, then the movement of deep sourced fluid/gas upward through the system can be verified. In this study sub-vertical disturbances in the seismic section – seismic chimneys up to 300m wide and cutting up through 900ms of section are seen to feed the free gas zone, so are important as they indicate active migration pathways up through weaknesses in the sedimentary column. These seismic chimneys are seen to emanate from the edge of high amplitude pinching out packages, which must therefore be lateral carrier beds, or reservoirs that leak fluid vertically where they pinch-out. If several different types of shallow seismic anomaly can be seen near each other this gives more indication of the type of fluid involved, so migration pathways can be estimated, and an insight into the hydrocarbon system can be gained.

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Multi-scale Controls on Natural Gas Leakage and Migration in the Nile Delta Fan, offshore Egypt

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We present results of an integrated approach to understanding physicochemical controls on gas migration and leakage through mudstone caprock sequences in part of the western Nile Delta. There are numerous seismic bright spots in the region which indicate the presence of gas. However, the ubiquitous production of biogenic gas generated from sediments with TOC contents ranging from about 0.5 to 1.5 % precludes the use of seismic data to track flow or leakage; seismic data can be used to indicate the presence of gas but not its origin.

In some areas thermogenic gas from pre-Messinian sources is mixed with the biogenic gas; its presence can be used to infer migration and leakage routes. In the area of interest, gas samples were taken below, within and above the reservoir at a spatial resolution of 5-10 m. Gases were sampled into sealed tubes ("isotubes") from the degassing mud at the flowline coming out of the borehole. Data quality was checked against MDT data and found to be robust. The data show that thermogenic gas is present throughout a 200m, mud-rich section beneath the reservoir, and a 400m hemipelagite section overlying the reservoir. This implies that migration and leakage have occurred through the bulk volume of the sediments, and not through specific conduits such as faults. We cannot rule out migration through microfractures but note that whilst leakage is occurring at the structural high, pore pressures are low so that hydraulic fracturing is unlikely. Analysis of the gas profiles suggests that gas is being lost by advection rather than diffusion, in which case the rate of loss is a function of the relative permeability of the cap rock. The structure is not thought to be full to spill, implying that column height may be controlled by the rate at which gas is added to the structure and the rate at which it is lost.

Analysis of the seal units using MICP show that there are at least some units which today have sufficiently high threshold capillary entry pressures to retain gas columns greater than those actually observed. It is thus possible that we are observing a palaeoleak, occurring when the cap rock was closer to the surface and less compacted. However, the cap rock is not homogeneous on a range of spatial scales, so that the leaking gas is likely to be exploiting connected, lower capillary entry pressure units. We are currently combining core analysis with the use of conventional and image logs to investigate the occurrence of lithological heterogeneities which could play an important role in gas migration and leakage in this area.

NOTES

Modeling shallow marine carbonate depositional systems.

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Geological Process Models (GPMs) have been used in the past to simulate carbonate stratigraphies, and to explore the interaction of controls that produce heterogeneity. These heterogeneities are key considerations in order to understand fully the porosity and permeability changes that are so prevalent in carbonates. No previous GPMs to our knowledge, however, have directly included a key physicochemical control on carbonate production in reef and lagoon environments, namely the supersaturation of calcium carbonate in seawater. We use residence time of water in the lagoon and reef areas as a proxy for supersaturation in a new process model, Carbonate GPM. Residence times in the model are calculated using a particle tracking algorithm which tracks virtual particles along flow patterns derived from wave set up. We show that representing supersaturation as a function of distance from open marine sources as in previous models cannot correctly predict the supersaturation distribution over a lagoon due to the complexity of the flow regime. In Carbonate GPM, carbonate production is also controlled by water depth and wave power dissipation. Once deposited, sediment can be eroded, transported, and re-deposited via both advective and diffusive processes. We also show that including the fundamental control of supersaturation can explain the formation of typical complex, three-dimensional carbonate stratigraphies by, amongst other processes, lateral shifts in the locus of carbonate deposition on timescales comparable to so-called 5th order sea level oscillations. Importantly this is achieved using only a limited number of simple underlying physical and chemical processes, without the need for explicit modeling biological interactions. Biological production is without doubt an intermediate component in the production machinery, but not necessarily a component that must be invoked to generate spontaneous complexity.

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The relationship between petroleum, exotic cements and reservoir quality in carbonates: a review

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Exotic minerals, i.e. those that do not have an obvious source of components within the host rocks, can be major porosity occluding cement and replacement phases in subsurface carbonate reservoirs. Here we present and discuss petrographic and fluid inclusion data from a number of petroleum systems. These have had different geological histories but a common factor is the presence of exotic mineral cements and late stage dissolution. The effect of these cements and late stage dissolution on reservoir quality is also considered.

Petroleum filling does not appear to inhibit the precipitation of exotic cements in the way that it appears to inhibit the precipitation of calcite. Burial dolomite and anhydrite are the most important of these volumetrically but they are often accompanied by other late stage cements such as fluorite, kaolin, quartz, barite, celestite, sphalerite and galena, generally in much smaller quantities. In accounting for the concentration of the material contained in these cements compared with the host rocks, stylolitisation is a possible mechanism in some cases, but, in many others, import from sources external to the reservoir is required.

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How synchronous are calcareous nannofossil events across latitudes in the Latest Cretaceous ?

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Upper Cretaceous chalk is an important reservoir for oil in many parts of the world, e.g. the North Sea, USA, Commonwealth of Independent States and Caspian Sea. The combination of research on calcareous nannofossil biostratigraphy promoted by oil industry in these chalk reservoirs and the proliferation of studies on onshore and DSDP/ODP sites has led to a better understanding of latitudinal differences in nannoplankton assemblage composition. Palaeobiogeographic separation of nannofloras is most apparent in the Campanian and Maastrichtian and the global correlation of events in this interval has the lowest resolution (Burnett, 1998). The up-to-date UC nannofossil biozonation scheme of Burnett (1998) provides globally correlatable biozones and three different sets of subzones for the 'boreal', 'intermediate-tethyan' and 'austral' provinces. These subzones can not be widely correlated in the uppermost Cretaceous. In addition, Bralower et al. (1995) have produced a global combined magnetobiochronological scheme for the entire Upper Cretaceous that integrates nannofossil events, planktic foraminifera events and the geomagnetic polarity timescale. This scheme has proved to be robust and has been widely used in palaeoceanographic cruises. However, it is based on a limited dataset. Since this study, several onshore and offshore sites have provided both nannofossil and palaeomagnetic data from the Upper Cretaceous that can help testing the synchroneity of nannofossil events with regard to the magnetostratigraphic succession.

We did a review of sites that provide both a good magnetostratigraphic and a good nannofossil biostratigraphic resolution through the upper Campanian—Maastrichtian interval in past and recent literature. Nannofossil bio-events were then plotted with regard to the global geomagnetic polarity timescale across distinct palaeolatitudes. This allowed us an estimation of the extent of well-known diachronism of *Nephrolithus frequens* first occurrence from the Austral Realm to the North Atlantic area. Also we address certain complications within the intermediate-tethyan province. In particular, we show that the first occurrence of *Micula murus* which defines the base of nannozone UC20b is highly diachronous across latitudes. This taxon first occurs at the top of magnetochron C31r in the Equatorial Atlantic Ocean, migrates northward and southward in the late Maastrichtian and first occurs in the upper part of magnetochron C30n at intermediate palaeolatitudes (Fig. 1). This results in a reversal with respect to the first occurrence of *Lithraphidites quadratus* which defines the base of nannozone UC20. This pattern of *M. murus* is being reinforced by its paleoceanographic significance since the migration of this supposedly warm-water taxon takes place during the mid-Maastrichtian warming event (Fig. 1). These results are very important for oil industry and for academic research and must be taken into account for large-scale correlations in the uppermost Cretaceous using nannofossil biozonation schemes.

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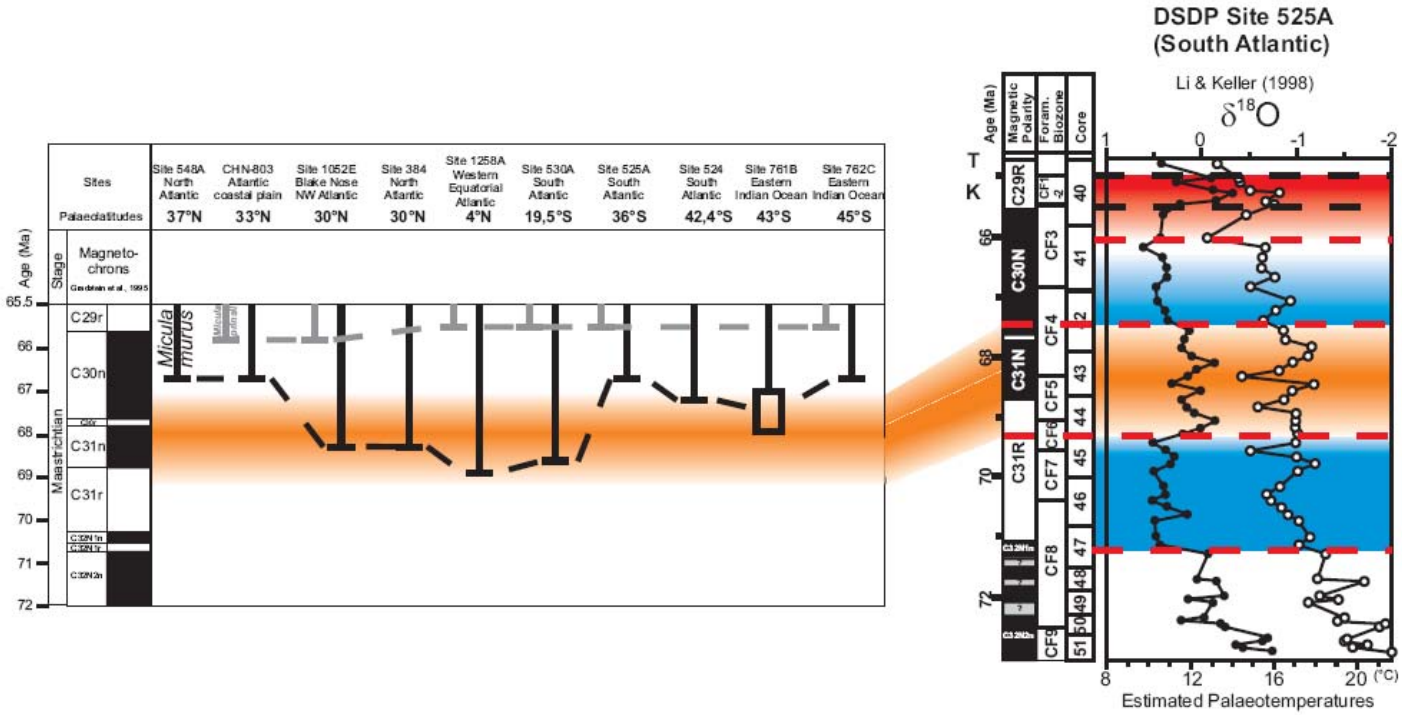

Fig. 1 : Evidence of the latitudinal migration of *Micula murus* during the mid-Maastrichtian warming event.

NOTES

Test microevolution in planktonic foraminiferal index species in response to environmental changes during the Cenomanian-Turonian interval in the US Western Interior Basin: Consequences for high resolution biostratigraphic correlations.

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While ammonites are used to precisely define the position of the Cenomanian-Turonian boundary, changes in the planktonic foraminiferal assemblages are less indicative and seem to occur over a broad interval of time coeval with the contemporary oceanic anoxic event (OAE2). This global expansion of the oxygen minimum zone led to the disappearance of rotaliporids, complex planktonic foraminifera which previously occupied deep oceanic waters and which are widely used as a stratigraphic index.
This planktonic foraminiferal turnover corresponds to the traditional "zone à grosses globigérines", defined as the Whiteinella archaeocretacea Partial Range Zone. The base of this partial range zone overlays the last occurrence of Rotalipora cushmani (top of the R. cushmani total range zone) and its top underlies the first occurrence of Helvetoglobotruncana helvetica (base of the H. helvetica total range zone).

In the late Cenomanian strata of the Western Interior Seaway, two keeled species of rotaliporids are recorded: R. cushmani and Thalmanninella greenhornensis. Inflated forms - Rotalipora planoconvexa and Thalmanninella multiloculata - co-occur with these keeled morphotypes. where they preserve the same morphological features as the keeled forms (e.g. supplementary apertures, coiling ratio), the inflated morphotypes are characterised by the peripheral keel not being expressed on each chamber or even being totally absent. Indeed, Th. multiloculata and R. planoconvexa preserve juvenile characters (i.e. the development of the keel is suppressed). Such a shift in developmental rate represents an heterochrony (where there is change in the timing and/or rate of ontogenetic processes controlling the development of morphological traits). Thus, Th. multiloculata and R. planoconvexa are respectively neotenous forms of Th. greenhornensis and of R. cushmani, such heterochrony reflecting adaptive strategy. With this test microevolution, the rotaliporids may have remained in shallower habitats, thereby escaping an expanding oxygen-minimum zone.
However, all morphological gradations have been observed between the keeled and the globular morphotypes. This wide variation in transitional forms in the assemblages containing Th. greenhornensis/Th. multiloculata and R. cushmani/R. planoconvexa reflects their responses to environmental pressures.

Ten outcrops, spanning the Cenomanian-Turonian boundary interval, were examined across the Western Interior Basin, following two transects from Arizona to Kansas and from South Dakota to Texas. High resolution correlation between these sections indicate that the last occurrence of R. cushmani and the first occurrence of the index species H. helvetica are diachronous at the basin scale. Thus, the first appearance of H. helvetica is a problematic biomarker horizon. Furthermore, forms transitional between H. helvetica and its ancestor Whiteinella praehelvetica, are commonly identified in the terminal Cenomanian, during the acme of oceanic anoxic event. H. helvetica differs from its ancestor W. praehelvetica in having a true keel throughout all chambers of the last whorl. The transitional forms are mostly globular but the last two or three chambers of the final whorl have a peripheral keel. In term of taxonomy, transitional forms are difficult to attribute to a particular species because there is a continuum between W. praehelvetica and H. helvetica.
As R. cushmani and H. helvetica are index species, the classification of transitional forms affects the biostratigraphic models of different authors. Indeed, such specimens are often classified according to criteria chosen by each individual micropalaeontologist, and this separation can be arbitrary.

Beyond resolving biostratigraphic uncertainty, the presence or absence of a keel could be a tool to constrain environmental changes in time and in space. Thus, microfacies analyses prove that whilst globular morphotypes predominate in anoxic environments, transitional and keeled forms are associated with more favourable oxygenated environments.

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KEYNOTE:

Commercialisation of Intellectual Property Derived From Academic Research

Andrew Hurst, University Aberdeen, Department of Geology & Petroleum Geology

As an academic researcher activities are a balancing act between things that one finds interesting and things that people/organisations find interesting and are willing to pay for. As I am inspired by almost everything to do with earth science this gives me plenty of scope. Of course one's scientific limitations are important when determining what research can be embarked upon with any credible hope of success. Any individual's limitations compel one to find colleagues who have complementary skills and with whom one can communicate; a critical skill.

An academic research portfolio typically contains several projects that will be at different stages of activity and development. Some projects will, at their outset, be commercially oriented others not, some will be sponsored by industry and others not etc, hence expectations of commercial advantage will vary. What is invariably true is that whatever I believe to be research of commercial value will not be viewed by others in a similar way and this is a source of anguish and confusion for many scientists. My rule of thumb is "an idea shared is an idea with enhanced value." This is an important idiom as there are almost no fantastic ideas, lots of genuinely poor ones, and just few modest ideas. In my experience the modest ideas are the ones to identify and harvest. If academia is genuinely interested in capitalising on E&P-related intellectual property it cannot afford to be selfish. If the E&P industry is genuinely interested in benefiting from academic research it must dedicate genuine time and resource to the process. For both parties arrogance has to be avoided.

By using my own modest record in commercialisation of research I will demonstrate how different strains of research may produce intellectual property that can be turned into commercial value. Academic drivers and justification for commercial ventures will be outlined and I will describe some simple rules of engagement and describe how and why academia and the E&P industry share some common goals.

NOTES

KEYNOTE:

The Role and Value of External Research to StatoilHydro's Exploration Goals

Bruce Alastair Tocher, StatoilHydro ASA, Postboks 7200, NO-5020 Bergen, Norway

StatoilHydro's technical expertise and activity level on the NCS is second to none and the group is rapidly building its international portfolio. The forthcoming challenges are to elevate our expertise in the race for prime acreage and make a major contribution to increasing the resource replacement rate. In order to address these challenges a new Technology Strategy for StatoilHydro has been developed which identifies those technologies which aim to help the company develop as a performance-driven internationally competitive organisation. Exploration is identified as one of seven key technical areas in this new strategy, with Resource Replacement the primary business driver.

Innovative, vibrant research programmes are regarded as an essential element in StatoilHydro's future development, and considerable resources are being invested to achieve the corporate aims. This investment includes both internal and associated external research projects. The EXPLORE Programme is responsible for developing and executing StatoilHydro's exploration research strategy; a key element of which is to identify and build close relationships with world-leading external researchers and research insitutions. Previous experience has shown that close integration of our internal and external projects can make a significant positive impact on our business challenges.

The EXPLORE Programme, as with the other research programmes in StatoilHydro, is also charged with the responsibility for looking beyond only short-term research tasks; medium to long-term challenges have also been identified and research projects initiated, or planned, to address these. With respect to the latter, StatoilHydro's strategy of building strong and proactive relationships with leading institutions, as well as active technology monitoring is seen as an essential element in our aims to rapidly incorporate new ideas and technologies into our research and business development.

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Wednesday 12 November

KEYNOTE:

Perspectives on Working for a Small Start-Up / New Entrant Company on the UKCS and NCS

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In recent years the push to make the most out of the remaining exploration and production potential of the UKCS and NCS, combined with high oil prices, the withdrawal of some major oil companies and changes in fiscal regimes has seen a significant change in the number and type of companies active in these sectors. In the early 2000's, both the UK and Norway were still largely dominated by large multi-national and state-owned oil and gas companies. More recently, however, there has been an unprecedented influx of small start-up companies and new-entrants that has resulted in record activity in recent licensing rounds, such as the 24th and 25th seaward licensing rounds in the UK, and the 2006 and 2007 APA rounds in Norway. Although it remains to be seen what the long-term future holds for many of the small companies that have emerged over the last few years, some of them have already demonstrated that small, efficiently run organisations can exploit opportunities that would be uneconomical for larger companies to pursue.

For today's geoscience graduates these changes have significantly broadened the range of potential employers available, and opened up some exciting and challenging career opportunities for those looking for an alternative to working for the established players in the industry. The choice between working for a large oil company or a new start-up is an interesting one to consider, as they clearly offer very different introductions to the oil and gas industry: Working for a big company will usually provide access to a structured career development programme and a large network of peers and experienced staff to provide support and mentoring, whereas working for a smaller company may provide opportunities to work in a more independent manner and to take on greater responsibility at an earlier stage. Similarly, new graduates working for large companies may have opportunities to work on large fields and developments, whilst those working in smaller companies may gain a broader understanding of the industry through working on multiple projects in a smaller organisation where they are exposed to many different parts of the business.

NOTES

The use of seismic attributes and spectral decomposition in interpretation of forward models of Mass Transport Complexes

M.Szuman, L.Nielsen, M.Huuse, B.Kneller

Mass transport complexes have been broadly studied and recognized on most continental margins. Throughout such deposits three main geological features are typically recognizable on conventional seismic data: a) continuous blocks without apparent internal deformation represented by high-amplitude continuous reflections; b) low- and high-amplitude reflections geometrically characteristic of slump deposits; c) low-amplitude, semitransparent chaotic reflections indicative of debris flow.

Our study investigates the accuracy of this interpretation by analysis of synthetic seismograms based on outcrop data of two end member MTC's: debris flow and slide. Results of our studies show that the seismic expression of these deposits is much more complex and our ability to interpret them correctly is far from satisfying. As expected, the capability to interpret these deposits on seismic data shows very strong dependency on the internal lithology and burial depth. However, the impact of internal geometry, size and orientation of the individual blocks in combination with acquisition parameters has a profound effect on seismic expression. Therefore, an interpretation focused only on analysis of reflection amplitude can provide very misleading results. Additional use of seismic attributes like instantaneous frequency and instantaneous phase, together with spectral decomposition, allowed us to develop a set of rules and predictions about the general structure of MTC's and their internal geometries which can lead to improving our understanding of these deposits, their role in oil reservoirs and their influence on other depositional systems via the creation and destruction of accommodation space.

NOTES

3D seismic interpretation and visualization of glaciogenic structures in the North Sea

Julien Moreau, University of Aberdeen

Abstract to be circulated at conference.

NOTES

Deltaic evolution in a strike-slip setting: impacts of a changing tectonic regime on petroleum habitat

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The Okhotsk Sea (Russian Far East) is underlain by material accreted to the Eurasian margin in the Early Cenozoic. It may represent a separate microplate, situated close to a triple-junction between the Eurasian plate to the west, the North American plate to the NE and the Pacific plate to the SW. The western boundary of the putative Okhotsk microplate is represented by a major dextral strike-slip system which has been accommodating relative plate motions with Eurasia since some time in the Paleogene. The Amur River, the world's tenth largest river, began to deposit a thick deltaic sequence across this active plate boundary in the Early Miocene and has continued to do so until the present day.

The first stage of deltaic deposition occurred during a period of transtension which resulted in the formation of the North Sakhalin Basin. Sedimentation was strongly structurally controlled by a series of SW-NE trending extensional faults and sediment thicknesses vary strongly as a result. The second stage of deltaic deposition occurred during a period of relative tectonic quiescence with fault movement being restricted to pure strike-slip (transcurrent) movement. This resulted in the deposition of a much more continuous and homogenous unit which blanketed the earlier structures. This was followed by a phase of Pliocene-Recent transpression which resulted in the uplift of Sakhalin and the confinement of the delta to a N-S trending passage in the Tatar Strait and Sakhalin Bay and the rapid progradation of the sub-aqueous part of the delta to the north of Sakhalin.

It is apparent that deltas deposited in tectonically active settings do not fit conventional models of deltaic development. Structural control has a major influence on the generation of accommodation space, in particular the formation of deep sub-basins and the uplift of barriers around which the delta must develop. Strike-slip settings, such as in the western Sea of Okhotsk, result in the tectonic dismemberment and large scale displacement of different parts of the delta. Looking at the changes in geometries of deltaic units allows inferences to be made about the controlling tectonic processes and to improve understanding of the evolution of a plate boundary through time. This in turn allows a deeper understanding of the distribution of the elements of petroleum systems in such settings.

NOTES

The formation of magma-poor rifted margins

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Magma-poor rifted margins are natural laboratories to study how extreme extension leads to breakup: the paucity of magmatism means that extension approximates a constant volume process and there are nor thick sequences of basalts to obscure the tectonics. The fourteen magma-poor margins whose crustal structures are best known all show extreme crustal thinning accompanied by normal faulting, the serpentinization of the mantle beneath crust thinned to less than 8±2 km, and the unroofing of mantle within the continent-ocean transition. As a result such margins are very different from less extended and less thinned regions such as the North Sea. Two main processes appear to dominate the evolution of such margins: polyphase faulting and crustal embrittlement leading to mantle serpentinization. As the crust extends, thins and cools, ductile creeping layers in the mid- and deep crust become progressively more brittle, resulting in increased coupling between the upper and lower crust, and eventually the embrittlement of the entire crust. Faults can then cut from the surface across the Moho, bringing water into the mantle and causing its serpentinization. Increased coupling and the development of serpentine detachments predict the development of late stage asymmetry once the entire crust is brittle: such asymmetry is commonly observed. The embrittlement of the crust makes lower crustal flow and crustal depth-dependent stretching (DDS) increasingly difficult: no evidence for significant crustal DDS can be inferred from the crustal structure at any magma-poor margin. Instead, thinning appears to have been accommodated by large degrees of extension, involving multiple phases of faulting where stretching factors exceed 2 and in some case accompanied by detachment faulting. The resulting complex fault block geometries cannot be fully recognized on time sections. The implication is that prerift and early synrift sequences are likely to be dismembered and scattered across the margin, rather than occurring either semi-continuously as implied by some models of crustal DDS. This has obvious implications for the distribution of both source and reservoir at such margins.

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KEYNOTE:

The East Java Mud Volcano: What Caused Indonesia's Worst Ongoing Environmental Disaster?

Richard Davies, University of Durham

Abstract to be circulated at conference.

NOTES

Mesozoic-Cenozoic evolution of the Niger Delta: implications for reservoir quality

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The Niger River, which extends for 4180 km and drains an area of about 2 million km2, is generally believed to the principal source of sediments of the Niger Delta. However, there are published suggestions (e.g. Iloeje, 1981) that drainage to the Niger Delta may have been radically different in the past, coming principally from the present-day Benue River (Fig. 1).

Figure 1: The Niger and Benue river systems today.

This hypothesis postulates that an ancient upper Niger system rose in the Guinea Highlands, flowed NE and emptied into Lake Araouane, situated SW of Timbuktu, Mali. In Quaternary time, a completely separate, lower Niger system developed, flowing southeast-ward and cutting its valley head-wards; this captured the other river and drained off the lake through to the Atlantic Ocean, leaving only shallow pools, marshes, swamps and alluvial and lake deposits to mark where it once existed (Fig. 2).

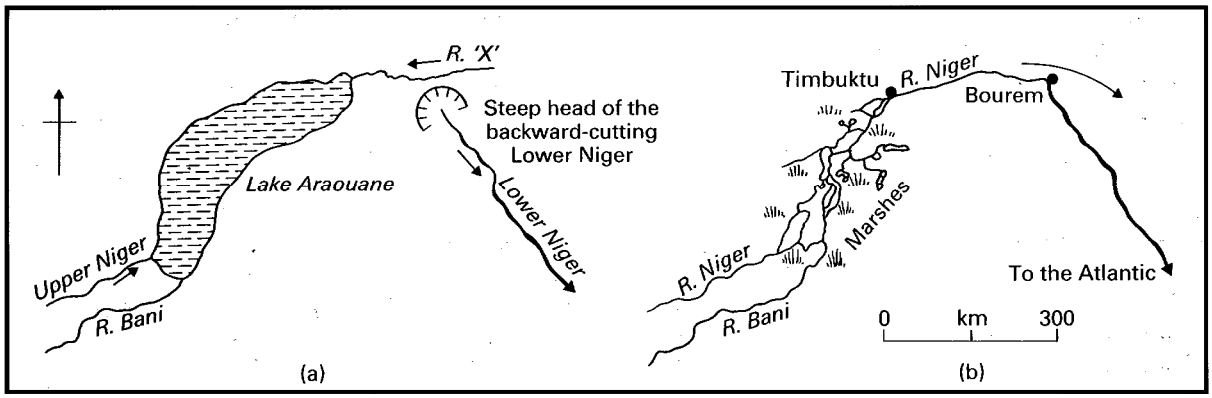

Fig. 1: The Niger system: (a) before (b) after capture (Iloeje, 1981)

While most of the sediments that originated before the capture and subsequent elongation of the Niger system remained trapped in the inland lakes, the Benue, a far older river, related to Cretaceous rifting of the Gondwana supercontinent, continued its sediment supply unhindered, prompting the argument that the Benue River may have actually been the source of most of the sediments of the delta. The actual contribution of River Niger to the development of the Niger Delta is the subject of this investigation.

The hypothesis has profound implications for prediction of reservoir sand composition in the Niger Delta. This paper presents preliminary results of on-going research using heavy mineral techniques and associated proxies to determine the stability of sediment supply to the Niger Delta through time. The research strategy involves surface and subsurface sampling to identify light and heavy mineral associations, as well as: single-grain detrital zircon dating using ICPMS; garnet and rutile geochemistry; and clay XRD. Preliminary results suggest high variability in age (500-1100 million years) of U-Pb zircons from sampled rivers. Variable Ruzi index values of 16.7 – 57.1 have also been recorded, implying source variability.

NOTES

Quartz cementation in the North Sea basin: A high precision SIMS investigation.

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Quartz cement is the most abundant diagenetic mineral in reservoir sands, reducing porosity and thus reservoir quality. The majority of quartz is thought to be sourced internally via pressure solution, although it is also possible that silica is sourced from adjacent shales as a result of clay mineral reactions such as the transformation of smectite to illite.

Previous studies suggest that the extent of quartz cementation increases as a function of temperature. The rate controlling step is proposed to be quartz precipitation, which increases as a function of temperature. This hypothesis is testable in two ways: firstly, one expects to see more quartz cement in hotter sandstones; secondly, since the extent to which oxygen isotopes fractionate from water to mineral varies as a known function of temperature, one would expect to see predictable variations in δ18O values within a quartz overgrowth. Until now, however, it has been impossible to determine an isotopic history across the cement stratigraphy. We have used the analytical capabilities of the Wisc-SIMS CAMECA 1280 ion microprobe, with a spatial resolution of 10-12μm (analytical precision better than ±0.38‰, 2SD) to determine a unique high precision cementation history.

Seven samples from the Ness formation of the Northern North Sea were selected from 6 different wells, presently lying at 2.6 - 4.6km subsea (106-156oC). Using BSEM and SEM-CL microscopy the quartz cement present in each of the sandstone samples has been quantified. In these samples, cement abundance appears to be controlled primarily by grainsize, clay content and rock fabric. Unusually, only a small amount of CL zonation was observed.

Quartz overgrowths from the 7 samples analysed average δ18O = 21.69‰ (±0.38‰, 2SD), ranging from +27.5‰ to +19.0‰ and decreasing from older (cooler) to younger (hotter) overgrowths. Decreasing δ18O is consistent with cementation at higher temperatures, if we can assume a constant δ18Ofluid. We are currently looking for greater constraints on cementation histories using fluid inclusion thermometry and also considering how δ18Ofluid may have changed as a result of water-rock isotope exchange related to clay mineral transformations. Improved understanding of the full mechanisms involved in cementation will have important implications on how we predict the commercial potential of a sandstone unit as well as its basic properties.

NOTES

North Sea Giant Sand Injectites: Petroleum Significance And Numerical Modelling

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Sand injectites are intrusive clastic bodies commonly present in various parts of the world and their role in petroleum systems is substantial. Their significance in associated oil fields ranges from almost insiginificant to being the main reservoir. This paper presents two noteworthy large scale sand injectite complexes: the Volund giant injectite complex from the Norwegian North Sea block 24/9 and the Danica structure located in the Central Graben of the North Sea block 29/6. Volund is proved to be a considerable oil field whereas Danica awaits confirmation by the drill bit. Each of the injectites covers more than 10 km2 and is made up of up to 1 km3 of sandstone. Both of the injectites are located within the Balder to Frigg stratigraphic level and produce very similar seismic signature (Fig.1). Despite their similarity their formation is interpreted rather differently; Volund is believed to be entirely injected from below to form a saucer shaped body with protruding low-angle dykes that terminate in form of sills ~200-250 meters above a central sill, whilst Danica is thought to be made up by a remobilised central sandstone-filled channel with injectites on its sides and crest.

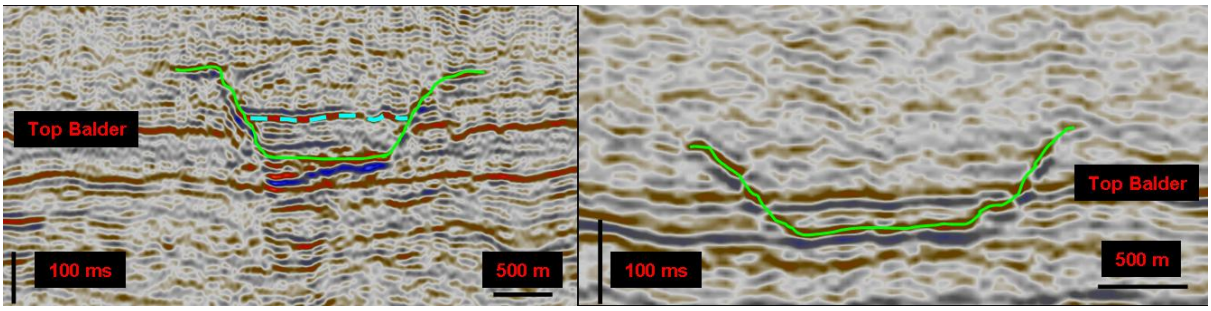

Fig.1. Two large scale sand injectite complexes. On the left the Volund injectite complex (green line outlines its shape) and showing the jack-up of the Top Balder reflection (blue dashed line) above a central sill which suggests that the complex is entirely injected. On the right, Danica with injected wings and completely flat Top Balder overlying a likely depositional sand body.

Despite their global occurrence, sand injectites are still poorly understood in terms of their emplacement mechanics, source sand and timing of injection. Therefore, numerical modelling has been undertaken in order to further elucidate their formation. Various possible triggering mechanisms enabling sand injection have been studied, including: meteorite impact, earthquake, vertical transfer of fluids, etc. The results allow us to constrain some of the questions regarding mechanism underlying sand injectite formation, and may allow the prediction of sub-seismic reservoir distribution and volumes.

Poster Presentations

Fylla Structural Complex offshore SW Greenland: A Structural and Tectonic Study based on Seismic, Magnetic and Gravity Data

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I present a combined seismic, magnetic and gravity study of Fylla Structural Complex (FSC), offshore southern West Greenland. The FSC is characterized by a number of distinct structural styles, each defined by an assemblage of tectonically related elements and their spatial arrangement. It is shown that the Cretaceous–Cenozoic tectonic development of the FSC is defined by late-Early Cretaceous rifting and extension along NNW–SSE/NW-SE trending structures and pronounced early Campanian rifting and extension along NNE–SSW trending structures. The later event resumed during the late Paleocene along the same structures.

The variation in magnetic signal throughout the Fylla Structural Complex can be ascribed to the character of the structural basement. In areas where non-magnetic pre-Cretaceous sediments constitute the basement, magnetic lows are observed. Up to 4 km thick, truncated pre-Cretaceous sediments are thus interpreted from 2D magnetic modelling in the southwestern part of the complex. These sediments are interpreted to be remnants of Lower Paleozoic dolomitic carbonate rocks, or alternatively old and hard cemented sandstone.

Finally, a strong correlation is found between Upper Cretaceous post-rift sediments, the depth to the Top pre-Cretaceous basement, the Moho topography, and the pre-rift crustal thickness. Areas of great basement depths, a shallow Moho and a thin crust, are consequently draped by thick sequences of Upper Cretaceous post-rift sediments. The maximum crustal attenuation is found in an intersection area of the dominating NNW–SSE, NW–SE, and NNE–SSW trending rift structures, where the crust is no more than 11 km thick and the depth to the Top pre-Cretaceous basement is up to 6.5 km. This area is furthermore characterized by the maximum amount of post-rift sediments, but only a small amount of Lower Cretaceous syn-rift sediments, hence indicating enhanced late syn-rift uplift and erosion here.

NOTES

The sedimentology of redeposited chalk

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Redeposited facies in the Upper Cretaceous Chalk Group constitute major hydrocarbon reservoirs in the North Sea Central Graben. Existing facies models are largely based on publications from the early 1980's dealing with core material from the Norwegian sector. However, the recognition, interpretation, and predictability of redeposited chalk facies remain uncertain. This project aims to improve existing facies models by investigating and comparing redeposited chalk units from a variety of settings. Long cores from the Danish and British sectors are interpreted in terms of depositional process and facies–porosity relation. These interpretations are integrated with a seismic investigation of the study areas (phd project by Janus Bruun Christiansen). Outcrops showing large-scale remobilization in the Upper Cretaceous chalk of southern UK are investigated to document possible source mechanisms for redeposition of chalk. This leads to an integrated scheme covering most aspects of chalk redeposition.

NOTES

Generating synthetic borehole geophysical data from down-well geological observations; initial results from a 1D study

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Logging tools measure a range of petrophysical parameters; some directly, such as sonic velocity, and others by proxy, such as density and porosity. These parameters are controlled by geological variables such as grain size, mineralogy, sorting and pore-fluid chemistry. We present results from an approach that simulates borehole geophysical logging tool responses based solely on using geological observations as input.

Attaining good agreement between measured borehole geophysical data and analogous synthetic data is of significance to the E&P community who seek to understand how nuanced variations in geological systems may influence the parameters measured by borehole geophysical logging tools, and hence the synthetic seismograms that are based on these data. This work represents the first step in converting field-observations into quantitative petrophysical parameters that can be used to relate inaccessible subsurface hydrocarbon prospects to outcropping analogues that can be studied in detail.

To evaluate the accuracy of this method, a detailed geological interpretation of approximately 100 m of well-core data has been used to generate synthetic wireline responses, which have in turn been compared to the measured borehole geophysical data encountered down the same well. Synthesised borehole geophysical logs have a greater vertical resolution than the measured data, with the general trends observed in the measured data being replicated in the synthetic data.

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Characterising Fractured Basement using the Lewisian Complex: Implications for Petroleum Potential in the Clair Field

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The Clair Field lies 75km west of Shetland in the Faroes-Shetland Basin. It covers an area of 220km2 and lies under 150m of water. Clair has reservoirs in Devonian and Carboniferous sediments and almost certainly in fractured basement rocks that are uplifted in the footwall of the Spine Fault. The basement of the Clair field is poorly understood but is thought to be broadly equivalent to the Lewisian Gneiss Complex (LGC) of Scotland based on regional geological and preliminary comparison of core materials with onshore rock types.

The LGC comprises tonalite-trondjemite-granodiorite gneisses; mafic & ultramafic dykes and metasedimentary and metavolcanic sequences. Until recently, the LGC was thought to be derived from the heterogeneous reworking of a single Late Archaean protolith, but this has evolved into a model where the LGC consists of perhaps six separate terranes that were assembled at various times during the Proterozoic. The project focuses on discovering which terrane has the closest affinities with the Clair basement. In addition, the geometric, spatial and geologic attributes of fracture systems developed in the LGC on the Scottish mainland (Assynt and Rhiconich terranes) are being used as analogues for subsurface basement fracture systems. These will hopefully provide valuable constraints upon the 'connected volume' in the Clair basement reservoirs and will help maximise production in this significant hydrocarbon reservoir.

The LGC is highly fractured and these fractures formed at different stages in the geological history. There is regionally consistent field evidence to suggest that the main fracture forming periods occurred during the Proterozoic (ca 1600-1400Ma, 1200Ma and 1000Ma), Palaeozoic and Mesozoic. Each of these events is associated with specific fault kinematics and characteristic fault rock assemblages. One of the aims of this project is to determine if the fracture patterns at outcrop can be scaled up to what is seen regionally, i.e. do these onshore patterns relate to what is seen in seismic and therefore can they be used directly as an analogue for the Clair basement?

In order to compare offshore and onshore fracture datasets, several different approaches have been taken. For the onshore datasets these include: remote mapping of the regional 2D fracture patterns within the LGC; fieldwork focussing on 1D line-sampling of selected outcrops; and terrestrial laser scanning. Offshore, basement core has been analysed for lithology and fracture density. Seismic reflection attribute fault maps will also be analysed to assess for the regional scale structures in the Clair basement.

Initial results from the regional 2D mapping indicate that the prominent fracture orientations are NE-SW and NW-SE and that fracture density increases proximal to major structures. Offshore the most prominent fracture orientations occur in a NNE-SSW direction which is described as the main fluid pathway through the basement. What is very clear from the basement core is that lithology plays an important role in the fracture density recorded throughout the samples. This is similar to the situation observed onshore where results suggest that the granitic Rhiconich terrane is fractured less than the tonalitic Assynt terrane.

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