MSc Petroleum Geoscience Symposium

4th September 2018

- Acknowledgements -

Programme
Morning sessions in the Boiler House Auditorium

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	09:00	**Introduction and welcome**	
North Sea & Norwegian Sea	09:15	Daniel Joel	The reservoir potential of the Lower Cretaceous Lange Formation, Gimsan Basin, offshore Norway
	09:35	Pir Kartal	Sedimentological and sequence stratigraphic analysis of the Neogene to Quaternary succession of the Norwegian North Sea
	09:55	Khawaja Fahd Noor	Salt tectonics in the Mid-North Sea High and Southern North Sea, evaluation of the Mesozoic plays
	10:15	**Refreshments and poster session**	
Continental Europe & North Atlantic	10:35	Ben Marsh	Hinterland basins of the Apennines
	10:55	Marietta Giannakakou	Platform to basin transition and petroleum implications of the Southern Adriatic, Italy
	11:15	Brendan Vaz	Examination of 3-D seismic data to find evidence of a Miocene base level fall in lacustrine deltaic sediments of the Pannonian Basin, Hungary
	11:35	Annabel Causer	Tectono-structural evolution of the Iberian-Newfoundland conjugate margins
	11:55	**Refreshments and poster session**	
Australasia	12:05	Molly Cosgrove	Regional tectonostratigraphic analysis of the eastern Banda Arc
	12:25	Wilman Beltran	Seismic analysis of Triassic traps and reservoirs: Exmouth Plateau - NW shelf Australia
	12:45	**Lunch and poster session**	

Programme
Afternoon sessions in the Boiler House Auditorium

12:45 *Lunch and poster session*

Modelling & Techniques	13:45	Debbie Papadopoulou	Cooling paths to understand landscape evolution: Applying multiple geochronological and thermochronological datasets in the southern Rockies
	14:05	Alexander Hazel	The influence of microporosity on the effective permeability of sandstones
	14:25	Yiqiao Wu	Digital rock physics analysis: carbonates
	14:45	Katherine Nash	The evolution of sills into shallow magma chambers and the use of sills as hydrocarbon reservoirs
	15:05	Liam O'Flynn	Analogue modelling of regional and counter-regional listric fault systems

15:25 *Refreshments and poster session*

African offshore Basins	15:45	Melanie Smith	Regional tectonostratigraphic analysis of the Outeniqua Basin, offshore South Africa
	16:05	Adrien Mergnat	Contourite features offshore Madagascar
	16:25	Ben Panting	Determination and function of thin bedded pay within the Elon Field, Equatorial Guinea
	16:45	Gerson Itembo	Structural characterisation of deep features, offshore Côte d'Ivoire Basin
	17:05	Robert Morgan	Analysis of contourite depositional systems offshore Namibia, West Africa

17:25 *Award of prizes, closing remarks and reception*

Daniel Joel

The reservoir potential of the Lower Cretaceous Lange Formation, Gimsan Basin, offshore Norway

The Lower Cretaceous Lange Formation contains the Intra-Lange sandstones which were found to represent two separate turbidite complexes within the Gimsan Basin, Unit A and Unit B. These turbidites displayed moderate reservoir capabilities, containing a total of 5.2 million Sm^3 of gas. The use of a high quality 3-D dataset allowed for the identification of sand bodies within the Gimsan Basin, establishing that they reside in a mixed sand/mud submarine fan system. Turbidite complex Unit A is a small (10 km long) E-W trending system originating from the Bremstein Fault Complex (BFC). Unit B is much larger (>25 km long), and originates outside of the study area, is emplaced parallel to a N-S system of faults before meeting its origin at the Sør High further north. The integrated use of well data and analogues alongside the seismic data allowed for the determination of the internal characteristics of these submarine fans. Unit A hosts a higher sand content, with porosity of 18% and permeability of 180 mD. Conversely, Unit B displays a higher claystone content, causing compartmentalisation of sandstone reservoirs. As a result, it has permeability values of 40 mD with porosities of 18%, similar to Unit A. The Intra-Lange sandstones within these turbidites were charged by the Upper Jurassic Spekk Formation and sealed by overlying Cretaceous claystones, with stratigraphic trapping. These findings provide important new understanding of the depositional system and the potential for a new extractable resource, in a time where finding new fields is becoming increasingly difficult.

Supervisor: *Domenico Chiarella (RHUL)*

Data provided by: Spectrum Geo Ltd. and Norwegian Petroleum Directorate.

Pir Kartal

Sedimentological and sequence stratigraphic analysis of the Neogene to Quaternary succession of the Norwegian North Sea

The Møre Basin, mid-Norwegian margin, is part of a passive margin buried by a set of Neogene to Quaternary clinoforms. The upper part of the clinoforms is truncated by a Pleistocene upper regional unconformity, which is a glacial erosional unconformity. The Neogene to Quaternary interval comprises ten sub-sequences based on the architecture of the reflectors, reflection configuration and stratal terminations. This project aims to perform sequence stratigraphic analysis of this Neogene to Quaternary succession.

Sequence stratigraphy is based on identifying unconformity-bounded sedimentary packages in seismic data. The studied Neogene to Quaternary interval of the Møre Basin comprises three sequences. Systems tract evolution of the study area is determined by analysing changes in sediment influx, tectonic processes and relative sea-level change. Potential reservoir distribution and deposits are analysed using the system tract interpretation and with the support of RMS amplitude attribute. Potential reservoir deposits identified include lowstand systems tracts (LST), transgressive systems tracts (TST), low density turbidites and highstand systems tracts channel fills.

The main depositional environments for LST and TST low density turbidites are slope and submarine fans. The best hydrocarbon play for this study area is the LST low density slope turbidite sequence and submarine fans as a reservoir, which is directly in contact with transgressive and highstand source and seal facies both below and above.

Supervisor: Domenico Chiarella (RHUL))

Data provided by: Spectrum Geo Ltd. and the Norwegian Petroleum Directorate

Khawaja Fahd Noor

Salt tectonics in the Mid-North Sea High and Southern North Sea, evaluation of the Mesozoic plays

The Mid-North Sea High (MNSH) is a Palaeozoic ridge that appeared as a continuous barrier and separated the southern Permian basin from the northern Permian basin during Late Permian times.

This project focuses on the style of deformation associated with the Mid-North Sea High flank and the Silver Pit Basin (SPB), involving the Permian salt (Zechstein). State-of-the-art seismic techniques, time structure maps, attribute maps and thickness maps are used to understand and constrain the evolution of MNSH area and to evaluate the relationship between basement and Mesozoic structures in terms of hydrocarbon prospectivity. This study is important from an industry perspective, because the SPB, a mature basin, is now of interest for gas fields that were not economic a few decades ago.

The main objective of this project is to elucidate the timing of the salt movement, present the type of linkage within the basin and on the MNSH and deduce a relationship between the sub- and supra-salt structures, and evaluate their hydrocarbon potential.

This study shows that multi-stage deformation in the MNSH (extension, inversion, uplift, erosion) complicates further hydrocarbon exploration, as a working petroleum system is not possible or limited.

Supervisor: *Jürgen Adam (RHUL)*

Data provided by: *PGS*

Ben Marsh

Hinterland basins of the Apennines

The Valdelsa basin is a 60 km x 25 km NW-SE striking basin and is one of the many hinterland basins within the northern Apennines. Hinterland basins are largely unexplored across the world, with the majority of research and exploration carried out in their foreland cousins. This research proposes a new geologic history for the Valdelsa basin, which was originally thought to be Neogene in age with its evolution directly linked to the Apennine orogeny of the Late Oligocene.

This project has integrated 2-D seismic data, well data and gravity surveys provided by Eni. Earthquake focal mechanisms supplied by the INGV allowed a picture of present day stress to be developed.

The Valdelsa basin is laterally segmented into two sub basins. These are half-graben structures bounded by master normal faults approximately 10-15 km in length and act as main controls for both sub basins. A 2 km wide NE-SW trending basement high segments these basins and acts as the site for a switch in polarity in the dip directions of the bounding faults. Clear growth strata can be observed in the two sub basins with Eocene and Jurassic packages showing thicknesses in excess of 500 m. Miocene packages that thin against these master faults form harpoons, indicating inversion throughout the basin.

These new observations suggest a much earlier formation for the Valdelsa basin and potentially other hinterland basins of the northern Apennines. Jurassic extension might be linked to the opening of the Tethys Ocean and later inversion through the Messinian might be a direct result of the Apennine Orogeny. This led to a period of tectonic quiescence during the Pliocene, except for minor inversion, potentially linked to the now ongoing rifting of the Tyrrhenian basin.

Supervisors: Nicola Scarselli (RHUL); Jonathan Craig (ENI)

Data provided by: Eni, INGV

Marietta Giannakakou

Platform to basin transition and petroleum implications of the southern Adriatic, Italy

The Southern Adriatic Basin is located offshore SE Italy, from the Gargano Promontory to Leuca, some 350 km along the Italian coast and 90 km into the Adriatic Sea. It represents a common foreland for both the western Apennine fold and thrust belt and the eastern Dinarides and Albanides. The domain has undergone two cycles of tectonic activity: a Mesozoic extensional phase, due to the opening of Alpine Tethys; and a Cenozoic compressional phase, driven by the convergence between the African and Eurasian plates.

The Apulian platform, following the early Jurassic separation of the African plate, underwent a Mesozoic drifting period, in which the high sedimentation rates that defined it as an isolated platform led to thick carbonate sequences. After a long hiatus, the compressional regime of the Neogene gave the basin an even higher sedimentation rate, fed by clastic influx derived from the adjacent fold and thrust belts.

This project provides new insight into the regional tectonostratigraphic framework of the southern Adriatic and the study of the platform to basin transition, through seismic and log interpretation, gross depositional environment maps and conceptual 3-D depositional models.

Supervisors: *Agust Gudmundsson (RHUL); Stefano Borello, Paolo Pace (GE Plan); Ashley Price*

Data provided by: GE Plan

Brendan Vaz

Examination of 3-D seismic data to find evidence of a Miocene base level fall in lacustrine deltaic sediments of the Pannonian Basin, Hungary

Traditional sequence stratigraphic techniques suggest that lowstand systems tracts are associated with deep water sedimentation in a marine setting. However, in a closed lacustrine setting like the Pannonian Basin, Eastern Europe, different conditions control the relative base levels which in turn controls the deep water sedimentation. Sequence stratigraphic study in this basin has resulted in contrasting results, so an alternative technique called the 'shelf-edge trajectory analysis' was used to ascertain the relative changes in the base levels and comment on the deep water sedimentation.

This study focusses on the Szolnok and parts of the Magyar Merge Central 3-D seismic surveys, in the eastern part of the Pannonian basin. Major progradational, aggradational and retrogradational clinoforms were identified on the basis of their trajectories and RMS amplitudes were used to identify key features associated with these sequences. An incised valley feature was observed in both the seismic surveys and seismic stratigraphy confirmed that they occurred in the same tectonic mega-sequence. Results of the clinoform trajectory analysis showed that the trajectories observed in this study are either rising or horizontal, suggesting no relative base level fall was observed in the clinoforms in this part of Lake Pannon. However, a major incised valley feature is observed on the shelf in both the surveys. This incised valley might have formed as a result of a minor relative base level fall.

This study suggests that the progradational sequences are associated with toe of slope lobes and basin floor fans, while the aggradational clinoforms are associated with detached lobes on the slope and some basin floor deposits; suggesting that deep water sedimentation dominantly occurs in the progradational sequences as compared to the aggradational sequences. It is suggested that the local climatic conditions, most likely a wetter climate, might have resulted in a relative base level rise, while less humid conditions during a warmer period (evaporation) might have resulted in a steady base level. Subsidence has also contributed to the relative rise in the base level in the longer term. This study suggests that the observations made regarding deep water sedimentation cannot be applied to other marine or lacustrine settings because of the unique nature of the Pannonian basin.

Supervisors: Domenico Chiarella (RHUL); Stephen Morse (Lyme Bay Consulting)

Data provided by: Oil & Gas Development Ltd.

Annabel Causer

Tectono-structural evolution of the Iberian-Newfoundland conjugate margins

The Iberian-Newfoundland conjugate margins are one of the most extensively studied non-volcanic rifted margins in the world. A well-constrained new plate kinematic model illustrates the paleo-positions of Iberia and North America at 10 Ma intervals between the initial stages of seafloor spreading (83 Ma) and the present day. This model, constructed utilising magnetic anomaly isochrones and fracture zone traces aims to provide new insight into the formation of the North Atlantic Basin and serves as a tool to analyse the formation and evolution of the conjugate Iberia-Newfoundland extended continental margins.

By reconstructing margin-wide seismic lines to their pre-drift positions, the conjugate margin transects are analysed in pairs instead of in isolation. The fit of conjugate sections when reconstructed using alternative plate models can be used to assess the suitability of kinematic reconstructions, and to quantify the uncertainties in them. Furthermore, analysing seismic data in this way provides a better super-regional overview which, in turn, provides insight into rifting processes along the conjugate margin and better constraint of the formation and evolution of offhore deep water areas. These currently represent a promising target for hydrocarbon exploration. In the long term, this new kinematic model may also act as a starting point for studies of, amongst others, paleo-bathymetry, sediment thickness and tectono-stratigraphic interactions in the North Atlantic.

Supervisor: *Jürgen Adam & Lucía Pérez-Díaz (RHUL)*

Data provided by: *TGS*

Molly Cosgrove

Regional tectonostratigraphic analysis of the eastern Banda Arc

The Banda Arc is a 1000 km long arcuate subduction zone situated in eastern Indonesia between three converging plates: Pacific, Eurasian and Indo-Australian. It comprises an inner volcanic arc, outer non-volcanic arc islands, and a continuous system of troughs. It is now accepted that the spectacularly curved Banda Arc is the result of northward subduction of a single oceanic slab. As the Australian plate has moved northwards, the Banda oceanic slab has rolled back to the southeast and the mantle has separated from the lower crust. This has created increased resistance to plate motions, gradually folding the slab. The Seram Trough is located in the northeastern part of the Banda Arc. The trough has been interpreted as a zone of strike-slip faulting, a subduction zone trench, and a foredeep associated with the development of a fold-and-thrust belt. The trough is too shallow for a subduction trench (only ~ 3 km deep), and is largely aseismic. This study uses new 2-D broadband seismic data and high resolution multibeam bathymetry images to clarify its tectonic evolution. The deformation within the study area is dominated by strike-slip faulting in the west, and a series of folds and thrusts in the east. This is supported by GPS observations which imply that convergence is more influential in the east. Variations in wedge growth attributed to oblique convergence may have contributed to the development of a shallow carbonate platform in the west, and simultaneous deposition of deeper progradational sequences in the east. These sequences have become incorporated within the fold-and-thrust belt as it has continued to evolve. This thesis challenges the existing theory that the Seram fold-and-thrust belt is a classic forward thrusting model, and proposes that it is instead a more complex system of thrusts with a general forward transport direction.

Wilman Beltran

Seismic analysis of Triassic traps and reservoirs: Exmouth Plateau - NW shelf Australia

The Rankin Platform (RP) and Exmouth Plateau (EP) are NE-SW and NNE-SSW trending sub basins of the North Carnarvon Basin, NW Shelf of Australia. The area has been affected by several rifting episodes, including late Paleozoic NW-SE extension and a Triassic-Jurassic WNW-ESE second rifting stage. By the Late Cretaceous and Paleocene, the margin had evolved into a passive carbonate margin.

This project documents a detailed tectono-stratigraphic analysis of the Brigadier Trend, located in a structurally complex interaction between RP and EP. The interpretation of the Olympus 3-D seismic survey identified three main mega-sequences: pre-rift deposition of a >6 km thick Triassic sequence, followed by ~1 km of syn-rift deposition during the Late Triassic (Rhaetian) and Middle Jurassic (Callovian). Finally, the deposition of 2.5 km of post-rift Cretaceous and Cenozoic carbonate sequences took place in a passive margin setting.

Three main structural domains were identified in the Brigadier trend: a western domain controlled by west-dipping normal planar faults and antithetic east-dipping faults; the central area characterized by NNE horst and graben structures limited for hard linkage faults systems. Finally, an eastern domain was defined in the Victoria Syncline; this domain is composed of a broad southern syncline and a northern complex horst structure.

A detailed interpretation was made to analyse the Triassic and Jurassic extensional fault systems. Five fault sets were interpreted which constrain the evolution of the Brigadier trend; a major set of NNE striking extensional planar faults, with a second set associated with ENE trending faults. The third set of NE striking faults affected the Victoria Syncline; this fault system is associated with pre-existing Paleozoic structures. A minor reactivation of the main Jurassic faults affected the Cretaceous succession, while sediment and subsidence controlled polygonal fault tiers during the Cretaceous and Paleogene.

This tectono-stratigraphic and fault analysis have significant implications for hydrocarbon exploration in the Rankin Trend, including the basin evolution, integrity of the traps and generation and migration of hydrocarbons.

Supervisor: Ken McClay (RHUL)

Data provided by: BP Exploration Operation Company Ltd.; Spectrum Geo Australia Ltd.

Debbie Papadopoulou

Cooling paths to understand landscape evolution: Applying multiple geochronological and thermochronological datasets in the southern Rockies

Geochronological and thermochronological dating techniques have been widely applied to develop time-temperature pathways for rocks and to understand the processes that sculpt the surface of the Earth. Thermochronology and geochronology are based on the principals of radioactive decay, the diffusion of daughter isotopes and the behaviour of spontaneous fission tracks in minerals. By constraining the thermal histories of rocks, thermochronology provides a powerful and flexible tool to understand tectonics, geomorphology and landscape evolution. However, interpreting absolute age data is notoriously complicated because of uncertainty in what part of a rock's history a measured age relates to.

The ultimate goal of this project is to provide an automatic, objective way to manipulate large multiple thermochronology and geochronology datasets worldwide, using 'big data' datasets like the Neftex® Insights *Hard Rock Geochemistry Dataset*. In order to evaluate and quality control the data, a regional-scale trial of this concept was designed. The area of interest is the US portion of the Rocky Mountains, in the vicinity of New Mexico, Arizona, Utah, Colorado, Idaho and Wyoming, and incorporating parts of the Basin and Range domain further west.

Thirty-five time-temperature plots were extracted, by combining different dating methods and target minerals applied to groups of specific rocks/rock suites. Each dating technique records the timing of the sample's cooling through a different closure temperature. There are significant uncertainties in both measured age and assumed closure temperature for each mineral/isotopic system. This leads to compounded uncertainty in the derived cooling paths. Cooling rates (°C/Ma) are similarly subject to the same uncertainties, providing scope to experimenting with different cooling path trajectories and resultant cooling rates. The preferred cooling rates were gridded to produce maps showing the spatial distribution of high and low cooling rates, which are compared to the possible geological processes that might result in cooling. This in turn provides a check on the quality of the interpretation.

Generating cooling rates automatically from large thermochronological and geochronological datasets must overcome the obstacles of large uncertainty and operator subjectivity, but this project provides the first evaluative step towards that target.

Supervisors: Ian M. Watkinson (RHUL); Fabian Kohlmann, Graeme Nicoll, Jonathan Wilson

(Halliburton)

Data provided by: Halliburton (Neftex Exploration Insights)

Alexander Hazel

The influence of microporosity on the effective permeability of sandstones

Micro-Computed Tomography (micro-CT) studies are used to resolve the porosity-permeability relationships of different formations at the pore-scale. There has been limited success at resolving the relationships in formations with wide-ranging pore sizes, such as carbonates and tight sandstones. This is due to the unknown permeability behaviour of sub-resolution pores (micropores). This study treats micropores as permeable and impermeable to set a range of outcomes in two deltaic, sub-arkose CO_2 sequestration targets. The Doddington and Knorringfjellet sandstones are homogeneous and heterogeneous formations in Northumbria, United Kingdom and Svalbard, Norway respectively. The two micro-CT volumes are segmented to separate resolvable pores (macropores), micropores and grains. The connected porosity of each micropore case is calculated and a grain-based pore network model is used to compare the key attributes. The single-phase flow permeability of the Doddington is 3013 mD to 3725 mD and the Knorringfjellet is 7.3 mD to 60.1 mD. The wide range of outcomes bounds previous work in the Doddington, but the Knorringfjellet result is considerably higher than the laboratory result in a different sample. This could be due to larger scale heterogeneity in the formation related to bioturbation. The narrow throat sizes of formations with substantial microporosity can have an outsized effect on the permeability of a sample. Understanding how micropores behave is key to accurately modelling flow in heterogeneous rocks and this study provides the widest range of outcomes depending on its permeability.

Supervisor: *Saswata Hier-Majumder (RHUL)*

Data provided by: *BGS*

Yiqiao Wu

Digital rock physics analysis: carbonates

It remains difficult to understand the relationships between porosity and permeability, especially in micro-scale structures. Carbonates are porous and permeable rocks with very complex macro and micro pore spaces, which are difficult and unpredictable to investigate. This study, based on 2-D scanned images, uses digital analysis of micro-scale structures to investigate the porosity and permeability of three carbonates (Estaillades, Savonnières, and Massangis Jaune) with different pore network structures. The Pore Network Model method was used to analyze pore geometry and permeability behavior of carbonates in the total and macro pore space in digital analysis. The complex relationships between total and connected porosity in macro and micro pore space were then investigated as well as the permeability of each carbonate sample. Although this work is not an attempt to develop a new predictive model, it is still positively an attempt to introduce a new developing method to analysis pore space and qualitatively interpret complex carbonates with different characteristics such as coordination number of pores and throats.

Supervisor: *Saswata Hier-Majumder (RHUL)*

Data provided by: *Ghent University's Centre for X-Ray Tomography*

Katherine Nash

The effects of igneous sills on the petroleum system in sedimentary basins

Igneous sills are found in sedimentary basins worldwide. They are known to impact a petroleum system in a multitude of positive ways; functioning as fractured reservoirs, creating permeability to improve reservoir quality elsewhere and acting as a trap or seal. Sills increase the geothermal gradient of basins and encourage maturation of organic matter, improving the chance of hydrocarbon occurrence.

This study has compiled a new catalogue of information about igneous sills to improve our understanding of sill geometry, dimensions and internal structure. Igneous sills develop in extensional settings, form a part of complex volcanic systems and are often fed from dykes or other sills. Host rocks play a role in sill emplacement and propagation, as does magma type, fluid pressure and magmatic overpressure. The final size of the sill determines how much of the petroleum system is affected, and these impacts have been modelled using COMSOL Multiphysics. It is understood that any sill size larger than 50 m will have a significant thermal impact. Sills can also have negative impacts on a petroleum system. They can cause hydrocarbon migration issues, drilling problems and cause over-maturation. It can be concluded that sills do impact petroleum systems and it is crucial that we understand them, as the need for unconventional oil and gas resources will increase in the future.

Supervisor: Agust Gudmundsson (RHUL)

Liam O'Flynn

Analogue modelling of regional and counter-regional listric fault systems

Extensional growth fault systems can be found in a wide variety of geological settings and scales, from small scale soft sediment listric faulting to regional scale extensional systems such as passive margins. With the range of environments where these fault systems occur, particular attention is paid to intermediate scale listric fault systems, where this scale is suitable for affecting potential petroleum systems. As such, understanding the evolution and formation of these systems is paramount to assessing whether growth fault-related petroleum systems are to be successful.

Analogue modelling has been used as a forward modelling tool to develop a greater understanding of these systems for many years. This research project sets out to provide new insights into the formation and development of listric fault systems by running two sets of kinematic models and to analyse them through high resolution optical monitoring software known as digital image correlation (DIC).

The two sets of experiments use two static footwall geometries: a simple listric fault and a more complex ramp-flat geometry in order to observe the fault framework that develops in each. Furthermore, a set of parameters were chosen to be changed with each successive experiment, allowing for more accurate representations of the natural analogues that these scaled models are attempting to replicate.

The analysis conducted in this research project concluded that the hangingwall structures produced in growth fault systems are intrinsically linked to the bounding fault angle and curvature. These insights produced exciting new results from DIC analysis of strain distribution and fault nucleation which in turn has interesting implications for the potential of petroleum systems.

Supervisors: Lucía Pérez-Díaz & Ken McClay (RHUL)

Melanie Smith

Evaluation of the rift system to understand structural evolution and basin infill within the Outeniqua Basin, offshore South Africa

The Outeniqua Basin, offshore South Africa, is divided into four sub basins: Algoa, Gamtoos, Pletmos and Bredasdorp (east to west), which are clearly defined in 2-D seismic data. The sub basins are separated by large normal faults and basement highs and are also defined in surface data with individual depocenters on the hangingwall. The sedimentary basins were formed in response to the rifting of South America from South Africa along the Agulhas-Falkland fracture zone. Throughout all sub basins the syn-rift sequence is the dominant tectono-stratigraphic feature and highlights the distinctive structural characteristics. The episodes of syn-rift show the most deformation, with folding structures forming to accommodate extension. These include extensional fault propagation folding resulting in synclines on the immediate hangingwall and anticlines on the footwall. Transitional episodes from the end of rifting to the beginning of shear motion show less distinctive structural features and more passive depositional features. Drifting episodes show no evidence of structural interactions and more depositional features such as clinoforms. The drift phase is the only phase to exhibit characteristics throughout all basins. Later uplift events impacted the shape of sub basins. The appearance of the sub basins show very different structural geometries and basin infill. However, all sub basins can be correlated back to similar tectonic events with basins' responses to the different events all distinctive. These findings help increase understanding of the individual formations of the sub basins and the evolution of the wider Outeniqua Basin.

Supervisors: Ken McClay (RHUL); Alex Bump (BP); Ashley Price

Data provided by: BP Exploration Operating Company Ltd.

Adrien Mergnat

Contourite features offshore Madagascar

The Morondava Basin, offshore Madagascar, has always been of great interest regarding sedimentological processes and hydrocarbon exploration. However, the Paleogene succession has been poorly studied. The study of Paleocene strata in this basin will considerably improve the understanding of the geological evolution of this area and of clastic deposition on passive margins.

Using 3-D seismic data from the Grand Prix Bloc to create time-structure and RMS amplitude maps, contourite depositional and erosional features were delimited, which present possible trap and seal characteristics. These features present a stacking pattern making possible the reconstruction of the depositional system in the Paleocene Morondava Basin. In addition, encountering sand bodies in ancient buried channels provides new opportunities, as these features are favourable for hydrocarbon reservoir and trap potential.

This analysis of the Paleocene in the Morondova Basin serves as a reminder that even areas of great interest to oil and gas companies can still present unknowns and lead to the discovery of new features previously unseen in similar basins.

Supervisors: Javier Hernandez-Molina & Nicola Scarselli (RHUL); Gabor Tari (OMV)

Data provided by: OMV

Ben Panting

Determination and function of thin bedded pay within the Elon Field, Equatorial Guinea

The Rio Muni basin is a petroleum basin which despite enjoying commercial success is relatively overlooked and under-studied. This is particularly true with respect to late Cretaceous aged reservoir targets located at the head of major canyons.

This study focuses on the Elon canyon, a large type 1 canyon system 3.5 km wide and 1.5 km deep. The Elon canyon fill is complex, dominantly characterised by a randomly filled modified embedded stack. This study employs an integrated approach from the scale of the canyon down to bed scale, utilising a rich suite of subsurface data including 3-D PSDM seismic data, Bayesian inversion products, conventional wireline, core data, special core analysis and production data.

Integrated seismic amplitude and facies mapping has characterised the inter-canyon channel system as a channel levee complex for which average reservoir interval thickness is 290 m. Thin bedded sands have been proven as attractive secondary reservoir targets and succeed in providing an effective means of communication between discrete bodies of massive sands.

A prospective target within the channel levee complex has been identified in the Campanian turbidite sands, where production potential from thin bed sands is likely to be greatest. Within this zone, the dominant style of thin bed is the thick-thin beds classified as lithofacies 2; thicknesses range from 2-20 cm, porosities range from 10-16 % and permeability is 680 mD.

Although thin beds are unlikely to contribute significant increases to the effective stock tank oil in place (STOOIP, while in production), thin bedded zones of the reservoir should not be overlooked. Their in-place resources offer opportunities to increase production value by perforating behind pipe prospects at relatively low cost and may offer opportunities for infill or step out drilling.

The key findings of this study are important – the Elon field has been in production for ~ 18 years and was acquired by the current operator in 2017, following acquisition there has been a focus on production efficiency and stimulation programmes to enhance oil recovery and extend commerciality late into the natural life of the asset.

In the context of declining production from the field, this study is of value to the operator as an evaluation of the effectiveness of thin bedded formations, and key findings may be used to develop future production strategies or mature the research to work past the limitations of this report. Ultimately, thin beds are considered an important resource for increasing value late into the natural life of the field.

Supervisors: Nicola Scarselli, Domenico Chiarella (RHUL); Matthew Drake (Trident Energy)

Data provided by: Trident Energy

Gerson Itembo

Characterisation of deep features, offshore Côte d'Ivoire Basin

This study focuses on the western part of the Ivory Coast margin. The evolution of this margin involved complex rifting and structural styles. The margin lies between two major transform faults: the St. Paul Fault Zone and Romanche Fault Zone. Its evolution is not well understood, due to the later tectonic events that happened during the syn-tectonic phase. Structural interpretation in the western part of the Ivory margin using 3-D seismic data shows two distinct structural domains: extensional and transpressional domains. The extensional domain shows highly rotated fault blocks at low angles, which have experienced extension and trend predominantly NW-SE. It also shows a series of normal faults that are interpreted as collapsed crest structures. The geometries of some of these faults display a growth fault and the presence of growth packages reveals that these faults were developed during the Aptian-Albian time. The transpressional domain was recorded in the western part of the study area. It is recognised by the deformation of the syn-rift sequence resulting in the development of folding, thrusting and strike-slip faults with a different trend from those faults identified in the extension domain. Some of these structures generated a suitable place to accommodate hydrocarbon and show the presence of direct hydrocarbon indicators. A 2-D schematic reconstruction has been created with different stages, showing how some of these deep structures developed in this part of the Ivory Coast margin.

Supervisors: Nicola Scarselli (RHUL); David Mitchell (SCDM Energy Ltd.)

Data provided by: SCDM Energy Ltd.

Robert Morgan

Analysis of contourite depositional systems offshore Namibia, West Africa

The attention on contourite systems has dramatically expanded in recent years, backed by an ever growing and developing research and focus into their formation, evolution and significance. Despite this, the real potential of contourite deposits is still in its infancy when compared to other deep water processes. However, with the need for innovative and creative thinking to supply an ever-growing global energy need, the potential for contourites and their significance in the hydrocarbon industry are starting to become recognised. The analysis of 2-D seismic data, accompanied by ODP, DSDP and exploration wells recognises the extent and the evolution of contouritic bodies on the Namibian margin since the Early Cretaceous, with a focus in the north of the margin. Numerous contourite bodies have been identified at different stratigraphic intervals, their formation and evolution has been hypothesised and considered within this study in the aim of better understanding the complexity of processes behind them. The formation of these contourite bodies have been tied to global changes in sea level, plate tectonics and the opening of oceanic gateways with the intention of determining key factors behind not just their deposition, but their absence. The observation of high amplitude reflections in relation to contourite channels is interpreted as coarser grained sediments that are associated with higher energy fluctuations of bottom currents during the formation of the contourites. The interpretation of lithology from seismic amplitude is further discussed to determine other elements of the petroleum system - (e.g. source rock, seal) - to help emphasise the unique potential of these still poorly understood deposits. The completion of this work is to improve the identification of contourites, both present-day and ancient, and to further the understanding of the controls on their formation, distribution and evolution with an aim to have their full potential recognised.

Supervisors: *Javier Hernández-Molina (RHUL); Francois Raisson (Total); Antoine Thieblemont (RHUL & Total)*

Data provided by: *Total*

Zuratul-Anne Kani

The relationship between the Main Boundary Thrust & the Khairi-Murat Thrust within the North Potwar Deformed Zone, northern Pakistan (poster only)

The North Potwar Deformed Zone (NPDZ) makes up the northern region of the Potwar Plateau and Salt Range, part of a foreland fold-and-thrust belt of the Western Himalayan Syntaxis in Pakistan. The area is bounded to the north by the Main Boundary Thrust (MBT), and to the south by the Khairi-Murat Thrust (KMT).

Due to the complex nature of the NPDZ, with its tight folds and steep dips, seismic data from the area is of poor quality. An unconventional interpretation approach, beginning by picking artefacts and differentiating between noise and real data was necessary, before interpretation of geological features. Seismic data was constrained at the surface by a digitised geological map of the study area at 1:150,000 scale and at depth using formation tops from the Bhal Saydan-02 well. The integration of the two helped produce a geologically meaningful interpretation. Several possible seismic interpretation models were produced to understand the role and the relationship between the Main Boundary Thrust and Khairi-Murat Thrust, and a single model was taken forward after critiquing its validity.

The Main Boundary Thrust ramps up-dip towards the south and is segmented across the plateau, with blind thrusts splaying through its hanging-wall accommodating shortening. The Khairi-Murat Thrust is the forward breaking expression of the Main Boundary Thrust, marking the southern leading-edge of the NPDZ. Therefore, the MBT and KMF are interconnected in the subsurface, and are not two separate thrust sheets branching upwards from a Precambrian evaporite basal decollement at 10 km depth, which was the previously accepted theory. The role of the Main Boundary Thrust in accommodating north-south shortening across the NPDZ is greater than that of the Khairi-Murat Thrust.

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