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Annual Conference 2017 - Student PhD Project Abstract Booklet

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Kayode Adeoye-Akinde

Email: Kayode.Adeoye-Akinde.2016@live.rhul.ac.uk

Institution: Royal Holloway

Supervisors: Professor Agust Gudmundsson, Dr Saswata Hier-Majumder

Project title: **New methods for forecasting the permeability of fractured reservoirs**

Abstract

Naturally fractured carbonate reservoirs make up a large proportion (>60%) of the global hydrocarbon resources. Fractures are a controlling factor which dictates the ease or difficulty of fluid flow in a system, that is, its permeability. In addition to permeability, porosity is one of the key characteristics of reservoirs. Both permeability and porosity are crucial for the production of stored fluids from a fractured/porous medium. The fractures govern reservoir permeability when they are linked and form a network of fractures, that is, reach the percolation threshold. The mechanical behaviour of rocks also has impacts on permeability, i.e. during hydraulic fracturing.

High heterogeneity and anisotropy, especially with alternating strata within the same reservoir, still makes the geometry and permeability of an in-situ fracture network challenging to predict. Study of outcrops analogous to reservoir rocks is important to better understand in-situ fracture networks and permeability, especially the fracture formation, propagation, and arrest/deflection. Understanding the mechanical behaviour of rocks during pressure changes, such as during hydrocarbon production, water flooding, and dewatering are important to predict reservoir performance.

This project combines field data (strike, dip, aperture and strike/dip dimensions) from various rocks (limestone, sandstone, shale, and igneous rocks) acquired primarily from the UK, especially the Bristol Channel, with statistical and numerical modelling (using the Finite Element Method) to better forecast hydrocarbon fracture network properties and permeability. One aim of the project is to bridge the gap in fracture data obtained at the core level (cm-scale) and at the seismic level (km-scale). Hence, outcrop-scale fractures will be analysed using the power-law size distribution and the maximum entropy method to forecast likely in-situ subsurface reservoir fracture properties.

Results will have a significant impact on many of the CDT research themes. Specifically, the results will help to better forecast permeability and fluid flow in fractured rocks (with coupled geomechanics and fluid transport), such as in oil, gas, geothermal and groundwater systems.

Muhammad Ahsan

Email: muhammad.ahsan15@imperial.ac.uk

Institution: Imperial College London

Supervisors: Professor Anna Korre, Dr Zhenggang Nie

Project title: **Geological life cycle inventory model development for conventional and unconventional hydrocarbon resources**

Abstract

Innovation and technological expansion in the natural gas resource exploitation business has led to a significant development of gas fields around the world during the last three decades. Whilst the combustion of natural gas has half the carbon emissions of coal, within the extraction and processing stages of natural gas, there has been increasing concern over the environmental burdens that result during and after these processes.

Presently, the environmental assessment of industrial practices at natural gas production sites focus on greenhouse gas (GHG) emissions and consider only the surface engineering and operational activities (surface constraints) while largely disregarding the subsurface geological constraints and the corresponding engineering production strategy implemented. However, there exists a direct relationship between the reservoir properties and the eventual life cycle environmental impact for a given field during its life and it is vital to consider this in order to reliably estimate GHG and other emissions and to control their levels.

This research work aims to develop an innovative Life Cycle Assessment model for natural gas reservoirs which considers geological system characteristics in the emission modelling. The initial work carried out so far is focusing on unconventional shale gas production and looking to estimate the reservoir initial gas in-place, create a production strategy (production rates, number of wells and life span of wells) and to design the production facility, which has a direct effect on the emission profile during the life time of the project. The model currently under development is being tested using data from a shale gas field in the US producing natural gas from the Barnett Shale. The model incorporates a Volumetric Estimations technique, Flowing Material Balance and Advance Decline Curve analysis to estimate the field gas in-place and Estimated Ultimate Recovery. An uncertainty analysis is carried out using Monte Carlo Simulation (50,000 realisations) to estimate the effects of variation in the petrophysical and fluid properties on the number of wells and production facility design.

This geological model will later be integrated with the surface emission model to encapsulate total and reliable field GHG emissions over the life of the facilities.

Iain Anderson

Email: ia205@hw.ac.uk

Institution: Heriot-Watt University

Supervisors: Dr Jingsheng Ma, Dr Xiaoyang Wu (BGS), Professor Dorrik Stow

Project title: **Analysis of shale mineralogy and fabric and its induced anisotropic seismic response for hydrocarbon exploration and production**

Abstract

Unconventional hydrocarbons have been an important part of the global energy industry since the latter part of the 20th Century. In order to fulfil international climate change commitments, there is a growing demand for 'cleaner' fossil fuels such as natural gas, in favour of 'dirty' fossil fuels such as coal. Furthermore, the UK is facing an increasing reliance on gas imports to balance out its falling domestic production. Exploration for new energy sources including shale-gas reservoirs is key to address the balance in the UK and power the long-term transition to renewables.

Exploration for shale-gas resources in the UK began in the early 2010s. The Bowland Shale was immediately recognised as the formation with the most potential. Despite several years of research, the geomechanical, geophysical and rock physical properties remain poorly understood, as most studies have focused on resource estimation and/or geochemistry. Shales are incredibly complex due to their marked heterogeneity and macro- to nano-scale complexities in rock properties, mineralogy and fabric. This heterogeneity complicates their seismic imaging through the development of strong anisotropy. Understanding this anisotropy is imperative when processing seismic data, as well as extracting seismic attributes such as AVO.

Focusing on the Bowland Shale, the project aims to:

• Generate new data on the rock properties and heterogeneity of the system. This will encompass varying scales of investigation: from microstructural (e.g. clay alignment from SEM), to wireline-log scale mineralogy, and eventually upscaling to seismic reflection behaviour.

• Build a rock physics model to link elastic rock properties to mineralogical and microstructural variations in the shale, using anisotropic effective medium models.

• Develop a refined methodology to calculate the seismic reflectivity varying with azimuth and polar angle, and then compare anisotropic seismic response with varying kerogen content, porosity, and fabric heterogeneity in the rock matrix. Consider the implications for extracting such data quantitively from a real seismic dataset.

• Further model the seismic response to overpressure resulting from injection of high-pressure fluid-proppant-matrix into the shale reservoir, and consider the interaction on seismic wave propagation during the hydraulic fracturing stage.

This project is a collaboration between the BGS (Edinburgh Anisotropy Project, BGS Shale Gas team) and Heriot-Watt University.

Mark Ashworth

Email: ma174@hw.ac.uk

Institution: Heriot-Watt University

Supervisors: Dr Florian Doster, Professor Sebastian Geiger

Project title: **Modelling of Geo-mechanical – Hydro-mechanical Coupling in Fractured Reservoirs**

Abstract

Over 60% of the world's conventional hydrocarbon resources are located within fractured (carbonate) reservoirs. Trying to maximise recovery from these remaining reserves is one of the current challenges facing the oil and gas industry. One particular consideration when dealing with fractured reservoirs is the role that geomechanics plays in controlling fracture deformation. This previously and often neglected aspect of reservoir development has large implications on the producibility of a reservoir, as fractures can greatly impact the permeability of the system. To better understand these complex, heterogenous systems we therefore require robust modelling and simulation techniques.

The most popular practice for simulating the coupled fluid and geomechanical problem is to solve the respective problems using dedicated softwares. The two problems are then coupled through an iterative scheme. The alternative to this, a fully coupled approach, solves the fluid and geomechanical problems simultaneously, within the same platform. However, current methodologies of doing this, which utilise a finite-element (FE) framework, don't allow for the natural embedment of discontinuities within the discretisation. Additionally, the desirable quality of mass conservation for the fluid problem is lost with a conventional FE approach.

The main aim of this project is therefore to improve the way in which we model and simulate the coupled fluid and geomechanical problem. To do this we would like to combine and adapt a recently developed finite-volume (FV) approach for simulating geomechanics, with the standard FV approach for flow simulation. With a fully integrated FV framework we would like to study the coupled response of fractured rock masses. In doing this we hope to develop new dual-continua models, the industry standard approach for field scale simulation of fractured reservoirs, which include geomechanical effects.

Charlotte Beasley

Email: cb721@exeter.ac.uk

Institution: University of Exeter (Camborne School of Mines)

Supervisors: Dr Kate Littler, Professor Stephen Hesselbo, Dr Aisha Al Suwaidi (Petroluem Institute, Abu Dhabi), Dr Laura Cotton (School of Biological Sciences, University of Hong Kong)

Project title: **Investigating Paleogene strata from Oman and the UAE; new insights from integrated chemostratigraphy, sedimentology and biostratigraphy**

Abstract

The Middle East contains some of the world's largest known reserves of oil and gas; these hydrocarbon-bearing units are well studied in terms of their reservoir properties and sedimentology. Unconventional gas production in the UAE is an area of active research in order to extend the life of mature basins; despite this, there is a lack of understanding of the units' formation and the palaeoenvironmental implications. The current available literature on the Palaeogene units of the UAE and Oman is limited and makes assumptions based on science which has since moved forward significantly.

The Palaeogene (~66-23Ma) is a period of significant global climate changes; the Palaeocene-Eocene Thermal Maximum (~56Ma) represents a time of highly increased CO2 and CH4 levels, rapid climate warming and higher sea levels – the consequences of this are of great importance in terms of how anthropogenic rapid climate change will affect us in the future. Further to this, the Eocene-Oligocene boundary (~34Ma) is thought to mark the beginning of ice sheet formation on Antarctica, the causes and implications of this still lack understanding.

Through the use of both cores and outcropping sediments, this project will focus on understanding the palaeoenvironments of the UAE and Oman through the Palaeogene by using various chemostratigraphical, sedimentological and biostratigraphical techniques. Understanding how low latitude regions responded during periods of extreme climate fluctuations in the past is important in our understanding of today's response to climate changes.

Donald Christie

Email: D.N.Christie@soton.ac.uk

Institution: University of Southampton

Supervisors: Dr Esther Sumner, Dr Frank Peel (Imperial College London), Dr Gillian Apps (University of Texas, Austin), Dr Doug Paton (University of Leeds),

Project title: **Reconstructing the ocean floor shape in turbidite basins using seismic interpretation, forward modelling and outcrop analogues**

Abstract

Topography of the sea floor is a vital control on the deposition of the turbidite systems, and in particular the distribution of reservoir sand within the deposits. Turbidity currents that tend to develop the most favourable reservoir properties develop different reservoir geometries, which depend on several variables, including slope gradient and whether the topography is static or dynamic during deposition.

The oil and gas industry spends considerable efforts studying turbidite deposits and billions of dollars drilling them. However, there is no established, rigorous method for reconstructing sea floor topography in structurally active settings (e.g. Salt, Fold and Thrust Belts, extensional regions) and there are major problems with the techniques commonly used.

This project combines the interpretation of seismic and field data with innovative forward modelling to develop a working method for estimating palaeotopography and turbidite geometry. This method will then be tested against world-class outcrop examples of turbidite basins in the European Alps, and will also be tested against sub-surface examples from active exploration areas such as the Gulf of Mexico.

Karl Clark

Email: k.clark1@keele.ac.uk

Institution: Keele University

Supervisors: Dr Ian Stimpson, Dr Oliver Wakefield (BGS)

Project title: **Sedimentary controls on secondary processes: Deformation bands in reservoirs**

Abstract

Deformation bands are the main deformation element of fault zones in porous sandstones (1) . The relationships between deformation bands and larger scale faults have been well documented (2) as have relationships to bulk lithology (3), but little attention has been given to controls on deformation band formation by facies directly, and the inherent variables such as grain size distribution, grain angularity and composition.

This project undertakes a detailed field campaign using the well-exposed, mixed aeolian-fluvial Sherwood Sandstone Group (SSG) of the Cheshire Basin as a principal case study. The SSG contains a full range of aeolian and fluvial facies types and, crucially, is well exposed in a range of outcrops that allow a three-dimensional insight. Its importance in the Cheshire basin is highlighted by continued research as an oil reservoir, with the Bowland shale as its source, as well as shale gas, an anologue to the East Irish sea and North Sea basins, and more recently has been highlighted for its potential as a low enthalpy geothermal resource (4).

A detailed sedimentological framework will establish the geometries and distribution of both aeolian and fluvial facies types. This framework will be used to construct models that detail i) the occurrences, geometries and connectedness of deformation bands, and, ii) porosity and permeability data of both deformation bands and lithofacies. The results from this completed project could therefore be used to better highlight lithofacies types that are more or less susceptible to deformation band formation and as such, address aspects of reservoir management.

Ryan Claydon

Email: RXC095@student.bham.ac.uk

Institution: University of Birmingham

Supervisors: Professor Joe Wood, Professor Sean Rigby (University of Nottingham)

Project title: **In-situ Upgrading of Oil Using Naturally Occurring Clay Minerals and Hydrotalcites**

Abstract

Petroleum reserves are dwindling and while the development of renewable energy technologies is paramount, unconventional petroleum reserves must be liberated to ensure the continued development of non-OECD countries whose reliance on fossil fuels is growing.

While Heavy Oil is known for its poor physio-chemical properties, several EOR methods are in development to increase the efficiency of production in addition to upgrading the oil in-situ. One such technology includes In-Situ Combustion (ISC), which aims to combust a proportion of the Oil-In-Place (OIP) through injection of oxygen-rich air to generate thermal cracking zones. The combustion front generates a high temperature oxidation energy, resulting in sufficient heat and flue gas to stimulate pyrolysis, catalytic cracking and aquathermolysis of hydrocarbons.

Catalyst pellets are typically packed around the production liner annulus and thus accommodate the catalytic cracking as oil passes into the wellbore. However, catalytic properties of conventional refinery pellets are not designed to accommodate efficient catalytic cracking of heavy oil. They “coke-up” due to pore plugging, and the high metal content of the oil poisons and deactivates the active sites. As such, the essence of this project aims to formulate catalysts, using materials analogous to naturally-occurring minerals such as anionic clays, to enhance the performance of the catalyst in the presence of the heavier feeds, notably producing higher yields of the more valuable naptha and middle distillate fractions. Additionally, amphiphilic properties are being incorporated into a portion of the catalysts to assess their potential in aquathermolysis reactions, which can arise in the reservoir at the oil-water contact.

Furthermore, the failure to realise the optimum catalytic cracking temperature within the catalyst bed has led to the investigation of electrical heating methods, such as microwave heating. These are being tested as heat sources which may be physically drawn through the production liner to target specific areas of the catalytic bed, while the combustion front moves parallel to the horizontal production well. As a result, carbon-doped materials with sufficient dielectric properties are being incorporated into the catalyst matrix to accommodate the heating from this electrical source.

David Cox

Email: david.cox-2@postgrad.manchester.ac.uk

Institution: University of Manchester

Supervisors: Dr Mads Huuse, Professor Jonathan Redfern, Dr Wim Kouwe (Cairn Energy), Dr Paul Knutz (GEUS)

Project title: **Impact of glaciation on Arctic petroleum systems: seismic geomorphology and petroleum systems modelling offshore West Greenland and West Norway**

Abstract

The Arctic remains the last frontier for oil and gas exploration and poses unique challenges and considerations to both industry and academia. The reward, however, could be great as predictions estimate the Arctic to hold 30% and 13% of the world's undiscovered gas and oil, respectively. Recent exploration activities along the western Norway and Greenland continental margins have provided an extensive geophysical archive that contains the shelf and deep water parts of these dynamic systems, imaging them to a high level of detail. This has allowed high-resolution mapping of depositional sequences and elements along with fluid flow phenomena, which help constrain the presence of petroleum systems.

This project aims to use this data to help understand and define the range of impacts that glaciation can have on subsurface stratigraphy and petroleum systems within Arctic regions, including glacial erosion and deposition, subsurface pressure changes and differential isostatic loading which ultimately lead to the leaking or preservation of hydrocarbons. This will use investigations into fluid flow, climate reconstructions and hydrocarbon prospects and discoveries to inform and develop petroleum systems modelling techniques that consider and quantitatively analyse the ranging impact of glaciation. This work will then be used as a basis for consideration when exploring for oil and gas in Arctic regions, with the aim of achieving more successful exploration efforts in the future.

Amy Elson

Email: A.L.Elson@soton.ac.uk

Institution: University of Southampton

Supervisors: Dr Jessica Whiteside, Professor John Marshall

Project title: **Unconventionals of Green River Formation Oil Shales**

Abstract

Unconventional resources such as shale oil are some of the most important foci for current petroleum exploration and production. The Lower Eocene Green River Formation (GRF) of the western United States documents a ~15-million-year record of unusually large, productive lakes that deposited an estimated 750 billion barrels of oil equivalent, one of the largest oil shales in the world.

The surface-exposed GRF is a thermally immature system that can act as a model for deeply buried source rocks. The GRF contains intervals with up to 40% TOC and displays rhythmic lithofacies changes attributed to climatically induced lake expansion and contraction. Understanding the origin, frequency and geometry of these organic-rich layers is crucial to understanding variability in unconventional sources. This project will examine the controls on the sources and carbon isotope compositions of organic matter in the GRF in the context of models for productivity and carbon burial. Specifically, I will utilize outcrop-based work and study of over 500 m of core to inventory organic biomarkers preserved in the oil shales, and generate compound-specific carbon and hydrogen isotopes on multiple fractions to separate hydrological change from ecosystem changes.

Previous biomarker and compound-specific isotope studies have not been performed within a comprehensive stratigraphic context – the existing literature comprises isolated data from a few beds. The ability to place results in a detailed stratigraphic and basinal context is key, because it provides the foundation for understanding core and down-hole data in industry. I am specifically interested in the Mahogany Zone interval – the quintessential oil shale – with one of the highest kerogen concentrations of any Paleogene oil shale worldwide. This project will result in a fundamental understanding of oil shales in their broader context, which can then be applied towards similar deposits in other areas (e.g., Europe) with little or no outcrop exposed.

Georgios-Pavlos Farangitakis

Email: georgios-pavlos.farangitakis@durham.ac.uk

Institution: Durham University

Supervisors: Professor Ken McCaffrey, Dr Jeroen van Hunen, Professor Richard Davies (University of Newcastle), Dr Lara Kalnins

Project title: **Structural and Thermal Evolution of Continent-Ocean Fracture Zones**

Abstract

Continent–Ocean fracture zones are fossil transform offsets located along passive rifted continental margins and are responsible for the kinked appearance of some present-day continental margins (Lorenzo 1997). A fracture zone in general, is defined as an “extensive linear zone of irregular topography of the oceanic basement, characterized by steep-sided or asymmetrical ridges, troughs or escarpments, caused by a lateral offset of the plate boundary” (Muller & Roest 1992). Corresponding to the landward continuation of the continent-ocean fracture zone is the transform margin, which is defined as “a continent-ocean boundary superposed to active or previously active transform faults” (Mericer de Lepinay et al. 2016). Continent-ocean margins have been the focus of petroleum exploration since the discovery of the Jubilee field offshore Ghana. Subsequently, a number of these margins have been established as petroleum-rich areas or are being explored currently such as: a) Ghana-Ivory Coast; b) Barreirinhas Basin; c) Exmouth & Wallaby Plateaus; d) Voring Transform Margin; e) Bothnia-Senja Fracture Zone; f) Mozambique margin; g) Orphan Basin. However, petroleum exploration and de-risking for prospects on these margins presents a number of challenges. According to Nemcok et al. (2016) the risk factors controlling petroleum exploration at transform margins are: (1) uncertainty over the post-breakup uplift patterns in space and time; (2) poor knowledge of structural architecture and associated topography; and (3) diachronous timing of the transform fault activity.

On this PhD project I will be working on datasets from transform margins that display different stages of their evolution. In the first phase, available academic seismic data have been downloaded and uploaded on Petrel 2015™ for structural interpretation. The bulk of these datasets are from the Gulf of California which represents the younger stage of a transform margin. Once interpretation is complete, faults and horizons will be combined to enable a structural framework to be built which will assist in identifying the tectonic provinces in the Gulf of California and provide a clear image of how the evolution of transform margins and COFZs initiates. In future, we will make a comparison with seismic interpretations from mature transform margins from available academic 2D seismic data such as the Falklands transform margin. Access to industrial datasets in W. Australia, W. Africa and Norway would allow us to further delineate the structural evolution of a mature transform margin.

Throughout the project, different types of numerical modelling studies will be conducted on these margins to identify their thermal and structural evolution. Thermal and flexural parameters will be input in numerical models in order to establish the effect of the passing rift on the topography, thermal maturation of source rocks and deformation of the crust adjacent to the Continent-Ocean Boundary. The combination of numerical modelling with the structural framework built from the seismic interpretations will allow for the following results: a) in mature margins a detailed 4D interpretation of the margin evolution will be constructed which will investigate mature source rock zones, b) in early stage rifts, such as the Gulf of California we will be able to pinpoint the specific zones where deformation is localised and thus are more likely to be places where structural trapping occurs and also provide an insight on the future development of the margin.

Thomas Fender

Email: t.fender1@newcastle.ac.uk

Institution: Newcastle University

Supervisors: Dr Cees van der Land, Dr Mohamed Rouainia,Dr Zeyun Jiang (Heriot-Watt University), Professor Gary Couples (Heriot-Watt University), Professor Tom Wagner (Heriot-Watt University)

Project title: **Evolution of mechanical properties of organic matter in fine grained rocks**

Abstract

The mechanical behaviour of shales is controlled by the elastic properties of both their inorganic and organic components. The application of mechanical testing techniques is challenging due to the micrometer size of individual components. Additionally, the initial composition of the organic matter (organofacies) and different degrees of diagenesis and catagenesis change their physical and mechanical properties. Here we present the Young's of organic matter within shales from different depositional and maturity.

The development and continued improvement of techniques such as nanoindentation and Atomic Force Microscopy (AFM) enable in-depth analysis of features less 1μm in size across polished rock surfaces. The recent application of combining AFM with quantitative imaging techniques to geologic samples allow the measurement of mechanical properties in a nondestructive manner at a resolution of less 100nm. A tip (initial diameter approximately 10nm) of known Young's modulus is oscillated onto a sample with a similar modulus in a 'tapping' motion. The tip-surface interaction and the force required to deform the surface by 1-2nm is recorded. The gradient of force-displacement curve is used to calculate Young's modulus.

In this project, shales are categorised and related by Probability Density Functions (PDFs) of organic matter stiffness; relating shales by depositional environment and maturity. Two comparable shales are the Eagle Ford shale with the Tarfaya Oil shale of Morocco, owing to similar ages and depositional environments. Likewise, correlations may exist between Barnett shale and the Bowland shale as both contain significant proportions of type III terrestrially derived organic matter. An increasingly bimodal distribution in Young's modulus indicates that organic matter becomes increasingly complex with maturity, but little is known about the initial complexity in modulus resultant from variable organic precursors. Knowledge of these relationships will help play assessment and development by enabling predictions of organic matter geomechanical response to the stress exerted during hydraulic fracture. This may initiate complex fracture stimulation models aiming to access hydrocarbons within previously inaccessible intraparticle organic pores.

Laura-Jane Fyfe

Email: r01lcf16@abdn.ac.uk

Institution: University of Aberdeen

Supervisors: Dr Nick Schofield, Professor Adrian Hartley, Professor John Howell, Dr David Muirhead, Prof John Underhill (Heriot-Watt University)

Project title: **Hydrocarbon prospectivity of the inshore basins along Scotland's West Coast**

Abstract

The inshore sedimentary basins along Scotland's West Coast, from the North Minch Basin to the North Channel Basin, represent a still largely unknown area of offshore geology and petroleum geology within the UKCS. Although the area has been subjected to some exploration efforts with three wells drilled in the late 80's and early 90's, a lack of integrated studies means that a full understanding of the geological evolution and petroleum prospectivity of the area is not established. The four wells drilled West of Scotland showed many elements needed for a petroleum system to operate including good source and reservoir rock intervals, with Upper Glen 1 also encountering gas concentrations in the Lower Jurassic. However there are still major unknowns which will be fully assessed during this PhD though:-

1. Analysis of Seismic data

2. Analysis of high resolution bathymetric data

3. Assessment of high resolution Gravity & Magnetic data

4. Fieldwork assessing Source/Reservoir/Seal quality along with an assessment of the depositional environment and controls on thickness distribution

5. A Geochemical evaluation of Source rocks within the area

6. Integration of offshore wells and onshore field observations to understand basin evolution and formulate regional stratigraphy

Jonathan Hall

Email: jrh633@student.bham.ac.uk

Institution: University of Birmingham

Supervisors: Dr Steve Jones, Dr James Bendle, Dr Tom Dunkley-Jones

Project title: **The Neogene evolution of the NE Atlantic: multi-proxy constraints on stratigraphy, palaeoclimate and palaeogeography**

Abstract

The aim of this project is to generate a new palaeoenvironmental, palaeogeographic and palaeoclimatic understanding of the Neogene NE Atlantic. This project will focus on the multi-proxy environmental analysis of several industrial and scientific boreholes on the NW European continental margin, together with outcrop sampling of Icelandic Pliocene marine successions. The geochemical analysis (inc. stable isotopes, trace metals and biomarkers) of well preserved organic- and inorganic-walled microfossils will facilitate the development of new palaeoenvironmental reconstructions, including estimations of ocean temperatures. This project also seeks to refine and evaluate geophysical estimates of post-rift basin subsidence using micropalaeontological and geochemical evidence, including the analysis of benthic foraminiferal assemblages (water depth) and fluctuations of terrestrial and marine biomarkers (shoreline distance); such findings should enhance the seismic interpretation of deepwater sedimentary basins (inc. Rockall Basin) in this area of active frontier exploration.

Key objectives include:

1. Determining stratigraphic control and the uplift/subsidence history of north-east Atlantic basins using biomarker and microfossil techniques.

2. Delivering relevant results to industrial partners and providing a framework for improved interpretation of existing and future regional geophysical surveys and basin models.

3. Generating an extensive multi-proxy sea-surface temperature, terrestrial temperature, palaeoenvironmental data set (including atmospheric pCO_2 reconstructions) for the NE Atlantic during the mid-Pliocene and Miocene warm periods.

4. Addressing key hypotheses concerning Neogene climate, proxy biases and model sensitivities to CO_2.

James King

Email: james.king2@univ.ox.ac.uk

Institution: Oxford University

Supervisors: Professor Joe Cartwright, Professor Bruce Levell

Project title: **The propagation and growth of polygonal faults**

Abstract

Polygonal faults systems are a fascinating geological phenomena found exclusively in fine-grained sediments. Polygonal faults are layer bound normal faults that form complex three-dimensional networks, which when observed in plan view display spectacular interconnected polygonal patterns. Understanding the nucleation, propagation, and termination of polygonal faults systems has vast implications and applications to any field where faults can influence the integrity of fine-grained sealing/cap rocks such as petroleum geoscience, carbon capture storage and nuclear waste storage site planning. It is currently unknown to what extent polygonal faults act as conduits for sub-surface fluid flow. The genetic mechanism(s) to explain polygonal fault nucleation, propagation, and subsequent termination have remained elusive despite over two decades of research, however, recent research suggest that diagenesis can induce shear failure in fine-grained sediments. Novel analysis of polygonal faults in 3D seismic data from several locations with contrasting physical parameters, with particular emphasis on upper polygonal fault tips, are anticipated to provide new insights into potential nucleation, propagation, and termination mechanisms. Detailed fieldwork of analogous faults in silts and mudstones of the Taranaki Basin, New Zealand will be undertaken in conjunction with seismic interpretation where fault outcrop characteristics beneath the seismic resolution will be analysed. This research aims to bridge the gap between present ambiguity and future understanding.

Bartosz Kurjanski

Email: r01bk16@abdn.ac.uk

Institution: University of Aberdeen

Supervisors: Dr Brice Rea, Professor John Howell, Dr Matteo Spagnolo, Dr David Cornwell

Project title: **Characterisation of glacigenic reservoirs and landsystems using sedimentology, geomorphology and virtual outcrop mapping**

Abstract

Studies of the rock record show that during the last 2.5 billion years, Earth has undergone several shifts between periods of relatively high ice cover (icehouse) and warmer periods where glaciers were either missing or present in small isolated pockets (greenhouse). From a geological point of view, Earth at present is in an icehouse period which began around 34 Ma ago during the Late Cenozoic. In that time glaciers were advancing and retreating several times but never disappeared. The Quaternary began 2.6 million year ago and has seen repeated glacial-interglacial cycles culminating in the Middle and Late Pleistocene 781 and 11.5 ka when ice sheets, at glacial maxima, were approximately three times as extensive as now and reached latitudes of 50o N in Europe and North America.

Before present there were at least five major icehouse periods: Permo - Carboniferous (326-267 Ma), Late Devonian to Early Carboniferous (361-349 Ma) and Late Ordovician (445.6-443.7). The last one probably continued in Early Silurian over present South America. All these glaciations have been identified from the rock record in sedimentary basins which were previously parts of the Paleozoic supercontinent - Gondwana and were located closer to the South Pole at that time. The two oldest icehouse periods were the most severe and occurred in the Cryogenian in the Neoproterozoic (740-630 Ma) and in the Paleoproterozoic (2.3-2.2 Ba). Sedimentary packages of glaciogenic origin are recognized in numerous locations around the world. Ancient sedimentary packages are preserved only in sedimentary basins that underwent subsidence prior to, or during, deposition (e,g. Bonaparte and Canning Basins in NW Australia, South Oman Salt Basin, Parana Basin in Brazil, Ghadames- Illizi Basin, North Africa, Murzuq Basin in Libya). Most recently, Pleistocene sediments are also preserved on uplifted areas such as eastern and central European lowlands corresponding to the ability of ice sheets to accumulate sediments above the erosional base. These sediments are frequently targeted as freshwater aquifers demonstrating their excellent porosity and permeability.

Many basins that have undergone glaciation have proven petroleum systems and are targets of successful oil and gas exploration; but glaciogenic sediments are rarely targeted as the main producing facies. Although having an obvious potential to host hydrocarbons in relatively sandy/gravely packages, the distribution of glaciogenic sediments appears to be more complex, and less predictable, than sequences of aeolian, fluvial or marine origin. For this reason glaciogenic sequences are largely understudied and underexplored.
Latest discoveries made in the North Sea in the Quaternary succession (Aviat and Peon fields) that are clearly of glaciogenic origin are demonstrating new opportunities to unlock additional resources in the relatively easily accessible, shallow section. What was once regarded as a shallow gas hazard might now be considered a commercially attractive target for relatively low cost/low risk exploration.

This project aims to broaden our knowledge regarding glaciogenic sediment and landform distributions in order to assess potential reservoir, seal and source rock candidates within glaciogenic successions. To achieve this goal a complex sedimentological and geomorphological study of Pleistocene and older outcrops as well as modern glacial landscapes will be conducted using sedimentology, virtual outcrop mapping and geomorphology to create a series of depositional models of glaciogenic sequences. These models will be applied to available seismic and well data giving a baseline for further exploration in the North Sea as well as other basins that have undergone glaciation.

Eamon McKenna

Email: e.mckenna.1@research.gla.ac.uk

Institution: University of Glasgow

Supervisors: Dr Cristina Persano, Professor Roderick Brown, Dr Brian Bell, Professor Finlay Stuart (SUERC), Dr Alison Monaghan (BGS)

Project title: **Constraining the thermal histories of the Carboniferous Midland Valley of Scotland: a potential resource for unconventional gas and shale oil?**

Abstract

Situated between the Southern Uplands and the Highland Boundary fault, the Midland Valley of Scotland has a history of oil and gas exploration that dates back to the 1850's and the birth of the hydrocarbon industry. Economic exploitation of oil-shale units continued through the 20th century until the price of oil and gas left further exploration uneconomical and the focus of the hydrocarbon industry migrated to the offshore North Sea prospects.

The economical units of the Midland Valley of Scotland were deposited in a series of Late Devonian and Carboniferous sedimentary basins which formed in the foreland of the Variscan orogen. Such is the complexity of the geological history of the Midland Valley that several very different regional tectonic models have been proposed, all of which express the need for major switches in tectonic regime to satisfy the geological observations. Alongside the complex tectonic history, the Midland Valley has also experienced widespread volcanic activity throughout the Carboniferous and into the Permian.

Despite this complex geological history, the Midland Valley may still be considered a potential resource for unconventional oil and gas. However, little work has been done to quantify the thermal history of the basins and therefore the maturity of the organic matter cannot be constrained with great confidence. It is the aim of this project to constrain the time-temperature pathway of the Carboniferous rocks of the Midland Valley using low temperature thermochronology, primarily apatite fission track (AFT) and Uranium-Thorium/Helium in zircon (U-Th/He). The time-temperature pathway, will provide robust, quantitative constraints on the maturity of the organic matter and on the exhumation histories of the evolving sedimentary basins. This will be the pioneering thermochronological study in the University of Glasgow using Laser Ablation on the recently acquired Inductively Coupled Plasma Mass Spectrometer (LA-ICP-MS). This technique provides rapid data acquisition, removes the need for neutron irradiation of samples in a nuclear reactor and enables multi-element analysis, delivering fission track, uranium-lead and rare earth element data with a single ablation.

Hamish Mitchell

Email: william.mitchell15@imperial.ac.uk

Institution: Imperial College London

Supervisors: Dr Alex Whittaker, Dr Lidia Lonergan, Professor Mike Mayall

Project title: **Quantifying the relationship between structural growth rate and the morphology of submarine channels and reservoir facies from shelf-edge to deep water**

Abstract

Despite substantial research in slope and deep-water settings across the globe (Deptuck et al., 2003, 2007; Ferry et al., 2005; Heinio and Davies, 2006; Kolla et al., 2007; Georgiopoulou & Cartwright, 2013), the factors which control the long-term behaviour and dynamics of submarine channels—particularly on slopes undergoing active deformation—remain poorly understood. Many continental margins are characterised by thick prisms of clastic sediment above a layer of mobile substrate i.e. salt (Gulf of Mexico, Angola and Brazil) or shale (Nigeria and NW Borneo) (Prather et al., 1998; Prather, 2003; Morley, 2009). Such settings are dominated by structures associated with gravitational collapse, typically consisting of an extensional domain across the shelf and upslope regions, and a compressional domain further downslope. Whilst it is widely recognised that the development of seafloor bathymetry through gravity-driven tectonic activity is a major control on the location and configuration of submarine channels, a limited understanding of the time-integrated erosivity of submarine channels and limited direct observations of turbidity currents make quantitative analysis complex (Mitchell, 2004; Mitchell, 2005; Jolly et al., in press). Consequently, we do not have a quantitative conceptual model for the response of submarine channels to an imposed perturbation in the way we do for fluvial systems.

The Niger Delta provides an excellent location to analyse the interaction between deep-water submarine channels and gravity-driven tectonics, with a wide range of structural styles and sediment delivery systems across a number of intra-slope basins. A 3D, time-migrated seismic volume extending a distance of ~120 km from the shelf edge to the base of slope will be used for this study. Recent work by Jolly et al., (2016) on a subset of this volume provides independent detailed measurements of the long-term rates of shortening and cumulative strain across several of the major folds and thrusts structures creating present-day bathymetry. This allows the response of submarine channels to an imposed perturbation to be investigated with a quantitative link to the tectonic boundary conditions. Furthermore, a recent study by Jolly et al., (2017) clearly demonstrated present day submarine channel morphologies are indeed sensitive to structural growth rates. Yet, in order to fully understand the behaviour of these systems, their evolution from the shelf edge to deep water needs to be constrained with the temporal and spatial evolution of thrust-related structures across the Niger Delta system as a whole.

This study combines seismic techniques with concepts from landscape dynamics to quantitatively investigate how the growth of gravitational-collapse structures at, or near the seabed have influenced the morphology of submarine channels along their entire length from the shelf edge to their termination in deep water. The analysis will be further extended to buried and non-active channel systems through seismic facies analysis and mapping of the channel thalweg and margins, to deduce the morphological evolution of submarine channel systems for a given rate of tectonic shortening.

Vanessa Monteleone

Email: v.monteleone@soton.ac.uk

Institution: University of Southampton

Supervisors: Professor Tim Minshull, Hector Marin Moreno (NOCS)

Project title: **Crustal and sedimentary structure of the Eastern Black Sea Basin from long-offset seismic reflection data**

Abstract

The Eastern Black Sea is a deep water basin (2200 m water depth) which was formed by the clockwise rotation of the Mid Black Sea Ridge away from Eurasia in Cretaceous-Palaeocene time. The basin is filled by up to 10km of mainly Tertiary sediments. Within these sediments lies a thick low-velocity region attributed to overpressures and associated to a regional source rock, the Maykop Formation. The basin appears to be underlain in part by oceanic crust, but the distribution of oceanic and thinned continental crust remains poorly known, and the structures accommodating the stretching are still poorly imaged. The stretching appears to increase to the west, so the basin forms a natural laboratory to study processes of crustal stretching and breakup and subsequent sediment deposition and compaction.A series of densely sampled wide-angle seismic profiles acquired in 2005 provide a strong constraint on the crustal structure and type in the Turkish sector of the basin, but there are fewer constraints on the conjugate Russian sector.

The aim of the project is to use a series of profiles acquired across the basin in 2011-2012 using 10.2km streamer and a large airgun source to map the key horizons, such as the top of the acoustic basement and the Moho, examine crustal reflectivity patterns as an indicator of crustal type, and constrain lithologies and overpressure from velocity information. These recently acquired long-offset deep reflection data, in combination with constraints from wide-angle seismic and other data will investigate the nature and thickness of the crust, the mechanism of extension within the basin and the extent and magnitude of the overpressured zone.

Christina Nikolova

Email: cn16@hw.ac.uk

Institution: Heriot-Watt University

Supervisors: Dr Tony Gutierrez, Dr Eileen Bresnan (MSS), Dr Alejandro Gallego (MSS), Dr. Louise O'Hara Murray (Oil & Gas UK), Professor Ibrahim Banat (Ulster University), Professor Roger Marchant (Ulster University)

Project title: **Development of natural and sustainable bio-dispersants for the Oil & Gas industry**

Abstract

Oil pollution occurs naturally in the environment but can also be caused by human activities such as oil and gas exploration and production. In the event of an oil spill in the marine environment, the most common treatment is the use of chemical dispersants. Dispersants act as surface active agents that help the oil to break down into small droplets (less than 100μm) and disperse it in the water column making it readily available to oil-degrading microorganisms. However, the impact of dispersant on the natural bioremediation process is largely unexplored with some studies suggesting that chemical dispersant may inhibit biodegradation rather than enhancing it. In addition, chemical dispersants can be toxic to some marine organisms and can persist longer in the environment due to their low rates of biodegradation. The development and use of cost-effective natural dispersants is a promising solution for oil spill clean-up efforts.

Naturally occurring oil-degrading bacteria produce surface active compounds that act as effective surfactants or dispersants. In contrast with chemical dispersants, biodispersants have been shown to be nontoxic and readily degradable, therefore not posing additional pollution threat. However, production of biodispersants for a large-scale industrial application is currently very limited due to low yields and high costs for producing and downstream processing. In my PhD project I aim to develop new promising biosurfactants by screening for overproducing marine bacteria from the Gulf of Mexico and optimize their production process through novel approaches such as using sustainable growth substrates like waste products from different industries. The most promising bacterial strains will be cultured and their biosurfactant extracted which consequently will be tested for efficiency of dispersing crude oil and toxicity.

Izabella Otalega

Email: izabella.otalega@strath.ac.uk

Institution: University of Strathclyde

Supervisors: Dr Joanna Renshaw, Professor Zoe Shipton

Project title: **Assessment of the Potentially Toxic Element sources in the UK Unconventional Gas Resources**

Abstract

A number of academic and public concerns have been noted regarding the risk of environmental contamination with the naturally occurring potentially toxic elements (PTEs), including radioactive materials (NORM), arising from the shale gas/oil production. Shale gas/oil reservoirs are known to contain PTEs, often at concentrations significantly higher than in other sedimentary rocks. The elements present, their concentration, geochemical form and mobility in the environment will depend on the local geology and geochemistry. Development of the reservoir has the potential to mobilise PTEs from the target formation during all stages of the production. Several studies have reported variable concentrations of PTEs in the flowback and production waters from shale gas/oil reserves in the United States. In some cases, the levels reported for certain PTEs exceeded the Maximum Contaminant Levels (MCLs) for Drinking Water set by the U.S. Environmental Protection Agency. Some attention has also been paid to the disposal and potential mobilisation of PTEs from drill cuttings generated during the development of shale gas wells in the USA.

The potential range of PTE (content and characteristics) that may be released from shale gas/oil extraction in the UK is relatively unknown. Therefore, the aims of my project are to assess: (1) the potential PTE contaminant sources from shale gas in the UK; (2) whether standard industry reservoir characterisation is sufficient to accurately predict the PTE contaminant source present in a potential reservoir; (3) the potential impact of a nationwide industry on UK water treatment and radioactive waste disposal facilities.

I will be undertaking laboratory analysis of core and outcrop material, groundwater and wastewater for a range of shale gas/oil geological environments from around the UK and overseas case studies to evaluate the potential risk from PTEs in the UK. The aim is to enable the early assessment of the PTEs risk during the exploration phase, allowing for the planning of risk reduction strategies and appropriate treatment processes prior to extraction, and therefore reducing the potential for PTEs release at later stages. My work will also inform an assessment of potential cumulative environmental risk from such produced waters, and whether the existing UK water treatment infrastructure will be adequate in the case of future resource development.

Eleanor Pitcher

Email: enxep4@nottingham.ac.uk

Institution: University of Nottingham

Supervisors: Professor Sean Rigby, Dr Matthew Hall, Professor Joe Wood

Project title: **Novel characterisation methods for pore systems of seal rocks in reservoirs used for downhole hydrogen production and storage**

Abstract

Seal rock, also called cap rock, is a crucial and sometimes overlooked factor in the evaluation of a potential hydrocarbon accumulation, and is critical in downhole gasification and storage of hydrogen. Although a seal rock can be considered as a seal to hydrocarbons, it is erroneous to regard it as a completely impermeable layer. The retention of different fluids by overlying seals is controlled by the capillary entry pressure, and/or the permeability and the extent of diffusive losses (molecular transport) through the fluid-saturated pore space. The microstructure of cap rocks is highly complex and anisotropic and contains very small-diameter pores (~angstroms). Also, in clastic rocks, like sandstones, pores are observed between compacted grains and in the form of micro- and meso-porosity, often attributed to the presence of clays. Furthermore, the presence of a wide range of pore sizes makes it difficult to obtain the complete pore size distribution with a single conventional technique. Therefore, cap rock morphology is difficult to characterize, making it necessary to use different methods that are complementary. In this project, we propose to develop a novel combination of complementary and multi-scale characterisation methods to enable a more accurate study of cap-rock cores, and provide the information needed for secure decisions regarding gas production and storage.

Charlotte Priddy

Email: c.priddy@keele.ac.uk

Institution: Keele University

Supervisors: Dr Stuart Clarke, Dr Jamie Pringle, Dr Phil Richards (BGS)

Project title: **Climatic cyclicity and environmental interactions in arid continental basins: The Leman Sandstone, Southern North Sea**

Abstract

Arid continental basins commonly comprise sedimentary fill from fluvial and aeolian environments, and while the preserved facies associations within each environment has been studied in great depth, the relationships between coeval depositional environments has received little attention. The temporal and spatial distributions of these environments can greatly affect reservoir quality and basin-scale migration.

The project will evaluate the interactions and controlling mechanisms affecting linked ephemeral fluvial and aeolian systems in outcrop and a sub-surface North Sea analogue. It will elucidate the relative impacts of climate change and tectonism on facies distributions and interactions in these systems, and provide a three-dimensional fluid-flow model pertinent to migration and reservoir evaluation.

This work will use well-exposed sedimentary successions through arid continental depositional systems within the intra-cratonic basins of the Western USA, principally the Wingate, Moenave and Kayenta formations of the Colorado Plateau, to provide a well-constrained analogue for environmental interaction and facies distribution within the Leman Sandstone.

The key objectives are to:

• Use three-dimensional models of facies interactions, coupled with their dependence on regional climatic cyclicity and localised active tectonism, to provide control on the evolution of the Leman Sandstone, the development of significant erosive surfaces, facies distribution and petrophysical properties at a variety of scales.

• Demonstrate the generic effects on potential flow pathways of sedimentary variation within ephemeral-aeolian-playa environments using stochastic migration modelling techniques.

Chantelle Roelofse

Email: RoelofseC@cardiff.ac.uk

Institution: Cardiff University

Supervisors: Dr Tiago Alves, Dr Joana Gafeira (BGS-Edinburgh)

Project title: **Fluid flow paths through sedimentary basins: Implications for exploration in challenging geological environments**

Abstract

Fluid flow features recognised in 3D seismic data may represent paleo- or modern paths for fluid on their way from source to reservoir, or from source to surface. Their presence is key to the recognition of active petroleum systems and associated geohazards as well as assessing potential Carbon Capture and Storage sites. This PhD project aims to improve understanding of the physical processes behind the breaching of seal units and the escape of hydrocarbons from structural traps and reservoirs.

The key objectives are:-

1. Use semi-automated methods to identify and characterise fluid flow features in subsurface units, in particular pipes and pockmarks, to reconstruct the migration history of hydrocarbons in time and space. These methods were created by the BGS, using ArcGIS.

2. Correlate local and regional events (tectonic, eustatic or magmatic) with main periods of fluid flow in sedimentary basins.

3. Correlate the sub-surface distribution of fluid flow features with local structures, such as faults and salt structures, so that the main paths for fluid are recognised in complex sedimentary sequences.

3D seismic data and borehole data from the Central North Sea, the Gulf of Mexico and NW Australia (Browse Basin) will be analysed to provide detailed seismic attribute, geomorphological and stratigraphic information on the sequences crossed by fluid flow features.

Sascha Holland

Email: sascha.roest-ellis@spc.ox.ac.uk

Institution: Oxford University

Supervisors: Dr Nicholas Tosca, Professor Paul Wright (PW Carbonate Geoscience / National Museum of Wales)

Project title: **Authigenic mineral corrosion and the origins of secondary porosity in lacustrine carbonate reservoirs: An experimental approach**

Abstract

The project is a sedimentological and geochemical investigation into the Pre-Salt carbonates of Brazil. The Pre-Salt carbonates are of significant economic importance as major hydrocarbon bearing reservoirs. The first and most significant discoveries were in the Santos and Campos Basins offshore Brazil within lacustrine carbonate reservoirs. Subsequent discoveries on the African conjugate have been discovered such as in the Kwanza Basin, Angola and the Toca Basin, offshore Congo Basin.

The carbonates formed in highly alkaline lacustrine environments in early rift-settings with the chemistry of the lake water influenced in-part by the volcanic drainage basin. The chemical composition and conditions controlled the mineralogy and texture of the facies by abiotic and/or microbial control. Subsequent early diagenesis is a major control on the development of reservoir properties. The reservoirs are not typical and are highly variable, with unusual relationships between the predominant calcite, dolomite and Mg-silicates (Stevensite). Lack of extant analogous systems and little previous research identifies the need for significant research to understand the conditions for the development of the minerals and thus characterise the facies. In particular, fundamental understanding of dolomite and Mg-silicate synthesis and diagenesis in the system is lacking.

This project focuses on the formation of the carbonates and development of reservoir properties by investigating the relationship between dolomite and Mg-silicate clays and the early diagenesis of these minerals. The methods used include experimental synthesis of minerals and amorphous phases under different conditions. Analysis of these products will constrain the conditions needed for the production and destabilisation of dolomite and Mg-silicates. The analysis aims to characterise the origin of these minerals in the Pre-Salt carbonates. The investigation will be further enhanced by analytical data collection of reservoir and non-reservoir facies samples from the Pre-Salt of Brazil.

The project is carried out at the University of Oxford under the supervision of Nick Tosca, and with the International Centre for Carbonate Reservoirs (ICCR) research group, which is partnered industrially by BG Group (a subsidiary of Royal Dutch Shell) and Petrobras.

Catriona Sellick

Email: catriona.sellick@durham.ac.uk

Institution: Durham University

Supervisors: Professor Chris Greenwell, Dr Nicola de Paola, Dr Pablo Cubillas, Ian Collins (BP)

Project title: **Understanding the controls of fines migration in sandstones**

Abstract

Fines migration is a particular challenge within low salinity enhanced oil recovery, where by partially desalinated seawater floods are used to deliver tertiary oil recovery. On one hand, the release of fines (very small mineral particles, such as clay minerals or small sandstone grains) can aid enhanced oil recovery in sandstone systems through carrying adhered oil. However, the ensuing mobility of fines can counter the effect of releasing oil droplets through pore blocking and hence reduction in permeability within sandstone by shutting down migration pathways. In order to effectively sustain production through tertiary oil recovery operations a fundamental understanding of the causes of fines migration, and the ways in which fines mobilise to block pores, is needed.

A large number of previous studies have been carried out focusing on the properties of the fluid flowing through the sandstone, and how these properties affect the mobilisation of fines by looking at changes of permeability of the sandstone over time during core flooding. However, less work has been carried out looking at the initiation and propagation of fines mobilisation, how the fines are expected to move through the pore network, and what causes the fines to cease movement and cause a reduction in permeability. Using visualisation techniques such as micro-CT and SEM, coupled with modelling techniques, both on a molecular scale and flow modelling, the specific movement of fines in the pore spaces may be elucidated.

Raquel Serrano

Email: r.y.serranocalvo@dundee.ac.uk

Institution: University of Dundee

Supervisors: Dr Mark Cutler, Dr Glyn Bengough

Project title: **Understanding hydrocarbon impacts on vegetation and detection with remote sensing**

Abstract

Hydrocarbon spills have a major environmental impact, often with significant economic consequences. Every year, 3 to 5% of produced oil is lost onshore and seeps in to soils, rivers, and sediments. According to the World Energy Council, oil production in 2020 will be 4594 million tonnes, with a further 4049 million tonnes of gas, leading to an estimated 230 million of tonnes lost in to the wider environment every year.

Traditional methods for investigating hydrocarbon leakage, such as drilling or geophysical methods, are expensive, time consuming and destructive. The use of remote sensing techniques (including hyperspectral reflectance and fluorescence sensors) have shown potential for monitoring vegetation stress due to hydrocarbon contamination have in previous investigations, but are yet to be used in a regular operational way due to a fundamental lack of understanding of soil contaminant-plant-radiation interactions.

This research project focuses on the physical impacts of hydrocarbons on soils and its impact on vegetation, and how these impacts may be best detected using remote sensing methods. Comparing the results obtained in the laboratory and in situ test sites, new methods for the monitoring of soil contamination by hydrocarbons will be developed and tested, hopefully leading towards methods for detection and aiding response in case of accidental spillage. By using remote sensing we aim to be able to detect the impacts of hydrocarbons on vegetation at early stage, developing methods for detecting hydrocarbon contamination/ spill zones using aircraft and satellite-based remote sensors. Such methods should be applicable across wide areas and also facilitate monitoring the recovery of sites post-spill.

Panayiota Sketsiou

Email: r03ps16@abdn.ac.uk

Institution: University of Aberdeen

Supervisors: Dr Luca De Siena, Professor Nick Rawlinson, Dr David Cornwell

Project title: **Extending the life of mature basins in the North Sea and imaging sub-basalt and sub-intrusive structures using seismic intensity monitoring**

Abstract

Despite the advances in seismology in recent years which have enabled us to image the subsurface with much greater detail than ever before, there are still challenges of crucial interest to the Oil and Gas industry which need to be addressed. One of them is how to monitor fluid accumulation and propagation in the subsurface. The purpose is to extend the life of mature basins in the North Sea. The reason "standard" seismic imaging techniques fail in these environments is because of complex physical processes, such as attenuation, scattering and resonance, which affect the seismic wave fields as well as the complex geology of the area.

The aim of the project is to use non-standard imaging techniques of scattering and attenuation tomography to solve the problem of locating/tracking gas and fluid movements in the subsurface, and image sub-basalt and sub-intrusive structures. The project's area of interest is the Rockall Basin, in the West of Scotland. The techniques mentioned above have been tested in Deception Island's volcanic caldera and have been proved effective in monitoring fracture opening, imaging buried fluid-filled bodies and tracking water/gas interfaces. The data needed for the implementation of this project consist of unexploited seismic intensities from previous passive surveys as well as active surveys, sourced from the University of Aberdeen SeisLab. Finally, the tomographic results will be connected to both the lithology of the sampled medium and the petrology of the area.

Euan Soutter

Email: euan.soutter@postgrad.manchester.ac.uk

Institution: University of Manchester

Supervisors: Dr Iane Kane, Dr Mads Huuse, Dr Kristina Bakke (Statoil)

Project title: **Deep-marine reservoir heterogeneity in steep-sided minibasins - influence of basin physiography on sedimentological processes and basin-fill character**

Abstract

Deep-marine sedimentary deposits are a product of the initial sediment gravity flow character and the character of the receiving basin. In small (a few to tens of km) mini-basins, flows interact with the bounding walls of the basin. The rate of flow deceleration against basin margins affects the style of deposition, with rapid deceleration often resulting in thick bedded sandstones which terminate abruptly, whilst gradual deceleration develops thin bedded turbidites which may 'run-up' topography for considerable distances. Soft-sediment failure, developing slides, slumps and debris flows, are also common in these settings. Together, these processes can result in complex reservoir characteristics, and variable stratigraphic trapping potential. This project will address this with a combined field-, core- and seismic-based project.

The field study will focus on the Annot Sandstone of SE France, where multiple sections reveal the facies variability within the onlapping units. The study will examine the poorly studied eastern margin of the Annot sub-basin, and will utilise a brand-new helicopter-based lidar survey of the well known Chalufy onlap sections. Core from salt-walled mini-basin reservoirs of the UK Central Graben will be compared and contrasted to the outcrop examples, and used to better understand a subsurface analogue revealed in 3D seismic data again from the salt-walled mini-basins of the Central Graben. The project, through the development of conceptual models, will deliver an enhanced understanding of reservoir heterogeneity in complex basin settings and will be particularly relevant to the often more complex and subtle hydrocarbon prospects presently targeted in mature basins.

Jack Stacey

Email: jack.stacey@postgrad.manchester.ac.uk

Institution: University of Manchester

Supervisors: Dr Cathy Hollis, Dr Greg Holland, Dr Hilary Corlett (Alberta Geological Survey)

Project title: **Determination of basin-scale fluid flux to understand porosity distribution within mature carbonate basins.**

Abstract

The differentially dolomitised Devonian carbonate reef and platform deposits of the Western Canada Sedimentary Basin (WCSB), Alberta have been extensively studied due to their importance as prolific hydrocarbon reservoirs. Existing literature on the WCSB has previously focussed on individual carbonate deposits, with only a handful of papers addressing the regional controls of dolomite formation and occurrence. Existing models suggest regional aquifer flow of basin-derived brines associated with the Antler (Devonian - Mississippian), Columbian (Jurassic), and Laramide (Cretaceous) Orogenies may have been responsible for formation of dolomite in the deep subsurface. However, the interplay between regional aquifers and faulting has been overlooked, despite focussing on hydrothermal fault-related dolomitisation in the past.

This study will utilise the Middle Cambrian Cathedral Formation in the Canadian Rocky Mountains as a field analogue to the Devonian of the deep WCSB in order to define the geometry of dolomite bodies. The Cathedral Formation contains similar replacement and cement dolomite phases to the Devonian, and formed under comparable diagenetic conditions related to the orogenic events listed above. Dolomitising fluids utilised fault networks to migrate up-dip from the basement, forming similar geometries to those observed in the Devonian.

In addition to the fieldwork carried out in Canada, this project will focus on the petrographical characteristics of both the Cambrian and Devonian. Stable isotope geochemistry of dolomite phases will aim to determine the paragenetic evolution of the basin and timing of dolomitisation. Further to this, noble gas geochemistry may be utilised to define the source of the crustal fluids and whether this is related to volcanism. Novel approaches may also include integration of seismic data in order to build a predictive reservoir model based on extrapolated dolomite geobodies in the subsurface.

Paul-Ross Thomson

Email:Paul-Ross.Thomson.2016@live.rhul.ac.uk

Institution: Royal Holloway

Supervisors:Dr Saswata Hier-Majumder, Professor Agust Gudmundsson

Project title: **Numerical modelling of reactive multiphase flow in low-porosity reservoirs**

Abstract

As the search for energy sources widen and methods become more unconventional, the interaction between damage (fracture) generation and chemical reaction during porous flow has an increasingly significant role to play in the energy sector. Although the theory of such flow is now well established, high resolution models of reactive porous flow through reservoirs of complex shape has remained a challenge. This study will bridge the gap by employing a recently developed massively parallel finite elements based numerical model of reactive multiphase flow and damage generation in a compacting medium. While finite elements permits modelling reservoirs of complex shape and permeability structures, the incorporation of damage and multiphase flow also tracks the generation of new high permeability pathways in response to the flow while accounting for pre-existing fractures. This work will be particularly applicable in the field of extending the life of mature basins and in unconventional oil and gas resources.

Faraaz Ahmad

Email: faraaz.ahmad@postgrad.manchester.ac.uk

Institution: University of Manchester

Supervisors: Dr Sam Shaw, Prof Katherine Morris, Prof Kevin Taylor, Peter Evans (BP)

Project title: **Radionuclide Fate in Naturally Occurring Radioactive Materials (NORM) Relevant to the Oil Industry**

Abstract

During extraction and production of oil and gas, naturally occurring radionuclides dependent upon the chemical conditions of the reservoir, can be transported from the subsurface to the produced waters which can lead to precipitation events and accumulation of inorganic solids such as barite (barium sulphate), celestite (strontium sulphate), gypsum (calcium sulphate) and calcite (calcium carbonate). Such minerals can accumulate in large volumes within pipe lines, valves, storage tanks, wellheads, tubulars and may also deposit on and contaminate production equipment.

Naturally occurring radionuclides (NOR's - mainly isotopes of radium) can co-precipitate and incorporate not only in inorganic mineral scales but also within sludges and drilling muds coercing them to be radioactive and to form what is known as Technologically Enhanced NORM (TE-NORM). The daughter radionuclides which are most dominant and have the highest activity in TE-NORM in the oil and gas industry are; radon-222 (222Rn), radium-228 (228Ra), radium-226 (226Ra), polonium-210 (210Po) and lead-210 (210Pb) which arise from the uranium and thorium decay.

The management of TE-NORM is a significant liability for industry. The formation of scales and sludge can cause blockage of pipe lines and tubulars leading to the need for descaling operations which engender radiation exposure and protection issues to workers and the environment due to the potential risk of contamination. Additionally, as major oil fields enter their decommissioning phase, forward management of NORM contaminated plant is a challenge as these materials may be classified as radioactive waste.

This project will focus on characterising TE-NORM materials from the oil and gas industry and further the understanding of radionuclide uptake at a molecular scale into relevant materials (e.g. pipe mineral scale) to allow a better understanding of their environmental origin and hazard.

Tanya Beattie

Email: tscb1n14@soton.ac.uk

Institution: University of Southampton

Supervisors: Dr Ian Harding, Prof John Marshall

Project title: **Source rocks, thermal history and unconventionals in the Weald Basin**

Abstract

The Weald Basin in southeast England is a well-known host of gas and oil deposits, however these deposits often prove to be limited in extent. Potential source rocks in this basin include the Weald Clay, although there are some significant unknowns about this clay, which are the lateral and vertical distribution of organic matter through the unit and the thermal maturity of the clay. Preliminary total organic carbon (TOC) values indicate generally low values throughout the unit but with localised high TOC peaks. Vitrinite reflectance studies reveal that high palaeogeothermal gradients were present and that the lowest part of the Weald Clay often has a 'dog leg' with much steeper temperature gradients.

Determining the source rock properties of the Weald Clay will be achieved by studying the TOC values and Vitrinite reflectance of cuttings and core samples from commercially released wells. TOC peaks will then be tied to wireline log data, correlated across the basin and then palynologically calibrated. These results will then be used to produce a detailed understanding of the thermal history of the Weald Basin and associated source rocks as well as a map of the location and stratigraphic level of the optimal source rock within the Weald Clay.

Adam Cawood

Email: adam.cawood@abdn.ac.uk

Institution: University of Aberdeen

Supervisors: Dr Clare Bond, Prof John Howell

Project title: **Quantifying strain partitioning in multi-layers in fold-forelimbs: implications for reservoir quality and connectivity.**

Abstract

The forelimbs of fold thrust belts are poor to seismically image, forming underconstrained elements of sub-surface models. A key challenge is to predict damage localisation in forelimbs. Understanding how different layers accommodate strain and partition deformation, in rock multi-layers has implications for understanding sub-seismic deformation induced ‘damage’; this damage, or enhancement, impacts reservoir quality and connectivity in conventional and unconventional resources. Since early papers on fracture spacing in multilayers (e.g. Ladeira and Price, 1981) the concept of mechanical stratigraphy and strain partitioning within multi-layers has been recognised. In this project we will use high-resolution virtual outcrop geology (via LiDAR scanning and GigaPan) to quantify strain partitioning in multi-layers, both ductile and brittle, for a set of classic fold-thrust outcrops. Deliverables: The project will focus on fold-thrust outcrops in multi-layers, including examples from Pembrokeshire and Utah, to take apart, layer-by-layer, the deformation fabrics and strain accommodation. The virtual outcrops will be enhanced by in-field measurements and material analysis, including logging, laboratory facies analysis and thin section work. The work will result in strain partitioning models between different lithologies, and multi-layer sequences, allowing predictions of bedding parallel slip, deformation localisation and style.

Anran Cheng

Email: anran.cheng@stcatz.ox.ac.uk

Institution: University of Oxford

Supervisor: Prof Chris Ballentine, Prof Barbara Sherwood Lollar (University of Toronto)

Project title: **Quantifying crustal fluid systems using noble gas isotopes**

Abstract

Groundwater plays a key role in hydrocarbon systems; various hydrogeological conditions can result in different formation and migration mechanisms. The interest in understanding the flow system is also driven by questions related to fracking, CCS and radioactive waste disposal. Consequently, establishing quantitative models that describe the physical framework of hydrocarbon/groundwater systems are essential for building a predictive understanding of fluid occurrence, composition and transport.

Noble gas (He, Ne, Ar, Kr, Xe) isotopes, with distinctive isotopic composition of different sources, chemical resistivity and high sensitivity to physical processes, are proven to be good indicators of the age and source of fluids, as well as of their transport processes. During my PhD, I will start with understanding the crustal fluid system by analysing the whole suite of noble gas isotopes collected from one basin and progressively developing quantitative models. The models would be improved and verified by samples collected from other systems at a later stage.

Emily Crowder

Email: emily.crowder@abdn.ac.uk

Institution: University of Aberdeen

Supervisors: Dr David Cornwell, Professor Nick Rawlinson (Cambridge)

Project title: **Seismic imaging without a source: Towards cost effective and low environmental impact hydrocarbon exploration**

Abstract

The goal is to develop and test new methodologies that will make ambient noise seismic imaging more useful for hydrocarbon exploration. Structure at the exploration scale can be revealed using this method, but much more work is required before it could be considered useful to industry. In this project, I will develop and apply innovative ambient noise methods that exploit both body and surface waves generated by natural and anthropogenic noise sources. Objectives are:-

(1) Developing a data-processing workflow that enhances the ambient noise signal for various types of waves in various environments, with particular emphasis on enhancing high frequency energy. New advances suggest that quantifying the spatial distribution of noise sources can lead to marked improvements in imaging results.

(2) Developing methods that push the boundaries of what is currently possible in terms of spatial resolution of near surface structure. Including: exploiting the ellipticity of Rayleigh wave particle motion, which has the potential to greatly improve recovery of structure in sedimentary basins; enhancing the amplitude of body wave reflections; and implementation of advanced Bayesian tomography methods.

(3) Application of the new methodology to realistic datasets. First, testing using synthetic data generated by software that solves the full elastic wave equation, second, applications to data collected in Australia and the UK will be carried out.

Laura Duran

Email: ld24@hw.ac.uk

Institution: Heriot-Watt University

Supervisors: Dr Tony Gutierrez, Prof Ian Head (Newcastle), Dr Jeff Polton (NOC), Dr Eileen Bresnan (Marine Scotland Science), Dr Alejandro Gallego (Marine Scotland Science)

Project title: **Evaluating the resilience of sea surface and deepwater systems to recover from oil spills in the Faroe-Shetland Channel**

Abstract

One of the most catastrophic anthropogenic pollution events in the marine ecosystem are oil spills. With the rapid economic development and energy demand around the world, marine petroleum exploitation and transportation has increased steadily, and with it also the risk for catastrophic oil spills and detrimental impacts to marine ecosystems. In the last years, an increase of oil activity and pollution in the North Sea has created interest in the study of hydrocarbon degrading bacteria. The Faroe Shetland Channel is considered one of the most representative areas of the North Sea due to the increase in oil activity as well as because of the two currents, from the Arctic and from the North Atlantic that defines this region. In this project a previous study of the microbial communities of the Faroe Shetland Channel will be extended and related to hydrocarbon concentrations, biodegradation kinetics and modelling the fate of oil in the event of a major spill in the FSC. The findings of this study will provide a better understanding of the consequences of an oil spill on marine ecosystems, to evaluate the microbial response and feed this knowledge into future oil-spill contingency plans.

James Foey

Email: j.a.l.foey@keele.ac.uk

Institution: Keele University

Supervisors: Dr Ian Stimpson, Dr Tom Randles (British Geological Survey), Steven Rogers

Project title: **The influence of halokinesis on shallow-marine sediments in salt basins: The Fulmar Formation, Central North Sea, UK**

Abstract

The Upper Jurassic Fulmar Formation hosts significant accumulations of hydrocarbons across the Central North Sea, with currently over sixty discoveries within the play. However the number of new exploration wells targeting Fulmar plays is decreasing despite ample opportunities for continued exploration. The Fulmar sediments have accumulated within Late Jurassic salt collapse basins, formed by the dissolution of mobile Zechstein salt walls. However the formation of economic reservoirs within such settings is complicated requiring a careful balance between the rate of sediment supply and salt wall dissolution.

The aim of the project is to construct depositional models that describe the likely depositional environments and distribution of facies both within Jurassic collapse basins and between them. In order to achieve this, the project will investigate the influence of halokinesis upon the sedimentology of the Fulmar Formation by examining the temporal and spatial distribution of facies between the collapse basins and their relationship to the magnitude of salt dissolution and relative sedimentation rates in the central North Sea.

The project will utilise core, wireline and 3D seismic data from across the North Sea and incorporate an analogue study in-order to improve the understanding of facies geometry and juxtaposition. Understanding the effects of facies distribution and their connectivity will benefit both industry and academia by providing a predictive tool for play genesis applicable to the Fulmar and similar salt influenced hydrocarbon plays.

Callum Fry

Email: crf1g11@soton.ac.uk

Supervisors: Dr Justin Dix, Prof Joe Cartwright (Oxford), Prof Jon Bull

Institution: University of Southampton

Project title: **High-Resolution 3D Seismic Imaging of Polygonal Fault Systems**

Abstract

Over the last twenty years Polygonal Fault Systems (PFS) have been identified in over 100, fine grained sedimentary basins worldwide. These aggregated complexes of small normal faults have been the focus of extensive study due to the role they play in controlling the permeability of top seals for conventional hydrocarbon accumulations. More recently it has been proposed that the processes that form PFS could also generate shear failure at even smaller scales (potentially but not exclusively as a hierarchy of analogous structures) which could have far reaching implications for different types of resource exploitation (shale gas; methane hydrates) and underground repositories for both carbon capture and storage (CCS) and nuclear waste.

This project aims to plug the resolution gap through the high-resolution imaging of near surface outcrops of the Tertiary, London Clay deposits of the Outer Thames Estuary. This will be done by building upon previous bathymetric and 2D boomer surveys with true 3D high resolution volumes (decimetre voxels), using the 3D-Chirp system designed at UoS. These interpretations can then be compared with the same stratigraphic horizons imaged with more conventional techniques across the Southern North Sea, enabling fine scale structures to resolved and analysed for the first time.

Ilaria Gaiani

Email: ilaria.gaiani@durham.ac.uk

Institution: University of Durham

Supervisors: Prof Andy Aplin, Prof Chris Greenwell, Ruarri Day-Stirrat (Shell, Houston)

Project title: **Quantitative porosity characterization in carbonate-rich shales: the Eagle Ford example**

Abstract

Shales are fine-grained clastic sedimentary rocks and present sub-nanometre to micron-scale porosities that can host large quantities of oil and gas. However, the interconnectivity of the porosities is usually very low and the pore structure highly heterogeneous. For a successful reservoir characterization, it becomes crucial to generate a quantitative description of the pore system and its connectivity.

This project aims to characterize the pore system of the Eagle Ford Formation, a Cretaceous carbonate-rich shale that trends across Texas. Its high percentage of carbonate, together with its large lateral extent and thickness, bring this formation to be one of the best shale plays of the United States.

Up to now, a total of 46 samples from the Lower Eagle Ford Formation was provided by Shell, Houston. First, XRD and standard geochemical analysis (Rock eval pyrolysis, TOC %) will be performed in order to quantify the mineralogy and the thermal maturity of the shale. Next, the petrography and diagenesis of the samples will be described by means of microscopy studies (transmitted light, SEM). MICP, XRCT and gas adsorption analyses will then be performed to obtain the bulk volume of the porosities, their size distribution and their connectivity.

Finally, to gain insight into the chemical origin of the organic matter and its behaviour in the pore system, a combination of AFM with nano-Raman will be used. The simultaneous use of these two techniques will provide a description of the wetting proprieties of the rock surfaces and of the chemical reactions affecting the shales when they enter in contact with the migrating fluids.

Allan Hollinsworth

Email: a.hollinsworth.1@research.gla.ac.uk

Institution: University of Glasgow

Supervisors: Dr Daniel Koehn, Prof Martin Lee, Dr Andrea Hamilton (Strathclyde), Prof Zoe Shipton (Strathclyde)

Project title: **Understanding porosity-permeability evolution of basement faults using 4D computed X-ray tomography**

Abstract

Fault zones are important sites for crustal fluid flow, specifically where they cross-cut low permeability host rocks such as granites and gneisses. Fluids migrating through fault zones can cause rheology changes, mineral precipitation and pore space closure, and may alter the physical and chemical properties of the host rock and deformation products. It is therefore essential to consider the evolution of permeability in fault zones at a range of pressure-temperature conditions to understand fluid migration throughout a fault's history, and how fluid-rock interaction modifies permeability and rheological characteristics.

Field localities in the Rwenzori Mountains, western Uganda and the Outer Hebrides, north-west Scotland, have been selected for field work and sample collection. Here Archaean-age TTG gneisses have been faulted within the upper 15km of the crust and have experienced fluid ingress.

The Rwenzori Mountains are an anomalously uplifted horst-block located in a transfer zone in the western rift of the East African Rift System. The north-western ridge is characterised by a tectonically simple western flank, where the partially mineralised Bwamba Fault has detached from the Congo craton. Mineralisation is associated with hydrothermal fluids heated by a thermal body beneath the Semliki rift, and has resulted in substantial iron oxide precipitation within porous cataclasites. Non-mineralised faults further north contain foliated gouges and show evidence of leaking fluids. These faults serve as an analogue for faults associated with the Lake Albert oil and gas prospects.

The Outer Hebrides Fault Zone (OHFZ) was largely active during the Caledonian Orogeny (ca. 430-400 Ma) at a deeper crustal level than the Ugandan rift faults. Initial dry conditions were followed by fluid ingress during deformation that controlled its rheological behaviour. The transition also altered the existing permeability. The OHFZ is a natural laboratory in which to study brittle fault rocks, and younger Mesozoic age faults may provide analogues for the West Shetland basin.

Samples have been collected from both of these localities, and will be examined by optical and scanning electron microscopy. X-Ray micro-tomography will also be used to analyse the permeability characteristics of the fault rocks. Our understanding of fault zone permeability is crucial for a number of research areas, including earthquake geoscience, economic mineral formation, and hydrocarbon systems. As a result, this research has relevance to a variety of industry sectors, including oil and gas (and ccs), nuclear waste disposal, geothermal and mining.

Hosne Jahan

Email: enxhj3@nottingham.ac.uk

Institution: University of Nottingham

Supervisors: Dr Sean Rigby, Prof Joe Wood (Birmingham)

Project title: **Achieving effective and low-impact production of heavy oil**

Abstract

This project will aim to better understand relevant environmental science, and thereby improve the efficiency and assess the impact of the THAI-CAPRI in-situ combustion-based recovery process for heavy oil and bitumen deposits.

Improving the efficiency of THAI requires greater understanding of various types of multi-phase flow, through the heavy oil deposits, and this work will provide parameters for reservoir-scale models. The project will use STARS simulation methods to study flow problems, particularly migration of heavy oil mobilised by heat and/or combustion gases, and injection of nanoparticulate, downhole-upgrading catalysts in the gaseous oxidant. Very little information is currently available on these types of flows for geological porous media. Obtaining this information will improve design and operation of the recovery process.

Modelling will be used to assess the impact of THAI process on any hydrocarbon deposits in overlying layers due to various effects ranging from conduction of heat, and high pre-heating steam injection pressure, through to permeation of the cap-rock by oxidant and/or combustion gases. The simulations will be used to look at potential risk from different levels of permeability of the cap-rock, either pre-existing or induced by the combustion process. Simulations will be used to test for the potential for anomalous pressure zones arising due to reservoir heterogeneities during combustion.

Luke Jenkins

Email: luke.jenkins@earth.ox.ac.uk

Institution: University of Oxford

Supervisors: Prof Chris MacMinn, Prof Joe Cartwright

Project title: **Modelling gas injection and migration through layered sedimentary sequences**

Abstract

Gas migration within sedimentary basins is central to both Carbon Capture and Storage (CCS) and hydrocarbon exploration, both of which involve fluid flow over large length and time scales (100 m to > 100 km; 1 yr to > 1 Myr). Seismic imaging is the primary tool for in-situ gas detection in both cases, but it is limited in resolution and can only provide qualitative information about the presence and distribution of gas. Theoretical models can be a strong complement to seismic observations, providing quantitative tools to inform physical understanding, answer basic feasibility questions, and, in CCS, to assess environmental risk and estimate storage capacity. We are developing a new model for gas injection into and migration through a multi-layered sedimentary sequence, where the source may be a wellbore (as in CCS) or a natural influx from a deeper source rock or reservoir. Our model incorporates compressibility in both fluids and, crucially, we also allow for leakage of both fluids across the seals, where the gas is subject to a capillary threshold.

Detailed modelling of fluid migration through layered sedimentary sequences will allow us to better understand how leakage enables inter-layer pressure communication, and how this impacts the evolution of the gas distribution in the sequence both during and after injection. Furthermore the model supports lateral and vertical heterogeneity in the permeability field, and in the capillary threshold pressure, allowing us to evaluate the effect of leakage within highly-heterogeneous sequences.

Michael Lacey

Email: michael.lacey@postgrad.manchester.ac.uk

Institution: University of Manchester

Supervisors: Dr Cathy Hollis, Dr Nima Shokri

Project title: **The effect of pore size and geometry on flow in carbonate pore systems**

Abstract

An estimated 60% of the world's oil and gas reserves are sourced from carbonate rock formations, yet the complexity of their pore systems is not yet fully understood. Carbonates have more unpredictable, multiscale pore networks, compared to siliciclastic equivalents. Understanding the effects of pore sizes and geometries on fluid flow would be beneficial to a number of processes, including reservoir flow simulation; understanding fluid entrapment and ultimately increasing recovery efficiency.

The project will look at fluid flow in porous carbonates at multiple scales in order to understand the controlling factors for fluid flow in complex, heterogeneous carbonates. X-Ray Computed Tomography will be used to create a database of pore geometric parameters for a number of samples. This database will then be used to create a micro-model for use in time-lapse two-phase flow experiments to assess fluid flow through models with differing pore geometries. These experiments will allow visualisation of the effects of pore geometry on recovery efficiency and entrapment, under different conditions of wettability.

Tin Tin Naing

Email: tin.naing@exeter.ox.ac.uk

Institution: University of Oxford

Supervisors: Dr Stuart Robinson,Prof Mike Searle, Prof Gideon Henderson

Project title: **Exploring the petroleum potential of a frontier province: Cretaceous stratigraphy and environments of coastal Myanmar**

Abstract

As a frontier exploration province, the Rakhine Basin which extends from onshore to offshore NW Myanmar. The basin lies in the active ocean-continent convergent plate boundary where Indian Plate is subducting beneath the Myanmar Plate. It lies in an active subduction regime and possesses very complex geological history. The stratigraphy and structure of the Rakhine Basin is poorly known and very little detailed structural mapping has been done on the area.

This project will be focused on the age and depositional environments of the onshore Cretaceous of coastal Myanmar, and identify and characterise possible source rocks deposited during the Cretaceous including those associated with oceanic anoxic events. These objectives will be achieved through a combination of geological mapping, integrated stratigraphy, facies analysis and organic geochemistry. The benefits of the project will make significant contributions of oil and gas exploration and increasing the geological background in Myanmar. A better understanding of the geological history for the Cretaceous sequence that will effect to identify prospects for hydrocarbon exploration in Rakhine Basin.

Hossam Osman

Email: h.osman14@imperial.ac.uk

Institution: Imperial College London

Supervisors: Prof Matthew Jackson, Prof Sebastian Geiger (Heriot-Watt), Prof Chris Pain

Project title: **Next generation reservoir simulation of complex reservoirs using control-volume-finite-element methods and unstructured, adaptive meshing**

Abstract

Reservoirs are inherently heterogeneous. The depositional environment, compaction, deformation and cementation can lead to variability in properties from the micro- to the macro-scale. The petrophysical properties associated with these heterogeneities can vary over many orders of magnitude and length-scales. It is well known that increased geological complexity leads to lower recovery factors. There is therefore a need for better modelling and simulation workflows such that optimal production strategies can be devised.

Conventional reservoir modelling workflows have adopted k-orthogonal meshes that are fixed in time and space. Due to the complex geometries found in reservoirs, a more flexible approach to meshing is needed that can capture (1) complex geological architectures, and (2) key aspects of flow that change through time. The goal of this research is to further develop the new reservoir simulation methods proposed by Jackson et al. 2015, that incorporate adaptive, unstructured meshes, by testing production scenarios of interest to the industry. These will include flow in fracture models and the reservoir scale SPE 10 comparative study model. This project will also aim to add to the current workflow by developing a well modelling methodology which will allow accurate modelling of complex well trajectories and flow in near-well regions. Numerical issues that arise during testing will also be resolved as part of this work.

Marco Pizzi

Email: m.pizzi15@imperial.ac.uk

Institution: Imperial College London

Supervisors: Dr Mike Mayall, Dr Lidia Lonergan, Dr Alex Whittaker

Project title: **Predicting slope reservoir distribution and quality through quantification of tectonics influence and autocyclic processes**

Abstract

Prolific hydrocarbon provinces occur in deep-water slope systems when sediment dispersal systems have interacted with the development of tectonically driven sea-floor topography forming structural and combined traps. The typical reservoirs are large, channel-complex systems and stacked sheet sands. Mass Transport Complexes (MTC's) are a common component of slope systems; they are rarely reservoirs, but can play a critical role in controlling the distribution of channel and sheet reservoirs. The aim of the project is 1) to quantitatively investigate the relationship between sea-floor deformation and the architecture of the reservoirs and 2) Integrate the impact of MTC's and autocyclic processes on reservoir distribution.

The slope region of the Niger Delta is an excellent area in which to examine this problem. An aerially extensive 3D seismic reflection dataset that extends ca. 120 km for the shelf edge to the toe of slope will be used for this study. The Niger Delta is commonly divided into an upslope region affected by extensional tectonic due to gravitational collapse which in turn produced contraction at the toe of slope where a thrust and fold belt has been growing since at least middle Miocene times. The growing folds have created topographic relief on the seabed with the main result of diverting, deflecting or ponding the incoming gravity flows and the turbidite channel belts, similar to processes described in other basins such as the fill-and-spill models in the Gulf of Mexico. Comprehensive mapping of the internal stratigraphy and variation of the seismic facies in channel complexes, sheets and MTC's within the Plio-Pleistocene growth sequence will be undertaken and integrated with previous work that has quantified the rate and timing of structural growth. In this way the impact that depositional elements interacting with each other, and with seafloor topography, have on distribution and location of the reservoir facies will be investigated, with the aim of reducing risks involved in the exploration and development of these types of reservoirs.

Daniel Possee

Email: djp1g15@soton.ac.uk

Institution: University of Southampton

Supervisors: Dr Derek Keir, Dr Kate Rychert, Dr Nick Harmon

Project title: **Seismic Imaging of the Crust and Upper Mantle beneath Haiti and the Caribbean Sea**

Abstract

Recent work by the US Geological Survey has indicated that the Greater Antilles is host to at least 142 million barrels of oil and 159 billion cubic feet of gas. This increases to a potential 940 million barrels of oil and 1.2 trillion cubic feet of gas that is currently undiscovered. The lack of understanding of earth structure and evolution, as well as the hazardous transpressional fault systems are major reasons why the majority of these hydrocarbons remain unexplored and unused.

The aims of this project are therefore to undertake passive seismic imaging beneath Haiti and the Caribbean Sea in order to understand crustal and mantle structures in the subsurface. The project will utilise an array of seismic stations deployed during the Trans-Haiti project, recording for a two-year period over 2013-2014. In addition, data from existing permanent stations from Haiti and the Dominican Republic will be used to increase both the density and spatial coverage of the network.

Initial work of the project will focus on imaging the nature of seismic anisotropy across the strike-slip fault systems that bisect Haiti striking east-west, which will reveal constraints on deformation in the deep crust and upper mantle. The results of this project should provide valuable information required for tectonic, geological and thermal history interpretations, which will be critical for petroleum prospectivity evaluation of the sedimentary basins in the region.

Jack Richardson

Email: JCR116@student.bham.ac.uk

Institution: University of Birmingham

Supervisors: Dr Carl Stevenson, Prof Ian Alsop (Aberdeen), Dr Nick Schofield (Aberdeen), Dr Craig Magee (Imperial)

Project title: **Revealing the internal flow of salt structures**

Abstract

The mobilisation and intrusion of salt plays a major role in the evolution of basins. Although the geometry and distribution of salt structures can be easily examined, the internal dynamics of salt intrusion are only partially understood. Modelling the influences of salt intrusion in basins, in particular predicting the future structural and thermal evolution of a basin and the related effects on the hydrocarbon habitat, are limited.

In order to overcome this impasse in salt tectonics, detailed and high quality strain data is required from salt outcrops. To obtain structural data we will use anisotropy of magnetic susceptibility (AMS) measurements on oriented samples from mine exposures. This technique measures the distribution and orientation of any detrital magnetite or Fe-bearing clay minerals within the salt. Where these are absent, the crystal lattice of halite or gypsum can also produce a measurable signal.

Fabric data derived from AMS analysis will provide crucial information about the strain field allowing a comprehensive view of the flow of the salt. Fabrics mapped in 3D from mine exposures will generate the first internal flow model for salt based on empirical data.

David Taylor

Email: david.taylor-8@postgrad.manchester.ac.uk

Institution: University of Manchester

Supervisors: Dr D. Hodgetts, Prof. J Redfern, Dr E. Finch

Project title: **Numerical simulation of braided river systems for improved object and MPS based reservoir modelling**

Abstract

Current object-based reservoir modelling approaches do not allow for the generation of geologically realistic geometries and relationships between facies. This problem has been addressed to some extent by the introduction of Multi-Point Statistics or MPS approaches which allow a training image to be used to define facies geometries and relationships, though a training image still needs to be built, and this is often done with object based modelling. The problem of initially defining relationships between facies therefore has not been solved, but simply moved to another part of the modelling workflow.

The project aims to develop and use numerical simulation of braided fluvial systems to build geologically realistic geobodies, or objects, to directly populate the reservoir model, and/or provide more realistic training images for MPS modelling. A processed-based approach will generate models from their fundamental controls, rather than 'best-fit' object-based models. Each model will be calibrated against global modern river systems and their geological counterparts, both offshore and onshore, ensuring all scales of geological deposits are realistically represented within the braided fluvial system. Trends for populating subsurface-derived petrophysics can then be deduced, providing more realistic models of flow for reservoir management and production. Specific conditioning data will use the Triassic of the Bay of Fundy, and sub-surface North Sea data, adding to a large in-house digital outcrop database to test pattern-matching algorithms. Additionally, the models will provide a virtual training centre for investigating the factors controlling braided river formation and evolution.

Tom Utley

Email: thomas.a.utley@durham.ac.uk

Institution: University of Durham

Supervisors: Prof Bob Holdsworth, Prof Ken McCaffrey, Andy Conway (ConocoPhillips), Dr Richard Jones (Geospatial Research Limited)

Project title: **A reservoir-scale structural reappraisal of onshore Devonian analogues of the Clair Group in the Fair Isle-Shetland region**

Abstract

The Clair field, situated to the west of Shetland, represents the largest hydrocarbon resource in the UKCS and is comprised of fractured Devonian sandstones that overlie an up-faulted ridge of fractured Precambrian metamorphic basement. The onshore, broadly extensional Orcadian basement has long been used as an analogue for the Clair field. During development of the field, especially with the development of the Clair Ridge, increasing complexity in both the sub-surface structure and basement cover relationships suggest that strike slip tectonics may have played a role in the evolution of Clair during the Devonian period.

The project will reappraise the stratigraphy, structure and tectonic evolution of an alternative onshore analogue to Clair, using the Fair Isle-Shetland-Foula region as an analogue for looking at the role of Palaeozoic tectonics on basin development and later Mesozoic reactivation. This will be achieved through detailed studies of exposed basement-cover contacts and the structure of the overlying sandstone-dominated sequences exposed in large coastal sections. Fieldwork will be supplemented by the use of photogrammetry and terrestrial LiDAR to capture the geology of key localities. 3D models of the stratigraphy and structure will be created for use in numerical simulations of fluid flow, up-scaling and reservoir quality studies. The findings will be compared and applied to the current information and models which concern the stratigraphic and structural architecture of the Clair field and its regional tectonic setting.

James Van Tuyl

Email: VanTuylJ@cardiff.ac.uk

Institution: Cardiff University

Supervisor: Dr Tiago Alves, Dr Lesley Cherns, Dr David Gamboa

Project title: **Carbonate platforms on Equatorial Margins: Geometry, evolution and importance as hydrocarbon reservoirs**

Abstract

Carbonate platforms are ubiquitous on Equatorial Margins, comprising prolific reservoirs. Reservoir potential depends on basin-scale factors, including depositional facies variations, secondary dissolution, karstification and dolomitisation. The relationship between the 4D evolution of carbonate platforms and secondary processes that may enhance reservoir potential, renders the correct interpretation of platform geometry vital in understanding their economic importance.

Research on carbonate platforms often relies on outcrop analogues. However, this project uses high-resolution 3D seismic and borehole data from NW Australia (Browse Basin) to characterize the growth and demise of Cenozoic carbonate platforms, through analysis of geomorphological features associated with enhanced reservoir potential and the way(s) the platforms grew in time and space on a margin characterized by oceanic currents and winds. Field analogues from SE Spain (Almeria) will document variations in depositional facies produced by geomorphological and eustatic changes.

In summary, this project aims to:
a) Reconstruct the 4D evolution of carbonate platforms on the Browse Basin, identifying regions of best reservoir potential.
b) Correlate local and regional sea-level variations with main periods of platform growth (and demise) in Equatorial waters.
c) Identify major oceanographic, climatic and tectonic events in both NW Australia and SE Spain, and resulting impacts on the evolution of carbonate platforms.
d) Identify the distribution and types of faults, salt structures and mass-wasting deposits on the carbonate platforms of NW Australia, and their control(s) on karst systems.

Claire Veillard

Email: claire.veillard14@imperial.ac.uk

Institution: Imperial College London

Supervisors: Dr C. John, Dr S. Krevor

Project title: **Diagenetic processes in carbonate reservoirs: from direct investigation to modeling of pore-scale diagenesis**

Abstract

Dolomitization [ie: the transformation of calcite into dolomite] is a common diagenetic process affecting 50% of the world's carbonate rocks. It consists in the replacement of Ca by Mg ions in the mineral lattice and has various effects on the pore space. A mole per mole replacement of calcium by magnesium results in a 13% gain in porosity. Moldic porosity can also be formed by dissolution of dolomite. However, overdolomitization can make a reservoir completely tight. Understanding dolomitization is therefore critical for the oil and gas industry.

Yet, the dolomitization process itself is still poorly understood. The present project focuses on the Late Oligocene to Late Miocene Marion Plateau (offshore NE Australia), a well-suited carbonate platform for studying early marine dolomitization. The carbonate primary fabric is very homogeneous and affected by dolomitization in various degrees, ranking from barely to completely dolomitized. Thus, facies with variable degrees of dolomitization can be recovered and used as a "timeline" of the evolution of dolomitization within the Marion Plateau. Another advantage of the region is that the Marion Plateau has been intensely studied and the chronostratigraphy is very well constrained. The platform growth is mainly controlled by sea level variations caused by long-term Antarctic glaciation events. There are also circumstantial evidences from pore-water geochemistry that the dolomitizing fluid is normal seawater, and that dolomitization might still be active today.

In this project, we propose to use the clumped isotopes method to infer the origin and thermal history of dolomitization of the Marion Plateau. Developed in the last decade, the method consists in measuring the amount of clumping of 13C-18O bonds in the carbonate lattice. Based on equilibrium thermodynamic, the amount of clumping, i.e. the abundance of mass 47 isotopologue of CO2 relative to a stochastic distribution only depends on temperature. Therefore, the method allows calculating the temperature of dolomite growth independently from the parent fluid composition. In parallel to the fluid and temperature characterization, Marion Plateau samples will be analysed at the pore scale. Measurements in 2D (thin sections) and 3D (XCT scanner) aim to characterize the various stages of dolomitization with various parameters such as crystal size, distribution, nucleation sites, tortuosity etc. Finally, all the previous results will be parameterized in reactive transport models (RTM's). Modelling objectives are to emulate the natural samples at pore-scale to provide constraints on the kinetic and geochemical parameters needed for dolomitization at low-temperature.

Stavros Vrachliotis

Email: stavros.vrachliotis@pet.hw.ac.uk

Institution: Heriot-Watt University

Supervisor: Prof John Underhill, Dr Rachel Jamieson

Project title: **The causes and consequences of punctuated contraction on passive continental margins**

Abstract

The evolution of passive continental margins has typically been understood by a standard rift-drift model in which the locus of active tectonism migrates and localises towards the basin centre after continental breakup and formation of oceanic crust. Acquisition of seismic data along passive continental margins worldwide has permitted closer examination of the stratigraphic relationships within the post-rift section and found anomalous periods of deformation (folding and uplift), which do not fit the model of passive subsidence.

Passive margins, particularly, the Atlantic Margin have been studied in greater detail in recent years due to the acquisition of high fidelity subsurface datasets to evaluate oil and gas prospectivity. The results of those studies show that the Atlantic and other passive continental margins are characterized by seismic-scale folding and unconformity development which post-date active rifting and cannot be adequately explained by passive mechanisms such as sea-level variations, soft sediment deformation or differential compaction. The identification of such events suggests that these margins were affected by compression, uplift and erosion at various times and that continental margin evolution was not driven solely by passive thermal relaxation following syn-rift stretching, but was punctuated by short-lived phases of basin inversion.

Such margins can also host large scale geological features like volcanic intrusions and extrusions as well as mobilised salt deposits that render the subsurface a demanding environment for seismic data acquisition and interpretation. Advances in seismic acquisition and processing have recently led to a better and deeper imaging of the subsurface allowing for a more accurate interpretation of the deeply buried and more ambiguous marginal parts along with their relation to the subsequent marginal evolution. This provides a new opportunity to study the evolution of passive margins and to add to and challenge the previous assumptions about their formation.

The overall aim of the project is to understand the evolution of selected areas of passive continental margins and place them in a regional context. A particular focus is given to periods of deformation that are anomalous with respect to the standard model of margin formation and have not been satisfactorily described in literature, in part due to poor imaging at depth. The project uses new subsurface seismic and well data from strategic areas such as the Namibian offshore to understand the effects of rifting through time and examine the impacts that deformation has on both the geological evolution of the margin and the relevant petroleum systems.

Faye Walker

Email: faye.walker@abdn.ac.uk

Institution: University of Aberdeen

Supervisor: Dr Nick Scholfield, Dr Malcolm Hole, Prof David Jolley, Dr Simon Holford (Adelaide), Dr Margaret Stewart

Project title: **Linking rifting history and magmatic cyclicity West of Britain (WoB)**

Abstract

The tectonic and volcanic evolution of basins to the west of Britain (WoB), particularly the Rockall Basin, is largely uncertain. Although a Rockall petroleum system has been shown to exist (e.g. the Benbecula discovery), the basin is underexplored with only a few wells drilled to date.

Following recent success in exploration associated with volcanic stratigraphy (e.g. Rosebank field), the prospectivity of the Rockall Basin is currently being reevaluated. However, in order to undertake a regional correlation of strata it is necessary to have a detailed volcanic stratigraphic framework and understanding of how this relates to rifting. Using regional seismic data combined with well control, plus biostratigraphical and geochemical control, my project aims to determine the detailed rifting history of the basin and how this relates to the magmatism. This will be accomplished using the following methods:-

1. Analyse 3D seismic and well data to form a detailed volcanic and magmatic stratigraphy WoB.
2. Integration with emplacement temperatures derived from mineralogical data.
3. Integration with mega-regional rifting history.

Jack Walker

Email: J.Walker8@newcastle.ac.uk

Institution: Newcastle University

Supervisor: Dr Cees van der Land, Dr Martin Jones, Dr Christian Maerz, Dr Howard Armstrong (Durham), Prof Andy Aplin (Durham), Dr Jonathan Imber (Durham), Dr Edward Hough (BGS), Dr Jan Hennison (BGS)

Project title: **Shale Gas in the UK – Geochemical mapping of critical shale properties across Carboniferous basins**

Abstract

The Pendleian Upper Bowland Shale Formation (UBSF) is a target for UK shale gas extraction. Reliable well correlation is limited due to grain size homogeneity, but needed as folds and extensional faults increase uncertainty. Currently, maximum flooding surfaces - so called 'marine bands' - are used as stratigraphic marker beds. Marine bands are enrichments of specific goniatite index fossils, formed during periods of enhanced fossil preservation. As UBSF goniatite fossils are poorly preserved and challenging to identify, organic and inorganic geochemical analyses are used alongside biostratigraphy. However, the exact relationship between marine band geochemistry and basin palaeoceanography is poorly understood..

Here we present a lateral comparison of sedimentological, palynological, biomarker and elemental data across two cores (from north west UK) and at outcrop (Clitheroe), transecting the palaeobasin.

Janis Aleksans

Email: j.aleksans.1@research.gla.ac.uk

Institution: University of Glasgow

Supervisor: Dr Daniel Koehn

Project title: **Dynamics of hydrofracturing and micro-seismic signals in porous versus tight rocks.**

Abstract

There are still many open questions on the dynamics of hydrofracturing and fluid-solid interactions in geological systems. Monitoring fluid movements and fracturing during fluid injection is currently a key topic for exploration and production of unconventional hydrocarbons. In this project we will analyse the development of fracture patterns and their associated micro-seismic signals. We will expand an in-house developed hydromechanical simulation code that deals with fracturing as a function of fluid pressure and gravitational and tectonic forces.

The model is state of the art (see Ghani et al. 2013) and is under constant development. It solves the full time-dependent coupling between a deforming solid and a compressible fluid in a porous rock. The main aim and objectives of the proposed project are to:-

a) gain insights into the dynamic scaling of hydrofracturing in time and space

b) understand the differences of fracture development in porous versus tight systems with the possibility to include complementary modelling techniques

c) extract detectable signals from the model including local solic movements and elastic energy release during fracturing, and relate them to micro-seismic signals, used for fracking monitoring and

d) compare signals from the model with those from natural systems and calibrate the model under different scenarios in order to use it as a predictive tool for industry.

Our objectives are directly linked to the NERC strategic directions in developing new and innovative tools to understand our planet and help in exploration and production of new resources. The deliverables are:-

a) further develop the existing simulation code to understand controls on hydraulic fracturing

b) expand the model to produce geophysical signals that can be compared to real measurements and

c) calibrate and use the model as a predictive tool

Elizabeth Atar

Email: elizabeth.atar@durham.ac.uk

Institution: University of Durham

Supervisor: Prof Andy Aplin

Project title: **Temporal and Spatial Heterogeneities in the Jurassic Kimmeridge Clay.**

Abstract

The investigation of mudstone heterogeneity is a key tool used by both palaeoclimatalogists and the petroleum industry alike. Mudstones capture the most 'complete' sedimentary record and therefore make excellent datasets for investigating the climatic, tectonic and geographic controls on sediment deposition, oceanic and atmospheric processes, environmental perturbations, and the evolution of flora and fauna. This information can enhance our understanding of organic richness, quality and thickness within proven and yet-to-be discovered source rocks.

This project aims to determine whether or not a global-scale climate model can be invoked as a key driver in the heterogeneity and the variations in organic carbon enrichment observed in the Kimmeridge Clay Formation. A combination of petrographic and geochemical data, including mineralogical, elemental, RockEval, carbon and lithium isotopes data, is being used to ground truth an atmospheric model, which invokes an orbitally-modulated expanded atmospheric Hadley Cell as the main driver behind widespread deposition of organic-rich sediment throughout North-West Europe in the Upper Jurassic. This work has potentially profound implications for hydrocarbon prospectively as it may demonstrate the use of ocean-atmospheric coupled climate models are source rock prediction tools.

Results to date suggest that climate played a key role in the deposition of the Kimmeridge Clay Formation in Dorset and Yorkshire, but it is not yet clear to what extent oceanographic responses and/or changes in weathering patterns affected the mudstone deposition. Further work includes more detailed coupled ocean-atmosphere climate modelling and investigation in to the sedimentology and geochemistry of laterally equivalent deposits at higher latitude.

Ulrike Baranowski

Email: ukb407@bham.ac.uk

Institution: University of Birmingham

Supervisor: Prof Tom Dunkley Jones

Project title: **Early Eocene Palaeoenvironmental and Tectonic Reconstructions of the Rockall Trough.**

Abstract

The aim of this project is to generate a new palaeoenvironmental, palaeogeographic and palaeoclimatic understanding of the early and middle Eocene NE Atlantic. This has been made possible by the re-sampling of existing core material from the Rockall Trough, which include a sequence of early and middle Eocene marly clays with exceptional microfossil preservation. The preservation of calcareous nanofossils (coccoliths), foraminifera, dinoflagellates, pollen and spores in one sequence provides a unique opportunity to produce an integrated assessment of marine and proximal terrestrial environments, palaeoclimate, palaeoceanography and palaeobathymetery.

This PhD project will work on components of this microfossil assemblages to develop new assemblage-based and geochemical proxy derived (stable isotopes, trace metals, organic biomarker) palaeoenvironmental reconstructions of the early and middle Eocene. This project also seeks to integrate geophysics-derived estimates of uplift and subsidence at the site with micropalaeontological evidence for changes in water depth (benthic assemblages) and shoreline distance (terrestrial inputs). The rate of uplift-subsidence in this region is an important component in understanding seal breaching events in regional oil fields, and also in re-constructing the broader Palaeogeography of the NE Atlantic including the timing of the opening of the proto-Greenland Scotland Ridge oceanic gateway to the Arctic.

Ginny-Marie Bradley

Email: ginny-marie.bradley@postgrad.manchester.ac.uk

Institution: University of Manchester

Supervisor: Prof Jonathan Redfern

Project title: **Developing better reservoir models for Early Palaeozoic, (pre land plants), mixed continental/marine depositional systems, with improved reservoir characterisation and architectural input**

Abstract

My research focuses on the sedimentology, processes of deposition and geometries of deposits from Lower Palaeozoic fluvial systems and how this influences the reservoir. These systems are believed to be different from that of "modern" fluvial systems due to the lack of vegetated overbank, which not only gives stability to the fluvial system due to rooted plants but also introduces fine-grained material, such as clay and mudstones. In fluvial systems it is known that the fine-grained element can baffle or block the migration of oil and gas through the reservoir creating compartmentalisation. It is possible that in pre-land plant systems this does not happen and there may be other factors that influence migration through the reservoir interval such as sorting, maturity or cementation. Current models of meandering and braided systems are not applicable to the sheet-braided systems before vegetation colonised land.

The main fieldwork for this PhD will focus on the outcrops in Kalbarri, Western Australia, where a river gorge has exposed over 50km of Cambrian to Silurian fluvial to marine sandstones; the Tumblagooda Sandstone. The age of the formation is still much in debate.

Reservoir models will be produced by using differential global positioning system (DGPS), digital photogrammetry and drone photogrammetry. This dense dataset along with outcrop logging will allow the mapping of facies, geological object distribution and architecture of the channels and their geometries.

David Byrne

Email: david.byrne@earth.ac.uk

Institution: University of Oxford

Supervisor: Prof Chris Ballentine

Project title: **Using noble gas isotopes to develop a mechanistic understanding of shale gas processes**

Abstract

The discovery of shale gas in UK Shales demonstrates how important this source of natural gas will be for UK and Europe; with estimated gas reserves significantly more than the sum of all known UK gas fields. Nevertheless, gas reserves do not directly translate into extractable gas volumes. Estimates of gas in place require knowledge of how the gas is trapped within the rock, absorbed on its surface, or dissolved in the pore space waters – all of which are poorly understood and no doubt will vary from shale to shale. An improved understanding of the controls on gas production from each of these sources is required for more accurate estimates of ultimate gas recovery and will provide critical information in the development of more efficient extraction techniques.

Ricardo Celestino

Email: R.F.S.Celestino@exeter.ac.uk

Institution: University of Exeter

Supervisor: Prof Stephen Hesselbo

Project title: **Lower Jurassic Source Rocks of Germany and Netherlands**

Abstract

The pattern of Early Jurassic 'black shale events' that relate to global perturbations to the carbon cycle s becoming quite well known for the Early Jurassic, where several such events have been described from NW Europe basins and elsewhere. What is much less well known is how these black shale events relate to regional or global sea-level changes, and the effects of basinal tectonics and palaeogeography on organic matter enrichment and quality within individual basins.

This project takes advantage of extensive industry core and geophysical data from the Lias of Germany and the Netherlands. I will integrate the available data and set the black shale occurences within an overall framework of basin evolution to determine the fundamental controls on local organic enrichment. Detailed chemostratigraphic, petrological (SEM, EDS) and organic geochemical studies will be undertaken, in addition to working with wire-line log and seismic reflection datasets, in order to arrive at an interpretation across the complete range of observational scales. I am part of a larger team of industry-funded researchers working on diverse aspects of mudrock science, both at Oxford and Exeter, and will benefit from access to state-of-the-art analytical and imaging facilities at both institutions.

Eoin Dunlevy

Email: eoin.dunlevy@postgrad.manchester.ac.uk

Institution: University of Manchester

Supervisor: Dr Mads Huuse

Project title: **Shelf edge processes and reservoir architecture on high-sedimentation rate clastic/volcanic basin margins, Taranaki Basin, New Zealand**

Abstract

The importance of shelf margin evolution has increased in recent years as hydrocarbon exploration targets have shifted to deepwater areas; this has resulted in a need for greater understanding of sediment dispersal along continental margins in order to predict position, timing and nature of deepwater deposits. The evolution of these continental margins can be studied in detail by dissecting clinoform architectures. These clinoforms are controlled by the interplay of accommodation and sediment supply which has traditionally been studied using sequence stratigraphy and more recently trajectory analysis.

This study focuses on the Giant Foresets Formation in the Taranaki Basin, New Zealand and utilises regionally extensive 2D and 3D seismic datasets calibrated with petroleum exploration wells. Using these data this project aims to investigate along margin (approx. 300km) variability in sediment distribution and the relationship to clinoform stacking patterns. These observations will be put into a sequence stratigraphic framework in order to relate interpretations back to eustatic, tectonic and oceanographic processes with the ultimate goal of aiding in prediction of deepwater deposits.

Victoria Elliott

Email: victorie@earth.ox.ac.uk

Institution: University of Oxford

Supervisor: Prof Joe Cartwright

Project title: **The effects of subsidence, burial and uplift on prospective shale gas reserves; insights from the structural and thermal history of northern England's Carboniferous Basins**

Abstract

The Carboniferous Bowland and Cleveland Basins of Northern England have recently been estimated to contain abundant shale gas reserves in studies conducted by the British Geological Survey (Andrews 2013) and UK academics (Slowakiewicz 2015).

Most existing wells in these basins were drilled for conventional hydrocarbon exploration and production. As a result, the majority of such wells only penetrate (or core) the upper Carboniferous successions and younger, meaning there are few boreholes that penetrate the shale succession of interest. This presents uncertainties as it is leaves wide areas unsampled for subsequent geochemical analyses or to be tested with geophysical logging tools. A key uncertainty is the thermal maturity of the deep, lower Carboniferous shales that are rarely sampled for thermochronological testing i.e.Vitrinite Reflectance Analysis.

The primary aim of the project is to evaluate how basin subsidence, burial and uplift affect prospective shale gas bearing successions. The key elements that are suspected to be affected are the maturity of organic matter, duration of petroleum generation, flow rate and retention and preservation of resource.

Datasets that will be analysed in an attempt to constrain the geological history include onshore 2D seismic reflection data, well data, well and outcrop samples. Analyses that will be conducted include the interpretation of the 2D seismic data, with particular interest in the mapping of unconformities and lateral thickness changes in seismic stratigraphic packages. This combined with detailed well stratigraphy information will enable the construction of burial and subsidence curves for various positions throughout the basin. Thermochronological methods such as Apatite Fission Track Analysis (AFTA) and Vitrinite Reflectance will be employed to constrain the amount and rate of uplift. Integrating these methods will ultimately enable the construction of 2D and 3D models of the basin history in terms of subsidence, burial, uplift and subsequent erosion.

Ross Grant

Email: rjg1@hw.ac.uk

Institution: Heriot-Watt University

Supervisors: Prof John R. Underhill, Dr Rachel Jamieson

Project title: **Unravelling the controls on the Permian and Mesozoic structural-stratigraphic evolution of the southwestern margin of the Southern North Sea**

Abstract

The Southern North Sea Basin is a prolific (gas-prone), hydrocarbon province and as such benefits from good data coverage in the basin centre where the majority of the prospectivity has historically been found. However, with the maturation of the basin, attention has shifted to the less well understood margins of the basin. This study focuses on the SW margin of the basin where Upper Permian age evaporites of the Zechstein are well known to have a major control on prospectivity in the prolific gas basin, providing a regional super-seal to the main prospective Rotliegend Group (Leman Sandstone) reservoirs below. The evaporites have also served to decouple sub- and supra-Zechstein structures, allowing large amounts of thin-skinned extension to occur in the supra-salt cover during the Mesozoic leading to the formation of a complex graben system around the basin periphery.

Our strategic study location permits the investigation of the role that basinal evaporites deposited beyond the Zechstein (Z1-Z2) carbonate-anhydrite dominated shelf, have in controlling and decoupling structural styles in the supra-Zechstein section from those in the sub-salt section. Using well-calibrated, detailed 3D seismic interpretation along the SW margin of the basin we assess:

1. The impact the interplay between basement structure, Zechstein shelf-to-basin facies changes, and complex overburden deformation have had on the structural styles and post-Zechstein tectonic evolution of the graben during punctuated Mesozoic extension during the Mesozoic and Late Cretaceous-Early Cenozoic basement inversion.

2. The implications for hydrocarbon prospectivity due to the profound effects on seismic imaging and depth conversion by the occurrence of thick, low velocity sediments within the graben, and the effect strong lateral and vertical variations in velocity between anhydrite, dolomite and halite associated with the Zechstein shelf-edge have on velocities.

Furthermore, we have revealed the detailed palaeomorphologic nature of the Zechstein shelf-edge to be more complex than previously envisaged thus offering further insight into the geological evolution of this ancient carbonate-evaporite margin.

This study has significant implications not only for our understanding of the evolution of the basin, but also for future exploration in the area. It is hoped the results will provide an improved understanding of the nature and distribution of traps containing the highly prospective Rotliegend Leman Sandstone Formation in the underexplored areas of the basin margin were past exploration success has been poor. Furthermore, detailed, high-resolution and well-constrained study of a carbonate–evaporite basin margin system analysing its role in the structural and stratigraphic evolution of the basin and its influence on the petroleum system has generic applications in other basins where data quality may be poorer.

Jonathon Hardman

Email: r01jph14@abdn.ac.uk

Institution: University of Aberdeen

Supervisor: Dr Nick Schofield

Project title: **Unlocking the intra and sub-basalt hydrocarbon prospectivity West of Shetland**

Abstract

The intra-basalt and sub-basalt domains of Faroe-Shetland Basin (FSB), represent arguably the last frontier area of hydrocarbon exploration of the UK territorial waters. A major oil and gas discovery was made within the Palaeocene/Eocene lavas in the form of the Rosebank field in 2004. Unusually, the reservoir intervals are a series of intra-basaltic fluvial to shallow marine sequences, separated by basalt lava flows and other volcanic products, giving rise to a new hydrocarbon play concept.

The project will

1. Undertake 3D seismic and well analysis (including Biostrat and Geochemistry) to form a detailed stratigraphic link between the uplift related incision events and lava stratigraphy

2. Identify major sediment routes into the lava field from the Judd Basin area (and elsewhere)

3. Aim to identify areas of potential future intra- & sub-basalt prospectivity.

Jamie Hizzett

Email: jlh2g14@soton.ac.uk

Institution: University of Southampton

Supervisor: Dr Esther Sumner

Project title: **Understanding how turbidity currents interact with the seafloor and oil and gas pipelines**

Abstract

Turbidity currents dominate sediment transport into many parts of the deep ocean, and form some of the world's largest sediment accumulations, which can contain major oil and gas reserves. These flows may travel at speeds of up to ~20 m/s, and erode the seafloor. The sediment concentration of turbidity currents has never been measured directly in the deep ocean, in any location, and understanding their character is a major scientific challenge. They pose a credible threat to offshore seafloor oil and gas infrastructure and nearshore Liquified Natural Gas (LNG) terminals.

The largest and fastest turbidity currents may rupture pipelines leading to catastrophic loss of hydrocarbons to the marine environment. Even relatively dilute and low impact turbidity currents may generate scour around seafloor structures, causing structural or operational issues which can be technically challenging to remedy in ultra-deep water settings. A greater understanding of potential impacts and consequences of turbidity currents is required; hence this project aims to provide quantitative and directly applicable inputs to industry risk assessments and mitigation strategies. This will include calibration of numerical models, as well as providing recommendations for pipeline route acceptance criteria or areas for safe installation.

The first part of the PhD will use a novel experimental technique (electrical resistivity tomography) to analyse dense, near-bed layers within turbidity currents, and their implications for impact forces on seafloor infrastructure. Near-bed dense layers exert most stress on seafloor structures, and may also cause scour. These layers have previously been extremely difficult to document and analyse. A NERC Oil and Gas Catalyst award has funded development of electrical resistivity tomography that enables measurement of sediment concentration profiles within dense near-bed layers. After linking the velocity, turbulence and sediment concentration properties, these links will be parameterised and implemented in existing numerical hazard models to quantify impact stressed exerted on seafloor structures.

The PhD will then consider the origin of deepwater near-surface crusts that hamper installation of seabed structures, and implication for scour by turbidity currents. Existing cores as BOSCORF in Southampton and industry datasets will be analysed to constrain their geotechnical properties. Geotechincal testing will be combined with SEM images to determine the origin and structure within the crust. Outputs formulated from experimental and theoretical work will be incorporated within existing industry-developed Finite Element software to assess stresses imparted by turbidity currents, and the significance of scour for pipeline integrity.

Rachael Hunter

Email: rmh1@hw.ac.uk

Institution: Heriot-Watt University

Supervisor: Prof John Underhill

Project title: **Investigating the Role of Structural Inheritance and Crustal Heterogeneity in the Evolution of the North Sea**

Abstract

Continental crust is inherently heterogeneous and most areas are underlain by a deformed and fractured crustal substrate. The role of structural inheritance, where these basement lineaments exert control on subsequent phases of tectonic deformation, is often considered a primary control on fault geometry and sedimentary basin evolution. However, many structural models still tend to assume a homogeneous crust and the effects of inheritance remains incompletely understood especially where different configurations and orientations of faults are superimposed. The aim of this PhD research is to investigate the effects of structural inheritance in the North Sea Trilete Rift System due to its multi-phase tectonic evolution and extensive subsurface data library. Seismic stratigraphic and structural interpretation of strategically chosen case studies will be undertaken to permit an assessment of the pre-syn-rift (sub-Lower Jurassic) North Sea basin configuration and the extent to which this influenced the subsequent syn- and post-rift evolution. Initial results have highlighted the influence of structural inheritance within both the Utsira High and East Shetland Platform areas. In the former, this directly influenced the evolution and hydrocarbon prospectivity of the Johan Sverdrup Field through creation of the structural closure, while in the latter case the inherited structures played a role in controlling the distribution of the Nuggets turbidite fans. These studies have demonstrated the importance and variability of the effects of structural inheritance and will be later integrated with others targeting areas displaying differing structural trends to not only enhance our understanding of inheritance controls in the North Sea, but also more widely through its generic application to rift transection by offering an analogue to other basins limited by data coverage and resolution.

Nathaniel Forbes-Inskip

Email: nathaniel.forbesinskip.2014@live.rhul.ac.uk

Institution: Royal Holloway

Supervisor: Prof Agust Gudmundsson

Project title: **New Methods for Maximising Shale Permeability and Minimising Risk During Hydraulic Fracturing**

Abstract

Within the framework of rock-fracture mechanics, rock physics and sedimentology there are three aspects of hydraulic fracturing of gas shales that need to be addressed:-

1) how to maximise the surface areas, interconnectivity and permeability of the induced fracture network

2) how to confine the network within the target layers (e.g. so that fractures do not propagate up into aquifers) and

3) how to assess and mitigate induced earthquake risk

All three relate to the composition and lamination/layering (fissility) of the shales and adjacent rocks. More specifically, hydraulic fracturing of gas shales requires that fluid-driven fractures propagate through numerous contacts of laminated/layered rocks. Field studies show that such contacts commonly arrest or deflect fractures, thereby decreasing the chances of forming well-interconnected, extensive and highly permeable fracture networks.

This project will provide field and laboratory tested theoretical tools for maximising the chances of forming an extensive high-permeability fracture network that is confined to the target layer and minimises seismic risk.

Scott Jess

Email: r01sj14@365abdn.onmicrosoft.com

Institution: University of Aberdeen

Supervisor: Prof Randell Stephenson

Project title: **Resolving the timing of major erosion events along the West Greenland-Baffin-Bylot continental margins**

Abstract

The continued exploration for oil and gas reserves requires a greater understanding of frontier geology. My research focuses on the recent geological history of the eastern Baffin Island and western Greenland, which border the Labrador Sea, Davis Strait and Baffin Bay, areas of frontier exploration since the 1970s. Recent investigations have produced two possible scenarios to explain the regions low relief, high elevation topography with the suggestion of erosion to near sea level preceding a Neogene uplift regime has been opposed by the proposal of slow continuous erosion over the past 800Myrs.

Low temperature thermochronology is used as a method of understanding margin evolution; however with new developments and techniques becoming available to the discipline, a re-examination of older work and the incorporation of new data could yield more effective conclusions. Initial work focuses on the tectonic history of onshore west Greenland and its controls on basin fill, with later work moving further afield and exploring other margins surrounding Baffin Bay and their histories.

Bhavik Lodhia

Email: b.lodhia14@imperial.ac.uk

Institution: Imperial College London

Supervisor: Dr Gareth Roberts

Project title: **Uplift and Deposition of Sediment at Passive Margins: Examples from Africa**

Abstract

It is generally accepted that histories of sedimentary flux at passive margins contain information about uplift and erosion histories onshore. Inversion of drainage inventories for uplift histories suggests that we can quantitatively link long-term uplift onshore and delivery of sediment to passive margins. We use an inventory of 14882 river profiles in Africa to invert for Cenozoic histories of uplift and predict erosion rates. We test our model by comparing predicted rates of sedimentary flux to our measurements of solid-sediment flux offshore Mauritania-Senegal and the Mozambique Channel. The drainage inventory was extracted from the 3 arc second SRTM dataset. The stream power erosional model was calibrated using independent observations of marine terrace elevations and ages. Solid sedimentary flux was measured from decompacted isopach volumes mapped using dense 2D seismic reflection and well data. Our preliminary results suggest that we can close the loop between Cenozoic uplift onshore and efflux to west and east Africa's passive margins. Calculated uplift and erosion is staged and suggests that African topography was rejuvenated during the last ~30 Ma.

Sean O'Neill

Email: sean.oneill@durham.ac.uk

Institution: University of Durham

Supervisor: Dr Stuart Jones

Project title: **Pore pressure distribution, overpressure evolution and reservoir quality variations across a tectonostratigraphically complex basin, Taranaki Basin, New Zealand**

Abstract

The Taranaki Basin is New Zealand's only hydrocarbon producing basin, and lies onshore and offshore in the central-west of the North Island. The polyphase nature of the Taranaki Basin has led to a complex pore pressure history, generating significant variations in present day vertical and lateral distribution of overpressures. Cretaceous to Early Miocene Formations can be found both normally pressured (near or at hydrostatic) and significantly overpressured (>1500 psi/10 MPa) at the same depth in separate parts of the basin.

The Northern Graben of Taranaki Basin is characterised by rapidly subsided narrow fault bounded grabens, which contain up to 8 km of predominantly fine grained sediments. These grabens act as independent pressure compartments with laterally sealing faults and thick competent top seals, which inhibit lateral and vertical drainage leading to maintenance of significant overpressures of up to 4000 psi (28 MPa), calculated to be 730 psi (5 MPa) below fracture pressure. In comparison, the Western Stable Platform has remained relatively quiescent since the Cretaceous, and is characterised by progradational deposition on a structurally undisturbed, regionally subsiding sea floor. Increased sedimentation rates from the mid-Miocene drove the formation of limited amounts of overpressure, though this been laterally drained to stratigraphically shallower depths through high permeability pathways in the Paleogene stratigraphy, producing the near hydrostatic conditions observed today.

One dimensional burial history modelling has shown that distinct tectonic regimes present within the basin have generated a huge variation in the onset and subsequent development of pore pressures across the Taranaki Basin. This knowledge will enable the prediction of where shallow anomalously high overpressures maybe present and crucially where low vertical effective stress has allowed for the preservation of excellent reservoir quality to significant depths. This project will allow for the accurate spatial definition of overpressure which is crucial to implementation of effective well design, drilling safety, determination of hydrocarbon column heights and for exploration migration analysis.

Katy Oakes

Email: k.oakes@dundee.ac.uk

Institution: University of Dundee

Supervisor: Dr Michael Brown

Project title: **Assessing the impact and mitigation of earthquake hazards on O&G production infrastructure**

Abstract

Offshore production platforms, surface seabed infrastructure and drilling wells are increasingly being developed in hazardous environments where seismic loads and faults pose a threat to the integrity of vital energy supply chains. Earthquake fault interaction with oil and gas developments has significant damaging potential. Consequences may include discharge to the environment, threat to human life or major disruption of supply, all of which carry substantial financial penalties.

The direct impact of faulting interaction with jack-up rigs has surprisingly received little attention. Structural interaction with dip-slip faulting would generate differential vertical and horizontal displacements, possibly leading to the buckling of some of the key elements of the structure. Significant displacements could cause severe damage or even collapse. Previous work at the University of Dundee surrounding simple surface structures onshore has shown that it is possible to influence the nature of the fault-structure interaction in superficial deposits, (even changing the direction of the propagating fault), allowing the development of more robust structures or well arrangements.

This project will include the application of finite element modelling, assessing the impact of faulting on jack-up rigs. Key findings would be verified through the use of elevated G centrifuge testing using a bespoke earthquake faulting box for both superficial and weak rock analogues. This performance of jack-ups will be assessed and may well lead to improved design of foundation arrangement and deployment strategies for seismically active, fault prone regions.

The project will provide guidance for the development of new infrastructure in earthquake faulting zones and also for assessing the performance of retrofit options of existing infrastructure. The research will identify mitigation techniques and optimal structural and foundation arrangements, aiming to prevent the risk of catastrophic failure, loss of life and environmental discharge.

Asiri Obeysekara

Email: a.obeysekara14@imperial.ac.uk

Institution: Imperial College London

Supervisor: Prof J.P.Latham

Project title: **A Fully Coupled Discrete-Continuous Numerical Approach for Hydrofracture Interaction and Flow Modelling**

Abstract

Extraction of gas from shale rock and increased interest in storage of CO2 in the depleted basins has led to a growing interest to enhance the UK's geomechanical reservoir modelling capabilities by better understanding fluid driven fractures. The project hopes to improve current understanding of fractures and fluid flow through improvements in the numerical modelling of hydraulic fracturing: specifically the coupling formulation, enhanced fracturing realism in 2D and 3D, extension of the models to include poroelasticity of rock and fluid-leak off effects. Recent coupling schemes for modelling of hydraulic fracture propagation in porous media have been demonstrated using numerical methods with the cohesive crack model. The hydro-mechanical equations are solved using coupled Biot equation and Darcy's law to investigate fluid leak-off rate and length of fracture extension. The work reported in these recent studies have made considerable progress, however, the research has largely been focused on fracture propagation and has tended not to consider the role of poroelastic exchange of fluids between the pore spaces and inside the fracture. Using FEMDEM 2D and 3D codes 'Solidity' coupled to Multiphase flow code 'IC-FERST' in porous media this project hopes to take a further step forward and study fracture initiation together with fracture propagation in 2D and 3D with elastic response of the porous media. It is envisaged that enhanced modelling capabilities as well as the increased understanding of hydraulically induced fracture initiation and propagation will provide the knowledge and tools needed to tackle new and complex geomechanical problems in reservoir modelling and tackle the environmental impact in the oil and gas sector.

Nathan Rochelle-Bates

Email: nathan.rochelle-bates@postgrad.manchester.ac.uk

Institution: University of Manchester

Supervisor: Dr Stefan Schroeder

Project title: **Regional tectonostratigraphy of the pre-salt in the Benguela-Namibe Basins, Angola**

Abstract

Hydrocarbon discoveries in the pre-salt provinces of Angola and Brazil have put the Namibe and Benguela basins into the spotlight as a potential extension of this pre-salt play towards the south. Translation of these new plays into viable commercial success requires reducing the associated risks of frontier exploration and petroleum systems prediction. This, in turn, depends on improved understanding of the geological evolution of the South Atlantic at several scales of observation. My project is an integrated outcrop and subsurface study that aims to put constraints on the regional tectonostratigraphic framework: stratigraphic relationships of various rock units, depositional environments, basin configuration and paleogeography. The first part of the project will consist of GIS based outcrop mapping with the aim of producing a structural model, followed by analysis of offshore seismic datasets.

Tom Snell

Email: thomas.snell@durham.ac.uk

Institution: University of Durham

Supervisor: Dr Nicola De Paola

Project title: **Modelling Fluid Overpressure Driven Faulting and Seismicity within Low Porosity Seal and Tight Reservoir Rocks**

Abstract

Understanding how the development of overpressured fluid patches along seal and tight reservoir fault zones can act as nucleation sites and trigger earthquakes is critical. The main aim of the project is to deliver a set of numerical models where the strength evolution of seal and tight reservoir fracture/fault patterns is predicted as a function of the non-linear variation of their transport properties and pore fluid pressures, assuming natural fracture/fault patterns geometries. Predictions on whether fluid induced fracturing/failure can lead to earthquake nucleation or stable sliding creep conditions.

Silvia Sosio De Rosa

Email: silvia.sosio-de-rosa@strath.ac.uk

Institution: University of Strathclyde

Supervisor: Prof Zoe Shipton

Project title: **Fault zone architecture and deformation mechanisms of a normal fault in poorly lithified sediments, Miri (Malaysia).**

Abstract

The hydraulic behaviour of faults at depth plays an important role in the exploration and production of hydrocarbons, as well as in several other subsurface engineering applications, such as CO2 storage and radioactive waste disposal. Faults can act as conduits, barriers and combined conduit-barrier systems to fluid flow, and their overall bulk hydraulic behaviour is strongly deteremined by the internal fault zone architecture. The object of this study is a 25 m throw normal fault that cuts poorly consolidated deltaic sandstone-shale sediments of the Baram Delta (Miri, Borneo). The normal fault offers unprecedented 3D along-strike and sub-vertical exposure in due to the clearing of an area of land of land of 1 km^{22}. The aim is to investigate the highly variable nature of 1) the architecture of the fault and 2) the properties of the deformation elements and their influence on the hydraulic behaviour of the fault.. In the study area the succession is dominated by sand beds, with some interbedded clay-rich beds 0.2-2 m thick. The damage zone is characterised by deformation bands, zones of shear, folding and later fractures.The normal fault offers unprecedented 3D along-strike and sub-vertical exposure due to the clearing of an area of land of 1 km^2. The outcrop contains a major fault trending ENE-WSW and dipping south. It is not possible to correlate any bed from the footwall to the hanging wall because the main fault displaces the entire exposed stratigraphy, therefore only the minimum offset is constrained by the thickness of the hanging wall (25 m). The kKey observations are related to the along-strike thickness (1 cm - 80 cm) and clay content (<5% - 90%) variability of the fault core. Thin section analysis of the samples collected in Miri show particulate flow as dominant deformation mechanism, combined with cataclasis, pressure-solution and growth of authigenic clays.

Aleksandra Svalova

Email: a.svalova@newcastle.ac.uk

Institution: Newcastle University

Supervisor: Dr Geoffrey Abbott

Project title: **Ultrasound spectrometry of the aggregation of asphaltenes during the formation of water-in-oil emulsions**

Abstract

This project examines the stability of water in oil emulsions (WOE) occurring during crude oil production and natural disasters. Asphaltenes, one of the indigenous components of crude oil, have been shown to be crucial to the formation of WOE together with resins, waxes and other compounds. Asphaltenes form above a critical nanoaggregate concentration (CNAC), however the mechanisms of subsequent emulsions formation are poorly understood. Ultrasound spectroscopy will be used to elucidate such processes due to a high sensitivity to physico-chemical changes in propagation media. Modern statistical methods will also be employed to understand correlations between ultrasound velocity and asphaltene concentration, as well as crude oil chemistry, rheology and marine environment.

Johanne Vad

Email: jv63@hw.ac.uk

Institution: Heriot-Watt University

Supervisor: Professor Theodore B. Henry, Professor J. Murray Roberts, Sophie Green (British Geological Survey)

Project title: **Environmental assessment of deep-water sponge fields in relation to oil and gas activity: a west of Shetland case study**

Abstract

he UK's Atlantic Margin supports diverse seabed ecosystems meeting the criteria of United Nations Vulnerable Marine Ecosystems (VMEs) and UN Convention on Biological Diversity Ecologically and Biologically Significant Areas (EBSAs). Deep-water sponge fields are among the least understood VMEs and EBSAs yet they provide important ecosystem services west of Shetland (SEA4) and the Hebrides (SEA7). Recent analyses for both industry and government identified sponge grounds in areas of interest to the oil and gas sector, but their sensitivity to oil spills remains a significant knowledge gap. This project aims to fill this gap through three complementary objectives to: 1 Completing a visual surveys of sponge density and occurrence in the FSC MPA 2 Conducting experimental exposures to determine sponge response to oil/oil dispersant mixtures; 3 Analysing microbial community of deep-water sponges in the FSC MPA and specifically testing for the presence of oil degrading bacteria. The project will conclude with industry recommendations on the capacity for deep-water sponges to naturally recover from an oil spill or whether dispersants will facilitate or hinder this recovery.

Nick Ward

Email: wardni@cardiff.ac.uk

Institution: Cardiff University

Supervisor: Dr Tiago M. Alves

Project title: **The scale and geometry of differential compaction on passive continental margins**

Abstract

Differential compaction is a process that occurs during burial in nearly all sedimentary basins around the globe. It can form features at outcrop (metres) to seismic-scale (kilometres). Many studies have focussed on the seismic expression of structures related to differential compaction, providing qualitative analyses on large, discrete structures, but rarely quantify smaller, more subtle structures. This presentation will look in detail at how differential compaction influences petroleum systems and seafloor sediment distribution.

High quality 3D seismic data from Espiríto Santo Basin, offshore Brazil, were interpreted to quantify the magnitude and timing of differential compaction. Statistical methods and seismic attributes were used to analyse structures over a) submarine channel complex, b) a mass-transport deposit (MTD). In both the MTD and channel complex, differential compaction was controlled by discrete lithological variations. During progressive burial of the features, compaction related anticlines formed over individual slide blocks and the channel axes. Coarse-grained siliclastics deposited along the axis of the channel complex created a broad anticline after only 200 m of burial. Small, isolated channels within the complex accumulate coarse-grained sediment downslope of knickpoints. Differential compaction over these isolated channels led to anticlines with four-way dip closure, forming effective structural traps.

Lithological variations in the MTD lie between carbonate remnant or rafted slide-blocks, and the surrounding muddy-debris flow matrix. The limestone compacted less than the muddy matrix during burial, forming broad anticlines over larger blocks (> 5 km wide) and narrow, repetitive anticlines over smaller blocks.

Petroleum systems in these areas are strongly influenced by differential compaction. Coarse-grained siliciclastic sediment ponds within depocentres, structural traps form over reservoir strata, and fine-grained sediments overlying the reservoir strata act as seals. A caveat in these findings are without borehole data in the study area, it is hard to predict reservoir architecture within these features. However, differential compaction both above the channel and the MTD exerts a clear control on the sediment distribution of a basin. This information can also be used to understand possible effects of differential compaction during the burial of more recent MTDs close to the surface today.

Xiaodong Yang

Email: xy3g14@soton.ac.uk

Institution: University of Southampton

Supervisor: Professor Lisa McNeill

Project title: **Are deep-water fold belts on passive margins different from fold belts in orogenic belts?**

Abstract

I am a structural geologist with interests in tectonics and seismology. My project focuses on the difference between deep water fold-thrust belts driven by gravity on passive margins (e.g. NW Borneo) and those caused by plate convergence on active margins (e.g. Makran). I have used and developed the Coulomb Wedge Model for thrust systems to define the limitations of existing published models. I used FEM (Abaqus) methods to create forward models of thrust systems to understand the mechanics and the way that the system and individual faults develop through time. I combined these theoretical studies with detailed analysis of natural thrust systems in 2D and 3D seismic data, including fault displacement analysis, shortening, and fault activity history. In addition to these, my study also involves the calculation of fault strength and prediction of fluid pressure along basal detachment, and their relationship with structural styles, fault activity and strain distribution in a thrust system.