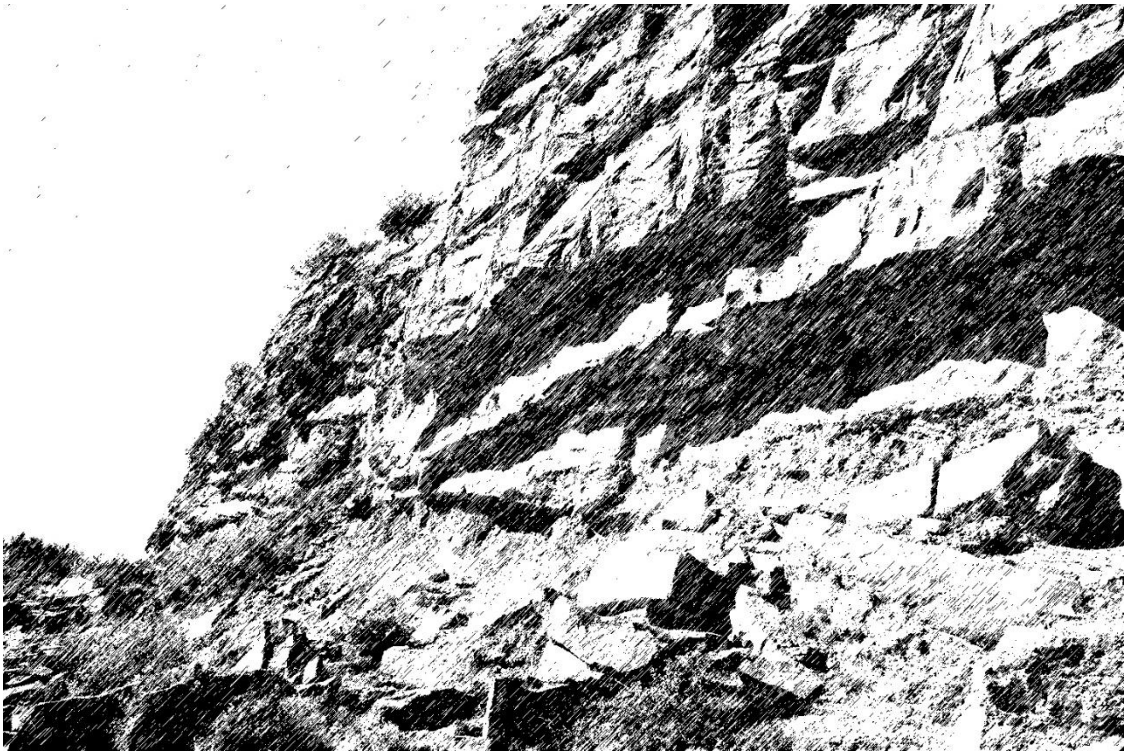
ROYAL HOLLOWAY UNIVERSITY OF LONDON

MSc Petroleum Geoscience Symposium

5th September 2019



- Acknowledgements -

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- Programme -

Morning sessions in the Shilling Building Auditorium

	09:30		Introduction and welcome
North Sea, Norwegian Sea; West Africa, South America	09:45	Fred McEwan-Read	Compressed air energy storage potential in salt diapirs, in the coastal areas of the southern North Sea
	10:05	Morgan Figgins	Lithology and porosity prediction of Cretaceous deposits of the Norwegian Sea using supervised machine learning
	10:25	Alexander Piragua Alarcón	Tectono-stratigraphy of Cenozoic reservoirs, Congo Fan System
	10:45	Monika Jarmalyte	Paleo-environmental reconstruction in a thrusted context, onshore South America
	11:05		Refreshments and poster session
Australian Margins	11:30	Temitayo Fambegbe	Assessing the oil fairway on the Yampi Shelf in the Browse Basin, NW Australia
	11:50	Thomas Howlett	Cenozoic deep water seismic facies associations in the Northern Carnarvon Basin, NW Australia
	12:10	Oscar Marin Castaño	Sedimentary evolution through the Cretaceous in the Northern Carnarvon Basin, NW Australia
	12:30	Felix Anderson	Reducing exploration risk in the Houtman sub-basin, offshore northern Perth Basin, SW Australia
	12:50		Lunch and poster session

- Programme -

Afternoon sessions in the Shilling Building Auditorium

	12:50		Lunch and poster session
Western Pacific Basins	14:00	Mustafa Batuhan Ertekin	Seismic and sequence stratigraphic study of the Neogene-Quaternary Taranaki Basin, New Zealand: implications for reservoir prediction
	14:20	Ben Hart	Relationships between intramontane basin evolution and active strike-slip tectonics, Sulawesi, Indonesia
	14:40	Luz Adriana Diaz Delgado	Carbonate development in Salawati-Misool, Indonesia
	15:00		Refreshments and poster session
Modelling & Machine Learning	15:30	Mahesh Kajendran	Geothermal energy sources and their potential for the United Kingdom
	15:50	Rory Ellis	3-D grain size analysis from microtomographic images of the Brae Formation Sandstone, North Sea
	16:10	Zayad Al Zayer	Digital rock forensics using machine learning and computer vision, combining approaches for identifying core integrity and basic classification
	16:30	Thomas Melgar-Jennings	Experimental analysis: 3-D fault structure and kinematics
	16:50		Award of prizes, closing remarks and reception

Fred McEwen-Read

Compressed air energy storage potential in salt diapirs in the coastal areas of the Southern North Sea

Renewable energy sources are imperative to ensure a low carbon future and a reduction in greenhouse gas emissions. However, the majority of renewables are unable to deliver sufficient amounts of electricity during peak demand times. Energy storage systems like hydro-pumping reservoirs or Compressed Air Energy Storage (CAES) allow storage of excess renewable energy during high generation and low demand times and flexible generation of electricity during peak demand times. In this, first of its kind study, combined seismo-stratigraphic observations, geo-spatial data and well data were interpreted in a play fairway style analysis, to assess the regional potential for CAES in salt structures in the Southern North Sea. The solution-mined caverns required for CAES can be located within the Zechstein mega-halite sequence. Two leads were established which have been assessed in terms of their storage volume, theoretical operating pressures, and quantitative energy storage. This study finds that the potential for CAES salt caverns is greatest in the UK sector. The most promising leads identified are within the Silverpit basin (Quad 44) imaged in the PGS 3-D seismic MegaSurveyPlus and close to sources of electricity (wind farms). Both leads in the MegaSurveyPlus can accommodate 27 caverns over two levels: Lead 2 “Eel”, is most suitable for development due to its proximity to proposed wind farms and existing infrastructure and could store 0.33 TW. This is approximately equal to the annual energy consumption of 70,000 people in the UK. CAES has the unique potential to be an emission-free alternative to gas turbine power stations in the European energy mix, and its potential within the Southern North Sea is vast.

Supervisor: *Jürgen Adam (RHUL)*

Data provided by: *PGS.*

Morgan Figgins

Lithology and porosity prediction of Cretaceous deposits of the Norwegian Sea using supervised machine learning

This project aims to test the applicability of machine learning for lithology and porosity prediction of the Nise Formationand compare it to conventional petrophysical methods. Fifty-nine well logs in the Vøring Basin are predicted, testing 4 algorithms: linear regression, decision tree, random forest, and gradient boosting to establish which algorithms are best suited and achieve the highest accuracies. Six features from wireline log data have been selected for the machine learning: density, sonic, gamma, measured depth, deep resistivity and medium resistivity, along with 10 training wells for lithology prediction and 32 training wells for porosity prediction. Random forest was proven to have the highest performance for porosity prediction with a blind test score of 85.3% whereas XGBoost was the highest performing algorithm for lithology prediction, with a blind test score of 89.0%. Cross-plots, confusion matrices and a well correlation from the predicted results prove the validity of machine learning when compared to literature. Key findings include: some lithologies are harder to predict than others, accuracy is affected by volume of training data, and the Nise formation is thicker, higher quality and more continuous towards the centre of the Vigrid syncline. Using predicted data, a porosity depth cut-off defines the reservoir floor of the Nise Formation, proving the applicability of machine learning on an exploration scale. This method of machine learning has proven to be reliable, fast and cost saving and could be utilised in basins around the world.

Supervisors: *Domenico Chiarella (RHUL); Erik Larsen & Behzad Alaei (Earth Science Analytics)*

Data provided by: *Norwegian Petroleum Directorate*

Alexander Piragua Alarcón

Tectono-stratigraphy of Cenozoic reservoirs, Congo Fan System

The study area, covering the proximal zone of the present-day Congo Fan System, is located in the southern margin of the Lower Congo basin and the northern sector of offshore Kwanza basin. This is a world class petroleum province with presence of giant oil and gas fields. This area, characterized by gravity-driven extension (detachment on Aptian salt) recorded in the post-rift interval, has played a very important role in the distribution and architecture of deep-water reservoirs. The principal aim of this project is intended to study the structural controls on Cenozoic turbidite sand deposition. The methodology implies a regional to local analysis, from the general to the particular both in area and stratigraphic interval. The stratigraphic target of this research is the Cenozoic interval, mainly the Malembo Formation (Oligocene-Pliocene). Initial screening identified a zone for detailed study where the thickest section of Cenozoic interval is present and where there is a high probability of reservoir occurrence. Emphasis was particularly placed on the Miocene because this interval has a wide distribution and is the thickest Cenozoic unit. The Miocene interval was divided into five informal seismic units: Miocene 1, Miocene 2, Miocene 3, Miocene 4 and Miocene 5, based mainly on their seismic character and stratigraphic position. The units Miocene 2 and 4 contain reservoir facies and were accumulated during the Middle Miocene and Upper Miocene respectively. During the Middle Miocene, sedimentation took place with high rates of accommodation in the grabens and half-grabens of the extensional and transitional domains with an important structural control (N-S trending faults). Several sources of sediment developed during the Middle Miocene and they are responsible of the presence of a series of discrete sand bodies. By the Upper Miocene the N-S faults are inactive or less important, the accommodation is not considerable and it is likely that the high sedimentation rates outpaced the accommodation rate. The amount of sand bodies is restricted and localized during the Upper Miocene. Compared to the Middle Miocene there is an increase in the presence of channel complexes. Two fixed sediment sources are interpreted by the Upper Miocene. There are a number of ways in which depositional elements responded to the structural controls during Miocene. These responses or processes correspond to the channel–structure interactions, namely: blocking, confinement, diversion and deflection.

Supervisors: *Nicola Scarselli (RHUL); Paul Bellingham & Neil Hurst (ION)*

Data provided by: *ION*

Monika Jarmalyte

Paleo-environmental reconstruction in a thrusted context, onshore South America

The Cretaceous Cushabatay Formation, located in the Ene Basin of Central Peru, has been studied using lithological, petrographical and x-ray diffraction data from 36 surface outcrop and 28 side-wall core samples. As a frontier basin, the high uncertainty because of a lack of subsurface data makes this a high-risk exploration area. To increase the chance of success in the basin, data from the first drilled well (BSE-1X) are integrated with surface outcrop data to reconstruct the paleo-environment of the Cushabatay sandstone reservoir. Well BSE-1X drills through the Cushabatay three times, suggesting that the three repetitions are stacked by NE-propagating thrusts. Six packages were identified on the gamma-ray log by correlating each Cushabatay repetition with a surface gamma-ray trace. Seismic line P108-14K-09, which has been interpreted by 'PlusPetrol' was balanced to its pre-deformational geometry in order to extrapolate the position of each Cushabatay repetition and surface outcrop samples. Each 'package' represents an environment that has been previously identified by 'PlusPerol'. Stacked maps for mineral composition, clay type, mica presence and extent of each package on the surface has shown that the youngest intervals have an increased distribution across the study area. The oldest interval in the Cushabatay is distributed in a confined and restricted environment that is interpreted to originate from a shallow sloping mountain range in the west. Arc growth during the earliest Cretaceous is coeval with local uplift that eroded Cushabatay 'package 2', leading to its absence in the SW. As sea level was increasing southwards, onset of a laterally continuous estuarine environment represents the youngest Cushabatay deposits that were deposited in a NE direction as a result of higher accommodation space relative to previous uplift. Much of the environment is inferred and assumed particularly in the most south-eastern edge of the basin. Lack of complete sidewall core data and scarce distribution of samples means the uncertainty of the distribution increases away from the reconstrued seismic line, as well as in the deeper section of the well.

Supervisors: *Nicola Scarselli (RHUL); Marine di Matteo (SCDEM)*

Data provided by: *SCDEM*

Temitayo Fambegbe

Assessing the oil fairway on the Yampi Shelf in the Browse Basin, NW Australia

The Browse Basin, NW shelf of Australia, hosts large accumulations of gas in the NW-NE regions of the basin. Oil accumulations are smaller, though significant discoveries are present on the SE shelf of the Browse Basin. Complex migration pathways have been previously established providing routes from the distal Caswell sub-basin to the proximal Yampi Shelf. Gwydion and Cornea are the two main oil and gas discoveries on the Yampi Shelf. Substantial appraisal drilling has concentrated on but is not limited to the Casewell sub-basin at the Ichthys, Crux, Burnside and Scott Reef to name a few. Multiple Mesozoic source rocks are located in the Lower Cretaceous and Lower-Middle Jurassic formations.

This study is focused on the Lower Cretaceous K20-K30 Echuca Shoals Formation supersequences as the main target and the J30-K10 Vulcan Formation supersequences as a secondary target. Both formations consist of intraformational regional seals and reservoir units. To better predict source rock distribution, migration pathways and key petroleum elements, basin modelling has been undertaken to understand burial history and timing of hydrocarbon expulsion. Migration pathway scenarios have been modelled to forecast where oil accumulations lie on the Yampi Shelf and along migration pathways. Seismic data (2-D), substantial well data and previous discoveries are used to model potential migration pathways in the Browse Basin, to reveal numerous petroleum systems in the basin. Reservoir units of the Echuca Shoals and Vulcan formations are thickest in the Caswell sub-basin and thin towards the Yampi Shelf. Seal integrity greatly varies in the Browse Basin, seals on the Yampi Shelf are thicker over the eastern region of the shelf (Gwydion field) and thin towards the west of the shelf (Cornea field). Intricate migration pathways are modelled using orthocontours to help navigate through and locate potential structural and stratigraphic traps. Sandstone units in the Echuca Shoals Formation potentially act as carrier beds forming oil and gas columns in stacked reservoirs. Complex migration pathways and multiple source rock pods have led to a renewed exploration interest on the Yampi Shelf. The results of this study have implications for understanding migration in other regions of complex source rock distribution.

Supervisors: *Ian M. Watkinson (RHUL); Joseph Jennings, Michael Treloar & Xinli Jia (Halliburton)*

Data provided by: *Halliburton STEPS*

Thomas Howlett

Cenozoic deep water seismic facies associations in the Northern Carnarvon Basin, NW Australia

The interaction between along-slope and down-slope processes has the potential to create a wide variety of complex hydrocarbon traps. This study investigates this relationship by using a dataset from the Northern Carnarvon Basin, on the NW margin of Australia. The dataset is composed of four separate 3-D seismic surveys which have been stitched together to create a merge with a combined area of 8,500 km^2, along with two 2-D lines and three regional wells.

Although this study is focused on the Cenozoic which is too shallow to be economically viable, its intended purpose is to be an analogue which can be applied to other areas around the world that could be more economically viable.

By picking seismic facies and carrying out attribute calculations including root-mean-square (RMS) amplitude and semblance extractions, it became evident that there is a relationship between along-slope and down-slope processes, with each one positively and negatively impacting the other. Bottom currents in the area weaken the slope through erosion which eventually fails as a result of tectonics and gas escape. The generated mass transport complex drowns out any influence of the bottom current. Gradually the bottom current reworks the deposited sediment into a contourite. This process has repeated itself in the study area creating a complicated patchwork of sediment accumulations and possible traps.

In order to better understand this alternation, case studies which display the similar occurrences of processes have been used to see if there is a relationship between gravity-driven processes and bottom current-driven processes. One of these case studies comes from the SE coast of Brazil and the other case study from the Algarve Margin.

Supervisors: *Javier Hernandez-Molina & Nicola Scarselli (RHUL)*

Data provided by: *Geoscience Australia.*

Oscar Marin Castaño

Sedimentary evolution through the Cretaceous in the Northern Carnarvon Basin, NW Australia

The Northern Carnarvon Basin is one of the most prolific hydrocarbon provinces in Australia with reserves of 4.3 km^3 (152 Tcf) of gas and 0.04 km^3 (278 MMbls) of heavy-oil related to Triassic, Jurassic, and Lower Cretaceous reservoirs. The oil industry activity in this basin has motivated the research of new possible reservoirs in its sedimentary sequence. Regional studies have focused on understanding the basin's evolution, its sedimentary environments and the behavior of the paleocurrents. These analysis have shown that during the Cretaceous there were depositional processes associated with mounded features formed under the influence of bottom-currents. The mounded features, known as contourite-drifts, are of great interest in hydrocarbon exploration, due to successful results offshore Brazil, where high-quality reservoirs were deposited by the interaction of contourite deposits and gravitational processes.

Due to the interest in developing new exploratory plays in the Northern Carnarvon Basin, this research is focused on understanding the evolution of the depositional processes during the Cretaceous, specifically on the Exmouth Sub-basin around the Gorgon field. A large 3-D seismic survey (Gorgon Merge 3-D), regional 2-D seismic lines and well data provide excellent information to decode the dominant process (contourite vs. turbidite) and the possible reservoir distribution into the 3-D survey area. Based on these datasets, provided by Geoscience Australia, it is proposed that the Cretaceous in the study area evolved from an extensional basin with the deposition of syn-tectonic sequences during the Early Cretaceous to a passive margin during the Late Cretaceous. These changes in the basin allowed the evolution of the depositional processes and corresponding sedimentary sequences.

In general, depositional processes were dominated by bottom-currents, but these processes have evolved in three main stages: the first stage was associated with the Early Cretaceous,deposited during a lowstand system tract and the dominant depositional processes were associated with clastic sediments supplied by deltaic environments; the second stage between the late Early and Late Cretaceous was dominated by bottom-currents – sediments were reworked by circulation of SW to NE flowing water masses, forming a large elongate detached drift. Its sediments are fine-grained sequences. In addition, during deposition of the contourite drift, it interacted with gravitational deposits such as turbidites and mass transport deposits due to the continental slope and the relief placed around it around and reworked by currents. Finally, during the last stage of the Cretaceous, bottom-currents still reworked the deposits but sea level was falling, as evidenced by active gravity processes due to the significant relief of the contourite drift. This interaction between depositional process allows a comprehensive view of the depositional environments and reservoir distribution through the Cretaceous.

Supervisor: *Javier Hernandez-Molina & Nicola Scarselli (RHUL)*

Data provided by: *Geoscience Australia.*

Felix Anderson

Reducing exploration risk in the Houtman sub-basin, offshore northern Perth Basin, SW Australia

Exploration in the Houtman Sub-basin, SW Australia, has been limited despite its proximity to the highly prospective onshore Perth Basin and the presence of a charge system within. This study combines tectono-stratigraphic, structural and petroleum systems analyses of seismic, petrophysical and geochemical data to show that despite key risks in the timing of charge and trap integrity, multiple hydrocarbon generation and preservation scenarios exist. Five main tectonic phases have been identified; two main rifting events: Permian ENE-WSW extension and Jurassic-Cretaceous NW-SE extension culminate with the separation of Greater India from SW Australia in the Valanginian, with up to 1 km of uplift and erosion. Seven structural and stratigraphic play types have been identified within Ordovician to Cretaceous strata, with source intervals recognised in the Permian, Early Triassic and Middle Jurassic. Modelling of Early Triassic source intervals show that oil charge precedes Toarcian-Berriasian trap formation, and key Jurassic source intervals are largely immature. However, further considerations such as pre-rift early entrapment and remigration, as well as enhanced maturity effects from Cretaceous volcanism support both hydrocarbon generation and entrapment; additionally, an evaluation of post-breakup restructuring suggests that preservation is probable. This study concludes that while unexplored, numerous mechanisms for hydrocarbon generation, entrapment, and preservation exist within the Houtman Sub-basin which may hold significant prospectivity.

Supervisor: *Nicola Scarselli (RHUL);*

Data provided by: *Geoscience Australia.*

Mustafa Batuhan Ertekin

Seismic and sequence stratigraphic study of the Neogene-Quaternary Taranaki Basin, New Zealand: implications for reservoir prediction

The Taranaki Basin has developed between the Pacific and Australian plates on the west coast of New Zealand. Sequence stratigraphic and trajectory analysis of Neogene-Quaternary sediments was conducted to better understand the migration and depositional processes of the basin through time. The trends observed are low angle ascending regressive, stationary, high angle ascending regressive and descending regressive trends. In addition, it was observed that the region showed differences in the geometry of the northern and southern parts after a certain period. The northwards progradation of clinoforms is observed in the study area, developing during the Plio-Pleistocene. Twelve different sub-sequences were defined, including top-basement. Sub-sequences were defined by 4 different stages, which are related to sea level changes. During stage 2 and stage 4, relative sea level-fall indicates forced regression, and during these two stages, a Falling Stage Systems Tract (FSST) is observed. As a result of the sequence stratigraphic study, three systems tracts: FSST, Highstand Systems Tract (HST) and early Transgressive Systems Tract (TST) were defined. Potential reservoir locations and styles have been predicted based on the systems tract definition. Key probable reservoirs are located in shoreline and shoreface throughout the study area during the predominant period of HST. In the case of FSST, the possible reservoirs are related to deep water submarine fans. Probable reservoirs in the early TST phase are hypothesised to have developed in low density turbidity flows and debris flows, estuarine deltas and back-stepping beaches. The predicted reservoirs may hold significant prospectivity for petroleum, though a full analysis of migration pathways and maturity also needs to be conducted.

Supervisors: *Domenico Chiarella & Nicola Scarselli (RHUL)*

Public domain data

Ben Hart

Relationships between intramontane basin evolution and active strike-slip tectonics, Sulawesi, Indonesia

The Indonesian island of Sulawesi is home to an array of intermontane basins that have a complex history of interactions with active faulting. This project uses Shuttle Radar Topography Mission (SRTM) 30 m spatial resolution topographic data to provide new insights into basin characteristics, genesis, evolution and relationships. A classification scheme of these basins within a strike-slip dominated landscape has been generated using key features of each basin present. Existing ideas for the Quaternary structural evolution of the study area have been challenged, with new findings such the juxtaposition of the Towuti basin alongside the Mahalona basin in the recent past. Circa 1-2 ka megalithic monuments preserved across the landscape have also been plotted using published literature and high-resolution remote sensing imagery in the Napu basin, the Bada basin and the Besoa basin. By combining these archaeological data with fluvial terrace mapping and modern drainage analysis, the relationships between drainage evolution, incision and deposition, lake formation, human settlements and neo-tectonic faulting have also been assessed. This has led to the confirmation of a previously suggested zone of lithospheric extension in central Sulawesi and the potential for an older history of the island's major structures. This study provides a basin classification scheme and methodology suitable for use in similar strike-slip dominated mountainous regions.

Supervisor: *Ian M. Watkinson (RHUL)*

Public domain data

Luz Adriana Diaz Delgado

Carbonate development in Salawati-Misool, Indonesia

The Seram Trough is one of the troughs generated by the oblique convergence between the Outer Banda Arc and the Bird´s Head of New Guinea, in eastern Indonesia. It is a 1 to 3 km depth foredeep formed by flexural loading associated with the active thrusting between the Bird´s Head peninsula and Seram island. During its development, a carbonate platform was generated on the forebulge zone within the thrust setting and was developed above a widespread erosive unconformity of Pliocene age. Since it is still not clear to what extent eustacy and tectonic subsidence influenced carbonate platform drowning events, this study analyses the tectonic subsidence and eustacy effects on the carbonate platform development combining seismic interpretation, the back-stripping technique and a global eustatic curve. This study shows that first-order seismic features are governed by tectonic subsidence, while second and third order ones are a consequence of eustatic changes. This research concludes that accommodation space creation for consequent carbonate sedimentation was mostly driven by tectonic subsidence; however, eustatic oscillations had an important role in the resulting carbonate platform architecture. Identification of patterns in eustatic sea level oscillations and tectonic subsidence that lead to carbonate configurations such as those in the Seram Trough, could be a powerful tool to support hydrocarbon exploration studies in areas with similar tectonic settings, with good potential where low seismic resolution can be a challenge.

Supervisors: *Robert Hall & Amy Gough (RHUL); Peter Burgess (University of Liverpool)*

Data provided by: *TGS*

Mahesh Kajendran

Geothermal energy sources and their potential for the United Kingdom

In order to reach the UK's 2050 greenhouse gas emissions target, geothermal resources will have to contribute substantially to meeting carbon-free energy needs. Though the UK does not possess conventional geothermal systems as seen in volcanically active regions, an extensive use of shallow low enthalpy resources allow the exploitation of heat using Ground Source Heat Pumps (GSHP), at depths between 1.2-200 m. Deep geothermal resources in the UK consist of High Heat Production (HHP) granites at depths greater than 4.5 km. The use of Enhanced Geothermal Systems (EGS) allows access to a potential total power generation of 2280 MW. However, public opinion may prevent future large-scale application of deep geothermal power plants, because induced seismicity is often perceived as an unsolicited and uncontrollable side effect of deep fluid injection. In this work, numerical modelling has been utilised to study the processes of fault slip and earthquake triggering by an induced hydrofracture that (i) approaches, (ii) meets with, and (iii) enters a pre-existing, natural fault. The results indicate that the modelled fault, whose dip varies from 50° to 85°, is most likely to slip when it is steeply dipping. Although EGS is an attractive theoretical prospect, it is hampered by high drilling costs and seismicity, neither of which impact the use of heat pumps. It is concluded that heat pumps could be a major contributor to the reduction of the UK's greenhouse gas emissions, perhaps by up to a third because of their versatility and general applicability in the UK.

Supervisor: *Agust Gudmundsson (RHUL)*

Public domain data

Rory Ellis

3-D grain size analysis from microtomographic images of the Brae Formation Sandstone, North Sea

3-D measurements of grain size from 8 samples of the Brae Formation sandstone (North Sea) have been performed in order to characterise the reservoir properties. The Brae Formation is the primary reservoir rock in the Miller Oil Field, located at the western edge of the South Viking Graben. This study is focused on core plugs derived from two cored wells (16/7b-20 and 16/7b-23) and located within the depth interval between 4040 m and 4064 m. Sedimentological analysis indicates that well 16/7b-23 penetrates the proximal part of the system, while well 16/7b-20 is located in a more distal portion.

A binary segmentation technique has been used to separate the solid matrix from the macroporosity using both automated and manual thresholding methods on a grayscale image stack, acquired from micro computerised tomography (CT) scans. Once segmented, the grain boundaries were identified and a label analysis of each grain was conducted to measure the average grain size. In a separate set of measurements, this study calculated macroporosity and permeability of these samples. The results indicate that grain size in the sandstones varies between 200-550 μm. The better sorted samples, displaying a small standard deviation, are characterised by higher values of macroporosity. The grain size also shows a direct correlation with the permeability in the samples where a connected network of macropores were identified.

Supervisor: *Saswata Hier-Majumder (RHUL)*

Data provided by: *Natural History Museum*

Zayad Al Zayer

Digital rock forensics using machine learning and computer vision, combining approaches for identifying core integrity and basic classification

Core imaging and classification is an important step for generating a digital database of subsurface geology. The British Geological Survey collection contains cores from over 15,000 onshore and 8,000 offshore boreholes. Many cores have been photographed at high resolution, creating an archive of over 100,000 core tray images.

In this work, a new method using both deep learning and computer vision to automate the process is developed. To test the feasibility of the technique, a subset of 62 core tray images, captured with 3 light spectra (red, green, blue) is used. A pre-trained neural network is used to segment the image, which is followed by traditional computer vision techniques for edge detection. The process of calculating the number of fragments and area of each fragment present in each individual core image is also automated. An index for core integrity is based on the output of these measurements. The workflow demonstrates that deep neural networks and computer vision can be leveraged to quantify and non-intrusively assess geophysical properties at a large scale, as well as being able to provide basic facies classifications, using only a subset of the data, with open-source Python libraries.

This core integrity index will allow users to quickly and consistently assess core condition, and in particular degradation. By automating this process it is possible to quickly assess tens to hundreds of metres of core to identify areas suitable for sampling. It also provides semi-quantitative information on how representative individual core samples are of bulk rock properties. This will improve integration between core analysis and other datasets, for example wireline logs.

Supervisors: *Saswata Hier-Majumder (RHUL); Andrew Kingdon & Mark Fellgett (BGS)*

Data provided by: *BGS*

Thomas Melgar-Jennings

Experimental analysis: 3-D fault structure and kinematics

The current primary method of interpreting the geometry and kinematic evolution of fault structures is through their interpretation from static cross-sections (e.g. via seismic data) or outcrop studies. The structural interpretation (fault continuity) and kinematic analysis of faults (timing and episodicity of fault movement) depends on simplified structural and kinematic concepts (cross-cutting relationships, sequential fault growth). This study applies a dynamic modelling approach with scaled analogue experiments using dry loose silica sand and high-resolution strain analysis with digital image correlation (DIC) to simulate the dynamic evolution of extensional faults. A key outcome of the experimental results is that features such as multi-phase activity of fault displacement, significantly altered fault structure and fault nucleation characteristics cannot be ascertained through static interpretation alone. To allow for comparison between static and dynamic interpretation results, fault interpretation has been conducted following two contrasting methodologies; (1) Static section analysis of final stage analogue models (extensional) through the generation and interpretation of a 3D volume using Petrel 2016. (2) Dynamic analysis of time-series 2D image data of model evolution and fault development, applying DIC using DaVis8. Through comparison it has been revealed that faults are not strictly continuously active, supporting vertical segmentation and multi-phase activity leading to reactivation or alteration to fault segment structure. Additionally, faults exhibit complex inter-relationships, including proportional deactivation of older faults against the growth of younger faults of the same attitude, and apparent transferal of displacement activity across adjacent faults.

There is potential for further kinematic analysis of 3D fault systems, along with additional fault displacement and fault seal analysis through the integration of additional data, using computer-based models underpinned by analogue model data. Through critically assessing the methodology this study concludes that a multi-platform, integrated approach to geological challenges provided by fault formation is critical to further understanding.

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

- Notes -