



Triassic stacked fluvial channels, Kerrouchen Basin, Morocco

Fieldwork

New results from fieldwork on Cretaceous and Jurassic sections in Senegal, Cap Verde and Morocco

New project commenced on Triassic Synrift in Eastern Morocco - opening gas play

New Projects

Low-T Geochronology sampling in Senegal planned for October 2018

New Sponsors

Total and ENI become NARG sponsors

New Starts

Orrin Bryers and James Lovell-Kennedy join as new PhDs. Two other PhDs and 1 MRes expected to commence in 2018/9. Dr Remi Charton starts as new NARG Postdoc leading our GIS Project,

Building a GIS database: making our research more accessible

The project to build a GIS database is well underway, being led by Remi Charton and Kofi Owusu. The NARG GIS database is built with the need of the PhD students, academic staff and sponsors of the research group in mind. It is designed to be an evolving platform inside which data and knowledge can be added, edited, and shared by multiple users.

The database will cover North Africa, from Morocco to Egypt, and extend south to Mauritania, Senegal and The Gambia. More details on Page 3.

MOU Signed with Petrosen



NARG have signed an MOU with Petrosen and started a joint study in collaboration with the University of Dakar (UCAD).

Sampling of onshore and offshore wells was undertaken in April for biostrat and provenance / reservoir studies.

Further details see Page 11

PhD Success!

Four NARG PhDs have successfully completed in 2018.

Tim Luber's thesis, *Integrated analysis of Lower Cretaceous stratigraphy and depositional systems: the Essaouira-Agadir Basin of Morocco*, graduated in July after final submission January. Tim is now working with Equinor.

Remi Charton completed his thesis on the *Phanerozoic Vertical Movement in Morocco* and passed his viva in May. He has now joined NARG as a Postdoc

Mohamed Salem graduated in July, with a thesis: *Subsidence Mechanisms and Tectonic Control on Seismic Stratigraphy and Reservoir Characterization of the Kolla Graben and adjacent highs, west central Sirt Basin, Libya*.

Angel Arantegui also successfully defended his thesis, *Characterisation of Mesozoic Depositional Systems along the Atlantic Passive Margin of Morocco North Aaiun-Tarfaya Basin* in June.

More to come in 2018!

Contents Highlights

- Triassic study Page 2
- New heavy minerals lab established for provenance studies.... Page 4
- Latest publications Page 10
- Staff and researcher list Page 12

Welcome to our New Sponsors



WILEY

The Depositional Record

The journal of the International Association of Sedimentologists

Open Access

Congratulations — your article was one of our top downloaded articles in recent publication history!

Richard Newport's (PhD now working with Shell International) recent paper from his NARG research "Examining the interplay of climate and low amplitude sea-level change on the distribution and volume of massive dolomitization: Zebbag Formation, Cretaceous, Southern Tunisia", published in The Depositional Record, was one of the journal's top 20 most downloaded recent papers!

Chasing the Triassic Fluvial systems of Eastern Morocco

The Triassic syn-rift continental clastics were deposited at the onset of rifting. They are proven reservoirs in the Essaouira Basin and the recent Sound Energy gas discovery in Tadrara, on the High Plateaux, has re-invigorated interest in the play. Reservoirs are tight fluvial sandstones and a key factor is understanding reservoir quality and distribution. The system has potential offshore on both conjugate Atlantic margins where there is limited overburden.

Extensive work by NARG in the Argana and Essaouira Basins has focussed on characterising the main reservoir intervals and building analogue reservoir models.

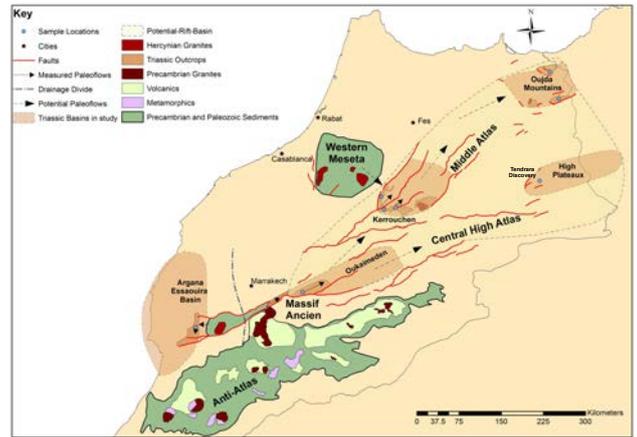
This new phase of research will focus on:

- Integrating all recent research to improve the regional depositional models
- Understanding the structural framework and controls on the depositional system.
- Provenance studies to assess the sediment routing and reservoir characteristics.

James Lovell-Kennedy is currently undertaking a MRes study and will commence a PhD in Sept 2018 looking at the provenance of the Triassic fluvial systems. This will make use of the new heavy mineral separation lab established at the University of Manchester, and with the NERC NIGL Facility. A linked MSc will start in TuDelft in September, under the supervision of Dr Allard Martinus, modeling axial versus transverse fluvial system interaction and the resultant development of depositional packages in these synrift basins.

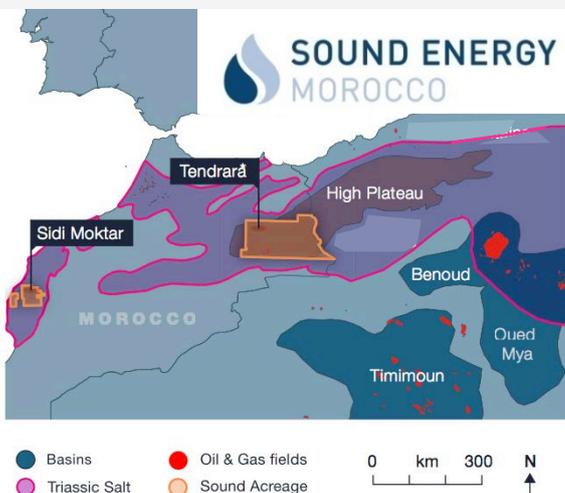
Work completed to-date:

- Recon field work completed in the Kerrouchen Basin and at Oujda with supervisor Prof Jonathan Redfern, logging and sampling for provenance analysis
- Poster presented at the 2nd Milan Heavy Mineral School, outlining results from fieldwork and planned future analysis. The school was an opportunity to learn from researchers at the world leading Laboratory for Provenance Studies (LfPS) how to utilise their novel techniques in Manchester
- Completed petrographic analysis of samples from the Kerrouchen Basin, Oukaimeden Basin and Tadrara Basin
- Heavy Mineral separation and grain mount preparation has been completed for this initial dataset, with sample analysis underway and results expected by September
- We are able to utilise the cutting edge Raman Spectroscopy technique to perform analysis which will simultaneously gather abundance and varietal data of heavy minerals for provenance analysis

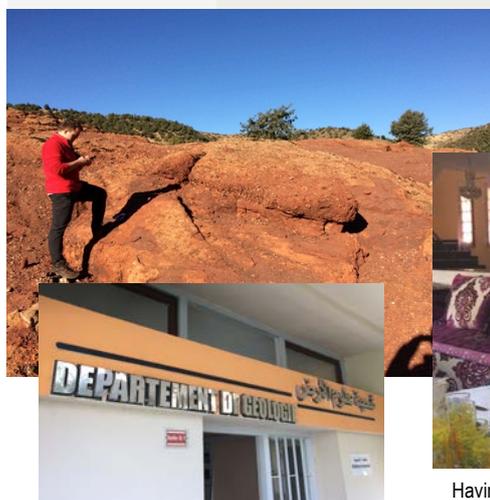


NARG Recent Publications on the Triassic Systems in Morocco

- Mader, N. K. and Redfern, J. (2011). A sedimentological model for the continental Upper Triassic Tadrart Oudou Sandstone Member: recording an interplay of climate and tectonics (Argana Valley; South-west Morocco), *Sedimentology*, 1365-3091 DOI: 10.1111/j.1365-3091.2010.01204.x
- Redfern, J., Shannon, P.M., Williams, B.P.J., Tyrell, S., Leleu, S., Fabuel Perez, I., Baudon, C., Stolfova, K., Hodgetts, D., Speksnijder, A., Haughton, P.D.W, Daly, J.S., (2011) An integrated study of Permo-Triassic basins along the North Atlantic passive margin: implication for future exploration. *Geological Society, London, Petroleum Geology Conference series*, v. 7, p. 921-936, doi: 10.1144/0070921
- Baudon, C., Fabuel-Perez, I. and Redfern, J. (2009). "Structural style and evolution of a Late Triassic rift basin in the central High Atlas, Morocco; controls on sediment deposition." *Geological Journal*, 44(6): pp. 677-691.
- Baudon, C., Redfern, J & Van Den Driessche P; J. (2012), Permo-Triassic structural evolution of the Argana Valley and implications on the kinematics and impact of the Atlantic rifting in the High Atlas, *Journal of African Earth Sciences*, 65, 91-104.
- Mader, N. K., Redfern, J. & El Ouataoui, 2017, Sedimentology of the Essaouira Basin (Meskala Field) in context of regional sediment distribution patterns during upper Triassic pluvial events: In *Journal of African Earth Sciences*. 130, p. 293-318 26 p. DOI: 10.1016/j.jafrearsci.2017.02.012
- Fabuel-Perez, I., Hodgetts, D. and Redfern, J. (2010). "Integration of digital outcrop models (DOMs) and high resolution sedimentology; workflow and implications for geological modelling; Oukaimeden Sandstone Formation, High Atlas (Morocco)." *Petroleum Geoscience*, 16, 133-154.133-154.
- Fabuel-Perez, I.; Redfern, J.; Hodgetts, D., (2009), Sedimentology of an intra-montane rift- controlled fluvial dominated succession: The Upper Triassic Oukaimeden Sandstone Formation, Central High Atlas, Morocco, *Sedimentary Geology*, v. 218, iss. 1-4, pp. 103-140.
- Fabuel-Perez, I., Hodgetts, D., & Redfern, J., (2009), A new approach for outcrop characterization and geostatistical analysis of a low-sinuosity fluvial-dominated succession using digital outcrop models; Upper Triassic Oukaimeden Sandstone Formation, central High Atlas, Morocco *AAPG Bulletin*, 93, 6, pp. 795-827



Sound Energy have two blocks both with Triassic plays. They have been very supportive of the research, providing access to well data, core and cuttings.



James logging and sampling some Triassic coarse alluvial fan conglomerates, Kerrouchen Basin, Morocco

Having a Cous Cous lunch in the home of Prof Oujidi (on the left) from Oujda University, who very kindly spent a few days showing us the best outcrops in the region (his PhD field area).

Low-T geochronology campaign in Mauritania



GIS Database

A pilot study was completed in 2017, initiated by Carmen Luber and Kofi Owusu to develop a GIS database that incorporates the extensive field data (samples and analytical results) acquired by NARG, integrated with published data across the region.

This work is now being built on and extended by Remi Charton working closely with Kofi.

All new projects are now utilising ArcGIS to archive data and provide rapid access to research information. The NARG GIS database is built to meet the needs of the PhD students, academic staff and sponsors of the research group in mind. It is designed to be an -evolving platform inside which knowledge is added, edited and shared.

The database will ultimately contain about 30 layers covering North Africa, from Morocco to Egypt, and extending south to Mauritania, Senegal and The Gambia. These include a synthesis of extensive literature reviews of specific analyses (e.g. outcrops, cross-sections, fossils, fission track ages...), industry data (on/offshore well and seismic data location, hydrocarbon fields, blocks...), and NARG data (sample locations, field photographs, reports and results from nearly 20 years of NARG research in the area). As base layers, partners will be able to choose from a fairly high-resolution geological map, DEM, magnetic and gravity data; all enriched by lots of geographical references.

The database will be stored on a secure server located in Manchester University, and will be accessible (view and edit) from the net to our partners. The database will be updated regularly to capture the latest research results.

At the moment, the database is extremely dense in Morocco and we are busy expanding the coverage to cover the entire north African continent



Building Collaborations

Fieldwork would not have been possible without the support of the *Office Mauritanien des Recherches Geologiques* of the I.R of Mauritania. The Director *El Hachemy Ould Sidaty* and the adjunct Director *Abdellahi Ahmedou Bellal* of the OMRG are gratefully thanked for the support they have given. Links have now been made with Petrosen, UCAD and the Earth Institute in Senegal to continue these studies south.

The samples collected during our field campaign of February 2017 (Fig.1) have been successfully processed and apatites measured for Apatite Fission Tracks and U, Th He. To our knowledge this is the first consistent set of exhumation ages from the Mauritanides of Mauritania.

Continuing the "anomalous" pattern documented in Morocco the measurements confirm our working hypothesis that large portions of the passive continental margin of NW Africa experienced exhumation during post-rift, and that, therefore, could have been the source for the terrigenous sediments targeted by hydrocarbon exploration in the Mauritania offshore

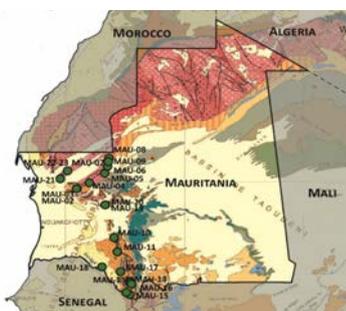


Figure 2 - Samples collected during the NARG 2017 campaign in Mauritania

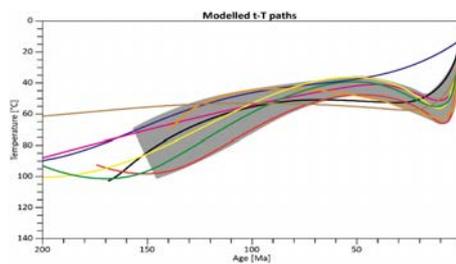


Figure 1 - Time-temperature curves for the analyzed Mauritania samples

The results show apatite fission track (AFT) central ages ranging between 90.2 and 235.7 Ma. Most of the AFT ages are Early Cretaceous to early Late Cretaceous and two AFT ages are Late Triassic to Early Jurassic. Mean track lengths show a normal distribution indicating a relatively slow cooling through the partial annealing zone (APAZ: 110-70 °C).

(U-Th)/He (AHe) analysis produced uncorrected ages ranging between 50.1 and 102.5 Ma, while the α -ejection corrected ages vary between 68.8 and 150.3 Ma. Both uncorrected and corrected AHe ages are younger than the respective AFT ages.

Modeling of time-temperature evolution has started. The preliminary t-T paths show an overall consistent thermal history with the dominant trend being characterized by a slow and prolonged cooling phase (exhumation) from Jurassic to Palaeocene times, followed by a short heating phase during the Eocene-Oligocene, and a final rapid cooling phase (~ 2 – 5 °C/Myr) between the mid-Miocene and the Present.

More modeling work is being performed to provide better constraints to the source-to-sink evolution of the Mauritania margin (final results and related publication expected before the end of the year). At the same time, we are preparing the next campaign dedicated to the southward continuation of the Mauritanides in Senegal. The campaign will take place in October 2018. Eventually, we will dispose of a high-quality data set defining the geometry and kinematics of Mesozoic exhumation all along the passive continental margin of NW Africa.



Sampling by Dr Mohamed Gouiza (Leeds University) during the NARG 2017 campaign in Mauritania



Provenance Studies

This integrated regional analysis is being undertaken by **PhD Emmanuel Roquette** who started in January 2017. It builds on the work of Tim Luber, who has defined the early Cretaceous depositional systems and stratigraphy and initial concepts on the drainage system, and the work of Remi Charton at TuDelft on low T-geochronology of the hinterland, generating information on likely source areas.

The aims are to: (i) develop a robust regional palaeogeography and tectonostratigraphic model highlighting the evolution from source to sink, (ii) understand the controls, timing and volume of the sediment supply to the margin delivered via fluvial systems and (iii) constrain the importance of sediment recycling, mixing and storage, and how they are influenced by the tectonostratigraphic evolution of the margin (iv) whether differential uplift in the hinterland resulted in a change of sediment sources and reorganization of sediment routing across the margin. This project applies sandstones petrography and geochemistry (including detrital feldspar and zircon geochronology) to trace sandstones provenance and to establish a source-to-sink model for the Mesozoic succession.

A 2 week field season was completed in April to log and sample additional basin sections and sample outcrops previously studied by Tim Luber. The field season was then continued in the main sources candidates of the provenance model for the Lower Cretaceous: the High Atlas and extended to the Anti Atlas to study the Cambrian subsidence and sedimentation system. The objective of this "source" work to sample and predict the lithic and isotopic signal that the sources would yield if they are supplying sediments during the Cretaceous. A Master's research project to analyse those source signatures is being carried out by Petroleum Engineering Master's student Osama Ahmed.

The heavy mineral separation lab is now operational and the separation of the heavy fractions of the Barremian/Aptian fluvial sandstones has begun to allow heavy mineral and isotopic analytical work. A successful application was made to for the use NERC NIGL isotopic facilities, which will allow us access to state of the art dating facilities. Isotopic work is scheduled to begin mid-July.

The initial encouraging results were presented at the BSRG conference in Newcastle (Dec17) and at the Heavy Mineral School of Milan (Feb18) and will also be presented at the Conjugate Margin Conference in Halifax (Jul18).



Sampling of the Pan-African volcanic series of the High Atlas, potential major source of sediment during the Barremian



Additional Lower Cretaceous transition zone outcrop logged and sampled in Tamzergout village, Eastern EAB

Cryogenic Heavy Mineral Separation Lab

A cryogenic heavy mineral separation lab is now operational in-house allowing the complete processing of samples prior to petrographic or isotopic work. This is being led by Emmanuel Roquette and James Lovell-Kennedy for the Cretaceous and Triassic clastics studies.

A new large capacity jaw-crusher has been set up, samples are crushed to 1mm before being dry sieved (with meshes= $< 250 \mu\text{m}$) and wet sieved (at $30 \mu\text{m}$ to remove all clays) using disposable nylon meshes to avoid cross contamination. The heavy minerals are separated with sodium heteropolytungstate (density ca 2.80 g/cm^3) and recovered by partial freezing of bottom 2cm of separation sample tubes with liquid nitrogen.

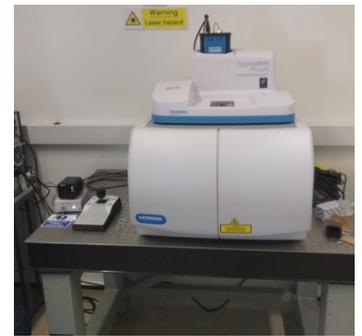


Grain mounts are prepared in house by laboratory technician Steve Stockley and identified using Raman Spectroscopy.

Separation fume cupboard



Liquid nitrogen use for the heavy mineral recovery



Raman microscope for petrographic identification



Zircon grains picked from Cretaceous fluvial sandstones in preparation for isotopic work




The project is being undertaken in collaboration with Dr Shane Tyrrell, at NUI Galway, who brings a wealth of experience and facilities including lead isotope analysis of detrital feldspars. We also are grateful for support from Stephen Crowley (Senior Experimental Officer at the University of Liverpool).

We acknowledge the award of funding to use the NERC NIGL facility.



Modelling salt tectonics offshore Morocco



Leonardo Muniz Pichel, working with Mads Huuse, Emma Finch, and Jonathan Redfern, is nearing completion of his thesis, which in part examines the evolution of the Essaouira salt basin. This study expand on previous work in the basin by integrating interpretation of new seismic (2D and 3D) and well data with both numerical and kinematic models to: 1) test earlier concepts, 2) investigate the origin and mechanisms controlling different geometries and kinematics along the margin; 3) analyse the effects of pre-salt topography and regional events on salt deformation; and 4) evaluate the timing and generation of allochthonous salt and their potential effects on paleo-bathymetry.

Leonardo was been awarded a travel/conference grant of \$500 by the AAPG and presented some of his results at the **Penrose Conference "Advances in salt tectonics: observations, applications, and perspectives: In honour of Martin P.A. Jackson"** in February, 2018

Offshore well and 2D seismic data to evaluate the Moroccan Atlantic margin salt basins has been kindly provided by ONHYM. Kosmos are also gratefully acknowledged for permission to access their 3D data.



The results offer improved understanding of the sequential evolution of the salt-related deformation, the types and evolution of structural styles and how pre-salt geometries impact salt tectonics and depocentre evolution offshore Morocco. This contributes to regional knowledge of the distribution of potential traps and reservoirs in the deepest and more commercially interesting supra-salt interval (i.e. Jurassic and Lower Cretaceous, Tari et al., 2012), an improves the understanding of syn-rift salt basins across the world.

He will submit in September. He has already one paper published, under review and a third on the way.

Graduation



Some pictures from Remi Charton's viva defence in TuDelft in May and Tim Luber's graduation in Manchester this July



Jurassic Carbonate Reservoir Characterisation

Investigating the depositional style, evolution and diagenetic history of Atlantic Margin Carbonates



Aude Duval-Arnould: 4th year PhD supervised by Stefan Schröder, Jonathan Redfern and Luc Bulot, is working on Jurassic depositional systems and strata architecture.

Final fieldwork was completed in 2018 and she has just finished drafting her first paper on “Lias post rift deposits and carbonate platform development; soon to be submitted.

The second paper will examine “Callovian ramp deposits – sedimentology and biostratigraphy”. Work on revising the biostratigraphy is being undertaken with Dr Luc Bulot and collaborators.

Right: Two “Biostrat Banditos” Luc Bulot and Moussa Massour discuss Oxfordian stratigraphy



Left: Aude examines massive anhydrite within Liassic sabkha deposits



Aude explains the stratal architectures of Oxfordian reefs at Tidili on the NARG Sponsors trip

Nawwar Al-Sinawi (3rd year PhD) is working on the project **Dolomitization of Jurassic Carbonates in the Western High Atlas of Morocco: processes and implications for reservoir properties**, supervised by Cathy Hollis, Stefan Schröder and Jonathan Redfern. Recent field, petrographical analysis and ¹⁸O/¹³C isotope suggests that dolomitization across the Agadir-Essaouira Basin (AEB) originated as a result of seawater reflux, locally overprinted by fault activity.

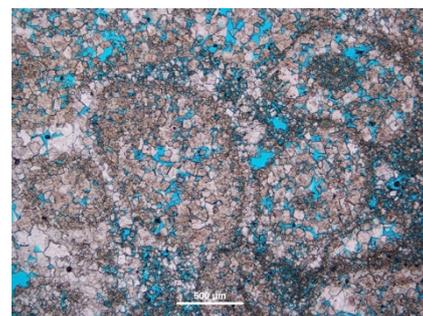
Sinemurian dolostones outcropping in the north west of AEB (Amsittene Anticline) are characterized by euhedral-subhedral dolomites, replacing wackestones and ooidal grainstones. These dolostones have enhanced porosity that reaches up to 11% compared to 0.2-0.5% of the parent limestones. Pliensbachian stratabound dolostones of ooidal grainstone texture outcropping in the south of AEB (Barrage Aquesri and Askouti) are the most porous facies during that time where the average porosity ranged between 7-8%. Oxfordian carbonates are more heterogeneous and dolomitization occurs in a range of facies (mudstone, wackestone, grainstones, floatstones and boundstones) and dolostones can be stratabound and non-stratabound.



Above: Nawwar and Aude in the field.

These dolostones show partial replacement by euhedral dolomites and are massively overprinted by anhedral-saddle dolomites indicating structural influence. Porosity values within Oxfordian facies varies between 0.5-8% in dolostones and 0.1-5% in limestones; which evidences a heterogeneous. Ongoing detailed geochemical analysis using x-ray diffraction, cathodoluminescence, clumped isotopes, rare earth elements and fluid inclusions will assist in identifying the origin of dolomites. These data will then be used to construct predictive models for dolomitization in Jurassic strata from Morocco that can be extrapolated and applied to Central Atlantic exploration.

Right: Photomicrograph illustrating intercrystalline porosity (blue) after dolomitization of Sinemurian ooidal grainstones, north west of Jebel Amsittene, Morocco boundstone, Tidili roadcut, Morocco



Conferences Presentations

ACE 2018- Utah, USA, 20-23rd May 2018 (poster): Al-Sinawi, N., Duval-Arnould, A., Hollis, C., Schröder, S., Redfern, J. Bertotti, G. Characterization and Origin of Oxfordian Dolomites in the Western High Atlas, Morocco.

Conjugate Margins Conference, Halifax, Canada, 20-23rd August 2018 (talk): Duval-Arnould, A., Al-Sinawi, N., Schröder, S., Hollis, C. and Redfern, J. Facies, stratigraphic evolution and dolomitization of the Jurassic carbonate system, Agadir-Essaouira Basin, Morocco: an outcrop analogue for the Central Atlantic Margin.

Petex, London, UK, November 2018 (poster/talk): Al-Sinawi, N., Hollis, C., Schröder, S., Redfern, J. Petrography and geochemistry of Jurassic dolostones, Western Morocco.

Biostratigraphy Update



Completed:

- Integrated revised Aptian stratigraphy for Morocco / NW Africa completed and almost published.
- Integrated revised stratigraphy for the Middle Jurassic of Sidi Ifni completed. Paper to be submitted shortly. Collaboration with Drs. Roberto Gatto and Stefano Monari (University of Padua, Italy)
- Re-evaluation of integrated ammo-planktic-forams biostratigraphy vs. C13 across C/T boundary completed for Errachidia and Tarfaya.
- Callovian/Oxfordian biostratigraphic framework (ammonites + brachiopods) completed. Poster presented at PalAss annual meeting in December 2017 (London).

In progress...

- Cenomanian-Turonian Tarfaya biostratigraphy (in collaboration with Christina Ifrim, University Heidelberg): preparation of material completed, photography in progress. Full description of fauna in progress.
- Aptian Morocco: Description of a biostratigraphic significant new genus will be submitted for publication by end August. Includes correlations with GOM.

Prospective...

- A University of Manchester MSc student will work on evolution of ammonite faunas across the Aptian-Albian boundary (material collected by Tim Luber / Luc Bulot). Objective: better appreciation of Aptian palaeobiogeography and inter-regional correlations in North Africa (Algeria, Tunisia and Egypt).
- Cladistic analysis of Aptian ammonites (Cheloniceratinae) of Atlantic Morocco vs. southern Margin of Tethys and GOM with ICAL colleague Robert Brocklehurst. Objective: impact of T/R cycles on necto-benthic ammonite evolution in shelf environments... implications for inter-regional correlations.

Romaniceras
Yubariceras
reymenti, Lower
Turonian, Oued
Zehar, Tarfaya,
Province,
Morocco



Epicheloniceras, Upper Aptian, Mramer,
Essaouira Province, Morocco

Biostratigraphic framework for the Berriasian to early Barremian Essaouira-Agadir Basin



We have commenced a new outcrop-based study to build a biostratigraphic framework for the Berriasian to early Barremian intervals in the Essaouira-Agadir Basin using an integration of ammonite, calpionellid, foraminifera and C13/O18 isotope analyses.

This will allow a deeper understanding of depositional, palaeogeographical and stratigraphic processes during the Early Cretaceous which in turn will provide further constraints on the understanding of potential deep-water reservoirs offshore on the Morocco Atlantic Margin."

PhD Orrin Bryers started in July, and is currently collating all available literature, and planning to have a first field season in October 2018



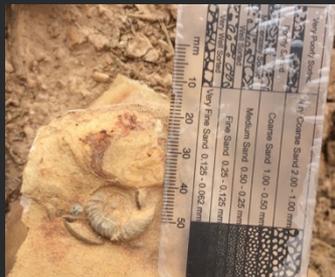
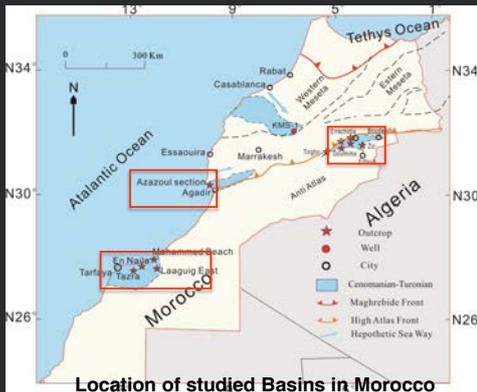
Source Rock Hunter- Controls on Cenomanian- Turonian source facies development



Photo of wadi section near Errachidia and location map (below left) of sections studied across Morocco

PhD Jianpeng Wang is finalising his thesis, to be submitted in Sept 2018. He has been working on a regional evaluation of the OAE2 interval, supervised by Prof Jonathan Redfern, Prof Kevin Taylor and Dr Luc Bulot, a project that spans the Cenomanian-Turonian to examine depositional controls on source rock development, comparing the development along the Tethyan and Atlantic margins.

The project is undertaken in collaboration with ONHYM, through support of Directeur de l'Exploration Pétrolière M. Mohamed Nahim and Zakaria Youfi



Early Turonian ammonite, found after many hours of search at the Goulmima section



Errachidia at dawn

Key aims:

- Source rock timing
- Controlling factors of black shale deposition and quality
- Global controls (OAE2) vs local controls on source richness.
- Paleoenvironmental controls to optimize source development, shallow and deep marine
- Productivity, preservation, terrigenous influx
- Role of C/T boundary



Jianpeng at the Errachidia section, where the black shales are only apparent after breaking the rocks.

Recent field work in Errachidia was targeted at refining the biostratigraphy (long days painstakingly looking for ammonites at key sections, which eventually yielded results), and further characterizing the very high TOC black shales identified in the Turonian section. These shales are hard to spot at outcrop as they weather light tan, but on breaking a fresh surface they are jet black with a very strong bituminous smell.

The work is revising our understanding both on the timing of significant organic enrichment in the CT section, and the impact of local palaeogeography on source rock distribution. First papers are expected in late 2018.



Regular steering meetings, workshops, fieldtrips and visits to sponsor offices allow close co-operation on research projects.

This benefits the students, many of whom take internships with the sponsors and later have been employed by them, and also the companies, allowing knowledge exchange and rapid delivery of research results

2018 NARG Morocco Workshop and Field Course



In May 2018 we organized another successful 1-day workshop in Marrakech followed by a 5-day field course for sponsors of NARG and invited guests. Attendees included representatives from Statoil (Equinor), Repsol, Woodside, Sound Energy and ONHYM.

This was an opportunity to exchange knowledge and showcase the new research being undertaken on the sections. As usual there were a lot of lively debates and exchange of ideas. It was also a chance to experience the wonderful culture of Morocco.



Group photo



Introducing the Early Cretaceous story at the Tamri section

Dr Luc Bulot (ably supported here by Remi Charton and Aude Duval-Arnould) holds court and explains the Aptian ammonite biostratigraphy at the baking hot type section in Tiskatine.



The CT source rock interval section along the coast near to Azazaoul

Knowledge Exchange and Impact



(right) In the distance the outcropping Jurassic Oxfordian reefs at Assif el Hade, part of Aude and Nawwar's field area.



On the coast examining Jurassic corals near Cap Rhir



- 18 years working across Northern Africa
- Regional petroleum system studies
- 15+ Academic Staff, 10+ PhDs
- 60 academic papers / reports
- Based at University of Manchester and TuDelft
- Collaboration with many other institutions Aarhus, Galway, VUA, Bordeaux, Padova, UCAD

Recent Publications and Upcoming Conference Presentations

Recent Publications:

Mader K, N., Redfern, J., Ouataoui M., (2017), Sedimentology of the Essaouira Basin (Meskala Field) in context of regional sediment distribution patterns during upper Triassic pluvial events. *Sedimentology*, doi.org/10.1016/j.jafrearsci.2017.02.012

Luber T, L., Bulot, L.G., Redfern, J., Frau, C., Arantegui, A., Masrour, M., (2017), A revised ammonoid biostratigraphy for the Aptian of NW Africa: Essaouira-Agadir Basin, Morocco., *Cretaceous Research*, 79, p 12-34, <http://dx.doi.org/10.1016/j.cretres.2017.06.020>

Muniz Pichel, L., Finch, E., Huuse, M. & Redfern, J. (2017), The influence of shortening and sedimentation on rejuvenation of salt diapirs: A new Discrete-Element Modelling approach, *Journal of Structural Geology*. DOI: 10.1016/j.jsg.2017.09.016

Camille Frau, C, A, J.-B, Tendil, Cyprien Lanteaume, Jean-PierreMasse, AntoinePictet Luc G.Bulot Tim L. Luber, Redfern, J., Borgomano J, R., Léonide, P., Fournier F., Massonnat G., (2018), Late Barremian–early Aptian ammonite bioevents from the Urgonian-type series of Provence, southeast France: Regional stratigraphic correlations and implications for dating the peri-Vocontian carbonate platforms. *Cretaceous Research*, Volume 90, p, 222-253 <https://doi.org/10.1016/j.cretres.2018.04.008>

Frau, C., Bulot, L.G., DelanoyY, G., Moreno-Bedmar, R, J.A., Masse, J.-P.; Tendil, A.J.-B., Lanteaume, C. 2018. The Aptian GSSP candidate at Gorgo a Cerbara (Central Italy): an alternative interpretation of the bio-, litho- and chemostratigraphic markers. *Newsletters on Stratigraphy* 51/3, 311-326. DOI: 10.1127/nos/2017/0422.

Benyoucef, M., Mebarki, K., Ferre, B., Adacib, M., Bulot, L.G., Desmares, D., Villier, L., Bensalah, M., Frau, C., Ifrim, C., MALTI, F.-Z. 2017. Litho- and biostratigraphy, facies patterns and depositional sequences of the Cenomanian-Turonian deposits in the Ksour Mountains (Saharan Atlas, Algeria). *Cretaceous Research* 78, 34–55. DOI: 10.1016/j.cretres.2017.05.013

In Press / Submitted:

Casson, M.A., Cavin, L., Jeremiah, J., Bulot, L., Redfern, J. 2018. Fishing in the Central Atlantic, an earliest Cenomanian ichthyodectiform, DSDP 41-367, Cape Verde Basin. *Journal of Vertebrate*

Tim L. Luber T.L., Bulot L.G.¹, Redfern J., Mohamed Nahim³, Jason Jeremiah⁴, Mike Simmons⁵,¹⁰, Stéphane Bodin⁶, Camille Frau⁷, Mike Bidgood⁸, Moussa Masrour, A revised chronostratigraphic framework for the Aptian of the Essaouira-Agadir Basin, a candidate type section for the NW African Atlantic Margin. *Cretaceous Research*

Recent Grant Awards



Max Casson was awarded a European Consortium for Ocean Research Drilling (ECORD) Research Grant 2018 to Max Casson - sponsoring merit-based awards for outstanding young scientists to conduct innovative research related to the International Ocean Discovery Program (IODP). The research may be directed toward the objectives of upcoming or past DSDP/ODP/IODP expeditions, using core material and/or data – as part of our ongoing stratigraphic framework.



Successful application made by Emmanuel Roquette to the NERC Isotope Geosciences Facilities IP-1784-1117 on Detrital zircon constraints on uplift and subsidence history the Mesozoic. NERC Isotope Geosciences Facilities Steering Committee NIGL, British Geological Survey Keyworth . Grant in kind from NERC of £29,000, with work to be carried out in collaboration with Dr Mike Millar

2nd International Congress on Permian and Triassic
 8th Meeting of Moroccan Group of Permian and Triassic
GMPT-8
 24 to 27 April 2018
 Faculty of Sciences Ben M'Sik



Jonathan Redfern was a keynote speaker at the recent conference in Casablanca. He gave an overview talk entitled "Assessing the Contribution of local versus continental drainage systems on the provenance of Upper Triassic fluvial deposits, Morocco"

A great opportunity to meet with the leading Moroccan and International geologists working on Triassic.

NARG Activities in MSGBC - Mauritania, Senegal and The Gambia



North Africa Research Group
www.narg.org.uk



Ongoing Research:

Collection of data from field localities in Senegal and Cap Verde is complete and on a recent visit to Petrosen in Dakar we sampled core and cuttings from exploration wells, which together with re-sampling of IODP material has generated a lot of new data for analysis over the coming months.



A provisional biostratigraphic framework is now in-place for the deep basin and we aim to extend this on to the shelf by incorporating data from Senegal.

Multi-disciplinary analysis has been performed in-house and with NARG collaborators. We are interpreting results from organic geochemistry working with James Armstrong. We aim to finish this initial stage of the project before the end of the year for publication and presentation at two conferences. Whilst in Houston to present at the PESGB/HGS Africa Conference, Max and Jonathan will also be collecting data from exploration wells drilled offshore Suriname, along the South American Equatorial margin, to integrate into the Central Atlantic framework.

Latest publication:

Casson, M.A., Cavin, L., Jeremiah, J., Bulot, L., Redfern, J. 2018. Fishing in the Central Atlantic, an earliest Cenomanian ichthyodectiform, DSDP 41-367, Cape Verde Basin. *Journal of Vertebrate*

Sampling core and cuttings at Petrosen

Prof Jonathan Redfern and Max Casson (NARG / University of Manchester) visited the Petrosen offices in Dakar in March 2018. The team were introduced at a meeting with Mamoudou KA, the Data Manager, to Prof Rafael Sarr from UCAD and his students Astou Leye and Aminiata Sall and to El Hadji Mansour Thiam from Petrosen, who will all work with NARG on this joint project.

A meeting was held between the project team and the General Manager Mamadou FAYE and Directeur E&P Joseph Medou, to discuss the project. NARG presented work undertaken already on the DSDP wells and on Cape Verde.

Initially 8 wells have been selected for re-evaluation; these were chosen to provide representative samples of the depositional system, spatially along strike from north to south and a dip profile from the onshore to the east to the onshore in the west. The deepest wells were selected to encounter the most complete stratigraphic record.



Sampling core and looking at well data reports with Prof Rafael Sarr from UCAD and his students as part of the joint Petrosen/NARG/UCAD study

Visit to Cap de Naz

On Friday, 30.03.18, the team (Maoudou Ka, Prof Raphael Sarr, Prof Jonathan, Max Casson, El Hadji Mansour Thiam (Petrosen), Prof. Rafael Sarr, Astou Leye, Aminiata Sall visited Cap de Naze, Popenguine to re-collect samples from the Campanian Unit IV located near the top the cliff face and examine the ammonite bed that had been reported in a publication by Prof Rafael Sarr.



Cap de Naz Cretaceous outcrops



Re-collecting samples from the Campanian Unit IV that were lost in transit



NARG in the field with Petrosen and UCAD, a steamy hot day in Senegal!



A poster prepared by NARG, using the acquired drone data and summarising the geology, was presented to the Popenguine Reserve rangers

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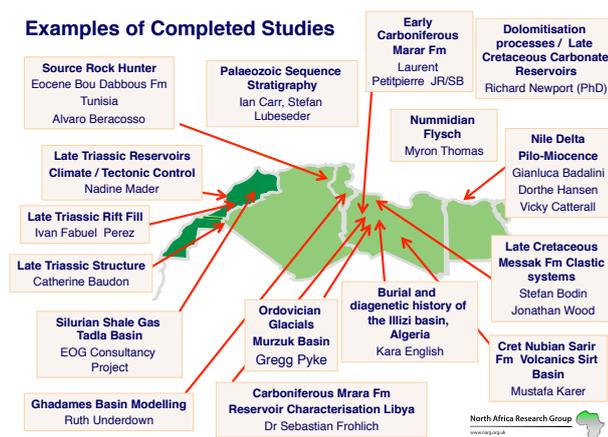
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Examples of Completed Studies



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