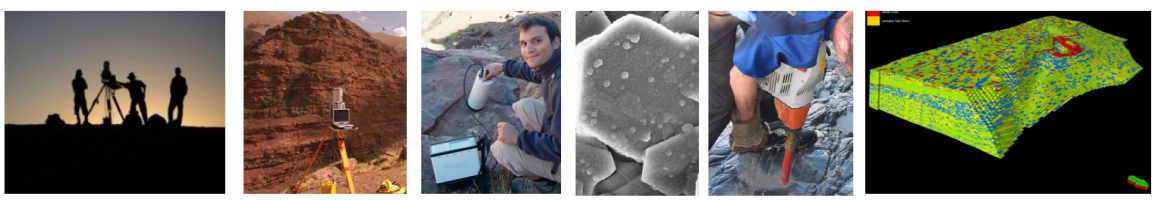
North Africa Research Group
(NARG)

University of Manchester
TuDelft
Herriot Watt University
2018



North Africa Research Group (NARG)

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1. Background: The **North Africa Research Group (NARG)** was founded in 2000 and conducts multi-disciplinary research with a petroleum geoscience theme in northern Africa. Current focus has been on Morocco, Algeria, Egypt, Libya and Tunisia. The research includes projects with integrated sedimentology, geochemistry, seismic interpretation, petrophysics and reservoir engineering. The group involves collaboration between Manchester, Heriot-Watt and TuDelft Universities, all of whom have an established record of petroleum geoscience and engineering research, supported by a group of international oil companies with the desire to promote research in this area.

2. Academic Institutions: The Research group is housed at the University of Manchester, where the majority of the researchers are currently based. Research is carried out by the University of Manchester, Heriot Watt University and TuDelft. The group is led by Prof Jonathan Redfern. We are also in a number of collaborations on specific projects, working with Galway University and University of Marseille, Aarhus University. Our biostratigraphy specialist group drwas on expertise globvaly, Led by Prof Luc Bulot, who in 2017 will relocate from Marseille to Manchester.

3. Current sponsors of the research group: BP, Chevron, Cairn, Repsol, Hess, Kosmos , Statoil and Wood side(correct as of 12/6/2018). A number of these sponsors joined the group at it foundation.

4. Membership: Sponsors join for a period of 3 years, which can subsequently be renewed on an annual basis or for further 3-year periods. Fees increase by 5% annually. New sponsors are also required to pay an initial "Back Cost" entry fee of 1-year subscription, plus the annual subscription. This can be paid over the three years, giving a **cost for new members** of: **£56500, £58500, £61425 for 2017/8/9.** Invoices are issued normally from 1st July. New sponsors are entitled to all previous PhD research theses, publications, and any reports, data (subject to availability) and powerpoint presentations. New company sponsors become full members of the group immediately, with full rights on the Steering Committee and access to all previous research. Sponsors are required to sign the Sponsors Contract, which is common to all participants.

5. Facilities: the research group has access to world-class facilities at the collaborating Universities. This includes full geochemical and sedimentological laboratories, with SEM, XRD, Ion probe and noble gas mass spectrometers, cold cathodoluminescence, UV fluorescence microscopes and fluid inclusion stages. Comprehensive analytical geochemistry facilities including: ICP-MS, ICP-AES, XRF, XRD, pyrolysis, GC-MS. Manchester also has analytical rigs for rock mechanics. Both Manchester and Heriott Watt have modern petrophysical suites. NARG also has a dedicated field GR, portable core drilling, LIDAR and DGPS. The group has access to a full suite of industry standard software including Schlumberger Petrel, VRGS, RocDoc, Oasis Montaj, MatLab, Zetaware, Genex and TemisPak, Pertromod, 2D and 3DMove.

6. Research Themes: The North Africa Research Group undertakes a wide range of research projects, as PhDs, PostDoctoral Research Projects or shorter studies. The research themes are decided by the Steering Committee, which meets twice a year. They are agreed by consensus and reflect the broad research interests of the sponsor companies and universities. Companies are encouraged to be involved in the studies, by providing data, supporting the students in the field, providing internships for the PhDs and participation in workshops that are held on a regular basis.

7. Confidentiality: Any data provided by a sponsor company is held under strict confidentiality, as outlined in the Sponsor Contract. This data will not be shared or seen by other sponsors unless explicit permission is granted. The research results and interpretation are provided to all sponsors (maps etc). Original data may only be provided if permissions are received from the donor company. Permission is sought prior to any publication that includes confidential data.

8. Publication Policy: The aim of the group is to publish all research in leading academic journals. Companies gain access to these results in advance as the research progresses, and also receive pre-prints of all papers. Companies can also access all the interpreted data and field data, subject to availability (sample size etc).

9. Data: All data collected in the field, and all interpreted data is made available to the sponsor companies. Field locations are currently being incorporated into a global GIS database.

10. Workshops and Field courses: NARG undertakes workshops, both in sponsors company offices and workshops open to the wider academic and industry community. Dedicated field courses are also organised for training. Past courses have been held in Morocco and Canada for sponsor companies.

11. Conferences: full acknowledgment is given to the sponsor companies on any presentations made by the research group. The group aims to present research at all leading conferences.

12. Researchers: Research is undertaken by academic staff at the host Universities (a full list is provided in section 17), who also support and supervise a number of PhDs and Postdoctoral researchers. Currently (2018) the research group has 9 PhDs, 1 MRes student and 1 PostDoc (see list secton 17). In addition we regularly have MSc students funded by ONHYM and other Petroleum Geoscience MSc students at Manchester regularly undertake projects based on NARG data, with results available to the group.

At least 2 further PhDs directly funded by NARG will commence in 2018, with funds already in place. Each new sponsor allows us to fund at least one new PhD in addition to the above.

In total 14 PhDs have been successfully completed, plus 1 MRes project. The group has also supported a number of postdoctoral researchers over the years.

13. Links to North African Institutions: The North Africa Research Group has established strong links with universities and government organisations in North Africa, including ETAP in Tunisia, ONHYM in Morocco, LPI and NOC in Libya.

14. Examples of Completed Research Projects: The group has completed a number of major regional studies across North Africa:

14.1 Third order sequence stratigraphic framework for the Palaeozoic reservoirs of North Africa
14.2 Depositional systems, stratigraphy and reservoir characterisation of the Early Cretaceous of Libya and Tunisia.
14.3 Early Carboniferous – Marar Formation and overlying Assedjefar FM, Ghadames Basin Libya
14.4 Nummidian Flysch depositional system and provenance
14.5 Late Triassic Syn-Rift Sequences – High Atlas, Argana Basin and Fundy Basin, Nova Scotia.
14.6 Deepwater Slope Channel and Mass Flow Complexes, Nile Delta
14.7 Ordovician Glaciogenic Reservoir Systems, Murzuk Basin, Libya
14.8 Source Rock Hunter Project and Basin Modelling
14.9 Carbonate Reservoir Studies: Dolomitisaton of Late Cretaceous Reservoirs, North Africa and Spain
14.10 FRAC -Fractured Reservoir Analogues Carbonates.
14.11 Diagenesis and thermal history of the Illizi Basin during the Ordovician, Algeria.
14.12 Controls on carbonate reservoir development, Kotla Graben, Sirt Basin, Libya.

14.1 Third order sequence stratigraphic framework for the Palaeozoic reservoirs of North Africa

This study was undertaken by Stefan Lubeseder, supervised by Prof Jonathan Redfern. The aim was to develop a third-order sequence stratigraphic framework for the Silurian and Devonian of North Africa, focusing on Morocco, Algeria, Tunisia and Libya. Due to the stability of the Saharan Craton during this period, Palaeozoic stratigraphy is relatively uniform across the area, allowing a regional study. Palaeozoic rocks form important reservoir and source rocks in North Africa, from the Cambrian to the Carboniferous. A sequence stratigraphic scheme together with the geometry of depositional systems and the key characteristics of their boundaries was developed, which offers as a valuable tool for the prediction of reservoir units in areas beyond data control. The outcrop studies can also serve as analogues to reservoir units in the subsurface. The final PhD thesis contain large inter-regional chronostratigraphic correlation charts, constructed to illustrate the intracratonic depositional model for North Africa. Practically, the study was split into three parts:

Morocco field case study:
Silurian: Silurian sections were studied in the Tafilalt area as well as in the Dra Plain of southern Morocco (Anti-Atlas). The emphasis was on the Ludlowian "Orthoceras" limestones and the so-called "*Scyphocrinites*" limestones at the Silurian/Devonian boundary. These limestone levels were studied in terms of their biostratigraphic position, depositional system, and inter-regional sequence stratigraphic significance. Silurian "Orthoceras" limestones are known from various other parts of the world and the study provided a significant contribution to the understanding of these beds.

Publications:
Lubeseder, S. (2008). Palaeozoic low-oxygen, high-latitude carbonates: Silurian and Lower Devonian nautiloid and scyphocrinoid limestones of the Anti-Atlas (Morocco). Palaeogeography, Palaeoclimatology, Palaeoecology, 264(1-2): 195-209

Lubeseder, S., Redfern, J., Boutib, L., (2009), Mixed siliciclastic-carbonate shelf sedimentation- Lower Devonian sequences of the SW Anti-Atlas, Morocco Source: *Sedimentary Geology*, 215, 1-4, pp. 13-32

Lubeseder S., J. Redfern, L. Petitpierre, S. Fröhlich. (2011). Stratigraphic trapping potential in the Carboniferous of North Africa: developing new play concepts based on integrated outcrop sedimentology and regional sequence stratigraphy (Morocco, Algeria, Libya). *Geological Society, London, Petroleum Geology Conference series 2011, v. 7, p. 725-734*, doi: 10.1144/0070725

PhD Thesis:

Stefan Lubeseder 2005: Silurian and Devonian Sequence Stratigraphy of North Africa: Regional Correlation and Sedimentology (Morocco, Algeria, Libya)

14.2 Depositional systems, stratigraphy and reservoir characterisation of the Early Cretaceous of Libya and Tunisia.

The project commenced in 2006 with a PhD undertaken by Mustafa Karer and supervised by Prof Jonathan Redfern, and was extended to include a field based study led by Dr Stephane Bodin and Prof Jonathan Redfern, with PhD student Jonathan Wood. This latter involved extensive fieldwork in the Murzuk Basin Libya and along the Jeffara Arch (Libya and Tunisia). The research involved collaboration with the LPI Libya and University of Sphax, Tunisia. Aims were to understand the evolving depositional systems, revise the stratigraphy /sequence stratigraphy and characterise /evaluate potential Early Cretaceous reservoirs. The study extended to the subsurface in the Sirt basin, where the "Nubian" sandstones are one of the main reservoir targets. This phase was completed in 2012, with a series of publications and the successful completion of Jonathan Woods PhD. This project may be extended in future to incorporate further subsurface data, and extend to Egypt and the wider region.

The separate but linked project undertaken by Mustafa Karer (funded by the Libyan government / LPI, with data sponsored by Wintershall) examined the Nubian sandstone and associated igneous activity in the Hameimat Trough, Sirt Basin, Libya. The research utilized high-resolution 3D seismic data, combined with gravity, aeromagnetic, well data and cuttings samples. This project provides valuable insight into seismic imaging of intrusive and extrusive igneous events within the Nubian (Sarir Sandstone) in the Sirt basin, Libya. The presence of volcanics can prove a hazard to drilling, and of emplacement volcanics can have serious detrimental effects on reservoir volume and quality. A number of major oil fields in eastern Sirt basins produce from the Early Cretaceous Nubian sandstone. This significant reservoir is highly structured and has a poorly understood facies distribution. As drilling targets deeper reservoirs or more complex structural areas, developing a better understanding of the Nubian is crucial to successful future exploration. In some localities the Nubian contains significant interbedded volcanics, which have affected and often degraded reservoir quality. The volcanics also affect the seismic response and this makes the exploration program very challenging.

Publications:
Bodin, S., Wood, J., Petitpierre, L., Redfern, J. (2010). " *Timing of Early to Mid-Cretaceous tectonic phases along North Africa: New insights from the Jeffara escarpment (Libya-Tunisia)*." Journal of African Earth Sciences 58, 3. pp 489-506.

Wood, J.D., S. Bodin, J. Redfern, M.F.H. Thomas, (2014), Controls on facies evolution in low accommodation, continental-scale fluvio-paralic systems (Messak Fm, SW Libya), Sedimentology V 301 p49-69.

PhD Theses:

2009: Mustafa Karer (now with Haliburton Libya): Nubian Sandstones, Hameitmat Trough, Sirte Basin Libya, Evaluating the sedimentology, reservoir characteristics and distribution, and the interbedded igneous units, their origin, distribution and impact on reservoir quality. Libya Gov. Funded

2012 Jonathan Wood (now with Shell International): Sedimentological characterization and regional palaeo-environmental implications of the Messak Fm, SW Libya. NARG Sponsored

14.3 Early Carboniferous – Marar Formation and overlying Assedjefar FM, Ghadames Basin Libya

The project commenced in 2008 and was led by Dr Sebastian Frohlich (now at Statoil) and Prof Jonathan Redfern, with PhD student Laurent Petitpiere, following an earlier pilot study carried out by Dr Stefan Lubeseder. The project involved extensive fieldwork in Libya on the southern margin of the Ghadames Basin (in part supported by Woodside). Results provide valuable new insights into the depositional environments, and have identified a series of significant incised valleys in the Carboniferous, possible reservoir targets in the subsurface. The work address the underlying controls on the system, and refines outcrop to subsurface correlation. In future the project could be extended into the subsurface in Algeria, where these units may offer significant reservoir potential.

Publications:

Fröhlich S., J. Redfern, L. Petitpierre, J. Marshall, M. Power, P. Grech (2009), Diagenesis and reservoir quality evolution of Lower Carboniferous fluvial channels, western Libya) . Journal of Petroleum Geology

Fröhlich, S., Petitpierre, L., Redfern, J., Grech, P., Bodin, S., Lang, S. (2010). "*Sedimentological and sequence stratigraphic analysis of Carboniferous deposits in western Libya: recording the sedimentary response of the northern Gondwana margin to climate and sealevel changes.*" Journal of African Earth Sciences 57 (4), pp. 279-296

Lubeseder S., J. Redfern, L. Petitpierre, S. Fröhlich. (2011). Stratigraphic trapping potential in the Carboniferous of North Africa: developing new play concepts based on integrated outcrop sedimentology and regional sequence stratigraphy (Morocco, Algeria, Libya). *Geological Society, London, Petroleum Geology Conference series 2011, v. 7, p. 725-734*, doi: 10.1144/0070725

PhD Thesis:

2012 Laurent Petitpierre (now with Statoil): Sedimentology and Stratigraphy of the Early Carboniferous Marar Formation in Western Libya. NARG sponsored.

Reports: Preliminary Evaluation of the Carboniferous interval: Dr Stefan Lubeseder pilot study

14.4 Nummidian Flysch depositional system and provenance

The Numidian Flysch is the most widespread tectono-stratigraphic unit in the western Mediterranean. It outcrops in the Alpine nappe belt, in southern Spain, Morocco, Algeria, Tunisia, Sicily and southern Italy. In Sicily and Tunisia it is an Oligocene to mid-Miocene flysch-type deposit sourced from the north-African passive margin and deposited into an east-west trending foreland basin. This study was supervised by Dr Stephane Bodin and Prof Jonathan Redfern, and undertaken as a PhD by Myron Thomas (now Shell). The study focused on outcrops in northern Sicily and Tunisia, evaluating the sedimentology and provenance within the context of the basin as a whole. Special emphasis is placed upon the controls on deposition and provenance of the clastic supply, which until this study were largely unknown. Future work is intended to extend this study to the west into Algerian and Morocco.

Publications:

Thomas, M. F. H., Bodin, S., Redfern, J., Irving, D. H. B. (2010). "*A constrained African craton source for the Cenozoic Numidian Flysch: Implications for the palaeogeography of the western Mediterranean basin*." Earth Science Reviews 101, 1. pp 1-23.

Thomas, M.F.H., S. Bodin, J. Redfern Comment on European provenance of the Numidian Flysch in northern Tunisia'by Fildes et al.(2010) Terra Nova 22 (6), 501-503

Lubeseder S., J. Redfern, L. Petitpierre, S. Fröhlich. (2011). Stratigraphic trapping potential in the Carboniferous of North Africa: developing new play concepts based on integrated outcrop sedimentology and regional sequence stratigraphy (Morocco, Algeria, Libya). *Geological Society, London, Petroleum Geology Conference series 2011, v. 7, p. 725-734*, doi: 10.1144/0070725

PhD Thesis:

2011: Dr Myron Thomas (now with Shell International): Sedimentology of the Nummidian Flysch – NARG Sponsored

14.5 Late Triassic Syn-Rift Sequences – High Atlas, Argana Basin and Fundy Basin, Nova Scotia.

These projects were run as a lead collaborator in the Atlantic Triassic Project, combining the research power of the Universities of Manchester, Aberdeen and UCD Dublin (Prof Pat Shannon). NARG researchers were Nadine Mader (PhD completed 2008, currently with Maersk) and Ivan Fabuel Perez (PhD completed 2009 currently with Exxon) and Xavier Van lanen (funded by Shell and currently with Statoil). Academic staff from NARG working on this project included Prof Jonathan Redfern, Dr David Hodgetts and Prof Brian Williams. Dr Cat Baudon worked on the project as a PostDoc at Manchester, and the students were also supported by Dr Sophie Leleu from Aberdeen University. This involved an integrated analysis of Late Triassic rift sequences in Canada, Morocco and the North Atlantic (and seismic data from Norway and W Britain). Manchester led the research use of LIDAR and field sedimentology in Morocco, characterising reservoirs in the systems, and also looking at the structural controls using field based analysis in the High Atlas of Morocco, the Argana Basin Morocco and Fundy Basin Canada. A number of publications have come out from this research.

Publications:

Redfern, J., Hodgetts, D. & Fabuel-Perez, I. (2007). Digital analysis brings renaissance for petroleum geology outcrop studies in North Africa. In: *First Break* 25, pp. 81-87.

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

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.

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.

Van Lanen, X.M.T., Hodgetts, D., Redfern, J., Fabuel-Perez, I. (2009). " *Applications of digital outcrop models; two fluvial case studies from the Triassic Wolfville Fm., Canada and Oukaimeden Sandstone Fm., Morocco."* Geological Journal, 44(6): 742-760.

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.

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

Mader, N. K. and Redfern, J. (2011). A sedimentological model for the continental Upper Triassic Tadrart Ouadou 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

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.

Rarity, F. X. M. T. van Lanen, D. Hodgetts, R. L. Gawthorpe, P. Wilson, I. Fabuel-Perez, and J. Redfern (2013), LiDAR-based digital outcrops for sedimentological analysis: workflows and techniques. Geological Society, London, Special Publications, 387, doi:10.1144/SP387.5

Mader K, N., Redfern, J., Ouataoui M., 2017 (in press) Sedimentology of the essaouira basin (meskala field) in context of regional sediment distribution patterns during upper triassic pluvial events. doi.org/10.1016/j.jafrearsci.2017.02.012

PhD Theses:

2006: Dr Nadine Mader (now working for Maersk): Sedimentology, third order sequence stratigraphy and controlling factors on facies distribution in the Triassic of North Africa. NARG Funded

2009: Dr Ivan Fabuel Perez (now in Exxon): 3D Modelling of Late Triassic Continental mixed fluvial systems; integrating LIDAR with high resolution sedimentology of fluvial facies: High Atlas, Morocco NARG Funded

2011: Dr Xavier Van Lanen (now with Statoil): Quantitative Outcrop Analysis / Integrated Reservoir Modelling of Triassic Fluvial Facies, Minas Basin, Nova Scotia, Canada. Shell International funded.

14.6 Deepwater Slope Channel and Mass Flow Complexes, Nile Delta

This research was undertaken by PhD student Victoria Catterall, supervised by Prof Jonathan Redfern and Prof Rob Gawthorpe. PostDoc researcher Dr Dorthe Hansen (now Statoil) also contributed to the work. This project studied deepwater depositional processes, controls and evolution of the Nile Delta, Egypt, in the context of submarine channel evolution, and generation and interaction with mass-transfer-complexes. It utilized an extensive 3D database provided by BG Group. This work was undertaken within a sequence stratigraphic framework, with the results providing new and important quantification of the slope system evolution in terms of architecture, structure and morphology.

Publications:

Catterall, V., Redfern, J., Gawthorpe, R.L., Hansen, D.M & Thomas, M.H.F (2010), Architectural Style and Quantification of a Submarine Channel-Levee Systems located in a structurally complex area: Offshore Nile Delta, *Journal of Sedimentary Research,* v. 80; no. 11; pp. 991-1017; DOI: 10.2110/jsr.2010.084

PhD thesis:

2010: Dr Victoria Catterall (now with ExxonMobil): Evolution and morphology or deepwater channels, offshore Nile Delta, Egypt. NERC / BG Group Case funded

14.7 Ordovician Glaciogenic Reservoir Systems, Murzuk Basin, Libya

This project undertaken by PhD student Gregg Pyke at Heriot Watt (now at Oxy) was supervised, Dr Andy Gardiner, Prof Patrick Corbett, and also Prof Jonathan Redfern, and examined the Controls on Reservoir Quality within the Cambro-Ordovician Sandstones of the Saharan Platform. Extensive fieldwork was been undertaken in the Murzuk Basin, integrated with a large subsurface dataset, built into a regional Petrel model. Diagenesis of the Memouniat reservoir has been modeled using the Touchstone software ™

Publications:

No publications have been forthcoming from this work. A number of ppt presentations and extended abstracts are available on the NARG secure server.

PhD Thesis:
This work has still to be submitted for a PhD. A number of ppt presentations and preliminary reports are available to the sponsors.

14.8 Source Rock Hunter Project and Basin Modelling

Early work on regional source rocks was undertaken by postdoctoral researcher Dr Sebastian Luning, supported by Stefan Lubeseder and Dr Jonathan Redfern. This work aimed to assess the source rock quality of Palaeozoic shales from outcrop studies, that had proved difficult to quantify due to intense weathering. The project included the analysis of a number of methods to allow more accurate regional mapping of source rock facies including surface exposures. Based on their characteristic uranium gamma-radiation and pyrite framboid distribution, the original organic richness of the Silurian / Upper Devonian shales in weathered outcrops was mapped in Libya. A model for the distribution of the rich source rocks was developed. Fieldwork was carried in the Moroccan Anti-Atlas where the Frasnian and Silurian hot shales were studied at outcrop using a portable gamma-ray spectrometer. The unit is typically marked by enrichment in uranium. Additional fieldwork was carried out on the Silurian Tannezuft Shales outcrops documented in Ghat (SW Libya) and Algeria for the Silurian and Devonian source facies.

The project was continued by Dr Alvaro Jimenez Berracosso (now with Repsol). New field investigations were carried out in north central Tunisia, examining the organic-rich sediments of the Bou Dabbous Fm (lower Eocene). The research addressed the controls on the development of the organic richness and assess its distribution stratigraphicaly and aerially, in order to improve source rock quality predictions.

Other research (oncluding proprietary consulting projects) has focused on the Silurian (Tanezuft Shales) in Libya and Morocco, Cenomanian /Turonian and Toarcian source rocks.

Future work will initially focus on the Cenomanian / Turonian in Morocco, with Prof Kevin Taylor from the University of Manchester. These outcrops, integrated with available offshore well and seismic data, will provide an analogue for offshore source intervals along the Atlantic margin. Development of the online database is continuing for all the main source horizons and potentially significant intervals.

NARG has also been working on basin modelling projects, integrated to petroleum system analysis, since its inception. We have access to the lasts basin modelling software, and through collaborations, can undertake heat flow and subsidence history analysis (FT, Vr etc). The capability is enhanced now through the membership of TU Delft.

Publications:
Burwood R., Redfern J., and Cope M. (2003) Geochemical evaluation of East Sirte Basin (Libya) petroleum systems and oil provenance. In *Petroleum Geology of Africa: New Themes and Developing Technologies*, Vol. 207 (ed. T. J. Arthur, D. S. MacGregor, and N. R. Cameron), pp. 203-204. Geological Society of London Special Publication.

Lüning, S., Craig, J., Loydell, D. K., Storch, P. & Fitches, W. R. (2000): Lowermost Silurian 'hot shales' in North Africa and Arabia: Regional Distribution and depositional model. Earth Science Reviews 49: 121-200.

Lüning, S., Adamson, K., Craig, J. (2003a): Frasnian 'Hot Shales' in North Africa: Regional Distribution and Depositional Model. In: Arthur, T. J., Macgregor, D. S., Cameron, N. (Eds.), Petroleum Geology of Africa: New Themes and developing technologies, Geol. Soc. (London) Sp. Publ. 207: 165-184.

Lüning, S., S. Kolonic, D. Loydell, J. Craig (2003b): Reconstruction of the original organic richness in weathered Silurian shale outcrops (Murzuq and Kufra basins, southern Libya). GeoArabia 8: 299-308.

Lüning, S., S. Kolonic, E. M. Belhadj, Z. Belhadj, L. Cota, G. Baric, T. Wagner (2004): Integrated depositional model for the Cenomanian-Turonian organic-rich strata in North Africa. Earth-Science Reviews 64: 51-117.

Underdown, R., and Redfern, J., (2007), The importance of constraining regional exhumation in basin modelling: a hydrocarbon maturation history of the Ghadames Basin, North Africa., Petroleum Geoscience, V 13, p 1-19

Underdown, R., and Redfern J., (2007), Constraining the burial history of the Ghadames Basin, North Africa: An integrated analysis using sonic velocities, vitrinite reflectance data and apatite fission track ages. Basin Research, Volume 19, Number 4, pp. 557-578 (22)

Underdown, R., and Redfern, J., (2008), Petroleum Generation and Migration in the Ghadames Basin, North Africa: A 2D Basin Modelling Study, AAPG Bulletin, V. 92, No. 1 , pp. 53-76.

Bodin S., E. Mattioli, S. Frohlich, J.D. Marshall, L. Boutib, S. Lahsini, J.Redfern (2010). "*Toarcian carbon isotope shifts and nutrient changes from the Northern margin of Gondwana (High Atlas, Morocco, Jurassic): Palaeoenvironmental implications.*" Palaeogeography, Palaeoclimatology, Palaeoecology, 297, pp 377-390.

Reports:

Additional reports are available of the Jurassic source rocks of Fuerteventura, and regional source rock analysis of the Silurian in Morocco and Libya.

PhD Thesis:

2006: Dr Ruth Underdown (now a school teacher): Assessing the impact of regional unconformities on the maturation and migration of hydrocarbons within the Ghadames Basin, North Africa. NARG Funded

14.9 Carbonate Reservoir Studies: Dolomitisaton of Late Cretaceous Reservoirs, North Africa and Spain

The influence of dolomitisation on Late Cretaceous carbonates in North Africa is often critical to reservoir development. The study has analysed the superbly exposed section along the Jeffara escarpment of southern Tunisia, together with analogue outcrops in Northern Spain. These outcrops provide an excellent opportunity to study the extensively dolomitised Upper Albian-Lower Turonian shallow water carbonates of the Zebbag Formation (Rhadouane, Kerker and Gattar Members), and similar facies in Spain, which are potential outcrop analogues for reservoirs currently under production and appraisal in North Africa. This study comprised a multi-disciplinary, multi-scale approach using field, petrographical and geochemical data to better constrain the depositional history, diagenetic history and source of diagenetic fluids.

Publications:

Newport, R., Hollis, C., Bodin, S. and Redfern, J. 2017 , Examining the interplay of climate and low amplitude sea-level change on the distribution and volume of massive dolomitisation: Zebbag Formation, Cretaceous, Southern Tunisia. Depositional Rec.. doi:10.1002/dep2.25

2 papers in preparation

PhD Thesis: Richard Newport (2014)

14.10 FRAC -Fractured Reservoir Analogues Carbonates.

This project was led by postdoctoral fellow Dr Guy Spence. Outcrop analogues of subsurface naturally fractured carbonate hydrocarbon reservoirs in Egypt were studied to improve our understanding of fracture development and prediction in these complex reservoirs. Field studies were undertaken in Egypt prior to the political situation changing. The project involved the use of DGM /LiDAR 3-D field mapping of fractured carbonate outcrops, sedimentary logging, sampling and mapping. Data processing and analysis used the Manchester in-house software VRGS and Schlumberger's Petrel software. The aim was to improve understanding of fracture characterisation and property modeling.

Publications:

Spence, G.H., Redfern, J., Aguilera R., Bevan, T., Cosgrove, J.W., Couples, G., Daniel, J-M. (eds) (2014), *Advances in the Study of Fractured Reservoirs*. Geological Society, London, Special Publication v. 374. and papers therein

14.11 Diagenesis and thermal history of the Illizi Basin during the Ordovician, Algeria.

Kara English (completed) is funded by Petroceltic (providing data and funding) and NARG.

This study focuses on the southern Illizi basin in Algeria, where a substantial new dataset has been acquired by Petroceltic International as part of the recent appraisal of the Ain Tsila gas-condensate discovery. A number of complementary methods are being used to constrain the thermal and burial history of the Ordovician reservoirs in the Ain Tsila field. These techniques include: estimates of missing stratigraphy based on regional observations and cross-sections, estimates of the magnitude of exhumation based on sonic velocity 'over-compaction' of regionally homogeneous shale and sandstone packages, estimates of peak burial temperature and paleo-geothermal gradients based on vitrinite reflectance data, and constraints on thermal history provided by apatite fission track (AFT) data. The resulting burial history models combine all available fluid inclusion and source rock data to generate a model of the timing of hydrocarbon generation and migration from the primary source rocks within the basin. These models are being used to predict the timing of a potential early-oil fill within the Ordovician reservoirs in the Ain Tsila field, and also the timing of the main gas- condensate charge. These burial history models will be utilized in order to construct some conceptual sandstone diagenesis models using Touchstone software, and to determine if any predictions can be made regarding the (spatial and vertical) variation of reservoir quality across the Ain Tsila field.

Publications:

English K.L., Redfern , J., Corcoran, D.V., English, J.M., Yahia R.C. 2016. Constraining burial history and petroleum charge in exhumed basins: New insights from the Illizi Basin, Algeria. AAPG Bulletin. DOI: 10.1306/12171515067

English, K., Redfern, J., Bertotti, G., English, J., Cherif, R.Y. 2016. Intraplate uplift: new constraints on the Hoggar dome from the Illizi basin (Algeria). Basin Research . doi: 10.1111/bre.12182

English, J., English, K., Corcoran, D.V., Fabrice Toussaint F., 2016, Exhumation charge: The last gasp of a petroleum source rock and implications for unconventional shah resources, AAPG Bulletin 100(1):p 1-16

14.12 Controls on carbonate reservoir development, Kotla Graben, Sirt Basin, Libya.

Mohammed Salem (2nd year) is funded by the Libyan Government, with data supplied by AGOCO:

The evolution of the Western Sirt Basin in the region of the Dahra Platform, Amin High and Kotla Graben is being evaluated by integrating 2D /3D seismic and data from 36 wells. Three tectonic styles can be identified involving regional Pre-rift intra-continental sag, complex multi-stage rifting and modification by wrenching. A major horst-graben system configuration has been delineated, which allows mapping fault distribution and timing throughout the area. Time, interval velocity, isochron, depth, isopach and lithofacies contour maps of the selected (12) horizons have been constructed. These maps are being used to interpret the subsurface architecture of the area from thickness, depth variations and velocity anomalies, in terms of tectonic effect and its control on thickness and facies distribution throughout the Dahra Platform and Kotla Graben area.

15. Current Research Projects:

15.1 Characterisation of Cretaceous Depositional Systems along the Atlantic Passive Margin, Morocco

An interdisciplinary and multi-scale research project to characterize and evaluate the evolution of the Cretaceous depositional systems Onshore Morocco along the Atlantic Seaboard, extending offshore along the Morocco passive margin. To improve understanding of the depositional systems, facies modeling and basin evolution, with the implications for petroleum systems and modeling reservoirs, source distribution, generation and migration, and seal. The research will undertake detailed analysis of onshore outcrops to develop improved sedimentological models and establish depositional facies distributions through time, provenance, diagenesis and improved

chronostratigraphy.

This project commenced in January 2014, and 1st results have been delivered to the sponsors. The project will be integrated with analysis of available offshore subsurface data provided by ONHYM, including an offshore 2D seismic grid and access to well data and reports. NARG has singed an MOU with ONHYM to cooperate ion this study, building on the very strong links over the last 10 years. Additional data will be provided by sponsoring companies, to assist in mapping the offshore in order to constrain the source to sink models, and assess the evolution of the Cretaceous system and controls on sedimentation (salt tectonics) and basin evolution.

Research team comprises 6 PhDs (Tim Luber (completed 2017), Angel Arantegui (to complete 2018), and Leonardo Muniz Pichel (Brazilian Gov Scholarship) (to complete 2018) based in Manchester and Remi Charton in TuDelft (to complete 2018). Academic staff supervision from Prof Jonathan Redfern, Prof Giovanni Bertotti and Prof Joep Storms from Manchester, TU Delft and Amsterdam (VUA). New for 2017 Emmanuel Roquette, co supervised by Dr Shane Tyrrell University of Galway.

15.2 Provenance study of the Early Cretaceous depositional systems, Agadir and Tarfaya Basin, Morocco.

This project commenced in January 2017. It will apply an array of techniques, including heavy mineral analyses, zircon, and feldspar to assess the possible provenance locations and contribution history for the Early Cretaceous depositional systems, linking existing work being undertake on the sedimentology on the margin and Fission Tack modelling of potential source areas. To be conducted in collaboration with UCD / Galway University, Eire.
PhD: Emmanuel Roquette : Supervisors: Stefan Schroeder, Jonathan Redfern, Shane Tyrrell (Galway)

15.3 Jurassic Carbonate reservoir characterisation and evolution along the Atlantic Margin:

The study will focus on stratigraphic architecture, paleogeography and facies trends of Jurassic carbonates along the Moroccan Atlantic Margin, as well as age relationships in the basin. Part of the work will be outcrop-based, by conducting a regional stratigraphic-sedimentological study. Results will be integrated with subsurface datasets, seismic and well data. The study will have impact on active oil and gas exploration, in the light of hydrocarbon discoveries in Jurassic carbonates both in Morocco and in the conjugate basins of Canada. Reconnaissance studies of the Jurassic Outcrops north of Agadir have already been conducted. Students are being interviewed for an early January start. In addition ONHYM are funding one of their staff to undertake an MRes at Manchester as part of this study.

PhD: Aude Duval Arnaud. Supervisors: Dr Stefan Schroder and Prof Jonathan Redfern. An additional PhD commenced in 2016, Nawwar Al-Sinawi (PDO sponsored) to examine the diagenetic history of the carbonates.

15.4 Source Rock Hunter: Controls on distribution and quality of the Turonian / Cenomanian Source rocks along the Atlantic Margin

This project being undertaken by PhD student Jianpang Wang (Chinese Gov. Scholarship) has commenced, supervised by Prof Kevin Taylor and Prof Jonathan Redfern. The aims is to characterise the Cenomanian / Turonian source rocks outcropping onshore Morocco and correlate with the offshore penetrations. Geochemical data will be collated and new data produced from examination of outcrop and cuttings data. The study will address the controls and processes of source rock development and enrichment. It is anticipated this will extend south along the Atlantic margin and also include an element of basin modelling. This will contribute to the NARG Source Rock Hunter project.

15.5 Biostratigraphy and depositional evolution of the West Africa Margin: Mauritania-Senegal-Guniea Buissau

Commenced 2017, to examine the stratigraphy and evolution of the Atlantic margin from Mauritania through Senegal to Guinea-Buissau. The study will focus on refining our understanding of the structure, stratigraphic architecture, age relationships, palaeogeography, facies trends. The work will integrate data from existing wells (cuttings data and wireline log data), limited outcrop studies and analysis of onshore / offshore seismic and gravity / magnetic data to define stratal relationships and seismic facies.

Key areas for study include: building a stratigraphic framework, assessing regional unconformities, developing evolution models for the basin fill and assessing key controls

Fieldwork already undertaken in Senegal and Caop Verde, with additional sampling for LowT Geochronology in Mauritania. MOU with Petrosen signed and access grantred to onshore / offshore well and seimsic data. Collaborative project initiaited with Petrosen and UCAD (Dakar University)

15.6 Low –T Geochronology of the Maurinitides, assessing the exhumation history of Mauritania

Project commenced in 2017, with fieldwork to sample the Mauritinides in Mauritania. 80 samples collected and currently being processed for apatite fission track studies. the work will extend the comprehensive dataset in Morocco. Further fieldwork and sampling is expected in Senegal to augment sampling. Results expected mid 2018.

15.7 Provenance and Reservoir Characterisation: Triassic Continental sandstones, Eastern Morocco

This project commenced in Sept 2017 with a 1 year MRES student. Sampling and fieldwork has been undertaken in the Kerrouchen Basin and we have confidential access to subsurface data from the Tendrara Field supplied by Sound Energy. The project will assess the regional stratigraphy, build GDE maps for the region and undertake preliminary provenance analysis (heavy minerals and petrography. It will be followed by a PhD starting in 2018 to extend this work to involve further provenance studies and fieldwork.

16. New Projects commencing in 2018/9 :

16.1 The Early Cretaceous evolution on the Morocco Atlantic Margin: establishing an integrated stratigraphic framework and depositional model for the Berriasian to early Barremian interval

PhD studentship to start in June 2018 to examine the evolution of Berriasian to Barremian interval of the Early Cretaceous depositional system that outcrops along the Atlantic margin of Morocco north of Agadir. The study will define a new biostratigraphic type section, integrating ammonite, calpionellid calcareous nannofossil and benthic foraminifera analysis, with C13/O18 isotope stratigraphy and sequence stratigraphic interpretation. It will focus on refining our understanding of the stratigraphic architecture, age relationships, paleogeography and facies trends across the margin. The work will involve extensive outcrop studies and also integrate data from existing wells (cuttings data and wireline log data).

A focus of the study will also characterise the coral buildups in the Hauterivian : provide improved age constraint, map their geometry and assess the significance and impact these buildups have on post Hauterivian paleogeography and palaeotopography. The project will also assess potential salt tectonic movements in relation with condensation and hiatuses that affects the early Lower Cretaceous sequences. Integration will be made with work completed in Morocco by NARG on the younger Barremian to Aptian section and the results will be correlated to global type sections. The Early Cretaceous is a potential reservoir for hydrocarbons offshore, and this work will further constrain the interval and refine models for the depositional system that controls deep-water reservoir development.

PhD: Orrin Bryers (commences June 2018) Supervisors: Prof Jonathan Redfern, Dr Luc Bulot, Dr Stefan Schroeder, Prof Giovanni Bertotti

16.2 Seismic-stratigraphic evolution of the West Africa Margin: Mauritania-Senegal-Guinea Bissau

To commence in 2018 and examine a regional seismic 2D grid provided by TGS along the margin, to define the tectono-stratigraphic evolution of the Atlantic margin from Mauritania through Senegal to Guinea-Bissau. Working in collaboration with existing PhD already commenced. The study will focus on refining our understanding of the structure, stratigraphic architecture, age relationships, palaeogeography, facies trends and igneous intrusions styles and ages across the margin. The work will integrate data from existing wells (cuttings data and wireline log data), limited outcrop studies and analysis of onshore / offshore seismic and gravity / magnetic data to define stratal relationships and seismic facies. To commence September 2018

It is anticipated the 2 additional PhDs will commence in 2019, with decisions to be made at the next Steering meeting.

17. List of researchers:

Staff:

Manchester
Prof Jonathan Redfern
Dr David Hodgetts
Dr Cathy Hollis
Dr Stefan Schroeder
Dr Mads Huuse
Prof Kevin Taylor
Dr Luc Bulot

Heriot Watt
Prof Dorrik Stow

TUDelft
Prof Giovanni Bertotti
Prof Joep Storms

PostDocs:
Remi Charton *(TuDelft)*

Administrative Assistant:
Kofi Owusu

Current PhDs:
Angel Arantegui (NARG Manchester)
Mohamed Salem (Libyan Gov. Sponsors)
Aude Duval (NARG Manchester)
Jianpang Wang (Chinese Gov. Scholarship)
Leonardo Muniz Pichel (Brazilian Gov Scholarship)
Nawwar Al-Sinawi (PDO Scholarship)
Emmanuel Roquette (NARG Manchester)
Max Casson (NARG Manchester)
James Lovell-Kennedy (NARG Manchester)
Orrin Bryers (NARG, Manchester)

Completed PhDs (University / currently with):

Dr Ruth Underdown (Manchester / Teacher)
Dr Stefan Lubeseder (Manchester/ Wintershall)
Dr Nadine Mader (Manchester / Maersk)
Dr Ivan Fabuel Perez (Manchester / Exxon)
Dr Vicky Catterall (Manchester / Exxon)
Dr Mustafa Karer (Manchester/ Consultant)
Dr Xavier Van Lanen (Manchester / Statoil)
Dr Jonathan Wood (Manchester / Shell)
Dr Laurent Petitpierre (Manchester / Statoil)
Dr Myron Thomas (Manchester / Shell)
Dr Richard Newport (Manchester / Shell)
Dr Kara English (Petroceltic Scholarship)
Habid Awatif (MRes) Onhym Scholarship
Tim Luber (NARG Manchester)
Remi Charton *(TuDelft)*

Pending PhDs:
Gregg Pyke (Heriot Watt / Oxy)

Previous PostDocs (*currently with:*)

Dr Ian Carr (Worthing College)
Dr Sebastian Luning (Galp Energia)
Dr Gianluca Badalini (Shell)
Dr Dorthe Hansen (Statoil)
Dr Stefan Lubeseder (Wintershall)
Dr Sebastian Frohlich (Statoil)
Dr Stephane Bodin (Aarhus Univ)
Dr Alvaro Jimenez (Repsol)
Dr Catherine Baudon (Independent)
Dr Guy Spence (Consultant)

Associate Researchers:

18. Selected Publications:

Burwood R., Redfern J., and Cope M. (2003) Geochemical evaluation of East Sirte Basin (Libya) petroleum systems and oil provenance. In *Petroleum Geology of Africa: New Themes and Developing Technologies*, Vol. 207 (ed. T. J. Arthur, D. S. MacGregor, and N. R. Cameron), pp. 203-204. Geological Society of London Special Publication.

Badalini G., Redfern J., and Carr I. D. (2002) A synthesis of current understanding of the structural evolution of North Africa. *Journal of Petroleum Geology* 25(3), 249-258.

Fello, N., Lüning, S., Štorch, P., and Redfern, J. (2006), Identification of early Llandovery (Silurian) anoxic palaeo-depressions at the western margin of the Murzuq Basin (southwest Libya), based on gamma-ray spectrometry in surface exposures. *GeoArabia* 11 (3): 101-118.

Redfern, J., Hodgetts, D. & Fabuel-Perez, I. (2007). Digital analysis brings renaissance for petroleum geology outcrop studies in North Africa. In: *First Break,* 25, 81-87.

Underdown, R., and Redfern, J., (2007), The importance of constraining regional exhumation in basin modelling: a hydrocarbon maturation history of the Ghadames Basin, North Africa., Petroleum Geoscience, V 13, 1-19

Underdown, R., and Redfern J., (2007), Constraining the burial history of the Ghadames Basin, North Africa: An integrated analysis using sonic velocities, vitrinite reflectance data and apatite fission track ages. Basin Research, Volume 19, Number 4, 557-578(22)

Underdown, R., and Redfern, J., (2008), Petroleum Generation and Migration in the Ghadames Basin, North Africa: A 2D Basin Modelling Study, AAPG Bulletin, V. 92, No. 1 , 53-76.

Hansen, D.H., , Redfern,J., Federici, F., di Biase, D. and Bertozzi, G.,(2008), Miocene igneous activity in the northern subbasin, offshore Senegal, NW Africa, Marine and Petroleum Geology, Volume 25, Issue 1, 1-15

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

Lubeseder, S., Redfern, J., Boutib, L., (2009), Mixed siliciclastic-carbonate shelf sedimentation- Lower Devonian sequences of the SW Anti-Atlas, Morocco Source: *Sedimentary Geology*, 215, 1-4, pp. 13-32

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.

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.

Van Lanen, X.M.T., Hodgetts, D., Redfern, J., Fabuel-Perez, I. (2009). " *Applications of digital outcrop models; two fluvial case studies from the Triassic Wolfville Fm., Canada and Oukaimeden Sandstone Fm., Morocco."* Geological Journal, 44(6): 742-760.

Fröhlich S., J. Redfern, L. Petitpierre, J. Marshall, M. Power, P. Grech (2009), Diagenesis and reservoir quality evolution of Lower Carboniferous fluvial channels, western Libya) . Journal of Petroleum Geology

Bodin S., E. Mattioli, S. Frohlich, J.D. Marshall, L. Boutib, S. Lahsini, R.Redfern (2010). "*Toarcian carbon isotope shifts and nutrient changes from the Northern margin of Gondwana (High Atlas, Morocco, Jurassic): Palaeoenvironmental implications*." Palaeogeography, Palaeoclimatology, Palaeoecology, 297, pp 377-390.

Bodin, S., Wood, J., Petitpierre, L., Redfern, J. (2010). " *Timing of Early to Mid-Cretaceous tectonic phases along North Africa: New insights from the Jeffara escarpment (Libya-Tunisia)*." Journal of African Earth Sciences 58, 3. pp 489-506.

Thomas, M. F. H., Bodin, S., Redfern, J., Irving, D. H. B. (2010). "*A constrained African craton source for the Cenozoic Numidian Flysch: Implications for the palaeogeography of the western Mediterranean basin*." Earth Science Reviews 101, 1. pp 1-23.

Fröhlich, S., Petitpierre, L., Redfern, J., Grech, P., Bodin, S., Lang, S. (2010). "*Sedimentological and sequence stratigraphic analysis of Carboniferous deposits in western Libya: recording the sedimentary response of the northern Gondwana margin to climate and sealevel changes.*" Journal of African Earth Sciences 57 (4), pp. 279-296

Catterall, V., Redfern, J., Gawthorpe, R.L., Hansen, D.M & Thomas, M.H.F (2010), Architectural Style and Quantification of a Submarine Channel-Levee Systems located in a structurally complex area: Offshore Nile Delta, *Journal of Sedimentary Research,* v. 80; no. 11; pp. 991-1017; DOI: 10.2110/jsr.2010.084

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.

Lubeseder S., J. Redfern, L. Petitpierre, S. Fröhlich. (2011). Stratigraphic trapping potential in the Carboniferous of North Africa: developing new play concepts based on integrated outcrop sedimentology and regional sequence stratigraphy (Morocco, Algeria, Libya). *Geological Society, London, Petroleum Geology Conference series 2011, v. 7, p. 725-734*, doi: 10.1144/0070725

Thomas, MFH. S Bodin, J Redfern Comment on European provenance of the Numidian Flysch in northern Tunisia' by Fildes et al.(2010) Terra Nova 22 (6), 501-503

Bodin S., Fröhlich, S., Boutib, L., S Lahsini, S., and Redfern J (2011). Early Toarcian Source-Rock Potential in the Central High Atlas Basin (Central Morocco): Regional Distribution and Depositional Model. Journal of Petroleum Geology 34 (4), 345-363

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

Mader, N. K. and Redfern, J. (2011). A sedimentological model for the continental Upper Triassic Tadrart Ouadou 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

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.

Huuse M., D. P. Le Heron, R. Dixon, J. Redfern, A. Moscariello and J. Craig (2012) Glaciogenic reservoirs and hydrocarbon systems: an introduction. *Geological Society, London, Special Publications* v.368; p1-28. doi: 10.1144/SP368.19

Jiménez Berrocoso, A., Bodin, S., Wood, J., Calvert, S.E., Mutterlose, J., Petrizzo, M.R., Redfern, J., 2013. Dynamic sedimentary conditions during periods of enhanced sequestration of organic carbon in the central southern Tethys at the onset of the Cenozoic global cooling. Sedimentary Geology 290, 60-84

Wood, J.D., S. Bodin, J. Redfern, M.F.H. Thomas, (2014). Controls on facies evolution in low accommodation, continental-scale fluvio-paralic systems (Messak Fm, SW Libya), Sedimentology V 301 p49-69.

Spence, G.H., Redfern, J., Aguilera R., Bevan, T., Cosgrove, J.W., Couples, G., Daniel, J-M. (eds) (2014), *Advances in the Study of Fractured Reservoirs*. Geological Society, London, Special Publication v. 374.

English K.L., Redfern , J., Corcoran, D.V., English, J.M., Yahia R.C. 2016. Constraining burial history and petroleum charge in exhumed basins: New insights from the Illizi Basin, Algeria. AAPG Bulletin. DOI: 10.1306/12171515067

English, K., Redfern, J., Bertotti, G., English, J., Cherif, R.Y. 2016. Intraplate uplift: new constraints on the Hoggar dome from the Illizi basin (Algeria). Basin Research . doi: 10.1111/bre.12182

English, J., English, K., Corcoran, D.V., Fabrice Toussaint F., 2016, Exhumation charge: The last gasp of a petroleum source rock and implications for unconventional shah resources, AAPG Bulletin 100(1):p 1-16

Newport, R., Hollis, C., Bodin, S. and Redfern, J. 2017 , Examining the interplay of climate and low amplitude sea-level change on the distribution and volume of massive dolomitisation: Zebbag Formation, Cretaceous, Southern Tunisia. Depositional Rec.. doi:10.1002/dep2.25

Mader K, N., Redfern, J., Ouataoui M., 2017 (in press) Sedimentology of the Essaouira basin (Meskala field) in context of regional sediment distribution patterns during upper triassic pluvial events. 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 NWAfrica: Essaouira-Agadir Basin, Morocco., Cretaceous Research, 79, p 12-34, http://dx.doi.org/10.1016/j.cretres.2017.06.020

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