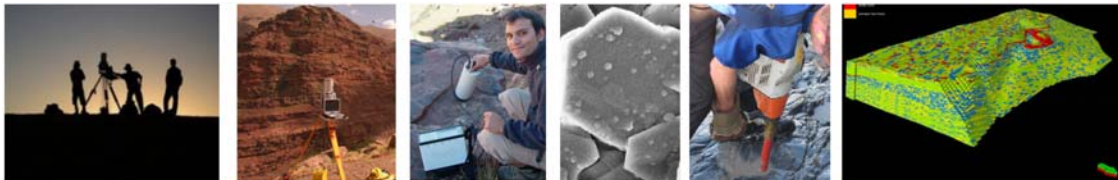




North Africa Research Group (NARG)

University of Manchester
Herriot Watt University
Bremen University



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

Academic Institutions: The Research group is housed at Manchester University, where the majority of the researchers are currently based. Research is carried out by the University of Manchester, Heriot Watt University and Bremen University. The group is led by Prof Jonathan Redfern.

Current sponsors of the research group: Hess, Anadarko, Conoco, BG Group, Wintershall, RWE, Maersk, Repsol, Pluspetrol, Occidental. A number of these sponsors joined the group at its foundation.

Membership: Sponsors join for a period of 3 years, which can subsequently be renewed for further 3 year periods. New sponsors pay an initial "Back Cost" entry fee of 2 years subscription, plus the annual subscription. Current fees for 2009-10 are: £30,387.66, these increase by 5% annually. New sponsors are entitled to all previous PhD theses, publications and any reports and powerpoint presentations. New company sponsors become full of the group, with full rights on the Steering Committee. Sponsors are required to sign the Sponsors Contract, which is common to all participants.

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 Heriot Watt have modern petrophysical suites. Bremen provides FT analytical facilities. NARG also has 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 3D Move.

Research: 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.

Confidentiality: Any data provided by a sponsor company is held under strict confidentiality, as outlined in the Sponsor Contract. The research results and interpretation are provided to all sponsors (maps etc) and any original data provided may be presented if permissions are received from the donor company. Permission is sought prior to any publication that includes confidential data.

Publications: 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.

Data: All data collected in the field, and all interpreted data is made available to the sponsor companies.

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

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.

Researchers: Currently the research group funds 3 Postdoctoral Research Fellows: Dr Stephane Bodin, Dr Guy Spence and Dr Álvaro Jiménez Berrocoso. They are all based at Manchester University. There are 3 PhDs currently undertaking research funded by NARG, Laurent Petitpierre (3rd Year), Myron Thomas (2nd Year) and Jonathan Wood (2nd Year). Two other PhDs are linked to NARG (Vicky Catteral, 3rd Year, and Xavier Van Lanen (3rd Year). Five PhDs have been successfully completed: Dr Stefan Lubeseder, Dr Ruth Underdown, Dr Nadine Mader, Dr Ivan Fabuel-Perez, Dr Mustafa Karer.

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.

Ongoing Research Projects: Currently the group is undertaking a number of major regional studies across North Africa:

1. **Early Cretaceous Depositional Systems, Stratigraphy and Reservoir Characterisation:** Libya and Tunisia. The project commenced in 2008 and is led by Dr Stephane Bodin, with Jonathan wood (2nd Year PhD). Involves extensive fieldwork in the Murzuk Basin Libya and the Jeffara Arch (Libya and Tunisia). The research has involved collaboration with the LPI Libya and University of Sfax, Tunisia. Aims are to understand the evolving depositional systems, revise the stratigraphy /sequence stratigraphy and characterise /evaluate potential reservoirs. The study extends to the subsurface in the Sirt basin, where the “Nubian” sandstones are one of the main reservoir targets. Potential that the project will extend to Egypt and wider region. First research paper submitted in Journal of African Earth Sciences.

2. **Early Carboniferous Depositional Systems and Controls on Reservoir Development** – evaluation of the Marar Formation and overlying Assedjefar, both potential reservoirs in the Ghadames basin. The project was led by Dr Sebastian Frohlich (now at Statoil), and is now led by Prof Jonathan Redfern, with Laurent Petitpierre (3rd year PhD). Two research papers have been submitted. The project has involved extensive fieldwork in Libya (in part supported by Woodside). Results are providing valuable new insights into the depositional environments, and have identified a series of significant incised valley. Work continues to address the underlying controls on the system, and to refine outcrop to subsurface correlation. The project will be extended into the subsurface in Algeria, where these units may offer significant reservoir potential.
3. **Numidian Flysch Depositional System**- 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 being undertaken by Myron Thomas (2nd Year PhD) focuses 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, which until now have remained largely unknown. First paper submitted in Earth Science Reviews in June 2009.
4. **North African and Atlantic Margin Late Triassic Syn-Rift Sequences** – this project is run in collaboration with the Atlantic Triassic Project, a collaboration of the Universities of Manchester, Aberdeen and Dublin. NARG researchers are Nadine Mader (PhD completed 2008) and Ivan Fabuel Perez (PhD completed 2009) and Xavier Van lanen (funded by Shell). Staff working on this project include Prof Jonathan Redfern and Dr David Hodgetts. Previous researcher: Dr Catherine Baudon. This involves an integrated analysis of Late Triassic rift sequences in Canada, Morocco and the North Atlantic (Norway, W Britain). Manchester is leading the research using LIDAR and field sedimentology to characterise reservoirs in the systems, and also looking at the structural controls using field based analysis in Morocco and Canada. A number of publications have started to come out from this research (2009). It is anticipated that this research will continue with new PhDs funded in 2010 in Manchester and UCD-Dublin.
5. **Deepwater Slope Channel and Mass Flow Complexes Offshore North Africa**: Led by Prof Jonathan Redfern and Prof Rob Gawthorpe, with PhD student Victoria Catteral. Previous researcher Dr Dorthe Hansen (now Statoil). This project studies the geologic evolution of the Nile Delta, Egypt in the context of submarine channel evolution, and generation and interaction of mass-transfer-complexes. It utilizes an extensive 3D database provided by BG Group. This is undertaken within a sequence stratigraphic framework, with the result being quantification of the slope systems evolution in terms of architecture, structure and morphology
6. **Ordovician Glaciogenic Reservoir Systems and Reservoir Characterisation**: Prof Jonathan Redfern, Dr Andy Gardiner and PhD student Gregg Pyke (now at Oxy). This project examines the Controls on Reservoir Quality within the Cambro-Ordovician

Sandstones of the Saharan Platform. Extensive fieldwork has been undertaken in the Murzuk Basin, integrated with a large subsurface dataset, built into a regional Petrel model. Diagenesis in the Memouniat reservoir has been modeled using the Touchstone software™

7. **Source Rock Hunter Project** – this is a new project that commenced in 2009. A regional source rock evaluation, integrating new field-based sampling, review of published material and information available from sponsor companies. The project is led by Álvaro Jiménez Berrocoso in collaboration with Dr Stéphane Bodin and Prof Jonathan Redfern. The first phase will be carried out in north central Tunisia, examining the organic-rich sediments of the Bou Dabbous Fm (lower Eocene). The research will address the controls on the development of the organic richness and assess its distribution stratigraphically and aerially, in order to make source rock quality predictions. In tandem, a regional database is being established for all the main source horizons and potentially significant intervals, to include the Infracambrian, Ordovician, Carboniferous, Triassic, Jurassic and Palaeogene.
8. **FRAC -Fractured Reservoir Analogues Carbonates**. This project is led by Dr Guy Spence. Outcrop analogues of subsurface naturally fractured carbonate hydrocarbon reservoirs in North Africa will be studied to improve our understanding of these complex reservoirs. Field studies are planned in Egypt and Tunisia, and the project will involve use of DGM /LiDAR 3-D field mapping of fractured carbonate outcrops, sedimentary logging, sampling and mapping. Data processing and analysis will use the Manchester in-house software VRGS and Schlumbergers Petrel software. The aim is to improve understanding of fracture characterisation and property modelling.

Other projects and completed consultancy reports and paper based studies are detailed on the website <http://www.narg.org.uk>

Planned Future Research Projects:

Offshore North Africa Regional Tectonics and Depositional Architecture: Dependent on funding, a regional evaluation of offshore North Africa –Eastern Mediterranean is proposed to start in 2010. This will incorporate newly acquired seismic data offshore, and comprise a broad regional study to evaluate the regional tectonics, define seismic sequences, develop regional palaeogeographies, address sequence stratigraphy, reservoir source and seal units distribution, and neotectonics. This will build upon earlier studies offshore, and draw upon research and fieldwork being undertaken onshore.

Further carbonate research: the University of Manchester has established a Carbonate Research Group, led by Dr Cathy Hollis. It is anticipated that further carbonate projects will be offered through NARG.

List of researchers:

Staff:

Manchester
Prof Jonathan Redfern
Dr David Hodgetts
Dr Cathy Hollis
Dr Mads Huuse
Prof Rob Gawthorpe
Dr Duncan Irving

Heriot Watt

Dr Andrew Gardiner
Prof Patrick Corbett
Prof Dorrik Stow

Bremen

Dr Frank Lisker

Post Doctoral Researchers:

Dr Stephane Bodin
Dr Guy Spence
Dr Álvaro Jiménez Berrocoso

Previous PostDocs (currently with)

Dr Gianluca Badalini (BG)
Dr Dorthe hansen (Statoil)
Dr Catherine Baudon
Dr Sebastian Frohlich (Statoil)
Dr Stefan Lubeseder (Wintershall)

Research Assistant:

Myron Thomas

Current PhDs:

Laurent Petitpierre
Jonathan Wood
Gregg Pyke
Myron Thomas

Associated PhDs:

Vicky Catteral
Xavier Van Lanen

Completed PhDs:

Dr Nadine Mader
Dr Ruth Underdown
Dr Stefan Lubeseder
Dr Ivan Fabuel Perez
Dr Mustafa Karer

Recent 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, 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, 13-32

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, 2008
Database: GeoRef

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, 103-140.

Lubeseder, S., Carr, I, D.; Redfern, J, (2003) Abstracts; AAPG Hedberg conference; Paleozoic and Triassic petroleum systems in North Africa, A third-order sequence stratigraphic framework for the Devonian of Morocco; its implications for enhanced regional correlation of the Devonian in North Africa, AAPG

Baudon C., Fabuel-Perez I., & Redfern J., Submitted Sept 2009, Structural style and evolution of an Upper Triassic rift basin in the Central High Atlas, Morocco: controls on sediment deposition. *Geological Journal*

Publications in press / prep

Baudon, C., Redfern, J & Van Den Driessche P; J, (Submitted Oct 2009), Permo-Triassic structural evolution of the Argana Valley and implications on the kinematics and impact of the Atlantic rifting in the High Atlas, *Tectonophysics*

Catterall, V., Redfern, J., Gawthorpe, R.L., Hansen, D.M & Thomas, M.H.F (in review)
Architectural Style and Quantification of a Submarine Channel-Levee Systems located in a structurally complex area: Offshore Nile Delta, *Journal of Sedimentary Research*

Bodin S., L. Petitpierre, J. Wood, I. El Kanouni, J. Redfern (submitted Journal of African Earth Sciences Oct 2009). Timing of Early to mid-Cretaceous tectonic phases along North Africa: New insight from the Jeffara Arch (Libya-Tunisia).

Lubeseder S., J. Redfern, L. Petitpierre, S. Fröhlich. (submitted PSCVII Spec Publication Sept 2009) 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).

Fröhlich, S., Petitpierre, L., Redfern J, Grech P, Bodin S, & Lang S. in press 2009. Sedimentological and sequence stratigraphic analysis of Carboniferous deposits in western Libya: recording the sedimentary response of the northern Gondwana margin to climate and sea level changes. *Journal of African Earth Sciences*

Bodin S., Mattioli E., Fröhlich S., Marshall J., Boutib L., Lahsini S., Redfern J. (submitted August 2009) Documentation of Early Toarcian (Jurassic) carbon isotope negative shifts and nutrient changes along the Northern Gondwana margin (High Atlas, Morocco): palaeoenvironmental implications, Palaeogeography, Palaeoclimatology, Palaeoecology

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

Karer, M., and Redfern, J., (in prep 2009) Predicting the distribution of igneous units within the Lower Cretaceous Nubian Sandstone of the eastern Sirt Basin, Block C97-1, Libya

Karer, M., and Redfern, J., (in prep 2009) Characterising igneous units within the Lower Cretaceous Nubian Sandstone: Block C97/1, Sirt Basin, Libya

Karer, M., and Redfern, J., (in prep 2009) A geophysical investigation of the structural style and evolution of the Eastern Sirt Basin, Block C97/1, Libya.

Thomas, M., Redfern, J., Irving, D., & Bodin, S (submitted to Earth Science Reviews July 2009), A constrained African-craton source for the Cenozoic Numidian flysch: Implications for the western Mediterranean basin palaeogeography

Completed PhDs:

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

Dr Nadine Mader (2006): Sedimentology and sediment distribution of Upper Triassic fluvi-aeolian reservoirs on a regional scale (Central Algeria, SW Morocco, NE Canada): an integrated approach unravelling the influence of climate versus tectonics on reservoir architecture

Dr Ruth Underdown (2006): An integrated Basin Modelling Study of The Ghadames basin, North Africa

Dr Mustaf Karer (2009): Characterising controls, Distribution , Age and Origin of Igneous Units within the Nubian Formation, Sirt Basin, Libya: An Integrated Geophysical Study (restricted access)

Being corrected:

Dr Ivan Fabuel-Perez (2009): 3D reservoir modelling of Upper Triassic continental fluvial dominated systems. Integration of Digital Outcrop Models with high-resolution sedimentology: Central High Atlas, Morocco

Submitted for viva in 2010:

Dr Gregg Pyke: Cambro-Ordovician Reservoirs of the Saharan Platform: An integrated approach to reservoir quality prediction

Contact Details:

Prof Jonathan Redfern, Research Group leader

Tel: +44 (0)161 275 3773

Email: jonathan.redfern@manchester.ac.uk

School of Earth, Atmospheric and Environmental Sciences
The University of Manchester
Williamson Building,
Oxford Road,
Manchester,
UK,
M13 9PL

Web Page: <http://www.narg.org.uk/>