Keele University

BSRG Sedimentary Research

British Sedimentological Research Group AGM
Keele University
19th - 22nd December 2015

Abstract Volume

This event has been kindly sponsored by:

IAS International Association of Sedimentologists

Statoil

RPS ichron part of the RPS Group

BETA Radiocarbon Dating — Consistent accuracy Delivered on time — Beta Analytic Ltd.

CMG Clay Minerals Group

badley ashton Reservoir Geoscience

bp

Robertson

CGG Passion for Geoscience

Welcome

Welcome to the British Sedimentological Research Group's 54th annual meeting. The Basin Dynamics Research Group of the Department of Geography, Geology and The Environment at Keele University is honoured to be convening this year's AGM. We are looking forward to showcasing the skills and facilities that make Keele a leading example of a campus community within the UK.

This year's conference programme is extensive - a result of the range and quality of the input from the BSRG membership - with excellent contributions from both student members and established researchers. We have a full technical programme covering all aspects of sedimentology, from sedimentary environments to subsurface and applied applications, and the teaching of sedimentology.

Alongside the technical programme this year, we have a full social programme including the icebreaker reception in the University's Sustainability Hub on the edge of campus and the conference dinner in the centre of campus in the majestic Keele Hall.

We hope you enjoy the meeting and we would very much like to thank all our sponsors for their financial support.

Hazel Beaumont

Keele University

Convenor:	Hazel Beaumont
Planning committee:	Stuart Clarke, Tomas Cain, Molly Watson
Abstract reviewers:	Hazel Beaumont, Stuart Clarke, Tomas Cain
Core workshop:	Oliver Wakefield, Steven Banham
Reservoir quality workshop:	Sanem Acikalin
Field trip:	Jonathan Redfern, Ian Kane and David Hodgetts
Conference website:	Lois Jackson

Acknowledgements

The convenors of this year's AGM are grateful to the Keele Event Conference Team, especially Lois Jackson who has gone out of her way to manage the online registration, delegate joining instructions, the website and the booking of the halls and facilities. We also thank the staff of the Department of Geography, Geology and The Environment at Keele University; notably Ian Wilshaw and Stef Everill who have handled many of the challenges that have arisen. Thanks go to Oliver Wakefield (who has provided support in every way possible), and Steven Banham, Sanem Acikalin and Jonathan Redfern who are running various workshops and fieldtrips for this AGM. Finally, thank you to everyone who submitted abstracts to make this meeting a success, especially those that did not need re-formatting! You are true heroes!

Also, we cannot forget the students who are wearing the orange t-shirts! They have given up their time, made sweet trees (for the conference dinner), packed bags and are at everyone's every beck and call! Thank you!

Transport information

Driving

Sat nav postcode: ST5 5BJ

From the North: Leave the M6 motorway at Junction 16. At the motorway roundabout turn right onto the A500 for Crewe and Nantwich. Continue for about two miles, go left at the roundabout, continue for a further mile and go left at the next roundabout onto the A531 towards Betley. Continue on this road for approximately eight miles until you reach the Keele University entrance. From the motorway junction to Keele the journey time is about 20-25 minutes.

From the South: Leave the M6 at Junction 15 and follow the signs for the A519 into Newcastle-under-Lyme. The University is signed from the first roundabout. From the motorway junction to Keele the journey time is about 15-20 minutes.

From the East: If you are travelling on the A53 follow signs to Newcastle-under-Lyme. If you are using the A50, join the A500 (south) and then turn right at the roundabout at M6 Junction 15 and follow directions from the south (above). Travel from the M1 is easiest using Junction 23A onto the Derby bypass and following signs for the A50.

From the West: Follow signs for the A525 towards Newcastle and turn right at roundabout at main University entrance (signposted).

Buses

From Keele Campus to Newcastle, Stoke-on-Trent, Stoke-on-Trent Train Station and Hanley:

First Group bus Route 3 or D&G bus 85/85B. Bus stops are located all along the Campus ring road, and all stops on the inside of the ring road (opposite side of the road from Keele Hall) service these routes. The nearest stop is on the ring road outside of Keele Hall. Please note D&G buses terminate at Newcastle bus station.

From Newcastle, Stoke-on-Trent, Stoke-on-Trent Train Station, and Hanley to Keele Campus:

First Group bus Route 3 or D&G bus 85/85B. Hanley is known as the city centre and has a bus station.

Stoke-on-Trent train station: if you come out of the main entrance cross the road and turn left there is a bus stop which will take you into Newcastle town centre and up to Keele Campus and is marked on the map (Page 7). Newcastle town centre also has a bus station, which is on the eastern side of the Newcastle Ring Road and marked on the map (Page 7). Please note D&G buses terminate at Newcastle bus station.

From Keele Campus to Keele Village, Crewe, and Crewe Train Station:

First 3 or D&G 85/85B. Bus stops are located all along the Campus ring road and all stops on the outside of the ring road (the same side of the road to Keele Hall) service this route.

From Crewe and Crewe Train station to Keele Campus:

First 3 or D&G 85/85B: From Crewe train station you need to head out of the main entrance, turn right and cross the road to the Crewe Arms Hotel for the nearest bus stop.

Taxis:

- Roseville Taxicabs 01782 613456 / 01782 631234
- Sids Private Hire Taxis 01782 565200
- Castle cars 01782 63111
- ABC Supreme 01782 822228

Keele University Safety Bus:
A minibus will be running on the night of the conference dinner from 23:30 – 01:30. The bus is free and will take you from outside the Students Union on Keele campus to Newcastle town centre.

Safety information

The fire exits in Keele Hall, the Sustainability Hub and the Department of Geography, Geology and The Environment are clearly marked in the standard manner. The maps included with your Welcome Pack also show the assembly points (Page 6). Please familiarize yourself with the nearest fire exit to all facilities. No fire drills are planned for BSRG, so any fire alarm is a real situation.

In case of fire, the assembly points for the various venues are:

Keele Hall: In the main courtyard car park

Sustainability Hub: In the main car park

Department of Geography, Geology and the Environment: In the car park outside the main entrance

In case of fire, please make you way to the assembly points via the nearest usable fire exit, and follow all instructions from the convenors, the organisers, and the students in the wonderfully coloured orange T-shirts!

Luggage / lost property

Luggage during the event can be stored in the Sneyd room of Keele Hall.

Any lost property found should be handed into the Keele Hall reception. It will be passed onto 24 hour security which is in the Darwin Building, across the road from the Student's Union.

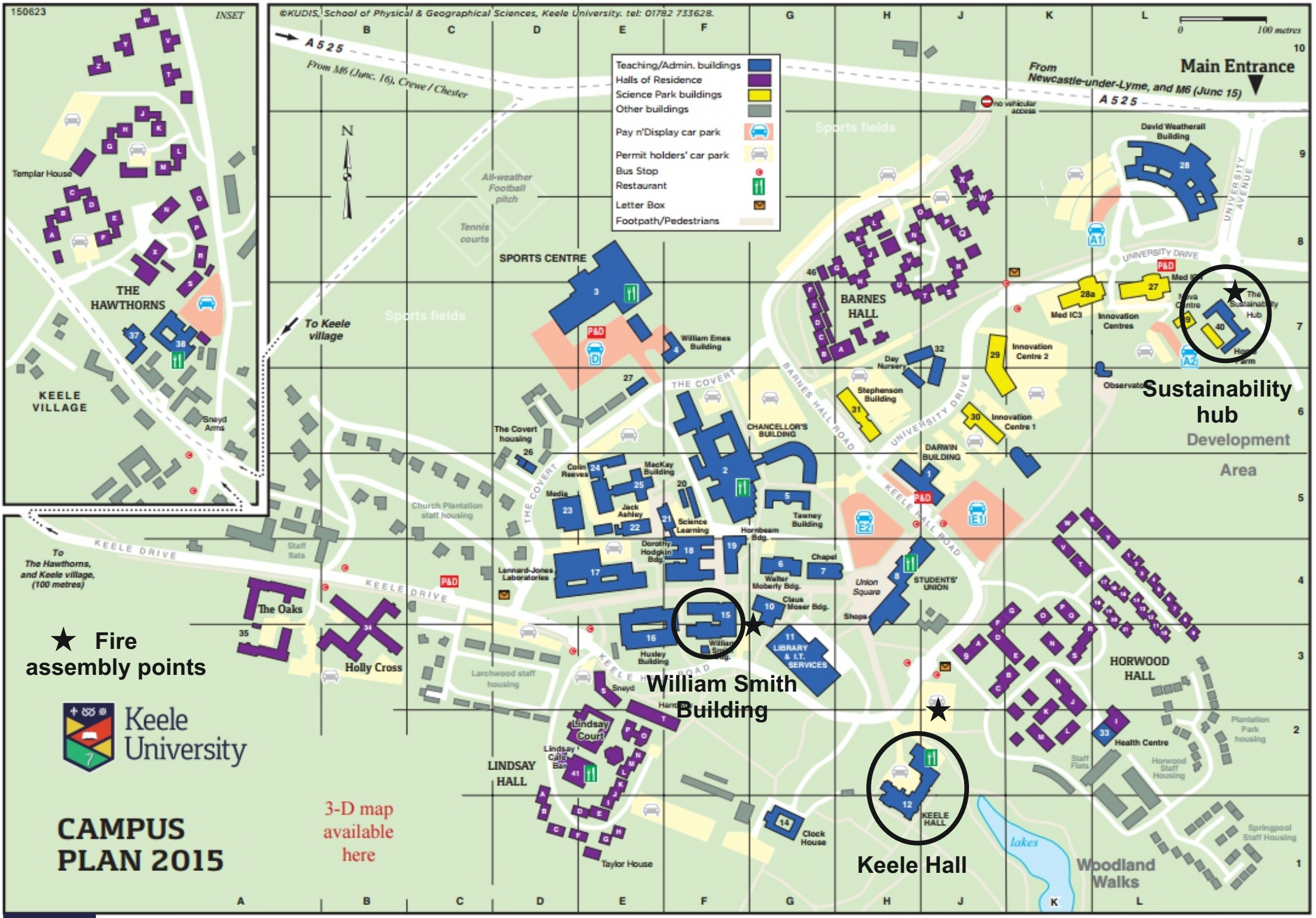
Ice breaker and conference dinner

Ice breaker: Sunday 20th of December at 19:00 in the Sustainability Hub, Home Farm, Keele University, Keele, Newcastle, Staffordshire, ST5 5AA

Conference dinner and drinks reception: Monday 21st of December at 19:00 in Keele Hall. As part of this year's conference dinner there will be a drinks reception at the Terrace within Keele Hall.

BSRG 2015 Programme

Workshop	Location	Convenors	Information
Core	Keyworth core store, British Geological Survey, Keyworth, Nottingham, NG12 5GG	Dr. Oliver Wakefield Dr. Steven Banham	Mixed aeolian-fluvial successions are very much the preserve of arid and semi-arid environs where the predominant absence of moisture inhibits vegetation growth and allows for aeolian processes to operate unimpeded. Despite the sparsity of moisture in these environments, episodic high-magnitude rainfall events can lead to the development of short-lived fluvial systems. The resultant relationship between the accumulated aeolian and fluvially derived sediments can be complicated and are recognised to occur on a myriad of spatial- and temporal-scales, both competitively and symbiotically, resulting from combinations of autogenic and allogenic controlling factors. The 2015 BSRG core workshop will look at examples of such interactions using a number of borehole cores from both the UK mainland and offshore. The boreholes provided from the British Geological Survey's National Geological Repository.
Fieldtrip	Castleton, Derbyshire	Professor Jonathan Redfern, Dr Dave Hodgetts Dr Ian Kane	Characterising elements of the Carboniferous Petroleum System around Castleton Derbyshire. This one day BSRG fieldtrip will examine some classic outcrop locations in Derbyshire, near Castleton. We will introduce the geological setting and examine three main elements of the Carboniferous depositional system; Namurian Edale Shale deepwater mudstones, Mam Tor deepwater sandstones and Dinantian platform carbonates. These form elements of the East Midlands petroleum system, and are also facies equivalent to the Bowland shale, the UK'ss main shale gas target. This will be followed by a long (and warm) Christmas lunch in a local pub in Castleton. Weather conditions likely to be arctic… so lots of warm clothing, waterproofs etc are required and plans will be flexible to take account of conditions.
Reservoir quality	William Smith Building, Keele University	Dr Sanem Acikalin	Pore-scale knowledge is becoming ever more important for risk assessment in siliciclastic reservoirs. At the same time it is often the weakest link in a model. This awareness course is designed to help attendees understand every geological aspect of the decision tree used in clastic reservoir pore system analysis. The course covers the controls on pore system evolution from deposition to present day, contrasting the roles of depositional attributes and diagenetic processes, with a special emphasis on predictability. Pore system degradation pathways will be discussed and visualised with the help of representative diagrams and photomicrographs.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INSET
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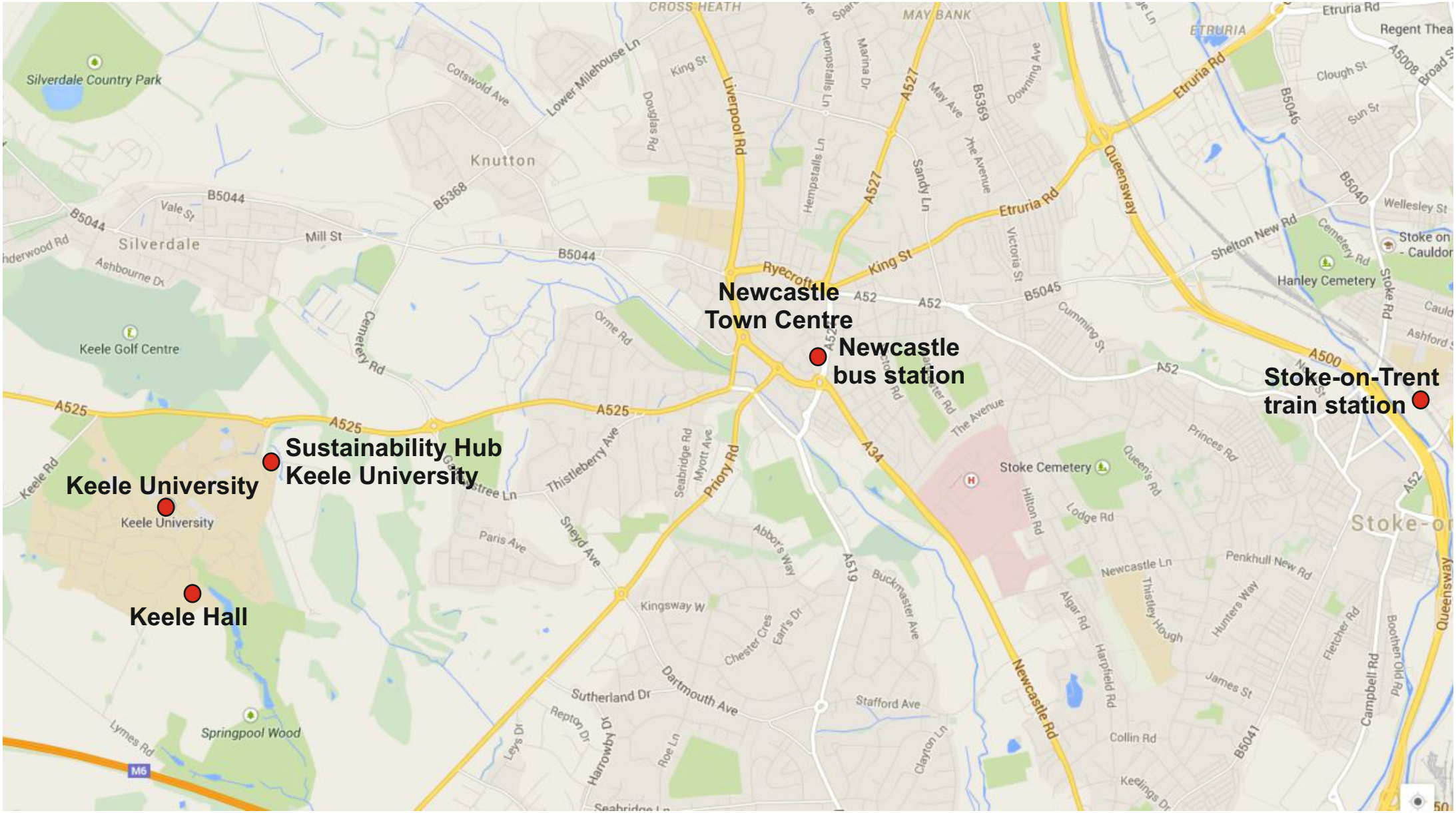
100 metres
A525
From M6 (Junc. 16), Crewe / Chester
From Newcastle-under-Lyme, and M6 (Junc 15)
Main Entrance
no vehicular access
Teaching/Admin. buildings
Halls of Residence
Science Park buildings
Other buildings
Pay n'Display car park
Permit holders' car park
Bus Stop
Restaurant
Letter Box
Footpath/Pedestrians
N
Templar House
THE HAWTHORNS
KEELE VILLAGE
Sneyd Arms
To Keele village
All-weather Football pitch
Tennis courts
Sports fields
SPORTS CENTRE
William Emes Building
BARNES HALL
David Weatherall Building
UNIVERSITY AVENUE
UNIVERSITY DRIVE
Med IC3
Innovation Centres
Innovation Centre 2
Innovation Centre 1
Day Nursery
Stephenson Building
Observatory
Sustainability hub
Development Area
THE COVERT
BARNES HALL ROAD
The Covert housing
CHANCELLOR'S BUILDING
DARWIN BUILDING
KEELE HALL ROAD
Colin Reeves
MacKay Building
Media
Jack Ashley
Science Learning
Tawney Building
Hornbeam Bdg.
Dorothy Hodgkin Bdg.
Lennard-Jones Laboratories
Walter Moberly Bdg.
Chapel
Claus Moser Bdg.
Union Square
STUDENTS' UNION
Shops
Church Plantation staff housing
KEELE DRIVE
To The Hawthorns, and Keele village, (100 metres)
Staff flats
The Oaks
Holly Cross
Larchwood staff housing
Huxley Building
LIBRARY & I.T. SERVICES
William Smith Building
Lindsay Court
LINDSAY HALL
Taylor House
Clock House
KEELE HALL
HORWOOD HALL
Health Centre
Plantation Park housing
Horwood Staff Housing
Springpool Staff Housing
lakes
Woodland Walks
★ Fire assembly points
Keele University
CAMPUS PLAN 2015
3-D map available here

Map displaying Keele University, Newcastle-under-Lyme and Stoke-on-Trent train station



Monday 21st December

	Ballroom		Salvin Room	
08:30		Introduction Prof. Mark Ormerod		
08:45		Can we create a brighter future for the UK petroleum industry? Richards P.C., British Geological Survey		
09:15	**Linked depositional systems Chairs: Rob Raine and Steven Banham**	Depositional interactions between the basin margin and the contemporaneous basin centre in an arid continental setting. Gough A., Clarke S.M. and Richards P.C.	**Teaching of sedimentology Chair: Sian Davies-Vollum**	Teaching Sedimentology: opportunities for interdisciplinary, variety, innovation and employability. Davies-Vollum S., Satterfield D., Suthren R., Whiteley M.
09:30		How are mass failures and sediment flows triggered at offshore river deltas? Clare M.A., Hughes-Clarke J.E., Talling, P.J. and Cartigny M.J.B.		Teaching Geology to Non-Geologists: getting back to the rocks. Noad J.
09:45		Investigating the hybrid terrestrial to coastal sedimentology of the Ballagan Formation, Lower Carboniferous, Scotland. Bennett C.E., Kearsey T., Davies S.J., Millward D.		Teaching geological sedimentology within geography degree schemes at Swansea University. Owen G.
10:00		Anatomy of Cambrian alluvium in the Erquy- Fréhel Group, France: Discerning marine vs non-marine influences in the pre-vegetated rock record. McMahon W.J., Davies N. and Gupta S.	**Characterization of mudstone-rich successions**	There and Back Again, a Mudstone's Holiday: Reworking of Mud and its Implications. Trabucho-Alexandre J.P.
10:15	**Break**			
10:45	**Reservoir quality and diagenesis Chairs: Stephan Stricker, Mark Brodie and Peter Andras**	Scale invariance of clastic injectites and their application to forward seismic modelling. Cobain S.L., Hodgson D.M. and Peakall J.	**Characterization of mudstone-rich successions: sedimentology, mineralogy and diagenesis Chairs: Miquel More and Rhodri Jerret**	Characterising the Wealden Mudstones: Mineralogy, Geochemistry, and Palaeoenvironments of the Weald Basin, southeast England. Akinlotan O.
11:00		Controls on sandstone reservoir quality from the UK continental shelf. Olierook H.K.H and Worden R.H.		The Bowland Shale at Outcrop: Understanding the Role of Modern Weathering in the UK. Emmings J., Davies S., Stephenson M., Vane C. and Leng M.J.
11:15		Clay mineral distribution in modern estuarine sands: A predictive tool for the hydrocarbon industry. Griffiths J., Worden R. H., Woolridge L. J., Utley J.E. and Duller R. A.		Clay mineral transformations, compaction and overpressure generation in siliciclastic mudstones. Andras P., Aplin A.C., Goulty N.R. and Sargent C.
11:30		Down-dip termination of sandy fan systems – new insight from the Pennsylvanian Ross Sandstone Formation, western Ireland. Obradors-Latre A., Pierce C., Haughton P, Shannon P., Pulham A., Lacchia A., Barker S.		Mudstone-dominated basin margin progradation: processes and implications. Poyatos-Moré M., Jones G.D., Brunt R.L., Hodgson D.M. and Flint S.S.
11:45		A 2-stage model for illite growth in sandstones. Wilkinson M.		Septarian Concretions and Limestone Beds within Organic-rich Mudstones: A Study of Diagenesis and Stable Isotopic Compositions in the Eagle Ford Formation. McAllister R.T. and Taylor K.G.
12:00		Fluid transport in the Sherwood Sandstone: influences of diagenesis and sedimentalogical facies. Thompson J., Hough E., Wakefield O.J.W. and Cripps C.		Multi-scale 3D quantification of an organic-rich mudstone, the Carboniferous Bowland Shale. Ma L., Taylor K.G., Peter L.D., Dowey P.J. and Courtois L.
12:15	**Lunch**			

13:00	**Reservoir quality & diagenesis Chairs: Stephan Stricker, Mark Brodie and Peter Andras**	Impact of facies variability on static reservoir connectivity: the North Brae Example. Omoniyi B. and Stow D.	**Deep water systems: processes and products Chairs: Sarah Cobain, Hannah Brooks and Gilbert Kelling**	Let it Flow: Understanding transportation of soft-bodied organisms in sediment-density flows. Enright O., Minter N., Sumner E., Mángano G. and Buatois L.
13:15		Enhanced reservoir quality in HPHT reservoirs of the Triassic Skagerrak Formation, Central North Sea. Stricker S., Jones S. and Aplin A.		New flow structure identified by direct measurements of turbidity currents in the Congo Canyon. Azpiroz M., Cartigny M.J.B., Talling P.J., Parsons D.R., Simmons S., Clare M.A., Sumner E.J. and Pope E.
13:30		Characterisation and modelling of heterogeneity in thinly bedded, shallow-marine sandstone reservoirs. Onyenanu G., Jacquemyn C., Graham G.H, Hampson G.J., Fitch P.J.R. and Jackson M.D.		Novel bedforms and primary current stratification in cohesive mixtures of mud and sand. Baas J., Best J. and Peakall J.
13:45		Biofilm origin of clay coated sand grains: Understanding the fundamental processes governing the origin and distribution of clay-coated sand grains in petroleum reservoirs through a modern day analogue. Wooldridge L.J., Worden R.H., Griffiths J., Duller R.A. and Utley J.E.		Turbulent behaviour of non-cohesive sediment gravity flows at unexpectedly high flow density. Baker M., Baas J.H., Malarkey J. and Kane I.A.
14:00		Diagenetic evolution of a Lower Miocene Sandstone Kishartyán, Northern Hungary. Szőcs E., Hips K., Józsa S. and Bendő Z.		The influence of confinement on depositional sheet turbidite system architecture. Liu Q. and Kneller B.
14:15	**Break**			
14:45	**Fluvial sedimentology: from channel to basin scale processes, controls and architecture Charis: Amanda Owen, Catherine Russell and Cathy Burns**	How to build a fluvial succession: think lobes as well as valleys. Nichols G., Nautilus		
15:15		Forward stratigraphic modelling of the architecture of meandering river deposits. Yan N., Mountney N.P., Dorrell R.M. and Colombera L.	**Deep water systems: processes and products Chairs: Sarah Cobain, Hannah Brooks and Gilbert Kelling**	The effect of confinement on Basin-floor lobe stacking patterns. Bell D., Hodgson D.M. and Stevenson C.J.
15:30		Quantification of fluvial meander bend shape: new insights into the evolution of ancient point-bar deposits. Russell C., Mountney N.P., Hodgson D.M. and Colombera L.		Glacial cycles in the Cryogenian record: a sedimentological perspective from the southern Kingston Range, California. Le Heron D.P., Busfield M.E., Ali D.O and Tofaif S.
15:45		Bottomsets of dune and unit bar cross-stratification. Herbert C.M and Alexander J.		K/Pg Boundary: Fossilized Trees Transported to a Deep Sea Environment in Baja California – Mexico. Catharina A.S. and Kneller B.
16:00		A comparative study of fluvial crevasse-splay deposits. Burns C., Mountney N.P., Hodgson D.M. and Colombera L.		Towards a classification of hybrid event beds. Fonnesu M., Haughton P., Patacci M., Felletti F. and McCaffrey W.
16:15	AGM			
17:00	Posters			
17:45	Pub			
19:00	Conference dinnner and drinks at the Terrace bar (optional)			

Tuesday 22nd December

	Ballroom		Salvin Room	
08:30			Deep water systems: processes and products; Chairs: Sarah Cobain, Hannah Brooks and Gilbert Kelling	Ponded fan development and evolution within a salt-controlled mini-basin. Doughty-Jones G., Lonergan L. and Mayall M.
08:45				Degradation and aggradation of a basin margin: Sedimentology, stratigraphy, and origin of stacked erosional mass transport complexes. Brooks H.L., Hodgson D.M., Brunt R.L., Flint S.S. and Peakall J.
09:00	Fluvial sedimentology: from channel to basin scale processes, controls and architecture Charis: Amanda Owen, Catherine Russell, Cathy Burns	Understanding system scale connectivity in fluvial systems. Owen A., Hartley, A.J., Weissmann, G.S., and Nichols, G.J.		The Annot … down-system: chasing confined turbidites in mountain belts. Butler R.
09:15		Big river development: A sedimentary facies analysis of Pliocene/Pleistocene deposits of the Euphrates fluvial system, Syria. Kearsey S., Stow D., Gardiner A. and Tatum D.		Multi-pulsed turbidity currents – flow dynamics and geological implications. Ho V.L., Dorrell M.R., Keevil G.M., Burns A.D. and McCaffrey W.D.
09:30		Rates of surface lowering and landscape development in Southern South Africa: a cosmogenic view. Richardson J.C., Vanacker V., Lang A. and Hodgson D.M.		Controls on turbidite deposition on an actively deforming basin: an example from the Numidian of Sicily. Pinter P.A., Butler R.W.H., Hartley A.J. and Maniscalco R.
09:45		Stratigraphic heterogeneity induced by allogenic and autogenic factors in a Paleogene low net-to-gross fluvial succession, Tremp-Graus Basin, southern Pyrenees, Spain. Arévalo O.J, Mountney N.P. and Colombera L.		Depositional Pattern associated with Experimental Turbidity Currents going through a Break-of-Slope. Pohl F., Eggenhuisen J., de-Leeuw D., Cartigny M., Tóth F. and Hermidas N.
10:00		Surfaces, sediments, and supergene enrichment in Northern Chile and Southern Peru. Evenstar L.A., Stuart F.M., Mather A.E., Cooper F.J., Sparks R.S.J. and Hartley R.J.		Swept away by a turbidity current in Mendocino submarine canyon, California. Sumner E.J. and Paull C.K.
10:15				Tb or not Tb: Banding in turbidite Sandstones. Stevenson C., Hodgson D.M. and Peakall J.
10:30	**Break**			
11:00	Recent advances in sedimentary provenance Chairs: Christof Liebermann and Tim Breitfeld	Ages and provenance of Upper Cretaceous to Paleogene sediments in Sarawak, Borneo: connections between terrestrial and deep marine settings at the Sundaland margin. Breitfeld H.T., Galin T. and Hall R.	Deep water systems: processes and products Chairs: Sarah Cobain, Hannah Brooks and Gilbert Kelling	Sediment heterogeneity and the role of contourites in promoting long runout submarine debris flows. Gunn N., West J., Murphy B. and McCaffrey B.
11:15		The provenance evolution of the Permo-Triassic fill of the Korotaikha Basin and its constraints for the timing of the Pai-Khoi fold-and-thrust-belt (Russian Arctic). Heilbronn G., Curtis M., Morton A., Hyden F. and Lopez-Mir B.		Sediment delivery to the deep water under differing eustatic sea level scenarios. Harding R., Huuse M. and Gawthorpe R.
11:30		Provenance of Sediments from Sumatra, Indonesia. Liebermann C., Hall R. and Gough A.		Megaclasts in submarine slope channels: rolling, tractional shear by turbidity currents or debris flow origin? Bozetti G., Kane I. and Kneller B.
11:45		Fault-induced coarse clastic sedimentation related to the initiation of a Permian continental margin forearc basin in South Island, New Zealand. Robertson A.		Frontal or lateral submarine lobe fringes? Distinctive sedimentary facies, geometries and pinchout architecture. Spychala Y.T., Hodgson D.M., Prélat A., Flint S.S. and Mountney N.P.
12:00		Establishing the provenance of Lower Cretaceous Sandstones, offshore western Ireland. Barry A., Tyrrell S., Morton A. and Robinson P.		Effect of internal and external architecture on submarine channel development. Kelly R., McCaffrey W., Dorrell R. and Burns A.
12:15				Sedimentary processes and depositional architecture of sand-prone sediment waves in ancient deepwater channel-lobe transition zones. Hofstra M., Hodgson D.M., Peakall J. and Flint S.S.
12:30	Glacial sediments Chair: Richard Waller	Sedimentological and Stratigraphic Architecture of an Hirnantian Palaeovalley, NW Saudi Arabia. Tofaif S.A., Le-Heron D.P. and Melvin J.		Grain size fractionation between turbidity current deposits on channelized slope and related unconfined basin floor deposits: Insights from flume experiments. de-Leeuw J., Pohl F., Eggenhuisen J. and Cartigny M.J.B.

12:45	**Lunch**			
13:30	**Coastal to shallow marine systems Chairs: Luz Cartesio, Tim Luber and Oliver Jordan**	The Potential, Power and Pitfalls of the Geological Model. Jordan O., Statoil		
14:00		Grain size controls on the morphology and stratigraphy of river-dominated deltas. Parsons D., Burpee A., Slingerland R., Edmonds D., Best J., Cederberg J., McGuffin A., Caldwell R. and Nijhuis A.	**Advances in sedimentation and tectonics Chairs: Alastair Robertson, Chris Jackson and Tomas Cain**	Sedimentology of Lower Old Red Sandstone outliers on the Grampian block: implications for a northwards extension of the Midland Valley Basin. McKellar Z., Hartley A.J. and Macdonald D.I.M.
14:15		The effects of tidal bores on estuarine sedimentology. Keevil C. and Parsons D.		Factors controlling stratal pattern and facies distribution of fluvio-lacustrine sedimentation in the Sivas mini-basins, Oligocene (Turkey). Ribes C., Kergaravat C., Crumeyrolle P., Lopez M., Callot J-P and Ringebach J-C.
14:30		Expressions of shallow marine conditions in the Early Carboniferous of the Northumberland Basin. Sherwin J., Davies S., Smithson T. and Richards K.		Characteristics of deformation bands and relationship to primary deposition: an outcrop study from the Wirral, north-west England. Hough E., Wakefield O.J.W., Cripps C. and Thompson J.
14:45		Facies analysis and architecture of an unstable shelf edge rollover: Tanqua Depocentre, Karoo Basin, South Africa. Gomis-Cartesio L.E., Poyatos-More M., Hodgson D., Flint S.S. and Brunt R.	**Quantitative sediments Chairs: Nigel Cassidy & Jamie Pringle**	A virtual-outcrop based study of the Jurassic Page Sandstone Formation. An approach to multiscale geomodeling of aeolian reservoir analogues. Pierce C., Howell J., Reike H., Fyfe L-J. and Healy D.
15:00		Stratigraphy and palaeoclimate of Spitsbergen during the Early Cretaceous. Vickers M., Price G., FitzPatrick M., Watkinson M. and Jerrett R.		First field test of the theory of ignition and dissipation in turbidity currents – results from Squamish prodelta, British Columbia. Hizzett J. L. Hughes-Clarke J. E., Cartigny M. J. B., Talling P. J., Clare M. A. and Sumner E. J.
15:15		No evidence for sea level fall in the Cretaceous strata of the Book Cliffs of Eastern Utah. Howell J., Eide C.H. and Hartley A.J.		An improved Jacob's staff with compass, spirit level and rotatable laser for high-precision stratigraphic thickness measuring. Patacci M.
15:30	**Break**			
16:00	**Coastal to shallow marine systems Chairs: Luz Cartesio, Tim Luber and Oliver Jordan**	Role of relative sea-level change in controlling preserved facies architecture in a coal-prone, marginal marine succession: Cretaceous Neslen Formation, Utah, USA. Shiers M.N., Mountney N.P. and Hodgson D.M.	**From cradle to grave: exploring the complex nature of carbonates Chairs: Katie Cooper, Miles Frazer and Kirsten Dutton**	Syn-depositional porosity evolution in the Abu Dhabi Sabkha: A glimpse below mats & crusts. Wang J., Court W.M., Paul A. and Lokier S.
16:15		Post-rift stratigraphy of Central Atlantic Margin: Evolution of Depositional Environments in the Early Cretaceous of the Essaouira-Agadir Basin, Morocco. Luber T., Redfern J., Bulot L., Arantegui A., Charton R., and Bertotti G.		A sabkha in Newcastle? Exploring biomineralization processes in a lab environment. Dutton K.E, Serk H., Sherry A., Lokier S., Head I.M. and Land C.
16:30		Fifteen French maids and a plover in a pear tree: a previously unrecognized feeding trace from the Miocene of eastern Borneo. Noad J.		Facies and depositional environments identified in the Lower Jurassic succession from Wadi Naqab, United Arab Emirates. Mircescu C.V., Hönig M., John C.M. and Jacquemyn C.
16:45				Diagenesis in a carbonate-evaporite system: Dolomitisation, Dedolomitisation and Limestone neomorphism in the Zechstein (Permian NW Europe). Tucker M., Mawson M., Slowakiewicz M. and Perri E.
17:00				Basin-scale mineral and fluid processes at a Lower Carboniferous platform margin. Breislin C., Banks V., Hollis C., Juerges A., Marshall J. and Riding J.
17:15				Is biogeochemistry the key to understanding meteoric diagenesis in modern environments? Cooper K., Whitaker F. and Anesio A.

Poster programme

Fluvial sedimentology: from channel to basin scale processes, controls and architecture **Charis: Amanda Owen, Catherine Russell and Cathy Burns**	
1	Climate change and the response of river landscapes: insights from the sedimentary architecture of fluvial systems across the Paleocene-Eocene boundary. Colombera L., Mountney N.P. and Arévalo O.J.
2	Utilising a new 'Intersection Shape Method' to predict heterogeneity in fluvial point-bar deposits. Russell C., Mountney N.P., Hodgson D.M. and Colombera L.
3	Flocculation characteristics of freshly eroded aggregates. Manning A.J., Wendling V., Gratiot N., Legout C. and Michallet H.
Characterization of mudstone-rich successions: sedimentology, mineralogy and diagenesis **Chairs: Miquel More and Rhodri Jerret**	
4	An uninterrupted lacustrine record of the Early Danian Dan-C2 hyperthermal event: Boltysh impact crater, Ukraine. Ebinghaus A. and Jolley D.W.
5	The use of portable X-ray fluorescence spectroscopy (pXRF) in cyclostratigraphic studies of mudstones. Saker-Clark M., Coe A.L. and Kemp D.B.
6	Paleoenvironment and sea level fluctuations during source rock deposition in Morocco during the Cenomanian/Turonian oceanic anoxic event. Wang J., Redfern J. and Taylor K.G.
Recent advances in sedimentary provenance **Chairs: Christof Liebermann and Tim Breitfeld**	
7	Origin of Upper Cretaceous volcaniclastic sandstones (Kannaviou Formation) in SW Cyprus. Chen G., Robertson A. and Ustaömer T.
8	Understanding the Eocene-Oligocene stratigraphy in the South Sumatra Basin, Southeast Asia, using a heavy mineral study. Gough A. and Hall R.
Arid continental systems and cold cliamte sedimentology **Chairs: Oliver Wakefield, Jo Thompson, Richard Waller and Cathy Delaney**	
9	Can modern analogues be used to reconstruct pre-land plant environments? A case study from the Ordovician-Silurian Tumblagooda Sandstone, Western Australia. Bradley G.-M.
10	Spatial and temporal variations in grounding line proximal sedimentation in the Anvers Palaeo-Ice Stream Trough, western Antarctic Peninsula. Roseby Z., Cartigny M., Smith J., Hillenbrand C-D., Talling P., Larter R., Hogan K. and Sumner E.
Linked depositional systems **Chairs: Rob Raine and Steven Banham**	
11	The Continental Shelf: a Conveyor or Filter of Sediment to Deep Water. Cosgrove G., Hodgson D., McCaffrey B. and Mountney N.
12	Aeolian and Fluvial interactions for reservoir characterisation: Examples from the Wingate and Kayenta Formations, Utah, U.S.A. Elson A. and Clarke S.M.
13	Simulation of hydrodynamics and sediments deposition at estuary of river-dominated shallow-water delta. Zhang Y., Bao Z., Jiang L., Zhao Y. and Gong F.
From cradle to grave: exploring the complex nature of carbonates **Chairs: Katie Cooper, Miles Frazer and Kirsten Dutton**	
14	Mats & crusts: A microbial extension to Wilson's standard facies model. Court W.M., Jiayi W., Paul A. and Lokier S.
15	Controls on stratigraphic development and reservoir distribution of shelf margin carbonates: Jurassic Atlantic margin - western Morocco. Duval-Arnould A., Schröder S. and Redfern J.
Deep water systems: processes and products **Chairs: Sarah Cobain, Hannah Brooks and Gilbert Kelling**	
16	Interpreting syn-depositional sediment remobilisation and deformation beneath submarine gravity flows – a kinematic boundary layer approach. Butler R., Eggenhuisen J., Haughton P., and McCaffrey B.
17	Characterisation of Deep-Lacustrine, Partially-Confined, Slope Apron Turbidite Fans: Examples from the North Falkland Basin, South Atlantic. Dodd T.J.H
18	New insights into flow-bedform interaction from direct monitoring of turbidity currents. Hage S., Cartigny M.J.B., Clare M.A., Talling P.J., Sumner E.J., Vardy M.E., Hughes Clarke J.E. and the 2015 Squamish Field Team
19	Late-Eocene canyon formation and the interplay between down-slope and along-slope processes during the Cenozoic evolution of the Donegal-Barra fan area, Rockall Basin. Owens M., Haughton P. and Georgiopoulou A.
20	Width analysis of submarine channel bends. Palm F.A., Peakall J., Hodgson D.M. and Gardner J.
21	Sediment routing in confined turbidite basins of Lake Pannon. Tőkés L., Törő B., Várkonyi A., Fodor L. and Sztanó O.
Coastal to shallow marine systems **Chairs: Luz Cartesio, Tim Luber and Oliver Jordan**	
22	Evolution of Clastic Coastal Depositional Systems in the Campanian of the Western Interior Seaway, North America. van-Cappelle M., Hampson G.J. and Johnson H.D.
23	Clinoform architectures and trajectories in the Taranaki Basin, New Zealand. Dunlevy E., Huuse M. and Flint S.
24	Are shallow-water carbonates a reliable archive for global environmental change? Hönig M.R. and John C.M.
25	Formation of siderite concretions and the porewater geochemistry of Norfolk salt marsh, UK. Lina C.Y., Antlera G. and Turchyna A.V.
26	Towards a classification and quantification scheme for overbank sandstones in a delta top setting. Rahman M.M., Macdonald D.I.M. and Howell J.A.
27	Bedform development and morphodynamics in mixed cohesive sediment substrates. Ye L., Parsons D.R., Manning A.J. and COHBED Project Team
Carboniferous sedimentary systems **Chairs: Leo Newport, Catherine Breislin, Sarah Kenworthy and Joe Emmings**	
28	Basin-Scale mineral and fluid processes at a palaeo-platform margin, Lower Carboniferous, UK. Breislin C., Banks V., Hollis C., Frazer M., Juerges A., Marshall J., Riding J. and Whitaker F.
29	The Carboniferous Bowland Shale Formation (UK): Understanding the Sedimentological and Diagenetic Processes within a potential Shale Gas Exploration Play. Newport S.M., Taylor K.G., Hough E. and Worden, R.H.
30	Shale-gas potential of mid-Carboniferous mudrocks (Kinderscoutian), Cleveland Basin (Yorkshire, England). Tucker M., Slowakiewicz M., Pancost R., Vane C., Harding R. and Collins A.

Quantitative sediementology: sensing and modelling **Chairs: Nigel Cassidy and Jamie Pringle**	
31	Cyclic steps formed by dredger-induced turbidity currents, Western Scheldt Estuary, The Netherlands. Vellinga A., Cartigny M., Clare M., Mastbergen D., van-den-Ham G., Koelewijn A., de-Kleine M., Hizzett J., Azpiroz M. and Parsons D.
Reservoir quality and diagenesis **Chairs: Stephan Stricker, Mark Brodie and Peter Andras**	
32	Quantify Porosity from Cuttings using QEMSCAN. Alexander J., Omma J., Omma H., Benedictus A. and Cortes M.
33	Triassic to Early Jurassic climatic trends recorded in the Jameson Land Basin, East Greenland: clay mineralogy, petrography and heavy mineralogy. Andrews S.D., Decou A., Alderton D.H.M. and Morton A.
34	Waking (another) sleeping giant? The effect of carbonate diagenesis on pore systems in the Bakken Formation, USA. Brodiea M., Aplina A., Gluyasa J. and Hart B.
35	Targeting tight aquifers in deep sedimentary basins for geothermal exploration. Brown C., Cassidy N., O'Neill M. and Spivey D.
36	Improved reservoir models from outcrops using Virtual Outcrops and Multiple Point Statistics. Mullins J.R., Howell J.A., Buckley S.J. and Kehl C.
37	Timing, mechanisms and impact of compactional fluids migration on the hydrocarbon charging of reservoir during burial: example of the Lodève Basin (South of France). Laurent D., Lopez M., Chauvet A., Thomas M., Imbert P., Sauvage A-C. and Buatier M.
38	Diagenetic Controls on Reservoir Quality of Collyhurst Sandstone, East Irish Sea Basin, United Kingdom. Oluwadebi A.G. and Taylor K.
39	Biofilm origin of clay coated sand grains: Understanding the fundamental processes governing the origin and distribution of clay-coated sand grains in petroleum reservoirs through a modern day analogue. Wooldridge L.J., Worden R.H., Griffiths J., Duller R.A. and Utley J.E.
40	Diagenetic history and reservoir quality of the Carboniferous and Permo-Triassic reservoirs in the Rathlin Basin, Northern Ireland. Raine R.
41	Determining the applicability of synthetic gamma ray logs as an analogous method for reservoir quality: Case study from Styrrup Quarry, Doncaster, UK. Mitten A.J., Pringle J.K. and Clarke S.M.
Recent advances in sedimentation and tectonics **Chairs: Alastair Robertson, Christopher A.L. Jackson and Tomas Cain**	
42	The stratigraphic architecture of shallow marine systems in syn- to post-rift settings. Barrett-Crosdil B., Hodgson D. and Collier R.
43	The Ghaggar-Hakra Formation: The final chapter? Beaumont H., Clarke S.M., Burley S.D., Taylor A. and Mohapatra P.
44	Facies variations on active thrust-top basins: a study case of Numidian turbidites of Sicily. Pinter P.R., Butler R.W.H., Hartley A.J. and Maniscalco R.

Talk abstracts

Characterising the Wealden Mudstones: Mineralogy, Geochemistry, and Palaeoenvironments of the Weald Basin, southeast England

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This study presents detailed clay mineralogical and geochemical studies of the Ashdown and Wadhurst Clay Formations (Late Berriasian-Middle Valanginian) in the Weald Basin, southeast England. The main clay minerals are illite (53%), kaolinite (31%), illite-montmorillonite (10%), vermiculite (5%) and illite-smectite (1%). Illite-montmorillonite is reported as one of the mixed-layered minerals for the first time. The clay mineral assemblage reveals granitic and/or gneissic sources, dry and humid climate with high but irregular precipitation, intensive weathering, and good drainage system. The elemental composition of these sediments is presented via X-ray fluorescence (XRF) and Spectral Gamma-ray (SGR) methods for the first time in the published literature. The concentrations of Zr, Cr, Ni, Rb, and Sr suggest that the sediments may have been directly or indirectly sourced from stable cratons. Elements such as Mo and Co confirmed the presence of anoxic and reducing conditions at the sites of deposition. The enrichment of Mo and the presence of Fe provided evidence for early diagenesis within the strata. The spectral gamma-ray data is consistent with fresh water origin of the sediments. The higher quantity of Thorium in relation to Uranium indicated humid and hot palaeoclimatic conditions at the source areas that favoured intense weathering. The results of these analyses reinforce the importance of the mineralogy and geochemistry of sediments as useful tools for understanding the palaeodepositional conditions of the adjacent basin especially when traditional data are not available or insufficient.

Clay mineral transformations, compaction and overpressure generation in siliciclastic mudstones

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Clay mineral diagenesis has a considerable effect on the physical properties of siliciclastic mudstones, with important implications for pore pressure prediction. The dominant clay mineral reaction, the conversion of smectite to illite, involves a series of dissolution and reprecipitation reactions which results in a significant change in the orientation of the whole clay fabric. Unloading is a direct result of clay mineral diagenesis and concomitant fabric destabilisation, due to the local transfer of load from dissolving detrital clay grains to fluid. Pore pressure is then a function of the rate at which it is generated by clay mineral diagenesis (and other mechanisms such as disequilibrium compaction) and the rate at which it is dissipated by compaction and fluid flow.

We have found clear evidence for chemical compaction (porosity loss / sediment volume reduction) associated with illitization of smectite in Cretaceous mudstones at Haltenbanken from measured physical, textural, and mineralogical properties, and from log responses. We also see continuing compaction of diagenetically mature, illitized mudstones with increasing effective stress. We interpret our data to discriminate between two models for the chemical compaction of diagenetically altered mudstones proposed by previous researchers: (effective) stress-independent chemical compaction and chemically-enhanced mechanical compaction. Key evidence in favour of the chemically-enhanced mechanical compaction model comes from density logs in association with the pore pressure history. This model is also consistent with the petrographic evidence that clay-rich siliciclastic mudstones have a clay-supported matrix both before and after illitization. Established methods of pore pressure estimation do not correctly account for the mechanical and chemical contributions to mudstone compaction, except empirically or in favourable circumstances where use can be made of data from offset wells with similar lithology, burial history and temperature history.

Stratigraphic heterogeneity induced by allogenic and autogenic factors in a Paleogene low net-to-gross fluvial succession, Tremp-Graus Basin, southern Pyrenees, Spain

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Low net-to-gross fluvial accumulations commonly comprise isolated channel bodies embedded in thick overbank successions, in which multi-scale lithological heterogeneities resulting from combined allogenic and autogenic controls can give rise to complex preserved stratal architectures. Laterally continuous exposures (5 km) of Paleogene fluvial strata of the Tremp-Graus Basin in the Arén-Esplugafreda sector (southern Pyrenees, Spain) are used to undertake a lithofacies and architectural analysis based on acquisition of quantitative and qualitative sedimentological data. Constraints on potential eustatic, climatic and tectonic controls in this succession allow evaluation of the architectural response of a fluvial system to allogenic drivers. This succession records deposition by an ephemeral fluvial system in an arid environment where multiple streams undertook repeated and apparently frequent avulsions, likely in relation to flash-floods. The analysis undertaken provides an opportunity to model a low net-to-gross fluvial system developed in response to combined allogenic and autogenic controls.

Outcropping channel bodies have been mapped using high-resolution orthophotographs, LiDAR DEM's and GPS data; lithofacies associations and architectural elements have been characterized by field analysis. Two main facies associations of fluvial deposits are defined which correspond to channelized bodies and overbank deposits. The channelized facies association comprises gravelly and sandy deposits arranged in four types of architectural elements, defined according to their geometry and internal architecture. Ribbon and poorly channelized sheet-like bodies represent single-storey channel-fill elements, whereas compound bodies and amalgamated complexes are the product of superimposed episodes and represent multi-storey, multi-lateral channel-fill elements. The overbank facies association comprises extensive intervals of pedogenic altered floodplain siltstone, along with non-confined sheet-like bodies composed of bioturbated and pedoturbated very-fine-grained sandstone. The studied succession is dominated by overbank deposits (commonly more than 80%); vertical connectivity between sand bodies is therefore limited. Compound bodies and amalgamated complexes with significant thickness (over 5 metres) and good lateral continuity (hundreds to thousands of metres) occur mainly in the uppermost part of the studied interval, which records a major allogenic palaeoclimatic change associated with the Paleocene-Eocene Thermal Maximum.

New flow structure identified by direct measurements of turbidity currents in the Congo Canyon

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Direct measurements of turbidity currents are exceptionally rare, yet are crucial for quantifying the impacts of these potentially damaging flows on expensive seafloor infrastructure. We present *high-resolution* (every 5 seconds) direct measurements of a *one-week* duration turbidity current that demonstrate a flow structure that differs significantly from current models.

Existing turbidity current models, which are largely based on scaled physical experiments, suggest thick slow flow heads acting as shield for thinner faster bodies that feed heads with their sediment-laden load. In contrast, our new data shows a turbidity current with a fast (~2 m/s), 30 m-thick head followed by a slower (~0.8 m/s) flow body of almost 80 m thickness. As a consequence, the head is outrunning the body and thereby continuously stretching the flow. The body of the flow appears to switch between two distinct flow modes: 1) thinner periods with enhanced turbulence and sediment concentration below a near-bed velocity maximum, and 2) thicker periods that have a more homogeneous distribution of turbulence and sediment throughout the vertical depth. These two flow modes resemble supercritical and subcritical regimes previously described in laboratory flows and question the classical concepts that point to supercritical turbidity currents occurring on steep slopes and subcritical flows occurring on more gentle slopes.

Novel bedforms and primary current stratification in cohesive mixtures of mud and sand

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The use of sedimentary structures as indicators of flow and sediment morphodynamics in ancient sediments is essential for reconstruction of formative flow conditions generated in a wide range of grain sizes and sedimentary environments. Yet, the vast majority of past research has concerned bedforms generated in essentially cohesionless sediments that lack the presence of mud within the flow and within the sediment bed itself. However, most sedimentary environments possess fine-grained sediments, with recent work demonstrating how the presence of such fine sediment may substantially modify the fluid dynamics of such flows. It is thus increasingly evident that the influence of mud, and the presence of cohesive forces, is essential to permit a fuller interpretation and understanding of many modern and ancient sedimentary successions.

In this presentation, we summarize the fluid dynamics of turbulence modulation generated by the presence of fine suspended sediment, and use this knowledge to propose a new extended bedform phase diagram for bedforms generated in mixtures of sand and mud under rapidly decelerated flows (Fig. 1). This diagram provides a phase space using the variables of yield strength and grain mobility as the abscissa and ordinate axes, respectively, and defines the stability fields of a range of bedforms generated under flows that have modified fluid dynamics due to the presence of suspended sediment within the flow. We also show data on a range of bedforms generated in such flows, from laboratory experiments and examples from ancient sediments, including: i) heterolithic stratification, comprising alternating laminae or layers of sand and mud; ii) the preservation of low amplitude bed-waves, large current ripples, and bed scours with intrascour composite bedforms; iii) low angle cross-lamination and long lenses and streaks of sand and mud formed by bed-waves; iv) complex stacking of reverse bedforms, mud layers and low-angle cross-lamination on the upstream face of bed scours; and v) planar bedding comprising stacked mud-sand couplets.

Turbulent behaviour of non-cohesive sediment gravity flows at unexpectedly high flow density

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Experimental lock exchange-type turbidity currents laden with non-cohesive silica-flour were found to be highly dynamic at remarkably high suspended sediment concentrations. These experiments were conducted to produce sediment gravity flows of volumetric concentrations ranging from 1% to 52%, to study how changes in suspended sediment concentration affects the head velocities and run-out distances of these flows, in natural seawater.

Increasing the volumetric concentration of suspended silica-flour, C, up to C = 46%, within the flows led to a progressive increase in the maximum head velocity. This relationship suggests that suspended sediment concentration intensifies the density difference between the turbulent suspension and the ambient water, which drives the flow, even if almost half of the available space is occupied by sediment particles. However, from C = 46% to C = 52% a rapid reduction in the maximum head velocity was measured. It is inferred that at C = 46%, friction from grain-to-grain interactions begins to attenuate turbulence within the flows. At C > 46%, the frictional stresses become progressively more dominant over the turbulent forces and excess density, thus producing lower maximum head velocities. This grain interaction process started to rapidly reduce the run-out distance of the silica-flour flows at equally high concentrations of C ≥ 47%. All flows with C < 47% reflected off the end of the 5-m long tank, but the head velocities gradually reduced along the tank.

Bagnold (1954, 1963) estimated that, for sand flows, grain-to-grain interactions start to become important in modulating turbulence at C > 9%. Yet, the critical flow concentration at which turbulence modulation commenced for these silica-flour laden flows appeared to be much higher. We suggest that Bagnold's 9% criterion cannot be applied to flows that carry fine-grained sediment, because turbulent forces are more important than dispersive forces, and frictional forces start to affect the flows only at concentrations just below the cubic packing density of spheres of C = 52%. These experimental results also imply that natural flows may be able to transport vast volumes of non-cohesive sediment with relative ease, especially considering that the experimental flows moved on a horizontal slope.

Establishing the provenance of Lower Cretaceous Sandstones, offshore western Ireland.

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This study aims to establish the provenance of Lower Cretaceous sandstones in a range of basins offshore western Ireland via a multiproxy approach. This will, in turn, help constrain sediment pathways, palaeogeography and potentially aid in well correlation for the Lower Cretaceous in these basins.

Western Irish offshore basins share similar basin evolution histories. Late Jurassic to Early Cretaceous rifting was followed by thermal subsidence with further rifting in the Late Cretaceous. The Lower Cretaceous in the Erris and Porcupine basins is dominated by a largely marine sequence comprising deep-water shales and turbidites, interrupted by fan delta systems linked to uplift of basin margins during Aptian-Albian times. A similar succession is inferred for the eastern margin of the Rockall Basin.

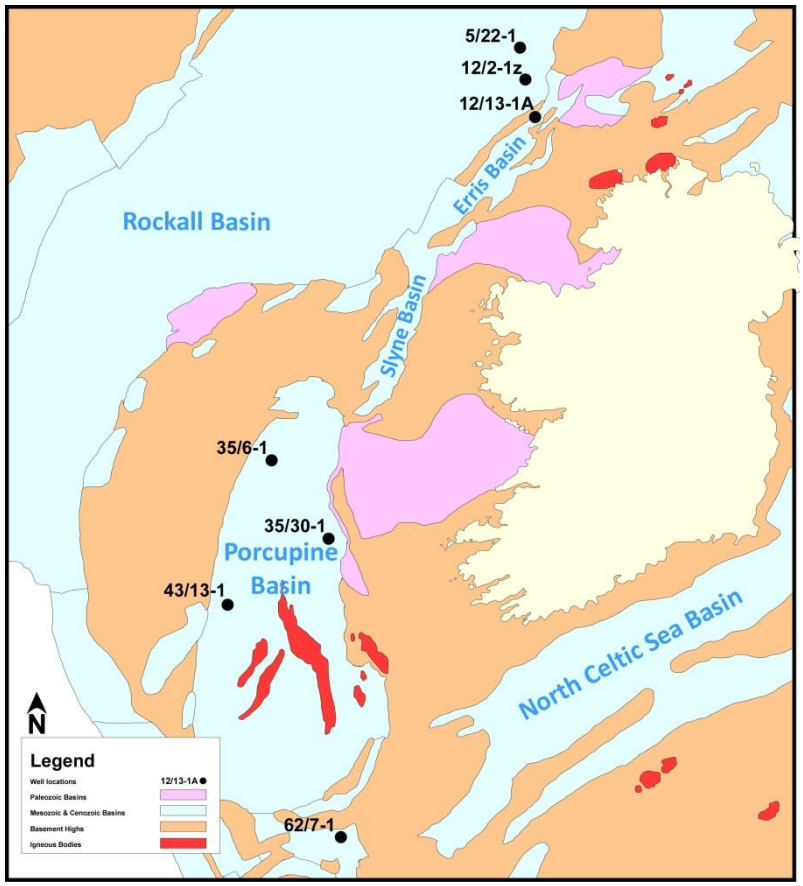

Fig.1. Irish Offshore basins and the sites of sampled wells.

Heavy mineral analyses from a range of wells along the Erris and Porcupine basins and from the Goban Spur (12/13-1a, 35/6-1, 43/13-1 and 62/7-1) have revealed a distinct lack of apatite across all wells (Fig.1). This may be indicative of selective removal during prolonged storage on the adjacent wide continental shelf. The variation in heavy mineral assemblages may indicate source switching over time, perhaps reflecting uplift of the hinterland or more cryptic climatic fluctuations.

Pb-in-K-feldspar data have also revealed multiple sources of detritus in both the Porcupine and Erris basins. Well 12/13-1a, in the Erris Basin, contains a minimum of three provenance signals correlated with Archaean (Lewisian), Grenvillian and Caledonian (Donegal Granites) sources. While the Archaean signal has also been

found in Triassic/Middle Jurassic sandstones of the nearby Dooish well (12/2-1z), the Grenvillian and Caledonian signals are absent, indicating uplift of the hinterland or significant pathway rerouting prior to the Early Cretaceous. Sampled intervals from the Porcupine Basin also comprise of the Grenvillian signal found in well 12/13-1a, with additional signals which appear to indicate derivation from the western Irish offshore. The presence of Grenvillian material in both basins and the absence of Caledonian detritus in the Porcupine Basin, may indicate a significant drainage divide, buffering the delivery of sand southward from NW Ireland during the Early Cretaceous.

Let it Flow: Understanding transportation of soft-bodied organisms in sediment-density flows.

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Understanding if organisms within fossil assemblages have been transported great distances is fundamental to the study of palaeoecology. Despite this, the sedimentology of fossil-enclosing deposits is often overlooked and taphonomic analyses instead focus on post-depositional decay and preservation. One such example is the world-famous Burgess Shale. Its exquisite fossil preservation has enabled insights into the anatomy of early soft-bodied organisms and their evolution during the Cambrian explosion. However there is still a fundamental debate with regards to the transport these organisms have undergone. Namely, whether they were living within or close to the environment of deposition, or could they have been transported from one environment to another?

Using an annular flume tank, experiments have been initially designed to explore fundamental factors of sediment-density flows that may be causing damage to soft bodied organisms. These factors include grain angularity, transport duration and sediment concentration. Sedimentological samples have also been collected from Burgess Shale localities during summer 2015 so that re-evaluation of the flow type could be fed back into the experimental design. From experiments such as these, we can begin to set constraints on the amount of transport, if any, that these fossil organisms would have endured.

The effect of confinement on Basin-floor lobe stacking patterns

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The stacking patterns and depositional architecture of submarine lobe deposits in depocentres experiencing basin-wide confinement is relatively poorly understood. Investigating the controls on these deposits, and the influence of confining slopes on their architecture is important as most basins exhibit confinement to some degree. Extensive exposures of the Eocene Upper Broto turbidite system in the Jaca Basin, NE Spain, permitted the collection of 20 detailed sedimentary logs (890 m of cumulative section) and >100 restored palaeocurrents, in an 80 m thick stratigraphic interval over a 32 km^2 area. This dataset permits the analysis of the stacking pattern and architecture of submarine lobes in a confined setting.

Three main lithofacies in tabular sandstone packages are identified: 1) thick-bedded, amalgamated sandstones, interpreted as lobe axes; 2) medium-bedded structured sandstones, interpreted as lobe off-axis deposits; 3) thin-bedded sandstones, interpreted as lobe fringe deposits. The tabular sandstone packages (lobe axis and off-axis) are sharply bound by metre-scale fine-grained thin-bedded packages (lobe fringe). This stacking pattern is interpreted to represent autogenically-driven compensation of lobes.

Palaeogeographic reconstructions, using multiple correlation panels with 3D constraint, integrated with published lobe dimensions, support the compensational stacking interpretation, and indicate that lobes were only weakly confined by the basin margins. In contrast, 35 km downdip of the study area, sheet-like stacking of sandstone beds in the same stratigraphy suggest that compensationally stacked lobes and sheet-like sandstones exist in the same stratigraphy. This longitudinal relationship is explained by the higher-density (parts of) flows depositing updip to contribute to lobe formation, whereas the lower-density (parts of) flows deposit as basin-wide sheet sandstones that are confined at the scale of the basin. Therefore, both sheet-like, and compensational stacking patterns can exist contemporaneously. This has implications for confined systems where sheet-like stacking patterns are reported, as compensational stacking of lobes may exist proximally within the basin.

Investigating the hybrid terrestrial to coastal sedimentology of the Ballagan Formation, Lower Carboniferous, Scotland

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The Tournaisian Ballagan Formation of Scotland consists of an interbedded succession of fluvial, alluvial, lacustrine, hypersaline and marginal marine sedimentary rocks. Field and core sections allow a unique window into this linked depositional system. This study is part of the TW:eed Project (Tetrapod World: early evolution and diversification), investigating the rebuilding of ecosystems after the end Devonian mass extinction.

The sedimentology of the formation is compared from two ~500 m thick sections, the Burnmouth field section and the Norham Core, both situated near Berwick-Upon-Tweed. Three facies associations are identified: 1) The Overbank Facies Association comprises laminated grey siltstones, palaeosols, thin sandstones, sandy siltstones and lenticular conglomerates; 2) The Saline-Hypersaline Lake Facies Association comprises cementstones (dolomitic beds), laminated grey siltstones and evaporites. 3) The Fluvial Facies Association comprises erosive-based cross-bedded sandstone units with conglomerate lags at their base and rippled siltstone at their top. The Overbank and the Saline-Hypersaline Lake facies associations are interbedded on a metre to sub-metre scale, with a heterogeneous distribution; marker beds cannot be identified between the field and core sections.

The rare marine fauna (brachiopods, orthocones, *Spirorbis*) and ichnofauna (*Serpula, Chondrites, Phycosiphon*) present do not occur in identifiable 'marine bands'. This could mean that marine conditions were 1) short-lived; 2) marginal (e.g. brackish); or 3) difficult to identify. A range of methods is used to address this interpretation challenge:

- Regional scale: Documentation of BGS borehole and field data of evaporitic sediments and marine fossils to investigate palaeogeography;
- Facies scale: The sedimentology of each facies (e.g. palaeosols, cementstones) has identified a mosaic of co-existing sub-environments;
- Borehole: Logging has revealed fine-scale sedimentary detail from siltstones that is poorly exposed at the field site;
- Bed scale: Bulk carbon isotope geochemistry and carbonate isotope geochemistry has been used to try and distinguish the environment;
- Micro scale: Integrated micropalaeontology and palynology give further insight into palaeosalinity;

The combined interpretation of these datasets is enabling us to piece together the timing, nature and duration of marine incursions.

Megaclasts in submarine slope channels: rolling, tractional shear by turbidity currents or debris flow origin?

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In the Campanian to Maastrichtian-aged Rosario Formation, Mexico, mafic volcanic boulders over 5 meters in diameter occur within submarine slope channel-fills. These exceptionally large clasts have diameters similar to the depth of the channel thalwegs within which they occur. They are enclosed by well-organized clast-supported conglomerates of pebble to cobble grade, and subordinate sandstones. These deposits are characterized by structures interpreted to represent suspension and tractional transport by turbidity currents. In close association with the boulders, forming a basal/marginal rim, are more poorly sorted deposits including mudstone, pebbly mudstone, mudstone clasts, heterolithic clasts, sandstone and sandstone clasts, and very poorly sorted matrix-rich conglomerates. In the terrace area of channels within the same system occur carbonate boulders associated with thin bedded turbidites, with pebbly mudstone adjacent to the lower 20 to 30 cm of the boulders' margins. To account for the presence of these clasts, two alternative models are presented: 1) the boulders rolled into the canyon and continued to move downslope due to shear by turbidity currents and the effect of kinetic sieving which lifts larger clasts to the top of a mixed grain size sediment load; or 2) the boulders were transported within cohesive mass flows which deposited en-masse, but due to subsequent erosion, the finer-grained components of the deposit were eroded leaving a winnowed boulder field lying across the paleo-channel belt. Ultimately, the second model is favoured based on the presence of debritic material at the basal rim of the boulders, and an analysis of the required shear strength required to move a boulder in a turbulent flow versus the yield strength required to maintain such a clast in a debris flow. The model may explain the presence of apparently isolated boulders observed on the modern seafloor, and imaged in high resolution shallow seismic, with implications for the assessment of paleo-seismology and mapping of seafloor sediments.

Basin-scale mineral and fluid processes at a Lower Carboniferous platform margin.

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Fault-controlled dolomite has been well studied and described in various localities in the Pennine Basin and North Wales. Fluid flow modelling (Frazer et al., 2014) indicates sufficient fluid volumes for dolomitisation could have been supplied along faults from the juxtaposed basinal sediments however geochemical models (PHREEQ) indicate insufficient Mg. RTM shows geothermal convection could have operated but geochemical data is consistent with dolomitisation from evolved basinal brines that interacted with siliciclastic sediments and/or volcanics, possibly a result of overprinting by compactionally driven fluids prior to mineralisation. What is investigated in this study is whether geothermal convection provided a precursor to basin dewatering, and if this process is important on other platforms.

The Derbyshire Platform is a Carboniferous rimmed shelf, the westernmost expression of the East Midlands Platform. On the SE platform margin, 50km^2 of Visean limestones have been dolomitized, forming two major bodies with an association with major NW – SE trending basement lineaments and volcanics. The onset of compressional tectonics associated with the Variscan Orogeny resulted in multiple phases of NW-SE and NE-SW trending fault/fracture controlled calcite cementation and Pb-Zn-F-Ba mineralization (Hollis and Walkden, 2002).

This study uses outcrop and newly available core from the southern margin of the Derbyshire-East Midlands Platform to better constrain the timing and mechanism for dolomitisation. Dolomitisation is usually fabric destructive with a range of textures that suggest multiple phases of fluid flux. Geochemical data indicates slightly modified seawater, with a contribution from hydrothermal fluids, was responsible for dolomitisation. New data on a refined paragenesis is used to test the hypothesis that dolomitisation by geothermal convection of seawater during early burial was an important pre-requisite for later dolomitisation by hotter, more evolved basinal brines. Demonstration of a feedback mechanism between these processes has the potential to inform arguments that favour mass fluid transfer during burial diagenesis.

Ages and provenance of Upper Cretaceous to Paleogene sediments in Sarawak, Borneo: connections between terrestrial and deep marine settings at the Sundaland margin

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The Kuching and Sibu Zones are major tectonic subdivisions of West and Central Sarawak in NW Borneo. The Kuching Zone is characterised by terrestrial fluvial to marginal marine deposits of Late Cretaceous to Early Cenozoic age. These were deposited in various sedimentary basins, of which the Melawi and the Ketungau Basins are the largest. In this study the sediments along the northern margin of the Ketungau Basin and the Kayan Group of West Sarawak were analysed. In contrast to the terrestrial sediments of the Kuching Zone, the Sibu Zone is composed of deep marine turbidite deposits, named the Rajang Group. Although differing in depositional environment, the sediments of the Rajang Group are reported to be of similar age to those of the Kuching Zone. The two zones are separated by the Lupar Line, which is often described in the literature as a suture zone marking a collisional event at a poorly defined time in the Cretaceous or Early Cenozoic, which would imply different source regions and character of the sediments. We present new heavy and light mineral data, as well as U-Pb zircon ages for sediments of the Kuching and Sibu Zones. They show similar provenance characteristics and age patterns interpreted to indicate that the two zones had the same source regions, were connected from the Late Cretaceous onwards, and formed a large-scale sedimentation system. The main source areas alternated between the Tin Belt of Peninsular Malaysia, which provided Permian-Triassic and Precambrian zircons and multiple recycled material, and the Schwaner Mountains of SW Borneo which supplied first- to moderately recycled Cretaceous material. Detrital zircons with ages close to the depositional age of the sediments indicate contemporaneous volcanism throughout the Paleogene. Volcanic quartz and volcanic rock fragments are common in the sediments and confirm volcanic input, previously largely unrecognised. The abrupt change from terrestrial sediments in the Kuching Zone to deep marine sediments in the Sibu Zone suggests a narrow steep continental Sundaland margin at the position of the Lupar Line, which is interpreted not as a suture zone but a major strike-slip fault zone.

Degradation and aggradation of a basin margin: Sedimentology, stratigraphy, and origin of stacked erosional mass transport complexes

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Commonly, seismic data indicate that mass-transport deposits (MTDs) are (partially) confined by erosion surfaces, but this is less commonly observed at outcrop. Detailed understanding of processes and products of MTDs is vital as they constitute a significant proportion of stratigraphy in deep-water settings and play a key role in hydrocarbon exploration as seals and traps. This study examines a series of exhumed, stacked, seismic-scale MTDs overlying large-scale erosion surfaces.

We focus on a 3 km long and 150 m high outcrop of the Permian Ecca Group in the Laingsburg depocentre, Karoo basin, South Africa. The section is distal to a well-documented succession of basin floor turbidite units. Thirteen sections through the full outcrop as well as numerous detailed shorter sections were collected to establish a stratigraphic framework with surfaces traced out laterally. Within the outcrop, 3 large scale confining surfaces (50- >100 m in depth, > 3 km in width) cut downwards to the NW. Based on differences in lithology, architecture, bed thickness and continuity; flow process (turbidite/MTD) and sedimentary structures, 16 units have been identified. The MTDs range in scale and morphology including, smaller (metre scale) and larger (10s of metres scale) slumps and debris flows and several 10s of metres high and >100m wide mega-clasts entrained from underlying lithostratigraphic units. The rugose top surface of the MTDs results in significant lateral variability at bed and outcrop scale. Thick graded beds onlap onto these surfaces and indicate 3D confinement of flows, which decreases upwards as the erosional relief was healed.

The surrounding stratigraphy suggests that these submarine landslides were emplaced in an area of interplay between two regional scale deepwater systems. Palaeocurrent analysis suggests that the outcrop preserves the lateral margins of the MTCs. Entrainment of mega-clasts from the underlying basin-floor succession, and the deep erosion, suggests steepening of the basin margin during sedimentation. This outcrop example allows the examination of bed-scale interaction of MTDs and turbidity currents within a seismic scale outcrop. Application of results to subsurface data sets will provide better constraints to geological models, which are required to understand the significant variability of mass transport complexes and their impact on sedimentation processes.

A comparative study of fluvial crevasse-splay deposits

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Crevasse-splay deposits form a volumetrically significant component of fluvial overbank successions. However, there are relatively few detailed studies on the morphology and internal facies composition of crevasse splays compared to fluvial-channel-fills.

This work presents a comparative study of crevasse-splay deposits of the Cretaceous Neslen Formation (Utah) and the Jurassic Salt Wash Member of the Morrison Formation (Utah, Colorado). These successions accumulated under greenhouse humid and semiarid to arid climates, respectively. The aim of this study is to develop predictive depositional models to account for sedimentological differences and similarities in crevasse-splay deposits across different depositional settings.

Crevasse splays in both the Neslen and Morrison formations thin and fine away from the genetically related channel elements from which they emanate. Proximal parts of individual splay elements are dominated by upper-stage plane beds, climbing-ripple strata and erosional gutter casts; medial parts comprise small-scale deformed beds; distal parts comprise lower-stage plane argillaceous silt beds. In both studied stratigraphic units, the size of the splay bodies is scaled with the size of genetically related parent channel bodies with channel-to-splay thickness ratios ranging from 6:1 to 2:1. There are common lateral facies changes observed within splay elements, which reflect similarity in genetic processes, and represent an underlying pattern for splays from different settings.

The geometries of splays in the Morrison Formation vary in relation to the grainsize of associated channel elements; conglomerate-filled channel bodies are related to splay elements that exhibit more wavy bed boundaries compared to splay elements that emanate from sand-prone channel bodies. Splay elements in the Morrison Formation are separated by palaeosols with intense bioturbation, pedoturbation and rhizolith development, and that reflect a well-drained substrate; splays in the Neslen Formation are either separated by floodplain fines or compensationally stacked forming composite splay bodies or splay dominated succession, which reflects a water-saturated substrate prone to peat (coal) accumulation.

Similarities between crevasse-splay deposits arise due to common formative mechanisms of splay evolution and accumulation. Differences arise in response to allogenic controls including climate regime, basin setting, rate of accommodation generation, floodplain drainage state and vegetation cover and type.

The Annot … down-system: chasing confined turbidites in mountain belts

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Sand fairway mapping in turbidite systems is a key, but under-used, tool for understanding basin configurations in evolving mountain belts. The Annot system (Eo-Oligocene) of the western Alps is arguably the most studied such succession. But these existing researches have focused on the southern sector, rather proximal to the original sediment source (Corsica-Sardinia and the Maures-Esterel massif) together with the time-equivalent (but volcaniclastic) Western Champsaur sandstones of the Hautes-Alpes. Further time-equivalent strata exist in the Eastern Champsaur (adjacent to the Ecrins massif) and Aiguilles d'Arves areas (north of the Ecrins) but have resisted sedimentological and stratigraphic studies – presumably because they are deformed. Thus only the southern 100km of the system has been studied in any detail: at least the same extent down-system is effectively unknown. Indeed many regional tectono-stratigraphic syntheses imply that the Annot system was deflected or perhaps even ponded against the Ecrins massif in the ancestral orogenic foredeep. These assumptions are challenged here. Recent work in the Eastern Champsaur (Vinnels et al., 2010. J. Sedim. Res.) indicates that southward-derived quartz sandstones of Annot affinity were deposited by turbidity currents that continued to pass northwards over what is now the Ecrins massif. Likewise the volcaniclastic sand fairways of the Western Champsaur, sourced from SW, show abundent bypass facies. These turbidites once also continued over the Ecrins. Relationships in Champsaur show that the two sand fairways operated broadly synchronously but were separated by a growth thrust zone (the Selle fault). The Ecrins was also deforming at this time but presumably basement uplift was outpaced by regional subsidence: turbidite sedimentation swamped it. The continuity of the quartz-sand fairway is found in the Aiguilles d'Arves, with m-thick coarse sandstones and significant bypass facies. They are also associated with breccia lobes interpreted as lying at the mouths of submarine canyons that cut through the developing Ecrins massif. Sediment bypass is evident even in these apparently distal settings – so how much further did the Annot and associated turbidites extend – and where are the fines? The research shows that simplistic models of forelandward-migrating deformation in the Alps are misleading – as is the use of regional transgressive surfaces (e.g. the "Nummulitic unconformity") for charting orogenic processes. The ancestral Alpine foredeep was highly structured and actively deforming so that patterns of erosion, transgression and sedimentation reflect both the regional subsidence and local modulations formed by active structures.

K/Pg Boundary: Fossilized Trees Transported to a Deep Sea Environment in Baja California – Mexico

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The Rosario Formation, in the central portion of the Peninsular Ranges Forearc Basin, crops out along the western margin of the Baja California Peninsula, Mexico. It represents a Late Cretaceous, deep marine and relatively steep slope environment, with mass transport deposits, debrites, and hemipelagic mudstones incised by several submarine canyons and entrenched slope channel systems. The San Fernando and San Carlos Channels are examples of such features that cut the fine-grained background slope sediments and contain coarse grained turbidites filling the channels themselves. A large number of fossilized tree trunks were found within the slope mudstones, and allowing for the regional structural dip of these deposits, they coincide with the K/Pg boundary, which can be inferred across the slope sediments between the top of the San Fernando Channel System and Mesa San Carlos. The tree fossils preserve original structures, such as growth rings, nodes from branches and bark, and some show also burnt and carbonized portions. Their diameter can exceed 50cm, and the total length preserved may be a few meters, although smaller pieces are more common. They are found in one interval, overlying mudstones and capped by a few meters of sand-rich debrites, a persistent bioclast-rich debrite, with thickness varying from 30cm to 1m, and in some places a tuff with thickness around 20m, which has yielded an age coincident with the K/Pg boundary. The transport mechanism of these fossilized trees is still uncertain, but given their occurrence within debritic deposits they are likely to have been transported and deposited by the same mechanisms that generated the debrites. We suggest they may be associated with a catastrophic event related to the Chicxulub impact itself, in the Yucatán Peninsula, 2700 km distant from this locality. The next steps of this research include the gathering of biostratigraphic data on the slope mudstone deposits, to place the K/Pg boundary precisely, and understand better the facies architectures and depositional processes involved.

How are mass failures and sediment flows triggered at offshore river deltas?

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Rivers and offshore turbidity currents are probably the two most volumetrically important sediment transport processes on Earth, and form many of its largest sediment accumulations. It is thus important to understand how they are linked. It has been proposed that various processes trigger turbidity currents offshore from river mouths including direct plunging of river discharge (hyperpycnal flows), slope failure caused by low tides and gas expansion, earthquakes or rapid sedimentation, and elevated bed shear stresses that erode delta-mouth bars, but these hypotheses are poorly tested in a quantified manner. In this study, a suite of statistical tests is applied to an unprecedentedly large record of delta-front failures and flows. Most previous studies have observed less than ten events, and this has not allowed for robust statistical analysis. The submarine delta at Squamish, British Columbia provides an exceptional natural laboratory where 106 turbidity currents were monitored over 147 days during 2011. This dataset provides sufficient number of observations for statistical analysis of event timing, frequency and triggers. Elevated periods of river discharge are shown to be a significant control on when the turbidity current system 'switches on' (i.e. becomes active). The combined effects of river discharge and tidal elevation, interpreted to cause elevated bed shear stresses on the delta lip, are the most significant controls on flow timing. Of these two factors, river discharge is the dominant control on flow recurrence, as the seasonal discharge maximum correlates with more frequent flows. Each 1 m^3/s increase in river discharge explains a 1% increase in offshore sediment flow likelihood, once a critical threshold is reached. The largest peaks in river discharge do not create hyperpycnal flows, however, and instead result in delayed delta lip failures. Delta lip failures may also occur during periods of lower sediment input, which appears to be promoted by low tide conditions. This study provides new insights into the dynamics and frequency of submarine deltas which has wide implications for hazard assessment and understanding deep-sea sediment transport.

Scale invariance of clastic injectites and their application to forward seismic modelling

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Scale invariance allows geologists to apply known and quantifiable outcrop data to inform and populate large-scale models and low resolution datasets, particularly through physical modelling, forward modelling and in the construction of 3D geological models. However, many systems are scale invariant but property and process variant, for example, clinoforms are observed across a wide range of scales, including ripple- and delta-scale, but where a ripple foreset has a narrow grainsize range, a delta slope will present dramatic facies variation. Here we show for the first time that clastic injection processes and products are an example of a scale and property invariant system, forming similar architectures with a narrow grain size range, from mm to m scales.

Outcrop analysis from the Karoo Basin, South Africa has led to the identification of six injectite morphotypes: Morphotype 1: Low-angled bowl, Morphotype 2: Anastomosed injectite, Morphotype 3: Abrupt step, Morphotype 4: Bifurcated injectite, Morphotype 5: Connecting vertical injectites, and Morphotype 6: Composite intra-bowl injectites. These were upscaled by a factor of 4 and synthetic seismic sections were constructed, incorporating injectite geometry and applying physical rock properties from a North Sea Tertiary discovery, Northern North Sea. The synthetic seismic was compared to seismic data from the North Sea discovery, after which different sand injectite morphologies were identified as common to both data sets. Application of upscaling and forward seismic modelling approaches to improve understanding of subsurface clastic injectite, therefore, does not require the use of large-scale outcrops as subsurface analogues; unlike most geological systems.

Clastic injectite complexes are being targeted as hydrocarbon reservoirs, therefore the approach taken in this study is applicable in many other basin-fills around the world to identify the presence and understand the impact of sand injectites on reservoir performance. Scale invariance is an important aspect to consider when using outcrop data to populate a system with individual facies; both geometries and facies distribution can be upscaled. However, maintaining a good representation of the original geological observation and interpretation is important in generating a robust and reliable model.

Is biogeochemistry the key to understanding meteoric diagenesis in modern environments?

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During early meteoric diagenesis carbonates are highly susceptible to drastic modifications to their depositional porosity and permeability. These initial alterations can often exert a significant influence on the later stage of diagenesis. By understanding the key processes involved in meteoric diagenesis this increases our ability to predict the structure of porosity and permeability network for carbonate sequences in the subsurface. This work focuses on the process of dissolution of carbonate, which generates porosity.

Field observation suggest that extensive dissolution features, caves, form at the top of the freshwater lens in carbonate island settings. This is through to either be due to the fact that the recharge waters are undersaturated with respect to carbonate upon reaching the top of the freshwater lens, or when they mix with phreatic waters it causes further undersaturation driving dissolution. The results of reaction transport models, numerical simulations coupling together fluid flow and geochemical reactions, showed that recharge waters interacting with phreatic waters at the top of the freshwater lens only generated very low levels of dissolution, suggesting that geochemical processes are not the only sets of reactions taking place in the subsurface driving dissolution.

Through field investigations we propose that biogeochemical processes are equally as important to dissolution at the top of the freshwater lens. Although the sampled meteoric waters were undersaturated with respect to carbonates; they rapidly reach equilibrium upon interacting with the exposure surface precluding dissolution at the top of the freshwater lens. However, these waters are likely to have contributed to the observed well-developed epikarst of the study area. The meteoric waters reaching the top of the freshwater lens transported important nutrients and dissolved organic carbon, incorporated through their interactions with the surface vegetation, to the oligotrophic subsurface environment. At the top of the freshwater lens, the heterotrophic communities consumed this organic carbon, releasing CO_2 into the water and catalysing further dissolution at the top of the freshwater lens.

Teaching Sedimentology: opportunities for interdisciplinary, variety, innovation and employability

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The breadth of content and skills embodied by the subject of sedimentology provides the opportunity teach in multiple learning environments, engage in innovative teaching practice and embed employability skills. Field and practical-based work are essential components of sedimentology and provide opportunities to teach in different environments outside the normal classroom setting. This allows the inclusion of a variety of learning experiences, which can in turn address different student learning styles. Field-based studies in particular create learning environments that can contribute to transformative learning experiences. The emphasis on field and practical based learning experiences in sedimentology promotes experiential learning, founded on the tenets of Kolb's learning cycle. For example field examination of clastic sequences can be used to determine their economic potential as oil, gas or water reservoirs, thus connecting experiential learning in the field with theoretical calculations. The use of a variety of teaching environments can also facilitate experimentation with innovative teaching practice. Teaching outdoors or in a laboratory or practical class setting opens up possibilities for using technology that may not be possible in a standard classroom setting. For example students can create mini documentaries in the field that focus on modern sedimentary environments and structures using simple equipment, multi-media presentation techniques and software. Sedimentology requires the development of a variety of field, practical, quantitative and problem solving skills. These skills are highly transferrable and can help build student employability. For example, students develop practical, geoscience specific skills in the study of an oil well, combining analysis and interpretations of thin sections, core and wireline data; in grain size analysis exercises they develop more generic statistical skills. Teaching sedimentology gives the instructor scope to create innovative, experiential learning exercises and assessments in which transferrable skills can be embedded across a variety of learning environments. The subject provides a rich learning experience for students and a stimulating teaching environment for instructors.

Ponded fan development and evolution within a salt-controlled mini-basin.

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A deep-water ponded sequence within a salt-controlled mini-basin has been imaged in unprecedented detail using a high resolution three-dimensional (3D) dataset. The ponded interval consists of four sequences, each of which contains at least one lobe complex.

Each fan lobe complex is composed of a single feeder channel, a number of trunk channels terminating in a diverging network of smaller distributary channels commonly fringed by a high amplitude band. The association of single trunk channel, the distributary channels and bright amplitudes comprises a lobe. The lobes are on average 1.6 km long by 1.3 km wide, the trunk channels range from 60 – 200 m wide, and have thicknesses up to 15 m. The distributary channels have widths of less than 30 m.

Each of the four lobe complexes show different patterns of topographic growth on the edge of the basin, the direction of the input point, progradation or retreat of the system, compensation off-set stacking and impact of a growth fault within the basin.

These high resolution plan-view images link to the fine-scale sedimentological studies that have been carried out outcrops from numerous basins. The sheet sands described in outcrop studies can be correlated with features seen in the plan-view amplitude extraction maps: we record, feeder and trunk channels (larger singe channels), densely channelised lobes (channelised sheet facies) passing laterally into more branched, thinner channels and lobe elements (channelised and amalgamated sheets) then terminating in a high amplitude fringe (amalgamated and layered sheets). These features are often hard to link spatially in outcrop settings where only dispersed sections are available but this unique dataset allows the linkages between these facies to be explored. This new example can be used as a unique analogue to enhance the understanding of reservoir heterogeneities within deepwater fan systems in ponded basins throughout the world.

A sabkha in Newcastle? Exploring biomineralization processes in a lab environment.

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The sabkha in Abu Dhabi is an extreme and unique environment in many respects. Aridity and extremely high salinity make the coastal location an ideal environment in which microbes can flourish to form extensive microbial mats. Buried beneath these microbial mats lies an alternation of 'palaeo mats', evaporites and carbonate rich sediments representing a late Holocene prograding carbonate-ramp system.

This presentation will focus on the geological setting of the study area and the design parameters of an experiment to test the conditions under which microbial action, and thus, potential microbially-mediated mineral growth occurs, particularly in relation to extracellular polymeric substances (EPS) excreted by the microbes. The changing physiochemical properties of EPS have a key role in mineral nucleation and precipitation, however, it has proved challenging to quantify these processes across a microbial mat system. Samples from both the field and from the experimental set up will be analysed using confocal microscopy in order to obtain three-dimensional imagery which can be used in calculating the EPS within the total cell volume.

Alongside confocal microscopy, XRD, independent community analysis and SEM will be used to analyse the mineralogical and microbial content respectively. Cation and anion analysis of natural sabkha fluids enhances our understanding of the water geochemistry of the sabkha as well as constraining the chemistry for the experimental medium. The experiment has been undertaken under conditions that closely simulate those recorded from the natural sabkha system. The initial focus has been on simulating the diurnal cycle and the water geochemistry of the sabkha. The next step will be to further test boundary conditions such as temperature, sediment inundation and varying salinity in order to establish the most influential.

Figure 1a/b: Modern surface microbial mats in the Abu Dhabi sabkha and transferred into a tank for lab based experimentation and analysis.

Sabkha-hosted microbial mats are complex systems, the understanding of which requires a multidisciplinary approach including biogeochemistry, geomicrobiology and carbonate sedimentology. Understanding the processes that occur within these mats has the potential to provide some insight as to their preservation potential into the sedimentary record. Features similar to those found today have been documented within Mesozoic formations from the Middle East and, thus, this sabkha is considered as an important modern analogue.

The Bowland Shale at Outcrop: Understanding the Role of Modern Weathering in the UK (sponsored by the Mineralogical Society, Clay Minerals Group)

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A key question for understanding and assessment of potential UK shale gas resources is what controls the distribution, abundance and type of organic matter (OM) that is preserved? The Bowland Shale (late Mississippian), deposited in a marine epicontinental basin, has potential as a UK unconventional hydrocarbon resource. There are few legacy boreholes with core through the Bowland Shale Formation to address this question; however, exposures across Lancashire and Yorkshire provide excellent spatial coverage. Data from these sites will provide insights into the controls (sedimentological, biological, geochemical) on the spatial distribution of OM in approximately time-equivalent sample locations.

In an exposed succession (124 m in thickness) of the Bowland Shale, located in the Craven Basin, Lancashire, the dominant mudstone lithology is interbedded with decimetre scale, carbonate-cemented silty to fine sandy turbidites likely representing at least 40 events. A suite of outcrop drill cores were acquired within a small stream and in the weathered slope; these cores were then subsampled at several depths into the outcrop. We delineate the effect of modern weathering on the organic and inorganic geochemical data measured, with a comparison to several thin sections and palynological separations.

In the vicinity of natural fractures and on weathered slopes, a variety of geochemical changes are associated with modern weathering, including; the development of ‘paper shale’ texture, oxidation of sulphides, accumulation of oxidation products within OM and leaching of trace metals (e.g., Sn). Away from these features (in streams, away from fractures) our visual observations and the geochemical signal are interpreted to represent fresh, unaltered mudstone.

These preliminary data indicate that in fresh (unweathered) mudstones TOC ranges between 4 to 6 wt. % and exhibits exceptionally low oxygen index (OI; typically < 10), low hydrogen index (HI; 150) and T_{max} at 430°C. Palynological and $\delta^{13}C$ results corroborate the RE data, which indicate a dominance of (marine) amorphous OM. If outcrop samples satisfy the criteria for unaltered material, this fresh material can be used to generate spatial and temporal geochemical data. We will use these data to examine controls on the distribution, abundance and type of organic matter preserved in this formation.

Surfaces, sediments, and supergene enrichment in Northern Chile and Southern Peru.

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The Pacific Paleosurface (PPS) is a relict surface on the western margin of the Andean orogen that can be traced continuously for over 1200 km in northern Chile and southern Peru. It is 50 to 70 km wide, dips 3–4° to the west and comprises relict alluvial and fluvial fans sourced from the high Andes. In northernmost Chile, it has been incised by deep (≤ 1000 m) river valleys – known locally as quebradas – that drain from the Andes to the Pacific Ocean. The formation, preservation, and incision of the PPS record both the uplift history of the Andes and the switching of the climate to hyperaridity. It also has economic significance as its formation has been linked with the end of supergene copper enrichment in the region.

The age of the PPS is debated. Early studies suggested that it formed and was incised over a short period of time between 14 and 10 Ma. However, new evidence suggests that is a composite surface that formed in distinct pulses from the Oligocene to the Pliocene. Exposure ages of boulders determined using cosmogenic nuclides range from 25 Ma to <1 Ma, with currently no clear explanation from the age range.

In this presentation we will take a regional view of the Pacific Paleosurface and its underlying geology bringing together previous studies on sedimentology, surface exposure ages, the timing of supergene enrichment, and seismic profiles. These are combined with new regional mapping of the paleosurface using multispectral satellite data and field observations throughout northern Chile and southern Peru. New ^{3}He cosmogenic exposure ages are placed into this regional framework to better constrain when the surface formed. The combination of these data demonstrates that the PPS is not of a single age, but has evolved through time. We also show how relative uplift of both the Coastal Cordillera and Andes has affected the depositional centers of the main fluvial and alluvial systems.

Towards a classification of hybrid event beds

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Hybrid event beds (HEBs) are a type of deep-water sediment gravity flow deposit comprising a basal clean (H1) and/or banded (H2) sandstone overlain by a muddier sandy facies (H3) emplaced during the same transport event. They generally have a tabular geometry but an internal complexity in terms of relative thickness and texture of the component divisions. HEBs are increasingly recognised in outcrop and in hydrocarbon reservoirs, requiring an improved understanding of their textural make-up, association, context and impact on reservoir properties.

Although HEBs share the described common characters that allow them to be differentiated from 'classic' turbidites, observations from a range of sedimentary basins show great variability in their sedimentological character. The texture of the relatively mud-rich H3 division and the size and shape of substrate clasts within it are key feature for classification and process interpretation. Two important and recurring bed associations are identified: (1) a range of commonly thick beds in which the H3 division can include very large substrate slabs and blocks, evidence of extensive autoinjection and clast break-up, and dense mudclast concentrations, all set in a sandstone with elevated interstitial clay. This association typically is found in outer fan and confined sheet systems in a down-dip position. (2) beds in which H3 divisions are characterised by high levels of dispersed clay, floating mudstone clasts and matrices that are enriched in hydraulically-fractionated components (mica, organic matter, clay flocs). Beds with thin H3 divisions typically pass down-dip to those in which H3 is expanded. This association is found in fan lobe successions where it can alternate with turbidites.

The two associations are interpreted to reflect different modes of flow transformation. In the first case, the rafts and chaotic textures are related to local substrate delamination processes that culminated in the formation of a linked cohesive debris flow because of intense internal shearing and clast disaggregation. The second association formed by mud entrainment at channel mouths, proximal lobe locations or flow expansion points and developed through progressive longitudinal flow transformation and rapid deceleration and may include deposition from transitional flows.

Facies analysis and architecture of an unstable shelf edge rollover: Tanqua Depocentre, Karoo Basin, South Africa

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The position and character of paralic systems relative to the shelf-edge rollover is a major control on the sediment transport from continents to oceans. While seismic datasets provide insights into basin margin geometry, outcrop studies of exhumed shelf margins are key to bridge the gap between seismic resolution and facies architecture. This study presents an example of a highly erosive shelf-edge rollover, with depositional-strike and dip control, in the Paardeberg Ridge and Geelhoek localities of the Tanqua depocentre, in the Karoo Basin, South Africa.

Here, a lower silt-rich slope turbidite succession is overlain by a 4-5 prograding prodelta parasequences, up to 25-75 m-thick. These are abruptly overlain by a 30 m-thick package of deformed delta front lobes and tabular thick-bedded sandstones with abundant climbing ripple and low angle lamination, interpreted as undeformed mouth bars. In the Paardeberg Ridge, they are truncated by 20 m-thick channelized bodies, filled by fining- and thinning-upward packages with basal mud clast conglomerates overlain by thick-bedded structureless sandstones and bar forms that pass vertically and laterally into thin beds with asymmetric and symmetric-rippled tops. 7km towards the N, in the Geelhoek locality, a similar succession is eroded by a 1.2 km-wide major surface cutting 100 m of stratigraphy and filled by thick-bedded (<3m) slope turbidites and hyperpycnites, displaying complex gullied geometries and passing vertically into thick units of aggradational thin beds.

In the Paardeberg Ridge, channelized elements are thicker, deeply incised and truncate underlying prodelta facies down dip while up dip they cut deformed proximal delta front deposits or older channel fills. In the slightly basin ward Geelhoek locality, there are no channelized geometries in the deltaic sandstones, however erosive surfaces are common and deeper in the upper slope succession. Combined with the gullied and thick aggradational packages of thin beds these facies and architecture suggest confinement and backfilling processes within upper slope valleys.

This study suggests that when paralic systems reach a weak, unstable and relatively steep shelf-edge, local remobilisation and gravitational collapse of delta lobes can create discrete irregular surfaces that evolve into long-lived conduits, and incisions become wider and deeper across the shelf edge rollover. This contributes the maintenance of a highly erosive profile and promotes channelizing and bypass at shelf-edge rollover and upper slope positions.

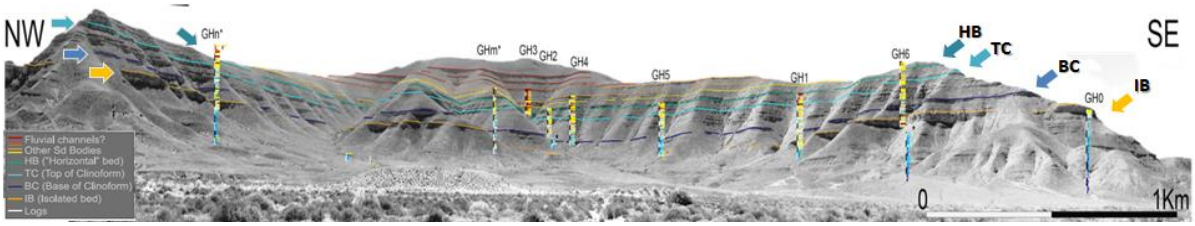

Photo-panorama of the Geelhoek semi-arc outcrop, where IB parasequences is been cut towards the end of the valley (NE).

Depositional interactions between the basin margin and the contemporaneous basin centre in an arid continental setting

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Intracontinental basin margins are often dominated by deposition within alluvial fan environments which are long-lived throughout basin development. Alluvial fan deposition is controlled by: 1) varied transport mechanisms; 2) interactions between the fan and contemporaneous distal environments; 3) long-term allocyclic climatic variations; and, 4) autocyclic controls of climate, tectonics, base level and sediment supply. Away from the basin margin, the alluvial fans interdigitate with contemporaneous depositional environments of the basin centre.

This work considers a well-exposed analogue for continental basin margin systems through the examination of the Permian-aged Cutler Group sediments of the western U.S.A. The Cutler Group was deposited into the intracratonic foreland Paradox Basin, which was fully disconnected from marine conditions throughout the majority of the lower Permian. A series of spatial facies models have been developed for the Cutler Group alluvial fan system itself, and for the unique deposits of the zone of interaction. Throughout this zone of interaction, the alluvial fans interdigitated with the distal subdivisions of the Cutler Group, including: 1) the terminal fluvial fan of the Organ Rock Formation; 2) the periodically flooded aeolian erg of the Cedar Mesa Sandstone; and 3) the restricted aeolian system of the White Rim Sandstone.

In this work we present spatial and temporal facies models that characterise the varied sedimentation across the Paradox Basin, and how it responds to cyclic controls. These controls affect sedimentation differently in the proximal basin, zone of interaction, and within the distal deposits. The models provide an improved understanding of how auto- and allocyclic controls affect the zone of interaction between basin margin and basin centre environments.

The models developed for the well-exposed analogue of the Cutler Group can be used to better understand similar, but poorly exposed systems. For example, the Brockram Facies of northern England forms part of the stratigraphy in an area proposed for a nuclear waste repository. A better understanding of the complexity of these basin margin environments is essential to fully understand the limitations of this proposed area.

Clay mineral distribution in modern estuarine sands: A predictive tool for the hydrocarbon industry

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One of the major causes for porosity- and permeability-loss in sandstone reservoirs is the growth of authigenic quartz cements at depths >2.5 km (>80-90°C). Chlorite, an iron-magnesium rich clay, can form well-developed grain coats which preserve anomalously high porosity in deeply buried sandstone reservoirs through the inhibition of authigenic quartz cements. Illite and kaolinite clay minerals are typically reported as being detrimental for sandstone reservoir quality through their ability to block pore throats and diminish permeability. The dominant control on the type and occurrence of clay minerals in the subsurface is the initial (depositional) mineralogy owing to their isochemical behaviour during burial diagenesis.

To overcome the limited spatial resolution of core based investigations in sandstone reservoirs, a modern estuarine analogue study of clay mineral distribution has been constructed to aid reservoir quality prediction. This research focuses on the origin, abundance and distribution of clay minerals within the Ravenglass estuary, UK. X-ray diffraction was performed on surface sediment and shallow (< 1 m) cores to reveal the mineralogy and mineral proportions of the framework grains, bioclasts proportions and clay grade (<2 μm) material. Clay mineral maps combined with LIDAR imagery, bioturbation density, grain size and salinity were produced to better understand the fundamental processes governing clay mineral distribution patterns.

Hinterland geology and climate controls the sediment mineralogy (type and abundance) transported into the Ravenglass estuary. Chlorite is relatively enriched toward the channel axis, resulting in an increase of chlorite abundance toward the foreshore within coarser sediment. Illite is relatively most abundant toward the estuarine margin, and within the ebb-tidal delta. Kaolinite shows a ubiquitous distribution. Clay mineral proportions analysed within one metre cores further support evidence of clay mineral segregation and expulsion of chlorite relative to illite and kaolinite toward the foreshore.

Clay mineral grain size combined with local estuarine drainage patterns and bathymetry control clay mineral distribution patterns in the Ravenglass estuary. This remarkably high resolution dataset reveals the controls on clay mineral distribution within a marginal marine system, allowing for the prediction of sandstone reservoir quality on a stratigraphic reservoir-scale basis.

Sediment heterogeneity and the role of contourites in promoting long runout submarine debris flows.

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Submarine landslides represent a significant geohazard to offshore infrastructure – yet our inability to predict travel distances of sediment packages resulting from slope failure is a serious limitation in the hazard assessment process. One relatively unconstrained factor is the role that contourite deposits play in slope instability and subsequent runout characteristics; variations in grainsize of sediments formed by such processes will influence the development/dissipation of pore fluid pressures which will in turn influence stability. Extensive contourite-associated slope instability is recognised on the continental margin of Uruguay, which has been studied to develop and test models of landslide runout, using 3D seismic data provided by BG Group and ANCAP.

Geomorphological mapping of seafloor landslides shows an association between along slope (contouritic) topographic features and downslope features including debrites. Two large Mass Transport Complexes (MTC) have been identified hosted within contourite deposits (plastered drifts) associated with a northward flowing current. These failures are typical of large translational (i.e. planar slip surface) failures seen elsewhere on passive continental margins, indicating a possible geotechnically 'weaker' layer in the sediment mass predisposing the slope to failure. Preliminary review of the seismic data indicates the presence of sandy contourite horizons as the possible failure surfaces, which are likely 'weak' due to their well sorted, low density, high porosity and high water content. Laberg, J. S., et al. (2003) performed consolidated undrained triaxial testing on contourites and identified contractive behaviour upon shear, resulting in a rapid increase in porewater pressure and shear band development. This is thought to be a contributory factor in the fluidisation during slope failure leading to debris flow generation (and hence long run-out distances). To investigate the properties of the Uruguayan contourite sediments, Multi Sensor Core Logging (MSCL) of shallow sediment cores donated by BG Group and ANCAP to the NOC has been undertaken to derive p-wave velocity, bulk density, magnetic susceptibility and electrical resistivity values. Sediment cores contain materials the properties of which can be used to constrain the ages of failures, and are here used to highlight possible 'weak' layers and failure trigger mechanisms, such as past climatically-induced sea level changes.

Sediment delivery to the deep water under differing eustatic sea level scenarios

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The timing and conditions under which coarser grained sediment bypasses the shelf to the deep water is crucial for the hydrocarbon industry in understanding the distribution of reservoir quality sands. Traditionally, deposition to the deep water was thought to be controlled by global sea level and associated with eustatic sea level lows. Recently, instances of basin floor deposition are interpreted to occur during eustatic highstands, highlighting sediment supply, shelf geomorphology and process type on the shelf affect the likelihood of sediment depositing into the deep water, basinwards of the shelf edge.

For the first time, eight basin floor fans and their associated feeder canyons and incised valleys, plus ten line source slope systems have been imaged using horizon slicing techniques and seismic amplitude extractions (Fig. 1) with full 3D control within in the Plio-Pleistocene section of the southern North Sea; at the time, an epiperic sea of 200-400 m water depth. The deep water systems are linked updip to their corresponding shelf edge trajectory and shelf characteristics. High resolution continuous basin-wide 3D seismic data calibrated by 170 boreholes and high resolution chronostratigraphy are used to link the deep water sedimentary systems to marine isotope stages (MIS) 103 and 82 between 4.2 Ma and 2.15 Ma, spanning the Late Pliocene to the Earliest Pleistocene 41,000 year glacial-interglacial cycles. This has enabled a detailed analysis of the position of sediment bypass during several global sea level scenarios and therefore evaluate the importance of eustacy on the delivery of sediment beyond the shelf edge.

The study highlighted that the number of glacial-interglacial cycles and deep water depositional systems do not coincide. For instance between 2.58 Ma and 2.44 Ma at least eight distinct submarine depositional systems occur within three glacial-interglacial cycles (MIS 101-96). During this period, which is associated with high sedimentation rates, deepwater deposition corresponds to rising, flat and falling shelf edge trajectories. This suggests that sediment supply can override the eustatic sea level signal. Seismic architectures are a more reliable indicator of base level changes linked to eustacy than incision events and deep water deposition.

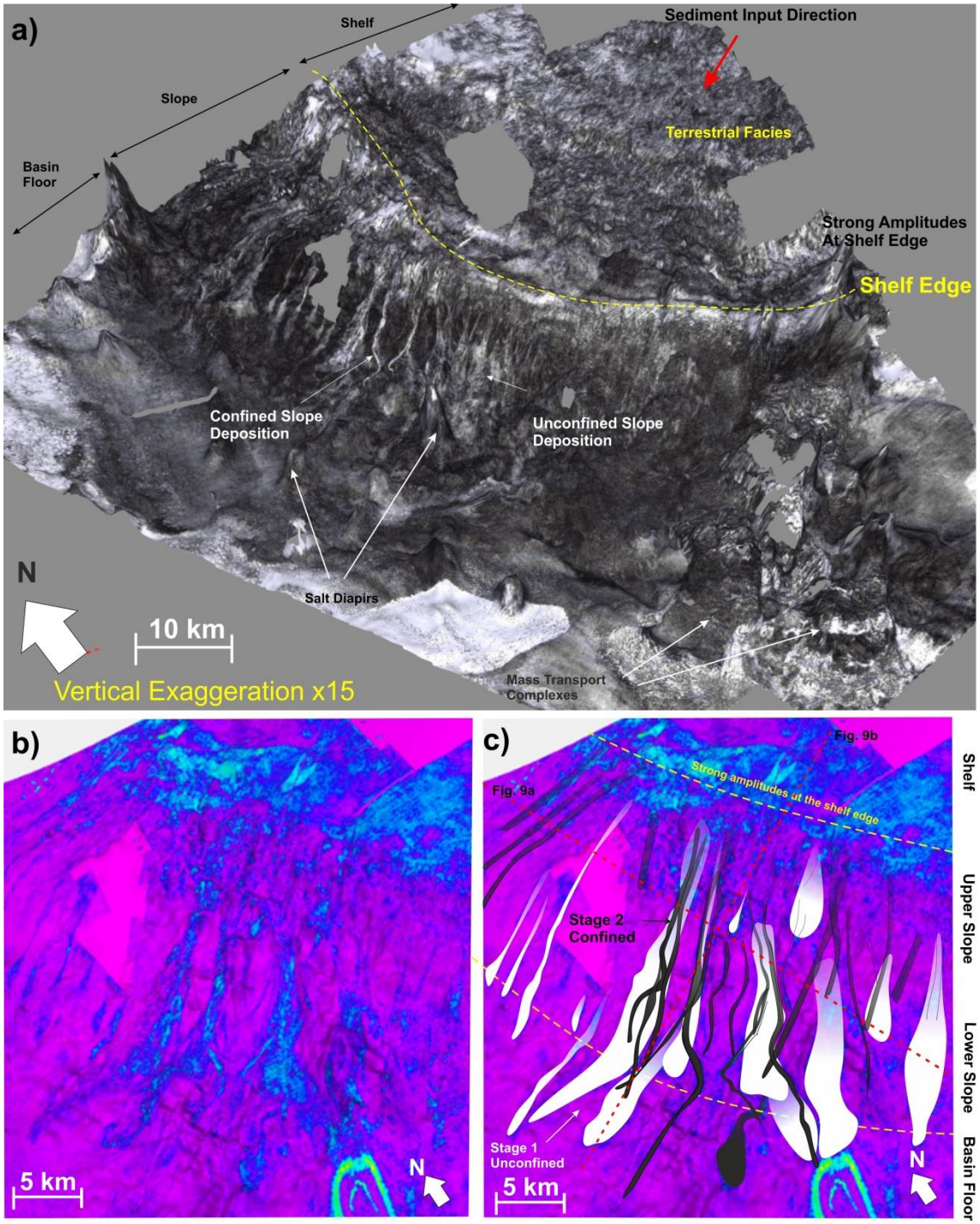

Fig 1.Seismic RMS Amplitude Extraction Example of line source *Pleisto 1A* channel levee complex. a) RMS amplitude extracted between Top and Base *Pleisto 1A* onto a surface. b) Un-interpreted zoomed in RMS amplitude extracted on seismic surface. C) Interpreted zoomed in RMS amplitude extracted on seismic surface.

The provenance evolution of the Permo-Triassic fill of the Korotaikha Basin and its constraints for the timing of the Pai-Khoi fold-and-thrust-belt (Russian Arctic)

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This study provides insights into the Permo-Triassic evolution of the Pai-Khoi fold-and-thrust-belt in Arctic Russia. The NW-SE trending Pai-Khoi fold-and-thrust-belt (PKFB) is a key feature of the Arctic Uralides, linking the Polar Urals with Novaya Zemlya (see Figure 1). The initiation of deformation along the PKFB is poorly constrained to sometime in the Triassic. Determining the timing of its evolution is essential to better understand the spatial and temporal tectonic differences exhibited along the Arctic Uralides, as well as, the wider tectonic evolution of the South Kara Sea region and its petroleum system.

The Permo-Triassic Korotaikha Basin (KB) located to the south of the PKFB, is widely accepted to be its foreland basin, but its depositional history also spans Uralian orogenesis within the Polar and Subpolar Urals to the east. CASP carried out field work in the central and eastern parts of the remote Korotaikha Basin. Sedimentological studies (facies, palaeocurrent and clast-count) were integrated with subsequent multi-technique sediment provenance analyses on 34 sandstone samples to provide a powerful tool for unravelling changes in sediment provenances. Provenance analyses included petrographic, conventional heavy mineral and single-grain geochemistry (apatite-REE, garnet major element and chrome-spinel) determinations.

Evidence will be presented for the presence of three main sand types. Two compositionally and temporally distinct sand types are characteristic of Permian and Early Triassic strata, and are consistent with derivation from the Polar and Subpolar Urals. The third sand type, typical of late Early to Middle Triassic strata, is interpreted to contain a significant recycled component of Permian to Early Triassic age strata. Deposition of the third sand type is coincident with a fundamental reconfiguration of palaeocurrent directions.

This combination of sedimentological and sediment provenance data is interpreted to constrain the onset of deformation and uplift along the PKFB to the late Early Triassic. PKFB uplift resulted in the formation of a topographic barrier that obstructed sediment transport into the South Kara Basin.

Figure 1- Overview map of the curved Arctic Uralides (depicted with a thick red line) spanning the Urals, Polar Urals, Pai-Khoi, Novaya Zemlya and the Taymir Peninsula. This map shows the location of the study area: the Pai-Khoi fold-and-thrust-belt (PKFB) and the Korotaikha Basin (KB). Modified from Scott et al. (2010).

Bottomsets of dune and unit bar cross-stratification

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Dune and unit bar migration forms sets of high angle cross-strata (foresets) and may also form bottomsets. Bottomsets have higher preservation potential than foresets, but they are less well documented and relatively poorly understood. Bottomsets vary greatly in thickness and internal structure, they are often finer grained than the associated foresets and have different grain fabrics. Consequently bottomsets can act as small local, or laterally extensive, partial barriers to flow and lead to sandstone reservoir heterogeneity and anisotropy.
Examples of bottomsets from a 50 m exposure of the Roaches Grit, Staffordshire will be presented. Bottomset characteristics vary both laterally within and vertically between planar cross-stratified sets. Their internal structure ranges from back-flow ripple cross-laminated to massive sandstone. One bottomset contains a pebble lag. Bottomset thickness varies laterally over relatively short (< 1 m) or relatively long (> 10 m) distances in different parts of the exposure. They wedge out entirely at some points.

Lateral variation in bottomset characteristics is generally common in fluvial deposits, because flow or sediment conditions vary in both space and time in rivers altering one or more of the parameters that influence bottomset formation. Bedforms that migrate in unsteady flow conditions will have bottomsets that vary in thickness, internal structure or grainsize. Such bottomsets will have higher vertical permeabilities at some points, reducing their ability to act as barriers to pore-fluid flow.

First field test of the theory of ignition and dissipation in turbidity currents – results from Squamish prodelta, British Columbia

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Turbidity currents are one of the most important sediment transport processes on Earth and pose a potential hazard to seafloor infrastructure. These flows are driven downslope by their excess density and are hypothesised to either entrain more sediment, causing them to erode sediment and accelerate ('ignition'), or deposit sediment and decelerate ('dissipation'). We present the first field-scale study to test the 'ignition-dissipation' hypothesis and to analyse how turbidity currents evolve on their path across the seafloor. A unique dataset of 93 near-daily bathymetric surveys containing 106 mass wasting events and 30 turbidity currents was collected by John Hughes Clarke et al., in 2011 of the Squamish delta in the Howe Sound, BC, Canada. The data enables the analysis of the volume and location of sediment erosion and deposition along the full length of the flow path.

The three flows in this study originated in different ways: a small delta lip failure; a large delta lip failure; and an event with no discernible head scarp. The small lip failure transformed from a dissipative flow into an ignitive flow midslope, entraining 600 m^3 of sediment during ignition, before dissipating once again. The large lip failure remained a dissipative flow, entraining relatively little sediment, blanketing the upper Southern channel with sediment. On the day following the large lip failure, a flow was initiated in in ~60 m water depth that could not be linked with any obvious source. The flow ignited and eroded the entirety of the upper channel to reach a flow volume of ~8200 m^3. The dissipative or waning phase of both the small lip failure and event of unknown origin occur when the seafloor gradient falls below 3^o, prior to reaching the lobe.

Two of the three turbidity currents analysed ignite thus supporting the 'ignition-dissipation' hypothesis. The present analysis shows that ignition is not related to the flow trigger and that relatively large failures do not necessarily result in long run out flows. Perhaps the largest dissipative flows lead to the largest ignitive flows, resulting from a greater supply of unconsolidated sediment for the ignition process.

Sedimentary processes and depositional architecture of sand-prone sediment waves in ancient deepwater channel-lobe transition zones

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Sediment waves in modern deepwater channel-lobe transition zones are common geomorphological features, however they have not been widely identified at outcrop. Consequently, their process record and depositional architecture are poorly constrained. Several locations from an exhumed Permian fine-grained base-of-slope system (Unit B, Karoo Basin, South Africa) show exceptional preservation of distinctive lenticular sand-prone bedforms and the architecture and facies characteristics are presented in detail. Due to their dimensions (0.5-3.5m thick, 20-100m long) and wave-like morphology, they are here classified as sediment waves. The palaeogeographic location of both outcrops, and the lack of confining surfaces, support a channel-lobe transition zone setting.

In one of the two study areas, the lenticular bedforms show clear steep (10-25°) sigmoidal internal truncation surfaces, which are unequally spaced (20-100m), dominantly upstream-facing, and always overlain by banded sandstone facies. Due to the lack of bed splitting and recurring facies trends, this depositional architecture is interpreted to record significant spatio-temporal energy fluctuations during a single flow, resulting in upstream bedform accretion. The limited evidence of reworking suggests a primary depositional control on the development of sediment wave morphology. The variable wavelength and presence of climbing ripple-lamination below internal truncation surfaces indicates that flow variability is not solely related to hydraulic fluctuations, which would be expected in areas of abrupt flow expansion. The sediment wave architecture is thought more likely to be to a great extent controlled by internal flow compensation effects.

Elsewhere, the sediment waves are smaller (<1.5 m thick), dominated by climbing ripple-laminated facies and lack the banded facies and internal truncation surfaces. These differences in sediment wave characteristics between the two study areas are likely to be related to their positions relative to the channel-mouth. The depositional architecture of these deep-water sediment waves highlights the importance of understanding the process response to the dynamic erosional and depositional relief present in channel-lobe transition zones.

Characteristics of deformation bands and relationship to primary deposition: an outcrop study from the Wirral, north-west England

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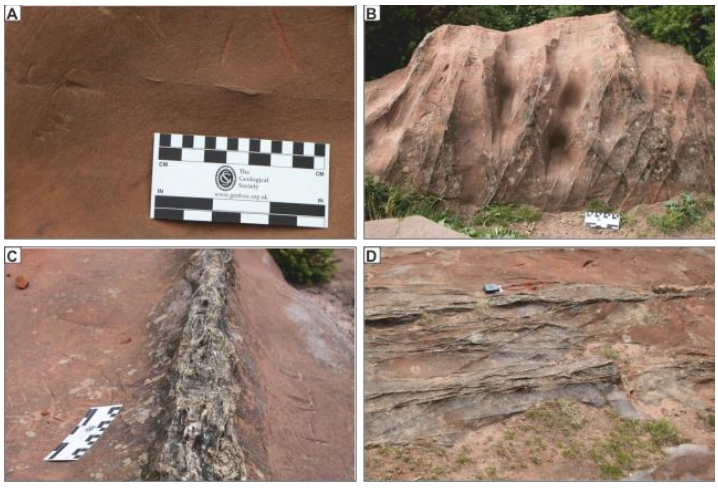
The gross environment of deposition has been recognised as a major influence on the development of deformation bands. Deformation bands represent local zones of grainsize reduction/crushing and fusing that develop in response to the accommodation of stress, and typically develop in sandstones. As they can result in crosscutting planes of low permeability compared to undeformed rock, deformation bands can degrade reservoir quality, and have an adverse impact on the performance of economically important hydrocarbon reservoirs, aquifers or potential repositories for carbon capture.

Outcrop of the Middle Triassic (Anisian) Sherwood Sandstone Group from Thurstaston Hill and West Kirby (Wirral, north-west England) comprises a series of stacked dune and interdune facies, with rare heterolithic fluvial associations (channel and channel lag). Aeolian dunes are characterised by relatively large-scale, low- to high-angle cross-sets with common bimodal 'pinstripe'- type lamination, with interdunes typified by planar and ripple-laminated sandstone and silty sandstone. A striking feature is the development of deformation bands which are locally pervasive. Initial data collection shows that deformation bands are more common in grainfall and grainflow facies, becoming rare/not observed in trough, planar cross-bedded and pebbly sandstone facies. Their morphology has been categorised into 4 distinct classes based on the spatial density and relationship between individual deformation bands (see image). The permeability of these features, assessed in the field by mini-permeameter, does not appear to be related to the class of the deformation band. These features have a high permeability contrast with the surrounding sandstone, and permeability values up to two orders of magnitude lower than undeformed sandstone is indicated.



Caption: Four classes of deformation bands:
(a) Individual 'thread'; (b) conjugate set; (c) braid; (d) composite.

Where present in reservoir rocks such as the Leman Sandstone of the North Sea, or regional aquifers such as the Wilmslow Sandstone onshore, present day bulk permeabilities may be higher in fluvial facies with no deformation bands, rather than silt and clay-poor aeolian facies that host these features. Deformation bands may have a stronger influence on fluid flow toward the end of the production history of a well or field, when reservoir pressures are depleted. These observations, could mean that reappraisal of reservoirs is required to optimise production in declining fields/aquifers.

No evidence for sea level fall in the Cretaceous strata of the Book Cliffs of Eastern Utah

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A core component of the sequence stratigraphic model is the implicit assumption of a semi-sinusoidal relative sea-level curve, and the occurrence of "sequence boundaries" formed during intervals of sea-level fall, recognized primarily by the presence of incised valleys. Late Cretaceous paralic deposits exposed in the Book Cliffs, Utah, USA have long been one of the main testing and teaching grounds for high-resolution sequence stratigraphy. The commonly accepted sequence stratigraphic model for the Santonian-Campanian section recognises up to ten sequence boundaries. Analysis of each proposed sequence boundary indicates no conclusive stratigraphic evidence for any relative sea-level falls during this period of deposition in the Book Cliffs area. These observations indicate that a key aspect of the sequence stratigraphic model is not applicable in outcrops that are widely considered to be one of the type areas for sequence stratigraphic teaching and research. This has important implications for the use of the sequence stratigraphic approach during greenhouse times.

The Potential, Power and Pitfalls of the Geological Model.

Oliver Jordan, Statoil UK

The geological model combines both actual data and conceptual understanding into a unified solution, be that process, depositional or stratigraphic. As the shallow marine realm offers a clear insight into different process subdivisions (e.g. storm wave base), an inherent link with a fundamental deposition control (relative sea level) as well as a good resolution of biostratigraphic information (which is often lacking in continental and deep marine settings), it has frequently formed the basis for conceptual geological model development (i.e. sequence stratigraphy, cyclicity). These conceptual geological models often form the basis of stratigraphic prediction. The source to sink methodology represents a different approach to understanding & predicting basin stratigraphy and has hitherto focused on the 'erosional engine' (Allen, 2008) within the continental zone and the ultimate sediment sink of the slope and basin floor (Martinsen et al., 2009). The shallow marine shelf represents an outlier to its counter-parts as it is both capable of acting as sediment source (e.g. wave ravinement), transporter (longshore drift, tidal currents) and sink. Shelf dynamics remain difficult to quantify because of the complex interplay of fluvial, wave, tide and gravity-derived processes which are superimposed on longer-term allogenic tectonic and climate perturbations. Furthermore, while modern systems can demonstrate how the shelf variability (regardless of catchment properties) influences the likelihood of sediment being provided to the deep basin, they only represent one unique timescale. It is crucial to recognise that the preservation of any geological system varies considerably and that the preserved stratigraphy may not be truly *representative* of the sedimentary system (Ager, 1973; Sadler, 1981). Understanding the shelf sediment budget and the dispersal of sediment across a shelf will not only help develop the source to sink approach but will also have theoretical and practical implications for basin stratigraphy across different spatial & temporal scales.

Big river development: A sedimentary facies analysis of Pliocene/Pleistocene deposits of the Euphrates fluvial system, Syria

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Quaternary deposits can provide good analogues for big river systems in the geological record, as well as contributing to our understanding of their evolution. We have undertaken a detailed study of the sedimentary characteristics of the Pliocene and Quaternary fluvial deposits of the Euphrates fluvial system with both these aims in mind.

Developed in the Late Miocene, the Euphrates River is a long-lived, large river system (~2800km in length) that drains SW Asia. There is widespread preservation and locally good exposure of fluvial deposits enabling detailed sedimentary study.

A total of 16 facies have been identified in the Euphrates deposits and classified into 6 facies groups: (1) gravels/pebbly sands, (2) sands and muddy sands, (3) silts, muds and marls, (4) chaotica, (5) paleosols and calcretes, and (6) limestone. A range of sedimentary features in the Pliocene and Quaternary clastics confirms the origin of both successions as continental, dominantly fluvial suites of rocks. Estimations of flow dimensions/energy show a systematic decrease in energy from Quaternary to Recent, probably related to decreasing tectonic activity and rising base level. The general location and flow direction of the river has remained similar.

The Euphrates fluvial system has developed from small, short lived isolated cut and fill channels in the Pliocene though to a broad meandering system in the modern day. The Quaternary deposits represent a braided to meandering system of similar scale to that of the modern day Euphrates. Channel widths range from 50-500 m, and channel depths from 3-7 m (preserved section). Stacked channel units are up to 25 m thick. Lateral migration appears to have been rapid and extensive over a broad flood plain, with outcrop correlation of units for > 1 km. Crevasse splay lobes have a width of 30-60 m and thickness of 0.5-1.5 m. However, even for Quaternary deposits, preservation of channel form and architecture is an issue for accurately determining the scale of sedimentary features and therefore the size of the river. Our initial estimates would suggest that the early Quaternary system was more energetic than the modern Euphrates, transporting coarser grained material and demonstrated higher-energy flow conditions.

The effects of tidal bores on estuarine sedimentology

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Tidal bores are found within estuarine systems throughout the world. These upstream migrating hydraulic jumps occur in river-estuary systems with a high tidal range, where the geometry of the local system acts to funnel the incoming tide into a landward bound wave. Tidal bores can have an undular or breaking shape, dependant on local conditions, with some examples travelling over 100 km upstream. A wide range of bore magnitudes may be observed, with variations in height from a few centimetres to up to 9 m.

At present the sedimentary processes and deposits resulting from the passage of tidal bores are not fully understood. Following the passage of a tidal bore a large suspended sediment load is entrained within the flood tide. The nature of the local bed will lead to varying transport and deformation effects that are dependent on grainsize and substrate cohesion. The effects of tidal bores have begun to be described in ancient deposits and the robust recognition of tidal bores within a sedimentary system may act as a useful facies indicator.

This paper will examine flow-sediment dynamics during tidal bores within modern systems. These dynamics will be coupled to the deposits produced by the passage of a bore. Improving the process-product linkages in these highly dynamic environments will allow better recognition of these features in the ancient. Moreover, due to the interactions between tidal ranges, bore heights and system geometry, the recognition of tidal bore deposits in ancient systems will also facilitate improved recognition and inference of system scale from local deposits.

Effect of internal and external architecture on submarine channel development

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Seafloor channels are the main conduit through which turbidity currents transport sediment to the deep ocean. However, the hydrodynamic-morphodynamic relationship between turbidity currents and their containing channels, involving several different feedback systems, is poorly understood. Processes dictating the evolution of the channel (over long timescales) and the structure of individual currents (over relatively short timescales) are interlinked. However the scales of co-dependency of flow and topography are unknown. It is therefore unapparent to what extent flow dynamics and the development of a channel are pre-determined. To answer this, we must consider several factors, perhaps foremost being the relative spatial and temporal dominance of both the current and the channel. This talk will present preliminary numerical modelling results of the impact of far-field channel architecture (i.e levee) and conditions on current dynamics. Future research plans (both experimental and numerical) will also be outlined, with focus on the morphodynamic evolution of the channel and proximal architecture (i.e. levee crest) and the role and evolution of channel sinuosity.

Glacial cycles in the Cryogenian record: a sedimentological perspective from the southern Kingston Range, California.

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The Kingston Peak Formation of the Death Valley area, California, is viewed as a lens through which to interpret both Cordilleran stratigraphy and the number of glacial cycles in the Cryogenian. In its type area, the Kingston Range, the eponymous strata have been interpreted to record both Sturtian and Marinoan pan-glacial events. Here, on the basis of high resolution sedimentary logs and lithofacies analysis throughout the entire section at its thickest extent, we demonstrate that this view is unfounded. Two clast-poor, muddy diamictite intervals within the succession- one at the base, and one near the top- have been used to support Sturtian and Marinoan events previously. Here, we show that the uppermost muddy diamictite is genetically related to the underlying strata with no reason to interpret a non-conformity between them. Analysis of palaeocurrent data from > 500 m of underlying strata support the existence of a consistent SE-oriented palaeoslope during deposition. Lowermost beds of the muddy diamictites near the top of the succession are intercalated with graded sandstones and sandy, matrix supported conglomerates. The graded beds (turbidites) and matrix-supported conglomerates (debrites) testify to a subaqueous setting, with the compositionally and texturally distinct diamictites indicating a glacial origin. We thus conclude that, in its type area at least, the Kingston Peak Formation comprises the record of only one (probably Sturtian) pan-glacial event.

Grain size fractionation between turbidity current deposits on channelized slope and related unconfined basin floor deposits: Insights from flume experiments

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The grain size distribution of turbidity current deposits differ from the distribution in the bulk flow as a result of grain size stratification within the flows. Levee deposits of submarine channels are derived from overspill of the fine-grained top of a flow whereas lobe deposits are derived from the coarser-grained base of the flow. In outcrop and subsurface data it is rarely possible to correlate deposits from individual events between these disparate environments. Laboratory experiments provide a valuable opportunity to study the fractionation of sediment between the channel-related slope deposits and basin floor lobes.

In the experiments presented here turbidity currents of similar composition were run down channels with different degrees of confinement. The turbidity currents were supplied from an external mixing tank and had a broad initial grain size distribution (D_{10}=22 µm, D_{50}=130 µm, D_{90}=223 µm). A ~4m long slope-channel was dipping at 11° and terminated on a horizontal basin floor. The channel depth was varied between the experiments but never exceeded half of the flow depth. The turbidity currents in the deeper channels deposited less sediment on the slope and more on the basin floor. Additionally, the sediment deposited on the slope had a smaller median grain size than the deposits on the basin floor. As a result, the turbidity current discharge and grain size distribution changed along the trajectory of the system. The volume and grain sizes that are extracted from the flow are strongly influenced by the degree of confinement on the slope. The lobes that were formed in the experiments extended further into the basin when a deep channel sourced them. This was a result of the larger sediment delivery to the basin floor by deep channels. Thus, the gradual establishment of progressively deeper slope channels can drive progradation of a clastic deep water system in the absence of external forcing.

Provenance of Sediments from Sumatra, Indonesia

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The island of Sumatra is situated at the south-western margin of the Indonesian archipelago. Sumatra is affected by active continental margin volcanism at the Sunda Trench, west of Sumatra. This is a result of the active northeast directed subduction of the Indian plate under the Eurasian plate. Stratigraphically, Palaeozoic meta-sedimentary rocks form the basement of Sumatra, these are limited in extent to the Barisan Mountains, a northeast-southwest trending mountain chain. Cenozoic sedimentary rocks are widespread throughout the entire island but are grouped into fore-arc, intramontane and back-arc basins. Controversially, these basins are older than the current magmatic arc of the Barisan Mountains. Consequently, a classical arc-related generation model is not applicable.

The Cenozoic formations are well classified due to continued hydrocarbon production, but little is known about the provenance history. Regional case studies inferred a mixed source, with material derived from the Malay Peninsula, in addition to from more localised sources, e.g. the Barisan Mountains. Currently, dominant provenance is inferred through sedimentological architectures, and the reconstruction of past depositional environments. Thus far, only a few provenance studies focussed on the heavy mineral assemblage of the sedimentary rocks of Sumatra, none of them involving detrital zircon geochronology. Nevertheless, the understanding of the provenance history of the Cenozoic formation of Sumatra can contribute significantly at several stages of hydrocarbon exploitation.

This work represents a multi-proxy provenance study of sedimentary rocks from the main Cenozoic basins of Sumatra, alongside sediment collected from modern river systems. This project refines the sedimentary provenance in two ways; first by studying the heavy mineral assemblages to identify sediment routing pathways and dispersal patterns of the sediments. Secondly, by U-Pb zircon dating using LA-ICP-MS to identify the age-range of the potential sediment sources.

A combination of preliminary U-Pb zircon age-data and thin section analysis confirm the assumption that the palaeo-sedimentary provenance was derived from a mixed source, both the Malay Peninsula and more localised sources such as the Barisan Mountains. In contrast to this, the analysis of the modern river sands suggests that the current sedimentary fluvial systems are mainly sourced from the recent volcanic arc.

Multi-pulsed turbidity currents – flow dynamics and geological implications

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It is common practice to infer the longitudinal structure of overpassing turbidity currents from the vertical structure of their deposits. Such currents may initiate with a complex longitudinal flow structure (e.g., by being sourced from retrogressive sea floor slope failures) or acquire such structure during runout (e.g., following flow combination downstream of confluences). A key question is whether, or for how far, such complex flow structure is preserved within turbidity currents as they run out and thus if flow initiation mechanism and/or proximity to source may be inferred from deposits. To address this question, physical modelling has been conducted to investigate dynamics of single-event vs. multi-pulsed density-driven currents, with focus on the interaction of different pulses.

A lock exchange gravity flow generation methodology was adopted, using two lock boxes set up in series at one end of a flume enabling the generation of multi-stage flows. The relative timing of each lock gate was controlled via pneumatic lock control box. The spatial evolution of flows was captured by an array of five HD interlinked cameras. Control parameters included the initial volumes and densities of the flows and the gate release timings. For multi-pulsed flow setting, the secondary surge inevitably intruded into and progressively merged with the primary surge. The research highlights the importance of flow process modelling in the interpretation of geological deposits, and seeks to establish constraints on the length scales over which signals may be transmitted downstream by turbidity currents and recorded in their deposits.

Post-rift stratigraphy of Central Atlantic Margin: Evolution of Depositional Environments in the Early Cretaceous of the Essaouira-Agadir Basin, Morocco.

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Mesozoic outcrops along the Moroccan Atlantic coast are the only exposed continuous stratigraphic postrift succession along the Atlantic passive margin in NW Africa. This study analyses Early Cretaceous outcrops in the Agadir-Essaouira Basin (EAB), to address the style and evolution of depositional systems through time, and improve understanding of controls on the system.

The Early Cretaceous of the EAB was deposited on a large low-relief shelf that inherited its physiography from the broad Jurassic carbonate platforms and potential early salt diapiric movement.

Extensive mapping, sedimentary logging, and biostratigraphic analysis allow precise dating of regionally-correlatable sequence stratigraphic surfaces in Hauterivian to Aptian times. The turnover of the Hauterivian and the Barremian is recorded as a time of maximum flooding, constrained by high-resolution biostratigraphy and the development of an ammonite-polyzonal horizon. Although characterized as a mud-dominated succession, two significant intervals of coarse clastics are identified in the early Hauterivian and late Barremian to earliest Aptian. At these times, shallow-marine/fluvial successions reach close to the shelf margin (~30 Km). A strong candidate for a forced regression is recognised with onset in the uppermost part of the late Barremian *G. sartousiana* ammonite zone. The late Barremian to earliest Aptian interval offers a chance for coarse clastics delivery and feeder systems for potential associated deepwater fan deposits targeted in hydrocarbon exploration offshore. The sequence is terminated locally by fluvial deposits incising into the underlying deltaic and shoreface deposits. A subsequent abrupt transgression close to the base of the early Aptian (*D. forbesi* ammonite zone) drowned the system with a return to a mudstone dominated succession.

The results constrain timing, provenance and evolution of depositional environments in this underexplored basin and are linked to a study in the Tarfaya Basin (southern Morocco). Key candidate provenance locations are the Meseta, Massif Ancien, and the Anti-Atlas. Low-temperature geochronology studies of the hinterland, have also allowed the definition of an important paleogeographic divide to the Tethys. The source-to-sink project is a valuable analog for regions to the South (Mauretania and Senegal) and the conjugate margin of Nova Scotia, where similar sequences have been noted in the Hauterivian to Aptian.

Multi-scale 3D quantification of an organic-rich mudstone, the Carboniferous Bowland Shale

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Multi-scale 3D X-ray computed tomography (XCT) and 3D electron microscopy (3D - EM) imaging techniques were used to produce 3D images with a resolution spanning three orders of magnitude from ~7.7 µm to 7 nm for one typical Bowland Shale (Northern England), identified as the largest potential shale gas play in the UK. These images were used to quantitatively assess the size, geometry and connectivity of pores and organic matter. The data revealed four types of porosity: intra organic pores, organic interface pores, intra and inter mineral pores. Pore sizes are bimodal, with peaks at 0.2 µm and 0.04 µm corresponding to pores located at organic-mineral interfaces and within organic matter, respectively. These pore-size distributions were validated by nitrogen adsorption data. The multi-scale imaging of four pore types shows that there is no connected porosity at these scales with equivalent diameter of 20 nm or larger in this sample. However, organic matter and clay minerals are connected and so the meso porosity (~5 nm) within these phases provides possible diffusion transport pathways for gas. The mineral component percentages were quantified at all scales by XRD and TOC measurements.

This work confirms multi-scale 3D imaging as a powerful quantification and visualization method for shale reservoir characterisation allowing the representative volumes of pores, organic and mineral phases to be defined to model shale systems. The absence of connected porosity at scales greater than 10nm shows potential importance of the organic matter network in controlling hydrocarbon transport in these low permeability systems.

Septarian Concretions and Limestone Beds within Organic-rich Mudstones: A Study of Diagenesis and Stable Isotopic Compositions in the Eagle Ford Formation

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The Late Cretaceous (Cenomanian-Turonian) Eagle Ford is an organic rich mudstone in south west Texas, USA, currently targeted for shale gas & oil. Diagenesis in the Eagle Ford is poorly understood, but is essential to help identify sweet spots and enhance shale production. This study will focus on septarian concretion and limestone beds present within the organic rich-mudstones in the lower section of the formation.

Bulk stable C and O isotope analysis of inorganic carbonate, supported by standard petrological techniques, highlight the differences and similarities in diagenesis between the mudstones, septarian concretions and limestone beds.

Isotopic $\delta_{13}C$ signatures and petrological analysis suggests the carbonate within the organic rich mudstones is entirely derived from marine material. SEM analysis and $\delta_{18}O$ signatures indicate recrystallisation has occurred at depth during late diagenesis. We infer 5-10% of total carbonate content has been precipitated at 4-5 km depth through thermo-chemical organic complexation, which has not altered the $\delta_{13}C$ signature.

The $\delta_{13}C$ signatures of the septarian concretions suggest carbonate is derived from bacterially mediated redox reactions at the sediment water interface. The septarian concretions display 10-30µm calcite crystals under PPL that represent rapid carbonate precipitation. There is no organic carbon present in these samples suggesting carbonate was precipitated via aerobic oxidation of organic matter and sulphate reduction. The mechanisms that produced their shape and distribution are still not understood.

The presence of calcified radiolarian shells in the limestone beds suggest enhanced levels of primary productivity in the photic zone. Increased productivity results in an increase in photic level predators. Coccoliths and calcispheres, along with heterotrophs, make their shells out of carbonate. They fall to the sea floor and produce a limestone bed across the entire Eagle Ford Fm. Despite a large input of marine derived carbonate, $\delta_{13}C$ indicate 40-50% of carbonate is diagenetic. $\delta_{18}O$ values indicate recrystallisation has occurred at 2-3km depth and has destroyed the original shell fragments. Volcanic activity and clastic sediment starvation, related to sea level change is also thought to be a factor in producing the limestone beds.

Sedimentology of Lower Old Red Sandstone outliers on the Grampian block: implications for a northwards extension of the Midland Valley Basin

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The relationship between the Highland Boundary Fault (HBF) and Lower Old Red Sandstone (LORS) deposition remains controversial. The 9km thick LORS succession of the northern margin of the Midland Valley Basin (MVB) ranges from Wenlock to Emsian in age and is heavily dominated by conglomerates in the east, passing westwards into sandstones and siltstones. Deposition occurred mainly through fluvial and alluvial systems with facies developing mainly across the Strathmore region of the MVB, with associated deposits occurring across adjacent areas of the Scottish Highlands. Current models of mid-Silurian to early Devonian sinistral movement on the HBF fail to address the relationship between the main LORS deposits and the associated outliers. The sedimentology of LORS outliers present to the north of the HBF allow more informed palaeogeographical reconstruction of the LORS depositional history. In addition different models for timing of movement on the HBF can be better constrained.

Anatomy of Cambrian alluvium in the Erquy- Fréhel Group, France: Discerning marine vs non-marine influences in the pre-vegetated rock record

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Distinguishing fluvial versus marine origins for siliciclastic Precambrian and Cambrian strata can be problematic. Sheet-like cross-bedded and planar-stratified sandstones predominate in both environments at this time, and without fossil information, confident diagnosis can be challenging. As a consequence, a large number of individual Precambrian and Cambrian formations have been variably interpreted as marine or non-marine in different studies. A database of 399 Archean-Cambrian, purportedly-fluvial formations demonstrates that quartz-rich rocks make up a significant portion of the reported alluvial record – contrary to the prevailing assumption that, in Precambrian-Cambrian strata, arkoses dominate alluvium and quartz arenites dominate shallow marine successions. Coupling petrographic and architectural data may help environmental interpretations of rocks deposited in this interval. An original field investigation of the Lower Cambrian Erquy-Fréhel Group of northern France demonstrates the challenge of distinguishing marine from non-marine. The upper Fréhel Formation comprises metre-scale sheet sandstone elements typified by laterally-persistent, stacked, trough cross-stratification. Downstream accretion surfaces are overwhelmingly the dominant element, and evidence for lateral and upstream-accretion is rare. Unlike depositional elements and lithofacies, sandstone maturity is not consistent throughout, varying from arkosic to quartz arenitic. It is possible that the increased compositional maturity in certain strata arose due to prolonged residence at the shoreline, though no unambiguous marine indicators were identified. The lower Erquy Quartzite is dominated by planar parallel-laminations and low-angle inclined stratification and is both compositionally and texturally mature, suggesting a fully marine origin. Future work is underway to test the initial suggestions from this case-study (and database) that, in pre-vegetation alluvium, textural immaturity appears to be more closely associated with alluvial sedimentary architecture than sandstone petrography.

New approach to characterize complex pore networks in carbonate rocks

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Numerous studies document the relation between 2D pore geometries and petrophysical properties in carbonate reservoirs. In these studies, the dominant pore size (DomSize) and perimeter over area (PoA) constitute the most common pore shape descriptors. The PoA routinely serves as a proxy of pore shape complexity: a decrease in PoA indicates a simpler, more globular pore shape, characteristic of intraparticle or pelo-oomouldic porosity, whereas a higher ratio indicates a more complex, dendritic and elongated shape typical of vuggy and fracture porosity.

However, when measuring different samples, PoA becomes largely dependent on (a) pore size (or DomSize), and (b) the number of pores included in the calculation. Therefore, this parameter provides misleading information since one assumes that PoA directly reflects the pore shape complexity. Here, a new pore geometry parameter is proposed to better characterize the pore shape complexity without the obstructive effect of area. The PoA of a pore is calibrated using the PoA of a theoretical disk of the same area to generate the dimensionless ΔPoA parameter:

$$\Delta\text{PoA} = \frac{\text{PoA pore} - \text{PoA disk}}{\text{PoA disk}} \quad (1)$$

A globular pore will yield a low ΔPoA between 0 (perfect disk) and 1 (ovoid), while complex and elongated shapes will give values greater than 3. Analysing a larger pore population requires to measure an average pore area and calculate its ΔPoA. Repeated measurements on thin sections from a giant carbonate reservoir confirm the relevance of this new approach. The variable complexity of carbonate pore fabrics is more accurately quantified. When combined with other porosity descriptors, ΔPoA better predicts the petrophysical properties of carbonate rocks with multi-modal pore networks.

Facies and depositional environments identified in the Lower Jurassic succession from Wadi Naqab, United Arab Emirates

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Lower Jurassic rocks are important reservoir in the Middle East, and outcrops have been used as analogues to subsurface reservoirs to constrain inter-well heterogeneities. In this study, we focus on the Lower Jurassic succession from Wadi Naqab, which consists largely of decimetre-metre thick carbonate beds that are laterally continuous. The goals of our study was to improve biostratigraphic dating of the carbonate rocks, and to constrain their environment of deposition. To this effect, hand specimen collected in the field were examined as well as thin sections. Twenty different microfacies types were grouped in four distinct facies associations based on associated depositional environments. Facies association A comprises four different microfacies types with textures ranging from mudstones to wackestones. The presence of fenestral structures together with the associated sedimentary features point to deposition within tidal flats. Facies association B contains abundant grainstones and evidence of deposition in a high energy environment. Sorting ranges from poor to very good. Ooids are present, although in a smaller proportion compared with other types of clasts. Bioclasts are broken, some of them presenting a micritic rim. Facies association C includes seven microfacies sub-types (C1-C7), are largely unsorted, and grain size varies from very fine to fine. The presence of cyanobacteria nodules, thick shell bivalves and gastropods in these low energy limestones indicates deposition in protected, restrictive lagoons. Facies association D comprises wackestone-packstone and is interpreted as an outer ramp, shallow marine deposit. The sorting is medium to poor indicating transport on a short distance. The abundance of echinoderm plates suggests that these rocks were deposited in a well-oxygenated, open marine, shallow environment.

In conclusion, we observe a transition from inner ramp tidal flats and shoals in the lower part of the succession towards restricted lagoons in the uppermost part. All these observations indicate that this succession has a shallowing upward tendency. The presence of thick restricted lagoons in the upper part of the succession suggests that as the carbonate ramp was prograding, conditions were becoming more restrictive in a landward direction.

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How to build a fluvial succession: think lobes as well as valleys

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'River' and 'Valley' are words that go together when we consider modern landscapes, but this association is somewhat misleading when considering fluvial stratigraphy. Whilst some fluvial successions form as valley-fill, these mostly occur in coastal plain settings as part of a cycle of sea level fall and rise. Aggradation of deposits on a basin plain by Distributive Fluvial Systems is widespread in both modern and ancient settings and an understanding of how these build up is important in the interpretation of fluvial stratigraphy.

An analogy can be drawn with submarine fan systems: they are recognised as building up by channel and lobe progradation and switching. In much the same way a depositional lobe is built up by a distributive river system by nodal avulsion creating new channel pathways across the basin plain around which overbank splays build up a floodplain succession. Channel deposits form as the river migrates within a channel belt and when the channel is abandoned by avulsion. In this scenario the fluvial succession is built up by a cycle of lobe formation and avulsion across a distributive system.

Whilst we may associate rivers with valleys, this connection is mainly relevant to non-depositional tributary systems that will not result in successions of river channel and overbank deposits. Fluvial stratigraphy more commonly forms as a result of lobes of channel and overbank facies on avulsing distributive systems.

Fifteen French maids and a plover in a pear tree: a previously unrecognized feeding trace from the Miocene of eastern Borneo

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Fieldwork examining Middle Miocene deposits in eastern Borneo led to the discovery of fossil mangrove deposits. A variety of trace fossils were preserved in these sediments, including interpreted mangrove lobster and bird footprints. The bird tracks were unusual in that they lack the imprint of a halux, while having a slender, symmetrical, tridactyl trace, with a length of around 33 mm. These characteristics indicate that it is very likely that the track maker was from the plover family.

A further enigmatic zigzag trace, looking almost as though someone had scribbled into the bedding plane, presented a greater challenge. Each "stroke" was around 8 mm in length and 2 mm across, with an amplitude of around 3 mm. The trace fossil was preserved as a cemented linear feature, more than 20 cm in length, on a sandstone bedding plane. The sandstone bed was interpreted as marking the abandonment surface of an ancient mangrove creek.

Extensive literature searches failed to yield examples of any similar fossil traces, but a chance encounter with fifteen French maids by a coastal lagoon in St. Lucia, South Africa, led to a surprising solution to the puzzle. The maids were posing for photographs, with a backdrop including a bloat of hippos basking in the shallows. While trying to photograph the hippos the author came across several plovers feeding on the mudflats. The traces they were creating included footprints, prod marks and striking zigzag patterns in the mud, representing a scythe-like mode of feeding as the plovers swept their beaks back and forth through the sediment.

The trace fossil, which has provisionally been named *Commeoichnus puella* (*nomen nova*: the Latin term for “sweeping back and forth trace”; Latin word for “maid”), is therefore interpreted as a bird feeding trace. Of the spectrum of modern avian feeding methods, only prod marks have previously been identified in the fossil record. The discovery of this fossil sweeping feeding trace has spurred on efforts to identify other, previously unrecognized or incorrectly attributed, bird feeding traces preserved in ancient coastal deposits. Its presence in sedimentary rocks will also help to identify them as probable paralic deposits.

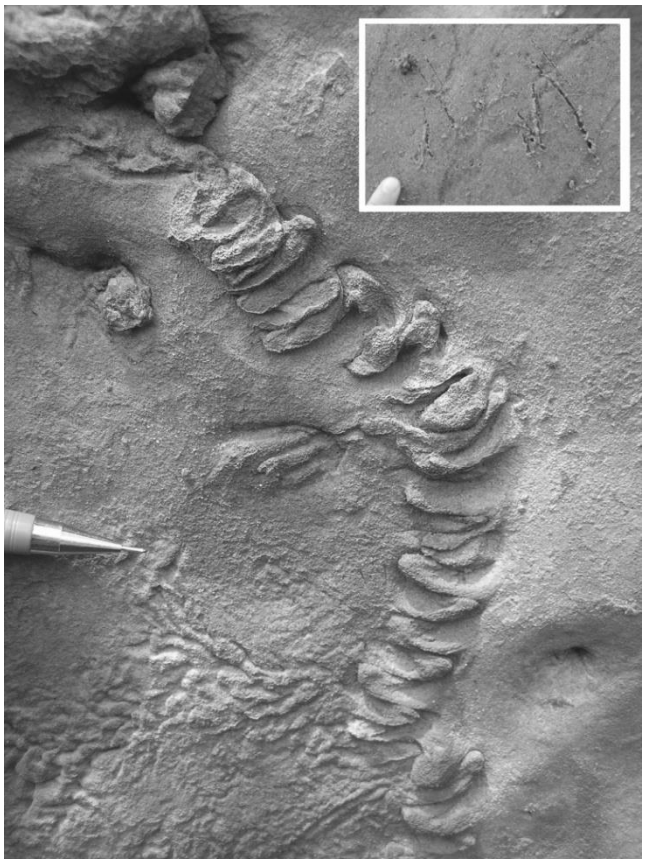

Figure 1 Photograph showing fossil trace; inset showing photograph of recent plover feeding trace

Teaching Geology to Non-Geologists: getting back to the rocks

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In the oil and minerals industry, it is important that the various disciplines understand each others' roles. Fortunately, it is relatively straightforward to introduce non-geologists to the science of Geology, because it is based primarily on observation and interpretation, rather than on complex equations. Outcrops provide ideal analogues to appreciate scale, sedimentology and structure.

Over the past ten years I have set up several "Geology for non Geologists" training courses (G4NG) around the globe. Typically the course is divided into a classroom session followed by a geological field excursion. Outcrops are chosen to demonstrate the widest possible range of depositional environments, and typical themes to be explored in class and in the field include sedimentology, palaeontology, structural geology, oil genesis and migration, and basin evolution.

Field safety is obviously of key importance. Following a briefing on the outcrop, the group is divided into teams to maximise the learning experience. Simple exercises are undertaken at each outcrop to introduce new concepts, and to teach the participants how to observe rocks and then interpret them. The exposures and exercises are carefully chosen to build the skills and knowledge of the participants. At the completion of each exercise a team is chosen to present their findings to the others.

While it is obviously not possible to "make" a geologist from an engineer over the course of a few days, the G4NG courses provide a great opportunity to provide key awareness of basic geological concepts that can then be directly applied back in the workplace, while ensuring that geologists and their counterparts are "speaking the same language".

Down-dip termination of sandy fan systems – new insight from the Pennsylvanian Ross Sandstone Formation, western Ireland

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Sandy deep-sea fan systems terminate distally by downlap, onlap or ponding; the distinction is important to predict distal fan fringe reservoir potential and character. The Pennsylvanian Ross Sandstone Fm. in western Ireland forms part of a thick (>2200m) progradational and shallowing-upward basin-fill succession. It crops out in sea cliffs around the outer Shannon Estuary (Loop Head peninsula) where a combination of behind-outcrop drilling and biostratigraphy have established a 490 m-thick stack of at least nine sandy deep-water fan systems separated by variably-expressed condensed sections. Palaeoflow measurements indicate a north-easterly dispersal and it is likely the system was weakly confined laterally within a pre-existing trough (reflecting earlier Mississippian-age crustal extension). But how did these fan systems feather out distally? New and legacy borehole constraints and outcrop work on the eastward extension of the Ross help constrain the down-dip character of the fan stack.

Coring of the basal Ross in the west (Loop Head, Ballybunion) show that the advance of the system was preceded by a distinctive precursor cycle involving first many stacked thin (cm/dcm thick) mudflows, followed by isolated outsized and unusually coarse-grained hybrid event beds. The former are interpreted as a muddy fringe deposited by the clay-damped wakes to flows that left most of their sand up-dip, implying a strongly feathered sand limit, controlled by flow dynamics. These deposits are restricted to the outer Shannon area and none are present further to the east. The overlying fan systems are dominantly fine-grained sand and biostratigraphy confirms they shale out down-dip within 50 km. The Ross-equivalent successions in east Clare and Kerry are thinner (40-150 m thick) and mostly in an alternation of barren and goniatitic mudstones. These are directly overlain by mass-transport complexes and subordinate sandstones attributed to the overlying Gull Island slope system. Much of the Ross sand was thus trapped in a more rapidly subsiding westerly depocentre. The distal fan fringe was pinned by a slowly back-rotating axial counter slope that forced flows to decelerate, preventing them from escaping further to the east, but never with sufficient gradient to induce flow ponding.

Controls on sandstone reservoir quality from the UK continental shelf

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Reservoir quality is one of the fundamental aspects of petroleum exploration and production. The UK continental shelf comprises a wide range of basins, stratigraphic ages, depositional environments and burial histories, but a synthesis of its controls on reservoir quality has not been published. We have gathered petrographic, petrologic, petrophysical and contextual data from all publically-available reports, papers and theses in order to determine its controls on sandstone reservoir quality, specifically porosity and permeability (Figure 1). The UK continental shelf can be subdivided into eight chronostratigraphic periods (Devonian, Carboniferous, Permian, Triassic, Lower Jurassic, Middle Jurassic, Upper Jurassic, Lower Cretaceous and Paleogene) that share common depositional and diagenetic controls on reservoir quality.

Provenance exerts a first order control on the primary composition of sandstones through time. There is a general trend of increasing mineralogical maturity through time as a result of increased reworking of existing sedimentary rocks. Depositional environment is perhaps the most important control on reservoir quality for any of the stratigraphic intervals. Calcite and (Fe-)dolomite are the dominant carbonate cements that exert a major influence on reservoir quality for all chronostratigraphic intervals. Illite and kaolinite also exert first order controls on reservoir quality. Illite is common in the Devonian, Permian and Triassic as a result of arid to semi-arid climates, whereas kaolinite is common during the tropical Carboniferous and the warm temperate Jurassic to Palaeogene. Quartz is a ubiquitous cement in reservoirs exceeding ~80°C during their burial history. However, in Upper Jurassic and Lower Cretaceous formations, microcrystalline quartz sourced from siliceous sponge spicules exerts a first order control. All these factors influence an increase of porosity and permeability through time, from an average 13 % and 25 mD in the Devonian to 26 % and 1650 mD in the Palaeogene, respectively.

By considering the major controls on reservoir quality variability within a stratigraphic interval, we are able to provide the controls on porosity and permeability from hydrocarbon fields on the UK continental shelf. In the future, this approach will also be used to evaluate the controls on reservoir quality in other basins.

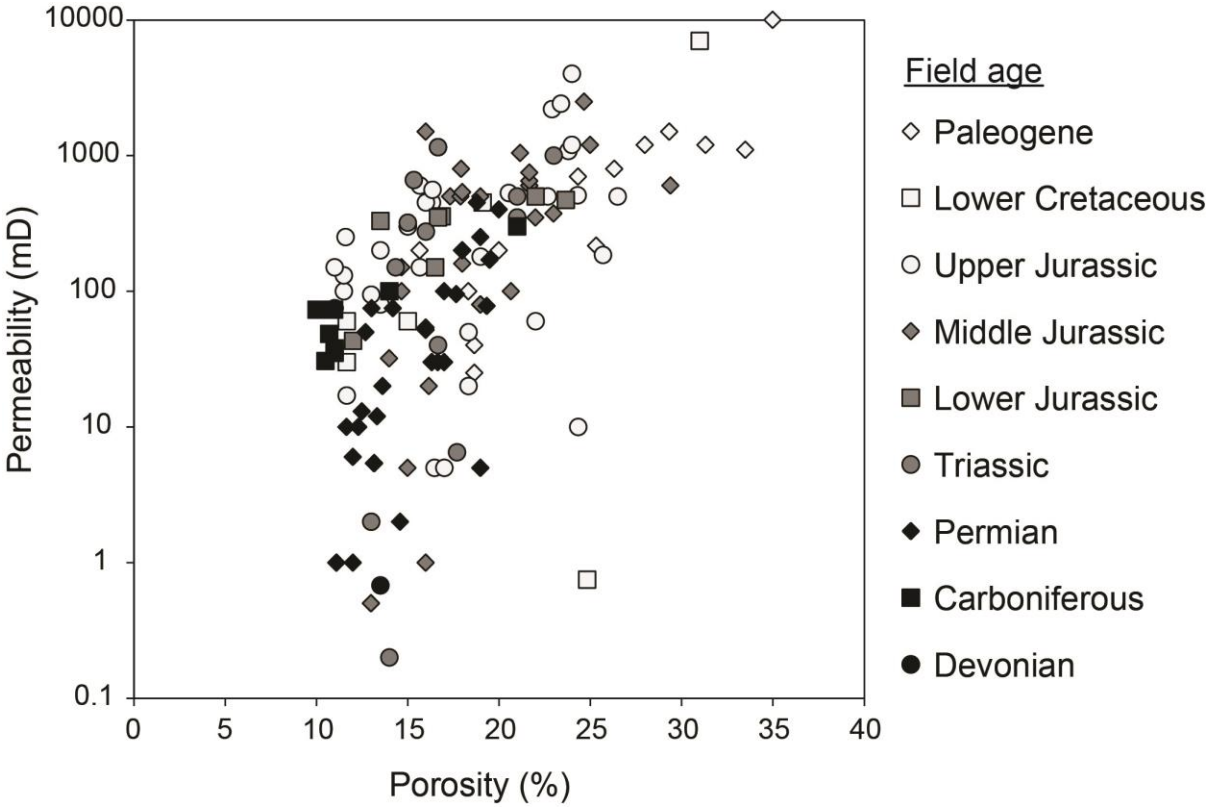

Figure 1: Arithmetic averages of porosity and permeability for 148 UK hydrocarbon fields, grouped by stratigraphic interval.

Impact of facies variability on static reservoir connectivity: the North Brae Example

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Capturing high-frequency heterogeneities introduced by thin-bedded turbidite (TBT) successions has become absolutely necessary in predicting the distribution of barriers and baffles to hydrocarbon flow.

In producing turbidite fields where TBT constitutes a significant proportion of the reservoir unit, failure to adequately assess stratigraphic compartmentalization during the early stages of model building can significantly favour the dominant thick and medium-bedded counterparts and downplay the key uncertainties that impact reservoir connectivity, and consequently pose a threat to optimising hydrocarbon recovery in such turbidite fields.

We have modelled a range of hypothetical scenarios using subsurface data from the mixed turbidite succession of the North Brae Field, UKCS, in addition to outcrop data from the mainly TBT succession of the Basque-Cantabrian Basin to assess the impact of these small-scale heterogeneities on net-to-gross distribution and static reservoir connectivity. Preliminary results support our hypothesis that TBT heterogeneity must be taken into account from the outset.

Further work will focus on running simulation on the static reservoir models to assess the impact of TBT facies variability on dynamic connectivity and thereby produce a range of hydrocarbon recovery scenarios.

Characterisation and modelling of heterogeneity in thinly bedded, shallow-marine sandstone reservoirs

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Wave-dominated shallow-marine sandstone reservoirs contain significant intervals of thinly bedded facies characterised by the presence of interbedded sandstones and shales. The facies contain gutter casts, which are sand-filled erosional scours formed by storm-generated flows. The gutter casts may increase connectivity between sandstone beds that are otherwise isolated by shales, thus creating effective vertical permeability. The 3D geometry and dimensions of gutter casts, and patterns in their spatial distribution are uncertain. These aspects of facies architecture and their impact on reservoir performance are being addressed using data from an outcrop analogue (``G2'' parasequence, Grassy Member, Blackhawk Formation), which is exposed in closely spaced, branching canyon walls in the Book Cliffs, Utah, USA.

A 3D high resolution digital outcrop model (DOM) that measures c. 65 m x c. 20 m x c. 15 m of the outcrop analogue has been constructed using digital photogrammetry combined with eleven measured sedimentary logs. Gutter cast morphology and dimensions are being characterised in cross-sections from cliff faces with various orientations, in order to develop a 3D template for later reservoir modelling.

Understanding system scale connectivity in fluvial systems

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Understanding variations in channel connectivity in fluvial systems is crucial to help us understand how fluid flows at a system scale. This can have great implications when trying to effectively exploit key resources such as hydrocarbons, aquifers and mineral deposits. Uranium distribution in sandstones is strongly influenced by sandstone body connectivity, and can therefore be used as a proxy for fluid flow. We analyse channel belt connectivity, and therefore permeability, at the system scale in the Salt Wash fluvial system (SW USA), where large deposits of uranium are present. More than 90% of recorded uranium-vanadium deposits in the Salt Wash fluvial system are located where net sandstone represents 40-55% of the succession and where channel belts form 20-50% of the succession. Below the 40% sandstone and 20% channel belt cut-off levels, uranium deposits are rarely observed, suggesting a loss in effective connectivity allowing the enrichment and precipitation of uranium when all other conditions needed are met. This change in uranium distribution coincides with a change in gross-scale fluvial architecture at a critical transition zone between facies tracts on the system. This relationship implies the reduction in channel belt connectivity is directly related to facies distribution associated with distributive fluvial systems. By directly relating uranium distribution to key characteristics such as sandstone percentage and channel belt percentage, a quantified predictive system scale model of channel belt connectivity, and therefore permeability, can begin to be built from a rock record example.

Teaching geological sedimentology within geography degree schemes at Swansea University

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Swansea University offers geology as a minor component alongside physical geography within geography degrees. On account of available staff expertise and the need to complement geographical experience and interests, the focus of geology provision is on sedimentology. Emphasis is placed on teaching through fieldwork, so that students develop practical experience and ability in the subject as well as gaining a theoretical understanding. Particular challenges are associated with students with a geographical background, and approaches to address some of these challenges will be outlined. Geography students typically have less experience of fieldwork activities than do geology students, as a consequence of which they may have less confidence in some key field skills; they have less experience of other aspects of geology, such as structural geology, that contribute to the interpretation and understanding of features preserved in deformed rocks; they have less experience of, and therefore more difficulty in coping with, some 3-dimensional aspects of geology including the significance of sections with different orientations cut through strongly 3-dimensional features such as sedimentary structures; and - being geographers - many struggle to think in terms of temporal chronologies rather than spatial arrangements, which is a particular issue when collating and writing up field reports. In the light of these issues, it is a challenge to ensure that sedimentology learning within a geography degree scheme is at a level appropriate to the year of study. By being aware of students' prior experience, focussing on certain key aspects of the subject, and adopting imaginative approaches to teaching sedimentology, including the use of training videos, students can reach a high level of ability as they progress through the degree scheme and can gain a sound understanding of sedimentology that complements their studies in physical geography. This presentation will outline some of the approaches that have been adopted and consider how sedimentology can be taught effectively within degree schemes other than 'pure' geoscience.

Grain size controls on the morphology and stratigraphy of river-dominated deltas

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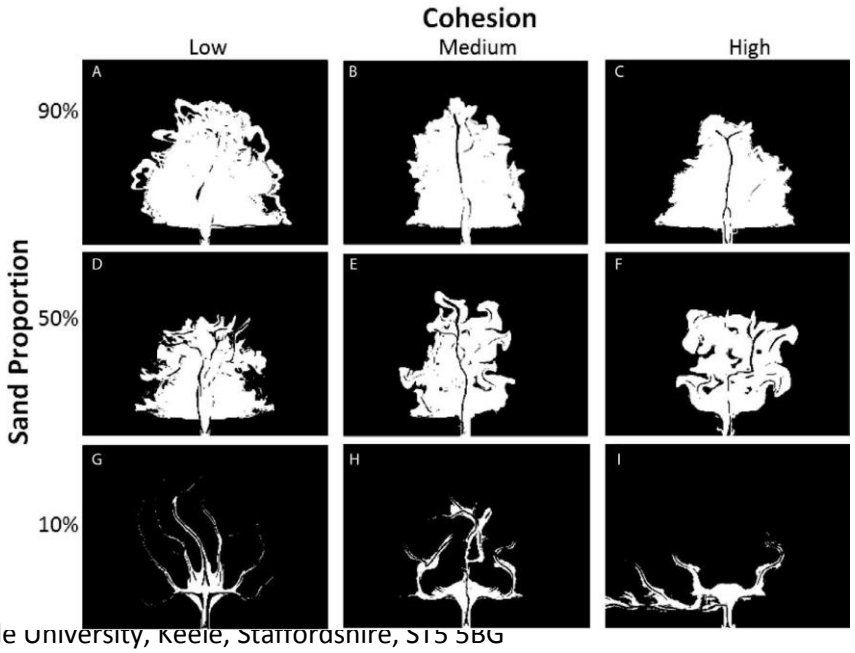
The proportions of sand and mud that make up a river-dominated delta strongly determine its topset morphology, which in turn controls its internal facies and clinoform geometry. These relationships allow prediction of the stratigraphy of a delta using the character of its topset and reconstruction of deltaic planform from measures of clinoform geometry. This paper presents results from the Delft3D modeling system which was used to simulate nine self-formed deltas that possess different sediment loads and critical shear stresses that are required for re-entrainment of mud. The simulated deltas were set to prograde into a shallow basin without waves, tides, Coriolis forcing, and buoyancy. Model results indicate that sand-dominated deltas are more fan-shaped whilst mud-dominated deltas are more birdsfoot in planform, because the sand-dominated deltas have more active distributaries, a smaller variance of topset elevations, and thereby experience a more equitable distribution of sediment to their perimeters. This results in a larger proportion of channel facies in sand-dominated deltas, and more uniformly-distributed clinoform dip directions, steeper dips, and greater clinoform concavity. These conclusions are consistent with data collected from the Goose River Delta, a coarse-grained fan delta prograding into Goose Bay, Labrador, Canada and also allow us to undertake a re-interpretation of the Kf-1 parasequence set of the Cretaceous Last Chance Delta, a unit of the Ferron Sandstone near Emery, Utah, USA. We argue that the Last Chance delta likely possessed numerous distributaries with at least five orders of bifurcation.



An improved Jacob's staff with compass, spirit level and rotatable laser for high-precision stratigraphic thickness measuring

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High precision stratigraphic thickness measurements and estimates of measurement uncertainty are valuable to many applications of sedimentology and stratigraphy at different scales (e.g., bed statistics, reconstruction of palaeotopographies, depositional processes at bed scale, architectural element analysis), especially when a quantitative approach is applied to the data analysis.

A new Jacob's staff design including a compass and spirit level holder and a laser holder is proposed. The first combines a compass and a circular spirit level on a movable bracket and the second introduces the ability of a laser to move vertically and to rotate on a plane parallel to bedding. The new design allows greater precision in stratigraphic thickness measurements while containing the cost and maintaining speed of measurement to a level similar to that of a traditional Jacob's staff. Greater precision is achieved as a result of: a) improved 3D positioning of the rod thanks to the use of a revised compass and spirit level holder; b) more precise sighting thanks to the ability to shift the laser beam vertically and laterally; c) reduced error when shifting the trace of the log laterally (i.e. away from the dip direction) and d) improved measurements of bedding necessary to orientate the Jacob's staff, both thanks to the ability to turn the laser beam. The new laser holder can also be used to verify parallelism of a geological surface with the bedding by creating a visual planar datum in the field and allowing determination of surfaces which are cutting the bedding at an angle (e.g., erosion, amalgamation surfaces, etc.).

Although defining the precision of the new instrument is challenging and awaits further work, a short compilation of examples shows that stratigraphic thickness measuring errors can be significant and that the largest errors are most likely to occur when outcrop conditions are difficult (often the situation when a Jacob's staff is required). In these scenarios the new Jacob's staff can help to improve precision of stratigraphic thickness measurements and hence to reduce the associated uncertainty in the description and interpretation of the dataset.

Controls on turbidite deposition on an actively deforming basin: an example from the Numidian of Sicily

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Outcropping turbidite systems of the central Mediterranean-Alpine region are widely used as analogues for a variety of deep-water hydrocarbons reservoirs. Understanding whether the system is unconfined and deposited on relatively unstructured basin floor or confined by actively deformed basins is important for the prediction of sand distribution and therefore the applicability of analogues. Here we consider the Numidian turbidite system (Oligocene-Miocene) of Sicily - for many the type example of thick massive submarine sandstones. The tectonostratigraphic setting of the Numidian is analogous to the Angostura (Trinidad) - Scotland (Barbados) sand systems of the Caribbean and associated ultra-deep water exploration. New mapping and detailed sedimentology in the Nebrodi Mountains (northern Sicily), allied to existing paleontology, challenge conventional ideas on the Numidian system as a whole and how it can be used to inform deep-water hydrocarbon systems. Rather than having being deposited within an unstructured foredeep by relatively unconfined flows, we show that Numidian deposition was strongly confined by active structures. The system was controlled by thrust related folds and their intrabasin submarine slopes, together with basin floor architecture inherited from the underfilled passive continental margin. Thrust-top basins filled diachronously implying a large scale tectonic control both on sand fairways and facies variations along their margins. Existing models wrongly suggest that facies variations between adjacent outcrops on Sicily (and elsewhere) result from long-range stratigraphic variations being juxtaposed by later large-displacement thrusts. Our research reveals a much simpler tectonic structure but a more complex stratigraphic arrangement for the Numidian on Sicily - a characteristic of confined turbidite systems.

A virtual-outcrop based study of the Jurassic Page Sandstone Formation. An approach to multiscale geomodeling of aeolian reservoir analogues.

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Excellent exposures of the aeolian Page Sandstone Formation (Bathonian – Bajocian) around Lake Powell have been studied as aeolian reservoir analogues. The study is based on an extensive virtual outcrop model gathered using terrestrial LIDAR combined with ground based and UAV (drone) acquired images. A petrophysical dataset was also collected and integrated with 12 traditional outcrop logs. The Virtual Outcrop Model encompasses a c. 1 km^2 cliff-outcrop volume (with the Page Fm. extending up to 55 m thick locally) on the Manson Mesa and several outlying knobs providing excellent 3D control on the facies architecture at several different scales of heterogeneity.

The deposits of the Page Fm. represent the downwind migration of subordinate aeolian bedforms superimposed on larger often slipfaceless compound dunes. The compound dune sets punctuated by a series of six regional super-surfaces (Havholm and Kocurek, 1994). This hierarchal complexity which includes 8 lithofacies distributed in a framework with at least 4 orders of bounding surface provides an excellent opportunity to develop multi-scale modelling techniques for aeolian reservoirs. Geocellular models have been built at the micro (facies) and macro (system) scales. These were conditioned from the field data and a revised depositional model. To address the mesoscale (architectural element) a series of processes using three-dimensional quantitative, bedform forward modelling software (after Rubin, 1987) are under development. The models can then be populated with the petrophysical data and used to determine Representative Elemental Volumes for the different scales of heterogeneity within the system.

Depositional Pattern associated with Experimental Turbidity Currents going through a Break-of-Slope

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In turbidity current systems break-of-slopes are often associated with a channel-lobe transition zone and occur at the transition from continental slope to abyssal plain, or perched on irregular or stepped slopes. Turbiditic deposits in break-of-slope settings can form reservoirs for hydrocarbons depending on their upslope termination. In high-efficiency system, where grains are transported far into the basin, the deposits are located on the basin floor detached from the slope forming a stratigraphic trap, while in low-efficiency system the deposits are connected onto the slope making the formation of a stratigraphic trap unlikely. Therefore, the better understanding of the control factors on the systems efficiency in a break-of-slope setting is of interest for hydrocarbon exploration.

The change in flow properties of a turbidity current going through a break-of-slope are well described in several experimental studies and build a strong foundation for the work presented here. However, the link between the flow properties and the resulting depositional pattern remains poorly constrained. This study will use experiments that focus on the scaling of the depositional behavior of turbidity currents to illustrate which geometrical factors of a break-of-slope setting lead to slope-attached and slope-detached depositional patterns. The plane and the slope angle have a very distinct effect on the flow properties and the linked depositional pattern. These effects are clearly reflected in the velocity and turbulence profiles of the flows, making it possible to link the flow properties to the onset of deposition. With steeper slopes the flow velocity increases and the onset of deposition is shifted further into the basin (i.e. efficiency is increasing). Steeper plane angles will lead to a downward shift on the elevation of the velocity maximum and reduce the amount of deposition on the plane. However, the onset of deposition is observed to occur at the same position, apparently it is controlled only by the steepness of the incoming slope. The experimental results will be linked to outcrop studies of a comparable deep-marine turbidite system from the Karoo basin (South Africa).

Mudstone-dominated basin margin progradation: processes and implications

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Many studies emphasize the accretion of coarse-grained material at the shelf-edge rollover as a major mechanism for basin margin progradation, despite fine-grained sediment (clay and silt) representing a volumetrically more significant component of clinothems. The timing and processes controlling fine-grained sediment transport across the shelf and onto the slope is an understudied facet of basin stratigraphy.

Exhumed basin margin-scale clinothems of the Permian Waterford Formation in the Karoo Basin, South Africa, offer a unique outcrop example of margin development through the accretion of fine-grained material under flooded shelf conditions. Abrupt basinward shifts of wave-dominated sandstone topsets over a thick mudstone succession and beyond a previously established sand-rich shelf-edge rollover suggest that increments of basin margin progradation occurred exclusively via deposition of dilute mud-rich gravity flows.

Detailed outcrop and core study of mudstones reveals a high content of organic debris and mica. Thin beds show normal and inverse grading, internal erosion surfaces and generally moderate to low bioturbation, reflecting relatively stressed and constantly supplied prodeltaic and outer shelf regions. The low gradient geometry of the Karoo Basin margin and prevailing storm-dominated conditions allowed fine-grained hyperpycnal deposits to be re-suspended and to travel as fluid mud for tens of km across the shelf and beyond the shelf-edge rollover.

Despite the large volume of river-derived fine-grained sediment in continental shelf successions, neither clinoform trajectory analysis nor conventional depositional models adequately account for progradation of basin margins in the absence of sand supply. This study therefore represents a rare example of exhumed mudstone-rich shelf-edge rollover deposits documented in outcrop and core, and demonstrates how fine-grained sediment can represent a significant component of basin margin progradation.

The influence of confinement on depositional sheet turbidite system architecture

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Deepwater submarine environments are commonly characterized by a complex seafloor morphology comprising a mosaic of small depositional basins (minibasins) several kilometers across. Turbidity currents that run into these areas can be sufficiently large to spread across the entire basin floor. The degree of confinement experienced by flows depends on the height and volume of the flow compared to the confining seafloor topography, which my completely trap flows or only partially confine them. Many confined sheet-like turbidite systems consist of amalgamated sandstone and non-amalgamated alternations of sandstone with siltstone/mudstone, which may be tabular on a small scale. Controlling factors of these turbidite beds are decided mainly by flow magnitude; sand/mud ratio; flow concentration; degree of confinement. Lots of field and experimental work has been done qualitatively on the first three parameters, however, models of the effects of flow confinement on turbidite architecture are not well developed.

Outcrop studies provide a good opportunity to fill the gap between seismic and well logs. Seismic data provides information over a large area, but with limited resolution, whereas log and core data provide detailed measurements, but only over a limited area. Exceptionally well-exposed sheet-like turbidite systems in the syn- to post- glacial Pennsylvanian of western Argentina occupy basins ranging in scale from paleofjords, hundreds of meters across (Jejenes Formation of Las Lajas, San Juan province), to paleovalley of a little more than a kilometre across (Jejenes Formation of Quebrada Grande, San Juan province), to sub-basins of at least 10km width (Guandacol Formation of La Rioja province). They present a unique opportunity to compare and contrast the architectures resulting from different degrees of confinement and also they can be used as partial analogues to intraslope basins of various sizes on the basin seafloor.

Factors controlling stratal pattern and facies distribution of fluvio-lacustrine sedimentation in the Sivas mini-basins, Oligocene (Turkey)

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The Sivas Basin, located in the Central Anatolian Plateau of Turkey, is a foreland basin that records a complex interaction between sedimentation, salt tectonics and regional shortening during the Oligo-Miocene leading to the formation of numerous mini-basins.
The Oligocene sedimentary infill of the mini-basins consists of a thick continental succession, the Karayün Formation, comprising a vertical succession of three main sub-environments: (i) playa-lake, (ii) fluvial braided, and (iii) saline lacustrine. These sub-environments are seen as forming a large Distributive Fluvial System (DFS) modified through time as a function of sediment supply and accommodation related to regional changes in climate and tectonic regime.

Within neighbouring minibasins and despite a similar vertical stratigraphic succession, subtle variations in facies assemblages and thickness are observed in stratigraphic units of equivalent age, thus demonstrating the local control exerted by halokinesis. Stratigraphic and stratal patterns reveal in great detail the complex interaction between salt tectonics and sedimentation including different types of halokinetic structures such as hooks, wedges and halokinetic folds. The regional variations of accommodation/sediment supply led to coeval changes in the architectural patterns recorded in the mini-basins.

The type of accommodation regime produces several changes in the sedimentary record: (i) a regime dominated by regional accommodation limits the impact of halokinesis, which is recorded as very small variations in stratigraphic thickness and facies distribution within and between mini-basins; (ii) a regime dominated by localized salt-induced accommodation linked to the subsidence of each individual mini-basin enhances the facies heterogeneity within the DFS, causing sharp changes in stratigraphic thickness and facies assemblages within and between mini-basins.

Can we create a brighter future for the UK petroleum industry

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The last year or so has seen a significant decline in the oil price and a concomitant fall in exploration activity on the UKCS, with the loss of thousands of jobs and the mothballing of projects. However, the Yet to Find numbers used by most workers are reckoned to be about 6 billion barrels of oil, plus significant amounts of gas, so continued exploration effort should yield substantial new reserves. Yet, we are finding it in very small increments and only very slowly. The talk will examine some of the things that are being done, or could be done, to facilitate faster and more efficient exploration, and will ponder the long-term future of the UKCS.

Rates of surface lowering and landscape development in Southern South Africa: a cosmogenic view.

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New techniques are being used to calculate erosion rates from areas of landscape denudation characterised by bedrock rivers, which can be compared to downstream areas of net aggradation of sediment. Southern South Africa is characterised by large-scale erosion surfaces, including extensive pediments and multiple strath terraces that document discordant river evolution through resistant quarzitic lithologies of the Cape Fold Belt (CFB). The timing and rate of erosion is poorly constrained. New cosmogenic ages from surfaces in South Africa were dated using *in situ* produced ^{10}Be. Strath terraces in deeply incised rivers at two sites within the CFB indicate slow rates of erosion (1.54 - 11.79 mMa^{-1}), which are some of the lowest rates recorded globally. Four pediment surfaces and a depth profile of the thickest pediment were also dated, and the results indicate that there are low rates of surface lowering on the pediments (0.44 - 1.24 mMa^{-1}). The pediments are long-lived features (*minimum* exposure ages of 0.47 - 1.09 Ma), and are now deeply dissected. Given the *minimum* exposure ages, calculated river incision rates (42- 203 mMa^{-1}) suggest that after a long period of geomorphic stability during pediment formation there was a discrete phase of increased geomorphic activity. The calculated *minimum* exposure ages are considered dubious and the pediments must be older due to: 1) known rates of surrounding river incision (published and ours); 2) the conditions and time for ferricrete formation on the pediment surfaces and; 3) the deeply incised catchments in the CFB on which the pediments sit. The pediments are fossilised remnants of a much larger geomorphic surface that formed after the main phase of exhumation in southern Africa, and form a store of sediment that currently sits above the surrounding rivers that have some of the lowest erosion rates in the world. These results indicate that steep topography can prevail even in areas of low erosion, and that whilst cosmogenic dating of landscapes is an exciting development in earth sciences, care is needed when applying dates and rates especially in ancient settings.

Fault-induced coarse clastic sedimentation related to the initiation of a Permian continental margin forearc basin in South Island, New Zealand

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An overall fining-upward sequence of breccia-conglomerates, sandstones and volumetrically minor mudrocks (Upukerora Formation; 0-c.750m thick) overlies the Early Permian (275-285 Ma) Dun Mountain Ophiolite. Field, petrographic and geochemical data indicate that much of the coarse clastic debris was derived from the subjacent ophiolitic basement. However, volcanic rock clasts of intermediate to felsic composition and quartz-rich intrusive rocks (including plagiogranite) are over-represented compared to the exposed ophiolite. This suggests the existence of a related oceanic magmatic arc that is no longer preserved, except probably as blocks in a melange (Otama Melange) in the south. In addition, chemical data (e.g. Rare Earth Elements) suggest that some of the fine- to medium-grained sediment was derived from a continental margin arc. Two alternative hypotheses are: First, the ophiolite-derived clastics relate to late-stage magmatism in an oceanic setting (e.g. rifted ridge), or secondly, the clastics accumulated on the ophiolite after an up to 20 Ma hiatus (based on U-Pb dating). The second hypothesis is supported by: 1. The clastic sequence unconformably overlies different levels of the ophiolite pseudostratigraphy (i.e. basaltic extrusives; gabbroic rocks) in different areas; 2. Reported extrusive rock intercalations are inferred to be gravity slide blocks derived from the ophiolitic basement (also magmatic intrusions are absent). 3. The Upukerora Formation passes upwards without a break, first into a mixed carbonate-volcaniclastic-terrigenous sequence (Wooded Peak Fm.), and then into a mixed volcaniclastic-terrigenous sequence (Tramway Formation), the latter including a Mid-Late Permian detrital zircon age population. Both of these sequences include continental margin-derived sediment of similar composition to that within the Upukerora Formation. The Upukerora Formation is interpreted to record a phase of extensional faulting that initiated a Late Permian-Triassic continental margin forearc basin (Maitai Group). Very coarse clastic material, including very large (10s of m) detached blocks of basalt and gabbroic rocks were shed down active, extensional fault scarps from relatively shallow water into a deeper water setting. Gravity flow processes dominated, ranging from rock fall, to debris flow, to slope-controlled grain flow and turbidity currents. The relatively fine-grained volcaniclastic-terrigenous sediment was derived from the E Australian (Gondwana) continental margin forearc as distal gravity flows.

Quantification of fluvial meander bend shape: new insights into the evolution of ancient point-bar deposits

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Quantifying and classifying the variability of fluvial bend shape in a meaningful manner is challenging because meanders are inherently complex natural systems. Quantitative and non-subjective approaches to the comparison of two or more systems predominantly rely on mathematical modelling software, for which results are readily interpretable in terms of geomorphic and sedimentary processes. In this study, the development of a novel metric, the 'Intersection Shape Method', has been implemented as a tool to differentiate between meander-bend types based on shape. Meanders are classified as simple, symmetrical, complex or angular; they are further assigned to one of 25 subdivisions of these categories. The analytical method considers the size of the polygon created when six lines, perpendicular to the centreline of the meander, are drawn at equally spaced points starting from a channel inflection point up to the apex. The area of the shape enclosed by these lines (As) is then divided by the perimeter (Ps) and plotted against the ratio of meander length to width. The position occupied by different meander types on the resultant graph enables relationships and typical meander-growth patterns to be considered quantitatively and objectively. The technique has been developed using data from 11 rivers covering 200 active meanders, shape attributes for which have been recorded from Landsat and aerial photograph imagery using Google Earth Pro software. The method for quantification and classification is here applied to demonstrate its value in the comparison of two specific case-study examples: the Ob River, Russia, and the Senegal River, Senegal. Linear morphometric measurements were made of 21 active meanders in each reach. This generically applicable method is readily employable and repeatable. It can be used to make quantified visual comparisons, which in turn can be used to predict and define the migratory behaviour of meander bends over the course of their lifetime based on the observed form of several meanders present within a river reach influenced by a common set of processes. This method can also be applied to make inferences about the morphological evolution of preserved point-bar elements in the ancient rock record.

Expressions of shallow marine conditions in the Early Carboniferous of the Northumberland Basin.

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The early Carboniferous Ballagan Formation exposed in the borders between England and Scotland hosts some of the most important vertebrate fossils that record the transition of tetrapods onto land and the development of early terrestrial ecosystems. This study is part of the TW:eed Project (Tetrapod World: early evolution and diversification), investigating the rebuilding of ecosystems after the end Devonian mass extinction. Research has largely focussed in the Tweed Basin, where the sedimentary rocks record predominantly alluvial, lacustrine and hypersaline depositional settings, with some indications of marginal marine environments. There are key sections in the Northumberland Basin, however, that preserve important fauna but in settings where the sedimentological evidence suggests marine deposition.

Two sections in the Northumberland Basin have been analysed in detail; a 10 metre exposure in Coquetdale and a shorter, 1.7 metre, section in Whitrope Burn. It has only been through combining detailed outcrop logging and sampling on a centimetre scale with analysis of polished cut rock surfaces of dolostones, and thin sections of some of the finest grained material that the key, and sometimes surprising, evidence for understanding the local conditions has been revealed. In two localities, Coquetdale and Whitrope Burn, the dolostones (cementstones), characteristic of the Ballagan, contain sedimentological detail (e.g. characteristic grain-size profiles and bioturbation) which indicate marine conditions. In the coarser packages wave-ripples, gutter casts, bioturbation, and some of the fauna present suggest marine conditions. The marine-influenced dolostones and shallow marine, wave-rippled bay-fill sediments alternate with wet floodplain deposits indicating a marginal marine to coastal environment.

It has become apparent that the marine influence from the west was an important factor in the deposition of the Ballagan Formation in the Northumberland Basin. This is in contrast to Ballagan exposures further east where the marine influence is greatly reduced.

Role of relative sea-level change in controlling preserved facies architecture in a coal-prone, marginal marine succession: Cretaceous Neslen Formation, Utah, USA

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Determination of the process response to modest variations in relative sea level in marginal marine environments, especially in low-gradient, low-relief coastal plain settings, is challenging. This is especially true in coal-prone coastal successions due to differential compaction. This work provides a method for decompacting coal-rich coastal plain successions to more effectively apply high-resolution sequence stratigraphic correlation techniques.

The Campanian lower Neslen Formation represents a tide- and wave-influenced fluvial coastal plain succession that accumulated along the margin of the Western Interior Seaway. Although a large-scale sequence stratigraphic framework is established, the stratigraphic response to minor variations in relative-sea level remains poorly constrained. The succession represents multiple coeval and competing sedimentary environments, which each respond differently to relative sea-level change.

Detailed lithofacies, architectural element and sequence stratigraphic analyses incorporate graphic logs, architectural panels, analysis of palaeocurrent data and ichnofacies, and the tracing of key stratal surfaces over a 30 km dip-oriented transect. The formation comprises architectural elements representative of: (i) fluvial and tidally influenced point bars that are sandstone dominated and heterolithic, respectively; (ii) distributary channels; (iii) wave-dominated shorefaces; (iv) mouth bars and bay-head deltas; (v) fine-grained, commonly coal-prone, floodplain and overbank regions.

The application of a decompaction routine improves correlation and enables regional-scale correlation within the established sequence stratigraphic framework. This method highlights a sandstone-prone interval containing architectural elements representative of different sub-environments, including tide- and wave-influenced mouth bars at the same stratigraphic level as fluvial dominated point bars. This approach has enabled refinement of paleogeographic maps of the coastline. The sandstone-dominated interval represents the accumulated deposits of a zone of mixed influence where competing interaction between fluvial, wave and tidal processes occurred. This zone is the most landward representation of minor sea-level fluctuation in the lower Neslen Formation; overlying flooding surfaces, up to and including the maximum flooding surface, are represented by wave-dominated shoreface parasequences.

This study has enabled the elucidation of time correlative intervals, for which accurate palaeoenvironmental reconstructions have been produced. Results highlight the importance of addressing differential compaction in producing time-correlated stratigraphic models, especially in strata containing appreciable amounts of coal.

Frontal or lateral submarine lobe fringes? Distinctive sedimentary facies, geometries and pinchout architecture

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Typically, the fringes of submarine lobe deposits are described as being heterolithic and rich in hybrid beds. They act as useful indicators of palaeogeographic setting and basin confinement and, in the subsurface, can form important permeability barriers and baffles. However, whether lobe fringe deposits in frontal and lateral settings have distinct sedimentary facies associations and architecture has yet to be determined. Extensive outcrop data and newly acquired core from research boreholes for Fan 4, Skoorsteenberg Formation, Karoo Basin, South Africa, permit the range of facies associations and rates of change in facies transitions in ancient lobes and lobe complexes to be quantified within a tightly constrained palaeogeographic context. Outcrop and core sections logged at bed scale were integrated with palaeocurrent measurements and correlated across an 800 km^2 study area with good 3D data distribution to constrain facies changes from lobe axis to lobe fringe in both down-dip and across-strike directions. Fan 4 comprises two sand-prone divisions that are compensationally stacked lobe complexes. They are separated by an interval of thin-bedded silt and sandstone intercalated with hemipelagic claystone, interpreted as lobe complex fringe. Lobe-fringe facies associations can comprise: i) thick-bedded structureless or planar laminated sandstones that show pinching and swelling and are associated with underlying debrites; ii) argillaceous and clast-rich linked debrites; or iii) current ripple-laminated sandstones and siltstones;. Commonly, frontal fringes contain high proportions of linked debrites and transition from thick-bedded sandstones over length-scales of 1 to 2 km, whereas lateral fringes tend to be current ripple-laminated and transition to thick-bedded sandstones over several kilometres. This distinct difference in facies is considered to be controlled by flow processes. Hybrid beds in a frontal fringe positions are interpreted to be deposited from the high-density core of the flow, whereas the ripple-laminated thin beds in lateral positions are interpreted to be deposited by more dilute (marginal) low-density parts of the flow. Constraining the rates of facies transitions, and range of fringe associations, is important to improve palaeogeographic reconstructions of basin-floor fans, and to help reduce uncertainty during hydrocarbon field appraisal and development.

Tb or not Tb: Banding in turbidite Sandstones

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Submarine gravity flows include a range of flow types from turbidity current to debris flow, and hybrid flows that are transitional between the two. Their associated deposits range from clean sandstones to mud-rich sandstones, and composite deposits of both mud-rich and clean sandstone. This contribution examines banding, an enigmatic hybrid facies comprising mud-rich bands intercalated within otherwise clean turbidite sandstones. A suite of core and outcrop data is presented from two exhumed ancient systems and a subsurface producing oilfield: the Karoo Basin, South Africa; the Neuquén Basin, Argentina, and; the Magnus Oilfield, North Sea. These data show that banding typically occurs towards the tops of beds, overlying structureless and planar-laminated sandstones. Banding is strongly associated with erosion of flows into muddy substrates with bands subtending directly from muddy erosion surfaces, and bands composed of a large amount of mud clasts. Banding is interpreted to be deposited from high-concentration flows that entrain mud clasts. These mud clasts settle through the flow, and come to rest on the top surface of the high-concentration basal layer (traction carpet). With time the mud clasts are dissagregated, which imparts cohesive forces at the top surface of the traction carpet. Transitional cohesive plug flows develop which suppresses turbulence, and results in the deposition of bands of mud and mud-rich sand. An improved understanding of banding is important towards recognizing the rich diversity of transitional flow types and associated processes that supply sediment to the deep abyssal plains of the oceans. From an applied perspective, the recognition that banding is closely associated with erosion has implications for the improved characterization of subsurface sandstone hydrocarbon reservoirs.

Enhanced reservoir quality in HPHT reservoirs of the Triassic Skagerrak Formation, Central North Sea.

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As the exploration of hydrocarbons moves into more complex and deeper basinal settings the need to understand the effect of high temperatures and high pressures (HPHT) on reservoir quality and rock properties becomes even more important. The fluvial channel sandstone reservoirs of the Triassic Skagerrak Formation in the Central North Sea exhibit anomalously high porosities (Figure 1A) and permeabilities considering their depth of burial (> 3500 mbsf). Despite the complex depositional setting, diagenetic history and high overpressure and temperatures encountered in the Skagerrak Formation, hydrocarbons are currently being produced. The Triassic Skagerrak reservoirs used in this study have encountered overpressures >40 MPa and temperatures of up to ~180°C at present day maximum burial. To identify the role played by HPHT in these reservoirs a multidisciplinary approach involving petrography, fluid inclusion analysis, and burial history modelling has been adopted. The interpretation of the results indicate that the generation of shallow overpressure in these fields has arrested mechanical compaction (Figure 1A) and also played an important role in minimizing pressure solution in the chemical compaction regime as evidenced by substantially reduced quartz cementation. The formation of robust authigenic chlorite (Figure 1B) and to a lesser extent illite clay coats with burial had a positive effect on porosity preservation even though permeability was marginally reduced in the illite-rich sandstones. Fluid inclusions found in the quartz overgrowths have identified the quartz cementation as late-stage with temperatures of formation between ~130-175^{o}C. This study has developed key criteria for enhanced reservoir quality maintenance, which allow pre-drill prediction of reservoir quality in the Triassic Skagerrak and provide valuable insights for other complex HPHT reservoirs.

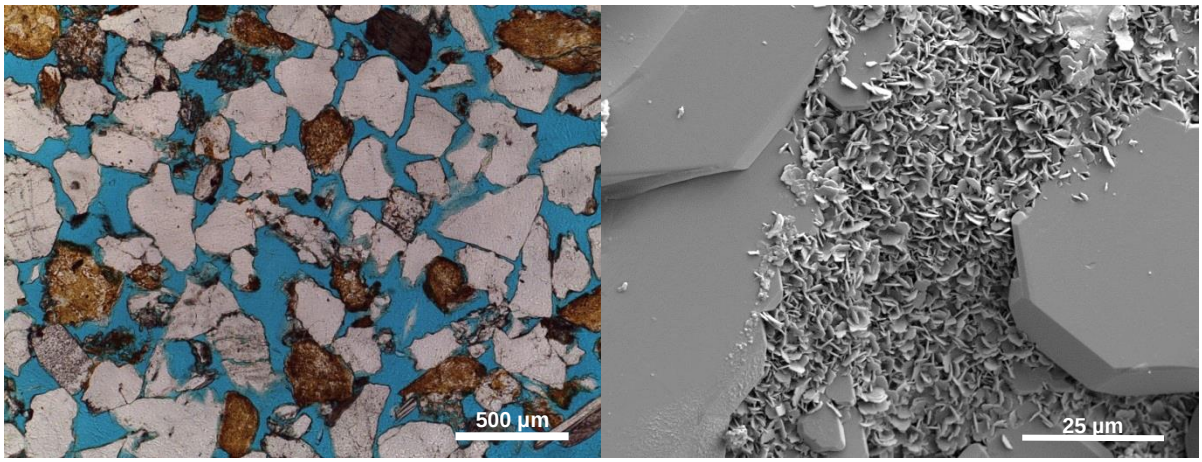

Figure 2: A) Thin section micrograph of an under-compacted Triassic Skagerrak sandstone with anomalously high porosity (30/7a-8); B) SEM image of chlorite grain coating and macroquartz overgrowths (22/29-5RE)

Swept away by a turbidity current in Mendocino submarine canyon, California

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Direct observations of turbidity currents in the ocean are rare, yet essential for validating and developing conceptual models of these enigmatic flows. We present a novel set of observations and measurements collected by a remotely operated vehicle entrained within a turbidity current in Mendocino Canyon, California. The flow had a two layer structure with a thin (0.5 to 30 m), relatively dense (<0.04 vol %) and fast (up to ~1.7 m/s) wedge-shaped lower layer overlain by a thicker (up to 89m) more dilute and slower current. The fast moving lower layer lagged the slow moving, dilute flow front by 14 minutes, which we infer resulted from the interaction of two initial pulses. The two layers were strongly coupled, and the sharp interface between the layers was characterized by a wave-like instability. This is the first field-scale data from a turbidity current to show (i) the complex dynamics of the head of a turbidity current and (ii) the presence of multiple layers within the same event. This data set provides a new perspective on the character of turbidity currents in the ocean. The data pose challenges not simply for understanding the dynamics of turbidity currents but also for how we interpret existing data based on cable breaks and how we might measure similar flows in the future.

The remotely operated vehicle '*Doc Ricketts*' that was used to make the observations presented in this study.

Diagenetic evolution of a Lower Miocene Sandstone (Kishartyán, Northern Hungary)

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The shallow marine sandstone (Pétervására Fm) was deposited via tidal currents during the Eggenburgian in the North Hungarian Bay. In the area of Kishartyán, erosion of the rocks created spectacular forms, such as bed-parallel, longitudinally-arranged, lensoid overhanging blocks. The goal of this study is to investigate the diagenetic history of this formation and if it is possible to find the relationship between sedimentary structures, diagenetic alterations and the present morphology of the sand bodies.

The sandstone is cross-stratified, burrow mottled or structureless due to bioturbation. Composition varies between subarenite and litharenite, grain size varies between very fine and coarse. The most abundant detrital grains are mono- and polycrystalline quartz. Sedimentary rock fragments, such as cherts and dolomites, and metamorphic rock fragments are also common. Ductile grains are represented by micas, altered volcanoclastic rock fragments and glauconites. The distribution of matrix and cement is heterogeneous and their quantity is variable. Matrix-rich sandstone is usually highly compacted, exhibiting long and concavo-convex grain contacts and deformed ductile grains. Matrix-poor sandstone can be well cemented or can have high open porosity, and in both cases the grade of compaction is moderate.

Circumgranular scalenohedral siderite around detrital dolomite clasts is the first eogenetic cement phase and it is abundant in all the investigated samples. Two different types of mesogenetic ferroan calcite cements were distinguished that postdate chemical compaction. 1. Grain-replacive calcite, which displays gradual transition to commonly zoned calcite spar cement. 2. The successive calcite phase fills the remaining pore spaces and it has either equant mosaic or granular morphology. Its Fe content is higher than that of the earlier phase. Other diagenetic components are albite overgrowths cement and replacement in detrital K-feldspars, K-feldspar and quartz overgrowths cements. In the matrix-rich samples, pore-filling kaolinite booklets and pyrite framboids are abundant; additionally mixed-layer illite-smectite structures are also present.

Fluid transport in the Sherwood Sandstone: influences of diagenesis and Sedimentalogical facies

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The Triassic age Sherwood Sandstone Group (SSG) is of great importance to the UK for several applied reasons: i) it is the lateral equivalent of the hydrocarbon producing Lower Triassic (Olenkian) Bunter Sandstone in the North Sea and the Middle Triassic (Anisian) Ormskirk Sandstone in the East Irish Sea; ii) it is a major aquifer in the UK; iii) it has storage potential for anthropogenic CO_2. Increased understanding of the SSG is required to further improve efficiency of extraction, protect aquifers and reduce overall risk associated with such activities. Despite these economically important uses, the SSG has previously seen little work to ascertain any possible connections between primary sedimentological facies and diagenesis. As such, this study has analysed 30 thin sections of fluvial sandstones from 5 boreholes in and adjacent to the Needwood Basin. Using optical microscopy and scanning electron microscopy a diagenetic history was deduced and analysed with respect to sedimentological facies. The diagenetic history of the Needwood Basin SSG is comparable with the SSG from other UK sedimentary basins, with the exception of a lower quantity of well-developed authigenic quartz, feldspar and increased framework grain and cement dissolution. The results indicate that primary sedimentological facies does have a control on subsequent diagenesis. The highest porosities were found in cross bedded sandstones and massive sandstones; the lowest porosities were found in conglomerates and muddy facies; low angled cross bedded sandstones and horizontally bedded sandstones displayed a wide range of porosities. The presence of diagenetic cements had a significant effect on porosity due simply to the reduction in available pore space: calcrete or dolocrete reduced porosity on average by 17.5%, baryte by 23% and iron oxide by 8%. This data can be used to populate databases for use in fluid flow modelling to inform the hydrocarbon industry as well as hydrogeology, predictive models for contaminant transport and green technology including Carbon Capture and Storage and geothermal energy.

There and Back Again, a Mudstone's Holiday: Reworking of Mud and its Implications

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Recent studies have shown that lithic grains recycled from older mudstones can be a significant component (i.e., a framework grain) of mudstones in the rock record (Schieber et al. 2010; Plint et al. 2012; Plint 2014; Schieber and Bennett 2013; Schieber 2015, 2016). Lithic grains of mudstone come into the environment of deposition as lithified, precompacted grains. For this reason, muds that consist mostly of lithic grains of mudstone will experience significantly different compaction histories than freshly deposited muds. The porosity and permeability, and how they evolve with burial, of a lithic mudstone and a laminated claystone will also be different: a lithic mudstone with an initial porosity of 48 vol% compacts about 30% less than a laminated claystone with an initial porosity of 85 vol%. Mudstones are the chief record used for environmental reconstructions in deep time. The composition of lithic grains of mudstone is inherited from the ancient environments in which they formed. The clay mineral assemblage of lithic grains of mudstone is unlikely to be in equilibrium with climatic conditions prevailing in the continental source areas at the time of redeposition. Sediments may thus contain recycled detrital clay minerals that are completely devoid of climatic significance for the time interval in question. Moreover, the organic and inorganic geochemical signature of a lithic mudstone will be contaminated by signals from the past carried by the lithic grains, and may, thus, not reflect synsedimentary environmental conditions. Grain size is sometimes used as a proxy for water depth and relative sea-level change (e.g., Williams et al. 2001). The grain size distribution of a lithic mudstone is meaningless in terms of sediment transport unless we recognize the composite silt to very fine sand lithic grains. Thus, identifying lithic mudstones is vital, if we are to interpret correctly the physical, chemical, and biological record stores in mudstones and the burial history and evolution of source rocks, unconventional reservoirs, and seals.

Diagenesis in a carbonate-evaporite system: Dolomitisation, Dedolomitisation and Limestone neomorphism in the Zechstein (Permian NW Europe)

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Carbonate sediments deposited in close proximity to evaporites usually endure a more complex diagenesis than those with no evaporite association. Sabkha and microbial dolomite precipitation followed by near-surface reflux dolomitisation is the norm. Local meteoric diagenesis may take place. During burial, dolomite recrystallisation takes place, along with anhydritisation and anhydrite cementation. Dedolomitisation – calcitisation of dolomite is also common, taking place soon after dolomitisation through subaerial exposure and contact with meteoric waters, and/or during burial to moderate depths (>400 m) with the dehydration of gypsum to anhydrite, and release of Ca^{2+}-rich fluids. The maturation of organic matter, releasing CO_2, may also promote dolomite dissolution and calcite replacement. In addition during moderate burial, primary limestones and nodular limestones may be recrystallised-neomorphosed to micro- and mega- spar and fibrous calcite. Neomorphism is probably also related to gypsum dehydration, the excess Ca-ions causing the original micritic carbonate to aggrade and replace primary fabrics. The early lithification of the carbonate sediment appears to be a control here, preventing compaction but also inhibiting neomorphism. During further burial, hydrothermal dolomite may precipitate, along with another phase of anhydrite, and possibly fluorite, barite, metal sulphides (pyrite, galena) and even native sulphur. Sulphate-reducing bacteria may be involved. On uplift, significant diagenetic alteration is typical: with evaporite dissolution, further dedolomitisation, and extensive collapse brecciation. The pattern of diagenesis in a carbonate – evaporite succession is illustrated from the Upper Permian Zechstein carbonates at outcrop in NE England and subsurface NW Europe.

Stratigraphy and palaeoclimate of Spitsbergen during the Early Cretaceous

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During the Early Cretaceous, Spitsbergen was located at a palaeolatitude of ~60°N. Abundant fossil wood derived from conifer forests, dinosaur trackways, enigmatic deposits such as glendonite horizons, and stable isotope data from the Early Cretaceous formations of Spitsbergen suggest that the climate at that time was much more dynamic than the traditional view of "invariant greenhouse" conditions on Earth. This project attempts to answer the following questions: Were global changes in the carbon cycle and climate during the Early Cretaceous reflected in the sedimentary regime of Spitsbergen, Svalbard? What can these sediments tell us about climate dynamics in the high latitudes from this time?

The Early Cretaceous succession in central Spitsbergen comprises a regressive-transgressive mega-cycle. This is made up of the deep water to wave-dominated, Berriasian-Hauterivian Rurikfjellet Formation; the deltaic, Barremian Helvetiafjellet Formation; and the coastal to deep water, Aptian-Albian Carolinefjellet Formation. A forced regression (expressed as a regional unconformity) marks the base of the Helvetiafjellet Formation. Two regions with excellently exposed Early Cretaceous strata were chosen for study in this project: The Festningen section, on the north-western side of Isfjorden; and outcrops found along Adventdalen, near Longyearbyen, ~40km southeast of Festningen.

We present the data collected in July 2015 from the Adventdalen area, and compare and correlate it with sedimentological and geochemical data collected from the Festningen succession in 2014. The Festningen section records a full sequence from the Berriasian to the Aptian, whereas the Longyearbyen sections only record Aptian-Albian deposition.

Through C-isotope stratigraphy and sequence stratigraphic methods, we consider whether the primary influences on the variations seen in the $\delta^{13}C_{terrestrial\ org}$ record of these successions are i) depositional setting (local environment and climate), ii) global C-cycle changes and climate, or iii) both; through considering relative sea level change and the eustatic vs local tectonic influence.

Furthermore, we attempt to elucidate the origins of enigmatic glendonites found in both regions. Glendonites are thought to be associated with cold-water (and therefore also cold-climate) conditions, although their mode of origin is poorly understood. By contextualising them sedimentologically and geochemically, we consider their usefulness as cold-climate indicators.

Syn-depositional porosity evolution in the Abu Dhabi Sabkha: A glimpse below mats & crusts

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The Abu Dhabi Sabkha is seen as the most important modern analogue for the dolomitic reservoirs of the Jurassic age Arab Formation. While there is general agreement that the hydrocarbon-bearing Arab Formation depositional system was very similar to that of the modern Sabkha, to date, no detailed analysis has been made that establishes a link between early syn-depositional diagenetic processes and the record of the geological past.

This study examined sediments from below the microbial mats and halite crusts of the Abu Dhabi Sabkha and describes sedimentary facies of both evaporitic and microbial character. The influence of the primary formation of shallow subsurface evaporite minerals on the development of porosity and preservation potential of buried microbial mats is demonstrated. A link is made to overlying surface sedimentary structures and textures, and lateral variations are described. The base of the Late Holocene sabkha parasequence is denoted by a well-developed, laterally extensive carbonate hardground. Despite their significance to sequence stratigraphic reconstructions, hardgrounds have, to date, been difficult to identify in cores from the Arab Formation, this study provides specific criteria to establish this correlation. The sediments above the hardground are texturally and mineralogically akin to those in the cemented horizon, these sediments host abundant, typically isolated, cm- to dm-sized gypsum crystals that can range from inclusion free (clear) to containing abundant inclusions of the host sediment. The inclusions contained within some of the gypsum crystals likely represent the remains of microbial mats from which the primary layering and original colour is still visible. Large gypsum lathes are absent from the supposed sabkha deposits of the Arab Formation, this study proposes a simple diagenetic process for this contrast. The layer of large gypsum crystals is overlain by an alternation of medium and finely grained gypsum sand to gravel that, in turn, transitions up-section into a bright white, approximately 10 cm thick, horizon of anhydrite. The parasequence is capped by a thick halite crust that binds wind-blown sand grains. The preservation potential of these units is also assessed.

A 2-stage model for illite growth in sandstones

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K-Ar age dates of authigenic illite in oilfield sandstones are conventionally interpreted as 'events' of illite growth, with no significant subsequent alteration, hence preserving the illite age. A two-stage model of nucleation and growth is proposed, with the implication that K-Ar ages are continuously modified during burial, and will require modelling for correct interpretation. Authigenic illite fibres viewed in a SEM, which rarely exceed a few 10's μm in length and a few μm in width, are formed of large numbers of much smaller so-called fundamental particles which can only be imaged on a TEM. Nucleation is more crucial for illite growth than for other minerals as the fundamental particles are very small (<< 1 μm) so that to grow 1 % of illite in 1 cm^3 of sandstone requires nucleation to occur c. 10^{13} times. It is also difficult – a simple model for heterogeneous nucleation indicates that it is far more difficult to nucleate illite than quartz (which itself usually grows syntaxially as overgrowths, avoiding the necessity of nucleation, as such). This leads to nucleation only under unusual conditions, e.g. during oil charging at high porefluid saturations which lead to a fibrous morphology.

However, the potassium content of the illite increases systematically with present day burial depth – but has no relationship with the depth at which the illite is supposed to have formed. In addition, the measured thickness of the fundamental particles increases systematically with depth, and the normalised crystal size distribution fits a surface-controlled growth mechanism – which does not fit with rapid growth at high supersaturation, but with slow thickening by spiral growth. These all show that the previously nucleated illite is altering, by the slow thickening of the fundamental particles, over 10's of millions of years.

Combining the above, the illite nucleates in 'events' associated with, e.g. oil charging, with the formation of thin, low-K fundamental particles. Subsequently, the fundamental particles thicken, and increase in K as the ratio of surface to interior decreases. As a consequence, K-Ar ages must be modelled with the addition of K-rich illite, and Ar-generation by radiometric decay, for full interpretation.

Biofilm origin of clay coated sand grains: Understanding the fundamental processes governing the origin and distribution of clay-coated sand grains in petroleum reservoirs through a modern day analogue

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The ability to predict the occurrence of clay coated sand grains is essential in the exploitation of deeply buried anomalously high porosity hydrocarbon-bearing sandstones, resulting through the inhibition of the normally ubiquitous porosity-occluding quartz cement. However at present there is limited understanding of the origin of clay coats and no all-encompassing predictive model of clay coat abundance and distribution at a facies scale. To address this, we have focused on the distribution and origin of clay-coatings in modern sedimentary environments as a crucial step towards building a predictive capability.

This study adopted a high resolution analogue approach using the Ravenglass marginal marine system, NW England, UK. The work involved detailed analysis of the modern sedimentary system, including mapping surface sedimentary bedforms and bioturbation-intensity, grain size analysis and shallow cores. A range of scanning electron microscopy techniques were employed to characterise surface and core sediment samples in unison with Raman spectroscopy to study the distribution patterns and characteristics of clay coats on sand grains.

These exceptional data sets have produced unique and highly detailed maps that have started to reveal, for the first time, the pivotal role that biofilms (specifically diatom generated) play in the formation and distribution of intertidal detrital clay coated sand grains. Illustrating another pivotal biological sediment interaction, an original mechanism of clay coat formation and offering a crucial step towards building a predictive model. The results of which can be applied to aid the prediction of advantageous grain coating chlorite in sandstone reservoirs and thus facilitate prediction where the degradation of reservoir quality in ancient, deeply-buried petroleum reservoirs by quartz cement has been inhibited.

Forward stratigraphic modelling of the architecture of meandering river deposits

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Stratigraphic successions of fluvial point bar elements are typically characterised by vertical and lateral heterogeneity whereby sand-prone packages are draped and partitioned by mud-prone deposits of variable thickness and continuity in response to temporal and spatial variation in depositional processes. A numerical stratigraphic model has been developed to assist in understanding physical and geomorphic processes by which lithofacies are distributed within fluvial point bar elements in response to changes in flow processes associated with temporal meander evolution, neck or chute cut-off, and major flood events. Using a mixed process- and geometric-based approach, the model is able to reproduce changes in morphology and architecture of channels and associated point bar elements due to bar expansion, translation and rotation. The model is employed to predict the 3D distribution of sand- and mud-prone deposits in both plan-form and section for single or multiple overlapping point bar and channel elements. The model uses stochastic approaches to depict inherent natural variability in architectural-element size, shape, orientation, distribution, and migration trajectory. Properties of real-world modern and ancient examples contained within an architectural database are used to determine the expected growth trajectories of different types of meanders and the distribution of lithofacies within accumulated elements. The distribution of facies varies predictably around meander bends according to bend tightness and distance from bend apex. Downstream translation of plan-form concave and convex meander segments tends to accumulate mud-prone counter-point bar deposits and sand-prone point bar deposits, respectively. The model also accounts for temporal changes in facies distribution in response to neck and chute cut-off, oxbow lake development, and nodal avulsion that induces abandonment of entire reaches. The model is employed to demonstrate its capability to simulate the evolutionary history of the following: (i) recent point bar and channel belt development from the Songhua River, China; (ii) ancient point bar elements from the Jurassic Scalby Formation, Cleveland Basin, England.

Poster abstracts

Quantify Porosity from Cuttings using QEMSCAN

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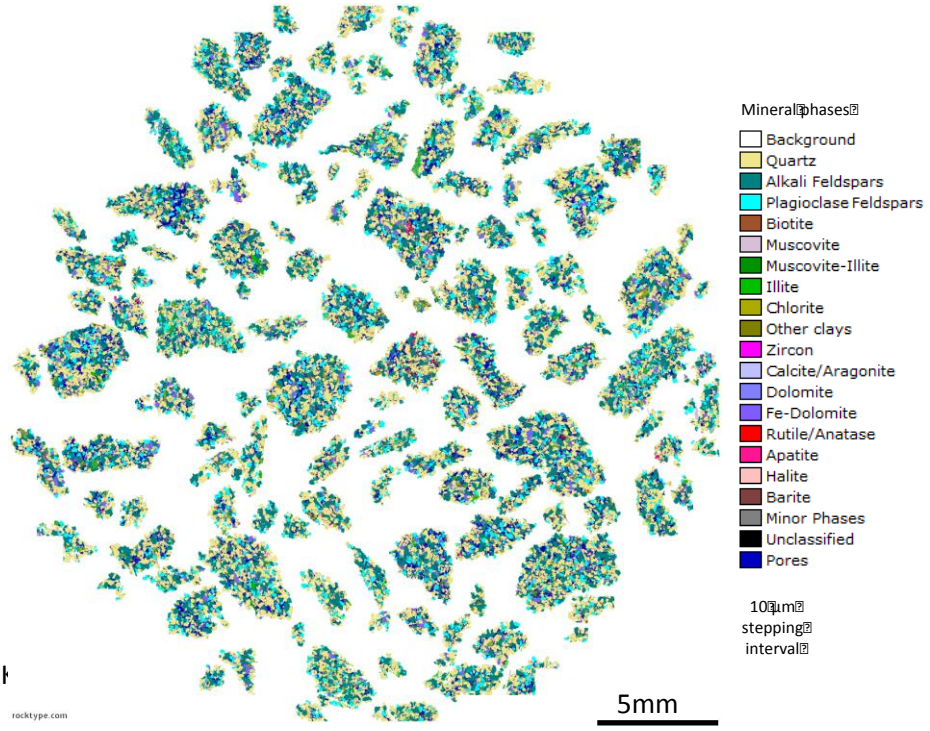
QEMSCAN by FEI is an SEM-based petrographic tool that provides a fully digital dataset of mineralogy, chemical composition, porosity, rock properties and rock texture, from a single analysis. Ditch cuttings represent a hugely underutilised resource that QEMSCAN analysis can transform into valuable data. This dataset particularly valuable as cuttings are collected for all wells and therefore represent the most frequent sampling of the reservoir available for analysis.

One of the challenges of working with cuttings is that one sample contains a variety of lithologies. Using QEMSCAN's iDiscover software, we are able to group cuttings into lithotypes based on their minerogical and textural characteristics. Host rock information is isolated from drilling mud contaminants by 'digital washing' of the images and data.

Whole rock porosity can be estimated from careful analysis of the lithotyped cuttings. This workflow includes the selection of representative cuttings for analysis and filtering of the resulting data to exclude the damage done to the host rock by the drill bit, which disaggregates the rock preferentially along larger pore networks.

To illustrate this method, we present QEMSCAN results from the Triassic Skagerrak reservoir of the CNS Skua Field well 22/24b-7. Core samples have been crushed to create 'synthetic' cuttings and the properties of the core samples and cuttings are compared, offering important information on the steps required to elucidate whole rock properties from cuttings material.

Lithotypes can be correlated to petrophysical logs and therefore this method creates the opportunity to upscale the properties of cuttings to the reservoir scale and improve reservoir models.



Triassic to Early Jurassic climatic trends recorded in the Jameson Land Basin, East Greenland: clay mineralogy, petrography and heavy mineralogy

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During the Early Triassic the Jameson Land Basin (Central East Greenland) was located around 30ºN, in the Northern arid belt, but by the Late Jurassic was positioned at a latitude of approximately 60ºN. This study examines the record of this transition through a largely continental succession using clay mineralogy, sedimentology, petrography and heavy mineralogy.

The Jameson Land Basin is aligned north-south and is 280 km long and 80 km wide. Following an Early Triassic marine phase the basin was filled by predominantly continental sediments. The Early to Late Triassic succession comprises coarse alluvial clastics (Pingo Dal Formation) overlain by a succession of fine grained evaporite-rich playa/lacustrine sediments (Gipsdalen Formation), indicative of arid climatic conditions. The overlying buff, dolomitic and then red lacustrine mudstones with subordinate sandstones (Fleming Fjord Formation) record reduced aridity. The uppermost Triassic grades into dark organic-rich, and in places coaly, mudstones and buff coarse grained sandstones of lacustrine origin that belong to the Kap Stewart Group, which spans the Triassic-Jurassic boundary, and appear to record more humid climatic conditions.

Clay mineralogy analyses highlight significant variations in the kaolinite/illite ratio, from both mudstone and sandstone samples, through the Triassic and into the earliest Jurassic. Complementary heavy mineral analyses demonstrate that the variations recognised in clay mineralogy and sandstone maturity through the Triassic-Early Jurassic succession are not a product of major provenance change or the effect of significant diagenetic alteration. The observed variations are consistent with sedimentological evidence for a long term trend towards more humid conditions through the Late Triassic to Early Jurassic, and the suggestion of a significant pluvial episode in the mid Carnian.

Understanding the impact of climatic and provenance change on sandstone maturity is key for hydrocarbon reservoir prediction in adjacent basins.

Climate change and the response of river landscapes: insights from the sedimentary architecture of fluvial systems across the Paleocene-Eocene boundary

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The Paleocene-Eocene Thermal Maximum (PETM) was a brief episode of extreme global warming that occurred at ca. 56 Ma. The preserved sedimentological expression of the PETM as recorded in different fluvial successions allows a significant test of the sensitivity of fluvial architecture to a climatic driver, and of the geomorphic impact of hyperthermal events on terrestrial landscapes.

To evaluate the response of fluvial systems to the PETM, a meta-study has been carried out to compare the sedimentary architecture of continental successions from four different basins (Tremp-Graus Basin, Spain; Uinta Basin, USA; Piceance Basin, USA; Bighorn Basin, USA). Sedimentological data derived from both original outcrop studies and published datasets were collated into a database that stores quantified architectural data in standardized format, to facilitate comparisons.

Sedimentological characteristics are compared in relation to their timing relative to the PETM, and across the studied successions, with the aim of detecting common threads and potential controls on particular responses. Features that are compared include the abundance, geometry and distribution of fluvial channel complexes, architectural elements and lithofacies, which can be interpreted in terms of geomorphic processes and forms.

Similarities in the evolution of large- and mid-scale sedimentary architecture of the studied successions, and particularly the fact that increased channel-body density is seen in intervals that correspond to or contain the PETM, in association with increased channel-fill and barform thickness, can been considered in terms of how these factors likely governed the mobility, planform density, size and geomorphic behaviour of fluvial channels. However, lithofacies data indicate that the response of channel-filling processes to the climatic signal was variable across the studied basins. Changes in the nature of the preserved sedimentary record of channel deposits (grainsize and sedimentary structures) across the PETM vary from modest to significant, and corresponding degrees of variations are inferred for the calibre of sediment supplied and the discharge regime. Results suggest that, if a common control had been the dominant cause of larger scale stratigraphic trends across the four basins, this must be a factor that has limited influence on in-channel depositional processes.

The stratigraphic architecture of shallow marine systems in syn- to post-rift settings

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Stratigraphic traps in mature hydrocarbon basins are targeting syn- and post-rift packages, with a need for more sophisticated stratigraphic models to enhance reservoir prediction capabilities. This project will address the challenge of developing widely applicable, shallow-marine stratigraphic models in syn- and post-rift settings, where the relative influence of major sedimentary controls generate a complicated depositional architecture. In syn-rift settings, parameters such as tectonic subsidence, eustatic sea level, sediment supply, process regime, climate and basin physiography interact to control accommodation and thus facies stacking patterns. In post-rift settings, dynamic gradients and depocentres that influence sediment dispersal patterns and processes need to be considered. A further factor is the role of provenance on the lateral variability of sediment flux and calibre along the length of partially submerged footwall highs. In considering the two settings, this study will focus on the stratigraphic architecture at the transition between the syn- and post-rift, where seismic resolution precludes the detailed reconstruction of the evolution, yet a better understanding would facilitate reservoir seal and trap prediction. At the transition, a 'break-up unconformity' is often defined but rarely described in detail. Hence, we intend to investigate the different ways this transition manifests in the rock record, particularly at outcrop scale, and to elucidate the interplay of the different controls on the stratigraphy. Quantifying such processes is an important procedure in developing conceptual models for industry application to subsurface systems. As such, the study will analyse exhumed (e.g. Lotena Formation, Neuquén Basin, Argentina) and subsurface (e.g. Fulmar Formation, North Sea) syn- to post-rift shallow marine systems, utilising a swath of data, including: 3D seismic, well-log, core and outcrop. It will also build on and incorporate previous studies from the Gulf of Corinth, Greece to contribute and further our scientific understanding of stratigraphic control interaction.

The Ghaggar-Hakra Formation: The final chapter

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The Ghaggar-Hakra sediments of the Barmer Basin, India are an example of a fluvial system. However, the facies, architectural elements and depositional environment have never been studied in detail. This work documents the depositional regime of this Lower Cretaceous fluvial system, to determine its style, the controls upon it and its hydrocarbon potential.

At outcrop, the deposits of the Ghaggar-Hakra Formation contain three dominant sandstone successions known as the Darjaniyon-ki Dhani, Sarnoo and Nosar sandstones, these three sandstones represent fluvial systems of differing fluvial style. The intervening mudrocks are mottled, with vertical fractures, soil slickenlines and a pedogenic nature, and are characteristic of floodplain deposits. The Darjaniyon-ki Dhani Sandstone is composed of gravel bars, in-channel and floodplain sediments. The sedimentary structures within are crude and of the succession is structureless, this system is a bedload dominated, low sinuosity fluvial system. The Sarnoo Sandstone comprises channel sediments, gravel bars, point bars, chute channels, sheetfloods and floodplain sedimentation. The sets and cosets of ripples and cross-beds are consistent suggesting a dominant flow direction and the development of point bars, indicate a high sinuosity fluvial system, flowing westwards. Capping the formation is the Nosar Sandstone which is highly erosive into the underlying floodplain and contains channel sediments, gravel bars, sheetfloods and small packages (≤1 m thick) of floodplain sediments. Here, the sets and cosets are irregular and there is a significant increase in the amount of quartz clasts when compared to the Sarnoo Sandstone, these architectural elements indicate a well-developed bedload dominant low sinuosity fluvial system, which flowed southwest.

This rejuvenation of the fluvial system between the Sarnoo and Nosar sandstone is suggestive of extensional tectonics as the differences in sedimentation, along with variations in palaeocurrent are attributed to the influence of local extension at the eastern basin margin. We suggest that fluvial style of the Ghaggar-Hakra in this area is very strongly influenced by the Indian – Madagascan event, which was orientated in a northeast – southwest orientation.

Can modern analogues be used to reconstruct pre-land plant environments? A case study from the Ordovician-Silurian Tumblagooda Sandstone, Western Australia

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The depositional processes and characteristics of clastic sediments in modern environments are influenced by terrestrial vegetation. Vegetation controls weathering and erosion rates and subsequent sediment supply; it also binds the substrate influencing how channels migrate. To evaluate the applicability of current depositional models that include the role of vegetation, this study examines the Ordovician-Silurian Tumblagooda Sandstone Formation of Western Australia.

The earliest study of the Tumblagooda Sandstone Formation (Hocking 1991) identified five facies associations and interpreted FA2 as deposition within an intertidal flat environment with intermittent exposure. Subsequently Trewin (1993) concluded that FA2 was dominated by aeolian processes and so interpreted the association to be continental. The aim of this reconnaissance study is to try to resolve the interpretation and detail the sedimentology in order to model the environment of deposition. It is possible that the factor influencing the different interpretations is the lack of land plants.

There is a lack of mud preserved in the sections which could be due to either mud not being generated; not being bound and preserved or the mud is being washed out into the distal basin.

Key sedimentary structures include double crested, ladder and symmetrical ripples, interpreted as deposition from bi-directional flow. Herringbone cross-stratification was not observed. Rain drop surfaces, adhesion structures, blown out, flat topped and washed out ripples suggest the environment was subjected to periodic exposure. Laterally discontinuous, erosive based fining upward units are interpreted as tidal channels. Not present are large scale aeolian dunes, inverse graded and pin striped lamina and interdune deposits. Body fossils are rare and there is no shell fragments found.

A working interpretation is that the deposits were formed within a restricted microtidal bay with an absence of mud deposits. The bay was sheltered by barrier sands which allowed small tidal channels to form. Water levels were shallow allowing only small ripples to form. At periods of low tide subaerial exposure allowed wind to rework ripples and develop adhesion surfaces. Laterally shallow interdistributary areas developed on large flat sandy planes with straight crested sandy bars. Occasionally when flow was more rapid, bars would become sinuous crested.

Basin-Scale mineral and fluid processes at a palaeo-platform margin, Lower Carboniferous, UK

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The Derbyshire Platform is a Lower Carboniferous rimmed shelf, the westernmost expression of the East Midlands Platform, located on the southern margin of the Pennine Basin. The SW margin of the Derbyshire Platform, has been pervasively dolomitised across an area of approximately 50km^3, primarily forming halos around NW – SE trending structural lineaments. The dolomite is cross-cut by NW-SE and NE-SW trending calcite, fluorite, galena and barite cemented fractures. This mineralisation has been dated as Late Carboniferous to early Permian in age, indicating that dolomitisation was an earlier, Carboniferous, event. The body is one of several discrete, fault-fracture controlled dolomite bodies that occur on Lower Carboniferous platform margins across the Pennine Basin and North Wales.

Fluid flow modelling indicates sufficient fluid volumes for dolomitisation could have been supplied along faults from the juxtaposed basinal sediments, but there was insufficient Mg to explain the calculated volume of dolomite. Reactive transport models indicate geothermal convection of seawater on the platform margin could have initiated dolomitisation, but preliminary geochemical data is consistent with dolomitisation from evolved basinal brines that interacted with siliciclastic sediments and/or volcanics.

This study will use outcrop and newly available borehole core from the southern margin of the Derbyshire Platform to better constrain the timing and mechanism for dolomitisation. Early results indicate that dolomitisation is usually fabric destructive with a range of textures that suggest multiple phases of fluid flux. Geochemical data suggests that slightly modified seawater, with a contribution from hydrothermal fluids, was responsible for dolomitisation. These data will be expanded to refine the interpretation and test the hypothesis dolomitisation by geothermal convection of seawater during early burial by seawater was an important pre-requisite for later dolomitisation by hotter, more evolved basinal brines expelled by compactional flow from ruptured, overpressured sediments in the adjacent Widermerpool Basin.

Waking (another) sleeping giant? The effect of carbonate diagenesis on pore systems in the Bakken Formation, USA.

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The largest continuous oil accumulation ever assessed by the USGS, the Bakken Formation in the Williston Basin, USA, is a mixed conventional and unconventional oil resource. Until recently the tight nature of the middle Bakken had made hydrocarbon extraction challenging. New opportunities opened up with the development of drilling techniques in conjunction with new ideas such as the 'sleeping giant hypothesis' by geologist Dick Findley. He suggested that large oil resources were present in the middle and could be accessed by identifying dolomitic horizons within the middle Bakken shales. We build on this hypothesis to identifying new sweet-spots within the middle Bakken.

Most oil is produced from the middle Bakken unit, a heterogeneous siltstone/sandstone unit in which variable amounts of dolomite and calcite cement exert a key control on porosity and thus reservoir quality. In carbonate-cemented zones, characterisation of the pore system by mercury intrusion experiments reveal pore throats <40nm in diameter, comparable to shale. Imaging of pores using highly polished BIB-SEM (broad ion beam) images supports this finding, indicating that carbonate-cemented zones of the middle Bakken are porous. Whilst porosity has been preserved and created at the core of some dolomite phases, these pores are unconnected, do not contribute to the reservoir quality and are not detected by direct porosity measurements.

Carbonate cement exerts a first order control on porosity and reservoir quality in the middle Bakken. Nevertheless, whilst XRD analysis indicates that regions of high porosity correlate with low dolomite abundance, detailed petrographic examination by electron microscopy reveals multiple phases of calcite, dolomite and ferroan dolomite, each of which contributes individually to the degradation of reservoir quality. Previous studies have struggled to unravel the timing and history of porosity-occluding carbonate cement due to its exceptionally fine-grained nature. We have used sequential acid dissolution in order to separate calcite and dolomite to determine the carbon and oxygen stable isotope composition by conventional mass spectrometry. The range of carbon and oxygen values is large and suggests multiple phases of cementation, allowing a more nuanced understanding and thus prediction of how carbonate cementation has influenced the destruction, preservation and creation of porosity.

Targeting tight aquifers in deep sedimentary basins for geothermal exploration

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Geothermal resources in the UK could prove a significant, low-cost energy source for domestic and industrial use. The scope of the project is to investigate the potential of developing deep (4 Km+) geothermal energy in the tight, sedimentary aquifers within the Cheshire basin. The low enthalpy geothermal resource involves wells that penetrate permeable aquifers, heated by conductive heat flow from the Earth's natural thermal gradient. Analysis of well logs, seismic datasets and outcrop exposures will be undertaken to improve the understanding of deep aquifers within the basin and their hydrogeological properties.

Two well sites have been investigated in the Crewe area of the Cheshire Basin, Leighton and Crewe Centre. Seismic interpretation has been used to better constrain aquifer thickness and predict potential geology for each well site. The Leighton well has shown a 2812 m gross thickness of aquifer, whilst the Crewe Centre well would provide a slightly lower gross thickness of 2654 m.

The project will be characterising the hydrogeological properties of the high porosity / permeability sandstone and conglomerate from Permo – Triassic rocks at these two sites. The gross thickness of aquifers could be in hydraulic continuity, depending on the lithology and extent of the Manchester Marl formation, impacting on the potential performance of the geothermal scheme. Sedimentary and petrophysical information from Westphalian strata in the Keele formation will be used to provide improved estimates of hydraulic conductivity in the deepest part of the basin and, therefore, better assessments of gross aquifer volume. Aquifers at greater depths could prove problematic due to reduced porosity and permeability through compaction and cementation.

Our preliminary geological and temperature predictions, based on existing deep boreholes (Prees and Knutsford), indicate that the base of the Permian (~4 km) will be at 75 – 90 ° C. At these temperatures, and with such significant gross rock volume of potential aquifers, the extraction of energy through geothermal resources could provide significant quantities of cheap energy through a binary power plant and optimised district heating network.

Interpreting syn-depositional sediment remobilisation and deformation beneath submarine gravity flows – a kinematic boundary layer approach

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Turbidite sandstones and related deposits commonly contain deformation structures and remobilised sediment that might have resulted from post-depositional modification such as down-slope creep (e.g. slumping) or density-driven loading by overlying deposits. However, we consider that deformation can occur during the passage of turbidity currents that exerted shear stress on their substrates (whether entirely pre-existing strata, sediment deposited by earlier parts of the flow itself or some combination of these). Criteria are outlined here, to avoid confusion with products of other mechanisms (e.g. slumping or later tectonics), which establish the synchronicity between the passage of over-riding flows and deformation of their substrates. This underpins a new analytical framework for tracking the relationship between deformation, deposition and the transit of the causal turbidity current, through the concept of *kinematic boundary layers*. Case study examples are drawn from outcrop (Miocene of New Zealand, and Apennines of Italy) and subsurface examples (Britannia Sandstone, Cretaceous, UKCS). Example structures include: asymmetric flame structures, convolute lamination, some debritic units and injection complexes together with slurry and mixed slurry facies. These structures may provide insight into the rheology and dynamics of submarine flows and their substrates – and have implications for the development of subsurface turbidite reservoirs.

Evolution of Clastic Coastal Depositional Systems in the Campanian of the Western Interior Seaway, North America

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The Late Cretaceous shallow marine deposits along the western margin of Western Interior Seaway of North America have been extensively studied and contain a wealth of data related to the nature and origin of clastic coastal depositional systems. A regional synthesis is presented in the form of a suite of palaeogeographic maps, which document the spatial and temporal evolution of the clastic coastlines during the Campanian. In this study, palaeogeographies for stratigraphic intervals contained within six ammonite zones from the Campanian have been compiled for New Mexico, Utah, Colorado and Wyoming. The six zones are chosen to represent the maximum transgression and regression for two wave-dominated and one tide-influenced interval in the Book Cliffs, which lies at the centre of the study area. Nine gross depositional environments have been mapped for each zone: (1) basinal limestones, (2) marine mudstones, (3) marine gravity flows, (4) shelfal sandstones, (5) shallow marine sandstones, (6) tide-influenced fluvial sandstones and mudstones, (7) fluvial sandstones and mudstones, (8) fluvial sandstones and (9) fluvial and alluvial conglomerates. For each interval, the depositional process (fluvial, wave and tidal processes) and associated types of coastal morphology have been mapped. Additionally, sediment transport pathways, active tectonics and thickness changes have been documented in order to assess their impact on lateral and vertical changes in sedimentation and depositional processes. All the shallow marine deposits contain thin tide-influenced intervals above abandonment surfaces, which were deposited in back barrier systems of transgressive shorefaces and estuaries, including incised valleys. However, it is notable that all tide-influenced regressive deltaic systems are located along the northern margin of the "Utah Bight" embayment during the middle Campanian. The southern margin and coastlines north of the embayment were exposed to a larger wave-fetch, which caused their coastlines to be more wave-dominated. In contrast, the northern margin of the embayment was protected against wave reworking, while the embayment amplified the tidal range causing an increase in tidal influence in the protected northern part of the embayment.

Origin of Upper Cretaceous volcaniclastic sandstones (Kannaviou Formation) in SW Cyprus

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There is current international interest in the initiation of oceanic island arcs (e.g. IODP Expeditions 350-352). Such early arc units may not be preserved in the stratigraphic record. However, related volcanogenic sediments may be widely dispersed and so can provide information on early island arc genesis.

In Cyprus, the U. Cretaceous Troodos Ophiolite formed above a subduction zone at ca. 90Ma and is overlain in the west of the island by volcanogenic sediments, dated palaeontologically at ca. 80 Ma (Campanian-early Maastrichtian). In the SW Pacific (e.g. Izu-Bonin region) arc volcanism followed ca. 8-10 Ma after supra-subduction zone ophiolite genesis. Do the Cyprus sandstones record early stage oceanic arc volcanism or instead the products of continental margin arc volcanism (known to have occurred elsewhere in the region during the Late Cretaceous)?

The Kannaviou Formation is represented by medium- to coarse-grained volcaniclastic sandstones, which were mostly deposited by gravity flows, interbedded with smectite-rich clays and deep-sea radiolarian mudstones. Abundant vesicular volcanic glass is present, together with common monocrystalline quartz, plagioclase and felsic volcanic lithics. Less common components include clinopyroxene, muscovite, biotite, hornblende and pelagic bioclasts. Fourteen samples were point-counted using the Gazzi-Dickinson method. The average framework composition ($Q_{24}F_{39}L_{37}$) is suggestive of a dissected arc, to transitional arc source. Scanning electron microscope images indicate the presence of abundant uncrystallised volcanic glass, together with other detrital and diagenetic components. Chemical analysis of major and trace elements using X-ray fluorescence indicates a magmatic arc source. Rare Earth Element analysis by Laser Ablation Inductively Coupled Plasma Mass Spectrometry is suggestive of an oceanic island arc source and, or a continental margin arc source using different discriminant diagrams. Ion microprobe analyses of volcanic glass, plagioclase, pyroxene and hornblende are compatible with a volcanic arc provenance. The terrigenous material, however, is indicative of a continental contribution.

To further characterise the provenance, on-going research includes additional fieldwork, U-Pb dating of detrital zircons and ion microprobe analysis of trace elements in volcanic glass. Upper Cretaceous felsic extrusive rocks occur in the Kyrenia Range, N Cyprus and may have a similar origin to the Kannaviou Formation; this is being investigated.

The Continental Shelf: a Conveyor or Filter of Sediment to Deep Water

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Despite recent advancements in source-to-sink analyses, the critical role played by the continental shelf in regulating sediment transfer to deep-water remains poorly understood. There is a need to better-constrain the buffering role played by the shelf on sediment dispersal patterns, in terms of both morphological and sedimentological parameters. The key question to be answered is '*how* and *when* is sediment of different calibre and maturity transported off the continental shelf?'

In order to address this problem, the sedimentary and geochemical character of quasi-coeval deep- and shallow- marine sandstones at IODP Expedition 313, Offshore New Jersey, USA, will be investigated; this provides an ideal study area due to the preservation of complete clinothem sequences. Furthermore, the New Jersey clinoforms provide the unique opportunity to characterise sediment of stratigraphically linked shelf (topset) and basin-floor (bottomset) deposits under end-member shelf-process regimes, and to assess how these properties change both spatially and temporally.

This investigation will strategically sample the glauconite-rich sandstones, for the quantitative analyses of grain size distribution, shape metrics and sorting. It is expected that the spectra of sedimentary characteristics will enable reconstructions of the hydrodynamic qualities of transport from the shelf, and the associated depositional processes within the deep-water. Additional geochemical analyses will indicate chemostratigraphic changes accompanying changes in textural maturity; specifically, the trace-element composition of sand and variability in glauconite maturity, density, and composition will be used as indicators of sediment residence time on the shelf.

It is anticipated that this dataset will provide a unique perspective into the boundary conditions, which control the sedimentary character of basin-floor sands. The excellent stratigraphic linkage and tight age control of genetically-related deposits at IODP Expedition 313, may also enable constraints to be placed on the relative flux and timing of sediment transfer across the continental shelf. In the future, similar approaches will be tried on shelf-basin data from the Palaeogene North Sea (Dornoch to Forties). This study aims to increase understanding of the complicated relationships that exist between quasi-coeval shelf and basin sands, and thus reduce ambiguity during the prediction of deep-marine sandstone reservoir qualities.

Mats & crusts: A microbial extension to Wilson's standard facies model

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The standard facies model for carbonate shelf margins introduced by James Lee Wilson in his 1975 book 'Carbonate facies in geologic history' presents an important summary of the different types of facies one might come across during analyses of sediments from both carbonate platform and shelf environments. In this study, an extension to Wilson's model will be presented that refines his standard facies belts for restricted platforms and platform evaporites (standard facies belts 8 and 9), with a specific focus on surficial microbial mat and evaporitic sedimentary facies.

Our facies belts are derived from spatial and temporal observations of sedimentary structures, textures and geochemical analyses of sediments from multiple transects across the Abu Dhabi Sabkha. These observations are compiled into a morphological zoning scheme, that contains seven major zones spanning the lower intertidal to supratidal. These facies belts can be broadly summarized as bioturbated lower intertidal peloidal packstone passing onshore into three microbial mat facies (spongy mat, leathery mat, warty mat) followed by a featureless transition zone before culminating in halite facies (ephemeral halite, long-lived halite). Each major zone has been further subdivided into sub-facies types that correspond to the major morphological sedimentary identification criteria.

First results of this study reveal that the facies belts can be followed continuously along the Abu Dhabi Sabkha coastline, but the lateral extension of individual belts most likely depends on subtle variations in slope angle. A high angle slope exhibits narrower facies belts whilst a low angle slope characterises wider facies belts. Under these circumstances, even a cm-scale transgression would severely change the distribution of facies belts across the Sabkha. Evidence for a present-day transgression is visible through backstepping of facies belts, amongst other indicators.

Characterisation of Deep-Lacustrine, Partially-Confined, Slope Apron Turbidite Fans: Examples from the North Falkland Basin, South Atlantic.

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Deep-lacustrine turbidite deposits are still globally vastly understood, with very few examples of such systems described in the literature. Lacustrine basins are well-documented as globally-prolific hydrocarbon provinces and tend to accumulate thick deposits of world-class source rocks. The North Falkland Basin (NFB) is no exception to this. If successfully charged, any adjacent or overlying sandstones have the potential to form excellent hydrocarbon reservoirs. Here, we use the prime example of the early post-rift, sand-rich Sea Lion turbidite fan from the NFB to detail and describe generalised facies distributions in such poorly-understood systems.

The NFB is a north-south trending failed-rift basin, associated with the opening of the South Atlantic in the Late-Jurassic to Early-Cretaceous. The Sea Lion Fan forms part of the early post-rift, stacked, slope-apron turbidite system that fringes the eastern-margin of the basin. This particular turbidite fan was drilled by exploration well 14/10-2 in 2010, leading to the first oil discovery in Falkland Islands territorial waters. Since the initial discovery well, the Sea Lion Fan has been penetrated by an additional seven appraisal wells.

The production of depositional facies models that accurately reflect the distribution of reservoir-quality sandstones in such systems is fundamentally crucial in understanding deep lacustrine turbidite fans. Here we present the results of the 14/10-2 discovery well drilled in the Sea Lion Fan. These data have been fully-integrated with 3D seismic data, wireline and conventional-core from other non-released wells, culminating in the production of a three dimensional static facies model of the Sea Lion Fan.

This particular example of a deep-lacustrine turbidite system indicates their potential to be highly complex, heterogeneous systems. The complex interplay between stacked facies zones, coupled with high-degrees of lateral variability in partially-confined systems, results in these systems being difficult to predict & model. As a consequence, given that there are still numerous examples of non-drilled, early-post-rift hydrocarbon targets within the NFB, improved understanding of such complex, heterogeneous systems is crucial in informing the future exploration efforts and ultimately future success of the North Falkland Basin.

Clinoform architectures and trajectories in the Taranaki Basin, New Zealand

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The importance of shelf margin evolution has increased in recent years as hydrocarbon exploration targets have shifted to deepwater areas; this has resulted in a need for greater understanding of sediment dispersal along continental margins in order to predict position, timing and nature of deepwater deposits. The evolution of these continental margins can be studied in detail by dissecting clinoform architectures. These clinoforms are controlled by the interplay of accommodation and sediment supply which has traditionally been studied using sequence stratigraphy, trajectory analysis and seismic geomorphology of 2-D seismic lines parallel to depositional dip.

This study focuses on the Giant Foresets Formation (GFF), which comprises a strongly progradational architecture from Late Miocene – Recent with continental margin-scale clinoforms up to 1500m in height.

This clinoform succession is being studied using regionally extensive 2D and 3D seismic datasets calibrated with petroleum exploration wells to investigate the along margin relationship between clinoform stacking patterns and sediment distribution. A sequence stratigraphic framework will be developed in order to relate interpretations back to eustatic, tectonic and oceanographic processes with the ultimate goal of aiding prediction of deepwater deposits.

Observations of regional patterns in shelf edge trajectories presented in this poster illustrate the basis of ongoing work relating along margin sediment distribution and clinoform stacking patterns.

Trajectory Analysis carried out on a series of regional 2-D seismic dip lines along the basin margin illustrate three major groupings in the trajectory of the shelf break. Group 1 shows a descending to flat trajectory, Group 2 a sharp rising trajectory and Group 3 a gently ascending trajectory. Along margin variation in these patterns are observed from south to north (proximal to distal) and are detailed further in this poster.

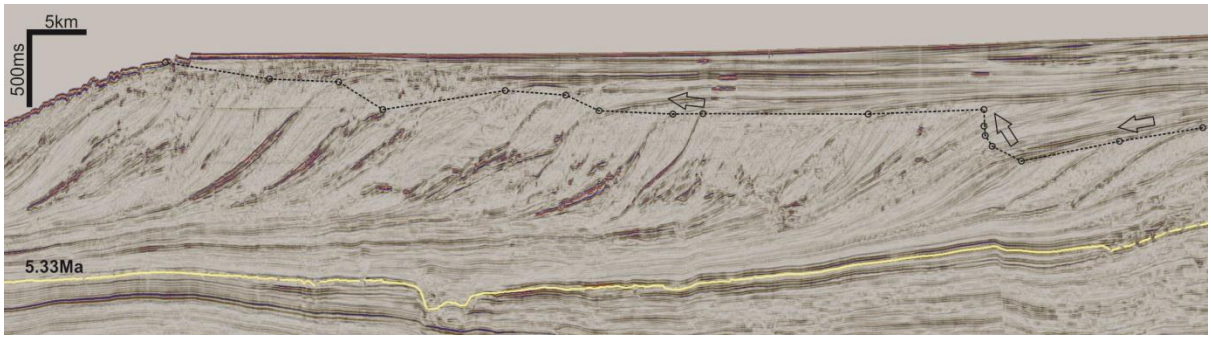

Figure 3 Seismic Line DTB01-31 in the Taranaki Basin New Zealand showing clinoforms of the Giant Foresets Formation and associated shelf edge trajectories.

Controls on stratigraphic development and reservoir distribution of shelf margin carbonates: Jurassic Atlantic margin - western Morocco

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The Late Permian-Triassic Atlantic rifting phase resulted in the opening of the central Atlantic margin during the Early Jurassic. Jurassic deposits recorded thus the initial post-rift sedimentation along the margin and constitute a new hydrocarbon play offshore Morocco. Discoveries in the Upper Jurassic reefal carbonates of Cap Juby in the Tarfaya Basin, southern Morocco, and of Panuke, in the conjugate margin of Nova Scottia, Canada, proved the hydrocarbon potential of this basin. In order to understand to potential of Jurassic reservoirs and possible source-rocks, a coherent sequence stratigraphy framework has to be established. The Atlantic basins of Morocco has been deformed by the Atlas orogeny and present, besides offshore wells from the Agadir-Essaouira and Tarfaya basins, outcrops of the complete Mesozoic succession, which makes it a favourable area for such a study.

Here we report on the initial results of a study on Jurassic detailed stratigraphy and structural evolution that aims to identify and constrain the potential Jurassic reservoirs and source-rocks facies. Two large-scale transgressive-regressive cycles form the Jurassic shelf margin deposits that are characterised by rapid facies changes.

In the east of the basin, the Anklout Anticline presents good exposures of the entire Jurassic, where a reference section has been logged. The base of the Lias is characterised by fluvial conglomerates and sandstones and a fast transition to a carbonate shoreface environment. The establishment of a peritidal environment represents the maximum of transgression characterised by grainstones alternating with dissolution breccias and stromatolites. Regression during the Middle Jurassic led to deposition of fluvial siliciclastics in the proximal study area, passing westward to shallow-marine carbonates. The second transgressive phase occurred from Callovian to Oxfordian and established marine conditions throughout the basin. The first part of the transgression is characterised by high energy bioclastic limestones and a level of marls marks the transition to the reef-dominated Oxfordian deposits. These levels are of particular interest because they constitute offshore reservoir. The last regression establishes reddish marls and dolomites facies, and is followed by the establishment of a peritidal environment during the uppermost Jurassic.

An uninterrupted lacustrine record of the Early Danian Dan-C2 hyperthermal event: Boltysh impact crater, Ukraine

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Continuous and well preserved terrestrial records of hyperthermal events and associated negative carbon isotope excursions (CIEs) are rare. The effects of such hyperthermals on sedimentary environments and associated ecosystems are thus less well constraint than those documented from marine strata. A core drilled in the central part of the K-Pg Boltysh meteorite impact crater, Ukraine, provides a high-resolution complete lacustrine record of the Early Danian Dan-C2 hyperthermal (at c. 65.2 Ma), which will allow a greater understanding of the interplay between climate warming and terrestrial environments.

The present study integrates sedimentological, palynological and sediment geochemical aspects to reconstruct lake evolution and ecological changes during the Dan-C2 CIE. Based on detailed core logging 3 main phases of lake evolution are distinguished: 1) pre-CIE rising fresh water lake, 2) main phase CIE fluctuating lake, and 3) shallow lake during CIE recovery. High clastic input from the crater rim via marginal delta systems is documented from the early phase of lake formation (stage 1), associated with mesic humid warm temperate plant communities. CIE inception marks the beginning of stage 2, which is characterised by decreased clastic input and by clay- and organic-rich facies becoming more abundant. Increased frequencies of savanna pollen associations indicate higher mean annual temperatures and reduced moisture availability. This phase is most notably characterised by fluctuations between anoxic and oxic lake conditions. With the beginning of CIE recovery (=stage3) deposition shifts to prolonged phases of clastic and organic-rich sediments. Savanna pollen associations remain the dominating group during the recovery stage before declining rapidly within the upper part of the recovery stage. A corresponding gradual increase of swamp cypress and pine type pollen marks a return to mesic forest and temperate climatic conditions.

Present investigations have indicated that plant species and communities show cyclic frequencies during the CIE main phase, correlating with changes in sedimentary patterns. Together, the sedimentology and palynology of the Boltysh crater demonstrate causal relationships between rapid climate change at the hyperthermal and lake sedimentological and ecological evolution. The characterisation of the fine scale record of this interplay and understanding of past climate forcing will help us to derive response patterns that could be expected under modern climate warming.

Aeolian and Fluvial interactions for reservoir characterisation: Examples from the Wingate and Kayenta Formations, Utah, U.S.A.

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Interactions between coexisting fluvial and aeolian environments are well studied for their relevance to hydrocarbon reservoir characterisation. Spatial interactions and the geometric control of one system upon another system are well known where one environment is dominant (Mountney, 2009). Comparatively less attention has been given to the temporal evolution from aeolian dominated environments to fluvial ones, and the degree the two environments compete in time.

In this work, we present preliminary interpretations of the boundary between the Jurassic aeolian ergs of the Wingate Formation and the ephemeral fluvial Kayenta Formation of the Paradox Basin, U.S.A. The boundary between the two formations is accepted to be abrupt regionally with the onset of the Kayenta immediately supressing the Wingate (Riggs and Blakey, 1993). However, field studies of exposures near the town of Moab, Utah (fig. 1), shows the two environments competing, switching repeatedly through time.

The cliff-forming Wingate Formation comprises aeolian sediment deposited in a large-scale erg system and sourced from the north-west of the Paradox Basin. The ledge-forming Kayenta Formation comprises sediment depositing primarily in a fluvial system and sourced from the Uncompahgre Plateau to the north-east (Bromley, 1991). Primary data include detailed sedimentary logging of the boundary, palaeocurrent, panelling and photogrammetry data. In-lab techniques include three-dimensional modelling to reconstruct the palaeoflow, facies and architectural element analysis and statistical analysis of element size.

Competition occurs between the two formations and the boundary is not sharp. Bedforms and thickness of fluvial deposits increase upwards through the Kayenta, causing restriction of the Wingate sediments and the dominance of parallel sandsheets. Despite clear evidence for extensive competition between the two environments over time, the Wingate Formation controls palaeocurrent and sediment routing throughout this transition, until the fluvial system of the Kayenta becomes fully established.

Interbedded aeolian and fluvial deposits can form a part of many continental clastic hydrocarbon reservoirs, such as the Rotliegend Group of the Southern North Sea (Sweet, 1999). Consequently, our studies provide new insight into the distribution of facies and the architecture of elements where fluvial and aeolian systems interact in time, and provide further control on reservoir characterisation.

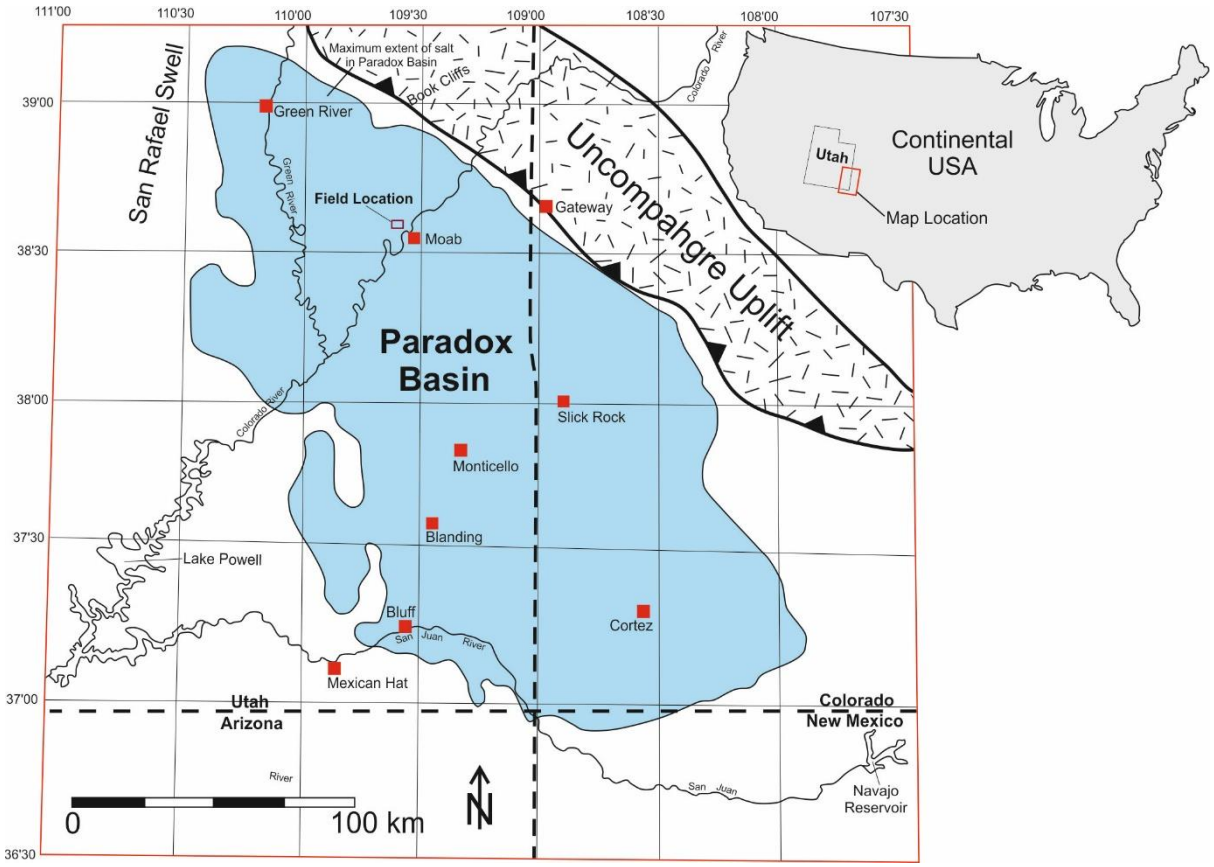

Figure 1: Field location north-west of Moab, within the Paradox Basin.

Understanding the Eocene-Oligocene stratigraphy in the South Sumatra Basin, Southeast Asia, using a heavy mineral study

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The Eocene and Oligocene Lahat, Lemat and Talag Aker Formations were deposited within the South Sumatra Basin on the Indonesian island of Sumatra, Southeast Asia. The South Sumatra Basin is further divided into sub-basins which formed during the Lower Oligocene when Sumatra underwent regional rifting. The formations were shed into these sub-basins during deposition, but it is unknown as to whether these basins were interconnected during deposition, or whether they were isolated.

The Eocene deposits (Lahat and Lemat Formations) are poorly exposed, with the exception of limited outcrops in mountainous regions. As such, the sedimentary architectures and environments prove difficult to interpret at outcrop scale. The limited exposure suggests that the environments grade from basin margin alluvial fans, through large terminal fluvial systems, and finally into fresh water lacustrine settings in the basin centre. Thin beds of coal are also identifiable throughout the basin-centre deposits, overlain by very thin beds of carbonates. This has led to suggestions that the basin was subject to a gradual marine transgression at the time of deposition. The Oligocene deposits (Talag Akar Formation) are better exposed, and show clear indications of having been deposited in a large, wide-spread fluvial system.

The Eocene Lahat and Lemat Formations are widely accepted as an important regional source rock, producing up to ten percent of hydrocarbons in the area. However, due to poor exposure little is known about these lithologies. The Oligocene Talag Akar Formation is an important reservoir rock in the Sumatran hydrocarbon play, and therefore the better characterisation of these deposits is also important. It is also an area of interest to ascertain whether these Oligocene rift basins were interconnected or isolated during deposition, as this will effect subsequent hydrocarbon migration in these basins.

This work presents a heavy mineral study from these formations, which helps to: 1) better categorise the depositional environments; and 2) ascertain whether there is a predominant sediment source from the Malay Peninsula (indicating a high degree of basin connectivity) or whether there is a mixed source from more localised regions (suggesting more isolated basins).

New insights into flow-bedform interaction from direct monitoring of turbidity currents

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Turbidity currents transport large amounts of sediment into the deep oceans and may travel at high speeds, posing a threat to important and expensive seafloor infrastructure. Despite their importance, we still know very little about their flow dynamics and bed interaction, as only a few direct monitoring studies of turbidity currents exist. Here we present exciting, preliminary results of the first direct monitoring of a turbidity current performed from multiple platforms (three vessels and two moorings) on the Squamish Prodelta, British Columbia.

The Squamish Prodelta is an ideal location to study turbidity current dynamics because flows can occur as frequently as daily during the spring and the summer freshet. These first results from the summer of 2015 focus on data acquired from a vessel moored over a channel thalweg, from which we deployed a novel array of geophysical sensors. Two multibeam sonars attached to the bow of the ship imaged the incoming turbidity current, and documented its interaction with crescentic bedforms that characterise the channel thalweg. A downward-looking Acoustic Doppler Current Profiler (ADCP) lowered from the back of the ship provided vertical profiles of velocity through time. Additionally, for the first time a Chirp sub-bottom profiler enabled imaging of the dense near-bed zone of the turbidity current which has so far been largely impenetrable by the higher frequency sonar and ADCP instruments.

This remarkable combination of datasets provides new insights into how turbidity currents interact with bedforms and the evolution of their velocity and concentration profiles through time.

Are shallow-water carbonates a reliable archive for global environmental change?

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Shallow-marine carbonate systems are very sensitive to surrounding environmental changes and have the potential to archive changes in climatic patterns or global cycles. Palaeoenvironmental studies of the Mesozoic Era often rely exclusively on such carbonate archives as much of the deep-sea record has been subducted. Using neritic carbonates as archive for global change does however bear pitfalls. Most commonly the sections include hiatuses as the shallow-marine carbonates were frequently exposed, or sedimentation was halted due to a carbonate factory crisis, potentially induced by environmental changes. Early as well as late diagenetic processes form a further difficulty when analysing these sedimentary archives, especially when measuring isotopic proxies. Deciphering the complex interplay of multiple factors that govern carbonate production, deposition and preservation in order to extract a meaningful palaeoenvironmental conclusion is thus a very complex task. In this study we focus on shallow-water carbonates in an important location, deposited at times of major environmental changes. We examine neritic carbonate sections from the Musandam Peninsula (Northern United Arab Emirates) of Late Triassic to Middle Jurassic age, which include globally recognised events such as the Triassic-Jurassic mass extinction and the Toarcian oceanic anoxic event (TOAE). The study site was situated close to the equator during the Late Triassic and the Early Jurassic. A detailed sedimentological examination as well as a multi-proxy stratigraphic analysis (biostratigraphy, carbon and strontium stable isotope stratigraphy) was performed. Results show that as long as diagenetically altered data is rigorously excluded, globally recognized carbon cycle perturbations are recorded as shifts in the stable carbon isotope signal for the Triassic-Jurassic transition and for parts of the Middle Jurassic. Moreover, isotopic shifts also correspond to major carbonate factory changes. The TOAE is however not recorded within the studied succession, due to non-deposition, which affected much of the Middle East.

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Timing, mechanisms and impact of compactional fluids migration on the hydrocarbon charging of reservoir during burial: example of the Lodève Basin (South of France)

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During the burial diagenesis, interstitial fluids initially trapped within the sedimentary pile are easily moving under pressure gradient before thermogenic hydrocarbon expulsion. However, the timing and mechanisms of fluid migration remain poorly understood, especially the impact on the early diagenesis of petroleum reservoir.

The Lodève Permian Basin (Hérault, France) is an exhumed half graben with exceptional outcrop conditions providing access to Ba-Cu-Pb mineralized systems and hydrocarbon trapped into syn-rift rollover faults. Architectural studies of fluid markers show two main markers of fluid migration consisting in cyclic infillings of fault zone and associated S_0-parallel veins during syn-rift faulting.

Contrasting fluid entrapment conditions are then deduced from textural analysis, fluid inclusion microthermometry coupled with isotope geothermometer and P/T basin modeling. Three main ore facies have been identified: (i) after hypogen karstification of fault zones, the first stage Br is characterized by an implosion breccia cemented by silica, nacrite, barite and chalcopyrite; (ii) the second event RB consists in succession of barite-sulfide ribbons precipitated under overpressure fluctuations; and (iii) the last stage SB is formed by sparry barites and coeval petroleum fluid inclusions, both entrapped under suprahydrostatic pressure conditions.

We conclude to a polyphase history of fluid trapping during syn-rift burial of the basin:

(a) Disequilibrium compaction initiates deep overpressure-driven basinal fluid migration towards basin margins where rollover normal faults accommodate the differential subsidence. The abrupt fluid pressure drop during coseismic dilation of fault zones leads to the first barite-sulfide mineralization event associated to high-temperature argilitization.

(b) Compactional fluid overpressure is then responsible for the periodic reactivation of fault plane according to seismic-valve process and bedded-control shearing at the reservoir-seal interface. These mechanisms induce cyclic polymetallic mineralization by the mixing between *in-situ* formation water and ascending basinal fluids.

(c) Finally, thermogenic fluids expulsion starts during late burial stage associated to last compactional fluids. Hydrocarbons thus migrate along the same regional pathways up to the rollover anticline and contribute to the hydraulic fracturing of the fault zone by buoyancy pressure.

This work provides new insights on the interaction between sedimentary compactional fluids and hydrocarbon during the early burial diagenesis of potential economic reservoirs.

Formation of siderite concretions and the porewater geochemistry of Norfolk salt marsh, UK

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We found several actively-forming carbonate concretions in the salt marsh sediments near Warham on the north Norfolk coast. Two concretions were collected on the bank of a tidal creek. Both samples were cut into parallel slices for mineralogical and geochemical analysis. For mineralogical analysis, we pulverized selected samples into powder prior to X-ray Diffraction (XRD) analysis. The XRD results showed that the carbonate concretions are primarily made up of quartz, Mg-calcite, siderite, orthoclase, albite and small amount of pyrite and gypsum. To examine the thermodynamic stability of minerals in the aqueous phase, we sampled porewater from two different sediment types found in the salt marsh – one replete in ferrous iron and one replete in sulfide. The porewater analysis showed distinct geochemistry in each pond. Thermodynamic calculations using PHREEQC indicated that the porewater of the iron-rich core is oversaturated with respect to siderite and undersaturated with respect to calcite, aragonite and dolomite. On the other hand, the sulfidic pond is oversaturated with respect to calcite, aragonite and dolomite and undersaturated with respect to siderite. In the future analysis, we wish to investigate further the mineral stability (ΔG) and use incubation experiments to better understand the biogeochemical processes that drive the precipitation of siderite in the salt marsh.

Flocculation characteristics of freshly eroded aggregates.

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In Europe, 260,000 km^2 of soils already suffer erosion by water. This worrying level of land degradation is expected to increase in the context of climate change, with situations particularly critical in mountainous environments. As any multi-use resource, there is growing human pressure on mountainous rivers. The quantity of suspended solids exported downstream depends mainly of their morphometric properties, including: size D, shape and effective density. Modellers employ a Rouse number to balance the turbulence with the aggregate settling velocity. However a Rouse profile relationship does not hold for highly concentrated riverine suspensions (10's $g.l^{-1}$), where processes such as flocculation, hindered settling and stratification interplay.

This study aims at improving sediment transport parameterisation, by examining the kinetics of fine soil aggregates (D, settling velocity Ws, density), once immersed in a turbulent flow. Thus observing the changing state, as soil aggregates become suspended sediment. Three Mediterranean materials (clay loam soil, black marl and molasse, both sampled in badlands) were tested in the grid stirred experiment. Hydrodynamic properties were monitored with ADV and turbidity sensors. For each soil, three suspended sediment concentrations SSCs (1.5; 5; 10 $g.l^{-1}$) representative of flood conditions were tested. Aggregate properties were obtained sampling at 4 depths above the grid, using the LabSFLOC – Laboratory Spectral Flocculation Characteristics (Manning, 2006) and laser techniques.

Results showed that once particles were injected in the tank, a quasi-equilibrium state was rapidly reached, after 1-2 minutes and floc/aggregate properties did not significantly vary with sediment load. For molasse at 10 $g.l^{-1}$ D ranged from 39 – 273 □m. Microflocs (D < 160 □m) only had Ws of 0.4-0.5 $mm.s^{-1}$, an order of magnitude slower than the peak sample Ws of 5.8 $mm.s^{-1}$. These fast settling aggregates represented 50%+ of the SSC. Microflocs exhibited effective densities covering an order of magnitude between 160-1600 $kg.m^{-3}$, which suggests that some degree of flocculation has occurred. Highly porous Macroflocs demonstrated effective densities < 40 $kg.m^{-3}$; these flocs fell at a Ws of about 1 $mm.s^{-1}$ and represented ~4% of the total SSC. The aggregation index was 50% and 90% for badlands materials and soil, respectively. The behaviour of the soils differ significantly from those observed for estuarine or coastal muds; for the later D and Ws increase with SSC. All results will be discussed.

Improved reservoir models from outcrops using Virtual Outcrops and Multiple Point Statistics

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Outcrop analogues of reservoirs are used because facies-scale reservoir heterogeneities are often not resolvable on seismic data and well data provides minimal 3D geometric control.

The population of traditional geocellular models are reliant on defining the geometry, size and directionality of facies proportions through the manual measurement of object dimensions or variograms from outcrops. These reservoir models are limited by the quality of available geological data and the limitations of the modelling algorithms for capturing complex shapes and facies relationships.

Multiple-point statistics (MPS) is a newly available property modelling technique reliant on defining representative training images (TI). A TI is a conceptual numerical description of the interpreted reservoir geology and should represent all possible dimensions and geometries of geobodies expected in the reservoir. The methodology has been limited by a lack of suitable TIs.

Recent advances in digital outcrop mapping methods, such as Lidar and photogrammetry, permit the rapid acquisition of high-resolution 3D "virtual outcrop" models. These provide a critical and underused source of quantitative and qualitative information for generating high quality TIs.

The aims of this study are to develop methods for using 3D virtual outcrops as training images and to develop a library of virtual outcrop derived TIs across a range of depositional environments; coupled with the streamlining of Lidar integration into subsurface models. This approach will significantly improve the prediction of the 3D variation of facies heterogeneity and its impact on reservoir performance.

Determining the applicability of synthetic gamma ray logs as an analogous method for reservoir quality: Case study from Styrrup Quarry, Doncaster, UK.

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Fluvial systems are some of the most dynamic environments. This makes the interpretation of their genesis difficult, but also the application of spectral gamma ray to these systems. The application of spectral gamma ray can be used in its most simplistic form to estimate clay mineral content; from this reservoir quality can be inferred. The estimation of reservoir quality in fluvial systems is extremely difficult from spectral gamma ray, as a number of allocyclic and autocyclic controls affect the deposition, that also directly affect the clay content within the reservoir rock.

Handheld spectral gamma ray data collected in the field can be highly affected by various modern processes such as weathering, plant growth and soil formation; for example, soil formation may produce a high thorium count. There is current speculation regarding the legitimacy of these outcrop-based spectral gamma ray studies. In particular, how representative are spectral gamma ray logs of outcrops, can they be applied reliably to wireline data and can a realistic and relevant interpretation be derived from them?

Sedimentological and spectral gamma ray data was collected from Styrrup Quarry, Doncaster, UK. Facies schemes were created, along with v_{shale} calculations from scanned thin sections processed in "*ImageJ*". The v_{shale} data was used as a proxy for the construction of synthetic gamma ray logs. The generated synthesised logs were then compared to API data obtained in the field.

The results suggest that synthetic gamma ray logs show similar trends to those of gamma ray logs acquired in the field. When used as an interpretive tool, synthetic gamma ray logs are not detailed enough to establish a relative interpretation of sediment genesis. However, when used as an indication of reservoir quality, synthetic gamma ray logs provide a more precise indication than field collected data. This is due to field data being distorted by weathering creating a bias toward poor reservoir quality, generated synthetic logs do not have this problem as they are a function of v_{shale}.

The Carboniferous Bowland Shale Formation (UK): Understanding the Sedimentological and Diagenetic Processes within a potential Shale Gas Exploration Play

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The Carboniferous Bowland Shale Formation is a succession of organic-rich mudstones deposited in a series of fault-controlled (half-)grabens within the Pennine Province (northern England), and represents the largest potential target for shale gas exploration within the UK. Variations in sedimentology and diagenesis play a major role in controlling reservoir quality but current knowledge for the Bowland Shale is limited, leading to significant uncertainty for exploration. This study focuses on a previously undescribed core within a marginal to basinal succession from the Bowland Basin and documents the scale and nature of microfacies compositional and diagenetic variability.

A detailed microfacies scheme has been constructed using scanned thin sections and optical microscopy based primarily on texture and composition, and refined through consideration of physical sedimentary structures, biogenic sedimentary features and diagenetic products. A total of six microfacies were identified and characterised within the Bowland Shale. A change in the dominant facies from calcareous mudstone (facies 2) within the lower Bowland to argillaceous mudstone (facies 1) within the upper Bowland suggests a transition from a carbonate-rich to a more clay-rich system with decreasing inputs from the surrounding carbonate shelves. These temporal variations are attributed to changes in basinal inputs and variations in eustatic sea level.

Common diagenetic features within all microfacies are clay and carbonate cements (including calcite, dolomite and minor siderite) as well as extensive pyrite framboid development. Carbonate nodules, predominantly dolomite, are often associated with facies 2 and rarely with facies 1, 3 (calcareous claystone) and 4a (calcareous siltstone). Nodules often show significantly less compaction than the host rock indicating an early diagenetic origin. Calcite veins occur throughout and are common within facies 2, 3 and 4b; they crosscut all other fabric including pervasive calcite cementation within facies 4b indicating a later diagenetic event. Within the borehole Total Organic Carbon (TOC) values range from 1.21wt.% to 11.16wt.%. Average TOC varies between the upper Bowland (3.61wt.%) and lower Bowland (4.45wt.%). TOC results were integrated with microfacies observations to reveal key associations between organic matter richness with the depositional framework, with the highest TOC values associated within calcareous mudstones (facies 2; avg. 4.49wt.%).

Diagenetic Controls on Reservoir Quality of Collyhurst Sandstone, East Irish Sea Basin, United Kingdom

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The Lower Permian Collyhurst Sandstone Formation is an important gas reservoir both offshore and onshore in the East Irish Sea Basin of Northwestern England. Contrasting characteristics between reservoirs units suggest that different diagenetic pathways occurred. This project looks at two different on-shore cored successions to elucidate these processes further. Petrographic analysis combined with scanning electron microscopy (SEM) as well as X-ray diffraction analysis have been used to study the paragenetic sequence of the diagenetic minerals within the formation as well as the control of diagenesis on reservoir quality. Mineralogical composition analysis suggests that Collyhurst formation ranges between subarkose to sublitharenite and lithic arenites. The eastern Collyhurst Sandstone consists of monocrystalline quartz ranging from 57% to 80% of the detrital quartz with less percentage of polycrystalline quartz (1.3% to 8.7%). Feldspar percentage is less than 9% while rock fragments ranging between 6.3% to 35.7%. The western part of the formation predominantly consists of fine grained sandstone (argillaceous sandstone) and silty mudstone. Early diagenesis includes the development of pore filling, non-ferroan calcite cement, ferroan and non-ferroan dolomite, with grain-coating haematite. Late diagenesis involves the formation of illite cement, occurring mainly as pore filling and pore bridging, with occurrence of mixed layer clay. Syntaxial quartz overgrowth and pore occluding quartz is common while albite, barite and siderite cement also occur as minor cement. Diagenesis plays a significant role on reservoir property in the study area. Compaction and cementation (mainly early carbonate and illite) have substantially reduced the rock porosity and permeability.

Late-Eocene canyon formation and the interplay between down-slope and along-slope processes during the Cenozoic evolution of the Donegal-Barra fan area, Rockall Basin.

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Slopes along the eastern margin of the Irish Rockall Trough are characterised by prominent canyons which incise the margin from the shelf edge and mid-slope to the base-of-slope. These appear to be relict features that were locally reutilised by discharge from the British-Irish Ice Sheet during the Pleistocene. Previous work based on regional 2D seismic lines attributed canyon formation to widespread slope failure associated with a phase of rapid Late Eocene differential subsidence. Trough deepening was accompanied by an intensification of bottom-current circulation and the development of the regional C30 unconformity. Large mounded features (the Erris Wedge) above the C30 unconformity at the base of the slope were attributed to mass-transport processes that excavated the canyons and were later modified by gravity currents.

A re-investigation of the Erris Wedge 'mounds' and associated canyons is currently underway using the Midelton seismic cube in the NE sector of the trough (beneath the Donegal-Barra fan). The C30 regional unconformity, constrained by well 5/22-1 to be of Late-Eocene age, incises a Lower Eocene drape forming canyons which range from 250-300 m in depth. Prominent mounded features are revealed by surface mapping and seismic stratigraphy as inter-canyon ridges that were initiated during canyon incision. Attribute analysis demonstrates the canyons were conduits for gravity currents that helped maintain the canyon morphology and these locally constructed channel networks at the base of slope that were deflected by local topography to flow parallel to slope. Canyons and inter-canyon ridges persisted through the Oligo-Miocene and are characterised by low-amplitude mounded reflectors suggesting bottom currents came to dominate over downslope transport. Intensification of these bottom currents combined with limited canyon spill-out resulted in amplification of the inter-canyon ridges and formation of the large mounds. Collapse features and extensive polygonal faulting within the mounds indicate instability but the mounds appear to be constructional features seeded on earlier erosional relief, not mass-transport deposits. The interplay between down and along-slope transport helped maintain an inherited sea floor topography that persists through to the present day, although it has been partly buried by glaciogenic sediment associated with the Pleistocene Donegal-Barra fan.

Width analysis of submarine channel bends

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Submarine channels occur worldwide in a wide range of environmental settings from isolated deep ocean channels to submarine fan channels. They play a significant role in continental margin evolution, sediment and nutrient transport from the continents to the oceans, and hydrocarbon exploration. However, the nature of channel evolution in submarine channel bends, and the associated processes, are poorly understood. One reason for this lack of understanding of channel evolution is that the morphometrics of channel bends are almost unknown. In particular, nothing is known about how channel width varies around bends. Laboratory experiments and numerical models have all assumed and utilised a constant channel width around bends. In contrast, it is known in river systems that channel width is variable around bends and in turn that this is strongly linked to bend migration, channel evolution, and sediment patterns. Here we present the first detailed quantitative study of bend morphometrics- from modern submarine channels, focussing on variation in channel morphometrics around bends.

Facies variations on active thrust-top basins: a study case of Numidian turbidites of Sicily

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Mediterranean turbidite systems are deposited adjacent and within developing orogens and there has been an increasingly recognition of the role of active structures within basins and their influences on facies distribution. Some turbidites basins such Marnoso-Arenacea, regarded to have been deposited in tectonically quiescent settings are now seen as influenced by advancing thrust fronts of the orogeny. Here we show outcrops examples on how active basin floor can control the facies distribution on a turbidite basin. This study case comes from the Nebrodi Mountains of Sicily, a region that contains the greatest expanse of Numidian strata (Oligocene-Miocene) in the central Mediterranean. The system was controlled by thrust related folds and their intrabasin submarine slopes, together with basin floor architecture inherited from the underfilled passive continental margin. Thrust-top basins filled diachronously implying a large scale tectonic control both on sand fairways and facies variations along their margins. Existing models wrongly suggest that facies variations between adjacent outcrops on Sicily (and elsewhere) result from long-range stratigraphic variations being juxtaposed by later large-displacement thrusts. Our research challenge this ideas and propose a much simpler tectonic structure but a more complex stratigraphic arrangement for the Numidian on Sicily. We outline the evidence for this deduction and develop the consequences for understanding of the Maghrebian orogenic system that has deformed this margin during the Neogene.

Diagenetic history and reservoir quality of the Carboniferous and Permo-Triassic reservoirs in the Rathlin Basin, Northern Ireland

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The Rathlin Basin, onshore Northern Ireland, represents an underexplored area, yet one prospective for hydrocarbons. The basin is filled with over 3 km of sediments and volcanics of Carboniferous to Palaeogene age. The internal structure of the underlying sedimentary basin is largely obscured by the thick cover of the Palaeocene Antrim Lava Group, which inhibits the acquisition of good quality seismic data. The principal targets for hydrocarbon exploration have been the Carboniferous and Permo-Triassic sandstones but to date only one exploration well has been drilled and there are only two other boreholes in the basin more than 1 km deep. Reservoir quality data on these potential reservoir rocks is sparse and this study adds significantly to the existing datasets. Detailed thin section petrography was carried out on 70 samples from the Carboniferous and Permo-Triassic from borehole and outcrop samples, along with poroperm, XRD and SEM analyses. Results show that the Carboniferous and Permo-Triassic reservoirs differ in their primary mineralogy, diagenetic history and resulting reservoir quality. The most noticeable difference between sandstones is the feldspar content, with many Permo-Triassic samples being feldspathic or subfeldspathic arenite, and Carboniferous samples almost exclusively quartz arenite. Although there was likely a depositional control on the original/primary feldspar content, uplift at the end of the Carboniferous and associated feldspar dissolution has resulted in 'diagenetic' quartz arenites. Residual hydrocarbons were discovered in Carboniferous strata from the Magilligan borehole, from the adjacent upfaulted Ballycastle coalfield, and a small amount of oil was recovered from the Ballinlea-1 well, located toward the basin depocentre. Deep burial led to the generation of hydrocarbons, probably from the Triassic onwards, with peak oil generation in the Palaeogene, but some reservoirs are likely to have been breached during faulting in the Palaeogene and/or Neogene. Sandstones display good reservoir quality and there is a thick regional seal. One uncertainty is the presence of good source rocks and their maturity, but the proximity of the Ballycastle coalfield and common evidence of hydrocarbon staining in samples suggests that this is not a major risk. The identification and structural integrity of potential traps is the key unknown.

Towards a classification and quantification scheme for overbank sandstones in a delta top setting

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Sandstones deposited in delta top environments are volumetrically important, but very heterogeneous as reservoirs. Delta top settings comprise a trunk channel, distributary channels and overbank deposits (including levees, crevasse splays, splay complexes, bay fill deltas and mires). The channel related sandstones are the major reservoir bodies and as such have received considerable attention in the literature. Sandstones in the overbank setting have been largely ignored. The current research aims to improve understanding of overbank delta top sandstones from a reservoir perspective providing a new classification scheme and dimensional data for the different elements.
The first stage of this work has been an analysis of Google Earth satellite imagery and historical maps of the modern Mississippi Delta. Quantitative data of crevasse splay dimensions indicates a wide variety of shapes and sizes. On the basis of geometry and hierarchy the deposits are classified as: 1) single crevasse splays; 2) laterally amalgamated crevasse splays and levee deposits and 3) bay-fill crevasse delta complexes. Single splays have a point source and are mostly fan shaped with a very few being elongate. Amalgamated splays are channel parallel sheets with multiple inputs. These are generally incorporated into levee deposits. Bay-fill crevasse delta complexes are larger lobate delta like features, fed by a channel that splays from the parent channel.

The use of Shreve's stream order technique to study the relationship between lobe dimension and branching in the bay-fill delta complexes suggests that there is an optimum size for lower order delta lobes across the different bay-fill complexes; however, higher order lobes showed more variability. Parent channel width does not appear to impact the size of the single crevasse splays or the bay-fill deltas and water depth is a key control on the degree and frequency of channel branching.

Spatial and temporal variations in grounding line proximal sedimentation in the Anvers Palaeo-Ice Stream Trough, western Antarctic Peninsula

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To predict the future behaviour of polar ice sheets in a warming world, it is important to understand how ice sheets and ice streams respond to changes in climate and sea level. By reconstructing the cause and style of ice stream retreat following the Last Glacial Maximum (LGM), we can gain a greater insight into the future dynamics of modern day ice sheets. It is possible to achieve such reconstructions by investigating sedimentary sequences deposited during the LGM and the subsequent deglaciation on polar continental shelves. This PhD project will focus on the deglaciation history of the Anvers Palaeo-Ice Stream Trough, western Antarctic Pensinsula. During a British Antarctic Survey research cruise with RRS "James Clark Ross" in 2014, geophysical data and marine sediment cores were collected from the trough. By combining the sedimentary facies in cores and the palaeoenvironmental changes archived within them, with corresponding acoustic sub-bottom profiles and multi-beam swath bathymetry data, we aim to reconstruct the last deglaciation of the trough in high-resolution. The sediment cores, collected along two transects, will allow us to better constrain the style and rate of retreat of the Anvers Palaeo-Ice Stream from the shelf and the spatial variability of retreat along and across the trough. Sediment facies will be classified using marine geological data sets, including physical and geochemical properties analysed with state-of-the-art core logging facilities, and radiocarbon ages obtained from calcareous microfossils and the acid-insoluble fraction of organic matter (AIO). This will allow us to infer depositional processes and to reconstruct the timing of retreat. Sediment types deposited during ice stream retreat are often difficult to interpret and as a consequence the reconstruction of the processes that led to their deposition is often challenging. This is due to the complex and highly variable processes occurring proximal to the grounding line of ice streams. This PhD project will seek to refine the distinction between subglacial and glaciomarine facies and between seasonally open marine and sub-ice shelf facies. Achieving this goal will ultimately help to test and improve ice-sheet models that aim to predict the future dynamics of ice sheets.

Utilising a new 'Intersection Shape Method' to predict heterogeneity in fluvial point-bar deposits

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The thickness, lateral and vertical extent, and connectivity of mud-prone deposits are highly variable within fluvial point-bar deposits. Analysing the distribution of such heterogeneities is important to better understand how flood events govern sedimentation in active meandering rivers. Muddy intervals act as baffles to flow in otherwise sandy, high-permeability reservoirs so analysis can be applied to increase recovery of hydrocarbons from preserved point-bar elements. Twenty-five classes of meander shape have been identified, and the occurrence of mud-prone heterogeneities associated with each type has been assessed. A planform morphometric analysis of modern systems has achieved this using the novel 'Intersection Shape Method' – a metric developed and implemented to differentiate between meander-bend types based on shape, to enable a non-subjective, quantitative, and therefore repeatable, classification of meanders. This technique has been developed using 6,400 measurements from aerial photographs of reaches of 11 rivers, and 200 active meanders. The 25 shapes can be divided into four categories: simple, symmetrical, complex and angular. The classes are based on the morphometry of a polygon outlined by six lines drawn perpendicular to the centreline of a meander, at equally spaced points starting from each inflection point up to the apex. This has been combined with qualitative facies modelling and literature analysis, to predict expected facies distributions in cross section. Results are compiled in a meander database from rivers that have evolved under the influence of a variety of climates, gradients, accumulation rates, river sizes and sediment load. The methodology can be applied in the following ways: (i) meander shape identification is possible by measuring planform morphometric parameters; (ii) cross-sectional geometries seen on outcrop can be used to infer scenarios of planform shape types and point-bar evolution; (iii) these estimations can be refined using the database as a means to isolate variables using real examples. The style and direction of scroll-bar migration trajectories within preserved point-bar elements directly controls the distribution of mud-prone heterogeneities. This technique can be applied to visually compare any fluvial meanders from any system, and predict heterogeneity from planform morphologies observed on seismic time slices, as well as aid outcrop interpretations.

The use of portable X-ray fluorescence spectroscopy (pXRF) in cyclostratigraphic studies of mudstones

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Cyclostratigraphic studies seek to create relative timescales for sedimentary successions based on the identification of Milankovitch cyclicities in climate proxies; this typically requires long, regularly spaced and high-resolution datasets of climate proxies. Commonly used techniques for data collection include time-consuming and costly analyses such as carbon-nitrogen-sulphur concentration and stable isotope analyses, and techniques where an indirect signal, reflecting a range of compositional variables, is measured such as magnetic susceptibility and colour. This study has examined whether portable X-ray fluorescence spectroscopy (pXRF) has the potential to provide a faster, cheaper and direct way of generating compositional data for use in cyclostratigraphy using the following stages: (i) a series of tests were devised to optimise sample handling and measurement protocols for pXRF analyses; (ii) application of the developed pXRF protocol to the analysis of 360 powdered mudstone samples from early Toarcian deposits from Whitby, Yorkshire, UK which have previously been shown to exhibit a regular cyclicity in [$CaCO_3$] and [S] data, and (iii) time series analysis of the pXRF data. The results show a very strong linear correlation of pXRF [Ca], [S] and [Fe] with measured [$CaCO_3$] and [S] from a Leco elemental analyser. Moreover, the statistically significant cyclicity previously recognised in elemental [$CaCO_3$] and [S] is also generally observable in the pXRF data. Some differences in the precise expression of cyclicity between Leco and pXRF data likely arise from differing precision of the respective instruments. These pXRF analyses demonstrate that data of appropriate quality for cyclostratigraphic studies can be produced quickly (approximately 100 analyses per day) and cheaply using pXRF. In addition, the use of powdered samples ensures that (i) data are directly comparable, as other geochemical analyses can be carried out on the exact same samples, and (ii) data quality is optimised by sample homogeneity and consistent measuring conditions.

Sedimentological and Stratigraphic Architecture of an Hirnantian Palaeovalley, NW Saudi Arabia

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Late Ordovician (Hirnantian) glacial deposits are of great economic importance in North Africa and the Middle East owing to their significance as hydrocarbon reservoirs. In NW Saudi Arabia, the sedimentary record of this glaciation is generally preserved in a meridionally-oriented palaeovalleys reflecting the northward flow of Hirnantian ice sheets. However, rare E-W oriented palaeovalleys also occur, the origins of which are not well understood. In northwest Saudi Arabia lies an unusual cross-shaped outcrop of sandstone, composed of both E-W and N-S oriented palaeovalleys which appear to intersect. This project is aimed at tackling the southern limb which measures about 6 km long and 1 km wide. This palaeovalley is asymmetrical, and its general N-S orientation veers NE at its northernmost limit. A total of 400 m of stratigraphic sections have been measured at a 1:50 scale which has enabled the identification of 14 lithofacies grouped into 7 facies associations. The palaeovalley fill is almost entirely composed of medium-grained sandstone with about 70% dominated by (i) thinly bedded well-sorted sandstone, (ii) moderate- to poorly-sorted sandstone with unique sedimentary structure resembling overlapping tongue-like projections, and (iii) heavily-deformed sandstone. Throughout the palaeovalley, cm-scale extensional faults that developed in soft sediment are commonly found, along with some sheath folds and a glacially striated surface found mid-way through the stratigraphy. These features are used to illustrate the syn-glacial nature of these sediments, with some features providing evidence for direct ice-contact.

Sediment routing in confined turbidite basins of Lake Pannon

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Uneven basin floor topography significantly alters the route of turbidity currents and the depositional architecture of turbidite systems. Confined basins can develop in a wide range of tectonic settings. The basement of the Pannonian Basin was highly irregular due to normal and strike-slip faulting during synrift extension in the Early to Middle Miocene, minor inversion around the turn of Mid/Late Miocene and recurrence of fault activity during the early Late Miocene. Lake Pannon inundated the relief in the Late Miocene, and even 600 to 1000 metres deep depressions were present. Profundal marls covered unevenly the floor of the deep regions as well as that of sublacustrine highs.

Selected 3D seismic datasets were interpreted and the syndepositional palaeotopography was approximated. Spectral decomposition was used to map geomorphological architectural elements. Well logs and core studies aided in constraining the stratigraphy and the evolution of deep-water architectural elements.

Two scales of confining topography can be identified. The higher irregularities are in the scale of depressions: they are 10s of kilometres in length, several 100s of metres in depth. The smaller ones are in the range of several kilometres in length and 100 metres in depth. This smaller scale confinement can be traced well on 3D seismic volumes. The direction of slope progradation is a major factor in the routing of turbidity currents. Where slope-parallel confining ridges exist, sediment spills into the lower subbasin at one spill point. The development of sheets with continuous seismic facies onlapping basement highs indicates confinement. Well-defined lobes with the channel-lobe transition right after the spill point could develop. As the lower subbasin filled and the base level rose, sediment was trapped in the upper basin, with compensationally stacked lobes. In the next phase of development, channels were still diverted from the covered range but found their way to the then levelled out lower basin. The smaller scale of confining topography was greatly reduced by the time the slope progradation reached the area, but the larger scale of topography still greatly affected slope development.

Shale-gas potential of mid-Carboniferous mudrocks (Kinderscoutian), Cleveland Basin (Yorkshire, England)

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The shale-gas potential of mid-Carboniferous mudrocks (Kinderscoutian) in the Cleveland Basin (Yorkshire, northern England) was investigated through the analysis of a cored section in the Malton-4 well using a multidisciplinary approach. Black shales are interbedded with bioturbated and bedded sandstones, representing basinal-offshore to prodelta – delta-front lithofacies. The total organic carbon (TOC) content of the shales reaches 2.5 wt %. Rock-Eval pyrolysis data indicate that the organic matter is mainly composed of Type III kerogen with an admixture of Type II kerogen. Tmax (436-454^{o}C), 20S/(20S+20R) C29 sterane ratios, and vitrinite reflectance values indicate that organic matter is in the mid- to late- mature (oil) stage with respect to hydrocarbon generation. Sedimentological and geochemical redox proxies suggest that the black shales were deposited in periodically oxic-dysoxic to anoxic bottom waters with episodic oxic conditions, explaining the relatively low TOC values. The Rock-Eval parameters indicate that the analysed mudrocks themselves have a limited shale-gas potential. However, burial and thermal history modelling, and VRr data from other wells in the region, suggest that more deeply-buried shales, in the Bowland-Hodder unit, will be within the gas window with VRr > 1.1 % at depths in excess of 2000 m. Thus, although no direct evidence for a high shale-gas potential in these Namurian shales of the Cleveland Basin has been found, this cannot be precluded at greater depths, especially if deeper horizons are more organic rich.

Cyclic steps formed by dredger-induced turbidity currents, Western Scheldt Estuary, The Netherlands

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This study reports the formation of cyclic steps on the seafloor due to the passage of dredger induced turbidity currents. A dredger discharged approximately 500m^3 of sediment per dump, in a waterdepth of 10-15m, creating scouring and a density current moving downslope. This experiment was part of a field-scale flow-slide experiment to investigate the mechanisms through which submarine mass-movements in loosely packed sand initiate. The experiment was performed by Stichting FloodControl IJkdijk in September 2014 in the Western Scheldt Estuary, the Netherlands.

The area where the dredger disposed of its sediment, and the cyclic steps formed, was mapped by repeat multibeam surveys to image pre- and post-turbidity current bed morphologies. The turbidity currents, generated by the dredger discharging its sediment, were monitored using three acoustic Doppler current profilers (ADCPs), 300 kHz, 600 kHz, and 1200kHz, and three multimode multibeam echo sounders (M3s), each with a different field-of-view. This allowed for detailed and holistic imaging of the current's characteristics. After the experiment, multiple samples of the deposit were obtained with a vibrocoring system.

The dredger-induced turbidity currents created a series of upslope-migrating bedforms. The pattern of the bedforms is consistent with that of cyclic steps, in which a series of hydraulic jumps separates Froude-supercritical-flow eroding the lee-side of the bedforms, from Froude-subcritical flow depositing on stoss-sides. Similar bedforms are frequently observed in steep submarine canyons and on steep deltaic foresets.

Although there is a broad understanding on how cyclic steps are formed, the dynamics of the turbidity currents creating this particular pattern of erosion and deposition is not yet fully understood. The increased number of observations of upper-flow-regime bedforms created by turbidity currents in the past few years suggests that Froude-supercritical flow in turbidity currents is prolific. This field-experiment, with such an array of different data: bathymetric, acoustic and sediment-core, is valuable as it is not limited by scaling issues that are common in laboratory approaches, and the flows are controlled in contrast to flows in natural systems.

Paleoenvironment and sea level fluctuations during source rock deposition in Morocco during the Cenomanian/Turonian oceanic anoxic event

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Organic matter-rich mudstones were widely deposited in the shallow rift shelf basins and deep marine basins of Morocco during the Late Cenomanian to Early Turonian, taking the form of exceptionally thick, TOC-rich successions. This deposition was coeval with an Oceanic Anoxic Event (OAE2), an extraordinary period distinguished by the uncommonly widespread distribution of OM-rich mudstone deposition and anomalously high sedimentary burial rates on both a regional and a global scale. These rocks are potentially major hydrocarbon source rocks. This study aims to investigate the distribution of mudstones and their hydrocarbon potential in the different paleo-bathymetric settings of basins in Morocco during C/T intervals as well as reconstruct the mechanisms of mudstone deposition related to OAE2 in this area.

Preliminary results through petrographic and mineralogical analysis show that the Upper Cenomanian Azazoul section at Agadir basin represents a shallow-subtidal facies to deep-subtidal environment with evident sea-level fluctuations during the Late Cenomanian. Two sequence boundaries can be recognized in the upper Cenomanian of this section as expressed by lithological changes, fossil assemblages and erosional surfaces. A sea level regression occurred prior to the OAE2, followed by a rapid transgression across the OAE2 interval leading to organic-rich mudstone deposition. Subsequently, sea level fell, indicated by a considerably thick and laterally extensive oyster bed. The upper two mudstones layers, expressed as black, laminated mudstones with high pyrite content, suggest a euxinic and dysoxic environment during this time. Concurrently, the high amounts of kaolinite and absence of montmorillonite might indicate a humid climate during the OAE2 interval in this area. Further organic and inorganic geochemical analysis will be applied to investigate how the OAE2 affected the distribution and quality of source rock in this area.

Biofilm origin of clay coated sand grains: Understanding the fundamental processes governing the origin and distribution of clay-coated sand grains in petroleum reservoirs through a modern day analogue

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The ability to predict the occurrence of clay coated sand grains is essential in the exploitation of deeply buried anomalously high porosity hydrocarbon-bearing sandstones, resulting through the inhibition of the normally ubiquitous porosity-occluding quartz cement. However at present there is limited understanding of the origin of clay coats and no all-encompassing predictive model of clay coat abundance and distribution at a facies scale. To address this, we have focused on the distribution and origin of clay-coatings in modern sedimentary environments as a crucial step towards building a predictive capability.

This study adopted a high resolution analogue approach using the Ravenglass marginal marine system, NW England, UK. The work involved detailed analysis of the modern sedimentary system, including mapping surface sedimentary bedforms and bioturbation-intensity, grain size analysis and shallow cores. A range of scanning electron microscopy techniques were employed to characterise surface and core sediment samples in unison with Raman spectroscopy to study the distribution patterns and characteristics of clay coats on sand grains.

These exceptional data sets have produced unique and highly detailed maps that have started to reveal, for the first time, the pivotal role that biofilms (specifically diatom generated) play in the formation and distribution of intertidal detrital clay coated sand grains. Illustrating another pivotal biological sediment interaction, an original mechanism of clay coat formation and offering a crucial step towards building a predictive model. The results of which can be applied to aid the prediction of advantageous grain coating chlorite in sandstone reservoirs and thus facilitate prediction where the degradation of reservoir quality in ancient, deeply-buried petroleum reservoirs by quartz cement has been inhibited.

Bedform development and morphodynamics in mixed cohesive sediment substrates

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There remains a lack of process-based knowledge of sediment dynamics within flows over bedforms generated in complex mixtures of cohesionless sand and biologically-active cohesive muds. The work presented here forms a part of the UK NERC "COHesive BEDforms (COHBED)" project which aims to fill this gap in knowledge. Herein results from a set of large-scale laboratory experiments, conducted using mixtures of non-cohesive sands, cohesive muds and Xanthan gum (as a proxy for the biological stickiness of Extracellular Polymeric Substances (EPS)) are presented. The results indicated that both clay and EPS fractions in the initial bed conditions have a significant influence on the sediment transport over mobile beds. Higher clay and EPS fractions in substrates decrease bedform size, increase bedform evolution time and generally impedes the development of bedforms. Furthermore, winnowing and flocculation occur commonly in any flow condition with cohesive substrates (mud or EPS). Mud and EPS fractions in the initial bed decreases the winnowing efficiency, enhances the floc size and thus effect the grain settling velocity of the suspended material. And significantly, EPS has a higher efficiency in stabilizing the bed and enhancing the flocculation than clay alone, which highlights the necessity of including biological factors in sedimentological research in estuaries and coastal seas, particularly when considering morphodynamic rates of adjustment.

Simulation of hydrodynamics and sediments deposition at estuary of river-dominated shallow-water delta

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Based on Poyang Lake of China, this paper focused on the process of river flow into a lake of gentle slope. 6 sets of numerical simulation in different initial velocity conducted by Fluent software for analyzing the hydrodynamics, transportation and deposition of sediments in estuary of river-dominated shallow-water delta. The velocity of river flow decreases linearly in the direction of lake in the process of mixing. The influence distance of river is in direct proportion to initial velocity with a ratio of 3.2477. Hydrodynamic boundary layer developed along with mixing, and correspond with velocity in influence distance. The structure of bottom wall shear evolution present bimodal shape. This characteristic become more significant along with the increase of initial velocity. The influence distance of bottom shear increased in a ratio of 3.1151 with the initial velocity. A high concentration of sediments appears in the tail of mixing zone ranged from about 10 to 20m. A majority of sediments carried by river unload and deposit in this area.

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