52nd BSRG ANNUAL GENERAL MEETING

University of Hull

Programme and Abstracts

BSRG Sedimentary Research

University of Hull

Supported by:

Contents

Welcome

Welcome to the BSRG 2013 annual meeting. This year's AGM will be hosted at the University of Hull from the evening of the 18th December to the afternoon of the 21st December 2013.

The 52nd AGM sees BSRG come to East Yorkshire for the very first time. This is a fabulous time for us to host BSRG here in Hull as this year marks the return of Geology into our undergraduate programme. It is particularly symbolic given that Hull was to be the venue of the 1989 AGM that was moved to Leeds in the aftermath of the closure of Hull's Geology department that year!

As in previous years, we are looking forward to a strong turn-out from research students and early career researchers, together with established academics and practitioners in industry. We will once again have a series of topical sessions led by invited speakers, a technical session hosted by the Clay Minerals Group of Mineralogical Society of GB & Ireland, an icebreaker reception, conference dinner at The Deep aquarium, and a field trip to the Yorkshire coast.

The meeting is financially supported by a number of organisations, allowing us to keep registration costs to a minimum and ensuring that we are able to run an exciting programme. Support from sponsors has also enabled us to invite a series of invited speakers who will present exciting new results that span a range of sedimentological research areas.

Dan Parsons, Arjan Reesink and Claire Keevil
University of Hull

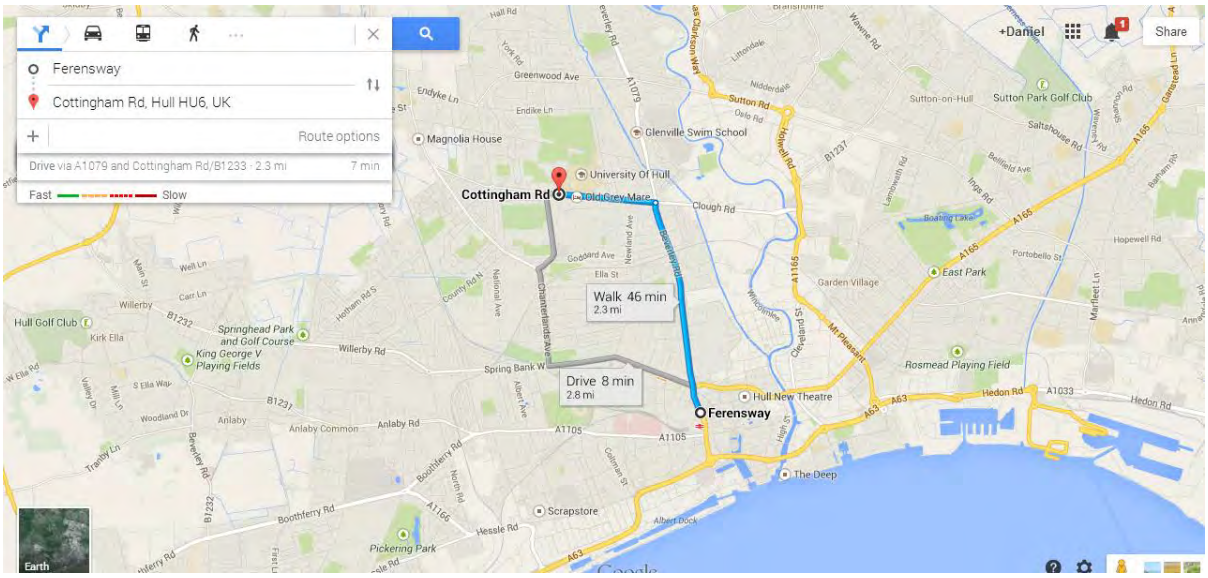
Travel and Orientation

The meeting is being held at Hull University Business School in the DERWENT BUILDING at the Main Campus of the University of Hull. The main campus is located in a residential district of North Hull on Cottingham Road. Detailed directions to the campus can be found:

http://www2.hull.ac.uk/theuniversity/directions-to-the-university/directions-to-hull.aspx

Arrival by train: Hull Paragon Interchange is in the city centre and provides easy access between rail, coach and local bus services all under the same roof. A taxi rank is located outside the main entrance of the station that will take you to the University (cost is about £6). Buses are also available from Paragon Interchange to the Hull campus on average every 10 minutes during the day. It will cost approximately £1.80 for a single fare.

For those arriving by car, there is a series of 'University' road signs that will direct you to the campus from the M62. We have limited parking but if you do intend to travel by car and require parking please let us know as soon as possible and we will endeavour to obtain a permit and provide you with instructions.



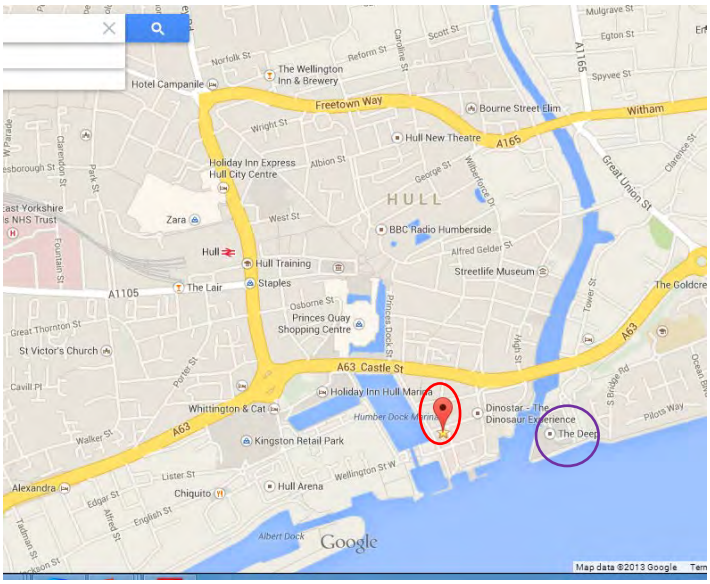
Map 1: Train Station to Main Campus

A bus service has been arranged to transport delegates from the conference hotels (rooms booked via VHEY) and the campus. These will be passing the hotels at approximately 0745 and 0815 to arrive at campus at 0815 and 0845 respectively each morning and will return delegates to the hotels (or the Deep for the conference meal) after the poster session on Thursday evening and after the sessions close on Friday.

The conference will be held in the DERWENT BUILDING (see campus map on next page). Plenary sessions will be held in the Allam Lecture Theatre, parallel sessions will be held within a seminar room at the same locality. The poster session will be held in the Derwent Café Bar area, where Tea and Coffee and Lunch will also be served both days. Signs from the main entrance will be posted.

ICEBREAKER

An icebreaker has been arranged for Wednesday night at a recently opened microbrewery named Brewery Wharf (http://brewerywharf.com/). This is within the Fruit Market area close to the city centre and near The Deep. This will begin at 1930 with a free bar (to start with at least!) and nibbles. Taxis will be available from the city centre for around £5. To walk follow signs for The Deep from the station along Ferensway, and then follow the signs to The Deep, when you arrive at the A63 cross the road and walk down east side of the marina - the fruit market is on the left.



Map 2: Brewery Wharf Location (red) & The Deep (purple)

CONFERENCE MEAL

The conference meal will be held at The Deep (http://www.thedeep.co.uk/). Buses have been arranged to take delegates back to their hotels after the poster reception on Thursday evening and an additional bus will go direct from campus to The Deep for a 1930 reception. The meal has been arranged for 2030, with tours of the aquarium and the Total Environment Simulator also available before this. For those making their own way to the meal, taxis are available from outside the station (Hull Interchange) for approximately £5 single fare. To walk to The Deep from the station, exit the station and cross the road towards House of Fraser department store and then follow the pedestrian signs to The Deep, it's a 15 minute walk (see Map 2).

PRESENTATIONS

Oral presentations:

Talk slots are 15 minutes long, including 3 minutes for questions, so please prepare your presentations accordingly. Keynote speakers' slots are 30 minutes including time for questions. Speakers should prepare their slides using Microsoft Powerpoint or Adobe PDF and be ready to upload their presentation onto the conference computer well in advance of their session.

Poster presentations:

Posters should ideally be prepared in portrait orientation and should be no larger than A0 in size. Landscape oriented posters will not fit on the display boards – although we will do our best to accommodate. Fixing materials will be provided. Those giving posters have the opportunity to "pop-up" and provide a 1-minute poster introduction in a dedicated session before the poster session on Thursday afternoon. If you would like to provide one slide to display during this session please send it in advance to agm2013@bsrg.org.uk.

FIELDTRIP

The Jurassic coast of Yorkshire

This one-day field trip on Saturday 21st will focus on exposures along the spectacular Yorkshire coast. The main focus will be on coastal outcrops between Bridlington and Scarborough. Lunch is provided. Coach pick-up at Hotels is available. Please ask the conference organisers to arrange this, otherwise pick-up will be from the Main Entrance at The University at 0900. We will return to Hull by 1700 and can drop delegates at the Station if requested.

Programme

52nd BSRG AGM, HULL 2013
Schedule & Timetable
ALLAM LT, DERWENT BUILDING

DAY 1: THURSDAY 19th December 2013			
815	900	Coffee	
900	915	Welcome and Introduction	
Session 1: [Plenary] - Carbonate Sedimentology (CHAIR: Dan Parsons)			
915	945	KEYNOTE: Facies Models for Carbonate Depositional Systems	Bosence, Dan
Session 2: [Plenary] - Novel Advances in Sedimentology (CHAIR: Dan Parsons)			
945	1000	The Use of Unmanned Aerial Vehicles in Sedimentology	Howell, John
1000	1015	The importance of spin: global submarine channel dynamics	Peakall, Jeff
1015	1030	Using sedimentology to help unravel the subduction-accretion & collision history of the southern margin of Eurasia (NE Turkey)	Robertson, Alastair
1030	1045	Sedimentology of a Welsh Ordovician Konservat-Lagerstätte	Jordan, Naomi
1045	1100	Discovery of major Middle Permian extinction in the Boreal Realm (Spitsbergen) with a possible causal link to Chinese volcanism	Bond, David
1100	1130	Coffee	
Session 1: Cont. (CHAIR: David Bond)			
1130	1145	Lime mud genesis: The microbial biofilm link	Pedley, Martyn
1145	1200	Using ICP-OES and ICP MS as a method of chemostratigraphic correlation and indication of environmental changes in Devonian carbonate reef complexes of the Canning Basin, Western Australia	Caulfield-Kerney, Sam
1200	1215	Controls on non-marine carbonate facies: the Purbeck Formation (Late-Jurassic to Early Cretaceous) of Dorset, Southern England.	Gallois, Arnaud
1215	1230	Reactive transport modeling of mixed fluid dolomitisation: Traditional coastal mixing zones and ascending freshwater-mesohaline mixing	Cooper, Katherine
1230	1330	Lunch	

52nd BSRG AGM, HULL 2013
Schedule & Timetable
NIDD ROOM, DERWENT BUILDING

DAY1: THURSDAY 19th December 2013		
815	900	Coffee
900	915	Plenary
Session 1: [Plenary] - Carbonate Sedimentology		
915	945	Plenary
Session 2: [Plenary] - Novel Advances in Sedimentology		
945	1000	Plenary
1000	1015	Plenary
1015	1030	Plenary
1030	1045	Plenary
1045	1100	Plenary
1100	1130	Coffee
Session 2: [Plenary] - Novel Advances in Sedimentology		
1130	1145	Plenary
1145	1200	Plenary
1200	1215	Plenary
1215	1230	Plenary
1230	1330	Lunch

ALLAM LT, DERWENT BUILDING

Session 3: [Plenary] - Deltaic, Fluvial and Coastal-Shelf Interactions (CHAIR: Jaco Baas)			
1330	1400	KEYNOTE: Deltas or Marine-Influenced Distributive Fluvial Systems - what does get preserved in the rock record?	Hartley, Adrian
Session 3: Cont. (CHAIR: Jaco Baas)			
1400	1415	Tidal to fluvial transition of the Sego Sandstone, Book Cliffs, Utah, USA	van Cappelle, Marijn
1415	1430	Influence of basin physiography on coastal-shelf sedimentary processes: Integrating ocean modelling and sedimentary facies analysis in the Mio-Pliocene, NW Borneo, South China Sea	Collins, Daniel A.
1430	1445	Flow structure and bedform morphology around a tidally influenced bar	Keevil, Claire
1445	1500	Assessing the influence of backwater hydraulics on sedimentological character of distributary channel fills in a tidally influenced deltaic system, Campanian Neslen Formation, Utah, USA	Colombera, Luca
1500	1530	Coffee	
Session 3: Cont. (CHAIR: Arjan Reesink)			
1530	1545	Modelling tectonic and eustatic sea-level processes in the Kyrenia Range, Cyprus, using sedimentology and new U-series data	Palamakumbura, Romesh
1545	1600	Subsurface classification of fluvio-deltaic sub-environments in the Triassic Mungaroo Formation, Exmouth Plateau, Australia	Stuart, Jennifer
1600	1615	The fluvial-tidal transition as a tool to assess the importance of tides in ancient deltas: implications for reservoir modelling	Gugliotta, M
1615	1630	Sedimentological, Ichnological and Paleontological Indicators of Tidal Influence and Brackish Water Conditions in Fluvial Coastal Plain Successions	Shiers, Michelle
Special Session [Plenary] (CHAIR: Dan Parsons)			
1630	1700	Poster Introductions	
1700	1900	Wine Reception and Posters	
1930	2359	Conference Meal (The Deep)	

NIDD ROOM, DERWENT BUILDING

Session 3: [Plenary] - Deltaic, Fluvial and Coastal-Shelf Interactions			
1330	1400	Plenary	
Session 4: Basins, Modelling and Reservoir Characterisation (CHAIR: Chris Jackson)			
1400	1415	Basin Architecture of the Zubair Formation and its Relationship to the Reservoir Characteristics in Selected Oilfields in The Southern Iraq	Al-Ziayyir, Haitham
1415	1430	An Automated Approach to the Measurement of Geometric Attributes from Modern Sedimentary Systems for Object Based Reservoir Modelling	Burr Nyberg, J.E.
1430	1445	Silliciclastic reservoirs hosted within Large Igneous Provinces: Parameters concerning Genesis and Distribution	Taylor, R.A.D
1445	1500	K-Ar ages dates of authigenic illite in oilfield sandstones – are they reliable?	Wilkinson, Mark
1500	1530	Coffee	
Session 4: Cont. (CHAIR: Dan Le Heron)			
1530	1545	Variations of Sediment Preservation Style in the Upper Jurassic of the Central North Sea Basin, UKCS: Halokinesis or Rift Influence?	Abu Bakar, Azli
1545	1600	3D Geologic and Reservoir Modelling of a Distributive Fluvial System Derived from lidar: A Case Study of the Huesca Fluvial Fan	Burnham, Brian S.
1600	1615	Influence of fluid pressure on the diagenesis of Triassic Skagerrak fluvial reservoir sandstones, Central North Sea, UK	Stricker, Stephan
1615	1630	Identifying depth and flow direction of injectites: diagnostic sedimentary structures	Cobain, S.
Special Session [Plenary]			
1630	1700	Poster Introductions	
1700	1900	Wine Reception and Posters	
1930	2359	Conference Meal (The Deep)	

ALLAM LT, DERWENT BUILDING

DAY 2: FRIDAY 20th December

Session 5: [Plenary] - Fine-granined systems (Clay Minerals Group Supported Session) (CHAIR: David Wray)			
900	930	KEYNOTE: From Nanopore to Wellbore: Penetrating the Shale Matrix	Aplin, Andrew
Session 6: Turbidites, Debrites and Mass Flows - dynamics & deposits (CHAIR: Jeff Peakall)			
930	945	Optimised turbulence enhancement during shear flow over a rib roughened boundary: implications for turbidity currents run-out length	Arfaie, A.
945	1000	Facies Trends and Large-Scale Architecture of the Pennsylvanian Ross Formation, Western Ireland - New Insight from Cores South of the Shannon	Obradors-Latre, A
1000	1015	Controls on the thickness and architecture of turbidite sandstones in MTD dominated settings, Vocontian paleomargin, SE France	de Leeuw, J.
1015	1030	Coalesced 3D scours on the base of a hybrid event bend from the Gottero Sandstone, NW Italy	Fonnesu, Marco
1030	1045	Inherent autogenic avulsion of aggradational submarine channels	Dorrell, R.M.
1045	1130	Coffee	
Session 6: Cont. (CHAIR: Marco Patacci)			
1130	1145	Architecture and Facies Characteristics of Scour-fills in Channel-Lobe Transition Zones, Karoo Basin, South Africa	Hofstra, Menno
1145	1200	An unexpected “switch-off” in turbidity current activity during the Palaeocene-Eocene Thermal Maximum	Clare, M.
1200	1215	The Fosado Turbidite Channel Complex (Eocene, South-Central Pyrenees, Spain)	Obradors-Latre, A
1215	1230	Finding order in chaos: The sedimentology of the Gwna mélange	Dartnall, Rosemary
1230	1330	Lunch	
1330	1400	**BSRG AGM Meeting**	
Session 6: [Plenary] - Cont. (CHAIR: Ian Kane)			
1400	1430	KEYNOTE: Half-way between the gutter and the scars: a review of mass transport deposits and look forward	Jackson, Chris

NIDD ROOM, DERWENT BUILDING

DAY 2: FRIDAY 20th December

Session 5: [Plenary] - Fine-granined systems (Clay Minerals Group Supported Session) (CHAIR: David Wray)			
900	930	Plenary	
Session 5: Cont. (CHAIR: Arjan Reesink)			
930	945	Diagenesis and non-mechanical compaction of overpressured shales	Andras, Peter
945	1000	Turbulence Modulation In Transitional Clay Flows: Kaolinite Versus Bentonite	Baas, Jaco H.
1000	1015	New method for settling velocity distributions: Two-population floc systems highlighted in British waters	Macdonald, Robert G.
1015	1030	Microconglomerate siltstones from the Early Carboniferous of Scotland: a key deposit for the preservation of early tetrapods	Bennett, Carys E.
1030	1045	Chemostratigraphy and provenance of clays and other non-carbonate minerals in chalks of Campanian age (Upper Cretaceous) from Sussex, southern England	Wray, D.S.
1045	1130	Coffee	
Session 7: Fluvial systems and Floodplains - dynamics and deposits (CHAIR: Nigel Mountney)			
1130	1145	Sedimentary structures formed under water surface waves during a sediment-laden flash flood that was observed by remote camera	Froude, M.J.
1145	1200	Flow Structures over Fixed 2D Bedforms in Transient States	Unsworth, C.A.
1200	1215	Statistically estimating the position of an apex for a distributive system	Owen, A.
1215	1230	The Great Flood: Alberta's "biblical" deluge of 2013	Noad, Jon
1230	1330	Lunch	
1330	1400	**BSRG AGM Meeting**	
Session 6: [Plenary] - Cont.			
1400	1430	Plenary	

ALLAM LT, DERWENT BUILDING

Session 6: Cont. (CHAIR: Ian Kane)			
1430	1445	Lateral facies changes and architecture of hybrid-like beds deposited in a ponded minibasin (Castagnola Fm, NW Italy).	Patacci, Marco
1445	1500	A progradational ice advance sequence in the Neoproterozoic Kingston Peak Formation, California	Busfield, M.E.
1500	1530	Coffee	
Session 6: Cont. (CHAIR: Dave Hodgson)			
1530	1545	Sedimentary facies in submarine canyons	Sumner, E.J.
1545	1600	Are you picking up what I'm putting down?: Long run-out flows that did not erode the seafloor	Stevenson, C.J.
1600	1615	Temporal and spatial evolution of a waxing then waning catastrophic density current revealed by chemical mapping	Williams, Rebecca
1615	1630	Debrite character and thickness distribution in MTD dominated setting: Middle Reservoir Zone, Britannia Field, North Sea	Teloni, Riccardo
1630	1645	Neoproterozoic ice sheets and olistoliths: the Kingston Peak Formation, Kingston Range, California	Le Heron, Daniel P.
1645	1700	Thin-bedded turbidites: a new approach toward better characterisation	Omoniyi, Bayonle

NIDD ROOM, DERWENT BUILDING

Session 7: Cont. (CHAIR: Nigel Mountney)			
1430	1445	Predicting fluvial reservoir architecture in salt-walled mini-basins through application of field analogues and stochastic modelling	Banham, Steven G.
1445	1500	Fluvial systems of the Ghaggar-Hakra Formation, Barmer Basin, Rajasthan, India	Beaumont, Hazel
1500	1530	Coffee	
Session 7: Cont. (CHAIR: Claire Keevil)			
1530	1545	What palaeo-environmental parameters do cross strata indicate?	Reesink, Arjan
1545	1600	Analysis of fine-grained floodplain facies as a tool to interpret spatial and temporal variation in avulsion style: Cretaceous Blackhawk Formation, Wasatch Plateau, Utah, U.S.A.	Flood, Yvette S.
1600	1615	Tetrapod terrestrialisation in the earliest Carboniferous: paleosol morphology and the floodplain environment of the Ballagan Formation	Kearsey, Timothy
1615	1630	How do drainage systems evolve during mid to late Large Igneous Province development?	Barker, A.R.
1630	1645	The Influence of Cohesive Sediments on Dune Development	Schindler, R.
1645	1700	Identification and interpretation of climatic cycles in alluvial fan sediments; a case study from the Permian Cutler Group, Utah, U.S.A.	Gough, Amy

52nd BSRG AGM, HULL 2013
Schedule & Timetable
DERWENT CAFÉ BAR AREA

1700 - 1900 THURSDAY 19th December

Posters

1	Carbonate-evaporite cyclicity in the Middle Miocene Fatha Formation of the Mesopotamian Basin, Kurdistan	Abdullah, Heero G.
2	Styles of interaction between fluvial and aeolian systems along the Skeleton Coast, northern Namib Desert	Alkathery, Mahmud
3	Styles of fluvial and aeolian system interaction in desert-margin settings: examples from modern systems	Al-Masrahy, Mohammed A.
4	Sedimentological process record of a sediment bypass zone in a base-of-slope setting: an outcrop study from the Laingsburg depocentre, Karoo Basin	Brooks, Hannah L.
5	Stratigraphic architectural complexity in fluvial overbank successions: examples from the Cretaceous Mesa Verde Group, Utah, USA	Burns, Catherine
6	The north-eastern Porcupine Basin: The provenance and petrography of Early Tertiary sands	Evans-Young, S.
7	Determining the palaeodrainage of the Nile river from a provenance study of the Nile delta cone sediments	Fielding, Laura
8	Sedimentology and depositional architecture of the shallow-marine to non-marine transition, Karoo Basin, South Africa	Gomis-Cartesio, Luz E.
9	The use of climatic cyclicity as a correlation method between proximal and distal deposits of arid continental basins	Gough, Amy
10	Palaeogeographic reconstruction of an ephemeral fluvial system, Karoo basin	Gulliford, Alice R.
11	Counter-flow ripples: formation, preservation and value for interpreting flow conditions	Herbert, Chris
12	Impact of vegetation patch shape on mean flow and turblunce characteristics	Jordan, David N.
13	Flow transformation in distal lobe environments: Skoorsteenberg Fm., Tanqua Karoo	Kane, Ian A.
14	Revising the base-Quaternary of the central North Sea using 3D seismic mapping	Lamb, Rachel
15	Outcrop analogues contributing towards the understanding of facies distribution and sedimentary architecture in Upper Cretaceous carbonate platforms (South Central	Lavi, Jonathan J.
16	Multi-scale 3D imaging of minerals, pores and organic matter in the Eagle Ford Shale Formation, Texas: implications for oil shale reservoir characterisation	Ma, Lin
17	Factors controlling floc settling velocity within San Francisco Bay, USA and comparisons with parameterization approaches	Manning, Andrew J.
18	Diagenetic modifications in the Eagle Ford Formation	McAllister, Richard T.
19	A geophysical investigation of relative sea level changes in Cemlyn Bay, North Wales	McCarthy, Rhys
20	Root traces and plant-soil interactions of two Middle Devonian trees, New York State	Morris, Jennifer
21	Equatorial sea surface seasonality in the Mississippian (Early Carboniferous) derived from brachiopod shell calcite	Nolan, L.S.P.
22	Deepwater sandstone fairways and their interaction with substrate: analogues from the Numidian turbidites (Miocene) of Sicily.	Pinter, Patrícia

23	New records of the Cotham Marble microbialite and implications lithostratigraphy, palaeogeography and depositional environment of the Rhaetian aged Lilstock Formation	Raine, Robert J.
24	Hypsometry and geology of drainage basins: toward understanding the long term landscape evolution of southern South Africa	Richardson, Janet
25	mLogger: a free mineral logger for mineralogical modal analyses	Roberson, Sam
26	Modelling complete particle-size distributions from operator estimates of particle size	Roberson, Sam
27	Sedimentary architecture of point-bar deposits in fluvial and tidally-influenced successions: examples from the Cretaceous Mesa Verde Group, Utah, USA	Russell, Catherine
28	Early Carboniferous marginal marine palaoenvironments preserve important vertebrate fauna in the Northumberland Basin	Sherwin, Janet
29	Dynamic Humber – Using Cellular-Automata to Model an Estuarine Environment	Skinner, C.
30	Controls on Fluvial and Tidal Sandbody Architecture from the Miocene Uncastillo Formation, Spain, the Eocene Green River Formation, Utah, and the Jurassic Lajas	Smaadal, Kristine
31	Reconstruction of channel and barform architecture in a fluvio-deltaic succession: understanding the significance of complex three-dimensional sedimentary architecture	Soltan, Roman
32	Raman spectroscopy as a method of heavy mineral identification	Stone, Tom
33	Key stratal surfaces traced over 30km from shoreface sandstone to distal mud-rich siltstones; paving the way for predicting sedimentary architecture in shale gas reservoirs	Vaitekaitis, Tracey V.
34	Seismic Characteristics of Hyaloclastite Deposits: Implications for Petroleum Exploration	Watton, Tim
35	The timing of silica diagenesis revealed by basin modelling	Wrona, Thilo
36	The Dynamics of Suspended Sediment over Bedforms in Mixed Sand-Clay-EPS Sediment	Ye, L.

Talk Abstracts

Carbonate-evaporite cyclicity in the Middle Miocene Fatha Formation of the Mesopotamian Basin, Kurdistan

Heero Ghareeb Abdullah*, Richard Collier, Nigel P. Mountney

School of Earth and Environment, University of Leeds, Leeds LS2 9JT

*Corresponding author: ml11hga@leeds.ac.uk

Five detailed vertical sections of the cyclical Middle Miocene Fatha Formation were measured and studied on the northeast margin of the Mesopotamian Basin in the Kurdistan region, northeast Iraq. The aim was to interpret the relation between carbonate and evaporite units of the formation. Specific objectives were to characterize sea-level changes and to test the general applicability of pre-existing sequence stratigraphic models of carbonate-evaporite cycles. The formation is one of the most extensively outcropping units in Kurdistan. It exhibits multiple stacked depositional cycles which each comprise, from base to top, calcareous mudstones, carbonates and evaporates that overall accumulated in a gently-dipping ramp environment. Two variations in the general style of cyclicity are noted: (i) the presence of a red, primarily claystone clastic unit above the evaporite element, especially in cycles present in the upper part of the formation; (ii) depositional cycles in which the evaporite unit is absent. The carbonate units include shallow-marine deposits rich in benthic foraminifera and these additionally contain coralline red algae (Rhodoliths), Rotalia, Pelecypods, Ostracods, Miliolids, Gastropods, Cephalopods, Bryozoans, and Brachiopods. The carbonate units are characterized by a range of sedimentary structures including planar-parallel lamination, wavy lamination, trough cross-bedding, ripple marks, load casts and flame structures, flute casts and bioturbation. Based on field observations and thin section characterization of the gypsum dominated evaporite units, three main sabkha evaporite textures are recorded: chicken wire, enterolithic and laminated evaporites and these are associated with greenish calcareous mudstones. Where present, red claystones interpreted to be of terrestrial origin were deposited above the sabkha unit.

Overall, the succession records a series of preserved sequences that are expressed as depositional cycles. Each cycle records a generally shallowing-upward, regressive package. A calcareous mudstone unit of probable offshore marine origin occurs above each flooding surface, the lower part of which may represent a transgressive system tract. This unit passes upwards into shoaling-up carbonates, deposited in a highstand system tract. Sabkha evaporitic units may have been deposited during late highstands and the red clastic units within falling stage and/or lowstand system tracts.

Variations of Sediment Preservation Style in the Upper Jurassic of the Central North Sea Basin, UKCS: Halokinesis or Rift Influence?

Azli Abu Bakar[1]*, Howard D. Johnson[1], Christopher A-L. Jackson[1], Tom McKie[2] and Caroline E. Gill[2]

[1]*Department of Earth Science and Engineering, Prince Consort Road, Imperial College London, SW7 2BP*

[2]*Shell UK, 1 Altens Farm Road, Nigg, Aberdeen, AB12 3FY*

*Corresponding author: a.abu-bakar11@imperial.ac.uk

The Upper Jurassic (UJ) succession of the Central North Sea (CNS) Basin in the United Kingdom Continental Shelf (UKCS) broadly comprises aggrading to prograding coastal fluvio-marine (Pentland Formation) to shallow marine (Fulmar Formation) Oxfordian sediments followed by retrograding shallow marine (Fulmar Formation) to deep marine (Heather and Kimmeridge Clay formations) Kimmeridgian and Volgian sediments. Within the rifted and salt-bearing CNS this stratigraphic architecture could reflect either (1) increasing accommodation space associated with basin rifting, or (2) movement of underlying salt bodies associated with the withdrawal of Permian Zechstein evaporates, or (3) variable combinations of rifting and halokinesis. These different geological controls have been investigated by (1) interpreting 3D seismic data across the UK CNS from the top of the pre-rift (Top Rotliegend Formation) through two syn-rift successions (Triassic and Upper Jurassic) and into the post-rift (Upper Cretaceous Chalk), and (2) integrating these seismic interpretations with core, well log and biostratigraphic data. The results show that the preserved sedimentary succession is far more variable than has previously been considered, resulting in established models, such as the pod-interpod model, failing to provide a reliable basis for sandstone reservoir prediction. Examples of this variability include inter-fingering of shallow marine and mass flow facies (e.g. southern nose of the Forties-Montrose High), alternating prograding and retrograding coastal facies (e.g. near the Curlew Platform and Marnock Terrace), and Oxfordian deep water sands in the Josephine Ridge area. Rapid thickness change within closely-drilled, isochronous sand units was also recorded. The most significant variability occurs in the older Oxfordian successions, which is thought to reflect the depositional reaction to early rifting and initial underlying salt movement. The younger Kimmeridgian and Volgian successions are thought to be less variable and more widespread due to an increase in the rate of relative sea level resulting in flooding of most parts of the CNS. The pod-interpod preservation style of UJ shallow marine sandstones is mainly restricted to the Western Platform area, which is probably related to late-stage salt collapse. The varying preservational styles of Jurassic sandstones require an understanding of the underlying Palaeozoic structure, which had a major control on accommodation space creation and destruction throughout the Mesozoic.

Basin Architecture of the Zubair Formation and its Relationship to the Reservoir Characteristics in Selected Oilfields in The Southern Iraq

Haitham Al-Ziayyir*, David Hodgetts

University of Manchester, School of Earth, Atmospheric and Environmental Sciences, University of Manchester, Manchester, M13 9PL, UK.

*Corresponding author: haitham.al-ziayyir@postgrad.manchester.ac.uk

The lower Cretaceous Zubair Formation is one of the most important and prolific oil reservoirs in the southern Iraq region. This study attempts to improve the understanding of the nature of pressure distribution within the Zubair Formation, and to show which factors such as seals, barriers and baffles are responsible for controlling that pressure.

The current study based on a multidisciplinary approach involves an assessment of the impact of clay minerals and diagenetic processes on seal capacity of the formation within the Mesopotamia Basin. The seal is mapped to investigate geometry and continuity, and distribution of overpressure across the area. Work has also been undertaken to demonstrate the basin architecture and to characterize the properties of the reservoir units of the Zubair within the basin and its fills. Mapping of the reservoir units, plays and migration pathways is made with the aid of GIS.

A large data set was used to accomplish this work comprising cores, logs and pressure data. SEM, EDX and XRD analyses were performed using data collected from six wells taken from sand /shale contacts. The clay mineralogy of the sand/shale contacts revealed the abundance of authigenic illite, illite /chlorite and chlorite in the Zubair shales at greater depths, with kaolinite is present in only a few samples. The economic viability of the Zubair Formation will be greatly increased by the improved understanding of reservoir sealing and compartmentalization, allowing for better reservoir management and improved recovery.

Keywords Zubair Formation, pressure distribution, seal capacity, clay mineralogy.

Diagenesis and non-mechanical compaction of overpressured shales

Péter András*, Andrew Aplin, Neil Goulty and Stuart Jones

Department of Earth Sciences, Durham University, South Road, Durham DH1 3LE, UK.
Funded by GeoPOP3 Industry Research Consortium

*Corresponding author: peter.andras@durham.ac.uk

Accurate pore pressure prediction is essential for well planning. Direct pore pressure measurements may be available from permeable reservoir formations. In mudrock sequences pore pressures can only be estimated indirectly, by empirical methods from seismic reflection data and wireline log responses.

In low temperature environments pore pressures can be estimated from porosity assuming that porosity loss is entirely mechanical and is driven by vertical effective stress according to Terzaghi's Principle. By establishing relationships between porosity and vertical effective stress for mechanically consolidated mudstones, pore pressure can be estimated from vertical stress (overburden thickness) and measured or log-inferred porosities.

In higher temperature environments, methods based on a porosity-effective stress relationship fail to deliver accurate pressure predictions. This is because in the deeper and hotter parts of basins porosity reduction continues due to chemical rather than mechanical compaction processes, and leads to underestimation of pore pressure. Temperature affects the kinetics and equilibrium of chemical processes; it causes mineral transformations, grain dissolution and cementation. The porosity-effective stress methods for estimating pore pressure must be used with extreme caution where siliciclastic or biogenic mudstones have been subjected to temperature-related mineralogical changes.

The overall objective of this project is to investigate the link between non-mechanical compaction, the consolidation state of mudrocks and their physical properties as determined by wireline logs. We have selected two suites of samples, one from the Lower Cretaceous offshore mid-Norway and one from the Triassic of the Central Graben, North Sea, both of which have undergone chemical diagenesis in a range of pore pressure environments. A set of different methodologies including XRD, BSEM, SEM CL, HRXTG, and MICP will be applied to describe the composition, texture and physical properties of mudstone samples. Results will allow us to test the extent to which mineralogical changes lead to porosity loss independent of pore pressure and the extent to which pore pressure signatures are retained by mudstone fabrics.

KEYNOTE:

From Nanopore to Wellbore: Penetrating the Shale Matrix

Andrew C. Aplin[1*], Eliza J. Mathia[2], Thomas F.T. Rexer[2], K. Mark Thomas[3]

[1]*Department of Earth Sciences, Durham University*

[2]*School of Civil Engineering and Geosciences, Newcastle University*

[3]*School of Chemical Engineering and Advanced Materials, Newcastle University*

Hydraulic fracturing combined with horizontal drilling is changing the face of the petroleum industry, allowing large volumes of gas and light oil to be produced from shales and other fine-grained sediments; around 30% of US dry gas is now produced from shales, up from 2% in 2000.

Whilst these engineering advances have allowed the unconventional industry to flourish, geoscience has a central and long-term role to play in the conversion of the gas resource into producible reserves. In terms of exploration, shales are mineralogically and sedimentologically heterogeneous on scales ranging from millimetres to kilometres, with important consequences for diagenesis, pore system evolution, gas storage and geomechanical properties. In terms of production, a key question is how gas which is stored in a typically nanoporous matrix is transported to a fracture network which connects to a wellbore in such a way as to allow commercially interesting rates of gas flow.

In this talk I will focus on our recent research on the Posidonia Shale, a potentially important gas shale target in Germany (and elsewhere in Europe). We have looked at the way in which matrix properties, pore systems and gas storage properties evolve in a maturation series from Ro = 0.53% (earliest oil window) to 0.89% (mid oil-window) to 1.45% (gas-window). Bulk porosity is lost through the oil window due to compaction and bitumen-filling of porespace, and is regained in the gas window as a result of gas-generating reactions in both kerogen and bitumen. We have used low pressure CO_2 sorption, mercury injection porosimetry and BIB-SEM/FIB-SEM to quantify pore volumes ranging in size from sub nanometre to micron. Each gives very different answers so that a combination of techniques is required to generate the quantitative data required to develop sound gas production models. For example: typically half the total porosity is within pores smaller than 6 nm, with important consequences for the producibility of sorbed gas occurs; on the other hand, only 10% of total porosity is typically visualised in (admittedly pretty!) BIB-SEM images.

Optimised turbulence enhancement during shear flow over a rib roughened boundary: implications for turbidity currents run-out length

A. Arfaie[1]*, A.D. Burns[1], R. Dorrell[2], J.T. Eggenhuisen[3], D.B. Ingham[1], W.D. McCaffrey[2]

[1]*Energy Technology and Innovation Initiative (ETII), University of Leeds, Leeds LS2 9JT, UK*

[2]*School of Earth and Environment, University of Leeds, Leeds LS2 9JT, UK*

[3]*Department of Earth Sciences, Utrecht University, PO Box 80021, 3508 TA Utrecht, Netherlands*

*Corresponding author: pm10aa@leeds.ac.uk

Many turbidity currents run over substrates that are dynamically rough, either through erosion of substrate to leave a rugose lower boundary, or via the construction of aggradational bed forms. Three important aspects of turbidity currents that have so far not been explored in great detail are the focus of this study. How do flow interactions with lower boundary roughness elements affect the dynamic structure of the flow? What is the optimum spacing of roughness that would maximise the turbulence within the flow? Can the sediment carrying capacity of the flow be significantly modulated by flow interactions with lower boundary roughness elements? To this end, a series of numerical investigations have been performed to study the effect of lower boundary roughness on turbulent flow in a two-dimensional channel. The roughness spacing to height ratio, w/k, has been investigated over a range from 0.12 to 402 by varying the horizontal rib spacing. A Reynolds Averaged Navier-Stokes (RANS) based turbulence modelling approach is adopted using a commercial CFD code, ANSYS-CFX 14.0. Measurements of turbulence intensity, eddy viscosity and friction factor have been made over this range to establish the optimum spacings to produce maximum turbulence enhancement, mixing and resistance to flow. A critical width-to-height ratio of $w/k \approx 7$ is confirmed to be associated with maxima in each of these variables, whilst a linear rate of turbulence enhancement is seen up to $w/k = 7$, followed by a comparatively slow exponential rate of decay beyond this critical ratio. Assuming that increased turbulent mixing enhances, and increased drag diminishes, flow run-out length, closer examination of the form of the variation of turbulent mixing and flow drag with varying roughness spacing is required to see if there is an optimal pacing to maximally enhance flow run-out length.

Turbulence Modulation In Transitional Clay Flows: Kaolinite Versus Bentonite

Jaco H. Baas[1]* and James L. Best[2]

[1]*School of Ocean Sciences, Bangor University, Menai Bridge, Isle of Anglesey, LL59 5AB*

[2]*Departments of Geology, Geography and Mechanical Science and Engineering and Ven Te Chow Hydrosystems Laboratory, University of Illinois at Urbana-Champaign, 1301 West Green Street, Urbana, IL 61801, USA*

*Corresponding author: j.baas@bangor.ac.uk

The last decade has seen a bloom in research on cohesive fine sediment, which has led to improved models for clay-rich sediment transport, in pure form or mixed with sand, and the depositional products of such flows. Sedimentary geology now benefits from, for example, hybrid and transitional flow models for deep-marine sediment gravity flow deposits, mobile fluid mud models for estuarine and shelf sea deposits, and floccule ripple models for muddy shallow marine sequences.

The transitional clay flow model describes how flow turbulence is modulated (enhanced or attenuated) between turbulent and laminar end members, as suspended clay concentration in the flow increases from zero to a value that is high enough to pervasively suppress turbulence production by the formation of stable bonds between the clay particles. This results in five distinct flow regimes: (1) turbulent flow; (2) turbulence-enhanced transitional flow, in which turbulence is enhanced throughout the flow; (3) lower transitional plug flow, in which turbulence intensity is high near the bed and low in a rigid plug within the outer flow region; downstream velocity is invariant with depth within this plug; (4) upper transitional plug flow, in which near-bed turbulence becomes dampened and the plug extends downward from the flow surface; (5) quasi-laminar flow, in which the rigid plug extends into the near-bed region.

The existing transitional clay flow model is based on kaolinite, a clay mineral which is common in nature, but has weaker cohesive properties than most other common clay minerals, such as illite and bentonite. New experimental data extend this model to bentonite, a swelling clay with much higher viscosity and yield strength than kaolinite. These data show that bentonite flows develop flow regimes that are similar to kaolinite flows. However, the regime boundaries for the bentonite flows were found at clay concentrations that were typically more than 50% lower than for the kaolinite flow. This strong turbulence modulation strengthens modern thinking that clays play a key role in process sedimentology, even at concentrations that were previously thought to be insignificant in affecting turbulent flow properties and depositional signatures.

Predicting fluvial reservoir architecture in salt-walled mini-basins through application of field analogues and stochastic modelling

Steven G. Banham[1,2*] and Nigel P. Mountney[1]

[1]*Fluvial Research Group, Earth and Environment, University of Leeds*

[2]*British Geological Survey, Murchison House, Edinburgh.*

*Corresponding author: steban@bgs.ac.uk

Hydrocarbon-bearing fluvial successions preserved in salt-walled mini-basins have been exploited commercially since the 1980s, yet the processes by which halokinetic events act to influence the character of fluvial drainage pathways and the style of accommodation generation – and thereby determine the distribution of accumulated fluvial architectural elements – remain relatively poorly understood. The reservoir potential of fluvial successions developed in salt mini-basins is primarily controlled by the proportion, distribution and style of interconnectivity of sand-prone elements that act to contribute to net reservoir. These key reservoir attributes are controlled by parameters related to both mechanisms of halokinesis and processes of sedimentation. Such parameters vary on a variety of spatial scales (regional- to sub-mini-basin scale) and also over a range of temporal scales (from prior to the accumulation of the salt to after the ultimate cessation of halokinesis); thus, development of models for prediction of likely fluvial reservoir architecture in salt mini-basins is not straight-forward. Key factors that act to influence reservoir potential include: (i) sub-salt basin geometries and pre-existing lineaments, which can control the maximum subsidence potential of the mini-basins and the orientation of the growing salt walls; (ii) regional dip, and orientation of regional drainage relative to the orientation of evolving salt walls; (iii) climate and provenance, which control rates of sediment delivery; and (iv) rates of halokinesis which control the distribution of drainage pathways and the state of basin fill over both space and time.

Generic tectono-stratigraphic depositional models based on fluvial-halokinetic relationships from multiple outcrop and subsurface examples have been developed to predict the expected distribution of fluvial architectures in the fills of salt-walled mini-basins. Together these models demonstrate how key controlling parameters interact to influence preserved fluvial architecture and reservoir potential. The models serve as the basis for a novel stochastic modelling approach to quantify expected sand-body connectivity of sand-prone fluvial units present in salt-walled mini-basins. The technique can be used to predict sand body distribution within basins during exploration, and assist in field appraisal and development strategies.

How do drainage systems evolve during mid to late Large Igneous Province development?

A.R. Barker*, A.J. Hartley, D.W. Jolley, M.J. Hole, R.A.D. Taylor, A. Ebinghaus and J. Millett

Department of Geology and Petroleum Geology, School of Geosciences, University of Aberdeen, Aberdeen, UK.

*Corresponding author: aaron.barker@abdn.ac.uk

Drainage systems within Large Igneous Provinces (LIPs) are affected by a complex interplay between volcanic activity, tectonics and climate. This project aims to produce a predictive model for subsurface hydrocarbon exploration and development in LIPs and focuses on mid to late LIP development, defined here as being after the main phase of eruptive activity.

The two ancient field examples studied are the Skye Main Lava Series (SMLS) in NW Scotland, and the Columbia River Basalt Group (CRBG) in NW USA. These represent two significantly different expressions of LIP volcanism. The SMLS covers around 1,500km^2. It forms one of a number of lava fields developed within the North Atlantic Igneous Province, and was emplaced by several eruptive centres in the form of overlapping flow fields. Fluvial systems were strongly influenced by gradient changes associated with these local centres, and by the formation of the nearby Rum Central Complex. In contrast the CRBG was sourced from up to two main fissure zones and covers approximately 164,000km^2, which means that potential correlation distances within fluvial systems are longer and the influence of volcanism on the drainage was simpler. By studying both lava fields, this research intends to discover which aspects of these drainage systems are common to LIPs, and which are unique to separate provinces.

Comparison between the modern and ancient study areas indicates that volcanism has a strong effect on drainage systems. In tectonically active areas such as the Lewiston Basin in the eastern part of the Columbia River Basalt Province, periods of volcanic quiescence are sufficiently long for basins to form after the main phase of volcanism, allowing the aggradation of thick sedimentary interbeds. In this case, the interbeds are up to 60m thick and dominated by siliciclastic fluvial channel and proximal overbank deposits. Due to the topography of the basin, these sediments thin laterally over ~10km to a palaeosol 50cm thick. Later, canyons parallel to the modern Snake River were incised up to ~250m into the underlying lava flows and interbeds, and were subsequently filled by intracanyon flows.

Fluvial systems of the Ghaggar-Hakra Formation, Barmer Basin, Rajasthan, India

Hazel Beaumont[1]*, Stuart Clarke[1], Andrew Taylor[2], Stuart Burley[1,3],Nicholas Whiteley[3] and Pinak Mohapatra[3]

[1]*Basin Dynamics Research Group, School of Physical and Geographical Sciences, Keele University, Keele, Staffordshire, UK*

[2]*Ichron Limited, Century House, Gadbrook Business Centre, Northwich, Cheshire, U.K*

[3]*Carin Indi Ltd., Vipul Plaza, Sun City, Sector 54, Gurgaon, India*

*Corresponding author: h.beaumont@keele.ac.uk

Fluvial systems are prolific in arid continental environments both present day and within the rock record. Ancient examples commonly form good hydrocarbon reservoirs in stratigraphic traps, resulting from interactions between their different architectural elements. The arrangement of sedimentary architectures is strongly dependent upon sediment accumulation, subsidence rates, localised structure, climate, and interactions with other contemporaneous environments. The Lower Cretaceous aged Ghaggar-Hakra Formation of the Barmer Basin, India, comprises three fluvial sandstone successions that appear to be atypical with respect to braided and meandering fluvial facies models. Providing insights into the understanding of arid fluvial environments controlled by high sediment supply and varying discharge.

The Nosar Member is the youngest fluvial succession of the Ghaggar-Hakra Formation and comprises medium- to coarse-grained sandstones preserved within channel elements. The preserved sedimentology includes stacked channels, channel lags and braid bars, all of which are typical in fluvial systems. However, channel elements also preserve significant amounts of matrix supported sediment components, syn-sediment deformation, tree debris, and fine-grained rip-up clasts despite an almost universal absence of preserved overbank.

From the sedimentology observed it is evident that the Nosar Member does not conform to recognised meandering or braided facies models. In this work we present an alternative facies model for the Nosar Member that is dominated by stacked channels, minimal overbank deposition and poorly developed geometries of braid bars. These atypical architectural elements are attributed to fluvial systems that are dominated by a high sediment supply and / or variable discharge due to flash flood events.

Microconglomerate siltstones from the Early Carboniferous of Scotland: a key deposit for the preservation of early tetrapods

Carys E. Bennett[1]*, Tim Kearsey[2], Sarah J. Davies[1], David Millward[2], John E.A. Marshall[3]

[1]*Department of Geology University of Leicester, Leicester, LE1 7RH*

[2]*British Geological Survey, Murchison House, West Mains Road, Edinburgh, EH9 3LA*

[3]*Ocean and Earth Science, University of Southampton, SO14 3ZH*

*Corresponding author: ceb28@le.ac.uk

This study is a contribution to the TW:eed Project (Tetrapod World: early evolution and diversification), a major research programme investigating the rebuilding of Carboniferous ecosystems following a mass extinction at the end of the Devonian. For the first time, microconglomerate siltstones are identified as key deposits preserving rare fish and tetrapod (first four-limbed vertebrates) material in the Ballagan Formation (Tournaisian) of Scotland and the Borders. The Ballagan Formation is characterised by fluvial sandstones, dolostone 'cementstones', paleosols, siltstones and gypsum from a coastal-alluvial plain setting.

Microconglomerate siltstones are matrix-supported with clasts of up to 1 mm within a siltstone matrix. Rounded clasts are composed of grey/black/red siltstones or fine sandstones, plant and wood debris, fish fragments (rhizodonts, actinopterygians, *Gyracanthus*), rare charcoal and rare tetrapod remains. Units, up to 1 metre thick, occur approximately every 4 metres throughout a 500m thick succession. Thinner units are laminated. Thick units generally have no internal structure or display soft-sediment deformation. Some thicker units contain centimetre-sized clasts and are classified as conglomerates.

Microconglomerate siltstones are associated with a range of facies, most commonly overlying brecciated palaeosols or infilling in desiccation cracks on brecciated surfaces of sandstones and cementstones. Units are typically topped by laminated grey siltstones. Secondary pedogenic alteration is common and stacked successions of paleosols and microconglomerates are common.

These microconglomerates are interpreted as the deposits of localised flooding events on a coastal-alluvial floodplain. Matrix and clasts are likely sourced from reworking of silt and fossil-rich sediments in dried-up water bodies on the floodplain. Laminated grey siltstones overlying microconglomerates indicate deposition in submerged ponds or lakes. Scolecodonts (marine worm jaws) found within one microconglomerate, may indicate marine transgressions played a role in the deposition of these units. Tetrapod and fish fossils are concentrated by the reworking process and are preserved by rapid deposition inhibiting disruption by bioturbation. Seasonal precipitation in a generally arid environment may have generated the flooding events. This study uses integrated sedimentology, palaeontology and palynology to identify the depositional environment of rare early Carboniferous tetrapods.

Discovery of major Middle Permian extinction in the Boreal Realm (Spitsbergen) with a possible causal link to Chinese volcanism

David P.G. Bond[1]*, Paul B. Wignall[2], Yadong Sun[3], Dierk Blomeier[4], Ivan Savov[2] and Steve Grasby[5]

[1]*Department of Geography, Environment and Earth Sciences, University of Hull, Hull, HU6 7RX, UK*

[2]*School of Earth and Environment, University of Leeds, Leeds, LS2 9JT, UK*

[3]*GeoZentrum Nordbayern, Universityy of Erlangen-Nuremberg, 91054 Erlangen, Germany*

[4]*Norwegian Polar Institute, Fram Centre, 9296 Tromsø, Norway*

[5]*Geological Survey of Canada, 3303 33rd Street N.W., Calgary, Alberta, T2L 2A7, Canada*

*Corresponding author: d.bond@hull.ac.uk

The Permian witnessed two mass extinctions that changed the course of life on Earth. The earlier of these two, the Middle Permian Capitanian extinction (260 Myr BP), lay for many years undiscovered in the shadow of the “Great Dying” at the close of the Permian. The Capitanian event wiped out >50% of marine invertebrate species and was discovered in the record of fusulinacean foraminifers in South China, where it is seen to precisely coincide with the onset of Emeishan large igneous province volcanism. Contemporaneous (but poorly constrained) terrestrial losses amongst plants and megafauna suggesting an event of inter-continental scale was triggered by volcanic and thermogenic emissions from Emeishan. Two seasons examining the cool-water, spiculitic carbonate platform of the Kapp Starostin Formation of west Spitsbergen has revealed the Capitanian extinction for the first time from a northern mid- to high-latitude (Boreal) setting, confirming its global extent.

In the absence of biostratigraphically useful fossils, we have generated a detailed carbon and strontium isotope chronostratigraphy to better correlate the Spitsbergen successions with China, the site of Emeishan volcanism. The suggested temporal link indicates that this volcanism was a killer of global extent, capable of affecting remote regions thousands of miles from its epicentre. Its effects were profound even in Spitsbergen, where brachiopod losses were as severe, if not more so, than in equatorial regions. To achieve such damage, Emeishan must have injected volatile gases and perhaps ash far into the upper atmosphere. Pyrite framboid distributions and redox-sensitive trace metals indicate that (unlike in China) marine anoxia – a common side effect of volcanism – probably featured in the Spitsbergen extinctions.

Although of less significance globally, the earlier, Capitanian extinction amongst brachiopods was just as severe in Spitsbergen as the terminal Permian event. The Capitanian event was one from which the brachiopods never really recovered, instead giving way to a Late Permian radiation of (mostly pectinid) bivalves. These faunas have a prominent Mesozoic character, suggesting that the transition from Palaeozoic fauna occurred in the aftermath of the Capitanian crisis, rather than during the Triassic as generally assumed.

Sedimentological process record of a sediment bypass zone in a base-of-slope setting: an outcrop study from the Laingsburg depocentre, Karoo Basin

Hannah L. Brooks[1]*, Rufus L. Brunt[2], David M. Hodgson[1], Stephen S. Flint[2]

[1]*Stratigraphy group, School of Earth and Environment, University of Leeds, Leeds LS2 9JT, UK*

[2]*Stratigraphy group, School of Earth, Atmospheric and Environmental Sciences, The University of Manchester, Manchester, M13 9PL.*

*Corresponding author: eehlb@leeds.ac.uk

Locations of long-term sediment bypass zones in ancient deep water settings are rarely identified at outcrop, meaning that their sedimentological characteristics are poorly constrained. Mapping and correlation of Units E and F of the Permian Fort Brown Formation, Karoo Basin, South Africa has led to the identification of wide and long (kms) tracts on the lower submarine slope with limited sand deposition updip of >50m thick sand-prone lobe complexes.

Here, the sedimentology and stratigraphic evolution of the sediment bypass zones are investigated in detail through correlation of closely spaced measured sections (40-800m spacing) in Units E and F. Unit E is a composite sequence consisting in the study area of two lowstand systems tracts, E2 and E3, each overlain by a combined transgressive/highstand systems tract of regional mudstone. Primarily, E2 consists of thin turbidite beds interpreted as lobe fringe or distal levee deposits. In the study area, E3 thins from11 m to <1m thick and comprises rippled thin-bedded sandstones that are interpreted as levee deposits. An E3-aged surface is identified that cuts down through E2 and around 10m of underlying mudstone over an outcrop distance of around 300m. The depth of incision is estimated to be 20-30m. The E3 erosional surface is overlain with <2 m of clast supported mudstone clast conglomerates and fine-grained sandstones containing floating mudstone clasts. This material is overlain by siltstone interbedded with low angle ripple laminated very fine-grained sandstone beds, and then filled in by the E-F mudstone unit. Farther down dip (east) E2 is present beneath E3 as the incision surface climbs up. Down dip of the incision surface E3 thickens to 40m over an outcrop distance of 75 m and comprises meter scale sandstones capped with thin argillaceous divisions that are interpreted as hybrid beds.

This outcrop study permits the analysis of sub-seismic scale characteristics of a sediment bypass zone. This will provide a deeper understanding of their nature and evolution including the development of recognition criteria for identification of sediment bypass zones in subsurface datasets.

3D Geologic and Reservoir Modelling of a Distributive Fluvial System Derived from lidar: A Case Study of the Huesca Fluvial Fan.

Brian S. Burnham*, David Hodgetts and Jonathan Redfern

University of Manchester, School of Earth, Atmospheric and Environmental Sciences, Manchester, M13 9PL, UK.

*Corresponding author: brian.burnham@manchester.ac.uk

The Huesca fluvial fan is a well-documented, Oligocene - Miocene age distributive fluvial system in the northern extent of the Ebro Basin, and is used extensively as an outcrop analogue for modelling fluvial hydrocarbon reservoirs. To further improve understanding of the system, modern mapping and modelling techniques using lidar integrated with Differential Global Navigation Satellite System (DGNSS) measurements were used to create sub-metre (spatially) accurate geologic models of the medial-distal portions of the system. In addition to the digital terrain data, traditional field logs and measurements were also collected near the town of Piracés in a series of amphitheatres and canal cuts that expose excellent two and three-dimensional views of the strata in the measured portion of the system. The geologic models and subsequent analyses derived from the data will provide a quantitative tool to further understand the depositional architecture, geometric relationship and lithologic characteristics across the studied portion of the distributive fluvial system.

Utilizing the inherent quantitative nature of the terrain data in combination with the traditional field data collected, an outcrop based geocellular model of the studied section can be constructed by using several geostatistical modelling approaches to describe geo-body geometries (thickness and width ratio) for the associated fluvial architecture, as well as facies distribution and petrophysical characteristics. The resolution of the digital terrain data (<10cm) allowed for an accurate integration of the field observations (palaeoflow, sedimentary structures and grain size distributions) into a more complete model of studied portion of the fluvial system.

The three-dimensionality of the exposure lends itself well to using lidar as a tool when mapping geo-body geometry and architecture across several kilometres. This approach leads to more accurate, quantitative reservoir and depositional models of the distributive fluvial system.

An Automated Approach to the Measurement of Geometric Attributes from Modern Sedimentary Systems for Object Based Reservoir Modelling

Björn J.E. Burr Nyberg[1,2]* and John A. Howell[2,3]

[1]*Uni CIPR, Allegaten 41,5007 Bergen, Norway*

[2]*Department of Earth Science, University of Bergen, Norway*

[3]*Department of Geology and Petroleum Geology, University of Aberdeen, Scotland*

*Corresponding author: bjorn.nyberg@uni.no

The measurement of quantitative geometric attributes to describe sandbody architecture is important in order to understand potential empirical relationships between depositional environments, structural regimes and climate controls on a large regional or global scale. While manual interpretation of mapped depositional systems allows for an accurate assessment of geometric attributes and geomorphologic shape, these measurements are either time consuming to gather and/or are a subjective interpretation limiting quantitative analysis and large scale comparison. The application of spatial science and remote sensing have previously been used to quantify that distribution and proportion of depositional elements however work on quantifying their shape for use in object based modelling is limited. This previous work often relates to the measurement of fluvial attributes such as braided indices that measure centerline proportions of a fluvial system or the application of minimum bounding box geometries on sandbody elements, neither of which describe its shape in a way that may be useful in automated classification for quantifying geostatistics.

A new methodology is proposed that quantitatively describes the geomorphological shape and geometric attributes of any mapped depositional environment by an automated method that measures centerline deviation, width and orientation along a features axial distance. Its application is demonstrated within the context of the WAVE classification of marginal marine systems. These descriptive parameters provide the capacity to directly describe a single sandbody geometry or as a mean user-defined geometry of grouped sandbody elements into either linear, crescentric or ellipsodal shapes with symmetrical or asymmetrical characteristics. These geostatistical properties of sandbody elements can thereby be directly applied in object based facies modelling of the subsurface by defining a sandbody shape combined with its geometric variability within the mapped depositional environment.

KEYNOTE:

Facies Models for Carbonate Depositional Systems

Dan Bosence*

Department of Earth Sciences, Royal Holloway University of London, Egham, Surrey,

TW20 0EX

*Corresponding author: d.bosence@es.rhul.ac.uk

This keynote will start with a romp through some published facies models for marine carbonates from the depictions of facies belts to 3D models to sequence stratigraphic models. Two areas where advances can be made will be addressed; firstly the need for a broader-scale view of facies models and secondly the need for new facies models for non-marine carbonate platforms:

It is now clear that different facies models are needed not only for different climatic belts (equatorial, tropical and temperate) but also to explain the major changes that have occurred in carbonate systems through time as facies reflect the evolution of different carbonate-producing organisms or to changing sea-water chemistry. Possibly, each carbonate platform could be regarded as unique and requires its own facies model. However, another method of addressing this potentially vast array of different facies models is to examine a lower-order classification based on the tectonic/basinal setting of carbonate platforms which can be shown to control the overall platform morphology, the stratigraphic architecture and the facies associations.

Current published facies models for non-marine carbonates focus on relatively small-scale accumulations. The Early Cretaceous (Presalt) of the south appears to have been an extensive, lacustrine system dominated by carbonate lithologies. There is little published data from carbonate accumulations that are 100s metres in thickness and 10s of kilometres across; some of which are multi-billion barrel hydrocarbon reservoirs. Developing facies model(s) for such systems is difficult as there appear to be no modern-day, or exposed ancient, analogues that adequately explain these deposits. A facies model is presented that pulls together pieces of the story from outcrop analogues with similar stratigraphic geometries (but incorrect facies), 3-D seismic (with limited resolution), core, fmi log and sidewall core data (all of limited sampling) from the Campos Basin, Brazil.

Facies models are needed as much in the 21st century as they were in the 1970s to help us understand the diverse processes involved in carbonate depositional systems, to document the array of different types of carbonate platforms in space and in time, and to provide a basis for facies prediction in the subsurface.

A progradational ice advance sequence in the Neoproterozoic Kingston Peak Formation, California

M.E. Busfield* and D.P. Le Heron

Department of Earth Sciences, Queen's Building, Royal Holloway University of London, Egham, Surrey, TW20 0BY, UK

*Corresponding author: Marie.Busfield.2011@live.rhul.ac.uk

The Neoproterozoic Kingston Peak Formation is a glacially influenced mixed clastic succession which outcrops throughout the Basin and Range province of eastern California. The formation is stratigraphically subdivided into four units (KP1-4, in ascending stratigraphic order), recording an initial non-glacial unit succeeded by three glacially-influenced successions. KP3 is by far the thickest and most extensive unit, which forms the entire exposed section at Sperry Wash, at the boundary of Death Valley National Park. In this section, distal thinly bedded turbidites initially lacking glacial influence are succeeded by equivalent facies bearing evidence of ice-rafted debris (IRD), increasingly interrupted by glaciogenic debris flow deposits up-section. These deposits are overlain by thick-bedded IRD-bearing turbidites, and capped by a thick accumulation of massive diamictite. Possible glaciotectonically deformed finely laminated sediments are interbedded with the diamictite facies, with fold vergence towards the south-west. The top of the succession demonstrates a return to thickly-bedded IRD-bearing turbidites, truncated by an angular unconformity with the Noonday Dolomite Formation. Overall the succession demonstrates a clear progradational signature, concomitant with an increase in evidence of glacial influence up section. This is interpreted to record a series of ice-distal glaciomarine turbidites, with advance of the ice front evidenced in the increased abundance of IRD, greater thickness of glaciomarine turbidites, and more frequent glaciogenic debris flows debouched off the ice front. Maximum ice advance is recorded by the deposition of ice-proximal diamictites and associated subglacial deformation structures, followed by resumed deposition of glaciomarine turbidites subject to secondary ice-rafting, indicative of initial ice sheet retreat.

Using ICP-OES and ICP MS as a method of chemostratigraphic correlation and indication of environmental changes in Devonian carbonate reef complexes of the Canning Basin, Western Australia.

Samuel Caulfield-Kerney[1*], David Wray[1], Ken Ratcliffe[2] and Ted Playton[3]

[1]*University of Greenwich, Kent, UK*

[2]*Chemostrat Ltd, London, UK*

[3]*Chevron Energy Technology Company, Houston, Texas, USA*

*Corresponding author: cs52@gre.ac.uk

The Canning Basin presents a perfect setting for developing alternative methods for high-resolution chronostratigraphic correlation, addressing problems such as subsurface data limitations and poor biostratigraphic resolution. Elemental Chemostratigraphy, has been widely applied successfully in siliclastic settings and is a developing practice in its application to carbonate settings such as the Lennard Shelf in the Canning Basin.

Elemental data have been obtained for ca. 50 elements on over 1800 hand samples collected from field sections in the Canning Basin reef complexes, including back reef, reef core and fore reef facies. The samples range from Givetian to Famennian in age and are taken from Windjana Gorge, the South Oscars Range and the Horse Shoe range locations. The study incorporates both attached and detached reef complexes.

A pilot study was conducted on platform top settings from the Windjana Gorge area. The results show high-frequency trends in Cr/Al_2O_3, K_2O/Al_2O_3 and Zr/Al_2O_3, which infer changes in heavy metal compositions, clay mineralogy and siliciclastic input respectively. Thus the Cr/Al_2O_3 and K_2O/Al_2O_3 indicate clay mineral input from the weathering and transport of feldspar baring minerals and meteoric water in local settings, and the Zr/Al_2O_3 can be used as proxies for grainsize and can reflect sea level and energy input changes at the time of deposition.

These ratios show periods of cyclicity within the strata and identified surfaces which can be used as a correlational constraint when coupled with other methods of chronostratigraphy such as facies analysis, rock magnetics and stable isotope analysis.

ICP OES and ICP MS analytical techniques where then applied to samples from the South Oscars Range, focusing on the slope samples from the Horse Shoe Range, which represents a fluctuating depositional environment. These elemental trends allow for the inference of local to regional input and correlational constraints boundaries that until now have not been recognizable in traditional sequence stratigraphy, making it a powerful tool in chronostragraphic correlation.

An unexpected "switch-off" in turbidity current activity during the Palaeocene-Eocene Thermal Maximum

M. Clare*, P.J. Talling and J. Hunt

National Oceanography Centre, Southampton

*Corresponding author m.clare@fugro.co.uk

A geologically short-lived (~170kyr) episode of global warming occurred at ~55Ma, termed the Palaeocene-Eocene Thermal Maximum (PETM). Global temperatures rose by up to 8^{o}C and a massive perturbation of the global carbon cycle occurred; creating a negative carbon isotopic (~-4% δ^{13}) excursion in sedimentary records. This interval has relevance to study of future climate change, and its influence on submarine landslides which may generate catastrophic tsunami or damage subsea structures. We present preliminary results of a study assessing frequency of turbidity currents, potentially initiated from large-volume (>0.1 km^3) slope failures, over an interval including the PETM (56.3 to 54.5Ma).

The Zumaia section, North-East Spain, is a remarkably complete and expanded Cretaceous to Eocene sedimentary succession. During the Palaeocene, the deep-water (~1000 m) Zumaia Basin was flanked by mixed-carbonate-terrigenous shelf systems. The sedimentary sequence provides clear differentiation between hemipelagic and turbiditic mud with only negligible evidence of erosion. We infer dates for 285 turbidites by converting hemipelagic bed thicknesses to time using interval-averaged accumulation rates. Multi-proxy dating techniques provide good age constraint.

The full record shows a near-exponential distribution of recurrence intervals with similar mean and standard deviations (~10% difference), suggesting a strong degree of time-independence. Proportional hazards modelling indicates that sea level does not exert a dominant single control on recurrence rate, nor does its first derivative. The initial fall in δ^{13} between 54.917 and 54.854Ma shows more scatter, however (~30% difference between standard deviation and mean). Most interestingly, a prolonged (~0.1Ma) hiatus in turbidity current activity occurs almost coincident with the peak of the δ^{13} excursion (i.e. the warmest part of the PETM). This is significantly greater than the mean recurrence interval of the full record (0.007Ma).

It has been proposed that the PETM was caused by landslide-triggered marine hydrate dissociation. Therefore, a greater intensity of landslide and resultant turbidity current activity would be expected; however, our findings are to the contrary. We review several other deep-water PETM sites that appear to show similar results and offer some explanations. Our work suggests that previous rapid global warming at the PETM did not trigger more frequent slides.

Identifying depth and flow direction of injectites: diagnostic sedimentary structures

Sarah L. Cobain*, David M. Hodgson and Jeff Peakall

School of Earth and Environment, University of Leeds, LS2 9JT, UK

*Corresponding author: ee09sc@leeds.ac.uk

Clastic injectites are widely recognised in hydrocarbon reservoir systems and impact connectivity and fluid flow. However the depth of injectite formation, and propagation direction, are typically poorly constrained, particularly in cores and outcrops. Here, analysis of features on the margins of exhumed clastic sills and dykes enables these properties to be determined for the first time. A diverse array of diagnostic structures is found in injectites located in the Karoo Basin, South Africa where the direction of net injection and the parent sand is well constrained. Injectite margin features include mudclast rich surfaces, planar or smooth surfaces, blistered surfaces and parallel and plumose ridged surfaces. Surfaces concentrated in entrained mudclasts occur in patches of up to $5m^2$ where clasts are often rounded and occur up to 10cm in diameter, smooth surfaces are completely flat and parallel with host strata. Blistered surfaces are recognisable by small (<2cm) dimples or bumps on an otherwise smooth surface. Ridged margins are characteristic of locations where injections are discordant with the stratigraphy; parallel and plumose ridges are asymmetrical, have up to 2cm relief and always display a superimposed set perpendicular to the steep slope of the large ridge-set. Plumose ridges are identical to parallel ridges displayed in a plumose fractal pattern. All features are indicative of propagation through brittle, fine grained sediments, indicating that injection occurred when the host mudstones were compacted, giving a palaeodepth of several hundreds of metres. Additionally, plumose ridges indicate local fracture propagation; with ridges radiating outwards from the point of fracture. Combined, these features are critical in distinguishing injected sands from those of a primary deposition and not only provide evidence that sands were injected at considerable depth, but can also indicate the propagation direction of the fracturing and associated injection.

Influence of basin physiography on coastal-shelf sedimentary processes: Integrating ocean modelling and sedimentary facies analysis in the Mio-Pliocene, NW Borneo, South China Sea

Daniel S. Collins*, Peter A. Allison, Howard D. Johnson, Alexandros Avdis, Jon Hill, Matthew D. Piggott

Department of Earth Science and Engineering, Imperial College London, South Kensington Campus, London, UK

*Corresponding author: d.collins12@imperial.ac.uk

Depositional facies in coastal sedimentary systems may reflect a complex interaction of tidal, fluvial and/or wave processes. Identifying the dominant depositional processes in marginal marine systems is critical for the prediction of stratigraphic architecture. Palaeotidal modelling can provide unique quantitative insight into the strength of tidal processes along ancient coastlines. However, what controls the tidal potential along a given coastline? And can we relate model results to observations made in outcrop?

We use Fluidity-ICOM to model tides and associated bed shear stress of the South China Sea during the Oligo-Miocene. Palaeobathymetric uncertainty has been evaluated through a suite of sensitivity tests. Results show that diurnal tides dominate and the predicted tidal range along palaeocoastlines of the developing South China Sea was higher (meso-macrotidal) relative to the present day (micro-mesotidal). A wider Luzon Strait and lack of through-flow across the Sunda Platform facilitated a larger transfer and storage of tidal energy from the Pacific Ocean. The higher ambient tidal potential, coupled with tectonically-controlled changes in shelf width and bathymetry, set up local funnelling and shoaling effects resulting in elevated bed shear stress offshore northwest Borneo, south and east Vietnam, the Beibu Gulf and Gulf of Thailand.

The Miocene Belait Formation (Berakas Syncline, Brunei) represents the onshore correlative to reservoir units in the prolific, hydrocarbon-bearing Baram Delta Province. Facies associations are attributable to a complex interaction of depositional processes in a shoreface-delta front to embayed coastal setting. On an inter-sand body to parasequence scale, exposures show discrete arrangements of broadly wave- or tide-dominated facies, each typically preserving a subordinate mixed-process signature. On an intra-sand body scale, a clear textural control on bedform type is consistent with combined-flow phase diagrams, justifiable through integrating facies analysis with numerical modelling results. The perceived absence of ‘typical’ upper shoreface facies in offshore Champion Field cores can in turn be ascribed to a limitation in the shoreface facies model employed.

Palaeotidal modelling therefore provides important indicative insight for predictive models of sedimentary processes and facies architecture for coastal-shelf deposition, in a given tectonic and oceanographic setting.

Assessing the influence of backwater hydraulics on sedimentological character of distributary channel fills in a tidally influenced deltaic system, Campanian Neslen Formation, Utah, USA

Luca Colombera*, Michelle Shiers, Nigel P. Mountney

Fluvial & Eolian Research Group, School of Earth and Environment, University of Leeds

*Corresponding author: l.colombera@leeds.ac.uk

Changes in the facies architecture of fluvio-deltaic distributary channels through the fluvial-to-marine transition zone are believed to record seaward decrease in the intensity of river flow and increase in the intensity of tidal currents. This concept is firmly embedded in current facies and sequence stratigraphy models.

However, a complex control is exerted by backwater hydraulics on fluvio-deltaic morphodynamics and this may be recorded in the preserved stratigraphy. The lowermost portions of modern rivers undergo flow acceleration and become erosional at high discharges due to drawdown of the in-channel water surface near the river mouth in relation to the fixed water surface at the shoreline. Consideration of this process leads to speculative predictions concerning the geometry and internal organization of distributary channel fills across a delta-plain setting and their relationships with other bodies. To test these predictions, fieldwork was carried out to examine sedimentological characters of channel bodies from an interval of the Campanian Neslen Formation of eastern Utah, which comprises a succession of sandstone, carbonaceous mudstone, and coal, deposited in a coastal-plain setting, in which significant evidence of tidal influence is preserved.

Three types of channel bodies are recognized in the studied interval, in terms of lithology and formative-channel behaviour: sand-prone laterally accreting channel elements, heterolithic laterally accreting channel elements and sand-prone aggradational ribbon channel elements. This investigation concentrated on the ribbon bodies since they possess characters compatible with laterally-stable distributaries developed in the zone of drawdown. The internal organization of these bodies is characterized by abundant scours at the storey and bed scales. The deposits mostly consist of cross-stratified, massive and cross-laminated fine sandstones, and intraclast lags. The bodies are locally burrowed, and do not display diagnostic tidal indicators, although cryptic evidence of tidal influence might be recorded by non-rhythmic organic drapes. The ribbon channel bodies have steep cutbanks and do not display horizontal transitions to genetically-related overbank sandstones. Overall, characters associated with some of these bodies may be ascribed to partial overprint of tidal signatures during flood-related drawdown within channels that are laterally stable and respond to floods solely by lowering of scour depth.

Evidence in the architecture of these sand-bodies to support the drawdown processes is equivocal; further work encompassing other depositional systems is required to better understand the role of backwater processes in controlling the architecture of distributary channel bodies and their downdip variations.

Reactive transport modeling of mixed fluid dolomitisation: Traditional coastal mixing zones and ascending freshwater-mesohaline mixing

Katherine Cooper[1,2]*, Yitian Xiao[2], Fiona Whitaker[1], Robert Goldstein[3], Zhaoqi Li[3], Evan Franseen[3], Sherry Stafford[2] and Gareth Jones[2]

[1]*School of Earth Sciences, University of Bristol, Bristol, UK*

[2]*ExxonMobil Upstream Research Company, Houston, USA*

[3]*Department of Geology, University of Kansas, Kansas, USA*

*Corresponding author: k.j.cooper@bristol.ac.uk

Coastal mixing zone dolomitisation was a popular model for dolomitisation during the 1980's and 1990's; however uncommon dolomitisation in modern mixing zones, along with the re-interpretation of key outcrops caused this model to fall from favour. Recently work at La Molata, a Miocene outcrop in southeast Spain, has suggested that mixing of ascending freshwater and mesohaline seawater could cause extensive dolomitisation over a relatively short timescale. The conceptual model suggests discharge of CO_2-rich freshwater from the underlying fractured basement into the carbonate succession. Through vertical flow and mixing with the mesohaline seawater, there is extensive dolomitisation.

Reactive transport models have been used to evaluate kinetic and hydrodynamic controls on dolomitisation in both a traditional coastal mixing zone setting and during ascending freshwater-mesohaline mixing. Some key geological variables, such as freshwater and seawater compositions, temperature, PCO_2 of the freshwater, and ground water flow velocity were tested for their control and sensitivity.

In the traditional coastal mixing zone, the reactive transport simulations failed to generate extensive dolomite, within 1 million years. Despite the geochemically favorable conditions for dolomitisation, where the mixed waters exhibited the potential to dissolve calcite and precipitate dolomite satisfying the Dorag theory for dolomitisation, the lack of active circulation of the magnesium-rich fluids limits the dolomitisation.

On the other hand, simulations of ascending freshwater-mesohaline mixing suggest that rapid dolomitisation can occur. The addition of freshwater recharge to the base of the model enhances the breadth of the zone of mixing, promoting extensive dolomitisation. The simulations suggest that early dolomitisation by mixed waters requires an additional driver, such as higher temperature fluids and/or higher kinetic rate constants, to overcome the kinetic barrier. The interaction between the freshwater and underlying basement may increase the temperature of the recharging fluids, thus generating optimum conditions for the dolomitisation to occur.

Finding order in chaos: The sedimentology of the Gwna mélange

Rosemary Dartnall[1]*, Ian Fairchild[1], David Schofield[2], Paul Smith[3] and James R. Wheeley[1]

[1]*Geosystems Research Group, School of Geography, Earth and Environmental Science, University of Birmingham, Edgbaston, B15 2TT, United Kingdom*

[2]*British Geological Survey, Columbus House, Greenmeadow Springs, Tongwynlais, Cardiff, CF15 7NE, United Kingdom*

[3]*Oxford University, Museum of Natural History, Parks Road, Oxford, OX1 3PW, United Kingdom*

*Corresponding author: rld126@bham.ac.uk

The Gwna Group, a 3 km thick sequence of chaotic mélange deposits of diverse clast lithologies, crops on Anglesey and the north-west coast of the Llŷn peninsula. The presence of greenschist rocks and a substantial blueschist unit imply the Monian Supergroup has an accretionary setting. The Gwna Group is unconformably overlain by transgressive Arenig sediments indicating a minimum depositional age of 475 Ma.

Mélanges are associated with processes such as mass flow events, diapirism and tectonic accretion. The violent and rapid depositional nature of these deposits dictates that primary features are commonly overprinted leading to contentious interpretations. This research is concentrated on the sedimentology of the Gwna mélange studying the depositional structures of the main components; the matrix and the clasts. Field and thin section observations of the Gwna mélange from Anglesey and Llŷn are tested against a set of formation specific characters to unravel the history of these complex and diverse rocks.

Diagnostic characters include;

- Regional tectonostratigraphic setting
- Mélange matrix;
    - Is it compositionally homogeneous or varied?
    - Can separate event beds be identified?
    - What is the nature of the contacts?
- Mélange clasts;
    - What are the clast lithofacies, depositional environment and size distribution?
    - Are they intra /extra basinal, intra /extra formational?
    - Is there stratigraphic repetition?
- What is the deformation history?
    - Is the structural history shared by both the clasts and the matrix?
    - Can primary sedimentology be separated from tectonic overprint?
    - Is there metamorphic continuity throughout the matrix and the clasts?

Early results show the Gwna mélange records a series of multiple dilute to clast rich debris flows from 18 cm to ~250 m thickness intercalated with deep marine and epiclastic in-situ sedimentation. The clast population includes siliciclastic, carbonate, volcaniclastic, intrusive and extrusive lithologies. Grain size ranges from sub-millimetre to ~800 m diameter within a broadly homogeneous muddy matrix. The clasts exhibit independent deformation histories. Combined with the low anchizone metamorphic grade, which is discontinuous between clasts and matrix these observations firmly imply a sedimentary genesis for the Gwna mélange.

Controls on the thickness and architecture of turbidite sandstones in MTD dominated settings, Vocontian paleomargin, SE France.

J. de Leeuw[1]*, J.T. Eggenhuisen[1], G. Friès[2], O. Parize[2], Gerard and W.D. McCaffrey[3]

[1]*Department of earth sciences, Utrecht university, The Netherlands*

[2]*Areva, Paris, France*

[3]*School of Earth and Environment, University of Leeds, United Kingdom*

*Corresponding author: J.deLeeuw@uu.nl

The Aptian succession of the Vocontian paleomargin (SE France) consists of marl-prone mass transport deposits, turbidite sandstones and pelagic marls. A detailed stratigraphic framework, established by previous workers, allows correlation of individual event beds for up to 80 kilometres in the down-dip direction. One thick-bedded turbidite sandstone is interbedded between two mass transport deposits and can be studied in several outcrops. The thickness of this sandstone bed is very variable; the current work aims to infer the origin of these thickness variations, and the implications for the large scale system architecture. Detailed outcrop descriptions, here focusing on the nature of the contact of the turbidite with the underlying and overlying mass transport deposits, are presented. Multiple origins for sandstone thickness variation are recognised. Loading and injection occur, but are restricted to a relatively small scale and result in only minor sandstone thickness variations. Elevated topography at the surface of the mass transport deposits is associated with internal compressional deformation zones; infill of this topography acted on a wide range of scales and results in thickness variations with amplitudes of up to ten meters. Several types of field data give direct evidence for interaction between the MTD seafloor topography and turbidity currents. These include locally highly variable flute directions and a scour hole upstream of a block that protruded at the surface of the MTD. In previous work, the lenticular geometry of the studied sandstone unit in the outcrops was attributed to channelization. The present work does not discount the possibility of channelization in the studied section of the slope system but it shows that much of the thickness variation of the sandstone at the scale of the outcrops is related to infill of MTD seafloor topography. This distinction is relevant because channel fill deposits are more likely to form elongated ribbons whereas infill of slope relief could result in sandstone with a patchy thickness distribution in plan view.

Inherent autogenic avulsion of aggradational submarine channels

R.M. Dorrell* and W.D. McCaffrey

School of Earth and Environment, University of Leeds, Leeds, LS2 9JT.

*Corresponding author: r.m.dorrell@leeds.ac.uk

Submarine channel avulsion drives the formation of large scale submarine fans deposits. Avulsion is caused by depositional and erosional processes, through turbidity currents in-filling the channel and/or eroding the bounding levees. Bypassing turbidity currents generate avulsion nodes through erosional processes and thus may be associated with high magnitude flow events and allogenic forcing. However, flow tuning effects probably decrease the magnitude range of flows reaching the medial and distal reaches of submarine fans, where avulsion commonly occur. Because deposition from an aggradational turbidity current implies that the volume and shape of the channel-levee system evolves with time it may be that autogenic forcing plays a role in avulsion. Therefore, a generic submarine channel-levee structure model is proposed to elucidate constraints on system evolution. Assuming constant flux flows, perturbation analysis of the model suggests that either 1) the cross sectional area of the channel will decrease or 2) the outer-levee slope will increase. Both of these can be seen to enhance the likelihood of avulsion, either by directly in-filling the channel or increasing lateral flow velocities and thus increasing the likelihood of crevassing and erosion at the levee crest. Therefore it is suggested that autogenic avulsion is an inherent feature of aggradational channels commonly found in the distal reaches of submarine fans systems.

Analysis of fine-grained floodplain facies as a tool to interpret spatial and temporal variation in avulsion style: Cretaceous Blackhawk Formation, Wasatch Plateau, Utah, U.S.A.

Yvette S. Flood* and Gary J. Hampson

Department of Earth Science and Engineering, Imperial College London, UK

*Corresponding author: y.flood11@imperial.ac.uk

Quantitative modelling and outcrop studies have emphasized the role of long-timescale (10^3–10^5yr) autogenic self-organisation on alluvial-to-coastal-plain stratigraphy independent of allogenic controls. These models are tested via sedimentologic analysis of fine-grained floodplain deposits and their relationship to channelized fluvial sandbodies in a well exposed alluvial-to-coastal-plain succession developed under a progressively decreasing rate of accommodation creation and progressively increasing distance from the coeval shoreline (late Cretaceous Blackhawk Formation, Wasatch Plateau, central Utah, USA).

The studied alluvial-to-coastal-plain succession contains fourteen lithofacies which are grouped into four associations: 1) channelized fluvial sandstone bodies of ribbon to sheet-like geometry, the latter with multi-storey, multi-lateral internal character; 2) non-channelized fluvial sandstone and siltstone bodies associated with immature palaeosols, and interpreted to record crevasse splay, levee, and crevasse channel development; 3) fine-grained floodplain deposits containing abundant coal beds; and 4) lagoonal deposits with a low diversity fauna of brackish water bivalves. Integrated analysis of palaeosol character, facies analysis, and architectural-element analysis indicates deposition on a rapidly aggrading floodplain that was frequently subject to periods of crevassing and channel-belt switching.

The character, relative abundance, and vertical stacking of the first three facies associations exhibit little variation stratigraphically, from base to top of the Blackhawk Formation (c. 250 m), or palaeogeographically between the northern and southern limits of the outcrop belt (c. 100 km). Additionally the proportions of palaeosol types and architectural elements are similar within each stratigraphic interval at the northern and southern limits of the outcrop belt. Local stratigraphic architectures record three styles of avulsion, representing avulsion by re-occupation of pre-existing channels, avulsion by progradation of crevasse-splay complexes, and avulsion by incision into aggradational floodplain fines. Avulsion style shows no consistent pattern with stratigraphic position or palaeogeographic location. In combination, these results suggest that floodplain sedimentation and local stratigraphic architecture are dominated by autogenic avulsion, which is consistent with previously documented, large-scale patterns of fluvial sandbody distribution in the outcrop belt. All three avulsion mechanisms operated in an apparently uniform manner over a range of tectonic subsidence rates (c. 80-700 m/Ma) and distances from the coeval shoreline (c. 0-100 km).

Coalesced 3D scours on the base of a hybrid event bed from the Gottero Sandstone, NW Italy

Marco Fonnesu[1]*, Marco Patacci[2], Peter Haughton[1], Fabrizio Felletti[3], William McCaffrey[2]

[1]*UCD School of Geological Sciences, University College Dublin, Belfield, Dublin 4, Ireland*

[2]*Institute of Geological Sciences, School of Earth and Environment, University of Leeds LS2 9JT, UK*

[3]*Dipartimento di Scienze della Terra, Università degli Studi di Milano, Via Mangiagalli 34, 20034 Milano, Italy*

*Corresponding author: marcofonnesu86@gmail.com

Erosion beneath sediment gravity flows can determine patterns of bed amalgamation and hence sand connectivity. Where significant clay is incorporated in the flow, this may impact on subsequent flow dynamics down-dip. Evidence for scouring beneath turbidites is commonly seen in outcrops, mainly in vertical profile or on limited bedding plane exposures where small-scale (cm to m-scale) sole structures are well documented. The presence of broader scour features is also often inferred on the basis of erosive steps although the 3D geometry of such features is generally unclear as it is rare to be able to inspect large-scale (10-100s m scale) bedding plane exposures. The Cretaceous-Palaeocene Gottero Sandstone on Mount Ramaceto, NW Italy provides one such example. Here an overturned syncline provides a spectacular inverted bed base on which a shallow (up to 15 cm) but extensive (100s m^2) scour field is preserved. This was formed beneath a flow that emplaced a 2.3 m thick sheet-like hybrid event bed that can be correlated laterally for up to four kilometres in what was a relatively distal setting.

The scour field comprises a composite erosional feature up to 150 m wide and at least 40 m long. It is made up of a terraced surface reflecting three levels of substrate erosion. The shallowest level is covered by small-scale grooves and flutes and is cut by larger elongate scours that coalesced to excavate the sea floor in patches down to a mid-level bed-parallel surface. The latter is then further incised by the deepest scours. Individual scours (40-150 cm across and 1-5m long) have distinctive asymmetric cross-sections with both inclined and undercut lateral margins. The undercut margins are associated with mudclast detachment.

The extent of erosion given the distal setting is curious and implies hybrid flow development could be triggered or enhanced by clay entrainment in relatively distal settings. Distal erosion may be promoted by enhanced turbulence during the early stages of flow transformation, as suggested by some experimental work (see Baas *et al.* 2011, *Sedimentology 58 1953-1987*). As scour coalescence results in mainly bedding parallel terraces, it can easily be overlooked in vertical sections.

Sedimentary structures formed under water surface waves during a sediment-laden flash flood that was observed by remote camera

M.J. Froude[1]*, J. Alexander[1], J. Barclay[1] and P. Cole[2]

[1]*School of Environmental Sciences, University of East Anglia, Norwich, UK.*

[2]*School of Geography, Earth and Environmental Sciences, University of Plymouth, Plymouth, UK.*

*Corresponding author: m.froude@uea.ac.uk

On 13th-14th October 2012, Tropical Storm Rafael triggered sediment-laden flash floods in the Belham Valley on the Caribbean island of Montserrat. Flow was strongly unsteady, turbulent with sediment concentration varying up to hyperconcentrated. Time-lapse images captured at >1 frame per second by remote camera overlooking a surveyed valley section show the development of trains of water surface waves at multiple channel locations during different flow stages. Waves grew and diminished in height and remained stationary or migrated upstream. Trains of waves persisted for <5 minutes, until a single wave broke, sometimes triggering the breaking of adjacent waves within the train. Channel-wide surges (bores) propagating downstream with distinct turbulent flow fronts, were observed at irregular intervals during and up to 7 hours after peak stage. When a bore front came into close proximity (within ~10 m) upstream of a train of water surface waves, the waves appeared to break simultaneously generating a localised surge of water upstream, that was covered by the bore travelling downstream. Those trains in which waves did not break during the passage of a bore temporarily reduced in height. In both cases, water surface waves reformed immediately after the surge in the same location. Deposits from the event, were examined in <4 m deep trenches ~0.5 km downstream of the remote camera. Laterally extensive lenticular and sheet-like units comprised of varying admixtures of sand and gravel are attributed to antidunes, and associated transitions from upper-stage-plane-beds. Some of the structures are organised within concave upward sequences which contain downflow shifts between foreset and backset laminae; interpreted as trough fills from chute-and-pools or water surface wave breaking. Atleast 90% of the deposit is interpreted upper flow regime origin. The sequence, geometry and lamina-scale texture of the sedimentary structures will be discussed with reference to remote camera images of rapidly varying, unsteady and pulsatory flow behaviour.

Controls on non-marine carbonate facies: the Purbeck Formation (Late-Jurassic to Early Cretaceous) of Dorset, Southern England.

Arnaud Gallois*

Royal Holloway University of London, Queens Building, Earth Sciences Department, Egham, Surrey, TW20 0EX, U.K.

*Corresponding author: arnaud.gallois.2012@live.rhul.ac.uk

The discovery of Lower Cretaceous, non-marine carbonate hydrocarbon reservoirs in the South Atlantic, has triggered the interest of understanding such complex deposits. Sedimentary facies and basin architecture are controlled by a range of environmental parameters (*i.e.* climate, hydrology and tectonic setting) but facies models are few and limited in their predictive value. This study is developing new depositional models for non-marine carbonates in a semi-arid climate setting in an extensional basin; the Purbeck Formation (Upper Jurassic – Lower Cretaceous) exposed in Dorset (Southern England).

Outcrop study coupled with subsurface data analysis and petrographic study constrain and improve published models of depositional settings. Facies models and palaeogeographic maps of these lacustrine to palustrine carbonates deposited in the syn-rift phase of the Wessex Basin will be presented.

Seismic data imaging Lower-Upper Jurassic in south Dorset shows East-West syndepositional extensional faults separated by relay ramps in the southern Wessex Basin. Regional thickness data indicate preferential accumulation of strata in east-west, extensional sub-basins and adjacent to a relay ramp.

Research has focused on the factors controlling the accumulation of in-situ microbialite mounds that occur within bedded inter-mound packstones-grainstones in the lower Purbeck. The microbialite mounds are located in three units (“Skull”, “Hard” and “Soft Caps”) separated by three paleosols (“Basal”, “Lower” and “Great Dirt Beds”) respectively within three shallowing-upward lacustrine sequences. These microbialite mounds are up to 4m high and composed of smaller-scale mounds of about 50cm high. Many of these small-scale mounds developed around trees, tree trunks and branches which are preserved as moulds (or silicified wood) and are divided into three sub-facies (Stromatolites, Thrombolites and Burrowed Collar).

The goals of the study are to predict the controls on the siting, the shape and the size of microbialite mounds and to constrain the facies models and palaeogeographic maps. Initial work indicates the location of the mounds is controlled by palaeotopography generated on subaerial exposure surfaces, fossil soils and early conifer trees. The new depositional models developed in this study consider the controls of the syn-rift setting of the Wessex Basin on the deposition and the location of the microbialite mounds.

Identification and interpretation of climatic cycles in alluvial fan sediments; a case study from the Permian Cutler Group, Utah, U.S.A.

Amy Gough* and Stuart M. Clarke

Basin Dynamics Research Group, School of Geography, Geology and The Environment, Keele University, Staffordshire, ST5 5BG.

*Corresponding author: a.gough@keele.ac.uk

During predominately arid climates, alluvial fan systems dominate deposition in proximal continental basins. Alluvial fan systems respond to both allocyclic climatic variations and autocyclic changes in base level, sediment supply and localised climate. The response of sedimentation to these localised, and small-scale, climate variations is preserved throughout the alluvial fan sediments. The identification and interpretation of these autocyclic responses can aid in the understanding of depositional systems within proximal continental basins.

This research focuses on the alluvial fan sediments of the proximal Permian Cutler Group of the Paradox Basin, western U.S.A. These fan sediments interdigitate with continental environments of deposition within the distal basin. During the Permian Period, the arid Paradox Basin was situated around equatorial Pangea. A northwards migration of the supercontinent resulted in an allocyclic wetting-upwards; this variation is prevalent in the environments of deposition that form the distal stratigraphy.

The alluvial fan sediments of the Cutler Group are often perceived as a homogenous clastic wedge, as clear subdivisions are difficult to identify. Alluvial fan depositional environments are sensitive to small-scale climatic variations, and the response of fan sedimentation to these often obscures the effect of the large-scale allocyclic alterations. As each identifiable architectural element throughout the alluvial fan environment responds to these variations in a unique manner, the small-scale cyclicity can be identified throughout the extent of the fan system. Maximum humidity can be identified through sheetflood and debris flow deposits. Increasing aridity leads deposits that pertain to fluvial and lacustrine-pond environments. At the point of maximum aridity, wind-blown environments dominate across the fan.

This work presents the depositional response of the alluvial fan architectural elements to autocyclic climatic variations. Climatic changes also affect the deposits at the point of interaction between the alluvial fan and the distal environments of deposition. There is scope for these resultant depositional architectures to act as a correlation technique between the proximal and distal extents of the basin. Lithostratigraphical correlations prove difficult to establish in laterally restricted fan environments, therefore, an understanding of the response to climate cyclicity can allow for the chronostratigraphical correlation of the deposits.

The fluvial-tidal transition as a tool to assess the importance of tides in ancient deltas: implications for reservoir modelling

M. Gugliotta[1]*, S.S. Flint[1], D.M. Hodgson[2] and G.D. Veiga[3]

[1]*Stratigraphy Group, School of Earth, Atmospheric and Environmental Sciences, University of Manchester, UK.*

[2]*Stratigraphy Group, School of Earth and Environment, University of Leeds, UK*

[3]*Centro de Investigaciones Geológicas (Universidad Nacional de La Plata – CONICET), La Plata, Argentina*

*Corresponding author: marcello.gugliotta@postgrad.manchester.ac.uk

The fluvial-tidal transition zone (FTT) is characterized by the interplay of unidirectional river currents, bimodal tidal currents and other marine processes such as wave action and biological reworking. In modern rivers, both estuaries and deltas, the FTT zone is identifiable and commonly subdivided in three main sub-zones on the basis of hydrodynamic conditions: tide-modulated unidirectional, ebb-dominant bidirectional and flood-dominant bidirectional sub-zones. In ancient systems, however, the FTT zone is poorly constrained. Its identification is crucial to assess the importance of tides in preserved sediments dispersal and to improve reservoir modelling.

This study provides an example from the Lajas Formation, which consists of middle Jurassic deltaic deposits that accumulated in the back-arc phase of the Neuquén Basin, Argentina.

Sedimentological logging, correlation panel construction, architectural element and facies analysis were combined with statistical analysis of rhythmicity in stratal thicknesses, to evaluate the degree of tidal influence during deposition.

The Lajas example shows a clear dissipation of tidal effects in the mouth bars, with little or no evidence of tidal influence in the distributary channels. The position of tidal bidirectional and modulated facies appear to be shifted seaward compared to modern and ancient examples of tide-dominated deltas. Minor influence is recorded in interdistributary areas, away from main fluvial axis.

The seaward shift of the reconstructed FTT of the Lajas Fm. is interpreted as a diagnostic feature to distinguish tide-influenced from tide-dominated deltas and can be used as a tool for a more precise evaluation of the role of tides in ancient systems.

This has important implications for (1) predicting the geometry of mouth bars, which might be less elongate and more interconnected if less tidally reworked; and (2) better understand of the grain size distribution in distributary channels and mouth bars, which will contain a minor amount of mud drapes and fluid muds when tidal action is weaker.

KEYNOTE:

Deltas or Marine-Influenced Distributive Fluvial Systems - what does get preserved in the rock record?

Adrian Hartley*

Department of Geology & Petroleum Geology, University of Aberdeen

*Corresponding author: a.hartley@abdn.ac.uk

Remote sensing analysis of the 97 largest (>30 km from apex to marine termination) deltas on Earth from different climatic and tectonic settings allow quantification of processes that are operative from delta apex to marine termination. Combing these observations with recent published work on the relationship between the upstream apex location and the backwater effect (the upstream point at which the base of a channel intersects sea-level) allow predictive models to be made for facies distribution within the fluvial dominated subaerial part of the deltaic systems including sand body extent and connectivity.

The apex point of a delta occurs where a fluvial channel distributes sediment as it either exits a valley or encounters the backwater effect, this leads to sand deposition and development of amalgamated fluvial channel sands. Downstream of the apex area there is a progressive decrease in sand deposition, an increase in overbank sediment accumulation and preservation potential, together with a decrease in channel sandstone body size and increase in soil development. Downstream of this low net area marine processes dominate, with the prevailing process (e.g. wave or tide) controlling the shoreline morphology and extent of marine influence at the downstream end of the system. Marine influence in the majority of the large deltaic systems examined forms a relatively minor proportion of the subaerial part of the delta (<30%). With the exception of the marine-influence toe of the deltaic system, all the features we observe are characteristic of distributary fluvial systems in non-marine settings. It is suggested that as the largest proportion of the subaerial part of a delta is a distributary fluvial system, this area could more accurately be referred to as a marine-influenced distributary fluvial systems (MIDFS) and then qualified by the dominant basinal process such as tide or wave-dominated.

Architecture and Facies Characteristics of Scour-fills in Channel-Lobe Transition Zones, Karoo Basin, South Africa

Menno Hofstra[1]*, David M. Hodgson[1], Jeffrey Peakall[1] and Stephen S. Flint[2]

[1]*Stratigraphy Group, School of Earth & Environment, University of Leeds, UK*

[2]*Stratigraphy Group, School of Earth, Atmospheric and Environmental Sciences, University of Manchester, UK*

*Corresponding author: eemh@leeds.ac.uk

Scour fields are commonly observed features in modern base-of-slope settings. However their signature is difficult to distinguish from channel-fills in the stratigraphic record, in part because scours can become loci for channelization. The depositional architecture of two downstream asymmetrical erosional depressions (15-25m deep, min. 1-1.5km long) are presented from the Karoo Basin, South Africa (Sub-unit A5, Laingsburg Formation & Fan 3, Skoorsteenberg Formation). The highly irregular basal erosional surfaces and downstream asymmetry in well constrained base-of-slope settings support an interpretation of scour-fills, which contrast in facies and architecture to typical channel-fills in the same stratigraphic units.

The initial infill consists of fine-grained and thin-bedded deposits, with relatively thick siltstones (>4 cm), multiple erosion surfaces, and contorted bedding. Where ripple-lamination is present, palaeocurrents are at a high angle to the regional patterns. The thicknesses of the individual coarse-grained siltstone beds and the palaeocurrent patterns of thin-bedded sandstones indicate the inability of low-energy fine-grained tails within turbidity currents to escape the local subtle confinement. This initial deposition after formation of the basal erosional surface is interpreted as a sediment bypass stage. The overlying architecture is largely aggradational with a distinct upstream stacking of beds and bedsets forming lobes; this stratigraphy is complicated by multiple internal m-scale erosion surfaces, interpreted to be the response to a combination of knickpoint migration and backfilling.

This study demonstrates that the architecture of submarine lobes in channel-lobe transition zones is complicated by the interaction of erosive and depositional processes. Scour-filling lobes should be considered as a distinct architectural element in subsurface investigations that does not comply with traditional submarine fan channel or lobe models.

The Use of Unmanned Aerial Vehicles in Sedimentology

John Howell[1]*, Aleksandra Sima[2] and Simon Buckley[2]

[1]*Department of Geology and Petroleum Geology, University of Aberdeen, UK*

[2]*UniCipr, University of Bergen, Norway*

Good outcrops commonly occur in steep inaccessible cliff sections. In order to study these in detail it has become common practice to use laser scanning (lidar) techniques combined with digital imagery to produce photorealistic 3D virtual outcrop models (VOM). The virtual outcrops allow for the collection of accurate, spatially constrained geometric data which in turn lead to a greatly improved geological understanding of sedimentary architecture and processes. Virtual outcrop models, especially of larger cliff sections, often suffer from problems associated with the orientation of the scanner with respect to the cliff section. Since the scanner is typically at the base of the cliff there may be scan shadow (parts of the cliff that are invisible from the ground) and also the images used to texture the models are taken from an oblique angle and suboptimal. One solution is to these problems is to mount the scanning system in a helicopter but this logistically challenging and extremely expensive.

Recent developments in unmanned aerial vehicles (UAVs or Drones) have resulted in a plethora of small, radio controlled flying machines becoming available at relatively low costs (from a few hundred pounds). These systems can carry a camera and provide an opportunity to collect image data from optimal angles with respect to outcrops. Parallel advances in 3D image modelling software mean that these data can then be combined photogrammetrically to produce 3D models comparable to lidar derived virtual outcrops.

A system which includes a radio controlled octicopter with twin cameras mounted on it has been tested. A series of work processes for the collection and processing of the data have also been developed. The method was tested on outcrops in the Ebro Basin, northern Spain and the results were benchmarked against lidar scans of the same outcrops. Results suggest that the method compares favourably with lidar scanning and in many cases gives better image quality providing an additional tool for the building of virtual outcrop models.

KEYNOTE:

Half-way between the gutter and the scars: a review of mass transport deposits and look forward

Christopher A-L. Jackson[1]*, David M. Hodgson[2], Joris T. Eggenhuisen[3] and Lorena Moscardelli[4]

[1]*Basins Research Group (BRG), Department of Earth Science & Engineering, Imperial College, Prince Consort Road, LONDON, SW7 2BP, UK*

[2]*School of Earth and Environment, Faculty of Environment, University of Leeds,Leeds, LS2 9JT 41, UK*

[3]*Faculty of Geosciences, Universeteit Utrecht, P.O Box 80125,3508 TC Utrecht, The Netherlands*

[4]*Statoil, 6300 Bridge Point Pkwy # 2-500, Austin, TX 78730, United States*

*Corresponding author: c.jackson@imperial.ac.uk

Mass transport complexes (MTCs) were originally defined as poorly stratified, highly heterogeneous, 'mass movement-deposited' sediments that were deposited by weakly turbulent to laminar, subaqueous sediment gravity-flows. The observation that MTCs typically occurred at the base of deep-water successions, below channel-levee deposits, led to them being interpreted as falling-stage or lowstand deposits; they were thus inferred to be of sequence-stratigraphic significance. Despite the fact that MTCs form spectacular features at outcrop and in seismic reflection datasets, the geometry, internal structure and emplacement of MTCs have been overlooked, in comparison to turbidity current deposits. Understanding the emplacement mechanisms, sedimentology, stratigraphic architecture and sequence-stratigraphic context of MTCs is important because: (i) they are volumetrically significant in many deep-water successions, (ii) they can form hydrocarbon seals and reservoirs, (iii) they can represent a hazard to drilling and seabed infrastructure; and (iv) they influence subsequent sediment dispersal patterns such that the commonly applied architectural models for turbidity current deposits are not applicable. Here, we will review the sedimentology, stratigraphic context and seismic expression of MTCs, in addition to the current state of knowledge regarding their emplacement processes. MTCs are readily identifiable in core, outcrop and in seismic reflection datasets, although there is much variability in the morphology of their bounding surfaces, internal stratigraphy, external morphology and size. Furthermore, based on the recognition that MTCs can be emplaced during highstand conditions and are not, therefore, simply triggered by falling sea-/base-level, we question the sequence-stratigraphic significance of MTCs and caution against a simple 'lowstand' interpretation. We will conclude by outlining key areas for future research, which include: (i) field-based analysis of MTCs; (ii) subsurface analysis of MTCs in the shallow and deep subsurface; and (iii) physical modelling of MTCs. Ultimately, achieving these aims requires an integrated approach that involves field-based sedimentologists, geophysicists and physical modellers.

Sedimentology of a Welsh Ordovician Konservat-Lagerstätte

Naomi Jordan[1]*, Joseph P. Botting[2,3], Lucy A. Muir[2] and Christopher Upton[4]

[1]*Department of Earth Science and Engineering, South Kensington Campus, Imperial College London, SW7 2AZ*

[2]*Flat 4 White Heather, Western Promenade, Llandrindod Wells, Powys, LD1 5HR, UK*

[3]*Nanjing Institute of Geology and Palaeontology, Nanjing 210008, China.*

[4]*1 Hamilton Terrace, Shoscombe, Bath BA2 8ND, UK*

*Corresponding author: n.jordan11@imperial.ac.uk

The Afon Gam Biota is an early Ordovician Konservat-Lagerstätte with some biotic elements similar to those of the Burgess Shale and Fezouata assemblages. It occurs within the Tremadocian Dol-cyn-Afon Formation from near Bala, North Wales. The exceptional preservation has only recently been recognised, and very little is yet known about the depositional environment.

Konservat-Lagerstätten are important for understanding evolution and the history of life, as they preserve soft tissues and soft-bodied organisms that are otherwise unknown. Understanding these fossil communities requires an assessment of taphonomic biases, which are dependent on the sediments, environmental conditions, depositional environment and chemical conditions during and after deposition.

The rock hosting the Afon Gam Biota is dominated by siltstone, with thin discrete pulses of sandstone and occasional mudstone. The fossils, which include sponges, arthropods, algae, echinoderms, brachiopods and worms, are preserved in iron sulphide (presumed pyrite), calcium phosphate, and aluminosilicate crystals and films, as well as moulds in the finer sediments.

The current interpretation, based on hand specimens, sedimentary logs, and thin sections, is that the biota was deposited by distal mass flows just below storm wave base. The rock primarily consists of numerous event beds of varying thickness, from a few millimetres to tens of centimetres. The different sedimentary conditions preserved different fossil assemblages and provide new insights into how taphonomic processes affect our understanding of observed Ordovician community structures.

Tetrapod terrestrialisation in the earliest Carboniferous: paleosol morphology and the floodplain environment of the Ballagan Formation

Timothy Kearsey[1]*, Carys E. Bennett[2], David Millward[1], Sarah J. Davies[2], John E.A. Marshall[3] and Michael.A.E. Browne[1]

[1]*British Geological Survey, Murchison House, West Mains Road, Edinburgh, EH9 3LA*

[2]*Department of Geology University of Leicester, Leicester, LE1 7RH*

[3]*Ocean and Earth Science, National Oceanography Centre Southampton, University of Southampton, SO14 3ZH*

*Corresponding author: timk1@bgs.ac.uk

This paleosol study is a contribution to the TW:eed Project (Tetrapod World: early evolution and diversification), a major research programme investigating the rebuilding of Carboniferous ecosystems following a mass extinction at the end of the Devonian. Several new localities in southern Scotland are yielding important new tetrapod fossils and providing fresh insights into this pivotal period for the evolution of life on land. Understanding the sedimentary facies of the Lower Carboniferous (Tournaisian) Ballagan Formation in SE Scotland is a key component in the study of the palaeoenvironments that preserved the earliest known terrestrial tetrapods.

The Ballagan Formation comprises a distinctive cyclic succession of mudstone and thin beds of dolostone ("cementstone"), interbedded with fluvial sandstone bodies. Locally, numerous thin beds of gypsum and anhydrite occur, commonly associated with abundant dolostone beds. This association of facies has been interpreted previously as representing deposition in a coastal alluvial plain setting.

Paleosols are very common throughout the formation. Five distinct types have been recognised in both natural exposures and in borehole core: 1) Entisols, thin (0.05-0.25m) and poorly developed; 2) Inceptisols that have a clay-rich horizon (Bt) which is commonly reddened; 3) Inceptisols those with a developed clay horizon which is gleyed, and with carbonaceous root-traces and rare Fe nodules; 4) Vertisols with pedogenic slickensides and sinuous surface cracks, and 5) Alfisols with drab-root haloes more than 1m long and sporadic calcrete nodules. Many of the paleosols are overlain by microconglomerates which commonly appear to infill vertic structures, where present, in the uppermost part of the paleosols.

The paleoenviromental picture that is emerging from the study of the paleosols suggests that the floodplain may have been occupied by areas of waterlogged soils, areas of intermittent waterlogging and areas where forested soils dominated. These distinct paleosols suggest the presence of quite different plant communities and provide key insights into the character and development of the paaleoenvironment inhabited by these early terrestrial tetrapods

Flow structure and bedform morphology around a tidally influenced fluvial bar

Claire Keevil[1]*, Dan Parsons[1], Phil Ashworth[2], Jim Best[3,4], Greg Sambrook Smith[5], Eric Prokocki[4], Andrew Nicholas[6], Steven Sandbach[6], Chris Simpson[7], Robert Strick[2] and Kiyomi Holman[8]

[1]*Department of Geography, Environment and Earth Sciences, University of Hull, Hull, HU6 7RX, UK*

[2]*Division of Geography and Geology, School of Environment and Technology, University of Brighton, Brighton, Sussex, BN2 4GJ, UK*

[3]*Departments of Geology, Geography and Geographic Information Science, Mechanical Science and Engineering and Ven Te Chow Hydrosystems Laboratory, University of Illinois at Urbana-Champaign, 1301 W. Green St., Urbana, IL, 61801, USA*

[4]*Department of Geology, University of Illinois at Urbana-Champaign, 1301 W. Green St., Urbana, IL, 61801, USA.*

[5]*School of Geography, Earth and Environmental Sciences, University of Birmingham, Edgbaston, Birmingham, B15 2TT, UK*

[6]*Department of Geography, College of Life and Environmental Sciences, University of Exeter, Exeter, EX4 4RJ, UK*

[7]*Fulcrum Graphic Communications Inc., TH2-168, Esplanade Avenue East, North Vancouver, BC, V7L 4X8, Canada*

[8]*Department of Geography, Simon Fraser University, 8888 University Drive, Burnaby, BC, V5A 1S6, Canada*

*Corresponding author: c.keevil@hull.ac.uk

All river-estuary systems contain a transitional zone between fully fluvial and fully tidal environments. This river-estuary transition zone is highly complex with fluvial and tidal currents interacting on daily, seasonal and annual cycles, which are superimposed upon each other. These varying cycles and the resultant daily shift in the position and magnitude of the transitional zone make the measurement and definition of flow processes and sediment transport difficult to define. Quantification of these processes will allow a fuller model of this complex zone to be developed.

The Columbia River Estuary, USA is a macrotidal estuary with well developed bar complexes within the transitional zone. A single bar has been chosen for study, at the upstream region of a large tidal bar complex. A series of detailed three-dimensional flow measurements were collected using an Acoustic Doppler Current Profiler around the bar during a spring tidal cycle. The flow measurements were repeated at several points in the tidal cycle to allow the interactions of bar geometry and the flow fields to be analysed. A high-resolution Multibeam Echo Sounder bathymetry survey was also carried out around the same bar, with repeated surveys conducted to investigate the spatial patterns of bedform migration around the bar across a tidal cycle.

The data shows the temporal and spatial variations in flow around a single bar across the tidal cycle in an area of low tidal influence. Fluvial flow can be seen to be slowed by the incoming tide and is reversed fully for periods; there is a strong spatial pattern to the reversal. The effects of the tides on bedform morphology and the evolution of these bedforms can also be seen. Large scale dunes are found throughout the survey area, with crest orientations corresponding to the dominant fluvial flow direction.

Variation in dune scale (<10 – 80 m) can be seen around the bar, but all show some modification due to the tidal flow. Smaller scale dunes can be seen to change orientation and steer around the bar head. The implications of these patterns in flow and sediment transport will be discussed in terms of the influence they have on the spatial trends of sedimentation.

Neoproterozoic ice sheets and olistoliths: the Kingston Peak Formation, Kingston Range, California

Daniel P. Le Heron[1]*, Marie E. Busfield[1], Anthony R. Prave[2]

[1]*Department of Earth Sciences, Queen's Building, Royal Holloway University of London, Egham, Surrey, TW20 0BY, UK*

[2]*Department of Earth and Environmental Sciences, University of St Andrews, St Andrews, KY16 9AL, UK*

*Corresponding author: daniel.le-heron@rhul.ac.uk

The Kingston Peak Formation is a diamictite-bearing succession that crops out in the Death Valley region, California, USA. An exceptionally thick (>1.5 km) outcrop belt in its type area (the Kingston Range), provides clear insights into the dynamics of mid Cryogenian (Sturtian) ice sheets in Laurentia. Seven detailed logs allow the lateral and vertical distribution of facies associations to be assessed. We recognise (1) a diamictite facies association (subglacial deposits, mostly re-worked as cohesive debris flows); (2) a boulder conglomerate facies association (ice-proximal debrites and high density turbidites); (3), a graded beds facies association (Bouma turbidites and downtract equivalents of the boulder conglomerates); (4), a lonestone-bearing facies association (hemipelagic muds and distal turbidites punctuated by ice rafted debris) and (5) a megaclast facies association (an olistostrome). The stratigraphic motif allows three glacial cycles to be inferred across the range. Ice minimum conditions interrupting the Kingston Peak are associated with the development of an olistostrome complex, succeeded by a thick accumulation of boulder conglomerates deposited during ice re-advance. The data testify to a strong glacial influence on sedimentation within this ancient subaqueous succession, and to highly dynamic ice sheet behaviour with clear glacial cycles during the Sturtian glaciation.

New method for settling velocity distributions: Two-population floc systems highlighted in British waters

Robert G. Macdonald[1]*, David G. Bowers[1], Jonathan Malarkey[1], David McKee[2], George W. Graham[3] and W. Alex M. Nimmo-Smith[3]

[1]*School of Ocean Sciences, Bangor University, Menai Bridge, Anglesey. LL59 5AB.*

[2]*Department of Physics, University of Strathclyde, Glasgow. G4 0NG.*

[3]*School of Marine Science and Engineering, Plymouth University, Plymouth. PL4 8AA.*

*Corresponding author: r.macdonald@bangor.ac.uk

The structures of unhindered settling deposits (pelagic drapes, Bouma E divisions etc.) depend crucially on the settling velocity distribution of the suspended particles. In a new method, data from two established ocean science techniques were combined to determine settling velocity distributions in freshwater and coastal ocean settings. In the field, particle volume distributions were determined with LISST laser-diffraction instruments and digital in-line holography. Cumulative settling velocity distributions were determined for the same size range by deploying settling velocity tubes on a boat and processing the basic data (time, water volume and filtered sediment mass) with a recently published model called *svtube*.

LISST particle volume distributions are in 32 logarithmically spaced size classes 2.5 – 500 µm. In-line holography treats particles independently and classes are made. The method is to consider each class independently, guessing an initial apparent particle density. From this guess, the initial mass, m_i is derived. Next from Stokes law, settling velocities are calculated at the limits of each size class and mass-in-class determined from the cumulative settling velocity distribution. This mass-in-class by settling velocity tubes, m_{SVT} is compared against m_i over a physically-reasonable range of apparent densities. The apparent density is chosen where the two masses are consistent. For eight stations and 32 classes, almost all solutions were unique. With apparent densities known, settling velocity distributions follow easily.

Eight stations in NW-UK waters covered Irish Sea, Hebridean Sounds, sea and freshwater lochs and Atlantic near-shelf-edge settings. LISST method (initially) shows, in all cases, two-population floc systems of microflocs and macroflocs. Microflocs were dense, up to 50 – 400 µm diameter and settled as quartz. Macroflocs were dominated by pore space, above 7 – 70 µm diameter and settled at the rate of dead biological particles. The crossover in particle populations was up to an order of magnitude of particle diameter. At most sites, little variation in settling velocity was determined within the crossover population. Fine silt to very fine sand sizes often fell with equal velocity where flocs dominated individual dense particles.

The program *svtube*, and the associated paper, are free to download via:

http://pages.bangor.ac.uk/~oss101/welcome.html

The Great Flood: Alberta's "biblical" deluge of 2013

Jon Noad*

Husky Energy, Calgary, Alberta, Calgary

*Corresponding author: jon.noad@huskyenergy.com

On June 20th 2013 more than 100,000 people were evacuated from their homes in Calgary. Over the following week large portions of the city were inundated by what was variously described as a "biblical" or 100 year flood. The result was Canada's costliest ever disaster, estimated at $1.7 Billion. In other southern Albertan localities, such as High River, where all 13,000 residents were evacuated, hundreds of people remain in temporary accommodation.

This presentation will examine various aspects of the flooding. One of the main causes was traced back to a weather system trapped over a small catchment basin some 80 km to the west of Calgary. Four days of torrential rain poured more than 250 mm of water, in addition to snow melt, into Cougar Creek. The "creek" should more correctly be described as an alluvial fan, and demonstrated this as huge boulders and trees were mobilised across a vast gravel plain. The resulting flows destroyed all access to Canmore and Banff, washing away the Trans Canada Highway.

The mass of water flowed towards Calgary, bolstered by heavy rains along its length. It burst its banks in many areas, flooding much of downtown Calgary. The Bow River demonstrated to the city planners that rivers will be rivers, depositing tons of sediment and eroding up to 40 m into its banks. On a lighter note the zoo's hippos almost escaped into the wild. Significant crevasse splay deposits (including manmade debris and sediment) were deposited, and studied in detail in a locality downstream from the city.

The previous "100 year flood" had occurred in 2005, after a hiatus of 70 years. Studies based on earlier floods suggested that there was a potential for a flow of 2400 m3/second in peak flood conditions, which is a concern as the maximum velocities seen in 2013 were only around 1458 m3/second. Yet this was more than three times the flow seen in 2005. Reasons for this may include changes in ground conditions, weather patterns, or is it simply that the worst is yet to come?

Facies Trends and Large-Scale Architecture of the Pennsylvanian Ross Formation, Western Ireland - New Insight from Cores South of the Shannon

A. Obradors-Latre[1]*; C. Pierce[1], P. Haughton[1], P. Shannon[1], A. Pulham[2], A. Lacchia[3], S. Barker[4] and O. Martinsen[4]

[1]*UCD School of Geological Sciences, University College Dublin.*

[2]*ESAC&T, Boulder, USA.*

[3]*Department of Geology, Trinity College Dublin.*

[4]*Statoil ASA, Norway.*

*Corresponding author: arnau.obradors-latre@ucdconnect.ie

The Ross Formation is well exposed in sea cliffs facing the Atlantic and Shannon estuary in western Ireland. It forms the sandy deep-water part of a major shallowing-upward Pennsylvanian succession. Over the last four years, a major behind-outcrop drilling program targeting the Ross Formation has focussed on the Loop Head peninsula in west Clare. This has provided a fully-cored composite Ross section (490 m thick) that underpins a new understanding of bed-scale variability and the vertical evolution of the system. The focus has now shifted to the key Ballybunion section on the south side of the Shannon, which sits obliquely down-dip (to the east) of Loop Head (c. 18 km away). This area is important in that outcrop studies have suggested that (1) the character of the lower Ross with abundant hybrid event beds (HEBs) may reflect a marginal fringe position; (2) an extra sandy section may be present in the uppermost Ross due to offset stacking of the youngest fan lobes and (3) some of the upper Ross mass transport units may extend across the estuary from Clare. Two new cores are now available 'behind' the Ballybunion cliff section: a 200 m long PQ borehole straddling the lower Ross and the upper part of the underlying Clare Shale (12-KY-UCD-09), and a 151.5 m long slimhole core acquired by the Geological Survey of Ireland (GSI 09/05). In addition, a re-analysis of the biostratigraphy is underway. Together the pair of Kerry boreholes and the adjacent outcrop provide a reference section (485 m thick) that can be compared with the new Loop composite section. Both sections have a precursor unit involving stacked thin mudflows overlain by outsized and unusually coarse grained HEBs. The muddier make-up of the latter at Ballybunion is consistent with a down-dip position. The initial onset of the main Ross system that follows is sandier at Ballybunion than at Loop, suggesting the former was more axial at this time. Thereafter HEBs appear not to be as important at Ballybunion. Several of the mass transport units and condensed sections extend across the Shannon estuary and tie the sections.

The Fosado Turbidite Channel Complex (Eocene, South-Central Pyrenees, Spain)

A. Obradors-Latre[1]*, E. Remacha[2] and M. Poyatos-Moré[2,3]

[1]*UCD School of Geological Sciences, University College Dublin.*

[2]*Departament de Geologia, Universitat Autònoma de Barcelona, 08193-Bellaterra, Spain*

[3]*Stratigraphy Group, School of Earth, Atmospheric and Environmental Sciences, University of Manchester, UK*

*Corresponding authors: arnau.obradors-latre@ucdconnect.ie

miquel.poyatos-more@manchester.ac.uk

In the Eocene of the South-Central Pyrenean foreland basin, the lower part of the Castissent tectono-sedimentary unit (TSU-3) is formed by the Fosado-Torla turbidite system. In this system, the Fosado Turbidite Channel Complex (FTCC) is a distinctive base-of-slope large-scale sandstone-rich body filling the lower part of the Atiart submarine canyon. Excluding a very general stratigraphic framework, little is known about this channel complex. Therefore, the aim of this project is to provide a first more detailed study concerning chrono- and lithostratigraphy, architecture and the main types of facies associations of this multi-storey channel system.

The Atiart canyon is a large-scale submarine erosional feature formed in middle Ypresian (Cuisian) times, within the Chron C22r, ca. 50.2 Ma. Its incision and fill was tectonically controlled by the Foradada fault and by the syn-sedimentary activity of the Atiart thrust. Later, the onset of Los Molinos thrust and the effects of the Samper out-of-syncline thrust (located in the hanging wall of the Atiart thrust) controlled the development of the upper unconformity of the Fosado-Torla system, expressed in the lower Charo canyon. Both the Atiart and the lower Charo unconformities define a third-order scale depositional sequence known as Castissent-1 depositional sequence. The FTCC is located in the hanging wall of Los Molinos thrust, passing transitionally upward into a thick mud-dominated slope succession.

The Fosado channel-overbank complex is a multi-storey and relatively sand-rich unit, reaching up to 240 m in thickness, and comprising five unconformity-bounded high-frequency units. Each unit contains channel sandstone bodies overlying hyperconcentrated-flow deposits which form the lower part of the high-frequency cycles. Channel bodies commonly show lateral accretion followed by vertical aggradation, and these may therefore be related to high-sinuosity channels, laterally associated to thin-bedded overbank deposits. Finally, the channel bodies are succeeded by thin-bedded drapes which cap the high-frequency units. Lower sandstones of the higher units show a pronounced aggradational pattern and consist of depositional channels with well-developed channel margin facies.

Lastly, the mudstone wedge that evolved above the FTCC comprises local minor hyperpycnal channel-overbank systems which are interpreted as slope deposits and which pass basinward into thin-bedded lower slope fine-grained lobes.

Thin-bedded turbidites: a new approach toward better characterisation

Bayonle Omoniyi*, Dorrik Stow and Andy Gardiner

Institute of Petroleum Engineering, Heriot-Watt University, Edinburgh, Scotland

*Corresponding author: bayonle.omoniyi@pet.hw.ac.uk

Many producing and marginal turbidite fields comprise a significant proportion of thin-bedded (TBT) and very thin-bedded turbidites (VTBT). Understanding their nature, properties and flow behaviour is critical in reducing key uncertainties and associated subsurface risks that impact hydrocarbon recovery from such reservoirs. Based on a large number of studies of modern, ancient and subsurface systems, we identify the principal geological attributes of TBTs and VTBTs that can be used to discriminate between different architectural elements in deep-water systems. These are: facies and facies associations; sand-shale ratio; sand/shale geometry and dimensions; sand connectivity; sediment texture; small-scale sedimentary structures; and small-scale vertical sequences of bed thickness. We further define four fundamental *attribute indices*, derived from attribute combinations, which influence vertical and horizontal flow: (1) the sand connectivity index, derived from the nature of bed/lamination cross-cutting relationships; (2) the sediment textural index, derived from the mean grain-size property: (3) the proximality index, derived from Bouma/Stow sequence combination and selected facies ratios; and (4) the micro-fracture index, derived from the micro-fracture density, style and distribution.

This approach is now being applied to subsurface core data from four North Sea Brae Field wells, initially to assess vertical connectivity in the sand/silt parts of the TBT–VTBT succession. The eight facies classes identified in the study are characterised by varying textural characteristics, bed thickness patterns, and reservoir indices. The sand vertical connectivity index (SVCI), in particular, is an important discriminator for the prediction of sand continuity and connectivity. The next step is to run flow simulations for combinations of attribute indices. We propose that discrimination of TBT-VTBT facies, attributes and attribute indices has great significance for exploration and production of marginal turbidite systems, and for a variety of tight and ultra-tight reservoirs in deepwater systems, as well as for better characterisation of deepwater shale properties.

Statistically estimating the position of an apex for a distributive system

A. Owen[1]*, G.J. Nichols[2], A.J. Hartley[3], G.S. Weissmann[4] and P. Jupp[5]

[1]*Department of Earth Sciences, Royal Holloway, University of London, TW20 0EX.*

[2]*Nautilus Limited, Ashfields Farm, Berkshire, RG18 9XY.*

[3]*Department of Geology and Petroleum Geology, School of Geosciences, University of Aberdeen, AB24 3UE.*

[4]*Department of Earth and Planetary Sciences, University of New Mexico, Albuquerque MSC03 2040, New Mexico, USA.*

[5]*School of Mathematics and Statistics, University of St Andrews, Fife, KY16 9SS.*

*Corresponding author: a.owen@rhul.ac.uk

Knowing the location of an apex can provide important and insightful paleoenvironmental information such as the potential location of a basin margin, as well as help estimate and understand facies distributions. The methodology presented here provides a robust statistical methodology whereby the position of the apex can be predicted. The methodology is based on the Von Mises distribution of paleocurrents within a system and adopts a methodology of maximum likelihood to help determine a series of confidence regions as is presented in Jupp *et al* (1987). This methodology has now been applied to R, a statistical computing software, in order for quick calculations and affective graphical results to be obtained.

To test the accuracy of the methodology a study was conducted on a modern day distributive fluvial system (DFS) to see if it could place the apex, the position of which is known, within an acceptable margin of error. The Gilbert DFS, situated in north-western Queensland, Australia, has an apex to toe length of approximately 170km. This DFS was chosen because the DFS has experienced limited human modification and excellent imagery of paleochannels and presently flowing channels is available. Paleocurrent directions were taken along stretches of rivers situated across the DFS. Thirty locations were selected at random to help simulate geological conditions. Despite the Gilbert DFS not having a clear radial morphology the reduced dataset placed the apex within a commendable 17km of the actual apex.

The method was then applied to the Salt Wash fluvial system, of the Morrison Formation, SW USA. The results produced an apex position that can help further constrain the Morrison Basin boundary, the position of which was previously poorly constrained. The results also provide important paleoenvironmental information about the Salt Wash fluvial system, specifically helping further constrain the size and distribution of facies of the system.

Although this methodology has been applied to two DFS, its wider application is clear to any environment in which flow radiates from a given point.

Modelling tectonic and eustatic sea-level processes in the Kyrenia Range, Cyprus, using sedimentology and new U-series data

Romesh N. Palamakumbura[1]*, Alastair H.F. Robertson[1], Dick Kroon[1], Hugh Sinclair[1], Mehmet Necdet[2] and Peter Van Calsteren[3]

[1]*Earth and Planetary Sciences Institute, School of GeoSciences, West Mains Rd., University of Edinburgh, EH9 3JW*

[2]*Geology and Mines Department, 1 Lefkonos, Strovolos, Lefkosia, Cyprus*

[3]*The Open University, PO Box 197, Milton Keynes, MK7 6BJ*

*Corresponding author: rpalamakumbura@gmail.com

The Kyrenia Range, in the north of Cyprus has uplifted from sea-level to ~1000m above modern sea-level (AMSL) during the Plio-Quaternary. The uplift took place in parallel with uplift of the Troodos Massif in the south of Cyprus. A series of geomorphological terraces formed along both northern and southern flanks of the Kyrenia Range, representing Mid-Late Quaternary deposits. On the northern side of the range, each terrace has a marine and a continental component whereas on the southern side the terrace deposits are entirely non-marine. The absence of marine deposits along the southern flank reflects the Late Pliocene closure of the Mesaoria seaway between the Kyrenia Range and the Troodos Massif. In contrast, the northern flank of the range bordered the Mediterranean Sea throughout the Quaternary. An interplay of tectonic uplift versus eustatic sea-level change (plus climatic change) controlled the depositional environments along the northern flank of the range. New U-series dating of *Cladocora* corals from the two lower marine terrace deposits (<40m AMSL) can be correlated with the eustatic sea-level curve to help develop an uplift model. Uplift rates during the Late Quaternary are calculated from these lower terraces as 0.5-0.1 mm/year. These rates are comparable to those reported from the adjacent Hatay coast of southern Turkey during the equivalent time period. In contrast, the correlations with the eustatic sea-level curve (i.e. marine high-stands), suggest faster uplift rates for the three older Late Quaternary terraces (~1-2 mm/year)(40-300m AMSL). There is also evidence for an earlier phase of rapid uplift in the form of large-scale, chaotic debris-flow deposits (with blocks up to 10m across), along both the northern and southern flanks of the range (~650m AMSL). The likely cause of this talus formation was rapid fault scarp degradation during Early to Mid-Quaternary time. Magnetostratigraphy, strontium isotopes and optically stimulated luminescence dating will be used to test and refine the working uplift model.

Lateral facies changes and architecture of hybrid-like beds deposited in a ponded minibasin (Castagnola Fm, NW Italy).

Marco Patacci[1]*, Sarah Southern[1], Fabrizio Felletti[2], Bill McCaffrey[1]

[1] *Turbidites Research Group, School of Earth and Environment, University of Leeds, UK*

[2] *Università degli Studi di Milano, Dipartimento di Scienze della Terra "A.Desio", Italy*

*Corresponding author: m.patacci@leeds.ac.uk

Hybrid-like beds (HEBs) are a class of gravity flow deposit including a basal sandy division followed by a chaotic division made up of both sand and clay in different proportions sometimes capped by an upper structured clean sandstone division. Although their existence has been documented nearly from the onset of the turbidite concept, HEBs have been the object of renewed attention in the last ten years, mainly as they can occur within hydrocarbon reservoirs. A range of generation mechanisms has been suggested, partly reflecting the wide variety of such deposits. Most models focus on the occurrence of rheological changes within the flow, with the chaotic mud-enriched division being deposited under transitional or laminar conditions. HEBs are thought to be more common at fan fringes or in close proximity to confining topography. However their depositional processes remain an object of on-going research, and thus our understanding of their character and distribution continues to evolve.

The Lower Miocene Castagnola Turbidite System (800-1000m thick) records the deep-water infill of a small (a few to tens of km^2) ponded piggyback sub-basin in the eastern part of the Tertiary Piedmont Basin (NW Italy). Six detailed sedimentary logs taken along a 3.1 km proximal-to-distal transect encompass a low net-to-gross (0.2), 250m thick interval. Generally, bed types comprise either thin (<1m), highly structured deposits, or thicker (1-5m) beds. The latter are commonly hybrid-like, with a poorly structured lower sandy division, overlain by a recessive division frequently enriched in mudclasts and capped by a sandstone that is usually highly structured. Thanks to the tabular nature of the bedding, all of these beds can be confidently correlated along the entire transect. The relative proportion of mudclast-rich intervals is highly variable, changing from over 75% of the bed to less than 25% within some tens of meters. The hybrid character does not appear to vary consistently with distality or proximity to the confining slope but it commonly occurs throughout the basin. This areal pattern challenges current models of hybrid-like bed distribution and has implications for better understanding the character and distribution of hybrid-like beds in similar settings in the subsurface.

The importance of spin: global submarine channel dynamics

Jeff Peakall[1]*, Remo Cossu[2] and Mathew Wells[2]

[1]*School of Earth and Environment, University of Leeds, Leeds, LS2 9JT*

[2]*Department of Physical and Environmental Sciences, University of Toronto, Ontario, Canada*

*Corresponding author: j.peakall@leeds.ac.uk

A marked latitudinal variation has been observed in the sinuosity of submarine channels, with all the most sinuous examples relatively close to the poles, and nearly straight channels towards the poles. However, the underlying mechanics controlling this distribution have been less clear, with the spin of the Earth and its associated Coriolis force, and / or latitudinal climatic controls on sediment and flow type, being suggested. Here we present the first-ever experiments of channelized turbidity currents running over an erodible bed under the influence of rotation. We systematically varied rotation speeds to mimic changes in Coriolis forces with latitude to analyze intra channel-deposition patterns as a function of latitude in sinuous and straight model submarine channels. The experiments revealed a striking systematic change in deposition and erosion between the poles and the equator. At low latitudes erosion and significant point bars formed on alternate sides of meandering channels but decreased with increasing latitude. At high latitudes erosion and deposition only occurred on opposite sides of channels and single point bars behind channel bends are almost absent. These findings support a conceptual framework that varying depositional patterns arise due to shifts in the force balance of centrifugal and Coriolis forces between different latitudes leading to strongly meandering channel systems near the equator but rather straight channels in high latitudes. In addition, field data from both the modern ocean floor and the ancient rock record show differences in channel geometries supporting this conceptual model. We hypothesize that channel deposits vary on a global scale which offers a new approach to interpret deep-sea architectural features.

So it appears that spin really is important, although its effects will be best seen in higher latitudes. In this respect at least there may be parallels with its modern day usage in politics[#].

[#] For example: “Alastair Campbell was a brilliant press officer, a master of media manipulation, and was even kind enough to write this quote for me” [John O’Farrell].

Lime mud genesis: The microbial biofilm link

Martyn Pedley*

Department of Geography, Environment and Earth Sciences, University of Hull, U.K.

*Corresponding author: h.m.pedley@hull.ac.uk

The origin of lime muds in the Phanerozoic record has puzzled carbonate workers for over 50 years. Theories include both mechanical and biological disintegration of pre-existing grains and lately also biomediation. These muds form in both freshwater and shallow marine shelf and ramp settings in vast quantity but how?

Long running (7 years) mesocosm experiments at Hull has been employed to examine microbial biofilm processes which lead to the precipitation of lime mud. Freshwater settings were chosen for the experiments on account of their relatively simple ionic composition though the processes and products are also comparable to marine settings. The two dominant carbonate producers in these settings are thrombolites and stromatolites. Both are capable of generating particles with sizes ranging from nanometer to millimeter. Thrombolitic fabrics were produced under slow flow conditions whereas stromatolite fabrics were generated under higher flow regimes. Individual crystals commenced growth as amorphous calcium carbonate nanospheres within the biofilm EPS. These ripened into microspar crystals at about 10 microns diameter. Precipitation was initiated in a basal layer after which further carbonate growths developed as suspended partitions within the EPS. Over time crystals co-joined and aggregated into curtains linking further basal layers. Biofilm damage (caused by increased turbulence, grazing and particle attrition) lead to disintegration of the EPS and yielded myriads of carbonate particles which became available for transported elsewhere.

Shallow seismic, GPR and percussion core analysis of closely related lacustrine microbial carbonates at Ruidera Natural Park Central Spain, provides a field scale analogue. These show that the carbonate factory (marginal thrombolitic microherms) has generated >18m of lime muds during the Holocene, a significant part of which has been redistributed by turbulence and associated gravity flows into gentle carbonate ramp slopes around the lake basin margins. The Ruidera lakes provide a convincing field model which corroborates the laboratory findings and demonstrates the effectiveness and importance of microbial biofilms as fine sediment producers in the geological record.

What palaeo-environmental parameters do cross strata indicate?

A. Reesink[1]*, D. Parsons[1], C. Unsworth[1], P. Ashworth[2], J. Best[3], R. Hardy[4], S. McLelland[1] and B. Murphy[1]

[1]*Department of Geography, Environment and Earth Sciences, University of Hull, Hull*

[2]*Division of Geography and Geology, School of the Environment and Technology, University of Brighton, Brighton, UK.*

[3]*Departments of Geology, Geography and Mechanical Science and Engineering and Ven Te Chow Hydrosystems Laboratory, University of Illinois at Urbana-Champaign, Illinois, USA.*

[4]*Department of Geography, Durham University, Durham, UK*

Although cross-strata formed by dunes are key evidence for the formative flows of fluvial, estuarine and shallow marine environments, the dynamics of dunes in spatially and temporally varying flows remain relatively poorly understood. Importantly, the bed shear stress that controls sediment transport, and hence dune adaptation, is largely controlled by both flow depth and water-surface slope, which can vary independently in time and space. For example, water-surface slope is out-of-phase with flow depth during short-lived flood waves (e.g. storm-related floods or tides), yet both vary in unison during longer-term changes in base flow (e.g. slow seasonal changes). Spatially, the magnitudes of depth and slope vary locally, for instance between the thalweg and bar tops, as well as downstream along a river between the tributaries and river mouth. Thus, there is clear need to understand the relative roles of depth and water surface slope in order to better understand and interpret the dune dynamics.

In order to investigate the relative importance of depth and water surface slope, uniform flow experiments were carried out in a 2 m wide and 11 m long flume, using sand with a D_{50} of 240 μm, and water depths of 0.175-0.225 m. The irregular geometry of the dunes that developed in the flume allowed antecedent morphology and bedform interactions to be identified as key controls on bedform merging, splitting and superimposition. The behaviour and influence of individual bed forms is unlikely to be identifiable when dunes have similar geometries because similar bed forms ought to respond identically. The adaptation of dune morphology was found to be more sensitive to stepwise changes in water depth and less sensitive to stepwise changes in discharge. These results confirm that spatial and temporal variations in the relative magnitudes of depth and water surface slope can indeed affect sediment transport, morphodynamics, and sedimentary preservation. The implication of such fundamental variability in the drivers of the hydraulic energy budget (depth, slope, velocity) is that the palaeo-hydraulic significance of cross-stratified sets from different environments may vary (estuaries & rivers; bar tops and thalwegs), even if the strata appear identical.

Using sedimentology to help unravel the subduction-accretion & collision history of the southern margin of Eurasia (NE Turkey)

Alastair Robertson[1]*, Osman Parlak[2], Timur Ustaömer[3], Kemal Taslı[4], Nurdan İnan[4], Paulian Dumitrica[5] and Fatih Karaoğlan[2]

[1]*School of GeoSciences, University of Edinburgh, EH9 3JW Edinburgh, UK;*

[2]*Çukurova Üniversitesi, Jeoloji Mühendisliği Bölümü, 01330 Balcalı, Adana, Turkey*

[3]*İstanbul Üniversitesi, Mühendislik Fakültesi, Jeoloji Bölümü, Avcılar 34320, İstanbul.*

[4] *Department of Geological Engineering, Mersin University, Mersin, Turkey*

[5]*Instiute of Earth Sciences, Université de Lausanne, Géopolis, 1015 Lausanne, Switzerland*

*Corresponding author: Alastair.Robertson@ed.ac.uk

A major Tethyan suture zone which is located adjacent to the southern margin of Eurasia is characterised by thrust sheets and melange, with a range of redeposited terrigenous and volcanogenic sedimentary rocks, pelagic sedimentary rocks and igneous/metamorphic rocks (including basaltic blocks within melange and Lower Jurassic ophiolitic/oceanic crust). The sedimentary rocks allow two alternative hypotheses to be tested: 1. The suture zone preserves an Andean-type active continental margin associated with northward subduction, accretion and arc magmatism during Mesozoic-early Cenozoic; 2. The suture zone preserves the remnants of *two different* subduction zones; first an Andean-type margin (as above) and secondly, an intra-ocean subduction zone. Sedimentological studies, combined with new ion-probe dating of the ophiolitic rocks, dating of radiolarites and calcareous microfossils, plus geochemical studies of the oceanic basaltic rocks, together support the two-subduction-zone hypothesis. Intra-oceanic subduction was associated with radiolarite/pelagic carbonate accumulation above Early Jurassic subduction-related oceanic crust. Basal oceanic sediments comprised locally derived volcaniclastic silt/sand, radiolarian ooze, pelagic ooze and hydrothermal Mn-oxide precipitates. Fragments of the oceanic lithologies were accreted to form an intra-oceanic subduction complex. In contrast, terrigenous and arc-derived volcaniclastic gravity flows and pelagic carbonates accumulated along the Eurasian active continental margin in a forearc basin, mainly during Late Cretaceous. Jurassic-Cretaceous terrigenous sediments, mostly turbidites, pass upwards into vocanogenic turbidites and pelagic carbonates, recording an important phase of Late Cretaceous continental margin arc magmatism. The inboard (northerly) slope of the forearc basin repeatedly collapsed during the Late Cretaceous resulting in large-scale debris flow emplacement. Subduction melange was first emplaced over the distal Eurasian margin during the Late Cretaceous owing to thickening of the accretionary prim. The two different subduction zones amalgamated during Late Palaeocene-Early Eocene. During progressive collision the forearc basin overfilled with thickening- and coarsening- upwards gravity deposits, including high-density turbidites and, finally fan-delta conglomerates. During suturing, the forearc basin was thrust southwards over the oceanic-derived accretionary wedge and further disrupted by northwards back thrusting. Final closure of the adjacent Tethyan ocean occurred prior to Late Middle Eocene time, followed by marine transgression and the accumulation of non-marine to shallow-marine sediments, including Nummulitic limestones.

The Influence of Cohesive Sediments on Dune Development

R. Schindler[1,2,*], D. Parsons[2], L. Ye[2], J. Baas[3], A. Manning[1,2,6], J. Malarkey[3], J. Hope[4], D. Paterson[4], R. Aspen[4], S. Bass[1], P. Thorne[5] and D. Lichtman[5]

[1]*School of Marine Science & Engineering, University of Plymouth, UK.*

[2]*Department of Geography, Environment and Earth Science, University of Hull, UK.*

[3]*School of Ocean Sciences, Bangor University, UK.*

[4]*Scottish Oceans Institute, University of St. Andrews, UK.*

[5]*National Oceanographic Centre, Liverpool, UK.*

[6]*Coasts & Estuaries Group, HR Wallingford, UK.*

*Corresponding author: robert.schindler@plymouth.ac.uk

Quantifying and modelling bedform dynamics is key to predicting natural sediment transport at local and regional scales. Such predictions rely strongly on accurate knowledge of relationships between the form and size of bedforms, hydrodynamic forcings, and bed material properties. Predictive tools are still based on highly simplified physical parameters, with assumptions that clastic sediment consists of a biologically inactive single grain size with bedforms that react instantly to changing flow energy.

Our experiments assess the effects of cohesivity by examining development of dunes in sediments of different (a) clay contents and (b) biological cohesivity imparted by *extracellular polymeric substances* (EPS) in a controlled laboratory environment.

Experiments were undertaken at the *Total Environment Simulator* facility at the University of Hull. The active channel was sectioned into a 10 x 2 m area within the tank. A flat sediment bed, with varying proportions of (a) sand:clay or (b) sand:clay:EPS, was subjected to a unidirectional flow for 10 h. Depth-mean velocity was 0.8 m s^{-1} corresponding to the centre of the dune regime for non-cohesive sands. Detailed measurements of the evolving bedforms were taken every 3 min.

Results indicate that physical and biological cohesion inhibits dune formation. Bedforms spanning the ripple-dune transition can occur under flows typical of cohesionless dunes, and their form is dependent on the clay and EPS content. Development curves show that the rate of growth is similarly affected by cohesivity, where high cohesivity can delay the availability of mobile grains and thus bedform generation.

The proportion of clay or EPS within a non-cohesive matrix, as well as the flow forcing, dictates the height, length and development rate of dune bedforms over a set period. We therefore offer a step-change in our understanding of the movement, formation and geometry of bedforms synonymous with coastal and estuarine waters globally. We can conclude that, if the effects of cohesive sediments are not included when they are present, predictive models will be inaccurate and in many cases misleading.

Sedimentological, Ichnological and Paleontological Indicators of Tidal Influence and Brackish Water Conditions in Fluvial Coastal Plain Successions

Michelle N. Shiers[1]*, Nigel P. Mountney[1], David M. Hodgson[2]

[1]*Fluvial Research Group, School of Earth and Environment, University of Leeds*

[2]*Stratigraphy Group, School of Earth and Environment, University of Leeds*

*Corresponding author: ee08ms@leeds.ac.uk

Characterisation of tidally influenced fluvial deposits is problematic due to the inherent complexity of the environment; energy regimes change spatially (upstream to downstream) and temporally (daily, monthly and annually) in response to tidal cycles and seasonal changes in river discharge. Furthermore, no single sedimentary structure is diagnostic of tidal influence; rather an association of sedimentary structures, with paleontological and ichonological salinity indicators, is required to determine likely depositional setting and relative position within the dynamic zone of tidal influence.

Many sedimentary structures routinely used as indicators of tidal influence, such as fine-grained drapes, can form in other environments that are subject to fluctuating energy regimes. Furthermore, trace fossils such as *Arenicolites* that are commonly used to infer tidal influence merely indicate salinity conditions. It is therefore important to adopt a holistic approach that integrates sedimentological, ichnological and architectural element characteristics to identify the range of sub-environments present in tidally influenced fluvial successions to constrain position within the fluvial to tidal transition zone.

The Campanian Neslen Formation (Mesaverde Group, Book Cliffs, Utah) records a transition from a delta-plain to coastal-plain setting, which preserves evidence for fluctuating tidal influence. Laterally continuous outcrops permit tracing of both vertical and lateral changes in sandstone-body architecture and determination of the degree of tidal influence within a 15 km^2 area between Crescent Canyon and Floy Wash where the outcrop style provides excellent three-dimensional constraint on the depositional architecture. Adoption of this multidisciplinary approach has allowed interpretation of the degree of tidal influence within a series of ribbon-like distributary channel bodies as well as laterally accreted channel belts that form extensive sheet-like sand bodies.

Recognition criteria for the degree of tidal modulation in fluvial successions is important from an applied perspective because the interaction of fluvial and tidal processes in both time and space results in complicated styles of stratigraphic heterogeneity that directly influences reservoir behaviour and performance.

Are you picking up what I'm putting down?: Long run-out flows that did not erode the seafloor

C.J. Stevenson*, P.J. Talling, E.J. Sumner, D.G. Masson, M. Frenz and R.B. Wynn

Submarine gravity currents, especially long run-out flows that reach the deep ocean, are exceptionally difficult to monitor in action, hence there is a need to reconstruct how these flows behave from their deposits. This study mapped five individual flow deposits (beds) across the Agadir Basin, offshore NW Africa. This is the only dataset where bed shape, internal distribution of lithofacies, changes in grain size and seafloor gradient, bed volumes, flow thickness and depth of erosion into underlying hemipelagic mud are known for individual beds. Some flows were 30-120m thick. However, flows with the highest fraction of sand were less than 5-14 m thick. Sand was most likely carried in the lower 5-7 m of these flows. Despite being relatively thin, one flow was capable of transporting very large volumes of sediment (~200 km^3) for large distances across very flat seafloor. These observations show that these relatively thin flows could travel quickly enough on very low gradients (0.02º-0.05º) to suspend sand several meters to tens of meters above the sea floor, and maintain those speeds for up to 250 km across the basin. Near uniform hemipelagic mud interval thickness between beds, and coccolith assemblages in the mud caps of beds, suggest that the flows did not erode significantly into the underlying seafloor mud. Simple calculations imply that some flows, especially in the proximal part of the basin, were powerful enough to have eroded hemipelagic mud if it was exposed to the flow. This suggests that the flows were depositional from the moment they arrived at a basin plain location, and deposition shielded the underlying hemipelagic mud from erosion. Reproducing the field observations outlined in this exceptionally detailed field dataset is a challenge for future experimental and numerical models.

Influence of fluid pressure on the diagenesis of Triassic Skagerrak fluvial reservoir sandstones, Central North Sea, UK

Stephan Stricker*, Stuart Jones, Neil Goulthy and Andrew Aplin

Department of Earth Sciences, Durham University, South Road, Durham DH1 3LE, UK.

*Corresponding author: stephan.stricker@durham.ac.uk

Current understanding of porosity preservation in sandstone reservoirs tends to be focused on how diagenetic grain-coats of clay minerals and microquartz can inhibit macro-quartz cementation. Reported anomalous high porosities from various deeply buried hydrocarbon reservoirs (>4000mbsf) are often linked to early diagenetic clay or microquartz grain-coats (Taylor et al., 2010). However, the importance of vertical effective stress (VES) in maintaining high primary porosity to depth is often underestimated.

In most basins deep burial is usually synonymous with low porosity and tight reservoirs. However where pore fluid pressures are high (low VES), the early arrest of compaction can allow preservation of high porosity and permeability to depths normally considered uneconomic in better drained, more permeable basins (e.g. Osborne and Swarbrick, 1997).The development of pore fluid pressure reduces the stress on intergranular and cement-grain contacts and so inhibits pressure dissolution and compaction (Nguyen et al., 2013).

This study focuses on the fluvial sandstones of the Triassic Skagerrak Formation, Central Graben, North Sea and is part of a wider industry research consortium dealing with overpressure called GeoPOP3. The Skagerrak fluvial reservoirs with high overpressures commonly have high porosities, less macro-quartz cement and variable amounts of diagenetic chlorite grain coats. Pore pressures within the Skagerrak Formation can exceed 35MPa at depths of 4000 mbsf where temperatures are above 140°C. Retained primary porosity up to 35% can be found in many of the fluvial channel sandstones.

Early results from on-going research using detailed quantitative petrography, SEM analysis and wireline data sets has identified the key diagenetic phases that has helped to preserve high porosities. Macro-quartz cements and other cementation processes have been inhibited by a combination of factors: presence of early diagenetic clay grain-coats and chlorite cements, the relatively low ambient VES reducing the deleterious effects of grain-contact pressure solution and late stage hydrocarbon migration. This research has important implications for understanding the role of overpressure for porosity preservation and the lesser role played by chlorite grain coatings in High-Pressure High-Temperature reservoirs

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Subsurface classification of fluvio-deltaic sub-environments in the Triassic Mungaroo Formation, Exmouth Plateau, Australia

Jennifer Y. Stuart*, Nigel P. Mountney, William D. McCaffrey

Fluvial Research Group, School of Earth and Environment, University of Leeds, UK.

*Corresponding author: eejs@leeds.ac.uk

Linking sedimentology to seismic facies is essential for the accurate interpretation of subsurface depositional environments, particularly when dealing with fluvial environments characterised by a complex arrangement of sub-seismic-scale depositional elements. This study addresses this challenge by mapping fluvial and fluvio-deltaic deposits of the Triassic Mungaroo Formation, using a high-resolution 3D seismic volume from the Exmouth Plateau of the Northern Carnarvon Basin, supported by lithofacies analysis of core and wireline data. Specific objectives are to: (i) catalogue sub-seismic-scale fluvial to deltaic architectural elements in core and wireline logs; (ii) map the plan-form morphology of seismic-scale fluvio-deltaic elements; (iii) classify key stratigraphic intervals according to their accommodation setting; (iv) match the intervals to likely modern analogues based on their interpreted morphological expression.

Seven sub-seismic-scale architectural elements are identified: primary (high-energy) channel, low-energy channel, proximal crevasse splay, distal crevasse splay, gleysol (swamp), lake, and inter-distributary bay. Flattening the seismic cube has enabled visualization of stratally-aligned slices, within which the various architectural element types can be mapped using attribute analysis to highlight fluvial deposit types. The following seismic element types were identified and mapped in GIS: valley, channel belt, channel margin, floodplain and gleysol (mire). Well-log data confirm that channel-margin elements contain sub-seismic scale sands of probable crevasse-splay and accessory channel origin.

Likely accommodation conditions and depositional sub-environments for three key intervals have been interpreted based on the dimensions and sub-areal proportions of seismic elements, together with wireline, lithofacies and palaeoflow analysis. Apparently higher-accommodation (or wetter) conditions led to the progressive aggradation of multi-lateral channel and valley elements (<7 km width), as well as the establishment of distributary channel networks and widespread gleysol development. Lower-accommodation (or comparatively dry) conditions resulted in accumulation of laterally constrained (<1 km width) channel elements, with associated channel-margin elements. Some low-accommodation intervals are apparently dominated by incised and often overprinting valley elements. The confinement of the fluvial system at this interval within valleys resulted in negligible coarse-grained sedimentation away from the master valley systems.

Sedimentary facies in submarine canyons

E.J. Sumner[1], C.K. Paull[1], R. Gwiazda[1], K. Anderson[1], E. Lundsten[1] and M. McGann[2]

[1]*Monterey Bay Aquarium Research Institute, Moss Landing, California, 95039.*

[2]*USGS, Menlo Park, California, 94025.*

Submarine canyons are the major conduits by which sediment, pollutants and nutrients are transported from the continental shelf out into the deep sea. The sedimentary facies within these canyons are remarkably poorly understood because it has proven difficult to accurately sample these heterogeneous and bathymetrically complex environments using traditional ship-based coring techniques. This study exploits a suite of over 100 precisely located vibracores collected using remotely operated vehicles in ten canyons along the northern Californian margin, enabling better understanding of the facies that exist within submarine canyons, their distribution, and the processes responsible for their formation. The dataset reveals three major facies types within the submarine canyons: extremely poorly sorted, coarse-grained sands and gravels with complex and indistinct internal grading patterns and abundant floating clasts; classical normally graded thin bedded turbidites; and a variety of fine-grained muddy deposits. Not all facies are observed within individual canyons, in particular coarse-grained deposits occur exclusively in canyons where the canyon head cuts up to the modern day beach, whereas finer grained deposits have a more complex distribution that relates to processes of sediment redistribution on the shelf. Pairs of cores collected within 30 meters elevation of one another reveal that the coarse-grained chaotic deposits are restricted to the basal canyon floor, with finer-grained deposits at higher elevations on the canyon walls. The remarkable heterogeneity of the facies within these sediment cores illustrate that distinctive processes operate locally within the canyon. In the authors' experience the canyon floor facies represent an unusual facies rarely observed in ancient outcrops, which potentially results from the poor preservation of ancient coarse-grained canyon deposits in the geological record.

Silliciclastic reservoirs hosted within Large Igneous Provinces: Parameters concerning Genesis and Distribution

R.A.D. Taylor*, A.J. Hartley, D.W. Jolley, M.J.Hole, A.Ebinghaus, J.Millett and A.R. Barker

Department of Geology-Petroleum Geology, University of Aberdeen, Aberdeen, UK.

*Corresponding author: ross.taylor@abdn.ac.uk

Petroleum hosted within volcanic and volcanically associated rocks is becoming of increasing importance to hydrocarbon exploration. Reserves of up to 240 mmbbl oil have been reported by Chevron in Palaocene-Eocene aged fluvio-estuarine sediments, intercalated with lava flows within the Faroe-Shetland basin. It is the purpose of this study to understand the impact on drainage systems and their deposits of high volume, high periodicity eruptions which occur during LIP initiation and what implications that may have for an active petroleum system. The Columbia River Basalt (CRB) Province, NW USA, provides an excellent analogue for the Rosebank development as fluvio-lacustrine deposits (ranging from <1-70m in thickness), are found to be intercalated with thick basalt flows (individual flows up to 100m thick) of the basal Imnaha and Grande Ronde formations (split into four magnetic polarity intervals: GR-R1, GR-N1, GR,R2 and GR-R2) which are commonly found to be regionally correlative across the Columbia basin. The Clearwater embayment is the selected study area and is a sub basin which marks the most easterly extent of the CRB's as they pinch out and abut against basin bounding Mesozoic and Pre Cambrian rocks which are the dominant sediment source for the interbeds.

Two main interbeds are found within the Clearwater embayment, the first lies above the Imnaha formation and below the Buckhorn springs member of the GR-R1 flow group. It ranges in thickness from 0.5m to 21.0m and can be found over a distance of 50km. Pebbly, medium-coarse grained sand is found to fill incised bedrock channels and characterizes the upstream deposits, with sand dominated heterolithics typical of splay type deposits and rhythmically bedded, silt dominated lacustrine deposits characterizing the downstream deposits. The second interbed lies above the Buckhorn Springs flow and below Center Creek flow (both GR-R1). It ranges in thickness from 40-70m and also can be found over a distance of 50km. Sub-basin wide, silt dominated lacustrine sediments form the basal deposits caused by lava-dam formation from continued GR-R1 eruptions. These deposits are overlain by sand dominated heterolithics characteristic of splay type deposits which in turn are overlain by coarse to very coarse grained multi-story, nested channel deposits with individual channel widths ranging from 20m to 150m. Shallow level intrusions of brecciated glassy basalt as well as tabular, sheet-like intrusions of GR-N1 age are common in this interval.

General thickening of interbeds and thinning of volcanic deposits (lava flows, hyaloclastites, pillow lavas etc.) is observed out towards the margins of the lava field which point toward an overall reduced risk during exploration. However localized eruption sites have been found to disseminate fluvial deposits on the margin as well as in the centre of the province, therefore this added risk should be considered when considering exploring in frontier LIP's.

Debrite character and thickness distribution in MTD dominated setting: Middle Reservoir Zone, Britannia Field, North Sea

Riccardo Teloni[1]*, Marco Patacci[1], Peter D.W. Haughton[2], Joris T. Eggenhuisen[3], Robert W.H. Butler[4] and William D. McCaffrey[1]

[1]*University of Leeds, Leeds, UK*

[2]*University College Dublin (UCD), Dublin, Ireland*

[3]*University of Utrecht, Utrecht, The Netherlands*

[4]*University of Aberdeen, Aberdeen, United Kingdom*

*Corresponding author: riccardo.teloni@gmail.com

Mass Transport processes may affect deep water reservoirs by remobilising or removing reservoir, whilst their deposits (MTDs or debrites) may produce topography that influences subsequent turbidite deposition. Debrites may also act as barriers to fluid flow in the subsurface. The highly drilled Aptian deep-water Britannia Field, Outer Witch Ground Graben, North Sea provides a good example of a mass transport-affected reservoir. During deposition of the lower and middle reservoir zones, a number of remobilisation phases interrupted the deposition of broadly tabular deposits; gross thickness variations in succeeding sandstones reflect deposition into the relict topography (both positive relief and evacuated areas) left by the mass failure. Using well data and outcrop analogues, the aim is to study debrite heterogeneity and morphotypes at different scales by investigating the relationship between debrite thickness and internal lithology.

Two main debris flow deposits were recognised in the Middle Reservoir ("Zone 40") of Britannia, named R3 and R4, and their character studied through detailed core logging. Debrite isopach maps, covering an area of 35 km^2, were built based on well correlations using data from 11 cored wells, gamma-ray logs from 30 uncored wells and cuttings. Debrites are made up of a muddy matrix with different proportions of isolated mud and sand clasts and/or floating sand grains. Isopach maps show that debrite thickness varies between 10 and 70m, resulting in an upper irregular morphology. In wells where R3 is locally thicker, it is usually comprises a higher proportion of sand and mud clasts, whilst where it is thinner, clasts are rarer. This relationship also appears to hold for debrites in the Lower Reservoir Section (R1-R2). Observations of ancient mass transport deposits on outcrop show similar relationships on a range of scales, from tens to hundreds of meters and up.

Preliminary observations seem to indicate a relationship between local debrite thickness and lithology. Better understanding of the factors causing upper surface rugosity might help to identify the range of remobilisation deposit morphotypes that collectively form the architecture of MTD dominated deep-water systems. In applied contexts this may improve the accuracy of well correlations.

Flow Structures over Fixed 2D Bedforms in Transient States

C.A. Unsworth[1]*, D.R. Parsons[1], A.J.H. Reesink[1], J.L. Best[2], P.J. Ashworth[3] and R.J. Hardy[4]

[1]*Department of Geography, Environment and Earth Sciences, University of Hull, Hull, HU67RX, UK*

[2]*Departments of Geology, Geography and Geographic Information Science, Mechanical Science and Engineering and VenTe Chow Hydrosystems Laboratory, University of Illinois at Urbana-Champaign, 1301 W. Green St., Urbana, IL, 61801, USA*

[3]*Division of Geography and Geology, School of Environment and Technology, University of Brighton, Brighton, Sussex, BN24GJ, UK*

[4]*Department of Geography, University of Durham, Durham, DH13LE, UK*

*Corresponding author: C.A.Unsworth@2011.hull.ac.uk

Flow processes measured in the laboratory over fixed, 2D or 3D bedforms have mostly been conducted at one flow depth and with bedform dimensions set by scaling laws based upon equilibrium flow conditions. These results thus have limited applicability to many natural situations where bedforms and flow fields are co-evolving at different rates in response to transient conditions, such as changes in flow depth and flow discharge associated with a flood. The research presented herein investigates flow processes over 2D fixed bedforms under a range of non-equilibrium, transient, states in order to quantify the spatio-temporal changes in turbulence associated with steady conditions that are set at non-equilibrium depths and velocities.

Flow field information was obtained via 2D Particle Imaging Velocimetry for a range of flow depths and mean flow velocities, mimicking conditions during the transient evolution of flow and bedforms during a flood wave. Changes in either flow depth or mean flow speed causes substantial migrations in the locations of maximum turbulence generation and dissipation. The flow field downstream of reattachment changes substantially with mean flow speed and flow depth. The turbulent wake zone after flow reattachment extends further downstream over the stoss slope and moves closer towards the bed with increasing mean flow speed. Wake stacking from upstream dunes over the flow separation zone can occur without a change in bedform geometry. These changes will likely drive morphological adjustment on the dune stoss side in response to a change in flow conditions. This flume research helps to describe the links between sediment transport lag, dune morphodynamics, and transient flow dynamics that have not been measured extensively before. The findings help to facilitate an analysis of the implications of variable dune height and flow depth as well as flow speed for flood wave propagation and bedform response.

Tidal to fluvial transition of the Sego Sandstone, Book Cliffs, Utah, USA

Marijn van Cappelle*, Gary J. Hampson and Howard D. Johnson

[1]*Department of Earth Science and Engineering, Imperial College London, Royal School of Mines, Prince Consort Road, London SW7 2BP, UK.*

*Corresponding author: m.van-cappelle12@imperial.ac.uk

Tide-dominated deltas are more poorly understood compared to their fluvial- and wave-dominated counterparts, partly because fluvial-tidal interaction results in more complex depositional processes and less systematic facies trends. Hence, there is still a need to develop more widely applicable facies models of such systems.

In this study, we document the vertical and lateral architecture of offshore, delta front and delta plain deposits in the proximal, tide-dominated deltaic strata of the Sego Sandstone in Utah, USA. Here, the regressive Upper Cretaceous Sego Sandstone is underlain by marine mudstones of the Mancos Shale and overlain by coal-bearing delta plain deposits of the Neslen Formation. The Lower Sego Sandstone contains four coarsening-upward regressive successions bounded by flooding surfaces, which are separated from the Upper Sego Sandstone by a prominent marine mudstone. The lowest sequence in the eastern (palaeoseaward) part of the study area is represented by a typical coarsening-upward regressive succession, comprising offshore mudstones grading upward into lower shoreface deposits with intercalated storm-beds. The second sequence passes gradationally upwards from offshore mudstones to storm-dominated lower shoreface deposits, which are overlain by laterally extensive, inter-channel tidal bar deposits across a low-relief erosion surface. The tidal bar deposits contain cross-bedded sandstones with mud drapes and mud clasts, with intercalated heterolithic lenticular and wavy bedded facies. These deposits are locally overlain by lithologically similar active channel-fill deposits and by abandoned channel-fill mudstones with metres of erosional relief at their bases. The remaining two sequences in the Lower Sego Sandstone consist of a variable intercalation of tidal mouth bars and usually low-relief, erosively-based tidal bar systems. In other cases, higher erosional results in the preservation of thicker bar systems. Tidal bar deposits of the Upper Sego Sandstone pass westwards (palaeolandwards) into tidal flat and delta plain deposits of the Neslen Formation, which comprise coal, carbonaceous shale, mudstones, and inclined heterolithic strata. This study documents the facies characteristics and stratigraphic architecture of a part of the Sego Sandstone and will emphasise the nature of the transition between delta front and delta plain deposits within a tide-dominated deltaic depositional setting.

K-Ar ages dates of authigenic illite in oilfield sandstones – are they reliable?

Mark Wilkinson[1]*, R. Stuart Haszeldine[1] and Anthony E. Fallick[2]

[1]*School of GeoSciences, The University of Edinburgh, Grant Institute, The King's Buildings, West Mains Road. Edinburgh, Scotland EH9 3JW*

[2]*Scottish Universities Environmental Research Centre, East Kilbride, G75 0QF, Scotland, UK*

*Corresponding author: mark.wilkinson@ed.ac.uk

Fibrous illite is one of the very few authigenic phases from typical oilfield sandstones that can yield an absolute (radiometric) age date. Consequently, there are hundreds of such ages published, despite the lengthy and costly process of sample extraction and analysis. It has become dogma that the ages correspond to an 'event' within the host sandstone, most commonly assumed to be hydrocarbon charging though other fluid flow events have been suggested. Almost all analyses have been interpreted as 'events', with no significant post-growth alteration, conveniently making the ages simple to understand.

It has been previously observed that the illite from the UK Northern and Central North Sea has systematically increasing K-content with burial depth. This is unexpected as it is difficult to reconcile with the hypothesis that the illite forms as an event and retains its composition during later burial – what might be expected is a correlation between K-content and the likely depth of initial formation, and this is conspicuously absent. If the composition of the illite is significantly altered after growth, then K-Ar ages would be more difficult to interpret due to either loss of Ar or gain of K. The situation is made more complex by the structure of illite – it is believed that individual fibres only nm thick, as imaged on an SEM, are not single crystals but are composites of so-called 'fundamental particles'. An examination of chemistry, fundamental particle thickness and length / width distribution suggest alteration of illite after initial crystal growth. Whether K-Ar ages of illite might need to be re-interpreted cannot be definitively answered at present; however, burial models involving both crystal nucleation and prolonged growth give a good fit to real data, supporting the hypothesis of post-growth alteration. Even if such growth does occur, there is evidence from studies of similar illite reactions in shales that a high proportion of Ar is retained, so that K-Ar ages are still useful, albeit requiring more interpretation than a simple 'event' age.

Temporal and spatial evolution of a waxing then waning catastrophic density current revealed by chemical mapping

Rebecca Williams[1,2]*, Michael J. Branney[1], and Tiffany L. Barry[1]

[1]*Geology Department, University of Leicester, University Road, Leicester LE1 7RH, UK*

[2]*Current address: Department of Geography, Environment and Earth Sciences, University of Hull, Hull HU6 7RX, UK*

*Corresponding author: Rebecca.williams@hull.ac.uk

Particle-bearing density currents are amongst the most catastrophic phenomenon on Earth. Their rapidly evolving flow dynamics cannot be measured directly, so understanding derives from models and interpretations of deposits. We report the first reconstruction of the temporal and spatial behaviour of a sustained radial pyroclastic density current as it waxed and then waned during its short lifespan.

The ca. 45 ka Green Tuff ignimbrite on the island of Pantelleria (Italy) is a near-circular deposit sheet thought to be the deposit of a single depletive catastrophic density current. It forms a thin veneer (~0.5 km^3) that covers the 83 km^2 island and drapes all topography, including both stoss and lee slopes, thickening from 30 cm to >10 m in paleovalleys. Superb 3D exposure allows exceptional access to both longitudinal and lateral variations from source. It comprises massive lapilli-tuff, with some local diffuse stratification. Clast imbrication and palaeoflow lineations show that the density current flowed radially outward from a central vent.

The deposit shows cryptic gradational compositional variation with height. Using Zr as a chemical tracer, the variations were used to divide the deposit into eight compositional zones that represent time slices during the sustained deposition. Detailed mapping of the chemical variations, revealed a complex cryptic 3D internal architecture that was not apparent in the field. This architecture shows how the sustained current initially was topographically restricted, but that its leading edge gradually advanced in all directions, encroaching upon and then ascending topographic highs. During peak flow the current reached its maximum extent and overtopped all topographic highs. After this, and while the current direction from source was maintained, the current's leading edge gradually retreated sourceward. We interpret the temporal changes in run-out distance as recording temporal variations in the mass flux of the current at source. Such behaviour has been predicted, e.g. by numerical models, but not previously distinguished in a natural deposit. This method and insight have implications for how other density currents (e.g. turbidity currents) evolve in time and space.

Chemostratigraphy and provenance of clays and other non-carbonate minerals in chalks of Campanian age (Upper Cretaceous) from Sussex, southern England.

D. S. Wray[1]* and C. V. Jeans[2]

[1]*School of Science, The University of Greenwich, Pembroke, Chatham Maritime, Kent, ME4 4TB, UK*

[2]*Department of Geography, University of Cambridge, Downing Place, Cambridge, CB2 3EQ, UK*

*Corresponding author: D.wray@greenwich.ac.uk

Mineralogical and geochemical analysis of acid insoluble residues derived from white chalks and marl seams of lower Campanian age from Sussex, UK has been undertaken. All display a broadly similar composition but plots of K_2O/ Al_2O_3 and TiO_2/Al_2O_3 indicate that most marl seams have an acid insoluble residue composition which is slightly different to that of the over- and under-lying white chalk, implying that marl seams are primary sedimentary features not formed through white chalk dissolution. On the basis of a negative Eu anomaly and trace element geochemistry one marl seam, the Old Nore Marl, is considered to be volcanically derived and best classified as a bentonite, it is considered to be the correlative of bentonite M1 of the north German succession.

Poster Abstracts

Carbonate-evaporite cyclicity in the Middle Miocene Fatha Formation of the Mesopotamian Basin, Kurdistan

Heero Ghareeb Abdullah*, Richard Collier, Nigel P. Mountney

School of Earth and Environment, University of Leeds, Leeds LS2 9JT

*Corresponding author: ml11hga@leeds.ac.uk

Five detailed vertical sections of the cyclical Middle Miocene Fatha Formation were measured and studied on the northeast margin of the Mesopotamian Basin in the Kurdistan region, northeast Iraq. The aim was to interpret the relation between carbonate and evaporite units of the formation. Specific objectives were to characterize sea-level changes and to test the general applicability of pre-existing sequence stratigraphic models of carbonate-evaporite cycles. The formation is one of the most extensively outcropping units in Kurdistan. It exhibits multiple stacked depositional cycles which each comprise, from base to top, calcareous mudstones, carbonates and evaporates that overall accumulated in a gently-dipping ramp environment. Two variations in the general style of cyclicity are noted: (i) the presence of a red, primarily claystone clastic unit above the evaporite element, especially in cycles present in the upper part of the formation; (ii) depositional cycles in which the evaporite unit is absent. The carbonate units include shallow-marine deposits rich in benthic foraminifera and these additionally contain coralline red algae (Rhodoliths), Rotalia, Pelecypods, Ostracods, Miliolids, Gastropods, Cephalopods, Bryozoans, and Brachiopods. The carbonate units are characterized by a range of sedimentary structures including planar-parallel lamination, wavy lamination, trough cross-bedding, ripple marks, load casts and flame structures, flute casts and bioturbation. Based on field observations and thin section characterization of the gypsum dominated evaporite units, three main sabkha evaporite textures are recorded: chicken wire, enterolithic and laminated evaporites and these are associated with greenish calcareous mudstones. Where present, red claystones interpreted to be of terrestrial origin were deposited above the sabkha unit.

Overall, the succession records a series of preserved sequences that are expressed as depositional cycles. Each cycle records a generally shallowing-upward, regressive package. A calcareous mudstone unit of probable offshore marine origin occurs above each flooding surface, the lower part of which may represent a transgressive system tract. This unit passes upwards into shoaling-up carbonates, deposited in a highstand system tract. Sabkha evaporitic units may have been deposited during late highstands and the red clastic units within falling stage and/or lowstand system tracts.

Styles of interaction between fluvial and aeolian systems along the Skeleton Coast, northern Namib Desert

Mahmud Alkathery* and Nigel P. Mountney

Fluvial & Eolian Research Group, School of Earth and Environment, University of Leeds, UK.

*Corresponding author: eemaal@leeds.ac.uk

A 6 to 22 km-wide, north-northwest trending dune field of the Skeleton Coast, northern Namibia forms a 2000 km^2 region of active aeolian construction and accumulation, within which bed-forms of various morphological types are present and attain heights up to 50 m. This coastal erg has developed because the regional climate is strongly influenced by the northward-flowing Benguela Current and its associated cold-water upwelling system offshore Namibia, which has resulted in anomalously low humidity and strong southerly, coast-parallel winds. The erg acts as a major obstacle to a series of fluvial systems that drain west-southwest-ward towards the coast. These fluvial systems are subject to ephemeral or intermittent flow but undergo marked changes in discharge in response to seasonal monsoonal rainfall events in their continental-interior catchments. Evidence for interaction between competing fluvial versus aeolian processes is present where the rivers intersect the erg. Significant and regionally extensive flood events have been recorded in 1934, 1982, 1984, 1988, 1995, 1997 and 2000. Analysis of a time-series of aerial photographs and satellite imagery reveals the history of a series of fluvial floods into the aeolian dune-field system.

During major flood events, rapid rises to peak discharge result in channel breaching and widespread flooding into adjacent interdune depressions at the erg margin. Standing flood waters within interdunes rapidly evaporate and infiltrate to deposits thin beds of cohesive mud that tend to resist aeolian reworking and accumulate progressively over multiple floods. The northern rivers that pass into the main part of the erg system (e.g. Hoanib and Hoarusib) are fed by large catchments and are characterised by relatively high-discharges. Along the eastern erg margin, episodic damming of fluvial systems results in the development of an extensive flood reservoir basin ponded behind a dune wall. Once the water-level within the basin attains a critical level it floods into the erg interior via so-called dune break-through at points where dune cols are overtopped. This process guides the northern rivers into the dune-field centre. The southern rivers (e.g. Koigab, Uniab and Hunkab) interact with the erg system in a different manner; they are characterized by short-timescale rises to peak discharge in the aftermath of floods emanating from catchments of restricted area. Discharge is rarely sufficiently high to result in dune break-through; instead, transient lake systems develop in the immediate aftermath of floods.

Styles of fluvial and aeolian system interaction in desert-margin settings: examples from modern systems

Mohammed A. Al-Masrahy* and Nigel P. Mountney

School of Earth & Environment, University of Leeds, LS2 9JT, England, UK

*Corresponding author: eemaa@leeds.ac.uk

Desert dune fields are not necessarily continuously covered with active aeolian bedforms; most additionally include other morphological bodies of aeolian-derived or aeolian-related sediment deposits including interdunes, sand sheets, soils, lacustrine systems, and perennial, intermittent or ephemeral fluvial systems developed between active aeolian dunes, especially at dune-field margins. A diverse range of styles of system interaction gives rise to considerable complexity in terms of geomorphology, sedimentology and preserved stratigraphy. This study proposes a generalised framework with which to account for the diverse styles of interaction known to exist between aeolian and fluvial depositional systems. Specific objectives of this work are to: (i) illustrate the variety of styles of aeolian fluvial interaction present in modern dune-field-margin settings; (ii) demonstrate the significance of aeolian dune type and orientation relative to fluvial-system orientation in determining the style of fluvial incursion into dune fields; (iii) demonstrate the role played by open versus closed interdune corridors in controlling the distance and style of penetration of fluvial systems into dune fields.

Ten distinct styles of fluvial-aeolian interaction are recognised: fluvial incursions aligned parallel to trend of linear chains of aeolian dune forms; fluvial incursions oriented perpendicular trend of aeolian dunes; bifurcation of fluvial systems around the noses of aeolian dunes; through-going fluvial channel networks that cross entire aeolian dune fields; flooding of dune fields due to regionally elevated water-table levels associated with fluvial floods; fluvial incursions emanating from a single point source into dune fields; incursions emanating from multiple sheet sources; cessation of the encroachment of entire aeolian dune fields by fluvial systems; termination of fluvial channel networks into playas within aeolian dune fields; long-lived versus short-lived styles of fluvial incursion.

The physical boundaries between the geomorphic systems are dynamic over short temporal timescales. Across desert margins where fluvial and aeolian systems interact, the location of assemblages of surface landforms may change gradationally or abruptly. The varied range of temporal and spatial scales over which aeolian-fluvial processes interact means that simple generalised models for the classification of styles of interaction must be applied with caution when interpreting ancient preserved successions, especially those known only from the subsurface.

Sedimentological process record of a sediment bypass zone in a base-of-slope setting: an outcrop study from the Laingsburg depocentre, Karoo Basin

Hannah L. Brooks[1]*, Rufus L. Brunt[2], David M. Hodgson[1], Stephen S. Flint[2]

[1]*Stratigraphy group, School of Earth and Environment, University of Leeds, Leeds LS2 9JT, UK*

[2]*Stratigraphy group, School of Earth, Atmospheric and Environmental Sciences, The University of Manchester, Manchester, M13 9PL.*

*Corresponding author: eehlb@leeds.ac.uk

Locations of long-term sediment bypass zones in ancient deep water settings are rarely identified at outcrop, meaning that their sedimentological characteristics are poorly constrained. Mapping and correlation of Units E and F of the Permian Fort Brown Formation, Karoo Basin, South Africa has led to the identification of wide and long (kms) tracts on the lower submarine slope with limited sand deposition updip of >50m thick sand-prone lobe complexes.

Here, the sedimentology and stratigraphic evolution of the sediment bypass zones are investigated in detail through correlation of closely spaced measured sections (40-800m spacing) in Units E and F. Unit E is a composite sequence consisting in the study area of two lowstand systems tracts, E2 and E3, each overlain by a combined transgressive/highstand systems tract of regional mudstone. Primarily, E2 consists of thin turbidite beds interpreted as lobe fringe or distal levee deposits. In the study area, E3 thins from11 m to <1m thick and comprises rippled thin-bedded sandstones that are interpreted as levee deposits. An E3-aged surface is identified that cuts down through E2 and around 10m of underlying mudstone over an outcrop distance of around 300m. The depth of incision is estimated to be 20-30m. The E3 erosional surface is overlain with <2 m of clast supported mudstone clast conglomerates and fine-grained sandstones containing floating mudstone clasts. This material is overlain by siltstone interbedded with low angle ripple laminated very fine-grained sandstone beds, and then filled in by the E-F mudstone unit. Farther down dip (east) E2 is present beneath E3 as the incision surface climbs up. Down dip of the incision surface E3 thickens to 40m over an outcrop distance of 75 m and comprises meter scale sandstones capped with thin argillaceous divisions that are interpreted as hybrid beds.

This outcrop study permits the analysis of sub-seismic scale characteristics of a sediment bypass zone. This will provide a deeper understanding of their nature and evolution including the development of recognition criteria for identification of sediment bypass zones in subsurface datasets.

Stratigraphic architectural complexity in fluvial overbank successions: examples from the Cretaceous Mesa Verde Group, Utah, USA

Catherine Burns*, Nigel P. Mountney and Luca Colombera

Fluvial Research Group, School of Earth and Environment, University of Leeds, LS2 9JT, UK

*Corresponding author: ee09ceb@leeds.ac.uk

Field-based studies of fluvial successions tend to be biased towards the analysis of sand-prone channel complexes that form laterally extensive and continuous outcrops. Considerably less attention has been afforded to the sedimentology and architectural analysis of finer-grained fluvial overbank successions despite such units constituting a volumetrically significant part of many fluvial successions. In many studies, extra-channel deposits are assigned to a single architectural element: the overbank. Despite this, considerable stratigraphic complexity is known to be present in such deposits, yet the origin of this complexity remains poorly understood and architectural relationships between elements in extra-channel settings are poorly constrained.

This work aims to develop a generalised depositional model to account for the complexity present in a series of fluvial overbank successions. This is achieved through a quantitative geometrical analysis of the bodies present in overbank successions of three fluvial formations in the Cretaceous Mesa Verde Group exposed in eastern Utah: the Castlegate Sandstone, the Neslen and the Farrer formations. Specific objectives are (i) to present criteria for the recognition of architectural element types present in overbank successions; (ii) to document the common facies associations and geometries of each of these elements; (iii) to show geometric relationships between neighbouring elements; (iv) to account for the origin of the various elements in terms of likely sub-environments.

Successions from all three formations have been recognised to be composed of a series of discrete architectural elements, each with their own facies association and geometry. Based on these defining characteristics and their interrelationships with one another, crevasse splay, levee, crevasse channel, floodbasin-lake delta and mire elements are all recognised. Architectural elements composed of finer-grained silt- and claystone facies encapsulate elements composed of fine sandstone, and a series of complex relationships record the spatial and temporal development of the various overbank sub-environments. Floodplain drainage state (inferred from colour variations that reflect changes in the preservation of organic matter) varies through the stratigraphy and appears to be controlled by element distribution.

The results permit appreciation of various architectural styles associated with overbank successions deposited in the same basin but in different settings and under variable boundary conditions.

The north-eastern Porcupine Basin: The provenance and petrography of Early Tertiary sands.

S. Evans-Young[1]*, P.M. Shannon[1], S. Tyrrell[1,2], D. Naylor[3] and J.S. Daly[1]

[1]*UCD School of Geological Sciences, University College Dublin, Belfield, Dublin 4, Ireland*

[2]*Now at: Earth and Ocean Sciences, National University Ireland Galway, Ireland*

[3]*Petrel Resources plc, 162 Clontarf Road, Dublin 3, Ireland*

*Corresponding author: sophie.evans-young@ucdconnect.ie

The Porcupine Basin, a north-south oriented deep-water basin offshore west of Ireland, is one of the largest sedimentary basins in the North Atlantic. A thick succession of Cretaceous and Tertiary sediments was deposited in a general thermal subsidence setting, interrupted by periods of minor rifting and regional epeirogenic movements and overprinted by eustatic sea-level changes. Petroleum exploration wells in the north of the basin have encountered reservoir quality sands of Cretaceous and Tertiary age. However, little is known about the composition of these sands or their provenance. Determining the sand source(s) will allow more accurate re-construction of palaeogeography and ancient drainage system scales and pathways for both the Cretaceous and the Tertiary.

Standard optical petrography, scanning electron microscopy and laser ablation multi-collector inductively coupled plasma mass spectrometry (LA-MC-ICPMS) were used to constrain the source of the Eocene Marine Sands. Analysis of 14 samples from four wells in the east central part of the Porcupine Basin has focussed on the Eocene marine and deltaic sands (lower to middle Eocene respectively). The sampled sandstones are medium- to fine-grained, sub-arkosic in composition and occasionally contain high proportions of lithic fragments. In addition, the Eocene marine sands are also often calcareous and contain abundant nummulites.

To constrain their likely provenance, the Pb isotopic composition of detrital K-feldspar was determined using LA-MC-ICPMS. The $^{206}Pb/^{204}Pb$ and $^{207}Pb/^{204}Pb$ data reveal two distinct populations that vary through the stratigraphy and appear in all four sampled wells (35/8-1, 35/13-1, 35/18-1 and 36/16-1). Population 1 is recorded in both Eocene marine and deltaic sands and appears to correspond to the late Caledonian Galway granites, onshore Ireland. However, these data also overlap with data from granite plutons in Donegal (onshore NW Ireland SE Ireland and Scotland cannot entirely be ruled out as a source. The second Pb population, found only in Eocene marine sand samples, cannot at present be linked to any characterised source, suggesting that these grains are derived from an as yet unidentified crystalline basement in the Irish offshore shelf area.

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Determining the palaeodrainage of the Nile river from a provenance study of the Nile delta cone sediments

Laura Fielding[1]*, Yani Najman[1], Ian Millar[2], Peter Butterworth[3], Ben Kneller[4] and Eduardo Garzanti[5]

[1]*Lancaster University*

[2]*NERC Isotope Geoscience Laboratory*

[3]*BP Egypt*

[4]*University of Aberdeen*

[5]*University of Milan-Bicocca*

*Corresponding author: l.fielding@lancaster.ac.uk

This study documents the palaeodrainage history of the Nile River, in particular the time of its transition from a small locally sourced drainage network to the initiation of an extensive catchment. Today, the Nile drains as far south as Lake Victoria, with the White Nile draining largely cratonic rocks of Archean to Proterozoic age and the Blue Nile draining Cenozoic Ethiopian Continental Flood Basalts and Neoproterozoic basement. However, the timing of catchment expansion to the river's current extent is highly debated. Two end member models are:

A) The Blue Nile did not connect with the lower Nile until the Late Messinian, and the White Nile not until 0.5 Ma. In this model, the pre-Messinian Nile delta sediments are locally derived from the Red Sea Hills (RSH) (Issawi and McCauley 1992).
B) The Blue Nile has been connected to the lower Nile since the Oligocene (Burke and Wells 1989).

Onshore fieldwork characterised each possible source area (Ethiopian flood basalts, Archean craton, and Neoproterozoic basement and Phanerozoic cover sequences of the RSH) using petrography, geochemistry and isotope studies. Tertiary-aged Nile delta sediments provide a unique archive of the river's palaeodrainage history, which were analysed from conventional core from exploration and appraisal wells in order to identify the occurrence (if any) of these sources in the delta geological record.

Heavy mineral, petrographic, U/Pb rutile and Lu/Hf zircon analyses indicate Blue Nile and/or RSH input to the Nile delta since at least the Oligocene with very little input from the White Nile. Sr and Nd whole-rock analyses of mud samples allow discrimination between the Blue Nile and RSH sources and may, subject to further analyses, confirm Blue Nile input to the delta since the Oligocene. U-Pb zircon analyses reveal the presence of 20-30 Ma zircons in both the modern river sediments from the Ethiopian Highlands and the Nile Delta core from the early Miocene to present day indicating a connection between the lower Nile and the Blue Nile since at least the early Miocene.

Sedimentology and depositional architecture of the shallow-marine to non-marine transition, Karoo Basin, South Africa

Luz E. Gomis-Cartesio[1]*, Miquel Poyatos-Moré[1], Stephen Flint[1], David Hodgson[2] and Rufus Brunt[1]

[1]*Stratigraphy Group, School of Earth, Atmospheric and Environmental Sciences, University of Manchester, UK.*

[2]*Stratigraphy Group, School of Earth and Environment, University of Leeds, UK.*

*Corresponding author: luz.gomiscartesio@postgrad.manchester.ac.uk

Stratigraphic successions that pass from shelf-delta to fluvial settings record the interplay of sediment flux from the hinterland and marine processes that redistribute sediment. This record can provide evidence for the palaeo-climatic and relative sea level history and physiological character of basin margins.

In the Permian Karoo Basin succession, the shallow-marine Waterford Fm. is overlain by the non-marine Abrahamskraal Fm. of the Beaufort Group. This temperate latitude shelf-deltaic to fluvial section is more than 200 metres thick with regional scale depositional dip and strike continuous outcrop control. Initial work based on sedimentary logging, facies analysis, mapping of key surfaces and photointerpretation of outcrops is being used to document stacking patterns of shallow-marine parasequences and to establish the depositional architecture and a preliminary sequence stratigraphic framework.

In the Grootfontein-Ouberg Pass area, thin-bedded prodelta facies stack in 5 to15 m-thick weakly progradational to aggradational cycles, with transitional bases and sharper tops, interpreted as wave-reworked distal mouth bar deposits. Above the uppermost thick aggradational unit, an abrupt facies change is marked by the onset of soft sediment deformation at the base of a 10-20 m thick *in-situ* deformed sandstone unit. Massive sandstones show channelized and amalgamated geometries, with palaeocurrents strike-oriented to the overall northward progradation direction. A candidate sequence boundary is interpreted at the erosive base of this package. An overlying aggradational succession with slightly coarsening and thickening-upward cycles contain HCS sandstones, with a progressive increase of coarser, dirty sands with trough cross-bedding and some accretionary features, occasionally alternating with tabular beds with sharp bases and tops.

This succession is interpreted to record system progradation across a low-gradient shelf, recording the change from a mixed fluvial/wave influenced shoreline to a non-coal bearing delta plain. Although this change has been mapped lithostratigraphically in the past, observations indicate that the relationship is transitional and non-isochronous, with an interfingering of delta plain and coastal plain deposits. This well-exposed example of the evolution of a mixed influence shoreline system with an overall aggradational to weakly progradational stacking pattern, in a moderate to high-latitude palaeo-climatic setting, contrasts with other published basin margin outcrop studies and provides a reservoir analogue with no coals or red beds.

The use of climatic cyclicity as a correlation method between proximal and distal deposits of arid continental basins

Amy Gough* and Stuart M. Clarke

Basin Dynamics Research Group, School of Geography, Geology and The Environment, Keele University, Staffordshire, ST5 5BG.

*Corresponding author: a.gough@keele.ac.uk

Proximal alluvial fan environments are long-lived throughout the evolution of continental basins, and the resultant deposits are often perceived as a homogeneous clastic wedge. Segregated archetypal arid continental deposits are identifiable in the distal basin. These environments evolve with allocyclic climatic alterations, and the resultant deposits cycle between decent reservoir and baffle lithologies. The interaction between the alluvial fan base and these distal environments can have a marked effect on fluid flow through the basin. The zone of interaction leads to; 1) pathways that connect isolated distal reservoirs 2) thief zones away from potential reservoirs 3) a bypass to charge these potential reservoirs or 4) an introduction of additional seals into the system.

The alluvial fan sediments of the Permian-aged Cutler Group are well exposed in the Paradox Basin, Utah, western U.S.A. These sediments grade from alluvial fan deposits in the proximal basin, through to typical continental environments of the distal extent of the basin. The zone of interaction between the proximal and distal parts of the Paradox Basin is informally referred to as the Arkosic Facies.

Longer-term allocyclic changes in climate are identifiable throughout the deposits of the distal portion of the Paradox Basin. The signature of these allocyclic changes are overridden by shorter-term autocyclic climatic alterations through both the alluvial fan deposits of the undivided Cutler Group and the Arkosic Facies. The observed sedimentary response of these depositional systems to climatic change can be used to interpret cyclicity through the proximal deposits, and can therefore lead to the identification of correlatable horizons throughout the proximal Cutler Group. Recognising the climate-driven horizons can aid in the prediction and correlation of subsurface stratigraphy at a basin scale to understand potential flow pathways throughout the alluvial fan and the Arkosic Facies.

This work will present evidence of climatic cyclicity in the proximal basin, and attempt to correlate this cyclicity through the zone of interaction to the distal extent of the basin. Initial results indicate that climatic cycles can be correlated to some degree, and therefore fluid flow pathways and barriers may be identifiable within the proximal sediments of continental basins.

Palaeogeographic reconstruction of an ephemeral fluvial system, Karoo basin

Alice R. Gulliford[1]*, Stephen S. Flint[1] and David M. Hodgson[2]

[1]*Stratigraphy Group, School of Earth, Atmospheric and Environmental Sciences, University of Manchester, Manchester M13 9PL. UK.*

[2]*Stratigraphy Group, School of Earth and Environment, University of Leeds, Leeds LS2 9JT. UK.*

*Corresponding author: alice.gulliford@postgrad.manchester.ac.uk

Multi-kilometre scale exposures of the lower Beaufort Group have allowed stacking pattern analysis of a hierarchy of channel belt complexes, channel-belts and constituent storeys to interpret spatial and temporal changes in amalgamation and palaeogeography. Sand bodies are dominated by flat and low angle lamination interpreted as upper phase plane bedding. The uniformly fine sandstone grain size enhances the development of upper phase plane bedding because with increasing current velocity, bedforms transform from current ripples into upper phase plane bedding without producing cross bedding. Storey boundaries are characterised by intra-formational conglomerate, characteristic of high energy, erosive rivers capable of transporting gravel sized sediment, suggesting that the system was grain-size limited. The presence of mudstone rip-up clasts, upper flow regime structures and wavy laminated sandstone indicate a highly variable, flashy discharge. Intercalated green to red mudstones and moderate maturity palaeosols are interpreted to be floodplain deposits, associated with this flashy to ephemeral fluvial system.

Within a 120 m thick succession at Klipkraal, individual channel-belt deposits are 4 m to 12 m thick, with a true width of 200 m to 1200 m. Two to three channel-belts are commonly amalgamated and show sub-vertical or lateral offset stacking. These amalgamated channel-belts are arranged into nine channel-belt complexes, interpreted to form four complex sets. Grain size and thickness of complexes increase up section from 8 m to 20 m. No incised valley fills are observed and individual complex sets do not exceed 35 m thick, due to localised incision and amalgamation. Within the overbank deposits, moderate maturity palaeosols dominate in the lower stratigraphy and these soils become more poorly-drained up section.

This upward change in architecture may be attributed to continued progradation of a distributive fluvial system; however the increased wetness observed does not readily fit the distributive fluvial system model. Despite no evidence of regional degradational surfaces or incised valleys, an alternative interpretation for the observed stratigraphic trends may be a series of splay systems, truncated by a sequence boundary and overlying unrelated low accommodation deposits.

Counter-flow ripples: formation, preservation and value for interpreting flow conditions

Chris M. Herbert* and Jan Alexander

School of Environmental Sciences, University of East Anglia, Norwich, NR4 7TJ, UK.

*Corresponding author: Christopher.Herbert@uea.ac.uk

Counter-flow ripples, which are also known as reverse-flow, counter-current, regressive and back-flow ripples are created in the lee of dunes, unit bars or other obstacles where the flow separation eddy is strong enough to rework sand (Boersma *et al*., 1968; Ashworth *et al*., 2000; Reesink & Bridge, 2007). Where these ripples form with dunes, both are controlled by the same flow conditions, whereas with unit bars the ripples may form in the same conditions as the bar or in subsequent flow conditions. The geometry of ripple-cross lamination together with the associated cross stratification gives more information about the depositional environment than the two structures considered separately.

This research aims to improve understanding of the formation conditions, the variation in geometry of resulting structures and interactions between the ripples and lee face avalanches.

Experiments have been undertaken to observe counter-flow ripple development and sedimentary structure formation in a range of flow conditions in a 10 m recirculating flume with unit bars. Unit bar height, mean water depth and discharge were varied in successive runs. The runs were observed and photographed through the glass side walls and flow velocities were measured with acoustic Doppler velocimeters.

In runs with flow over unit bars, the formation and behaviour of ripples varied with discharge (and velocity above the bar brink). At low mean flow velocity counter-flow ripples formed within the trough and slowly migrated toward the bar lee face. Grain flows buried and preserved the ripples. At higher mean velocities counter flow ripples were more transient features which formed and were destroyed within a few seconds. They formed within the trough and on the lee slope, interacting with the grain flows on that face. Evidence of these transient bedforms was less obvious in the deposits.

This poster will illustrate and discuss the range of counter flow ripple behaviours and sedimentary structures formed in different conditions.

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Impact of vegetation patch shape on mean flow and turbulence characteristics

David N. Jordan[1]*, Robert E. Thomas[1], Gareth M. Keevil[2] and Daniel R. Parsons[1]

[1]*Department of Geography, Environment and Earth Science, University of Hull, Hull, UK.*

[2]*School of Earth & Environment, University of Leeds, Leeds, UK.*

*Corresponding author: D.N.Jordan@2010.hull.ac.uk

This study presents field measurements of the streamwise, lateral and vertical variations of velocities and turbulence statistics monitored around and over patches of the in-stream macrophyte *Ranunculus penicillatus* ssp. *pseudofluitans* (Syme). Patch planform configuration was modified to investigate the influence of: 1. patch configuration on the flow field and 2. bidirectional feedbacks between patch configuration and the fluid. Three cases were tested: A. an unmodified patch; B. the same patch trimmed to a V-shape; and C. the same patch trimmed to form a triangular shape. Velocities were sampled for 180 s at 100 Hz using a profiling ADV deployed with a 0.5 m lateral and longitudinal spacing in a 2 × 2 m grid.

In case A, classical s-shaped streamwise velocity ($\bar{u}$) profiles were observed. Above the canopy $\bar{u}$ exhibited a logarithmic form, increasing to a maximum of ~0.4 m s^{-1}. Reynolds stresses ($-\overline{u'w'}$) exhibited a maximum at the top of the canopy (2.8 × 10^{-3} m^2s^{-2}). Below the canopy, penetration by turbulent structures was minimal and velocities were near zero. These conditions helped to intensify silt deposition on leaves and stems near to the bed and also directly on the bed within patches. Although planform reconfiguration had no detectable influence on the distribution of velocities upstream of the patch, noticeable changes occurred around its edges. For case B, $\bar{v}$- and $\bar{w}$-velocity profiles were asymmetrical, suggesting the existence of counter-rotating secondary flow cells around the two downstream extending limbs. Quadrant analysis indicated an increase in the proportion of both outward ($+u',+w'$) and inward ($-u',-w'$) interactions. For case C, free stream conditions extended towards the bed and the velocity gradient was steeper immediately above the canopy. Strong downwelling was observed at the downstream edge of the patch, rapidly scouring silt that had deposited previously.

These results will inform future investigations on what controls the growth and spatial distribution of vegetation. Identification of the hydrodynamic link between patch growth and the flow field and the resulting patterns of erosion and deposition may aid interpretation of the influence of paleo-vegetation on fluid and sediment dynamics in ancient fluvial systems.

Flow transformation in distal lobe environments: Skoorsteenberg Fm., Tanqua Karoo

Ian A. Kane[1*] and Anna S. M. Pontén[2]

[1]*Explore, Statoil Research Centre, Bergen, Norway*

[2]*Frontier Developments, Statoil Research Centre, Trondheim, Norway*

*Corresponding author: iank@statoil.com

In distal and marginal lobe fringe environments of fine-grained deep-marine fans, sandstones often have a muddy character different to that predicted by classical turbidite models. These muddy sandstones can be significant in terms of the volumetric reservoir proportion they represent and therefore their distribution has implications for reservoir potential, prediction and modelling. These beds often have characteristics suggestive of deposition from flows with mixed or composite turbulent-transitional-laminar rheology. Physical models have demonstrated that increasing the mud content of turbulent flows can drive a transition from turbulent to transient turbulent-laminar behaviour; additionally it has been demonstrated that increasing the mud content beyond a critical level can rapidly increase the erosive capability of a flow. Using petrological data, field- and core-based sedimentological logs, and photo-mosaics from the Skoorsteenberg Fm., we document that turbidite beds can pass downdip and laterally into muddy sandstone beds which become vertically stratified into discrete bed divisions. We conclude that flows which were initially turbulent underwent collapse as they left axes of flow focus beyond the channel-lobe transition, undergoing hydraulic jumps which initiated the erosion and entrainment of mud and sand. Increasing flow concentration resulted in damping of turbulence and drove a rheological transition from turbulent to transitional behaviour. The outcrop data are used to validate previous experimental work and a theoretical model developed for the Palaeogene Wilcox Fm., and to develop a predictive model for the distribution of transitional flow deposits in deep marine fans.

Revising the base-Quaternary of the central North Sea using 3D seismic mapping

Rachel Lamb[1]*, Mads Huuse[1], Margaret Stewart[2] and Simon H. Brocklehurst[1]

[1]*School of Earth, Atmospheric and Environmental Sciences, University of Manchester*

[2]*British Geological Society, Murchison House, Edinburgh*

*Corresponding author: rachel.lamb@manchester.ac.uk

The identification and mapping of the base-Quaternary boundary in the central parts of the North Sea is problematic due to the changing transition between Pliocene and Pleistocene deltaic deposits from uncomformable in the south to a conformable further north (Sejrup et al 1991; Gatliff et al 1994). The best estimates of the transition use seismic reflection data to identify a 'crenulated reflector' (Buckley 2012), or rely on correlating sparse biostratigraphy (Cameron et al 1987). Recent integration of biostratigraphy, pollen analysis, paleomagnetism and amino acid analysis in the Dutch and Danish sectors (Rasmussen et al 2005; Kuhlmann et al 2006) allows greater confidence in the correlation to a regional 3D seismic dataset and show that the base-Quaternary can be mapped across the entire basin.

The base-Quaternary has been mapped using the PGS MegaSurvey dataset from wells in the Danish Sector along the initially unconformable horizon and down the delta front into the more conformable basin giving a high degree of confidence in the horizon pick. The mapped horizon is presented here alongside the difference between this new interpretation and the traditional base-Quaternary (Buckley 2012). The new base-Quaternary surface reaches a depth of 1248 ms TWT with an elongate basin shape. The difference between the new base-Quaternary and the traditional base-Quaternary reaches a maximum of over 600 ms TWT in the south-west with over 300 ms TWT at the Josephine well (56°36.11'N, 2°27.09'E) in the centre of the basin.

The new base-Quaternary boundary has been investigated using seismic attributes across the horizon and in time slice to interpret the environments of the earliest Quaternary prior to the onset of glaciation. Analysis of aligned elongate furrows over 10km long, 100m wide and 100m deep suggest a deep marine environment with persistent strong NW-SE bottom currents in the deepest parts of the basin, while pockmarks are formed by the escape of shallow gas on the sides of a small delta in the eastern part of the basin. The advancement of large deltas from both the north and south into the basin make up the majority of the deposition of sediment into the basin.

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Outcrop analogues contributing towards the understanding of facies distribution and sedimentary architecture in Upper Cretaceous carbonate platforms (South Central Pyrenees, Spain)

Jonathan J. Lavi*, Cathy Hollis and Stefan Schröder

School of Earth, Atmospheric and Environmental Science, University of Manchester, Oxford Road, Manchester M13 9PL, UK

*Corresponding author: jonathan.lavi@postgrad.manchester.ac.uk

With the maturation of many giant carbonate reservoirs, it is becoming necessary to improve how reservoir heterogeneity is captured in subsurface reservoir models. Such models are commonly used for quality control and assessment of reservoir risk as well as planning and reservoir management. Outcrop analogue studies allow complex facies distribution and geometries on carbonate platforms, which are highly influenced by varying palaeoenvironmental conditions and often occur on sub-seismic scale, to be investigated. Such quantitative data on carbonate platform architectures from outcrops provide important information that can be used to optimise existing and future subsurface models.

The Upper Cretaceous carbonate platforms exposed in the Tremp region (South-Central Pyrenees, Spain) allow excellent study of their facies distribution and internal geometries. High resolution sedimentological data was gathered from several outcrops of both the Congost Formation (upper Turonian to mid-Coniacian) and the Sant Corneli Formation (Santonian), using a combination of field-based methods supported by petrographical analysis. These data give insight into platform geometries and allow interpretation of the palaeoenvironmental conditions, depositional and diagenetic processes.

Two alternating types of carbonate platforms can be distinguished within both studied formations; platforms dominated by coral- and rudist-buildups alternate with platforms featuring grainstone-dominated clinoforms. Field observations show that the coral- and rudist-buildups can appear in varying forms and geometries, generally either as isolated mounds of coral-rudist-buildups, or as laterally extensive biostromes constructed of slender hippuritid rudist colonies. The grainstone-dominated platforms are characterised by internal sigmoidal bedding and coarsening-up cycles, and frequently onlap onto the underlying strata, as characteristic of a prograding carbonate platform. The alternation between these platform types is interpreted to have resulted from changes in the dominant depositional processes through variations in palaeoenvironmental conditions that followed fluctuations of relative sea levels and eustatic as well as tectonic processes.

The results of this study provide a framework for further quantitative studies of the internal architecture, facies distribution and the resulting petrophysical variations within the Upper Cretaceous carbonate platforms of the area. Upscaling and forward modelling of such platforms will contribute towards reservoir assessment and development, and can be implemented where sub-seismic heterogeneities may affect reservoir quality.

Multi-scale 3D imaging of minerals, pores and organic matter in the Eagle Ford Shale Formation, Texas: implications for oil shale reservoir characterisation

Lin, Ma[1]*, Kevin G. Taylor[1], Peter D. Lee[2], Linda Campbell[1] and Kate Dobson[2]

[1]*School of Earth, Atmospheric, and Environmental Sciences, University of Manchester, M13 9WJ Manchester, UK*

[2]*School of Materials, University of Manchester, M13 9WJ Manchester, UK*

*Corresponding author: lin.ma@manchester.ac.uk

Shale gas and shale oil reservoirs are playing an increasingly important role in oil and gas production globally. The fine-grained nature of mudstones makes the characterisation of their reservoir properties challenging. X-ray coaxial tomography (X-ray CT) combined with scanning electron microscopy (SEM) can be used to resolve this problem and give us images of the microstructures in three dimensions (3D).

The Eagle Ford Shale Formation is of Turonian-Cenomanian, Late Cretaceous in age and present in South Texas, USA. The mineral composition is dominated by calcite, clay minerals and quartz. Thin section observations show foraminifera-rich and organic-rich laminations and foraminifera fragments are always filled with calcite and kaolinite. The pore types in the samples of Eagle Ford Shale studied can be divided into six main types: i) inter-particle pores, ii) intra-particle pores, iii) pores within organic matters, iv) pores within pyrite framboids, v) pores within or besides fossil fragments and vi) fracture porosity.

Multiscale 3D images were acquired using SEM and X-ray CT methods, with resolutions of 10µm (macro scale), 1µm (micro scale), 50 nm (low-resolution nano scale) and 7nm (high-resolution nano scale). In macro scale imaging, minerals more than 1mm diameter (e.g. calcite and clay minerals) are resolved; in micro scale imaging, organic matter particles in irregular shapes can be seen in addition to calcites and clay minerals. At the low-resolution nano scale, some inter-particle pores of calcite and matrix, pores within the organic matter and some fine fractures of several microns diameter or less appears to be resolved. Finally, most of organic matter pores, intraparticle pores and pyrite framboid pores can be clearly resolved only in the high-resolution nano scale slices.

It shows that many pores are connected at the nano scale although they are always in irregular shapes, especially intra-particle pores. Pores within pyrite framboids and organic matters are often isolated but some microchannels and microfractures may connect them at the nano scale. Through these 3D images, more details of shale reservoirs can be shown directly, such as the geometry and connectivity of pores organic matter, which is important in the exploration and exploitation of shale reservoirs.

Factors controlling floc settling velocity within San Francisco Bay, USA and comparisons with parameterization approaches

Andrew J. Manning [1,2,3]* and David H. Schoellhamer [4,5]

[1]*HR Wallingford, Howbery Park, Wallingford, Oxfordshire, OX10 8BA, UK*

[2]*Department of Geography, Environment and Earth Sciences, University of Hull, Kingston Upon Hull, Humberside, HU6 7RX, UK*

[3]*School of Marine Science and Engineering, Plymouth University, Drake Circus, Plymouth, Devon, PL4 8AA, UK*

[4]*U.S. Geological Survey, Placer Hall, 6000 J Street, Sacramento, CA 95819, USA*

[5]*Department of Civil & Environmental Engineering, University of California, Davis, USA*

*Corresponding author: andymanning@yahoo.com

Much of the sediment within San Francisco Bay (SFB) is cohesive and can therefore act as transport mechanism for pollutants which adsorb to clay minerals. Furthermore, muddy sediment can flocculate when resuspended; this significantly alters their transport characteristics, which poses a serious complication to the modelling of sediment pathways. The study aim was to determine factors that affect floc settling velocity along a longitudinal transect in an estuary. The INSSEV-LF video system measured floc diameters and settling velocities at 30 stations along a 147 km transect the length of San Francisco Bay, at a distance of 0.7 m above the estuary bed. The data was collected in conjunction with spatial water quality monitoring of SFB. It was anticipated that the floc information will provide some insight into the mobility of the suspended sediment within SFB and how this may affect water quality issues. Floc sizes (D) ranged from 22 μm to 639 μm and settling velocities (Ws) spanned 0.04 mm·s^{-1} to 15.8 mm·s^{-1} during the transect. Nearbed turbulent shear stresses throughout the transect duration were within the 0.2-0.5 Pa range which typically stimulates flocculation growth. The individual D-Ws-floc density data suggest the suspended sediments in SFB were composed of both muddy cohesive sediment and mixed sediments flocs. The macroflocs and microflocs (demarcation at 160 μm) sub-populations demonstrated parameterised settling velocities which spanned nearly double the range of the sample mean settling velocities (Ws_{mean}). The macroflocs tended to dominate the suspended mass (up to 77% of the ambient suspended solids concentration; SSC) from San Pablo Bay through to Carquinez Strait (the vicinity of the turbidity maximum zone). Microfloc mass was particularly significant (typically 60-100% of the SSC) in the northern section of South Bay and most of Central Bay. During slack tide, larger and faster settling flocs deposited, accounting for most of the longitudinal variability. The best single predictor of settling velocity was water flow velocity 39 minutes prior to sampling, not SSC or salinity. Resuspension and settling lags are likely responsible for the lagged response of settling velocity to water velocity. Parameterisation comparisons with the data are made.

Diagenetic modifications in the Eagle Ford Formation

Richard.T. McAllister*, Kevin.G. Taylor and Cathy. Hollis

University of Manchester, UK

*Corresponding author: richard.mcallister@manchester.ac.uk

The Upper Cretaceous Eagle Ford Fmn in southern Texas is a carbonate rich, organic marl currently being targeted for hydrocarbons (gas & oil) and produced through hydraulic fracture stimulation. The Eagle Ford Fmn is a sedimentological and mineralological complex formation, having been deposited in a range of depositional environments and subjected to intense diagenetic alteration.

This research focuses on a particular unit of the Eagle Ford Fmn known as Facies B. Facies B is predominantly an organic rich (5-10 TOC%) marl with HI values between 500-800$_{mgHC/gm\ OC}$, making it an excellent source rock. In addition, Facies B contains moderate amounts of carbonate (30-50% calcite) making it an ideal self-sourced reservoir which responds well to hydraulic fracturing. However within Facies B there are concretions (packstones and limestones), which can hinder the propagation of fractures. These concretions are laterally variable in outcrop and in core. Some are major beds up to 50cm thick and are continuous throughout outcrops. The bulk of these beds however are much thinner, 10-20cm thick and are only 1-2m long. These 'nodular' concretions are thought to be compositionally the same as the marls but cemented.

Petrographic analysis shows the variation in composition between the marls, cemented marls and packstone-limestone beds. The organic marls experienced early calcite precipitation, and this is limited to the replacement of foraminifera's and coccolith fragments. Calcite precipitation within the nodular concretions is more extensive and invasive. The nodular concretions occur in two phases. The nucleus is Fe-rich and Mg poor whilst the outer section of the concretion is the opposite. Localised diagenetic processes derived from early microbial activity, and abrupt changes in pore water chemistry, is interpreted to be the cause of the nodular concretions within the organic marls. Inorganic C and O isotope analysis indicates similar sea surface temperature (SST) and depositional environments for the organic marls and nodular concretions, suggesting the nodule concretions are purely diagenetic. ^{16}O & ^{18}O indicate differing SSTs for the packstone-limestone beds. Sequence stratigraphic processes are the most likely cause of packstone-limestone beds within the Eagle Ford Fmn.

A geophysical investigation of relative sea level changes in Cemlyn Bay, North Wales.

Rhys McCarthy*

School of Ocean Sciences, Bangor University, Menai Bridge, Anglesey, LL59 5AB, UK.

*Corresponding author: rwmccarthy@live.co.uk

This study, submitted as an MSc thesis, investigated in detail the relative sea level changes within Cemlyn Bay, North Wales. A geophysical survey consisting of a 'boomer' sub-bottom profiler and side scan sonar was adopted in order to understand and map the general stratigraphy and to relate to the sea surface features.

High resolution data of the shallow sub-surface coupled with seismic stratigraphy techniques have identified a total of 14 sediment horizons; 10 of the horizons were established as sea level transgression within Cemlyn Bay. Two horizons are eroded surfaces, where the lower of the two shows a rise in relative sea level from 20.98 m below ODN (Ordnance Datum Newlyn). This sea level rise was briefly interrupted by a regression in sea level of 14.00 m below ODN

Additionally, a sediment core of intercalated marine and terrestrial sediments collected from the intertidal zone reveals two peat layers at depths of 3.89 m below ODN and 4.33 m below ODN; the former peat layer correlated with the uppermost sub-surface horizon identified from one of the seismic profiles.

The survey seeks to explore the potential of Cemlyn Bay for the creation of sea level index points. Evaluation of the sedimentary horizons within Cemlyn Bay and the identification of peat layers in the intertidal zone indicate that this is a suitable location for the creation of sea level index points

Ultimately a geological model of the evolution of Cemlyn Bay was created based upon interpreted horizons from the seismic profiles. The geological model explains in simple terms the sequential evolution of Cemlyn Bay. The timing of relative sea level changes will need to be constrained in future study in order to fully explain the geological evolution of the bay area.

Root traces and plant-soil interactions of two Middle Devonian trees, New York State

Jennifer Morris[1]*, David Beerling[1], William Stein[2], Chris Berry[3], John Marshall[4], Charles Wellman[1], Jonathan Leake[1]

[1]*Sheffield University*

[2]*Binghamton University*

[3]*Cardiff University*

[4]*Southampton University*

**Corresponding author:* j.l.morris@sheffield.ac.uk

Outcrops of Middle Devonian (Givetian) strata at a quarry near Cairo, New York State provide a unique opportunity to study *in situ* roots of a mixed Devonian forest. In particular, the depth and morphology of rooting structures and an assessment of the nature and degree of plant-soil interactions can be obtained from detailed sedimentological and geochemical studies of the palaeosols in which the roots occur.

The rooting structures are preserved as moulds, with numerous occurrences across a well-exposed palaeosol horizon, capped in places by a siltstone rich in fish fragments. The palaeosol surface was expertly mapped by Stein and Berry, who identified the two main root types as likely belonging to archaeopteridalean progymnosperms and cladoxylopsid pseudosporochaleans.

Eighteen cores, up to 3m in depth, were drilled through the horizon. All cores penetrated through a series of stacked red palaeo-Vertisols, which likely developed in well-drained environments. The uppermost palaeosol is well developed, 1.6m thick, with numerous bifurcating drab-haloed root traces. The nature and dimensions of the two root types will be presented, as well as geochemical data on the elemental distribution through the soil profile and across individual roots as a measure of pedogenic and weathering processes and plant-soil interactions.

Equatorial sea surface seasonality in the Mississippian (Early Carboniferous) derived from brachiopod shell calcite

L.S.P. Nolan[1]*, M.J. Leng[1,2], S.J. Davies[1], L. Angiolini[3], V. Banks[2], F. Jadoul[3] and M.H. Stephenson[2]

[1]*Department of Geology, University of Leicester, Leicester, LE1 7RH.*

[2]*British Geological Survey, Nottingham, NG12 5GG, UK.*

[3]*Dipartimento Scienze della Terra A. Desio Via Mangiagalli 34, 20133 Milano, Italy.*

*Corresponding author: ln82@le.ac.uk

Brachiopod calcite offers enormous potential in being able to provide information on the seasonality of deep time sea surface temperatures (SST). This is because the calcite shell secondary layer can record primary seawater composition (Parkinson et al., 2005) and episodic growth (Angiolini et al, 2012) produces high-resolution archives for isotope profiling.

The main aim of this research is to derive temperatures for palaeoequatorial Mississippian seawater seasonality through sclerochronology and isotope profiling of fossil shells from the Derbyshire carbonate platform, UK. Little is currently known about seasonal temperature variations in the Carboniferous and interannual (seasonal) information is vital so that tie points can be placed within General Circulation Models (GCMs) for wider estimates of SST seasonality. Preliminary data from one well preserved shell of a species of *Gigantoproductus* indicates SST seasonality of ~ 5-6 ºC (over a 20 year period) (Angiolini et al., 2012), this is 1-2ºC greater than the seasonal temperature variation at the present day equator in both the Pacific and Atlantic. Other shells show variation of up to 14 ºC which suggests that diagenesis, undetected by preservation screening, has likely occurred.

Many shells from deep time are clearly altered but there are some data (Angiolini et al., 2012) that suggest 'vestigial signals' of seasonality within the brachiopod calcite maybe preserved. Some investigations of vestigial signals will be presented along with the best method screening protocol for brachiopod calcite.

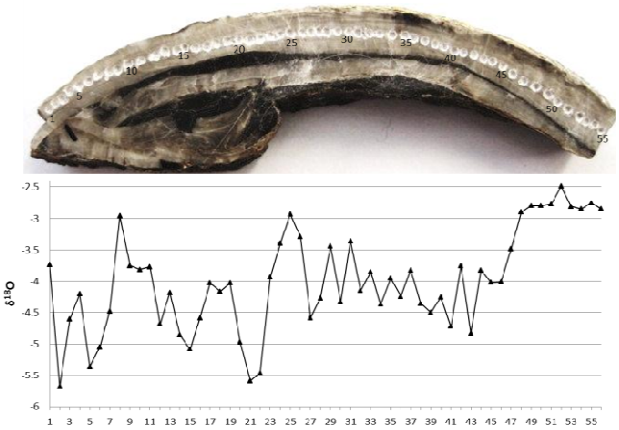

Figure 1. *Gigantoproductid* shell sectioned longitudinally and drilled at millimetre increments across growth lines. Numbers overlaying drill holes correspond to the sample number and their $\delta^{18}O$ value on the graph below.

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Deepwater sandstone fairways and their interaction with substrate: analogues from the Numidian turbidites (Miocene) of Sicily

Patrícia Pinter[1]*, Adrian Hartley[1], Rob Butler[1] and Rosanna Maniscalco[2]

[1]*University of Aberdeen, Aberdeen, United Kingdom*

[2]*University of Catania, Sicily, Italy*

*Corresponding author: ppinter@abdn.ac.uk

Deepwater quartz sandstones derived from mature cratons form reservoirs in many hydrocarbon provinces. The Numidian “flysch” is a clean quartz sand turbidite system derived from the African craton and deposited across its northern continental margin into the foredeep system of the ancestral Apennine orogen. The regional extent of these sands is well-established with the critical outcrops preserved within the Maghrebian-Apennine thrust belt of Sicily and southern Italy. The project consists in mapping the intra-Numidian stratigraphy in relationship to the underlying stratigraphy, to constrain local and regional basin architecture. Two areas were studied up to now – Mt. Salici and Pollina, Sicily – where key stratigraphic sections were logged and palaeocurrent data collected to establish facies schemes for the sandstones. Observations at outcrop and petrographic analysis are used to describe the facies. Modal analysis demonstrates that the Numidian sandstones are quartz-arenite type derived from craton interior. Four facies associations have been identified in these two areas: massive sandstones; conglomerates; interbedded mudstone–sandstone association; and mudstone facies association. Slide-slump units are present in more mud-rich associations. Samples for biostratigraphy (foraminifera and microfossils) were collected mainly from top and base of sandstones to establish chronostratigraphic context and correlation between the sections. Panoramic views were traced to follow lateral continuity and geometry of the beds. Palaeocurrent data support flow from SW (considering 100^{o} clockwise rotation of Sicily).

New records of the Cotham Marble microbialite and implications for lithostratigraphy, palaeogeography and depositional environment of the Rhaetian aged Lilstock Formation

Robert. J. Raine[1]*, Jonathan D. Radley[2] and Sam Roberson[1]

[1]*Geological Survey of Northern Ireland, Belfast, BT9 5BF*

[2]*School of Geography, Earth and Environmental Sciences, University of Birmingham, Edgbaston, Birmingham, B15 2TT.*

*Corresponding author: rob.raine@detini.gov.uk

During the Rhaetian, shallow seas covered much of southern Britain, with a large basin between landmasses' covering Wales, Cornwall, the Pennines and London. There is evidence that this basin experienced lagoonal sedimentation towards the top of the Penarth Group (Cotham Member of the Lilstock Formation). The 1.5–12 m thick Cotham Member represents deposition within this lagoon and towards the top contains a microbialite known as the Cotham Marble or 'Landscape Stone'. New records of this distinctive bed show that the dendritic texture described were in fact, columnar branching stromatolites, which in the southwest of England suffered from synsedimentary destruction of lamination. Other examples of the bed are better classed as thrombolites (clotted texture) and lack the laminated parts typical of other examples. This led previous workers to ignore the thrombolite bed and its identification as the Cotham Marble went unnoticed. New records from Gloucestershire, Worcestershire and Warwickshire suggest that a single shallow lagoon existed on a much larger scale than previously suggested. Geographic thickness variation from outcrop and boreholes suggest that the Cotham Member thickens to the east and that there were no major basinal structures active at the time. Short-lived uplift of the Bristol Channel Basin area during deposition of the middle Cotham Member may have acted to restrict the basin and caused fresh water conditions to become dominant. Below this point marine fauna is sporadically found within the member in Somerset and South Wales. Later, subsidence in the SW and uplift across the Worcester Basin and East Midlands Shelf resulted in a reversed thickness pattern for the overlying Langport Member and heralded increased marine influx into the lagoon. The branching stromatolites formed through boring of the microbial mat, resulting in individual high points, which promoted columnar growth. The boring appears to reflect two periods of change in the environment of deposition of the lagoon (marine inundation?). The thrombolite beds resulted from continuous deposition under these conditions and there is evidence of deeper water, suggesting a possible channel inlet. Mapping these thrombolites suggests a NE–SW trending control, possibly highlighting orientation of a channel.

Hypsometry and geology of drainage basins: toward understanding the long term landscape evolution of southern South Africa

J. Richardson[1]*, D.M. Hodgson[1], A. Lang[2] and A. Wilson[3]

[1]*Department of Earth and Environment, University of Leeds, UK*

[2]*Department of Geography, University of Liverpool, UK*

[3]**Chemostrat** *Ltd., Unit 1, Ravenscroft Court, Buttington Cross Enterprise Park, Welshpool, Powys, U.K. SY21 8SL*

*Corresponding author: eejcr@leeds.ac.uk

The geomorphology of South Africa has focused on debate surrounding the origin of the Great Escarpment; however the evolution of river systems across southern South Africa has not been assessed in detail. The switch from incision to deposition, the volume of sediment removed and the drivers of antecedence remain key unknowns, which have important implications for source-to-sink concepts in passive margin settings. A regional hypsometric analysis was undertaken to decipher the evolution of the landscape (with river systems possibly developing since the breakup of Gondwana, during the Cretaceous). SRTM (90m resolution) was used in ArcGIS with catchments extracted using the hydrology toolbox. A range of catchment sizes were extracted from: small coastal draining catchments, the Cape Fold Belt, the Great Escarpment face, and the Great Escarpment top. Hypsometric integral values were then calculated (values ranging from 0.66 – 0.13) and compared to catchment properties such as area, circularity, dissection and relief. Results indicate that the hypsometric integral is not sensitive to catchment dimensions (R^2 <0.17), therefore, factors such as lithology may be important. In order to assess this, hypsometric curves were compared to the relative distribution of lithologies at each height bin. Initial results indicate that the dominance of lithology and geological structure vary throughout the catchments studied, with some catchments dominantly affected by internal processes such as stream capture. Curves were grouped into 'type' catchments, with striking variations seen even between neighbouring catchments. The implication of this is that to decipher landscape evolution smaller units need to be considered. This data was ground-truthed, using geomorphic mapping and lithological resistance characterisation. In addition, samples were collected for chronometric techniques to assess the age of the landscape and the rates of erosion experienced, and ultimately make a linkage to the offshore depositional record.

mLogger: a free mineral logger for mineralogical modal analyses

Sam Roberson* and Rob Raine

British Geological Survey, Belfast, BT9 5BF, United Kingdom

*Corresponding author: samrob@bgs.ac.uk

A basic, free and easy to use mineral logger has been created in Microsoft Excel, using Visual Basic macros, with the purpose to make it freely available to all. Whilst it does not have the capability of purchased mineral counting systems it can be easily adapted to the specific list of minerals for which a particular study aims to focus on. mLog can be used to conduct a point count for a user defined sample size. The counter accesses a pre-defined mineral list and will stop when the desired sample size is reached. As counting progresses, both the number of counts and the percentage value are recorded and these can be exported automatically to a new worksheet at the end of each analysis. mLog can be downloaded free from:

http://sites.google.com/site/samrobersononline/resources.

Modelling complete particle-size distributions from operator estimates of particle-size

Sam Roberson[1]* and Gert Jan Weltje[2]

[1]*British Geological Survey, Colby House, Stranmillis Court, Belfast, BT9 5BF, United Kingdom*

[2]*Applied Geotechnology, Civil Engineering and Geosciences, Delft University of Technology, Stevinweg 1, 2628 CN, The Netherlands*

*Corresponding author: samrob@bgs.ac.uk

Estimates of particle-size made by operators in the field and laboratory represent a vast and relatively untapped data archive. The wide spatial distribution of particle-size estimates makes them ideal for constructing geological models and soil maps. This study uses a large data set from the Netherlands (n = 4837) containing both operator estimates of particle size and complete particle-size distributions measured by laser granulometry. This study introduces a logit-based constrained-cubic-spline (CCS) algorithm to interpolate complete particle-size distributions from operator estimates. The CCS model is compared to four other models: (i) a linear interpolation; (ii) a log-hyperbolic interpolation; (iii) an empirical logistic function; and (iv) an empirical *arctan* function. Operator estimates were found to be both inaccurate and imprecise; only 14% of samples were successfully classified using the Dutch classification scheme for fine sediment. Operator estimates of sediment particle-size encompass the same range of values as particle-size distributions measured by laser analysis. However, the distributions measured by laser analysis show that most of the sand percentage values lie between zero and one, so the majority of the variability in the data is lost because operator estimates are made to the nearest 1% at best, and more frequently to the nearest 5%. A method for constructing complete particle-size distributions from operator estimates of sediment texture using a *logit* constrained cubit spline (CCS) interpolation algorithm is presented. This model and four other previously published methods are compared to establish the best approach to modelling particle-size distributions. The *logit*-CCS model is the most accurate method, although both *logit*-linear and log-linear interpolation models provide reasonable alternatives. Models based on empirical distribution functions are less accurate than interpolation algorithms for modelling particle-size distributions in sandy sediments. Interpolation-based models represent a more practical approach to modelling distributions, because they can be adaptable to use as much data as available. Complete particle-size distributions modelled from operator estimates using the CCS algorithm are approximately six times less accurate than their equivalent distributions measured by laser analysis. Modelled distributions are limited by input data accuracy, rather than the specific interpolation algorithm used, which in comparison has very little influence.

Sedimentary architecture of point-bar deposits in fluvial and tidally-influenced successions: examples from the Cretaceous Mesa Verde Group, Utah, USA

Catherine Russell*, Luca Colombera and Nigel P. Mountney

Fluvial Research Group, School of Earth and Environment, University of Leeds, UK

*Corresponding author: eecer@leeds.ac.uk

Fluvial point-bar elements representing the preserved remnants of meandering rivers are recognised widely in the ancient rock record. However, the mechanisms by which such features accumulate and the controls on their internal stratigraphic architecture remain relatively poorly constrained. A preliminary sedimentological study has been carried out with the aim of developing a series of facies and sequence stratigraphic models with which to predict the expected internal facies and stratigraphic architecture, both within individual fluvial point-bar elements and between neighbouring elements. This has been achieved through analysis of a series of meandering fluvial and tidally-influenced point-bar elements in the Cretaceous Castlegate Sandstone and Neslen Formation of the Mesa Verde Group (Utah, USA).

Studied point-bar elements (each 5-12 m thick) internally comprise packages of strata composed of sandstone and silty-sandstone, many delineated by mud-lined inclined surfaces that dip at shallow or modest angles (<12 degrees) in the direction of point-bar propagation. Within these bodies, packages of either clean sandstone or so-called inclined heterolithic strata exhibit complex internal architectures. The geometries of these bodies has been carefully characterized by detailing the relationships between bounding surfaces of varying orders, which separate discrete packages, and palaeocurrent data: results document complex and spatially variable directions of bar growth that demonstrate a history of bend tightening and bar translation throughout individual episodes of point-bar development. The studied examples include point-bar bodies forming the fill of both single-storey and complex multi-lateral channel elements.

The style of lateral and vertical stacking of neighbouring point-bar elements and their relationship to neighbouring elements, such as abandoned channels, is dictated by a number of autogenic (intrinsic) factors including the scale, morphology, nature of migratory behaviour and frequency of avulsion of the original fluvial channel. Additionally, patterns of stacking of point-bar elements are apparently controlled by both autogenic and allogenic (extrinsic) factors, including overall progradation of the fluvial system over time, potential changes in climate regime and changes in rate of accommodation creation. Several studied point-bar elements exhibit evidence for modification by marine and tidal processes (e.g. mud drapes, mud-clast breccia, ichnofacies indicative of brackish water conditions). However, direct evidence for tidal reversal of the current is scarce: tidal processes appear to exert an influence on the style of sedimentation but the preserved signature of this influence is cryptic and has yet to be fully understood.

Early Carboniferous marginal marine palaeoenvironments preserve important vertebrate fauna in the Northumberland Basin

Janet Sherwin[1]*, Sarah J. Davies[1] and Tim Smithson[2]

[1]*Department of Geology, University of Leicester, Leicester, LE1 7RH*

[2]*University Museum of Zoology, Downing Street, Cambridge CB2 3EJ*

*Corresponding author: jes48@le.ac.uk

This study is a contribution to the TW:eed Project (Tetrapod World: early evolution and diversification), a major research programme investigating the rebuilding of Carboniferous ecosystems following a mass extinction at the end of the Devonian. The tetrapod (first four-limbed vertebrates) and fish fossils that are revolutionising our understanding of this key phase in the evolution of life are found in Early Carboniferous successions exposed across the Borders region of Scotland and England.

The Ballagan Formation represents deposition on extensive low-relief vegetated coastal-alluvial plains surrounding uplands. To date, there has been no sedimentological analysis of the layers preserving vertebrate fossils. The processes that deposit and preserve fragments are unknown and there is no detailed understanding of the depositional environment.

In Coquetdale, Northumberland, much of the fauna has been recovered from fine-grained layers between or just overlying cementstone units characteristic of the Ballagan Formation. The earliest Carboniferous bradyodont shark teeth and one of the largest known actinopterygian (fish) jaws from either the Devonian or Early Carboniferous are preserved at this location (together with rhizodont scales and eurypterid material).

The cementstones (10-50cm thick) are predominantly matrix-supported microconglomerates with sub-millimetre to millimetre-sized sedimentary clasts and bone fragments alongside abundant shell debris in a siltstone matrix and with a pervasive dolomitic cement. There are examples of intense bioturbation and laminated intervals towards bed tops. Although roots are observed in the succession, they are rare in the cementstones. Aspects of the fauna indicate a marginal marine influence. The cementstones at this location represent deposition following transgressions. The microconglomerates were deposited in standing bodies of water and, in some cases as the water shallowed, microbial mats trapped fine-grained sediment in laminae.

The cementstones are overlain by coarsening upward successions (metre to 2 metre thickness) from dark-grey siltstones to fine to medium-grained wave-rippled sandstones with roots. These successions represent the gradual fill of shallow-water bays where vertebrates are preserved by rapid deposition. This succession represents a more marginal marine setting than the Ballagan Formation succession studied in the Tweed Basin, but vertebrate fossils are preserved in microconglomerates in both basins.

Dynamic Humber – Using Cellular-Automata to Model an Estuarine Environment

C.J. Skinner* and T. Coulthard

Department of Geography, Environment and Earth Sciences, University of Hull

*Corresponding author: c.skinner@hull.ac.uk

Dynamic Humber is a research project developed at the University of Hull through the Centre of Adaptive Science and Sustainability (CASS), and supported through the Higher Education Innovation Fund. The project brings together researchers from a variety of disciplines to investigate the impacts of environmental change on the long-term physical, social and economic state of the Humber estuary and the East Coast margin, through three main strands – Morphodynamics, Numerical Modelling and Socioeconomic.

The objective of the Numerical Modelling strand is to enhance the CAESAR-Lisflood model to incorporate tidal inputs, with the purpose of modelling the long-term (100year) evolution of the Humber Estuary - the use of a Cellular-Automata landscape evolution model on an actual estuarine environment is both a novel and challenging development. The latest iteration of the CAESAR-Lisflood included a tidal stage mode and this has been successfully calibrated and validated for the Humber Estuary, reproducing the recorded tidal heights and timings along the length of the estuary for a sustained period of time.

Ongoing, the model is being further developed to allow for the representation of sediment dynamics, including fluxes of suspended sediments in and out of the mouth of the estuary, and the modelling of how these are likely to influence the morphology and tidal flows. From this the system's dynamic response to various environmental factors (rising sea levels, increased sediment yields, storm surges, tsunami, human development) can assessed and fed back into the other two strands of the project.

Finally, Dynamic Humber has the stated aim of being a stakeholder led project and as such the model will be open to further development, and application, as is required and requested by the projects partners.

Controls on Fluvial and Tidal Sandbody Architecture from the Miocene Uncastillo Formation, Spain, the Eocene Green River Formation, Utah, and the Jurassic Lajas Formation, Argentina

Kristine Smaadal[1]; Katrine Karlsen[1]; Øystein Spinnangr[1]; John Howell[2]

[1]*University of Bergen, Bergen, Norway.*

[2]*University of Aberdeen, UK*

Sandbody architecture is a key control on hydrocarbon reservoir performance. The sandbody architecture is controlled by the type of depositional system and the rate of accommodation creation. The purpose of this study is to compare sandbodies from three depositional systems (two fluvial and one tidal) in order to document the range of geometries which exist. Data were collected from Virtual Outcrop Models generated by Lidar scanning and are integrated with traditional sedimentary logs collected in the field.

The first area is located near Huesca, Northern Spain and contains the Uncastillo Formation. It is a part of the Huesca fluvial distributary system that was deposited in the endorheic Ebro Basin during the Miocene. In the second area in Eastern Utah, fluvial and deltaic sandbodies are studied in the fluvial/lacustrine Green River Formation. It was deposited in an arid climate in the Eocene in an internally draining basin formed during the Laramide orogeny. The third dataset is from the Jurassic Lajas Formation which crops out in the Neuquen Basin, Argentina. This 600 m thick succession comprises tidal delta deposits laid down in a fault- defined embayment.

Sandbody dimensions were measured from the virtual outcrops and show an integral link between barform and channel body geometry which is unique to each system. Results form the basis for a series of stochastic reservoir models that can be used to investigate the impact of sandbody geometry on connectivity and production.

Reconstruction of channel and barform architecture in a fluvio-deltaic succession: understanding the significance of complex three-dimensional sedimentary architecture

Roman Soltan* and Nigel P. Mountney

Fluvial Research Group, School of Earth and Environment, University of Leeds, Leeds, LS2 9JT, UK

*Corresponding author: ee07r2s@leeds.ac.uk

Complex three-dimensional tors and pinnacles that expose the Bashkirian Lower Brimham Grit succession at Brimham Rocks (North Yorkshire, England) have been the subject of high-resolution architectural analysis, which has enabled detailed lateral and vertical examination of genetically-related lithofacies assemblages. Combined lithofacies, architectural-element and palaeocurrent analyses reveal 3D relationships between depositional bodies, interpretation of which have enabled the development of a comprehensive depositional model for this upper delta plain fluvial succession and have facilitated the reconstruction of the palaeoenvironment to a level of detail that has rarely been attempted previously. Detailed architectural panels form the basis of a semi-quantitative technique for recording the variety and complexity of the sedimentary lithofacies present, their association within recognisable architectural elements and, thus, the inferred spatio-temporal relationship of neighbouring elements. Fluvial channel elements bounded by erosional surfaces are defined by a hierarchy of sets and cosets of sandstone facies with subtly varying compositions and textures. Sub-metre, crudely-parallel bedded, gravel- and pebble-grade conglomerate sets record deposition from tractional loads migrating as gravel sheets. Cosets of both trough and planar-tabular cross-bedded facies represent several types of laterally- and downstream-accreting macroforms (bars) for which specific interpretations are supported by complex and highly variable, yet predictable, patterns of palaeocurrent indicators and bounding surfaces. Smaller-scale, simple, cross-bedded sets represent the migration of isolated dunes within channels. The three-dimensional nature of the outcrop has enabled the detailed sedimentology and bed-set architecture to be mapped at a local scale, thereby facilitating the comprehensive reconstruction of relationships between internal facies associations and their parent architectural elements such that the spatial and temporal evolution of a series of downstream- and laterally-accreting macroforms can be related to fluvial processes of sedimentation. Overall, the succession represents the preserved product of an upper delta plain system traversed by a migratory fluvial braid-belt system, forming a poorly-confined network of fluvial channels that evolved between major sandy barforms.

Raman spectroscopy as a method of heavy mineral identification

Tom Stone[1]*, David Wray[1], Bruce Alexander[1], Tim Morgan[2] and John Martin[2]

[1]*University of Greenwich, Kent, UK*

[2]*Chemostrat Ltd, Welshpool, UK*

*Corresponding author: st55@gre.ac.uk

Raman spectroscopy is an effective tool for accurately identifying heavy mineral grains. The Raman spectrometer measures the energy shift of monochromatic light that is scattered from an incident mineral, and produces a spectrum that corresponds primarily to the chemistry and structure of the mineral. Comparison of spectra to a self-built database of known minerals makes it possible to quickly differentiate between different minerals including polymorphs and opaque grains.

Raman spectroscopy can complement traditional optical identification methods as it can accurately distinguish between minerals that may be problematic to differentiate optically, such as colourless zircon and titanite. Raman spectroscopy can also go beyond the capabilities of optical methods as it can differentiate between opaque and turbid grains that cannot be identified optically. The small analytical spot size allows for accurate characterisation of grains down to ~10µm, expanding the capabilities of heavy mineral analysis to include mudrocks. As the spectrum produced is partially controlled by the chemical composition of a mineral, semi-quantitative interpretations of variety within single mineral groups can be made.

A comparison of Raman spectroscopy to QXRD, SEM-EDS and optical heavy mineral analysis from Permian-Carboniferous sediments in the southern North Sea produces similar heavy mineral abundance data and suggests that these techniques can complement each other to produce heavy mineral data at a greater resolution than was previously viable for large-scale studies.

Key stratal surfaces traced over 30km from shoreface sandstone to distal mud-rich siltstones; paving the way for predicting sedimentary architecture in shale gas reservoirs.

Tracey V. Vaitekaitis[1]*, Kevin G. Taylor[1] and Simon A.J. Pattison[2]

[1]*The University of Manchester, M13 9PL, Manchester, UK.*

[2]*Brandon University, R7A 6A9, Brandon, Canada*

*Corresponding author: tracey.vaitekaitis@postgrad.manchester.ac.uk

The expansion of the shale gas industry means more interest is being directed toward understanding processes in, and depositional features of, mudstones. Previously extensively studied shoreface sandstones were correlated, via continuous outcrop, into distal lower shoreface and offshore siltstones and mudstones with the aim of establishing the distal extent of the expression of shoreface cycles. Both outcrop (mega- scale) and sample to thin section (micro-scale) features are studied

The most up-dip part of the succession studied (Tusher Canyon) is interpreted to contain four parasequences, all but the youngest containing more than one internal coarsening upward package. Mud-rich siltstones and very fine sandstones form the bases of these packages, which coarsen up to fine sandstones that are often well cemented, in an overall succession totaling 43.5 metres. 13.5 km downdip (SE) from the palaeo-shoreline a correlatable succession of over 40 metres thickness is found at Horse Canyon. The pattern of successions seen here is similar to those at Tusher Canyon, and cemented sandstones form at the boundaries between successions containing grey to buff mud-rich siltstones.

At Floy Canyon, a further 4km down-dip, the pattern is repeated with subtle bands of colour and hard, cemented beds reflecting similar numbers and thickness of successions as those seen up-dip. Repeated logging was carried out around Crescent Canyon, around 4 miles basinward of Floy Canyon. Here the package finally begins to thin significantly, and subtle colour bands become less obvious. Major cycle tops are visible at the surface of the outcrop while further notable layers are exposed by digging.

To date, we can say that stacked packages tens of metres thick can be confidently traced down-dip from the shoreface for at least 20 kilometres. We interpret these to be possible parasequences and parasequence sets. Initial observations suggest that this can be extended a further 10 kilometres or more in to the most distal, mud rich successions by carefully combining field observations with samples and petrophysical data. Further preparation and analysis of samples is ongoing and should reveal more of the depositional data required to fully understand this system.

Seismic Characteristics of Hyaloclastite Deposits: Implications for Petroleum Exploration

Tim Watton*

Statoil UK, Ltd. One Kingdom Street, London, W2 6BD.

*Corresponding author: timwa@statoil.com

Offshore sequences of volcaniclastic rocks (such as hyaloclastite deposits) are poorly understood in terms of their rock properties and their response to compaction and burial. As petroleum exploration targets offshore volcanic rifted margins worldwide, understanding of volcanic rock properties becomes important in terms of drilling, imagining and how the rocks may behave as seals, reservoirs, or permeability pathways. Recent studies have shown that hyaloclastite deposits may be able to aid basin-wide palaeo-environmental reconstruction (Wright et al. 2012). However, although geomorphologically similar to Gilbert-type deltas little is known about what governs the development seismic reflectors in hyaloclastite deposits or their velocity/density relationships. In this study, the mechanisms that govern reflection coefficient generation in hyaloclastite deposits are considered by using a combination of field studies, well data and seismic sections from Iceland, Hawaii and the Faeroe-Shetland Basin. Results show that hyaloclastite seismic response can be due to a number of reasons that include: interface roughness, primary sedimentology, diagenesis and secondary reworking processes. Furthermore, there is no clear observable density to p-wave velocity relationship in hyaloclastite deposits, yet they share similarities to carbonate lithologies in Vp/Vs ratio. An application of this research shows that high Vp/Vs response in hyaloclastite and volcaniclastic rocks can be misinterpreted as AVO anomalies yielding important lessons for exploration in the petroleum industry globally as exploration expands in the North Atlantic region (e.g. west of Shetland, United Kingdom, Faroe Islands and Norwegian margin) and South Atlantic margins (e.g. offshore Angola and Brazil).

The timing of silica diagenesis revealed by basin modelling

Thilo Wrona[1]*, Christopher A-L. Jackson[1], Mads Huuse[2], and Kevin G. Taylor[2]

[1]*Basins Research Group (BRG), Department of Earth Science and Engineering, Imperial College, London, SW7 2BP, UK*

[2]*School of Earth, Atmospheric and Environmental Sciences, University of Manchester, M13 9PL, UK*

*corresponding author: t.wrona11@imperial.ac.uk

Silica diagenesis, which involves the transformation of opal-A to opal-CT to quartz, influences subsurface fluid flow, compaction and the deformation of siliceous sediments/rocks in numerous basins. The timing of silica diagenesis is, however, very difficult to determine. When rock samples are available, analytical studies (e.g. isotopes and fluid inclusions) allow us to precisely determine the timing of diagenesis. In the absence of samples, we can only estimate the timing of silica diagenesis using seismic geomorphology. In this study, we aim to develop a method to determine the timing of silica diagenesis (in absence of samples) more precisely using subsurface data from the North Viking Graben, offshore Norway.

We apply 2D basin modelling techniques, constrained by well and seismic data, to determine the timing of silica diagenesis in the North Viking Graben, offshore Norway. Basin modelling requires four key steps: 1) selection of input parameters; 2) definition of boundary conditions; 3) simulation of physical processes; and 4) calibration of model results with observed data. The input parameters were geometry of the diagenetic boundaries, lithology and chronology, which we extracted from well and seismic data, as well as from previous studies. The boundary conditions included: a) water depth; b) seafloor temperature; and c) heat flow. We created four models using different seafloor temperature and heat flow curves in order to evaluate the sensitivity of our results. The simulation included modelling deposition, erosion, compaction and heat transfer. Finally, we calibrated each basin model by matching the modelled and present bottom-hole temperatures by adapting the heat flow.

Basin modelling allowed us to calculate past temperature variations in the North Viking Graben. Because silica diagenesis occurs at characteristic transformation temperatures, we were able to derive the timing of silica diagenesis from these temperature variations. Both silica transformations occurred in the Eocene and the associated boundaries migrated upwards until they were fossilised during the mid-Miocene, during a period of basin exhumation and erosion. Both silica transformations seem to have subsequently been reactivated during the latter part of the Miocene and, in the deepest part of the North Viking Graben, show evidence for migration at present.

The Dynamics of Suspended Sediment over Bedforms in Mixed Sand-Clay-EPS Sediment

L. Ye[1]*, D.R. Parsons[1], R.J. Schindler[1,2], and COHBED Project Team[3]

[1]*Department of Geography, Environment and Earth Science, University of Hull, Hull, UK.*

[2]*School of Marine Science & Engineering, University of Plymouth, Plymouth, UK.*

[3]*J. Baas, J. Malarkey and A. Davies (Bangor University); J. Peakall (University of Leeds); P. Thorne (NOC Liverpool); S. Bass, A.,Manning (University of Plymouth); D. Paterson, J. Hope, R. Aspden, E. Defew (University of St Andrews)*

*Corresponding author: L.Ye@2012.hull.ac.uk

Quantifying and modeling sediment dynamics in flows, including the complexities of sediment mixtures and their biological status, is a key to parameterizing physical processes at the flow-bed interface and ultimately to predicting natural sediment transport (French, 2010). Such predictions rely strongly on accurate knowledge of relationships between hydrodynamics and sediment properties. The work presented here describes laboratory experiments that have been and are being conducted using mixed cohesive and non-cohesive sediment and Xanthan gum as a proxy for the biological stickiness of Extracellular Polymeric Substances (EPS) (Vardy et al., 2007). The dynamics of suspended sediments were monitored and analyzed continuously in an experimental flume lab at the University of Hull's *Total Environment Simulator* flume/wave tank facility. The tank was sectioned into a 10 x 2 m flume channel and during the study period, we finished 16 flow runs with varying ratios of sand, clay and EPS. Unidirectionally pumped saline water at 15 PSU was used throughout. Suspended sediments were observed through (1) ABS profiles (2) vertically spaced OBS sensors, (3) LISST-100X, (4) physical water samples. In addition, water samples were analyzed using *LabSFLOC* (e.g. Manning et al., 2002). Consequently, the effects of varying suspended sands, clays and EPS on flocculation were monitored throughout. The results revealed strongly temporal variability in suspended sediment transport with various proportions of sand, clay and EPS. More clay and EPS increased the size of flocs formed in suspended sediments, while that delay sediments winnowing starting from bed to flow (suspension), which influenced the form and size of bedforms significantly as well.