Annual General Meeting

of the

British Sedimentological Research Group

School of Ocean Sciences

Bangor University

December 2009

Programme & Abstracts

Edited by David L. McCann

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Conference Programme—Summary

Venues

Main Arts Lecture Theatre (MALT)	Lecture Room 4

Monday 21st December

8:45–10:30 Plenary Session In MALT	
10:30–11:00 Tea & Coffee	
11:00–12:40 Deep Water Processes & Environments 1	11:00–12:40 Tectonics, Diagenesis, Sediment Routing 1
12:40–13:10 Poster Introductions In MALT	
13:10–14:00 Lunch In PJ Hall	
14:00–15:20 Deep Water Processes & Environments 2	14:00–15:20 Tectonics, Diagenesis, Sediment Routing 2
15:20-15:50 Tea & Coffee	
15:50–17:10 Deep Water Processes & Environments 3	15:50–17:10 Stratigraphy & Sedimentary Architecture
17:10–19:00 AGM In MALT, Followed By Dedicated Poster Session	
19:00–20:00 Reception In PJ Hall	
20:00–21:30 Conference Dinner In PJ Hall	
21:30–00:00 Bar & Entertainment In PJ Hall	

Tuesday 22nd December

9:10–10:30 Process Modelling 1	9:10–10:30 Sedimentology & Climate Change
10:30–11:00 Tea & Coffee	
11:00–13:00 Continental Processes & Environments	11:00–13:00 Shallow Marine Processes & Environments
13:00–14:00 Lunch In PJ Hall	
14:00–15:40 Process Modelling 2	14:00–15:40 CO_2 Release & Sequestration
15:40 Tea & Coffee	
16:10 End Of Meeting	

Table Of Contents

List of Registrants

Alexander, Jan—University of East Anglia—j.alexander@uea.ac.uk
Alrabib, Mohamed Ali—Manchester Metropolitan University—mrabeib2006@yahoo.com
Antrett, Philipp—RWTH Aachen University, Germany—antrett@geol.rwth-aachen.de
Baas, Jaco H.—Bangor University—j.baas@bangor.ac.uk
Banham, Steven G.—University of Leeds—eesgb@leeds.ac.uk
Barry, Gareth Manchester—Metropolitan University—garethjbarry@gmail.com
Bennell, Jim—Bangor University—oss006@bangor.ac.uk
Booth, Matthew—University of Edinburgh—m.g.booth@sms.ed.ac.uk
Bronlund, Siri—University of Bergen, Norway—siri.bronlund@student.uib.no
Cain, Stephen—16, Mandlebrote Drive, Littlemore—cainie81@hotmail.com
Cartigny, Matthieu—University of Utrecht, Netherlands—m.cartigny@geo.uu.nl
Cross, Lanu—Royal Holloway University of London—l.cross@es.rhul.ac.uk
Cummings, John—University of Liverpool—johnnyc@liverpool.ac.uk
Dale, Rachael—University of Leeds—eered@leeds.ac.uk
Davies, Alan G.—Bangor University, CAMS—a.g.davies@bangor.ac.uk
Davies, Roy—E.ON Ruhrgas Norge, Norway—roy.davies@eon-ruhrgas.no
Dowey, Patrick—University of Liverpool—pdowey@liverpool.ac.uk
Duller, Robert—Imperial College London—r.duller@imperial.ac.uk
Eggenhuisen, Joris T.—University of Utrecht, Netherlands—j.t.eggenhuisen@geo.uu.nl
Elliott, Gavin—Imperial College London—gavin.elliott@imperial.ac.uk
Filomena, Claudio—GeoZentrum Nordbayern, Germany—claudio.filomena@gzn.uni-erlangen.de
Frost, Peter—University of Exeter—peter.a.frost@ex.ac.uk
Ghadeer, Samer—University of Manchester—samer.ghadeer@postgrad.manchester.ac.uk
Gladstone, Lotty—University of Cambridge—lotty@bpi.cam.ac.uk
Graham, Jennifer J.—University of Leicester—jjg12@le.ac.uk
Grant, Jane—Bangor University—ospa44@bangor.ac.uk
Hampson, Gary—Imperial College London—g.j.hampson@imperial.ac.uk
Hartley, Adrian—University of Aberdeen—a.hartley@abdn.ac.uk
Heinemann, Niklas—University of Edinburgh—n.heinemann@sms.ed.ac.uk
Hendry, Jim—University of Portsmouth—jim.hendry@port.ac.uk
Hinds, David—ExxonMobil International Ltd—david.hinds@exxonmobil.com
Hodgson, David—University of Liverpool—hodgson@liv.ac.uk
Holgate, Nicholas—Imperial College London—n.holgate09@imperial.ac.uk
Howell, John—CIPR/Rocksource—john.howell@rocksource.com
Hu, Xiufang—University of Cambridge—xh236@cam.ac.uk
Humphreys, Alice—ExxonMobil Exploration Company—alice.humphreys@exxonmobil.com
Hunt, James E.—National Oceanography Centre, Southampton—jeh2g08@soton.ac.uk
Huuse, Mads—University of Manchester—mads.huuse@manchester.ac.uk
Huws, Dei—Bangor University—oss082@bangor.ac.uk
Jackson, Christopher—Imperial College London—c.jackson@imperial.ac.uk
Jago, Colin—Bangor University—oss072@bangor.ac.uk
Jeans, Christopher—University of Cambridge—cj302@cam.ac.uk
Jerrett, Rhodri—University of Liverpool—rhodders@liverpool.ac.uk
Jones, George—University of Liverpool—p.houghton@liverpool.ac.uk
Jordan, Oliver—Statoil ASA—olijo@statoil.com
Kane, Ian A.—University of Leeds—i.a.kane@leeds.ac.uk
Kilhams, Ben—University of Aberdeen—ben.kilhams@abdn.ac.uk
Kitson, David—Bryn Solutions—david@brynsolutions.com
Kitson, Wendy—SGS UK Ltd—wendy.kitson@sgs.com
Klausen, Tore—University of Bergen, Norway—tore.klausen@student.uib.no
Kulikova, Anna—Royal Holloway University of London—kulikova.annae@gmail.com
Langford, Harry E.—16, Magnolia Av., Longthorpe—h.e.langford@ntlworld.com
Le Ngoc, Anh—University of Manchester—anh.le@postgrad.manchester.ac.uk
Lee, David—University of Edinburgh—d.r.lee@sms.ed.ac.uk
Leppard, Chris—StatoilHydro Canada Ltd—clep@statoilhydro.com
Lewis, Matthew—Imperial College London—mattlewis8@msn.com
Limmer, David R.—University of Aberdeen—d.r.limmer@abdn.ac.uk
Malarkey, Jonathan—Bangor University—oss101@bangor.ac.uk

Marten, Kerry—Bangor University—osp208@bangor.ac.uk
Martin, Mike—BG Group—mike.martin@bg-group.com
Matthews, Wendy—BP—wendy.matthews@uk.bp.com
Mc Elhinney, Aine—University College Dublin, Ireland—aineymc@gmail.com
McArthur, Adam D.—University of Aberdeen—adam.mcarthur@abdn.ac.uk
McCann, David L.—Bangor University—osp41b@bangor.ac.uk
McClelland, Harry—University of Cambridge—hlom2@cam.ac.uk
Mellett, Claire—University of Liverpool—mellettc@liverpool.ac.uk
Mistry, Ajay—University of Liverpool—ajay.mistry@liverpool.ac.uk
Morris, Emma—University of Liverpool—eram2@liverpool.ac.uk
Mountney, Nigel—University of Leeds—n.mountney@see.leeds.ac.uk
Neill, Simon—Bangor University, CAMS—s.p.neill@bangor.ac.uk
Nichols, Gary—Royal Holloway University of London—g.nichols@es.rhul.ac.uk
Nicoll, Grant D.—University of Edinburgh—g.d.nicoll@sms.ed.ac.uk
Noad, Jon—Shell Canada—j.noad@shell.com
O'Hara Murray, Rory—University of Liverpool—roryohm@liverpool.ac.uk
Patacci, Marco—University College Dublin, Ireland—marco.patacci@ucd.ie
Peakall, Jeffrey—University of Leeds—j.peakall@see.leeds.ac.uk
Pierce, Colm—University College Dublin, Ireland—colm.pierce@ucd.ie
Prélat, Amandine—University Of Liverpool—amandine@liv.ac.uk
Price, Gregory—University of Plymouth—g.price@plymouth.ac.uk
Reesink, Arnold J.H.—Universities of Brighton & Birmingham—a.j.h.reesink@brighton.ac.uk
Rittersbacher, Andreas—University of Bergen, Norway—andreas.rittersbacher@cipr.uib.no
Roberts, Jen—University of Edinburgh—jen.roberts@ed.ac.uk
Robertson, Alastair—University of Edinburgh—alastair.robertson@ed.ac.uk
Robins, Peter E.—Bangor University, CAMS—p.robins@bangor.ac.uk
Rosen, Brian R.—Natural History Museum—b.rosen@nhm.ac.uk
Ross, Jessica—University of Leeds—jessica.ross86@gmail.com
Sambrook Smith, Gregory—University of Birmingham—g.smith.4@bham.ac.uk
Schmidt, Alja S.—Royal Holloway University of London—a.s.schmidt@es.rhul.ac.uk
Schulz, Henning—GeoZentrum Nordbayern, Germany—henning.schulz@geol.uni-erlangen.de
Scourse, James—Bangor University—oss048@bangor.ac.uk
Sevastjanova, Inga—Royal Holloway University of London—i.sevastjanova@es.rhul.ac.uk
Shoulders, Simon—BP—simon.shoulders@bp.com
Stevenson, Christopher—National Oceanography Centre, Southampton—chris.stevenson@noc.soton.ac.uk
Strachan, Lorna—University of Auckland, New Zealand—l.strachan@auckland.ac.nz
Sumner, Esther—National Oceanography Centre, Southampton—esther.sumner@noc.soton.ac.uk
Todd, David—Bangor University—ospa56@bangor.ac.uk
Tyrrell, Shane—University College Dublin, Ireland—shane.tyrrell@ucd.ie
Utley, James—University of Liverpool—etrsi@liverpool.ac.uk
Vackiner, Alexandra—RWTH Aachen University, Germany—vackiner@geol.rwth-aachen.de
van der Merwe, Willem—University of Liverpool—woeke@liverpool.ac.uk
van Landeghem, Katrien J.J.—Bangor University—k.vanlandeghem@bangor.ac.uk
Venus, Joanne—University of Leeds—eejhv@leeds.ac.uk
Verhagen, Iris—Bangor University—ospa03@bangor.ac.uk
Wakefield, Oliver J.W.—Keele University—o.j.w.wakefield@epsam.keele.ac.uk
Way, Oliver—Bangor University—ospa02@bangor.ac.uk
Wei, Taoyuan—University of Leeds—lectw@leeds.ac.uk
Wilkinson, Mark—University of Edinburgh—mark.wilkinson@ed.ac.uk
Wilson, Andrew—University of Liverpool—andrew.wilson@liverpool.ac.uk
Wilson, Faye—University of Leeds—fhawilson@googlemail.com
Witts, Duncan—Royal Holloway University of London—d.witts@es.rhul.ac.uk
Wright, Jonathan—Bangor University—ospa5a@bangor.ac.uk
Wynn, Russell—National Oceanography Centre, Southampton—rbw1@noc.soton.ac.uk
Yin, Daowei—University of Leeds—eedy@leeds.ac.uk
Yu, Fengling—University of Durham—fengling.yu@durham.ac.uk

Information for Oral Presentations

The time slot for standard oral presentations is 15 minutes, followed by 5 minutes for questions.

All presentations will be run on PowerPoint, Windows XP or Vista, unless agreed otherwise before the start of the meeting. All presentations need to be uploaded onto a computer and projected using standard data projection. It will not be possible to use a separate laptop. To avoid compatibility problems, it is recommended that presentations prepared with Microsoft Office PowerPoint 2007 are saved in PowerPoint 97–2003 file format before upload.

Presentations prepared on an Apple Mac computer should run on a standard PC. However, if preparing a presentation on an Apple Mac, please ensure to test PC compatibility before arrival.

Oral presentations, on a CD or USB storage device, must be uploaded to the correct PC, in MALT or Lecture Room 4, well before the start of the session, i.e. between 08.00h and 08.45h, during coffee, lunch and tea breaks, or between 17.00h and 18.00h.

Information for Poster Presentations

Felt-backed poster boards will be available from 08.00h on Monday in PJ Hall, and posters, once fitted, can stay there for the duration of the conference.

Poster boards are 2100 mm high and 1200 mm wide. Velcro for hanging the posters on the boards will be available in the poster room, but the supply is limited, so poster presenters are advised to bring their own Velcro.

Poster presenters are encouraged to introduce their work during the Poster Introductions, which will take place directly before lunch on Monday (see technical programme for details). Each introduction will last no longer than 60 seconds, and can be accompanied by one PowerPoint slide. These rules will be seen to scrupulously. The PPT slide must be uploaded onto the computer in the Main Arts Lecture Theatre before 11.00h or handed in at the Registration Desk before 09.00h.

The posters should be manned on Monday between 18.00h and 19.00h, but posters can be viewed at anytime. Drinks will be available during the Dedicated Poster Session.

Additional Information - Restaurants and Bars

Bangor

A selection of the more popular restaurants in Bangor includes:

Fat Cat Cafe Bar 161, High St.
Relaxed informal atmosphere. Good varied food. Large range of drinks and cocktails

Greek Taverna Politis 12-14, Holyhead Rd
Interesting Grecian-themed atmosphere, occasional live music.

Herbs 162, High St
Originally a vegetarian restaurant now offering a varied menu (Mediterranean, European, Thai, Pasta, Curry) with locally sourced produce. Local welsh art on display.

Java Restaurant 236, High St
Friendly staff, good quality international cuisine. Recommended for a good night out

Ristorante Pulcinella Pier Promenade, Garth Road
Friendly and unpretentious Italian food with generous portions

There are numerous other options with a range of pub food throughout the town and numerous Indian and Chinese restaurants.

Menai Bridge

A selection of the more popular restaurants in Menai Bridge includes:

The Bridge Inn, Menai Bridge
Good quality pub food. A bit pricier than usual pub offerings but often worth it

The Strait, Dale Street, Menai Bridge
Popular restaurant with a good reputation for contemporary food

Jade Village, Mona Road, Menai Bridge
A large Chinese restaurant. Good quality standard Chinese food with excellent service

There are a surprising number of Chinese and Indian restaurants in Menai Bridge plus food available at a number of pubs in the village

PROGRAMME AND EVENTS

Monday 21st December

Plenary Session in Main Arts Lecture Theature
Chair: Jaco H. Baas

8:45 Introduction

9:00 Rosen, B. & Darrell, J.—Darwin As A Carbonate Sedimentologist: His Reef Transects, Specimens And Facies Model At Cocos-Keeling Atoll

9:30 Scourse, J. et al—The Impact Of Sea-Level Change On The Hydro- And Sediment Dynamics Of The Northwest European Shelf Seas Since The Last Glacial Maximum: Modelling Insights

10:00 Kane, I. & Hodgson, D.—Marginalised In Sedimentological Society: Submarine Channel Levees

10:30–11:00 Tea & Coffee Break

Main Arts Lecture Theatre **Deep Water Processes & Environments 1** *Chair: Russell Wynn*	**Lecture Room 4** **Tectonics, Diagenesis & Sediment Routing 1** *Chair: Jim Hendry*
11:00 Sumner, E. et al—Deposits Of Flows Transitional Between Turbidity Current And Debris Flow	**11:00** Booth, M. et al—Field-Based Evidence Of Sedimentary And Tectonic Processes Related To Continental Collision
11:20 Gladstone, C. & Pritchard, D.—From A Dilute Turbidity Current To A Concentrated Flow Via Lofting	**11:20** Cross, L.—The Neogene Tectono-Stratigraphic Evolution Of Java, Indonesia
11:40 Stevenson, C. & Peakall, J.—Effects Of Topography On Lofting Gravity Flows: Implications For The Deposition Of Deep-Water Massive Sands	**11:40** Strachan, L. et al—The Waitemata Basin, New Zealand: A Basin On The Edge Of A Subduction Zone?
12:00 Eggenhuisen, J. & McCaffrey, W.—The Depositional Signature Of Positive Surges In Supercritical Turbidity Currents: Experimental Suggestions For The Origin Of Vertical Transitions In Turbidite Sandstones	**12:00** Robertson, A. et al—Ophiolite Emplacement: Evidence From Coarse Clastics Overlying The Jurassic Mirdita Ophiolite, Albania
12:20 Hodgson, D. & Kane, I.—Relative Timing Of External And Internal Submarine Levee Construction And The Implication For Submarine Fan Growth	**12:20** Elliot, G. et al—Evolution Of Submarine Fault Scarp Degradation Complexes: The Middle-Upper Jurassic Of The Halten Terrace, Offshore Mid-Norway

12:40–13:10 Poster Introductions In MALT

13:10–14:00 Lunch In PJ Hall

Main Arts Lecture Theatre **Deep Water Processes & Environments 2** *Chair: Ian Kane*	**Lecture Room 4** **Tectonics, Diagenesis & Sediment Routing 2** *Chair: Alistair Robertson*
14:00 van der Merwe, W. & Hodgson, D.—Criteria To Distinguish Slump And Slide Deposits And Their Distinction In Outcrop: The Utility In Returning To Their Original Definitions	**14:00** Vackiner, A. et al—Upper Permian Synsedimentary Tectonics In The Western North German Basin
14:20 Peakall, J. et al—Found: The 'Holy Grail' Of Deep-Marine Clastic Sedimentology?	**14:20** Sevastjanova, I. et al—Sundaland Basement And Sediment Provenance: U-Pb And Hf-Isotope

Monday 21st December (continued)

Main Arts Lecture Theatre **Deep Water Processes & Environments 2** *Chair: Ian Kane*	**Lecture Room 4** **Tectonics, Diagenesis & Sediment Routing 2** *Chair: Alistair Robertson*
14:40 Patacci, M. et al—Repetitions Within Contained Turbidite Beds Near Their Pinch-Out: Related To Internal Waves?	**14:40** Tyrrell, S. et al—Mesozoic Palaeodrainage Evolution In The Rockall Basin, Offshore Western Ireland
15:00 Wynn, R. et al—The Influence Of Subtle Gradient Changes On Deep-Water Gravity Flows	**15:00** Hendry, J. & Marshall, J.—Bacteria Versus Burial: What Is Responsible For The Cementation Of Liassic Ammonite Chambers?
15:20–15:50 Tea & Coffee Break	
Main Arts Lecture Theatre **Deep Water Processes & Environments 3** *Chair: Dave Hodgson*	**Lecture Room 4** **Stratigraphy & Sedimentary Architecture** *Chair: Gary Hampson*
15:50 Hunt, J. et al—Emplacement Of The El Golfo And Icod Turbidites In The Moroccan Turbidite System: Implications For Landslide Mechanisms And Turbidity Current Processes	**15:50** Noad, J.—The Twelve Sediments Of Christmas
16:10 McArthur, A. et al—Reconstructing Depositional Systems From A Coarse Grained Submarine Slope Succession	**16:10** Howell, J. et al—Empirical Understanding Of Sedimentary Architecture
16:30 Kilhams, B. et al—Characterising The Paleocene Submarine Fans Of The Central North Sea: Observations From Seismic And Core Analysis	**16:30** Dale, R. et al—A High Resolution Sequence Stratigraphic Model Of Marsdenian (Carboniferous) Sediments, In County Clare, Ireland
16:50 Prélat, A. et al—Quantitative Comparison Of Ancient And Recent Distributary Deep-Water Systems Using Outcrop And Seismic Datasets	
17:10–19:00 AGM In MALT, Followed By Dedicated Poster Session In PJ Hall	
19:00–20:00 Reception in PJ Hall	
20:00–21:30 Conference Meal In PJ Hall	
21:30–00:00 Bar & Entertainment In PJ Hall	

Tuesday 22nd December

Main Arts Lecture Theatre **Process Modelling 1** *Chair: Greg Sambrook Smith*	**Lecture Room 4** **Sedimentology & Climate Change** *Chair: James Scourse*
9:10 Cartingy, M. et al—Upstream Migrating Bedforms; A New Process-Based Interpretation	**9:10** Jeans, C.—How Valid Are The Climatic Signals Derived From Clay Mineral Assemblages? Examples From The Mesozoic Strata Of The U.K.
9:30 O'Hara Murray, R. et al—Simultaneous Measurements Of Turbulence And Sediment Dynamics Over A Vortex Ripple Under Irregular Waves	**9:30** Yu, F. et al—Reconstruction Of The East Asian Monsoon Variability Since The Mid-Holocene From The Pearl River Estuary, Southern China
9:50 Marten, K. et al—Observations And Prediction Of Co-Existing Wave And Current Ripples At Sea Palling, UK	**9:50** Neill, S. et al—Evolution Of Sediment Distribution Over The Northwest European Shelf Seas During The Last 12,000 Years
10:10 Reesink, A.—Origin And Significance Of Fully-Preserved Dunes In Large-River Deposit	**10:10** Cummings, J. et al—The Impact Of The Palaeocene Eocene Thermal Maximum In The Deep Seas: An Integrated Ichnological, Geochemical And Stratigraphical Approach

10:30–11:00 Tea & Coffee Break

Main Arts Lecture Theatre **Continental Processes & Environments** *Chair: Nigel Mountney*	**Lecture Room 4** **Shallow Marine Processes & Environments** *Chair: John Howell*
11:00 Rittersbacher, A. et al—An Empirical Approach Towards Understanding Fluvial Architecture	**11:00** Dowey, P. et al—Toward Understanding The Controls On Fe-Rich Clay Minerals In Estuaries: A Case Study From The Rio Anllns Estuary, NW Spain
11:20 Hampson, G. et al—Controls On Gross Sandbody Distribution And Stratigraphic Architecture In Coastal-Plain Strata, Blackhawk Formation, Wasatch Plateau, Utah	**11:20** Shoulders, S. et al—Depositional Systems In A Structurally Dynamic Basin; Decoding The Evolution Of The Pliocene In The West Nile Delta
11:40 Venus, J. et al—Heterogeneity Within Fluvial Facies: A Tool For Evaluating Depositional Models Of Dryland Fluvial-Aeolian Systems?	**11:40** Mellett, C. et al—Sedimentary Architecture And Environmental History Of Middle To Late Pleistocene Deposits From The Eastern English Channel
12:00 Antrett, P. et al—Syneresis Cracks On Seismic Data In The Upper Rotliegend In Northern Germany	**12:00** Graham, J. et al—Marsdenian Mudstones, Implications For Shale Gas Source Rock Development
12:20 Jerrett, R. et al—The Recognition Of High-Resolution Base-Level Changes In Coal Seams	**12:20** van Landeghem, K. et al—Evaluating A Shape-Based Sand Wave Migration Predictor From Swath Bathymetry Data In The Irish Sea
12:40 Langford, H.—Seeing Is Believing—Or Is It? A Comment On The Glacial Deposits Of Western County Clare, Ireland	**12:40** Jackson, C. et al—Sedimentology, Ichnology And Stratigraphic Development Of A Major Retrogradational, Shelfal Deltaic Succession In The Middle Miocene Of NW Borneo

13:00-14:00 Lunch In PJ Hall

Tuesday 22nd December (Continued)

Main Arts Lecture Theatre **Process Modelling 2** *Chair: Arjan Reesink*	**Lecture Room 4** **CO_2 Release And Sequestration** *Chair: Mark Wilkinson*
14:00 Wei, T. et al—High-Resolution Flow Dynamics Of Density Currents In The Xiaolangdi Reservoir, The Middle Yellow River, China	**14:00** Nicoll, G. et al—Utsira Overburden: Investigating Existing Fluid Migration Pathways—Implications For Long-Term CO_2 Storage
14:20 McCann, D. & Davies, A.—Long-Term Morphological Modelling Of A Sandy Estuary	**14:20** Haszeldine, S. & Wilkinson, M.—An Assessment Of The CO_2 Storage Potential Around Scotland
14:40 Sambrook Smith, G. et al—Quantifying The Dynamics Of Flow Within A Permeable Bed Using High-Resolution Endoscopic Particle Imaging Velocimetry (PIV)	**14:40** Heinemann, N. et al—CO_2 Storage Capacity Of The Bunter Sandstone Formation, UK Southern North Sea
15:00 Ross, J. et al—An Integrated Model Of Extrusive Sand Injectites And Sand Volcanoes	**15:00** Roberts, J. et al—To Leak Or Not To Leak? Investigating The Plumbing Of CO_2 Fluids In Central Italy
15:20 Huuse, M.—3D Seismic Imaging Of Sediment Remobilization And Fluid Flow—The Need For Outcrop Analogues	**15:20** Lee, D. et al—Carbonate Fracture Cements Record CO_2-Rich Flux Up A Fault Zone, Fladen Ground Spur, North Sea

15:40 Tea & Coffee

16:10 End Of Meeting

POSTER PRESENTATIONS

#01: The Nature And Origin Of Quartz, Clay Mineral And Carbonate Cement In The Upper Ordovician Mamuniyat Formation, Concession NC174, Murzuq Basin, SW Libya
Mohamed Alrabib, Kevin Taylor, Chris Perry

#02: A Stochastic Modelling Approach To Determine Sensitivity Of 3D Fluvial Channel Connectivity To Changes In Channel Morphology And Frequency
Steven G. Banham, Nigel P. Mountney, Stephen A. Cain, John D. Collinson, William D. McCaffrey, Jeff Peakall

#03: Impacts Of Land Use Change Upon The Nearshore Sedimentary Environments Of A Modern Tropical Carbonate Platform: Rodrigues, SW Indian Ocean
Gareth J Barry, Kevin G Taylor, Christopher T Perry

#04: Novel Training Images for Multipoint Statistical Modelling of Fluvial Systems: Examples from the Gulf of Thailand
Siri Brønlund, Roy Davies, John Howell

#05: Cyclic Steps Formed By Two-Layered Turbidity Currents On The Monterey Submarine Canyon Floor
Matthieu J.B. Cartigny, Jan H. van den Berg, Dick R. Mastbergen, George Postma

#06: Toward Understanding The Controls On Fe-rich Clay Minerals In Estuaries: A Case Study From The Leirarvogar Estuary, SW Iceland
Patrick J. Dowey, Richard H. Worden, David M. Hodgson

#07: Regional Grain-Size Trends In Fluvial Stratigraphy: Quantifying Subsidence Versus Sediment supply
Robert A. Duller, Alex C. Whittaker, Juan J. Fedele, Amy L. Whitchurch, John Armitage, Joshua Springett, Rosie Smithells, William Neal, Francis Patton, Philip A. Allen

#08: Characteristic Ultrasonic Patterns Across The Early Triassic Hardegsen Unconformity In Southern Germany
Claudio M. Filomena, Harald Stollhofen

#09: Sediment Transport Processes In Ancient Mud-Dominated Successions; A Comparison Of The Processes Of Sediment Deposition And Dispersal In Shallow (Up-Dip) Shelfal And Distal (Down-Dip) Basinal Environments
Samer Ghadeer, Joe H. S. Macquaker, Colin R. Hughes

#10: An Investigation Of Volcaniclastic Turbidite Emplacement In The Canary Basin: Implications For Volcanic Landslide Events
James E. Hunt, Russell B. Wynn, Aggeliki Georgiopoulou, Vicky Catterall, Doug G. Masson

#11: Cenozoic Coolwater Carbonate Sediment Waves On The Shelf Break Of The Great Australian Bight
Mads Huuse, the Galathea 3 Leg 8 team

#12: Seismic Images Of Glaciogenic Structures And Deposits Offshore NW Europe—Analogues For The Palaeozoic Of North Africa?
Mads Huuse, the GRASP team

#13: The Stratigraphic Transition From Slope To Shelf
George E. D. Jones, David M. Hodgson and Stephen S. Flint

#14: Reservoir Characterisation Of Barren Fluvial Sequences Using Rock-typing Analyses Of Core And Cuttings—Schooner Field, Southern North Sea, UK
Wendy Kitson, Matthew Power, Andrea Moscariello, Suzanne Burns, Deborah Walker

#15: Sedimentology And Sequence Stratigraphy Of The Lower Ferron Sandstone In Central Utah
Tore G. Klausen, John A. Howell

#16: 3D Seismic Analysis Of Enigmatic Strata-bound Folds In The Upper Cretaceous Chalk, Egersund

Basin, Eastern North Sea Basin
Matthew M. Lewis, Christopher A-L. Jackson, Paul S. Whipp

#17: Preliminary Results From Provenance Studies In The Indus Continental Shelf, Pakistan
David Limmer, Peter Clift, Cornelia Köhler, Matthew Cooper, Suzanne MacClachlan, Liviu Giosan

#18: On The Origin Of Convolute Lamination In The Turbidites Of The Aberystwyth Grits Group
Harry McClelland, Nigel Woodcock, Charlotte Gladstone, David Pritchard

#19: Integrating Research Borehole And Outcrop Data To Understand Sedimentary Processes Operating On Submarine Channel-levee Systems, An Example From The Karoo Basin, South Africa
Morris, E.A., Hodgson, D.M., Flint, S.S

#20: A Numerical Stratigraphic Model For Quantitative Prediction Of Sandbody Connectivity In Mixed Fluvial-Aeolian Successions
Nigel P. Mountney

#21: The Seismic Character Of A Bottom Simulating Reflector (BSR) Of The Cameroon Margin, West Africa
Anh Le Ngoc, Robert Gawthorpe, Jonathan Redfern, Ducan Irving

#22: Reconstruction Of Jurassic (Bathonian) Palaeosalinity Using Stable Isotopes And Faunal Associations
Gregory D. Price, Christie Teece

#23 Morphological Controls In Sandy Estuaries: The Influence Of Tidal Flats And Bathymetry On Sediment Transport
Peter Robins, Alan Davies

#24: A Sequence Stratigraphic Analysis Of The Cenozoic Succession Offshore Namibias
Henning Schulz, Harald Stollhofen, Stefan Back

#25: Fluid Mud Generated Grain-size Breaks In Turbidites Recording Very Large Volume Sediment Bypass
C.J. Stevenson, P.J. Talling, M. Frenz, R.B. Wynn, D.G. Masson

#26: How And Why Do Turbidites Differ From Textbook Models?
Esther J. Sumner, Peter J. Talling, Lawrence A. Amy, Russell B. Wynn

#27: Complex Fluvial Heterogeneity In Apparently Homogenous Stratigraphy: An Example From The Permian Cutler Group, S.E. Utah
Joanne Venus, Nigel P. Mountney, William D. McCaffrey

#28: Linked Climatic And Eustatic Controls On The Timing Of Fluvial, Aeolian And Shallow Marine Sedimentation In The Permian Cutler Group, Paradox Basin, SE Utah, USA: Response To Orbital Forcing?
Oliver J.W. Wakefield, Nigel P. Mountney

#29: Stratigraphy And Provenance Of Cenozoic Sediments In The Barito Basin, SE Kalimantan
Duncan Witts

ABSTRACTS

The Nature And Origin Of Quartz, Clay Mineral And Carbonate Cement In The Upper Ordovician Mamuniyat Formation, Concession NC174, Murzuq Basin, SW Libya

Mohamed Alrabib, Kevin Taylor, Chris Perry
Department of Environmental and Geographical Sciences, Manchester Metropolitan University
Email: mrabeib2006@yahoo.com

Keywords: Diagenesis, Sandstone, Quartz Cement, Ordovician

The Murzuq Basin is the one of a series of Palaeozoic intracratonic sag basins on the North African Saharan platform. The aim of this project is to determine controls on the distribution of quartz overgrowth cement and other pore filling authigenic minerals in the Ordovician Mamuniyat Formation reservoir. Petrographic data derived from cored sandstone intervals through the Mamuniyat Formation show that they are mainly fine- to medium-grains quartz arenite, with minor subarkose and sublithic arenite. The detrital mineralogy is dominated by monocrystalline and minor polycrystalline quartz grains, feldspar grains, lithic fragments, and mica (muscovite). The degree of compaction of these sediments generally is low to moderate. The dominant authigenic cement phase is quartz overgrowths cement (up to 13% by volume) and is the major mechanism for porosity reduction, as evidenced by SEI, BSEI and CL observations. Secondary porosity (up to 17%) is also present as a result of feldspar dissolution associated with kaolinite precipitation. Minor amounts of illite were noted in the studied samples, which can block pore throats, thereby reducing permeability. Late stage siderite (mean $\delta 13C = -10.4$ per mil; $\delta 18O = -13.5$ per mil) and minor dolomite cement are also present. Carbonate cement precipitation causes infilling of intergranular porosity and therefore significantly reduces porosity and permeability. Minor authigenic phases include pyrite, in the form of small framboids or patches, barite, anatase / leucoxene and hematite coating clay minerals. Results to date suggest that the major control on cementation is is the facies geometry characteristic of facies .

Syneresis Cracks On Seismic Data In The Upper Rotliegend In Northern Germany

Philipp Antrett[1], Alexandra Vackiner[1], Peter Kukla[1], Stefan Back[1], Harald Stollhofen[2]
[1]*Geological Institute, RWTH Aachen University,* [2]*North Bavarian Center of Earth Sciences, FAU Erlangen-Nuernberg*
Email: antrett@geol.rwth-aachen.de

Keywords: Syneresis Cracks, Upper Rotliegend, Southern Permian Basin, Germany, Playa Lakes

This study focuses on sedimentary facies distribution of Rotliegend strata in the Southern Permian Basin in East Frisia, Germany. It is based on 3D seismic, wireline and core data. The depositional environment of the Upper Rotliegend II was characterized by perennial saline lakes, accompanied by coastal parallel sand belts consisting of successions from wet, damp and dry sand flats to aeolian dunes with interdune deposits. Polygonal symmetries of different scales can be observed on seismic horizon slices in a certain depth interval. Diverse seismic attributes confirm their occurrence. Observed polygon sizes range from kilometre to meter scale. In most cases large-scale polygon-outlines are associated with faults in seismic sections. Similar polygon networks can be observed on satellite images of recent dry lakes in the western US described by Messina et al. (2005). Vast, kilometre long, cracks with several meters of depth have been described to develop as a result of syneresis processes. A field analogue study will be carried out to get a better knowledge of the development of the fissures and their impact on reservoir properties. Although regional extension and tectonic setting of the Rotliegend differ to the Death Valley region, information from cores of Panamint Valley (Jayko 2008) indicates that sedimentary facies are comparable.

Messina, P. et al, 2005. Macropolygon morphology, development, and classification on North Panamint and Eureka playas, Death Valley National Park CA. Earth-Science Reviews **73**, 309–322.
Jayko, A.S. et al, 2008. Late Pleistocene lakes and wetlands, Panamint Valley, Inyo County, California. *GSA SP* **439**, 151–184.

A Stochastic Modelling Approach To Determine Sensitivity Of 3D Fluvial Channel Connectivity To Changes In Channel Morphology And Frequency

Steven G. Banham[1], Nigel P. Mountney[1], Stephen A. Cain[2], John D. Collinson[3], William D. McCaffrey[1], Jeff Peakall[1]
[1]*Fluvial Research Group, School of Earth and Environment, University of Leeds,* [2]*Neftex Petroleum Consultants Ltd, Abingdon,* [3]*John Collinson Consulting Ltd, Beech, Staffordshire*
Email: eesgb@leeds.ac.uk

Keywords: Channel Connectivity, Channel Geometries, Fluvial, Modelling, Organ Rock Formation

Prediction of 3D channel-body connectivity is essential for the characterisation of subsurface reservoirs and for effective evaluation of their resource potential. Yet, even in mature hydrocarbon provinces, depositional sedimentary models inevitably rely on data from a relatively small number of usually widely spaced 1D wells. Therefore, most reservoir characterisations rely on the application of an outcrop analogue with which to elucidate 3D sedimentary architecture. However, even in well exposed outcrop successions, the geometric properties of channel systems cannot usually be fully constrained and estimates of key parameters including channel width, thickness, length, frequency, planform shape (sinuosity), trend and style of sand-body storey stacking typically each have associated uncertainty.
One method to determine the sensitivity of sedimentary systems to variations in estimates of channel size and shape is the application of a stochastic modelling approach to predict 3D sandbody connectivity for various scenarios. This

study uses Reckonnect stochastic modelling software to predict 3D channel-body shape and connectivity within the Permian Organ Rock Formation, a fluvial fan succession exposed in SE Utah, which is considered to be an analogue for a variety of fluvial reservoirs including parts of the Triassic Central North Sea. By selecting a range of most probable values of key geometric parameters for this mixed channelised and sheetflood succession, a probability envelope can be constructed which describes the range of possible channel connectivities. Crucial to the applicability of this approach is the speed of the modelling software, which allows multiple realizations to be executed in reasonable time.

Impacts Of Land Use Change Upon The Nearshore Sedimentary Environments Of A Modern Tropical Carbonate Platform: Rodrigues, SW Indian Ocean

Gareth J Barry, Kevin G Taylor, Christopher T Perry
Dept of Environmental and Geographical Sciences, Manchester Metropolitan University
Email: Garethjbarry@gmail.com

Keywords: Carbonate, Terrigenous, Preservation, Impact, Lagoon

Tropical shallow marine carbonate shelf and platform systems are important sites of calcium carbonate accumulation and play a significant role in the global carbon cycle, acting as both sinks and sources of carbon. Land-use changes in these systems can have major impacts upon terrigenous sediment inputs and, as a result, sediment composition and geochemical processes. Previous studies which have examined the impacts of anthropogenic inputs of iron-rich sediment (bauxite dust) on a carbonate system have documented significant modifications to sediment composition and carbonate diagenesis (Taylor et al. 2007). However, no comparable impact assessments in systems subject to high levels of naturally iron-rich terrigenous sediment input have been undertaken. This project is studying the impacts of terrigenous sediment inputs into the shallow marine carbonate environment surrounding the island of Rodrigues (SW Indian Ocean). Major land clearance for agricultural use on the island has occurred over the past 150–200 years, resulting in significant soil erosion that has delivered iron-rich terrigenous sediment into the islands nearshore lagoon environments. To date cores and sediment analyses have been used to delineate six facies within a major embayment (Baie Topaz), which are characterised by varying carbonate, total Fe and faunal grain composition. Initial analysis of these sediment cores, however, does not reveal a major shift in sediment composition related to land-use change, but rather a basin infill sequence. However, data on pollen and faunal assemblages and trace element geochemistry will be collected to test for broader modifications.

Taylor, K.G., et al, 2007. *Marine Chemistry*, 449–463.

Field-Based Evidence Of Sedimentary And Tectonic Processes Related To Continental Collision

Matthew G. Booth[1], Alastair H. F. Robertson[1], Ulvican Unlugenç[2], John E. Dixon[1], Stephen Vincent[3]
[1]*University of Edinburgh,* [2]*Çukurova University, Turkey,* [3]*Cambridge Arctic Shelf Program (CASP)*
Email: M.G.Booth@sms.ed.ac.uk

Keywords: Basin Evolution, Collision, Cenozoic, Turkey

This talk considers the Darende Basin (one of two basins being studied), a tectonically generated sedimentary basin in central eastern Turkey. The basin formed on the northern margin of the Tauride micro-continent during collision and suturing of the Mesozoic Tethys Ocean. The basin provides a good opportunity to study processes involved in orogenic assembly as the basin is well exposed and relatively undeformed.

The basin has a Jurassic-Cretaceous carbonate platform basement, overlain by southward-obducted ophiolites. Sedimentation on the emplaced ophiolites began in the Maastrichtian following a basin-wide transgression. Ophiolite-derived clastics accumulated in basin depocentres followed by Maastrichtian-aged rudist-rich patch reefs and microbial carbonates at the basin margins and on palaeotopographic highs. Inferred Early Paleogene extension initiated localised basalt-andesite volcanism. During the Early Eocene, inferred flexural subsidence created accommodation space which filled with a variety of facies including sandstones, limestones, marls, calcarenites, conglomerates and evaporites, successively recording deepening, shallowing and ultimately emergence.

We infer the following tectonically controlled stages: 1) Late Cretaceous extension possibly relating to northward subduction of remaining Tethyan oceanic crust; 2) Latest Cretaceous emergence possibly controlled by flexural uplift or sea-level change; 3) Early Eocene flexural subsidence, likely caused by initial collision of the Tauride microcontinent with Eurasia; 4) Late Eocene "hard collision" resulting in rift-shoulder uplift and restriction of the basin, culminating in subaerial exposure. No further marine sedimentation occurred in the basin after the Late Eocene.

Novel Training Images for Multipoint Statistical Modelling of Fluvial Systems: Examples from the Gulf of Thailand

Siri Brønlund[1], Roy Davies[2], John Howell[1]
[1]*Centre for Integrated Petroleum Research, University of Bergen,* [2]*E.on Ruhrgas Norge, Stavanger Norway*
Email: Siri.Bronlund@student.uib.no

Keywords: Reservoir Modelling, Fluvial, Multipoint Statistics

Multipoint Statistics (MPS) is a new method for populating facies in geocellular models which relies on the use of training images to describe the spatial and geometric relationships between facies in a volume. Training images can be taken from modern systems (aerial or satellite photos) or from sketches that describe the conceptual understanding of the geological relationships. Most recently training images have also been derived from outcrops, very high resolution seismic data and even process based modelling results. The goal of this project is to utilise very high resolution data

seismic data from the Gulf of Thailand to build 3D training images and to test the MPS algorithms against more conventional modelling techniques. The seismic data from the Gulf of Thailand include Pleistocene and Holocene fluvial deposits, laid down in a broad flat coastal plain. The data are very shallow and hence very high resolution, allowing the mapping of individual fluvial channels and compound incised valley fills. The data have been used to build a deterministic geocellular model that is $17 \times 67 \times 0.4$ km. This model accurately captures the details of the channel bodies and their spatial relationships. The model has then been used to test both MPS and more conventional modelling techniques. The accuracy of the modelling has been determined by comparing a series of geometric connectivity parameters between the base case and the stochastic models. In all cases the MPS provides an improved realization of the fluvial geometries. The approach has also demonstrated that deterministic 3D model can be used as alternative sources of MPS training images.

Upstream Migrating Bedforms; A New Process-Based Interpretation

Matthieu J.B. Cartigny, Jan H. van den Berg, George Postma
University of Utrecht, department of Earth Sciences
Email: m.cartigny@geo.uu.nl

Keywords: Cyclic steps, Bedforms, Upper-flow Regime, Hydraulic jump

Classical bedform stability diagrams relate flow velocities, flow depths and grain sizes to different bedforms. They cover a spectrum from the beginning of sediment movement to anti-dunes. However, recent developments have shown that this diagram is incomplete. More upstream-migrating bedforms are to be found in the upper-flow regime, namely cyclic steps. Lower flow-regime conditions are more common in fluvial settings; however upper flow-regimes may prevail on steep slopes (e.g. outwash plains) or flows with small excess densities (e.g. turbidity currents and pyroclastic flows). In these environments upstream migrating bedforms (e.g. cyclic steps) are often observed. The relation between cyclic steps and the more familiar bedforms is still poorly understood. The aim of this study is to investigate the hydro-dynamical processes that control the transition from anti-dunes to cyclic steps. Based on these experiments we conclude that bedforms in the upper-flow regime are fully controlled by hydraulic jumps. Such hydraulic jump is a transition between super critical and sub critical flows, which causes an abrupt decrease in flow velocity. As a result of this velocity decrease flow becomes depositional over a certain length to adjust the sediment load to the new flow velocity. Our experiments show that the depositional length following a hydraulic jump is triggering the transition from anti-dunes to cyclic steps. These results put upstream-migrating bedforms (for example subaqueous sediment waves) in a new perspective.

Cyclic Steps Formed By Two-Layered Turbidity Currents On The Monterey Submarine Canyon Floor

Matthieu J.B. Cartigny[1], Jan H. van den Berg[1], Dick R. Mastbergen[2], George Postma[1]
[1] *University of Utrecht, department of Earth Sciences,* [2] *Deltares, Delft*
Email: m.cartigny@geo.uu.nl

Keywords: Cyclic steps, Turbidity Currents Bedforms, Submarine Canyon, Sediment Waves

Multibeam images show that the floor of the upper reach of the Monterey submarine canyon is covered by a regular pattern of sand waves. The interpretation of these bedforms is still unsettled due to an apparent contradiction in migration direction. A sequence of images has shown upslope migration, while sand wave down-slope asymmetry suggests a downslope migration direction. Here we interpret these Monetery canyon sand waves as cyclic steps as. This is consistent with both the upslope migration and the downslope asymmetry. Earlier experiments have shown that turbidity currents have the capability for forming cyclic steps. Turbidity currents, that flush the Monterey canyon regularly, would then be the most likely cause of the formed cyclic steps. In this study, an existing numerical model for cyclic steps is modified and applied to the Monterey canyon morphology to support the cyclic step hypothesis. Agreement between numerically-predicted properties and measured characteristics of turbidity currents in the Monterey canyon strongly supports a cyclic step interpretation. In the numerical model, cyclic step geometries are related to flow properties of the overriding flow. The implications of these results for sediment waves in general are discussed based on examples of sediment waves found in both ancient and modern environments.

The Neogene Tectono-Stratigraphic Evolution Of Java, Indonesia

Lanu N. Cross
SE Asia Research Group, Department of Earth Sciences, Royal Holloway University of London
Email: l.cross@es.rhul.ac.uk

Keywords: Java, Neogene, Tectonic, Indonesia

Java, Indonesia, is situated along the southern margin of Sundaland with the Indo-Australian plate subducting along the Java Trench to the south. The island is the product of subduction related arc volcanism, interspersed with periods of carbonate growth and clastic input from the Sundaland to the north. The current understanding the tectono-stratigraphic evolution of Java is relatively poor. An inconsistent stratigraphy exists at present across the island and much of this is based upon work completed before modern tectonic theory and dated using inaccurate methods. New field observations backed by laboratory analyses have been used to generate a new working stratigraphic framework for Java, identifying several discrete phases of Neogene deformation.

Outcrop structural analysis coupled with dating using pelagic and benthic foraminiferal biostratigraphy suggest a major compression event during the Early Messinian (8Ma $\pm$ 0.5), which generated Java wide deformation

and uplifted much of northern shelf for erosion and Peneplanation. In West and Central Java the deep marine volcaniclastic units were uplifted. This phase of deformation probably coincides with the northward thrusting of the old volcanic arc. Structural features seen at outcrop imply a second major phase of deformation, which coincided with the initiation of modern volcanism in East Java. The flexural basin which once lay to the north of this arc became uplifted into a fold and thrust belt, corresponding with imbrication and folding of units previously deposited on the Messinian unconformity surface. Relative stratigraphic ages place this event as Late Pliocene-Early Pleistocene, an age consistent with existing published stratigraphic data yielding an uppermost Piacenzian age (1.9 ± 0.05Ma) (Jablonski and Tyler 1999) for the units in question. Since the Pleistocene there has been further uplift, folding Calabrian fluviatile units in the east, and shallow water to terrestrial volcaniclastics further west.

Jablonski, N. G. & Tyler, D. E. (1999). Trachypithecus auratus sangiranensis, A New Fossil Monkey from Sangiran, Central Java, Indonesia. *International Journal of Primatology* **20(3)**, 319–326.

The Impact Of The Palaeocene Eocene Thermal Maximum In The Deep Seas: An Integrated Ichnological, Geochemical And Atratigraphical Approach

John Paul Cummings, David M. Hodgson, Charlotte Jeffery-Abt, Richard H. Worden
STRAT group, Department of Earth and Ocean Sciences, University of Liverpool
Email: johnnyc@liverpool.ac.uk

Keywords: Ichnology, PETM, Clay Mineralogy, SGR, Basque Basin

A Phanerozoic peak in diversity of deep sea trace fossil communities was reached during the early Eocene. This diversification occurred during a period of severe, rapid, high magnitude, hyperthermal climatic events. The most prominent of these events was the Palaeocene-Eocene Thermal Maximum. Sea surface temperatures and bottom temperatures soared by as much as 10°C in as little as 1000 years. Extensive research has been published concerning the biotic and geochemical effect of the PETM. Here the effects of the PETM on benthic macrofauna communities are constrained using an ichnological approach. Detailed ichnological data obtained from 9 localities in the Basque basin, northeast Spain, spanning the mid Palaeocene–early Eocene is presented here. This data not only allows the effects of the PETM on benthic macrofauna communities to be measured but also allows rigorous testing of the utility of trace fossil assemblages in determining submarine fan environments during periods of climatic extremes. High resolution clay mineralogical analyses have been conducted utilising XRD, FT-IR and field based spectral gamma ray (SGR) measurements to give a powerful insight into weathering patterns on the continental hinterland in an attempt to correlate changes in terriginous sediment supply with ichnological diversity and bioturbation intensities. The Nereites, Palaeodictyon and Ophiomorpha rudis subichnofacies of the Nereites ichnofacies remain indicative of mud rich distal fan, sand rich outer-fan and proximal-axial fan environments respectively, during the early Eocene. However occurrences of Ophiomorpha in outer fan and off axis environments become much more common following the PETM and are correlated with several 'spikes' of kaolinite.

A High Resolution Sequence Stratigraphic Model Of Marsdenian (Carboniferous) Sediments, In County Clare, Ireland

Rachael Dale[1], Paul Wignall[1], Owen Sutcliffe[2]
[1]*ESSI, University of Leeds,* [2]*Neftex Petroleum Consultants Ltd*
Email: r.dale@see.leeds.ac.uk

Keywords: Sequence Stratigraphy, Deltas, Carboniferous

During the mid-Carboniferous, the Shannon Basin developed in the County Clare region of Ireland with clastic deposition dominating from the Namurian. In this clastic succession, five well-defined cycles of sedimentation occurred from the mid Kinderscoutian to late Marsdenian that form five cyclothems. The lower three examples have been named, whilst the upper two have retained an informal nomenclature (Cyclothem IV and V). Over the past 15 years, sequence stratigraphic studies have focussed on the lower three cyclothems, leaving the upper cyclothems poorly constrained sedimentologically. Biostratigraphically, Cyclothems IV and Cyclothem V were deposited between Bilinguites bilinguis (R2b) and Bilinguites superbilinguis (R2c1) zones of the Marsdenian, which helps to facilitate the development of an Exxon style-sequence stratigraphic model and a comparison with correlative successions in, Northern England. An interpretation of facies and an analysis of parasequence stacking patterns has enabled the recognition of three fourth-order sequences, whose own organisation allows a third-order stacking to be defined. Between the R2b3 to R2b5 marine bands, the development of mud-prone parasequences that lack sandstones made sequence boundary recognition difficult. Within the R2b5 biozone sand prone parasequences are recognised implying a basinward shift in facies. These sandstones are tentatively interpreted to represent a perched lowstand shelf delta. The duration of this lowstand, and its correlative in Northern England, was short-lived and occurred within one biozone. A potential third-order MFS is recognised that constrains the distribution of a third-order transgressive system tract in the late Marsdenian.

Toward Understanding The Controls On Fe-rich Clay Minerals In Estuaries: A Case Study From The Rio Anllóns Estuary, NW Spain

Patrick J. Dowey, David M. Hodgson, Richard H. Worden
Liverpool Diagenesis Research Group, University of Liverpool
Email: pdowey@liverpool.ac.uk

Keywords: Fe-chlorite, Clay Minerals, Estuary, Modern Analogue, Spain

Chlorite cement in petroleum reservoirs can be responsible for preservation of anomalously high porosity and permeability in deeply buried sandstones. Extensive interrogation of the published literature indicates that Fe-chlorite cements are most commonly recorded in reservoirs of estuarine and shallow marine settings, suggesting a fundamental autogenic control on the formation and/or distribution of Fe-chlorite precursor clay minerals. An understanding of the origin and distribution of chlorite precursor minerals in modern environments could be used as a predictive tool to assess reservoir quality in the subsurface. A number of key questions about the formation and distribution of clay minerals need to be addressed:

1. What control does hinterland geology and climate have on clay mineral formation in coastal sedimentary environments?
2. In what types of coastal depositional settings and environments are Fe-rich clays deposited?
3. What mode(s) of formation of clay mineral grain coats occur in modern environments?
4. What is the long-term preservation potential of clay minerals and clay coats that are formed in these environments?

The Rio Anllóns Estuary, Galicia, NW Spain provides a useful field laboratory to answer these questions because there are relatively low levels of management, a range of depositional environments, a large tidal range, good accessibility, and a hinterland geology which contains Fe-rich rock types. Geomorphic field mapping and detailed logging of m-scale sediment coring was undertaken, combined with analyses of sediment samples using SEM, XRD and FTIR. Initial results show how distribution of Fe-rich clay minerals can vary between depositional environments and with depth.

Toward Understanding The Controls On Fe-rich Clay Minerals In Estuaries: A Case Study From The Leirarvogar Estuary, SW Iceland

Patrick J. Dowey, Richard H. Worden, David M. Hodgson
Liverpool Diagenesis Research Group, University of Liverpool.
Email: pdowey@liverpool.ac.uk

Keywords: Fe-chlorite, Clay Minerals, Estuary, Modern Analogue, Iceland

An understanding of the origin and distribution of chlorite precursor minerals, such as berthierine, in modern environments could be used as a predictive tool to assess reservoir quality in the subsurface as chlorite cement can preserve porosity and permeability in deeply buried sandstones. Extensive interrogation of the published literature indicates that Fe-chlorite cements are most commonly recorded in reservoirs of estuarine and shallow marine settings, suggesting a fundamental autogenic control on the formation and/or distribution of Fe-chlorite precursor clay minerals. Previous work on the geographic distribution of berthierine (Odin, 1988) suggests that it forms principally between the tropics ($\sim 23°$N–$23°$S), with Fe-rich hinterland geology and high sea water temperatures key factors in this process. To test this hypothesis preliminary fieldwork on the Leirarvogar Estuary, SW Iceland (64°N) was undertaken. This location was chosen due to its geographic location, Fe-rich basaltic hinterland geology, macrotidal setting, spectrum of depositional environments, good accessibility and limited anthropogenic impacts. Initial geomorphic field mapping and surface sediment sampling was undertaken, and this has been combined with analyses of sediment samples using SEM, XRD and FTIR, which are presented here.

Odin, G.S., (ed.) 1988. Part B: the Verdine Facies, Green Marine Clays. Amsterdam, *Elsevier*.

Regional Grain-Size Trends In Fluvial Stratigraphy: Quantifying Subsidence Versus Sediment Supply

Robert A. Duller[1], Alex C. Whittaker[1], Juan J. Fedele[2], Amy L. Whitchurch[1], John Armitage[1], Joshua Springett[1], Rosie Smithells[3], William Neal[1], Francis Patton[1], Philip A. Allen[1]
[1]*Imperial College, London,* [2]*St. Cloud State University, Minnesota,* [3]*Keele University*
Email: r.duller@imperial.ac.uk

Keywords: Grain-Size, Self-Similar, Tectonic Subsidence, Sediment Supply

Regional grain-size trends in fluvial successions, together with the migration of specific grain-size discontinuities, contain important information on the overall dynamics of sediment routing systems and their sensitivity to external forcing mechanisms. In detail, the rate of downstream fining in a fluvial system is governed by: (1) sediment supply (calibre and discharge); (2) the spatial distribution of deposition; and (3) the detailed mechanics of sediment transport. A key challenge is exploring how these first two factors control the spatial distribution of grainsize in fluvial successions, without incorporating the latter, which are immeasurable from fluvial successions. Fedele and Paola (2007) address this by developing self-similar solutions for downstream grain-size fining, which have been successfully applied to small-scale field and laboratory experiments, raising the prospect of application to a wide variety of sedimentary basins. We compare model predictions to grain-size data collected from small length-scale (10–40 km) depositional systems, the Eocene Montsor and Collegats/Roca de Peso fan systems of the wedge-top Pobla Basin, Spanish Pyrenees, and from a large length-scale (450 km) depositional system, the Pliocene Broadwater Formation, Nebraska, U.S.A. Our results show that self-similar grain-size solutions provide a powerful means to assess grain-size trends in fluvial successions over a range of physical length scales, and allow decoding of the spatial distribution of deposition and time-averaged sediment discharge.

Fedele, J. & Paola, C. (2007). Similarity solutions for fluvial sediment fining by selective deposition. *J. Geophys. Res.*, **112**, F02038, doi:10.1029/2005JF000409

The Depositional Signature Of Positive Surges In Supercritical Turbidity Currents: Experimental Suggestions For The Origin Of Vertical Transitions In Turbidite Sandstones

Joris T. Eggenhuisen[1], William D. McCaffrey[2]
[1]*Faculty of Geosciences, Utrecht University,* [2]*School of Earth and Environment, University of Leeds*
Email: j.t.eggenhuisen@geo.uu.nl

Keywords: Turbidites, Hydraulic Jumps, Experimental Turbidity Currents

A typical internal vertical organisation is often recognised in ancient deposits of submarine turbidity currents (the "Bouma-sequence"): A massive, badly-sorted division (Ta) is overlain by a fining-upwards laminated division (Tb-e). The lower division has been interpreted as the result of quick deposition from a flow that is carrying a large surplus of sediment over it's carrying capacity. The upper division is the result of various phases of bed-load transport beneath relatively slow sediment fall-out. The two divisions are commonly separated by a by-pass surface, often coated with a thin coarse-grained veneer and scour features. Experimental reproduction of this full sequence has so far eluded researchers so that the coupling between the fluid mechanics of turbidity currents and the vertical transitions observed in their deposits is still unclear. We present vertical profiles of velocity from supercritical experimental turbidity currents moving down a continuous slope and propose that the transition from the rapid suspension dropout of the Ta division to sediment by-pass and scouring may be linked to the passage of a positive surge, a moving type of hydraulic jump.

Flow velocities in the body of turbidity currents are higher than in the head of the flows. Thus, in a Lagrangian framework moving with the speed of the nose of the flow, sediment-laden fluid is translated from the body towards the front and decelerated. The present experiments exhibit an internal hydraulic jump at some distance behind the front where this deceleration takes the flow conditions from supercritical to subcritical. In the Lagrangian frame, the architecture is that of a normal hydraulic jump: fluid passes from a supercritical state upstream, through a hydraulic jump to a subcritical state downstream. However, at any one point that lies in the advancing flow's path, subcritical flow precedes the passage of the hydraulic jump and is followed by supercritical flow.

Evolution Of Submarine Fault Scarp Degradation Complexes: The Middle-Upper Jurassic Of The Halten Terrace, Offshore Mid-Norway

Gavin M. Elliott[1], Paul Wilson[2], Christopher A-L. Jackson[1], Rob L. Gawthorpe[2]
[1]*Department of Earth Science & Engineering, Imperial College London,* [2]*Basin studies & Petroleum Geoscience, School of Earth, Atmospheric and Environmental Science, University of Manchester*
Email: Gavin.Elliott@imperial.ac.uk

Keywords: Syn-Rift, Fault Scarp, Norwegian Shelf, Jurassic, Salt Tectonics

The stratigraphic evolution of the Upper Jurassic of the Halten Terrace, offshore Mid-Norway, was driven by salt-influenced rifting. The late-Middle to Upper Jurassic rift-climax succession is dominated by deep-water claystones of the Melke and Spekk formations, but fine-grained sandstones have been also encountered. These sands are located adjacent to present-day fault scarps, and are thought to represent small fan systems derived from degradation of the Middle to Lower Jurassic Garn and Ile Formation sandstones. In the study area the majority of the Upper Jurassic sedimentary succession, aside from the hemipelagic claystone component, appears to have been derived from the footwall scarps.

The footwall crests show a variety of morphological features, with relatively organised, channellised systems being observed in some cases, in addition to large rotated blocks related to gravitational failure. In contrast to published examples of fault scarp degradation complexes (e.g. Statfjord & Snore), these show a hierarchy of erosion style. In one example, the fault footwall block has undergone significant rotation through its evolution and it is this that has driven syn-rotation collapse. This rotation has resulted in the formation of 1–2 km wide listric fault blocks and also smaller scale erosion features such as channels. The interaction of these tectonic and sedimentary systems reveals a complex erosion history that can be linked to the salt-detachment influenced main bounding fault. Importantly, these observations indicate that in this part of the Halten terrace, sediment derivation from low-relief footwall scarps is more important than regional sedimentary systems during the rift-climax.

Characteristic Ultrasonic Patterns Across The Early Triassic Hardegsen Unconformity In Southern Germany

Claudio M. Filomena, Harald Stollhofen
GeoZentrum Nordbayern, University of Erlangen-Nrnberg, Erlangen, Germany
Email: claudio.filomena@gzn.uni-erlangen.de

Keywords: Unconformity, Ultrasonic, Triassic

The detection of unconformities in monotonous sandstone successions, so-called cryptic sequence boundaries, can be a challenging task (Miall and Arush, 2001). They may be associated with significant petrographic changes over very short distances, particularly expressed by variations in detrital mineral assemblages, cementation, porosity and / or permeability. In the oil and gas industry, unconformities and associated porosity / permeability halos are potentially decisive in the development of hydrocarbon bearing reservoirs. To pinpoint the exact location of unconformities in well log datasets, offsets of sonic log curves are frequently used. In this study, sonic data from outcrop and well core sections in southern Germany are investigated with a mobile ultrasonic tester. The presented sections cover the Early Triassic Middle Buntsandstein Hardegsen Unconformity, mostly comprising a well developed paleosol. In sections where this paleosol is missing,

the location of the unconformity is controversial. Here, the ultrasonic tester is particularly helpful. Remarkable sonic offsets at the unconformity have been detected in all measured sections, correlating with variations in cementation and porosity. Thus the mobile ultrasonic tester may provide a useful and reliable tool to identify an unconformity also in absence of other characteristic features such as paleosols or changes in grain size or dip angle.

Miall, A.D. and Arush, M. (2001). Cryptic sequence boundaries in braided fluvial successions. *Sedimentology*, **48(5)**: 971–985.

Sediment Transport Processes In Ancient Mud-Dominated Successions; A Comparison Of The Processes Of Sediment Deposition And Dispersal In Shallow (Up-Dip) Shelfal And Distal (Down-Dip) Basinal Environments

Samer Ghadeer[1], Joe H. S. Macquaker[2], Colin R. Hughes[1]
[1] *University of Manchester,* [2] *Memorial University of Newfoundland*
Email: Samer.Ghadeer@postgrad.manchester.ac.uk

Keywords: Mudstone, Ripple, Gutter Cast

There are few studies of sediments deposited on ancient continental shelves that explicitly connect up-dip lithofacies variability in proximal sandy mudstone deposits with coeval variations down-dip in distal "shaley" basinal deposits. Most studies treat these palaeoenvironments in isolation, interpreting facies differences in updip deposits to changes in storm and tidal processes, in contrast to downdip, where facies differences are typically interpreted in terms of changing bottom water anoxia and varying primary production. The processes that control lithofacies variability are investigated in ancient, mud-dominated succession (Cleveland Basin, UK) using a combination of field observation, hand-specimen descriptions, optical, electron optical, and geochemical methods. These techniques reveal stacked successions of sharp-based, upward-fining, thin-beds (< 20–5 mm thick) that are composed of four main lithofacies types that also contain a wide variety of micro-textural fabrics. These include: (1) clay-bearing, silt-rich mudstones, (2) silt-bearing, clay-rich mudstones, (3) clay-rich mudstones; and (4) clay-, calcareous nannoplankton-, and organic carbon-bearing mudstones. These data indicate that while there are differences in the balance of sedimentological process occurring in different parts of the basin, there are also similarities between the proximal and distal settings. So while updip, most of the sediment was delivered by detrital inputs to the basin and downdip primary production was responsible for much of the sediment production, the influence of advective sediment transport is present in both. This is evidenced by the fact that microfabrics such as ripples, gutter casts and wave-enhanced gravity currents of fluid mud, likely facilitated by storm waves, are present in both.

From A Dilute Turbidity Current To A Concentrated Flow Via Lofting

Charlotte Gladstone[1], David Pritchard[2]
[1] *University of Cambridge,* [2] *University of Strathclyde*
Email: lotty@bpi.cam.ac.uk

Keywords: Transition Flow, Turbidity Current, Linked Debrite, Reversing Buoyancy, Lofting

A turbidity current that contains fresher and/or warmer less dense water than its surroundings may initially be denser than the ambient and propagate as a ground-hugging flow, but later reverse in buoyancy as its bulk density decreases through sedimentation to become lower than that of the ambient seawater. This reversal in buoyancy may be a significant mechanism controlling the structure and facies of turbiditic deposits. Buoyancy reversal followed by lofting may directly affect the relative distribution of fine and coarse material in the deposit, while buoyancy reversal itself may mediate the transformation between dilute and highly-concentrated suspension flows, especially in distal regions, and thus lead to the formation of complex turbiditic beds: in particular, the generation of distal cogenetic debrites may be possible (Pritchard & Gladstone, 2009). Field evidence from the Soufriere Hills Volcano, Monserrat, suggests that similar transformations occur within dilute pyroclastic density currents, where a mobile, basal concentrated flow, termed a surge-derived pyroclastic flow, develops through rapid sedimentation from the suspended load of the parent flow (Druitt et al., 2002).

Pritchard, D. and Gladstone, C (2009) Reversing buoyancy in turbidity currents: developing a hypothesis for flow transformation and for deposit facies and architecture, *Marine & Petroleum Geology*, **29(10)**, 1997–2010.
Druitt, T.H., Calder, E.S., Cole, P.D., Hoblitt, R.P., Loughlin, S.C., Norton, G.E., Ritchie, L.J., Sparks, R.S.J. and Voight, B., (2002). Small-volume, highly mobile pyroclastic flows formed by rapid sedimentation from pyroclastic surges at Soufriere Hills Volcano, Montserrat: an important volcanic hazard. *Geological Society of London*, Memoir **21**, 263–279.

Marsdenian Mudstones, Implications For Shale Gas Source Rock Development

Jennifer Graham[1], Sarah Davies[1], Joe Macquaker[2], Mike Norry[1]
[1] *University of Leicester,* [2] *Memorial University, Newfoundland*
Email: jjg12@le.ac.uk

Keywords: Marsdenian, Mudstones, Geochemistry

Organic-rich mudstones are commonly considered to be deposited in low energy settings as a consequence of suspension settling. Recent research is causing a new consensus to emerge, which suggests that mudstones were deposited in response to a rather more complex interaction of higher energy processes and exhibit significant spatial and temporal variability in spite appearing homogenous in hand specimen. This study aims to investigate the nature of the variability present in marine mudstones by determining: (1) key mechanisms responsible for fine-grained sediment accu-

mulation on shelves and (2) controls on type and amount of organic matter preserved in these settings.

High-resolution samples of a stratigraphically well-constrained (by Marine Bands) Marsdenian mudstone succession from 2 locations across England have been collected. Lithofacies variability present has been constrained by field and hand specimen analysis integrated with whole rock geochemical (XRF, XRD and Carbon/Sulphur analysis), palaeontological and detailed petrographic investigations.

The mudstones in this interval contain varying proportions of silt and clay as well as significant amounts of organic carbon (5–9.4% in the marine intervals and < 0.1 to 4.6% in enclosing non-marine mudstones). Most of the organic carbon is Type III kerogen. The clay and organic carbon-rich mudstones are enriched in As, Mo, U and V and contain lower abundances of Zr. In contrast mudstones enriched in silt are depleted in the aforementioned elements and enriched in Zr. Lithofacies and compositional variability are linked and can be tied to sediment dispersal mechanisms, length of sediment transport path and primary production during deposition.

Controls On Gross Sandbody Distribution And Stratigraphic Architecture In Coastal-Plain Strata, Blackhawk Formation, Wasatch Plateau, Utah

Gary J. Hampson[1], M. Royhan Gani[2], Hiranya Sahoo[2], Thomas O. Jewell[1], Kathryn A. Sharman[1], Nawazish Irfan[1,3]

[1]*Department of Earth Science and Engineering, Imperial College London,* [2]*Department of Earth and Environmental Sciences, University of New Orleans,* [3]*present address: Pakistan Petroleum Limited.*

Email: g.j.hampson@imperial.ac.uk

Keywords: Fluvial Sandbody, Connectivity, Coastal Plain, Avulsion, Incised Valley

Current models of coastal-plain facies architecture are tested using data from the Cretaceous Blackhawk Formation, which forms a thick (200–300 m) interval in a continuous, 100 km long escarpment along the eastern Wasatch Plateau, central Utah. Overall, the Blackhawk Formation exhibits trends of increasing size, abundance and interconnectedness of major fluvial channel-fill sandbodies from (1) its base to its top, and (2) south to north. The first pattern coincides with a change from rapidly subsiding, coal-bearing, lower coastal plain (few, small sandbodies) to slowly subsiding, coal-poor, upper coastal plain (abundant, large sandbodies). The second pattern coincides with thickening of the coastal-plain section from south to north, and is interpreted to reflect the location of a long-lived sediment entry point in the more rapidly subsiding northern part of the transect. There are significant local variations from these general trends. Some stratigraphic intervals in the lower part of the formation contain anomalously thick, wide sandbodies that are confined to valleys. In the middle and upper part of the formation, vertical and offset lateral stacking of sandbodies produces connected clusters that do not occur within valleys or at distinct stratigraphic intervals; these clusters are interpreted to record variations in avulsion style. The predominance of valley fills in the lower Blackhawk Formation likely reflects a lower coastal-plain setting, with valleys formed by the headward retreat of knick-points from falling-stage and lowstand shorelines. The occurrence of "avulsion clusters" in the middle-to-upper Blackhawk Formation likely reflects autocyclic processes at a regional scale on the upper coastal plain.

An Assessment Of The CO_2 Storage Potential Around Scotland

Stuart Haszeldine, Mark Wilkinson

School of GeoSciences, The University of Edinburgh and Scottish Centre for Carbon Storage

Email: stuart.haszeldine@ed.ac.uk

Keywords: Carbon Storage, North Sea, Saline Aquifer

A glossy report of the CO_2 storage potential around Scotland was presented to the assembled media by Rt Hon Alex Salmond MSP in Edinburgh Castle earlier this year. Storage in both depleted oil / gas fields and saline aquifers in the UKCS were assessed. Saline aquifers have the largest storage potential but also significant uncertainty regarding storage capacity. From 80+ saline aquifers studied, ten were identified with a total potential CO_2 capacity in the range 4,600–46,000 Mt; more than 200 years of Scotland's CO_2 output from its major fixed industrial sources. Initial costs of assessing potential saline aquifers are likely to be considerably higher than for oil and gas fields which have previously been fully evaluated during exploration and production: new boreholes are likely required. The majority of the UK's oil fields lie in Scottish waters, from these 29 were identified as having potential for CO_2 storage, along with four gas condensate fields and one gas field. CO_2-Enhanced Oil Recovery (EOR) may act as a stimulus for CCS especially if developers come to expect that the price of oil will be sustained at over US 100 per barrel for the period of their investment. The research was undertaken by BGS, Heriot-Watt University and University of Edinburgh, as members of the Scottish Centre for Carbon Storage, Element Energy, Senergy, University of Aberdeen, CO_2DeepStore, AMEC and Pöyry. It was funded by a broadly based consortium of industry organisations and the Scottish Government, who was the single largest funder.

Report at: http://www.geos.ed.ac.uk/sccs/regional-study/.

CO_2 Storage Capacity Of The Bunter Sandstone Formation, UK Southern North Sea

Niklas Heinemann[1], M. Wilkinson[1], G. Pickup[2], R. S. Haszeldine[1]

[1]*School of GeoSciences, The University of Edinburgh, The Kings Buildings, West Mains Road, Edinburgh,* [2]*Institute of Petroleum Engineering, Heriot-Watt University, Edinburgh*

Email: N.Heinemann@sms.ed.ac.uk

Keywords: CO_2 Storage, Pressure Buildup, Saline Aquifer, Numerical Simulation

One of the most promising mitigation strategies for green-

house gas accumulation in the atmosphere is the capture of CO_2 from combustion power plants and other major industrial CO_2 emitters and its storage in deep saline aquifers. If CO_2 is injected into subsurface rock formations, it encounters native brine which has to be compressed or displaced. The corresponding fluid pressure increase is an important factor which determines the CO_2 storage capacity of saline aquifers. The pressure increase controls the amount of CO_2 which can be injected into the formation before fracturing or faulting could compromise the storage operation.

If a grid of wells is used for injecting CO_2 into a storage site, the pressure of the wells will interfere with each other and cannot dissipate, and so the distance between the injection wells is a crucial parameter. We used ECLIPSE compositional simulation package (E300) (Schlumberger 2008) to determine the average well spacing for a large scale injection scenario into the Bunter Sandstone formation, UK southern North Sea, and used these results for a storage capacity estimation. Our results show that after an injection period of 30 years with an injection rate of 1 Mt of CO_2 per year per well, the storage capacity estimation is lower than previous static capacity estimates by a factor of approximately 0.5. The main conclusion is that if there is no mechanism for pressure dissipation during the injection process than fluid pressure increase has a significant impact on the calculated CO_2 capacity.

Bacteria Versus Burial: What Is Responsible For The Cementation Of Liassic Ammonite Chambers?

Jim Hendry[1], Jim Marshall[2]
[1] *University of Portsmouth, School of Earth and Environmental Sciences,* [2] *University of Liverpool, Department of Earth and Ocean Sciences*
Email: jim.hendry@port.ac.uk

Keywords: Ammonites, Lias, Cementation, Luminescence, Isotopes

Ammonites from the Whitby Mudstone Formation (Toarcian, NE Yorkshire) are well known from coastal exposures, and from fossil shops worldwide where their excellent preservation and pyritic sheen make them popular with collectors. Little attention has been paid to the cements occupying the chambers of these ammonites. In simple terms a pore-lining brown cement fringe is followed by one or more void-filling, yellowish to colourless sparry cements. We are investigating the cementation in detail, with two objectives: (i) to determine whether the brown cements are biofilm-related bacteriogenic precipitates as in septarian concretions; and (ii) to ascertain whether the cementation sequences records a history of pore fluid isotopic and chemical evolution during burial of the Cleveland Basin. We report our preliminary results.

Combined light microscopy, staining, photoluminescence (PL), cathodoluminescence (CL) and backscatter scanning electron microscopy (BSEM) reveal a complex and variable cementation history within and between the ammonites. Earliest fibrous cements have unusual botryoidal fabrics, heterogeneous distributions, and bizarrely inconsistent chemical zonations when observed using the different techniques. Subsequent sparry cements (calcite, dolomite, siderite) also differ between ammonites and even in adjacent chambers. These late cements are strongly zoned in BSEM but not in PL or CL. Early cement δ18O values range widely from -4.1 to -14.0 $^0/_{00}$ VPDB, the lowest values being similar to the late cements. Pooled δ13C values mostly fall between -8.3 and -14.4 $^0/_{00}$ VPDB.

The petrographic and geochemical complexity is interpreted as resulting from bacterially-mediated biofilm microenvironments and localised ultra-fine scale alteration during deep burial and high heat flow.

Relative Timing Of External And Internal Submarine Levee Construction And The iImplication For Submarine Fan Growth

Hodgson, D.M.[1], Kane, I.A.[2]
[1] *School of Environmental Science, 4 Brownlow Street, University of Liverpool* [3] *School of Earth and Environment, University of Leeds*
Email: hodgson@liv.ac.uk

Keywords: Submarine Levees, Precursor Lobes, Submarine Fan Growth

External submarine levees are constructed by parts of flows that spill out of channel belt confinement, and internal submarine levees form from flows that spill out of thalweg channels but cannot escape the main bounding surface. External levees form during the evolution of submarine channels, but their exact stratigraphic relationship is rarely observed or preserved. Commonly identified at the base of external levee successions are thick and coarse-grained sandstones. It is difficult to envisage these deposits being supplied by flows escaping significant erosional and/or constructional confinement, and therefore they are interpreted as frontal, or precursor, lobes. Furthermore, overlying deposits form an overall upward and lateral fining and thinning trend that indicates decreasing flow spill through time. To account for these observations a model is presented where as the external levee is constructed, flows at that point on the slope are increasingly confined and efficient in bypassing sediment farther into the basin. Therefore, external levee successions form during periods of increasing sediment supply (waxing conditions and basinward growth of submarine lobes). The time of most efficient sediment supply is when the flows are most confined. Ultimately the channel belt will aggrade, driven by decreasing flow magnitude and frequency, or lowered channel gradient (waning conditions and landward stepping of submarine lobes). The excess accommodation developed by entrenchment and/or external levee construction promotes the development and preservation of internal levee deposits. In this model, external levees form during waxing conditions (base-level fall), and internal levees form during waning conditions (base-level rise).

Empirical Understanding Of Sedimentary Architecture

John Howell[1,3], Simon Buckley[1], Andreas Rittersbacher[1], Nicole Richter[1], Kevin Keogh[2]
[1] *Centre for Integrated Petroleum Research, University of Bergen, Norway,* [2] *Statoilhydro, Stavanger, Norway,* [3] *Also Rocksource ASA, Bergen, Norway*

Email: john.howell@cipr.uib.no

Keywords: Stratigraphic Architecture, Fluvial Systems, Database

Stratigraphic architecture is controlled by factors which include climate, subsidence and sediment supply. This project aims to investigate these controls empirically by compiling a very large dataset of new and publically released information on sediment body geometries. The database includes a standardized nomenclature for sand body shape and is fully searchable on a series of different parameters including, depositional system, tectonic setting, palaeo-climate, palaeo-latitude, age and grainsize. The database has three key applications:

1. To allow the empirical investigation of the interaction of key factors on sandbody and shale geometries
2. To provide a database of body geometry for reservoir modelling
3. To provide a repository for a large volume of data from a variety of vintages and sources.

Publically released data from both published and unpublished sources dealing with both modern and ancient systems are currently being loaded into the dataset. New information have also been collected specifically for this project using novel data acquisition methods including oblique aerial, helicopter based lidar scanning (heli-lidar). The helilidar allows the very rapid collect of long (ten's km) geometrically constrained, 3D datasets from otherwise inaccessible areas. New methods for the processing and handling of these very large Virtual Outcrops have been developed which allow their visualization and the extraction of large volumes of geometrically constrained sediment body data.

Emplacement Of The El Golfo And Icod Turbidites In The Moroccan Turbidite System: Implications For Landslide Mechanisms And Turbidity Current Processes

James E. Hunt, Russell B. Wynn, Peter J. Talling, Michael Frenz, Doug G. Masson
National Oceanography Centre, Southampton
Email: jeh2g08@soton.ac.uk

Keywords: Turbidity Current, Subunit Facies, Volcaniclastic Landslide, Canary Islands

Two widespread volcaniclastic turbidites in the Moroccan Turbidite System can be linked to the volcanic flank collapses of northern El Hierro (El Golfo landslide; dated at ∼15ka) and Tenerife (Icod landslide; dated at ∼160,000ka). The distribution of these volcaniclastic turbidites is significant, as it indicates that both flows have travelled along or up-slope through the Agadir Basin for distances up to ∼1,000km from source. Furthermore, the sedimentary facies of these two deposits includes a distinctive series of vertically stacked sequences of turbidite sands interbedded with turbidite muds. The presence of this 'subunit' architecture within these two turbidites in the Agadir Basin can be linked to either (1) multistage retrogressive failure of the source landslide, or (2) basin margin reflections of the turbidity current.

A multidisciplinary approach has been adopted to study both of these widespread deposits, in an attempt to decipher whether multistage retrogressive failure is the primary cause of the stacked subunit architecture. Analysed datasets include: visual logs, grain size analysis, petrographic composition, bulk and grain-specific geochemistry and petrophysics.

Initial results for the Icod turbidite are encouraging, with five regular subunit packages being identified and correlated. Variations in subunit mineralogy and bulk geochemistry, in addition to grain size analysis, invoke a multistage event generated at source rather than an effect of flow reflection. Furthermore, investigations of the Icod turbidite demonstrate added complexities to the process of its emplacement, with grain size breaks and internal erosion surfaces indicating flow bypass, convolute rippled laminations indicating periodic dewatering, and a widespread contorted mudcap facies indicating post-depositional remobilisation.

An Investigation Of Volcaniclastic Turbidite Emplacement In The Canary Basin: Implications For Volcanic Landslide Events

James E. Hunt, Russell B. Wynn, Aggeliki Georgiopoulou, Vicky Catterall, Doug G. Masson
National Oceanography Centre, Southampton
Email: jeh2g08@soton.ac.uk

Keywords: Turbidity Current, Volcaniclastic, Landslide, Canary Islands

Giant landslides are prevalent during the erosional phase of volcanic island evolution, and have been found to affect the islands of Tenerife, La Palma and El Hierro in recent geologic time (Masson et al. 2002, and references therein). These landslides are potentially tsunamigenic, and thus warrant detailed study to understand their failure/emplacement processes and access their recurrence interval. Many landslides and debris avalanches generate long runout turbidity currents. This study will provide an overview of these volcaniclastic flow deposits recovered in cores from around the western Canary archipelago. The aim will be to constrain event frequency, pathways and processes, in addition to resolving the source failure mechanisms.

The studied cores have been visually logged and mineralogical analysis of turbidite samples carried out. Provenance of turbidites has been ascertained using a variety of bulk and grain-specific geochemical techniques. In addition, petrophysical examinations have been completed to enable correlations between cores, which have been aided by the use of biostratigraphic coccolithophore dating. Foraminiferal studies have yielded ?18O curves using stable isotope analytical techniques, resulting in correlation of events to key climatic episodes.

Volcaniclastic turbidites demonstrate a variety of compositions, supporting deposition from 1) erosional outflows from barrancos, 2) large scale flank collapses, and 3) remobilisation of volcanic and biogenic material previously deposited on seamounts. Provenance analysis of individual events

has highlighted the high flux of turbidites derived from El Hierro compared to Tenerife or La Palma. Furthermore, the presence of thick (>1.0m) granular turbidite deposits in the El Julan Fan (southwest El Hierro) has contributed to the generation of the Canary Debris Flow "concrete facies".

Masson, D.G., Watts, A.B., Gee, M.J.R., Urgeles, R., Mitchell, N.C., Le Bas, T.P., & Canals, M. (2002). Slope Failures on the Flanks of the Western Canary Islands. *Earth-Science Reviews*, **57**, 1–35.

3D Seismic Imaging Of Sediment Remobilization And Fluid Flow—The Need For Outcrop Analogues

Mads Huuse
Basin Studies Group, SEAES, University of Manchester
Email: mads.huuse@manchester.ac.uk

Keywords: 3Dseismic, sediment remobilization, fluid flow, analogues

3D seismic images reveal spectacular insights into the large-scale and basin-wide distribution of subsurface sediment mobilization and fluid flow phenomena that are never or only rarely reported from outcrop. This presentation will highlight the occurrence of large-scale sand remobilization, fluid flow pipes and pockmarks and ask whether similar-scale outcrop analogues for these phenomena exist and have either been ignored, forgotten or misinterpreted.

Cenozoic Coolwater Carbonate Sediment Waves On The Shelf Break Of The Great Australian Bight

Mads Huuse[1], the Galathea 3 Leg 8 team[2]
[1]*Basin Studies Group, SEAES, University of Manchester,* [2]*Universities of Aarhus and Copenhagen*
Email: mads.huuse@manchester.ac.uk

Keywords: Carbonate, Sediment Waves, Great Australian Bight

A spectacular field of late Cenozoic coolwater carbonate sediment waves is located on the outer shelf and shelf break of the Great Australian Bight. Previous work based on ODP Leg 182 site survey and core data suggested the large-scale bedforms were bryozoan reef mounds. However, more recently acquired multibeam bathymetry and additional high-resolution seismic data reveals a highly elongate nature of the bedforms reminiscent of large-scale bedforms normally attributed to physical sedimentation under the influence of strong bottom currents: 1) contourite wave fields, more often seen in continental slope settings and 2) transverse sediment waves, possibly associated with shelf edge cascading. Both of these models can be accommodated by the existing core data assuming the currents that shaped the wave field also facilitated the growth of bryozoans on the wave crests. The exact mode of formation is as yet not unequivocally determined but seems to imply a much greater physical sedimentation component than the largely biogenic accumulations previously invoked.

Seismic Images Of Glaciogenic Structures And Deposits Offshore NW Europe - Analogues For The Palaeozoic Of North Africa?

Mads Huuse[1], the GRASP team[2]
[1]*Basin Studies Group, SEAES, University of Manchester,* [2]*http://grasp.citg.tudelft.nl/*
Email: mads.huuse@manchester.ac.uk

Keywords: Glaciogenic, Offshore, Europe, Seismic

Seismic images from the NW European continental shelves display a variety of features attributable to erosion, deposition and deformation associated with the late Cenozoic glaciations. Glaciogenic structures range in size from tens to several hundred kilometres long ice stream depressions, and tens of km long mega-scale glacial lineations, to several tens of km long, few km wide and hundreds of metres deep tunnel valleys and glacial tectonics involving hundreds of metres long thrust blocks, down to few tens of metres wide and metres deep iceberg scours that can be seen at several levels through the Plio-Pleistocene from the Dutch North Sea to the Atlantic Margin. In NW Europe tunnel valleys serve as prolific aquifers whilst offshore glaciogenic sediments may contain hydrocarbons in hazard or reserves quantities or provide shallow reservoirs for carbon storage. Anomalous fluids and lithologies associated with the glaciogenic sequences further cause velocity anomalies of both regional and local nature, affecting the seismic imaging of underlying prospectivity. In North Africa, the late Ordovician glaciogenic sequence contains large hydrocarbon reserves, the exploitation of which is currently hampered by an incomplete understanding of these deposits and it is hoped that lessons may be learned by comparing the Pleistocene and the ancient that may enhance the efficient exploitation of the latter. This poster highlights the different manifestations of these features in 2D and 3D seismic data, emphasising their morphology and context with reference to the NW European glaciations and comment on their suitability as analogues for Palaeozoic hydrocarbon plays.

Sedimentology, Ichnology And Stratigraphic Development Of A Major Retrogradational, Shelfal Deltaic Succession In The Middle Miocene Of NW Borneo

Christopher A-L. Jackson[1], Howard D. Johnson[1], Christopher T. Baldwin[2]
[1]*Department of Earth Science & Engineering, Imperial College, London,* [2]*Sam Houston State University, Department of Geography and Geology, USA*
Email: c.jackson@imperial.ac.uk

Keywords: Deltas, Shelf Margin, NW Borneo, Ichnology, Stratigraphic Architecture

Outcrops on Labuan Island, offshore NW Borneo, expose a ca. 500 m thick, Early to Middle Miocene succession that passes from; (i) a lower, upwards-shallowing succession which documents the progradation of an unstable slope margin, followed by an abrupt basinwards shift, and the formation of a sequence boundary and associated incised valley complex; into (ii) an upper, broadly retrogradational succession comprising coarsening upward shelfal, river- to

wave-dominated deltas. This study concentrates on the younger, retrogradational succession, which consists of a series of 20–30 thick, coarsening upward units. The lower coarsening-upwards packages are dominated by muddy to sandy heterolithic facies with relatively low levels of low diversity bioturbation. The upper coarsening-upwards packages are sandier, hummocky cross-stratified and show an overall increase in diversity and absolute numbers of burrows (dominated by Skolithos/Cruziana ichnofacies and associated Ophiomorpha and Gyrolithes). This upward change in lithofacies and ichnofacies is interpreted to record a gradual change from more river-influenced deltaic conditions in the lower part to increased wave- and storm-influenced deltas in the upper part. This is consistent with overall biogenic responses, which appear to capture differences in "water quality", with flood-related pulses of high mud content punctuating an otherwise normal salinity margin. These changes may reflect either a temporal shift in the position of river mouths or a basin-wide change towards a higher-energy wave regime. Observations from this study will be placed within their regional geological context, and the implications for exploration and production along the NW Borneo margin will be highlighted.

How Valid Are The Climatic Signals Derived From Clay Mineral Assemblages? Examples From The Mesozoic Strata Of The U.K.

Christopher V. Jeans
Department of Geography, University of Cambridge
Email: cj302@cam.ac.uk

Keywords: Climate, Clay minerals, Validity, Mesozoic UK

Clay mineral assemblages are being used increasingly as an important tool in reconstructing Mesozoic climates in Europe. A pertinent question that needs discussion is the reliability of relating the type and variation of clay mineral assemblages to changes in climate. Examples from the Jurassic and Cretaceous strata of the British Isles will be discussed.

The Recognition Of High-resolution Base-level Changes In Coal Seams

Rhodri M. Jerrett[1], Stephen S. Flint[1], David M. Hodgson[1], Roy C. Davies[2]
[1]*School of Environmental Science, University of Liverpool, UK.,* [2]*E.ON Ruhrgas Norge, Stavanger, Norway*
Email: rhodders@liv.ac.uk

Keywords: Coal, Appalachian Basin, Sequence Stratigraphy, Petrology

Organic sedimentary rocks, such as coal and carbonaceous shale, preserve high-resolution records of ancient water-table (base-level) changes. In paralic (marine-influenced) settings, water-table (base-level) fluctuations can be correlated with coeval changes in relative sea-level. However, in continental strata, they may also respond to climatic fluctuations. By analysing variations in the internal composition of coal seams it is possible to investigate high-resolution accommodation changes during their formation. This study applies recently developed models for identifying high-resolution accommodation changes in coal-bearing strata to a total of ten coal seams deposited over ∼1 Ma in the Westphalian B (Duckmantian, Atokan) Four Corners Formation of the Central Appalachian Basin, USA. The number of coals included in this study and the number of samples analysed makes it one of the largest studies of its kind to have been undertaken in a single, continuous coal-bearing succession. Systematic changes in maceral and mineral composition of the coals enable the identification of subtle changes in depositional style and accommodation setting of peat accumulation throughout the deposition of the Four Corners Formation. By plotting these data on conceptual coal facies diagrams, it is possible to demonstrate a long-term trend of decreasing accommodation, followed by increasing accommodation. This is consistent with the record of accommodation change interpreted from the clastic strata of the Four Corners Formation, however, the coal seams also preserve a record of very high-resolution accommodation changes within each individual coal.

The Stratigraphic Transition From Slope To Shelf

George E. D. Jones, David M. Hodgson, Stephen S. Flint
University of Liverpool
Email: george.jones@liverpool.ac.uk

Keywords: Karoo Basin, Shelf-edge Deltas

The Waterford Formation overlies the Laingsburg and Fort Brown Formations (basin-floor to channelised submarine slope), and is overlain by the fluvial Beaufort Group, it is interpreted to represent the overall stratigraphic transition from upper slope to shelf environments of deposition. This study represents the first detailed research undertaken on the shelf-edge deposits of the Waterford Formation in the Laingsburg area, and presents an opportunity to examine an outcrop analogue of the well-documented seismically imaged clinoforms. The object of this study is to better understand the variability of the shelf to slope transition across strike and down dip. Work to date has identified an overall progradational succession (∼500 m thick) that coarsens and thickens upward. The succession is divided into three parts: 1) a ∼80 m thick lower portion that is characterised by 10–25 m thick coarsening upward interbedded siltstone and sandstone cycles; 2) a ∼240 m thick middle portion of 15–30 m thick coarsening upward cycles, which are dominated by numerous soft-sediment deformation units (debrites, slides, foundered beds) and thick sharp-based and sharp-topped sandstones; 3) a ∼200 m thick upper portion, which consists of alternating thin-bedded siltstone and thick-bedded sandstones units with little deformation. These three divisions are interpreted to be different environments of deposition, from prodelta, to stacked shelf-edge deltaics, to shelf deposits.

Marginalised In Sedimentological Society: Submarine Channel Levees

Ian A. Kane[1], David M. Hodgson[2]
[1]*School of Earth and Environment, University of Leeds,* [2]*Department of Earth and Ocean Sciences, University of Liverpool*

Email: i.a.kane@leeds.ac.uk

Keywords: Submarine Channel, Levee, Sedimentology, Turbidite

Submarine channel-fills form important hydrocarbon reservoirs in many areas of the world; they also commonly form dramatic outcrops which attract the attention of geologists. Consequently, their complex architectures and morphologies have been a focus for sedimentary and stratigraphic research over the past three decades. In contrast, levees that form adjacent to submarine channels, and build through overspill of partly channelised flows, have received less attention. This is despite them representing a primary depositional record coeval to the evolution of their genetically related channels and/or down dip deposits. The assumed simplicity of levees may be part of the reason that they have received less attention, combined with the fact that ancient outcrops are prone to weathering due to their fine grained nature; and that confident identification in outcrop and subsurface is not unambiguous. Thin-bedded sections may be encountered within many wells, but establishing criteria to distinguish between large scale 'external' levees and smaller scale 'internal' levees, and other channel margin thin-beds is problematic. In addition, intra-levee stratigraphy, hierarchies of levee elements, and stacking patterns of levees have not been developed and applied in a similar way to that of channel-fills. Taking this approach could provide important information on the evolution and stacking of adjacent channel-fills and the down-dip extent of sand. Criteria for the recognition of levee subenvironments, and a suggested hierarchical nomenclature, are drawn from the outcropping Upper Cretaceous Rosario Fm. of Baja California, Mexico, and from the late Permian Laingsburg Fm. of South Africa.

Characterising The Paleocene Submarine Fans Of The Central North Sea: Observations From Seismic And Core Analysis

Ben Kilhams[1], Adrian Hartley[1], Mads Huuse[2], John Marshall[3]
[1]*Department of Geology and Petroleum Geology, University of Aberdeen,* [2]*School of Earth, Atmospheric and Environmental Sciences, University of Manchester,* [3]*Shell E+P Europe, Altens Farm Road, Aberdeen*
Email: ben.kilhams@abdn.ac.uk

Keywords: Turbidites, Central North Sea, Seismic, Core

The Paleocene submarine fans of the Central North Sea are important petroleum reservoir units and, as such, have an extensive associated dataset of 3D seismic, well logs and core material. The provision of these datasets by Shell E+P Europe has enabled a regional-scale re-evaluation of such deposits. Observations from seismic and core analysis are presented as part of an ongoing PhD project which aims to map the reservoir quality and seismic stratigraphy of the Paleocene Maureen and Mey sandstone members and advance our scientific understanding of the syn- and post-depositional dynamics within the submarine fans.

The use of regional seismic data allows observations to be made about the extent, thickness, net to gross, bathymetric interaction and temporal evolution of the submarine fans. Observations from seismic data benefit greatly by comparison with core material. Currently, 21 different cores have been studied to evaluate the types of facies present and how these relate to bed connectivity, grain size distribution and porosity and permeability trends. This has enabled seismically derived maps to be ground-truthed and improved.

The eventual integration of geophysical, petrophysical and sedimentological observations into one database will enable powerful interpretations to be made with academic and industrial applications. Examples are presented of potential scientific advances including clarification of our understanding of the evolution of source material and an evaluation of the interaction of turbidites and topography.

The authors wish to thank PGS for the use of the Central North Sea MegaSurvey.

Reservoir Characterisation Of Barren Fluvial Sequences Using Rock-typing Analyses Of Core And Cuttings—Schooner Field, Southern North Sea, UK

Wendy Kitson[1], Matthew Power[1], Andrea Moscariello[2], Suzanne Burns[3], Deborah Walker[3]
[1]*SGS UK Ltd, Ellesmere Port,* [2]*Delft University of Technology,* [3]*SGS UK Ltd, Aberdeen*
Email: wendy.kitson@sgs.com

Keywords: Cuttings, Core, Mineralogy, QEMSCAN , Rock-typing

Accurate reservoir modelling relies primarily on the type, quality and amount of subsurface available data. Despite recent improvements in the resolution and reliability of data acquisition and interpretation tools, both using seismic and sophisticated wire line logging techniques, real direct reservoir observation is still represented primarily by cores or sidewall cores. Because of the operational complications and high costs associated with this type of data acquisition, cores or side-wall cores are typically limited to either a portion of the reservoir section, or to a small number of wells in a given area. These constraints inevitably raise questions as to how representative the core data are, especially when used to describe complex reservoirs characterised by lateral and vertical heterogeneity in facies, geometry and properties. The other direct type of subsurface data which are typically extracted "freely" from the entire reservoir sections are drill cuttings. Depending on drilling techniques cuttings can be collected at high-frequency intervals, providing a good vertical coverage and representation of the interval of interest. They are extracted from each well and are therefore aerially and vertically more statistically meaningful when compared with sparse and incomplete core data. This poster presents the results of a study made on a well known heterogeneous, clastic reservoir and demonstrates the value of high-resolution analysis of core and cuttings material. Automated mineralogical and textural analysis using ARQ (Advanced Reservoir Quality) technology has proven to be a fast, reliable and cost effective technique for rock-typing and reservoir characterisation.

Sedimentology And Sequence Stratigraphy Of The Lower Ferron Sandstone In Central Utah

Tore G. Klausen[1], John A. Howell[2]
[1]*Department of Geosciences, University of Bergen,* [2]*Centre for Integrated Petroleum Research, University of Bergen*
Email: Tore.Klausen@student.uib.no

Keywords: Wave Dominated Shoreface, Coal Deposits, Lower Ferron, Subsurface Modelling

Deposition of the Ferron Sandstone Member occurred during the widespread regression of the Western Interior Seaway during the Turronian. The Ferron is informally subdivided into two units. The Upper Ferron, ferronensis sequence is well exposed as a shallow marine and coastal plain clastic wedge along the edge of the Wasatch Plateau in central Utah. In contrast the The Lower Ferron, the hyatti sequence, has previously only been documented in the subsurface, where is forms a major coal bed methane accumulation in the Drunkards Wash, Buzzard Bench and Helper fields around the town of Price.

The aim of this study is improve understanding of the stratigraphy and sedimentology of the Lower Ferron unit. Correlation of over 200 borehole logs coupled with outcrop studies have resulted in a new depositional model for the system. This model suggest that the Lower Ferron is comprised of a series of aggradational to weakly progradational shoreface parasequences which prograded in an east to south-easterly direction. The model also suggests that a series of outcrops, previously interpreted as long shore bars, are in fact the downdip expression of these shorefaces. This model is supported by extrapolation of the facies tracts mapped in the subsurface, geometric reconstruction of the large scale structures and correlation of newly described bentonite horizons. This new model provides an improved understanding of the large scale stratigraphy of the Mesaverde clastic wedge in the San Rafael Swell area.

Evaluating A Shape-based Sand Wave Migration Predictor From Swath Bathymetry Data In The Irish Sea

Katrien J.J. Van Landeghem[1], Darren Wilcockson[1], Andy J. Wheeler[2], Neil C. Mitchell[3]
[1]*School of Ocean Sciences, Bangor University,* [2]*Department of Geology & Environmental Research Institute, University College Cork,* [3]*School of Earth, Atmospheric and Environmental Sciences, University of Manchester*
Email: katrien.vanlandeghem@gmail.com

Keywords: Sand Waves, Migration Predictor, Irish Sea

The migration of offshore sand waves remains problematic to monitor on a large scale while it can endanger the stability of any structure in and on the bed. The migration predictor constructed by Knaapen (2005) is purely based on the size and shape of the bedforms and was tested here with repeated records of seabed topography in the Irish Sea. Sand wave migration rates at a dozen sites have been determined from time series of high-resolution swath bathymetry data and varied spatially between averages of 0 m/y in the deeper areas, 6 m/y closer to the coast and 30 m/y near the sand banks. The wavelength, height and asymmetry of each repetitively surveyed sand wave (N=221) were plotted against the observed annualized migration rates. If correlating well, the mobility of all bedforms observed in the Irish Sea (N=1064; Van Landeghem et al., 2009) could be predicted and mapped. Moderate correlations were only found, however, between observed site-specific average sand wave migration rates and bedform asymmetry. No correlations were found with sand wave dimensions and the predictor by Knaapen (2005) underestimates the migration speed of the Irish Sea sand waves immensely, particularly near sand banks. We therefore need to be cautious when over-simplifying the hydrodynamic processes and sedimentary parameters involved in sand wave migration. More laboratory flume experiments are needed and more site-specific field data remains to be acquired.

Knaapen, M.A.F. (2005) *Journal of Geophysical Research*, **110**, F04S11
Van Landeghem, K.J.J. et al. (2009) *Marine Geology*, **263**, pp. 108-119

Seeing Is Believing—Or Is It? A Comment On The Glacial Deposits Of Western County Clare, Ireland

Harry E. Langford
16 Magnolia Avenue, Longthorpe, Peterborough, Cambs PE3 9QT, UK
Email: h.e.langford@ntlworld.com

Keywords: Glacial Diamictons, Glaciotectonite, Till Intrusion, Landfast Ice, Northwest County Clare

This presentation looks at a limestone breccia at Murroogh previously interpreted as a glaciotectonite, but certain criteria, including allocthonous clasts, are observed that question this interpretation. Further south along the coast, at Derreen, allocthonous clasts are observed in diamicton squeezed into joints in the bedrock limestone. A different facies architecture to that at Murroogh is observed here though, and different processes to those at Murroogh are evident. The calcareous breccia at Murroogh is overlain by a matrix-supported diamicton, and similar material is found eastward in the valley of the Caher River, at the aptly named Kyber Pass. This section is interpreted to be part of a streamlined subglacial landform. Looking westward along the section it does appear as if a boulder pavement is present in the deposit, but traversing the gaze 90° to the north reveals a completely different facies arctitecture.

Carbonate Fracture Cements Record CO_2-rich Flux Up A Fault Zone, Fladen Ground Spur, North Sea

David R. Lee, Mark Wilkinson, R. Stuart Haszeldine
School of Geosciences, University of Edinburgh
Email: d.r.lee@sms.ed.ac.uk

Keywords: Carbon Dioxide, Carbonates, Stable Isotopes, Fault

Oilfields located close to the Fladen Ground Spur in

the South Viking Graben are associated with relatively high CO_2 within the hydrocarbons (up to 35 % mol; e.g. Brae, Miller, T-Block fields). It has been speculated that the CO_2 in the fields is derived via movement up the graben-bounding fault from an unknown source at depth (James, 1990). A number of cores in the region which intersect the fault contain fracture filling carbonate cements, which potentially record the ascent of the CO_2. Successive generations of dolomite and calcite cements have been distinguished based on petrographic and geochemical characteristics. The pattern of zonation within the cements suggest an episodic nature to the faulting and subsequent CO_2 flux into the overlying reservoirs. Stable isotope measurements of the cements suggest an inorganic carbon source (e.g. thermal degradation of carbonates). The measured carbon isotope data can be well explained by Rayleigh fractionation models of ascending and progressively degassing basinal CO_2-rich fluids up the fault zone. From this modelling approach estimates can be made of the volume of gaseous CO_2 released from the fault over time.

James, A., T. (1990) Correlation of reservoired gases using the carbon isotopic compositions of wet gas components. *AAPG Bull*, **74**, **9**, 1441–1458.

3D Seismic Analysis Of Enigmatic Strata-bound Folds In The Upper Cretaceous Chalk, Egersund Basin, Eastern North Sea Basin

Matthew M. Lewis, Christopher A-L. Jackson, Paul S. Whipp
Department of Earth Science & Engineering, Imperial College, London
Email: mattlewis8@msn.com

Keywords: Upper Cretaceous, Chalk, Strata-bound Folding, 3D Seismic

Mapping of 3D seismic dataset from the Egersund Basin, eastern North Sea Basin, has revealed the presence of enigmatic morphological features in the Upper Cretaceous Chalk Group.

In cross-section, these features are best described as harmonic, symmetrical folds, which have amplitudes of ca. 0.010 ms (TWT) and wavelengths of ca. 600 m. The folds are strata-bound, being bound by flat-lying, largely undeformed reflection events. There is limited evidence for truncation at the base of the features, confirming their origin as folds rather than as products of erosion. In plan-view, the folds have an areal extent of at least ca. 500 km2 and, based on isochron mapping, appear to be confined to a sub-circular, syn-depositional, salt withdrawal-related depression. Folds trend primarily NW–SE and can be mapped for up to ca. 15 km, although bifurcation of fold hinges is observed. Thickening of overlying units into the fold troughs suggests syn-sedimentary deformation of the coeval seafloor.

Identifying a single process which formed these features is contentious, with their development currently being attributed to one, or both of the following processes; (i) gravity-driven buckle folding; or (ii) differential compaction-related folding. However, wireline log data suggests that the interval of interest is homogeneous, suggesting that a discrete, mechanically-weak detachment is not present, and the lithological variability does not appear to sufficiently pronounced to promote differential compaction. Therefore, further work is required to understand the origin, significance and basin-scale distribution of these enigmatic strata-bound folds.

Preliminary Results From Provenance Studies In The Indus Continental Shelf, Pakistan

David Limmer[1], Peter Clift[1], Cornelia Köhler[1], Matthew Cooper[2], Suzanne MacClachlan[2], Liviu Giosan[3]
[1]*University of Aberdeen, UK,* [2]*National Oceanography Centre, University of Southampton, UK,* [3]*Woods Hole Oceanographic Institution, USA*
Email: d.r.limmer@abdn.ac.uk

Keywords: Indus Shelf, Provenance, Holocene, Asian Monsoon

Previous studies from the sub-aerial Indus delta region have shown a marked shift in provenance since the last glacial maximum as reconstructed by bulk neodymium isotope. In order to build on this finding, cores were taken throughout the subaqueous delta and canyon system. From this dataset 31 core samples were chosen for neodymium and strontium analyses ranging in ages from 13,107 to 1039 yr BP. Additional provenance data is provided from archive cores, which were scanned for magnetic susceptibility and spectrophotometry (colour) in order to assess ratios of haematite and goethite minerals associated with fluvial and aeolian weathering. This is useful because haematite formation occurs in warmer, drier seasonal conditions, while goethite formation occurs under wetter regimes.

The increasing values of magnetic susceptibility towards the tops of the cores suggest a weakening of the summer monsoon, and increasingly amounts locally derived Aeolian sediment. This agrees with previous studies that suggest the Asian Monsoon has been gradually weakening since the last glacial maximum. Haematite and goethite ratios suggest possible increased fluvial weathering at the start of Holocene, with increased Aeolian input in more recent times. Additional data from grain size and clay mineralogy will also be completed to ascertain further information about source weathering and transport mechanisms, allowing us to build up a clearer picture of climate and provenance records in the region.

Observations And Prediction Of Co-Existing Wave And Current Ripples At Sea Palling, UK

Kerry V. Marten[1], Alan G. Davies[1], Peter D. Thorne[2], Paul S. Bell[2]
[1]*School of Ocean Sciences, Bangor University,* [2]*Proudman Oceanographic Laboratory, Liverpool*
Email: osp208@bangor.ac.uk

Keywords: Ripples, Wave, Current, Acoustics, Field Observations

For many years, researchers have strived to pin-down the

forces responsible for the formation of sand ripples, a major challenge in the constantly changing hydrodynamic conditions of the near-shore environment. As part of the authors PhD project, work continues to produce a practical algorithm for predicting near-shore processes at field sites. Using basic wave and current input parameters, the algorithm will predict both wave and current ripples, and corresponding suspended sediment concentration profiles, in a time-dependent sense. The dataset employed is part of the LEACOAST2 project (http://www.research.plymouth.ac.uk/cerg/leacoast2/), where co-located acoustic measurements of near-shore processes were recorded over month time-scales. The bedform data were collected using a 3D Acoustic Ripple Profiler, giving high resolution profiling over an area 5m in diameter. The data show long periods of small current dominated ripples; well-defined wave events with large wave vortex ripples; and periods when both wave and current ripples exist at the same time instances, only witnessed before in one other field study (Amos et al. 1988). These co-existing ripples are of particular interest, as they appear to form and migrate independently of one another, forced by perpendicular tidal currents and wave action. Validated formulae for predicting current ripples alone, and wave ripples alone, are applied, and shown to be systematically under-predicting the co-existing ripple dimensions. This is interpreted as spatial limitation upon ripple growth, by the mere existence of both types of ripples within the same area of sea bed.

Amos et al. (1988) Ripple generation under the combined influence of waves and currents on the Canadian continental shelf. *Continental Shelf Research*, **8, (10)**, pp 1129–1153.

Reconstructing Depositional Systems From A Coarse Grained Submarine Slope Succession: A Combined Lithofacies And Palynofacies Study Of The Upper Jurassic Helmsdale Boulder Beds Formation, Moray Firth Basin, Scotland

Adam D. McArthur, Adrian J. Hartley, David W. Jolley, Stuart G. Archer
Department of Geology & Petroleum Geology, University of Aberdeen
Email: adam.mcarthur@abdn.ac.uk

Keywords: Depositional Systems, Tectonic Activity, Sequence Stratigraphy, Palynology, Climate Change

A detailed integration of sedimentology and palynology has been conducted on the Kimmeridgian-Lower Tithonian Helmsdale Boulder Beds Formation, to constrain controls on the depositional systems of this coarse grained submarine slope succession. Sediments were deposited in the actively rifting Inner Moray Firth Basin, in the form of growth strata associated with the active Helmsdale Fault. These strata were recorded in bed by bed detail through a total of 915 m allowing the identification of seven key lithofacies types—siliciclastic siltstone, tiger stripe, sandstone, siliciclastic boulder beds, calcareous siltstone, bioclastic turbidites and bioclastic boulder beds. High resolution macro and palynoflora biostratigraphy has allowed correlation of the logged section with the sea-level curve for the Late Jurassic of Britain. This shows a clear relationship between finer grained sediments (siltstone, sandstone & bioclastic turbidites) and relative sea-level change. In contrast boulder beds do not correlate to relative sea-level change and can be used as a proxy for periods of major tectonic activity, defining three main peaks in activity within the Inner Moray Firth Basin. Furthermore a marked change in the depositional environment occurs in the Lower Tithonian (c.150 Ma) where the system gradually changes from siliciclastic rich to carbonate dominated. Palynofacies investigation shows this change in depositional system coincides with a marked change on the Scottish landmass, from a warm-temperate environment dominated by lowland vegetation represented by pteridophyte and sphenopsid spores to that of a semi-arid climate with gymnosperm pollen of representative of forest & savannah ecologies.

Long-term Morphological Modelling Of A Sandy Estuary

David L. McCann[1], Alan G. Davies[2]
[1]School of Ocean Sciences, University of Bangor, [2]University of Bangor, Centre for Applied Marine Sciences (CAMS)
Email: d.l.mccann@bangor.ac.uk

Keywords: Long-term Modelling, Morphodynamics, Dyfi Estuary, Morphological Factor Method

The morphodynamics of shallow, tidal environments rely on the complex feedback interactions between bathymetry and the overlying hydrodynamics. The long-term relationship between the two is difficult to model as the system's dynamics exist and act in varying temporal and spatial time-frames. The morphological Factor (MF) approach to long-term modelling allows the morphology of the system to exist in a separate reference frame to the hydrodynamics, speeding up computation time while keeping hydrodynamic updates relatively frequent.

The MF method is here applied to the finite element modelling package TELEMAC on relatively fine-scale grids (∼25 m). Computations of morphological evolution of the order 100 years are made of a scematised sandy tidal basin and the Dyfi Estuary, West Wales, U.K. Evidence of self-organisation is seen in the schematised case, with complex channel-shoal networks appearing spontaneously. Channel-shoal networks are seen to appear and evolve independent of river input or complex 3D physical effects. Results from the 'real' basin case (Dyfi Estuary) are shown from a preliminary 'high-stand' case with the interior of the estuary levelled off at 0 m relative to mean sea-level.

On The Origin Of Convolute Lamination In The Turbidites Of The Aberystwyth Grits Group

Harry McClelland[1], Nigel Woodcock[1], Charlotte Gladstone[1], David Pritchard[2]
[1] *University of Cambridge,* [2] *University of Strathclyde*
Email: hlom2@cam.ac.uk, lotty@bpi.cam.ac.uk

Keywords: Convolute Lamination, Turbidite, Aberystwyth

Grits

Convolute lamination is produced by the deformation of soft sediment in a wide range of aqueous environments. A variety of different mechanisms may be involved in its formation, including earthquake shocks, shear from a parent flow or subsequent flow and/or dewatering of underlying layers. Identifying the origin of primary convolute lamination in turbidites allows a better 'big picture' understanding of relationships between parent flow and sedimentation: it may provide insight into the different processes affecting the formation of the bed, including turbidity current propagation, particle deposition, dewatering and compaction.

The Silurian Aberystwyth Grits, Wales, exhibit convolute lamination in many turbidite beds. Although this sequence has been studied extensively, there has been little focus in recent decades on the internal deformation of the beds. In this study, detailed field logging has been coupled with high resolution orthogonal images through selected beds, SEM analyses and simple process-based modelling calculations. The new data set allows constraints to be placed on the key physical parameters governing the development of the convolute lamination, and several theories previously proposed for its formation can now be challenged or refined. Preliminary results indicate that there is a narrow 'window of opportunity' for the formation of convolute laminations in terms of bed thickness, grain size and mud fraction, and a close relationship between the deformation and the Bouma C-division, with the convolutions nucleating on underlying ripples and growing syn-depositionally. Further analysis is investigating the possible importance of flow-induced shear stresses and of the rheology of the bed during deposition.

Sedimentary Architecture And Environmental History Of Middle To Late Pleistocene Deposits From The Eastern English Channel

Claire L. Mellett, David M. Hodgson, Andrew J. Plater, Barbara Mauz, Andreas Lang
School of Environmental Science, University of Liverpool
Email: mellettc@liverpool.ac.uk

Keywords: Eastern English Channel, Sedimentary Facies, Environmental History, Pleistocene, Channel River

Submerged beneath the eastern English Channel lies a complicated network of Pleistocene palaeovalleys incised into Cretaceous and Tertiary strata. Commonly the valleys are underfilled, although in places up to 30m of coarse clastic sediment completely heals the incision surface. The infilled palaeovalleys are associated with extensions of contemporary rivers draining the North West European land mass and form tributaries of an earlier 'Channel River' that is considered to have flowed through the Northern Palaeovalley fed largely by the Thames and Rhine during periods of lowered sea level. The Northern Palaeovalley is the largest underfilled valley in the system and its origin is considered to be closely related to erosion of a land bridge that existed at Dover Straits during the Early Pleistocene. Little is known about the stratigraphic architecture and environments of deposition of the Pleistocene sediment. Given the lack of sediments preserved in the Northern Palaeovalley, adjacent deposits to the north and south have the potential to provide insight into the timing and processes that drove the formation of the palaeovalley complex. Analysis of over 70 vibrocores shows a stacked succession of alternating sands and gravels. Interpretation of high resolution seismic stratigraphy when tied to sedimentary facies architecture reveals new insights into the palaeoenvironmental conditions operating in the eastern English Channel throughout the Middle to Late Pleistocene. A sedimentary facies model has been developed where abrupt alterations between shallow marine and fluvial processes operated during phases of transgression / regression.

Criteria To Distinguish Slump And Slide Deposits And Their Distinction In Outcrop: The Utility In Returning To Their Original Definitions

Willem van der Merwe, David Hodgson
Stratigraphy Group, Department of Earth & Ocean Sciences, University of Liverpool
Email: woeke@liv.ac.uk

Keywords: Slide, Slump, Stress, Strain, Syn-sedimentary Deformation

Inconsistent application of the process-based terms slide and slump from qualitative observations of seabed, seismic and outcrop data over the last ∼40 years has hindered comparison studies. Semi-quantitative values can be calculated using the degree of disaggregation of the component material to differentiate between slumps and slides in subaerial and submarine settings (e.g. the Skempton ratio). However, the degree of disaggregation of the internal deformed beds can be highly variable in space, due to the rheology of sediments, the amount of fluids, and the slope angle. Here, we suggest that the use of slump and slide should revert back to the original definitions. Thus, a slump is a vertical, downward movement of an object (exhibits contractional and expansional domains) and a slide is a horizontal, lateral movement of an object over a plane (exhibits extensional and compressional domains). If syn-sedimentary deformation is identified in an exposure or in core it should be described by the main directional component of applied stress rather than the degree of disaggregation. If the deposits can be shown to have moved laterally above a basal movement plane and include areas of extension and compression then it can be identified as a slide. If the deposits have been deformed in situ (characterised by soft sediment deformation structures) and areas of contraction and expansion can be identified, without any lateral movement on a basal surface, it can be described as a slump.

Integrating Research Borehole And Outcrop Data To Understand Sedimentary Processes Operating On Submarine Channel-levee Systems, An Example From The Karoo Basin, South Africa

Morris, E.A., Hodgson, D.M., Flint, S.S
Stratigraphy Group, School of Environmental Science, University of Liverpool
Email: E.A.Morris@liv.ac.uk

Keywords: Laingsburg Formation, Submarine Slope Sys-

tems, Karoo Basin, Borehole Data

The Laingsburg Formation is a mud rich succession punctuated by 8 thick sand-rich units; Fan A and Units B–H. The main focus of this study is the characterisation of Units C and D on the northern and southern limbs of the Baviaans syncline. Extensive work has been carried out on the southern limb. Previously collected data, combined with recently drilled research boreholes and wireline log data are integrated to constrain the 3D evolution of the slope system in this area. Unit C is subdivided into 3 subunits using two regional internal claystones; C1, C2 and C3. On both limbs of the syncline, C1 and C2 are commonly thin bedded siltstones and fine-grained sandstones that have been interpreted as external levees that are adjacent to channel axis and possible internal levees deposits. C3 is also thin bedded sandstone and siltstone and is tentatively interpreted as a lobe fringe deposit as no channel-fills are identified. A similar depositional architecture is seem on both sides of the syncline. Unit D, however, forms a deeply entrenched slope valley on the southern limb, whereas on the northern limb it is thin-bedded and siltstone-prone, and is interpreted as an external levee. The channel stacking patterns and stratigraphy preserved in the levees deposits permit the development of detailed 3D palaeogeographic reconstructions across the syncline at the scale of channel complexes.

A Numerical Stratigraphic Model For Quantitative Prediction Of Sandbody Connectivity In Mixed Fluvial-Aeolian Successions

Nigel P. Mountney
Fluvial Research Group, School of Earth & Environment, University of Leeds
Email: n.mountney@see.leeds.ac.uk

Keywords: Aeolian, Fluvial, Stratigraphy, Reservoir Model, Architecture

Mixed fluvial-aeolian successions are widespread in the stratigraphic record and form several important hydrocarbon reservoirs. In systems where the water table influences sedimentation, accumulation of dune, interdune and associated fluvial deposits is determined by the ratio between the rate of relative water table rise and the rate of downwind migration of aeolian bedforms. Accumulations of these 'wet' aeolian systems are characterized by units of climbing dune strata separated by units of damp interdune and associated fluvial deposits. If the size of the dune and interdune units, the rate of bedform migration and the rate of aggradation all remain constant over space and time, the resulting accumulation has a simple architecture characterized by gradually climbing sets of uniform thickness. However, the dynamic nature of most aeolian dune systems means that such simple configurations are unlikely. Inherent complexity can be accounted for by a numerical model in which key controlling parameters are allowed to vary systematically both spatially and temporally. The range of synthetic stratigraphic architectures generated by the model can be used to account for all the best-known examples of aeolian dune and interdune architectures documented from the global stratigraphic record. Results have been used to classify dune system type whereby the many elaborate stratal architectures known to exist in nature can be accounted for by only four parameters that are allowed to vary over space and time. This modelling approach represents an effective way to populate reservoir models, to test sensitivity to various stratal configurations and to predict sandbody connectivity.

Evolution Of Sediment Distribution Over The Northwest European Shelf Seas During The Last 12,000 Years

Simon P. Neill[1], James D. Scourse[1], Katsuto Uehara[2]
[1]*Bangor University, School of Ocean Sciences,* [2]*Kyushu University, Japan*
Email: s.p.neill@bangor.ac.uk

Keywords: Palaeoceanography, Tidal Model, Wave Model, Bed Shear Stress, Sediment Distribution, Holocene, NW European Shelf Seas

Due to changes in relative sea level of order 100 m, the contribution of tides and waves to net bed shear stress in shelf sea regions has varied considerably over the last 12,000 years. Understanding the spatial and temporal distribution of this ratio leads to a deeper understanding of the erosion and deposition of sediments over the shelf seas throughout this time period. The 3D POLCOMS tidal model and the spectral wave model SWAN are here applied to palaeo time slices of the northwest European shelf seas over the last 12,000 years. The model simulations include a series of sensitivity tests to account for the influence of inter-annual variability in wind conditions on the resulting net bed shear stress. The results show that there has been a significant decrease over the last 12,000 years in shelf-scale mobilisation of coarse sediment. Since there was a lower magnitude of wave orbital velocity penetrating to the sea bed as a result of increasing relative sea level, this reduction in sediment mobilisation was primarily controlled by a shelf-scale decrease in wave-induced bed shear stress over the Late Glacial and Holocene. The predictions of net and residual bed shear stress for the modelled palaeo time slices are a useful tool with which to inform site-selection and subsequent interpretation of sediment cores. In addition, the modelled reconstructions of palaeo tidal range over the shelf seas demonstrates the potential errors associated with assuming a present-day tidal range when correcting palaeo sea level proxies from their deposited datum (e.g. palaeo mean high water spring tide) to palaeo mean sea level.

Neill, S.P., Scourse, J.D., Bigg, G.R. and Uehara, K. (2009) Changes in wave climate over the northwest European shelf seas during the last 12,000 years. *J. Geophys. Res.* **114**, C06015.

The Seismic Character Of A Bottom Simulating Reflector (BSR) Of The Cameroon Margin, West Africa

Anh Le Ngoc, Robert Gawthorpe, Jonathan Redfern, Ducan Irving
Basin studies and Petroleum Geoscience, School of Earth,

Atmospheric and Environmental Sciences, University of Manchester
Email: anh.le@postgrad.manchester.ac.uk

Keywords: Bottom Simulating Reflector (BSR), Gas Hydrate, Pockmark, Fluid Migration, Gas Chimney

3D seismic data analysis of the Cameroon margin, West Africa reveals a large area of gas hydrate located in the upper slope. It covers an area of approximately 350 km^2 in water depths ranging from 500–1500 m. The depth below the seafloor ranges between 0.09–0.21 s TWT, increasing with increasing water depth. The BSR is well imaged seismically and shows systematic variations in the reflection strength. The BSR shows a sharp change in amplitude from weak to strong when it crosses certain stratigraphic horizons and is associated with enhanced amplitudes of the seismic reflections below it. The high amplitude reflections below the BSR suggest the presence of free gas entrapped under the Gas Hydrate Stability Zone (GHSZ) thus causing a strong BSR. In response, the weak BSR is the result of the lack of free gas stored and/or lack of porous and permeable lithologies underlying the GHSZ. A widespread distribution of seabed fluid escape pockmarks is also observed. The pockmarks are classified into three styles defined by their appearance and distribution: (1) single pockmarks, (2) pockmark trains, and (3) pockmark clusters. Most of them are associated with the underlying BSR but some exist without the BSR. Each style of pockmarks relate to a particular type of migration pathway which can be used to explain the migration mechanism delivering gas to the shallow succession thus feeding the gas and gas hydrate seal.

Utsira Overburden: Investigating Existing Fluid Migration Pathways—Implications For Long-Term CO_2 Storage

Grant D. Nicoll[1], Andrew J. Cavanagh[2], Sebastian Geiger[3], R. Stuart Haszeldine[2]
[1] *The University of Edinburgh,* [2] *Permedia Research Group, Ottawa, Canada,* [3] *Institute of Petroleum Engineering, Heriot-Watt University*
Email: G.D.Nicoll@sms.ed.ac.uk

Keywords: Injectite, Fault, Anomaly, Chimney, Glaciation

The Utsira saline aquifer, the world's first storage site for anthropogenic CO_2, is situated in the North Sea, offshore Norway, and overlain by mudstone-dominated sediments of the Nordland Group. Since 1996, over 13 Mt of supercritical CO_2 has been injected into the sandstone reservoir at a rate of 1 Mt/yr. From 1999, the ascending CO_2 plume has been monitored by seismic and gravity surveys, it appears to remain trapped beneath the Nordland Group sealing formations and no evidence of CO_2 leakage from the storage site has been detected to date. However, analysis of long-term storage requires an understanding of existing and potential fluid migration pathways at the site, since a residence time of 5 to 10 ka is deemed necessary for carbon sequestration; low leakage rates, undetectable on monitoring timescales, may eventually compromise site integrity.
The stratigraphy of the Nordland Group contains numerous features related to past fluid migration, glacial and interglacial processes. We identified and analysed gas chimneys, pockmarks, high-amplitude seismic anomalies, unconformities, tunnel valleys and channels interpreted from detailed 3D mapping of the underlying Hordaland Group and overlying Nordland Group sediments deposited at the Utsira storage site. These features provide evidence of ongoing fluid flux and are potential migration pathways through the overburden in the event of seal failure. The complexity of the overburden stratigraphy and the presence of these features may increase the risk of long-term seal compromise for Utsira and proposed storage sites with a similar depositional history.

The Twelve Sediments Of Christmas

Jon Noad
Shell Canada, PO Box 100 Station M, Calgary, Alberta, T2P 2H5, Canada
Email: j.noad@shell.com

Keywords: Sediments, Formations, Favourites, Survey

The United Kingdom is blessed with an incredible variety of sedimentary deposits covering almost the entire Phanerozoic Eon. The Jurassic Coast has even been given World Heritage status for its geological austerity. Many of these deposits outcrop either inland or along our extensive and rapidly eroding coastline, and hence are familiar to most geologists who have either cut their teeth in the UK, worked there or visited on field trips.
With such a suite of sediments available I wondered which of them have set geologists' hearts racing. Which formations have stimulated discussion, and stuck in their minds? A trawl through the literature (and my memories of university studies) identified a set of rocks covering all the main depositional settings, and ranging throughout the Phanerozoic. However I decided to throw the question open to everyone on the BSRG mailing list to ensure that this was not too personal a smorgasbord of geological delights. Additional responses have been sought from the Geol Soc members, the GA members and from industry geologists.
While I am loath to give too much away prior to the conference, expect to see a full suite of sedimentary deposits including limestones, sandstones, shales and more. Depositional settings range from terrestrial to deep marine, and date from the Palaeozoic to Quaternary. The lack of a detailed definition of "favourite sedimentary deposit" has ensured that the net has been cast wide. The survey results, featuring responses from as many as hundreds of geologists, will be summarised along with highlights from each of the twelve most popular formations, and the Number One sedimentary deposit in the UK will be unveiled. Expect a few surprises along the way.

Simultaneous Measurements Of Turbulence And Sediment Dynamics Over A Vortex Ripple Under Irregular Waves

Rory OHara Murray[1], Peter Thorne[2], Ben Moate[2], David Hodgson[1]
[1] *The School of Environmental Science, The University of Liverpool,* [2] *Proudman Oceanographic Laboratory (POL)*

Email: roryohm@liv.ac.uk

Keywords: Sediment, Ripple, Irregular Waves, ABS, ADVP

The transfer of momentum in the near bed layer over steep (trochoidal) sand ripples and under regular waves is dominated by the process of vortex shedding—a highly effective mechanism of sediment entrainment. Whether this process occurs under irregular waves is an important question because of their predominance in nature. Nonintrusive acoustic measurements of the bedforms, flow and suspended sediments were collected under irregular waves in the Deltaflume of Deltares, Delft Hydraulics, the Netherlands. An Acoustic Doppler Velocity Profiler (ADVP) and an Acoustic Backscatter System (ABS) provided high resolution, simultaneous, collocated, measurements of velocity profiles and suspended sediment profiles above the crest of a 2D ripple. The ripple was round crested and had a wavelength and height of 0.33m and 0.047m respectively. Later, the instruments were translated ∼0.16m offshore to a position above the trough of the same ripple. The ADVP data was used to calculate the cross-shore component of the Reynolds stress, which together with the ABS results, were related to the phase of each wave. Peaks in the wave cycle ensemble averaged Reynolds stress and sediment concentration were coincident, and above the ripple crest occurred around flow reversal. Thus, under field scale irregular waves, concurrent measurements of turbulent momentum transfer and suspended sediment transport have been made over a field scale ripple. The results are consistent with the process of vortex formation which up until now has been postulated, though not well verified, to occur under irregular waves in the natural marine environment.

Repetitions Within Contained Turbidite Beds Near Their Pinch-Out: Related To Internal Waves?

Marco Patacci[1], Willian McCaffrey[2], Peter Haughton[1]
[1]*School of Geological Sciences, University College Dublin,* [2]*TRG, University of Leeds*
Email: marco.patacci@ucd.ie

Keywords: Internal Waves, Repetitions, Ponded Turbidites, Onlap

Turbidity currents can flow into structurally- or salt-controlled 'mini-basins' and form distinctive contained turbidites. Bed pinch-outs against the confining topography can exhibit a range of characteristic sedimentary facies trends.

Onlapping turbidites can show repetitions of sedimentary structures within each individual turbidite bed. Examples from the Annot Sandstone (SE France) and the Tabernas Basin (SE Spain) show that such repetitions are usually very significant near the onlap but become less evident or disappear when traced toward the deeper bathymetry. Repetitions can be up to 20 cm thick and usually consist of a sequence of laminated sandstone, massive sandstone (usually loading into the underlying laminated sandstone) and a veil of mudstone. In some other cases repetitions are much thinner (cm-scale) and expressed by colour banding and mud content change.

A series of experiments carried out at the Sorby Environmental Fluid Dynamics Laboratory (University of Leeds) has recently given new insight into flow behaviour during the ponding process. One of the key findings is that sustained turbidity flows form an internal concentration interface within the ponded sediment-bearing cloud. Where sharp density interfaces form, internal waves are prominent within the suspension cloud.

Internal waves within contained turbidity currents are suggested as a likely generation mechanism for the repetitions of sedimentary structures in onlapping turbidites beds. Other generation mechanisms (pulsing of the inlet flow, a series of bores or rebounds due to the multiple reflections) are considered and discussed against the suggested hypothesis.

Found—The 'Holy Grail' Of Deep-marine Clastic Sedimentology?

Jeff Peakall[1], Dan Parsons[1], Rick Hiscott[2], Ali Aksu[2], Roger Flood[3], Daniel Mouland[4]
[1]*School of Earth and Environment, University of Leeds,* [2]*Earth Sciences, Memorial University of Newfoundland,* [3]*School of Marine and Atmospheric Sciences, Stony Brook University,* [4]*Land and Seabed Imaging Facility, Memorial University of Newfoundland*
Email: j.peakall@see.leeds.ac.uk

Keywords: Submarine Channel, Turbidity Current, Gravity Flow, Holy Grail

Similarities can be drawn in our understanding of sea-floor submarine channels and geomorphological elements observed on other planetary bodies: Interpretation is still made dominantly on the basis of topographic data. Admittedly, the availability of short cores in many sea-floor channels is an advantage over planetary studies. Nevertheless, there is almost no measurement of the actual flows in submarine systems, just like in planetary geomorphology. Why? As sea-level has moved towards highstand most systems have shut-off completely, or only produce flows that are out of equilibrium with the features that they are traversing. Coupled to this, flows are very powerful and erratic, restricting measurements to a few vertical profiles in passive margin systems. The answer... As sea-level rose, and others systems were shutting off, the shallow sill (∼30 m) in the Bosphorus Strait was overtopped ∼6k BP and high-salinity Mediterranean waters started flowing as a gravity current into the Black Sea, producing a spectacular sinuous submarine channel network where flows and morphology are in equilibrium. Here we examine whether this is the 'Holy Grail' of deep-marine clastic sedimentology, where we could attempt to examine process-product relationships, as has successfully revolutionised our understanding of almost every other sedimentary environment on Earth. As a first step—we discuss the first cross-sectional flow data from an active submarine channel and examine what this means for existing laboratory / numerical models of fluid flow in submarine channels.

Quantitative Comparison Of Ancient And Recent

Distributary Deep-Water Systems Using Outcrop and Seismic Datasets

Amandine Prélat, Dave Hodgson, Steve Flint
University of Liverpool, UK
Email: amandine@liv.ac.uk

Keywords: Lobe, Comparison, Dimensions, Stacking patterns

Terminal submarine lobes are the down-dip depositional record of sediment gravity flows transported through continental margins. Based on exceptionally large exposures and behind-outcrop borehole cores; bed stacking patterns, environments of deposition, lobe dimensions and lobe volumes have been described and compared between different systems. Lobe dimensions of Fan 3 exposed in the Tanqua depocentre are compared to five other examples that have different basin configurations, sediment caliber, tectonic setting, seabed topography, age and delivery system (Golo system of Corsica, eastern France; Kutai Basin, offshore Indonesia; Amazon Fan, offshore Brazil and Congo Fan, offshore West Africa). Despite the differences, lobe deposits are characterized by two distinct planform shapes that are related to the amplitude of the basin floor topography. Secondly, average volumes of lobes from the same five systems are comparable and not controlled by the scale of the delivery system (drainage basin area and river discharge). This indicates an autogenic control on the maximum size of a lobe before a new one is deposited. Finally, a variety of bed stacking pattern can be found within lobe deposits. Bed thickness trends of lobes in Fan A exposed in the Laingsburg Karoo, the Great Valley Group and the Pico Fm., California show a common increasing to decreasing patterns in distal environments. However, the pattern can change laterally depending on the stacking of smaller scale elements and underlying depositional relief.

Reconstruction Of Jurassic (Bathonian) Palaeosalinity Using Stable Isotopes And Faunal Associations

Gregory D. Price, Christie Teece
School of Geography, Earth and Environmental Sciences, University of Plymouth
Email: g.price@plymouth.ac.uk

Keywords: Salinity, Jurassic, Brachiopod, Dorset

The Bathonian of the UK is an interval from which salinity-controlled benthic faunas are particularly well known demonstrated through sedimentological, palaeoecological and stable isotope evidence. Although local facies variations are complex, greatest faunal diversity is found in Oxfordshire, where facies associations suggest a low-energy backbarrier to platform interior environment. Published studies suggest that faunal diversity decreases in north-eastern Oxfordshire and through Northamptonshire, representing shallower, probably lagoonal environments. It has also been suggested that low diversity Bathonian faunas indicative of substantially reduced salinities occur as far south as Dorset (e.g. the Boueti Bed). The oldest beds examined in this study, the mudstones of the Wattonensis Beds (of the Fullers Earth), are of known marine origin based on a diverse typical marine assemblage and are considered as being deposited in an offshore to deeper shelf environment. The overlying Boueti Bed marks the base of the Forest Marble and consists of a rubbly, detrital, micritic limestone. Oxygen isotope values of belemnites (Belemnopsis sp.) from the Wattonensis Beds range from -1.4 to -0.7 permil and carbon isotope values range from -2.3 to -0.5 permil. The isotope values of well-preserved Rhynchonella sp. from the Wattonensis Beds range from -2.4 to -1.3 permil for oxygen and -1.1 to 0.6 permil for carbon. Significantly a similar spread of values is seen for the well-preserved brachiopods, (Goniorhynchia boueti,) from the Boueti Bed, ranging from -3.3 to -1.0 permil for oxygen and -0.9 to 1.0 permil for carbon. These data are also consistent with published data derived from the Bathonian of Oxfordshire. Given the marine origin of the Wattonensis Beds and overlap of data, the reduced faunal diversity of the Boueti Bed is therefore unlikely to be the result of reduced salinity on the basis of the stable isotope signatures. The reduced faunal diversity of the Boueti Bed may consequently be due to a combination of a number of other factors including, sediment substrate, productivity or food and oxygen supply.

Origin And Significance Of Fully-preserved Dunes In large-river Deposits

A.J.H. Reesink
SET - University of Brighton & GEES - University of Birmingham, UK
Email: a.j.h.reesink@brighton.ac.uk

Fully-preserved dunes are single cross sets that have maintained the shape of their formative dunes and their existence can potentially provide important information about the controls on bedform preservation. Unfortunately, few descriptions of fully-preserved dunes in sandy alluvial deposits exist. Ground-penetrating radar (GPR) data from mid-channel bars in the Paran River near Corrientes, Argentina, are used to show the sedimentological context in which fully-preserved dunes are found and some explanations of their formation are presented. The fully-preserved dunes in the sandy Paraná River are characterised by a strong reflection from the top surface, lower-amplitude basal reflections and lower-amplitude, high-angle internal reflections. These fully-preserved dunes have heights of 0.6 $\pm$ 0.2 m with a maximum of 1.2 m, lengths of 24 $\pm$ 11m with a maximum of 54 m, and widths in the same order of magnitude as the lengths. Approximately 90% of the fully-preserved dunes are overlain by large-scale unit-bar foresets with heights exceeding 0.5 m. Some of these overlying unit-bar foresets comprise several reactivation surfaces that are interpreted as low-flow structures, and dune heights vary systematically as much as 0.8 m along trains of dunes, which suggests that the dune forms are buried over multiple high- and low-flow events. Three potential mechanisms for full preservation are: (1) abandonment of the dunes during low flow and burial by fine-grained cohesive sediment that prevents further erosion; (2) rapid burial of the dunes; and, (3) stagnation of the dunes in the wake zone in the lee of (unit) bars and subsequent burial by the unit-bar bottomsets and foresets. Differences in the relative importance of

these mechanisms point at respectively (a) stage variability (b) aggradation rate, and (c) migration rate, as the key factors controlling bedform preservation. Based on the GPR data, it is suggested here that the effect of bar-scale morphology on dune migration, and therefore preservation, is currently underestimated in fluvial sedimentology.

An Empirical Approach Towards Understanding Fluvial Architecture

Andreas Rittersbacher[1], John A. Howell[1,2], Simon J. Buckley[1]
[1]*Centre for Integrated Petroleum Research, University of Bergen, Norway,* [2]*Rocksource ASA, Bergen, Norway*
Email: andreas.rittersbacher@cipr.uib.no

Keywords: Heli-Lidar, Fluvial, Book Cliffs, Virtual Outcrop

Preserved fluvial architecture is a function of a series of complex, interrelated controlling mechanisms which include climate, base level change and source area characteristics. Fluvial systems in the rock record are typically heterogeneous and systems may cover thousands of square kilometres. Individual sandbodies are typically in the order of 10s to 100s of metres wide and may show significant variability. The lateral and vertical stacking of the sandbodies is a key point for understanding the interplay between the controlling parameters. A major challenge is the measurement of sufficient, spatially constrained geometric data to investigate the geometries in a statistically meaningful way. Outcrops such as the Cretaceous deposits in the Book Cliffs and the Tertiary Green River Formation of Nine Mile Canyon in Utah are suitable for addressing this problem. Geometrically constrained, virtual outcrop data have been collected from three areas using a novel, helicopter-mounted lidar system. This system has allowed the collection of very large virtual outcrops up to 30 km long and >100 m high. The data have been processed and are being used to extract large volumes of geometric data at a variety of scales from the channel belt to the individual bar form. Comparison of the different systems allows investigation of individual parameters. Comparing for example sandbody geometries of a coastal plain complex of the Blackhawk Formation with fluvio-deltaic sandbodies of the Green River Formation allows discussion on the role of changing climate and drainage systems in otherwise similar depositional environments.

To Leak Or Not To Leak? Investigating The Plumbing Of CO_2 Fluids In Central Italy

Jennifer J. Roberts, Rachel A.Wood, R. Stuart Haszeldine, Stuart V. Gilfillan
Scottish Centre for Carbon Storage, University of Edinburgh
Email: jen.roberts@ed.ac.uk

Keywords: CO_2, Carbon Capture And Storage, Travertine, Neotectonics

Italy is a region of anomalously high natural CO_2 degassing; it is estimated that 9.2Gt/yr of CO_2 is released through the crust from CO_2 seeps. Travertine (continental carbonate) formation is also widespread in Italy and is related to high pCO_2 waters. Interestingly, CO_2 flux is much reduced in the most seismically active belt in the Apennines where unusual seismic sequences have been attributed to the presence of trapped CO_2 fluids at depth. In addition, hydrocarbon exploration drilling in Central Italy frequently encountered CO_2 accumulations, some of which are geographically related to CO_2 seeps implying breaching of the reservoir seal, analogous to leakage scenarios from engineered CO_2 storage sites.

A detailed study on the structural and geochemical relationships between deep CO_2 reservoirs, surface CO_2 seep sites and travertine deposits will describe the internal "plumbing" within the crust in this region. This will improve our scientific understanding of processes that generate seismicity in Central Italy, and will also be important for understanding and preventing CO_2 leakage from carbon storage sites.

Ophiolite Emplacement: Evidence From Coarse Clastics Overlying The Jurassic Mirdita Ophiolite, Albania

Alastair Robertson[1], Volker Hoeck[2], Friedrich Köller[3], Corina Ionescu[4], Kujtim Onuzi[5], Dashamir Ghega[5]
[1]*University of Edinburgh,* [2]*University of Salzburg,* [3]*University of Vienna,* [4]*Babes-Bolyai University, Romania,* [5]*Institute of Geological Research, Albania*
Email: Alastair.Robertson@ed.ac.uk

Keywords: Ophiolite, Sediments, Albania, Palaeoenvironments, Tethys

Based on the example of the well-exposed Jurassic Mirdita ophiolites in central and southern Albania we will show how sedimentology sheds light on the emplacement of oceanic lithosphere (i.e. ophiolites) onto a continent. These ophiolites are locally covered by ophiolite-derived breccias and conglomerates of latest Jurassic (Tithonian)-Early Cretaceous age, followed by post-emplacement, Upper Cretaceous-Palaeogene shelf carbonates. We recognise several facies types that depositionally overlie the emplaced oceanic crust, mainly represented by basaltic lavas and chert. A local, sparse pelagic matrix of the clastic sediments indicates initial accumulation in an open-marine setting. The rounding of some ophiolite clasts shows that parts of the ophiolites were eroded in a high-energy shallow-marine, to fluvial setting. In some areas coarse ophiolite-derived breccias and conglomerates were eroded from a rugged topography in shallow water or subaerial settings. Resulting talus was deposited mainly by mass-flow and rock-fall processes. After emplacement the ophiolites were subaerially weathered and eroded, creating laterite and mixed clastic-carbonate sediments in deltaic, lagoonal and shallow-marine settings. In the regional context, the Albanian ophiolites were emplaced rapidly onto the Korabi-Pelagonian microcontinent during Late Jurassic time. However, they remained near sea level and were not greatly uplifted until continental collision took place during Palaeogene time.

Morphological controls in sandy estuaries: the in-

fluence of tidal flats and bathymetry on sediment transport

P.E. Robins, A.G. Davies
University of Bangor, Centre for Applied Marine Sciences (CAMS)
Email: ucx003@bangor.ac.uk

The morphodynamics of shallow, vertically well mixed estuaries, characterised by tidal flats and deeper channels, have been investigated. This study examines what contributes to flood/ebb-dominant sediment transport in localised regions through a 2D model study (using the TELEMAC Modelling System). The Dyfi Estuary in Wales, U.K. has been used as a case study, and, together with idealised estuary shapes, has shown that shallow water depths in the inner estuary lead to flood-dominance while tidal flats and deep channels cause ebb-dominance in the outer estuary. For medium sands and with a 'flattened' bathymetry (i.e. no tidal flats), the net sediment transport switches from ebb-dominant to flood-dominant when the parameter a/h (local tidal amplitude ÷ local average water depth, which is a Froude number describing the dominant barotropic tidal flow) exceeds 1.2. A similar pattern, albeit with greater transport, was simulated with tidal flats included and also with a reduced grain size. This suggests that a similar classification proposed by Friedrichs and Aubrey (1988) for flood/ebb-asymmetry of the tide in estuarine systems as a whole, may not represent the local sediment transport. Through the Dyfi simulations, the above criterion is shown to be complicated further by augmented flow past a spit at the estuary mouth and erosion of the bed to form a self-maintaining scour-hole. Simulations of one year of bed evolution in an idealised flat-bottomed estuary, including tidal flow past a spit, recreate the flood/ebb-dominance on either side of the spit, and the formation of a scour-hole in between. The erosion is reduced as the hole deepens suggesting the establishment of a self-maintaining equilibrium state.

Friedrichs, C.T., Aubrey, D.G. (1988). Non-linear tidal distortion in shallow well-mixed estuaries: a synthesis. *Estuarine, Coastal and Shelf Science* **27**, 521–545.

Darwin As A Carbonate Sedimentologist: His Reef Transects, Specimens And Facies Model At Cocos-Keeling Atoll

Brian Rosen[1], Jill Darrell[2]
[1]*Department of Zoology, Natural History Museum, London,*
[2]*Department of Palaeontology, Natural History Museum, London*
Email: B.Rosen@nhm.ac.uk

Keywords: Charles Darwin, Atolls, Subsidence, Specimens, Facies Model

Darwin's bicentennial year has helped to highlight and re-evaluate his often overlooked geological work, youthful foundations of which were laid in North Wales. In fact, Darwin's first great scientific theory (1835, 1837) and first scientific book (1842) were on coral reefs, a masterly synthesis of biological, sedimentological and tectonic evidence culminating in his elegant subsidence theory of coral atolls. Although successively modified after his death as the implications of glacio-eustasy were grasped, the essence of his theory, that thick shallow-water carbonate edifices of atolls accumulated on the subsiding foundations of oceanic basaltic volcanoes, was thoroughly vindicated, also posthumously, by seismic surveys, deep atoll drillings, and plate tectonics.

The origin of atolls was a popular enigma at the time of the Beagle voyage, and the British Admiralty instructed FitzRoy, her captain, to include them in his investigations. Darwin, stimulated by tectonic observations he had made in the Andes, devised his atoll subsidence theory in South America and Tahiti before actually getting the chance, late in the voyage, to examine his first example at Cocos-Keeling in the Indian Ocean. There, he most needed to check that (1) reefs were biogenic, (2) reef building occurred only in shallow depths, (3) growth was most vigorous at seaward edges, and that (4) the atoll's features showed evidence of drowning. Here we assess his evidence, especially from his Cocos-Keeling transects and specimens (in the Natural History Museum), and discuss his atoll facies model (MS), which remarkably perhaps, anticipates Walthers Law by some 40 years.

An Integrated Model Of Extrusive Sand Injectites And Sand Volcanoes

Jessica A. Ross, Jeff Peakall, Gareth M. Keevil
Earth Sciences, School of Earth and Environment, University of Leeds
Email: ear4jar@leeds.ac.uk

Keywords: Fluidisation, Injectite, Sand Volcano

Sand injection is becoming a widely recognised phenomenon whose ubiquity and significance has led to a marked increase in research on these features. However, the understanding of the physical mechanisms that control the genesis of sand injectites remains limited, dominated by inference from outcrop and seismic studies. Here we address this limitation through a set of experiments focussed on the development and evolution of extrusive fluidisation features in non-cohesive bedded sequences. Fluidisation and the onset of piping are shown to occur sequentially through a series of discrete phases, with initial void formation, development of infiltration horizons and partial fluidisation, rupture, and finally pipe formation and sediment venting. Critically, the morphology of pipes, the stability of piping and the temporal evolution of venting are shown to exhibit considerable variability. In particular, pipes may be either stable or itinerant, migrating laterally over large distances and producing deposits that are morphologically similar to those typically interpreted in outcrop as being the product of en masse liquefaction rather than localised, dynamic fluidisation. These differing elements are synthesised to produce an integrated model of the genesis of extrusive sand injectites and sand volcanoes. The implications of this model raise some interesting questions which are discussed.

Quantifying The Dynamics Of Flow Within A Permeable Bed Using High-resolution Endoscopic Particle Imaging Velocimetry (PIV)

Gregory H. Sambrook Smith[1], Gianluca Blois[1], James L. Best[2], Richard J. Hardy[3], Jamie R. Lead[1]
[1]*University of Birmingham,* [2]*University of Illinois,* [3]*Durham University*
Email: g.smith.4@bham.ac.uk

Keywords: Particle Imaging Velocimetry, Hyporheic Zone, Pore Flow

Flow within permeable river beds plays a significant role in both the channel morphodynamics and in important environmental processes such as dissolved oxygen exchange, nutrient availability and contaminant transport. However, current knowledge of this critical 'hyporheic' zone remains largely unquantified, principally due to the technical difficulties involved in collecting velocity data within the pore spaces. Although numerical models are being developed to predict flow pathways within permeable river beds, their validation also demands accurate experimental data at the grain/pore scale.

Direct investigations using quantitative visualization techniques are inherently challenging due to practical difficulties in imaging through the opaque solid matrix of a permeable bed. In the present study, a fully endoscopic PIV system is described that has been developed and employed to collect velocity data on the scale of the individual pore space. A pulsed Nd:YAG laser has been used to fully illuminate the interstitial measurement plane, whilst a 4Mpxl, image-intensified camera, coupled with a high-sensitivity rod-based borescope, allows capture of high-resolution images of seed particles within the flow. This experimental configuration will be described to demonstrate the great potential of the technique for studying flow within porous beds.

The experimental investigation presented herein details experiments in a laboratory flume in which spheres were used, in a simple geometrical packing, to simulate a porous natural gravel river bed. The boundary conditions of flow depth and mean flow velocity were varied to examine the changing flow fields within the first four pore spaces. Additionally, the impact of the bed topography, in the form of a simple particle cluster, was also examined to detail its effect on the local subsurface flow. This paper will present details of the instantaneous and time-averaged flow fields within a representative pore volume that quantify the complex nature of the interstitial flow structure.

A Sequence Stratigraphic Analysis Of The Cenozoic Succession Offshore Namibias

Henning Schulz[1], Harald Stollhofen[1], Stefan Back[2]
[1]*Geozentrum Nordbayern,Universität Erlangen-Nürnberg,* [2]*WTH Aachen*
Email: henning.schulz@gzn.uni-erlangen.de

Keywords: Sequence Stratigraphy, Post-Breakup, South-Atlantic, Namibia

Multiple phases of volcanism, uplift and subsidence are recorded after the breakup of the Namibian South Atlantic margin segment—features which are regarded as atypical when compared to published examples of other post-breakup continental margin successions. It is currently not understood whether these geodynamic processes are only of regional or a broader, South Atlantic intercontinental importance.

On the basis of 5000km of high resolution 2D wireline seismic data offshore central Namibia, the regional differences in uplift, subsidence and sedimentation rates are analysed. This data stretches along 400 km of coastline covering an area of 45.000 km^2. Combined with well-logs and biostratigraphy of 3 wells the late Carboniferous and Cenozoic successions are segmented into their subdivisions and mapped throughout the whole study area. Measured thicknesses of each subdivision are compared and the study area is divided into regional basins with different uplift and subsidence history. In addition, the Cenozoic subdivisions are analysed using principles of sequence stratigraphy to get a better correlation to existing sea-level curves.

The Impact Of Sea-level Change On The Hydro- And Sediment Dynamics Of The Northwest European Shelf Seas Since The Last Glacial Maximum: Modelling Insights

James Scourse[1], Katsuto Uehara[2], Mattias Green[1], Simon Neill[1], Tom Rippeth[1], Katrien Van Landeghem[1]
[1]*School of Ocean Sciences, Bangor University,* [2]*Research Institute for Applied Mechanics, Kyushu University, Fukuoka, Japan*
Email: oss048@bangor.ac.uk

The postglacial flooding of the continental shelves by rising sea level resulted in a 7% increase in the areal extent of the global ocean with implications for key elements of the Earth system including atmospheric $_pCO_2$ concentrations and the functioning of the meridional overturning circulation. These implications can be assessed using numerical shelf sea palaeotidal and palaeowave models. In this paper we review recent two-dimensional modelling simulations of the northwest European shelf seas parameterized using output from different generations of glacial isostatic adjustment (GIA) to define coastline position and palaeotopographies for timeslices since the Last Glacial Maximum (LGM). Comparison of palaeotidal model output with observational geological data on seasonal stratification dynamics indicates that, while the simulations are insensitive to GIA model input, the description of the ocean tide boundary is critical (Uehara et al., 2006); 'best fit' simulations are achieved using output from a time-dependent global ocean tidal model rather than adopting a 'fixed' boundary based on the modern tide. This has implications for tidal mixing in the glacial North Atlantic and mechanical energy available for driving the meridional overturning circulation (Green et al., 2009). The palaeotidal simulations generate output on tidal amplitudes, peak bed stress vectors and seasonal stratification dynamics. Tidal amplitude series for specific locations can be used to correct sea-level index points for past tidal variation. By combining contemporary estimates of seasonally averaged shelf sea–atmosphere CO_2 exchange with model outputs describing areal change in the distribution of mixed vs. seasonally stratified watermasses, we demonstrate that the relative growth of these different regimes provides a mechanism which

can explain the direction, rate and timing of a number of previously unexplained transitions in the atmospheric $_pCO_2$ record derived from ice-core measurements (Rippeth et al., 2008).The results demonstrate the influence of rising sea level on atmospheric $_pCO_2$ and the important role of the contemporary continental shelf seas in the global carbon cycle. Though palaeotidal bed stress data illuminate changes in sediment transport vectors and help to explain large moribund bedforms (Scourse et al., 2009; Van Landeghem et al., 2009), palaeowave models demonstrate that waves had a more important contribution to large-scale sediment transport than tides in parts of the northwest European shelf during the last deglaciation (Neill et al., 2009).

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Sundaland Basement And Sediment Provenance: U-Pb And Hf-isotope Dating Of Detrital Zircons From The Malay Peninsula And West Java

Inga Sevastjanova, Benjamin Clements, Robert Hall
SE Asia Research Group, Department of Earth Sciences, Royal Holloway University of London
Email: i.sevastjanova@es.rhul.ac.uk

Keywords: Sundaland, Basement, Provenance, Zircon, Hf-isotopes

Sundaland comprises Indochina, the Thai-Malay Peninsula, Sumatra, Java, Borneo, and the shallow shelf between these landmasses. The basement of Sundaland is composed of Gondwana-derived continental blocks, volcanic arcs, and accretionary complexes that are allochthonous to the Eurasian margin. The Malay Peninsula lies on two of these blocks—Sibumasu and East Malaya; West Java lies on the SW Borneo and West Sumatra continental blocks, and on the Woyla oceanic fragments. Abundant Permian-Triassic, Jurassic and Cretaceous granitoids intrude the continental blocks. These granitoids are the major sources of detrital zircons in Sundaland.

554 Hf-isotope analyses from 13 samples have been carried out on detrital zircons from modern rivers draining the Malay Peninsula and Paleogene sandstones in West Java dated using U-Pb techniques in order to determine basement ages beneath the Malay Peninsula. Crustal model ages suggest that basement is heterogeneous. Both Sibumasu and East Malaya basement are Paleoproterozoic, although they are not of comparable age. Some basement fragments are possibly Neoarchean but there is no evidence for basement older than 2.8 Ga beneath the Malay Peninsula. Zircon Hf-isotope data confirm previous interpretations that Central Sundaland, including the Malay Peninsula, contributed large volumes of sediment to West Java during the Paleogene.

Depositional Systems In A Structurally Dynamic Basin; Decoding The Evolution Of The Pliocene In The West Nile Delta

Simon Shoulders, Ed Jones, Hannah Ross
BP Egypt, Building C, Chertsey Road, Sunbury on Thames, Middlesex
Email: simon.shoulders@bp.com

The West Nile Delta is a dynamically evolving basin where base level change, sediment loading and the gravitational collapse of the sediment wedge all control the distribution of accommodation space with time. Whilst it is possible to map faults and fault displacements in considerable detail using seismic data, only by integrating the evolution of accommodation space and distribution of sandy facies with the pattern of faulting can we understand the evolution of the basin with time.

The evolution of the Pliocene of the West Nile Delta is controlled by three key ingredients: Stable basement; a long-lived mud-dominated sediment input point from the Rosetta branch of the Nile system; and fluctuating base-level. Subsequent to the lower Pliocene flooding event, the West Nile Delta has been dominated by muddy background sedimentation with the deposition deepwater turbidite systems. Commonly these take the form of channelized systems, or levee systems centred on a (now) mud-filled channel. High net to gross, sinuous, stacked, turbidite channels display variable morphologies along their length filling erosive canyons or sitting within constructional levees. A single channel system may extend for over 100 km. Levee systems centred around mud-filled channels are generally less extensive than the major channelized systems and usually sit within a single seismic cycle.

Tectonics is principally driven by gravitational collapse of the sediment wedge and although there is clear evidence for the inheritance of underlying basement features there is no clear evidence for inversion during the Pliocene.

This presentation will focus on the events of the Upper Pliocene Piacenzian (P78) lowstand and lowermost

Gelasian (P80) flood and the subsequent structural re-equilibration of the basin and shift in accommodation space distribution.

Effects Of Topography On Lofting Gravity Flows: Implications For The Deposition Of Deep-water Massive Sands

Christopher J. Stevenson[1], Jeff Peakall[2]
[1]*National Oceanography Centre, Southampton,* [2]*School of Earth and Environment, University of Leeds*
Email: chris.stevenson@noc.soton.ac.uk

Hyperpycnal flows are an example of gravity currents that display reversing buoyancy. This phenomenon is generated by the sediment-laden, fresh water interstitial fluid being less dense than that of the ambient seawater. Thus after sufficient particles are sedimented the flow can become positively buoyant, forming a rising plume. Hyperpycnal flows are generated in the marine environment by sediment-laden fresh water discharge into the ocean. They frequently form at river mouths and also generated in proximal ice-melting settings and are thought to be responsible for transporting a large proportion of suspended river sediment onto and off the continental shelf. Here we present experimental results of lofting gravity currents upon interaction with topography. Topography, triggered a localised lofting zone on its upstream side. This lofting zone was maintained in a fixed position until the bulk density of the flow had reduced enough to allow lofting along its entire length. The obstructed lofting zone is associated with a sharp increase in deposit thickness. By inference these lofting dynamics are applied to improve understanding of the potential for hyperpycnal flows to deposit deep-water massive sands. This study provides for the first time a novel depositional mechanism by which large volumes of sand can be deposited in the absence of traction and the fines removed, leaving thick deposits of structureless sand with a low percentage of mud. This model provides a framework by which the geometries of deep-water massive sands can be predicted within specific depositional and basinal settings.

Fluid Mud Generated Grain-size Breaks In Turbidites Recording Very Large Volume Sediment Bypass

C.J. Stevenson, P.J. Talling, M. Frenz, R.B. Wynn, D.G. Masson
National Oceanography Centre, Southampton
Email: chris.stevenson@noc.soton.ac.uk

Sharp surfaces across which there is an abrupt upward decrease in grain size (grain size breaks) have been observed in turbidites from numerous disparate locations around the world, including both ancient outcrops and modern cores. Understanding how these grain size breaks form is important because they are a departure from classical models of turbidite evolution. Here we present unusually detailed analyses of grain size breaks from the Moroccan Turbidite System, offshore Northwest Africa. Excellent core control, from over 300 shallow piston cores, coupled with a strong chronostratigraphic and geochemical framework has enabled extensive correlation of individual turbidites over ~2000km. Such detailed field data enables grain size breaks to be documented in across flow and down flow directions, confirming that the missing grain sizes are found long distances down slope. Two types of grain size break are recognised, both overlain by ungraded mud. The first type is underlain by fine sand (typically rippled). The second type is underlain by ungraded structureless mud-rich sand deposited from a cohesive debris flow. In both cases, the missing grain sizes are interpreted to have been bypassed within cohesive fluid mud layers. Such grain size breaks occur throughout the Moroccan Turbidite System, and could provide evidence of large scale fluid mud generation.

The Waitemata Basin, New Zealand: A Basin On The Edge Of A Subduction Zone?

Lorna J. Strachan, Phil Shane, Christine Fildes
Geology Programme, School of Environment, University of Auckland, New Zealand
Email: l.strachan@auckland.ac.nz

Keywords: Waitemata Basin, Megaturbidite, Subduction, New Zealand, Conglomerate

Sedimentary basins at convergent and collisional margins are relatively well understood, with a range of modern examples that corroborate plate tectonic and basin formation theory. A ubiquitous feature to these models is the assertion that associated subduction zones are laterally extensive features. Very few studies predict basin formation at the lateral terminus of a subducting slab.

This presentation aims to describe some unusual results from a combined sedimentological, geochemical and radiometric dating pilot study of deep marine Waitemata Basin sediments which suggest that this basin may have formed at the lateral terminus of a subduction zone.

The Miocene Waitemata Basin has long been considered an inter- or intra-arc sedimentary basin formed between twin chains of arc volcanoes in Northland, New Zealand. This interpretation has been instrumental in constraining the inception of the present day Pacific and Indo-Australian convergent margin through the North Island.

Waitemata Basin polymict megaturbidites reveal an unusual clast assemblage with a dominance of non-arc, intraplate Ocean Island Basalts (OIB) and a conspicuous absence of arc material. Megaturbidites were emplaced by debris flows, hybrid flows and high concentration turbidity current flows on the contemporaneous slope and basin floor and have been precisely dated at 20 Ma by 40Ar–39Ar methods yielding an age 3 Myrs younger than previously documented.

These new data, although preliminary, cast serious doubts on previous basin interpretations and tectonic setting. An alternate plate tectonic setting model is suggested that accounts for the existence of a short lived rapidly subsiding basin and OIB-like magmagenesis.

Deposits Of Flows Transitional Between Turbidity Current And Debris Flow

Esther J. Sumner[1], Peter J. Talling[1], Lawrence A. Amy[2]
[1]*National Oceanography Centre, Southampton,* [2]*Saudi Aramco, Dharan*

Email: Esther.Sumner@noc.soton.ac.uk

Keywords: Linked Debrite, Turbidite, Annular Flume, Experiments

The relationship between submarine sediment gravity flows and the character of their deposits is poorly understood. Annular flume experiments were used to investigate the depositional dynamics and deposits of waning sediment-laden flows. Decelerating fast (> 3 m/s) flows with fixed sand content (10 vol.%) and variable mud content (0–17 vol.%) resulted in only four deposit types. Clean sand with a mud cap that resembled turbidity current deposit (turbidite) formed if the flow was turbulent when deposition began, or if the muddy fluid had insufficient strength to suspend the sand. The clean sand could contain structures if mud content was low (< 6%) and the deceleration period was greater than 300 s. Ungraded muddy sand with a mud cap that resembled debris flow deposit (debrite) formed if the flow became laminar before sand could deposit. Clean sand overlain by ungraded muddy sand and a mud cap formed either from a transitional flow or by late stage settling of sand from a muddy suspension. These deposits resemble enigmatic submarine flow deposits called linked debrite-turbidites. The experiments provide a basis for inferring flow type from deposit character for submarine sediment-laden flows.

How And Why Do Turbidites Differ From Textbook Models?

Esther J. Sumner[1], Peter J. Talling[1], Lawrence A. Amy[2], Russell B. Wynn[1]
[1]*National Oceanography Centre, Southampton,* [2]*Saudi Aramco, Dharan*
Email: Esther.Sumner@noc.soton.ac.uk

Keywords: Marnoso Arenacea Formation, Agadir Basin, Turbidite, Bouma Sequence

Facies models such as the iconic Bouma sequence are widely suggested to be representative of turbidites, as evidenced by their ubiquitous presence in sedimentology textbooks. Here these models are viewed as hypotheses that can be tested by comparison to unique long-distance correlations (120–250 km) of individual beds from two different turbidite systems. The twelve beds studied show the following significant differences from established models: 1) the distribution of structures is more complex than facies models suggest, despite all of the deposits being emplaced in relatively simple basin plain settings; 2) planar laminae are a major building block of the deposits; 3) turbidites can contain dunes; 4) coarse sands can contain a type of coarse laminae (stepped laminae) that is distinct from planar laminae both in appearance and in the grain size in which it forms; 5) beds sometimes exhibited an unusual dewatering fabric that gave the deposit a crenulated fabric; 6) abrupt changes in grain size occurred both within clean sands and between sands and muds; 7) bed shape is tabular; 8) linked debrite-turbidites are common to both of the systems studied. The detailed, long distance (120–250 km) correlations presented in this study do not support the hypothesis that facies models such as the Bouma sequence are representative of 'real' turbidites.

Mesozoic Palaeodrainage Evolution In The Rockall Basin, Offshore Western Ireland

Shane Tyrrell, Peter D.W. Haughton, J. Stephen Daly, Patrick M. Shannon
Sand Provenance Centre, UCD School of Geological Sciences, University College Dublin, Ireland
Email: shane.tyrrell@ucd.ie

Keywords: Provenance, Rockall Basin, Pb, K-feldspar, Drainage Evolution

The Rockall Basin, offshore western Ireland, is a frontier area for hydrocarbon exploration but the age and location of sand fairways through the basin are poorly known. Recent exploration drilling on the eastern basin margin (well 12/2-1 and sidetrack 12/2-1z) led to the Dooish gas condensate discovery which is hosted in sandstones of putative Permo-Triassic and Middle Jurassic age. The Pb isotopic composition of detrital K-feldspar offers a powerful method of determining the provenance of arkosic and sub-arkosic sandstones, and has proved particularly useful in investigations of sand dispersal into Mesozoic basins on the NW European margin. New Pb isotopic data from sandstones in well 12/2-1z suggest that three isotopically distinct basement sources supplied the bulk of the K-feldspar in the reservoir sandstones. Archaean and Proterozoic rocks, to the east and north of the eastern Rockall Margin, are the likely sources. More distal sourcelands to the north-west cannot be ruled out but there was no significant input from southern sources, such as the Irish Massif. Importantly, the relative contribution of these sources varies stratigraphically, with one source consistently available while the others intermittently supply detritus. This could be caused by the periodic rejuvenation of specific tributary systems, possibly linked to variations in uplift rates in the hinterland, or may be the result of subtle climatic factors affecting the delivery of grains to the basin. The stratigraphic variation in provenance highlights the potential of the Pb-in-K-feldspar provenance technique as a tool in the correlation of unfossiliferous sandstones.

Upper Permian Synsedimentary Tectonics In The Western North German Basin

Alexandra Vackiner[1], Philipp Antrett[1], Peter Kukla[1], Harald Stollhofen[2], Stefan Back[1]
[1]*Geological Institute, RWTH Aachen University,* [2]*North Bavarian Centre of Earth Sciences, FAU Erlangen*
Email: vackiner@geol.rwth-aachen.de

Keywords: Synsedimentary Tectonics, Upper Rotliegend, Southern Permian Basin, Germany, Aeolian Sediments

Rotliegend and Zechstein synsedimentary tectonic activity in Northern Germany and the Southern North Sea have not been fully understood yet. This analysis is focussed on the Upper Rotliegend II aeolian system including dune successions and wet to dry interdune environments deposited in the western North German Basin (as part of the Southern

Permian Basin). Sedimentary environments include a vast perennial saline lake with sand belts parallel to the shoreline. For interpretation purposes seismic and well data including wireline logs and four cores in Upper Rotliegend strata were available. Seismic interpretation revealed an extensional fault pattern of predominantly NNW–SSE oriented normal faults with vertical offsets of up to 900 metres. Graben and halfgraben structures partly developed during the Upper Rotliegend II or were reactivated from an Upper Carboniferous or Lower Rotliegend structural grain. Local depocentres developed as a result of complex relay ramps and pull-apart subbasins caused by left lateral transtensional stress. Palaeotopography, fault activity and the development of accommodation space through Rotliegend and Zechstein times can be derived from isopach maps. Dune bodies preserved in the wells from Upper Rotliegend II show maximum thicknesses of 3 meters. This indicates that there was only a limited supply of sediment available. Limited accommodation space in an area of locally lower subsidence rates and high wind velocities most likely prevented the evolution of higher dunes.

Complex Fluvial Heterogeneity In Apparently Homogenous Stratigraphy: An Example From The Permian Cutler Group, S.E. Utah

Joanne Venus, Nigel P. Mountney, William D. McCaffrey
Fluvial Research Group, School of Earth and Environment, University of Leeds
Email: eejhv@leeds.ac.uk

Keywords: Fluvial, Heterogeneity, Aeolian, Cutler Group, Permian

The mixed fluvial-aeolian Permian Cutler Group Undivided succession crops out extensively in the area west of Moab, southeast Utah. In overview, the succession appears to be laterally homogenous, being composed chiefly of sandstone bodies that overlie each other in an apparent layer-cake manner. However, analysis of the detailed stratigraphic architecture demonstrates that internally these sandstone bodies are composed of a complex arrangement of multistorey and multi-lateral channel and bar macroforms, each delineated by major bounding surfaces and many partitioned by thin but persistant units of argillaceous strata.

A detailed stratigraphic framework for the succession—constructed from measured sedimentary logs, architectural panels and photomosaic panels—is here used to demonstrate the complex form of lateral variations in facies association and styles of architectural interaction. Evidence for penecontemporaneous interaction between competing fluvial and aeolian processes is widespread. For example, aeolian dune facies are typically bimodally-sorted and contain a relatively high proportion of mica, which is indicative of the localised reworking of sediment from a fluvially-derived sediment source. Conversely, the presence of well-sorted 'millet seed' frosted grains in fluvial sheetflood and channel fill facies indicates the widespread fluvial reworking of sediment derived from mature aeolian dunes.

Effective characterization of this complex and laterally variable architecture is important for developing predictive models with which to better characterize subsurface successions. Whilst useful for characterization of hydrocarbon reservoirs, this approach is also important for predicting reservoir character in deep saline aquifers that are currently being considered as potential long-term underground sequestration sites for CO_2.

Heterogeneity Within Fluvial Facies: A Tool For Evaluating Depositional Models Of Dryland Fluvial-Aeolian Systems?

Joanne Venus, Nigel P. Mountney, William D. McCaffrey
Fluvial Research Group, School of Earth and Environment, University of Leeds
Email: eejhv@leeds.ac.uk

Keywords: Fluvial, Aeolian, Heterogeneity, Depositional Models, Dryland

Recent studies of modern dryland fluvial systems have identified several limitations in the generic applicability of previously accepted depositional models for mixed fluvial-aeolian successions. Although the sedimentology of modern dryland fluvial systems and the nature of their interactions with coeval aeolian dune fields are now relatively well documented, current models for the prediction of preserved facies architectures within ancient examples of such systems remain limited by a paucity of detailed outcrop studies with which to further refine, test and validate their wider applicability. The continued development of such models is essential if subsurface hydrocarbon reservoirs and deep saline aquifers that are currently being considered as potential sites for carbon sequestration are to be effectively characterized to the level of detail required to adequately predict the long-term fate of injected CO_2.

The Permian Cutler Group Undivided of the Paradox Basin, SE Utah is one well exposed example of an ancient mixed fluvial-aeolian succession, within which facies at the 'interwell' scale (100s metres) exhibit clear lateral variations in heterogeneity, within a sand-dominated succession which, at a wider scale, is apparently homogenous. This variation makes lateral correlation between even closely spaced logs difficult and this has a significant impact on the ability to predict the presence and lateral persistence of porous reservoir units and intervening low permeability baffles. A range of architectural elements and sedimentary logs from the outcrop study demonstrate this lateral and vertical facies variability and have here been used to develop a suite of predictive depositional models for such systems.

Linked Climatic And Eustatic Controls On The Timing Of Fluvial, Aeolian And Shallow Marine Sedimentation In The Permian Cutler Group, Paradox Basin, SE Utah, USA: Response To Orbital Forcing?

Oliver J.W. Wakefield[1], Nigel P. Mountney[2]
[1]*School of Physical Sciences & Geography, Keele University,* [2]*School of Earth & Environment, University of Leeds*
Email: o.j.w.wakefield@epsam.keele.ac.uk

Keywords: Eustasy, Fluvial, Aeolian, Transgression, Incised Valley

The Pennsylvanian-Permian lower Cutler beds are exposed in the Paradox foreland basin of southeast Utah and represent the lowest stratigraphic formation within the predominantly non-marine Cutler Group. The succession records a complex tripartite system in which competing aeolian, fluvial and shallow marine processes operated. Preserved sedimentary architectural relationships highlight a link between the timing of relative sea-level changes and synchronous changes in climate.

Relative falls in sea level can demonstrably be linked to episodes of increased aridity, which together acted to trigger episodes of aeolian dune-field construction. At the height of climatic aridity, the upwind aeolian sediment supply became exhausted and the dune fields progressively deflated in a downwind direction. At this time fluvial systems were largely confined to a series of shallow incised valleys. Relative rises in sea level are recorded by the back-filling of incised valleys with fluvial and shallow marine strata. In landward areas, extensive braidplains developed across the coastal plain. In more basinward areas, at least ten episodes of marine transgression are recorded as a series of thin but extensive limestone tongues.

The resultant sedimentary expression of this complex succession demonstrates clear cyclic changes whereby arid climatic episodes occurred synchronously with relative sea-level lowstands and humid episodes with highstands. The uniform thickness of each transgressive-regressive cycle suggests a periodic driving mechanism which is most easily explained by the so-called long-term (412 Ka) eccentricity cycle of glacio-eustatic origin, as has been proposed for the sedimentation within similar age basins across the North American mid-continent.

High-resolution Flow Dynamics Of Density Currents In The Xiaolangdi Reservoir, The Middle Yellow River, China

Taoyuan Wei[1], Jeff Peakall[1], Dan Parsons[1], Jim Best[2]
[1]*School of Earth and Environment, University of Leeds,* [2]*University of Illinois upon Urbana-Champaign*
Email: lectw@leeds.ac.uk

Keywords: Spatial And Temporal Evolution, Slope Break, Pulse, Secondary Flow

Xiaolangdi Reservoir, a major impoundment of the Yellow River completed in 2001, is one of the largest traps for water and sediment on the planet. The entry of the Yellow River into the reservoir is dominated by density underflows and offers an ideal location for turbidity current research.

Detailed fieldwork was conducted through high resolution hydraulic instruments (Echosounder, ADP, OBS etc.) within the reservoir in the summer of 2007. Bathymetric measurements in the reach where the river channel enters the reservoir exhibit a distinct break in slope and a rapid deepening of a leveed subaqueous channel. A series of ∼4 km longitudinal transects of flow measurements evidence the transition from river inflow to density underflow, and it is possible to distinguish three flow regimes downstreamwise: river inflow; plunging flow and density underflow. Flow acceleration and transformation created by the positive slope break is evaluated and is shown to have an important influence on flow dynamics. Cross-section surveys also suggest possible reversal of secondary flow through the subaqueous channel at a major bend apex. A force balance analysis implies that different combinations between Coriolis and centrifugal force can explain the lateral flow evolution along the channel. At-a-point surveys emphasize a range of interactions between suspended sediment (obtained by acoustic backscatter calibrations) and flow velocity in the form of discrete pulses, and highlights some important considerations for depositional/erosional processes, and the consequent deposits produced by density underflows and thus underlines the need to better understand these dynamics for sedimentation engineering management.

Stratigraphy And Provenance Of Cenozoic Sediments In The Barito Basin, SE Kalimantan

Duncan Witts
South East Asia research Group, Royal Holloway University, London
Email: d.witts@es.rhul.ac.uk

Keywords: Stratigraphy, Provenance, Kalimantan, Palynomorphs

Cenozoic sediments of the Barito Basin record the early stages of basin formation, showing a progressive evolution from terrestrial to marine conditions and a regression to fully terrestrial environments. Current work places these successions as middle Eocene and younger. This study focuses on the two terrestrial elements of the succession.

The oldest sequence is the Tanjung Formation and is suggested as Eocene to Early Oligocene in age. The formation sits unconformably above basement rocks of Cretaceous age and older. The formation is composed of alluvial conglomerates and floodplain deposits. An increasing marine influence is recorded up section. Early petrographic studies and heavy mineral analysis indicate geochemically mature but texturally immature compositions. Initial provenance work implies sediment arrived from the south during Eocene times. This contrasts to previous work that suggests a north-western source.

The Warukin Formation overlies the carbonates of the Berai Formation (a marine succession separating the terrestrial sequences), and contains thick sequences of sands and coals. Petrographic studies and heavy mineral assemblages have revealed a high abundance of reworked material.

Field studies have suggested several sources for these sediments: the Schwaner Mountains to the west and the Bawean and/or Karimunjawa Arches to the south. The influence of each source region is under investigation.

Palynomorphs assemblages are currently being examined in order to constrain the ages of the terrestrial sequences, better understand depositional environments, and to assist in stratigraphic correlation.

The Influence Of Subtle Gradient Changes On Deep-Water Gravity Flows

Wynn, R.B[1], Talling, P.J.[1], Masson, D.G.[1], Le Bas, T.P.[1], Cronin, B.T.[2], Stevenson, C.J.[1]
[1]*National Oceanography Centre, Southampton,* [2]*Deep*

Marine, 9 North Square, Footdee, Aberdeen
Email: rbw1@noc.soton.ac.uk

Keywords: Turbidity Current, Gravity Flow, Channel, Deep-water, Gradient

The influence of subtle gradient changes on deep-water gravity-flow processes and deposits is often hard to assess in outcrop or subsurface sequences, but new studies of modern systems are providing valuable insights. The Moroccan Turbidite System, off northwest Africa, is unique in that individual gravity-flow deposits can be correlated across distances of several hundred kilometres, both within and between depositional basins. An extensive dataset of shallow sediment cores is analysed, in order to investigate the influence of gradient changes on individual siliciclastic gravity flows passing through this system in the last 160,000 years. The largest flows (deposit volumes >100 km^3) are capable of travelling for more than 1000 km across slopes of less than 0.1°. The deposits of these flows display significant lateral heterogeneity as a consequence of changes in seafloor gradient. Increases in gradient can lead to sediment bypass and/or erosion, and unconfined flows may become channelised. Decreases in gradient can lead to significant changes in sand-mud ratio and the deposition of thick mud caps, while small-volume flow deposits may pinch out completely. One of the largest flows shows evidence for multiple transformations as it crossed the Agadir Basin, producing a complex deposit containing gravel lags and linked debrites. Although the observed changes in slope angle appear remarkably subtle, the relative changes in slope are significant, and clearly exert a major control on flow behaviour. Such variations in slope would not be detectable in outcrop or subsurface sequences, yet will generate significant complexity in deep-water reservoirs.

Reconstruction Of The East Asian Monsoon Variability Since The Mid-Holocene From The Pearl River Estuary, Southern China

Fengling Yu[1], Yongqiang Zong[2], Jeremy M. Lloyd[1], Guangqing Huang[3], Melanie J. Leng[4,5], Christopher Kendrick[4], Wyss W.-S Yim[2]
[1]*Department of Geography, University of Durham, UK,* [2]*Department of Earth Sciences, The University of Hong Kong, China,* [3]*Guangzhou Institute of Geography, China,* [4]*NERC Isotope Geosciences Laboratory, British Geological Survey, UK,* [5]*School of Geography, University of Nottingham, UK*
Email: flyu00@hotmail.com

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This study aims to reconstruct East Asian Monsoon (EAM) variability during the mid-Holocene, developing a relatively new proxy of bulk organic carbon isotopic signature (δ13C) and C/N from the Pearl River estuary, southern China. Sources of sediments within an estuary include river-derived terrestrial input, in situ brackish-water suspended sediment and tide-derived marine input. This study assumes the proxy can help differentiate sources of sediments relating to monsoon-driven freshwater flux and help reconstruct monsoonal precipitation history during the mid-Holocene. Modern samples were collected from terrestrial areas, including plants and soil samples, through to estuarine areas, including seasonal estuarine suspended organic matter and surface sediment. Results suggest that bulk organic δ13C and C/N ratios are good indicators for sources of estuarine sediments, and thus can be used to infer relative changes in monsoon-driven freshwater flux. For example, lower δ13C values reflect a greater level of contribution of freshwater organic carbon, i.e. stronger monsoonal freshwater discharge. Analysis of an estuarine core shows that freshwater discharge from the Pearl River catchment gradually declined from 6400 to 2000 cal. years BP, suggesting a gradual weakening of summer monsoon precipitation, responding to the weakening insolation controlled by the orbital-driven precession cycle. Superimposed on this are wet/dry intervals, ranging from centennial- to millennial- scale, driven by solar activities. Changes in ENSO and high-latitude cooling events might be responsible for dry/wet events at centennial- to decadal-scale. It also suggests possible decoupling of thermal and moist conditions of the EAM before 4500 cal.

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