British Sedimentological Research Group
55th Annual General Meeting
Cambridge
18th-20th December 2016
ABSTRACT VOLUME

WELCOME

Welcome to the 55th BSRG Annual General Meeting at the University of Cambridge. This year we have the pleasure of hosting over 260 researchers representing 61 universities, companies and organisations, from 13 different countries. With 184 talk and poster presentations spread over two days, this abstract volume should help you navigate your way around the conference and Cambridge.

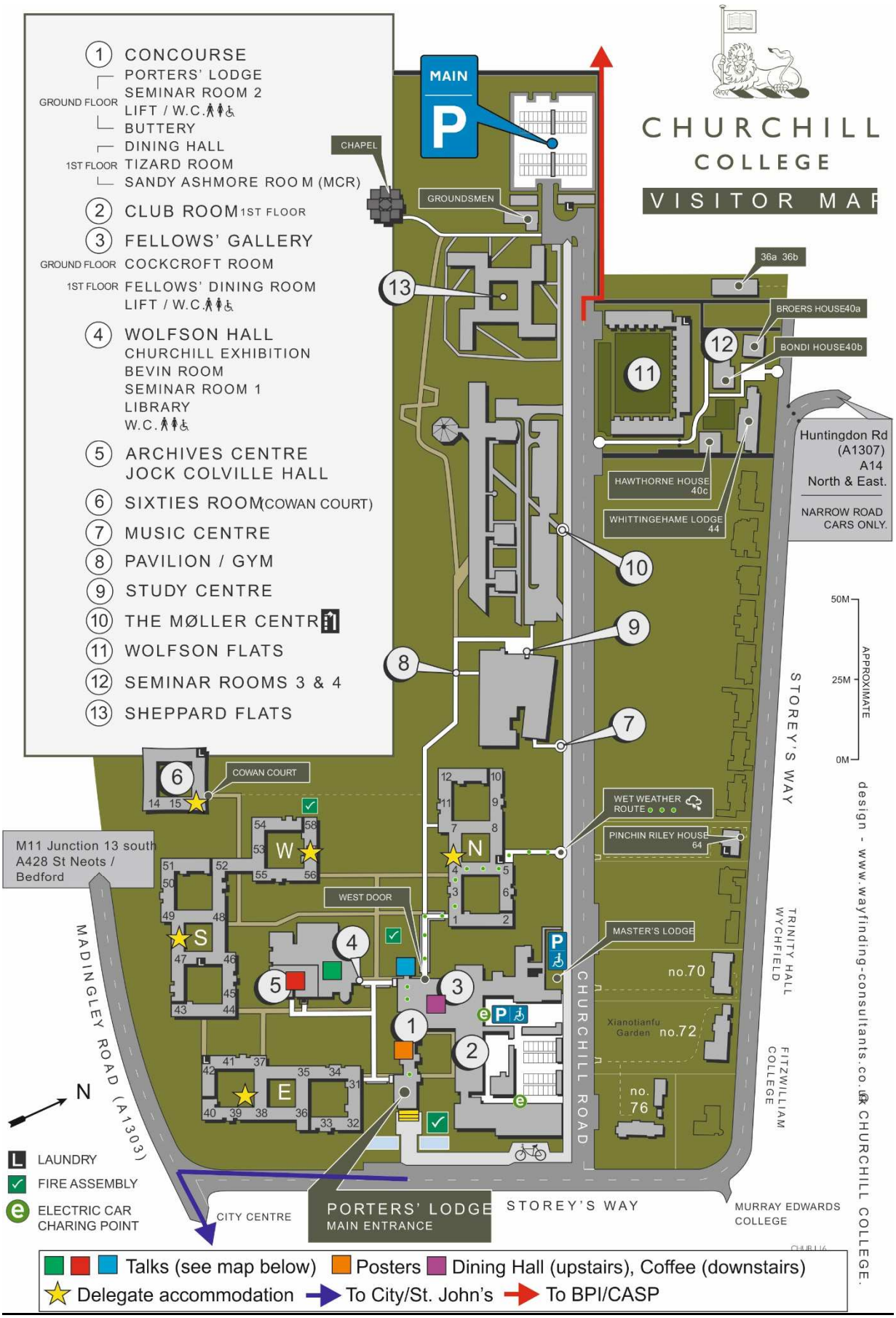
This booklet contains:

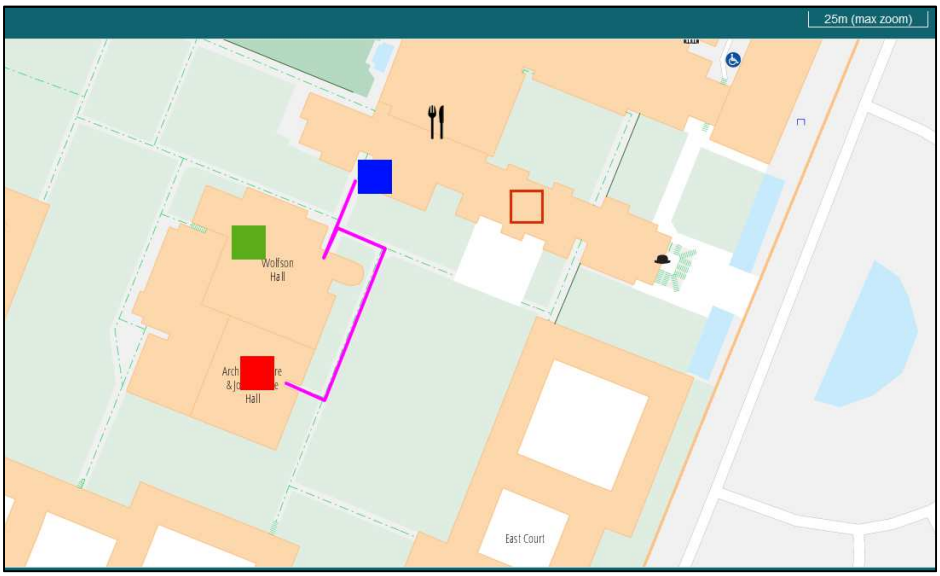
We are grateful to the following sponsors for helping to make this conference possible, in particular to BP, whose generous contribution has helped subsidise a high number of student places at the meeting:

Conference Convenors:

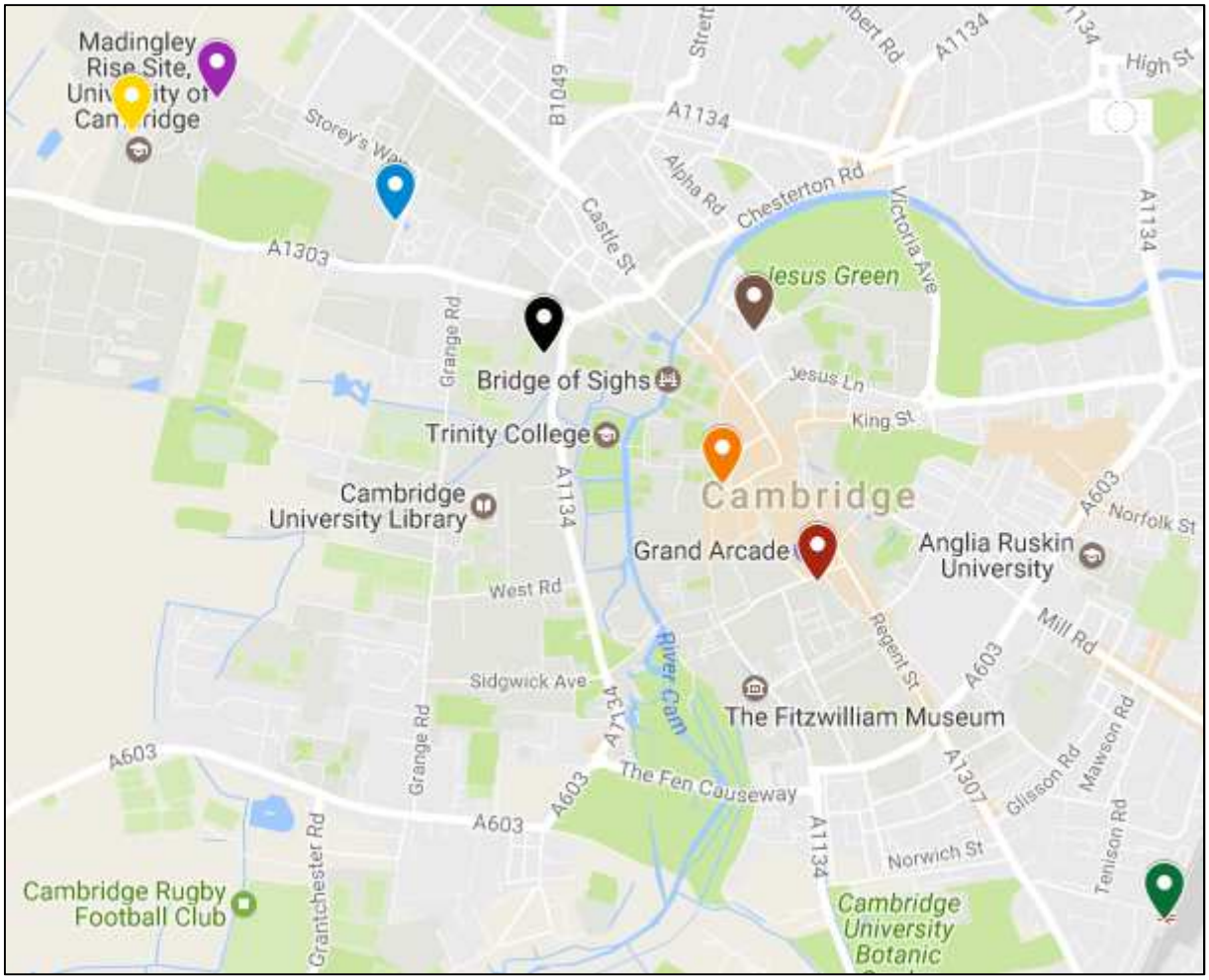
Neil Davies (Department of Earth Sciences) Lotty Gladstone (BP Institute) Stephen Vincent (CASP)

USEFUL INFORMATION & MAPS





Map of part of Churchill College showing locations of presentations. Open square = poster presentations; Green square = Wolfson Theatre; Red square = Jock Colville Hall; Blue square = JCR Games Room. Pink line shows access routes between the different locations. Knife-and-fork symbol shows location of Buttery (downstairs, coffee breaks) and Main Dining Hall (upstairs, breakfast & lunches). Bowler hat symbol shows main entrance to the college.



Map of Cambridge and key locations. Blue = Churchill College, Purple = CASP, Yellow = BPI, Black = St. John's (annual dinner), Red = Sedgwick Museum (icebreaker), Green = Train station, Brown = Maypole pub (after conference dinner), Orange = Cambridge University Press bookshop

Internet Access

Eduroam is available at both Churchill College and the Sedgwick Museum.

At Churchill, Wi Fi is available in all public areas, meeting rooms and bedrooms. No password is required – guests should connect to the wireless network called "CHURCHILL COLLEGE".

Internet access is also available in all bedrooms, via a wired connection for which an Ethernet cable is required. These cables can be purchased at the Porters' Lodge for £4.00 if delegates do not have their own.

The network available to guests is a 10Mpbs (megabytes per second) broadband line, shared between the guests. There is a maximum download limit of 1GB (gigabyte) for Wi Fi and 2GB for wired access. Should this limit be exceeded, internet access will be interrupted for a 24 hour period.

Luggage Storage

Luggage can be stored during the conference in the TV Room (adjacent to the JCR Games Room in which some of the talks will take place), but the conference organisers and college take no liability for loss, theft or damage of items in the storage room.

Breakfast for delegates staying in College

Breakfast will be available in the main dining hall of the college from 07:30-08:30 each day. This is only available to delegates who have booked bed and breakfast accommodation in the college.

Information during the conference

The registration desk (in the main college concourse) will be manned by volunteers for much of the conference. If you need to contact the organisers during the conference, please use the email address bsrg2016@bpi.cam.ac.uk.

Getting away

If you are leaving Cambridge by train, there are buses that leave from outside the college to the train station (turn right when walking out of the college main entrance, then left at the T-junction: the bus stop is on the left hand side of the road, two minutes walk from the college). The 'U' service, run by Whippet, costs £2 for a ticket, and leaves every 15 minutes (at 05, 20, 35, 50 minutes past the hour, until 1935) with a journey time of 19 minutes.

Taxi Numbers

Panther Taxis: 01223 715715/ 01223 424424/ 01223 523523
CamCab: 01223 704704

Eating & Drinking

Lunch is provided during the conference. If you are looking for somewhere to eat in Cambridge, the centre of town (20 minutes walk from college) has a wide range of options. The following is a partial list of decent pubs around the different conference venues – most of which also serve food:

Close to St. John's (after conference dinner)

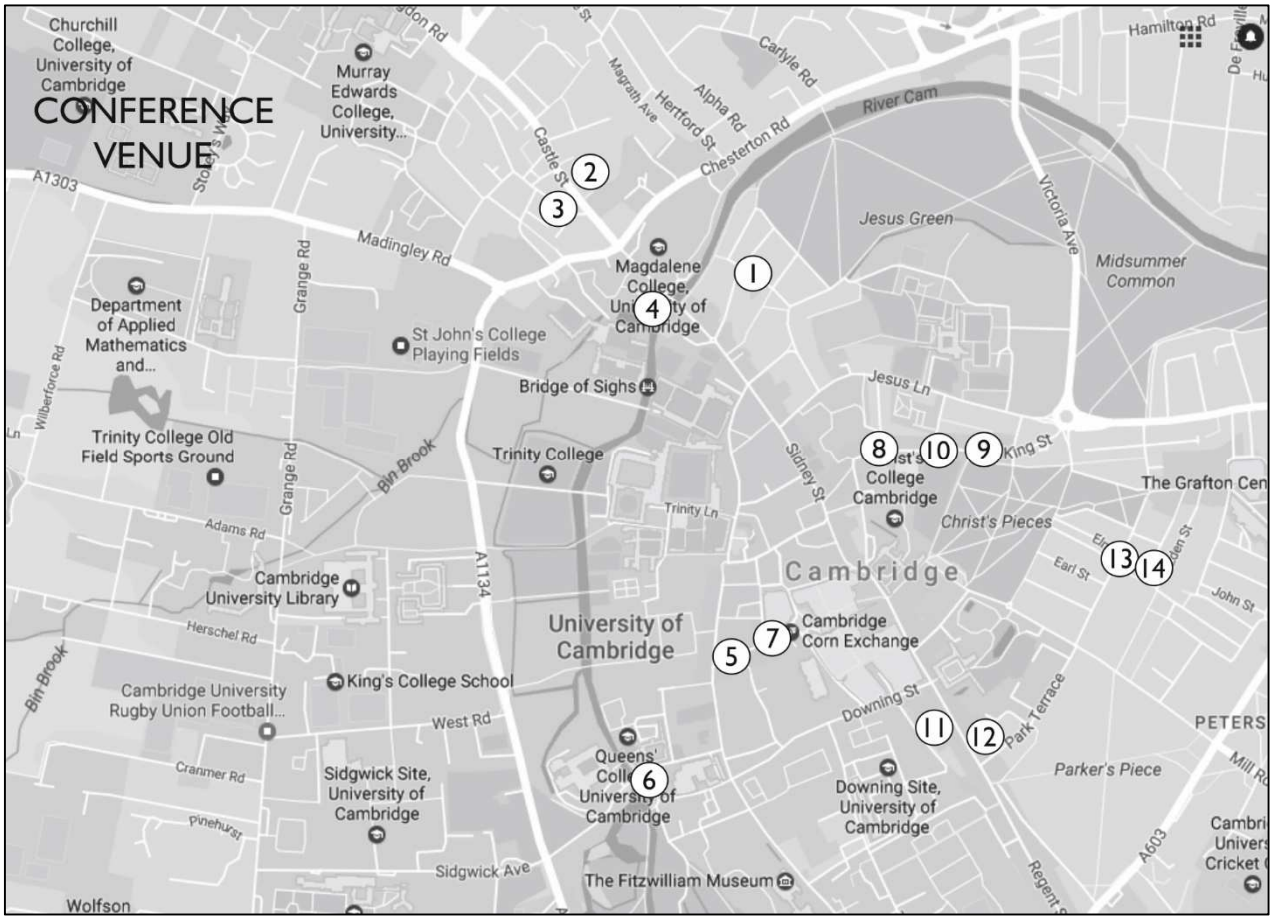
1. The Maypole, 20a Portugal Place, CB5 8AF - This is open until midnight and is a short walk from St. John's college after the conference dinner.

Close to Churchill College:

2. The Castle, 38 Castle Street, CB3 0AJ
3. The Architect, 43 Castle Street, CB3 0AH
4. The Pickerel, 30 Magdalene Street, CB3 0AF

Close to the city centre:

5. The Eagle, 8 Bene't Street, CB2 3QN
6. The Mill, 14 Mill Lane, CB2 1RX
7. The Pint Shop, 10 Peas Hill, CB2 3PN
8. Cambridge Brew House, 1 King Street, CB1 1LH
9. St. Radegund, 129 King Street, CB1 1LD
10. Champion of the Thames, 68 King Street, CB1 1LN
11. The Regal (Wetherspoons), 38-39 St. Andrews Street, CB2 3AR
12. Grain & Hop Store, 69-73 Regent Street, CB2 1AB
13. The Elm Tree, 16a Orchard Street, CB1 1JT
14. The Free Press, 7 Prospect Row, CB1 1DU



BSRG AGM 2016 – CONFERENCE SCHEDULE

SUNDAY 18th DECEMBER 2016

Day: Workshops & Fieldtrip

1730-2030: Icebreaker Reception, Sedgwick Museum of Earth Sciences

MONDAY 19th DECEMBER 2016

SESSION 1 – KEYNOTES & GENERAL SESSION (Wolfson Theatre)
Session chair: Lotty Gladstone (University of Cambridge)

0830-0845 – Welcome
0845-0915 – Peter Burgess (keynote): *How realistic is my sequence stratigraphic interpretation? Quantitative methods to help address this question*
0915-0945 – Joris Eggenhuisen (keynote): *Things I used to know: the static bed, threshold of motion, bed load, and suspended sediment transport*
0945-1000 – Adrian Hartley: *Braided or Meandering: Are Fluvial Facies Models Useful?*
1000-1015 – Martin Wells: *Searching for the source of Early Cretaceous clastic reservoirs in the Middle East*
1015-1030 – Jaco Baas: *Novel Mixed Sand-Mud Bedforms and Primary Current Stratification in the Aberystwyth Grits and Borth Mudstone Formations*

---1030-1100: Coffee & Discussion (Buttery)---

SESSION 2A – DEEP MARINE SEDIMENTARY ENVIRONMENTS I (Wolfson Theatre)
Session chair: Peter Haughton (University College Dublin)

1100-1115 – Gillian Apps: *Stratal modelling and structural paleotopography in deepwater basins*
1115-1130 – Sarah Southern: *Varied Stratigraphic Expressions of Slope Channel Evolution*
1130-1145 – Franziska Palm: *Variation of cross-sectional geometries in submarine channels*
1145-1200 – Lilla Tokes: *Degree of confinement of turbidity currents and deposit tabularity across different scales based on meta-data analysis*

SESSION 2B – SHALLOW MARINE & NEARSHORE SEDIMENTARY ENVIRONMENTS (Jock Colville Hall)
Session chair: Gary Nichols (RPS Nautilus)

1100-1115 – Claire Keevil: *The region of fluvial dominance within the tidal-fluvial transition*
1115-1130 – Arnoud Slootman: *Geological record of shallow-marine, supercritical tsunami backwash: Field observations and numerical simulation*
1130-1145 – Arjan de Leeuw: *Field insights into sediment delivery to the northwest Black Sea: the Late Miocene fluvio-deltaic Balta Fm of the East Carpathian Foreland*
1145-1200 – M. Mostafizur Rahman: *Detailed architecture of fluvio-deltaic sandstones: a subsurface and virtual outcrop (VO) study of the Scalby Formation, NE England*

SESSION 2C – SEDIMENTARY CLIMATE RECORDS & GLACIAL ENVIRONMENTS I (JCR Games Room)
Session chair: Gregory Price (Plymouth University)

1100-1115 – Elizabeth Atar: *Atmospheric and oceanic controls on the deposition of the Kimmeridge Clay Formation*

1115-1130 – Alena Ebinghaus: *Increased seasonality across the early Danian Dan-C2 hyperthermal: A case study from the Boltysh impact crater, Ukraine*
1130-1145 – Zvi Steiner: *The effect of bioturbation in pelagic sediments: Lessons from radioactive tracers and planktonic foraminifera in the Gulf of Aqaba, Red Sea*
1145-1200 – Madeleine Vickers: *Are glendonites reliable indicators of cold climates? Evidence from their paragenesis*

SESSION 3A – DEEP MARINE SEDIMENTARY ENVIRONMENTS II (Wolfson Theatre)
Session chair: Peter Haughton (University College Dublin)

1205-1220 – Jan de Leeuw: *Inversion of turbidity current flow properties from grain-size distribution of submarine channel deposits*
1220-1235 – Pauline Cornard: *Supercritical bedforms, field evidence and implications, in a deep-marine base-of-slope environment, Middle Eocene, Ainsa Basin, Spanish Pyrenees*
1235-1250 – Andy Pulham: *Sedimentary Structures in Deepwater Paleogene Wilcox Core Data, Gulf of Mexico, USA; Some New Insights into Deposition of Sands from High Magnitude Turbulent Flows*
1250-1305 – Lotty Gladstone: *The development of convolute lamination: insights from field observations and simple calculations*

SESSION 3B – ALLUVIAL FANS & S2S (Jock Colville Hall)
Session chair: Gary Nichols (RPS Nautilus)

1205-1220 – Björn Nyberg: *Global Drainage Patterns of Modern Sedimentary Basins and the Anthropocene*
1220-1235 – Martin Stokes: *Alluvial fans as recorders of volcanic island denudation*
1235-1250 – Sam Brooke: *Decoding sediment transport dynamics on alluvial fans from spatial changes in grain size, Death Valley, California*
1250-1305 – Stephen Watkins: *Are landscapes buffered to high-frequency climate change? A comparison of sediment fluxes and depositional volumes in the Corinth rift, central Greece, over the past 130 kyrs*

SESSION 3C – SEDIMENTARY CLIMATE RECORDS & GLACIAL ENVIRONMENTS II (JCR Games Room)
Session chair: Gregory Price (Plymouth University)

1205-1220 – Marie Busfield: *On the hunt for Cryogenian striated pavements…*
1220-1235 – Thomas Vandyk: *Descent into the Snowball: the sedimentary record of entry into Cryogenian glaciation in Death Valley, California*
1235-1250 – Dan Le Heron: *A diamictite dichotomy: Glacial conveyor belts and olistostromes in the Neoproterozoic of Death Valley, California, USA*
1250-1305 – Stephen Davison: *Glacial or non-glacial? A new field-based examination of the Permo-Carboniferous Sakoa Group of southern Madagascar*

---1305-1355: Lunch (Main Dining Hall)---

SESSION 4 – KEYNOTES (Wolfson Theatre)
Session chair: Stephen Flint (University of Manchester)

1355-1425 – Jan Alexander (keynote): *Some sedimentary consequences of discharge variability and rate of change*

1425-1455 – Massimiliano Ghinassi (keynote): *Planform evolution of meandering river channels and their sedimentary products: expansional vs. downstream-migrating point bars*

SESSION 5A – MODERN DEEP MARINE ENVIRONMENTS (Wolfson Theatre)
Session chair: Stephen Flint (University of Manchester)

1500-1515 – Matthieu Cartigny: *Knick points in turbidity current channels; dynamics and preservation potential*
1515-1530 – Maria Azpiroz: *First detailed measurements of turbidity currents downstream from submarine canyon bend show sustained river-reversed secondary circulation*
1530-1545 – Marta Payo Payo: *Influence of Coriolis forces on turbidity currents*
1545-1600 – Sophie Hage: *Linking cyclic steps of crescent-shaped bedforms and lenses of massive sand through direct field observations*
1600-1615 – Chris Stevenson: *Reconstructing the 1929 Grand Banks Event, offshore Newfoundland*

SESSION 5B – ANCIENT LIFE & SEDIMENTARY ENVIRONMENTS (Jock Colville Hall)
Session chair: Sarah Davies (University of Leicester)

1500-1515 – Neil Davies: *Indirect signatures of life in the alluvial stratigraphic record*
1515-1530 – Ginny-Marie Bradley: *Lower Palaeozoic pre-land plant paralic systems: A case where the present is not the key to the past…?*
1530-1545 – Anthony Shillito: *Shapes on a plane: exceptionally preserved substrates provide palaeoenvironmental insights into intervals of non-deposition*
1545-1600 – Carys Bennett: *The habitats of tetrapod terrestrialisation in the early Carboniferous*
1600-1615 – Jon Noad: *The Sedimentology of Bone Beds: a review and report on a new Triassic marine bone bed*

SESSION 5C – PROVENANCE & PROPERTIES (JCR Games Room)
Session chair: Shane Tyrrell (NUI Galway)

1500-1515 – Jessica Franklin: *Provenance of Triassic Sandstones – assessing the link between source area and sandstone reservoir quality*
1515-1530 – Iain Greig: *Heavy Mineral Stratigraphy and Provenance of Triassic Sediments of the Central North Sea*
1530-1545 – Brenton Fairey: *Detrital mica and zircon geochronology as evidence for the Devonian-Carboniferous "Old Red Staging Area" and development of super-mature sediments in the southern Irish offshore*
1545-1600 – Christof Liebermann: *Provenance of Sediments from Sumatra, Indonesia*
1600-1615 – Shuqing Yao: *Unravelling the controls on fault-associated dolomitisation geometries: examples from the Benicàssim outcrop analogue (Maestrat basin, E Spain)*

---1615-1640: Coffee & Discussion (Buttery)---

SESSION 6 – GENERAL POSTER SESSION (Main Concourse)

1640-1840 – Posters (see details below) & Prize-giving

---1900-2200: Conference Dinner (St. John's College)---

TUESDAY 20th DECEMBER 2016

SESSION 7 – AGM, KEYNOTE & GENERAL SESSION (Wolfson Theatre)
Session chair: Stephen Vincent (CASP, University of Cambridge)

0845-0930 – BSRG AGM
0930-1000 – Alastair Robertson (keynote): *Sedimentology and oceanic island arcs*
1000-1015 – Sarah Davies: *Early Mississippian palaeoenvironments and their significance for tetrapod preservation*
1015-1030 – Jeff Peakall: *A first process model for channel-lobe transition zones*
1030-1045 – Hugh Sinclair: *Abrasion set limits on gravel flux to the Ganga foreland basin*

---1045-1115: Coffee & Discussion (Buttery)---

SESSION 8A – SUBAQUEOUS SEDIMENTARY ENVIRONMENTS (Wolfson Theatre)
Session chair: David Hodgson (University of Leeds)

1115-1130 – Thomas Dodd: *Depositional architectures within deep lacustrine turbidite fans: examples from the Early Cretaceous, North Falkland Basin*
1130-1145 – Luz Elena Gomis Cartesio: *Lateral Variability In Upper Slope, Shelf Edge And Shallow Marine Stratigraphy Along A 70 Km Strike Transect: Karoo Basin, South Africa*
1145-1200 – Miquel Poyatos-More: *Spatial-temporal evolution of sedimentary systems, transition zones and stratigraphic sequences in an exhumed basin margin succession*

SESSION 8B – CARBONIFEROUS SEDIMENTARY BASINS (Jock Colville Hall)
Session chair: John Howell (University of Aberdeen)

1115-1130 – Sarah Newport: *Sedimentology and microfacies development within a slope to basin floor mudstone succession: Carboniferous Bowland Shale Formation, NW England (UK)*
1130-1145 – Joe Emmings: *Through Highs and Lows: Burial of Organic Matter in the Mississippian Bowland Shale*
1145-1200 – Lucy Manifold: *Controls on facies heterogeneity within the Carboniferous of the Pennine Basin*

SESSION 8C – TECTONICS & SEDIMENTS (JCR Games Room)
Session chair: Maurice Tucker (University of Bristol)

1115-1130 – Tamsin Blayney: *Indentation of the Pamirs with respect to the northern margin of Tibet: constraints from the Tarim basin sedimentary record*
1130-1145 – Mark Wilkinson: *Why are the Highlands high? Cenozoic uplift and erosion in Scotland*
1145-1200 – Stephen Vincent: *From rifting to orogeny; using sediments to unlock the secrets of the Greater Caucasus*

SESSION 9A – DEEP MARINE SEDIMENTARY ENVIRONMENTS III (Wolfson Theatre)
Session chair: David Hodgson (University of Leeds)

1205-1220 – Xiaoming Zhao: *A submarine fan: juxtaposition of slope aprons with straight channels*
1220-1235 – Marco Pizzi: *Sedimentation versus deformation rates as a control on the architecture of deep-water channel systems: observations from the toe-thrust region of the Niger Delta slope*
1235-1250 – Marco Patacci: *Petrography of turbidites and XRD analysis of their mudstone caps, insights from the Castagnola system, NW Italy*

1250-1305 – Andrea OrtizKarpf: *Influence of Salt-Related Seabed Topography on Mass-Transport Complex (MTC) Sedimentation*

SESSION 9B – SEISMIC & SEQUENCE STRATIGRAPHY (Jock Colville Hall)
Session chair: John Howell (University of Aberdeen)

1205-1220 – Tim Luber: *Qualitative and quantitative description of a late Barremian to Aptian forced-regression, Essaouira-Agadir Basin, Morocco*
1220-1235 – Bonita Barrett: *3D sequence stratigraphic modelling: shallow marine systems along active fault segments*
1235-1250 – Chris Jackson: *Seismic geomorphological analysis of the Farsund Basin, offshore southern Norway: Identification of Rivers, Reefs and Shorelines*
1250-1305 – Catherine Russell: *Reducing uncertainty in seismic interpretation of fluvial successions through prediction of point-bar form and heterogeneity*

SESSION 9C – CARBONATES & EVAPORITES (JCR Games Room)
Session chair: Maurice Tucker (University of Bristol)

1205-1220 – Ed Hough: *Primary sedimentary structures in bedded halite – indicators of depositional conditions from the mid-Triassic of the UK*
1220-1235 – Hao Tang: *Early Cambrian archaeocyathan-microbialite reefs in South China*
1235-1250 – Alan Smith: *Molar-tooth structure: a Precambrian calcite network dependent on bacterial EPS?*
1250-1305 – Andreas Paul: *Exploring the potential for the formation of discrete stromatolite build-ups from microbial mats in the Abu Dhabi coastal sabkha*

---1305-1355: Lunch (Main Dining Hall)---

SESSION 10 – KEYNOTE (Wolfson Theatre)

1355-1425 – Sanjeev Gupta (keynote): *'Robotic' sedimentary geology on Mars - reconstructing ancient sedimentary systems at Gale crater*

SESSION 11A – CONTINENTAL SEDIMENTARY ENVIRONMENTS I (Wolfson Theatre)
Session chair: Neil Davies (University of Cambridge)

1430-1445 – Steve Banham: *Anatomy of an ancient aeolian sandstone on Mars: the Stimson formation in Gale Crater, Mars*
1445-1500 – William McMahon: *The 'Forgotten' Torridonian: Alluvial (upper flow regime) and aeolian bedforms in the pre-vegetation Meall Dearg Formation, NW Scotland*
1500-1515 – Zoe McKellar: *Sedimentary analysis of the Lower Old Red Sandstone of the northern Midland Valley, Scotland*
1515-1530 – Catherine Cripps: *The influence of allogenic controls on facies variability within two basins: the Triassic Sherwood Sandstone Group of Central and Northern England*

SESSION 11B – EXPERIMENTS & MODELLING IN SEDIMENTOLOGY I (Jock Colville Hall)
Session chair: Esther Sumner (University of Southampton)

1430-1445 – Florian Pohl: *CHANGE! A turbidity current's transition from bypass to deposition – Experimental results & comparison to a field case from the Karoo, South Africa*

1445-1500 – Viet Luan Ho: *Multi-pulsed Turbidity Currents – A Scaling Analysis and Applications for Turbidite Interpretation*
1500-1515 – Paul Jarvis: *Formation and evolution of transverse bedforms: An experimental study*
1515-1530 – Age Vellinga: *Why do some turbidity currents create upstream migrating bedforms while others do not?*

SESSION 11C – PREDICTING SEDIMENTARY ARCHITECTURE (JCR Games Room)
Session chair: Michael Flowerdew (CASP, University of Cambridge)

1430-1445 – Ewan Gray: *Predicting facies distribution in Triassic fluvial systems of the central North Sea using subsurface data*
1445-1500 – Adam McArthur: *Application of deep-water palynofacies scheme to classify reservoir architecture in the Campos Basin, offshore Brazil*
1500-1515 – Menno Hofstra: *The depositional architecture of basin-floor fan systems by wireline log character: an integrated dataset from the Karoo Basin*
1515-1530 – Aurélia Privat: *Early post-rift facies and architectural changes within a coarse-grained deep-water system deposited above a Mass Transport Complex (MTC)*

SESSION 12A – CONTINENTAL SEDIMENTARY ENVIRONMENTS II (Wolfson Theatre)
Session chair: Neil Davies (University of Cambridge)

1535-1550 – Giacomo Medici: *Characterizing flow heterogeneities in a red-bed fluvial succession: Triassic St Bees Sandstone Formation (NW England, UK)*
1550-1605 – Amanda Owen: *Understanding fluvial facies distribution within sedimentary basins: Bighorn Basin, Wyoming*
1605-1620 – Michelle Shiers: *Controls on the depositional architecture of fluvial point-bar elements from a coastal plain setting*

SESSION 12B – EXPERIMENTS & MODELLING IN SEDIMENTOLOGY II (Jock Colville Hall)
Session chair: Esther Sumner (University of Southampton)

1535-1550 – Orla Bath Enright: *Gone with the flow: transportation of soft-bodied organisms in turbidity currents*
1550-1605 – Megan Baker: *The Effect of Clay Type on the Properties of Cohesive Sediment Gravity Flows*
1605-1620 – Diana Sher: *Gravity currents: entrainment, stratification and self-similarity*

SESSION 12C – CLAY MINERALS (JCR Games Room)
Session chair: Michael Flowerdew (CASP, University of Cambridge)

1535-1550 – Luke Wooldridge: *Biofilm origin of clay-coated sand grains*
1550-1605 – Joshua Griffiths: *Predicting Clay Mineral Distribution in Sandstone Reservoirs Using an Analogue Holocene Estuarine Succession*
1605-1620 – Chris Jeans: *Red Chalk, Secondary Bentonite and Volcanogenic Glauconite*

---1620-1640: Coffee & Discussion (Buttery); Meeting Closes---

POSTERS

There is a designated 2 hour poster session, in which each presenter has been allocated a 20 minute slot (indicated below), during which time they can be found next to their poster and will be on hand to verbally present their data and results, and answer any questions. Poster boards are numbered as follows.

GROUP 1 – CONTINENTAL SEDIMENTARY ENVIRONMENTS

1. Emese Szocs: *Diagenetic evaluation of Pannonian lacustrine deposits in the Makó Trough, southeastern Hungary* [1640-1700]
2. Alena Ebinghaus: *Lake sedimentological and ecological response to hyperthermals: Boltysh impact crater, Ukraine* [1700-1720]
3. Nigel Woodcock: *Sedimentological and ichnological analysis of the Upper Carboniferous Bude Formation, Culm Basin, SW England* [1720-1740]
4. Roger Burgess: *Triassic Palynology; correlation and environmental reconstruction of the Skagerrak Formation from the central North Sea* [1740-1800]
5. Colm Pierce: *A multiscale analysis of the Entrada Formation – an approach to erg reconstruction and geomodelling of a wet aeolian reservoir analogue* [1800-1820]
6. Ross Pettigrew: *Aeolian- Sabkha Interactions in the Cedar Mesa Sandstone, Southwestern USA* [1640-1700]
7. Alexander Whittaker: *Alluvial fan sensitivity to glacial-interglacial climate change: Case studies from Death Valley* [1700-1720]
8. Hugh Sinclair: *Cosmogenic nuclide concentrations in Neogene rivers of the Great Plains reveal the evolution of fluvial storage and recycling* [1720-1740]
9. Tom Perkins: *Chemical weathering fluxes and processes in the Mekong River* [1740-1800]
10. David Somerville: *Image analysis of fluvio-lacustrine depositional environments, East African Rift: sedimentary architectures and relationship to rift stage* [1800-1820]
11. Oscar Javier Arevalo: *Role of tectonics and climate on the preserved record of a low net-to-gross ephemeral fluvial succession, South-Central Pyrenees, Spain* [1640-1700]
12. Simon Jackson: *Modelling fluvial, aeolian and lacustrine response to differential rates of accommodation generation in developing salt basins* [1700-1720]
13. Ru Wang: *Fluvial response to sea-level change: revised sequence stratigraphic models for different basin and climatic settings* [1720-1740]
14. Alistair Swan: *The effects of fluvial architecture on the internal heterogeneity of a medial distributive fluvial system outcrop, Upper Jurassic, Colorado* [1740-1800]
15. Justina James Saroni: *The Fluvial Architecture of the Price River Formation, Mesaverde Group, Book Cliffs, Utah, U.S.A.* [1800-1820]
16. Joseph Ainsworth: *A preliminary Ground Penetrating Radar study of Fluvial Architectures at Spireslack, Ayrshire, Scotland* [1640-1700]
17. Jose Montero: *Application of quantitative analysis of fluvial sedimentary architecture to improved facies and reservoir modelling workflows* [1700-1720]
18. Catherine Burns: *Constructing fluvial floodplain successions; a hierarchical approach to the characterization of crevasse-splay deposits* [1720-1740]
19. Na Yan: *A Stratigraphic Model of Fluvial Meander-Bend Evolution for 3D Facies and Architecture Prediction* [1740-1800]
20. Peter Wooldridge: *Anastomosing fluvial systems in the Tournaisian? An investigation into fluvial systems of the Lower Carboniferous, Ballagan formation, Scotland* [1800-1820]
21. William McMahon: *Negligible microbial matground influence on pre-vegetation river functioning: evidence from the Ediacaran-Lower Cambrian Series Rouge, France* [1640-1700]

22. Kirsten Dutton: *Microbially mediated carbonate mineralisation in extreme environment microbial mats* [1700-1720]
23. Maurice Tucker: *Mineral precipitates in modern microbial mats: crystallites, spheroids and the role of EPS* [1720-1740]
24. Andreas Paul: *The elusive link between pore-water chemistry and early cement phases: Case study from the shallow subsurface of the Abu Dhabi coastal sabkha* [1740-1800]
25. Irdawati Lokman: *Facies analysis of humid-tropical, syn- to early post-rift coastal plain deposits: the Miocene K Group of the Malay Basin* [1800-1820]
26. Stephen Lokier: *Sun, Sand and Salt: The continental sabkhas of Abu Dhabi* [1640-1700]
27. Stephen Lokier: *Underneath the Mangrove Tree: The complex facies of mangrove systems* [1700-1720]
28. David Millward: *The climatic implications of Lower Mississippian evaporites in equatorial northern Britain* [1720-1740]
29. Andrew Mitten: *The Scottish Carboniferous Research Park: Educating geoscientists in fluvial to marginal marine sedimentology and subsurface reservoir analogues* [1740-1800]

GROUP 2 – MARINE SEDIMENTARY ENVIRONMENTS

30. Andrew Mitten: *Calciclastic mass flows from the Darriwilian/Sandbian boundary at Abereiddy Bay, Pembrokeshire, Wales, UK: Implications for Avalonian sea-level correlation* [1800-1820]
31. Aude Duval-Arnould: *Stratigraphic evolution of carbonate ramp and reef system along the Agadir-Essaouira Basin. Middle to Upper Jurassic Atlantic margin-western Morocco* [1640-1700]
32. Domenico Chiarella: *Cyclicity of toeset geometry as feature to recognize tide-modulated deposits* [1700-1720]
33. Domenico Chiarella: *Deltaic river-dominated to tide-influenced process regime change: a field-based example from the Lower Pleistocene of the Messina Strait (southern Italy)* [1720-1740]
34. Massimiliano Ghinassi: *Sedimentology and stratal architecture of subtidal point bars: an example from the Venice Lagoon (Italy)* [1740-1800]
35. Grant Cole: *Stratigraphy and Architecture of a Tectonically Influenced Shallow Water Delta Succession, Early Cretaceous Maestrat Basin, Spain* [1800-1820]
36. Bebhinn Anders: *Fluctuating sand supply to a prograding delta: provenance of the Mullaghmore Sandstone Formation, NW Carboniferous Basin, Ireland* [1640-1700]
37. William Mitchell: *The interaction of sediment systems and structurally-induced seafloor topography within a tectonically controlled intra-slope basin on the southern lobe of the Niger Delta* [1700-1720]
38. Grace Cosgrove: *New insights into wave-dominated deposition in continental shelf settings: high-resolution sediment character analysis from coeval topset, foreset and bottomset deposits* [1740-1800]
39. James Foey: *Predicting the Distribution of Shallow Marine Facies within Halokinetically Controlled Basins: Insights from the Upper Jurassic Fulmar Formation, UKCS* [1800-1820]
40. Keiran Blacker: *Linking in-situ geophysical and geotechnical properties of the Dogger Bank Formation to depositional and post-depositional processes* [1640-1700]
41. Andy Emery: *Role of deglaciation, sea-level rise and isostatic adjustment in marine transgression of the Dogger Bank* [1700-1720]
42. Eva Zimmer: *Seismic geomorphology linked to sequence stratigraphy of an Eocene shoreface in the Outer Moray Firth* [1720-1740]
43. Will Zhao: *Post-eruptive Submarine Terrace Development of Capelinhos, Azores* [1740-1800]
44. Ammar Balila: *Submarine slope channels and sand delivery to the basin floor in the pre-land plant world: a case study from a sediment-supply-driven succession in Arabia* [1800-1820]

45. Daan Beelen: *Shelf-edge trajectory analysis; the role of differential compaction* [1640-1700]
46. Michael Steventon: *Clinoform degradation, mass-transport complex (MTC) emplacement, and the healing of outer-shelf relief: a 3D seismic reflection case study from the Santos Basin, offshore Brazil* [1700-1720]
47. Hannah Brooks: *The long-term evolution of an exhumed deepwater stepped-slope profile* [1720-1740]
48. Cian McGuire: *Using benthic foraminifera to solve problems in deep-water sedimentary systems* [1740-1800]
49. SophieCullis: *The Deep-Marine Architectural Knowledge Store: A database approach to enhance meta-analyses of deep-marine systems* [1800-1820]
50. Zoe Roseby: *Deglacial history of the Anvers Palaeo-Ice Stream Trough, western Antarctic Peninsula* [1640-1700]
51. Keziah Blake-Mizen: *Reconstructing southern Greenland Ice Sheet history during the Plio-Pleistocene intensification of Northern Hemisphere glaciation: Insights from IODP Site U1307* [1700-1720]
52. Alex Piotrowski: *Reconstructing deep ocean circulation pathway and strength with grainsize-specific Nd isotopes on the lithic fraction of marine sediment* [1800-1820]
53. Charlotte Allen: *Evolution, processes and deposits of high latitude submarine fans* [1720-1740]
54. Daniel Bell: *Fundamentally Different Proximal and Distal Lobe Stacking Styles Within the Same Stratigraphic Interval: Upper Broto System, Jaca Basin, Spain* [1740-1800]
55. Qun Liu: *"Submarine Lobes" or "turbidite sheet sandstones", are they the same? Examples from the Carboniferous of NW Argentina* [1800-1820]
56. David Lee: *Applying neural network analysis to wireline data for the recognition of lobe sub-environments within basin-floor systems: a case study from the Karoo Basin* [1640-1700]
57. Kévin Boulesteix: *Deepwater mudrock depositional processes and sequence stratigraphy in the Permo-Triassic icehouse to greenhouse transition, Karoo Basin, South Africa* [1700-1720]
58. Tim Cullen: *The response of density underflows to rift basin floor topography and palaeoclimate: Examples from the Gulf of Corinth, Greece* [1720-1740]
59. Rachel Healy: *Thin-Bedded Turbidites; Characteristic Facies, Their Distribution and Process Sedimentology* [1740-1800]
60. Marta Payo Payo: *Trawling induced turbidity currents* [1800-1820]
61. John Torley: *Criteria for the recognition of supercritcal bedforms and its implications on reservoir heterogeneity, insights from fieldwork-based studies, Morillo and Guaso Systems, Ainsa basin, Spain* [1640-1700]
62. Ross Ferguson: *Textural characteristics of deep-marine gravity flow deposits: Insights from the Aberystwyth Grits Formation, Cardigan Bay, Wales* [1700-1720]
63. Jaco Baas: *Bedforms and Primary Current Stratification Generated by Hybrid Flows: Examples from the Laboratory and the Aberystwyth Grits Formation* [1720-1740]

GROUP 3 – MODELLING, EXPERIMENTS & SEDIMENT PROPERTIES

64. Isabella Masiero: *Orpheus: a new simple numerical model for mixed siliciclastic and carbonate sediment erosion, transport and deposition* [1740-1800]
65. Joana Silva: *Breaching Failure of Underwater Sediment Embankments* [1800-1820]
66. Isabel de Cala: *Testing the sensitivity of bedform phase space: flow velocity vs. sediment cohesion* [1640-1700]
67. Isabel de Cala: *Dune cross-stratification in turbidite systems* [1700-1720]
68. Maarten Heijnen: *Regimes of submarine channel evolution* [1720-1740]

69. Yvonne Spychala: *Lost in translation? Bridging the gap between lab and field– comparative studies of flume tank experiments and outcrop studies* [1740-1800]
70. Peeradon Samasiri: *Mixing in axisymmetric gravity currents* [1800-1820]
71. Megan Baker: *Know Your Clay: The Effect of Clay Mixtures on the Properties of Cohesive Sediment Gravity Flows* [1640-1700]
72. Andrew Manning: *Quantifying Flocculation Settling Dynamics of Natural Fine-grained Suspended Sediments: "Floccin' Across the USA!"* [1700-1720]
73. Iris Verhagen: *The effect of early compaction on detrital grain-coating clays* [1720-1740]
74. Jack Walker: *Geochemical signals associated with 'marine band' formation in the Lower Carboniferous Bowland Shale Formation, Northern England* [1740-1800]
75. Alex Lipp: *Testing the use of sulfur isotopes and sulfur concentrations as facies indicators in Precambrian and Phanerozoic sedimentary rocks* [1800-1820]
76. Michael Morton: *Sedimentology and Geochemistry of Eocene-Early Miocene Source Rocks from Paratethys* [1640-1700]
77. Auwalu Yola Lawan: *Predicting sedimentary facies using non-destructive core log X-ray fluorescence geochemistry: Comparing the Brent Group and Cook Formation, North Sea* [1700-1720]
78. James Mullins: *The application of Process-based sedimentological models as training images for Multi Point Statistics: A case study from the Ferron Sandstone, Utah* [1720-1740]

GROUP 4 – SEDIMENTARY BASINS, TECTONICS & VOLCANICS

79. Sean O'Neill: *Where has all the porosity gone?: Linking pore pressure evolution and reservoir quality in the Taranaki Basin, New Zealand* [1740-1800]
80. Sunday Okunuwadje: *Preliminary studies of diagenetic controls on Cenozoic clastic reservoir analogues, Southern California, USA* [1800-1820]
81. Catherine Breislin: *Basin-Scale Mineral and Fluid Processes at a Lower Carboniferous Platform Margin* [1640-1700]
82. Romesh Palamakumbura: *Pliocene-Pleistocene sedimentary-tectonic development of the Mesaoria (Mesarya) Basin, in northern Cyprus, in an incipient, diachronous collisional setting* [1700-1720]
83. Gloria Heilbronn: *Constraining onset of deformation in Pai-Khoi fold-and-thrust belt (Russia), via multi-proxy provenance study* [1720-1740]
84. Amy Gough: *The evolution of the Lahat, Lemat, and Talang Akar formations of the South Sumatra Basin, Southeast Asia* [1740-1800]
85. Robert Raine: *Stratigraphy and reservoir quality of the Permian in Northern Ireland* [1800-1820]
86. Steven Andrews: *Stratigraphic development of the Permian to Triassic of East Greenland: An expanded and complete P-T boundary succession?* [1640-1700]
87. Edward Fleming: *Investigating the impact of the Hornsund High on Triassic sedimentation in the western Barents Shelf* [1700-1720]
88. Mohit Tunwal: *Thermal history modelling in an extensional basin* [1720-1740]
89. Lloyd White: *Characterising the variation in heavy and light mineral modes from some of Indonesia's most explosive volcanoes (Merapi, Bromo, Sinabung and Toba)* [1740-1800]
90. Guohui Chen: *Geochemical discrimination of Upper Cretaceous volcaniclastic sediments: Kannaviou Formation, W Cyprus* [1800-1820]
91. Dominique Tanner: *High-temperature silica maturation causes non-equilibrium isotope fractionation beneath the El Indio paleofumarole: implications for diagenesis* [1640-1700]

Schedule At-A-Glance

Monday 19th December

Time	Wolfson Theatre	Jock Colville Hall	JCR Games Room
730	*Breakfast (only for delegates staying in Churchill) (Dining Hall)*		
745			
800			
815			
830	*Welcome*		
	1 - Keynotes/General		
845	**Burgess keynote**		
900			
915	**Eggenhuisen keynote**		
930			
945	**Hartley**		
1000	**Wells**		
1015	**Baas**		
1030	*Coffee & Discussion (Buttery)*		
1045			
	2A - Deep Marine I	***2B - Shallow Marine***	***2C - Climate/Glacial I***
1100	**Apps**	**Keevil**	**Atar**
1115	**Southern**	**Slootman**	**Ebinghaus**
1130	**Palm**	**A de Leeuw**	**Steiner**
1145	**Tokes**	**Rahman**	**Vickers**
	3A - Deep Marine II	***3B - Alluvial fans/S2S***	***3C - Climate/Glacial II***
1205	**J de Leeuw**	**Nyberg**	**Busfield**
1220	**Cornard**	**Stokes**	**Vandyk**
1235	**Pulham**	**Brooke**	**Le Heron**
1250	**Gladstone**	**Watkins**	**Davison**
1305	*Lunch (Dining Hall)*		
1315			
1330			
1345			
	4 - Keynotes		
1355	**Alexander**		
1410			
1425	**Ghinassi**		
1440			
	5A - Modern Deep Mar.	***5B - Life & Sediment***	***5C - Provenance***
1500	**Cartigny**	**N Davies**	**Franklin**
1515	**Azpiroz**	**Bradley**	**Grieg**
1530	**PayoPayo**	**Shillito**	**Fairey**
1545	**Hage**	**Bennett**	**Liebermann**
1600	**Stevenson**	**Noad**	**Yao**
1615	*Coffee & Discussion (Buttery)*		
1630			
	6 - General Poster Session		
1640	**Poster Session Presentations - see next page**		
1700	**Poster Session Presentations - see next page**		
1720	**Poster Session Presentations - see next page**		
1740	**Poster Session Presentations - see next page**		
1800	**Poster Session Presentations - see next page**		
1820			
1900	*Conference Dinner (St. John's College)*		

Tuesday 20th December

Time	Wolfson Theatre	Jock Colville Hall	JCR Games Room
730	*Breakfast (only for delegates staying in Churchill) (Dining Hall)*		
745			
800			
815			
830			
845	*AGM*		
900			
915			
	7 - Keynotes/General		
930	**Robertson**		
945			
1000	**S Davies**		
1015	**Peakall**		
1030	**Sinclair**		
1045	*Coffee & Discussion (Buttery)*		
1100			
	8A - Subaqueous	***8B - Carboniferous***	***8C - Tectonics***
1115	**Dodd**	**Newport**	**Blayney**
1130	**Gomes-Cartesio**	**Emmings**	**Wilkinson**
1145	**Poyatos-More**	**Manifold**	**Vincent**
	9A - Deep Marine III	***9B - Seismic/Sequence***	***9C - Carbonates***
1205	**Zhao**	**Luber**	**Hough**
1220	**Pizzi**	**Barrett-Crosdil**	**Tang**
1235	**Patacci**	**Jackson**	**Smith**
1250	**OrtizKarpf**	**Russell**	**Paul**
1305	*Lunch (Dining Hall)*		
1315			
1330			
1345			
	10 - Keynote		
1355	**Gupta**		
1410			
	11A - Continental I	***11B - Modelling I***	***11C - Architecture***
1430	**Banham**	**Pohl**	**Gray**
1445	**McMahon**	**Ho**	**McArthur**
1500	**McKellar**	**Jarvis**	**Hofstra**
1515	**Cripps**	**Vellinga**	**Privat**
	12A - Continental II	***12B - Modelling II***	***12C - Clay Minerals***
1535	**Medici**	**Bath Enright**	**Wooldridge**
1550	**Owen**	**Baker**	**Griffiths**
1605	**Shiers**	**Sher**	**Jeans**
1620	*Coffee & Discussion (Buttery)*		
1635	*Meeting Closes*		

Poster Presentations

Poster session runs 1640-1840 on Mon 19th Dec, but presenters guaranteed in attendance for presentation during the following slots

	GROUP 1	GROUP 2	GROUP 3	GROUP 4
	Continental	Marine	Modelling	Basins
1640-1700	Ainsworth	Anders	Baker	Andrews
	Arevalo	Beelen	de Cala 1	Breislin
	Lokier 1	Blacker	Morton	Tanner
	McMahon	Duval-Arnould		
	Pettigrew	Lee		
	Szocs	Roseby		
		Torley		
1700-1720	Ebinghaus	Chiarella 1	de Cala 2	Palamakumbara
	Dutton	Blake-Mizen	Lawan	Fleming
	Jackson	Boulesteix	Manning	
	Lokier 2	Emery		
	Montero	Ferguson		
	Whittaker	Mitchell		
		Steventon		
1720-1740	Woodcock	Chiarella 2	Heijnen	Heilbronn
	Burns	Allen	Mullins	Tunwal
	Millward	Baas	Verhagen	
	Sinclair	Brooks		
	Tucker	Cullen		
	Wang	Zimmer		
1740-1800	R Burgess	Ghinassi	Masiero	O'Neill
	Mitten 1	Bell	Spychala	Gough
	Paul	Cosgrove	Walker	White
	Perkins	Healey		
	Swan	McGuire		
	Yan	Zhao		
1800-1820	Pierce	Cole	Silva	Okunuwadje
	Lokman	Balila	Lipp	Chen
	P Wooldridge	Cullis	Samasiri	Raine
	Saroni	Foey		
	Somerville	Liu		
		Mitten 2		
		Payo Payo		
		Piotrowski		

KEYNOTE ABSTRACTS

Some sedimentary consequences of discharge variability and rate of change

Jan Alexander

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Most of the understanding of sediment entrainment, bedform development, channel geometry and sedimentary facies architecture has been developed by considering processes occurring when velocity and discharge is unchanging in time (i.e. flow is steady). It is standard practice to apply theories developed for steady conditions to flows which are inherently unsteady, by considering "average" conditions, or "channel forming" conditions. Some advances have been made by considering processes in differing flow conditions, assuming change is instantaneous between periods of constant conditions. The consequences of flow unsteadiness can be far greater than represented by these approaches, because change itself may be as important as the end point conditions. Flow unsteadiness occurs on a wide range of scales, and both the magnitude and rate of change have considerable implications for sediment transport and deposition. Deposit characteristics at scales from individual particles to geological formations are influenced by flow unsteadiness. Although several sedimentary consequences of unsteadiness are being researched in different contexts around the world, there is a lot that is not known about sediment transport and deposition in unsteady flows that is not currently being researched. This talk will consider a little of the complexity of unsteady flow and some sedimentary consequences with the aim of stimulating discussion.

How realistic is my sequence stratigraphic interpretation? Quantitative methods to help address this question

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Interpretations of strata take many forms, but in some cases there is a danger that the interpretation is derived more from a model than it is from observational evidence. This is particularly true of the sequence stratigraphic method in which observations of strata often lead to interpretation of ordered patterns taken to be indicative of particular accommodation-supply controls, for example cycles of relative sea-level. In such cases robust evidence, independent of any underlying model, is essential to properly support the interpretation.
Independent evidence of ordered pattern is best provided by comparing the arrangement of strata with what can happen by chance. By defining statistical metrics that characterise the facies and thickness arrangement of strata in an observed vertical succession we can quantitatively compare observed strata with randomly shuffled but otherwise equivalent vertical successions. If the metrics for the observed strata are unlikely to occur in randomly shuffled strata, this is strong evidence for a non-chance ordered pattern that could arise, for example, from periodic external forcing by relative sea-level. The same facies metric can also be used to identify what we could consider an ideal cycle in the strata; the ordering of facies classes that gives highest transition probabilities along diagonals of a transition probability matrix can be taken as a quantitative definition of an ideal cycle for the strata being analysed. Sequence stratigraphic interpretations backed by this kind of quantitative evidence are more likely to be realistic interpretations than similar interpretations without such evidence.
Independent evidence to determine if a particular accommodation-supply interpretation of stratal geometries is realistic can be provided by analysis of a stratal control space. A stratal control space is an area or volume with axes of, for example, subsidence, sediment supply and eustasy. A stratal control space can be populated with probabilities derived from analysis of accommodation and supply time series to indicate the likelihood of occurrence of any particular combination of control rates. A stratal control trajectory is a history of supply and accommodation rates, interpreted from outcrop or subsurface data, and plotted as a series of linked points forming a trajectory through a stratal control space. Any trajectory can be analysed to determine what control is dominant, and to determine how probable and therefore how realistic the interpretation is.

Things I used to know: the static bed, threshold of motion, bed load, and suspended sediment transport.

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Many sedimentological studies involve interpretation of formative conditions of the sedimentary rock record. The interpretative framework used for this inversion of dynamic conditions from static end results is often based on 20th century hydraulics of sediment transport. In its most simple form this framework uses a tri-partite division of regimes: sediment is moved as bedload if the threshold of movement is exceeded, the sediment goes into suspension if it is exceeded further, and this transport is underlain by a bed of static sediment particles, a state to which all sediment also returns at the end of a sedimentation event. While the application of this simple framework in sedimentary deposit analyses is robust, often sufficient, and thus successful, it lags behind modern conceptions of the dynamics of solid particles in fluids. This presentation will review recent treatments of physical processes operating during transport of particles in fluids that can be directly applied to sedimentology, and highlight where these insights can critically advance our interpretation of sedimentary rocks.
The talk will describe sediment transport regimes from gentle flow all the way to vigorous energetic conditions. It will start by demonstrating that minute amounts of sediment can be transported both as bedload and suspended load at the gentlest of flow conditions, and that the threshold of motion therefor does not exist. A rich suite of grain-fluid-grain interactions occur at higher energies, which are successfully described with frictional-type rheologies and the kinetic theory of gasses. A distinct flow-deposit interface, i.e. a bed, is missing in these regimes. In the overlying turbulent suspension regime, it has recently become clear what the dynamic linkages between specified turbulent structures and the absolute load of sediment are. Finally, the presentation demonstrates that fluid flow through the porous bed is important in bedforms forming common sedimentary structures.

Planform evolution of meandering river channels and their sedimentary products: expansional vs. downstream-migrating point bars

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Facies models for fluvial point bars are commonly based on the assumption that meander bends increase their sinuosity as meander-bend apices migrate transverse to the channel-belt axis (i.e. bend expansion). Widespread application of this model in the ancient record enhanced detection of laterally accreting bars, hindering identification of further morphodynamics, which can be observed in modern meandering rivers. Despite downstream-migrating fluvial point bars (DMFPB) are less known than the classical expansional ones (EXFPB), observations from modern rivers show that downstream migration is a widespread process, and highlight that planform evolution of point bars is commonly a combination between lateral accretion and downstream migration.
EXFPB and DMFPB will be compared here in terms of: i) conditions required for their development; ii) sedimentology and stratal architecture ; iii) geometries of related channel belt deposits.
The occurrence of resistant banks is required for development of DMFPB. Lateral confinement of channel belts, either morphological or tectonic, can trigger formation of adjacent DMFPB. In relatively confined settings, EXFPB are dominant, although isolated meander bends can migrate downstream after impinging against, erosion-resistant channel fill mud.
In both DMFPB and EXFPB, the coarser deposits occur upstream. Nevertheless, upstream bar deposits are rarely preserved where meander bends migrate downstream. Downstream-bar deposits are similar in DMFPB and EXFPB, where a clear a downstream decrease in grain size occurs. Fine-grained counter-point bars or coarse-grained eddy-accretion deposits can characterize the tail of DMFPB, specifically where the channel-flow impinges at high angle against the outer bank.
Channel belts dominated by EXFPB are floored by irregular surfaces hosting elongated, spoon-shaped depressions becoming deeper moving away from the channel-belt axis. Differently, belts dominated by DMFPB develop cross-sectional configurations featuring two main marginal trenches, commonly filled with bar tail deposits. Different rates of aggradations are also considered to affect geometries of channel-belt deposits.

'Robotic' sedimentary geology on Mars - reconstructing ancient sedimentary systems at Gale crater

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Mars provides the only other evidence aside from Earth of the significant flow of water at a planetary surface. Four decades of orbital observations have revealed a rich record of erosional and depositional landforms that are inferred to have formed by ancient aqueous processes. These results provide important information to reconstruct past climatic conditions on Mars and the evolution of palaeoclimates. Furthermore, they inform us about the potential for rocks on Mars to contain a record of ancient microbial life. However, numerous questions remain about the relative timing, magnitude and duration of water activity on Mars, and the sequence of events in the evolution of water flow at the martian surface. As a result, orbital records require testing against in situ field-based observations to accurately reconstruct martian palaeoenvironmental evolution.
In this talk, I will describe how the Mars Science Laboratory team have been analysing sedimentary rocks at Gale crater to investigate the environmental history of early Mars. Through detailed sedimentary, stratigraphic and geochemical investigations of rover observations, we have been able to derive a robust model for sedimentary evolution of potentially habitable environments at Gale. In particular, I will show how classic field observations enable us to reconstruct a first order stratigraphy for these martian rocks and reconstruct a variety of sedimentary facies that range from alluvial fan conglomerates, cross-bedded fluvial sandstones, lacustrine mudstones and aeolian sandstones.
I will conclude by highlighting the role of sedimentology in upcoming missions.

Sedimentology and oceanic island arcs

Alastair Robertson

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So why am I talking about the importance of sedimentology in oceanic island arcs? During my PhD work in the 1970s in Cyprus, I ran into a c.750m sequence of Late Cretaceous arc-derived volcaniclastics (Kannaviou Formation), of no known source (but see poster by Guohui Chen et al.). In the l980s, while working on Jurassic ophiolites in California (Coast Range Ophiolite), I found that I was dealing was an emplaced oceanic arc. During the 1990s, I encountered the Cretaceous Dras oceanic island arc in the Ladakh Himalayas. In the noughties, the Cretaceous ophiolites of SE Turkey turned out to be arc related. Most recently, in South Island New Zealand, I find myself working on a >10 km-thick Permian oceanic arc apron (Brook Street Terrane). Prior to and during this time, the oceanic community has, of course, carried out co-ordinated research on oceanic island arcs, mostly in the W Pacific region. Building on exploratory 1970s DSDP results, the Mariana arc and related back-arc basins were drilled as a transect and the Izu-Bonin segment further north was explored, followed by drilling of the Tofua arc and the adjacent Lau marginal basin, north of New Zealand, with many fantastic discoveries. A couple of years ago, IODP dedicated three expeditions (6 months; funding >$20 million) to drill a transect across the Izu-Bonin back arc-arc-fore arc. Major results include establishing the timing and setting of initial arc volcanism (c. 50 Ma), the role of back-arc rifting and fore-arc development. Condensed fore-arc tuffaceous sediments chart the geological history of the oceanic arc system, including initial volcanism, arc rifting and amalgamation with Honshu (Eurasia). Surprisingly, oceanic arc magmatism (i.e. future ophiolite!) may not have initiated along an oceanic transform as commonly assumed, but perhaps instead adjacent to a pre-existing Cretaceous continental margin arc, bordering Eurasia.

TALK PRESENTATIONS

Stratal modelling and structural paleotopography in deepwater basins

Gillian Apps[1], Frank Peel[2], Donald Christie[3] and Esther Sumner[3]

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Tectonic activity is commonly inferred from evidence of structural relief at the sea floor, such as indicators of slope instability. We challenge this preconception with a simple forward model that generates stratal patterns and basin topography through time using only three variables: the rates of clastic sediment surface rise, structure growth, and pelagic sedimentation.
Whether topography develops in a structurally active basin depends on the relative rates. Behaviour is bimodal: above a critical ratio, topography grows rapidly, but below it, topography is rapidly swamped, creating near-flat seafloor.
This is shown by the modern Gulf of Mexico. Where sediment flux to the slope is low, sea floor topography is dramatic, with highs over salt highs and lows in the salt withdrawal basins. However, where sediment flux is high, there is little to no structural surface relief; the slope topography is the depositional Mississippi fan surface.
The same is also true of outcrop areas. For example, it is assumed that the Grès d'Annot basin (in which slope failure was rare) was structurally quiescent, while Muttekopf-Gosau was strongly active. Our models suggest that the rate difference may have been quite subtle, with Gosau above the tipping point ratio, and Annot below it.
Our current 2D modelling illustrates how basin topography evolves through time. It is simple and fast; it is designed to allow a user to do multiple runs and iterate towards the best fit of observed stratigraphy. We favor this approach, which uses data to condition the model until it matches observations, as opposed to a complex forward-modelling strategy, which requires the user to know the "unknowable" (e.g. the scale of turbidity currents)
Modelling 3D paleotopography will require a cross-discipline effort, integrating seismic, well, core and outcrop data with sound understanding of structural and depositional processes.

Atmospheric and oceanic controls on the deposition of the Kimmeridge Clay Formation

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Atmospheric circulation has long been evoked as a key driver in the formation of black shales. Optimum conditions for the burial of organic carbon prevail when the supply of nutrients enhances productivity and depletes oxygen in the ocean bottom waters. In the present day, the flux of nutrients to the oceans is particularly high under the inner and outer limbs of the Hadley Cell. Under the ascending limb of the Hadley Cell, nutrient flux to the ocean is increased due to enhance continental weathering and runoff. At the outer limb of the Hadley Cell, surface winds diverge and surface ocean waters are displaced, which promotes upwelling of colder nutrient rich water. In both scenarios, enhanced nutrient supply drives the production of organic carbon and the creation of ideal preservation conditions.
A climate model, computed for the Upper Jurassic, predicts that the Hadley cell was expanded and located over the UK sector during the deposition of the Kimmeridge Clay Formation. We have a conducted a multiproxy geochemical and petrographic study of a laterally equivalent cross section ranging from Dorset (UK) to Longyearbyen (Spitzbergen) to investigate the hypothesis that changes in the location of the Hadley Cell was a key driver of variations in the amounts of organic matter preserved in the Kimmeridge Clay Formation.
The chemical weathering and rainfall proxies are high and constant throughout the studied section suggesting there was no significant changes in climate. However, TOC and $CaCO_3$, both related to productivity in surface waters and ocean circulation/bottom water conditions, are variable and correlate. This suggest that the Hadley Cell may have played an important role in Upper Jurassic black shale formation but that subtle oceanographic and bathymetric controls may have had a more important role.

First detailed measurements of turbidity currents downstream from submarine canyon bend show sustained river-reversed secondary circulation

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Turbidity currents form submarine channels whose extent rivals or exceeds the channel systems formed by rivers systems on land. In rivers, the combination of centrifugal forces and radial pressure gradients in bends induces cross-stream circulation that coupled with downstream flow generates a helical flow. In rivers, the cross-stream (or secondary) circulation is directed towards the outer bend at surface level and the inner bend at the riverbed. This flow structure governs watercourse evolution through patterns of erosion and deposition in meandering rivers. Whilst there are thousands of direct flow measurements for rivers there are few measurements for turbidity currents. Turbidity current dynamics have consequently been studied mainly through experimental and mathematical modelling approaches; with a small number of direct measurements from field-scale density currents. These different approaches have demonstrated contradictory results in terms of the orientation of secondary circulation; whether it is river-like or river-reverse.
Here we present the first measurements of the secondary circulation within full-scale oceanic turbidity currents. We consider 10 individual flows in the Congo Canyon with highly variable sizes from 20 to 80 m thickness reaching velocities higher than 1.5 m/s. Our results, from turbidity currents following a tight bend in the Congo Canyon, display a secondary circulation structure comprising two stacked cells that are maintained for a large variety of flow sizes. The lowermost cell has a consistent river-reverse circulation orientation. These results are important because river-reversed secondary flow will tend to transport sediment towards the outer bend. This means that point bars on the inner bend, which are classically observed in rivers, would not form in submarine canyons.

Novel Mixed Sand-Mud Bedforms and Primary Current Stratification in the Aberystwyth Grits and Borth Mudstone Formations

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Novel bedforms and primary current stratification were discovered in the Silurian Aberystwyth Grits and Borth Mudstone Formations (West Wales), which allowed these deep-marine sedimentary facies to be interpreted as the depositional products of turbulent, transitional and laminar sediment gravity flows (sensu Baas et al., 2009, Sedimentology).
Recent experiments (Baas et al., 2016, J. Geol. Soc.) have shown that decelerating flows carrying cohesive clay and non-cohesive silt and sand produce unique bedforms. Owing to the ability of cohesive clay to modify flow and bed properties – causing turbulent flow to change to different types of transitional and quasi-laminar flow – 'classic' current ripples change into large ripples, and washed-out ripples and upper-stage plane bed change into, amongst others, low-amplitude bedwaves, as clay content is increased. At very high clay content, where turbulence is strongly attenuated or suppressed, cohesive plane bed is most common. These cohesive plane beds consist of heterolithic horizontal stratification in the form of alternating mud and sand/silt laminae, formed in steady flow, thus without the need to invoke periodic fluctuations in flow velocity. These new bedform types were captured in a phase diagram of non-dimensional flow strength against clay content (as yield strength).
To verify if these laboratory-scale bedforms have natural equivalents, fieldwork was conducted in the distal, mudstone-rich, part of the Silurian deep-marine Aberystwyth Grits and Borth Mudstone Formations (West Wales). Multiple examples of sedimentary structures in mixed sand-mud were found. As these current-induced structures were remarkably similar to those observed in the laboratory, their mode of formation was attributed to various types of turbulent, transitional and quasi-laminar flow, thus providing the opportunity to expand the interpretation of sediment gravity flow deposits in core and outcrop to a wider range of realistic deep-marine sedimentary processes.

The Effect of Clay Type on the Properties of Cohesive Sediment Gravity Flows

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Cohesive clay-laden sediment gravity flows (SGFs) have not received the scientific attention they deserve, considering the abundance of clay on earth and the many examples of clay-laden SGF deposits. Cohesive SGFs are complex owing to the dynamic interplay between turbulent and cohesive forces.
Laboratory experiments using a lock-exchange tank were conducted to contrast the behaviour of flows laden with weakly cohesive kaolinite clay and strongly cohesive bentonite clay at a range of concentrations, in natural seawater. Initially, increasing the volumetric concentration of kaolinite and bentonite within the flows led to a progressive increase in the maximum head velocity of the flows, due to the increased density difference between the flow and ambient fluid, which drives the flow.
Increasing the volume concentration of kaolinite and bentonite above 22% and 17%, respectively, reduced the mobility of the flows, expressed by a decrease in both the maximum head velocity and run-out distance of the SGFs. We infer that increasing the concentration of clay particles enhances the opportunity for the particles to collide and form clay flocs and gels. This increases the viscosity and shear strength of the flows at the expense of shear-induced turbulence.
A greater volumetric suspended sediment concentration of kaolinite is needed compared to bentonite to produce similar run-out distances and maximum head velocities. Strongly cohesive bentonite flows were able to create a stronger network of particle bonds than weakly cohesive kaolinite flows of a similar concentration, producing flows with a lower mobility.
These experimental results can be used to improve our understanding of the deposit geometry and run-out distance of fine-grained SGFs in the natural environment. We suggest that natural high-density SGFs that carry weakly cohesive clays (e.g. kaolinite) reach a greater distance from their origin than flows that contain strongly cohesive clays (e.g. bentonite) at similar suspended sediment concentrations.

Anatomy of an ancient aeolian sandstone on Mars: the Stimson formation in Gale Crater, Mars

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Aeolian systems are widely documented across the solar system, however aeolian strata, the preserved expression of migrating dune fields, have only been documented on Earth and Mars. The Stimson formation, Gale crater, represents one of only two examples of aeolian strata documented on a planet other than Earth. Since landing in Gale crater in 2012, the Mars Science Laboratory (MSL) rover *Curiosity* has traversed the plains north of Aeolis Mons (informally Mount Sharp) documenting the stratigraphy preserved within the crater to determine habitability of the ancient Martian surface.

Recently, the rover Curiosity encountered the Stimson formation, a cross-bedded sandstone which unconformably overlays the lacustrine Murray formation mudstones. The unconformity is documented to undulate with an amplitude of 10 m locally over 230 m and regionally by 140 m over 1.8 km of lateral traverse south towards Mount Sharp. Where grains can be observed, the Stimson formation is characterised by well-sorted medium-grained sandstones with occasional bi-modally sorted medium- and very-coarse grained sandstones. These sandstones comprise large-scale cross-bedded sandstones (sets up to 0.8 m thick) characterised by mm thick self-parallel laminations interpreted to be wind-rippled laminations. The cross-strata dip predominantly toward the north-east, suggesting transport oblique to the regional slope direction. Cross-sets are separated by interdune migration surfaces that subdivide the succession. However fine-grained interdune facies associated with these surfaces are not identified anywhere on the traverse.

We interpret the Stimson formation to be the preserved expression of a dry aeolian system which accumulated on a deflationary unconformity. This is attributed to: large preserved cross sets; migration of bedforms oblique across the regional slope; and absence of fine-grained interdune deposits. The Stimson formation represents a later stage in the drying out of Gale crater, where dunefields migrated across the desiccated and deflated lakebed deposits represented by the Murray formation.

3D sequence stratigraphic modelling: shallow marine systems along active fault segments

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The North Sea hydrocarbon province is mature and exploration targets are increasingly focussed on stratigraphic and combination traps in syn- and early post-rift successions. These systems are active during tectonic subsidence and marine transgression and preserve a complicated depositional architecture that is challenging to predict with conventional sequence stratigraphic models. Despite the advances of sequence stratigraphic theory there remains a lack of understanding of the interplay of the major controls (tectonic displacement, eustatic sea level and sediment supply) in 3D. A solid understanding would facilitate identification of reservoirs, and prediction of their geometry and calibre in syn- and post-rift settings, where elucidating the interplay of these controls is critical. We address this challenge with a novel, geometric, 3D sequence stratigraphic model that integrates tectonic constraints to sequence stratigraphy and considers both along-strike and down-dip variability in shallow marine facies distribution on a fault segment-scale. The model generates a 3D accommodation surface in the hangingwall of a normal fault, and stacking patterns and systems tracts are predicted in time and space for the given set of controls. Conceptual tests have been undertaken to assess the sensitivity of sequence architecture to major sedimentary controls, with a focus upon the expression of the syn- to post-rift transition. Exhumed systems from modern rifts are analysed as analogues (e.g. Gulf of Corinth, Greece). Results demonstrate the along-strike and down-dip variability of sequence architectures in a number of real scenarios, and demonstrate a diachronous nature to sequence boundaries and other key sequence stratigraphic surfaces. The results challenge classic sequence stratigraphic theory that such surfaces are time-equivalent and thus correlatable. Diachroneity on a fault-length scale has direct implications for static reservoir model generation and hydrocarbon volume and production rate predictions. Work is being undertaken to invert the model for predictions in areas with less data constraint.

Gone with the flow: transportation of soft-bodied organisms in turbidity currents.

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The manner in which soft-bodied organisms and evidence for their activities passes into the fossil record has been at the forefront of experimental taphonomy. However, the question remains as to what, if any, kind of transport these animals could have endured before being deposited and could they actually survive such transport? The latter is based on the "Doomed Pioneer" hypothesis, in which organisms living in an oxygenated environment are caught up in a turbulent flow and transported to an oxygen deficient environment. These organisms then colonize and create trace fossils in anoxic sediment, at least briefly, before eventually expiring. This has a significant impact on interpreting trace-fossils in deep-marine settings.
Annular flume tank experiments have been used to determine the effects of turbulent sediment-density flows on the durability and preservation potential of the polychaete *Alitta virens*. A first set of experiments tested the impacts of transport duration, grain angularity and sediment concentration on the damage state caused to freshly-euthanized subjects. Flow duration and grain angularity were both found to be important factors that had statistically significant effects on the state of damage experienced by polychaetes within sediment-density flows. A further set of experiments was conducted to explore the "doomed pioneer" hypothesis in which the live specimens were subjected to a turbulent transport regime in order to explore their survival potential after transport and under different treatments of water temperature and oxygen. Results from the doomed pioneer experiments also produced statistically significant results. All polychaetes survived the turbulent transport regime and were also capable of burrowing, however, the time taken to burrow was significantly higher than by those that had not undergone transport.

The habitats of tetrapod terrestrialisation in the early Carboniferous

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Tetrapod terrestrialisation in the Carboniferous may be linked to changes in the environment. To investigate this, the sedimentology of 142 tetrapod localities from the mid Devonian to end Carboniferous is reviewed. Articulated fossils are common in black shale, siderite nodules, palaeosols and carbonate rocks, and disarticulated fossils in conglomerate. Organic-rich environments, including coal swamps, preserve the greatest concentrations of specimens. Trackways are preserved in lagoonal carbonate rocks or sandstone capped with a mudstone layer. Tetrapod fossils preserved in floodplain settings are more common than those in fluvial bodies from the Visean onwards. Two Tournaisian successions are studied to examine this transition.
Semi-articulated terrestrial tetrapods from the Ballagan Formation of the Scottish Borders are preserved within sandy siltstone; organic-rich, matrix-supported siltstone with millimetre-sized siltstone and sandstone clasts. 71% of sandy siltstone beds overlie desiccated surfaces or palaeosols, representing a landscape of low vegetation (Inceptisols and Entisols), saline marshes/mires (gleyed Inseptisols) and forests (Vertisols). Rare, disarticulated tetrapod bones occur within fluvial conglomerate lags associated with pedogenic mudstone clasts. Tetrapods occupied the terrestrial environment, and were deposited after death in temporary floodplain lakes following seasonal flooding events.
Contemporaneous tetrapods occur in the Horton Bluff Formation, Nova Scotia. Trackways occur within wave-rippled fine sandstone, topped by a microbial layer. Disarticulated bones occur within conglomerate lags or coarse, erosive-based sandstone beds with aeolian quartz grains, interbedded with grey siltstone interpreted as marginal marine bay fills. Gleyed Inceptisols and *in situ* lycopsid stumps indicate periodic terrestrial conditions. Tetrapods lived along coastal bays or lagoons and disarticulated remains may have been derived from land.
These studies indicate that early terrestrial tetrapods exploited floodplain environments but a marine connection was important in terms of taphonomy and ecology. The rise of lycopsid forests and onset of major land plant diversification in the early Carboniferous opened up new floodplain habitats for tetrapods.

Indentation of the Pamirs with respect to the northern margin of Tibet: constraints from the Tarim basin sedimentary record.

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The Pamirs represent the indented westward continuation of the northern margin of the Tibetan Plateau, dividing the Tarim and Tajik basins. Their evolution may be a key factor influencing aridification of the Asian interior, yet the tectonics of the Pamir Salient are poorly understood. We present a provenance and palaeomagnetic study of the Aertashi section, a Paleogene to late Neogene clastic succession deposited in the Tarim basin to the north of the NW margin of Tibet (the West Kunlun) and to the east of the Pamirs. Our detrital zircon U-Pb ages coupled with zircon fission track, bulk rock Sm-Nd and petrography data document changes in contributing source terranes during the Oligocene to Miocene which can be correlated to regional tectonics. We propose a model for the evolution of the Pamir and West Kunlun (WKL) in which the WKL formed topography since at least ~200 Ma. By ~25 Ma, movement along the Pamir-bounding faults such as the Kashgar-Yecheng Transfer System had commenced, marking the onset of Pamir indentation into the Tarim-Tajik basin. This is coincident with basinward expansion of the northern WKL margin, which changed the palaeodrainage pattern within the Kunlun, progressively cutting off the more southerly WKL sources from the Tarim basin. An abrupt change in the provenance and facies of sediments at Aertashi has a maximum age of 14 Ma; this change records when the Pamir indenter had propagated sufficiently far north that the North Pamir was now located proximal to the Aertashi region.

Lower Palaeozoic pre-land plant paralic systems: A case where the present is not the key to the past…?

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Lower Palaeozoic and Precambrian sandstones are commonly texturally and compositionally mature and have a notable lack interbedded mudstones. Many documented sections are described as being super mature clean quartz arenite sandstones with a maximum of 2% preserved mud. These predate the evolution of vascular land plants with the first appearance documented during the Devonian. Terrestrial vegetation has a significant influence on depositional processes and characteristics of clastic sediments in modern environments. Vegetation binds substrate, controls weathering and erosion rates, influences run-off, sediment supply and subsequent depositional architecture.
A review of published research suggests key defining tidal features such as flaser bedding, tidal mud drapes and tidal couplets are largely absent from the lower Palaeozoic rock record and this study assesses the possible reasons for this linked to the evolution of vascular land plants.
A case study is presented for the Tumblagooda Sandstone Formation of Western Australia. It comprises stacked sand-rich facies with well-preserved bedforms and intervals of exceptionally preserved trace fossils, typical of early Palaeozoic sequences. Previous workers have suggested alternate models for deposition, from a mixed intertidal flat and fluvial environment to an exclusively continental environment. The lack of mud in the sections and an absence of marine fauna is not typical of modern shallow marine systems. However the overwhelming evidence from the preserved sedimentary features and facies supports a re-interpretation as deposition within a shallow subtidal environment progressing into an intertidal environment, frequently punctuated by sheet style fluvial events.
Three-dimensional outcrop models reconstructed from drone photogrammetry have also been used to document the geometries and stacking of architectural elements to use for future reservoir modelling. The ability to access remote outcrops with high resolution images has revealed more sheet channelisation of fluvial and tidal channels, suggesting these systems are different due to a lack of vascular land plants.

Decoding sediment transport dynamics on alluvial fans from spatial changes in grain size, Death Valley, California

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How fluvial sediment transport processes are transmitted to the sedimentary record remains a complex problem for the interpretation of fluvial stratigraphy. Alluvial fans represent the condensed sedimentary archive of upstream fluvial processes, controlled by the interplay between tectonics and climate over time, infused with the complex signal of internal autogenic processes. With high sedimentation rates and near complete preservation, alluvial fans present a unique opportunity to tackle the problem of landscape sensitivity to external boundary conditions such as climate.

For three strongly-coupled catchments-fan systems in the tectonically quiescent northern Death Valley, we measure grain size trends across well-preserved Holocene and Late-Pleistocene deposits. Our results show that fan surfaces dated from the Late-Pleistocene are, on average, 50% coarser than counterpart active or Holocene fan surfaces, with clear variations in input grain sizes observed between surfaces of differing age. Furthermore, the change in ratio between mean grain size and standard deviation is stable downstream for all surfaces, satisfying the statistical definition of self-similarity.

Applying a self-similarity model of selective deposition and downstream fining, we constrain using regression analysis a single model of relative mobility distinct to alluvial fans. Corrected for local grain size, we discover that independent best-fits produce a modelled prediction of grain size mobility without the need to constrain local hydrological parameters. These predictions show changing sediment transport regimes between fan surfaces with very low mobility for grain sizes above 40mm and a high degree of sensitivity to the variance of grain size, not just the magnitude.

These results support recent findings that alluvial fan sediment characteristics can be used as an archive of past environmental change. Significantly, the self-similarity methodology offers a means to constrain relative mobility of grain sizes from field measurements where hydrological information is lost or irretrievable.

On the hunt for Cryogenian striated pavements…

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Evidence of glaciation has been recorded on nearly every modern continent during the Cryogenian, representing the most geographically widespread glaciation(s) in Earth's history, and yet despite exceptional preservation of glaciogenic deposits, subglacially striated surfaces are extremely rare. Well known examples have been recorded beneath the Smalfjord Formation in Svalbard, the Jequitaí Formation in Brazil and beneath the Mineral Fork tillite in northern Utah. However, recent reconnaissance to the latter section casts some doubt on this interpretation. The stratigraphic position and morphology of the polished surface, alongside shape and orientation of the striae themselves do not resemble classic glacially striated pavements, raising the possibility that Cryogenian striated surfaces are even more rare than previously considered. It remains to be addressed whether their rarity is a factor of preservation potential, or suggestive of particular glaciological conditions which need to be met for their formation.

Knick points in turbidity current channels; dynamics and preservation potential.

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High-resolution bathymetric images of turbidity current channels reveal the existence of a wide range of bedforms within these systems. Knick points are the dominant bedform on a kilometre scale in most sandy systems. These knick points are thought to initiate and maintain submarine channels, and they would therefore play a key role the transport of sediment and nutrients to the deep sea. In contrast to their important role very little is known about knick points. What drives the formation of a knick point? Are they remnant headwalls of landslide, or are they related to turbidity currents? Are they a purely erosional feature? Do they have any preservation potential in the rock record?
Here we present data collected from knick points in an active turbidity current channel on a fjord floor in British Colombia, Canada. These data show how trains of knick points migrate several hundred metres upstream every year. We use repeat surveys to show how knick points are a combined erosional-depositional feature. Furthermore, we have deployed several instruments over the knick points to study how the knick points interact with the passing turbidity currents. Finally, we use repeat surveys and cores to explore the potential architecture and facies association associated to knick points.

Supercritical bedforms, field evidence and implications, in a deep-marine base-of-slope environment, Middle Eocene, Ainsa Basin, Spanish Pyrenees.

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A novel approach to understanding the stratigraphic development of submarine fans, including their internal architecture and stacking patterns, is to consider the relative importance of deposition from supercritical versus subcritical flows. In recent years, many researchers have focussed on supercritical- and subcritical-flow deposits using flume-tank experiments (e.g., Cartigny el al., 2011; Postma et al., 2014; Postma & Cartigny, 2014) or from direct observations on presently active deep-water systems (e.g., Hughes et al., 2012).
Using outcrop and core examples from a base-of-slope environment in the Middle Eocene Ainsa Basin, Spanish Pyrenees, associated with published experimental work, a range of deposits are interpreted as upper-flow regime bedforms. Such beforms involve a wide range of grain sizes and different sedimentary structures, such as backset bedding, spaced stratification, upflow cross lamination, and scour-and-fill structures. This contribution focusses on the interpretation of several bedforms observed on the field and cores and interpreted as produced under supercritical-flow conditions, with a particular emphasis on structures formed in the zone of hydraulic jumps.

The influence of allogenic controls on facies variability within two basins: the Triassic Sherwood Sandstone Group of Central and Northern England

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Allogenic controls (tectonics, eustasy, and climate) on sedimentation are thought to exert the most influence on depositional trends seen within sedimentary basin fill. This study examines two adjacent early Triassic basins, with similar allogenic factors of climate, eustasy and sediment supply. What is unclear is how the expression of facies/depositional trends might manifest in these two tectonically different, but otherwise similar, basins.

The East Midlands shelf, is a passive shelf-edge basin marginal to the South Permian Basin. The Needwood Basin, in contrast, is a half graben created by extensional tectonics and typified by normal synsedimentary faulting. Much of the sediment supply to the basins was derived from a single sediment source (the London-Brabant High and Armorican Massif) located in present-day SE England and Northern France, with a local input to the Needwood Basin from the Pennine high.

Architectural element and lithofacies analysis on three selected outcrops, and borehole logging on 8 boreholes, was conducted from across the two basins. This indicates that both basin successions comprise amalgamated channel fill, with emphasis on downstream accreting elements. In the East Midlands Shelf (Yorkshire-Nottinghamshire), the sedimentary basin infill is characterised by sandy, trough cross-bedded sequences; palaeoenvironmental interpretation suggests a sandy braided river environment. Successions from the Needwood Basin are indicative of a higher depositional energy, possibly influenced by proximity to several sources of sediment into an actively subsiding basin.

Tectonic allogenic forcing factors exert a large degree of influence on depositional trends in both basins. Most notably, the degree of subsidence and distance from the basin margin is thought to have the most effect on facies type and distribution. This enhances our understanding of facies predictability and depositional trends away from data points, and can feed into the development of better reservoir models.

Indirect signatures of life in the alluvial stratigraphic record

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The erosional and depositional processes within alluvial environments are controlled by a number of physical parameters which pertain to both fluid flow and sediment properties. While these parameters control sedimentary characteristics, the parameters themselves can be influenced by a multitude of other extrinsic factors – one of which is life. Today, Earth's rivers traverse landscapes that are populated with a huge diversity of eukaryotic and prokaryotic organisms. Eukaryotes are known to exert direct and specific effects on the sedimentary and geomorphic characteristics of rivers, both passively and as geomorphic engineers (e.g., binding by plant roots, beaver dams, large animal trampling). Recent research also shows prokaryotes can affect sedimentary processes; particularly as surficial covers (microbial mats) or changing the material properties of granular sediment (EPS secretion). Given these observations from modern environments, there is merit in understanding the indirect influence of life on Earth's ancient sedimentary processes and products, and how this may have evolved through geological time. With reference to multiple ancient examples of plant, animal and microbial influence, we demonstrate: (1) any one given locality is unlikely to shed light on the most fundamental life influences on sedimentation, due to a lack of preservation of a 'smoking gun'; (2) specific instances of indirect life signatures may be determined through detailed sedimentological study of exceptional localities; and (3) the most significant influences of life on sedimentation can be elucidated by comparing global strata deposited before and after the evolutionary onset of specific life-sediment interactions. A fuller understanding of the indirect signatures of life in the alluvial stratigraphic record has implications for our understanding of the co-evolution of life and the Earth's surface, the potential range of controls on sedimentation during specific intervals of geological history, and an appreciation of the fundamental controls underlying sedimentary and geomorphic characteristics of modern rivers.

Early Mississippian palaeoenvironments and their significance for tetrapod preservation

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Examples of early Mississippian terrestrial habitats are preserved in sedimentary rocks that crop out across the borders of England and Scotland as the Tournaisian Ballagan Formation. New discoveries of land-based tetrapod taxa in this formation are of international importance because tetrapods were thought to be very uncommon in this part of the geological record. Early Mississippian finds provide a new insight into the late Devonian primitive aquatic forms and the terrestrial fauna with robust pentadactyl limbs recovered from late Mississippian successions.

The Ballagan Formation represents deposition across an extensive coastal-alluvial plain. Fluvial systems include multi-storey meandering and sheet-like bodies and single channel forms. Diverse palaeosols, with a dominance of entisols and inceptisols, suggest relatively brief periods of soil development on the floodplain. Mean annual rainfall estimates from palaeosol compositions are 1000–1500 mm yr^{-1}.

Key vertebrate (actinopterygians, rhizodonts, dipnoans, chondrichthyans and tetrapods), invertebrate and plant fossils are preserved in sandy siltstones, a previously under-recognised floodplain facies. Interpreted as the deposits of cohesive debris flows, originating from overbank floods and localised floodplain transport at times of high rainfall, these matrix-supported siltstones incorporate lithic clasts and preserve some fossils with a greater degree of articulation compared to those found in basal conglomerates of fluvial channel sandstones.

Dolostone beds from successions in the Scottish Borders represent an unusual floodplain lake environment, inhabited by actinoptergyians, rhizodonts, molluscs and ostracods. An associated ichnofauna indicates repeated, short-lived marine interactions. These marine incursions influenced lake development and evaporite-bearing beds are associated with dolostones. Dolostones in Northumberland, further south, represent more lagoonal to marginal marine settings.

Early Mississippian tetrapods occupied a complex mosaic of sub-environments that existed for *ca*.12 million years and experienced a strongly seasonal climate. The region provided a range of habitats for tetrapods to develop terrestrial capabilities and suitable settings for their preservation.

Glacial or non-glacial? A new field-based examination of the Permo-Carboniferous Sakoa Group of southern Madagascar.

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The Sakoa Group of Southern Madagascar was first described in the early 1970's, comprising a series of massive and stratified diamictites, coarse to fine sandstones and dark grey mudstones, resting upon an eroded Precambrian gneiss basement.

The base of the sequence was formerly interpreted as being of glacial origin and probably equivalent to the Dwyka glacials of Southern Africa. This interpretation was subsequently rejected in favour of an alluvial fan and debris flow origin, citing an apparent lack of glacigenic features such as striated surfaces or clasts and the presence of clasts with a rounded morphology.

New observations from fieldwork in southern Madagascar show the basal Sakoa Group does indeed have characteristics strongly supportive of a glacigenic origin, including massive diamictites with floating clasts, stratified diamictites with probable dropstones and metre-scale folds which do not affect adjacent beds. Comparison with Quaternary sequences of unequivocal glacial origin in the northern UK show that where the substrate is composed of granitic gneiss, striated surfaces and clasts are not present. Clast morphology in the Sakoa diamictites closely resembles that of clasts in the Quaternary tills and sediment textures of the two sequences are indistinguishable. There are also striking parallels with disputed glacigenic rocks of Proterozoic age in the same region of northern Britain.

The conflict of interpretation between a glacial or debris flow fan origin is one which continually re-surfaces in studies of ancient diamictite sequences and will doubtless continue to do so. However, the detailed comparisons of the basal Sakoa sequence with recent and ancient glacial analogues suggest that the original glacigenic interpretation is correct.

Depositional architectures within deep lacustrine turbidite fans: examples from the Early Cretaceous, North Falkland Basin.

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Throughout the last decade, deep lacustrine turbidite fans have been the main reservoir target for hydrocarbon exploration in the North Falkland Basin. These deposits remain poorly understood, with few examples of such systems described in the literature. A number of vertically-stacked, turbidite fans have been mapped using conventionally-processed 3D seismic data, along the eastern margin of the North Falkland Basin. A critical examination of these fans in plan-view has led to the identification of a suite of depositional architectures. These architectures include: feeder systems, sinuous channels, terminal mouth bars, constriction of flow, flow deflection and flow baffling. Most of these architectures were intersected during recent hydrocarbon exploration drilling, which resulted in the collection of a high-quality data set, including 550 m of conventional core data. This has permitted further characterisation of the seismically-defined architectures through sedimentological analysis. When the observations made through seismic interpretation are combined with the observed sedimentology, it is clear that deep lacustrine turbidite fans are highly complex and internally heterogeneous systems.
In the North Falkland Basin, the identification of these seismically-defined depositional architectures commonly suggests the presence of reservoir-quality sandstones. In addition, the features indicate multiple scales of internal heterogeneity within deep lacustrine turbidite fans. Furthermore, the complexity offered by the internal heterogeneity is compounded by both compensational and vertical stacking of multiple fan systems, creating a challenging 3D system to model. These observations are important given the numerous examples of undrilled, early-post-rift hydrocarbon targets within both licenced and unlicensed acreage in the North Falkland Basin. Advancing the understanding of deep lacustrine turbidite fans is therefore crucial in informing hydrocarbon exploration efforts and ultimately future success of the North Falkland Basin and word-wide.

Increased seasonality across the early Danian Dan-C2 hyperthermal: A case study from the Boltysh impact crater, Ukraine

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Past hyperthermal events are understood to have caused major environmental and ecological disturbances, including rapid increases in global mean temperature, mass extinction, ocean acidification, and seawater deoxygenation. In addition, a number marginal marine and terrestrial sites that record the Palaeocene-Eocene Thermal Maximum, Eocene Thermal Maximum 2, and Toarcian hyperthermal events, suggest an amplification in seasonality and increased storm activity concomitant with warming.
Here, we present borehole data from the K/Pg Boltysh meteorite impact crater, Ukraine, which contain ~400 m of latest Cretaceous to early Danian lacustrine sedimentary rocks. Carbon isotope data and available age data indicate that this succession encompasses the Dan-C2 hyperthermal. We examine this unique sedimentary rock record to assess climate change and potential changes in seasonality during early Danian warming.
Facies analysis of the Boltysh borehole indicates a more pronounced variability in sediment supply, lake facies, stratification and water chemistry prior to and across the onset of the carbon isotope excursion that demarcates the Dan-C2 event. This is supported by regular moisture availability oscillations inferred from palynological examinations. Together, these data suggest that the Dan-C2 hyperthermal was associated with phases of increased seasonality, supporting the current understanding the impact hyperthermals had on climate. Nevertheless, more detailed research on micro-scale sedimentation is required to better constrain the timing and scope of seasonality changes.

Through Highs and Lows: Burial of Organic Matter in the Mississippian Bowland Shale

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The Mississippian Bowland Shale Formation represents a potential unconventional hydrocarbon resource in the UK. Understanding the distribution and type of organic matter (OM) is vitally important for understanding this resource, but the origin and role of preservation of OM during this period is poorly understood, particularly from a carbon-cycle perspective. For example, we do not understand the role of phytoplankton during this time (e.g., the 'phytoplankton blackout'); also the continued terrestrialisation of land plants undoubtedly had knock-on effects in the marine realm (e.g., input of terrestrial OM, nutrient supply).
Comparing sedimentological, palynological and geochemical data from three locations within the Craven Basin (Lancashire, UK), reveals the Bowland Shale to be highly heterogeneous, both in terms of sediment delivery mechanism and type of OM preserved. Palynological and organic geochemical (Rock-Eval pyrolysis, $\delta^{13}C_{org}$, n-alkane biomarkers) data indicate the Bowland Shale contains a range of marine, mixed and terrestrial-dominated OM compositions. This variation is primarily linked to changing sedimentary process and water column chemistry, in response to sea level fluctuation and the increasing influence of deltas.
Sea level highstand facies, termed 'marine bands', were deposited under an influx of 'open marine' waters that promoted carbonate export into deeper waters, locking-up of detrital sediments in proximal positions and high rates of primary production in the water column that triggered widespread, strongly Fe-limited bottom water anoxia. Marine bands exhibit consistently high trace element enrichment factors for redox-sensitive elements (e.g., Mo, U), and a strongly marine OM composition.
Lowering of sea level led to tens of metres of sediment accumulation deposited as storm-derived rip-up clasts and by mass transport processes. Water column redox conditions during lowstands were more variable, and progressively became more oxic, so that the youngest sediments record trace element compositions typical of 'average' (oxic) shale and comprise mixed to dominantly terrestrial OM.

Detrital mica and zircon geochronology as evidence for the Devonian-Carboniferous "Old Red Staging Area" and development of super-mature sediments in the southern Irish offshore.

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Detrital zircon ages from onshore Upper Devonian sedimentary rocks of the Munster Basin and Permian to Cretaceous sedimentary rocks of the North Celtic Sea and Fastnet basins suggest multiple stages of sedimentary recycling over a ca. 400 Ma period in southern Ireland. Total fusion $^{39}Ar/^{40}Ar$ analysis of detrital micas provides an additional parameter to better constrain sediment sources. Detrital mica ages also provide an opportunity to further the understanding of sedimentary recycling processes when coupled with detrital zircon ages because mica, unlike zircon, is known not to survive multiple sedimentary cycles. Detrital zircon ages for the Munster Basin indicate that Caledonian and Laurentian sources played the largest role in sediment provision. Offshore detrital zircon ages broadly indicate the same sources but with the significant addition of a peri-Gondwanan component. Five samples, ranging in depositional age from Permian to Cretaceous and spread across the North Celtic Sea and Fastnet basins, were analysed to obtain a suite of 281 $^{39}Ar/^{40}Ar$ detrital mica ages. Three Devonian to Carboniferous detrital mica samples were analysed from the Old Red Sandstone in the Munster Basin to produce a dataset of 143 $^{39}Ar/^{40}Ar$ ages. All samples, with one exception, are complimented by detrital zircon data. The new detrital mica data indicates a Late Caledonian (ca. 430-380 Ma) ultimate source for most samples. Two samples differ from this trend – one onshore sample shows mica ages of an Early Caledonian (Grampian) source and a single sample from the Triassic in the Fastnet Basin shows a Neoproterozoic source. The dominant Late Caledonian detrital mica ages in onshore and offshore sediments provide further evidence that sediments in the offshore basins of southern Ireland are the end-product of multiple cycles of erosion and deposition. The Munster Basin acted as a Devonian to Carboniferous "Old Red Staging Area" before final deposition into the North Celtic Sea and Fastnet basins.

Provenance of Triassic Sandstones – assessing the link between source area and sandstone reservoir quality

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Sandstone reservoir quality is controlled by the interaction of a number of critical factors and processes such as provenance, diagenesis, burial and compaction. A key influence on porosity/permeability is the ultimate source of the sediment, as this will control the primary framework mineralogy which can be subsequently modified during diagenesis. However, the extent of this influence is not fully understood. The link between source area, sandstone petrography and reservoir quality will be tested and assessed in this study in order to move towards first order quantitative modelling of sedimentary systems and their detrital products, focussing on a well characterised, though heterogeneous, sedimentary system – the Lower Triassic of NW Europe (Sherwood Sandstone Group and equivalents).
The project will initially focus on the Slyne Basin, offshore west Ireland, where Triassic reservoir sandstones of varying quality have been identified at a range of depths (1km – 4km), including those of the Corrib gas field. Logged sections from wells 18/20-2z, 18/25-3, 18/20-4 and 27/5-1 can be correlated across the basin using the base of the Mercia Mudstone Group. The gamma response from wireline logs from these wells are significantly high, however this is a reflection of feldspar as opposed to clay content. The wireline logs also show significant variation in porosity and permeability throughout the section indicating changes in reservoir quality and possibly diagenetic characteristics. This project will investigate if any variations in supply of sediment to the basin has led to these heterogeneities. This will be achieved through high resolution sampling, multi-proxy provenance analysis (Pb in K-feldspar, U-Pb zircon and heavy mineral analysis) and petrographic/diagenetic assessment of these intervals.

The development of convolute lamination: insights from field observations and simple calculations

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Convolute lamination is a fold structure common in turbidites, attributed to the deformation of sediment during or soon after deposition of the host bed. The formational processes are still not fully understood. Through field observations on the classic Aberystwyth Group, Wales (Silurian), in which "convolute bedding" was first defined, and the modern Icod turbidite (~165 ka), bed 14 from the Moroccan Turbidite System, the structures are re-described in detail. Estimated bed and flow properties are used to assess the plausibility of different mechanisms using simple calculations on timescales and lengthscales.
Convolute lamination typically occurs in intervals 2-10 cm thick, spanning the top of the cross-laminated very fine sand Bouma C division, through the D division of interlaminated silt and clay. Growth geometries confirm that the deformation occurred during and not after sedimentation of the host graded bed. Folds show a down-flow asymmetry and doubly-vergent diapiric geometries ("mushroom" structures). Grain size measurements indicate there is an optimal 'window' in terms of average grain size and mud content, within which convolute lamination develops. We propose that this window correlates with a bed density inversion and that this unstable density gradient can arise from the natural packing of a turbidite formed from suspension deposition: when basal clean sand with pores infilled by water normally grades into finer sand with pore spaces infilled by an increasing proportion of mud, a sediment layer is created where the bulk bed density increases with height.
Quantitative analysis suggests that horizontal shear-driven Kelvin-Helmholtz instability and vertical buoyancy-driven Rayleigh-Taylor instability are both theoretically effective in forming folds. Viscous bucking instability of the surface sediment layer is less plausible, as is water-escape. Convolute lamination in the Aberystwyth Group was most likely formed by buoyancy overturn caused by a density inversion within the sediment layer, which was amplified and modified by current shear during growth.

Lateral Variability In Upper Slope, Shelf Edge And Shallow Marine Stratigraphy Along A 70 Km Strike Transect: Karoo Basin, South Africa.

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Key sedimentary transition zones occur through the interaction of numerous depositional processes, resulting in a complex heterogeneity in ancient basin margin successions. They are well studied along depositional dip profiles, but their strike variability is generally less constrained.
In the Karoo Basin, a 80 km-long, NW-SE exposure has been characterized by 53 logs with 9910m of cumulative thickness, 2500 paleocurrent measurements and photo-panels. Dominant sediment transport was to N-NE, with E-W and NE-SW bidirectional components, indicating the outcrop belt has a strike orientation relative to the progradation direction of the basin margin.
In the south, upper slope to shelf-edge parasequences (50-75m-thick) show abundant current ripples and inverse-to-normal grading in dirty siltstones and sandstones. They are interpreted as river-dominated, wave-influenced prodelta and mouth bar deposits incised by distributary channels (up to 25m-thick, 700m-wide). Parasequences are partly truncated by 10s m-thick upper slope gullies and by a 100m-thick, 1.5km-wide shelf-incised canyon. Overlying shelf parasequences are thinner (15-50m), with symmetrical ripple top and combined-flow bedforms, interpreted as wave-influenced deltaic or shoreface deposits. Transition to terrestrial deposits includes channels and crevasse splays within delta plain mudstones. Along strike to the north, upper slope to shelf-edge parasequences are thinner, include wave reworking indicators and no evidence of gullying or incision. Overlying shelf parasequences are thicker, sandier and more amalgamated, interpreted as shoreface, foreshore and strandplain deposits.
Although the succession reflects NE progradation of the basin margin, coastal processes results in complex along-strike architecture. Southern environments were river-dominated with sediment bypass to deeper parts of the basin across a steeper and more erosive margin. Waves and storm current redistribution towards the north resulted in higher net-to-gross and sand connectivity on the shelf but no incision, bypass and sand supply to the slope.
This work provides a good analogue for capturing along-strike heterogeneity in mixed-influence shallow-marine reservoirs.

Predicting facies distribution in Triassic fluvial systems of the central North Sea using subsurface data

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Subsurface studies rely heavily on the sedimentological use of wireline log datasets, to predict lithology and facies distribution. Despite conditioning to core observations, the interpretation of well logs is often highly subjective and unreliable. This study tests the use of varied artificial neural networks to create robust, repeatable and auditable facies interpretations from well logs.
The study focusses on the Mid-Late Triassic Skagerrak Formation of Quads 22, 29 & 30 of the central North Sea, which comprises alternating sandstone and mudstone dominated members deposited as distributive fluvial systems derived from UK Caledonian and Fennoscandian catchments. The climate induced expansion and contraction of these DFS is interpreted to control the distribution of the mudstone and sandstone members. Climatic shut down of the DFS results in deposition of the mudstone members, which can then be used as correlative markers. The expression of these events becomes more difficult to identify in the more proximal parts of the DFS, towards the N/NW.
Predicting the facies distribution within the systems is key to understanding the stratigraphy and palaeogeography of the larger fluvial system. Utilising neural networks allows facies association trends to be identified regionally in a large number of wells, in different parts of the basin and between members. The consequent gross depositional environment map allows quantification of facies distribution and their prediction of reservoir potential in un-drilled parts of the basin.
This project is part of the wider Triassic project at the University of Aberdeen, which includes palynology and heavy mineral analysis. Ultimately these aspects will be incorporated to provide temporal and provenance controls on quantitative facies distribution.

Heavy Mineral Stratigraphy and Provenance of Triassic Sediments of the Central North Sea

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The Heron Group of the Central North Sea, which is comprised of the Early Triassic aged Smith Bank Formation and Mid-Late Triassic aged Skagerrak Formation, consists of a relatively faunally barren and variably thick, seemingly monotonous sequence of alternating clastic red-bed deposits. Closer inspection reveals a more complex array of fluvial-alluvial sandstones and floodplain-playa-lacustrine mudstones that together represent a long-lived dryland continental succession.
Traditional lithostratigraphic correlation of Triassic packages across the Central North Sea region relies strongly on the fortunate presence of thick intra-formational mudstone units that have allowed an evolving lithostratigraphic framework to be constructed based on alternating sandstone and mudstone dominated members. However, although drilled sandstone or mudstone packages can be attributed to particular members with some confidence in the UK southern Central Graben where the Skagerrak sequence has been relatively well preserved from major erosional events, correlation and identification becomes difficult where mudstones are poorly preserved.
In contrast, heavy mineral analysis is independent of these constraints, providing a potential chronostratigraphic and/or provenance specific correlation tool that has allowed individual depositional packages to be characterised, modifying published correlation schemes. With the advancement of heavy mineral techniques since similar Skagerrak studies were published over two decades ago, this study has applied more recent conventional and varietal techniques to both newly drilled areas and historical wells. Future inclusion of geochemical data aims to determine the spatial and temporal variability in provenance, linking these depositional systems to their evolving catchment areas.
The project to date has focussed on UK Quadrants 22, 29 and 30 as a core area with the aim of establishing a robust framework in this area prior to extending focus from the Central Graben over to the Norwegian-Danish Basin as part of a wider basinal study. Provisional results and future plans for this study are presented.

Predicting Clay Mineral Distribution in Sandstone Reservoirs Using an Analogue Holocene Estuarine Succession

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Quartz cementation of sandstones buried to depths > 2.5 km (> 80-90°C) is one of the major causes of porosity and permeability. Fe-Mg enriched chlorite grain coats can preserve anomalously high porosity in deeply buried sandstones reservoirs through the inhibition of authigenic quartz cements. In contrast, pore-filling illite and kaolinite typically reduce reservoir quality through porosity and permeability reduction. Since the key elements in clay minerals (Fe-, Al- and Si-oxides) are largely insoluble, clay diagenesis can be assumed to be isochemical during burial, therefore, the dominant control on the occurrence and type of clay (chlorite, illite or kaolinite) is primary depositional mineralogy. This study provides the first modern estuarine analogue to predict reservoir clay mineral precursor distribution. X-ray diffraction was performed on the fine fraction (<2 μm) of surface samples (< 2 cm), and cores (< 15 m) in order to understand the fundamental processes that govern clay mineral distribution within the post-Holocene estuarine succession. Surface clay mineral maps and shallow cores show; chlorite is most abundant within the outer estuary; illite is most abundant within the inner and central estuarine tidal flats; kaolinite displays a relatively ubiquitous distribution. Hinterland geology and climate (weathering intensity) control clay mineral type and abundance. Clay mineral properties combined with estuarine hydrodynamics control clay mineral distribution patterns. Clay mineral distribution throughout the Holocene succession is largely controlled by changes in relative sea-level and the transition from an open, wave-dominated system, to a wave- and tidal-dominated sheltered system. The unique dataset with transferable fundamental controls on clay mineral distribution allows for the prediction of reservoir quality on a stratigraphic, reservoir-scale basis.

Linking cyclic steps of crescent-shaped bedforms and lenses of massive sand through direct field observations

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Discontinuous lenses of massive sand are widely recognised in sedimentary record, yet their origin is debated. In modern canyons massive sand deposits have been shown to be associated to crescent-shaped bedforms. Recent flow observations have also shown how crescent-shaped bedforms are produced by a flow instability called cyclic steps. Based on these observations it has previously been hypothesised that cyclic steps are associated to crescent-shaped bedforms that produce discontinuous lenses of massive sand. The present study shows for the first time direct measurements from active flows and the deposits they leave behind that confirm the hypothesis.
Here we present three-dimensional observations from the cyclic steps process occurring in delta channels on the submarine Squamish Delta, British Columbia (Canada). State-of-the-art imaging techniques (2 fixed Multibeam Sonars and Acoustic Doppler Current Profilers) are used to describe and quantify the flow character of the cyclic step process on the crescent-shaped bedforms. We use high resolution repeat bathymetrical survey to constrain the sedimentary architecture that are formed by the upslope migration of the crescent-shaped bedforms. Finally, the flow process, morphology and architecture are linked to the characteristic facies by a train of sediment cores taken along two bedforms.
Not only does the data confirm the previous hypothesis, it also allows us to refine our model. We show that the classical cyclic steps model based on experiments is an oversimplification of the process. The flow observations show how lateral variability of the pre-existing bedforms and the unsteady nature of sediment gravity flows generate a much more dynamic interaction as is commonly sketches in idealised drawings. The main product of the observed cyclic steps corresponds to massive sands, i.e. Ta units from the Bouma sequence, which cannot be correlated from one coring location to another. We attribute this key result to the high variability of cyclic steps found in the field compared to standard conditions set up in labs. Flow dynamics of field cyclic steps indeed differs not only from one event to another but also within a single flow such as the one monitored.
This study allows to come up with a revised model that links cyclic steps processes to crescent-shaped bedforms and discontinuous lenses of massive sand. The results are key to confidently reconstruct flow characteristics from the sedimentary record, and therefore carry direct consequences for a broad range of sedimentological studies.

Braided or Meandering: Are Fluvial Facies Models Useful?

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Recognition of fluvial planform (i.e. braided or meandering) is important as it aids in developing accurate paleogeographic reconstructions as well as understanding subsurface fluid flow. However, facies models developed to identify these different fluvial styles are not appropriate for the majority of rivers in modern day basins and their rock record counterparts. The original facies models for meandering and braided rivers were established in the 1970's and are still widely used, even though it was noted in the early 80's that use of these models was both inappropriate and difficult to reconcile with observations of modern day rivers and their deposits.
Through analysis of fluvial systems in modern day sedimentary basins and those preserved in the rock record, we show that the classic end-member braided and meandering fluvial models are only appropriate in specific and limited areas of modern sedimentary basins. We argue that the majority of what we see in the modern day and what is preserved in the rock record are sandy meandering fluvial systems for which we have no appropriate recognition criteria. Key characteristics of sandy meandering fluvial systems include predominantly downstream accreting dunes and bars that comprise laterally extensive sheet-like amalgamated channel-belts - features considered characteristic of braided fluvial systems. Braided systems are over interpreted in the rock record as the traditional facies models for fluvial successions apply largely to small, single story systems yet many meandering rivers are large and create deposits that are easy to misinterpret as braided – especially with restricted (subsurface) datasets.

Multi-pulsed Turbidity Currents – A Scaling Analysis and Applications for Turbidite Interpretation.

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Submarine turbidity currents transport clastic sediments from continents to deep seas and their deposits – turbidites – can provide a record of overpassing flows' dynamics. Turbidites commonly exhibit a continuously upward-fining grading profile which is referred to as 'normal grading'. However, some turbidites show deviations from the standard grading structure such as multiple intervals of coarsening-up sediments within a single turbidite unit. Such turbidites are referred to as being 'multi-pulsed' and are interpreted to be deposited by turbidity currents characterized by complex (multi-pulsed) longitudinal flow structures. The currents can be generated due to i) retrogressive submarine slope failures or ii) combination at confluence of single flows sourced from different upstream attribute channels. Questions arise as to how far from source such a complex flow structure may persist and over what length scale multi-pulsed turbidites are expected to be found in the deposits.
Experiments to model denser than ambient saline flows were conducted. The generation of multiple pulse components within a multi-pulsed flow was enabled by setting two lock boxes in series at one end of a flume. Research methodologies include direct flow visualization, sample siphoning to measure spatio-temporal density structures and velocity profiling to collect velocity data time series. Experimental results show that i) pulses always merged within the studied experimental configurations and ii) the signal of flow generation was preserved more accurately proximally, progressively distorted approaching the point of pulse merging and eventually shredded distally. In order to study the dependence of dimensionless parameters characterizing the merging length scale, a scaling analysis was conducted by varying experimental boundary conditions including initial fractional ratio between the flows and the ambient, aspect ratio of the lock boxes and delay time between pulses. The analysis provides a tool to estimate the persistence of pulsing signatures in natural turbidites.

The depositional architecture of basin-floor fan systems by wireline log character: an integrated dataset from the Karoo Basin

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Cored sections within deep-water hydrocarbon targets are generally less extensive than the retrieved wireline data. Therefore, electrofacies analysis is widely applied to help the prediction of sedimentary facies distributions and improve the accuracy of facies modelling. The statistical methods used to determine electrofacies often result in a cluster of facies with significant overlap in petrophysical properties, and therefore accompanies large uncertainties.
An alternative approach is to correlate wireline responses within submarine fan systems directly to architectural elements, including lobe sub-environments, channel-related architectures and mass-transport complexes. An extensive integrated dataset, including outcrop, core and wireline data, from basin-floor fan systems in the Karoo Basin is here presented. From the outcrop dataset, architectural element thicknesses, facies proportions and facies transitions are constrained. By the integration of core and wireline data, recognition criteria are established to support identification of different architectural elements based on petrophysical properties such as the gamma ray, neutron density, resistivity and sonic velocity response. Along with absolute values, the thickness of the response signal and the level of signal fluctuation, related to bed thickness and vertical facies variability, can be utilised to identify different depositional elements. This can be applied, for example, to make distinction between frontal and lateral lobe fringes in lobe-dominated environments.
The use of criteria for detailed recognition of depositional elements, as well as larger scale stacking patterns can significantly increase the understanding of the architecture and evolution of submarine fan reservoirs, where wireline data forms the primary data source.

Primary sedimentary structures in bedded halite – indicators of depositional conditions from the mid-Triassic of the UK

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Solution-mined salt caverns in bedded halite successions of the UK host several operational and planned underground gas storage schemes. The sedimentology and associated engineering behaviour of halite is increasingly recognised as an influence in the planning, design and construction of storage caverns, as the crystal fabric and distribution of non-halite units can affect their morphology, which impacts operational processes (e.g., the operating pressure ranges) and the placement of facilities in the subsurface.
Thick successions of bedded halite, with thin interbedded mudstones are developed in the Mid-Triassic (Anisian – Ladinian), in the Cheshire (Northwich Halite Member) and west Lancashire (Preesall Halite Member) basins of north-west England. Analysis of borehole core from these lateral correlatives allows comparisons to be made between accumulations from different sedimentary basins, and the sedimentary structures to be understood in a modern context. Depositional fabrics within the halite beds include primary laminated halite (with cuboid, chevron and cornet fabrics, dissolution seams and erosional surfaces) and banded halite. The non-halite lithologies include some anhydrite but predominantly haselgebirge through to laminated and structureless mudstone, with evidence of load structures and desiccation. These indicate accumulation in a predominantly shallow setting, with karst structures (pipes and fissures) indicating rare periods of emergence, and the accumulation of cumulate facies in intervals of deeper, stratified of brine. Indicators of flow are rare, restricted to ripple-lamination in mudstones, and re-worked oriented clasts of anhydrite. Diagenetic features influenced by post-depositional halite mobilisation include the development of chickenwire textures and recrystallized zones of halite.
Brecciation of the succession is linked to four distinct processes: penecontemporaneous haloturbation, emergence and desiccation, post-depositional structural processes and the dissolution of halite in the modern freshwater groundwater zone (so-called 'wet rockhead'). Wet rockhead processes are poorly understood, although relationships between brecciated and laminated zones indicates new models for the development may be required.

Seismic geomorphological analysis of the Farsund Basin, offshore southern Norway: Identification of Rivers, Reefs and Shorelines

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In the subsurface, widely spaced boreholes typically constrain only the 1D-to-quasi-3D distribution of sedimentary facies, thus hampering our ability to reconstruct the interaction between depositional systems and structures in tectonically active basins. 3D seismic reflection data can be used to provide relatively high-resolution, plan-view images of the Earth's subsurface at multiple stratigraphic levels, allowing us to assess the stratigraphic development of basins, even where boreholes are lacking.
In this study we undertake seismic attribute analysis of 3D seismic reflection data to constrain the Jurassic paleo-geomorphological evolution of the Farsund Basin, offshore southern Norway. We identify a series of likely west-flowing Early Jurassic rivers, the distribution of which were controlled by relatively small, syn-depositional salt-detached faults, rather than major E-trending faults dominating the present structure. Subsequently, following Middle Jurassic flooding, a series of carbonate reefs, expressed as sub-circular amplitude anomalies, developed. We identify two distinct reef morphologies, which we infer represent growth in differing water depths controlled by differential compaction of sub-reef strata across underlying faults. Subsequently, during the Late Jurassic, pyritic, anoxic lagoonal shales were deposited, acting to shut down carbonate production. Within the Upper Jurassic we identify a series of curvilinear features, arranged into discordant sets at the top of a clinoform-bearing interval. We interpret these as shoreface clinoforms and capping beach ridges, indicating a potential decrease in relative sea level. The distribution of these Upper Jurassic clinoforms appears to be controlled by fault-related topography, marking the onset of Late Jurassic-Early Cretaceous rift-related faulting.
We show how seismic attribute-driven, seismic geomorphological analysis can be used to constrain the geometry and evolution of non- to shallow-marine depositional systems. Furthermore, the identified depositional patterns can be related to and can thus help constrain the structural development of tectonically active basins.

Formation and evolution of transverse bedforms: An experimental study

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A fluid flow across a sediment bed exerts a shear stress on the erodible surface. Provided this stress exceeds a critical threshold, grains can be eroded and transported by the flow, leading to the formation of perturbations on the surface profile. These grow, propagate and interact with each other to develop into larger-scale bedforms. We investigate the formation and evolution of these disturbances in a thin, large-diameter annular flume (radius 50 cm, height 30 cm, channel width 6 cm), containing a sedimentary layer (sand/ballotini) overlain by water. The flume rotates past submerged, fixed paddles, creating a shear flow which erodes and transports the sediment. The small ratio between the channel width and the radius keeps flow in the cross-channel direction small, resulting in the formation of nearly transverse bedforms.
In this talk, I will present results from experiments looking at the destabilisation of an initially flat bed, including the wavelength of the initial disturbance, the growth rate of perturbations and the resultant coarsening of the bed profile as ripples coalesce to form larger dunes. A second set of experiments examines the interaction between colliding pairs of preformed dunes of variable sizes, offering insight into the mechanisms through which coarsening occurs.
Finally, details of a recently commissioned new flume, with twice the original radius (1 m) and variable channel width (2 – 9 cm), will be presented. Additionally an improved motor assembly will allow counter rotation between the flume and the paddles. In this set-up we will be able to: significantly reduce the secondary cross flows, leading to the formation of fully transverse bedforms; and achieve higher shear stresses meaning we can explore a wider range of flow regimes. I will briefly discuss how this apparatus will help us attain a greater understanding of the fundamentals of bedform formation.

Red Chalk, Secondary Bentonite and Volcanogenic Glauconite

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The Upper Albian Red Chalk of eastern England is wonderfully well exposed in the Cliffs at Hunstanton on the Norfolk coast. Here it has been a spectacular problem for students of geology for well over a century as well as a sight much enjoyed by generations of holiday makers. A new hypothesis brings together new geochemical evidence, Upper Albian secondary bentonites, and volcanogenic glauconites. It suggests a hydrothermal or volcanogenic origin for the strikingly red colour of the Red Chalk related to the early stages in the opening up of the proto-Atlantic Ocean in mid-Cretaceous times.

The region of fluvial dominance within the tidal-fluvial transition

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Sediment transport processes within river-estuary systems are governed by the complex interplay between tidal and fluvial hydrodynamics, resulting in a poorly defined transition zone between fully tidal and fully fluvial bedforms. This transition varies on a range of spatial and temporal scales. Investigations have predominantly focussed on the tidally-dominated region of the transition, with little investigation of the process-to-product regimes within more fluvially-dominated regions of the transition zone.
Two distinctive tidal-fluvial systems have been investigated: the high fluvial-flux mesotidal Columbia River estuary (USA), and the smaller fluvial-flux macrotidal River Severn (UK). Geophysical and sedimentological data collected within both systems reveal fluvial depositional patterns, with little obvious tidal influence. However, flow data reveal a significant, although short lived, tidal component of flow with comparable maximum tidal and fluvial flow velocities in both systems.
This data suggests that the models of the tidal-fluvial transition, whilst accurately describing regions of high tidal influence should be amended within the fluvially-dominated region. At present descriptions of this region are limited and are mainly depositional in character. This data set links the flow regimes to the resultant deposits allowing a fuller understanding of the tidally-influenced-fluvially-dominated region of river-estuary systems. As a consequence the model within this complex region of the tidal-fluvial transition can be refined to more accurately reflect the full extent of the tidal-fluvial regime and constrain the resultant deposition.

A diamictite dichotomy: Glacial conveyor belts and olistostromes in the Neoproterozoic of Death Valley, California, USA

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Multiple intercalations of glacially derived and slope-derived diamictites testify to the drawbacks of correlating Neoproterozoic diamictites more widely, but shed new light on the close interrelationship of these processes in the Cryogenian world. In the Neoproterozoic of Death Valley, California (USA), rifting of Rodinia occurred concomitantly with a major glacial event that deposited the Kingston Peak Formation. A new sedimentologic investigation of this formation in the Silurian Hills demonstrates, for the first time, that some diamictites are ultimately of glacial origin. Abundant dropstone textures occur in interstratified heterolithic deposits, with clasts of identical composition (gneiss, schist, granite, metabasite, quartzite) to those of boulder-bearing diamictites suggesting a common source (the glacial conveyor belt). In stark contrast, megaclast-bearing diamictites, yielding clasts of carbonate and siliciclastic preglacial strata as much as 100 m across, are interpreted as olistostromes. The occurrence of syn-sedimentary faults within the succession allows glacial versus slope-derived material to be distinguished for the first time.

Field insights into sediment delivery to the northwest Black Sea: the Late Miocene fluvio-deltaic Balta Fm of the East Carpathian Foreland

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The NW Black Sea contains the basin's largest clastic system, which is currently dominated by the Danube and delivers 90 MT of sediment per year. This is 75% of the flux through the Nile and more than twice the flux through the Niger. Recent successes of the Domino and Lira wells highlight this region's large hydrocarbon exploration potential. Our ongoing field-based research is tailored to provide better constraints on the composition of potential clastic reservoirs in both the Romanian and Ukrainian offshore. Special emphasis is placed on an understanding of the spatial, temporal and compositional evolution of the different sediment supply systems during the Late Miocene, Pliocene and Pleistocene. Key elements addressed are the timing of the arrival of the Danube, and the significance of the Balta Delta of Moldova and Ukraine; a largely underappreciated, and frequently overlooked clastic system.
In this talk, we focus on sedimentary facies analysis of the Balta Fm, which was integrated with a review of published local literature, micropalaeontological results and historical borehole information. The lowermost part of the formation is clay dominated and consists of subordinate delta front sand bodies interspersed between muds. The middle unit contains separate delta plain channels or channel belts encased in thick muds. These are overlain by a unit with amalgamated delta plain channel deposits with only minor amounts of associated mud. The abundance of upper flow regime sedimentary structures in channel sands, the absence of peats (or coals) and the presence of calcareous nodules suggest a strongly seasonal and relatively dry climate with a flashy discharge regime. The Balta Fm offers an excellent example of a largely prograding fluvio-deltaic system that came into being due to a high sediment flux from the uplifted Carpathians and was accommodated in a broad foreland basin.

Inversion of turbidity current flow properties from grain-size distribution of submarine channel deposits

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The grain size of suspended sediment typically decreases upward in a turbidity current and this is the main control on the grain-size distribution of channel-fill and levee deposits. Here we present an integrated perspective on grain size segregation in turbidity currents using flume experiments, numerical modelling and deposit samples from channel-levee systems in outcrop and on the seafloor. Samples from the Amazon submarine channel from ODP cores are used to illustrate the grain size segregation in large natural currents. In addition, a simple model is presented, based on the Rouse equation, that can predict the full grain-size distribution of the suspended sediment at each level in a turbidity current. Flume experiments are used to verify the model.
Deposit grain size data from a submarine channel exposed in the Magallanes basin in Chile is used to reconstruct the flow properties of turbidity currents that flowed through this channel. Samples from the channel axis represent the suspended sediment at the base of turbidity currents while the channel margin deposits represent elevated terraces. There is a sharp decrease in grain size toward the margin, despite a limited amount of interpreted relief between the channel axis and margin (3-6 m). Sand grains larger than ±130 μm were absent on the channel margin and where thus only suspended up to a few meters above the bed. The model can accurately reproduce the grain-size distribution at both levels in the flow when the shear velocity of the turbidity current is set at 2-2.5 cm/s. This implies that the current was highly stratified and had a low sediment concentration of 0.1-0.5 %. The methodology can be applied to a wide range of outcrop and seafloor datasets, where it can be used to estimate the volume and composition of sediment that is transferred to lobes downstream.

Provenance of Sediments from Sumatra, Indonesia

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The island of Sumatra is situated at the south-western margin of the Indonesian archipelago. Sumatra is affected by active continental margin volcanism along the Sunda Trench, west of Sumatra. Exposures of the Palaeozoic meta-sedimentary basement are mainly limited in extent to the northeast-southwest trending Barisan Mountain chain. The younger Cenozoic rocks are widespread across Sumatra; these formations are well studied due to hydrocarbon enrichment, but little is known about the provenance history. A comprehensive sedimentary provenance study of the Cenozoic formations can aid in the wider understanding of Sumatran petroleum plays.
This work represents a multi-proxy provenance study of sedimentary rocks from the main Cenozoic basins of Sumatra, alongside sediment from present-day river systems. This project refines the provenance in two ways: first, by studying the heavy mineral assemblages of the targeted formations, and secondly, by U-Pb detrital zircon dating using LA-ICP-MS to identify the age-range of the potential sediment sources. Preliminary age-data, heavy mineral compositions, and thin section analysis from two fieldwork seasons indicate a mixed provenance model, with a proximal igneous source (e.g. the Barisans), and mature basement rocks (e.g. Malay-Peninsula, ?Sumatran basement).
An increase of the proximal signature in Miocene strata suggests a pulse in the uplift of the Barisan Mountains at the Oligocene-Miocene boundary. Volcanic quartz support this hypothesis. Zircon ages as old as Archean are present both before and after the major Barisan uplift; a prominent Triassic age group can be correlated with the Main Range Province granitoids reported from the Malay-Peninsula.
The analysis of modern river sands suggests that the current sedimentary fluvial systems are mainly sourced from the recent Barisan-related volcanic arc. Zircon age patterns of the modern river sands resemble the populations found in the sedimentary strata, whereas, the heavy mineral composition is highly diluted by the recent igneous sources.

Qualitative and quantitative description of a late Barremian to Aptian forced-regression, Essaouira-Agadir Basin, Morocco.

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Forced regressive systems represent important times of coarse clastic sediment delivery into the deep part of sedimentary basins. Analysing the shallow-marine to fluvial transition zone is key to qualitative and quantitative understanding of these systems, by studying their dynamics, scale, timing, input points and sediment volumetrics.
The late Barremian to early Aptian is well exposed in the Essaouira-Agadir basin (Morocco) and detailed field logging and biostratigraphic sampling of a regressive wedge are generating valuable data to constrain clastic delivery offshore.
The early late Barremian is dominated by shelfal mudstones with sporadic sandstone interbeds, it is, in places, sharply overlain by shoreface deposits or associated deltaic deposits. The succession is characterized by significant progradation, with shoreline shift of 20-30 km and is interpreted as a forced regression. High-resolution biostratigraphy places this regressive package within a maximum range of 1.7 Ma from the late Barremian (*H. sartousiana* ammonite zone) to early Aptian (*D. oglanensis* ammonite zone). It exhibits a strong thickening- and coarsening-upward trend and is in many places topped by incised valleys, filled with either fluvial coarse clastic material, tidal deposits or fine-grained marine and continental fill. Well-exposed fluvial successions allow measurement of channel dimensions and palaeocurrent indicators. Together with petrographic data, this is being used to constrain the volumetrics and characteristics of sediment transported. The succession is regionally capped by a ravinement surface that records the retreat of the shoreface and progressive flooding. The location of the main feeder systems into the deep basin have been mapped and regional GDE maps will help de-risk the spatial position of associated deep-water fan deposits, a major target for hydrocarbon exploration.

Controls on facies heterogeneity within the Carboniferous of the Pennine Basin

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This projects aims to assess the interplay of structural, depositional and diagenetic processes on platform margin architecture, to improve reservoir quality prediction within carbonate platforms formed in extensional basins. Such platforms are important targets for hydrocarbon exploration, but facies architecture, syndepositional fracturing and diagenetic overprint contribute to heterogeneous and multiscale pore networks which complicate reservoir quality prediction. In the Pennine Basin, Mississippian (Asbian-Brigantian) flat-topped carbonate platforms formed during back-arc extension[1]. This study focuses on the Derbyshire Platform, northern England, and the North Wales Platform. These easily accessible outcrops allow description of the platform margin and thereby the influence of normal fault growth on facies distribution, platform growth and diagenesis. The two field areas also allow for comparison between a land attached (North Wales) and a land detached (Derbyshire) platform.
Field mapping and petrographical analysis defines a complex array of facies from microscopic to outcrop scale. The margin is dominated by carbonate mud mounds with well-defined core- and flank facies. Skeletal grainstone shoals infill the topography between mounds. Behind this margin, platform interior Asbian limestones comprise stacked, upward-shallowing crinoidal packstone-grainstone facies, capped by exposure surfaces. At the end of the Asbian, a correlatable palaeosol indicates that the platform top was exposed, potentially by footwall rotation. On the North Wales Platform, this surface is marked by a siliciclastic input.
On the Derbyshire Platform, non-skeletal mounds become a common component of the inner shelf, which is otherwise dominated by bedded, cherty brachiopod-rich packstone. This project is currently investigating the relationship between faulting and the distribution/geometry of these mud-dominated build-ups. If a fault control is demonstrated, then three hypothesises will be considered as to the why faults produce preferential conditions for the growth: 1) the mounds form on topographic footwall highs, 2) faults provide preferential environmental conditions, and/or 3) geothermal circulation nucleates mound growth.

Application of deep-water palynofacies scheme to classify reservoir architecture in the Campos Basin, offshore Brazil

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Deep-water depositional systems are notoriously complex to model, particularly in the subsurface and fresh approaches to understanding stratigraphic organization are important. For the first time we apply a new, high-resolution palynofacies classification of deep-marine architectural elements, to a subsurface dataset from the Campos Basin, Brazil. The primary objective is to determine the value of the classification scheme, previously developed at outcrop, for applied studies of reservoir architecture.
Interpretations of 2D seismic data, twelve wireline well-logs, and three cores identify the general sedimentary system as a submarine slope, transient-fan system, encompassing channel-levee and lobe systems. However, detailed interpretations of sub-environments are limited to rare cored intervals. Seventy-five samples from Cretaceous to Paleogene sediments were taken from ditch cuttings and cores to examine their particulate organic matter. Three hundred pieces of matter were recorded per sample, along with their size and shape. Sixteen categories of organic matter were encountered, dominated by allochthonous terrestrial material, but also including relatively autochthonous marine matter. Variations in the proportions of particles were used to interpret depositional sub-environments. Statistical analysis was used to investigate the validity of cuttings samples and compare the dataset with the classification scheme. Results show that samples are representative of the broad geophysical and petrophysical interpretations. However, the palynofacies allows higher resolution interpretation of elements, e.g. outer external levee. Moreover, intervals previously interpreted to be dominated by hemipelagic sedimentation are largely shown to be composed of thin-bedded turbidites and mass-transport deposits.
This successful application to a subsurface dataset, even in non-cored wells, proves the value of integrating across a wide range of scales for improved modelling of depositional systems. Palynofacies provides new insights into deep-water reservoir hierarchy, understanding of which is crucial for maximising resource recovery.

Sedimentary analysis of the Lower Old Red Sandstone of the northern Midland Valley, Scotland

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The 9 km thick Lower Old Red Sandstone (LORS) succession of the northern part of the Midland Valley Basin (MVB), Scotland, ranges from Wenlock to Emsian in age and largely comprises conglomerates in the east passing westwards into sandstones and siltstones. This study focuses on fluvial conglomerates and sandstones of the LORS that crop out in the northern part of the Midland Valley Basin. Predominantly of fluvial origin, these facies accumulated across the Strathmore area with associated deposition occurring northwards across the Highland Boundary Fault on to the adjacent Grampian Highlands. Throughout this area, a number of sections have been logged, and lateral facies variations have been correlated across the three limbs of the major folds that dominate the structure of the basin. Several lithofacies and facies associations have been identified and include five conglomerate and four sandstone sublithofacies, with a subordinate mudstone lithofacies, representing braided fluvial and floodplain depositional systems. These investigations have allowed the construction of a model for a largely braided fluvial setting, describing a large distributary fluvial system sourced from the east-north east and extending across both the MVB and Grampian terranes.

The 'Forgotten' Torridonian: Alluvial (upper flow regime) and aeolian bedforms in the pre-vegetation Meall Dearg Formation, NW Scotland

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Pre-vegetation fluvial systems have traditionally been thought to have had erratic discharges, rapid runoff rates and very high sediment discharges; characteristics typically associated with deposition by ephemeral sheetfloods. Recently this has been challenged as a wider variety of pre-vegetated fluvial styles have been reported; emphasising that our understanding of these anactualistic sedimentary systems requires further investigation. The Mesoproterozoic Meall Dearg Formation is the least studied unit of the classic "Torridonian Sandstones" of NW Scotland. Here, multiple lines of evidence are presented from new field investigations suggesting that it was predominantly deposited by high-energy alluvial events, with subordinate aeolian deposits: (1) Upper- and transitional-upper flow regime bedforms are common (antidune stratification, horizontal laminations, humpback cross-stratification, low-angle cross-stratification, chute and pool structures); (2) Successively-lower flow-regime sedimentary structures are commonly stacked, recording the waning of individual floods; (3) Subcritical subaqueous dune fields with superimposed ripple marks separate many sandbodies; (4) Ripple marks exhibit drainage lines and variable strikes, implying extensive pooling of draining water during low flow stages; (5) Desiccated mudstones occasionally occur between sheets; and (6) Reticulate markings and Manchuriophycus suggest that microbial matgrounds colonized substrates during quiescent intervals. At one locality (Enard Bay), Meall Dearg facies are exclusively aeolian. The mutual exclusion of fluvial and aeolian bedforms may be due to the greater propensity for fluvial reworking of aeolian deposits in pre-vegetation environments. This interpretation of the Meall Dearg Formation is in accordance with traditional hypotheses concerning Precambrian alluvium, suggesting that it is premature to reject wholly the concept of abundant high-energy sheetflood sedimentation on pre-vegetation Earth. A database of 384 pre-vegetation fluvial formations also supports caution in this regard, as plots demonstrate upper-flow regime bedforms comprise >50% described lithofacies in 34% of the successions.

Characterizing flow heterogeneities in a red-bed fluvial succession: Triassic St Bees Sandstone Formation (NW England, UK)

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Red-bed successions of fluvial origin represent porous media which host important hydrocarbon and geothermal resources; additionally, they serve as important groundwater aquifers. Hence, a quantitative study on the geological heterogeneities present in such successions at a range of scales and burial depths is important to provide insights for both groundwater protection and enhancement of fluid recovery in reservoirs.

The fluvial St Bees Sandstone Formation represents an ideal succession for the study of heterogeneity, since it accumulated in a series of rapidly subsiding rift basins, which allowed the accumulation and preservation of fine-grained mudstone and siltstone of floodplain interbedded with a medium-grained channel-sandstone. Additionally, vertical joints terminate at bedding surfaces forming cubic matrix blocks (1.5x1.5x1.5 m) that define a pervasive stratabound system. These matrix blocks are mainly developed in channelized fluvial architectural elements in which sandstones represent the most permeable lithology (porosity 9-26%; K_h= 0.1-4000 mD; K_v =0.02-860 mD). Mud-prone overbank architectural elements occur both at the top of channel belts and as interbedded bodies within channelized elements. Overbank elements are characterized by lower porosity and permeability values (porosity 3%-20%; K_h 0.01-263 mD; K_v 0.001-75 mD), and therefore represent an important lithological heterogeneity. Another heterogeneity is represented by white, in-channel silty sandstone drapes (porosity from 8% - 10%; permeability values of a few millidarcies) representing flow baffles.

A range of sedimentological and hydro-geophysical techniques reveal how bedding-parallel fractures dominate the flow at shallow depths (<200 m). Vertical stratabound joints, which are de-limited by bedding fractures, enhance water flow by establishing connection between sub-horizontal fissures. Upscaling of intergranular permeabilities and pressure build-up derivatives indicate how the matrix represents a significant component for conducting flow in the deep St Bees Sandstone aquifer (200-1100 m). Despite this, temperature and conductivity logs reveal how bedding fractures connected by stratabound joints still provide partial contribution to flow up to depths of 1100 m.

Sedimentology and microfacies development within a slope to basin floor mudstone succession: Carboniferous Bowland Shale Formation, NW England (UK)

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The Bowland Shale Formation comprises a succession of organic-rich mudrock deposited in a series of fault controlled half -graben during the Carboniferous (~335Ma to ~313Ma) in the Pennine Province (U.K.), and represents the largest potential target for shale gas exploration within the UK. Variations in sedimentology and diagenesis play a major role in controlling reservoir quality but current knowledge for the Bowland Shale is limited, leading to significant uncertainty for exploration. Centimetre-scale sedimentary logging, thin section analysis, and geochemical techniques (TOC & RockEval™) based on 125 m of continuous core from the Bowland Basin enables the study of sedimentological processes acting within a slope-to-basin-floor mudstone succession. Deposition within the mudstone succession is dominated by turbidites and debrites. Lenticular fabric (lenses 50 < 800 μm) occurs within all mud-rich facies. The lenses represent remobilised soft-sediment mud-rich clasts, providing evidence for traction throughout the succession. Finer-grained facies within the Bowland Shale Formation contain the highest TOC values (< 12 wt. %). Variation in organic matter content within facies appears linked to the degree of dilution from reworked sediments, i.e. the development of lenticular fabric. Depositional (carbonate) composition shows a strong control on the development of carbonate cements within the formation. Deposition of the Bowland Shale within the studied section is interpreted to represent a system of slope aprons originating from a carbonate-rich shelf. Facies variations demonstrate a change from a carbonate dominated to a mixed carbonate and siliciclastic shelf environment. The sedimentology of mudstone successions provides key insights into basin processes which in turn have a significant impact on bulk rock properties, and thus prospectivity, within these unconventional reservoirs.

The Sedimentology of Bone Beds: a review and report on a new Triassic marine bone bed.

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A bone bed can be defined as a single sedimentary stratum with a bone concentration that is unusually dense, relative to adjacent deposits. Many diverse and striking examples have been identified in the fossil record, ranging from Ordovician to sub-Recent in age. Bone beds can be subdivided in a variety of ways; by the number of taxa represented; the size of the particles; the cause of death; carnivores versus herbivores; and by depositional setting.

The most frequently inferred causes of bone bed formation relate to drought, flooding and hydraulic sorting. Other causes include "log jam" assemblages, storm related deaths, ash falls, traps, miring, serial predation, poisoning (for example red tides), cold, fire and disease. The final concentration of bones may be attributed to biotic (due to herding), abiotic (winnowing or reworking), or passive attritional (due to low deposition rate) processes.

Depositional environments can be ascertained by examining the lithology and sedimentary structures. The taphonomy of the vertebrate material may also provide important clues as to the setting in which the bones accumulated. Published work suggests that around 50% of recorded bone beds were deposited in fluvial environments. The other important classes of bone bed, each representing more than 10% of published studies, include lacustrine, marine and coastal deposits. Clastic deposits make up more than 75% of the overall records.

Using several case studies, we will examine how bone beds may be preserved, and how the sedimentary structures and facies associations can be utilized to build up a picture of the causal processes that led to their deposition. Examples will be drawn from both terrestrial and marine settings. The former is represented by published data from Dinosaur Provincial Park, while the latter features a previously unreported marine bone bed from the Triassic Sulphur Mountain Formation of Kananaskis Country, both in Alberta. The data presented will be used to build models that utilize sedimentary structures to classify bone beds.

Global Drainage Patterns of Modern Sedimentary Basins and the Anthropocene

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Source-to-sink detail the evolution of detrital production, transport and deposition along its sediment routing pathway from source to its ultimate sink. An understanding of the sediment pathways along S2S systems is an important aspect in numerous fields of inquiry from quantifying biochemical cycles to sediment budgeting. In particular, many studies have applied modern S2S systems as analogs for an improved understanding on the geomorphology that relate to subsurface reservoirs under various autogenic and allogenic controls. The sink of many global modern S2S research is assumed to be the marginal and deep marine environment; however, large terrestrial sedimentary basins are also providing significant accumulations of alluvial sediments such as in the Mississippi, Ganges, and Niger Deltas. This generates individual sediment routing pathways (or sub-catchments), which are all important to understand the distribution of alluvial depositional environments and to quantify the anthropogenic influence along the S2S system.

A new methodology depicting 239,831 drainage patterns (watersheds) to modern terrestrial sedimentary basins has been developed. The results show that globally, passive margins (63%), foreland (15%) and intracratonic (12%) settings drain the most continental area to the coastline and that the potential sediment discharge of each tectonic regime is derived primarily from the source region although foreland and intracratonic settings have a significant contribution internally from the sedimentary basin. Despite terrestrial sedimentary basins aerial coverage of 16% of the landsurface, 32% of the world's population resides within depositional settings and 96% of major dams occur in erosional settings. The results highlight the considerations that are needed when selecting modern anthropogenically-modified S2S analogs for an equivalent subsurface system. The new global watershed dataset furthermore allow for improved quantitative studies of S2S geomorphology relationships (e.g., river length, shelf width, slope width, elevation) by allogenic and autogenic controls to help improve subsurface prediction.

Influence of Salt-Related Seabed Topography on Mass-Transport Complex (MTC) Sedimentation

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The distribution and geometry of mass transport complexes (MTCs) can be influenced by seabed topography. More specifically, MTCs may be ponded, diverted or blocked by bathymetric features. Although the interaction between mass-flows and seabed relief has been previously documented, its effect on the architecture of the resulting deposits has not been investigated in detail. In this study, we use 3D seismic reflection data from the Santos Basin, offshore Brazil to investigate the effect of salt-related seabed topography on the gross distribution and internal architecture of an areally extensive (c. 4650 km^2) MTC.
The MTC is composed of low-amplitude, chaotic seismic reflections, interpreted as debrites, and occurs in the Oligocene-Recent stratigraphy. The MTC was deposited on a topographically complex seabed characterised by a series of linked minibasins developed between salt diapirs. Changes in the thickness and seismic facies of the MTC reflect changes in the underlying bathymetry. First, megaclasts that range in size between 1 and 10 km^2, and which are surrounded by a chaotic, debritic matrix, are confined within the minibasins. Downdip of the minibasins, on the more weakly confined basinfloor, the MTC comprises debritic material containing few megaclasts. Towards the minibasin margins, seismic reflections become locally more continuous and parallel. This seismic facies variability suggest that most of the coarser material was confined within the minibasins, with only the finer portion overflowing flanking bathymetric highs. The increased continuity of the seismic reflections towards the margins could suggest local substrate entrainment.
The relationship between changes in the thickness and the distribution of the seismic facies, with changes in the underlying bathymetry suggest that the characteristics of the flow changed in response to seabed topography. This inferred lithological variability has important implications for the lateral heterogeneity of MTCs which impacts their ability to act as seals to hydrocarbon reservoirs.

Understanding fluvial facies distribution within sedimentary basins: Bighorn Basin, Wyoming

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Recent advances in fluvial sedimentology has resulted in an increased understanding of facies distributions and fluvial architecture variation at the system scale. System scale examples have now been described in a quantitative manner, and highlight the predictive nature of distributive fluvial systems (DFS). However, there are few rock record studies that have quantitatively assessed fluvial facies and architecture distribution at the basin scale. It is hypothesised that the DFS model should enhance our ability to successfully predict fluvial facies and architecture variability within a sedimentary basin based on observations from modern basins. To test this hypothesis, a near entire basin scale study of Paleocene and Eocene strata from the Bighorn Basin, Wyoming, has been undertaken to assess how applicable the DFS model is at the basin scale. Excellent exposure and a good chronostratigraphic framework makes the Bighorn Basin an excellent candidate for such a study, with over 28 localities and a total of 4000m of succession analysed over 8,700 km^2.
Initial analyses of facies, sand proportion and geometry data reveal a complicated pattern. Basin margin to basin centre trends are not as evident as was initially expected, with only very broad decreases in sand and channel proportions being observed from basin margin to basin centre, with many anomalies being observed. However, by taking a systems approach, whereby key sediment inputs and individual sedimentary systems were identified, downstream trends become much more apparent. Importantly, an axial system is identified, which is interpreted to have caused a more complicated distribution in facies data at the basin scale. This study highlights the importance of deconstructing basin scale data and the value of having conceptual models derived from modern datasets.

Variation of cross-sectional geometries in submarine channels

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Submarine channels are abundant geomorphic features on the seabed and play a key role in continental margin evolution and as a supplier of nutrients and sediments into the deep ocean. They are distributed worldwide and exhibit a wide diversity of settings and channel types from isolated-deep-ocean channels to submarine-fan channels. However, most studies classify submarine channels as a single group rather than distinguishing them as different types. Yet different types of submarine channel may have different dimensions. This is important for key questions such as how submarine channels geometries compare to rivers. In this study, our aim is to identify whether different submarine channel types vary in terms of their cross-sectional geometry. Submarine channels are divided into six types: (I) axial, (II) submarine-fan, (III) slope, (IV) non-marginal-ocean, (V) isolated-deep-ocean and (VI) canyon-like channels. Cross-sections from primary data and from previously published literature (multibeam or from top surface of 3D seismic datasets) were obtained for each channel type. Morphometric parameters of channel width, channel depth, channel-bed width, cross-sectional shape and area are analysed for each cross-section. The results indicate a variation of channel parameters on: (I) a small scale (variation between cross-sections for a given channel), (II) a medium scale (variation between channels within a given channel type) and (III) a large scale (variation between channel types). On the large scale, two distinctive groups were identified in the width-depth ratio: (I) submarine-fan, slope and non-marginal channels have width-depth ratios between 13 and 18, whereas (II) axial, isolated-deep-ocean and canyon-like channels have width-depth ratios between 32 and 85. The identification of different channel geometries through a quantitative analysis is important for understanding flow and sedimentation processes within channels, and for comparing submarine channels to rivers on Earth and channels on other planetary bodies.

Petrography of turbidites and XRD analysis of their mudstone caps, insights from the Castagnola system, NW Italy

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The particulate load of turbidity currents can be divided into coarser (silt/sand/gravel) and finer (mud) components. The coarser component has been the subject of most deposit research, because of its prominence at outcrop and its role in forming hydrocarbon reservoirs. Recently, increased attention has been given to the role of clay in affecting flow behaviour and deposit character. However, the number of studies investigating mudcap character and thus volumes and role of mud is limited. This is partly because mudcaps tend to crop out poorly, and partly because mud often bypasses down-dip where events cannot easily identified or linked to their sandier counterparts.
The Castagnola system (NW Italy) is an excellent natural laboratory to study turbidite mudcaps. First, fully ponded conditions dominated for a significant part of its infill (i.e., sand and mud were trapped together). Second, rapid basin fill and low rates of hemipelagic deposition mean that most mud is turbiditic. Finally, two sediment sources with differing petrographic signature were synchronously active, allowing comparison between the source of the sandstones and their mudcaps.
Thin section (sandstones) and XRD (mudcaps) analyses were conducted on over 50 beds. Results indicate a correlation between sandstone and mudcap source signature. However, while most sandstone beds show tight clustering around two petrographic types, mudcaps show signatures that are more mixed. Hence, it is thought that the turbidity currents must have had a 'single source' composition (sand and mud) at initiation, but that the mud became mixed following acquisition of mud particles en-route, likely through substrate erosion; sand was apparently rarely eroded en-route. Further work aimed at constraining the amount of mixing will better define the proportion of mud acquired by the flows en-route and therefore help constrain the pattern of flow evolution and the resulting implications for the character and distribution of the deposits.

Exploring the potential for the formation of discrete stromatolite build-ups from microbial mats in the Abu Dhabi coastal sabkha

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Discrete stromatolite build-ups are documented from both marine and terrestrial environments worldwide. These stromatolites form through a combination of trapping and binding of allochthonous grains and the direct precipitation of autochthonous carbonate minerals, mediated and/or controlled by the associated microbial fauna. Until now, however, a link between stromatolite build-ups and microbial mats has not been clearly established. While both microbial mats and stromatolite build-ups commonly occur in close proximity, no direct evidence has been proposed to support a connection between their growth forms. Here, we report evidence for a previously undescribed mechanism for the formation of stromatolite build-ups from precursor microbial mats in the coastal sabkha of Abu Dhabi. The proposed model genetically links the development of discrete microbialites from earlier microbial mats through a combination of inundation, erosion, and early lithification. We propose that under optimal environmental conditions, these processes will produce distinct stromatolite bodies akin to those described in Shark Bay (Western Australia) or Highbourne Cay (Great Bahama Bank).

Influence of Coriolis forces on turbidity currents

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The Var Turbidite System, located in the vicinity of Nice (northwest Mediterranean Sea), has been studied for over fifty years mainly on the basis of seismic profiles and cores. This study focuses on how Coriolis forces might influence hyperpycnal flows in this system. Due to the low velocities of these flows and the size of the system, Coriolis forces may play an important role in the evolution of turbidity currents and in the final deposition pattern. Coriolis forces' influence has long been acknowledged in turbidity currents deposits but it is often neglected when studying and modelling turbidity currents. Coriolis' influence becomes important when the spatial and temporal scales of Earth's rotation and of the flow are similar. This study presents the first attempt to simulate the evolution and deposition of hyperpycnal flows in this system. The influence of Coriolis forces on the spatial evolution of the turbidity currents and the construction of the Var Sedimentary Ridge is evidenced and supported. The simulations in which Coriolis is not taken into account show a quasi-symmetric pattern of spreading and sedimentation of the flow which is only partially constrained by the Var Sedimentary Ridge. When Coriolis is taken into account the turbidity current is deflected to the right once the confinement of the canyon walls is lost. Part of the current flows through the Western Spillover Channel and part continues along the Var Sedimentary Ridge, contributing to its development. Flow intensity and inertia modulate the Coriolis effect. If the flow does not reach the thickness needed to overspill the Western Spillover Channel the flow continues along the Var Sedimentary Ridge. Coriolis forces can also help to explain the higher sedimentation rates observed in the distal part of the ridge, enabling a novel interpretation of how turbidity currents may propagate on the deep-sea.

A first process model for channel-lobe transition zones

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Channel-lobe transition zones (CLTZ) have been understood in terms of their planform geomorphology, marked by prominent scattered offset scours, and sediment waves downstream, however the mechanisms for initiating and maintaining these zones have not been clear. Models have typically been restricted to considering a single large hydraulic jump at the base of slope. However it has been unclear how an array of scours forms under such a large jump. Furthermore, experimental studies have shown that such hydraulic jumps are associated with rapid sedimentation of material from suspension, in marked contrast to the extensive areas that CLTZs can extend over. Here we detail the first process model of channel-lobe transition zones, based on a detailed field investigation of a saline gravity current in the southwest Black Sea. In the Black Sea we analysed the three-dimensional flow structure and dynamics of a series of linked hydraulic jumps in stratified, density-driven, flow. Field observations suggest a newly identified type of hydraulic jump, that is a stratified low Froude number (<1.5-2) subaqueous hydraulic jump, with an enhanced ability to transport sediment downstream of the jump, in comparison to hydraulic jumps in other subaerial and submarine flows. These novel field data underpin a new process-based conceptual model of channel lobe transition zones that explains the scattered offset nature of scours within such settings, the temporal variations in infill and erosion between adjacent scours, how sedimentation is maintained across the CLTZ, and why the locus of deposition, and the formation of sediment waves is so far downstream of the scour zone. The model also suggests that CLTZ flows have Froude numbers below those required for the formation of cyclic steps, suggesting that such features may dominate the continental slope, but are unlikely to be present downstream of CLTZ unless channel slope dramatically increases.

Sedimentation versus deformation rates as a control on the architecture of deep-water channel systems: observations from the toe-thrust region of the Niger Delta slope

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In the deep-water slope areas of the southern lobe of the Niger Delta, gravity-driven deformation has resulted in the development of a fold and thrust belt since middle Miocene times. Over time the interaction between tectonically driven sea-floor topography and sediment dispersal systems have allowed for the formation of structural and combined traps. The typical reservoirs comprise large channel-complex systems and sheet sands, but their distribution and vertical assemblage is ultimately controlled by the rate of sediment accumulation versus structural deformation (S/D). This study explores how turbidite channel characteristics change in response to variation of S/D ratios.
A 3D seismic survey covering an area of 6200 km^2 in the outer fold and thrust belt has been used to map the facies and structural evolution of a piggy-back basin bounded between two thrusts-folds. Within the syn-growth interval of the piggy-back basin three main units between 12.8 and 3.7 Ma in age, which record the structural and stratigraphic evolution of the basin have been mapped. Isopach maps of these units show shifting depocentres with time as a response to the tectonic activity on different thrust-faults.
Channel-complex systems occur at different levels within the three units, showing specific characteristics, and proving that varying strain rates have had a major control on their location as well as on their architecture. The integration of the isopach and amplitude maps with measurements of structural strain across the thrusts bounding, and within the piggy-back basin has shown that periods of relative, low, strain-rate (-0.008/Ma) correlate with laterally shifting channel-levee complexes. In contrast, during periods of relative, high, strain- rate (-0.045/Ma), channels tend to stack vertically. These results suggest that simple subdivisions in S/D ratio over or lower than 1 is not detailed enough to address the greater variability seen on seismic data.

CHANGE! A turbidity current's transition from bypass to deposition – Experimental results & comparison to a field case from the Karoo, South Africa

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Turbidity currents can bypass large parts of their suspended sediment load. Typically, it is only after passing a break-of-slope that deposition starts. Previous models suggest that coarser grains are deposited first as they settle faster. Subsequent depletion of coarser grains and later arrival of finer grains at the bed produce downstream fining. This trend is described by several experimental and field studies. Contrary to this we found a downstream coarsening following a break-of-slope in both experimental and natural turbidites.
We released Shields scaled turbidity currents into a 2D-flume with an installed break-of-slope. The break-of-slope triggered a downstream increase in thickness accompanied by a drop of sediment concentration, although the flow remains supercritical. Bed shear stress dropped after the break-of-slope, resulting in deposition. Vertical grain size profiles of the turbidity current reveal a downstream increase in grain size at the base of the flow, associated with an increase in sorting. We propose that deposition is capacity driven, and hence that the deposits resemble the basal flow characteristics. A downstream coarsening can then be explained by the enrichment of coarser grains at the base of the flow over time – as consequence of their higher settling velocity – resulting in downstream coarsening of the deposits.
The experimental results are linked to a comparable turbidite system from the Karoo basin (South Africa) which can be traced in palaoeflow direction for >5 km. The deposits rapidly increase in thickness downstream of a bypass zone from a few meter up to 40 m, within a distance of ~400 m. Thinsections taken from the deposits provide a downstream coarsening trend similar to the experimental results. Hence, the natural turbidity currents processes may resemble the experimental ones. The comparison of Shields scaled synthetic deposits to ancient turbidites allows us to reconstruct flow properties of past turbidity currents.

Spatial-temporal evolution of sedimentary systems, transition zones and stratigraphic sequences in an exhumed basin margin succession

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Constraining the stratigraphic architecture in 3D over multiple scales is needed to understand the controls on the spatial-temporal evolution of basin margins. The Karoo Basin provides system-scale exposures of shelf/shelf-edge systems passing down dip through slope valleys and channel-levees into basin-floor lobes, offering excellent analogues across a range of scales. Outcrop and core observations, combined with geometric analysis from correlation panels, allow positioning of several sedimentary transition zones through time, from which dimensions of different segments of the Karoo basin-fill were deduced. Facies partitioning and grain-size proportions were obtained for each segment, and architectural elements were defined from mapping of sedimentary bodies. Results indicate a mixed sand/mud basin margin, with a sand-rich basin floor, mud-rich slope and a mixed, accretionary shelf.
Radiometric ages integrated with magnetostratigraphy suggest the 2km-thick succession deposited in a 6 My period. It is subdivided into 6 composite sequence sets: in CSS1-3, basin floor sand-rich deposition occurred in an area of increased subsidence around Laingsburg, and correlate to a mud-rich succession 40 km along margin in Tanqua; CSS4-5 comprise sand-rich basin floor-to-slope deposits in Tanqua with equivalent mixed sand/mud slope systems in Laingsburg; this across-strike variability in sediment distribution is progressively healed by basin-margin clinothems of CSS6.
Dating supports average 300Ky duration for composite sequences and 100Ky for sequences. However, deep-water sequences are increasingly compensational and sand-rich downdip and more condensed than shelf sequences, which show lateral variability but generally sand-poor slopes. High-sand aggradation and absence of clear sequence boundaries in the shelf resulted from intrinsic-extrinsic controls in a high-latitude, greenhouse setting. Major differences with the underlying deep-water deposits are attributed to a different basin-margin physiography at that time. The shelf strata are therefore a poor analogue to the shallow-marine systems that fed the Karoo deep-water succession, and cautions against applying simple models for progradational basin margins.

Early post-rift facies and architectural changes within a coarse-grained deep-water system deposited above a Mass Transport Complex (MTC)

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Local gradient changes and variable accommodation characterize the upper surface of mass transport complexes (MTCs). Bathymetric variability can influence the longitudinal and vertical processes occurring within coarse-grained sediment gravity flows, which are challenging to interpret from the rock record alone.
A 60 m thick succession of very coarse-grained and poorly-sorted matrix-rich sandstones deposited above a seismic-scale mass transport complex (MTC) is investigated in the Jurassic stratigraphy of the Los Molles Formation, Neuquén Basin. The facies types and architectural changes documented within the deep-water succession provide insights into the interactions between coarse-grained sediment gravity flows and uneven seabed inherited from the top of a MTC.
The succession was deposited in the Chacay Melehue hemi-graben outcrops along a 6.5 km long oblique downdip longitudinal profile which permitted correlation of individual beds between 16 stratigraphic sections (1:25 scale). Two units are defined: Unit 1 comprises heterolithic facies grading upwards into poorly sorted, very coarse- to fine-grained, thin- to medium-bedded sandstones with abundant pebble-sized clasts; Unit 2 comprises three thick conglomeratic event beds of very poorly-sorted, granular to medium-grained mud-rich sandstone matrix, supporting polygenic gravels ranging from pebble to boulder and large clasts.
The sandstone-rich division of the deep-water succession studied is interpreted as a lobe complex emplaced by an out-of-equilibrium sand-rich system, which recorded a progressive decrease of confinement from Unit 1 to Unit 2. The MTD-related topography controlled stratigraphic trapping of considerable sand volumes in Unit 1. Once the MTC-related accommodation was filled, relief associated with individual supra-MTC sandbodies produced subtle changes in depositional processes in the Unit 2.
Predictive stratigraphic outcrop-based models can provide insights into spatial distribution and internal architecture of heterogeneous sandbodies able to generate multiscale net/gross variations that make-up the internal complexity of subsurface reservoirs hosted in lobes above MTCs.

Sedimentary Structures in Deepwater Paleogene Wilcox Core Data, Gulf of Mexico, USA; Some New Insights into Deposition of Sands from High Magnitude Turbulent Flows

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Recent acquisition of petrophysical and rock data in the deepwater, Paleogene Wilcox Formation, offshore Gulf of Mexico, USA has delivered many 100s meters of conventional core that record a broad variety of mass flows, turbidite and hybrid event beds. A wide spectrum of sedimentary structures are exquisitely expressed in Computed Tomography (CT) data volumes and extracted images. These high resolution (voxel size less than very fine sand) volumes can be orientated via well data and provide a means to catalog the spectrum of sedimentary structure types, their internal architecture, vertical motifs and their paleocurrent trends.
Wilcox deepwater sands are very fine to fine grained, averaging commonly very fine upper (88-125 microns). Sand composition is lithic arkose-feldspathic to litharenite. Sediment source is from the North American continent with a potential for Appalachian to Laramide Rockies drainage that fed deltaic shelf margins in SE Texas and Central Louisiana. Deepwater transport distances to the location of the core data is 600-700 kilometers and via a slope underlain, in part, by shallow buried, mobile salt.
Our focus is on sedimentary structures in sands that are interpreted as the depositional products of high magnitude, fully turbulent to dominantly turbulent, sediment gravity flows. Context of the sedimentary structures are thicker sand intervals (commonly 10s feet) and in stratigraphic sections interpreted as submarine channels and/or proximal and axial deepwater lobe settings.
We suspect that our description and initial classification of these high energy sedimentary structures includes bedforms that are operating at the threshold of flow velocities capable of entraining and suspending fine sand; the uppermost flow regime and a realm classically of upper plane beds and antidunes. Should these structures be fully explained by flow types and depositional setting within the myriad of deepwater sub-environments, then considerable value will be added to future deepwater reservoir characterization.

Detailed architecture of fluvio-deltaic sandstones: a subsurface and virtual outcrop (VO) study of the Scalby Formation, NE England

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Fluvio-deltaic sandstones are significant petroleum reservoirs around the world. Sandstones deposited in these settings are volumetrically important but very heterogeneous as petroleum reservoirs. Fluvial and delta top settings comprise channel deposits and overbank deposits which include levees, crevasse splays, splay complexes and mires. Channel sandstones are the main reservoirs and as such have received considerable attention in the literature. Crevasse splay sandstones may provide additional reservoir and additional communication between channel bodies. There is a lack of understanding of crevasse splay sandstones in terms of facies associations, size, quantitative geometry and role within petroleum reservoirs.
This study used the Scalby Formation (Ravenscar Group, Middle Jurassic) is exposed along the Yorkshire coast. The formation has been used as an analogue to the Ness Formation of the Brent Group. The Bathonian Scalby Formation unconformably overlies the marine Scarborough Formation. It comprises the lower fluvial sandstone-dominated Moor Grit Member and the upper floodplain-paralic mudstone-dominated Long Nab Member. The succession was deposited under humid, subtropical climatic condition in a fluvio-deltaic and paralic setting.
The research collected data by traditional field observations supplemented with a virtual outcrop created by UAV photogrammetry from the Long Nab area. Twenty-seven core sections from boreholes drilled by IFP in the late 80's just behind the outcrop were also logged. Four major sedimentary facies have been identified: sand-dominated channel fill; tidally influenced heterolithic channel fill; crevasse splay sandstones; and floodplain mudstone (both subaerial and subaqueous). The close well spacing and virtual outcrops permits their architecture to be determined in detail. All remotely and directly sampled data along with behind outcrop borehole data will be used to simulate a high resolution 3D geocellular model of a 1 km^2 area. This model will provide a unique three-dimensional insight into the geometry, architecture and connectivity of crevasse splays and channel facies.

Reducing uncertainty in seismic interpretation of fluvial successions through prediction of point-bar form and heterogeneity

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Meandering fluvial reaches exhibit highly variable morphological form, yet published interpretations of ancient meander-belt deposits do not reflect the stratigraphic complexity known to be associated with such variability. An improved understanding of the causes of stratigraphic complexity is important to enable subsurface predictions of sedimentary lithofacies distribution and architecture from analysis of relatively low-resolution seismic datasets. Quantification and classification of plan-form geomorphologic details of active and recent fluvial point bars, and integration with small-scale lithofacies distributions and heterogeneity observed in outcropping successions, has enabled the development of tools with which to predict the 3D sedimentary architecture of ancient successions.
Active fluvial systems were studied to quantify spatio-temporal relationships between scroll-bar behaviour and meander shape. The rivers selected were classified by a range of parameters, including climatic regime, gradient and discharge. Quantitative comparison of meanders with markedly differing morphologies has been enabled through the development of a novel method. Measurements of 35 morphometric parameters of 520 active meander bends from 13 different rivers were acquired using Google Earth Pro. Twenty-one scroll-bar geometries were assessed according to a classification scheme independent of meander shape.
The following findings arise: (i) the most likely scroll-bar configuration relates to expansion and rotation, which accounts for 18% of meanders; (ii) meander forms can be classified into four groups that collectively comprise 25 specific shapes; (iii) fluvial systems with different gradients, sediment calibre, channel sizes, accumulation rates and climate regime exhibit different, yet predictable, characteristics in meander and scroll-bar development; (iv) the most likely paths of temporal evolution in scroll-bar types in a bend becoming mature and approaching cut-off are quantifiable, thereby improving understanding of a fragmented geologic record. This method can be applied to predict high-resolution lithological heterogeneity from relatively low-resolution seismic slices, thereby helping to constrain reservoir models and predict stratigraphic heterogeneity prior to drilling.

Gravity currents: entrainment, stratification and self-similarity

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We present a series of new laboratory experiments to measure the mixing in finite volume release currents propagating along a two-dimensional horizontal channel. A light attenuation technique was used to measure the distribution and evolution of the density of the flow, and dye studies were used to follow the motion of the current and the ambient fluid. Two regimes found to be present after the slumping phase. In the first regime, the main part of head of the current retains its original density and the flow travels with a constant speed. In the second regime the position of the head increases with time as $x_n \approx 1.7B^{1/3}t^{2/3}$, while the depth-averaged reduced gravity in the head decreases through mixing with the ambient fluid according to the relation $g'_n \approx 4.6H^{-1}B^{2/3}t^{-2/3}$. The fluid with the original density reaches the front of the current, at a speed which is approximately 1.35 times that of the front. A strong circulation develops in the head of the current; as current fluid reaches the front of the flow, it rises and mixes with ambient fluid which is displaced upwards over the advancing head. The continuing flow gradually adjusts to a self-similar profile in which a fraction in the range 0.63–0.7 of the fluid displaced by the current mixes into the current. This mixing process has numerous implications for density-driven flows in nature and the environment, such as the propagation of volcanic ash flows and particle sedimentation from turbidites, and for assessing the hazards associated with the release of dense volatile phases in industrial accidents or natural events such as the 1986 CO2 release from Lake Nyos in Cameroon.

Controls on the depositional architecture of fluvial point-bar elements from a coastal plain setting

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The internal lithofacies distribution and external geometry of point-bar elements records the evolution of the associated channel through time. This work aims to refine traditional facies models of point-bar elements and discusses how autogenic and allogenic controls govern point-bar development and preservation, some instances of which do not conform to established models.
Within the Campanian Neslen Formation (Mesaverde Group, Utah), 42 point-bar elements located within an established sequence stratigraphic framework have been analysed through the combined use of sedimentary logs (n=67), stratigraphic panels and palaeocurrent analysis (n=1021). Results demonstrate that point-bar elements increase in thickness, aspect ratio and amalgamation stratigraphically upwards. Four distinct point-bar element 'types' are identified based on lithofacies assemblage and external geometry. Two of these types conform to traditional facies models; however two types exhibit unusually low proportions of cross-bedded sandstone and higher proportions of massive, horizontally laminated and ripple cross-laminated sandstone. The occurrence of these atypical point-bar assemblages is restricted to the lower and middle parts of the formation. A relational database, which provides data on the geometry of many examples of point-bar elements and facies proportions, is used to compare facies assemblages and aspect ratios of point-bar elements in the Neslen Formation to other comparable successions.
The deposition of point-bar elements with lower proportions of cross-bedded sandstone in the lower Neslen Formation is attributed to low stream power and hence lower sediment supply interpreted for this interval. The upwards increase in aspect ratio and amalgamation of point-bar elements through the Neslen Formation reflects a temporal decrease in the rate of accommodation generation and/or increase in sediment supply. This change in accommodation is reflected by the decreased occurrence and poorer quality of coal upwards. The high level of detail encapsulated in the point-bar models allows for the recognition of hitherto undescribed point-bar assemblages.

Shapes on a plane: exceptionally preserved substrates provide palaeoenvironmental insights into intervals of non-deposition

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It is arguably under-appreciated that bedding plane surface textures and microtopographies reveal fundamentally different insights into ancient sedimentary environments than internal hydrodynamic bedforms or stratigraphic architectures. This is because they may preserve features imparted onto sedimentary substrates during intervals of depositional stasis, and as such they can reveal an array of palaeoenvironmental characteristics that are unrecorded during intervals of active sedimentation. Using a number of Palaeozoic case studies, this presentation illustrates what the abundance and diversity of structures seen on bedding planes reveal about palaeoenvironmental conditions, and discusses how well-preserved ancient substrates may enter the rock record. Multiple examples are drawn from the Silurian Tumblagooda Sandstone, a 1.2 km thick succession of fluvial and tidal sandstone facies, cropping out near Kalbarri, Western Australia. This formation is renowned for its wide array of surficial trace fossils (e.g. *Diplichnites*, *Protichnites*, *Siskemia*), however less attention has been paid to the immaculately preserved abiotic surface textures that commonly co-occur in association, particularly within tidal facies. Such features include setulfs, adhesion warts and ladder ripples, along with microtopographic features such as bar tops and ponds. The preservation of apparently delicate surface textures and microtopographies suggest that a significant number of bedding planes in the Tumblagooda Sandstone record largely unaltered primary substrates; providing a unique window onto palaeoenvironmental and palaeoecological conditions during intervals of sedimentary stasis. The observed diversity of ancient substrate signatures is explained with reference to variations in modern substrate morphology that can be observed during short intervals of depositional stasis.

Abrasion set limits on gravel flux to the Ganga foreland basin

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The Ganga foreland basin traps approximately 10% of the sediment flux delivered from the Himalayan mountain range. A fraction of that is delivered as gravel (all grains > 2mm), but the bulk is sand and silt in channel and floodplain settings. The gravel to sand transition in the rivers of the Gangetic Plains is abrupt, and is located between 10 and 40 km downstream from the mountain front. An intriguing observation is that the position of the gravel/sand transition relative to the mountain front is the same for small foothills-fed river catchments (<350 km^2) as for large catchments (>30,000 km^2) fed from the high Himalaya. A volumetric analysis of the gravels relative to the sediment yield from upstream catchments indicate that the smaller catchments generate higher proportions of gravels (>10% by volume) than the larger catchments (1-10%). An analysis of the provenance of the pebbles in the gravels indicates that the bulk of the pebbles were derived from the Lesser Himalaya or were quartzite lithologies which occur throughout the catchments; no clasts were present from the Tethyan Himalaya, and very few from the High Himalaya. Based on these observations, we applied a model of clast abrasion in rivers calibrated against flume experiments. The results indicated that the bulk of the pebbles generated at a distance >100km upstream of the mountain front were likely to have been abraded into sand grains, with the exception of quartzite lithologies. Therefore, we propose that pebble abrasion sets a limit on the gravel flux from mountain catchments. This has implications for the impact of earthquake generated gravel flux to the plains. For example, the 2015 Gorkha earthquake in Nepal appears unlikely to generate a significant change in gravel bedload to the Plains, in contrast to the Wenchuan and Chi-Chi earthquakes, both of which were proximal to the mountain front, caused significant aggradation in channels (10-18m) and consequent flooding.

Geological record of shallow-marine, supercritical tsunami backwash: Field observations and numerical simulation

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Tsunamis are marked by distinct phases of uprush associated with coastal inundation, a short stagnant water phase, and backwash, during which tsunami waters retreat. While the returning flow may erode the shoreface and transport large volumes of sediment to the offshore, the locus where supercritical returning flow transforms into subcritical advancing flow can be a site of important sediment accumulation. Using a combination of field observations and numerical simulations, we investigate the potential signal of these phenomena in the geological record. We expect large tsunamis to generate offshore bars with scour-and-fill structures associated with antidune stratification. While the recognition of such bedforms is challenging in sandy depositional systems due to their long wavelength (exceeding many tens to hundreds of meters), we present an outcrop in a coarse grain-size setting where these features can be clearly identified and described. We advocate that the apparently structureless or faintly-stratified deposits, which typically comprise the fining-upward basal division of shallow-marine sandy tsunamiites, in fact consist of landward-dipping backset strata that formed under a migrating hydraulic jump during the basinward retreat of tsunami waters. Numerical simulations that focus on the internal stratification of the backwash-generated offshore bar support this hypothesis. Our work clarifies the nature of the backwash phenomenon and associated deposits, which is indispensable to tsunami risk assessment in coastal areas.

Molar-tooth structure: a Precambrian calcite network dependent on bacterial EPS?

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"Molar-tooth" (MT) structure has long been regarded an enigmatic feature of late Archean to Proterozoic fine-grained siliciclastic and/or carbonate sediments. The structure is widespread and commonly forms networks of calcite veins in silty carbonates that appear to have originated as gas and/or liquid voids that were rapidly filled with and lithified by calcite. The first phase of calcite cementation appears to have been the creation of sub-spherical bodies that are morphologically similar but smaller than those produced experimentally by some modern bacteria. Some MT grains accumulated as granular masses that behave as fine-grained silt-sized sediment which occasionally shows cross-lamination. A second phase of calcite precipitation filled in the remaining pore spaces and lithified the network. During burial the surrounding sediments were compacted, causing the network to deform because it was more rigid than the enclosing sediment, giving rise to the characteristic contorted calcite network of the present day. Decompaction measurements suggest that some MT formed within 1-2 m of the sediment-water interface. Experiments on artificial clay slurries laced with yeast and sugar, created voids, but those most closely resembling MT structures required a seal. The seal allowed higher than hydrostatic pore-fluid pressures to be produced in the voids. In the case of MT structures the gases generated by the decay of buried organic material, probably mostly microbial mats, created the voids. Extracellular polymeric substances (EPS) generated by bacteria in the mats could have provided a plausible seal allowing the gases to accumulate. In the absences of a seal the gas bubbles would not have accumulated. If this interpretation is correct, then MT structures are another indicator of the importance of bacteria in the late Archean to late Proterozoic history of life on Earth.

Varied Stratigraphic Expressions of Slope Channel Evolution

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Submarine slope-channel fills are the composite product of an intricate history of sediment erosion, bypass and deposition processes that are associated with sediment gravity flows. Channel fills are proportionally dominated by thick-bedded sandstones, which provide a biased record of channel infilling by deposition from high-density turbidity currents. Processes of erosion and bypass, as well as deposition from more dilute currents, are less evident as they are recorded by features that are proportionally subordinate or less readily preserved (e.g., mudstone-prone drapes, siltstone-dominated thin-bedded turbidite successions). Subsequently, it is harder to deduce the relative roles of these processes during channel evolution, and their influence on preserved channel-fill architecture.
Well-exposed, stacked-slope channel fills from the Cretaceous Tres Pasos Formation of Chile provide a unique opportunity to document the varied stratigraphic expressions of channel evolution. Qualitative observations of channel-fill architecture, augmented with a suite of quantified sedimentological characteristics from over 100 sections measured through individual channel-fills, highlight three distinct styles of channel-fill architecture; these differ according to the proportion and architecture of sandstone that is preserved in channel-margin strata. In general, vertical trends within channel-margin strata record an overall temporal increase in flow energy during infill (e.g., increases in sandstone grain size and proportion, and mudstone-clast conglomerates), which differs from evidence for flow energy decrease recorded in channel-thalweg (axis) strata (e.g., decreased amalgamation). Variations in channel-fill style record the varied interaction of gravity flows with the relief and morphology of the active channel floor; this surface is sculpted during channel inception and is continually modified by differential erosion and deposition between the axis and margins of the channel. Careful observations provide insight as to how channel histories become expressed in the stratigraphic record, and provide inputs for stratigraphic (reservoir) models.

The effect of bioturbation in pelagic sediments: Lessons from radioactive tracers and planktonic foraminifera in the Gulf of Aqaba, Red Sea

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Studies of recent environmental perturbations often rely on data derived from marine sedimentary records. These records are known to imperfectly inscribe the true sequence of events, yet there is large uncertainty regarding the corrections that should be employed to accurately describe the sedimentary history. Here we show in recent records from the Gulf of Aqaba, Red Sea, how events of the abrupt disappearance of the planktonic foraminifer *Globigerinoides sacculifer*, and episodic deposition of the artificial radionuclide ^{137}Cs, are significantly altered in the sedimentary record compared to their known past timing. Instead of the abrupt disappearance of the foraminifera, we observe a prolonged decline beginning at core depth equivalent to ~30 y prior to its actual disappearance and continuing for decades past the event. We further observe asymmetric smoothing of the radionuclide peak. Utilization of advection-diffusion-reaction models to reconstruct the original fluxes based on the known absolute timing of the events reveal that it is imperative to use a continuous function to describe bioturbation. Discretization of bioturbation into mixed and unmixed layers significantly shifts the location of the modelled event. When bioturbation is described as a continuously decreasing function of depth, the peak of a very short term event smears asymmetrically but remains in the right depth. When sudden events repeat while the first spike is still mixed with the upper sediment layer, bioturbation unifies adjacent peaks. The united peak appears at an intermediate depth that does not necessarily correlate with the timing of the individual events. In a third case, a long lasting sedimentary event affected by bioturbation, the resulting peak is rather weak compared to the actual event and appears deeper in the sediment column than expected. These effects are likely to make recorded sedimentary events start shortly before the real events and end long after their true termination.

Reconstructing the 1929 Grand Banks Event, offshore Newfoundland

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The 1929 Grand Banks submarine landslide has been seminal in our understanding of deep-water sediment gravity flows. It is an exceptionally rare example of an event where flow velocity has been directly measured by cable breaks and its deposits described from cores taken along the flow pathway. Despite the direct measures of flow speed, key flow parameters, in particular sediment concentration, have yet to be constrained. Concentration is a 1st order control on flow dynamics and character of deposits, hence, is a crucial property to understand. Here we present new core and bathymetry data from a channel within the lower parts of the Grand Banks slope. This new data constrains the trimline of deposits from the 1929 Event, which is used as a proxy for flow thickness. With the addition of this new data, we can constrain the key flow parameters of slope, flow thickness and flow velocity. We then employ three independent approaches to quantitatively reconstruct the bulk sediment concentration of the 1929 Event. Our calculations show the bulk sediment concentration was between 1-2 % vol. over a thickness of ~200 m. This is the first estimate of sediment concentration for a large-volume flow, which is validated by direct measurements.

Alluvial fans as recorders of volcanic island denudation

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We report remote sensing, field survey and geochronological results of Quaternary alluvial fan development on Santo Antão in the arid Cape Verde archipelago, offshore West Africa. Fans are large coastal coalescent forms restricted to southern edifice flanks. The largest fan (6km long, ~4km wide, area ~10km2) comprises a single surface (Qf0). Cosmogenic 3He dating of surface boulders yields age groupings of ~80-50ka (distal) and 20-10ka (proximal). Qf0 dissection exposes poorly sorted fluvial fan sediments interbedded with (undated) lavas and an Argon dated tephra (~193ka). Boreholes reveal a 180m fan sediment-lava sequence suggesting prolonged fan sedimentation and volcanic activity. A single active channel dissects the Qf0 surface from the coast (~4m deep, ~ 200m wide in distal fan; ~60m deep, ~10m wide in proximal fan), inland into a backfilled flank margin catchment area (30km2; 1500m relief) with incision increasing to ~110m. Catchment infill comprises inset fill terraces and lava flow channel infilling/damming. The steep volcanic edifice morphology restricts coastal fan development, inhibiting accommodation space and enhancing erosion through base-level fluctuations when fans do form. Flank collapses modify the steep edifice margins, creating space, sediment supply and drainage routing conducive for fan building. Volcanic hydrothermal alteration is important for island morphology where altered rocks can be readily exploited by fluvial erosion, e.g. south island coalescent fan catchments. Sedimentation is long lived (pre-Middle Pleistocene) with the Late Pleistocene Qf0 surface abandonment-incision linked to climate-related sediment-water variability linked to African Humid Periods and base-level change.

Early Cambrian archaeocyathan-microbialite reefs in South China

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Archaeocyaths and calcimicrobes constructed early Cambrian reef systems, well-known globally but poorly preserved in south China. We describe well-preserved archaeocyathan-microbial reefs from a previously undescribed site, Tangjiahe, northeastern Sichuan, revealing the nature of microbialite reefs in the Xiannudong Formation. Three reef units (R1-R3, lower to upper) are interbedded with limestones. R1 is 3.5 m-thick, low-relief and undetermined size, so may be a mound or biostrome, built by *Epiphyton* with few archaeocyaths. *Epiphyton* aggregations, 1 to 10 mm across, are irregularly shaped, and connect with each other laterally to build a loose and porous framework with rare archaeocyaths, amongst which light-gray sediment is accumulated, and form geopetal structures in some cases. R2 consists of a 2.7 m thick, 6 m wide mound enclosed in oolite. The R2 framework is built by intergrown *Renalcis* and *Tarthinia* forming upward-expanding tufted, fan-shaped aggregations (0.5 to 2 cm in diameter), encrusted by lighter-coloured sediments which provide substrate for more microbe growth. Archaeocyath fossils are uncommon, mostly not *in situ* and bound by microbes in the framework. R3 comprises a *ca.* 1 m thick small microbialite mound and an overlying thin stromatolite bed, both are enclosed in oolite. The mound framework consists of archaeocyaths (5 to 8 mm in diameter) bound by microbial micrite, with abundant cavities infilled with micrite and siliciclastic sand. Most archaeocyaths are not in place and may have been. Micrite binding archaeocyaths is clotted and likely attributed to microbial. The three reef units are separated from higher energy sediments, and archaeocyaths are rare and not the main framework builders, indicating their construction depended on low energy water to develop. The reefs give new insight into construction of these South China Early Cambrian reefs and show that they are comparable to other similar reefs.

Degree of confinement of turbidity currents and deposit tabularity across different scales based on meta-data analysis

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Turbidity current flow confinement and ponding due to interaction with seafloor bathymetry have long been recognised as major controls on depositional patterns. Confined basins have been identified from many settings, with areas ranging from 10s to 1,000s km^2. One of the pieces of evidence used to infer confinement is deposit tabularity; however, tabularity has been described from beds and bedsets ranging in thickness from 0.1 to 30 m, and in lateral continuity from 300 m to 10 km. The aims of the study are to quantify tabularity in different settings and determine controls on its development.

A meta-data approach using the Deep-Marine Architecture Knowledge Store data base has enabled key aspects of the basin geometry, including width, length, area, shape variability (tortuosity), slope relief and sediment entry point location to be captured. In addition to tabularity, independent evidence for confinement was collected including onlap style, mudcaps, palaeoflow (flow deflections or reversals), lateral facies changes (e.g. hybrid event bed development) and effects of confinement on architectural elements, such as channel routing or lobe stacking patterns.

Tabularity can be described by the correlatability of beds and the thickness change of correlated beds between logs. Quantifying tabularity from published log panels has its limitations: the distance between logs, their vertical resolution, the precision of measurement and the sample size are never identical. A high correlatability (>50%) at the bed scale over distances >500 m is found in basins where other evidence suggests that at least the sandy parts of the flows were ponded. Thickness change is larger closer to a confining slope, or with increasing dominance of hybrid event beds, but also in basins of larger area. Tabular units of amalgamated beds are also regularly associated with confinement; however, their correlatability and thickness change values do not enable their discrimination from unconfined lobes.

Descent into the Snowball: the sedimentary record of entry into Cryogenian glaciation in Death Valley, California

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The Cryogenian Period (~720-635 Ma) witnessed at least two extreme, possibly global, glaciations popularly known as Snowball Earth events. A key issue facing climatologists, the modelling community, and geologists alike is how Earth entered these glaciations. Unfortunately, given the tendency of ice sheets to cannibalise and rework their underlying substrate, sedimentological records of glacial onset have remained elusive. With this in mind this talk presents an apparently complete sedimentary record spanning the onset of the Cryogenian glaciation from the Silurian Hills of Death Valley, California.

In the Silurian Hills, pre-glacial rocks consist of stratified, matrix-supported conglomerates passing upwards into recrystallized sandy, microbial and pure limestones. These are stratigraphically followed by syn-glacial diamictites. The pre-glacial interbedded limestones and conglomerates are interpreted as intercalated lacustrine or shallow marine and fluvial deposits. The syn-glacial diamictites meanwhile are intercalated with delicately laminated silty interbeds containing unequivocal dropstones, probably deposited in a subaqueous fan setting. Limestones immediately beneath the syn-glacial succession contain silty laminae reminiscent of the overlying syn-glacial silty interbeds. The contact between the pre-glacial and syn-glacial units is concordant. Across this contact nearly pure limestones, containing rare disseminated coarse detrital quartz, pass upwards into diffusely stratified carbonate-matrix conglomerates and ultimately massive carbonate-free diamictites. These relationships are suggestive of a transitional relationship between pre-glacial and syn-glacial deposits, implying the record of Earth's descent into glaciation has been preserved.

Why do some turbidity currents create upstream migrating bedforms while others do not?

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Submarine canyons are major conduits for sediment to be transported from the continental shelves to the deep marine. Turbidity currents are the main mechanism transporting sediment through these submarine canyons. Due to the small density contrast between turbidity currents and ambient seawater, many of these currents are prone to be in the supercritical flow regime. In open channel flows this leads to the formation of upstream migrating bedforms such as antidunes and cyclic steps. Turbidity currents can similarly create upstream migrating bedforms, which are observed in many submarine canyons; but not in all of them. Here, using a novel depth-resolved numerical model, we explore the physical controls on upslope migrating bedform development. Why do some turbidity currents create upstream migrating bedforms, and others do not?

A series of turbidity currents, with different initial concentrations, flow velocities, and thicknesses are simulated using a computational fluid-dynamics model. The sediment bed, initially with a random rugosity, is free to be reworked by the turbidity currents.

Neither sediment concentration, flow thickness nor flow velocity appear to be a good predictor on whether upstream migrating bedforms are created by turbidity currents. Froude numbers have been used previously to determine whether open channel flows will create upstream migrating bedforms. The densimetric Froude number in turbidity currents, however, appears to be unable to identify which flows create these upstream migrating bedforms. We suggest that the mixing intensity, as characterised by the gradient Richardson number, is a key control to for formation of upstream migrating bedforms. Our results show that care should be taken when applying depth-average or open-channel-based models to upstream migrating bedforms generated by sediment density flows.

Are glendonites reliable indicators of cold climates? Evidence from their paragenesis

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Glendonites are calcite pseudomorphs after the mineral ikaite, and have been found in marine sediments throughout geological time. Ikaite is a metastable, hydrated form of calcium carbonate, which is only stable under specific conditions: between -2 and +5 °C, and with high alkalinity and phosphate concentrations. Glendonites are often associated with cold climates due to the strong temperature control on ikaite growth, and the coincidence in the geological record with episodes of global cooling (e.g. Kemper 1987).
Glendonites are found in the Lower Cretaceous succession on Spitsbergen. During the Early Cretaceous, Spitsbergen was at a palaeolatitude of ~ 60°N, and was part of a shallow epicontinental sea that formed during the Mesozoic as Atlantic rifting propagated northwards. The glendonite horizons are found in the Upper Hauterivian and Upper Aptian deposits, coincident with a global cooling event which spanned the Aptian-Albian boundary, but post-dating the Valanginian cooling event ("Weissert Event"). In both cases, however, the glendonite-bearing sediments were deposited in the offshore transition zone, although the glendonites may be found in different facies. Petrological analysis of glendonite structure revealed multiple diagenetic phases of growth, with evidence for oscillating chemical conditions. Together, this evidence suggests that local environmental conditions may have a stronger control on their formation and preservation than global climate.
We present a new model for ikaite growth and slow transformation to glendonite in marine sediments, which points to a more complex suite of diagenetic transformations than previously modelled. Furthermore, we critically assess whether such pseudomorphs after marine sedimentary ikaite may be indicators of past cold water conditions based on evidence from combined sedimentological, stratigraphic, petrological and geochemical techniques.

From rifting to orogeny; using sediments to unlock the secrets of the Greater Caucasus

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The western Greater Caucasus formed by the tectonic inversion of the western strand of the Greater Caucasus Basin, a Mesozoic rift that opened at the southern margin of Laurasia. Facies analysis has identified fault-bounded regions of basinal, turbiditic and hemipelagic sediments. These are flanked by areas of marginal, shallow marine sediments to the north and south. Subsidence analysis derived from lithology, thickness and palaeowater depth data indicates that the main phase of rifting occurred during the Aalenian to Bajocian synchronous with that in the eastern Alborz and, possibly, the South Caspian Basin. Secondary episodes of subsidence during the late Tithonian to Berriasian and Hauterivian to early Aptian are tentatively linked to initial rifting within the western, and possibly eastern, Black Sea, and during the late Campanian to Danian to the opening of the eastern Black Sea.
Initial uplift, subaerial exposure and sediment derivation from the western Greater Caucasus occurred at the Eocene-Oligocene transition. Oligocene and younger sediments on the southern margin of the former basin were derived from the inverting basin and uplifted parts of its northern margin, indicating that the western Greater Caucasus Basin had closed by this time. The previous rift flanks were converted to flexural basins that accumulated thick, typically hemipelagic and turbiditic sediments in the early, underfilled, stage of their development. A predominance of pollen representing a montane forest environment (dominated by Pinacean pollen) within these sediments suggests that the uplifting Caucasian hinterland had a paleoaltitude of around 2 km from Early Oligocene time. The closure of the western Greater Caucasus Basin and significant uplift of the range at c. 34 Ma is earlier than stated in many studies and needs to be incorporated into geodynamic models for the Arabia-Eurasia region.

Are landscapes buffered to high-frequency climate change? A comparison of sediment fluxes and depositional volumes in the Corinth rift, central Greece, over the past 130 kyrs

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Sediment supply is a fundamental control on the stratigraphic record. However, a key question is the extent to which tectonics and climate affect sediment fluxes in time and space. To address this question, estimates of fluxes must be compared with measured sediment volumes within a closed basin, for which the tectonic and climatic boundary conditions are constrained.
The Corinth rift, Greece is one of the most actively extending basins on Earth, with modern day extension rates of up to 15 mm/yr. The Gulf of Corinth is a closed system and has periodically become a lake during marine lowstands over the late Pleistocene. We estimated suspended sediment fluxes through time for rivers draining into the Gulf of Corinth using an empirically-derived BQART method. WorldClim climate data, palaeoclimate models and palaeoclimate proxies were used to estimate discharges and temperatures over the last 130 ky. We used high-resolution 2D seismic surveys to interpret three seismic units over this period and we used this data to derive independent time series of basin sedimentary volumes to compare with our sediment input flux estimates.
Our results predict total Holocene sediment fluxes into the Corinth Gulf of 20 km^3, within a factor of 2 of the measured sediment volume in the central depocentres over this timescale. Sediment fluxes vary spatially around the Gulf, but imply catchment-averaged erosion rates of 0.2 to 0.4 mm/yr. Moreover, BQART predicted sediment fluxes and sedimentation rate measurements both indicate a 25% reduction during the last glacial period compared to the Holocene. At the last glacial maximum mean annual temperatures were lower by 5 degrees, although precipitation was similar, or lower, than present. Consequently, our results demonstrate that sediment export to the basin is sensitive to glacial-interglacial cycles. However, precipitation constraints alone are insufficient to understand sediment flux sensitivity to climate change.

Searching for the source of Early Cretaceous clastic reservoirs in the Middle East

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Some of the world's largest oil fields are located in the Middle East, with reservoirs in Early Cretaceous clastics. These Hauterivian-Albian reservoirs are world class accumulations, often containing 10s billion barrels of oil initially in place. They comprise multiple ~120 m thick pay intervals (that's about the height of the London Eye) of up to 90% net to gross, deposited in non-marine to paralic settings on a very shallow gradient passive margin ramp. Apart from the Early Cretaceous clastic influx the palaeo-equatorial margin was dominated by carbonate deposition throughout the Mesozoic. By the time of the Early Cretaceous clastic influx, the Proterozoic Pan African Mountains and Hercynian uplifts had likely been reduced to a low-lying hinterland. The question remains where did all this Cretaceous clastic material come from and what caused the sudden influx?
Heavy mineral analysis and detrital zircon geochronology from the supergiant Rumaila field in southeast Iraq was used to infer an Arabian Shield provenance. Furthermore we postulate that Early Cretaceous mantle-plume-related uplift in the northern Arabian Shield was responsible for the clastic influx.
These findings have implications not only for enhancing regional geological understanding but also reservoir-scale geological understanding that impacts the development and recovery of important hydrocarbon resources in the Middle East.

Why are the Highlands high? Cenozoic uplift and erosion in Scotland.

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The Scottish Highlands rise to c. 1500m above sea level. Rival ideas for the origin of the topography include that it is a relic of the uplifted and eroded Caledonian Mountain chain of Lower Palaeozoic age; or that all the present-day topography results from uplift associated with the opening of the northern Atlantic Ocean in the Palaeocene, sculpted by the Pleistocene glaciation. Although almost all of the exposed rocks in the Highlands are today of Devonian or older age, there are Mesozoic half-graben basins to the both the east and west of the area (the Inner Hebrides and the Moray Firth / North Sea). This has suggested that the Highlands were also once the site of Mesozoic basins, now eroded away, an idea perhaps first championed by J.W. Judd in 1878. Modern analysis of apatite fission track data has been interpreted to support this hypothesis, implying substantial post-Mesozoic uplift.
To quantify post-Mesozoic uplift, the thickness of rock eroded from the Highlands is calculated by balancing preserved sediment volumes in surrounding basins with the palaeo-surface area of the Highlands exposed to erosion. This suggests that a c. 2000 – 2400 m average thickness of rock (zero porosity) has been eroded in the Cenozoic. Assuming the well-documented change from sand-dominated sediments in the Paleocene and Eocene to later mud-dominated sediment as a change from the erosion of sediment to the erosion of metamorphic basement, then 1900 – 2400 m average thickness of clastic sediment (including porosity) was present at the start of the Cenozoic, plus any overlying Chalk. It is suggested that this has been subsequently eroded away due to uplift associated with the opening of the North Atlantic. Before then, the Highlands may have been much like the Inner Hebrides at the present day - an area of half-graben filled with Mesozoic sediment.

Biofilm origin of clay-coated sand grains

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Clay-coated sand grains have been widely reported to be one of the main causes of anomalously high porosity in deeply buried sandstone reservoirs. Post compaction, the major cause for porosity- and permeability-loss within deeply buried clastic sediment is the growth of quartz cements. Clay-coated sand grains result in the preservation of primary porosity through the inhibition of this normally-dominant, porosity-occluding quartz cement. Despite their potential significance, the origin of clay-coated sand grains remains ambiguous and is a key inhibiting factor in attempts to constrain a predictive capability.
This work adopted a high resolution analogue methodology, focused on the Ravenglass Estuary, UK. The study involved high resolution surface and core sedimentary and biological data sets across a fluvial to marine transect of depositional environments. Analytical techniques involved a combination of fieldwork, scanning electron microscopy, environmental scanning electron microscopy, automated SEM-EDS mineralogy, biomarker analysis, microbial carbohydrate analysis and Raman spectroscopy. This sedimentary framework has produced uniquely detailed maps of the spatial and stratigraphic distribution of clay-coated sand grains, sediment heterogeneity and biofilm abundance, which can be applied to help in the prediction of clay-coated grains in the subsurface. This work has also placed specific focus on the mechanism of clay coat formation to further constrain predictive models and understand the confined geographical distribution of chlorite clay-coated sand grains.
Here we report that clay-coated sand grains primarily derive from a biofilm mediated method of formation and preservation within modern marginal marine systems. This biological-sediment interaction revolutionises the understanding of the origin and distribution of clay-coated sand grains in deeply buried sandstones.

Unravelling the controls on fault-associated dolomitisation geometries: examples from the Benicàssim outcrop analogue (Maestrat basin, E Spain)

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Fault-associated hydrothermal dolomite bodies (HTD) are a key component of dolomitised reservoirs. The bodies can have a variety geometries, and predicting them in the subsurface is critical for reservoir management. The study of outcrop analogues can significantly contribute to understanding the fundamental depositional, structural and diagenetic factors that control the distribution of dolostones and thus reservoir quality. In this study, we use the world-class Aptian-Albian Benicàssim outcrop analogue (E Spain) to unravel the main controls on the transition between fault-restricted and stratabound dolomitisation geometries. For this purpose, we combine (i) high-resolution mapping of facies, structures and reaction fronts with the help of LIDAR and UAV virtual outcrop models and (ii) detailed logging and correlation of facies and stratigraphic sequences.
The results show that dolomitisation is restricted to the uppermost part of the Benassal Formation and tends to replace layers near maximum flooding zones. Non-dolomitised limestones tend to have very low permeability and occur in muddy facies which have dense networks of wavy-like stylolites. We propose that the overlaying formations probably acted as fluid pressure seals, favouring the flow of dolomitising fluids through the uppermost parts of the Aptian-Albian carbonate succession. Dolomite tends to form in the rock's matrix first, triggering the replacement of the whole rock. Pre-dolomitisation diagenetic process probably altered the permeability of the rock, resulting in beds with abundant stylolite networks and lower-permeability facies being preserved.
Dolostones extend several km away from large-scale faults, which are considered as conduits for the dolomitising fluids. The flow and replacement directions appear to result in a continuum of dolostone geometries, from massive and "Christmas tree" shapes next to faults to stratabound away from them. Some stratabound dolostones have many more limestone stringers than others, and are bounded by smaller-scale faults which are generally less continuous. Depositional characteristics such as shallow water facies which are orientated perpendicular to the palaeoshoreline seem to increase the occurrence of limestone stringers. Moreover, isolated fracture patterns limit dolostone continuity at different scales, while connected fracture systems facilitate much longer lateral extensions.

A submarine fan: juxtaposition of slope aprons with straight channels

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The deep-water plays of West Africa have been prolific producers, and remain an important exploration area. A key challenge in unlocking the potential of such plays is in understanding how common deep-water facies architecture models apply and how local conditions control the reservoir architecture. Here we use high-resolution 3D seismic data to illustrate evolution of a turbidite system on the mid-slope of the Niger continental margin: the Bakana Submarine Depositional System (BSDS). Its depositional element type changes along flow direction from lobes, to straight channels to slope aprons over 18 km.
The lobes comprise three overlapping lobe complexes at different scales. Turbidity current flow pathways and the geometries of the lobe complexes are controlled by the orientation of growth faults in a minibasin with limited subsidence-related accommodation development in local grabens. The lobes transition downstream into parallel, straight channels clustered with each other. These channels are relatively small at 150 – 200 m in width and 30 – 45 m in depth with typical width to depth ratios of 4 to 5; they deeply incise the underlying strata. Channel fill is mud-dominated in the upper reaches, but sand-dominated downstream. These straight channels are associated with significant increase in slope gradients (from <2° to >3°). The straight channels transition down-current into slope aprons that are 2,100 to 3,100 m in length, 600 to 1,700 m in width, 10 to 30 m in thickness; a gradual increase in muddy deposits along localised flow directions.. The slope aprons develop where the slope decreases abruptly from >3° to <2°.
The localised slope gradients and growth faults play an important role in the variability of the BSDS. Therefore, it is important to assess local controls during exploration and production of deep-water reservoirs.

POSTER ABSTRACTS

A preliminary Ground Penetrating Radar study of Fluvial Architectures at Spireslack, Ayrshire, Scotland.

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Ground Penetrating Radar (GPR) is a near-surface geophysical technique, and has been previously used to obtain 3D sedimentary architectures of both modern and ancient fluvial successions. Obtaining multiple 2D profiles behind outcrop exposures should allow 3D architectures to be extracted and then used to create high-resolution deterministic 3D numerical models.

This research has collected a GPR dataset at Spireslack quarry in Glenbuck, Ayrshire, Scotland. Spireslack quarry is an ex-open case coal mine and is presently designated as SCARP (Scottish Carboniferous Research Park), a long term educational resource exposing Carboniferous geology.

This preliminary study collected 2D profile behind the B1 outcrop face exposing channelized fluvial features; here the soil was thinnest, giving the best chance of good signal penetration. A Sensors&Software PulseEKKO™ 100 system was used to collect both 50 MHz and 100 MHz frequency data, to determine the optimal equipment, resolution and achievable depth. Data was then processed using REFLEXW™ v.3 software before being incorporated into Schlumberger PETREL™ software to create a 3D model.

GPR results imaged a fluvial channel and point bar set that had significant di-electric permittivity contrasts. Penetration depths were ~20 m, depending upon GPR antenna frequency. A very near-surface, thick limestone bed, dominated the profiles at the very near surface.

Study implications suggest GPR is promising at this location to allow the capture of 3D sedimentary architectures, although recommendations should be to collect further data using lower (25 MHz) frequency profiles and where overlying soil has been removed.

Evolution, processes and deposits of high latitude submarine fans.

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This project aims to develop new models for the stratigraphic evolution of submarine fan systems in high latitude regions, through a combination of seismic, core and outcrop datasets from high latitude settings; as well as identifying the influence of glacially-derived sediments through a series of flume experiments. Modern and ancient examples will be analysed in order to assess the temporal and spatial variations of submarine fan architecture.

Recent work has shown the differing evolution and architecture between low and high latitude submarine fans. Most research has focussed on the process/product relationship within low latitude submarine fan systems, with little focus on climatic-driven elements, such as the influence of sediment calibre, source and input on fan evolution. It has been hypothesised that the Coriolis force dominates the evolution of large submarine channel systems in high-latitude settings, with a marked difference in erosional and depositional processes from their low-latitude counterparts.

The current end-member model for low-sinuosity systems is characterised by deposition from coarse-grained flows. However, fine-grained, glacially-sourced sediments form an important component of polar deepwater systems. Ice streams deliver large volumes of sediments to the glacial termini, which is subsequently deposited down-slope via debris flows, turbidity currents and mass-transport complexes, as well as pelagic sedimentation of ice-rafted debris and suspended meltwater plumes. Facies variations within fans reflect the variety of input and transport processes active at glacial margins, representing fluctuations in ice sheet extent and sediment delivery.

Within high-latitude settings, there is potential for large variations in fan evolution and deposition through sediment character variability, as well as the influence of the Coriolis force on flow processes.

Fluctuating sand supply to a prograding delta: provenance of the Mullaghmore Sandstone Formation, NW Carboniferous Basin, Ireland

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This pilot project sets out to investigate the sedimentary infill of the NW Carboniferous Basin (NWCB), initially focussing on the Viséan [Carboniferous, Mississippian] Mullaghmore Sandstone Formation (MSF), onshore in north county Sligo, Ireland. This research specifically aims to constrain links between sediment supply and the depositional architecture of this ancient fluvial/deltaic system through high-resolution sedimentological and provenance analysis. This type of approach helps reconstruct the palaeogeography of the NWCB and its hinterland and will shed light on how the sedimentary system evolved through time.

An almost complete lithostratigraphic section through the MSF was examined and logged in the field, and distinct facies packages have been identified. High-resolution sampling through the succession was carried out and a multi-proxy provenance approach, using optical microscopy, scanning electron microscopy, major and trace element whole rock data, U-Pb zircon and Pb-in-K-feldspar analysis, has been employed. Importantly, this broad approach integrates provenance information obtained from both labile and stable mineral phases (feldspar and zircon respectively), potentially maximising insight into variations in sand supply. Results suggest a large-scale sedimentary supply system, with derivation from multiple sources located to the north of the NWCB during the mid-Viséan, including sediment sourced from elsewhere in NW Ireland, NW Scotland and eastern Greenland. The provenance signal appears to fluctuate throughout the sampled (lithostratigraphic) interval, with supply varying from a mixed to a more unimodal signal, tentatively coincident with changes in sedimentary facies and sand type.

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Stratigraphic development of the Permian to Triassic of East Greenland: An expanded and complete P-T boundary succession?

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The Permian-Triassic boundary contains a record of Earth's greatest mass extinction event. Sections through which this extinction event can be examined are rare, and are often condensed resulting in a poor resolution of the timing of its various component stages. Spectacular exposures through an expanded Permian-Triassic succession exist in East Greenland, however the completeness of these records has been a matter of considerable debate. To address this issue a regional synthesis has been undertaken, incorporating newly collected data with previously published work.

Following a Late Permian transgression, carbonate reef development accentuated pre-existing basin topography. Continued transgression led to the deposition of organic rich mudstones. During the latest Permian fluctuating sea level resulted in the localised erosion of the carbonate reefs which still formed bathymetric highs within the basin. At this time clastic systems also began to prograde in to the basin resulting in turbidite deposition in offshore regions. Erosion and shallow water deposition was focussed around the basin margins where carbonate reef development had been most extensive. The Early Triassic is marked by transgression and the blanketing of the region with mudstones and fine grained turbidite sandstones.

This study demonstrates the localised nature of erosion during the Permian-Triassic transition in East Greenland. Continuous offshore mudstone and turbidite deposition is recognised across the boundary were examined only a short distance from the basin margin and around areas of inherited basin topography. The synthesis undertaken provides a stratigraphic framework for further research on this important interval.

Role of tectonics and climate on the preserved record of a low net-to-gross ephemeral fluvial succession, South-Central Pyrenees, Spain

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The late Paleocene to earliest Eocene sedimentary succession exposed in the Arén–Esplugafreda sector, South-Central Pyrenees, Spain, represents the preserved record of a low net-to-gross, ephemeral fluvial system deposited under the influence of arid seasonal conditions. Detailed mapping and acquisition of quantitative sedimentological data has allowed the definition of four stratigraphic intervals (1 to 4 from base to top), which accumulated in response to variable climatic and tectonic controls.

Constraints on timing and magnitude of these allogenic controls are available thanks to regional and local studies, which include a biostratigraphic and magnetostratigraphic framework, palaeoclimatic interpretations from clay mineralogy and stable isotopic geochemistry analyses, and structural reconstructions supported by geochronology and thermochronology. From this well-constrained geological background it has been possible to evaluate the response of this fluvial system to varying palaeoclimatic conditions, which occur superimposed upon the effects of Pyrenean uplift.

Remote sensing analysis using LiDAR-derived DEMs and high-resolution orthophotographs enabled detailed mapping of channelized and floodplain elements across an area of 3km^2. Field-based analysis has involved the measurement of 15 regional stratigraphic sections (882m cumulative thickness), GPS-mapping of architectural elements, and graphic logging (246 logs) of data, recording the internal facies composition, palaeocurrent orientation (330 measurements), external geometry and connectivity of 164 channelized elements assigned to 4 distinctive genetic types.

The architectural style varies through the 4 stratigraphic intervals. Interval 1 (~100m) indicates deposition during tectonic quiescence associated with a gentle fluvial plain over which multiple avulsions occurred. Interval 2 (~40m) exhibits a reduction in channelized element thickness related to a decreasing sediment supply. Interval 3 (~165m) records an increase in sediment delivery associated with the reactivation of the Pyrenees uplift. Interval 4 (~50m) is contemporary with the occurrence of the Paleocene-Eocene Thermal Maximum, and records the superposition of a climatic driver in a tectonically active basin.

Bedforms and Primary Current Stratification Generated by Hybrid Flows: Examples from the Laboratory and the Aberystwyth Grits Formation

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New bedforms and primary current stratification were discovered in the deep-marine Silurian Aberystwyth Grits and Borth Mudstone Formations (West Wales), which compare well with the depositional products of turbulent, transitional and laminar sediment gravity flows (sensu Baas et al., 2009, Sedimentology).
Experimental research by Baas et al. (2016, J. Geol. Soc.) has shown that decelerating flows carrying cohesive clay and non-cohesive silt and sand produce bedforms that do not fit existing classification schemes. Cohesive clay is able to modify flow and bed properties, causing turbulent flow to change to different types of transitional and quasi-laminar flow. As a result, 'classic' current ripples change into large ripples, and washed-out ripples and upper-stage plane bed change into e.g. low-amplitude bedwaves, as clay content is increased. At very high clay content, turbulence is strongly attenuated or suppressed, and cohesive plane bed is most common. These cohesive plane beds consist of heterolithic horizontal stratification in the form of alternating mud and sand/silt laminae, formed in steady flow, thus without the need to invoke periodic fluctuations in flow velocity. These new bedform types were captured in a phase diagram of non-dimensional flow strength against clay content (as yield strength).
Fieldwork in the distal, mudstone-rich, reaches of the Silurian Aberystwyth Grits and Borth Mudstone Formations of West Wales revealed many examples of sedimentary structures in mixed sand-mud. These current-induced structures were remarkably similar to those observed in the laboratory, allowing us to attribute their mode of formation to various types of turbulent, transitional and quasi-laminar flow. This project provides the opportunity to expand the interpretation of sediment gravity flow deposits in core and outcrop to a wider range of realistic sedimentary processes.

Know Your Clay: The Effect of Clay Mixtures on the Properties of Cohesive Sediment Gravity Flows

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The majority of experimental work on cohesive sediment gravity flows (SGFs) has focussed on flows carrying a single clay type. However, this is not realistic for natural SGFs, which typically contain a mixture of clay minerals. To improve our understanding of these natural flows, lock-exchange experiments were conducted, investigating the run-out distance, head velocity, and visual properties of SGFs carrying mixtures of strongly cohesive bentonite clay and weakly cohesive kaolinite clay at a fixed 20% volumetric concentration.
As the proportion of bentonite within the flow was increased, the maximum head velocity and run-out distance of the flows decreased. It is inferred that increasing the proportion of this strongly cohesive clay mineral within the flow increases the flow viscosity and shear strength, leading to a reduction in flow mobility.
Interestingly, the change in run-out distance from 0% kaolinite (100% bentonite) to 100% kaolinite (0% bentonite) was non-linear. Instead, the run-out distance was greater than would be expected if both clay minerals controlled the flow behaviour in an equal manner. Pure bentonite flows exhibit a greater change in mobility over the range of clay proportions used within the mixed clay flows than pure kaolinite flows. This could explain the sensitivity of the mixed-clay flows specifically to changes in the proportion of bentonite.
The present experiments suggest that high-density, mixed-clay, SGFs may have a longer than expected runout distance, led by the stronger cohesive clay. However, further experiments are needed to determine if this outcome is also applicable to mixed-clay flows with higher and lower total volumetric concentrations, thus covering the full range of flow types from low- and high-density turbidity currents to laminar mud flows. This work could make an important contribution to our understanding of the continuity and deposit shape of SGFs in the modern environment and in the geological record

Submarine slope channels and sand delivery to the basin floor in the pre-land plant world: a case study from a sediment-supply-driven succession in Arabia

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The early Silurian marine succession of central Arabia has been analysed from 3D seismic data in which 700m high clinoforms have been mapped for the first time in sedimentary successions dating to pre-vascular land plant times. These Rhuddanian-age shelf-prism clinoforms are also the most rapidly-prograding of any documented clinoforms within this category (167 km/Ma), filling an intra-cratonic basin on the Gondwana shelf in 3 million years following the end-Ordovician deglaciation and global sea level rise. The clinothem foresets form the submarine slope and extensive mapping has revealed a variety of sinuous slope channels. Evaluation of nearly 150 channel planforms shows low sinuosity values between 1.10 and 1.88 with the majority below 1.40. Channel widths range between 160 and 1260 m and channel thicknesses reach 170 m. Channel width-to-thickness ratios are between 5 and 11. Upper slope channels have lower sinuosity and aspect ratios and do not show lateral expansion or sinuosity change over time. These channels are mainly erosional with no levees. Lower slope channels have higher sinuosity and aspect ratios and show evidence of lateral expansion and downdip migration of meanders. These channels have submature planforms as their bends do not expand longitudinally or show clear bend cut-offs. This suggests a short-lived channel system, which could be linked to the rapid shelf-margin progradation.
Core from wells basinward of the mapped channels show stacked fine-grained turbidites interbedded with debrites and hyperpycnites in successions tens of metres thick, which is evidence for an early bypass phase in the evolution of the channels. This transfer of sand to the deep basin is in disagreement with published models for sediment partitioning in the pre-land-plant world, which argue that all bedload (sand) deposition occurs on the alluvial plain while only mud is bypassed to the shelf.

Shelf-edge trajectory analysis; the role of differential compaction

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Shelf-edge trajectory analysis of clinoformal strata on continental margins is used to 1) describe the architecture of sedimentary prisms, 2) complement conventional sequence stratigraphic interpretations by deducing the interplay of controls on sediment dispersal, and 3) support prediction of the timing and extensiveness of coarse-grained sediment bypass from shelf to deep basin e.g. the formation of basin-floor fans. Because of this, Shelf-edge trajectory analysis bears relevance to hydrocarbon exploration and geohazard assessment. The strong dip variability in lithology across clinoformal strata on continental margins means that significant post-depositional differential compaction is anticipated. Despite this, the role of differential compaction in modifying the primary stratal architecture of continental margin clinoforms and its impact on shelf-edge trajectories remains poorly constrained.
This study aims to determine the extent to which differential compaction modifies primary, near-surface trajectories, and to understand how this impacts the assessment of the controls on basin filling and deep-water sandstone prediction. Backstripping and decompaction was applied to outcrop, seismic and borehole data from a range of sedimentary basins including: Browse and Barrow Basins (NW Australia), van Keulenfjord (Spitsbergen, Norway), Karoo Basin (South Africa) and Washakie Basin (USA). Afterwards, shelf-edge trajectories were recalculated and compared to the original interpretations. Mud-rich bottomsets compact more than sand-rich topsets and flat-to-slightly-rising initial trajectories rotate basinward to appear as falling trajectories: hence the counterintuitive 'preservation' of topsets in flat and falling trajectories. Differential compaction also causes an apparent change in topset to foreset volume ratios (T/F) which have been linked to fluvial and basinal conditions on the shelf-edge and differences in the method of channel incision. Substantial changes in T/F ratios and the overall character of the trajectories imply that according to current models of sediment bypass and deep-water sand deposition, predictions made through shoreline trajectory interpretations may be inaccurate.

Fundamentally Different Proximal and Distal Lobe Stacking Styles Within the Same Stratigraphic Interval: Upper Broto System, Jaca Basin, Spain

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Compensational, or longitudinal and aggradational stacking patterns are recognized in deep-water lobe systems, and are typically ascribed to unconfined and confined systems, respectively. In contrast, other systems comprise 'isolated' sheet-like beds traceable for 10's to 100's km, which do not stack to form lobes. Proximal, medial and distal localities of the Upper Broto System are described over a 70 km depositional dip transect. Previous work describes sheet-like stacking; however new data reveal bed-scale correlation is problematic in both proximal and distal localities. Proximal localities preserve compensational stacking patterns and facies changes from thick- to thin-bedded turbidites over tens to hundreds of metres in dip and strike sections. Metre-scale scours and coarse-grained bed-top-lags indicate bypass of sediment to distal parts of the basin. Correlation between distal localities is also challenging due to the disparate nature of the outcrops and facies variability. However, anomalously thick (metre-scale) sheet-like beds are traceable for several kilometres along depositional dip and to a lesser extent along strike. Distal localities show an abrupt increase in the proportion of hybrid event beds (HEBs) compared to proximal and medial localities. Similarly, bed tops in distal locations often have a carbonate silt-rich upper division which is absent in proximal locations. Sole structures indicate a primary palaeoflow to the northwest; however ripple crests suggest a secondary flow component to the north. The abrupt appearance of HEBs, carbonate divisions and divergent palaeoflow indicators suggest distal HEB generation through flow deflection off the coeval southern carbonate-rich ramp. Larger volume flows deposited more sheet-like beds, whereas smaller flows deposited bed-scale compensational-like geometries. Overlap of these stacking patterns creates the complicated geometries observed. Therefore, a range of stacking patterns and bed architecture can exist within the same stratigraphic interval, and flow deflection off confining slopes can complicate the predicted architecture of submarine fans.

Linking in-situ geophysical and geotechnical properties of the Dogger Bank Formation to depositional and post-depositional processes

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The Dogger Bank is a large shallow topographic feature in the Central North Sea with water depths of 18 – 63m. As one of the proposed round 3 windfarm licence areas an extensive site-investigation was undertaken during 2010 and 2011 across Tranche A including extensive 2D-ultra high resolution reflection seismic surveys, 70 geotechnical and wireline boreholes and over 120 CPT tests. Analysis of this high resolution dataset at the multi-dimensional scale, from 1D borehole petrophysics to seismic facies analysis in 3D, has identified a series of complex relationships which control the in-situ physical properties.
The Dogger Bank formation was deposited during the last glacial period, approximately 150-17Ka. This period of time was dominated by multiple ice-sheet advance and retreat and associated glactiotectonic deformation, resulting in a mixture of subglacial and proglacial sedimentation. Each subsequent period of ice advance and loading was associated with glaciotectonic deformation and increased consolidation of the Dogger Bank sediments. By using geotechnical and geophysical borehole logs it is possible to identify the signal of these events, which are then tied to seismic facies in 2D and 3D. Using a geo-mechanical and petrophysical approach, at the borehole, it is possible to unravel the potential vertical and horizontal loading history of the Dogger Bank and infer the processes responsible for the current over-consolidation state of the sediments. Ultimately these processes control the present day strength of the sediment, and are therefore of key importance when considering the installation of structures at Dogger Bank.

Reconstructing southern Greenland Ice Sheet history during the Plio-Pleistocene intensification of Northern Hemisphere glaciation: Insights from IODP Site U1307

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Should it ever melt entirely, the Greenland Ice Sheet (GrIS) would contribute to ~7 metres of global sea-level rise. Understanding how the GrIS might respond to anthropogenic-induced global warming over the coming century is therefore important. Central to this goal is constraining how the ice sheet has responded to both warmer- and colder-than-present climate states in the geological past. Little detail is known about the GrIS prior to the Late Pleistocene, however, and large uncertainty exists in our understanding of its history across the last great climate transition, the Plio-Pleistocene intensification of Northern Hemisphere glaciation (iNHG; ~3.6–2.4 Ma). This window encompasses two intervals of climatic interest: (1) the mid-Piacenzian warm period (mPWP, ~3.3–3 Ma), widely considered an analogue for a future equilibrium climate state with atmospheric CO_2 levels comparable to modern and elevated sea-level and global temperatures relative to today; and (2) a subsequent gradual deterioration in global climate and decline in atmospheric CO_2 leading to the development of Quaternary-magnitude glaciations from ~2.5 Ma. Important unresolved questions include: to what extent did the southern GrIS retreat during the mPWP, and when did a modern-day sized GrIS first develop? To tackle these issues, this project focuses on the southern GrIS history that can be extracted from Eirik Drift IODP Site U1307 between ~3.4 and 2.2 Ma. To achieve this we have developed an independent orbital-resolution age model, one of the first for high-latitude marine sediments deposited during iNHG; and generated multi-proxy geochemical, sedimentological and magnetic datasets that track the provenance and size of glacially-eroded terrigenous sediment delivered to the study site by both ice-rafting and the Western Boundary Undercurrent. These records enable the reconstruction of GrIS extents over this key period in its history, and may go some way to revealing the deep ocean's role in this major transition.

Deepwater mudrock depositional processes and sequence stratigraphy in the Permo-Triassic icehouse to greenhouse transition, Karoo Basin, South Africa

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Many mudrock-dominated successions, due to their fine-grained characteristics, have been predominantly interpreted as deposited in relatively low-energy environments, principally by suspension settling through the water column (derived from hypopycnal plumes). However, recent works have begun to identify subtle stacking patterns in these successions, and a re-examination of mud transport processes has recognised the common occurrence of high- energy intermittent events (such as distal hyperpycnal or wave-enhanced sediment gravity flows). Moreover, recent studies have shown that most of the mud particles travel as silt or sand-size composite grains in either bed load or suspended load.

This project is based on the Permian mudrock succession of the Karoo Basin, with a particular focus on the Middle to Late Permian Tierberg Formation (Ecca Group). This formation was deposited during the Permian icehouse to greenhouse transition linked with the rapid movement of the African Plate from high to lower latitudes. A 950 m-long, fully-cored well in the Tanqua depocentre encompasses the entire Tierberg Formation, comprising mainly mudstone and siltstone deposits. Preliminary core analysis indicates the presence of well bedded packages alternating with a few m-scale distorted horizons, interpreted as slumped or remobilized units. Erosive-based, fining-upward siltstone beds are interbedded with mudstone-prone beds at a mm to cm scale, indicating regular fluctuations in energy.

One particular strand of the project is to understand the different sedimentary processes that are responsible for the accumulation of these thick mudrock successions and to compare the process balance with better documented Cretaceous greenhouse mudrocks of the Western Interior basin, USA and Canada. Another strand is to derive a sequence stratigraphic interpretation for this formation based on detailed sedimentological and geochemical analysis, which may ultimately allow a more confident correlation with a laterally equivalent, sand-rich basin floor succession, present only 40 km across-strike.

Basin-Scale Mineral and Fluid Processes at a Lower Carboniferous Platform Margin

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Fault-controlled dolomite has been well studied and described in various localities in the Pennine Basin and North Wales. Fluid flow modelling indicates sufficient fluid volumes for dolomitisation could have been supplied along faults from the juxtaposed basinal sediments, but geochemical (PHREEQ) models indicate insufficient Mg. Reactive transport models (RTM) show geothermal convection of seawater could have occurred but geochemical data is consistent with dolomitisation from evolved basinal brines that interacted with siliciclastic sediments and/or volcanics. What is investigated in this study is whether geothermal convection provided a precursor to dolomitisation by fluids expelled by basin dewatering, and if such a process is of global importance. The Derbyshire Platform is a rimmed shelf, the westernmost expression of the East Midlands Platform. On the SE platform margin, 50km2 of Visean limestones have been dolomitized, forming two major bodies associated with major NW – SE trending basement lineaments and volcanics. The onset of compressional tectonics associated with the Variscan Orogeny resulted in multiple phases of NW-SE and NE-SW trending fault/fracture controlled calcite cementation and Pb-Zn-F-Ba mineralization. This study uses outcrop and newly available core from the southern margin of the Derbyshire-East Midlands Platform to better constrain the timing and mechanism for dolomitisation. Dolomitisation is usually fabric destructive with a range of textures that suggest multiple phases of fluid flux. Geochemical data indicates slightly modified seawater, with a contribution from hydrothermal fluids, was responsible for dolomitisation. New data based on a refined paragenesis is now being used to test the hypothesis that dolomitisation by geothermal convection of seawater during early burial was an important pre-requisite for later dolomitisation by hotter, more evolved basinal brines. Demonstration of a feedback mechanism between these processes has the potential to inform arguments that favour mass fluid transfer during burial diagenesis.

The long-term evolution of an exhumed deepwater stepped-slope profile

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The effects of changes in slope angle and orientation on turbidity current behaviour have been investigated in many physical and numerical experiments and interpreted in outcrop, subsurface, and modern systems. However, the long-term impact of fixed and dynamic seabed topography on stratigraphic architecture of deep-water systems is more challenging to constrain. Extensive detailed fieldwork in the Karoo Basin, South Africa, has demonstrated the presence of a stepped slope profile, which provides opportunity to investigate the stratigraphic record of interactions between turbidity current behaviour, sediment dispersal patterns and subtle seabed topography.
This study focuses on the Permian Laingsburg and Fort Brown formations, where multiple large sand-rich systems (Units A-F) have been mapped from entrenched slope valleys, through channel-levee systems to basin-floor lobe complexes over a 2500 km² area. Here, we investigate thinner (typically <5 m in thickness) and less extensive Units A/B, B/C and D/E, which are developed stratigraphically between the larger scale systems. Typically, these units are sharp-based, and sand-rich, with scours and mudclast conglomerates that indicate deposition from high-energy flows. The mapped thickness and facies distribution suggest a lobate form. These units were deposited in similar spatial positions within the basin-fill, and suggest formation of accommodation on the slope prior to the larger B, C and E systems. That areas of increased slope accommodation were maintained throughout the deposition of successive deepwater units suggests an underlying structural control. The larger-scale systems were also affected by the development of this slope accommodation, but this is poorly recorded as they significantly modified the slope profile as they evolved. This study shows that the smaller systems are a more sensitive record of evolving seabed topography; they can be used to recreate more accurate palaeotopographic profiles and provide better understanding of the dynamic topography of evolving slope systems.

Triassic Palynology; correlation and environmental reconstruction of the Skagerrak Formation from the central North Sea

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The Skagerrak Formation is a Mid-Late Triassic clastic succession from the central North Sea comprising alternating fluvial sandstone dominated and playa/lacustrine mudstone dominated members. The Sandstone members form important primary and secondary reservoirs in the UKCS whilst the mudstone members can act as potential baffles/seals and lead to the compartmentalisation of these reservoirs. Hydrocarbon extraction has been hampered by a lack of knowledge regarding correlation at a basinal, sub-basinal and field scale and to date the identification; distribution and correlation of the different members is still poorly understood.

Palynology is a powerful tool for well correlation, age assessment and environmental reconstruction and is routinely used within the petroleum industry. However previous attempts at utilising palynology from Triassic sediments within the Central North Sea have generally yielded poor recovery due to a combination of PDC drilling techniques, oil based muds, poor palynomorph preservation and the heavily oxidised nature of these sediments. By utilising state of the art palynology processing techniques this study aims to maximise and concentrate palynomorph content from drillcore and well cuttings to construct a robust age model providing the chronostratigraphic framework needed to accurately correlate the different members within the Skagerrak formation as well as allowing for accurate environmental reconstruction.

The focus of this study is on quadrants 22, 29 & 30 from the Central North Sea with further worked planned to extend the study area into the Norwegian North Sea and Northern North Sea. This will then allow for a better regional understanding of the Skagerrak formation within North Sea and help aid further hydrocarbon exploration and exploitation.

Constructing fluvial floodplain successions; a hierarchical approach to the characterization of crevasse-splay deposits.

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Fluvial floodplain deposits represent an important component of the continental stratigraphic record, but less attention has been paid to these fine-grained successions in comparison to generally coarser-grained in-channel deposits. This work seeks to understand how floodplain successions are constructed and how they are preserved in the stratigraphic record. This is achieved through a comparative study of three ancient preserved overbank successions (Morrison Formation; Castlegate Sandstone and Neslen Formation) with a range of 15 analogous modern overbank systems. Quantitative aspects of the morphology and sedimentology of these splay bodies are stored in a fluvial architectural database, FAKTS.

In overbank areas adjacent to fluvial channels, crevasse-splay development drives floodplain aggradation. Constituent splay components are arranged at various spatial and temporal scales: (i) lithofacies arising from accumulation via fundamental flow processes; (ii) individual event beds (~1 m thick) comprising one or more lithofacies that thin and fine away from parent channels (single flood event timescale); (iii) A crevasse-splay comprising genetically related cosets of strata up to 3 m thick that record the initiation, growth, and abandonment of individual parts of the splay (10^1 to 10^2 year timescale); (iv) A stack of genetically related splays that have a geographically common breakout point (10^2 to 10^3 year timescale); (v) splay successions comprising a group of splay complexes that are not generated from the same breakout point but which accumulated in a single flood basin (10^3 to 10^4 year timescales).

Results of this study have enabled the construction of quantitative facies models that link the sedimentology and preserved stratigraphic architecture of crevasse-splay elements to external morphological form. Database output can be used to test the role of both allogenic factors, such as climate and basin type, and autogenic factors, such as parent channel form and intrinsic evolutionary behaviour, in controlling splay construction, accumulation and preservation.

Dune cross-stratification in turbidite systems

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Dune cross-stratification is a common structure in many depositional environments. However, despite being stable across a range of grainsizes and flow conditions, dunes are generally rare in turbidites (Arnott, 2012). When they do occur, they create a distinct facies within the turbidite sequence that has been identified in both ancient and modern turbidite systems, in outcrop and as part of subsurface hydrocarbon reservoirs. Previous studies have sought to suggest explanations for the formation of this usually absent bedform in turbidites: Wynn *et al*., (2002) suggest that dunes form in areas where flows undergo hydraulic-jumps, such as the channel-lobe transition zone, i.e., when flows experience higher levels of turbulence and lower sediment concentration; Kneller & McCaffrey(2003) propose a model which links dune formation to conditions when the sediment concentration near the bed is low; Stephenson *et a*l.,(2015) stress the presence of coarse grained cross-stratification in basal slope channel fills where dunes form beneath flows with low aggradation rates as fine sediment is bypassed down-system.
Whilst prior interpretations for dune formation may all be valid, little work has been done to identify the larger-scale controls on their formation. The overall project goal is to better define processes for dune formation across a range of environments, linked to a synthesis of associated controls. For example, systematic evaluation of patterns in the spatial occurrence of dunes in deep-water is lacking at system scale. At field scale, work is needed to identify patterns of dune spatial occurrence by interpreting the depositional environment in which dunes have formed and identifying common processes leading to dune formation. Initial observations from field work done on the ponded Eo-Oligocene fill of the Piera Cava minibasin, SE France found that dunes are locally common in proximal sections close to the local inbound base of slope, but absent in medial and distal sections 5 to 10 km downstream. However, short-range correlations show significant local variation in dune extent in proximal settings. An initial question is then posed as to whether these dunes are naturally variable within the system or have just formed at the edge of a dune field.

Testing the sensitivity of bedform phase space: flow velocity vs. sediment cohesion

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The project tests the sensitivity of van Den Berg and van Gelder's (1993) bedform-phase diagram based on non-cohesive sediment. It investigates how bedform dimensions are influenced by varying levels of clay-related substrate cohesion across a 3D experimental phase space comprising velocity-related mobility parameters, grainsize and cohesion - cf. Schindler et al. (2015) and Baas et al. (2013), who kept velocities constant. The project also studies winnowing, which is not sufficiently accounted for in either original bedform development models or in research conducted to test them.
Across the studies velocity range flow, bedform dimensions built on increasingly cohesive substrates were smaller and less steep than bedforms built on cohesionless substrates. The winnowing process highlights a more complex role of clay in a substrate than previously recognised by Schindler et al. (2015): winnowing promotes bedform growth by removing clay from the substrate and reduces bedform height by constructing 'clay horizons'.
This research also recognises that flow conditions have a simultaneous and sometimes greater influence over bedform dimensions than clay substrate content due to effects of velocity, turbulence and the influence of upper stage plane bed conditions upon bedforms that as a result were observed to become less steep and humpbacked in shape (Carling et al., 2000). It is suggested when calculating bedform steepness from bedform height and wavelength, bedform shape should also be taken into account as this can determine whether the reduction in bedform height/steepness is likely to be the result of flow conditions or substrate clay content. Empirical compilations of the relationship between steepness/height and clay content (e.g., Schindler et al., 2015) may lead to overestimates to the extent to which clay content influences bedform steepness and height without consideration of bedform shape.

Geochemical discrimination of Upper Cretaceous volcaniclastic sediments: Kannaviou Formation, W Cyprus

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Volcaniclastic sediments can provide critical information concerning island arc genesis either, in an oceanic or continental margin setting. The Late Cretaceous (c. 90 Ma) Troodos ophiolite is generally accepted as representing oceanic crust formed by spreading during the initiation of subduction. In W Cyprus, the ophiolite is depositionally overlain by c. 750m of volcaniclastic sediments (Kannaviou Formation) of Campanian-early Maastrichtian age, based on microfossil evidence. Medium to coarse-grained volcaniclastic sandstones were mostly deposited by a combination of settling out of air-fall tuff and redeposition by gravity flows. The sandstones are interbedded with smectite-rich clays and radiolarian mudstones which accumulated in a deep-sea setting. The sandstones include abundant undevitrified volcanic glass, together with common monocrystalline quartz, plagioclase and andesitic to felsic lithoclasts. Less common components include clinopyroxene, muscovite, biotite, hornblende and pelagic bioclasts. The petrographic evidence and major element discriminant diagrams suggest a magmatic arc source (e.g. SiO_2-K_2O/Na_2O). A dominantly oceanic volcanic arc provenance is supported by trace and Rare Earth Element discrimination plots (e.g. La-Th-Sc, Th-Sc-Zr), although a few samples fall in continental island arc fields. Electron microprobe analysis of volcanic glass grains is compatible with a volcanic arc provenance (e.g. CaO-Na_2O-K_2O). The compositions of detrital pyroxenes are suggestive of tholeiitic island arc volcanism (e.g. TiO_2-SiO_2-Na_2O, TiO_2-MnO-Na_2O). Plagioclase feldspars have 30-90% anorthite content, consistent with basic-intermediate source rocks. More effective discrimination could be achieved by planned ion probe analysis. Spider diagrams of the sandstones (both chondrite and Upper Continental Crust-normalised) show similarities with the composition of oceanic island arc sediments (specifically La/Th, Th/Cr, Th/Co and Cr/Zr ratios). However, the petrographic evidence of terrigenous material (e.g. muscovite; muscovite schist; polycrystalline quartz) is indicative of a subordinate continental contribution. The available evidence points to the accumulation of the Kannaviou Formation from mixed oceanic arc and continental margin settings.

Cyclicity of toeset geometry as feature to recognize tide-modulated deposits

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Diagnostic criteria to recognise tidal deposits have been studied extensively. The periodic (cyclical) changes in current speed typical of tidal currents produce several diagnostic sedimentary features. Common tide-diagnostic features in sedimentary deposits include bidirectional cross-strata, reactivation surfaces, tidal rhythmites and tidal bundles. In addition to these well-established criteria, less attention has been paid to the geometry of cross-strata. In particular, the toeset geometry variations (angular *versus* tangential) can be related to the cyclical variation in the current competence, as well as tidal-rhythmites.

One of the limitation of classical criteria is that they are based on observations related to the specific behaviours of heterolithic sediments. Thus, many of the diagnostic criteria to recognize tidal influence are not directly applicable to sand-dominated deposits. For this reason, the recognition of tidal cyclicity from the observation of the toesets geometry along the forward migration path of the bedform could be very useful in such sand-dominated tidal systems with cross-strata lacking mud drapes.

Based on the present study, cyclic change between angular and tangential toeset geometry along the forward migration path of the bedform can been interpreted as related to current modulation during a tidal cycle. In particular, cyclic alternance of toeset geometry from angular to tangential and vice versa is interpreted as a response to neap/spring tides. The neap tide produces an interval characterized by angular toeset geometry and the spring tide the tangential toeset geometry (Fig. 1). Then, cyclical changes in toeset geometry can be used and tested to recognise tidal environments and facies where other tidal sedimentary signals are faint or ambiguous.

Deltaic river-dominated to tide-influenced process regime change: a field-based example from the Lower Pleistocene of the Messina Strait (southern Italy)

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Tidal straits are elongate marine passageways connecting two wider basins, where the dominant hydrodynamic force results from tidal currents flowing parallel to margins.
Straits receive sediments mainly through deltaic system with other minor sediment supply provided by (i) debris aprons or landslides shed from steep margins; (ii) clastic sediments derived from the erosion of older deposits at the narrowest and usually shallower strait zone; and (iii) in situ carbonate factories.
Along the margins, tidal dunes and ripples are intercalated with shoreface and deltaic sediments. In particular, deltaic system sourcing tide-dominated passageways can be strongly influenced during their evolution by the effect of tidal currents. This type of delta can be strongly skewed in its coastal morphology and asymmetrically deflected towards the dominant tidal current direction, being intensely modified on the delta front. Related sediments are significantly reworked under the effect of the dominant tidal current forming elongate sandbodies, pseudo-spits or sand ribbons locally detached.
In this study, preliminary results carried out on a spectacular outcrop exposed along the northern border of the Messina Strait, between Calabria and Sicily are provided.
The studied deposits are early Pleistocene in age and unconformably back-step against the basement pertaining to the Calabrian Arc. Two main vertically-stacked intervals can be detected: (i) a lowermost interval consists of basal conglomerates and pebbly sandstones, including out-size basement blocks and shell fragments, for a total thickness of ca. 90 m; (ii) an overlying mixed siliciclastic-carbonate sandstone interval exhibits cross-strata and large-scale tidal foresets, for a total thickness of ca. 140 m.
These two intervals are suggested to be the result of the initial progradation of a river-dominated fan delta, impinging the Messina Strait during the early Pleistocene and changing into a tide-influenced delta after a dramatic phase of tectonically-induced transgression. Scour-and-fill features detected in the lowermost interval are interpreted as related to the effect of strong river-generated flash floods entering a shallowly-submerged basin margin and generating supercritical-flow structures. Cross-strata are interpreted as the effect of an intense tidal reworking in the delta-front sectors caused by the dominant current phase acting on this margin of the ancient Messina Strait.

Stratigraphy and Architecture of a Tectonically Influenced Shallow Water Delta Succession, Early Cretaceous Maestrat Basin, Spain.

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A combination of field data, remote sensing data, structural restoration and validation techniques are being used to evaluate the controls on delta mouth bar sandbody architecture in a superbly exposed succession of deltaic facies and coeval carbonates (Early Cretaceous Xert Formation) in the region of Aliaga, central Spain. A key aim of this study is to develop a methodology for correlation and characterisation of shallow-water delta sandbody architecture.
The field area falls within the Galve sub-basin - a component of the larger Mesozoic Maestrat rift basin system. These basins formed during an extensional phase affecting Iberia from the Oxfordian through to Albian, which created an epicontintental seaway connected to the western Tethys Ocean. Inversion during the Palaeogene left a strong E-W structural fabric, however, the Galve sub-basin has a N-S striking "Aliaga-Miravete" anticline. We hypothesise that this structure is the result of reactive salt tectonics related to extension of the overburden, and not due to Paleogene inversion. This is a new theory for the evolution of the Galve sub-basin, and the potential influence of salt tectonics on the architecture of the deltaic facies is being evaluated.
The shallow-water deltaic succession represents deposition during a high order regression that occurred within a longer term regional transgression. It was strongly river dominated, with progradation into a relatively shallow (20-30m) carbonate shelf setting. This limited mouth-bar complex thicknesses and increased the importance of bed frictional forces. Deltaic sand bodies have been deposited over an area >100km^2 and determining whether they are a single or multi-delta succession is a key objective of the study. Furthermore, the spatial and temporal relationships between the carbonate dominated abandonment facies that cap or are coeval with the delta parasequences, and the predominantly clean siliciclastic successions form another key objective of this study.

New insights into wave-dominated deposition in continental shelf settings: high-resolution sediment character analysis from coeval topset, foreset and bottomset deposits

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The established model of ocean-facing, wave-dominated clinothems predicts clean, higher quality sand in topsets, upwardly coarsening sandstones within foresets and sand-starved muddy bottomsets. The model is used for the interpretation of ancient shallow- and deep-marine deposits at the seismic scale, and has been used as a predictive tool for the location of reservoir quality facies within ancient depositional sequences. However, new insights from high-resolution grain character analysis of Atlantic Ocean facing Miocene clinothems (offshore New Jersey) indicate that the model does not account for bed- and event-scale heterogeneities.
Miocene clinothems from offshore New Jersey preserve chronostratigraphically-linked sequences, tied to the eustatic sea-level curve. We present data collected from three cores recovered during IODP Expedition 313 (M27, M28 and M29). The stratigraphic intervals targeted are quasi-coeval shallow- and deep-marine sandstones, spanning the major Miocene seismic sequence boundaries m5.3 to m5.47 (~16 Myr-18 Myr). A total of 284 m of core was sampled at c. 50cm intervals and high-resolution grain character analysis conducted on 498 sediment samples.
Key results include: (a) upwardly-fining foreset sequences, which contain between 20% and 60% mud by percentage volume; (b) significant downdip transport of sand-grade sediment into bottomset facies; and (c) and an increase in sorting, sphericity and roundness along the longitudinal sorting profile, including transport of the most spherical, rounded and well-sorted sediments into the bottomset facies. This investigation highlights the presence of depositional complexities overlooked by conventional grain character studies of wave-dominated shelf deposits. Statistical analysis of the grain character dataset indicates departures from the expected grain character profile associated with wave-dominated deposition and highlights that the sedimentary architecture of the New Jersey Miocene clinothems do not follow trends predicted by the traditional model of wave-dominated deposition.

The response of density underflows to rift basin floor topography and palaeoclimate: Examples from the Gulf of Corinth, Greece

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The recent discovery of the Johan Sverdrup field and others alike have necessitated a greater understanding of the stratigraphic and structural architecture of complex late syn-rift deposits around basement highs. The aim of this research programme is to use the syn-rift record of the Gulf of Corinth, Greece in order to i) understand the interaction of sedimentary flow processes, structural evolution and climate, and ii) investigate the key evolutionary responses of delta-toe and basin-floor fans. The area surrounding the Xylokastro horst block in the central Gulf of Corinth rift presents a superb natural laboratory to study the evolution of coarse-grained clastic deposits sourced from Plio-Pleistocene deltas. A key research objective is to constrain the temporospatial evolution of sediment routing through complex partially-linked basinal lows through the use of detailed structural and stratigraphic mapping and restorations, with added context from core-obtained palynostratigraphic climate indicators from a strategically sited research borehole.
The river-dominated, Gilbert-type, fan delta-toe to basin floor transition setting in the Xylokastro area encompasses an extremely broad range of depositional fabrics and architectures, from boulder clast debris flows through to thin-bedded classic turbidites, allowing a great spectrum of flow behaviour to be invoked in the context of a rapidly evolving depositional system. Coupled with this, the syn-depositional presence of fault-related rift topography is to be examined to ultimately investigate how such deposits may have been effected by the evolution of the Xylokastro horst and by the evolving rift margin of the Gulf of Corinth. Coarse-grained turbidite and debris flow systems continue to be confusingly cross-classified with regards to flow process and deposit terminology. This poster examines this, presenting potential composite classifications and offering potential avenues of investigation to be undertaken through this study.

The Deep-Marine Architectural Knowledge Store: A database approach to enhance meta-analyses of deep-marine systems

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Deep-marine environments remain a fertile area for research. These depositional systems display significant variability in styles of sedimentary architecture, and sedimentological studies of these systems are conducted with different aims, scopes and methodologies: this has resulted in the compilation of a wide range of deep-marine models. The variety in approaches to sedimentological characterization and the qualitative nature of most datasets and their resulting models pose a challenge for quantitative comparative studies between multiple systems. A relational database - the Deep-Marine Architectural Knowledge Store (DMAKS) – has therefore been developed as a repository for data on deep-marine siliciclastic architecture, storing information on basin-scale controls to the depositional systems, to facies-scale descriptions along with metadata (e.g., data types). The sedimentological data is codified in a standardised manner within the database, allowing compound analyses between multiple datasets to take place.
To showcase DMAKS's capabilities of quantitative analysis, database output relating to a sandy submarine fan case-study in the Golo system (East Corsican margin, Mediterranean Sea) has allowed the two-end-member lobe model of Deptuck et al., 2008 (Sedimentology, 55, 869-898) to be assessed against a larger data pool. The model has been re-evaluated through database analyses, including a comparative analysis of lobe dimensions (e.g., width-to-thickness ratios), quantification of spatial relationships between elements within each lobe type, and determination of facies proportions. Preliminary results quantitatively support the notion of differing lobe types within the Golo system, however it is possible that the two lobe end-members of Deptuck et al. represent arbitrarily-defined subsets of what could be a larger lobe type continuum; this question awaits further work. In the future, the database's ability to assess multi-variate controls will allow findings from single systems to be compared against others to better understand what organisational patters occur in common, and the influences of boundary conditions on organisational style.

Microbially mediated carbonate mineralisation in extreme environment microbial mats

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Microbial mats and their fossil counterparts, microbialites, are some of the earliest signs of life on Earth. The coastal sabkhas in Abu Dhabi, United Arab Emirates are a modern setting where microbial mats currently flourish in the hypersaline and arid environment. Microbes such as Cyanobacteria, Thermoplasmata and Sulphate-reducing bacteria thrive untouched by predators, which cannot flourish under the harsh environmental conditions present. Microbial mats are highly reactive with their microbial communities and geochemistry varying on a millimetre scale, controlling mineralisation processes.
Exact mineralisation rates within coastal sabkha microbial mats are not yet quantified. Defining this mineralisation pathway can explain how these organosedimentary structures become part of the rock record. By studying syndepositional lithification and the generation of primary porosity in Holocene to Recent microbial mats systems, we more clearly define the depositional configuration and primary mineralogy that forms a template for later diagenesis and eventual formation of reservoir porosity.
In order to constrain the factors effecting mineralisation and early lithification lab experimentation is required. Parameters for experimentation (primarily temperature, light, tidal cycle and water chemistry) have been established during fieldwork and applied to a laboratory simulation of sabkha microbial mats. Over the course of the first three months the microbial mat, submerged in a seawater medium, grew vertically, developing a moss like green surface. Thermogravimetric analysis has established that the newly grown mat biomass contains carbonate minerals, leading to an initial inferred carbonate mineralisation rate of approximately 1g per 2cm^2 (approx. per 10g surface mat material) per year. Further analysis will establish the extent to which the precipitated carbonate minerals result from microbial activity and the types of mineral included and establish how this value can be scaled up to sabkha area scale (km's).

Stratigraphic evolution of carbonate ramp and reef system along the Agadir-Essaouira Basin. Middle to Upper Jurassic Atlantic margin-western Morocco

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The Jurassic of the Agadir-Essaouira Basin records the initial post-rift deposition following the late Permian-Triassic rifting. The entire Jurassic succession is characterised by a mixed siliciclastic-carbonate depositional system including three main transgressions. The extension and the quality of the outcrops allow a good understanding of the lateral facies variations and the stratigraphic evolution of the formations. The Callovian to Upper Oxfordian limestones record a major marine transgression which began in the Early to Middle Callovian. This continuous carbonate succession is composed of three formations which present a large extent across the basin.

After the Bajocian-Bathonian red fluvial siliciclastics, the Ouanamane Formation (Callovian) records the development of open marine conditions with the progressive installation of a carbonate platform. It presents a silty base that evolves rapidly to fossiliferous limestones. The bulk of the unit is characterised by marly limestones alternating with fossiliferous oolitic packstones, locally floatstones with very abundant brachiopods, echinoderms and oysters. Intense bioturbation and encrusted and bored surfaces are common.

Marls mark the transition to the overlying Tidili Formation (Oxfordian), which is dominated by reefal deposits. The variations in facies occur over tens of meters and allow the observation of reef geometries and internal facies zonation. A phase of reef establishment is dominated by platy corals (*Dimorpharaea*) encrusted by stromatolites. This is followed by a boundstone with more diverse fauna of branching and massive corals. The reef bodies present lateral evolutions to bioclastic floatstones and mudstones. Scale of reef bodies varies from 10 m to several km.

The Iggui-El-Behar Formation (Upper Oxfordian–Kimmeridgian) records renewed regression and the disappearance of reefs. Facies are characteristic of low-energy environments, evolving from back-reef environments with corals and gastropods, to more proximal environments characterised by mudstones with foraminifers and more rarely gypsum, interpreted as intertidal to sabkha environments.

Lake sedimentological and ecological response to hyperthermals: Boltysh impact crater, Ukraine

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Past hyperthermals and associated negative carbon isotope excursions (CIEs) are inferred to have had significant impact on marine environments. However, little is known from terrestrial ecosystems due to the lack of complete and high-resolution data. Here, we present a detailed sedimentological study from a borehole drilled in the K/Pg Boltysh impact crater (Ukraine) which was filled with a c. 400 m thick succession of Early Danian lacustrine sediments. This succession was deposited during the Early Danian Dan-C2 hyperthermal as inferred from a negative shift in the carbon isotopes.

We use a combination of sedimentological, palynological and geochemical data to 1) characterise lake sedimentological and ecological development across the CIE and 2) to assess the environmental effect of hyperthermals on terrestrial ecosystems. Based on detailed facies analysis, 5 distinctive gradual stages of lake evolution are identified, indicating a strong relationship to carbon isotope shifts and associated climatic trends. Initial pre-CIE sedimentation was controlled by crater morphology and crater rim erosion. During the main phase of the CIE, sediment supply was increasingly characterised by inflow-evaporation ratio variabilities which affected seasonal stratification patterns and longer-term lake levels. An inferred increase in atmospheric pCO2 during the CIE, together with increasing mean annual temperatures, was likely responsible for periodic increases in bioproductivity.

Moisture availability oscillations inferred from palynological data largely correspond to fluctuations in lake facies and lake levels, and suggest that long-term lake evolution patterns were astronomically controlled. The gradual decline in sediment supply prior to CIE inception suggest that the Dan-C2 event did not initiate large-scale sedimentological changes, but amplified and promoted sedimentary response to orbital controlled climate change.

Role of deglaciation, sea-level rise and isostatic adjustment in marine transgression of the Dogger Bank

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The Dogger Bank is an area of the Southern North Sea that experienced marine transgression during the Holocene due to glacial melting. The rapid sea-level rise and corresponding flooding provides an excellent analogue to study the effects of future projected sea-level rise on coastal realignment and inundation processes.

In order to understand the process response of marine transgression on the coastline of the Dogger Bank in detail, further knowledge of the relative sea-level change in the Dogger Bank area is required. Holocene relative sea-level curves are problematic to define due to the combined effects of glacio-eustasy, hydro-isostasy and glacio-isostatic adjustment. Following deglaciation, eustatic sea-level rise was rapid at first, slowing down later, and punctuated by distinct meltwater pulses. Relative sea-level change at Dogger Bank is not only a consequence of variation in total ocean volume but is also due to glacio-isostatic adjustment driven by melting of local ice sheets. However, the magnitude of this is poorly constrained as the relationship of the British-Irish and Fennoscandian Ice Sheets in the North Sea basin and their location relative to the Dogger Bank area leads to uncertainty in GIA modelling. Actual measurements of past sea-level, such as basal peat/silt contacts, are useful to constrain relative sea-level changes. However, there are limited measurements for Dogger Bank due to the difficulty of obtaining samples in an offshore location.

This project aims to develop new relative sea level records for Dogger Bank based on shallow 2D seismic data as well as short vibrocore data. The vibrocore sedimentary facies linked to seismic facies mapping, constrained by the new sea level records, will allow the 3D distribution of Holocene depositional environments to be established, thereby enabling the study of the response and evolution of coastal environments to marine transgression.

Textural characteristics of deep-marine gravity flow deposits: Insights from the Aberystwyth Grits Formation, Cardigan Bay, Wales

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Submarine fan development is controlled by varying allo- and autogenic factors, which are often system specific. This results in sedimentary deposits that are highly complicated and heterogeneous. Due to the value of submarine fans as hydrocarbon reservoirs, our ability to predict and constrain this heterogeneity in the subsurface is critical to enabling better understanding of reservoir quality distribution. To accomplish this, a sedimentological and textural analysis has been conducted on the Aberystwyth Grits Formation, Wales. Bed-types identified at outcrop are classified based on their interpreted depositional processes into high-density turbidites, low-density turbidites, or hybrid event beds. Petrographic analysis of bed-types is used to compliment field observations by constraining their textural and compositional properties; reservoir quality is inferred using analogous facies types from the North Sea Magnus Field. High-density turbidites are dominant in proximal locations, exhibiting coarser average grain sizes and poorer sorting than their more distal equivalents: low-density turbidites and hybrid event beds. This is suggestive of flow capacity controlled en-masse deposition in proximal settings. On the basis of lower detrital clay content and coarser mean grain size, high density turbidites exhibit the most favourable textural characteristics for reservoir quality due to greater porosity and permeability. Hybrid event beds and low-density turbidites both exhibit finer mean grain size and higher detrital clay content, resulting in poorer overall reservoir quality. In addition, a numerical model of turbulent flow across a deep-marine lobe is used to predict the point of flow transformation from turbulent to transitional or laminar within the system due to loss of flow suspension capacity. This model matches evidence for flow transformation observed at outcrop and gives some confidence in understanding of bed-type distribution.

Investigating the impact of the Hornsund High on Triassic sedimentation in the western Barents Shelf

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The Triassic on the southwest Barents Shelf important for hydrocarbon exploration as several hydrocarbon source and reservoir rocks occur within this interval. Despite favourable conditions for hydrocarbon accumulation, the architecture of the depositional systems and varied provenance has caused difficulty predicting reservoir distribution and their properties.
Irregular palaeotopography is thought to have affected sedimentation. Late Palaeozoic rifting resulted in the uplift of prominent structural highs. In the exploration areas, the subsurface Loppa and Stappen highs acted both as sediment sources and barriers to sediment dispersal. The Hornsund-Sørkapp High is an analogous high that is well exposed in southern Svalbard, whose influence on sediment dispersal may be evaluated more cost effectively.
The results reveal Triassic shales rest on Permian carbonates in areas east of the high and the main potential for reservoir development lies in immature deltaic sediments sourced from the east. However, significant differences in sediment thickness, facies, and apparent provenance are seen across the high. Notably, on the top of the high, thin Early Triassic conglomerates rest unconformably on foliated Palaeozoic units belonging to the high. In addition, west of the high, the immature deltaic sediments sourced from the east are largely absent. Instead, mature Middle Triassic sandstones which were sourced from the west are developed.
The results imply the Hornsund High had a notable impact of sedimentation. The high was exposed in the Early Triassic resulting in the deposition of local conglomerate units. Following transgression, the influence of the high persisted into the Late Triassic, possibly creating a barrier to immature deltaic sediment sourced from the east.
The Loppa and Stappen highs, located in the exploration areas to the south of Hornsund, may have similarly affected sediment dispersal. If so, then the results could suggest poor reservoir development in the Late Triassic in areas west of the highs. However, they highlight the possibility of locally sourced Early Triassic, and westerly sourced Middle Triassic siliciclastic reservoirs, generally absent in areas to the east.

Predicting the Distribution of Shallow Marine Facies within Halokinetically Controlled Basins: Insights from the Upper Jurassic Fulmar Formation, UKCS.

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Sedimentary successions influenced by halokinesis have been well documented in the continental and deep marine realms, however sedimentary successions deposited in shallow marine environments have received relatively little attention, despite their economic importance. Facies distribution for typical shallow marine siliciclastic successions have been well studied, but these models don't account for halokinetic driven changes in deposition, where salt withdrawal can enhance basin subsidence, or salt-wall uplift can create topographic barriers to sediment transport paths. Enhancing this understanding will provide the basis for the construction of depositional models which can aid the prediction of reservoir quality and facies juxtaposition, both within the salt basins and between them where applicable.
The Upper Jurassic Fulmar Formation of the Central North Sea has been a major play fairway since the discovery of the Fulmar Field in 1975. The succession represents the deposition of shallow marine sediments into collapse basins formed above dissolving salt walls, that are scoured from adjacent Mesozoic mini-basin sediments. The distribution and facies of these sediments were controlled by the complex interplay of basin-scale tectonics, combined with active salt migration and dissolution.
Here we present an integrated study that utilizes core and wireline logs to develop depositional models that can be used to predict facies distribution within these basins. Core based studies and facies analysis, focusing predominantly on ichnofabric analysis are used to develop facies associations that enable direct correlation between core and wireline data. This correlation between facies associations and wireline data has provided the basis for a basin-scale correlation and the identification of potential reservoir units.
This multidisciplinary study provides a facies correlation tool that can be applied to the Fulmar Formation and other salt-influenced shallow marine successions, allowing for the development of exploration tools that enable the prediction of facies distribution both within and between halokinetically controlled basins.

Sedimentology and stratal architecture of subtidal point bars: an example from the Venice Lagoon (Italy)

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Mechanisms of sediment distribution along tidal meander bends were mainly developed on modern intertidal channels, which are easily accessible at the low tide stage. Subtidal meanders did not receive the same attention, and their stratal architecture and sedimentary features are poorly known. The present study aims at shading some light on subtidal point bars, analyzing a submerged meander of the southern Venice Lagoon (Italy), coupling sedimentological studies (sedimentary cores), geophysical analyses (sub-bottom profiles), and numerical modeling. The Venice Lagoon (ca. 50 km long and 10 km wide) is characterized by an average depth of about 1.5-2 m and a tidal range of about 1.0 m. During winter time, strong winds from NE cause the development of large waves, which winnow most of the lagoon floor. The study channel is 70-100 m wide, cuts up to 4 meters below a subtidal platform located about 1 m below the mean sea level.
The study bar does not show the classical epsilon-cross bedding and consists of horizontally-bedded, shell-rich sand abruptly overlying clinostratified beds made of massive mud and laminated sand with abundant plant debris. Sedimentological evidence and numerical simulations show that bar deposition stems out from interaction between the in-channel secondary helical flow and wave winnowing of the overbank and bar-top areas. The helical flow, more effective at low-water levels, distributes sediment from the channel thalweg to the bar and contributed to development of the "classical" clinostratified point bar deposits. Wave-winnowing, more effective at high-water level during storm events, caused frequent bar collapses and development of the truncation between clinostratified deposits and overlying horizontally bedded bar-top sediments. On the subtidal platform, sediment remobilized by the interaction between wave winnowing and tidal currents are drifted into the channel, forming peculiar accumulations both along the outer and inner bank.

The evolution of the Lahat, Lemat, and Talang Akar formations of the South Sumatra Basin, Southeast Asia

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The South Sumatra Basin initially formed in the Late Cretaceous as a result of east-west extension. Continued tectonic activity led to the further division of the basin into four clear segregated sub-basins. Sediment was locally sourced into these basins from the surrounding Barisan Mountains, Tigapuluh High, and potentially from the Lampung High. The Lahat and Lemat formations were deposited throughout the Eocene and early Oligocene. The basin margins were dominated by a series of pedimonts, alluvial fans, and braided fluvial systems, whereas the basin centre was typified by a relatively deep lacustrine environment. The sedimentation at the time was affected by contemporaneous volcanism along the Barisan arc, leading to intercalated tuffaceous beds.
Following on from the Lahat and Lemat, an infilling of the sub-basins, alongside a gradational marine transgression, led to the deposition of the Upper Oligocene and Lower Miocene Talang Akar Formation. The infilling of the sub-basins led to more spatially extensive depositional environments. The formation was deposited in basin margin fluvial and alluvial fan systems, alongside basin centre lacustrine, lagoonal, deltaic, shallow marine, and turbiditic environments.
This work presents conclusions from a field season to the South Sumatra Basin, which highlights the change from initial basin margin deposits of the Lahat and Lemat formations (alluvial and fluvial fans, with some lacustrine), through to the well-developed and stabilised depositional environments of the Talang Akar Formation (fluvial, marginal marine, and some deeper marine deposits). This is presented alongside a preliminary heavy mineral study which aims to better categorise the depositional environments, look at basin connectivity between the South and Central Sumatra Basins, and ascertain whether the main sediment source is localised, or from further afield, i.e. the Malay Peninsula.

Thin-Bedded Turbidites; Characteristic Facies, Their Distribution and Process Sedimentology

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The depositional architecture of a submarine fan is subject to the interaction of variables such as existing basin topography, grain size range, and the climatic and tectonic setting. Sediment supply is one such varying parameter. It can range from point sourced, with a single feeder system, to line sourced with multiple coeval entry points. While systems with multiple feeder channel have been identified in seismic datasets; Gulf of Mexico, and in modern systems; Lake Baikal, out crop examples are rare.
Previous work has indicated that the latest Permian Unit 5 in the Skoorsteenberg Fm, Tanqua, South Africa, was fed by multiple channel systems along strike that were active at different times (Hodgson et al. 2006). While aspects of the depositional evolution of Unit 5 have beend addressed (Wild et al 2005) a detailed study of the unit has yet to be made. Key aspects of Unit 5 to be constrained include the range of sedimentary facies, the geometry of depositional elements and the transition from channels to lobes. These aspects will be evaluated against underlying point-sourced systems.
The initial focus of this project is a literature review, supported by fieldwork observations and the integration of core and well logs, of intrachannel thin-bedded turbidites. It has been recognised thin-bedded turbidites can represent a secondary, or less commonly primary reservoir targets, such as the Gulf of Mexico (Clemenceau et al. 2000). However the detailed internal architecture of these reservoirs below seismic resolution remains uncertain. With the increased understanding of deep water depositional systems, a synthesis of thin bedded turbidites, including their depositional environments, within a base-of-slope to basin floor setting, related sedimentary facies and process sedimentology is long overdue since Mutti's classic 1977 paper.

Regimes of submarine channel evolution

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Erosional and depositional processes that control the morphological evolution of submarine channel-levee systems are poorly understood. One of the key questions is whether internal feedbacks between the flow and channel morphology will always cause a channel to evolve towards an equilibrium shape. Shields scaling allows incorporation of realistic forcing of erosion, bypass, and deposition, which is essential in studying the architecture of channel-levee systems. We present results from a series of Shields-scaled experiments that clarify how channels with different initial dimensions are modified by turbidity currents. Three regimes of channel evolution can be mapped on a diagram containing channel width, depth, and aspect ratio: a) equilibrium channels; b) incisional channels; and c) low aspect-ratio channels that are filled-in.
A total of five processes have been identified that change channel geometry: levee aggradation, channel aggradation, channel incision, bank erosion and bench formation. Velocity measurements were used to explore the mechanisms behind these processes in terms of bed shear stress and flow-confinement.
The five processes combine in three different channel regimes, which are distinguished based on characteristic geometric evolutions and the combination of geometry alternating processes that occur. The equilibrium channel regime consists of channels tending towards an equilibrium geometry. Channels in the incisional regime exhibit an erosional character and are associated with incisional episodes in channel evolution. The high aspect-ratio, oversized regime involves depositional channel infilling. The degree of confinement of the flow by the channel emerged as main controlling factor on what processes occurred and in what regime a channel was located. These three regimes can be mapped on a phase diagram containing channel dimensions. These results might be used in the future to enable qualitative reconstruction of paleo flow conditions based on observed depositional and erosional patterns.

Constraining onset of deformation in Pai-Khoi fold-and-thrust belt (Russia), via multi-proxy provenance study

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The NW-SE trending Pai-Khoi fold-and-thrust-belt (PKFB) is a key feature of the Arctic Uralides, linking the most northerly sector of the main Uralian orogen, the Polar Urals, with Novaya Zemlya, ~ 600 km to the NW. The PKFB plays a critical role in the tectonic evolution of the Arctic Uralides, yet the onset of deformation within the fold belt is poorly constrained, with estimates ranging from Permian to Early Jurassic. To address this issue the thick Permo-Triassic flysch and molasse deposits, that accumulated during the Uralian Orogeny across the Pai-Khoi region (Korotaikha and Kara basins), were studied to establish environments of deposition, as well as sediment provenance. These included petrographic, conventional heavy mineral, single-grain geochemistry and U-Pb on detrital zircons determinations.
An overall progradation from deep marine Cisuralian deposits to fluvial Guadalupian to Anisian-Ladinian sediments was observed in both the eastern and central part of the Korotaikha Basin, with the eastern part showing more proximal depositional environments. This is consistent with the principal source area of these deposits having been located in the Urals. A profound reconfiguration in palaeocurrent directions within the Triassic succession of the north-central Korotaikha Basin, together with variations in provenance characteristics, is interpreted to constrain the onset of uplift and exhumation in PKFB to be mid-Triassic in age.

Modelling fluvial, aeolian and lacustrine response to differential rates of accommodation generation in developing salt basins

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Many salt basins exhibit stratigraphic fills that record complex development in response to subsidence histories that varied spatio-temporally. For example, the presence of intraformational unconformities within the fill of such basins demonstrates differential tilting of the land surface at the time of accumulation. Thickening of accumulated successions in depocentres demonstrates differential patterns of subsidence and accommodation generation. In regions that experienced continental sedimentation, such styles of basin development exert a primary control on fluvial, aeolian and lacustrine system behaviour, and styles of accumulation and long-term preservation.
The aim of this study is to undertake a database comparison approach to investigate fluvial, aeolian and lacustrine system response to salt-walled mini-basin development. Specific objectives are: (i) to test the role of the rate of salt movement, associated salt mini-basin subsidence and salt-wall uplift in determining the nature of fluvial stacking patterns and trends; (ii) to assess how different halokinetic behaviours influence patterns of fluvial, aeolian and lacustrine system interaction.
Analysis employs a database approach whereby field- and literature-derived data describing facies and architectural-element distributions of continental successions preserved in salt basins from many settings are coded in a standardized format and stored within a relational database– FAKTS. The database is then interrogated to test how particular patterns of sedimentary architecture and system interaction are influenced by various styles of salt withdrawal and basin development.
Initial results demonstrate a complex interplay between autogenic and allogenic controls on fluvial stacking pattern response to the rate of salt movement. Complex spatio-temporal patterns of accommodation generation dictate fluvial channel-complex distribution and stacking patterns. Lacustrine basins develop in depocentres of blind salt basins that possess no outflow pathway. Aeolian system development is favoured on salt-wall highs, elevated above fluvial plains themselves confined to subsiding basin centres. Climate is an important secondary factor governing preserved sedimentary architecture.

Predicting sedimentary facies using non-destructive core log X-ray fluorescence geochemistry: Comparing the Brent Group and Cook Formation, North Sea.

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The Middle Jurrassic Brent Group sandstone of the Thistle Field (UK sector) and the Lower Jurassic Cook Formation of the Knarr field in the nearby Norwegian sector of the North Sea are both relatively iron-rich sandstones. The Thistle Field contains pore-filling and grain-replacing siderite (iron carbonate) as the main Fe-mineral. In contrast, the Knarr field contains grain-coating Fe-rich chlorite (iron-bearing clay). This study is intended to understand why some Fe-rich marginal marine sandstone contains siderite while others contain chlorite. Here we report on the link between sedimentary facies and geochemistry.
Core samples from the Brent Group Thistle well and Cook Formation Knarr well were analysed using non-destructive auto-core X-ray fluorescence (XRF) geochemical logging in an attempt to see if the multi-element geochemical data can be used to quantitatively or qualitatively discriminate sedimentary facies. High resolution core description and facies analysis of the core samples was conducted base on lithology, grain size, sedimentary structures, degree and type of bioturbation and carbonate cementation. Twelve and eleven sedimentary facies and or facies associations were identified from the Brent Group and Cook Formation respectively. Major and trace elements concentration data were acquired and related to sedimentary facies. The use of the various major element index plots allowed the discrimination of different sedimentary facies. This is interpreted to be the result of different minerals such as calcite, siderite, pyrite, biotite, muscovite, Illite, ilmenite and chlorite being associated with specific facies. Core X-ray flourescence techniques may thus be used as a relatively rapid and automated tool to discriminate facies and identify dominant mineral types. Chlorite- versus siderite-bearing Fe-rich marine sandstones has different geochemical signatures that can be quickly and repeatedly identified. This approach can be extended to sidewall cores and cuttings and could potentially be used in downhole logging. Hence, this technique is potentially important as a future screening tool for the sedimentological and diagenetic study of reservoir rocks

Applying neural network analysis to wireline data for the recognition of lobe sub-environments within basin-floor systems: a case study from the Karoo Basin

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A series of research boreholes in the Tanqua depocentre were fully cored and a suite of geophysical logs collected to investigate the subsurface expression of submarine lobe deposits previously established from extensive nearby outcrops. The resultant integrated dataset permits the analysis of wireline log responses which, when calibrated to core, can be used to constrain lobe sub-environments within lobe-dominated basin-floor fan purely from their wireline signature.
Based on previous work, four distinct lobe sub-environments have been identified within the core record related to facies associations determined from detailed sedimentary logging: 1) lobe axis – thick-bedded, amalgamated fine sandstones; 2) lobe off-axis – stratified medium-bedded sandstones; 3) lobe fringe – thin-bedded heterolithic packages of siltstones and sandstones, with local chaotic and mudstone-prone sandstones; 4) distal fringe – thin-bedded siltstones.
The facies associations identified in core, related to different lobe environments, are defined by a combination of petrophyscial characteristics such as gamma-ray, sonic velocity, and resistivity. Neural network analysis is used to predict facies associations linked to lobe sub-environments based on the calibrated wireline log response, with the method evaluated using core data from other wells in the study area. The advantage of this method in comparison with conventional electrofacies analysis is that it can be constrained to thickness expectations of the different lobe environments based on outcrop investigation. The application to subsurface datasets could allow better understanding of the 3D architecture of potential basin-floor reservoirs where only 1D wireline records are available, thus providing better constraint to geological models.

Testing the use of sulfur isotopes and sulfur concentrations as facies indicators in Precambrian and Phanerozoic sedimentary rocks

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Recent work has shown that the isotopic composition of pyrite within sediments is, to some degree, dependent on sedimentary facies. Furthermore, in theory, the degree of marine influence within a sedimentary environment should affect the sulfur geochemistry of the sediments: due to the much larger sulfur pool available in marine water relative to meteoric water. It may thus be possible to use sulfur isotopes and sulfur concentrations as a geochemical indicator of marine influence in the deposition of a given sedimentary rock. Potentially, this means that geochemistry could provide a powerful tool to explore marine influence in the sedimentary record, in strata where diagnostic sedimentological or palaeontological signatures are lacking.
We present pyrite concentrations and $\delta^{34}S_{Pyrite}$ data from a series of Precambrian and Phanerozoic successions and interpret them in the context of other sedimentary facies signatures of marine influence in their depositional environments. Particular attention has been paid to samples collected from marine and non-marine units of the Precambrian Torridonian Supergroup in Scotland, and the Ordovician-Silurian succession of marine rocks from Westerdale in the Howgill Fells, NW England.
Pyrite concentrations were determined by extracting the pyrite as sulphide, by reaction with reduced chromous chloride, and trapping the evolved hydrogen sulfide gas as zinc sulfide within zinc acetate. The concentration of the sulfide within this trap can be precisely measured spectrophotometrically by reaction with diamine reagent to produce methylene blue. This method is precise, and the extraction of pyrite is near quantitative.

"Submarine Lobes" or "turbidite sheet sandstones", are they the same? Examples from the Carboniferous of NW Argentina

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Submarine lobe refers to sediment bodies with a lobate shape. Turbidite sheet sandstones are used to describe sandstones with tabular architecture, always at a scale of 1 to as much as 100 km or more. The architecture of lobes and sheets is mainly controlled by flow efficiency and the degree of basin confinement. Confinement refers to the degree to which sediment gravity flows are influenced by the surrounding basin relief. Flow efficiency is mainly determined by flow volume, flow density and percentage of fines.
Cerro Bola, on the northern margin of the Paganzo basin proper, is 1000m thick and record three glacial to deglacial cycles. The study interval is within a succession of Pennsylvanian turbidites with a maximum thickness of 120 meters, deposited during the second deglacial cycle. These turbidites have been divided into five stages, of which two (named TS2 and TS4) have been chosen for detailed bed to bed correlation. The individual beds in TS4 could be well correlated all the way along the 10km outcrop in depositional strike direction and 15km in depositional dip direction, whereas the individual beds in TS2 could not be confidently correlated over a distance of 80 m . By comparing individual flow volume and percentage of fines, we have found that the beds in TS4 have larger flow volumes and higher percentage of mud. We can deduce that the bigger muddier flows are more likely to produce tabular individual beds across the entire basin . Thus the term lobe could only be applied to sandy systems that were too small to extend across the basin, and were thus insensitive to the confinement, whereas the term turbidite sheet sandstones is more suitable for the larger muddy systems (TS4) that can be regarded as being confined, even though experiencing the same topography as TS2.

Sun, Sand and Salt: The continental sabkhas of Abu Dhabi

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The coastal sabkhas of Abu Dhabi have been the focus of intensive research activities for more than half a century. It is therefore somewhat surprising that, to date, their continental counterparts have been neglected. While the coastal sabkha of Abu Dhabi is well understood, no focused sedimentological or mineralogical studies were conducted in the continental sabkhas that are hosted in the Rub al Khali desert of the UAE. Reconnaissance investigations have established that organic-rich microbial mats and evaporites, similar to those observed in the coastal sabkha, also occur in these continental sabkhas. Satellite imagery was employed to identify potential sites for investigation; field reconnaissance established the validity of sites in terms of anthropogenic influence and accessibility. At each site, surface features were described in detail, particularly with reference to any microbial communities; sample pits were dug in order to document sub-surface facies geometries and to recover both sediment and pore water samples for subsequent analysis. In each pit, a range of environmental parameters was measured, including surface and sub-surface temperatures, ground water salinity and dissolved oxygen. Sediment samples were subjected to a range of analyses in order to establish and quantify primary sediment composition and any early diagenetic mineral phases. The results of this study are used to build an atlas of sedimentary structures and textures that are associated with continental sabkha settings. These observations allow us to establish the defining sedimentological and early diagenetic characteristics that can be employed to identify similar depositional environments in ancient successions. This will, ultimately, enable the development of better reservoir models, in terms of lateral and vertical depositional and petrophysical facies variability, and fluid flow.

Underneath the Mangrove Tree: The complex facies of mangrove systems

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The extensive mangals of the United Arab Emirates are often cited as a recent analogue for Mesozoic reservoir facies from the Middle East. However, to date, there has not been any attempt to fully document and characterise the sedimentary facies and depositional geometries of these complex coastal systems. Such a paucity of data severely compromises palaeoenvironmental interpretations and the constraint of reservoir models. During this study, historical satellite imagery, literature reviews and ground-based reconnaissance were used to identify a natural mangal area in the vicinity of Yas Island. A transect was established with sampling stations at intervals of between 2 and 20 metres in order to accurately record the range of environmental conditions, both in terms of energy and in relation to the degree of tidal exposure. An array of environmental parameters were monitored., these included, but were not limited to, temperature, salinity, pH, current velocity, water depth, dissolved oxygen and turbidity. The surface sediment at each sample station was sampled at repeat intervals and subjected to a range of analyses including grain size and modal analysis, identification of biota and measurement of total organic content. The results of this study allow us to develop a mangal sediment facies map that accurately establishes the relationships between sediments, depositional setting and environmental parameters. These results can be employed to inform the interpretation of ancient successions deposited under similar conditions. Further, the findings of this study will aid in the development of accurate petroleum reservoir models that are constrained by a quantitative data set. Lastly, a comparison between the environmental and sediment characteristics of natural and artificial mangals will aid our understanding of the effects of these systems on the sedimentary dynamics of the UAE's coastline.

Facies analysis of humid-tropical, syn- to early post-rift coastal plain deposits: the Miocene K Group of the Malay Basin

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The gross tectono-stratigraphic setting of the K Group represents a ca. 10 Myr period (Late Oligocene to Middle Miocene) that records the Malay Basin's evolution from a syn-rift alluvial plain-dominated setting to a post-rift offshore shallow marine setting.
However, the depositional environment of the K Group is uncertain, with terrestrial, lacustrine and shoreface-deltaic depositional models previously suggested. The main aims of this study are (1) to evaluate the geological controls that underpin the depositional model, and (2) to apply this to an assessment of the sand body types and prediction of reservoir thickness and quality trends.
The initial results from a sedimentological analysis of c. 400 m of core from seven wells identify three facies associations (FA): (1) FA1 comprises coarse to pebbly, cross-bedded sandstones that are organized into 4 to 6 m-thick, fining upwards multi-storey sand bodies. These are interpreted as high-energy, bedload-dominated fluvial channels. (2) FA2 comprises 4m-thick coarsening upwards heterolithic sandstones with wave and current ripple cross-lamination and minor bioturbation. These are interpreted as deltas infilling shallow bodies of water (lakes to brackish water embayments), (3) FA3 comprises mudstones with variable, but generally minor non-bioturbation and an absence of marine microfauna. The FA3 is interpreted as flood-plain to shallow lake-coastal embayment.
Preliminary results suggest that the K Group records the initial entry of marine waters into the Malay Basin from the expanding South China Sea to the south-east, but these were dampened by high levels of fluvial discharge. In addition, alluvial plain gradients were sufficiently high for braided river systems to develop and to feed shallow water deltas that were infilling lakes and brackish water coastal embayments. The degree to which marine processes influenced delta front characteristics will be investigated in future work, but there is evidence minor wave and storm reworking, probably reflecting periodic tropical storms.

Quantifying Flocculation Settling Dynamics of Natural Fine-grained Suspended Sediments: "Floccin' Across the USA!"

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Many coastal and inland waterways are dominated by muddy sediments; typically a mixture of clay minerals and various types of organic matter. When cohesive sediment is entrained into suspension, the particles tend to flocculate. Flocs are less dense, but faster settling than their constituent particles thus affecting their depositional characteristics. As flocs grow, their effective densities generally decrease, but their settling rates rise due to the Stokes' Law relationship. Flocculation effects become even more complex when purely cohesive sediments are mixed with different ratios of non-cohesive sediments, and if biological activity (e.g., exudate production) affects the resultant cohesion. Developing instrumentation that can provide key physical and dynamical data on depositional rates of flocculating sediments is extremely important in advancing our understanding of natural flocculation processes. Complementary qualitative and quantitative data improve our understanding of the depositional and aggregational physical processes through parameterization.
This presentation will demonstrate recent advances in the study of the flocculation process through the use of video image technology. One such device pioneered at HR Wallingford, and implemented with co-authors, is the high-resolution floc video camera, LabSFLOC - Laboratory Spectral Flocculation Characteristics (developed by Prof. Manning). LabSFLOC can observe (directly or indirectly) floc spectral physical properties, including: floc size, settling velocity, effective density, porosity, shape, mass, and settling flux (using controlled volume referencing). These data are highly desirable for sediment transport modelers. Examples of floc measurements from locations in estuaries, tidal lagoons, river deltas, and lakes from locations across the US will be presented. In addition, we will demonstrate how video floc data can be used to parameterize floc settling characteristics for use in modeling.

Orpheus: a new simple numerical model for mixed siliciclastic and carbonate sediment erosion, transport and deposition.

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The range and variability of parameters and processes influencing carbonate strata in rift basins is difficult to fully evaluate from a qualitative outcrop or subsurface data approach alone. Stratigraphic forward models are able to evaluate parameters influencing carbonate strata development via sensitive analysis focused on mechanisms of carbonate platform evolution. Siliciclastic and carbonate sediment transport plays a key role in the stratigraphic development of syn-rift basins. For example hanging-wall depocenters can be filled with siliciclastic material and with carbonate detritus from footwall platform erosion (Dorobek, 2011).
This research will develop a pre-existing stratigraphic forward model, CarboCAT (Burgess, 2013), expanding it with more realistic representations of the main processes affecting carbonate platforms deposition in syn-rift basins. The first objective has been development of Orpheus, a new CarboCAT sub-routine enabling a realistic representation of sediment erosion, transport and deposition for both carbonate and siliciclastic deposition modelling. Orpheus represents different gravity-driven transport mechanisms in a very simple but logically consistent way, allowing the operator to define minimal parameters required to produce complex and realistic strata.
Transport occurs following a steepest-descent route and the model represents simplified approximations of channelized transport, debris flow transport and turbidity flow transport, based on different flow parameters for each type. Deposition starts when flow velocity falls below a velocity threshold and the sediments are form fan-lobe geometries that varying according to the flow types. Repeated deposition of flow events develops characteristic stacking patterns including compensation cycles. Initial results from Orpheus appear promising so we seek feedback on the validity and applicability of the model.

Using benthic foraminifera to solve problems in deep-water sedimentary systems

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The record of ancient contourites is very limited, primarily because no simple, unambiguous basis for their identification has been established. This is problematic for the study of the geological record of contourites, but also for analysis of ancient oceanic sedimentation and for industrial studies of ancient sand deposits on the slope, the origin of which remains ambiguous. New tools for distinguishing contourite and turbidite depositional systems therefore remain key to unlocking the unique potential of contourite depositional systems. One major environmental difference between channelized systems originating from turbiditic and contouritic processes is the variance of bottom velocity. Whereas in contourite systems bottom velocity at single sites varies over millennial timescales, in a turbidite system the passage of a single gravity flow event results in energy changes over the timescale of hours to days. Consequently, the bottom ecology in contourite systems will be in equilibrium with the bottom energy throughout deposition, whereas in a turbidite disequilibrium ecologies will arise subsequent to sand emplacement events. This raises the possibility of discriminating the resulting deposits using benthic microfossils such as foraminifera. This work is focused on the potential of benthic foraminifera assemblages to discriminate sand transportation mechanisms. It appears that ecological discrimination of the disturbance-succession patterns in a turbidite system are easily distinguished from the filter-feeding specialism of a contourite system. To test this concept benthic foraminifera assemblages in sediment cores collected from the Uruguay Slope and Gulf of Cadiz will be utilised. These areas of ocean floor encompass both large sediment drifts and large downslope canyons, where turbidite and contourite deposition occurs simultaneously. This work will coincide with contrasts and comparisons to key fossil contourite sections from the Oligocene of Cyprus.

Negligible microbial matground influence on pre-vegetation river functioning: evidence from the Ediacaran-Lower Cambrian Series Rouge, France

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The pre-Silurian alluvial rock record is dominated by successions of laterally-extensive, sheet-like sandstone strata with minimal mudrock; a depositional style frequently explained as representing fluvial processes particular to "pre-vegetation" Earth. However, while the sedimentological and geomorphological influence of Palaeozoic embryophytes and other higher vegetation has been commonly inferred, the influence of the non-marine microbial matgrounds that preceded them has been less well studied. The ?Ediacaran-Cambrian Series Rouge of northern France and the Channel Islands is a rare example of a predominantly alluvial succession which exhibits both pre-vegetation sedimentary motifs and evidence for the existence of terrestrial microbial mats. The latter include likely microbial sedimentary surface textures, the enigmatic matground "pseudofossils" *Aristophycus* and *Arumberia*, and probable mat fragments and mat-related microtextures preserved in argillaceous sediment. The sedimentological characteristics of the Series Rouge are described and analysed in order to assess the role of microbial influences on pre-vegetation alluvial systems. Near ubiquitously trough-cross bedded, sheet-braided facies with rarely preserved channel-forms indicate that alluvial sedimentation was dominated by in-channel dune migration, and depositional-strike successions reveal the periodic downstream migration of complex bar-forms. Lateral accretion elements and minor discontinuous lenses of more argillaceous material are locally present. Thus, despite the evidence for matgrounds, sedimentary architecture was essentially 'abiotic'. Using this evidence from the Series Rouge, we argue that the surficial cohesion provided by matgrounds did not exceed thresholds for reworking by hydrodynamic processes thus having little or no effect on their preserved sedimentary architecture.

The climatic implications of Lower Mississippian evaporites in equatorial northern Britain

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Evaporite-rocks formed in both marine and coastal plain environments in the mosaic of Mississippian sedimentary basins across northern Britain and Ireland. One Tournaisian succession – the Ballagan Formation of the Scottish Borders and adjacent areas – hosts recently discovered fossils of the earliest known tetrapods with terrestrial capability. Interpretation of the palaeoenvironments and habitats is important to understanding how and why this crucial event in the history of life on Earth occurred.
The Ballagan Formation comprises up to 520 m of grey siltstone and thin beds of dolostone, interbedded with sandstone units, abundant palaeosols and thin beds of sandy siltstone. The succession is interpreted to represent a coastal-plain setting with lakes and rivers, and subjected to episodic flooding as a result of heavy rainfall and from marine water influx during storms. Occurrences of gypsum and anhydrite are localised throughout the region in beds generally less than 1 m thick, as nodules, enterolithic veins, and chicken-wire and laminated forms. The evaporite-bearing beds are clustered within successions of dolostone and laminated grey siltstone that accumulated within bodies of standing water that probably became hypersaline.
The presence of evaporites in the Ballagan Formation has been taken previously to indicate an arid or semi-arid climate. However, the rocks are dominantly grey and there are no associated aeolian, arid-fluvial phenomena or well developed calcrete palaeosols to support this, though there are many desiccated and brecciated surfaces. Furthermore, such an assumption is contrary to the evidence adduced from other features such as flood-generated sandy siltstone beds, palaeosol geochemistry and tree rings that suggest a strongly seasonal tropical regime. In this poster, the evaporites are characterised in the context of their host rocks and their climatic significance is critically assessed.

The interaction of sediment systems and structurally-induced seafloor topography within a tectonically controlled intra-slope basin on the southern lobe of the Niger Delta

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The evolution of seafloor bathymetry through tectonic activity has long been recognised as a major control on the location and configuration of deep-water sediment transport systems. However, the relationship is complex, with a number of factors affecting the sediment system's response. The deep-water Niger Delta provides an excellent location to analyse the interaction between deep-water sediment systems and gravity-driven tectonics, with a wide range of structural styles and sediment delivery systems across tectonically controlled intra-slope basins. Contractional structures began developing in in the middle Miocene, forming above detachment horizons within the shales of the Akata Formation.

A 3D, time-migrated seismic volume extending a distance of ~100 km from the shelf edge down-slope was used to map sequence boundaries and structures within an elongate, structurally constrained intra-slope basin. Five seismic units were mapped and used to evaluate the structural and stratigraphic evolution of the basin. Four major structures were identified—a fault-propagation fold, an intra-basinal detachment fold, a transtensional strike-slip fault, and an up-dip thrust zone. Within the syn-kinematic interval, depocentres were recognised on the backlimb of the fault-propagation-fold constraining the basin to the south and the intrabasinal detachment fold; isochron maps document shifts in the location of depocentres as the accommodation space created through structural activity was filled and the slope healed.

Channel complex systems were identified in all seismic sequences. Localised off-stacking, avulsion, diversion and abandonment of channel-levee systems was observed in relation to topographic highs, whilst at regional scale the sediment transport field appeared fairly consistent, with a northeast-southwest transport direction prevailing. Transtension associated with the strike-slip fault also provided a long-lived routing system for channels. An unexpected outcome of the research was the discovery that the major, N-S trending transtensional fault was active prior to the deformation on the toe-thrust folds. The structure may represent an underlying crustal transform inherited from the Cretaceous opening of the South Atlantic Ocean.

The Scottish Carboniferous Research Park: Educating geoscientists in fluvial to marginal marine sedimentology and subsurface reservoir analogues.

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The teaching and practice of sedimentology commonly uses examples from the modern environment, coupled with an understanding of preservation potential, to develop facies models for the subsurface. The 'leap' from facies of the modern environment to those preserved within the subsurface commonly relies on theoretical representations, since few locations exist where the subsurface can be examined in 3D. This problem is exaggerated in fluvial settings where rapid spatial and temporal variations of facies make understanding the subsurface difficult

The Scottish Carboniferous Research Park (SCARP), Spireslack, Ayrshire, Scotland, provides an opportunity to study fluvial and marginal-marine sedimentology. The site is a detailed, extensive, 3D exposure providing excellent opportunities for educational and professional training in: sedimentology, reservoir characterisation and modelling from remotely sensed data, at a reservoir scale. Along with opportunities to develop new remote sensing techniques for subsurface data collection.

Research on the site using logging and 2D panelling has developed a coherent environmental interpretation. Quarry faces show meandering fluvial channel sets that evolve temporally into a tidally influenced shoreline environment and shallow marine setting, before returning to a fluvially dominated one. Thus, the site is an excellent opportunity to examine and teach fluvial sedimentology and its evolution in a stratigraphical context.

Current work on the site includes detailed spectral gamma ray analysis, with full waveform LiDAR and GPR. These datasets provide a comparison between real data and the remotely sensed, commonly employed to examine the subsurface. Future plans include: behind-face boreholes, to compare the use of spatially limited subsurface data for reservoir characterisation, to preserved architectures at the quarry faces. We present completed research on the site to provide a baseline sedimentological interpretation of the strata, along with teaching and training applications. The site has already provided an informative training ground for university groups, conference delegates and industry professionals.

Calciclastic mass flows from the Darriwilian/Sandbian boundary at Abereiddy Bay, Pembrokeshire, Wales, UK: Implications for Avalonian sea-level correlation.

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The Darriwilian and Sandbian succession at Abereiddy Bay has been previously studied because of its palaeontological and stratigraphical significance. The bay is now regarded as a type locality for the Abereiddian of the lower Darriwilian (Ordovician). The Caerhys Shale Formation has a well constrained depositional model. However, for the Castell Limestone Formation, such a model is absent. Lithofacies schemes and associations are produced from sedimentary logging to develop lithostratigraphical subdivisions of the formation, each of which provided a different sedimentological process of deposition. The sedimentology and subsequently interpreted depositional process are then further examined with hand-held spectral gamma ray data; from this, a relative sea level interpretation has been derived from interpretations of the water column and depth of the carbonate compensation depth. The Castell Limestone Formation is subsequently interpreted as a dynamic mass flow system with its strata displaying debrites, linked debrites, and mud-rich non-cohesive turbidites. It is suggested that the system may have been deposited due to the collapse of a hinterland carbonate platform. The implications for this mass wasting indicate a highstand sea level which is correlatable to the Avalonian sea level highstand derived from ocean water palaeochemistry during the Ordovician.

Application of quantitative analysis of fluvial sedimentary architecture to improved facies and reservoir modelling workflows

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Hydrocarbon recovery is intimately related to the petrophysical properties and the connectivity of highly permeable sedimentological bodies including in reservoirs. Facies modelling seeks to reproduce the geometry and distribution of these bodies in the 3D space, to provide a framework to construct property and flow models.
However, facies modelling is commonly based on two-point-variograms and object-based simulations that fail adequately reproduce complex geological shapes (e.g., highly sinuous fluvial channel bodies) or to honour conditioning data (e.g. well data) respectively.
Furthermore, the reliance on variograms to describe the heterogeneities away from the well control, commonly results in exclusion of fundamental geological features or inclusion of trends without geological meaning.
This project is developing new workflows that enable generation of model outputs with improved geologic realism than outputs commonly obtained through conventional methods. Results are being applied to model reservoirs that comprise fluvial meander-belt deposits. Simulation techniques based on multi-point statistics (MPS) are used to integrate complex geological patterns and to honour both soft and hard data.
A library of training images -from which MPS modelling algorithms replicate geologic patterns- is being developed. These training images incorporate fundamental features of the facies architecture of fluvial point bars and meander belts, expressed as facies models generated through mixed process-, geometric- and stochastic- based numerical simulations that are informed by quantitative architectural information drawn from a database of geological analogues.
The application of training images to different MPS algorithms (SNESIM, FILTERSIM, IMPALA) is being optimized. Common issues encountered in MPS modelling workflows are being addressed, including training-image preparation, selection of ideal modelling parameters (e.g., search-mask size, multigrids), excessive runtime performance, and handling of non-stationarity. A set of training images and associated modelling parameters is being devised for different types of channel-belt architectures, which will enable off-the-shelf training-image selection and application to suit a variety of modelling requirements.

Sedimentology and Geochemistry of Eocene-Early Miocene Source Rocks from Paratethys

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The Kuma Formation (Eocene) and the Maykop Series (Oligocene – Early Miocene) were deposited in a marginal marine setting within the Paratethys Ocean during times of mountain building across Europe and Asia. Uplift during the collision of Africa and Arabia with Eurasia episodically restricted the Paratethys Ocean and enhanced organic production and preservation in a number of sub-basins in Central and Eastern Europe. Hydrocarbon-producing sedimentary strata now exposed around the periphery of the Black Sea are the focus of this study. Specifically, the aim of the project is to understand the controls on source rock production and preservation in Eastern Paratethys through detailed sedimentological and organic geochemical analyses.
A Paleogene to early Neogene succession, including the Maykop Series type locality, is exposed on the Belaya River, south-west Russia. Detailed sedimentary logging and sampling (approximately every 50 cm) through 250 m of stratigraphy has been completed. RockEval pyrolysis was conducted on all samples to examine the source potential. The Kuma Formation is characterised by total organic carbon (TOC) values of 1-5.5% compared to values of between 1-3% in the Maykop Series. Detailed thin section analysis of the same samples reveals a range of facies including calcareous laminated marls with abundant, well-preserved foraminifera (Kuma Formation) to dark heterogeneous mudstones with occasional lenses and sporadic sand-sized quartz grains (Maykop Series). Within the Kuma Formation facies of dark fine-grained matrix interlaminated with parallel concentrated organic matter correlate with higher TOC values. In samples with lower TOC values the matrix is much lighter and distinctly lacks laminae of concentrated organic material supporting the hypothesis of a link between facies and TOC content.
The characterisation of Black Sea organic-rich mudstones will provide new insights into the processes and controls on source rock development in marginal marine settings in tectonically active settings.

The application of Process-based sedimentological models as training images for Multi Point Statistics: A case study from the Ferron Sandstone, Utah.

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Process-based models are designed to forward-model reservoir heterogeneity based on a series of predefined rules coupled with user defined input parameters based on knowledge of physical processes. The inherent complexity of depositional systems typically means that conditioning directly to subsurface data is extremely challenging. This problem can be addressed through applying the realistic geometries and structures created by process-based models as 3D training images for Multiple-Point Statistics (MPS).
To test this approach, a 1.5 x 0.8 x 0.5 km close-to-deterministic base case geocellular model was created from the well exposed deltaic deposits of the Cretaceous Ferron Sandstone at Ivie Creek, Utah. This model was derived from a UAV acquired virtual outcrop and guided through high resolution mapping of delta lobe elements directly onto the virtual outcrop surface and a series of sedimentary logs within the case study area. A comparable process-based model of a delta complex was generated using Delft 3D software and imported into Petrel. The Delft 3D model was used as a training image to condition a series of subsequent MPS simulations using different numbers of conditioning wells upscaled from sedimentary logs and boreholes acquired by the Utah Geological Survey. The resulting simulations were validated against the deterministic base case model through a visual and statistical comparison.
A key challenge in the MPS workflow is the available of representative 3D training images. Results suggest that process-based models are excellent candidates for training images when combined with regional knowledge, including depositional trends and available well data. This integrated approach demonstrates a valid methodology for producing more accurate reservoir models.

Preliminary studies of diagenetic controls on Cenozoic clastic reservoir analogues, Southern California, USA.

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The San Joaquin Basin and Salton Trough form a roughly NW-SE linear structure within southern California. They are separated from each other by the Mojave Desert and several faults including the San Andreas Fault. These two areas have similar late Cenozoic depositional systems ranging from alluvial to turbidite fans. Rock samples were obtained from Fish Creek Wash in the Salton Trough and along Chico Martinez Creek and in the Temblor Range around Bakersfield in the San Joaquin Basin. These were studied by petrographic thin section supported by Infinity Analyse and Petroledge software, combined with XRD and SEM-EDS to assess and compare the influence of diagenetic processes on reservoir quality distribution in both areas. The sandstones from the Salton Trough are arkosic – lithic arkosic with detrital composition consisting of quartz (average 36.2 %), feldspars (average 46.0 %) and rock fragments (average 17.8 %) whereas sandstones from the Bakersfield are arkosic with detrital composition consisting of quartz (average 58.1 %), feldspar (average 37.3 %) and rock fragment (average 4.6 %). Both areas show similarity in diagenetic patterns consisting of compaction, feldspar alterations and dissolution, microfracturing and authigenic cementation in the form of clay, feldspar, quartz, and calcite cementation. Calcite cement is the late phase and the most predominant authigenic cement occluding pores in both areas. It shows an inverse relationship with porosity. Authigenic smectite and mixed-layer smectite-illite clay are more common in the Salton Trough (averaging 1.85 %) relative to Bakersfield (averaging 0.65 %) while kaolinite is significant and confined only to the Bakersfield (averaging 1.5 %). Estimated thin section porosity values are higher in the Salton Trough than Bakersfield. Authigenic cementation has played a more important role in destroying original porosity than compaction. The effect of cementation to compaction is more pronounced in the Bakersfield than the Salton Trough area.

Where has all the porosity gone?: Linking pore pressure evolution and reservoir quality in the Taranaki Basin, New Zealand

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The Taranaki Basin (TB) lies onshore and offshore in central-west New Zealand. The basin has undergone rapid subsidence and burial, accumulating up to 9km of sediment since the Late Cretaceous with many overpressured regions of up to 4000psi/28MPa above hydrostatic. It has been shown that shallow early onset of high pore fluid pressure (low vertical effective stress) can inhibit pressure dissolution driven by mechanical compaction; thereby reducing the load borne by intergranular grain contacts and maintaining high primary porosities. This study has focused on the Palaeocene Farewell Formation which is dominated by high N/G multi-stacked multi-lateral fluvial sandstones that act as a primary reservoir within the TB. Kapuni Deep-1 well was drilled onshore to test the reservoir potential of the deep Farewell (>5000m TVD), which was found to be significantly overpressured (3000psi/21MPa) but displayed very poor reservoir quality with measured porosity and permeability of 2.88% and 0.095mD respectively.

1D basin modelling has shown that the Farewell Formation has experienced initial rapid burial leading to porosity loss through mechanical and subsequently chemical compaction. Rapid burial beginning in the Pliocene drove the formation of significant overpressure through disequilibrium compaction, but was too late to act in arresting porosity loss. Degradation of feldspars has led to precipitation of pore filling kaolinite and pore bridging illite which has further impacted the reservoir quality. Early pore filling and late precipitation of calcite cement in degraded feldspars has produced inter-granular volumes of >60%, which has the potential to produce significant secondary porosity. Bitumen filled fractures commonly display etched grains and indicate flushing by CO_2 rich fluids. Aqueous and oil fluid inclusions in quartz facture fills (110^0C) correspond to onset of Miocene uplift and reservoir charging. Although the overall reservoir quality is poor, the deep Farewell Formation could still be an attractive exploration prospect if secondary porosity and connected fractures are charged with movable hydrocarbons.

Pliocene-Pleistocene sedimentary-tectonic development of the Mesaoria (Mesarya) Basin, in northern Cyprus, in an incipient, diachronous collisional setting

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The Mesaoria (Mesarya) Basin exemplifies multi-stage basin development within a regional setting of diachronous continental collision. New facies evidence from the northern part of the basin, combined with field, well and geophysical data from the southern part of the basin enable the first detailed synthesis of the Plio-Pleistocene evolution of the basin.
The Early-Late(?) Pliocene was represented by major transgression and deposition of chalks and marls after the Messinian salinity crisis, reaching nearly 900 m in the southern part of the basin but <20 m in its northern part. Mudrocks in the southern part of the basin are associated with conglomerate channels that were sourced to the south of the basin, within the Troodos Massif which was already undergoing uplift.
The Pliocene-aged chalks and marls are overlain by Pleistocene shallow-marine facies in the form of benthic foram-rich grainstone, calcareous red algae-rich rudstone, medium to coarse-grained, cross-bedded grainstone, channelised-conglomerate and oyster/oncoid-rich floatstones. These deposits represent a shallowing of the marine environment across the entire basin from a hemipelagic, open-marine setting, to a restricted shallow-marine seaway and finally to lagoonal and deltaic settings. Associated channelized conglomerates were derived from the Kyrenia Range to the north of the basin, which by then had started to uplift. Overlying the entire sequence are aeolian carbonate deposits, representing the final switch to a non-marine environment.
The Mesaoria (Mesarya) Basin sedimentary and strucutal development was controlled by the on-going regional tectonic processes of the Eastern Mediterranean. During the Early Pliocene, sediment accommodation space was created in the southern part of the basin by subsidence along two c. E-W tectonic lineaments. First, down-to-the-north extension took place along the southern margin of the basin. Secondly, sinistral strike-slip/transtension(?) became active along the Ovgos (Dar Dere) fault zone, which transects the northern margin of the basin. The strike-slip tectonics relate to the coeval westward tectonic escape of Anatolia to the north towards the Aegean region to the west. The subsequent regression throughout the basin is explained by regional tectonic uplift. This was brought about by the inferred collision/underthrusting of the Erathosthenes Seamount with a north-verging subduction trench to the south of Cyprus. The sedimentary evidence indicates that Cyprus as a whole was uplifted simultaneously, including the Troodos Massif, the Kyrenia Range and the intervening Mesaoria (Mesarya) Basin.

The elusive link between pore-water chemistry and early cement phases: Case study from the shallow subsurface of the Abu Dhabi coastal sabkha

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The coastal sabkha of Abu Dhabi is a complex depositional system in an extremely arid climate. This depositional system is marked by the formation of primary carbonate and microbial deposits, and by the development of secondary evaporite and cement phases. A number of earlier studies have assessed the formation of these secondary phases, yet no research has established a relationship between lateral and vertical variations in the chemical composition of pore water and the nature of in particular the precipitating pore-filling cements, re-crystallisation features and dissolution.
This study aims to establish an understanding of the environmental and sedimentary factors that control early post-depositional changes to sediment composition as a result of sediment - pore water interactions. A particular focus is to characterise changes in the chemistry of the pore water throughout a tidal cycle, aiming at understanding how the influx of 'fresh' lagoonal sea water influences the chemistry of the pore water, and which elements are replenished on a daily basis. The initial data presented here is based upon the relationship between the petrographic analysis of sediment samples and lateral and vertical variations in the chemistry of in-situ sampled pore water. The pore water is characterised with respect to pH, salinity, alkalinity, dissolved organic carbon, and the concentrations of a variety of common metallic and non-metallic elements, including (but not limited to) Ca, Fe, Mg, P, S and Sr.

Trawling induced turbidity currents

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Bottom trawling fisheries promote recurrent sediment resuspension events over fishing grounds. Recent studies have shown how bottom trawling can drive seascape reshaping at large spatial scales and enhance sediment transport in submarine canyons. Present knowledge on the transfer and accumulation of sediment flows triggered by bottom trawling is based on snapshots of field data limited in time and space whilst a system scale picture of this process is needed. Our work focuses on the modelling of sediment transport and accumulation resulting from trawling activities in La Fonera submarine canyon, north-western Mediterranean Sea, thus contributing to an improved assessment of trawling impacts. Based on mooring data, an inverse model is used to reproduce sediment resuspension time series over an area defined on the basis of Vessel Monitoring System data. Our numerical process-based model simulates trawling-induced flows through the canyon and provides a 3D visualization of potential trawling impacts on sediment dynamics, including the identification of the propagation patterns of sediments resuspended by trawling. Flows coming from shallower fishing grounds are funnelled through canyon flank gullies towards the canyon axis, with part of the resuspended sediment reaching the continental rise out of the canyon across the open continental slope. Trawling-induced sediment flows promote sediment accumulation beyond the canyon mouth. Given the wide geographical distribution of bottom trawling, our results have far-reaching implications that go beyond La Fonera submarine canyon. Our study represents a starting point for the assessment of the sedimentary impact of bottom trawling in deep continental margins. This may allow the identification of potentially "damaging" and affected areas for sediment transport as well as trawling areas with lesser impacts, with the aim of fisheries management based not only on the short term impact on individual species but with a more long term vision of ecosystem processes.

Chemical weathering fluxes and processes in the Mekong River

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Geochemical fluxes and spatial trends in chemical weathering of the lower Mekong basin are evaluated using bedload and water sampling from Luang Prabang, Laos to Kratie, Cambodia in conjunction with water current velocity profiling during September 2016. Fused discs with a lithium metaborate solvent are made to analyse bedload samples using ICP-OES. Both forward and inverse methods are used to model water chemistry; the inverse model's silicate, carbonate and evaporite endmembers are considered in the context of the bedload chemistry. We find the Mekong is being diluted by tributaries in the Lower basin and attribute trends in silicate weathering to changes in sub-basin rock type, elevation and climate.

Aeolian- Sabkha Interactions in the Cedar Mesa Sandstone, Southwestern USA.

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Arid continental basin fill commonly comprises aeolian, fluvial, evaporitic, alluvial and lacustrine deposits. Though the distribution and preservation of the sediments of individual environments are well defined, the geometrical interrelationships between deposits of contemporaneous environments, and the temporal evolution through environments, have received relatively little attention despite the fact that interactions have the potential to significantly affect both basin-scale migration and reservoir character.
In this work we present a preliminary field study of aeolian – evaporitic – lacustrine interactions between extensive dune and sabkha deposits from the erg margin of the Cedar Mesa Sandstone, south-eastern Utah. We use detailed and regional logging across multiple areas to determine the sedimentology, depositional environments, spatial relationships, facies, and facies associations. Using these techniques 3D environmental models have been derived, showing the complex interactions between environments in both time and space, how these are preserved, and what the implications of these interactions mean for reservoir potential. Furthermore, ideas are presented speculating the climatic controls, separating localised effects from wider allocyclic processes.
The region shows extensive, yet sporadic, interfingering deposits of lacustrine, aeolian, fluvial and evaporitic origin. The interactions suggest a dominant control on preserved facies and geometries by the evaporitic system, even during drier times, with extensive reworking of aeolian sediments into sabkha-related associations of poor reservoir quality. This complex relationship of interbedded clean aeolian and evaporitic strata both compartmentalises and provides migration pathways to connect reservoir intervals.
The study provides evolutionary sedimentary models that can be applied to subsurface data from the arid Permian basins of the North Sea, UK – an active hydrocarbon province – in order to better characterise basin-scale migration and reservoir quality in terms of the evolving basin fill.

A multiscale analysis of the Entrada Formation – an approach to erg reconstruction and geomodelling of a wet aeolian reservoir analogue.

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Extensive cliff exposures of the Mid-Jurassic Entrada Formation across eastern and central Utah provide an opportunity to study wet aeolian system architecture and characterise transitions from aeolian to paralic systems (Kocurek, 1981). A new study in search of wet aeolian reservoir analogues has combined traditional outcrop logs with virtual outcrop models (VO's) to characterise these interrelationships spanning multiple scales at higher resolution than previously possible in the Entrada.
The focus is twofold; firstly understanding the dimensions and distribution of dune-interdune elements of the main Entrada erg system in central Utah allowing a re-assessment of the depositional architecture and secondly examining the regional interdigitation of the aeolian facies with marginal marine sediments resolving facies transitions and dune architecture from erg fairway to erg margin. The dataset comprises a 110 km long NW-SE orientated transect through the Entrada in central Utah from the San Rafael Swell to Bartlett Wash (near Moab) spanning ten separate localities. Conventional 1:50 scale log data at the localities is underpinned by VO's (gathered by UAV – drone) these range in scale from 700 m long to 3 km^2 in area. Each locality has been carefully selected to provide 3D exposure (i.e. avoiding simple straight vertical cliff acquisitions) representative of the local expression of the Entrada Formation. The localities are also targeted to maximise the coverage of strata bounded the J2 and J3 unconformities of Pirpiringos and O'Sullivan (1978).
The synthesis of this multiscale investigative approach allows the rapid assembly of large volumes of quantitative data spanning foreset to system scale. This data subsequently informs parent dune reconstruction, (here the internal architecture of the Slickrock Member of the Entrada is a major focus) and revised depositional models. The project will result in improved geocellular models for wet aeolian systems at the micro (facies), meso (bedform) and macro (system) scales.

Reconstructing deep ocean circulation pathway and strength with grainsize-specific Nd isotopes on the lithic fraction of marine sediments

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Changes in ocean circulation played a key role in deglacial climate change, however the physics of past deep ocean circulation is difficult to reconstruct. We present initial results of a new approach to constrain past North Atlantic Deep Water (NADW) circulation pathway and strength based on the advection of detrital sediment of different grain sizes whose source is constrained by Nd isotopes, trace element composition, and mineral magnetics. The North Atlantic has strong lithological contrast due to young volcanics in Iceland and ancient continental crust in Greenland. The modern vigorous Deep Western Boundary Current effectively distributes sediments derived from these terranes horizontally along the flow-path of NADW. Because the finer size fractions are transported further than coarse fractions, the distribution of fine Icelandic-derived sediments along the DWBC reflects deep ocean circulation pathway, strength, and sediment input.We present a comprehensive data set of Nd isotopes, REE concentrations, and magnetic mineralogy on samples from 14 North Atlantic cores which have been separated into 6 distinct sediment grain-size fractions (0-4 μm, 4-10 μm, 10-20 μm, up to 40-63 μm) granulometrically constrained by Coulter Counter and SEM. For the Holocene samples and periods of fast circulation, the DWBC core-sites have a high Icelandic component in their finest fractions which was transported great distances by strong circulation, while the coarser fractions are locally derived. Deglacial timeslices show marked changes in the Nd isotopic spectra across grain-sizes with spatial patterns indicative of slower circulation or greater detrital input.

Stratigraphy and reservoir quality of the Permian in Northern Ireland.

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The Larne and Lough Neagh basins in Northern Ireland contain thick Mesozoic to Cenozoic successions. The Permian aged rocks within the basins include volcanics, sediments and evaporites in excess of 1.2 km thick. In the deepest parts of the basins, exploration wells have not fully penetrated the base of the Permian strata. The condensed outcrop section at the basin margins and the paucity of deep boreholes has led to correlation across the basins being problematic. In the absence of reliable correlation between wells, a number of informal stratigraphical names have been proposed in the past. In all sections however, the Permian of Northern Ireland is divisible into two groups, a lower Enler Group (Early Permian) and an upper Belfast Group (Late Permian). The Enler Group is represented by sandstones, breccias and conglomerates, with volcanics proven in the middle of the Larne Basin. The Enler Group is unconformably overlain by the Belfast Group, which comprises mudstones, sandstones, an equivalent of the "Magnesian Limestone" and locally thick evaporites (halite and anhydrite). To date there have been no detailed petrographical studies of Permian sandstones from Northern Ireland and there are sparse reservoir quality data from a three metre core in the Larne No.2 well and a nine metre core in the Newmill No.1 well. This study presents a revised stratigraphy for the Permian of the Larne and Lough Neagh basins and provides new petrographical and reservoir quality data and observations for the Early Permian part of the succession. The results suggest that Early Permian sandstone reservoirs in these basins represent good targets for hydrocarbons or deep geothermal exploration.

Deglacial history of the Anvers Palaeo-Ice Stream Trough, western Antarctic Peninsula

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To predict the future behaviour of polar ice sheets in a warming world, it is important to understand how ice sheets and ice streams respond to changes in climate and sea level. By reconstructing the cause and style of ice stream retreat following the Last Glacial Maximum (LGM; ca. 23-19 ka BP), we can gain a greater insight into the future dynamics of modern day ice sheets. It is possible to achieve such reconstructions by investigating sedimentary sequences deposited during the LGM and the subsequent deglaciation on polar continental shelves. This project focuses on the deglacial history of the Anvers Palaeo-Ice Stream Trough, western Antarctic Peninsula shelf. Sediment types deposited during ice stream retreat are difficult to interpret and, as a consequence, the reconstruction of the processes that led to their deposition is often challenging. This is due to the complex and highly variable processes occurring proximal to the grounding line of ice streams. This project will utilise a multi-proxy approach to analyse sediment facies produced during the LGM, the subsequent deglaciation and under post-glacial, seasonally open-marine conditions. Different transitional lithofacies are formed between the grounding line of an ice stream and the open marine environment when an ice shelf is present or absent. The analysis of these transitional sediments in cores can therefore be used to reconstruct the style of retreat. Sub-ice shelf sediments are characterised by low biogenic content, due to reduced photosynthesis, and low grain size. In this study proxies for primary productivity have been used to show the absence of an ice shelf in the mid to outer-trough during the last deglaciation. Improving our understanding of the depositional and environmental setting at the time of ice stream retreat will ultimately help to test and improve ice-sheet models aiming to predict the future dynamics of ice sheets.

Mixing in axisymmetric gravity currents

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The entrainment of ambient fluid into an axisymmetric, turbulent gravity current is examined in this study. The current is produced by a rapid release of a finite volume of aqueous salt solution from a lock length r_0 into a diverging channel, $r > 0$, filled with a finite depth, H, of fresh water. This resembles the evolution of gravity currents in the absence of a confined channel, such as turbidity currents when they exit a submarine canyon to an abyssal plain. Experiments using dye tracers show the dense fluid reaches the nose of the flow, rises up, mixes with the ambient and moves backwards relative to the nose forming a circulation in the head region. The evolving density and the volume of the flow are measured using a light attenuation technique. We found that the volume of the current grows, due to mixing with the ambient, as $V \sim 0.2 r_n^{\frac{7}{4}} r_0^{\frac{1}{4}} H$, while the maximum depth decreases as $h_n \sim 0.5 H (r_0/r_n)^{\frac{1}{4}}$ where r_n is the location of the nose. From these results, we estimate that recirculating current fluid mixes with a fraction $E = 0.33 \pm 0.09$ of the ambient fluid that is directly ahead of the current and displaced upwards by it. The front position was found to advance as $r_n \approx (1.28 \pm 0.05) B^{\frac{1}{4}} t^{\frac{1}{2}}$ where B is the total buoyancy of the flow. We further determine the maximum vertical integral of the buoyancy $\left(\overline{g'}h\right)_n$ to measure the dilution rate and found it to decrease as $\left(\overline{g'}h\right)_n \approx (0.89 \pm 0.12) B r_n^{-2}$ which is consistent with the Froude number estimated for these currents. The experimental results are compared with a new idealised self-similar solution of depth-averaged equations that accounts for this mixing process and the vertical shear in the velocity and the lateral stratification of the buoyancy within the current.

The Fluvial Architecture of the Price River Formation, Mesaverde Group, Book Cliffs, Utah, U.S.A.

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The Price River Formation is one of a number of the Campanian-aged formations within the Mesaverde Group exposed in the Book Cliffs, Utah. The thickness of this formation was identified to be 620 ft. between Castlegate Sandstone and North Norn Formation along the Price River Canyon. The formation is characterised by laterally amalgamated channel belts and separated by poorly exposed flood plain in varying proportion. Variations in Architecture and lithofacies of the formation allow an understanding of the fluvial system response to controlling factors such as base level variation. This study is focusing on the analysis of the architectural elements, lithofacies and paleocurrent data with the aim of characterising the factors that influence sand body development. A number of logged sections and photo panels were taken from well-exposed outcrops along the Price River Canyon and nearby canyons and creeks. A series of well-log correlation panels from coal bed methane wells drilled throughout the study area were constructed and allow the direct calibration of outcrop data to the subsurface. The data gathered from outcrops and subsurface is important in defining the position of the Formation in Distributive Fluvial System (DFS) context. Initial results show that the lower part of the Formation is dominated by amalgamated channel belts and the upper part by isolated channels and floodplain facies. The Channel and in-channel architectural elements and their lithofacies were identified. The channel lithofacies are dominated by medium-grained crossbedded sandstone, whereas, massive mud/silt and very fine sandstone with paleosol properties were observed within the floodplain. The upward increase of floodplain facies and the decrease of the channel facies within the formation is probably due to the base level change. This can explain the retrograding fluvial system that conforms to established DFS model.

Breaching Failure of Underwater Sediment Embankments

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Submarine slope failure is an important mechanism that releases sediments stored on the continental shelf into the deep sea. Granular materials are known to change volume when sheared. When the sheared material is saturated with a fluid, the change in volume is associated with fluid motion and pore pressure gradients. Submarine slope failure can only be treated by combining sedimentology of underwater deposits with geotechnical treatment of embankments, and fluid flow in porous media.

The purpose of this study is to expand the knowledge on the mechanics of submarine slope failure and understand how sediments are released from the deposits. The initial soil composition has a dramatic influence in the way a flow slide starts. Failures can be triggered in loose sand through liquefaction, or in denser sand, where flow slides might be initiated through breaching characterized by slow release of sand grains. Breaching events are considered the prime mechanism to release sand from embankments and the source mechanism of sustained turbidity currents.

A set of experiments is performed in the Eurotank Flume Laboratory (Utrecht University) to study erosion, transport and deposition of sand during breaching failure. Previous experiments have simplified underwater embankments, neglecting the effect of deposit stratification, clay laminations and deposit geometries. Therefore, porosity, geometry and heterogeneity of the embankment are components to handle in order to investigate these processes. We will focus on the excess pore pressure that controls the slope failure, the retreating velocity of the breaching front and the turbulent particle suspension in the gravity current travelling from the breach surface into the basin. The negative excess pore pressure gradients may become sufficiently large to support vertical failure faces in non-cohesive, un-cemented fine to very-fine grained sand.

Slope failures in dilative deposits are an important mechanism on the morphology on the Earth surface.

Cosmogenic nuclide concentrations in Neogene rivers of the Great Plains reveal the evolution of fluvial storage and recycling

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The measurement of the duration of near surface residence of sediment grains from the stratigraphic record has huge potential. Geomorphological measurements using cosmogenic nuclides has enabled significant advances in understanding, however, their radiogenic half-life means they are not suitable for the stratigraphic record. Instead, we have applied the stable cosmogenic nuclide of ^{21}Ne to quartz-rich sediment to the rivers that have drained the southern Rockies during Neogene times. The Neogene sediments of Nebraska record rivers that flow from the Rockies eastwards into the Mississippi. This succession records episodes of incision and aggradation associated with regional tilting from 6 to 4 Ma and climate change. We sampled quartzite pebbles from Upper Miocene, Pliocene and modern river channels of the North Platte approximately 400 km from their mountainous source. The quartzite is derived from a single exposure of the Medicine Bow quartzites in Wyoming. The concentrations of ^{21}Ne in pebbles >400 km from their source are corrected for both non-cosmogenic accumulation at source. Based on 40 analyses of pebbles from these intervals, we demonstrate that approximately half of the pebbles record significant excess ^{21}Ne resulting from storage and transport, indicating a mixing of first generation and recycled pebbles throughout the succession. Furthermore, the numbers and concentrations of excess ^{21}Ne in the pebbles are comparable between the three time intervals indicating little change in the extent of storage and recycling of river sediment from late Miocene to present. These results represent the first application of stable cosmogenic nuclides to the stratigraphic record and point to a significant development in our ability to quantify sediment routing systems.

Image analysis of fluvio-lacustrine depositional environments, East African Rift: sedimentary architectures and relationship to rift stage

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Continental rifts are important areas of accommodation generation and sediment accumulation. Fluvial and lacustrine systems are major depositional environments within these settings; their arrangement and interaction is governed in part by complex rift-basin subsidence patterns, but also by other allogenic controls (e.g. climate) and autogenic controls (e.g. delta-lobe switching).
Although many qualitative models describing fluvial and lacustrine system interactions have been proposed previously, no systematic quantitative analysis of sedimentary architectures has hitherto been undertaken for these systems in rift settings using a relational database approach. This study aims to characterise variability of morphological and sedimentary expression of fluvio-lacustrine systems in continental rifts, from initiation to death.
Although aerial photography, satellite imagery and digital elevation data are widely used in geological studies, it is only in recent years that global-scale, high-quality imagery and elevation data have been made available by resources such as Google Earth©. This has allowed for systematic observation to formulate a global database of active continental rifts and their depositional environments.
Here, results of an image-based analysis of the East African Rift System (EARS) are presented to document the wide range of fluvio-lacustrine morphologies in continental rifts at various stages of development. Geomorphological maps have been constructed to determine facies distributions across rift basins. Datasets have been classified to categorize autogenic and allogenic factors that govern system evolution and accumulation, key to which is rift stage (initiation, linkage, climax, death). A database approach is used to relate system morphology and sedimentology to basin type.
Resulting models of rift evolution are being used to reconstruct palaeo-environmental evolution of a range of fluvio-lacustrine system types as rift systems evolve. Results have implications for characterising subsurface hydrocarbon reservoirs of fluvio-lacustrine origin in continental rifts, such as those of the Lake Albert Rift, Uganda, and the South Lokichar Basin, Kenya.

Lost in translation? Bridging the gap between lab and field– comparative studies of flume tank experiments and outcrop studies

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Turbidity currents are an important transport agent of sediment from the shelf to the abyssal plane. As direct observations are rare, our understanding of these currents depends largely on experimental and field studies. While experiments enable the study of flow properties, depositional characteristics, and stages of erosion and deposition, their translation to the large scales of natural systems is problematic. Outcrop studies permit the architecture and dimensions of turbidite systems to be assessed, but dynamic processes that shaped the static rock record have to be inferred through partly speculative interpretative frameworks. As direct translation from flume-tank experiments to outcrop and vice versa are not possible due to these differences in complexities of the systems, comparative studies need to 1) choose the appropriate scaling approach for the experiments, and 2) focus on observed trends (e.g. grain-fabric distribution) in similar fine/coarse grained settings rather than absolute quantifications.
Turbidity currents produce certain grain-fabric distribution trends depending on their properties and the topography they interact with. These textural trends in deep-marine sub-environments can be compared and integrated between experiments and the field. While still in its infancy, this approach has shown promising results for 1) channel-levee composition, and 2) depositional patterns at the break-of-slope. The main advantage of this methodology is that the experimental work allows us to systematically investigate the effects of changing a single variable (e.g. slope angle) on depositional trends, while outcrop studies serve as validation tool for the modelled results. Once validated on the basis of depositional characteristics, the links between these features and flow structure can be investigated more rigorously. The ultimate goal of this is to develop tools to predict: 1) flow characteristics of turbidity current; 2) sediment partitioning and depositional volumes in modern and ancient settings.

Clinoform degradation, mass-transport complex (MTC) emplacement, and the healing of outer-shelf relief: a 3D seismic reflection case study from the Santos Basin, offshore Brazil

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Sediment is typically delivered to submarine slopes by a combination of wave-, tide- and river-processes that prograde across the slope to the shelf edge, and strike-fed slope belts. Both of these processes drive the construction and progradation of continental margins. However, slope degradation and collapse is also a common process on many continental slope margins, resulting in remobilisation of previously deposited material down slope. Our understanding of how these process vary in time and space, and how they contribute to the development of continental margins, has been greatly enhanced by field-based studies. Commonly, however, these studies are limited to observations from broadly two-dimensional outcrop belts. Here we use a 3D seismic reflection survey located in the Santos Basin, offshore Brazil, to investigate the role that outer shelf-to-upper slope collapse, mass-transport complex (MTC) emplacement, and subsequent slope reestablishment have on margin progradation. These data image a series of early Palaeogene, south-eastward prograding clinoforms. Periodically, large tracts of the outer-shelf-to-upper slope collapsed, forming a strongly scalloped margin. Margin collapse resulted in the emplacement of at least two slope-attached MTCs on the proximal basinfloor. The basal surface of the lower MTC is characterised by deep (c. 10 m), slope parallel grooves, whereas more irregular relief defines the top of the composite MTC body. Within the MTCs, we identify a range of kinematic indicators indicative of extension and compression within the body of the parent flow during translation and arrest. Margin collapse generated accommodation on the outer shelf-to-upper slope; this accommodation was healed by clinoforms that nucleated at the headwall scarp, and prograded basinward, downlapping onto the underlying MTCs. We show that numerous degradational and constructional processes drive net-progradation of continental margins, and that 3D seismic data is a key tool in documenting the associated processes and their products.

The effects of fluvial architecture on the internal heterogeneity of a medial distributive fluvial system outcrop, Upper Jurassic, Colorado

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The Upper Jurassic Salt Wash distributive fluvial system (DFS) exposed in southern Utah and western Colorado is approximately 550 km in length and comprises clear proximal, medial and distal facies. The proximal portion of the system comprises over 70% net channel sandstones with only minor floodplain preserved. Medial DFS exhibits 40-70% net channel sands with minor amalgamation and thick, laterally extensive floodplain deposits. Distal DFS deposits include thick floodplain successions with minor isolated and unconnected channels (<40%). A strength of the DFS model is that it allows prediction of likely sand body thickness, distribution and net to gross within a basin-scale context. However, knowledge of sandstone body variability particularly with respect to architecture and connectivity specific to proximal, medial and distal parts of DFS are lacking, including smaller scale outcrop specific heterogeneity changes within multistorey sand bodies. This study uses an outcrop from the medial part of a DFS with a net gross of 43% to document lateral changes in fluvial channel belt sand body architecture and heterogeneity.
Preliminary results show that small scale sedimentary features within high net channel sands can cause porosity and permeability barriers for fluids if these sandstones were targeted as a form of reservoir. Storey surfaces, mud drapes and bar deposits all create internal complexity to the channel sandstones and will ultimately restrict fluid flow. Understanding the storey surface dimensions is crucial to understanding porosity and permeability distribution within the channel belts. With the use of LiDAR and sedimentary logs it is possible to constrain the variability of internal architecture elements by measuring heights, thicknesses and lengths of sedimentary features within the medial fluvial channel belt. Storey surfaces within the channel belts in the medial DFS have a width:height ratio of approx. 37:1 and can have a 10cm thick mud barrier across the entirety of the surface which, if replicated in the subsurface, could have a significant effect on vertical connectivity.

Diagenetic evaluation of Pannonian lacustrine deposits in the Makó Trough, southeastern Hungary

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The Makó Trough is the deepest sub-basin of the Pannonian Basin. As a possible shale gas and tight gas accumulation the area was explored by several hydrocarbon companies. In this study, we present the preliminary results on the diagenetic history and the porosity evolution of sandstones and shales. Petrographic (optical microscopy, CL, blue light microscopy) and geochemical methods (SEM-EDX, WDX, O and C stable isotopes) were applied on core samples of Makó-7 well (3408- 5479 m).
Processes which influenced the porosity evolution of the sandstones were compaction, cementation, mineral replacement and dissolution. The most common diagenetic minerals are carbonates (non-ferroan and Fe-bearing calcite, dolomite and ankerite), clay minerals (kaolinite, mixed layer illite-smectite and chlorite) and other silicates (quartz and feldspar). Initial clay mineral and ductile grain content also influences reservoir quality.
The volumetrically most significant diagenetic minerals are calcite and clay minerals. The petrography of calcite is variable (bright orange to dull red luminescence color, pore-filling cement, replacive phases which are occasionally scattered in the matrix). The δ13 C-PDB values of calcite range from 1.7 ‰ to -5.5 ‰, while δ18 O-PDB values range from 0.5 ‰ to -9.1 ‰, no depth related trend was observed. These data suggest that calcite occurs in more generations, i.e. eogenetic pre-compactional and mesogenetic post-compactional. Kaolinite is present in mottles in size similar to detrital grains, where remnants of feldspars can be seen. This indicates feldspar alteration via influx of water rich in organic derived carbon dioxide. Secondary porosity can be observed in carbonates and feldspars at some levels, causing the improvement of the reservoir quality.

High-temperature silica maturation causes non-equilibrium isotope fractionation beneath the El Indio paleofumarole: implications for diagenesis

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This study used *in situ* geochemical microanalytical techniques – sensitive high resolution ion microprobe for stable isotopes (SHRIMP SI), 157nm laser ablation inductively coupled mass spectrometry (LA-ICP-MS), cathodoluminescence imaging and electron microprobe element maps – to investigate the chemical evolution of trace elements and oxygen isotopes in quartz during high temperature silica maturation beneath the El Indio fossil fumarole system in Chile.
Clusters of quartz microcrystals from El Indio preserve residual metastable silica hydrates, and record the progressive maturation from amorphous silica hydrate (32-63% H_2O), to cryptocrystalline opal ± moganite, and eventually to anhydrous, double-terminated quartz microcrystals. As the silica polymorphs increase in crystallinity, water is progressively released from the structure of silica hydrates. This progressive dehydration of silica polymorphs results in non-equilibrium fractionation of $\delta^{18}O$, as ^{16}O is preferentially enriched in the liberated fluid, thus residual anhydrous quartz is enriched in $\delta^{18}O$.
Anhydrous, euhedral quartz crystals are very small (~250μm-2.5mm), but record complex oscillatory zonation of $\delta^{18}O$ from 3.6-16.2‰ (± 0.5‰), as well as oscillatory zonation of K and Al. One 300μm crystal contained a $\delta^{18}O$ range from 3.6-14.3‰. No correlation was found between $\delta^{18}O$ and Al or K content of the quartz host, texture or distance from the crystal rim.
El Indio is a useful case study, because here, silica hydrate was deposited in a feeder zone beneath a fossil fumarole field at ~480-680°C – so the system was only exposed to high temperatures (accelerating silica maturation) for a brief period of time, then quenched, allowing residual silica hydrates to be preserved. As temperature only affects the rate of maturation, these data aid our understanding of the chemical processes that occur during low-temperature silica diagenesis as well.

Criteria for the recognition of supercritcal bedforms and its implications on reservoir heterogeneity, insights from fieldwork-based studies, Morillo and Guaso Systems, Ainsa basin, Spain

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A new approach to understanding the development of submarine fans is to consider the importance of deposition from supercritical and subcritical flows. Previous work has suggested that for submarine slopes with gradients of > 0.5°, common to many deep-water slopes, contain abundant evidence of supercritical flow. Recently, the combination of seafloor observations with numerical and physical experiments has revealed that sediment gravity flows often contain the described structures in proximal sections. However, most deep-water sandstones are routinely modelled using the Bouma sequence for turbidites which fail to incorporate supercritical bedforms, such as antidunes, chutes and pools and cyclic steps. In light of this, fieldwork in the Middle Eocene Ainsa basin was undertaken, providing world class, 3-dimensional outcrops. Around 5000 beds in the Morillo and Guaso system have been measured in detail, paying particular attention to grain size, sedimentary structures and facies of individual beds. Analyses of this data, linked to sedimentary structures and facies in individual beds and bedsets can inform a criteria for the interpretation of supercritical bedforms. Subsequently the subcritical beforms can be re.evaluated.. Geostatistical analysis of these beds and bedforms is undertaken for the coarse-grained deposits, with any trends possibly relating to flow hydrodynamics, initial sediment volumes and source migration. The results of this research will contribute to an improved understanding of the processes in deep-marine systems, and directly benefit the hydrocarbon industry by providing better constraints to predict deep-water reservoir composition and architecture.

Mineral precipitates in modern microbial mats: crystallites, spheroids and the role of EPS

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Reports of dolomite occurring within microbial mats relate precipitation to microbial activities and associated EPS (mucilage). Other minerals precipitated include calcite (low-Mg, high-Mg, very high-Mg), aragonite, clay minerals and pyrite. In modern high-intertidal microbial mats from Qatar, TEM analysis shows mineral precipitation beginning in the topmost layer with an amorphous Mg-Si-Ca material forming within EPS around bacteria. With time and depth of burial within the mat, this develops into Mg-Si clay fibres and Ca-Mg-CO_3 crystallites. Calcite crystallites grow from a nano-point of nucleation to form conical bundles, splaying out 20-30°. Growth in two or more directions leads to dumbbell to stellate structures. The cones develop a triangular and then hexagonal shape, and eventually terminations form to give nail-head-type (rhombohedral) calcite crystals, 5-30 microns in length. Spheroidal structures within the mat vary from perfect spheres to more commonly being imperfect, almost with flat sides and edges, in some cases coalescing to form compound structures. There appear to be 2 sizes, nano-spheres and micron-spheres. The larger spheroids (0.5-2 microns, 'micropearls') could well be permineralised bacterial-algal cells, or coccoid bacteria themselves, whereas smaller ones (10s-100s of nm) may be permineralised viruses or bacterial vesicles, or simply the initial amorphous precipitates. Lower in the mat, felted layers of palygorskite-type fibres have an undulating, sheet-like form, similar to EPS. In the Qatar mat dolomite is present as micron-sized rhombs. The source of silica for the Mg-silicates could be wind-blown dust or diatoms, and the Mg-Ca from seawater. Silica dissolution-Mg silicate precipitation, and carbonate precipitation, are likely to have been driven by pH-SI-redox changes within the mat, related to micro-environmental changes induced by the microbes and their (+EPS) degradation.

Thermal history modelling in an extensional basin

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Temperature plays an important role in many geological phenomena. In sedimentary basins, maturation of hydrocarbon source rocks depends on the temperature history after deposition. Sedimentation rate, geothermal gradient and duration of sedimentation are therefore key parameters controlling the thermal evolution. The McKenzie model is a widely accepted model for extensional basin formation which can be used for estimating post-rift subsidence and rate of sedimentation.
In this work, a numerical model in 1D has been implemented based on McKenzie's model and allows the estimation of the thermal evolution of post-rift sediments and the rate of subsidence. The finite difference method is used to solve the heat equation in the sediments, crust and upper mantle. At each time step, subsidence due to thermal relaxation is calculated and added to the system. In this way the generalised moving boundary thermal diffusion problem is solved. Heat generated due to radioactivity may also be taken into account.
The numerical model when compared to the McKenzie model gives significantly lower thermal subsidence. Maximum possible thermal subsidence for the two models are compared with respect to the stretching factor. It shows a significantly higher stretching is required to achieve the same level of thermal subsidence when compared to the McKenzie model. For example in the McKenzie model a 5 km of thermal subsidence is achieved with a 280% stretching whereas the numerical model require 450%.
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The effect of early compaction on detrital grain-coating clays

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Grain-coating clays, predominantly chlorite, are generally perceived to play a key role in the preservation of porosity in deeply buried hydrocarbon reservoirs by preventing the formation of quartz cement. Well-known examples of these highly porous reservoirs are present on the Norwegian continental shelf. Early detrital grain-coating clays are often interpreted to be pre-cursors for these authigenic, porosity-preserving grain-coating clays. However, the stability of both the detrital and authigenic grain-coatings and how they can survive to deep burial depths remains poorly understood. This is especially important because the coverage of the grain-coating clays is key to their porosity-preserving potential. In order to better understand the effects of early compaction on detrital grain-coating clays, tri-axial compaction tests were carried out on clay-coated, surface sediment samples from the Ravenglass Estuary (Lake District, UK). Six samples, taken from two mud-flat localities, were prepared and four of these were subjected to normal loads of either ~3 MPa or ~6 MPa, roughly comparable to the pressures at burial depths of 175 m and 350 m respectively. After the triaxial experiments thin section samples were prepared. Subsequent analysis consisted of standard and backscatter microscopy and SEM-EDS analysis to study textural changes.The uncompressed samples show very similar grain-coating clays and textures to samples from similar locations in the estuary that have not been subjected to the sample preparation process. Early results show that at burial depths up to 350m most detrital grain-coating clays remain intact, but in some cases can break up or become detached from the quartz grains. These results have implications for understanding the formation of authigenic grain-coating clays at depth and the potential of these clays to prevent the formation of quartz cement.

Geochemical signals associated with 'marine band' formation in the Lower Carboniferous Bowland Shale Formation, Northern England.

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This project analyses the organic matter quality and thermal maturity of Bowland Shale Formation (BSF) marine bands in order to interpret conditions that promoted marine band formation. Organic-rich and goniatite-rich so called 'marine bands' are used as stratigraphic markers in outcrop and core and so understanding their formation and the factors that control their lateral extent is not purely of academic (e.g. palaeoceanographic) but of industry interest.

At present, marine bands are identified using their goniatite content (Andrews 2013; Church and Gawthorpe 1994; Waters et al. 2009) and may be associated with high gamma signals. The reliability of biostratigraphy and petrophysics is improved when used alongside sedimentology and geochemistry. Organic geochemistry can also be used to indicate water column stratification, terrigenous input, bottom water redox conditions and eogenetic processes (Peters and Moldowan 2005) whereas fossils are used to interpret the preservation extent, rate of evolution and mesogenetic compaction. Insight into the controlling factors that promote the formation of two or three of these BSF marine bands will allow high resolution correlation and characterisation across the basin. More than one marine band must be studied as it is likely that each is controlled by a number of factors to varying degrees.

The interpretations will be extrapolated and will be used to better characterise the Bowland Basin as a whole during the Mississippian. This project therefore aids prediction of the lateral extent of organic matter quality.

Fluvial response to sea-level change: revised sequence stratigraphic models for different basin and climatic settings

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In the 1980s and 1990s numerous models were proposed which argued that allogenic controls such as relative sea level and climate exerted a dominant control on preserved sedimentary architecture. This thinking is embodied in widely applied sequence stratigraphic models, including those developed for fluvial systems. Yet, a wide range of autogenic factors are known to additionally determine the proportion, geometry and spatial distribution of fluvial sandbodies accumulated in the preserved rock record. Identifying and quantifying the nature and impact of interdependent allogenic and autogenic controls, and their relationships are not straightforward: the preserved record of fluvial successions is highly varied.

A database approach is used to investigate fluvial response to sea-level change, a primary control on fluvial systems. Specific objectives are to (i) compare fluvial systems that accumulated in different phases of relative sea-level cycles; (ii) consider the range of controls of autogenic origin that govern fluvial successions; (iii) develop a set of revised sequence stratigraphic models for different basin and climatic settings, which account for interplay of both autogenic and allogenic controls.

The applied method utilises quantitative data extracted from literature-based case studies. Lithofacies and architectural element data are coded in a standardized format into the Fluvial Architecture Knowledge Transfer System (FAKTS), a relational database that stores many examples of fluvial successions. Database interrogation enables recognition of differences in preserved stratigraphic architecture between fluvial successions accumulated in different settings.

Initial results assess differences between fluvial successions accumulated on sub-aerially exposed continental shelves at lowstand and those in continental hinterlands, and within different systems tracts. Characteristic differences pertain to the scale and stratigraphic organization of fluvial architectural elements. Results form the basis for the development of a series of context-specific models which describe the process response of fluvial architecture in different types of physiographic, basinal, and climatic settings.

Characterising the variation in heavy and light mineral modes from some of Indonesia's most explosive volcanoes (Merapi, Bromo, Sinabung and Toba)

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Samples of volcanic ash were collected from three of Indonesia's most active volcanoes (Mt. Merapi, Mt. Bromo and Mt. Sinabung), together with ash from the ancient Toba supereruption. QEMSCAN was used to identify 20,000 heavy and 20,000 light mineral grains from each sample. These data were used to identify similarities and differences between each of the volcanic sources, and show marked differences between the ashes sourced from the Javanese volcanoes compared to those sourced from the Sumatran volcanoes. We also examined zircon aspect ratios for the samples where zircon was present. Previous workers have proposed volcanic zircons are typically acicular, yet our own observations of zircon-bearing igneous rocks suggest that this is not always the case. The QEMSCAN analyses were also used to estimate the overall grain-shapes and ellipticity of the mineral grains in each sample. However, as these analyses were obtained from polished grain mounts, the results on the morphology of each grain reflect the grain shape and orientation exposed through polishing, meaning that the assigned grain morphology attributes can only be used in an approximate sense. To build on this, we made unpolished grain mounts of heavy mineral separates for SEM imaging and semi-quantitative (EDS) mineral identification. The EDS was used to identify zircon grains and we manually classified all zircon according to their aspect ratio. This work shows that there can be considerable variation in aspect ratios of volcanic zircon and that not all arc volcanic ash contains zircon. The outcomes of this study demonstrate that care is needed when considering possible volcanic sources for detrital studies, particularly for ancient sedimentary rocks and in regions with extremely high uplift/erosion rates where the original volcanic source may no longer be evident.

Alluvial fan sensitivity to glacial-interglacial climate change: Case studies from Death Valley.

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The effects of climate change on eroding landscapes and the sedimentary record remain poorly understood. The measurement of grain size trends in stream-flow dominated deposits provides one way to address this issue because these trends embed information on the dynamics of sediment routing systems. Fundamentally, downstream stratigraphic fining is driven by selective deposition of sediment. The efficiency of this process is determined by the physical characteristics of the input sediment supply and the spatial distribution of subsidence rate, which generates the accommodation necessary for mass extraction.
Here, we measure grain size fining rates for alluvial fan systems in Death Valley, California, which have well-exposed modern and late Pleistocene deposits, where tectonic boundary conditions are known and where climatic variation is well-constrained. Our field data demonstrate that alluvial fan grain sizes and downstream fining rates clearly vary over the late Pleistocene in this study area, despite little evidence for significant changes in rates of faulting in the last 200 ky.
Two of these fan systems have well-exposed terraces dating to 70 ky—when the climate was 30% wetter than at present—as well as modern deposits. We apply a self-similar fining model to explore changes in sediment flux to the fans between these particular time periods. Our results show a 20% decrease in sediment flux and a clear increase in the down-fan rate of fining as the climate warmed and dried. This supports landscape evolution models that relate a decrease in precipitation rate to a decrease in sediment flux, but implies this relationship may be non-linear. Consequently, this study shows that alluvial fan stratigraphy can be highly sensitive to rapid climate changes and can be reconciled with numerical models. However, climatic sensitivity is lost when sediment is recycled over a time period longer than the duration of the climatic perturbation.

Sedimentological and ichnological analysis of the Upper Carboniferous Bude Formation, Culm Basin, SW England

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The palaeoenvironment of the Upper Carboniferous Bude Formation has been controversial for decades, despite excellent exposure on the Cornwall and north Devon coasts. Previous interpretations have ranged from deep marine to freshwater lake; if the Bude Formation is lacustrine, it represents one of the oldest known inhabited lake environments.
In this study, trace fossil and geochemical evidence were integrated into a sedimentological model to constrain sediment transport mechanisms, environmental setting and extent of marine influence. Ichnological and sedimentological data were collected during original fieldwork in Cornwall and Devon. Trace fossils were identified and compared to other Palaeozoic assemblages, and showed similarities to known freshwater lacustrine environments. Seventeen ichnotaxa were observed in siltstones deposited by gentle underflow currents. In contrast, graded event beds were deposited by turbidity flows, with occasional burrows observed in bed-tops. Geochemical analysis suggests the siltstones were deposited in freshwater, whilst marine conditions prevailed during deposition of black shales.
A predominantly freshwater lacustrine environment is proposed for the Bude Formation, with sediment transported into the basin by underflow and turbidity currents. Marine incursions recorded in black shales occurred during extreme highstands which led to overtopping of the lake sill. Further work should include denser sampling for geochemical analysis, which may be able to constrain individual marine incursions.

Anastomosing fluvial systems in the Tournaisian? An investigation into fluvial systems of the Lower Carboniferous, Ballagan formation, Scotland

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The Tournaisian Ballagan Formation, exposed along the coast in South East Scotland, provides a unique insight into early Carboniferous fluvial systems and terrestrial ecosystems recovering from the Hangenberg Crisis. These fluvial systems reflect the palaeoenvironmental and palaeoclimatic conditions during deposition.
Studied as part of the TW:eed project (Tetrapod world: early evolution and diversification), this investigation has included extensive sedimentary logging of several fluvial sandstone bodies, and mapping of these bodies on LiDAR, Hexicopter, ArcGIS and other photographic imagery. Field observations are complemented by palaeosol data generated as part of the wider project and by secondary quantitative analyses.
The study examines several fluvial sandstone bodies. The stratigraphically lowest is a 14 m thick sheet braid system. This is overlain by a 20 m thick interval of floodplain strata hosting numerous isolated sandstone bodies with the characteristics of anastomosing fluvial system deposits. This 'isolated sandstone bodies' interval coincides with the occurrence of gleyed inceptisols, typical of an extremely wet floodplain environment. An overlying series of dolostone beds indicate repeated floodplain submergence. The youngest sandstone body of the studied succession is a 20 m thick meandering system.
The isolated sandstone bodies would be the oldest anastomosing systems yet described. The results of this investigation should provide additional criteria for the identification of anastomosing fluvial deposits in the rock record. The study examines whether vegetation is a predominant control on fixed channel formation in these early Carboniferous successions, as widely accepted.

A Stratigraphic Model of Fluvial Meander-Bend Evolution for 3D Facies and Architecture Prediction

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Sinuous, meandering, channels characterise the lower reaches of many fluvial systems. Although fundamental types of meander-bend transformations have been recognised (expansion, translation, rotation, and combinations thereof), the relationships between the migratory behaviour of a river and the geometry and lithofacies organisation of deposits that arise from channel migration (e.g. point bars and counter point-bars) remain relatively poorly understood. Stratigraphic successions of fluvial depositional elements are commonly characterised by vertical and lateral facies heterogeneity that is indicative of highly variable mechanisms of accretion. Sand-prone packages are draped and partitioned by mud-prone deposits of variable thickness and continuity. Furthermore, at a larger scale, the morphology and preserved lithofacies of meander belts is influenced by both autogenic factors, such as frequency of nodal avulsion, and allogenic factors, such as climate-driven changes in sediment delivery and the role of differential subsidence in controlling direction and rate of meander-belt migration.
A numerical forward stratigraphic model – the *Point-Bar Sedimentary Architecture Numerical Deduction (PB-SAND)* – has been devised as a tool to help reconstruct and predict the complex spatio-temporal migratory evolution of fluvial meanders, their generated bar forms, and the associated lithofacies distributions that accumulate as heterogeneous fluvial successions. PB-SAND uses a combined process-based, geometric, and stochastic modelling approach. The modelling approach integrates quantified sedimentological data from real-world case-study examples stored in a relational database, the Fluvial Architecture Knowledge Transfer System (FAKTS). The model predicts the internal architecture and geometry of fluvial point-bar, counter point-bar and related elements in 3D.
One example application of PB-SAND is the simulation of fluvial response to coeval rift basin development, whereby point-bar connectivity and stacking pattern can be predicted in response to differential rates of fault-driven subsidence, accommodation generation, rates of fluvial-system lateral accretion and avulsion. PB-SAND serves as a practical tool with which to explore heterogeneity in subsurface hydrocarbon reservoirs.

Post-eruptive Submarine Terrace Development of Capelinhos, Azores

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Erosion of the coasts of volcanic islands by waves creates shallow banks. Subsided older versions of these features (guyots) have been targetted by scientific ocean drilling in the past so it may be useful to know more about how they originate, but how erosion proceeds with time to create banks and how it relates to wave climate is unclear. In this study, historical and recent marine geophysical data collected around the Capelinhos promontory (western Faial Island, Azores) offer an unusual opportunity to characterize how a submarine terrace developed after the eruption. The promontory was formed in 1957/58 during a Surtseyan eruption that terminated with extensive lava forming new rocky coastal cliffs. Historical measurements of coastline position are supplemented here with coastlines measured from 2004 and 2014 Google Earth images in order to characterize coastline retreat rate and distance for lava- and tephra-dominated cliffs. Swath mapping sonars were used to characterize the submarine geometry of the resulting terrace (platform edge position, gradient and morphology). Limited photographs are available from a SCUBA dive and drop-down camera deployments to ground truth the submarine geomorphology. The results reveal that coastal retreat rates have decreased rapidly with the time after the eruption, possibly explained by the evolving resistance to erosion of cliff base materials. Surprisingly, coastline retreat rate decreases with terrace width in a simple inverse power law with terrace width. We suspect this is only a fortuitous result as wave attenuation over the terrace will not obviously produce the variation, but nevertheless it shows how rapidly the retreat rate declines. Understanding the relationship between terrace widening shelf and coastal cliff retreat rate may be more widely interesting if they can be used to understand how islands evolve over time into guyots.

Seismic geomorphology linked to sequence stratigraphy of an Eocene shoreface in the Outer Moray Firth

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Geological analogues are commonly used to supplement sparse subsurface datasets, where widely spaced wells and low resolution seismic data limit direct observation of reservoir geometries. Analogue studies are traditionally based on outcrop data, which provides high quality cross-sectional information but is typically limited in plan view, or data from modern systems which provides excellent plan view information but is limited in the vertical direction.

The shallow, high frequency component of traditional 3D seismic volumes is typically ignored as studies are focused on reservoir depth. However, this is a massively underused resource of high quality geometric data that can be used as analogues for deeper, less well sampled reservoirs. The current study has focused on extracting data from these shallow portions of the PGS CNS/NNS MegaSurvey in the Outer Moray Firth. The study interval is an eastwards prograding Eocene shoreface succession which has been mapped in detail. Geomorphological measurements including width, length, thickness, clinoform dip and shoreline trajectory are taken to characterise the clinothems. All measurements are classified using the SAFARI data standard, which was developed to describe outcrop and modern reservoir analogues. A sequence stratigraphic interpretation was also carried out, based on mapping the shoreline trajectories.

Detailed mapping has broken the study interval into a series of bedsets and parasequences which equate to individual beach ridge sets. Mapping of the thickness of these illustrates the shifts in depo-centre. Measurements of clinoform dip and the rate at which they taper vary with different shoreline trajectories. Forced regressive clinothems show steeper bed tapering as well as higher clinoform dips than normal regressive or transgressive clinothems.

This case study achieves an overall improved understanding of the three-dimensional properties of a wave-dominated shoreface as reservoir analogue.

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