FRG ERG SMRG

UNIVERSITY OF LEEDS

Fluvial, Eolian & Shallow-Marine Research Group

Phase 5
Jan 2021 to Dec 2023

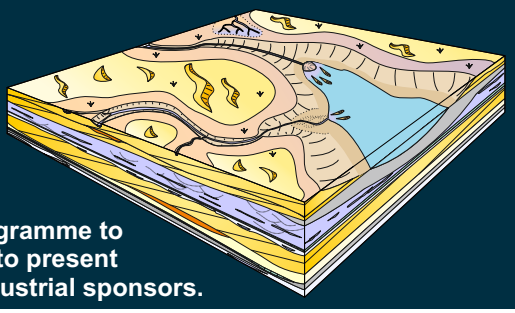
http://frg.leeds.ac.uk/

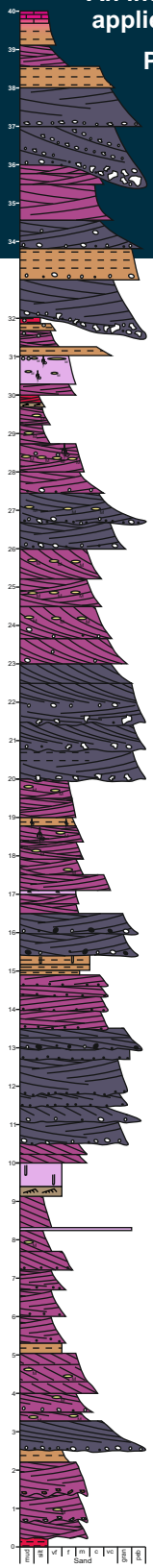
Internationally recognized research leader in the study and analysis of fluvial, aeolian & shallow-marine sedimentary systems and their preserved successions.

An industry facing research group integrating multi-disciplinary expertise in applied fluvial, aeolian and shallow-marine sedimentary research.

Principal aim: to conduct cutting-edge research into the application of fluvial, aeolian and shallow-marine sedimentology for developing a better understanding of issues relating to subsurface resource exploration, appraisal, development and production.

Specific objectives: develop a state-of-the-art knowledge transfer programme to distil current thinking and trends in applied sedimentology research; to present summary results and models in a format suitable for direct use by industrial sponsors.





Overview

A Joint Industry Project (JIP) research programme focussed on cutting-edge applied fluvial, aeolian and shallow-marine sedimentological research, with emphasis on characterization of subsurface sedimentary architecture, techniques for reservoir prediction, and a web-delivered Knowledge Transfer programme.

Principal FRG-ERG-SMRG 2021-23 Deliverables

- Company-wide access to:
  - Research results & knowledge transfer arising from the development and application of the world's largest databases of sedimentary architecture: the Fluvial Architecture Knowledge Transfer System (**FAKTS**), the Database of Aeolian Sedimentary Architecture (**DASA**), and the Shallow-Marine Architecture Knowledge Store (**SMAKS**)
  - Research results & knowledge transfer arising from the development and application of our specialist fluvial geomodelling software: **PB-SAND** (Point Bar Sedimentary Architecture Numerical Deduction)
  - Research results arising from our aeolian stratigraphic modelling software (**DuneModeller**)
  - Access to the entire back catalogue of research from all previous phases (> 1600 documents)
  - Searchable bibliographic database and recommended literature summaries
  - Digital online training and self-learning materials, video case studies and virtual outcrop guides
  - Cutting-edge novel and innovative approaches to reservoir modelling of sedimentary successions
  - Dedicated sponsors' meetings (e.g., Europe and USA)
  - Options for specially tailored field courses and training courses
  - Dedicated live and online webinar series

- Research outputs in:
  - Fluvial, aeolian & shallow-marine depositional models for subsurface prediction and correlation
  - Atlases depicting morphology of modern fluvial, aeolian & shallow-marine sedimentary systems
  - Process sedimentology
  - Novel and innovative approaches to subsurface reservoir characterization
  - External controls on fluvial, aeolian & shallow-marine sedimentary systems
  - High-resolution studies of fluvial, aeolian & shallow-marine stratigraphic architecture
  - Novel methods and techniques in sequence stratigraphy applied to subsurface successions
  - Seismic geomorphology
  - Quantitative numerical models for bridging the gap between sedimentological datasets and reservoir modelling workflows
  - Studies of tidally influenced fluvial, fluvio-deltaic and fluvio-lacustrine modern sediment systems, outcropping ancient successions and subsurface reservoir intervals
  - Software for numerical sedimentological & tectono-stratigraphic modelling and basin analysis

Membership & Costs

New sponsors are welcome to join at any time.
Full access to results from earlier phases.
Discounted rate for returning sponsors.
Get in touch at any time to discuss membership options (n.p.mountney@leeds.ac.uk).

Phase 1 – 4 Partners & Sponsors

Aker BP, Anadarko, Areva (now Orano), BHP, Cairn India (Vedanta), Chevron, CNOOC, ConocoPhillips, Equinor, Murphy Oil, NERC, Nexen, Occidental, Petrotechnical Data Systems, Saudi Aramco, Shell, Tullow Oil, Woodside, YPF

Fluvial, Eolian & Shallow-Marine Research Group
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University of Leeds, LS2 9JT UK

FAKTS and SMAKS are licensed by Petrotechnical Data Systems Ltd. (www.pds.group/ava-clastics)

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Research & Knowledge Transfer Programme: Deliverables

Research Outputs: The entire back catalogue of all research outputs from the Fluvial & Eolian Research Group over the past 20 years, plus outputs relating to shallow-marine sedimentology. This currently amounts to over **1600 documents** in the form of reports, theses, papers, posters, conference presentations, videos, knowledge transfer resources and software. Additionally, it includes summary metrics relating to sedimentary architecture and facies distributions for fluvial, aeolian, paralic and shallow-marine systems & preserved successions.

Bibliographic Database: A composite bibliographic database of fluvial, aeolian, paralic and marine references that brings together the search results from many different search engines, plus literature not caught by conventional searches, & provides a comprehensive list in one easy-to-search location. This database is updated regularly to incorporate all the latest research results. Books and special publications are being included, in addition to journal references.

Recommended Literature: Searchable lists of recommended reading where FRG-ERG-SMRG group members review the literature and recommend what we consider to be key papers in a variety of fields relating to fluvial, aeolian, paralic and shallow-marine literature.

FAKTS, DASA & SMAKS: Simple web-based access to the FAKTS, DASA and SMAKS relational databases that describe fluvial architecture. Geometrical properties of sedimentary architectural elements can be interrogated in a structured manner to filter out unwanted results, leaving only data that is of direct relevance for a given query.

Sponsors' Meetings: Dedicated online and in-person sponsors' meetings each year. The venue for person meetings will vary; typically Europe & USA (associated with international conferences; sponsor representatives to pay for their own travel and subsistence costs).

Atlas of Fluvial and Aeolian Facies: An annotated graphical encyclopaedia of facies examples for a wide range of fluvial, aeolian, paralic and shallow-marine systems and successions.

Fundamentals of Geoscience: A set of over 150 self-learning guides detailing everything from the basics of clastic sedimentology, to more detailed resources that provide guidance in the interpretation of fluvial, aeolian and shallow-marine stratigraphy, to guides detailing advanced concepts in sequence stratigraphy and correlation.

Workflows For Subsurface Interpretation: Guidance in how to design and implement workflows for the interpretation of subsurface fluvial, aeolian, paralic and shallow-marine successions.

Geostatistics: Examples of the application of novel geostatistical methods for subsurface characterization and prediction.

Taught Short-Courses: In-house bespoke taught short-courses available as an add-on.

Forward Stratigraphic Modelling Software: Access to fluvial and aeolian stratigraphic modelling software (e.g. **PB-SAND** and **DuneModeller**) for assessing likely reservoir heterogeneity; the software serves as a set of tools to assist with the development of reservoir models. Software start-up guides provide instruction on usage.

Company-Wide Access: All employees of the sponsor company worldwide gain access to the entire dataset and full set of resources, including the back-catalogue of research results from previous phases of FRG-ERG.

Rolling Programme of Research Projects: We will aim to start an average of 2 new PhD studentships or 1 post-doctoral research project per year; projects are designed to focus our research efforts in areas of applied sedimentology that are of primary interest to our sponsors.

Company Visits: Visits to the sponsor companies can be arranged as an add-on.

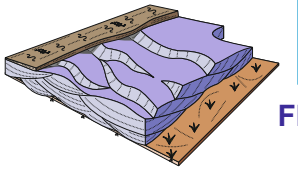
FRG-ERG Sponsor Field Trips: The option for members of sponsor companies to attend group field training courses to study a range of modern and/or ancient sedimentary successions, including fluvial, fluvio-deltaic, tidally influenced, aeolian and shallow-marine systems, depending on the interests of the sponsor companies. Trips will typically be to locations where FRG-ERG researchers are active.

Webinars: Regular programme of online talks and presentations; cover key topics in applied sedimentology.

Dedicated website: http://frg.leeds.ac.uk

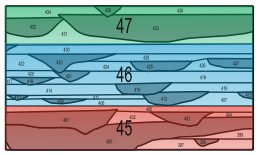
Above. Sandstone of shallow-marine origin recording transgression across coal-bearing, argillaceous coastal plain deposits, Cretaceous Neslen Formation, Utah, USA.

Research & Knowledge Transfer Programme: Deliverables



FAKTS

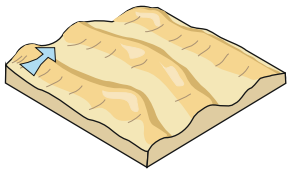
Fluvial Architecture Knowledge Transfer System



To enhance sponsor impact, FRG-ERG-SMRG has collaborated with external partner PDS to develop Ava Clastics, a product that enables direct coupling of FAKTS & SMAKS with modelling workflows: www.pds.group/ava-clastics

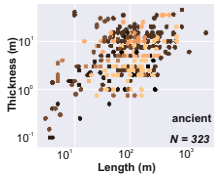
The **Fluvial Architecture Knowledge Transfer System** is a relational database tool for analysing numerical and descriptive data and information about fluvial architecture coming from fieldwork and peer-reviewed literature, from both modern rivers and their ancient counterparts in the stratigraphic record. The database encapsulates all the major features of fluvial architecture (style of internal organization, geometries, spatial distribution and reciprocal relationships of genetic units), classifying datasets – either in whole or in part – according to both controlling factors (e.g. climate type, tectonic setting), and context-descriptive characteristics (e.g. channel/river pattern, dominant transport mechanism). The database is populated with facies and architectural data taken from both the literature and derived from in-house field studies.

- Web-based front-end for simple FAKTS queries to enable derivation of quantitative output.
- Obtain width-thickness-length aspect ratio distributions for architectural elements (e.g. channels or splays).
- Calculate facies transition probabilities in both vertical and horizontal dimensions (parallel & perpendicular to palaeoflow).
- Track changes in proportions of facies or elements spatially within a depositional system.
- Filter search criteria to ensure that results remain highly relevant to the reservoir interval being characterized.
- Predict element shape & size as a function of independent external controls (climatic regime, basin type, subsidence rate).



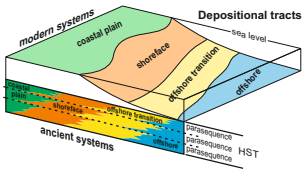
DASA

Database of Aeolian Sedimentary Architecture



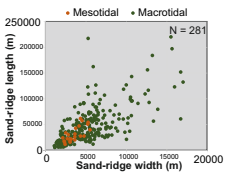
The **Database of Aeolian Sedimentary Architecture** records the architecture and spatio-temporal evolution of a broad range of modern and recently active aeolian systems, and of their preserved deposits in ancient successions. DASA currently stores data on >14,000 geologic entities relating to information on a variety of aeolian and associated non-aeolian entities of multiple scales (e.g., depositional, geomorphic & architectural elements, lithofacies, bounding surfaces), including attributes that characterize their type, geometry, spatial relations, hierarchical relations, temporal significance, and textural and petrophysical properties. Associated metadata are also stored (e.g., prevailing climate and tectonic regime, geologic age).

- Assess stratigraphic relationships between aeolian and associated fluvial, lacustrine and paralic depositional systems.
- Quantify the geometry of aeolian architectural elements, and hierarchical and spatial relationships between them.
- Calculate the probabilities of vertical and lateral transition from one type of aeolian deposit or landform to another.
- Consider the nature of aeolian bounding surfaces at different scales, and their nested, hierarchical relationships.
- Predict aeolian lithofacies types, proportions and distributions, and facies controls on grain-scale textural parameters.



SMAKS

Shallow-Marine Architecture Knowledge Store

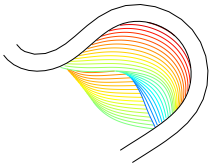


The **Shallow-Marine Architecture Knowledge Store** is a relational database devised for the storage of hard and soft data on the sedimentary architecture of ancient shallow-marine and paralic siliciclastic successions, and on the geomorphological organization of corresponding modern environments. The database allows incorporation of data from the published literature, which are uploaded to a common standard to ensure consistency in data definition. The database incorporates data on geological entities of varied nature and scale (i.e., surfaces, depositional tracts, architectural elements, sequence stratigraphic units, facies units, geomorphic elements), including attributes that characterize their type, geometry, spatial relations, hierarchical relations, and temporal significance. Geological entities are assigned to depositional systems, or to parts thereof, that can be classified on multiple parameters (e.g., shelf width, delta catchment area) tied to metadata (e.g., data types, data sources).

- Examine data from wave-, tide-, and fluvial dominated shallow seas, from backshore to shelf-edge settings.
- Quantitative characterization of modern and ancient shallow-marine and paralic clastic depositional systems.
- Serves as a repository of analogue information for subsurface reservoir successions.
- Can be applied to aid the development of depositional models for particular contexts.
- Assess the sensitivity of depositional systems to particular controlling factors.

Collectively, the three databases contain data relating to over 600 case studies.

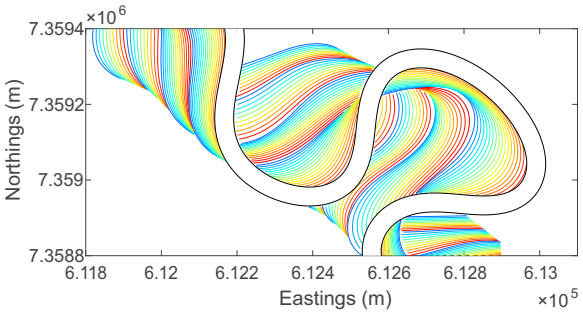
Research & Knowledge Transfer Programme: Deliverables



PB-SAND

Point Bar Sedimentary Architecture Numerical Deduction

The **Point-Bar Sedimentary Architecture Numerical Deduction** is a modelling tool for the reconstruction and prediction of the complex spatio-temporal evolution of fluvial meanders, their generated 3D lithofacies distributions and resulting heterogeneity. The model permits the reconstruction of point-bar geometries and internal sedimentary architectures using a deterministic approach to simulate accretion patterns as they evolve over a series of time steps. The input trajectories that control the planform morphology of point bars can be digitized from seismic images, from remotely sensed images of modern systems, or devised based on field observations of ancient outcropping successions.

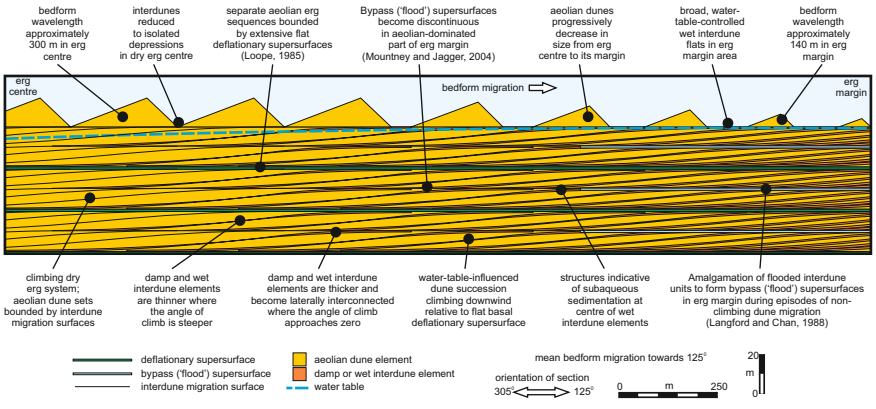


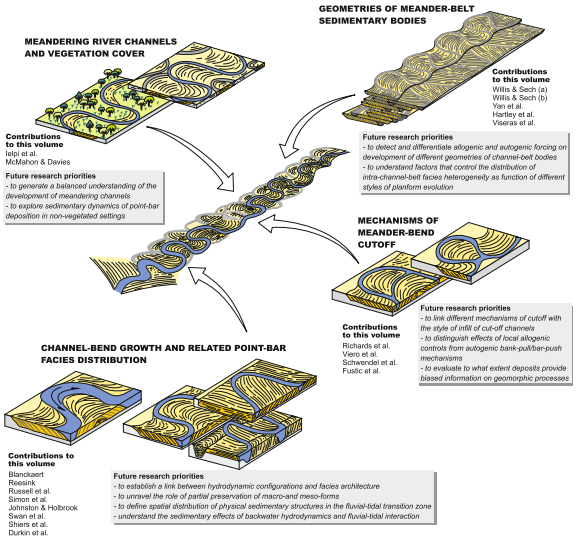
Model complex channel migration and bar accretion behaviour; populate the resultant 3D modelled volume with lithofacies using a deterministic approach conditioned using information from the FAKTS database.

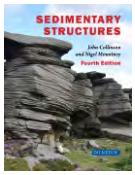
DuneModeller

Forward Stratigraphic Modelling for Prediction of Aeolian Dune Architecture

DuneModeller is a numerical model for predicting the response of aeolian systems to external and intrinsic controls. The range of synthetic stratigraphic architectures generated by the model accounts for all the principal aeolian stratigraphic configurations. Modelling results have enabled the erection of a scheme for the classification of dune system type whereby the many elaborate stratal architectures known to exist in nature can effectively be accounted for. The approach is used to model reservoir heterogeneity and to predict flow pathways for hydrocarbons, water, CO_2 and contaminants in subsurface reservoirs and aquifers, in which low-permeability interdune units and bounding surfaces might act as baffles or barriers.







Books

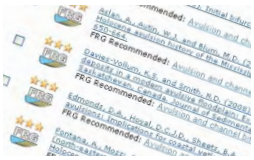
Articles, Text Books, Thematic Special Publications & Self-Learning Guides

Research from Phases 1 – 4 has directly led to the publication of >100 papers in leading international academic journals. Additionally, results have also been published in thematic special publications, and as field guides. The FRG-ERG-SMRG research team have also (I) edited entire specialist book volumes (e.g., IAS Special Publication 48: "Meandering Rivers and their Sedimentary Products in the Rock Record", Wiley), and (ii) have written a major research-led textbook ("Sedimentary Structures", Collinson and Mountney, Dunedin). Future book chapters relating to issues in applied-facing sedimentology are currently being prepared. Details of all published works are available on the publications page at **frg.leeds.ac.uk/**

Research & Knowledge Transfer Programme: Deliverables

Fluv-Lit

Fluvial Literature Review & Summary



Aeo-Lit

Eolian Literature Review & Summary

Fluv-Lit and **Aeo-Lit** are bibliographic and literature review databases that allow industry professionals to keep abreast of advances reported in the academic literature, and incorporate the latest thinking into their work. Additionally, these tools allow people new to non-marine clastic sedimentology to quickly develop an understanding of these depositional environments. These online searchable databases provide:

- A comprehensive listing of the entire field of literature relating to fluvial and eolian sedimentary environments.
- Listings and reviews of new publications.
- FRG-ERG ratings and lists of recommended papers by theme.
- Summaries of key recommended papers.

Review and recommendation is undertaken by experts in the field, and tailored for industry-professional end-users.

FoG

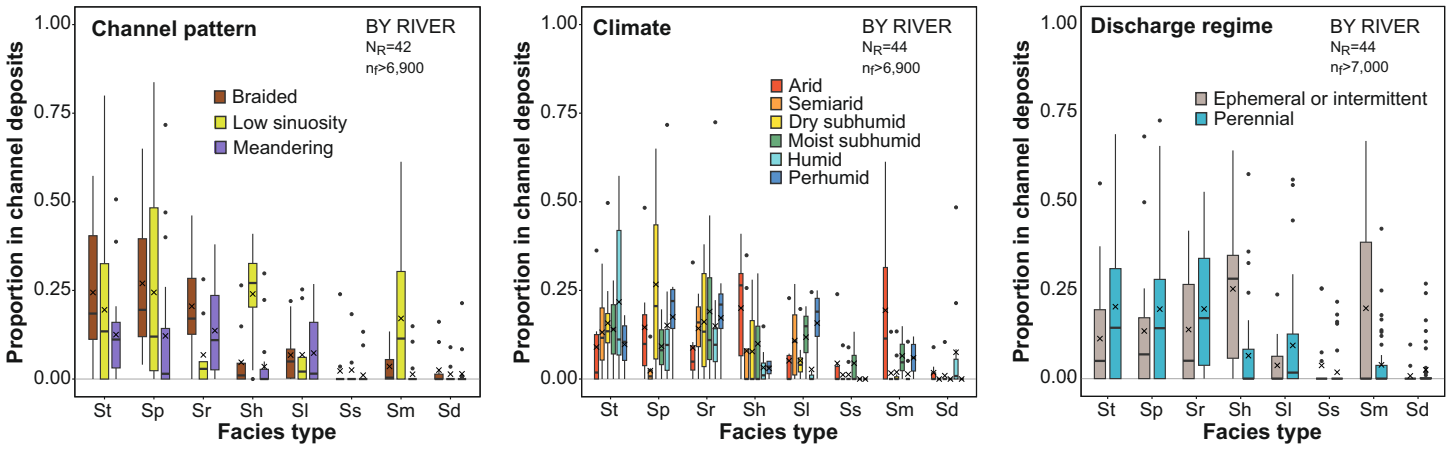
Fundamentals of Geoscience

- **Fundamentals of Geoscience** is a set of self-contained e-learning resources designed to enable non-geologists to gain knowledge in sedimentology & applied reservoir geology quickly and effectively.
- The resources serve as a refresher of core concepts for specialist geologists.
- Acts as a point of access to more specialised and detailed discussions through the provision of a series of integrated references.
- Serves as a source of high-quality graphic artwork that can be used by sponsors to illustrate their own presentations.

ATLAS

Atlas of Fluvial & Eolian Facies

- The **Atlas of Fluvial and Eolian Facies** is an illustrated encyclopaedia of facies examples from a range of fluvial and eolian system types, which can be used to characterize subsurface core & consider palaeoenvironmental significance.
- Enables non-specialists to recognise and become familiar with a range of common and unusual types of fluvial and eolian facies, the likely processes involved in their generation, and their likely palaeoenvironmental origin and significance.
- Provides a list of possible modern and ancient outcrop analogues to assist with the interpretation of core.
- Serves as a source of images and graphics that can be used by sponsors to illustrate their own presentations.



Above. Left-hand graph: the proportion of different sandy facies types forming channel complexes interpreted as the product of braided, low-sinuosity or meandering rivers. Middle graph: the proportion of different sandy facies types forming channel complexes interpreted as the product of rivers developed under the influence of different climate regimes. Right-hand graph: the proportion of different sandy facies types forming channel complexes interpreted as the product of rivers characterized by ephemeral or intermittent versus perennial flow. The data depicted are from modern sandy bedload rivers; similar data can be generated for ancient preserved fluvial successions. Data from FAKTS. Use data such as these to predict reservoir quality based on palaeogeography.

Selected Examples of Proposed FRG-ERG Phase 5 Research Projects

Theme 1: Creation of database-informed facies models

Quantitative facies models describing the sedimentary characteristics exhibited by types of fluvial systems or sub-environments (e.g., low-latitude coastal plain, dryland fluvial fan) and genetic units (e.g., channel bodies, deltaic distributary channels) will be generated using FAKTS. The compiled facies models will consist of sets of quantitative information relating to the proportion, geometry, reciprocal spatial relationships and distribution of sedimentary units at multiple scales (facies, architectural elements, large-scale depositional elements). Facies models will be constructed based on the synthesis of many case studies included in the FAKTS database. Quantitative facies models will also be built using data from the SMAKS database, for example for river-dominated coastal depositional systems or to describe the large-scale architecture of coarse-grained deltas. The models will be applicable to guide interpretations and predictions of subsurface successions, and will enable to constrain uncertainty associated with architectural variability.

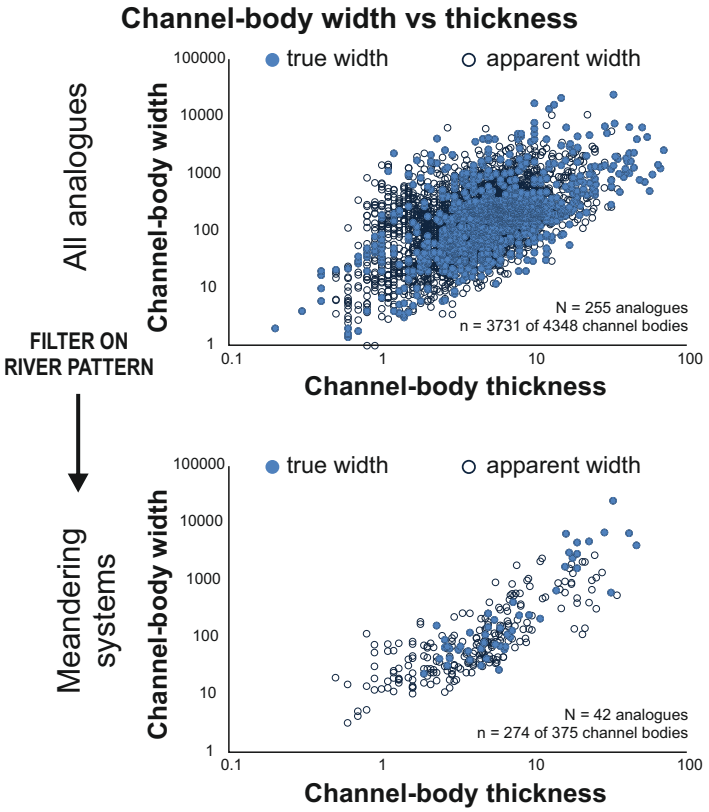
Above. Fieldwork, upper part of the Mesa Verde Group, Utah, USA.

Theme 2: Quantification of the static connectivity of fluvial system types

This work will aim to produce static connectivity metrics (e.g., size of connected clusters, connectivity functions, tortuosity) for net-reservoir units associated with different types of fluvial systems and at multiple scales (e.g., meandering river systems, proximal vs distal fluvial fan). This work will make use of FAKTS database output to condition stochastic simulations of fluvial architecture, generated by means of geostatistical and geometric-based techniques. Results can be used to generate conceptual models of reservoir connectivity for different types of fluvial depositional systems, to be referred to as predictive templates. Specific work components will include: (I) application of in-house forward stratigraphic modelling software that simulates the architecture of point bars and meander belts (PB-SAND) to the assessment of static connectivity associated with channel belts that display different types of morphodynamic behaviour; (ii) determination of the role of crevasse splays in controlling inter-channel-sandbody static connectivity as a function of net-to-gross and depositional geometries.

Theme 3: Quantification of the dynamic connectivity of fluvial system types

This work will aim to quantify the dynamic connectivity associated with types of fluvial systems that act as hydrocarbon reservoirs, with consideration of genetic units that are deemed as behaving as flow units, barriers or thief zones, and by means of stochastic simulations of fluvial architecture, informed by analogues from FAKTS or using specific outcrop examples. Results will be used to generate models characterizing dynamic reservoir behaviour during hydrocarbon production for different types of fluvial depositional systems, thereby providing likely scenarios of reservoir performance to be used as predictive templates. This work will entail further population of FAKTS with genetic-unit petrophysical properties, which is now underway. A particular work component will involve application of in-house forward stratigraphic modelling software that simulates the architecture of point bars and meander belts (PB-SAND) to the assessment of dynamic connectivity associated with channel belts that display different types of morphodynamic behaviour.

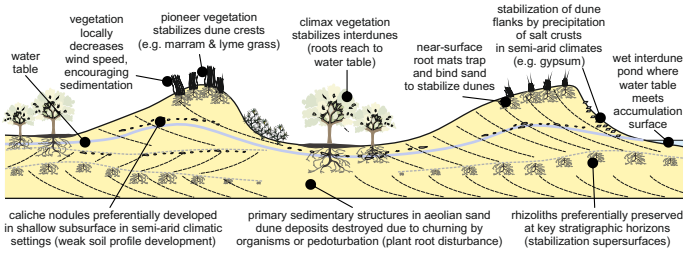


Above. The FAKTS database allows querying analogue data on proportions, spatial relationships and geometries of sedimentary units at multiple scales of observation, filtered on attributes that describe the type of depositional system. FAKTS can be used to develop quantitative metrics for synthetic analogue models with which to better characterize specific classes of fluvial successions.

Selected Examples of Proposed FRG-ERG Phase 5 Research Projects

Theme 4: Accommodation regime and alluvial architecture

Research is being conducted on the relationships between rates of creation of accommodation space, or temporal variations thereof, and aspects of fluvial sedimentary architectures, evaluated for different tectonic/environmental settings and at different timescales. Further analysis on the role of accommodation regime in controlling fluvial architecture will focus on comparisons between channel-complex architectures in fluvial to coastal-plain successions and correlative shallow-marine parasequence stacking patterns and shoreline trajectories, for selected outcropping successions (e.g., Blackhawk Formation, Ferron Sandstone Member, Neslen/Iles/Mt. Garfield Formations; Upper Cretaceous of the Western Interior Seaway, Utah).



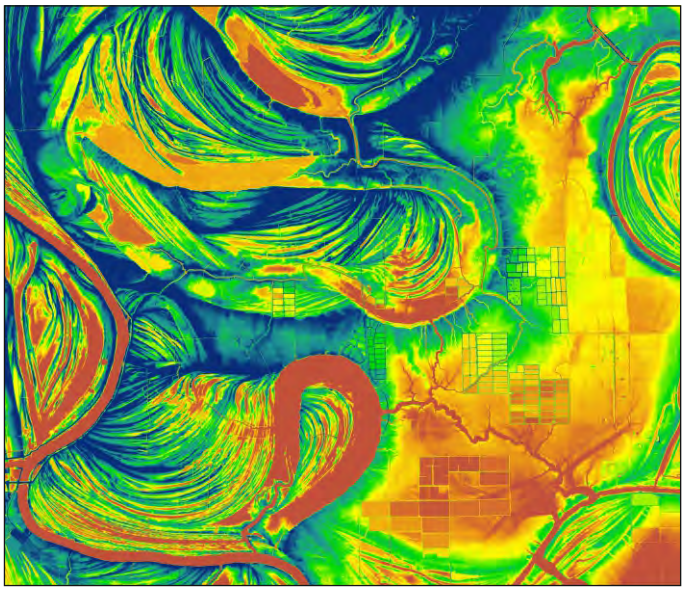
Above. Classification scheme used for summarizing the form and origin of stabilizing agents of biogenic and chemical origin in aeolian systems and their preserved successions.

Theme 5: Generation of a training image library for MPS reservoir modelling

Geostatistical modelling algorithms based on multi-point statistics replicate geological patterns drawn from training images. Geologically realistic training images are therefore required to achieve geologically plausible reservoir models. This work will aim to generate a set of 3D geocellular training images that are suitable to model different types of fluvial successions and that contain different types of sedimentary units, based on the application of analogue data from FAKTS. Analogue data will be used to generate training images through: (I) their use for constraining stochastic geocellular models, and (ii) as applied to forward stratigraphic modelling software that simulates the architecture of point bars and meander belts (PB-SAND). Each training image will be paired to a set of suitable modelling parameters to facilitate its application to MPS algorithms employed in industry (SNESIM, DS). The suitability of the training images to condition novel machine-learning-based facies-modelling tools will also be trialled. A specific sub-project will focus on the generation of training images suitable for modelling permeability contrasts in deposits of braided rivers, based on analysis of quarry exposures of the Quaternary of the Aar valley (Switzerland).

Theme 6: Compilation of a thematic set of quantitative facies models for fluvial, aeolian, paralic and shallow-marine systems

- Examples of models to be developed include those for braided and coastal plain systems and successions.
- Models for the architecture of genetic units (e.g. channel-complexes, deltaic distributary channels), as based on the synthesis of many case studies included in the FAKTS database, with the scope to guide interpretations and predictions, and constrain uncertainty associated with architectural variability.



Above. LiDAR image (USGS) depicting the complex internal anatomies of a series of large point bars in a reach of the present-day Mississippi River. Many point-bar elements contain multiple internal reactivation and adjustment bounding surfaces. These typically give rise to internal lithofacies heterogeneity. Preserved successions of these types of deposits tend to be highly compartmentalized. Forward numerical modelling using PB-SAND can account for and predict such heterogeneities in 3D.

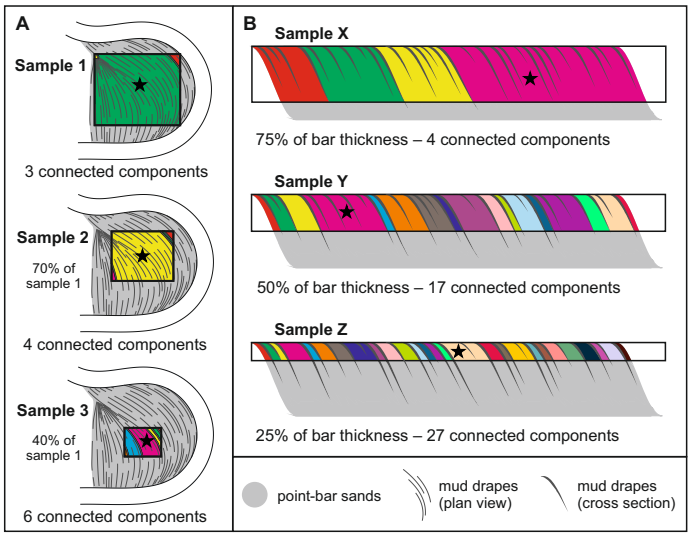
Theme 7: Sedimentary architecture and connectivity of reservoir-quality facies in fluvial overbank successions

- Determination of sedimentary architecture and connectivity for distributary and minor crevasse channels in floodplain-dominated, low net:gross fluvial successions.
- Correlation of subsurface well log data from a range of subsurface settings.
- Architectural-element analysis of low net:gross alluvial systems in Cretaceous, Jurassic and Pennsylvanian successions (e.g. Scalby Formation, NE England).
- Analysis of 3D seismic data and well-logs subsurface settings.
- Role of variable accommodation space regimes in controlling preserved sedimentary architecture.

Selected Examples of Proposed FRG-ERG Phase 5 Research Projects

Theme 8: Influence of marine processes on channel mobility and network, and implications for sandbody architectures

Marine processes control river morphodynamics in many ways. For example, tides prevent mouth-bar growth and causes stabilization of distributaries, and reduce lateral channel migration by inhibiting point-bar push. Wave-driven longshore transport can act to suppress channel avulsion through the construction of strandplains and by preventing channel lengthening and streambed aggradation. Backwater hydrodynamics in channels modulate sediment flux in such way that in-channel deposition enhances lateral migration and avulsion in the upper backwater zone, whereas bedload starvation at low flow decreases channel migration rates in more distal reaches. This research aims to quantify the importance of marine processes in controlling the behaviour of coastal rivers, and to elucidate the role of these factors in determining channel-body geometry, density, stacking patterns and internal heterogeneity in marine-influenced fluvial successions. The work will employ results of timelapse satellite-image analyses of modern tide- and wave-influenced deltas and coastal plains, associated with variable backwater lengths and for which the role of wave and tides can be quantified.



Above. Idealized examples that illustrate the effect of sample size on the number and size of connected components made of point-bar sands that are compartmentalized by mud drapes, in both plan view (A) and cross sections (B). In each sample (black frames), different connected components of point-bar sands are represented as variably coloured sectors. The largest connected components in each sample are denoted by stars. Although these examples are depicted as two dimensional sections, in reality all the metrics presented here result from 3D analysis. Analysis of the connectivity of point-bar sands in samples of variable planform and vertical extent allows assessment of the degree at which compartments and dead ends develop at different length-scales. The PB-SAND forward stratigraphic model, conditioned by data from FAKTS, can be used to undertake such analysis.

Theme 9: Relationships between alluvial facies architecture and overbank pedogenesis

Common controls exist that act on both pedogenesis and the development of fluvial architectures. For example, climate and relative sea-level changes act as common controls on both soil drainage conditions and channel-body amalgamation. These controls determine feedbacks between the geomorphic and sedimentological organization of fluvial systems and overbank pedogenic processes. Pedogenic processes are controlled by the configuration of fluvial systems, for example by the proximity to river channels and by the nature of overbank materials. In turn, pedogenesis controls reservoir quality, for example by determining overbank-sediment texture and in-channel intraclast composition and resulting eogenesis. This research aims to analyse relationships between characteristics of fluvial sedimentary architectures over a range of scales and pedogenic features. The work will include, but will not be limited to, field-based studies of stratigraphic architectures and palaeosols of successions of the Paleogene Tremp Group in the Tremp-Graus Basin (Spain).

Above. ~30 m-thick succession of vertically stacked palaeosols with thin sandstone beds of fluvial crevasse-splay origin; a protracted episode of floodplain aggradation. Jurassic Morrison Formation, south of Green River, Utah, USA.

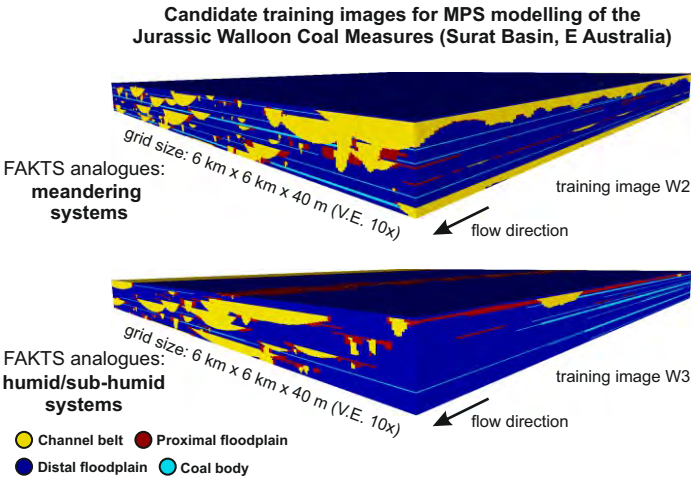
Theme 10: Compilation of quantitative facies models describing controls on aeolian system construction and preservation

- Models comparing aeolian successions from icehouse versus greenhouse settings.
- Models comparing aeolian successions from supercontinental interiors to those in coastal settings.
- Models relating the timing of sediment supply for aeolian construction to climate and sea-level change.
- Models demonstrating lithological heterogeneity arising from intrinsic bedform migratory behaviour.

Selected Examples of Proposed FRG-ERG Phase 5 Research Projects

Theme 11: Facies control on petrophysical heterogeneity

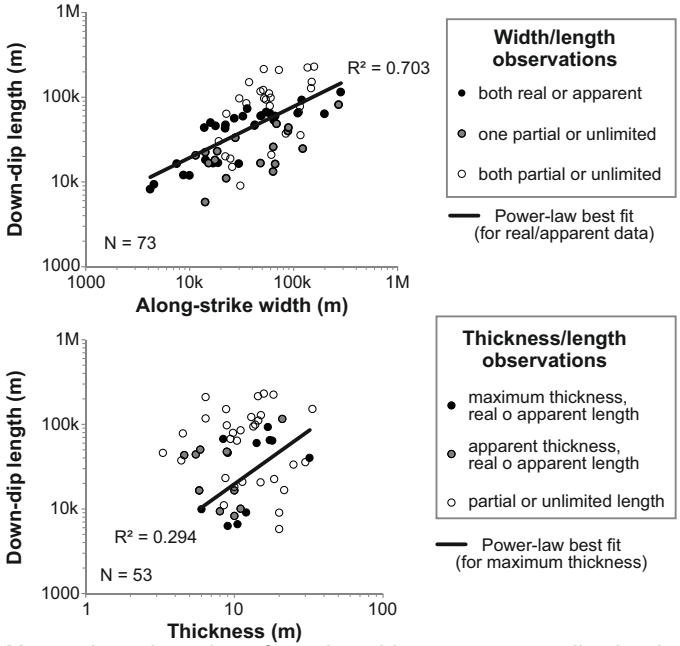
Lithofacies heterogeneity controls petrophysical heterogeneity directly, through the textural, structural and compositional properties of sediments, and indirectly, by determining the distribution of diagenetic features in preserved successions. Climate and tectonics act to determine the facies architecture, sediment composition and diagenetic history of alluvial strata. This research aims to unravel relationships between diagenesis of fluvial sandstones and sedimentological characteristics of depositional units, with the scope to improve the ability to predict reservoir quality, especially in data-poor situations. Work will be undertaken that includes the collation of data into FAKTS, quantitative data analysis, and the development of predictive models linking depositional products, their diagenetic alteration, and the resulting poroperm properties to descriptors of geological boundary conditions.



Above. Example object-based training images created for modelling the Walloon Subgroup (Jurassic, Surat Basin, Australia), based on analogue data from the FAKTS database.

Theme 12: Subsurface modelling of alluvial aquifers of interest for low-carbon energy applications

Aquifers hosted in fluvial to paralic strata are increasingly being sought as low-enthalpy geothermal resources for heating, and as targets for energy storage. Geological modelling of the stratigraphic architecture of these successions can improve subsurface predictions and management. Research will be undertaken on case studies of geocellular modelling that will include, but are not limited to, the study of: (I) the influence of connectivity on the operational feasibility of geothermal doublets, and (ii) the influence of facies heterogeneity on the sustainability of heat-pump fields. The project will allow lessons in subsurface modelling to be learnt that have generic relevance.



Above. Length-scales of stratigraphic compartmentalization in deltaic parasequences. Data from SMAKS.

Theme 13: Geogenic arsenic contamination in meander-belt aquifers

Meander-belt deposits that form aquifer units in Quaternary successions are commonly affected by natural contamination by arsenic, which is released by organic-rich abandoned channel fills and accumulates in point-bar elements. Understanding how the internal architecture of point-bar elements and the permeability contrasts of their deposits controls mobility and concentration of arsenic is important for planning the remediation of aquifers affected by arsenic pollution (e.g., Indo-Gangetic Plain). This research aims to improve our understanding of facies controls on spatial variability in arsenic concentration in unconfined aquifers hosted in point-bar units, through an integrated study of the sedimentology, geomorphology, water and sediment geochemistry, and hydrogeology of Holocene meander-belt deposits of the Po Valley (Italy). Geophysical characterization of the shallow subsurface could be undertaken to complement this dataset. This work will generate knowledge on point-bar facies heterogeneity and generic insight in fluid circulation and contaminant transport in sandy point-bar elements.

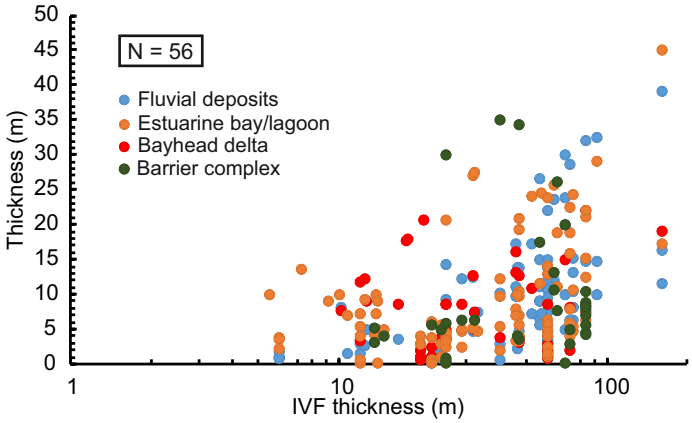
Theme 14: Internal sedimentary architecture and heterogeneity in point-bar and crevasse-splay elements in high-sinuosity fluvial successions

- Demonstration of the architectural relationship between the major sinuous channels and the adjoining levees and splays.
- Prediction of stratigraphic heterogeneity in tidally influenced successions: forward stratigraphic modelling for reservoir prediction.

Selected Examples of Proposed FRG-ERG Phase 5 Research Projects

Theme 15: Fluvial architecture of dryland distributive fluvial systems

Use FAKTS database to make quantitative comparisons between dryland fluvial successions at a variety of scales (facies, architectural element, depositional element). Determination of autogenic versus allogenic controls on sediment accumulation and preservation. Filtering of database results to draw out similarities and differences in architecture and sand-body connectivity between different types of systems. Case study examples matched to analogous reservoir intervals being characterized. Role of accommodation regime in controlling stacking patterns of sand bodies. Autogenic system behaviour as a control on fluvial architecture. Fan interaction with aeolian systems.



Above. Cross-plot of thickness of architectural elements within coastal-plain incised-valley fills versus IVF thickness (data from SMAKS). Predict sub-seismic resolution sandbody thickness from IVF imaged on seismic in pre-drill settings.

Theme 16: Characterization of aeolian and mixed aeolian-fluvial successions: implications for reservoir prediction

- Fluvial, aeolian, shoreline and shallow-marine system interactions: linked response to climate and relative sea-level change.
- Styles of fluvial-aeolian sedimentary interactions at desert dune-field margins: integrating modern, outcrop and subsurface datasets.
- Quantification of sedimentary architecture and heterogeneity for stratigraphic prediction in aeolian-fluvial reservoir successions.
- DuneModeller: a forward stratigraphic modelling tool for the prediction of heterogeneity in aeolian reservoirs: application to reservoir prediction in aeolian successions.
- Empirical relationships for prediction of preserved architecture in reservoir successions.
- Analysis of reservoir heterogeneity in mixed fluvio-aeolian successions (e.g. Permo-Triassic Rotliegend and Sherwood Sandstone Groups, UK): enhanced hydrocarbon recovery and suitability for long-term CO_2 storage.

Theme 17: Quantification of stratigraphic architecture and sand-body connectivity in the fluvial-to-marine transition zone (FMTZ)

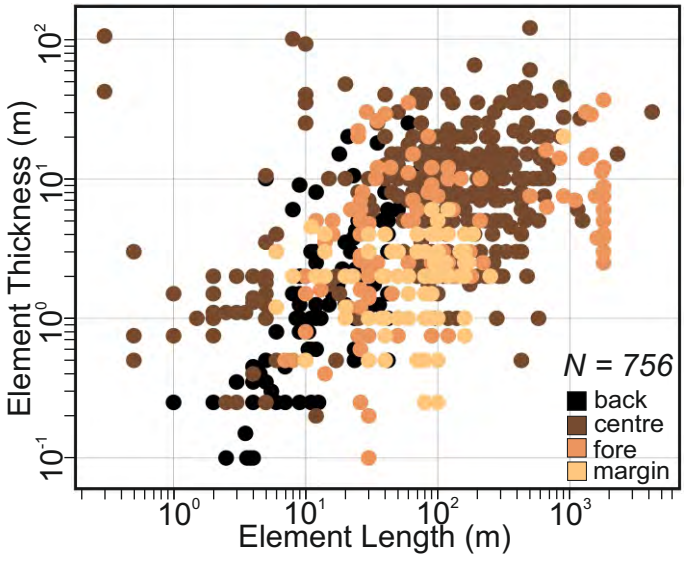
- Resolve factors that control the complex sedimentary architecture of estuarine and non-marine sandstone, mudstone and coal bodies in coastal plain and incised-valley settings.
- Architectural response to base-level and accommodation change.
- A new generation of sequence stratigraphic models: development, testing & refinement.

Theme 18: Numerical modelling of non-marine sedimentary & stratigraphic architecture

- Forward stratigraphic modelling of the role of salt tectonics in controlling fluvial drainage pathways in active salt-walled mini-basins: application to halokinetic hydrocarbon provinces.
- Role of tectonic movement in controlling fluvial system evolution in rift basins: insights from numerical modelling.
- A sediment-balance approach to modelling for prediction of fluvial stratigraphic architecture.

Theme 19: Tectonic controls on fluvial architecture in evolving rift & foreland basins

- Combined field-based and forward stratigraphic modelling study of controls on fluvial drainage pathways in rift and foreland basins.
- Implications for preserved stratigraphic architecture, sand-body distribution and connectivity in reservoirs.
- Role of tectonic movement in controlling accommodation generation in rift and foreland basins: impact on fluvial system evolution.



Above. Relationship between length and thickness of aeolian architectural elements colour coded by position within aeolian system (back-erg, erg centre, fore-erg, lateral erg margin). Use DASA to predict reservoir quality as a function of depositional setting.

Selected Examples of Proposed FRG-ERG Phase 5 Research Projects

Theme 20: Database of Aeolian Sedimentary Architecture (DASA) for tailored depositional models of subsurface aeolian successions

It is difficult to make direct quantitative comparisons between documented examples of individual case studies that describe aeolian systems and their preserved sedimentary architectures. To facilitate the quantitative sedimentological and stratigraphical characterization of aeolian systems, and to enable meaningful comparisons between systems, this study will develop and employ a novel relational database, **DASA**, to investigate sedimentary relationships within and between modern and ancient aeolian sedimentary successions. The aim of this study is to demonstrate the efficacy of using a database-informed approach to advance the quantitative characterization of aeolian systems for the purpose of gaining an improved understanding of the controls that govern patterns of aeolian sedimentation in a wide variety of settings, and over both time and space. Specific research objectives are as follows: (I) to use the database approach to detail aspects of the sedimentology and sedimentary architecture of modern and ancient aeolian systems; (ii) to devise DASA-informed quantitative depositional models for all major aeolian system types; to demonstrate the application of sequential filtering on specific criteria to generate quantitative architectural metrics for a specific subset of aeolian systems governed by a particular set of controlling conditions.

Theme 21: Forward stratigraphic modelling of allogenic versus autogenic controls on aeolian sedimentary architecture

This project will develop the current version of **DuneModeller** – a forward stratigraphic modelling tool for the prediction of heterogeneity in aeolian successions – by transforming it from a 2.5D numerical model (the current version) into a full 3D model. The resultant modelling tool will be applied to predict how controls on aeolian system evolution interact to give rise to a range of stratigraphic architectures. Results will be used for reservoir prediction in subsurface aeolian successions.

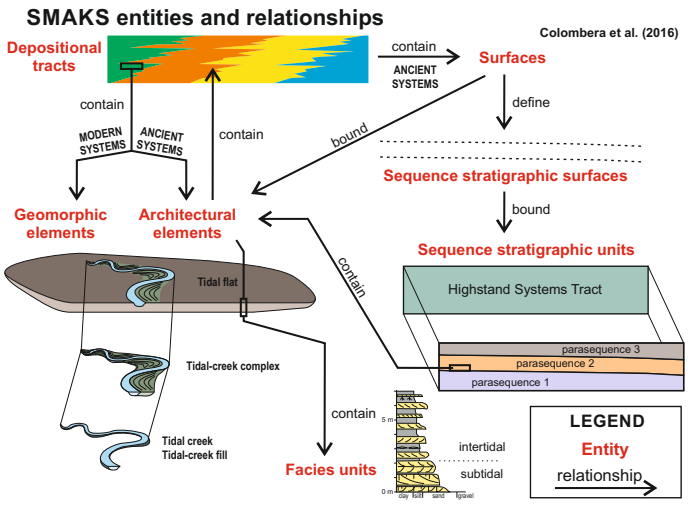
Theme 22: Accommodation and sediment-supply controls on the development of clastic shallow-marine successions

Examination of the factors that control the distribution and stacking of sand bodies in paralic and shallow-marine successions. Research will include analysis of (I) the rate of accommodation generation due to basin subsidence and autocompaction, (ii) the role of timing and point of sediment delivery to shorelines as a result of alluvial switching on the coastal plain, (iii) the rate of sediment delivery and outbuilding of sediment bodies in shallow-water settings as sediment is redistributed by a complex interplay of tidal and wave processes, (iv) the impact of high-frequency eustatic changes in sea level that are themselves linked to climate change that controls sediment yield. The research will involve collation of data from bespoke case studies, plus amalgamation of information available in the published literature. The **SMAKS** database will be used for data analysis and presentation of results. The research results will have implications for prediction of reservoir quality in subsurface paralic and shallow-marine successions.

Theme 23: Allogenic versus autogenic controls on the sedimentary architecture of mixed river-, tide- and wave-influenced shoreline and deltaic successions

Delta-lobe switching in response to river avulsion is often invoked as an autogenic mechanism for the generation of parasequences. However, studies recognize that a parasequence might contain more than one delta lobe, whereas others distinguish more than one parasequence in a single delta lobe. Furthermore, several hierarchies of constructional units are recognized that are equally made of contiguous delta top, front and prodelta deposits (e.g., delta lobes vs complexes). Stratigraphic architectures are further complicated by the relative roles of river-, wave- and tide-influence. SMAKS data on the architecture of modern deltas and of their late-Quaternary successions will be used to undertake a comparison between different hierarchies of deltaic constructional units and deltaic parasequences mapped in the rock record.

Our initial analysis supports the view that what are typically mapped as parasequences in subsurface datasets of deltaic successions may commonly contain the preserved expression of multiple deltaic 'lobes'. This has implication on the potential scale of compartmentalization of deltaic reservoirs, which might also be expressed at a scale lower than that of the individual parasequence. This study will provide a quantification of the geometry of constructional units that can be used for predictive purposes.



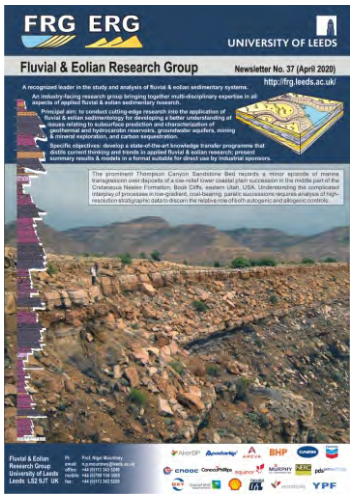
Fluvial, Eolian & Shallow-Marine Research Group

Phase 5
Jan 2021 to Dec 2023

Summary of Phase 5 Research Themes

- Database-informed quantitative facies models
- Methods for quantification of static & dynamic connectivity
- Accommodation regime and alluvial architecture
- Training-image libraries for MPS reservoir modelling
- Sedimentary architecture of fluvial overbank successions
- Alluvial facies architecture and overbank pedogenesis
- Facies control on petrophysical heterogeneity
- Alluvial and aeolian aquifers for low-carbon energy
- Compartmentalization of meander-belt successions
- Internal sedimentary architecture of point bars and splays
- Sedimentology of dryland distributive fluvial systems
- Tectonic controls on architecture in rift & foreland basins
- Numerical modelling of non-marine architecture
- Predicting 3D aeolian architecture from 1D core data
- Database-informed quantitative aeolian facies models
- Sedimentology of the fluvial-to-marine transition zone
- Influence of marine processes on channel networks
- Accommodation & sediment supply controls on shallow marine
- Sedimentation in fluvial-, wave- and tide-influenced deltas

Newsletter Updates



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FRG-ERG-SMRG is a community of expertise in clastic sedimentology & stratigraphy comprising Leeds-based workers and academic associates at other institutions.

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Nigel Mountney is Professor of Sedimentology at the University of Leeds. For the period 2014-2018 he acted as Chief Editor of the journal *Sedimentology*, the leading international journal in the field, and was a bureau member of the International Association of Sedimentologists (IAS). Nigel is currently Director of the Institute of Applied Geosciences (IAG) at the University of Leeds.

Dr Luca Colombera is Senior Research Fellow at the University of Leeds. He oversees geological database design, development and implementation, and has specialist expertise in the application of geostatistical methods for predicting subsurface sedimentary architecture. Together, Nigel and Luca lead the FRG-ERG-SMRG research programme.