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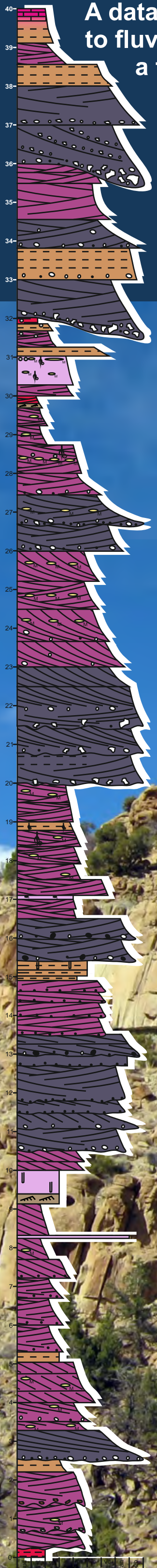
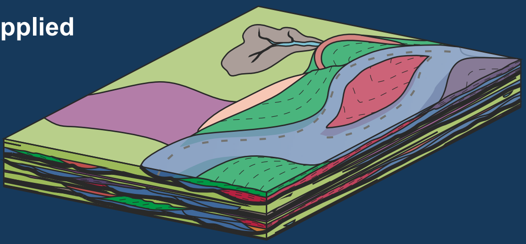
FAKTS: Fluvial Architecture Knowledge Transfer System



A database storing aspects of fluvial sedimentary architecture that can be applied to fluvial-reservoir characterization and prediction. The database serves as a tool with which to achieve the following primary goals:

- generate quantitative facies models for bespoke fluvial systems
- guide well correlation of fluvial sandstone bodies;
- condition object- and pixel-based stochastic reservoir models;
- predict the likely heterogeneity of geophysically-imaged geobodies;
- inform interpretation of lithologies observed in core and predict 3D architecture.



Fluvial sedimentary architectural expression of the Cretaceous Neslen Formation, Book Cliffs, Utah, USA

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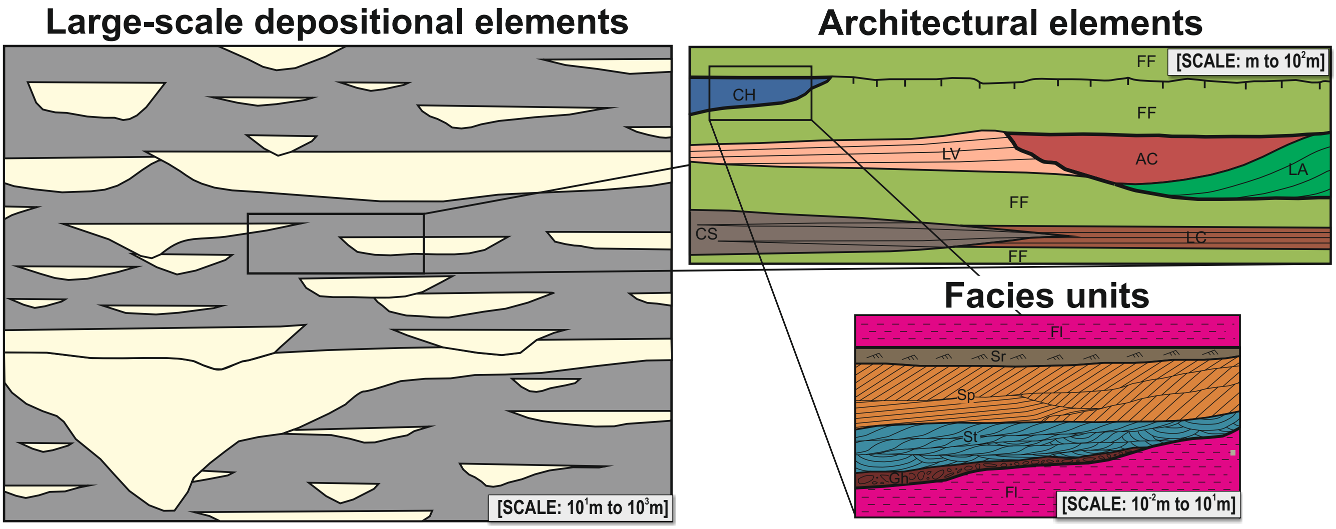
Introduction: Fluvial Architecture Knowledge Transfer System (FAKTS)

The Fluvial Architecture Knowledge Transfer System (FAKTS) is a research-led flagship initiative of the Fluvial Research Group (FRG) at the University of Leeds. FAKTS is a relational database storing **hard and soft data about fluvial sedimentary architecture** that has been populated with data derived from both original FRG fieldwork studies and peer-reviewed literature syntheses. The database incorporates information from both **modern rivers and ancient successions** that have been selected because they are considered to represent **potential analogues** to hydrocarbon reservoirs hosted in fluvial rocks, as well as groundwater aquifers suitable for generation of geothermal energy, and successions suitable to underground sequestration of CO_2.

FAKTS comprises a database system that is recognized as the most sophisticated repository yet developed for the storage and structured retrieval of quantitative information relating to fluvial sedimentary architecture. The FAKTS database is used to deliver core FRG research outputs.

International recognition for FAKTS: “an elaborate new database system from which to sample input parameters relating to depositional systems, architectural elements and lithofacies in order to construct reservoir models for development engineering purposes. This approach appears to be by far the most sophisticated in this category of model building.” Quote from Andrew Miall in his new book “Fluvial Depositional Systems”, Springer, p. 4-5.

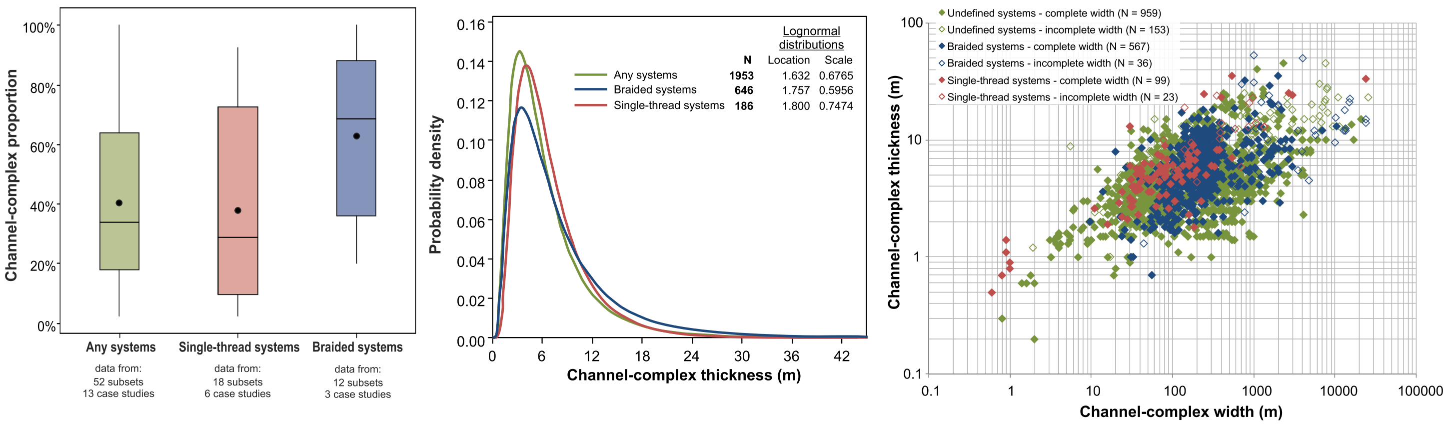


Large-scale depositional elements

Architectural elements

Facies units

Above. Illustration of the hierarchical nesting of smaller geo-bodies within parent types in FAKTS. The internal architecture of larger depositional elements can be characterized in terms of either architectural elements or lithofacies; facies are the building blocks of architectural elements. Results can be expressed in terms of proportions, transition probabilities, width-to-thickness ratios; such data serve to constrain inputs to reservoir models.



Above. FAKTS can be queried to return results describing many aspects of fluvial architecture. Query results can be plotted in a variety of forms to yield insight into the predicted extent and distribution of geo-bodies present in subsurface successions.

FAKTS

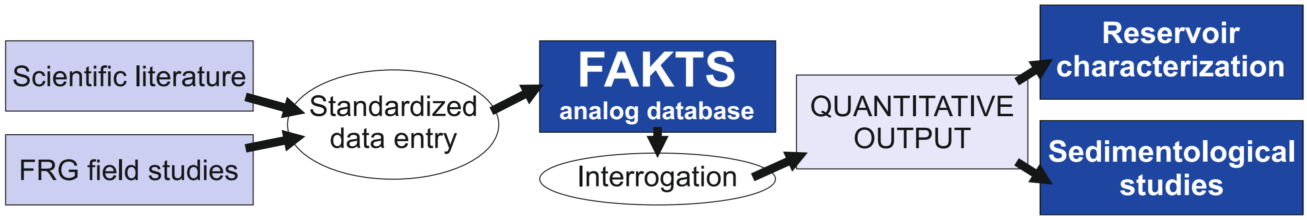
How does FAKTS work?

The FAKTS database is employed as a system for the digital reproduction of all the essential features of fluvial sedimentary architecture; it accounts for the style of **internal organization** of fluvial bodies, their **geometries, grain size, spatial distribution**, and the **hierarchical** and **spatial reciprocal relationships of genetic units** that comprise these geological bodies. FAKTS additionally **classifies depositional systems** – or parts thereof – according to both controlling factors (e.g. climate type, tectonic setting), and context-descriptive characteristics (e.g. channel/river pattern, dominant transport mechanism).

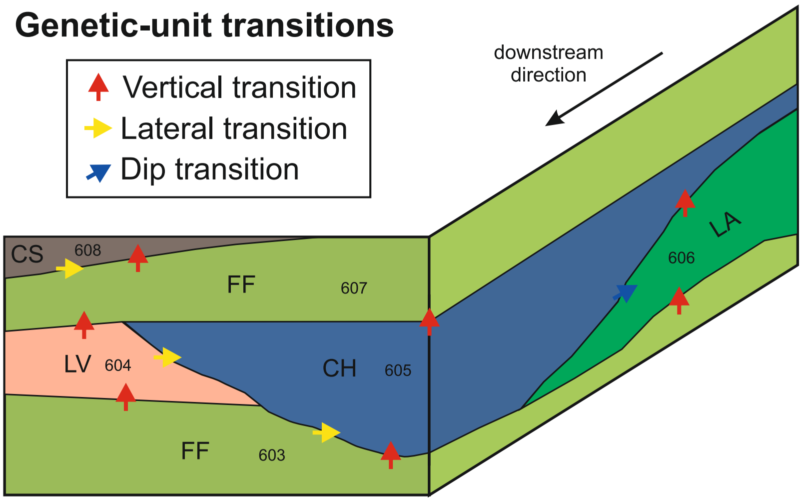
A simple version of the FAKTS database can be interrogated through a menu-driven online front-end hosted on the FRG web site. Sophisticated research questions are addressed by performing SQL queries by the FRG research team so that highly customized results can be obtained. The database **output consists of user-defined sets of quantitative information** on particular characters of sedimentary architecture, as derived from a suite of analogues, whose analogy to a particular reservoir is considered in terms of architectural properties and/or depositional-system parameters.

FAKTS output can be **applied to fluvial-reservoir characterization and prediction**. The database serves as a tool with which to achieve the following primary goals:

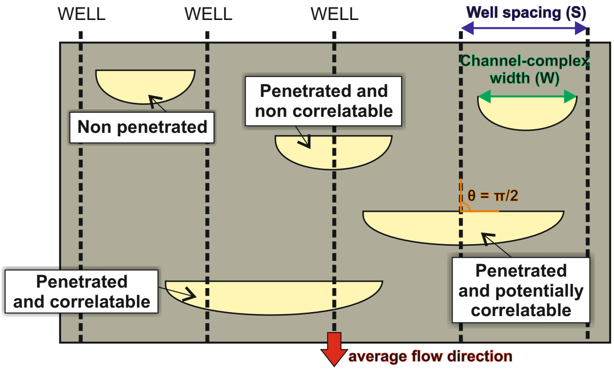
- generate quantitative facies models for bespoke types of fluvial systems using a series fo filters to specify particular environmental settings and controls;
- guide well correlation of fluvial sandstones;
- condition object- and pixel-based stochastic reservoir models;
- predict the likely heterogeneity of geophysically-imaged geo-bodies;
- inform interpretation of lithologies observed in core & predict 3D subsurface architecture.



Above. Workflow of data sourcing, standardization, input, query and application of the FAKTS database. The database stores information from >350 case studies of fluvial systems and their preserved successions, from both literature and FRG studies.


Genetic-unit transitions

Above. Spatial relationships between units are stored in the form of transitions between pairs of units, in three dimensions (vertically, along strike, up-dip). This enables spatial relationships between architectural elements and facies units to be examined, for example to predict systematic proximal-to-distal changes.

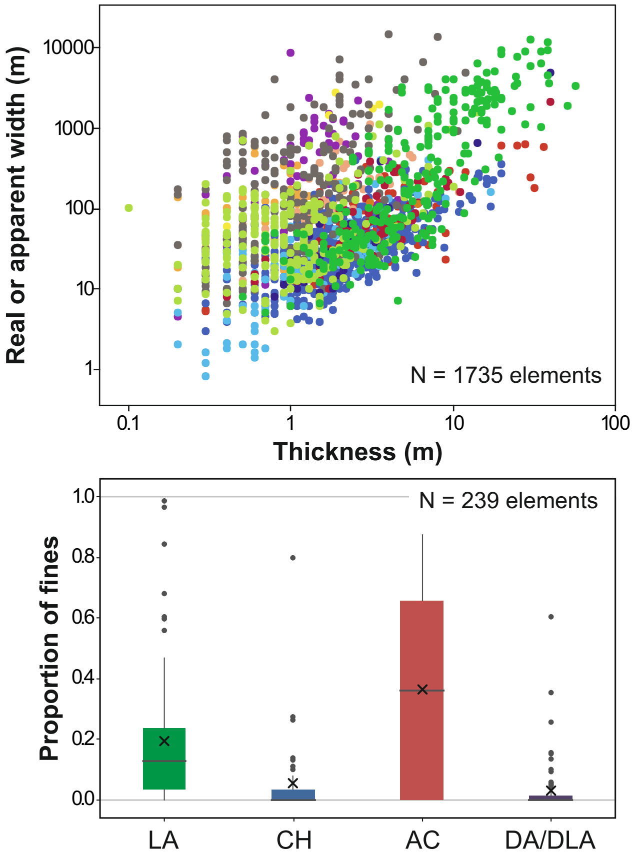


Above. FAKTS can be used for a variety of applied purposes. For example, the database can provide metrics with which to ascertain the likelihood of penetrating sand-bodies for well arrays of known spacing. It can be applied as a subsurface correlation tool. Moreover, it can be used to predict the size and volume of unpenetrated sand compartments in a reservoir volume.

FAKTS analysis at the scale of architectural elements and lithofacies units

Architectural-element types

- 🟥 Abandoned channel fill
- 🟧 Coal body
- 🟦 Aggradational channel fill
- 🟦 Crevasse channel
- ⬛ Crevasse splay
- 🟥 Downstream-accreting barform
- 🟪 Downstream/laterally accreting barform
- 🟩 Laterally accreting barform
- 🟫 Floodplain lake
- 🟧 Levee
- 🟪 Sandy aggradational floodplain
- 🟨 Gravity-flow body
- 🟩 Overbank fines
- 🟧 Scour-hollow fill

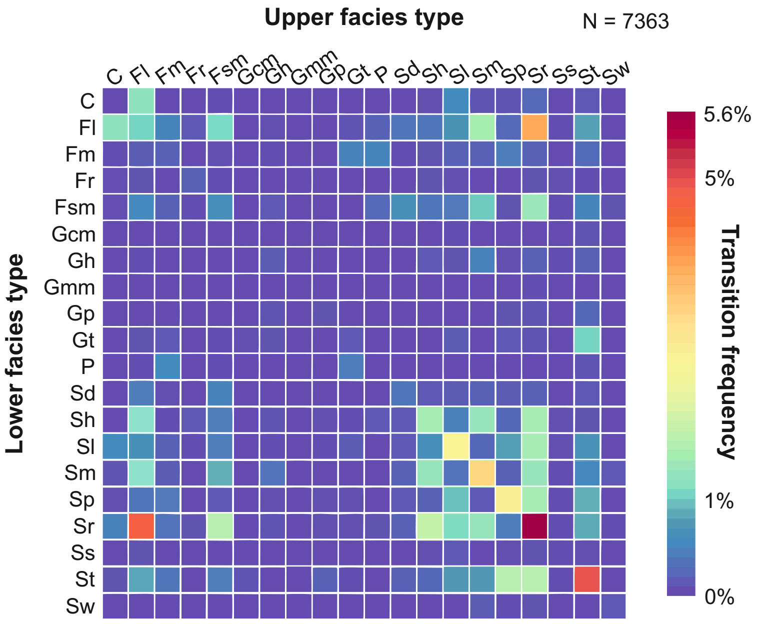


Above. Example FAKTS database outputs on the geometry (thickness and width) and facies organization (proportion of fine-grained facies) of different types of architectural elements.

Facies types

Gmm	Matrix-supported massive gravel
Gmg	Matrix supported graded gravel
Gcm	Clast-supported massive gravel
Gh	Horizontally-bedded/imbricated gravel
Gt	Trough cross-stratified gravel
Gp	Planar cross-stratified gravel
St	Trough cross-stratified sand
Sp	Planar cross-stratified sand
Sr	Asymmetric-ripple cross-laminated sand
Sh	Horizontally-laminated sand
Sl	Low-angle cross-bedded sand
Ss	Scour-fill sand
Sm	Massive or faintly laminated sand
Sw	Symmetric-ripple cross-laminated sand
Sd	Soft-sediment deformed sand
Fl	Laminated sand, silt and clay
Fsm	Laminated to massive silt and clay
Fm	Massive clay and silt
Fr	Fine-grained root bed
P	Paleosol carbonate
C	Coal or carbonaceous mud

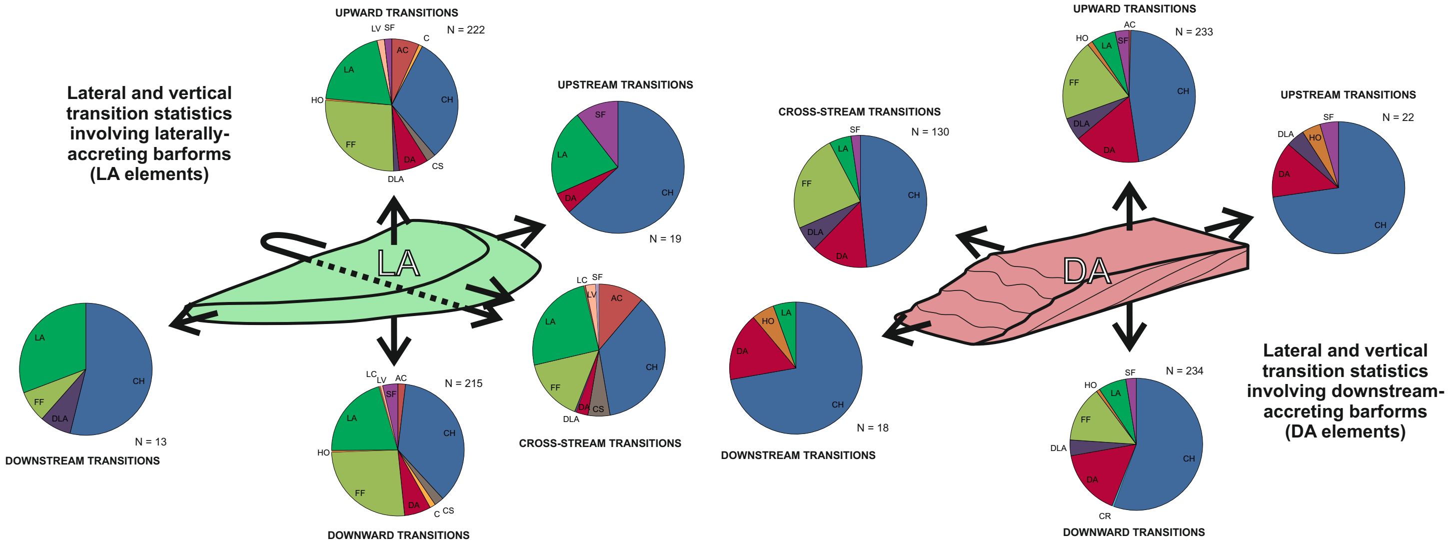
Vertical transition frequency of facies types in sandy meandering fluvial systems



Above. FAKTS 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.

How can FAKTS be applied for subsurface characterization?

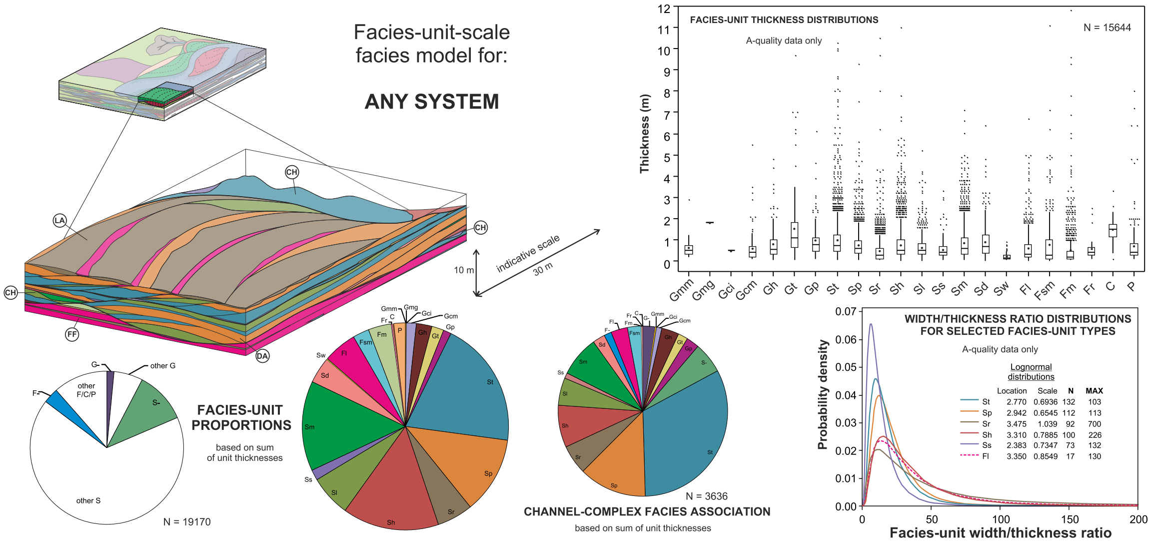
- Build quantitative facies models that describe the distribution of architectural elements within channelized and floodplain settings; characterize the scale, orientation and stacking of these elements and their style of juxtaposition relative to one another.
- Build models that describe the likely internal facies arrangements present in individual architectural elements; determine the relative proportions of facies that make up certain elements and predict their vertical, cross-stream and downstream transitions.
- Predict the expected dimensions of architectural elements away from the borehole; predict the most likely arrangement of neighbouring elements.
- Filter the output from the database such that only those data from fluvial systems that meet the specified search criteria are returned.
- Compare differences in sedimentary architecture for different types of fluvial system and controlling conditions: for example, compare differences in scale and connectivity of sand bodies in braided versus single-thread (meandering) rivers, or rivers developed in semi-arid versus sub-humid climatic settings, or pre-vegetation (i.e. pre-Silurian) fluvial successions versus post-vegetation successions, or fluvial successions preserved in rift basin settings versus those preserved in foreland basin settings.
- Compile exhaustive comparative statistics for different types of fluvial system: for example, calculate channel-complex proportion, channel-complex thickness and width and channel-complex connectivity for different fluvial types.
- Observe how the proportions of facies or architectural elements (and their transition probabilities) change as progressively more filters are included in a query: for example, compare a generic fluvial system, to a braided system, to a braided system developed in a semi-arid climate, to an ephemeral braided system.
- Plot width-thickness relationships for any element (not just channel bodies) and include filters to observe how such relationships vary between different fluvial system types.
- Undertake a full analysis of lithofacies composition for any architectural element type (and filter by fluvial system type, climate, basin setting, geological age, palaeolatitude etc).
- Make statistical comparisons between published case studies and compare with well data from your own reservoirs.
- Make statistical comparisons between modern systems and their ancient preserved successions; check the validity (or otherwise) of your preferred modern system as an analogue for your subsurface reservoir succession.



Above. Using FAKTS to examine probabilities of transition from one architectural element type to others in vertical, cross-stream and downstream directions. For example, both lateral accretion (LA) and downstream accretion (DA) elements are commonly juxtaposed adjacent to channel-fill elements (CH), yet both are commonly overlain by floodplain fines (FF).

FAKTS key features

- The genetic units included in FAKTS are equally recognizable in both the stratigraphic and geomorphic realms, and belong to three hierarchies of observation: depositional elements, architectural elements and facies units, in order of descending scale.
- The geometries of the genetic units are characterized by dimensional parameters describing their extent in the vertical, strike-lateral and downstream directions, relative to the channel-belt-scale flow direction (thickness, width and length); geometrical parameters are classified on type of observation (i.e. real, apparent, partial, or unlimited).
- The reciprocal relations among genetic units are stored by recording and tracking (i) the containment of each unit within its higher scale parent unit (e.g. facies units within architectural elements), and (ii) the spatial relations between genetic units at the same scale, recorded as transitions along the vertical, cross-gradient and downstream directions.
- The hierarchy of surfaces bounding the genetic units is also considered, through specification of bounding-surface orders for the basal surface of depositional elements and for surfaces across which architectural-element or facies-unit transitions occur.
- Additional attributes are defined and recorded to improve the description of specific units (e.g. braiding index for channel complexes, grain-size distribution for facies units), whereas accessory information (e.g. ichnological or pedological characters) can be stored for every unit in open fields.
- The database also stores statistical parameters referring to genetic-unit types and this enables storage of literature-derived data presented in this form.
- Within the database, each genetic unit or set of statistical parameters is assigned to a stratigraphic volume called a subset; each subset is a portion of a dataset classified on system controls (e.g. subsidence rate) and system-descriptive parameters (e.g. river pattern, distality relative to other subsets).
- For each case study of fluvial architecture, FAKTS also stores metadata describing, the methods of data acquisition employed, the chrono-stratigraphy of the studied interval, the geographical location, etc. A three-fold data-quality ranking system is also implemented for rating the reliability of datasets and genetic-unit classifications.



Facies-unit-scale facies model for:

ANY SYSTEM

FACIES-UNIT PROPORTIONS

based on sum of unit thicknesses

N = 19170

N = 3636

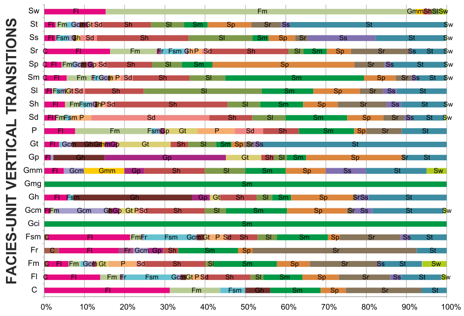
CHANNEL-COMPLEX FACIES ASSOCIATION

based on sum of unit thicknesses

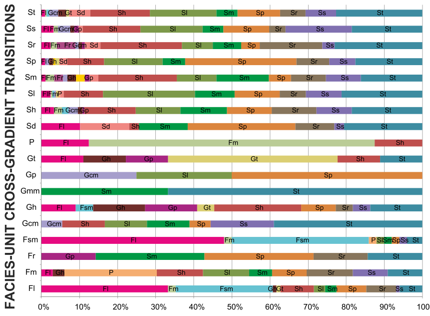
FACIES-UNIT LATERAL-EXTENT DESCRIPTIVE STATISTICS

facies type	mean width	min width	max width	mean length	min length	max length
Gmm	35.6	3.9	63.0	6.6	2.2	11.0
Gcm	11.2	1.9	23.0	12.7	2.1	34.0
Gh	30.2	2.5	82.0	15.4	6.0	56.0
Gt	94.2	4.0	300.0	21.4	2.7	60.0
Gp	24.0	15.0	39.0	18.5	7.1	30.0
St	20.1	1.3	257.0	13.3	0.8	95.0
Sp	20.5	1.1	300.0	18.1	1.4	150.0
Sr	24.0	0.4	250.0	17.8	2.7	138.0
Sh	27.3	1.3	250.0	22.2	2.0	146.0
Sl	16.2	1.0	174.0	14.1	1.0	65.0
Ss	7.7	0.1	50.0	9.6	0.7	48.0
Sm	29.2	1.2	220.0	12.5	1.2	95.0
Sd	8.9	1.0	27.0	6.4	0.8	26.0
Fl	21.0	0.6	250.0	14.5	2.8	34.0
Fsm	16.9	1.7	152.0	12.5	3.4	22.0
Fm	56.4	3.1	250.0	15.2	4.2	27.2
Fr	17.9	5.4	37.0	1.9	1.9	1.9
P	28.5	2.0	250.0			

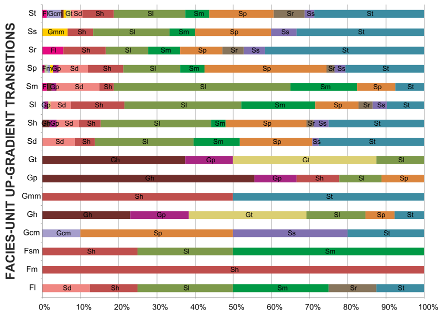
N = 2962 – all dimensions are expressed in metres



N = 15161 – Undefined facies units excluded



N = 1512 – Undefined facies units excluded



N = 784 – Undefined facies units excluded

FAKTS output

All data stored within FAKTS can be filtered on analogue depositional-system parameters or associated architectural properties to match with a given subsurface system of interest. Example outputs from the FAKTS database are presented throughout this document.

In its most basic form, FAKTS output consists of quantitative information about:

- proportions of genetic units within higher-scale units or volumes;
- geometrical parameters of genetic units;
- spatial relationships of genetic units in three dimensions.

This output can be employed to generate information directly applicable to subsurface problems, such as plots of genetic-unit width-to-thickness aspect ratios, tabulated genetic-unit transition statistics, statistical distributions of user-defined genetic-unit net-to-gross ratios.

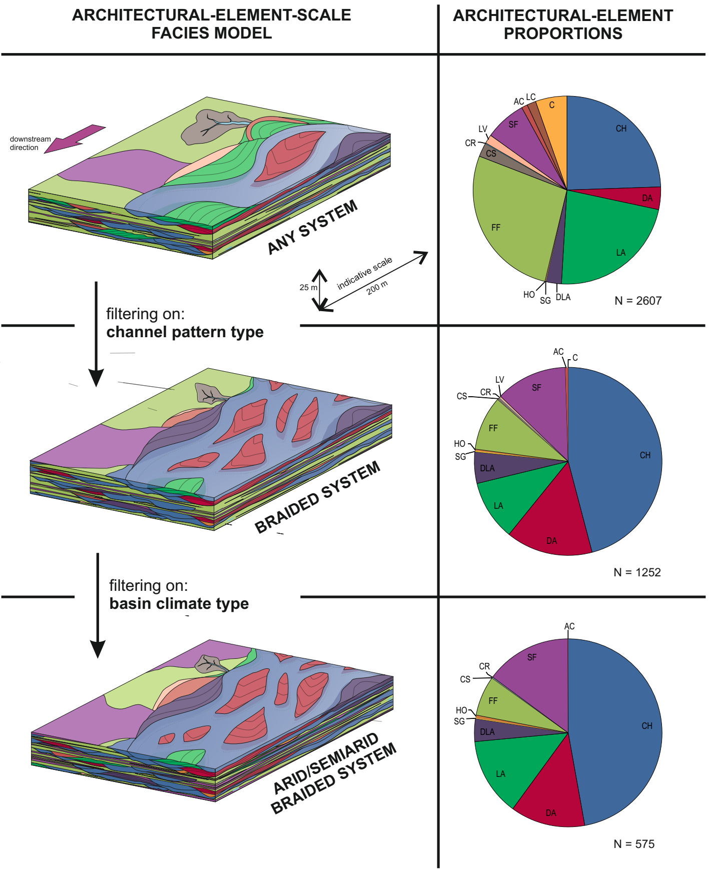
FAKTS content

FAKTS currently includes data associated with:

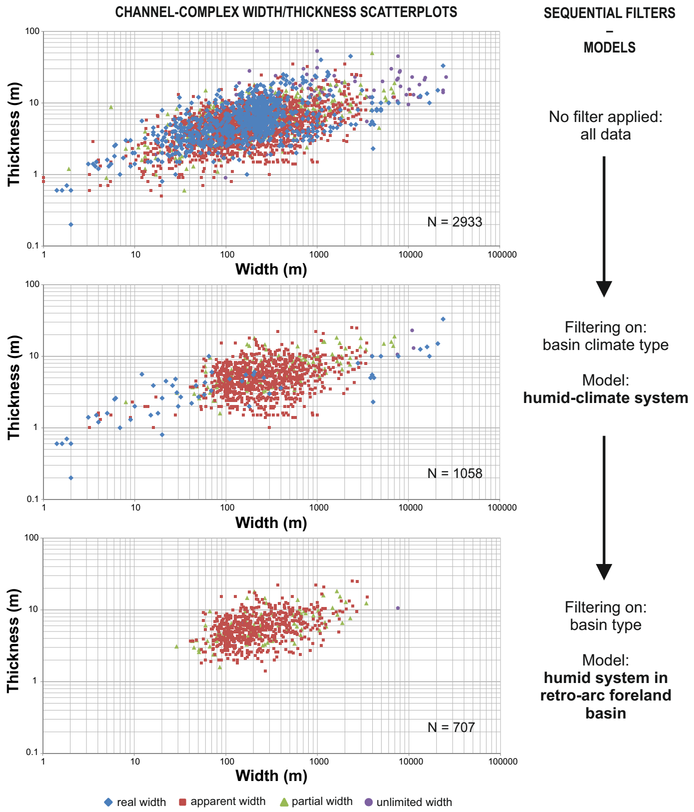
- 335 case studies;
- 1,566 subsets;
- 15,325 depositional elements;
- 14,109 architectural elements;
- 53,244 facies units;
- 427 datasets with substantial statistical summaries;
- statistical summaries relating to more than 10,000 additional genetic units.

Over 500 additional peer-reviewed articles have been identified as containing architectural data suitable for database input, which is on-going. Figures are correct as of June 2020.

The following pages present case examples of how FAKTS finds application to problems concerning the characterization and prediction of subsurface sedimentary heterogeneity.

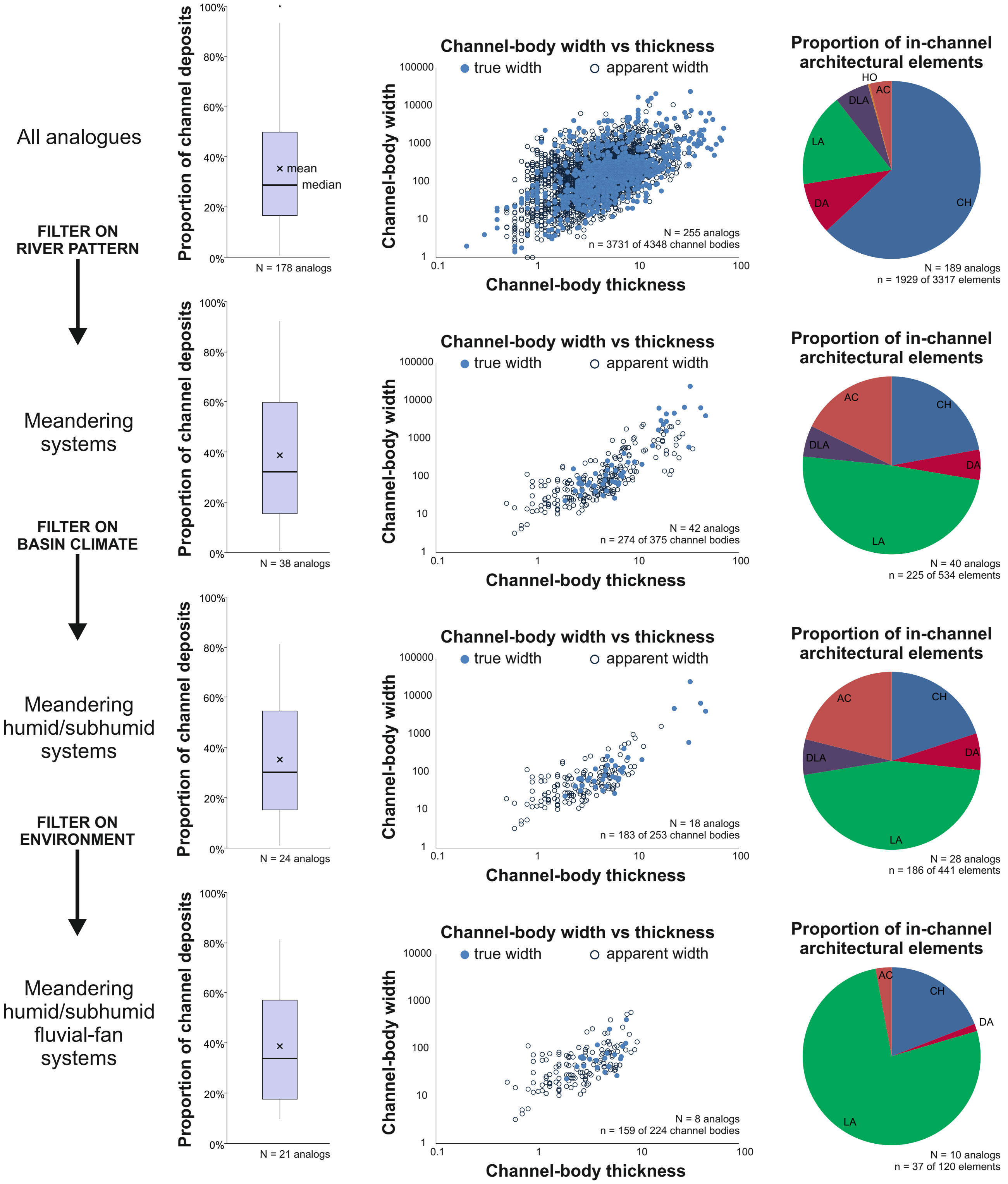


Above. Application of successive filters in FAKTS to examine the proportion of architectural elements typical of a particular class of fluvial succession: braidplain systems developed under the influence of arid or semi-arid climatic controls.



Above. Application of successive filters in FAKTS to examine the width-to-thickness relationships for fluvial successions developed under the influence of humid climatic conditions in retro-arc foreland basins.

FAKTS application 1: filtering data to yield refined results



Legend
Architectural elements
Channel deposits only

CH	🟦	Aggradational channel fill	DLA	🟪	Downstream- & laterally accreting macroform
DA	🟥	Downstream-accreting macroform	HO	🟧	Scour-hollow fill
LA	🟩	Laterally accreting macroform	AC	🟥	Abandoned-channel fill

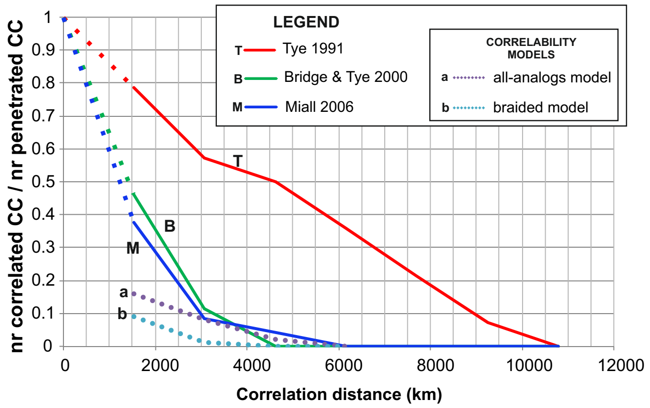
Above. Example application of filters to the FAKTS database, applied to fluvial systems classified on river pattern, climate and depositional context, for the derivation of outputs on the proportion and geometry of channel depositional elements and on the relative frequency of in-channel architectural elements of different types.

FAKTS application 2: sandstone well-to-well correlation

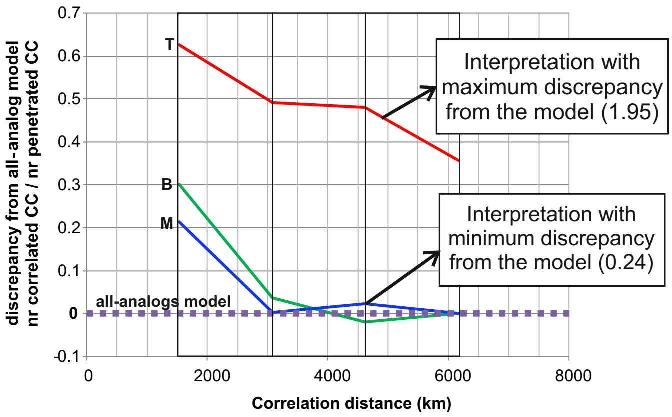
Output from FAKTS can be readily employed to compile empirical quantitative relationships that are commonly used to guide well correlation of fluvial sandstone bodies in subsurface reservoir characterizations.

One application of the database has been the development of a novel and innovative probabilistic method to assess the geological realism of subsurface well-to-well correlations of fluvial sandstone bodies across evenly spaced well arrays. Employing outcrop-analogue data to constrain sandstone-body width distributions for a given depositional system type, it is possible to generate a so-called 'correlability model', which describes realistic well-to-well correlation statistics for specific types of fluvial depositional systems. This approach can be applied for checking the realism of correlation-based subsurface interpretations.

Below, an example application of this particular method is presented to illustrate the method by ranking the quality of three published alternative interpretations of a stratigraphic interval of the Cretaceous Travis Peak Formation (Texas, USA).



RANKING INTERPRETATIONS ON DISCREPANCY FROM MODEL INCLUDING ALL SUITABLE *FAKTS* CASE STUDIES



Interpretation with maximum discrepancy from the model (1.95)

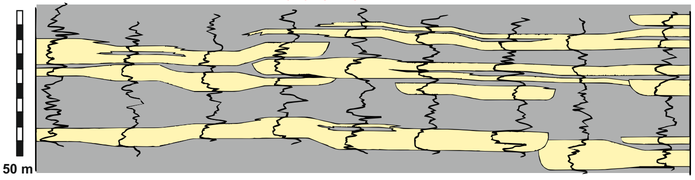
Interpretation with minimum discrepancy from the model (0.24)

FAKTS application: ranking channel-sandstone correlations in the Travis Peak Fm.

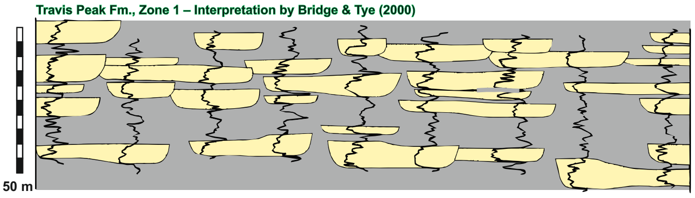
This approach to inform well correlations requires the generation of curves that quantify total probabilities of penetration and correlation of fluvial channel complexes as functions of well spacing and correlation distance respectively. These functions are based on analogue-derived sandstone-width distributions, and correlability models are obtained drawing values from these total-probability functions for multiples of the well-array spacing. By filtering FAKTS, the correlability models can be categorized on outcrop-analogue classifications (e.g. mixed-load system, system with 20% net-to-gross); in this example application, correlability models referring to (i) a generic fluvial system and (ii) to a braided fluvial system have been considered.

For three alternative correlation panels considered (see: Tye 1991; Bridge & Tye 2000; Miall 2006), the ratio between the number of correlated channel-complexes and the total number of channel-complexes in each panel has been computed and plotted for multiples of the well spacing. Overlaying plots of subsurface interpretations with the correlability model based on FAKTS analogues permits a graphical comparison of the degree of approximation of the correlation outcomes to the model, and ultimately allows ranking the three interpretations through quantification of their discrepancy from the model. Thus, through application of this method, FAKTS can be used to probabilistically rank inter-well correlations.

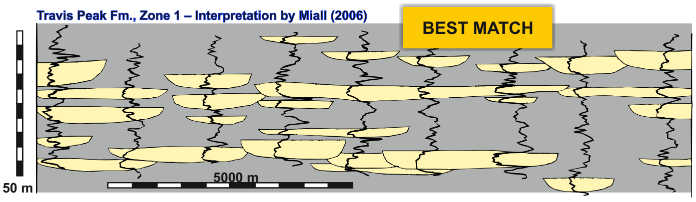
Travis Peak Fm., Zone 1 – Interpretation by Tye (1991)



Travis Peak Fm., Zone 1 – Interpretation by Bridge & Tye (2000)



Travis Peak Fm., Zone 1 – Interpretation by Miall (2006)



FAKTS application 3: guiding stochastic reservoir models

FAKTS permits derivation of various analogue-based parameters with which it is possible to constrain object- and pixel-based stochastic reservoir models, including:

- genetic-unit dimensional parameters as input to object-based models (e.g. channel-complex width-to-thickness aspect-ratio statistics);
- genetic-unit relative dimensional parameters as input to object-based models (e.g. statistics on relative thickness of genetically related channel fills and crevasse splays);
- 3D genetic-unit indicator auto- and cross-variograms as input to pixel-based models (e.g. horizontal indicator variogram of channel deposits for SIS models);
- 3D models of genetic-unit spatial relationships as input to plurigaussian pixel-based models (e.g. architectural-element lithotype rules);
- 3D genetic-unit transition statistics as input to pixel-based models that use transition-probability-based approaches (e.g. facies-unit transition probabilities).

In addition, all the above-mentioned constraints can be employed for the generation of geostatistical realizations that can be adopted as 3D training images with which to constrain multiple-point statistics (MPS) models.

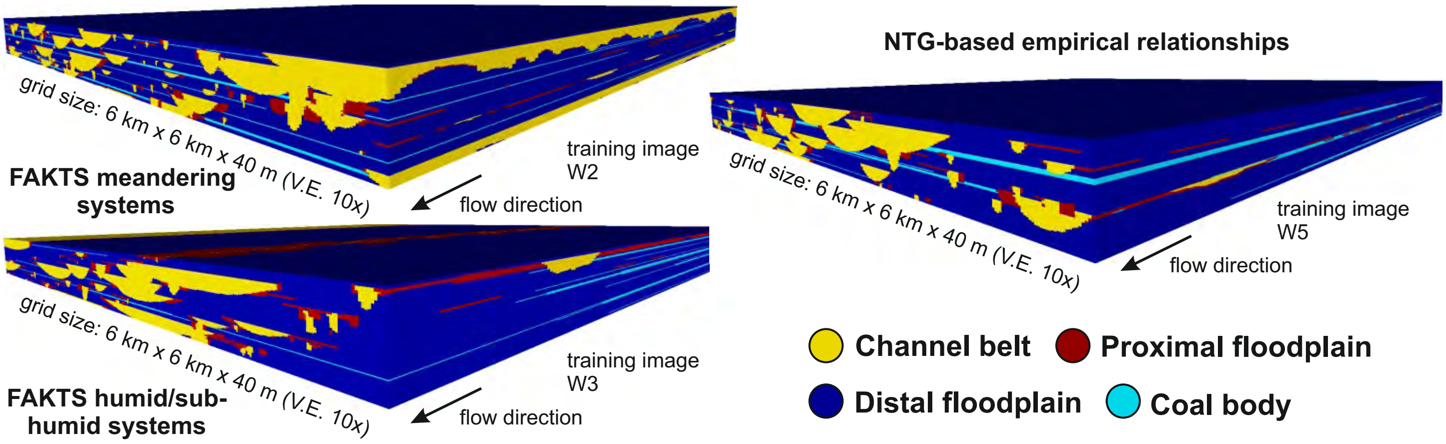
Examples are given of the application of output from FAKTS to the generation of purposely-defined MPS training images (below), and to guide reservoir modelling to more realistically predict the lateral extent of channel sandstone bodies on the basis of prior knowledge of reservoir-interval net-to-gross or sandstone thickness (page 17).

Example database-informed MPS modelling – Modelling Example: Surat Basin (Australia)

The application of database output to the production of training images for MPS reservoir modelling is here exemplified by the generation of training images suitable for simulating the subsurface architecture of the Walloon Coal Measures (Middle Jurassic of the Surat Basin; eastern Australia).

Information on the sedimentary architecture of potential modern and outcrop analogues has been obtained from FAKTS by filtering the database on a range of user-defined combinations of system parameters and architectural properties. In doing this, only depositional systems that can be considered as potential analogues to the specific case-study succession will contribute to the training image. A total of five alternative sets of output have been derived from FAKTS to variably inform the training images by defining analogy in terms of interpreted channel pattern (meandering), basin climate (humid to sub-humid), palaeo-latitude range (45°-75°), and net-to-gross.

Two alternative object-based approaches have been employed to generate the candidate training images; these differ in the way they allow for honouring if different types of available constraints (constraint on the reproduction of genetic-unit width distribution versus width-to-thickness aspect-ratio distribution).



Candidate training images for MPS modelling of the Jurassic Walloon Coal Measures (Surat Basin, E Australia). Analogue information used to populate models derived from FAKTS database.

FAKTS application 4: facies models for core interpretation

FAKTS can be applied for the generation of quantitative 1D facies models, which comprise sets of information on proportions, thicknesses, contact relations and grain sizes of types of lithofacies units, and which can be classified on any depositional-element category (e.g. braided system, delta plain) and/or any type of higher-scale genetic unit (e.g. channel complex, crevasse splay).

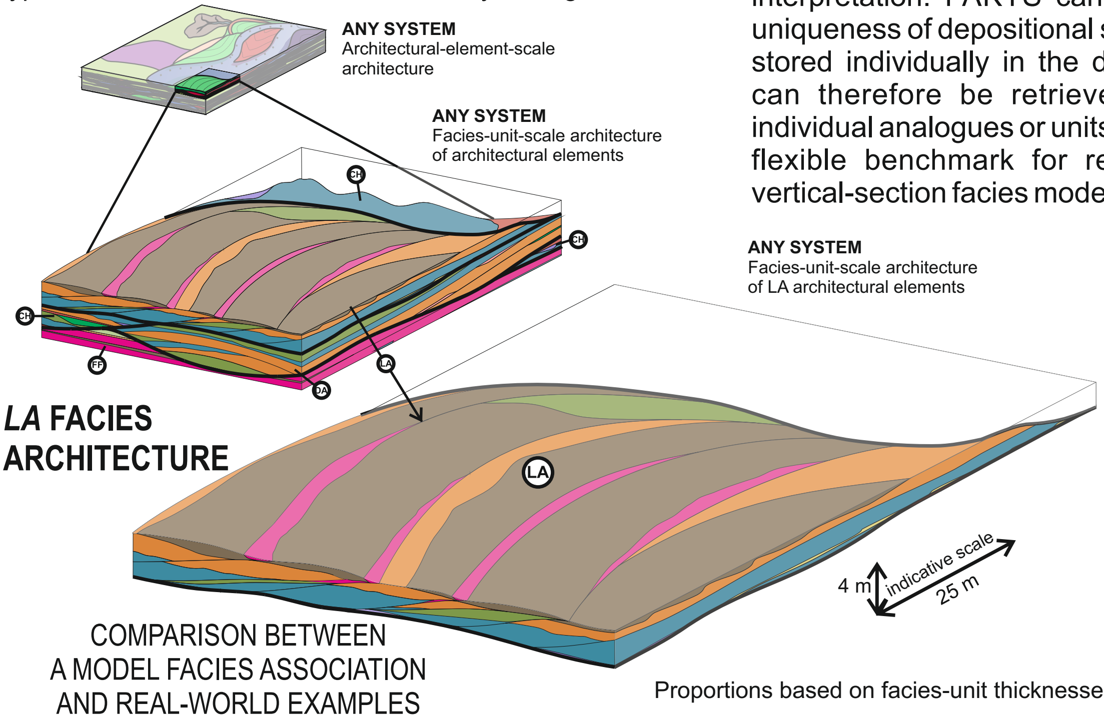
FAKTS-derived models can be readily applied to the interpretation of cored intervals, and the database can be queried for depositional systems or units displaying features matching with core observations.

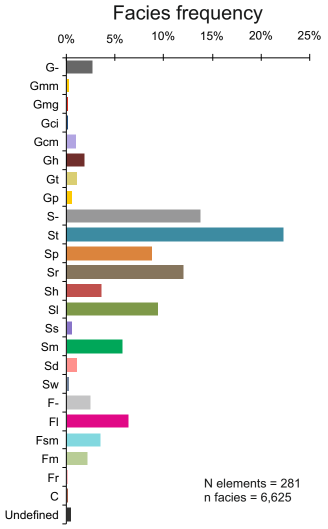
Example LA facies association

A model accounting for the facies architecture of lateral-accretion barforms is presented here; different lithofacies types contribute to the model in different proportions, which are quantified as the sum of facies-unit thickness. A comparison is made with the proportions of facies-unit types within individual lateral-accretion barforms stored in FAKTS, and expressed in tabulated form (e.g. 'St/0.11' means that 11% of that particular barform is estimated to be composed of trough cross-bedded sandstone).

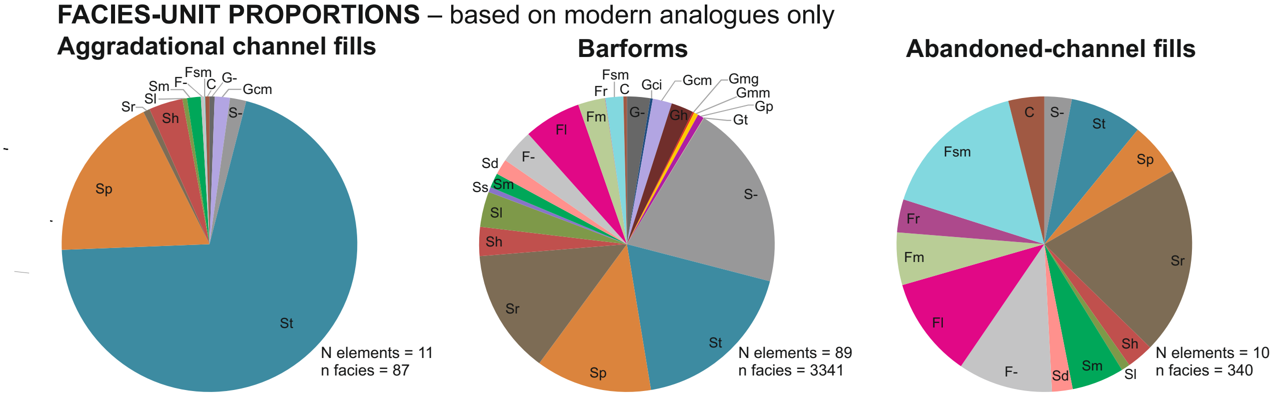
This comparison demonstrates how FAKTS can effectively reconcile the analogue and facies-model approaches to subsurface characterization and core interpretation. FAKTS can be used to highlight the uniqueness of depositional systems, since each one is stored individually in the database, and information can therefore be retrieved for comparison from individual analogues or units, thereby providing a more flexible benchmark for reference than traditional vertical-section facies models.

Below. FAKTS output on the proportion of different facies types in LA architectural elements from any analogue.





Proportions based on facies-unit thicknesses



Above. FAKTS output on the proportion of different classes of channel architectural elements documented in modern rivers.

FAKTS application 5: prediction of heterogeneity in seismically imaged bodies

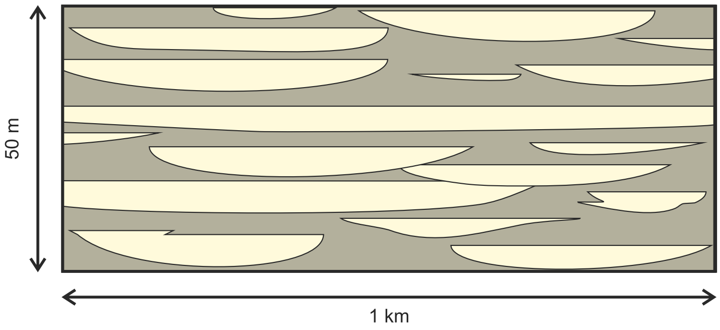
Output from FAKTS relating to the facies organization of classes of depositional and architectural elements can be used to predict the likely internal heterogeneity of sedimentary bodies mapped by high-resolution geophysical imaging techniques.

Example output from FAKTS that suits this type of application (see below) is in the form of distributions that quantify the likely net-to-gross of particular classes of architectural elements that are commonly recognized in the interpretation of seismic time slices.

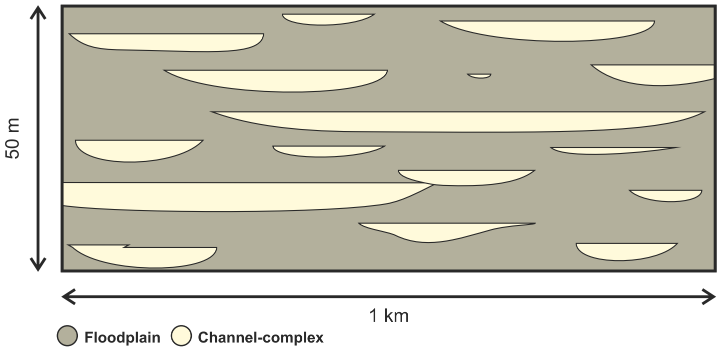
Other sub-seismic-scale features of sedimentary heterogeneity whose distributions within genetic units could tentatively be predicted include, for instance, the geometry of intra-reservoir flow barriers or potential thief zones, or the existence of grain-size trends. The application of FAKTS to the integration of seismic interpretations with analogue information is benefitting from on-going database development involving the inclusion of petrophysical properties of sedimentary units.

FAKTS is especially useful for predicting the internal facies composition of large architectural elements that can be imaged on seismic data (e.g. by examining seismic stratal surfaces) but for which no well penetrations have been made. Examples include large fluvial point-bar deposits in meander-belt reservoirs.

BRAIDED SYSTEM MODEL ARCHITECTURE



SINGLE-THREAD SYSTEM MODEL ARCHITECTURE

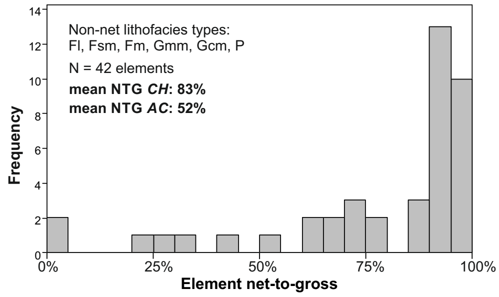


Example architectural-element net-to-gross prediction

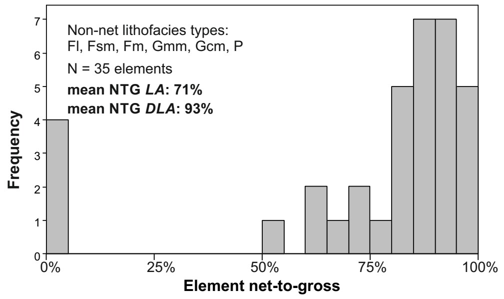
Information derived from a range of outcrop analogues has been used to compile the distributions of net-to-gross values for different classes of architectural elements that are typically interpreted in 3D seismic datasets; such information can be integrated with FAKTS output for the prediction of reservoir volumes and quality.

These results make use of user-defined net-to-gross values: they are based on the relative proportion of the different types of facies units contained in the architectural elements and in accordance with choices made by the users on the attribution of reservoir and non-reservoir facies-unit classes. This is an example of how output from FAKTS can be used to recognize, quantify and better constrain hitherto unseen reservoir potential.

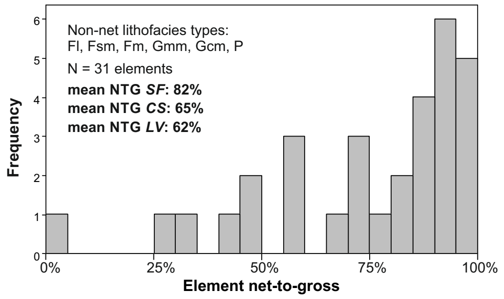
Channel fills (CH, AC)



Barforms with lateral accretion (LA, DLA)



Proximal-floodplain elements (SF, CS, LV)

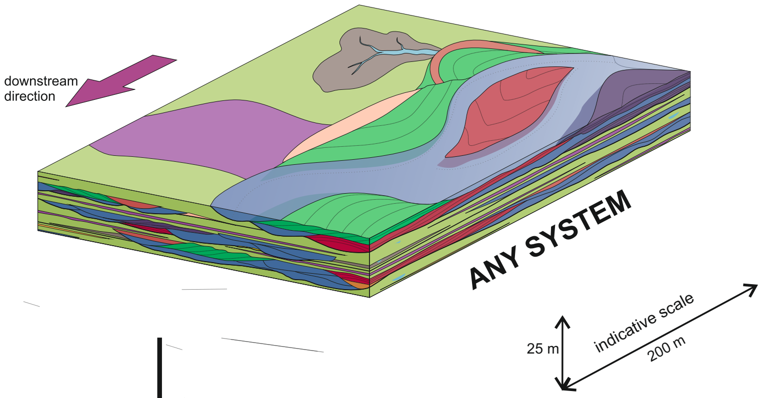


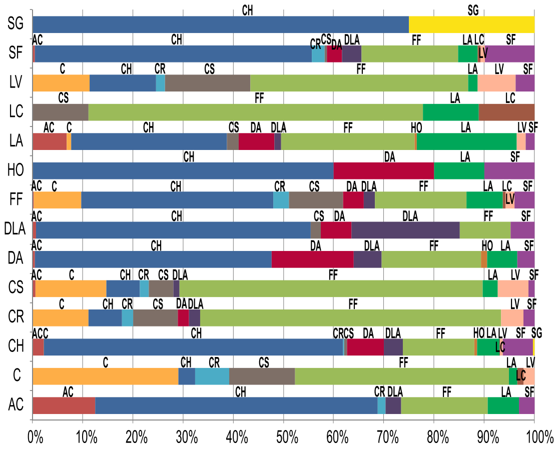
CH = aggradational channel fill; AC = abandoned channel fill;
LA = laterally-accreting barform; DLA = downstream- and laterally-accreting barform;
SF = sheetflood-dominated sandy floodplain; CS = crevasse splay; LV = levee

FAKTS application 6: building probabilistic facies models for different fluvial system types

ARCHITECTURAL-ELEMENT-SCALE FACIES MODEL

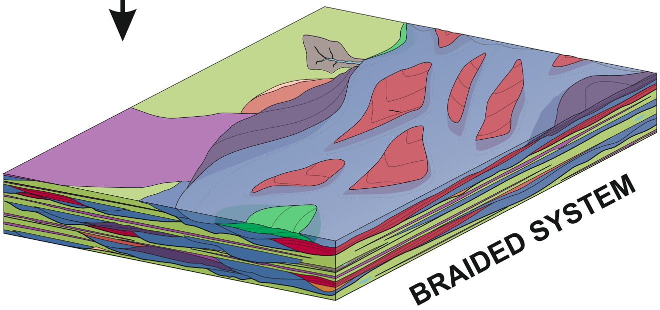
ARCHITECTURAL-ELEMENT VERTICAL TRANSITIONS

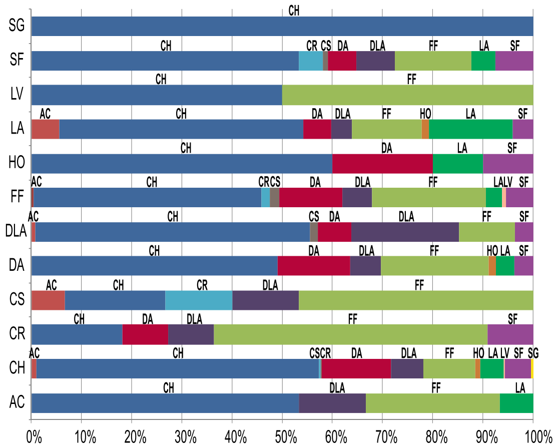




N = 3865 - Undefined architectural elements excluded

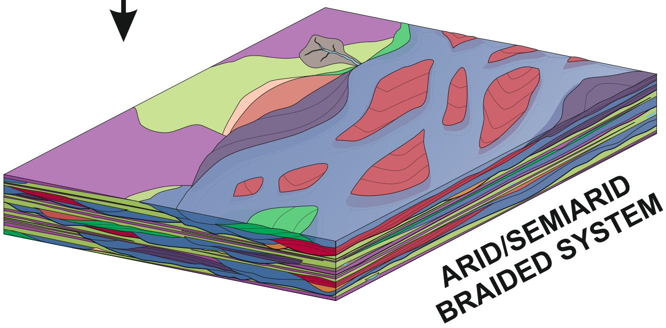
filtering on:
channel pattern type

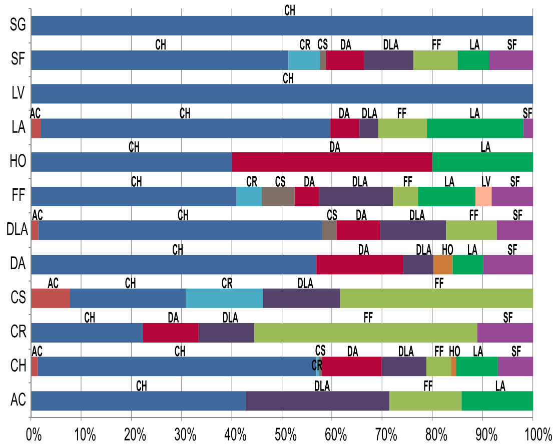




N = 1763 - Undefined architectural elements excluded

filtering on:
basin climate type





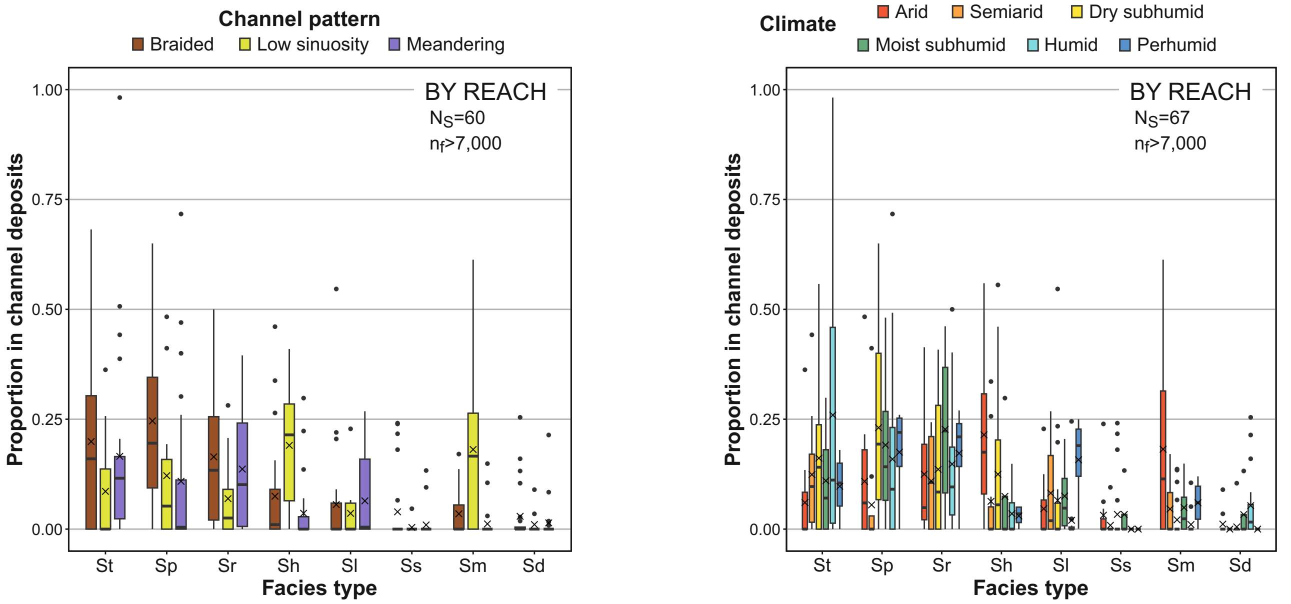
N = 765 - Undefined architectural elements excluded

Above. Example application of filters to the FAKTS database, applied to fluvial systems classified on river pattern and climate, for the derivation of outputs on the spatial relationships (vertical stacking) of architectural elements of different types. This approach can be used to evaluate the palaeoenvironmental context of successions observed in core or well-log data.

FAKTS application 7: suitability of modern fluvial systems as reservoir analogs

Environmental interpretations of subsurface fluvial successions are commonly based on facies observations from core and are often attempted by generalist geologists by reference to classic facies models. However, for fluvial channel deposits, the value of observations on lithofacies proportions for interpretations of depositional environment has yet to be assessed quantitatively. FAKTS has been used for comparative study of facies data from 77 reaches of 46 modern rivers. The observed variability in the proportion of facies assemblages in the channel deposits of sandy river systems is quantified for classes of environments categorized according to channel pattern (braided, low sinuosity, meandering), climatic setting (arid to perhumid), and discharge regime (ephemeral to perennial). By capturing the variability in facies organization within fluvial systems of certain types, these outputs serve as facies models that provide a measure of uncertainty to sedimentological interpretations. Concurrently, the statistical analysis presented enables a test of the significance of relationships between the relative proportions of channel lithofacies and parameters that either represent controlling factors (e.g., water-discharge characteristics) or covariates (e.g., channel pattern). For classes of river systems grouped by channel pattern, climate, and discharge regime, emerging features of facies organization can be identified. Statistically, it is observed that relationships exist (i) between channel pattern and the frequency of the preserved expression of bedforms, and (ii) between controls on river hydrology (climate, discharge regime and seasonal variability) and the record of upper and lower flow-regime conditions. Observations of the relative dominance of facies in channel deposits demonstrate limited value for interpretations or predictions in subsurface or outcrop studies, as variability within each type of depositional system is significant. Corehole data of fluvial channel deposits may be commonly over-interpreted.

Above. Satellite images of some of the modern rivers for which data are available in FAKTS.



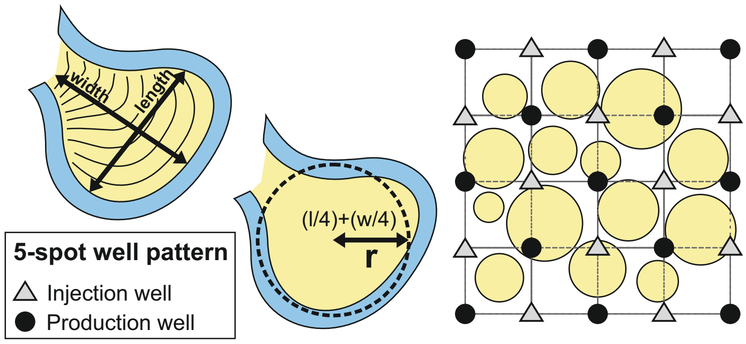
Above. FAKTS output on the distribution in proportions of different facies types in channel deposit documented in 67 reaches of modern river systems.

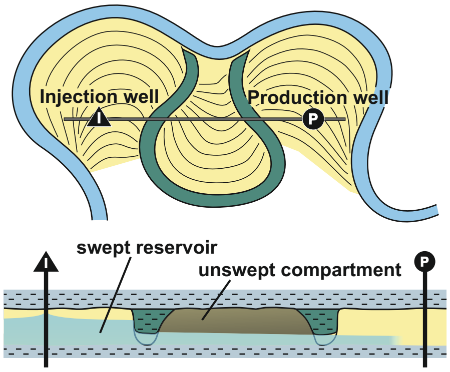
FAKTS application 8: geometry & compartmentalization of fluvial meander-belts

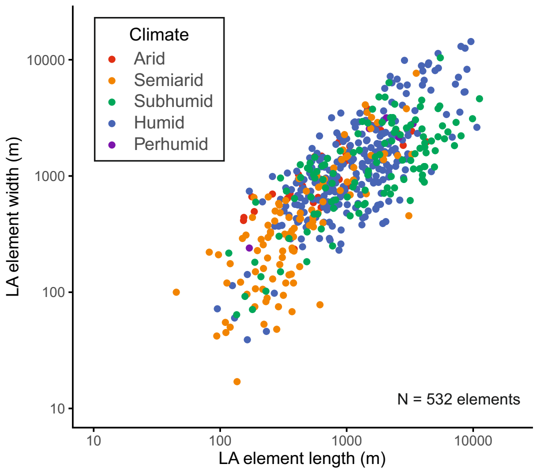
The preserved deposits of fluvial meander belts typically take the form of patchworks of sand-prone bar-form elements bordered by genetically related, muddy channel fills. In meander belts that act as hydrocarbon reservoirs, characteristics of sedimentary architecture, including the geometry of point-bar elements and the internal compartmentalization exerted by the presence of mud-prone abandoned channel fills, control the effectiveness of primary and enhanced hydrocarbon recovery. Therefore, a quantitative description of meander-belt architectures is desired to provide constraints to subsurface predictions.

To this end, an examination of sedimentological datasets, enabled by database-assisted analysis, is undertaken. Sixty-four database case studies of modern, ancient outcropping and subsurface fluvial depositional systems are characterized in a quantitative manner, to assess the relative importance of different styles of lithological compartmentalization, and to provide constraints that can be applied to inform predictions of the geometry and connectivity of bar-scale sandbodies in meander-belt reservoirs. The results of this study include: (i) a set of empirical relationships that relate dimensional parameters describing the geometry of point-bar elements, associated channel fills, channel complexes and potentially unswept compartments; (ii) probabilistic descriptions that relate well density to both the proportion of compartments intersected by a well array, and the maximum volume of untapped bar-form compartments.

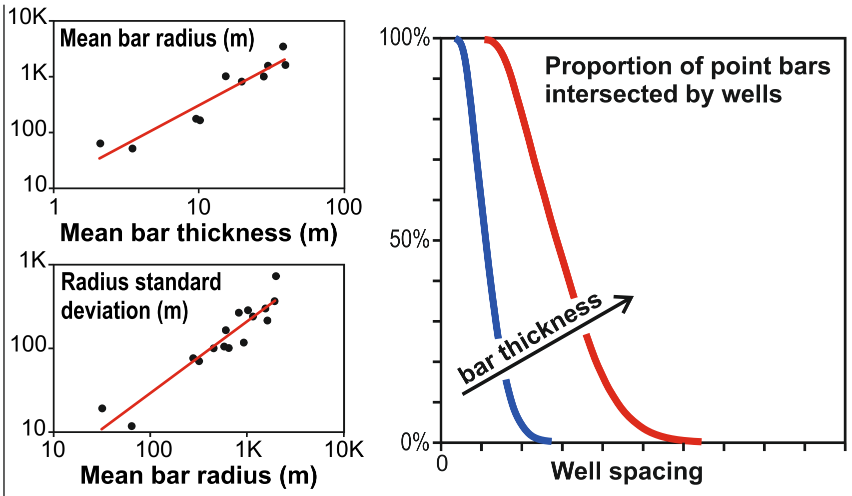
The resulting predictive tools can be applied to assist reservoir development and production, either directly or through incorporation into reservoir models. For example, it is shown how to use these quantitative constraints to predict the likely volume of point-bar reservoir compartments with potential bypassed hydrocarbons, and to optimize drilling strategies (e.g., whether and how to perform infill drilling or horizontal drilling), by providing a measure of the likely presence, size, spacing, and orientation of bypassed hydrocarbon volumes.





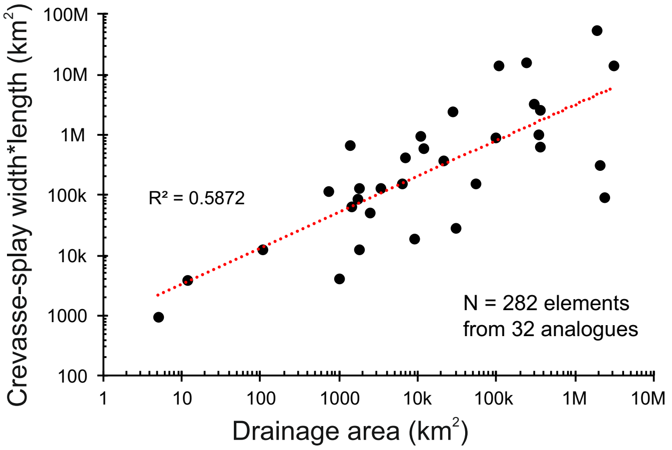


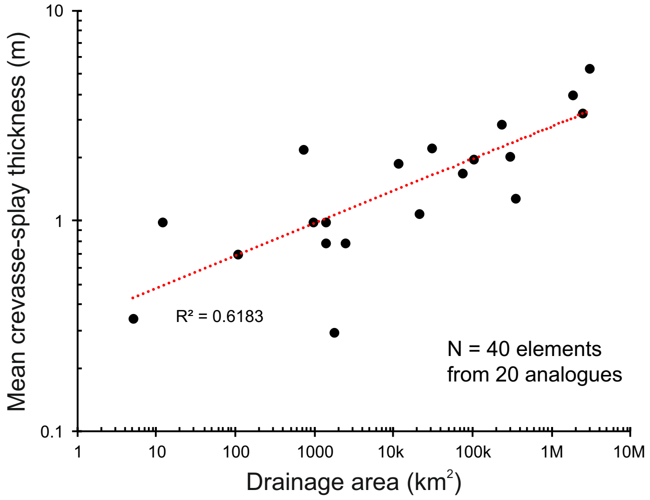
Above. FAKTS output on the planform size of point-bar elements, applicable to predictions of length-scale of stratigraphic compartmentalization in meander-belt fluvial reservoirs.

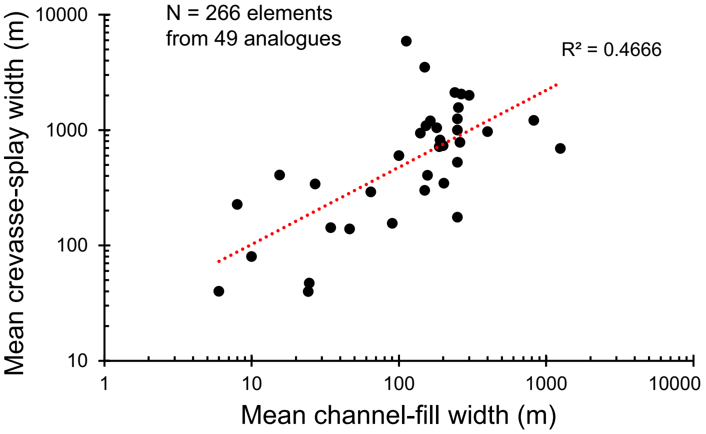


Above. FAKTS-based predictions of the planform size of point-bar elements can be employed in probabilistic models for predicting the number and maximum size of undrilled compartments under a programme of infill drilling.

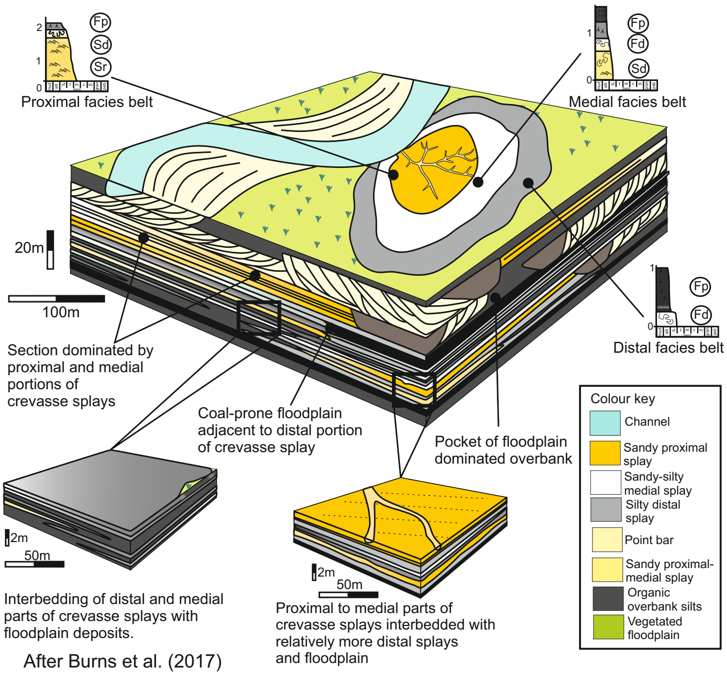
FAKTS application 9: prediction of the geometry of crevasse-splay deposits and analysis of their role as sand-body connectors in fluvial reservoirs



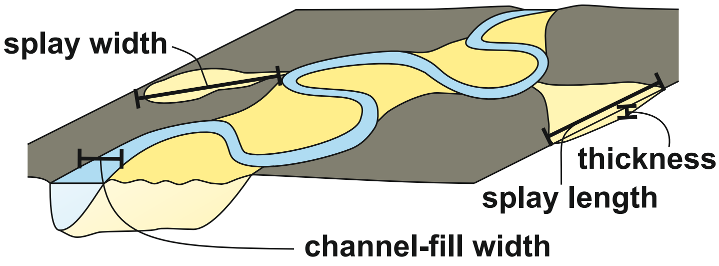




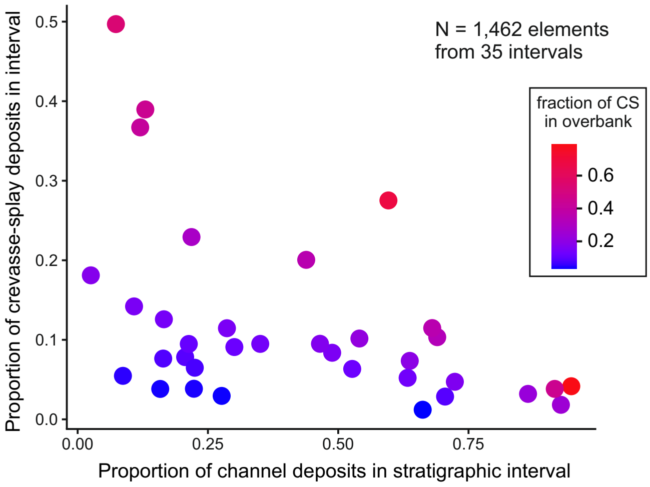
Above. FAKTS-derived empirical relationships for predicting the size of crevasse-splay sandbodies based on knowledge of river-system scale. In reservoir successions, splays can act to form connectors between larger channel-fill sandbodies. As such, the can play an important role in reservoir flow properties. Yet, the dimensions of splays are hard to predict from subsurface data sets alone.



After Burns et al. (2017)

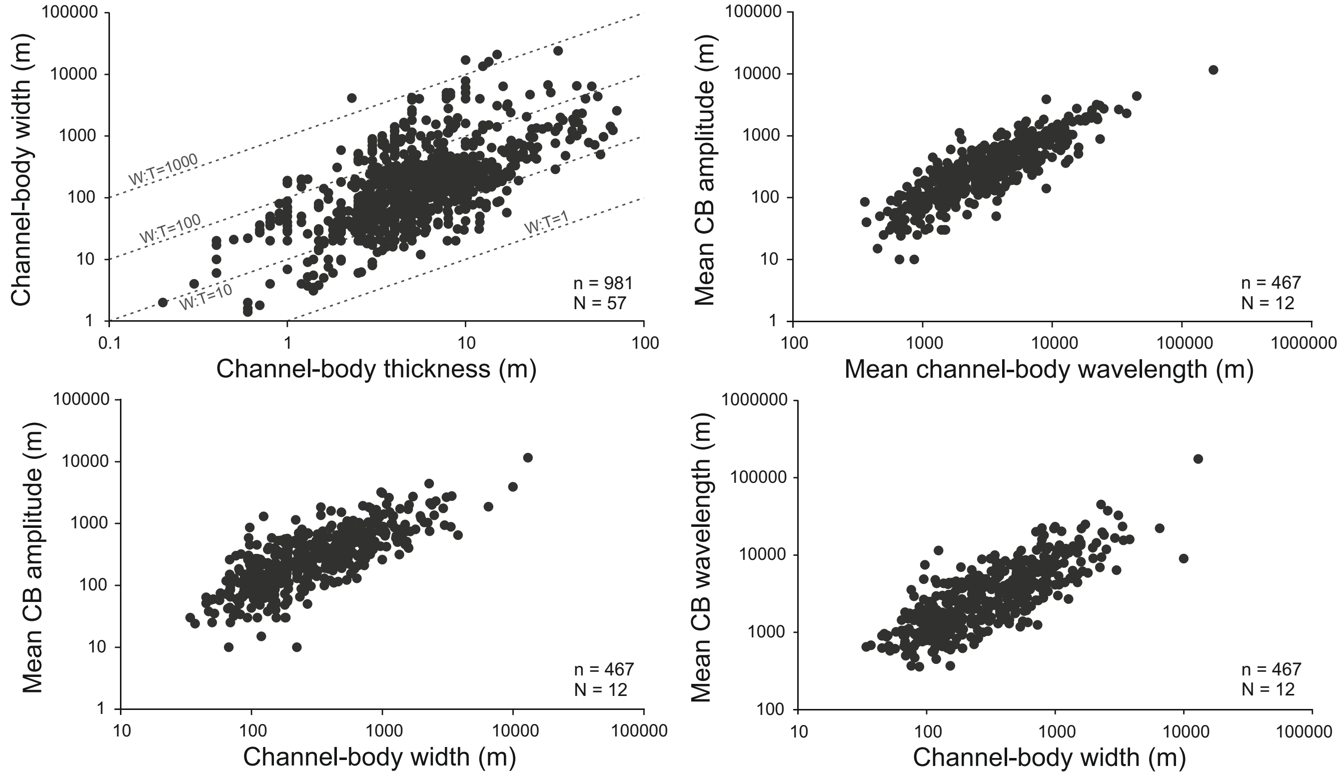


Above. Splays feed reservoir-quality sand to the floodplain.

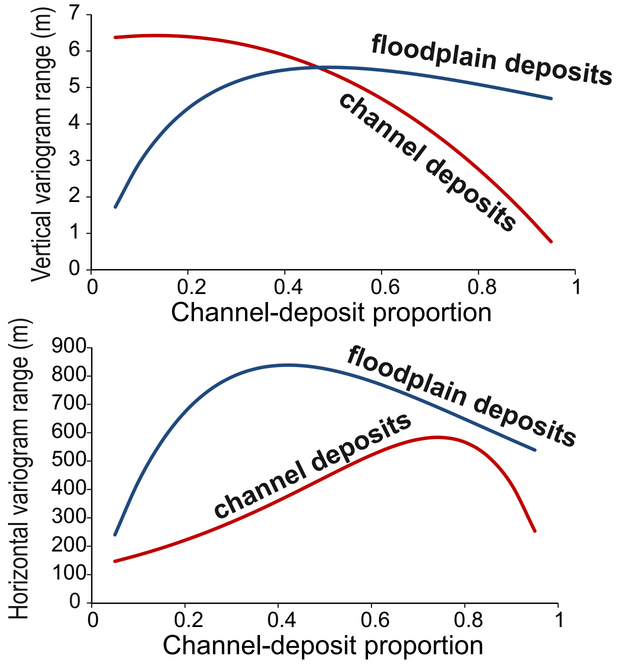


Above. FAKTS output on the relationships between the proportion of channel deposits in stratigraphic intervals and the proportion of crevasse-splay deposits, globally in the interval and as fraction of its overbank sediments.

FAKTS application 10: empirical characterization of fluvial channel bodies & application to variogram- and object-based reservoir models



Above. FAKTS output quantifying the geometry of channel-body depositional elements; this type of information can be used to constrain object-based reservoir models.

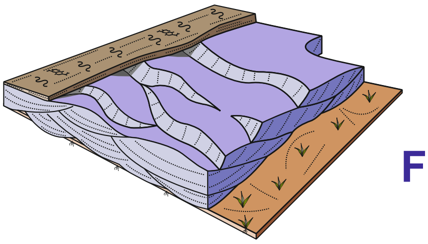


Above. FAKTS output on the proportion, geometry and transition statistics of sedimentary units can be used to define indicator-variogram ranges, applicable to constrain pixel-based reservoir models.

The distribution of channel deposits in fluvial reservoirs is commonly modelled with object-based techniques, constrained on quantities describing the geometries of channel bodies. To ensure plausible forecasts, it is common to define inputs to these models by referring to geological analogues. Given their ability to reproduce complex geometries and to draw upon the analogue experience, object-based models are considered inherently realistic. Yet, this perceived realism has not hitherto been tested against sedimentary architectures in the stratigraphic record.

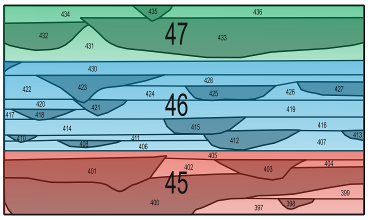
FAKTS can be used: (i) to provide tools for constraining both object- and pixel-based stochastic models of fluvial reservoirs in data-poor situations; (ii) to test the intrinsic realism of reservoir modelling algorithms by comparing characteristics of the modelled architectures against analogues.

FAKTS is used to indicate which modelling approaches return architectures that more closely resemble the organization of fluvial depositional systems known from nature, and in what respect. None of the most commonly employed variogram or object-based reservoir modelling algorithms fully reproduce characteristics seen in natural systems, demonstrating the need for subsurface-modelling methods to better incorporate geological knowledge.



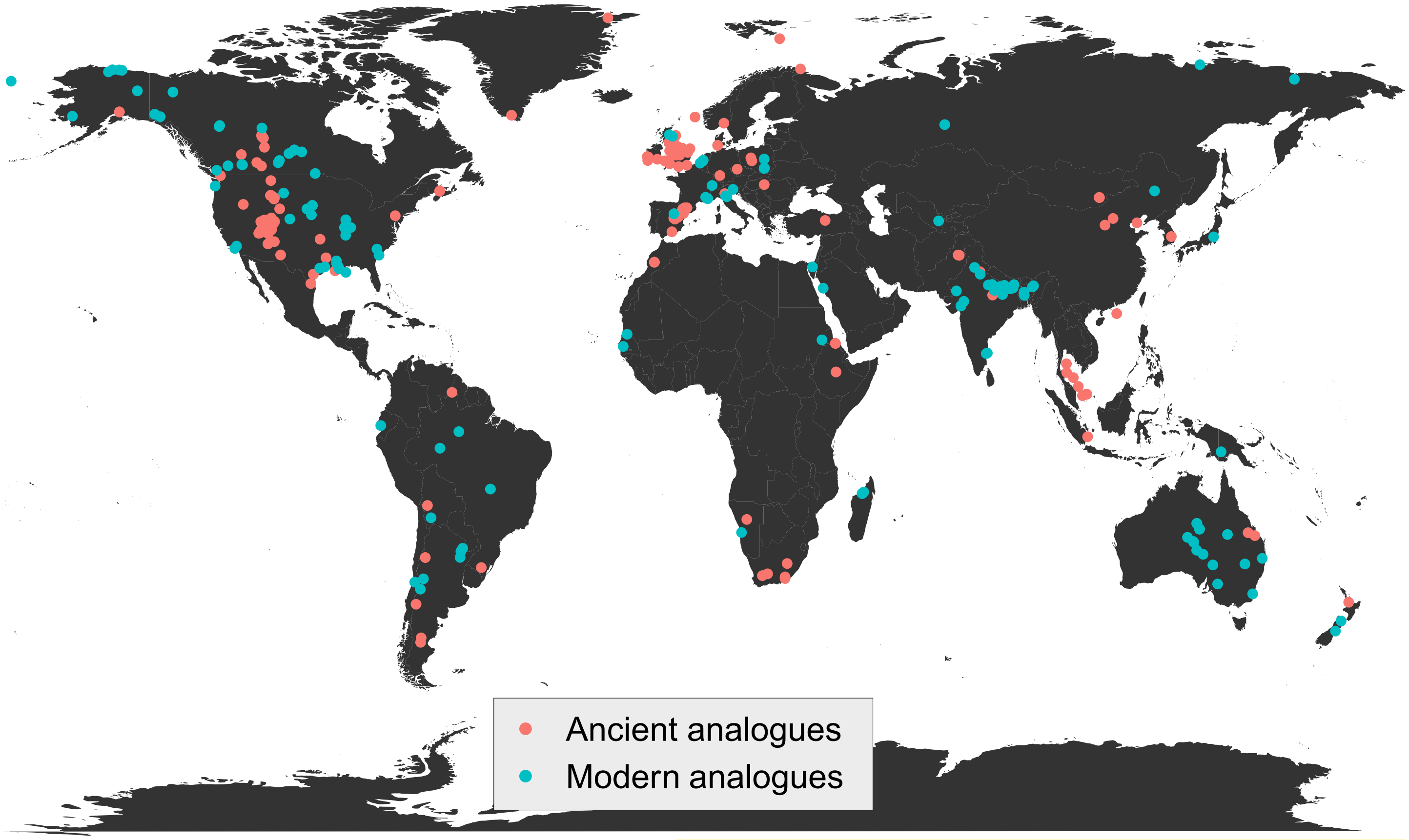
FAKTS

Fluvial Architecture Knowledge Transfer System



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.

- 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).
- Build bespoke facies models for particular classes of fluvial sedimentary succession.



Above. Geographic distribution of some of the >335 analogue studies contained in FAKTS, as of June 2020. Database population is on-going.

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/