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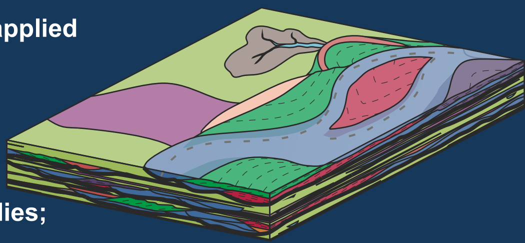
FAKTS: Fluvial Architecture Knowledge Transfer System



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:

- 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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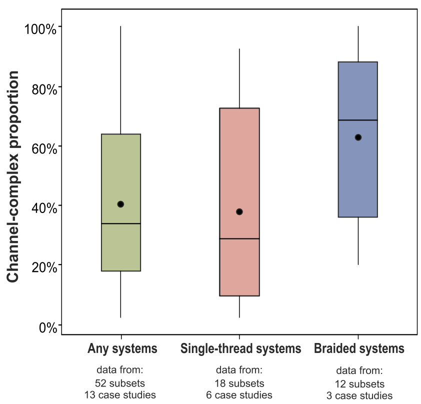
Fluvial & Eolian Research Group: FAKTS database

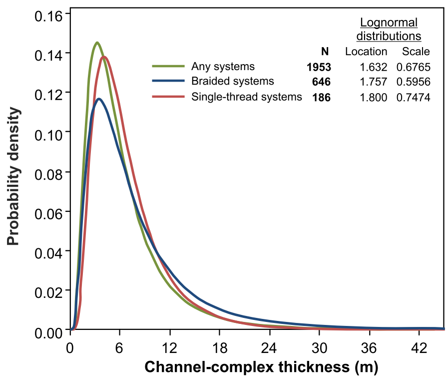
Introduction to the Fluvial Architecture Knowledge Transfer System (FAKTS)

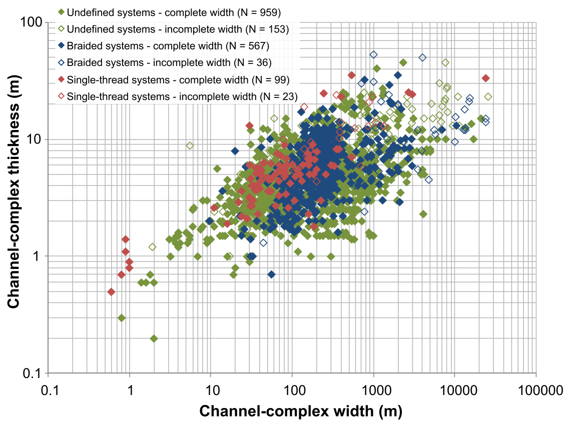
The Fluvial Architecture Knowledge Transfer System (FAKTS) is a research-led flagship initiative of the Fluvial Research Group (FRG) at the University of Leeds. FAKTS is a relational database storing **hard and soft data about fluvial sedimentary architecture** that has been populated with data derived 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.

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 available in its full form exclusively to FRG group sponsors

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.







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).

The FAKTS database can be interrogated either through a menu-driven online front-end hosted on the FRG web site, or by performing SQL queries on a downloadable version of the database in such a way 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 form a suite of analogues, whose analogy to a particular reservoir is considered in terms of architectural properties and/or depositional-system parameters.

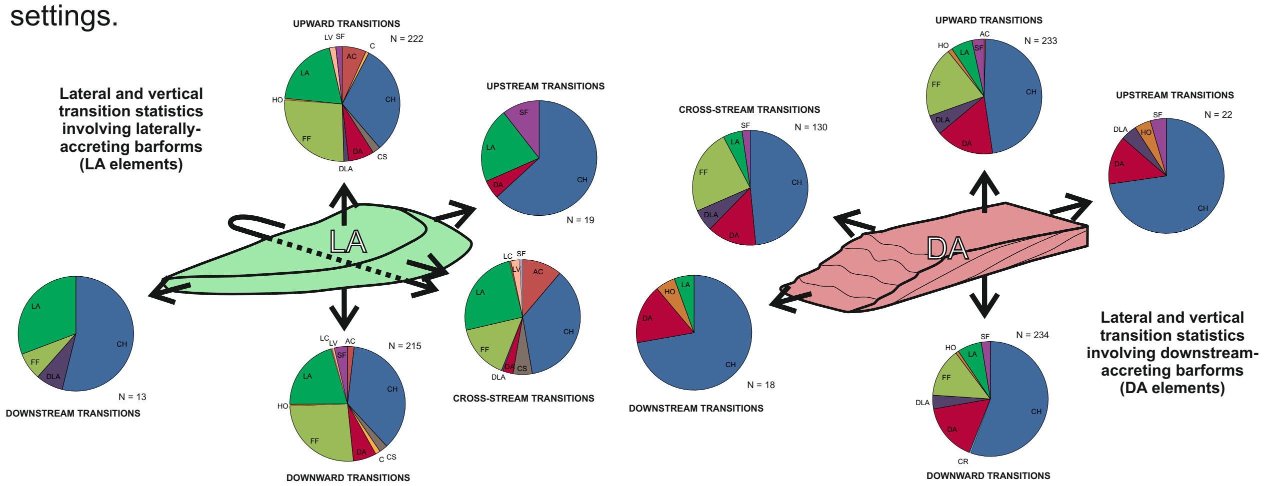
FAKTS output can be **applied to fluvial-reservoir characterization and prediction**. The database serves as a tool with which to achieve the following primary goals:

- 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.

Fluvial & Eolian Research Group: FAKTS database

How can FAKTS be applied to subsurface characterization problems?

- 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 channels) 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.



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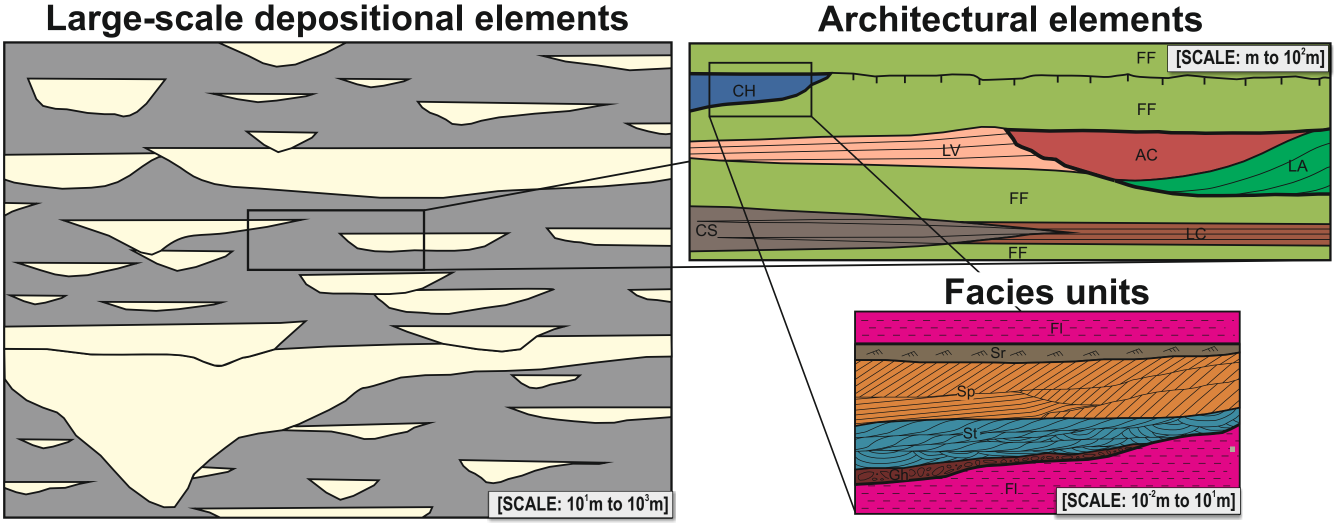
FAKTS key features

- 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 within 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 chronostratigraphy 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.

Illustration of the hierarchical nesting of smaller go-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.



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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, and the data retrieved can then be graphed or analysed in any spreadsheet application.

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 values.

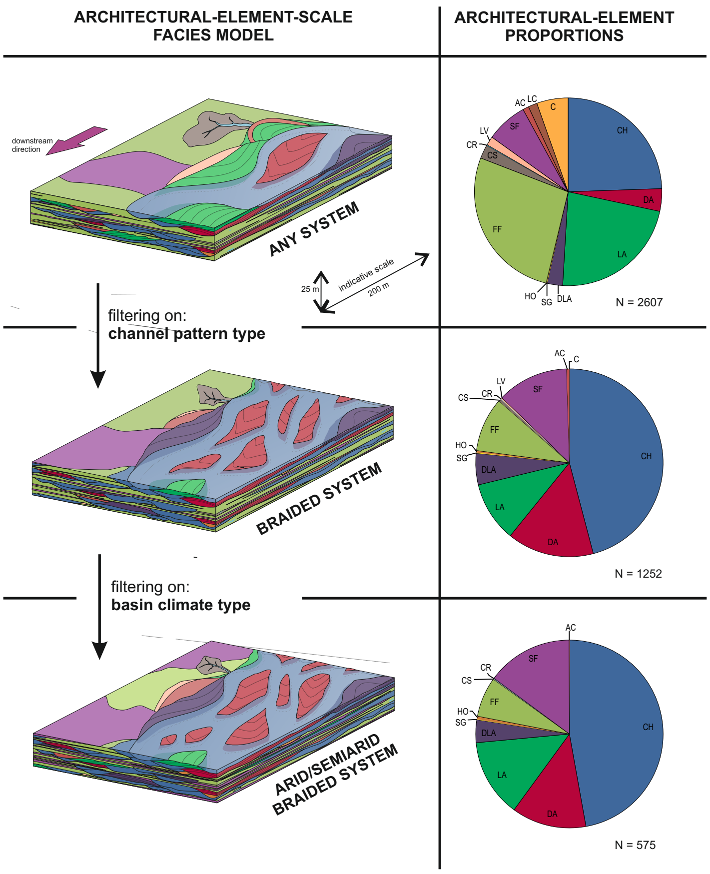
FAKTS content

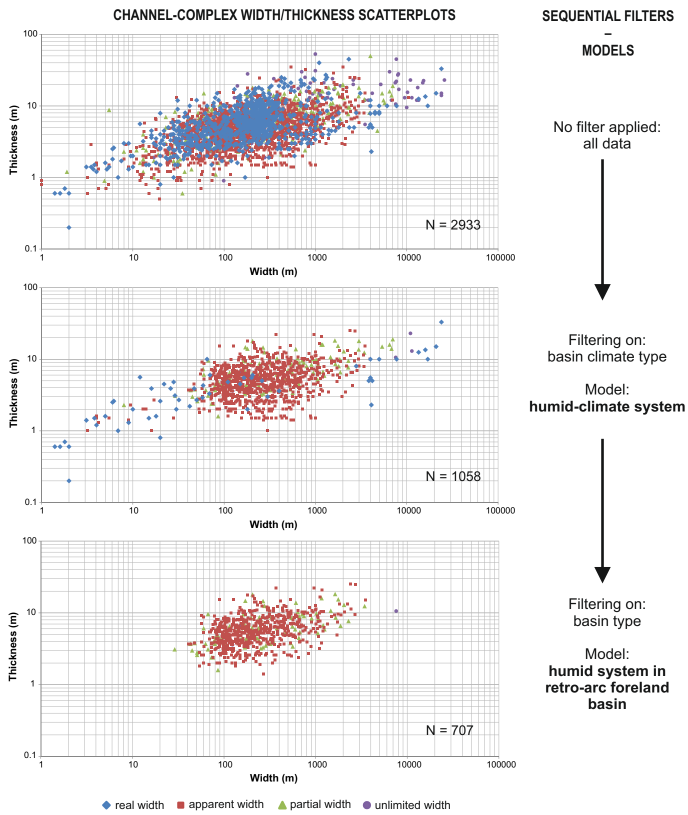
FAKTS currently includes data associated with:

- 121 case studies, comprising 72 ancient succession, 26 modern rivers, and other composite databases;
- 7,587 classified depositional elements;
- 4,087 classified architectural elements;
- 22,045 classified facies units;
- statistical summaries relating to more than 7,400 additional genetic units.

Over 490 additional peer-reviewed articles have been identified as containing architectural data suitable for database input, which is on-going. Figures are correct as of February 2014.

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





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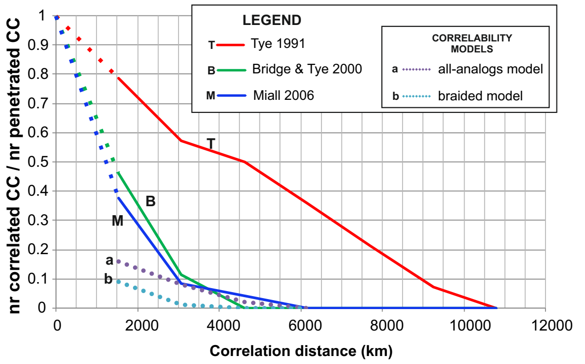
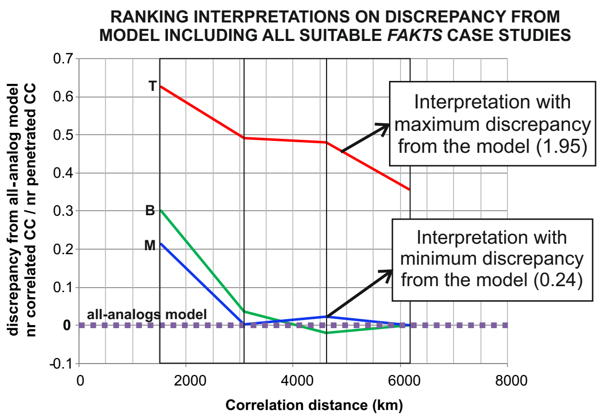
FAKTS subsurface application 1: sandstone well-to-well correlation

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).

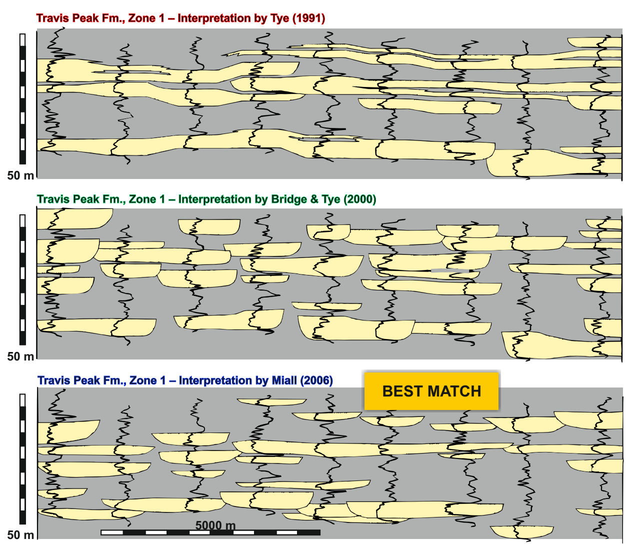




FAKTS application: ranking channel-sandstone correlations in the Travis Peak Fm.

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.



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FAKTS subsurface application 2: 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.

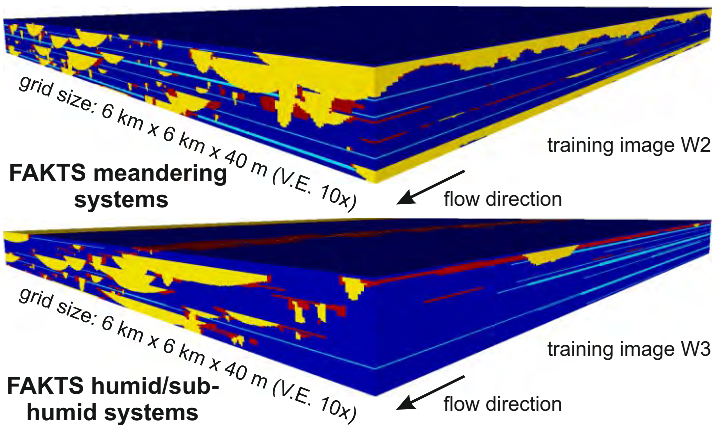
Below, examples are given of the application of output from FAKTS to the generation of purposely-defined MPS training images, and to guide SIS modelling to more realistically predict the lateral extent of channel sandstone bodies on the basis of knowledge of reservoir-interval net-to-gross.

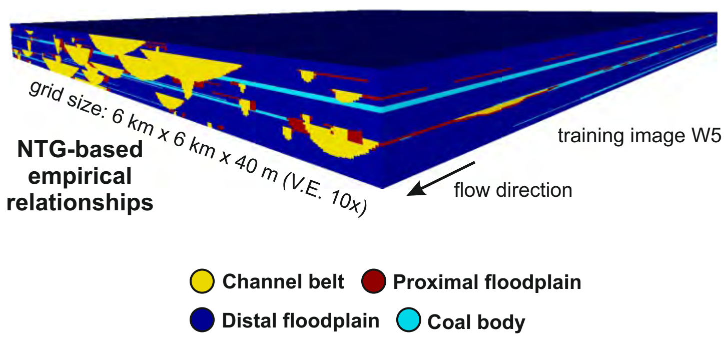
Example database-informed MPS modelling – Surat Basin (Australia)

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.

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FAKTS subsurface application 3: facies models for core interpretation

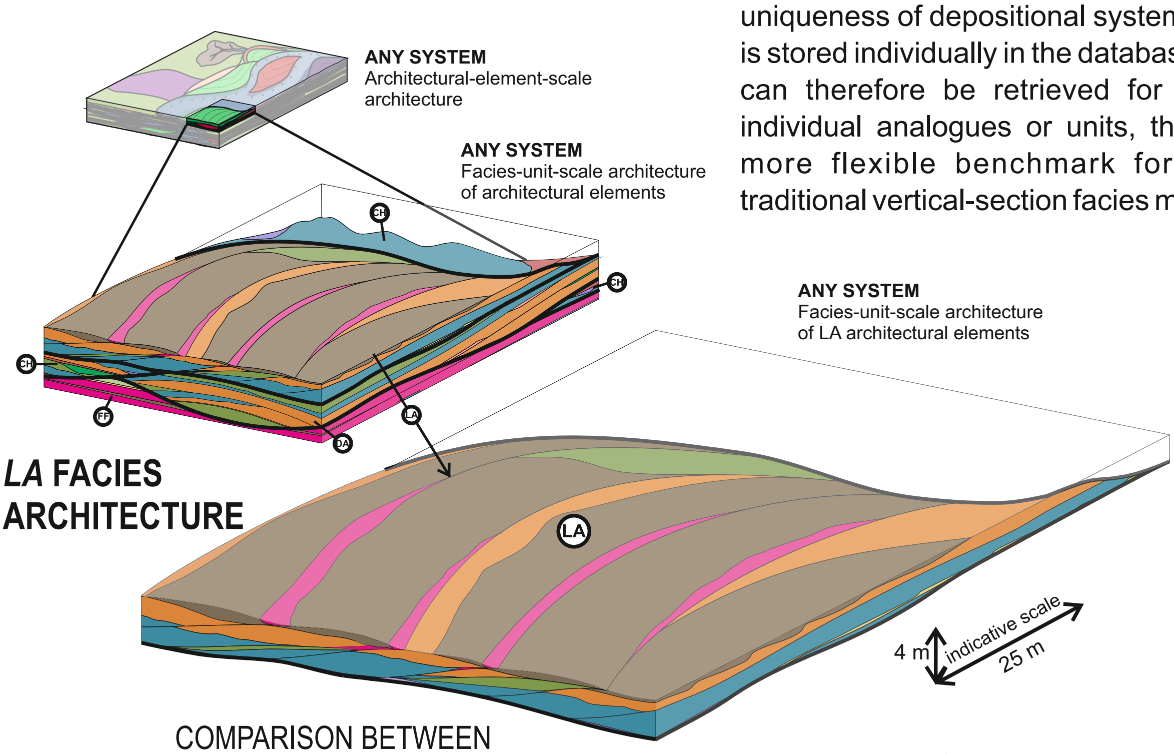
FAKTS can be applied for the generation of quantitative 1D facies models, which comprise sets of information on proportions, thicknesses, contact relations and grain sizes of types of lithofacies units, and which can be classified on any depositional-element category (e.g. braided system, delta plain)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

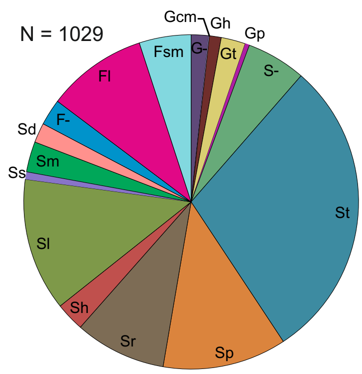
This comparison demonstrates how FAKTS can effectively reconcile the analogue and facies-model approaches to subsurface characterization and core interpretation. FAKTS can be used to highlight the uniqueness of depositional systems, since each one is stored individually in the database, and information 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.



COMPARISON BETWEEN A MODEL FACIES ASSOCIATION AND REAL-WORLD EXAMPLES

Proportions based on facies-unit thicknesses

Model facies association



lithofacies types

Code	Legend
G-	
Gmm	
Gmg	
Gcm	
Gci	
Gh	
Gt	
Gp	
S-	
St	
Sp	
Sr	
Sh	
Sl	
Ss	
Sm	
Sw	
Sd	
F-	
Fl	
Fsm	
Fm	
Fr	
P	
C	

Facies type/proportion database output - individual elements

Identifier	Facies association (lithofacies type/proportion in element)
436	St/0.11,Sp/0.44,Sr/0.44
439	S-/0.13,St/0.13,Sp/0.72,F-/0.02
443	St/0.28,Sp/0.45,S-/0.07,Sh/0.13,F-/0.06
447	S-/0.50,Fl/0.33,St/0.17
1233	Sl/0.43,Sh/0.24,Sp/0.10,St/0.24
1257	Sl/0.43,Ss/0.29,St/0.29
1388	Sl/0.72,Sm/0.14,St/0.15
1420	Sr/0.17,St/0.15,Ss/0.17,Sm/0.22,Sl/0.20,Fl/0.
1513	St/0.43,Gcm/0.12,Sl/0.45
1555	Sp/0.35,Sr/0.02,Sm/0.04,Sd/0.09,Sl/0.32,St/0.18
2646	St/0.66,Sr/0.06,Sd/0.15,Fl/0.12
2647	Sr/0.26,St/0.55,Ss/0.02,Sl/0.03,Sd/0.03,Fl/0.10
2678	F-/0.10,S-/0.76,Sp/0.14
2705	F-/0.14,Fl/0.14,G-/0.05,St/0.41,Ss/0.04,Sp/0.05,S-/0.16
2723	Fl/0.02,G-/0.08,Gh/0.01,Gp/0.02,Gt/0.04,S-/0.02,Ss/0.02,Sr/0.07,St/0.61,Sp/0.05,Sm/0.02,Sl/0.02,Sh/0.01,F-/0.02
[...]	[...]

FAKTS subsurface application 4: 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.

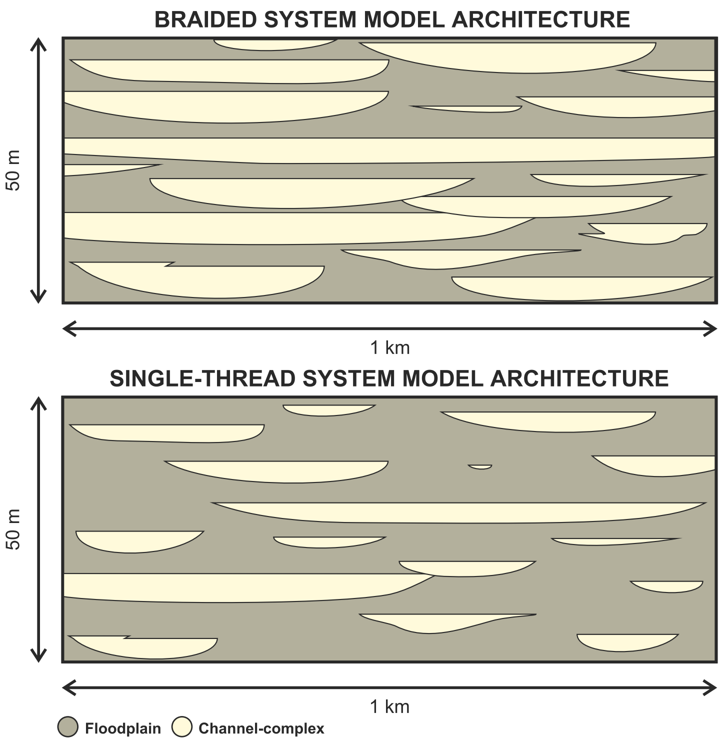
Example output from FAKTS that suits this type of application (see below) is in the form of distributions that quantify the likely net-to-gross of particular classes of architectural elements that are commonly recognized in the interpretation of seismic time slices.

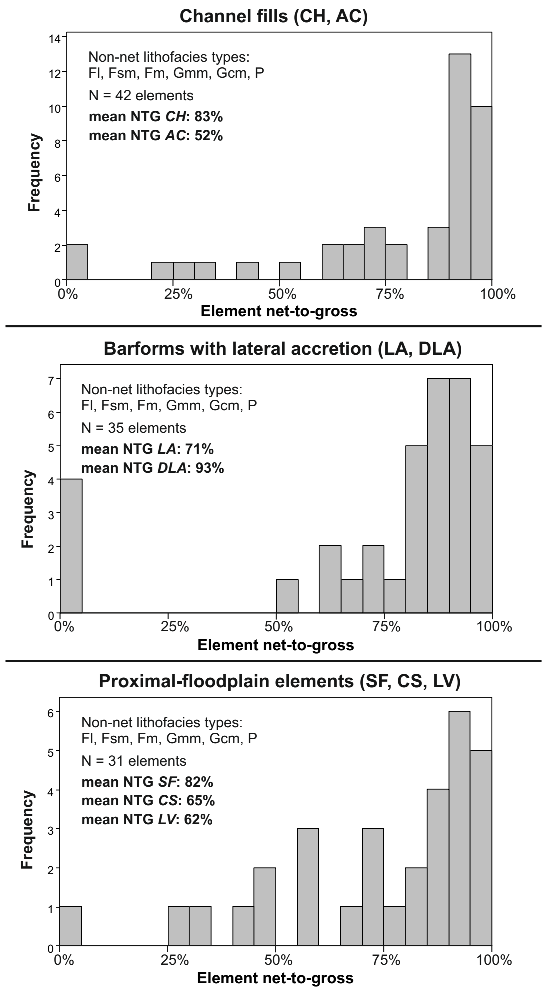
Other sub-seismic-scale features of sedimentary heterogeneity whose distributions within genetic units could tentatively be predicted include, for instance, the geometry of intra-reservoir flow barriers or potential thief zones, or the existence of grain-size trends. The application of FAKTS to the integration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

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.

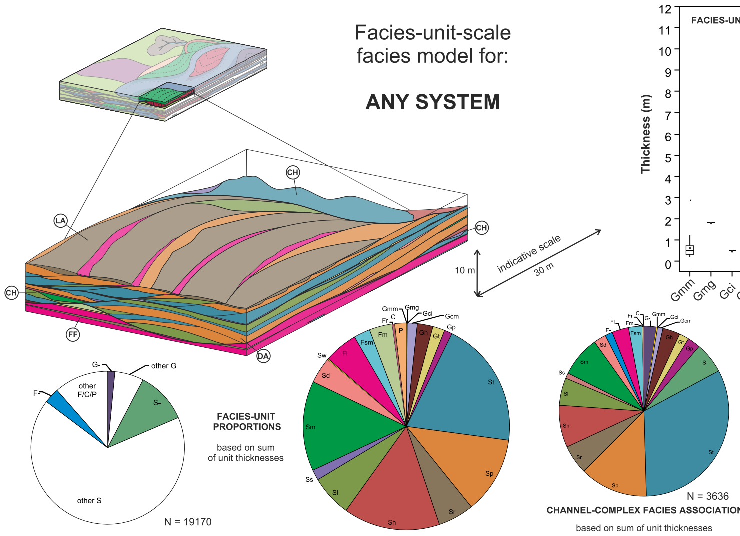
These results make use of user-defined net-to-gross values: they are based on the relative proportion of the different types of facies units contained in the architectural elements and in accordance with choices made by the users on the attribution of reservoir and non-reservoir facies-unit classes.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

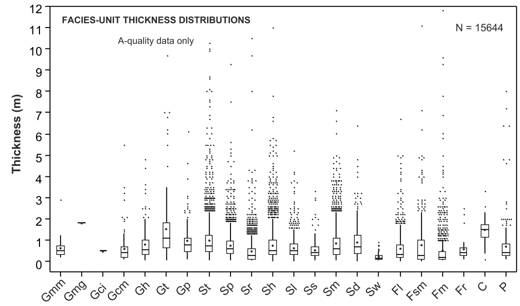


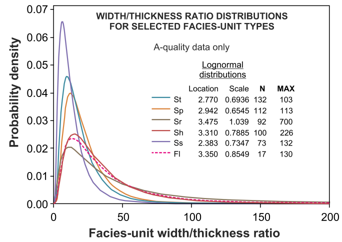


CH = aggradational channel fill; AC = abandoned channel fill;
LA = laterally-accreting barform; DLA = downstream- and laterally-accreting barform;
SF = sheetflood-dominated sandy floodplain; CS = crevasse splay; LV = levee

Fluvial & Eolian Research Group: FAKTS database



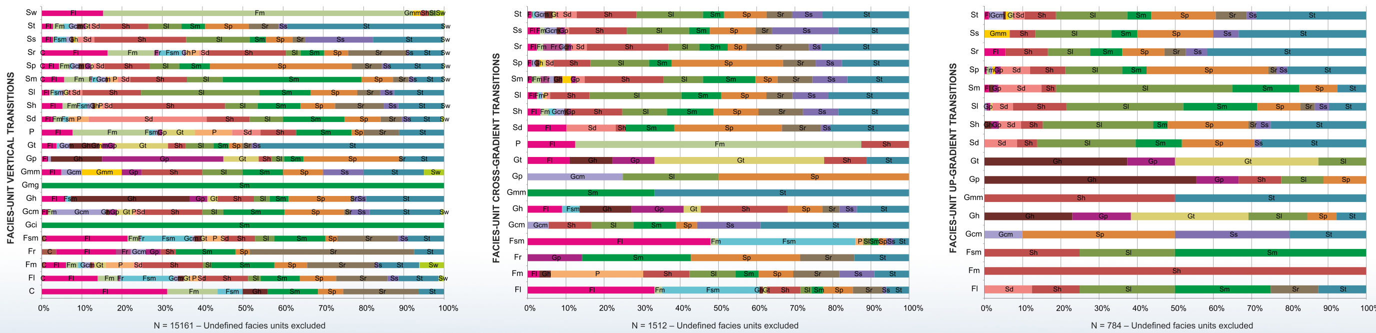




FACIES-UNIT LATERAL-EXTENT DESCRIPTIVE STATISTICS

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



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Pondering the significance of the Castlegate Sequence Boundary near Blaze Canyon, Book Cliffs, Utah