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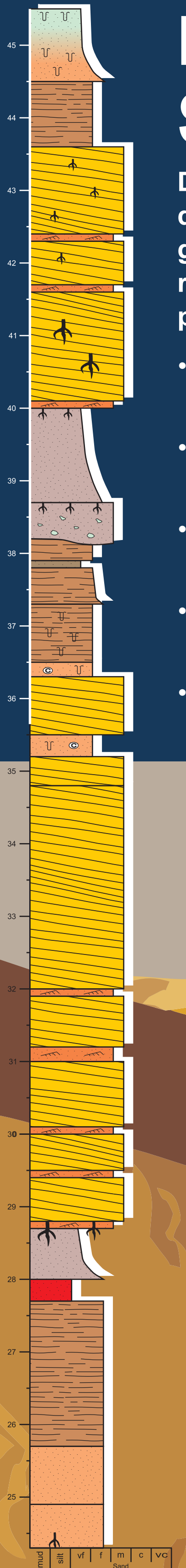
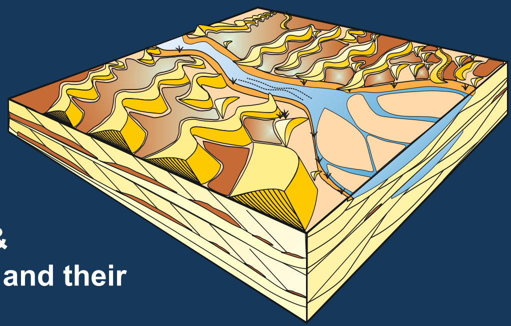


DASA: Database of Aeolian Sedimentary Architecture



DASA is the world's largest & most sophisticated relational database specifically designed to characterize the geomorphology, sedimentology, stratigraphic architecture & regional stratigraphy of modern & ancient aeolian systems, and their preserved successions.

- **develop quantitative facies models, specifically tailored for parameters describing particular spatio-temporal and environmental contexts;**
- **instruct & constrain forward stratigraphic models and 3D geocellular models for enhanced characterization of subsurface aeolian successions;**
- **empirical assessment of how aeolian systems respond to – and how associated architectures record – allogenic and autogenic processes that dictate stratigraphy;**
- **make quantitative predictions of lithological heterogeneities across multiple scales for subsurface aeolian geobodies that cannot be examined directly;**
- **generate informed interpretations of aeolian lithologies observed in core, for prediction of three-dimensional sedimentary architecture away from boreholes.**

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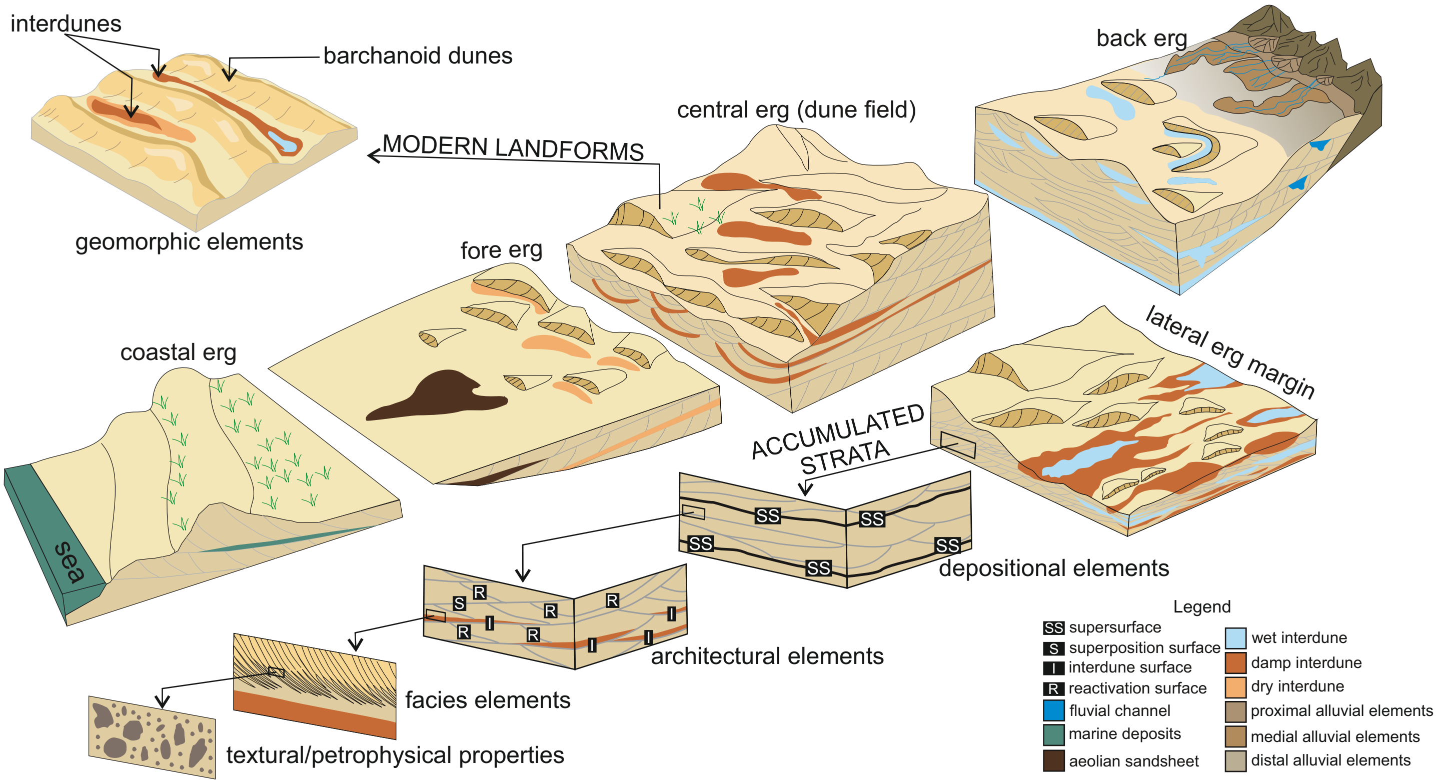
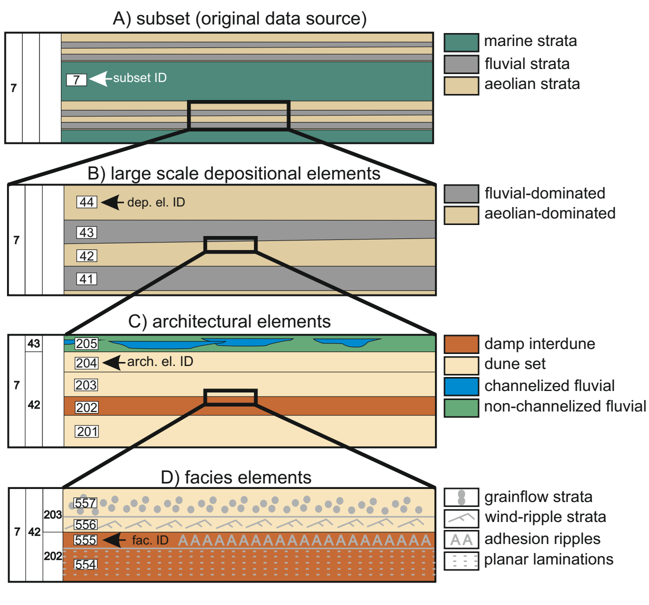
Introduction to the Database of Aeolian Sedimentary Architecture (DASA)

DASA is a relational database designed to effectively store data and information describing the architecture and spatio-temporal evolution of a broad range of modern aeolian systems and ancient aeolian successions. Case-study examples for which data are recorded have been selected for their potential as analogues to subsurface reservoirs in aeolian rocks. DASA is a novel, research-driven initiative devised by the Eolian Research Group (ERG) at The University of Leeds. DASA is the only database specifically conceived for the storage and structured retrieval of quantitative information relating to aeolian sedimentary architecture. DASA is available in its full form exclusively to ERG group sponsors. Examples of some the characteristics captured in DASA are shown in the figure below.



How Does DASA Work?

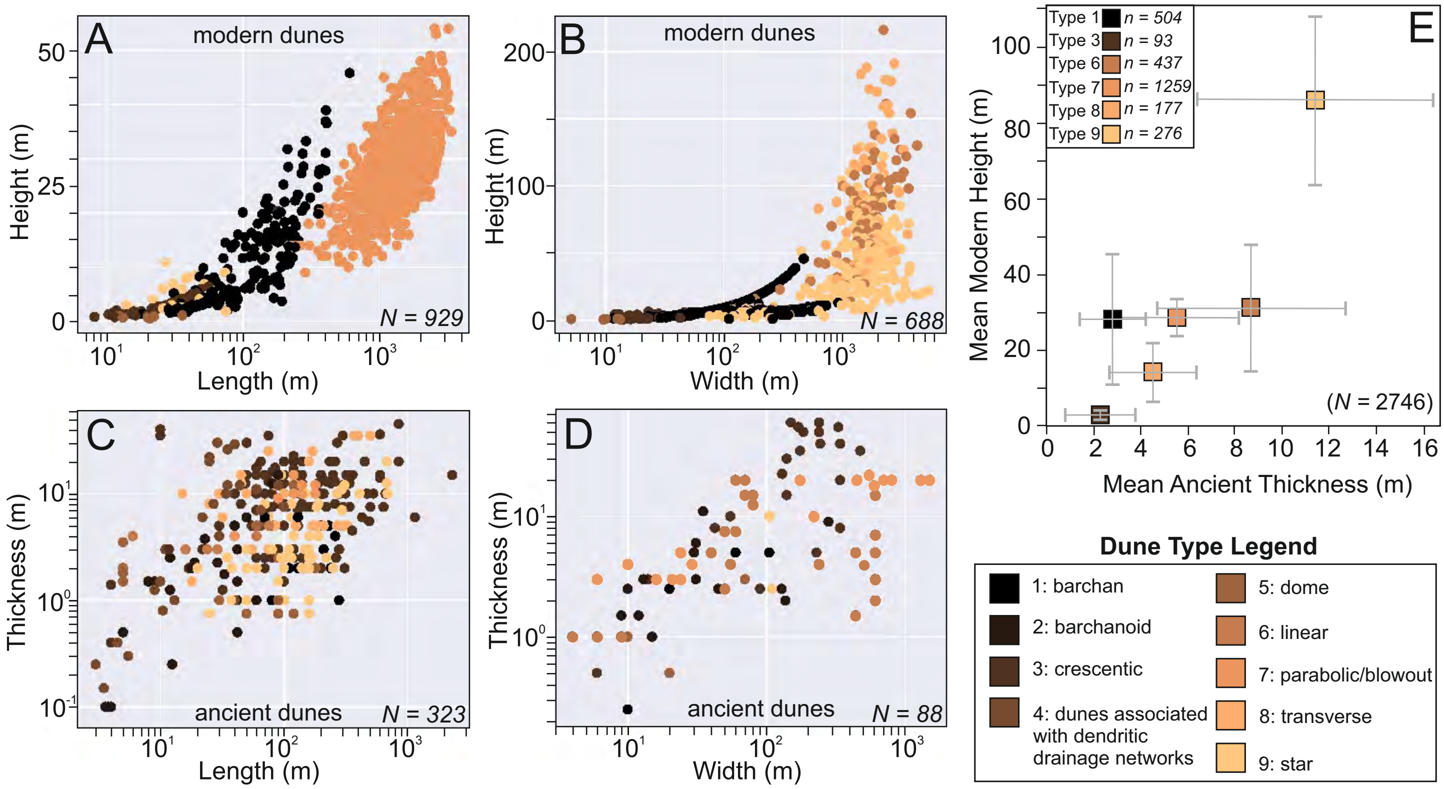
DASA records the hierarchical and containment relationships between elements of different orders; from largest to smallest the orders of scale in DASA are (A) subsets, (B) depositional elements, (C) architectural/geomorphic elements, (D) facies units and (E) textural and petrophysical properties; this is illustrated in the adjacent figure. DASA can record the containment of a lower-order (smaller scale) element within a higher-order (larger scale) element, and the nesting of elements within an element of the same order, using a parent-child relationship. This may be applicable, for example, where a dune set (child element) is present within a dune coset (parent element). DASA also records the nature of the juxtaposition of neighbouring elements of the same order and, where appropriate, the transitions between nested parent and child elements of the same order. Transitions between elements of the same scale may occur through different aeolian bounding surfaces; the surface type and any associated features, such as cementation or bioturbation, are also recorded in DASA. Quantitative measurements of element dimensions are supplemented by qualitative data. DASA also classifies depositional systems according to both external boundary conditions and context-descriptive characteristics.



Developing Structured Queries to Interrogate the Database

Interrogation of DASA using SQL queries generates quantitative data outputs, which characterize the geomorphology and sedimentary architecture of modern and ancient aeolian systems, respectively. All DASA queries can be tailored to deliver bespoke data outputs (e.g., systems with damp interdunes, or systems characterized by drying-upward successions, or systems with an associated secondary depositional element type that is of lacustrine origin). Bespoke outputs can also be classified on metadata (e.g., only Mesozoic aeolian systems, studies based on GPR data, or studies from Arizona, USA). This ability to specify conditional queries enables the bespoke selection of suitable data (i.e. geological analogues considered a close match to particular subsurface reservoirs; or modern analogues to ancient successions).The filtering process enables the user to select examples whose architectural properties and/or depositional-system parameters are considered to be analogous to a particular subsurface reservoir succession. DASA output will shortly also be available online through a front-end host interface on the ERG website. A series of example quantitative outputs are shown below and on the following pages to illustrate how DASA can be queried to generate bespoke output. Quantitative output can be used to help characterize systems at multiple scales from the palaeogeography of regions, to the petrophysical properties of individual facies.

Example 1: Comparisons of Modern & Ancient Dune Types



DASA provides a platform to make comparisons of the range of dimensions of modern aeolian forms, and of their preserved counterparts in accumulated sedimentary successions. In this example, compilations of cross-plots collate data from a wide variety of published sources, derived from original studies that considered different spatio-temporal settings and employed various methods of data collection. DASA can be queried using nomenclature adopted in the original source work; for example, the designated dune type. The figure illustrated here shows a comparison of dune scaling relationships for modern dunes and ancient dune sets, which have been subdivided according to identified dune type.

A) Height and length cross-plot of modern dunes.

B) Height and width cross-plot of modern dunes.

C) Thickness & length cross-plot, preserved dune elements.

D) Thickness & width cross-plot, ancient preserved dunes.

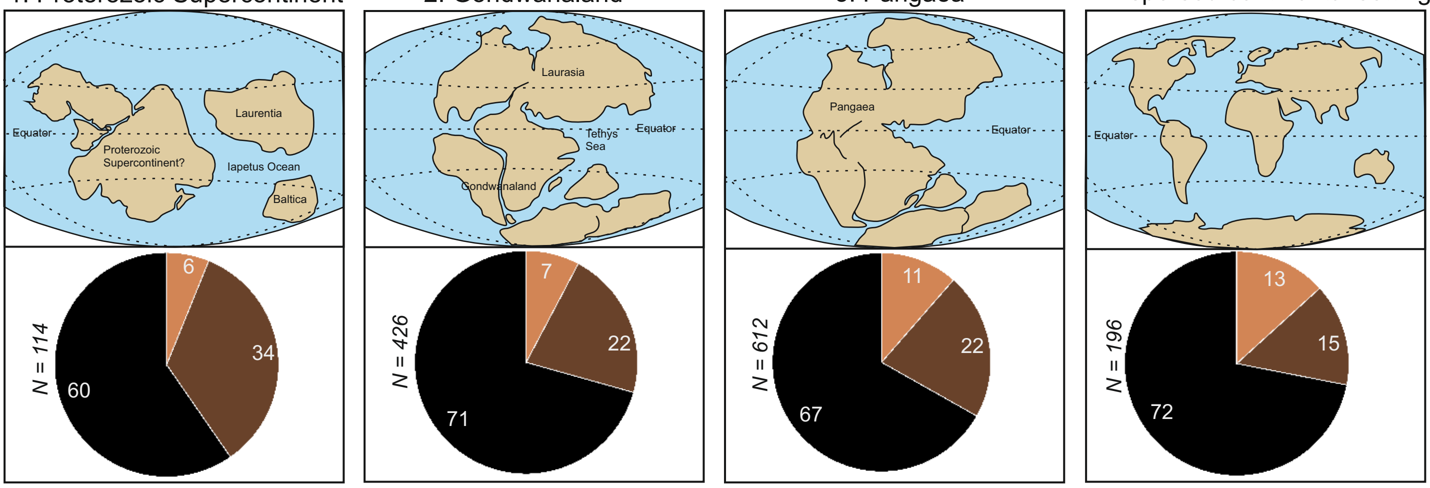
E) Modern dune height vs. preserved set thickness.

Colours relate to specific dune types. Understanding the relationship between modern and ancient aeolian systems is important: modern aeolian systems are widely applied as analogues to help better understand the environmental setting of subsurface successions. Yet, direct comparisons must be made with care.

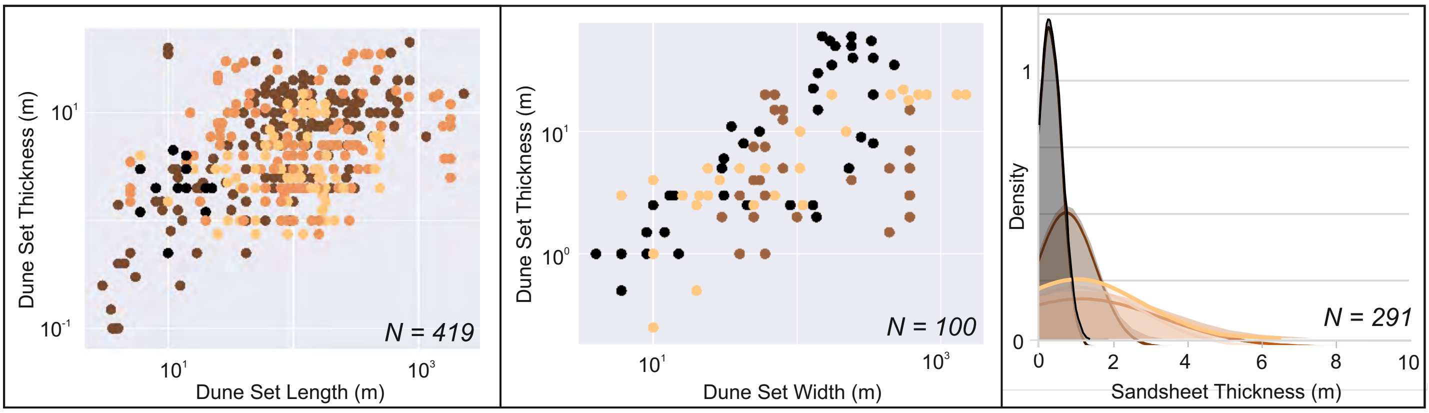
Applications of DASA

DASA can be used for the following purposes. (1) To quantify the interdigitation and 3D stacking of relatively more porous and permeable aeolian dune sets with non-dune elements (including interdunes, fluvial bodies and sabkhas), which tend to have poorer reservoir properties. (2) To record the presence and nature of aeolian bounding surfaces at different scales, and their containment between specific depositional, architectural and facies elements. Aeolian bounding surfaces can act as baffles and barriers to fluid migration, due to prominent grain-size contrasts across bounding surfaces, and due to the associated presence of diagenetic cements, for example the precipitation of carbonate and silicate minerals from percolating meteoric waters along bounding surfaces. (3) To characterise the configuration of common aeolian facies, such as wind-ripple, grain-fall and grain-flow strata, which can significantly impact horizontal and vertical permeability due to inter-facies variability in grain-size, sorting and packing. Composite analogues derived from DASA can be implemented to develop tailored quantitative facies models to predict three-dimensional lithological heterogeneity in aeolian reservoirs, to better constrain geocellular stochastic models, and to facilitate borehole correlations of aeolian dune sets or associated extra-aeolian elements.

Example 2: Spatio-Temporal Distribution of Architectural Elements



Pie chart legend: dune set, sandsheet, interdune. The pie charts show the distribution of elements in different supercontinental settings.



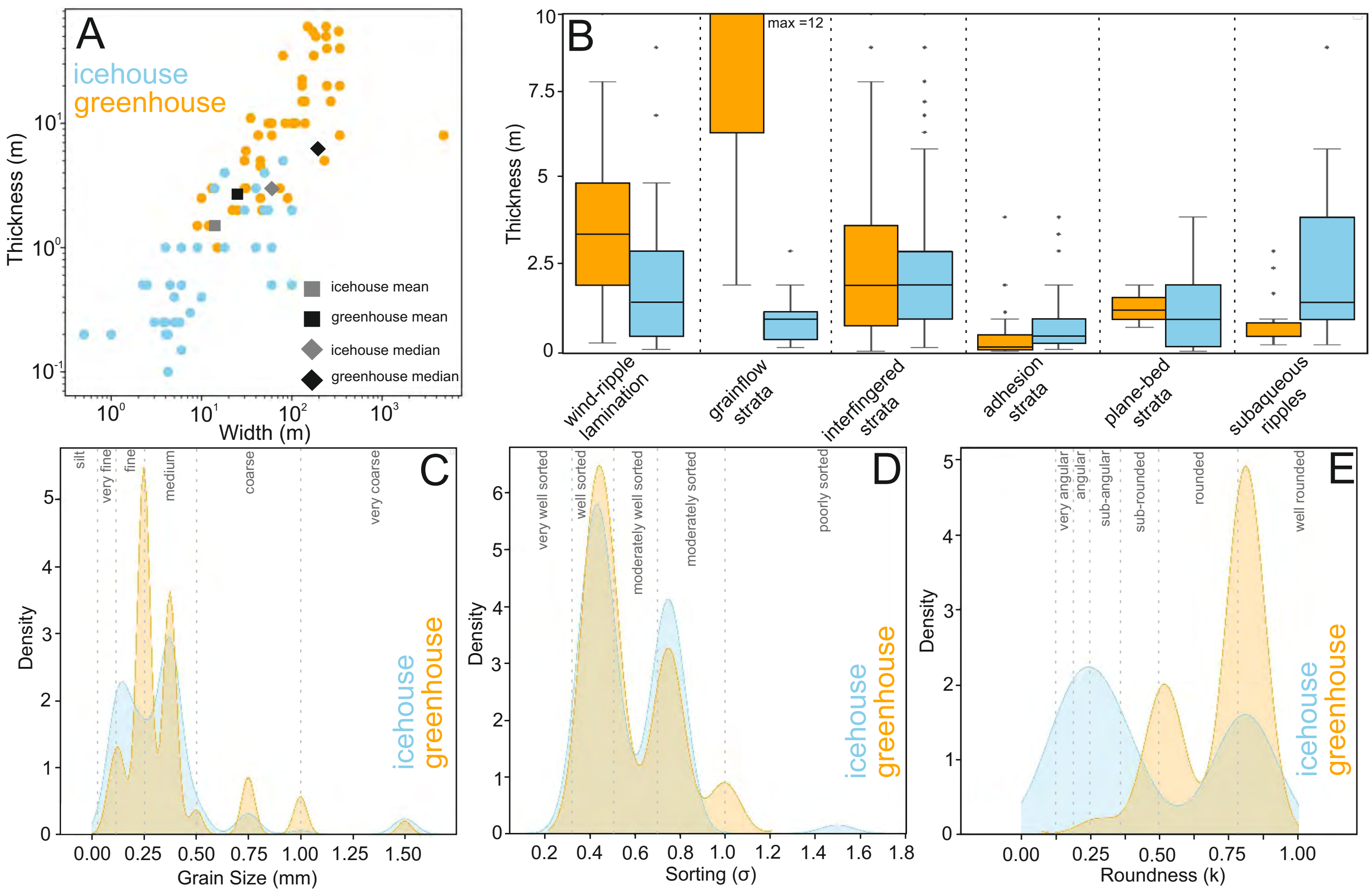
Scatter and density plot legend: Proterozoic Supercontinent, Gondwanaland, Pangaea, dispersed supercontinental setting

Architectural elements are fundamental building blocks of aeolian sedimentary successions. DASA permits tailored querying to quantify the geometry of architectural elements according to boundary conditions, which may influence preserved aeolian architectures. The above example illustrates how query filters might be applied to DASA to determine the relative dominance of particular aeolian architectural-element types through geological time, and for different palaeogeographic configurations. The above figure shows just one example of how DASA can be used to determine the manner in which aeolian sub-environments variably develop and are preserved as a function of their specific spatio-temporal settings, in this case because of controls exerted by regional and global palaeogeographic configurations. As such, DASA can be applied to characterize subsurface aeolian successions according to known boundary conditions.

DASA Content

As of June 2020, DASA contains data on 62 aeolian case studies: 28 modern aeolian systems and 34 ancient successions. DASA contains 252 subsets, 2,631 architectural elements, 3,651 geomorphic elements, 1,321 facies elements, and 2,881 and 802 architectural and facies element transitions, respectively. Quantitative and qualitative data extracted from the published literature have been standardized for database population. DASA stores data on aeolian and associated non-aeolian entities of varied types and scales (e.g., depositional elements, geomorphic elements, architectural elements, lithofacies, and bounding surfaces), including attributes that characterize their type, geometry, spatial relations, hierarchical relations, temporal significance, and textural and petrophysical properties. The application of DASA to all fields of fundamental and applied research in sedimentary geology relies on the collation of significant amounts of data; moreover, new datasets are being published frequently. As such, database population is ongoing and can never be considered finalized. As data from more case studies are added to DASA, quantitative output will be further enhanced. The inclusion of more data will enable more results to be returned for more specialized queries, notably where multiple filters are applied to yield targeted results.

Example 3: Distribution of Facies & Textural Properties in Aeolian Systems



Aeolian lithofacies have variable sedimentological and textural properties; understanding facies distribution, geometry and internal textural characteristics is important for gaining insight into depositional processes. DASA can be used to analyse quantitative facies metrics statistically, and to compare the geometries and textural characteristics of different aeolian facies units. In the example shown here, DASA is used to compare aeolian systems deposited under icehouse and greenhouse conditions.

A) Cross-plot showing thickness & width relationships for preserved aeolian facies units.

B) Comparison of the thicknesses of aeolian facies units.

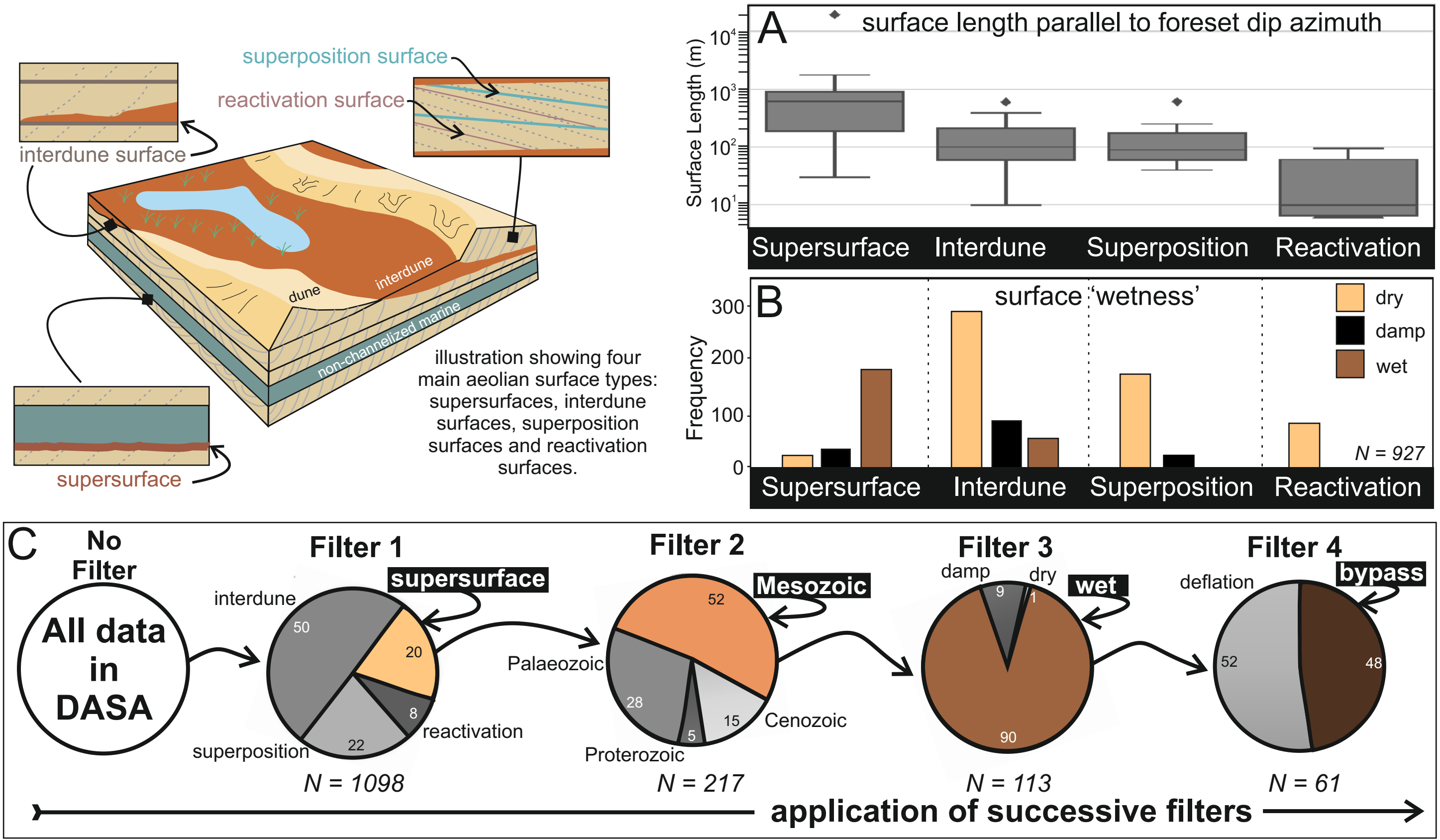
C) Comparisons of grain-size, D) grain sorting, and E) grain roundness, for icehouse and greenhouse aeolian systems.

Quantitative output from DASA can be applied to gain improved understanding of the hierarchical arrangement, geometry and textural properties of a broad range of aeolian facies types. DASA is a valuable resource for the generation of quantitative facies models, which can be applied to subsurface deposits.

Database Output

DASA output can be applied to aeolian-reservoir characterization and prediction. DASA output describes: (1) the development of bespoke quantitative facies models, specifically tailored for particular sets of boundary conditions (e.g., basin type, climate setting); (2) the empirical assessment of how aeolian systems and associated preserved sedimentary architectures represent a response to allogenic and autogenic forcings (e.g., changing rates of basin subsidence); and (3) the instruction of forward stratigraphic models and 3D geocellular subsurface models. The database serves as a valuable aid for quantitative characterization of the subsurface: it constrains inputs for stochastic modelling and subsurface heterogeneity modelling. The example output presented in this document illustrate just some of the many possible quantitative results that can be generated using DASA.

Example 4: Data Output Relating to Aeolian Bounding Surfaces



Aeolian bounding surfaces separate elements at multiple scales and can demarcate prominent changes in sedimentological character. DASA records both quantitative and qualitative data for all prominent bounding-surface types. DASA can be applied to compare attributes of bounding surfaces of different order; examples of quantitative data output are shown for four main aeolian bounding-surface types (supersurfaces, and interdune migration, superposition and reactivation surfaces).

A) Quantitative statistical summaries are shown describing the lengths of different surface types, which can be used to guide stratigraphic correlations in aeolian successions, where limited data precludes direct tracing of key stratal surfaces (e.g. across well arrays in the subsurface).

B) Qualitative data are also recorded in DASA to classify surface attributes. In the example above the relative wetness of the various surface types are shown.

C) The data in DASA can be used to develop bespoke queries to predict the character of aeolian surfaces in specific depositional environments, in both time and space. An example is shown: the percentage of supersurfaces (20% of all recorded bounding-surface types; Filter 1) that are Mesozoic in age (52% of supersurfaces; Filter 2), and that are "wet" (90% of Mesozoic supersurfaces; Filter 3), and that are bypass supersurfaces (48% of wet, Mesozoic supersurfaces; Filter 4).

Such bespoke queries demonstrate the power of a databasing approach for enhancing our understanding of the timing and mechanism of preservation of bounding surfaces of different types in the geological record, and of the characteristics that particular classes of bounding surface are likely to possess; such output can be used to build representative models of aeolian systems for different settings.

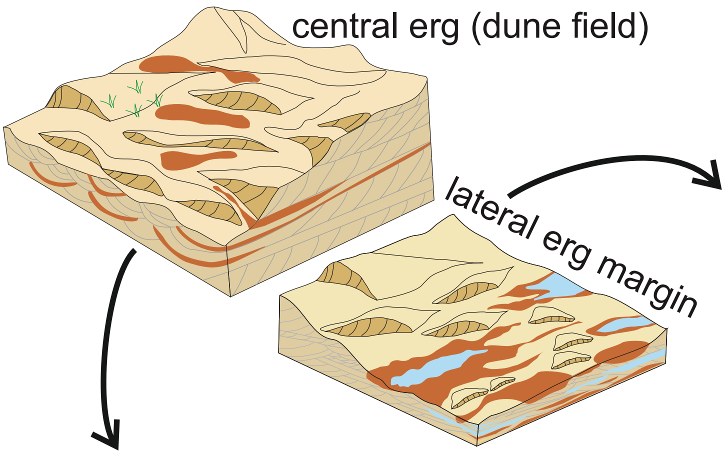
DASA: A Novel Resource

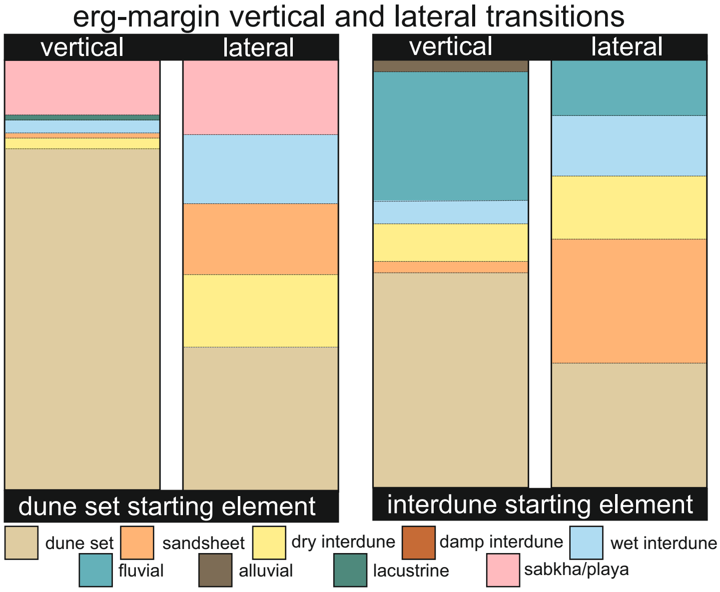
DASA is the first integrated large-scale relational database specifically designed to store quantitative data on the geomorphology, sedimentology and stratigraphy of modern and ancient aeolian systems, and their preserved successions. The flexible structure of DASA and the associated standardization of data types and terminology allow the synthesis of data from multiple sources (e.g., published and unpublished literature, technical reports and bespoke studies), of different types (e.g., modern vs ancient; outcrop vs subsurface), and collected using different methods (e.g., vertical measured sections, architectural correlation panels, virtual outcrop models).

DASA has been designed to capture all the fundamental attributes of aeolian architecture, including but not limited to the following: (1) the geometric properties of aeolian and associated non-aeolian bodies; (2) the spatial configuration of aeolian and related sedimentary and geomorphic units, including their vertical and lateral transitions; (3) the nature of bounding surfaces that separate aeolian and non-aeolian bodies.

Quantitative data incorporated within DASA are supported by associated qualitative data, including metadata describing age, location and broader environmental setting, together with information relating to original descriptions, interpretations and classifications of forms and deposits. Data on geological boundary conditions, such as tectonic setting and climatic conditions, are also stored to frame aeolian systems in time and space.

Example 5: Quantifying the Vertical and Lateral Juxtaposition of Aeolian & Associated Elements





central-erg vertical transition heatmap

	1(V)	2(V)	3(V)	4(V)	5(V)	6(V)
6	0.24	0.10	0.02	0.01	0.00	0.63
5	0.43	0.37	0.06	0.00	0.00	0.14
4	0.56	0.36	0.00	0.02	0.00	0.06
3	0.24	0.02	0.39	0.05	0.00	0.30
2	0.36	0.27	0.00	0.06	0.01	0.30
1	0.72	0.08	0.01	0.01	0.05	0.13

probability (0 – 1)

1 = dune set; 2 = sandsheet; 3 = dry interdune;
4 = damp interdune; 5 = wet interdune; 6 = non-aeolian

The construction of meaningful facies models requires a quantitative understanding of the expected vertical arrangement and ordering (i.e. stacking) and lateral juxtaposition of elements. The figures displayed here illustrate vertical and lateral transition statistics between types of architectural elements recorded in DASA, for specific dune-field physiographic settings. For central-erg settings this type of information is synthesized as a transition probability matrix, in this example depicted as a heatmap. For erg-margin settings this information is displayed as a stacked bar chart. Both examples show the probability of transitioning from one element type to another. These statistics can be used to characterize the internal facies organization of particular sub-environments and to quantify stratigraphic trends, through statistical evaluation of the most likely vertical or lateral successions of facies elements. Understanding the vertical and lateral stacking (i.e. order of juxtaposition) of different element types is especially important in the interpretation of subsurface aeolian successions known only from core or wireline-log records.

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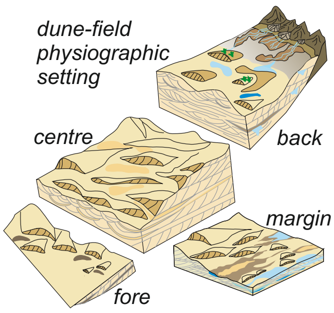
Building Quantitative Facies Models with DASA

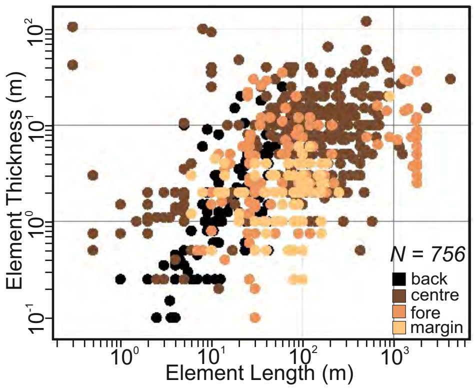
DASA queries can be filtered to yield quantitative outputs on aeolian elements at multiple hierarchical orders, associated with different observational scales. Examples of how filters can be applied to DASA to produce bespoke quantitative aeolian facies models are outlined below. DASA queries can be filtered to yield quantitative outputs on aeolian elements at multiple hierarchical orders, and associated with different observational scales. Examples of how filters can be applied to DASA to produce bespoke quantitative aeolian facies models are outlined below. Further examples are shown on the following page. These examples represent just some of the many filters that can be applied to develop bespoke facies models.

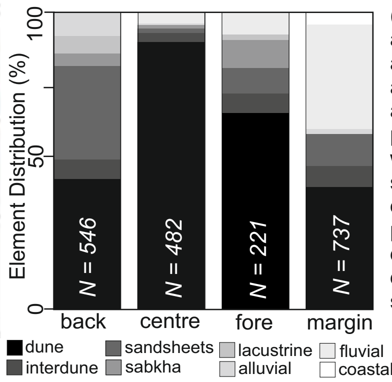
Example 6: Filtering DASA to Build Bespoke Quantitative Facies Models

1: Filter DASA according to dune-field location of interest



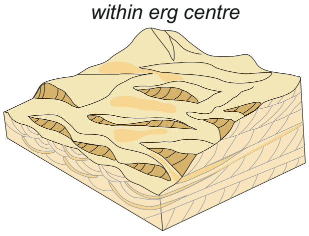
In this example, the erg centre is selected.



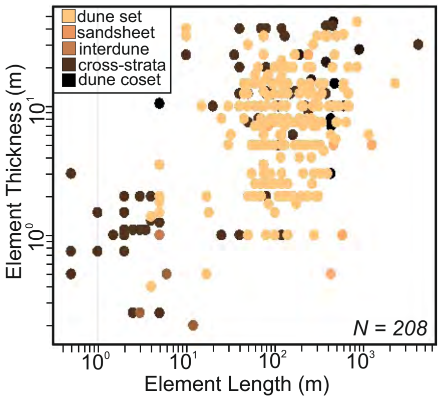


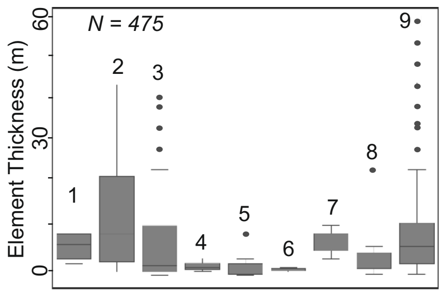
(1) All recorded aeolian and non-aeolian architectural elements are considered according to their physiographic setting within a major aeolian sand sea to yield outputs on their geometric properties and on their distribution within different dune-field settings.

2: Filter DASA according to architectural elements of interest



In this example, multiple aeolian architectural element types from the erg centre are selected.

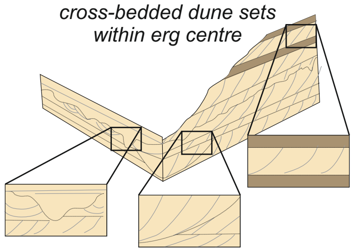




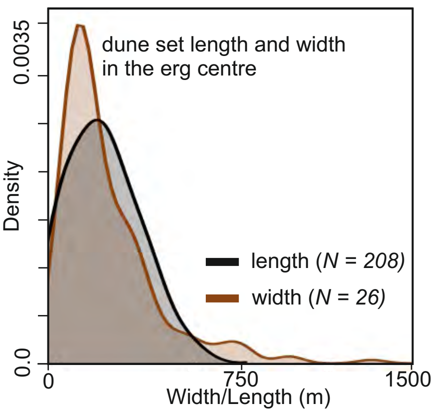
1: compound dune set; 2: dune coset; 3: cross-strata package; 4: reworked aeolian; 5: damp interdune; 6: wet interdune; 7: dry interdune; 8: sandsheet; 9: dune set

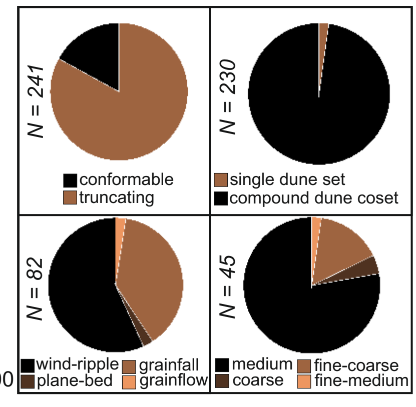
(2) The properties of selected architectural-element types within a central-erg setting are summarized; results demonstrate the relationships between recorded element length and thickness and the range of recorded thicknesses for these element types.

3: Filter DASA to select an individual element type and 4: examine properties of that element



In this example, cross-bedded dune sets within the erg centre are selected and the bounding surfaces, groupings and relationships between dune sets are viewed.





(3) An individual element type within a central-erg setting is considered. The length and width of dune sets are reported.
(4) The internal properties of dune-set elements within central-erg settings are considered. Quantitative outputs are reported, e.g. relative proportions of single vs. compound dune sets, the proportions of different facies types found in cross-bedded dune sets, and the proportions of different grain-size classes.

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Building Quantitative Facies Models with DASA

The DASA database approach can be used to provide highly specific outputs based on particular sets of criteria. In this way, DASA can be applied as a resource to aid subsurface characterization. The synthesis of data from a large number of case studies permits the development of composite geological analogues that capture stratigraphic and sedimentological variability, and that can be applied to quantify uncertainty in subsurface aeolian successions.

Composite analogues derived from DASA can be employed as quantitative facies models, which can be applied to:

(1) to predict three-dimensional lithological heterogeneity in subsurface successions identified as resource targets;

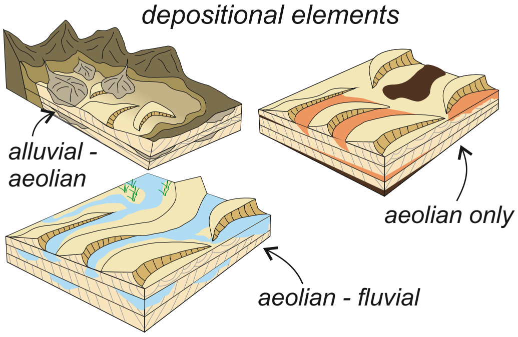
(2) to constrain geocellular stochastic models;

(3) to facilitate field-scale correlations of aeolian dune sets or associated non-aeolian elements.

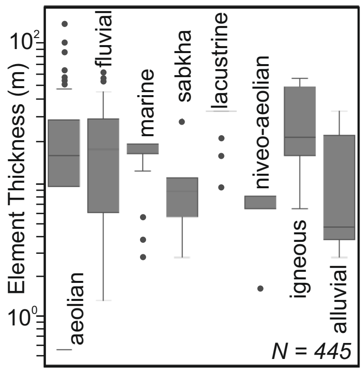
Example 7: Filtering DASA to Build Bespoke Quantitative Facies Models

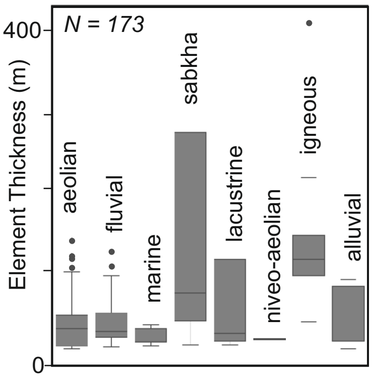
1: Filter DASA according to the primary depositional element type

examples of primary and secondary depositional elements



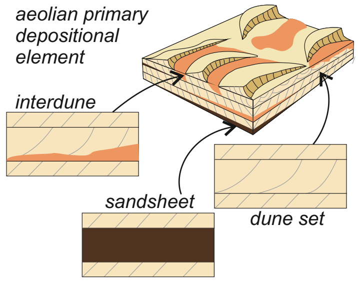
In this example, the depositional element type is aeolian only



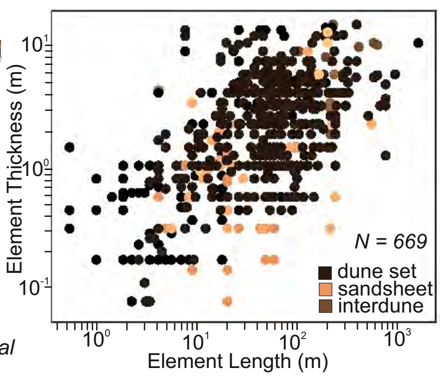


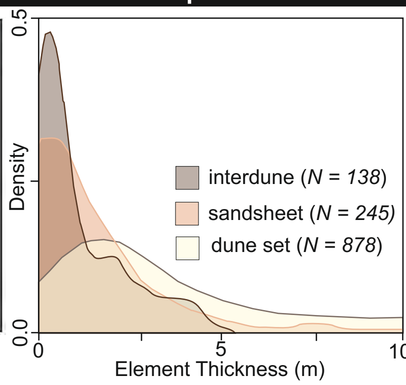
(1) All recorded elements are considered according to depositional-element type; the thickness distributions of all primary and all secondary depositional element types are reported.

2: Filter DASA according to required architectural elements within chosen depositional element type(s)



Interdune, sandsheet and dune set architectural elements are selected from primary depositional elements classified as aeolian

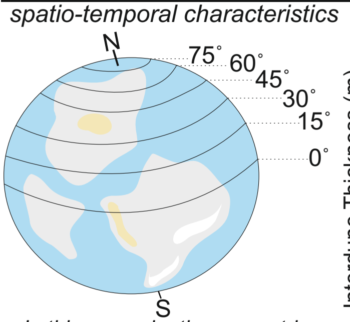




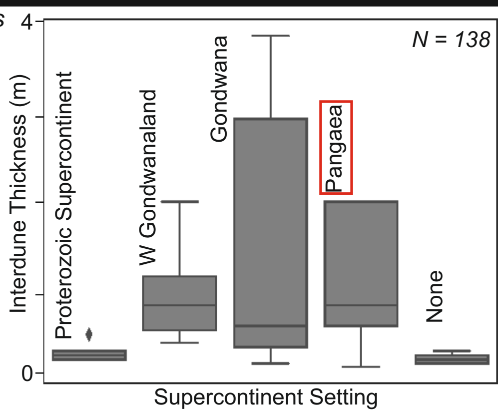
(2) The properties of architectural elements are filtered for a specific depositional-element type to characterize dune-set, sandsheet and interdune architectural elements from exclusively aeolian settings; the relationship between element lengths and thicknesses is reported, as are the thickness distributions of different element types.

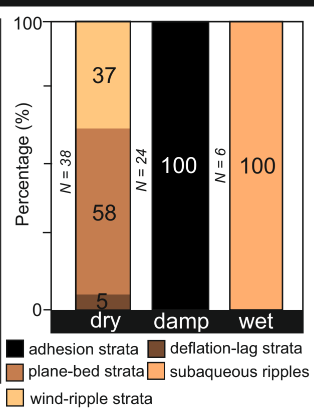
3: Filter DASA to select an individual element type, filter according to desired spatio-temporal variables and 4: examine facies of a specific architectural element type in a specific spatio-temporal setting

spatio-temporal characteristics

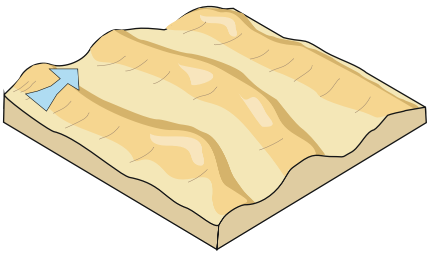


In this example, the geometric properties of interdunes are compared according to a variety of spatio-temporal characteristics



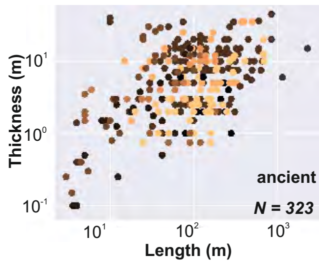


(3) An individual architectural-element type is depicted; the element type is viewed in the context of its palaeogeographic setting. In this example, interdunes are considered, for which thickness distributions are reported according to supercontinental setting.
(4) The facies properties of an individual element type are examined in the context of a specific supercontinental setting; in this case interdunes from Pangaea are considered. Facies proportions shown for dry, damp, and wet interdunes.



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). The digitization of aeolian architecture allows DASA to output quantitative metrics that span multiple scales, from larger-scale depositional elements to smaller-scale facies and texture.

- Capture fundamental attributes of aeolian architecture: (I) the **geometric properties** of aeolian & associated non-aeolian bodies; (ii) the **spatial configuration** of aeolian and non-aeolian sedimentary and geomorphic units; (iii) probabilities of **vertical and lateral transitions**; (iv) the nature of **bounding surfaces** that separate aeolian and non-aeolian bodies.
- 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.
- Develop quantitative facies models, specifically tailored for spatio-temporal & environmental context.
- Constrain of forward stratigraphic models and 3D geocellular subsurface models.
- Assess how aeolian systems respond to – and how associated architectures record – allogenic and autogenic forcings.