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1 **TITLE:** A Database of Aeolian Sedimentary Architecture for the characterization of
2 modern and ancient sedimentary systems

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7 **Highlights**

- 8 • The Database of Aeolian Sedimentary Architecture (DASA) is a novel relational
9 database designed to record attributes of modern and ancient aeolian systems
- 10 • DASA stores data on a variety of aeolian and associated non-aeolian entities
11 at multiple scales
- 12 • DASA allows quantitative characterization and comparisons of modern and
13 ancient aeolian sedimentary systems
- 14 • DASA is a valuable tool for constraining lithological heterogeneity in subsurface
15 aeolian successions

16 **Abstract**

17 The Database of Aeolian Sedimentary Architecture (DASA) records the architecture
18 and spatio-temporal evolution of a broad range of modern and recently active aeolian
19 systems, and of their preserved deposits in ancient successions. DASA currently
20 stores data on >14,000 geologic and geomorphic entities (including bounding surfaces
21 and transition relationships) extracted from >60 case-study examples documented in
22 the published literature. DASA stores data on a variety of aeolian and associated non-
23 aeolian entities of multiple scales, including attributes that characterize their type,

24 geometry, spatial relations, hierarchical relations, temporal significance, and textural
25 and petrophysical properties; associated metadata are also stored.

26 Database output describes (1) stratigraphic relationships between aeolian and
27 associated fluvial, lacustrine and paralic depositional systems; (2) the geometry of
28 aeolian architectural elements, and hierarchical and spatial relationships between
29 them; (3) the probabilities of vertical and lateral transition from one type of deposit or
30 landform to another; (4) the presence and nature of aeolian bounding surfaces at
31 different scales, and their nested, hierarchical relationships; (5) aeolian lithofacies
32 types, proportions and distributions, and (6) grain-scale textural parameters.

33 DASA is applied to quantitatively characterize and compare modern and ancient
34 aeolian sedimentary systems. Examples of database outputs demonstrate how DASA
35 outputs can be tailored for numerous applications, including: (1) the development of
36 bespoke quantitative facies models, specifically tailored for particular sets of boundary
37 conditions; (2) the empirical assessment of how aeolian systems, and associated
38 preserved sedimentary architectures, represent a response to allogenic and autogenic
39 forcings; and (3) the instruction of forward stratigraphic models and 3D geocellular
40 subsurface models. DASA is a valuable tool for the characterization of subsurface
41 aeolian successions, such that output can help to (1) predict three-dimensional
42 lithological heterogeneity in subsurface successions that are resource targets, (2)
43 constrain geocellular stochastic models, and (3) facilitate borehole correlations of
44 aeolian dune sets or associated non-aeolian elements.

45 **Keywords**

46 Database, sedimentary architecture, reservoir, quantitative geology, aeolian,
47 metadata, geomorphic, dune

48 **1. Introduction**

49 The preserved aeolian sedimentary record spans over three billion years of Earth
50 history from the Archean to present day (e.g., Clemmensen, 1985; Dott et al., 1986;
51 Voss, 2002; Cather et al., 2008; Simpson et al., 2012; Rodríguez-López et al., 2014).
52 Despite an extensive global sedimentary record (e.g., Ridgley, 1977; Ross, 1981;
53 Bateman et al., 2004; Holz et al., 2008; Dong et al., 2010) and recent extra-planetary
54 observations (e.g., Grotzinger et al., 2005; Metz et al., 2009; Banham et al., 2018),
55 meaningful comparisons between aeolian systems developed under differing
56 controlling factors are not straightforward. Traditional aeolian facies models,
57 developed from studies of both modern systems and ancient successions, have
58 attempted to capture stratigraphic complexities (e.g., McKee, 1966; Thompson,
59 1970a, 1970b; Brookfield, 1977, Kocurek, 1981; Loope, 1984; Langford and Chan,
60 1988; Mountney and Thompson, 2002; Mountney and Jagger, 2004; Mountney,
61 2006a; Kocurek and Day, 2018); yet, many such models are largely qualitative or – at
62 best – semi-quantitative, and are commonly case-specific. Thus, individual case
63 studies cannot adequately account for the wide variety of aeolian-system architectures
64 that might potentially develop through the action of a varied range of allogenic and
65 autogenic controls, which govern the geometry and arrangement of architectural
66 elements and their bounding surfaces. However, generalized models have been
67 proposed to explain the primary allogenic and autogenic controls that drive aeolian-
68 system construction, accumulation and preservation in the stratigraphic record (e.g.,
69 Kocurek and Havholm, 1993; Kocurek, 1999; Kocurek and Lancaster, 1999). Several
70 such models are quantitative in form (e.g. Rubin, 1987; Rubin and Carter, 2006;
71 Mountney, 2012). Moreover, some studies have generated large quantitative datasets
72 in the form of 3D virtual geological models assembled from mosaics of LiDAR and

73 photogrammetry datasets and presented as geo-models (e.g., Pierce et al., 2016).
74 Numerous studies of modern systems have considerably improved our understanding
75 of the physical conditions that dictate aeolian bedform arrangements (e.g., Bristow et
76 al., 2000a, Kocurek and Ewing, 2005; Beveridge et al., 2006; Kocurek et al., 2007;
77 Derickson et al., 2008; Ewing and Kocurek, 2010).

78 Despite the above-mentioned advances, it remains difficult to make direct quantitative
79 comparisons between documented examples of individual case studies that describe
80 aeolian systems and their preserved sedimentary architectures (Rodríguez-López et
81 al., 2014). To facilitate the quantitative sedimentological and stratigraphical
82 characterization of aeolian systems, and to enable meaningful comparisons between
83 systems, this study introduces and employs a novel relational database: the Database
84 of Aeolian Sedimentary Architecture (DASA). The use of databasing methodologies in
85 the broader field of sedimentology has increased in recent years (e.g., Baas et al.,
86 2005; Gibling, 2006; Colombera et al., 2012a, 2013, 2016; Cullis et al., 2019). DASA
87 represents the first example of a quantitative, relational database with global coverage,
88 designed specifically to investigate sedimentary relationships within and between
89 modern and ancient aeolian sedimentary successions (Fig. 1). Quantitative data
90 included in DASA are supported by associated qualitative data, including metadata
91 describing age, location and broader environmental setting, together with information
92 relating to original descriptions, interpretations and classifications of forms and
93 deposits.

94 The aim of this study is to demonstrate the efficacy of using a database-informed
95 approach to advance the quantitative characterization of aeolian systems for the
96 purpose of gaining an improved understanding of the controls that govern patterns of
97 aeolian sedimentation in a wide variety of settings, and over both time and space.

98 Objectives of this paper are: (1) to present a detailed explanation of the structure of
99 DASA, including explanation of the entities and relationships defined therein; (2) to
100 show multiple examples of how DASA can be queried to produce quantitative data
101 relating to aspects of the sedimentology and sedimentary architecture of modern and
102 ancient aeolian systems; (3) to show examples illustrating how DASA can be
103 sequentially filtered by the user, to provide quantitative architectural metrics for a
104 specific subset of aeolian systems governed by a particular set of controlling
105 conditions; and (4) to show how DASA can facilitate the generation of quantitative
106 geological analogues to subsurface aeolian reservoir successions.

107 **2. Methodology**

108 The Database of Aeolian Sedimentary Architecture is a relational database (see Codd,
109 1970), in which data are organized into a series of tables (Fig. 2). Each table holds
110 data on one entity type; the rows within each table represent instances (or records) of
111 that entity type and the columns represent attributes (or fields) associated with each
112 entry. In DASA, every table has a column storing a unique numerical identifier (primary
113 key), assigned to each row; rows in one entity table are linked to rows in different entity
114 tables through columns storing the unique numerical identifier of the linked row
115 (foreign key; Fig. 2). This means that the tables (entities) are related by logical
116 connections between them, as established by primary and foreign keys (Figs. 2, 3).
117 The entity-relationship model of DASA is based in part on those of other
118 sedimentological relational databases: the Shallow-Marine Architecture Knowledge
119 Store (SMAKS; Colombera et al., 2016), the Deep-Marine Architecture Knowledge
120 Store (DMAKS; Cullis et al., 2019) and the Fluvial Architecture Knowledge Transfer
121 System (FAKTS; Colombera et al., 2012a).

122 DASA stores data encompassing aeolian stratigraphy and sedimentology, relating to
123 both modern and ancient systems. A process of data standardization is applied upon
124 data entry to DASA to ensure the use of consistent terminology and to reconcile the
125 variety of source data types (e.g., outcrop, core, well-log, seismic, satellite imagery)
126 that were originally employed to characterize the aeolian systems.

127 DASA is written in SQL (Structured Query Language) and is managed via the *MariaDB*
128 (*MySQL*) database management system; *HeidiSQL* is used as a database front-end.
129 Information is retrieved from DASA using SQL queries, which return quantitative
130 outputs that can be filtered based on the parameters used to classify aeolian systems.
131 For example, to generate results relating specifically to wet (i.e. water-table influenced)
132 aeolian systems (*sensu* Kocurek and Havholm, 1993), or to wetting- or drying-upwards
133 aeolian systems (e.g., George and Berry, 1993; Howell and Mountney, 1996), or to
134 aeolian systems with a secondary fluvial influence (e.g., Scherer et al., 2007; Formolo
135 Ferronato et al., 2019; Reis et al., 2020). Additionally, the metadata and ancillary data
136 accompanying each DASA entry can also be used to filter results. For example, to
137 return results relating only to Permian aeolian systems, or only to aeolian systems
138 accumulated in intra-cratonic rift settings, or only to aeolian systems that developed in
139 Pangaeen supercontinental settings. The results of queries can be exported in a
140 tabulated form for later processing, using statistical software (e.g., SPSS, Minitab), or
141 accessed directly using a specialized programming language, such as Python or R.

142 **3. Database Structure and Overview**

143 Datasets entered into DASA are organized into case studies; a case study describes
144 a particular modern desert system (e.g., the Idhan Murzuq Desert; Table 1), or ancient
145 aeolian succession (e.g., Entrada Sandstone; Table 2). Case studies are associated

146 with one or more sets of data that are hereafter referred to as 'subsets' (cf. Colombera
147 et al., 2012a). Each subset represents a collection of data (e.g., a sedimentary log or
148 architectural panel) from an original data source (e.g., a publication or thesis). The
149 different subsets of a case study vary in the way they are classified with respect to
150 geological attributes and/or metadata; they are established to facilitate database
151 interrogation (Fig. 3A; Fig. 4A).

152 Each subset is divided into depositional complexes (Fig. 3B; Fig. 4B-C), which
153 describe both ancient and modern environments. In ancient environments, a
154 depositional complex is defined as a sedimentary body, typically composed of a suite
155 of smaller elements that characterize a net depositional setting. In modern
156 environments, a depositional complex is typically a planform area characterizing a
157 particular depositional setting (e.g., an aeolian dune field, or a part thereof).

158 Each depositional complex is divided into a series of architectural or geomorphic
159 elements (Fig. 3; Fig. 4D). Architectural elements are defined as distinct sedimentary
160 bodies with characteristic sedimentological properties (e.g., internal composition,
161 geometry) and are the products of sediment accumulation in a specific sub-
162 environment of deposition (e.g., a dune, a wet interdune, or a fluvial channel).
163 Geomorphic elements are defined as modern landforms (or their remnants) present at
164 the surface of the Earth, with distinctive physiographic characteristics; they are
165 classified by sub-environment type (e.g., a linear dune, a star dune, a zibar, a
166 sandsheet).

167 Both architectural and geomorphic elements can be subdivided further into facies
168 elements (Fig. 3F; Fig. 4E). Facies elements are defined as sedimentary bodies that
169 are distinguished from neighbouring sediments based on sediment composition,

170 texture, structure, bedding geometry, fossil content, or by the nature of their bounding
171 surfaces (Fig. 3F, 4E).

172 DASA records the hierarchical relationships between sedimentary units of different
173 orders, ranging in broadly decreasing scale from depositional complexes, through
174 architectural or geomorphic elements, to facies elements (Fig. 4). DASA records the
175 containment of a lower-order (smaller-scale) element within a higher-order (larger-
176 scale) element (e.g., nesting of a facies element within an architectural element;
177 nesting of an architectural element within a depositional complex; Fig. 3). In parallel
178 with this rigid hierarchy, DASA adopts an open hierarchy for certain units of the same
179 rank: geomorphic, architectural and facies elements (cf. Colombera et al., 2016; Cullis
180 et al., 2019). This allows hierarchical relationships between different units of the same
181 rank to be stored, using parent-child relationships. This may be applicable, for
182 example, where a dune set (child element) is present within a dune coset (parent
183 element), or where a barchan dune (child element) occurs superimposed on a
184 megadune or draa-scale bedform (parent element).

185 Hard data (e.g., quantitative measurements of element dimensions, grain-size
186 statistics, petrophysical properties) stored in DASA are supplemented by soft
187 (qualitative) data (e.g., interpretations of aeolian surface types, or facies element
188 types). The types of data contained in each particular subset may vary markedly,
189 depending on the manner by which the original data were collected and in terms of the
190 hierarchical levels they cover. To assign a measure of quality to query outputs, data
191 added to DASA are classified in terms of perceived quality (cf. Baas, 2005; Colombera
192 et al., 2012a, 2016), based on three categories ('A', highest quality, to 'C' lowest
193 quality) applied on the basis of expert judgement and quality criteria.

194 By utilizing this structure, DASA can effectively record all key aspects of aeolian
195 sedimentology and stratigraphy. The different entity types recorded in DASA are
196 outlined in some detail below. A full account of entity types (tables) and attributes
197 (columns) can be found in Supplementary Information 1. DASA is a flexible and
198 expandable system, which allows for the addition of new entity types (tables) or
199 attributes (fields) for capturing other geological entities or variables of interest.

200 **3.1 Table (Entity) Descriptions**

201 **3.1.1 Sources**

202 The 'sources' table describes the primary source of the data. This table records (1) a
203 full reference and (2) the data-source type (e.g., published literature, technical reports,
204 unpublished academic work).

205 **3.1.2 Case Studies**

206 The 'case studies' table contains metadata (i.e., data that describe and give
207 information about other data) relating to the geological background and geographical
208 setting of each entry. Examples of the metadata stored in the 'case studies' table
209 include: (1) chronostratigraphic information; (2) lithostratigraphic information; (3) the
210 geographical location, a broad palaeogeographical location and dune-field name; (4)
211 the basin name and basin type.

212 **3.1.3 Subsets**

213 In DASA, aeolian systems are subdivided into so-called subsets (cf. Colombera et al.,
214 2012a) of a particular case study. Subsets are named or numbered depictions of
215 collections of data within source material (Fig. 4A) and are differentiated on the basis
216 of attributes that describe their geological boundary conditions or context, or because

217 of their suitability to yield particular types of outputs. These attributes are reflected in
218 the contents of the 'subset' table, which contains data describing the depositional
219 system, its allogenic controls and metadata. Subsets are established to aid querying
220 of the database on parameters that characterize depositional systems.

221 **3.1.4 Subset Statistics**

222 A table is included in DASA specifically for recording data presented as statistical
223 summaries, which cannot therefore be assigned to a particular geological unit (e.g., a
224 specific depositional complex, architectural element, geomorphic element or facies).
225 Such data are instead stored as statistics for the entire subset. Examples of subset
226 statistics include mean dune spacing, mean dune height, and mean wavelength and
227 amplitude of dune along-crestline sinuosity.

228 **3.1.5 Depositional Complexes**

229 Subsets can be subdivided into depositional complexes, either on the basis of
230 stratigraphic divisions (e.g., on a sedimentary graphic log; Fig. 3B) or in planform (e.g.,
231 on an aerial photograph). Depositional complexes are assigned a primary and – if
232 appropriate – a secondary complex type; depositional complex types used in DASA
233 are outlined in Table 3 and the application of a primary and secondary depositional
234 complex type is illustrated in Fig. 4B-C. The terms 'primary' and 'secondary' qualify
235 the relative dominance of different types of deposits of different origins within a subset.
236 The primary depositional complex type defines the most abundant type of deposit in
237 the unit (e.g., as a fraction of a stratigraphic log (Fig. 4B-C), or of a planform area); the
238 secondary depositional complex type defines the second most common type. This
239 approach enables recording the interaction between aeolian and non-aeolian systems,
240 and facilitates database querying based on the sedimentary environment.

241 The 'depositional complex' table stores data on depositional complexes. Examples of
242 attributes recorded in the 'depositional complex' table include: (1) dimensional
243 parameters of the depositional complex; (2) whether the depositional complex is
244 indicative of a dry, wet, mixed or stabilizing aeolian system (*sensu* Kocurek and
245 Havholm, 1993); (3) whether the depositional complex has any recordable cyclicity
246 (e.g., wetting- or drying-upward trends; George and Berry, 1993; Howell and
247 Mountney, 1996); (4) the preservation mechanism of the depositional complex, for
248 example via bedform climbing (Rubin and Hunter, 1982; Mountney, 2012), or via
249 exceptional preservation following inundation by marine flooding (Glennie and Buller,
250 1983) or burial by extrusive igneous activity (Jerram et al., 1999, 2000a, 2000b;
251 Mountney et al., 1999a; Mountney and Howell, 2000); and (5) for modern depositional
252 complexes, the dominant wind direction and variability thereof (Fryberger, 1979).

253 **3.1.6 Architectural and Geomorphic Elements**

254 Depositional complexes can be subdivided into architectural or geomorphic elements
255 (Fig. 3D; Fig. 4D), classified to cover the variety of aeolian and associated non-aeolian
256 architectural and geomorphic element types that occur within aeolian systems (Table
257 4). In DASA, architectural elements describe the preserved 2D or pseudo-3D
258 architectures of specific aeolian and associated non-aeolian elements.

259 Architectural elements may be used to describe properties of both ancient and recent
260 deposits. The latter are recorded as architectural elements where the internal
261 structures of modern dunes are revealed, for example, in trenches or by a ground
262 penetrating radar (GPR) survey (Bristow et al., 2000b; Bristow, 2009; Tatum and
263 Francke, 2012a, 2012b). In the ancient record, architectural elements are most
264 commonly observed in outcrop, though are also recorded from some subsurface

265 datasets, for example by using GPR (e.g., Jol et al., 2003; Bristow et al., 2005), by
266 using seismic methods (e.g., Story, 1998), or by correlation of well logs (e.g.,
267 Strömbäck and Howell, 2002; Besly et al., 2018). In DASA, geomorphic elements
268 describe the planform, 2D or 3D morphologies of landforms observed at the Earth's
269 surface. DASA enables both the geomorphic expression and the deposit of an
270 accretionary landform (e.g., a dune) to be recorded, respectively as geomorphic and
271 architectural elements; this is applicable, for example, in cases where a dune is both
272 viewed in planform in an aerial photograph (geomorphic element) and in cross section
273 via dune trenching (architectural element) (e.g., McKee, 1966; Glennie, 1970, McKee
274 and Muiola, 1975).

275 The open hierarchy of DASA enables architectural and geomorphic elements to be
276 recorded in a way that reflects the hierarchy of sub-environments and/or of
277 architectures they represent (e.g., cross-strata package within a dune set). This
278 hierarchical arrangement is applied in the form of the relative containment of elements
279 within other elements. In some cases, architectural-element boundaries may be
280 ambiguous due to gradational element transitions between different sub-environment
281 types. In DASA the boundaries of architectural elements are determined from the
282 original source work (cf. Colombera et al., 2016).The employed data encoding
283 methodology, as developed and refined by Colombera et al. (2016), provides a flexible
284 approach to the subdivision of elements and allows DASA to be coded in a flexible
285 manner. However, it should be noted that this approach nevertheless relies on the
286 interpretations of architectural element boundaries as presented in the original
287 sources.

288 The 'architectural element' and 'geomorphic element' tables contain primary data and
289 metadata, including: (1) dimensional parameters; (2) element shapes and (3) element

290 sub-environment classification (Table 4). Some additional parameters recorded for
291 dune-set architectural elements, where appropriate, including foreset dips and
292 azimuths, for example. For dune geomorphic elements, additional parameters are
293 used, where appropriate, to record attributes such as the number of slipfaces,
294 wavelength and amplitude of along-crestline sinuosity, and orientation relative to wind
295 direction, and the lengths and angles of inclination of bedform stoss and lee slopes.

296 **3.1.7 Facies Elements**

297 The 'facies element' table contains primary data and metadata regarding the facies
298 that comprise architectural and geomorphic elements, including: (1) dimensional
299 parameters; (2) element shapes; and (3) types of facies (Table 5). Facies-element
300 types are not mutually exclusive and cover deposits at different scales; this approach
301 to classification was chosen because the database accommodates an open hierarchy
302 of facies, implemented in the same manner as that outlined for geomorphic and
303 architectural elements. A suite of further DASA parameters describing the lithology,
304 grading and lamination types of facies elements are shown in Figure 4F, alongside
305 parameters that describe post-depositional deformation (e.g., Rodríguez-López and
306 Wu, 2020), including physical, chemical, biogenic and structural features.

307 **3.1.8 Transitions Tables**

308 Any element may transition to a different element belonging to the same order (e.g.,
309 the architectural-element order; Fig. 3H-K) vertically or laterally; lateral transitions can
310 occur along a direction either parallel or perpendicular to the dominant foreset azimuth,
311 else to indicators of the overall (palaeo)wind direction. Transition tables record the
312 style of juxtaposition of neighbouring elements of the same order, and – where
313 appropriate – the transitions between nested parent and child elements of the same

314 order. Transitions between elements of the same scale may occur through bounding
315 surfaces (see below). Additionally, gradational transitions may occur where no
316 bounding surface is present (e.g., from deposits of a dry-interdune element upward
317 into the toeset deposits of an overlying dune element).

318 **3.1.9 Bounding Surfaces**

319 Brookfield (1977) identified a hierarchy of bounding surfaces (third-, second- and first-
320 order), and this classification scheme was later succeeded by nomenclature
321 summarized by Kocurek (1996), which defined bounding-surface types of broadly
322 equivalent status to those of Brookfield (1977): reactivation surfaces, superposition
323 surfaces, interdune migration surfaces. In addition, a higher-order class of bounding
324 surfaces is also adopted: the supersurface (Loope, 1985; Langford and Chan, 1988;
325 Fryberger, 1993; Kocurek, 1988, 1996). Reactivation, superposition and interdune
326 surfaces are chiefly the products of autogenic bedform migration; supersurfaces are
327 chiefly the product of allogenic forcing (Fryberger, 1993) but can also potentially be
328 generated by the regional migration of a major aeolian sand-sea (or erg) system
329 (Porter, 1986).

330 The surface table records data on bounding surfaces, including the following: (1) the
331 length, orientation and dip of the bounding surface; (2) association of features
332 (sedimentary structures) indicative of substrate conditions (e.g., dry, damp, wet)
333 associated with the surface; (3) association of features indicative of surface
334 stabilization; (4) a classification of surface type (i.e., environmental significance)
335 according to the schemes of Fryberger (1993) and Kocurek (1996); (5) a record of
336 sedimentary structures associated with the surface, for example palaeosols, (Basilici
337 et al., 2009; Dal' Bo et al., 2010), rhizoliths (Loope, 1988) and burrows (Ahlbrandt et

338 al., 1978; Krapovickas et al., 2016), amongst others. A ‘surfaces relationship’ table is
339 also present in DASA; this records any cross-cutting and truncation relationships
340 between two surfaces.

341 **3.1.10 Petrophysical and Textural Properties**

342 Instances of geomorphic, architectural or facies elements (e.g., an interdune, or a
343 sandsheet element) may be assigned specific petrophysical or textural properties;
344 these data are recorded in the ‘petrophysics’ and ‘texture’ tables. The ‘petrophysics’
345 table records any petrophysical attributes of a given element, such as values of
346 porosity and permeability. The ‘texture’ table records properties relating to grain
347 character, including grain size, sorting and roundness.

348 **4. DASA Output and Applications**

349 At the time of writing, DASA contains data on 62 case studies: 28 case studies refer
350 to modern aeolian systems (Table 1; Fig. 5); 34 case studies to ancient aeolian
351 systems (Table 2; Fig. 5). DASA contains 252 subsets, 2631 architectural elements,
352 3651 geomorphic elements, 1321 facies elements, 2881 architectural-element
353 transitions and 802 facies-element transitions. The application of DASA to fields of
354 both fundamental and applied research in sedimentary geology relies on the collation
355 of significant amounts of data; moreover, new datasets are being published frequently.
356 As such, database population is ongoing and open-ended. Database outputs
357 inevitably reflect the content of DASA at the time of database interrogation. If case-
358 studies representing a particular geographic location (e.g., the Colorado Plateau) or a
359 particular interval of geological time (e.g., Mesozoic) are over-represented, DASA
360 outputs will be biased accordingly. To mitigate such sampling biases, the case studies
361 that have thus far been included in DASA have a global distribution and cover a wide

362 span of geological time. Any sampling biases must however be considered when
363 interpreting the significance of database outputs.

364 Interrogation of DASA using SQL queries generates quantitative data outputs, which
365 can be used to characterize the geomorphology and sedimentary architecture of
366 modern and ancient aeolian systems, respectively. DASA queries can be tailored to
367 deliver bespoke data outputs, based on the classification of the aeolian system (e.g.,
368 systems with damp interdunes, or systems characterized by drying-upward
369 successions, or systems with an associated secondary depositional complex of
370 lacustrine origin). Bespoke outputs can also be classified on metadata (e.g., only
371 Mesozoic aeolian systems, studies based on GPR data, or studies from Arizona,
372 USA). The ability to perform queries defined on multiple attributes (for example a
373 specific geological age and a specific dune-field physiographic setting) enables the
374 selection of data from multiple geological analogues that meet specific criteria. As
375 such, quantitative data can be used to construct specialized bespoke models
376 describing attributes of systems for which no single case-study example is wholly
377 representative.

378 Outputs of DASA yield insights into the following: (1) the organization of aeolian
379 systems and their constituent architectural and geomorphic building blocks; (2) the
380 hierarchical containment relationships between elements of different scales; and (3)
381 the distribution and spatial relationships between elements from the depositional-
382 complex to the facies-element scale. Below, a series of example database outputs are
383 presented to illustrate the value of DASA as a tool for the detailed characterization of
384 aeolian sedimentary systems and their preserved successions. An SQL file containing
385 the DASA database and all of the data used to generate the following figures are
386 included in the supplementary information.

387 **4.1 Comparison of Modern and Ancient Analogues**

388 Understanding the relationship between modern and ancient aeolian systems remains
389 important: modern aeolian systems are widely applied as analogues to help better
390 understand the palaeoenvironmental significance of subsurface successions (e.g.,
391 Stanistreet and Stollhofen, 2002; Tatum and Francke, 2012a; Besly et al., 2018;
392 Kocurek et al., 2020). In particular, compilations of cross-plots between dune height,
393 length and width (e.g., Finkel, 1959; Long and Sharp, 1964; McKee, 1979; Wasson
394 and Hyde, 1983; Bishop 1997; Lancaster, 2009; Bhadra et al., 2019) are a valuable
395 tool for characterizing bedform relationships and understanding patterns of dune-field
396 evolution. DASA provides a platform to reconcile such data from a wide variety of
397 published sources, derived from original studies that considered different spatio-
398 temporal settings and employed various methods of data collection. DASA captures
399 data relating to both modern systems (i.e. geomorphic elements on the Earth's
400 surface) and ancient successions (i.e. architectural elements preserved in the rock
401 record), thereby providing a platform to make comparisons of the range of dimensions
402 of modern forms and of their preserved counterparts in accumulated sedimentary
403 successions.

404 DASA can be queried using nomenclature adopted in the original source work; for
405 example, the designated dune type. Figure 6 shows a comparison of dune scaling
406 relationships for modern dunes and ancient dune sets, which have been subdivided
407 according to identified dune type. Measurements from modern dunes record the
408 height, length and width of active bedforms at an instant in time. Measurements from
409 accumulated dune sets record the dimensions of the preserved dune elements, which
410 typically preserve only the lowermost parts of the original bedforms, and record the
411 passage or migration of those bedforms over an extended episode of time (Rubin and

412 Hunter, 1982; Kocurek, 1991). As such, the preserved dimensions of dune sets are
413 related in part to the geometries (e.g., the height, length, or width) and original
414 morphologies of the bedforms that generated them, but also to the time interval over
415 which the bedforms persisted, and the speed at which those bedforms migrated,
416 together with other aspects of migratory behaviour, such as the angle of climb
417 (Kocurek, 1991; Rubin, 1987; Rubin and Carter, 2006).

418 Scatter plots illustrate how different modern dune types have distinct scaling
419 relationships (Fig. 6A-C); for example, modern parabolic dunes have the largest
420 average height-to-length ratio of all dune types recorded in DASA (Fig. 6A). In the
421 accumulated stratigraphic record, however, no clear relationship between inferred
422 dune type and preserved set geometry is evident (Fig. 6D-F). Dune sets interpreted to
423 represent accumulated deposits of the same fundamental dune type can take
424 markedly different forms, with highly variable relationships between dune-set
425 thicknesses, lengths and widths (Fig. 6D-F; cf. Bagnold 1941; Glennie 1970, Tsoar
426 1982; Kocurek, 1991; Romain and Mountney, 2014). Preserved dune-set scaling
427 relationships (e.g., relationships between preserved dune-set thickness, length and
428 width) are not necessarily strongly related to formative dune type.

429 This statement is based on the assumption that, in all source works, the original dune
430 type was confidently interpreted from preserved dune sets; however, interpretations
431 of formative dune type from evidence in the rock record are not always straightforward.
432 For example, the preserved deposits of linear dunes can come to resemble those of
433 crescentic dunes if the migrating bedforms undertook a component of lateral migration
434 (Rubin and Hunter, 1985; Clemmensen, 1989; Rubin, 1990; Besly et al., 2018; Scotti
435 and Veiga, 2019). The data presented in Figure 6A-F suggest either that dune type
436 has no directly quantifiable relationship with the resulting preserved dune-set

437 geometry, else that our ability to interpret and reconstruct dune types from evidence
438 preserved in the ancient record is generally limited.

439 DASA also provides a unifying platform to directly compare modern and ancient
440 systems, and to explain mechanisms of aeolian dune accumulation to form sets of
441 strata. Direct comparisons of modern dune heights and ancient dune-set thicknesses
442 (Fig. 6G-H) show that, for all dune types, modern bedform heights are typically an
443 order of magnitude greater than the thicknesses of preserved dune sets. This finding
444 is congruous with the idea that only a small portion of the original dune height is
445 typically translated into the geological record and that dune-set deposition is the
446 product of bedform climbing at low (i.e. subcritical) angles (Rubin and Hunter, 1982;
447 Kocurek, 1981; Kocurek, 1991), whereby the rate of bedform migration was
448 considerably greater than the rate of vertical accumulation (Kocurek, 1991).

449 In some instances dune bedform topography can be preserved in the geological
450 record, to varying degrees, by geomorphic accommodation space where one set of
451 bedforms generates topographic relief and where local accommodation in interdune
452 depressions is subsequently filled by later bedforms (Langford et al., 2008; Fryberger
453 and Hern, 2014; Kocurek et al., 2020). In other cases, dune bedform topography can
454 be preserved by burial beneath extrusive volcanics (Clemmensen, 1988; Jerram et al.,
455 1999, 2000a, 2000b; Scherer, 2000, 2002), or by marine inundation, or other
456 sediments (Eshner and Kocurek, 1986, 1988; Fryberger, 1986; Chan and Kocurek,
457 1988; Strömbäck et al., 2005; Scotti and Veiga, 2019). Examples in which dune
458 topography is fossilized in the geological record are recorded in DASA but are not
459 depicted in Figure 6.

460

461 **4.2 Characterization of Aeolian Architectural Elements**

462 Architectural elements are the fundamental building blocks of aeolian sedimentary
463 successions. DASA permits tailored querying to quantify the geometry of architectural
464 elements from subsets classified according to boundary conditions, which may
465 influence preserved aeolian architectures. Figure 7 illustrates an example of how filters
466 might be applied to DASA to determine the relative dominance of particular aeolian
467 architectural-element types through geological time, and for different
468 palaeogeographic configurations. In the depicted example, the architectural elements
469 are grouped according to four palaeogeographic settings associated with (1) the
470 Proterozoic supercontinents (Rodinia and Columbia), (2) with Gondwanaland, (3) with
471 Pangaea, and (4) with geological times characterized by dispersed continental
472 landmasses for systems that developed since 38 Ma (Fig. 7A). The relative proportions
473 of dune-set, sandsheet and interdune elements are plotted for the different settings
474 (Fig. 7B-E), allowing an evaluation of the degree to which the global palaeogeographic
475 configuration might have controlled the occurrence of aeolian successions
476 characterized by particular architectural-element types. For example, sandsheet
477 elements form a markedly greater proportion of Proterozoic aeolian systems (Fig. 7B),
478 compared to all other settings (Fig. 7C-E): 34% compared to 15% in successions
479 younger than 38 Ma (Fig. 7E). The relatively greater proportion of sandsheet elements
480 in Proterozoic aeolian systems may reflect their increased prevalence prior to the
481 evolution of land plants (e.g., Rainbird, 1992; Long, 2006; Davies and Gibling, 2010).
482 The absence of the stabilizing effects of vegetation in Proterozoic settings likely
483 promoted enhanced winnowing of fluvial braid plains to form aeolian sandsheet
484 elements (e.g., Dott and Byers, 1981; Tirsgaard and Øxnevad, 1998; Eriksson and
485 Simpson, 1998; Abrantes, 2020). The relatively lower proportion of sandsheet

486 elements in aeolian systems younger than 38 Ma may reflect the stabilizing effects of
487 grasses, which evolved between 60-55 Ma (Jacobs et al., 1999; Kellog, 2000), and
488 which act to markedly retard aeolian winnowing, thereby reducing the supply of
489 sediment suitable for sandsheet accumulation.

490 Proterozoic dune-set element thicknesses (median = 1.2 m) and sandsheet element
491 thicknesses (median = 0.4 m) are markedly less than those of equivalent elements
492 known from successions of the Gondwanan (dune set median thickness = 5 m;
493 sandsheet median thickness = 2.0 m) and Pangaeian (dune set median thickness = 2
494 m; sandsheet median thickness = 2.0 m) supercontinents (Fig. 7F and 7I-K). This may
495 reflect the fact that the majority of Proterozoic successions are recorded from
496 intracratonic basin settings, which are preferentially preserved in the central parts of
497 stable ancient cratons (e.g., Shaw et al., 1991; Aspler and Chiarenzelli, 1997; Deb and
498 Pal, 2015), and which typically experienced low rates of subsidence compared to other
499 basin types (e.g., Bethke, 1985; Aspler and Chiarenzelli, 1997). This might have
500 favoured the accumulation and preservation of relatively thin genetic aeolian units, in
501 which aeolian dune-sets likely climbed at low-angles and accumulated sporadically
502 between long episodes of sediment bypass under conditions of low rates of
503 accommodation generation. Although the size of dune-sets could also be related the
504 size of the formative dunes, this is not likely related to the effects of accommodation
505 generation. The presence of vegetation in Gondwanan and Pangaeian settings may
506 have also acted to facilitate preservation of aeolian dune and sandsheet elements by
507 limiting the mobility of river systems that could have wandered across and largely
508 reworked aeolian sediments (Davis and Gibling, 2010; Reis et al., 2020). By contrast,
509 Proterozoic fluvio-aeolian systems that lacked vegetated floodplains were instead
510 more likely to be reworked by mobile rivers (Clemmensen and Dam, 1993; Aspler and

511 Chiarenzelli, 1997; Eriksson and Simpson, 1998; Els, 1998). Mixed fluvial-aeolian
512 successions of Proterozoic age are typically only preserved where high water tables
513 acted to retard and limit aeolian erosion (Trewin, 1993; Tirsgaard and Øxnevad, 1998).

514 Figure 7 shows just one example of how DASA can be used to determine the manner
515 in which aeolian sub-environments variably develop and are preserved as a function
516 of their specific spatio-temporal settings, possibly because of controls exerted by
517 regional or global palaeogeographic configurations. Examples of other potential
518 applications of this type of architectural-element characterisation are outlined below.

519 (1) The compilation of foreset-azimuth data for specific supercontinental or basin
520 settings; such datasets may be applied to aid the reconstruction of regional or localised
521 paleowind directions (e.g. Bigarella and Salumni, 1961, 1964; Glennie, 1983; Parrish
522 and Peterson, 1988; Scherer and Goldberg, 2007; Ballico et al., 2017; Scherer et al.,
523 2020). (2) The compilation of architectural element data for specific
524 paleoclimatological settings; such datasets may be applied to build quantitative facies
525 models describing aeolian accumulation under icehouse and greenhouse climate
526 conditions (e.g., Cosgrove et al., 2021)

527 **4.3 Characterization of Aeolian Lithofacies**

528 Aeolian lithofacies have variable sedimentological and petrophysical properties;
529 understanding facies distribution, geometry and internal textural characteristics is
530 important for gaining insight into depositional processes (Hunter, 1977). Figure 8
531 illustrates how DASA can be used to analyse quantitative facies metrics statistically,
532 and to compare the geometries and grain-size characteristics of different aeolian
533 facies. The ranges of thickness (Fig. 8B, C, E), length (Fig. 8B) and width (Fig. 8C),
534 and the textural properties (Fig. 8D) of facies elements can be quantified and used in

535 the generation of bespoke quantitative facies models. Database queries can be
536 tailored to specific allogenic boundary conditions.

537 In Figure 9, three particular facies types are considered: (1) adhesion strata, (2) strata
538 of interfingered grainflow, grainfall and/or wind-ripple origin, and (3) wind-ripple strata
539 (Fig. 9A-C). DASA enables quantification of the architectures and of the sub-
540 environments with which these facies are most closely associated (Fig. 9D-F). For
541 example, it is possible to determine the proportions of the following: (1) adhesion strata
542 that occur in damp and wet interdune environments (Fig. 9D); (2) interfingered strata
543 that occur in aeolian dune environments (Fig. 9E), and wind-ripple strata that occur in
544 sandsheet, or dry interdune, or water-table-influenced interdune settings (Fig. 9F).

545 The proportions of modal sand granulometric classes for the three example facies
546 units are also shown (Fig. 9G-I); all facies types are dominated by fine- and medium-
547 grained sand, which together form 91%, 75% and 65% of recorded modal grain sizes
548 in adhesion strata, interfingered strata, and wind-ripple strata, respectively. This
549 reflects the highly discriminant nature of sediment transport by the wind (Bagnold,
550 1941). Of note, the wind-ripple facies contains the largest proportions of coarse- and
551 very coarse-grained sand (modal grain size in 33% of recorded instances). Coarse-
552 grained wind-ripple deposits are especially common in aeolian sandsheet settings.
553 This is notably the case for sandsheets that represent remnants of eroded landforms
554 of original higher relief. The coarser grain-sizes found in sandsheet settings partly
555 reflects the effects of aeolian deflation, whereby the winnowing of finer-grained sand
556 leaves behind a coarser lag (Nielsen and Kocurek, 1986; Pye and Tsoar, 1990;
557 Mountney and Russell, 2004, 2006; Mountney 2006b).

558 Quantitative output from DASA can be applied to elucidate understanding of the
559 hierarchical arrangement, geometry and textural properties of a broad range of aeolian

560 and associated non-aeolian facies types. The configuration of stratal packages
561 comprising common aeolian facies (e.g., wind-ripple, grainfall and grainflow strata)
562 can significantly impact horizontal and vertical permeability due to inter-facies
563 variability in grain-size, sorting and packing (Hunter, 1977; Chandler et al., 1989;
564 Prosser and Maskall, 1993). As such, DASA can be applied to better constrain facies-
565 scale heterogeneity in aeolian reservoirs.

566 **4.4 Element Transitions**

567 The construction of meaningful facies models requires a quantitative understanding of
568 the expected vertical arrangement and ordering (i.e. stacking) and lateral juxtaposition
569 of elements. To this end, DASA can return statistics on transitions between elements
570 of the same rank (e.g., depositional complexes and architectural and facies elements),
571 and also between elements of different hierarchical scales (e.g., transitions from an
572 underlying depositional complex of a given type to an overlying facies type, which is
573 itself contained within a parent element of higher hierarchical order). The architectural,
574 facies and textural information described in the examples presented above can be
575 coupled with DASA outputs describing the mutual association of element types in
576 lateral and vertical directions.

577 Figure 10 illustrates vertical transition statistics between types of architectural
578 elements recorded in DASA. This type of information can be synthesized in transition
579 probability matrices, in this example depicted as a heatmap (Figure 10D), or as
580 stacked bar charts (Fig. 10E-F) to show the probability of transitioning from one
581 element type to another. Specific architectural element types can be considered in
582 terms of their probability or frequency of transition (vertically, or laterally along a
583 direction either parallel or perpendicular to the dominant foreset azimuth) into another

584 architectural-element type. This makes it possible, for example, to determine that: (1)
585 aeolian sandsheet elements are most frequently seen to transition vertically to
586 overlying dune sets (36% probability), or that (2) the probability of passing vertically
587 from an aeolian dune set, below, directly to a non-aeolian architectural element above
588 is 13% (Fig. 10E), and that this non-aeolian element has a 25% chance of being a
589 fluvial channel deposit (Fig. 10F). Transition statistics can also be derived for facies
590 and grain-size categories. These statistics can be used to characterize the internal
591 facies organization of particular sub-environments and to quantify stratigraphic trends,
592 through statistical evaluation (e.g. employing Markov-chain analysis; cf. Harper, 1984;
593 Brierley, 1989) of the most likely vertical or lateral successions of facies elements.
594 Understanding the vertical and lateral stacking (i.e. order of juxtaposition) of different
595 element types is especially important in the interpretation of subsurface aeolian
596 successions known only from core or wireline-log records (e.g., Chandler et al., 1989;
597 Krystinik, 1990; Prosser and Maskall, 1993; Shebi, 1995; Besly et al. 2018).

598 **4.5 Characterization of Aeolian Bounding Surfaces**

599 Within aeolian systems, bounding surfaces separate elements at multiple scales and
600 can demarcate prominent changes in sedimentological character. Such surfaces
601 might signify the juxtaposition of separate aeolian sequences representing entirely
602 different episodes of aeolian system construction and accumulation (e.g., Crabaugh
603 and Kocurek, 1993), else they might record subtle changes between alternating
604 episodes of dune accumulation via positive climb (e.g., Herries, 1993), non-climbing
605 bypass (e.g. Langford and Chan, 1988), and erosion through negative climb (e.g.,
606 Kourek and Day, 2018; cf. Loope, 1985; Mountney, 2012).

607 DASA records both quantitative and qualitative data for all prominent surface types,
608 and allows bespoke queries to be made on specific surface types and on any other
609 higher-level filters. Two examples of how bounding-surface data can be sequentially
610 filtered to meet particular specifications are shown in Figure 11A-B. Fig. 11A presents
611 output on the percentage of supersurfaces (20% of all recorded bounding-surface
612 types) that are Mesozoic in age (52% of supersurfaces), *and* that are wet (90% of
613 Mesozoic supersurfaces), *and* that are bypass surfaces (48% of wet, Mesozoic
614 supersurfaces). Fig. 11B presents output showing the percentage of interdune
615 surfaces (50% of all recorded bounding-surface types) found at palaeolatitudes in the
616 15-30° range (42% of interdune surfaces), *and* that are curved in shape (54% of
617 interdune surfaces from 15-30° latitude), *and* that are of a damp type (14% of curved
618 interdune surfaces from 15-30° latitude). Such bespoke queries demonstrate the
619 power of a databasing approach for enhancing our understanding of the timing and
620 mechanism of preservation of surfaces of different types in the geological record, and
621 of the characteristics that particular classes of bounding surface are likely to possess;
622 such output can be used to build representative models of aeolian systems for different
623 settings.

624 DASA can be applied to compare attributes of bounding surfaces of different order;
625 examples of quantitative data output for the four main aeolian bounding-surface types
626 (supersurfaces, and interdune migration, superposition and reactivation surfaces) are
627 shown in Figure 12. Quantitative statistical summaries describing the lengths of
628 different surface types, along directions that are both parallel and perpendicular to the
629 azimuth of mean foreset dip in aeolian dune sets, are shown in Figure 12B-C; such
630 statistical distributions of surface length can be used to guide stratigraphic correlations

631 in aeolian successions, where limited exposure precludes direct walking-out of key
632 stratal surfaces and across well arrays in the subsurface.

633 Data recorded in DASA reveal the following.

634 (1) Supersurfaces are twice more likely to be of deflationary type than of bypass type
635 (Fig. 12D). Deflationary and bypass supersurfaces represent negative and neutral
636 sediment budgets, respectively (Kocurek, 1988). The dominantly deflationary nature
637 of supersurfaces is not surprising, as sustained sediment bypass (where dunes remain
638 active but do not climb; e.g., Langford and Chan, 1988 requires sustaining a fine
639 balance between sediment supply and downwind bedform migration. Under these
640 conditions sediment supply is sufficient to maintain dune migration and to prevent
641 dunes from cannibalizing their accumulation surface, but insufficient to promote the
642 onset of bedform climbing (Mountney, 2012; “line of bypass” in his Figure 6).

643 (2) Supersurfaces are most likely to be associated with a ‘wet’ substrate (70%),
644 compared to a ‘dry’ (10%) or ‘damp’ (20%) substrate (Fig. 12E). Such relations indicate
645 the proximity of the water table at the time of supersurface development, which itself
646 might be related to aeolian system interactions with adjoining fluvial and marine
647 environments (Mountney et al., 1999b; Veiga et al., 2002; Scherer and Lavina, 2005,
648 2006; Scherer et al., 2007; Rodríguez-López et al., 2012; Basilici and Dal' Bo, 2014;
649 Ferronato et al., 2019; Reis et al., 2020).

650 (3) Twenty-five per cent of supersurfaces display evidence of surface stabilization,
651 whereas 75% are unstabilized (Fig. 12F). Supersurfaces typically record substantial
652 hiatuses in erg development and many are associated with sedimentary features
653 indicative of long-term substrate stabilization, including rhizoliths, deflationary pebble
654 lags and chemical cementation (Loope, 1985; Loope, 1988; Kocurek, 1991; Scherer

655 and Lavina, 2006; Basilici et al., 2009; Dal' Bo et al., 2010). However, such associated
656 features are not ubiquitous and cannot be relied upon to assist in the identification of
657 all supersurfaces. The lack of evidence for substrate stabilization for many
658 supersurfaces may reflect the large time scales required for the development of some
659 stabilizing features. For example, supersurfaces with abundant and prominent
660 rhizoliths in the Permian Cedar Mesa Sandstone of Utah are thought to have taken
661 10^4 - 10^5 years to develop (Loope, 1985; Mountney, 2006a). The dominance of
662 supersurfaces that lack evidence for significant substrate stabilization might indicate
663 that resumption of aeolian accumulation prior to the development of stabilizing
664 features was common in ancient systems. The lack of available tools with which to
665 effectively date aeolian successions means that determining the length of time
666 encapsulated by supersurfaces is, however, problematic. Additionally, the lack of
667 stabilizing features may also reflect the prevailing climatic conditions. For example,
668 the relatively rapid development of a protective mantle of vegetation is dependent on
669 the establishment of relatively more humid climatic conditions; this may have been
670 relatively rare in ancient systems preserved in the geological record.

671 (4) The substantial majority of supersurfaces (85%) have no appreciable relief and are
672 classed as planar (Fig. 12G); this reflects their mode of formation over regional extents
673 (Kocurek, 1991; Havholm et al., 1993); the majority of recorded supersurfaces are
674 both deflationary and wet, and deflation to a "flat" regional water table would typically
675 result in a planar surface (Stokes, 1968).

676 Bounding surfaces can potentially exert significant effects on reservoir heterogeneity
677 due to the juxtaposition of facies of different lithologies and permeabilities; the lateral
678 extent of facies-driven permeability contrasts across aeolian bounding surfaces can
679 fundamentally influence fluid-flow in reservoirs where a facies unit on either side of the

680 bounding surface has a permeability low enough to act to as baffle or barrier to fluid
681 flow (Nagtegaal, 1979; Lindquist, 1983; Krystinik, 1990; Crabaugh and Kocurek, 1993;
682 Herries, 1993; Shebi, 1995; Taggart et al., 2012). Additionally, the presence carbonate
683 and siliceous cements on some bounding surfaces can generate low-permeability
684 horizons within aeolian successions, which may be otherwise characterised by high
685 net to gross ratios (Driese, 1985; Chandler et al., 1989; Kocurek and Havholm, 1993).

686 **4.6 Creation of Quantitative Facies Models**

687 DASA queries can be filtered to yield quantitative outputs on aeolian elements at
688 multiple hierarchical orders, associated with different observational scales (Figs. 13
689 and 14). Two examples of how filters can be applied to DASA to produce bespoke
690 quantitative aeolian facies models are outlined below.

691 To produce a facies model that quantifies architectural-element properties (Figure 13),
692 filters can be applied in the following way.

693 (1) All recorded aeolian and non-aeolian architectural elements are considered
694 according to their physiographic setting within a major aeolian sand sea (*sensu* Porter,
695 1986; Fig. 13A) to yield outputs on their geometric properties (Fig. 13B), and on their
696 distribution within different dune-field settings (Fig. 13C).

697 (2) The properties of selected architectural-element types within a central-erg setting
698 (Fig. 13D) are summarized; results demonstrate the relationships between recorded
699 element length and thickness (Fig. 13E), and the range of recorded thicknesses, for
700 these element types (Fig. 13F).

701 (3) An individual element type within a central-erg setting is considered (Fig. 13G).
702 The thickness (Fig. 13H), length and width (Fig. 13I) of dune sets are reported.

703 (4) The internal properties of dune-set elements within central-erg settings are
704 considered (Fig. 13J). Quantitative outputs (Fig. 13K-M) are reported, such as the
705 relative proportions of single vs compound dune sets (Fig. 13M), the proportions of
706 different facies type found in cross-bedded dune sets, and the proportions of different
707 classes of modal sand grain-size (Fig. 13N-O).

708 To produce a facies model that quantifies facies properties of types of deposits (Figure
709 14), filters can be applied sequentially as follows.

710 (1) All recorded elements are considered according to depositional-complex type (Fig.
711 14A); the thickness distributions of all primary (Fig. 14B) and all secondary (Fig. 14C)
712 depositional complex types are reported.

713 (2) The properties of architectural elements are filtered for a specific depositional-
714 complex type, to characterize dune-set, sandsheet and interdune architectural
715 elements from exclusively aeolian settings (Fig. 14D); the relationship between
716 element lengths and thicknesses is reported (Fig. 14E), as are the thickness
717 distributions of different element types (Fig. 14F).

718 (3) An individual architectural-element type present in aeolian systems is depicted; the
719 element type is viewed in the context of its palaeogeographic and tectonic setting (Fig.
720 14G). In this example, interdunes are considered, for which thickness distributions are
721 reported according to classes of supercontinental setting (Fig. 14H) and basin type
722 (Fig. 14I).

723 (4) The facies properties of an individual element type are examined in the context of
724 a specific supercontinental setting; in this case interdunes from Pangaea are
725 considered. The proportion of dry, damp and wet interdune elements are reported (Fig.

726 14K), together with facies proportions shown for dry, damp, and wet interdunes (Fig.
727 14L-N).

728 The examples shown in Figures 13 and 14 demonstrate how outputs from DASA can
729 be filtered from the scale of entire depositional systems representative of large-scale
730 sedimentary environments (e.g., information regarding dune-field position or primary
731 depositional complex type), down to the scale of individual lithofacies units (e.g., the
732 facies and textural properties of particular types of bed sets). The examples described
733 here merely depict a small number of filters that might be applied.

734 **4.7 Characterizing Heterogeneities in Subsurface Aeolian** 735 **Successions**

736 The preceding examples illustrate how a database approach can be used to provide
737 highly specific outputs based on particular sets of criteria. DASA can be applied as
738 both a research tool to gain improved understanding of the controls that influence
739 aeolian systems and their preserved successions, and as a resource to aid subsurface
740 characterization. The characterization of subsurface aeolian reservoirs requires the
741 accurate determination of key reservoir parameters, including the lithology, geometry,
742 dimensions and spatial distributions of aeolian, and associated non-aeolian elements
743 (e.g., fluvial, playa-lake, and marine deposits, amongst others). Such key reservoir
744 parameters can be determined from DASA output. Additionally, the synthesis of data
745 from a large number of case studies permits the development of composite geological
746 analogues that capture stratigraphic and sedimentological variability. These
747 analogues can be applied to quantify uncertainty in subsurface aeolian successions.
748 Output from DASA can be applied, for example, in the fields of hydrocarbon
749 exploration, development and production, carbon capture and storage (CCS), deep

750 geothermal reservoir development, and in aquifer management (e.g., Medici et al.,
751 2016, 2019a, 2019b). DASA can be used for a number of applied purposes, examples
752 of which are as follows. First, to quantify the interdigitation and 3D stacking of relatively
753 more porous and permeable aeolian dune elements (dominated by packages of
754 grainflow strata) with non-dune elements (including interdune, fluvial and sabkha
755 deposits) that tend to have poorer flow properties (cf. Fig. 10; Nagtegaal, 1979;
756 Lindquist, 1983; Krystinik, 1990; Crabaugh and Kocurek, 1993; Herries, 1993; Shebi,
757 1995).

758 Second, to record the presence and nature of aeolian bounding surfaces at different
759 scales, and their occurrence between and within specific depositional complexes and
760 architectural and facies elements (Figs. 11 and 12). Aeolian bounding surfaces can
761 act as barriers to fluid migration, by exhibiting prominent grain-size contrasts (e.g.,
762 Shebi, 1995; Ciftci et al., 2004). Bounding surfaces can also transmit percolating
763 meteoric waters, resulting in the precipitation of carbonate and silicate cements (e.g.,
764 Chandler et al., 1989; North and Prosser, 1993), and in the acceleration of other
765 diagenetic processes, such as the compaction and mechanical infiltration of clays and
766 chlorite cementation (e.g., Bongiolo and Scherer, 2010; Dos Ros and Scherer, 2013).

767 Third, to characterize the statistically most likely configuration and orientation of
768 aeolian facies units (e.g., Figs. 8 and 9), such as those composed of packages of wind-
769 ripple, grainfall and grainflow strata. The three-dimensional arrangement of these
770 aeolian facies elements can significantly impact horizontal and vertical permeability
771 due to inter-facies variability in grain size, sorting and packing (Hunter, 1977; Chandler
772 et al., 1989; Prosser and Maskall, 1993; Howell and Mountney, 2001; Pickup and
773 Hern, 2002).

774 Some aeolian successions have historically been considered to form relatively
775 homogeneous tanks of sand due to inherent high net-to-gross ratios (e.g., Glennie,
776 1972). However, focused research has revealed many aeolian successions to be
777 highly lithologically heterogeneous at multiple scales (e.g., McCaleb, 1979; Weber,
778 1987; Fryberger, 1990; Prosser and Maskall, 1993; Taggart et al., 2012; Godo, 2017).
779 Such heterogeneity can be quantified by careful application of the database.

780 Aeolian successions are shown here to exhibit complex architectural arrangements of
781 aeolian and associated non-aeolian elements, and to be lithologically heterogeneous,
782 across a variety of scales (cf. McCaleb, 1979; Weber, 1987; Prosser and Maskall,
783 1993; Godo, 2017). Composite analogues derived from DASA can be employed as
784 quantitative facies models (cf. Colombera et al., 2013), applicable (1) to predict three-
785 dimensional lithological heterogeneity in subsurface successions that are resource
786 targets; (2) to constrain geocellular stochastic models (cf. Enge et al., 2007;
787 Colombera et al., 2012b; Howell et al., 2014), and (3) to facilitate borehole correlations
788 of aeolian dune sets or associated non-aeolian elements (e.g., Lallier et al., 2012;
789 Colombera et al., 2014).

790 **5. Conclusions**

791 DASA is the first integrated large-scale relational database specifically designed to
792 store quantitative data on the geomorphology, sedimentology and stratigraphy of
793 modern and ancient aeolian systems, and their preserved successions. The flexible
794 structure of DASA and the associated standardization of data types and terminology
795 allow the synthesis of data from multiple sources (e.g., published and unpublished
796 literature, technical reports and bespoke studies), of different types (e.g., modern vs

797 ancient; outcrop vs subsurface), and collected using different methods (e.g., vertical
798 measured sections, architectural correlation panels, and virtual outcrop models).

799 DASA has been designed to capture all the fundamental attributes of aeolian
800 architecture, including but not limited to: (1) the geometric properties of aeolian and
801 associated non-aeolian bodies; (2) the spatial configuration of aeolian and related
802 sedimentary and geomorphic units, including their vertical and lateral transitions; and
803 (3) the nature of bounding surfaces that separate aeolian and non-aeolian bodies.
804 Quantitative data incorporated within DASA are supported by associated qualitative
805 data, including metadata describing age, location and broader environmental setting,
806 together with information relating to original descriptions, interpretations and
807 classifications of forms and deposits. Data on geological boundary conditions, such as
808 tectonic setting and climatic conditions, are also stored to frame aeolian systems in
809 time and space.

810 The digitization of aeolian architecture allows DASA to output quantitative metrics that
811 span multiple scales, from larger-scale depositional complexes to smaller-scale facies
812 elements and sediment texture. Tailored quantitative outputs describing aeolian
813 architectures can be filtered to enable comparisons between aeolian systems
814 deposited under different boundary conditions. Some potential applications of DASA
815 to future research developments in aeolian sedimentology and stratigraphy include:
816 (1) the development of quantitative facies models, specifically tailored for parameters
817 describing spatio-temporal and environmental context; (2) the instruction of forward
818 stratigraphic models and 3D geocellular subsurface models; and (3) the empirical
819 assessment of how aeolian systems respond to – and how associated architectures
820 record – allogenic and autogenic forcings. DASA serves as a valuable tool for
821 quantitative subsurface characterization.

822 Data population is on-going as more studies of aeolian systems are published. The
823 database-informed approach to research that DASA enables has the potential to
824 revolutionize our understanding of processes and controls on aeolian sedimentary
825 systems, both modern and ancient.

826 **Data Availability Statement**

827 An SQL file containing all of the data presented in this paper are available and included
828 in the supplementary information.

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1741 **Figure Captions**

1742 **Figure Captions**

1743 1. Schematic diagram illustrating subdivisions of major aeolian dune-field (erg)
1744 systems, the scales of elements, entities and relationships stored in DASA, and
1745 some of its variables. Geomorphic elements represent modern aeolian landforms
1746 (i.e. those which are present intact or as remnant forms on the Earth's surface).
1747 Architectural elements predominantly represent aeolian and associated non-
1748 aeolian deposits preserved in the geological record. DASA stores information on
1749 both modern and ancient deposits at a variety of spatial scales. Within a subset

1750 (i.e. a collection of related data), larger scale depositional complex (e.g., a mixed
1751 aeolian-fluvial succession) contain individual architectural elements (e.g., a cross-
1752 bed dune set), which in turn contain lithofacies (e.g., wind-ripple lamination), which
1753 themselves have specific textural and petrophysical properties.

1754 2. Entity-relationship diagram illustrating the tables (entities) of DASA; the
1755 relationships between the tables are illustrated by the arrows. The name of each
1756 table is shown in capital letters; for each table, primary keys are shown in grey and
1757 foreign keys are shown in black. See text for further explanation.

1758 3. Schematic illustration of how subsets, depositional complexes, architectural
1759 elements and facies are uniquely indexed in DASA. Each progressively lower-order
1760 element is contained (nested) within a higher-order element. A) Subset (original
1761 data source); B) depositional complexes are associated with a subset; C) each
1762 depositional complex is assigned a unique identifier and recorded in the
1763 'depositional complex' table; D) architectural elements are contained within larger-
1764 scale depositional complexes; E) each architectural element is assigned a unique
1765 identifier and recorded in the 'architectural element' table; F) facies are contained
1766 within larger-scale architectural elements; G) each facies element is assigned a
1767 unique identifier and recorded in the 'facies element' table; H) schematic diagram
1768 illustrating how transitions between architectural elements are recorded in DASA;
1769 I) each architectural element is assigned a unique numerical identifier; J) each
1770 element may transition vertically or laterally (lateral transitions are recorded along
1771 a direction either parallel or perpendicular to the dominant foreset azimuth) to a
1772 different architectural element; each transition is uniquely numbered and the
1773 orientation of that transition is recorded; K) the spatial transition between
1774 architectural elements may occur across a surface (e.g., an interdune migration

1775 bounding surface); each surface is assigned a unique numerical identifier and
1776 various attributes associated with each surface are recorded. The methodology of
1777 recording architectural-element transitions and bounding surfaces is shown in
1778 parts H-K; an equivalent methodology is also employed for both depositional
1779 complexes and facies elements, and their transitions.

1780 4. Schematic diagram illustrating how subsets, depositional complexes, architectural
1781 elements and facies elements are recorded in DASA. A) Example of a subset
1782 (stratigraphic log); subsets are subdivided into primary and secondary depositional
1783 complex types. B) Example of a depositional complex with marine primary type and
1784 aeolian secondary type. C) Example of a depositional complex with aeolian primary
1785 type and fluvial secondary type. D) Depositional complexes are subdivided into
1786 architectural elements of different types. E) Architectural elements are subdivided
1787 into facies of different types. F) For each facies, different types of data are
1788 recorded, for example on dominant lamination types and on any secondary
1789 physical, biogenic or chemical disturbance or alteration.

1790 5. A) Global map illustrating the location of all modern case studies currently
1791 contained within DASA; B) bar chart displaying the various data types associated
1792 with modern subsets; C) bar chart displaying the latitudinal range of each of the
1793 modern case studies within DASA; D) Global map illustrating the location of all
1794 ancient case studies currently contained within DASA; E) bar chart displaying the
1795 various data types associated with ancient subsets; categories for additional
1796 source-data types are already enabled; the classification can be extended further,
1797 should new data types be incorporated; F) bar chart displaying the palaeo-
1798 latitudinal range of each of the ancient case-studies within DASA. The numbered
1799 locations shown in part A and D are outlined in Tables 1 and 2, respectively.

- 1800 6. A-F) Scatter plots displaying relationships between pairs of geometric parameters
1801 of modern (geomorphic) dune elements (A-C), and ancient dune-set elements (D-
1802 F), coloured by interpreted dune type. G) Box-and-whisker plots comparing various
1803 heights of modern dunes and thicknesses of ancient dune sets, for various
1804 interpreted dune types. H) Scatter plot showing the mean height (modern dune)
1805 and mean thickness (ancient dune sets) for all dune elements in DASA, coloured
1806 by interpreted dune type. The grey crosses for each data point indicate one
1807 standard deviation from the mean; the 'n =' refers to the total number of modern
1808 and ancient dunes. I) Schematic diagram illustrating the dune types as defined in
1809 DASA. Blue arrows indicate significant wind directions relative to bedform
1810 orientation.
- 1811 7. A) Schematic diagram illustrating palaeogeographic configurations of selected
1812 times of supercontinent assemblage, denoted as follows: 1 = Proterozoic
1813 Supercontinent; 2 = Gondwanaland; 3 = Pangaea; 4 = dispersed continental
1814 setting. B-E) Pie charts showing the proportions of dune set, sandsheet and
1815 interdune elements for each supercontinental setting. F) Box-and-whisker plot
1816 illustrating distributions in dune-set thickness for each supercontinental setting. G-
1817 H) Scatter plots displaying relationships between geometric parameters of dune
1818 set elements, coloured by supercontinental setting. I) Box-and-whisker plot
1819 illustrating distributions of sandsheet thickness for each supercontinental setting.
1820 J) Probability density function and K) cumulative density plots showing sandsheet
1821 thicknesses within each supercontinental setting. L) Box-and-whisker plot
1822 illustrating distributions in interdune thickness for each supercontinental setting. M-
1823 P) Pie charts illustrating the proportions of wet, dry and damp interdunes for each

1824 supercontinental setting. Q) Scatter plots displaying interdune thickness vs.
1825 palaeolatitude, coloured by supercontinental setting.

1826 8. A) Examples of various facies types recorded within DASA and some of the larger-
1827 scale architectural elements in which the various facies occur most commonly;
1828 each facies is numbered and corresponds with the presented legend. B-C) Scatter
1829 plots between geometric parameters of facies elements, coloured by facies type.
1830 D-E) Box-and-whisker plots illustrating distributions in: D) the modal grain size and
1831 E) thickness of each facies type.

1832 9. A-C) Idealized block models of: A) adhesion strata, B) interfingered strata and C)
1833 wind-ripple strata. D-F) Stacked bar charts illustrating the relative proportion of
1834 different architectural-element types in which the above facies are most likely to
1835 occur. G-I) Stacked bar charts illustrating the relative frequency of different modal
1836 sand grain-size classes of the above facies types. DASA can also record
1837 intermediate grain-size classes (e.g., lower-fine, upper-fine etc.), but these are not
1838 reported here.

1839 10. A-C) Hypothetical example of how transitions between architectural elements of
1840 different types are recorded in DASA. A) Hypothetical vertical log through an
1841 aeolian succession; B) vertical section and the transitions (T1 to T8) between the
1842 various architectural element types (no particular scale implied); C) description of
1843 the architectural element transitions in the hypothetical vertical log. The
1844 hypothetical example presented in parts A-C is for illustrative purposes only and
1845 does not reflect the real data summarized in parts D-F. D) Heatmap showing
1846 vertical transition probabilities between classes of architectural elements for all
1847 data currently stored in DASA. The architectural-element types are denoted as
1848 follows: 1 = dune set; 2 = sandsheet; 3 = dry interdune; 4 = damp interdune; 5 =

1849 wet interdune; 6 = all non-aeolian deposits. Underlying architectural elements are
1850 listed on the vertical axis of the heatmap; overlying architectural elements are listed
1851 on the horizontal axis and are additionally denoted with 'V' (for "vertical") in
1852 parenthesis. E-F) stacked bar charts illustrating the percentage of vertical element
1853 transitions from one element type to another; in Part E all transitions to non-aeolian
1854 elements are grouped in a single category; in Part F, vertical transitions relating
1855 exclusively to the non-aeolian element types are shown in detail.

1856 11. Two examples of sequential surface filtering. A) The percentage of recorded
1857 surfaces that are supersurfaces (A1), *and* are Mesozoic in age (A2), *and* are
1858 associated with wet surface sedimentary features (A3), *and* are classed as bypass
1859 surfaces (A4). B) The percentage of recorded surfaces that are interdunes (B1),
1860 *and* are deposited in palaeolatitudes of between 15-30° (B2), *and* have a curved
1861 shape (B3), *and* are classed as a 'damp' type (B4). The arrows indicate the
1862 sequential levels of filtering.

1863 12.A) Schematic diagram illustrating the occurrence of four major aeolian bounding
1864 surface types (supersurface, interdune migration, superposition and reactivation),
1865 their occurrence within an aeolian system, and their interactions with each other.
1866 B-C) Box plots showing distributions of surface lengths along directions that are,
1867 respectively, parallel (B) and perpendicular (C) to foreset dip. D-G) Bar charts
1868 illustrating the frequency of occurrence of various properties associated with the
1869 four surface types; D) the frequency of surfaces classified as bypass or deflation
1870 type; E) the frequency of surfaces classified as dry, damp or wet; F) the frequency
1871 of surfaces classified as stabilized or unstabilized; G) the frequency of surfaces
1872 classified as having a shape that is asymptotic (curved), irregular, planar, scalloped
1873 or trough.

1874 13. Example of how DASA can be applied to generate highly specific outputs suitable
1875 for the generation of bespoke quantitative facies models. A) Schematic diagram
1876 illustrating classes of dune-field location as recorded in DASA. "Margin" refers to
1877 lateral dune-field (erg) margins. B) Scatter plot of architectural-element thickness
1878 and length, for elements of any type, coloured by dune-field location. C) Stacked
1879 bar charts showing the percentages of different architectural-element types across
1880 different classes of dune-field location. D) Schematic diagram illustrating the erg
1881 centre. E) Scatter plot reporting architectural-element thickness and length for
1882 aeolian architectural element types from central-erg settings. Colours indicate
1883 aeolian element types; all aeolian element types are defined in Table 4. F) Box-
1884 and-whisker plot showing thickness distributions for different aeolian element types
1885 from erg-centre settings. G) Schematic diagram illustrating cross-bedded dune
1886 sets in central-erg settings. H-I) Probability density functions showing (H) dune-set
1887 thickness and (I) dune-set length and width in erg-centre settings. J) Schematic
1888 diagram illustrating some of the properties of cross-bedded dune sets recorded in
1889 DASA. K) Scatter plot showing dune-set thickness vs. dune-set length, coloured
1890 by the shape of the bounding surface that defines the shape of the base of the
1891 element, for all cross-bedded dune sets from erg-centre settings. L-O) Pie-charts
1892 showing the frequency of occurrence of various properties of cross-bedded dune
1893 sets from erg-centre settings, as follows: L) proportion of surfaces described as
1894 conformable or truncating; M) proportion of dune sets described as solitary or
1895 grouped; N) proportion of various facies within dune sets; O) proportion of various
1896 grain-size classes within dune sets.

1897 14. Example of how DASA can be applied to generate highly specific outputs suitable
1898 for the generation of bespoke quantitative facies models. A) Schematic diagram

1899 illustrating examples of various primary and secondary depositional types. Box-
 1900 and-whisker plots showing the thickness distributions of B) primary and C)
 1901 secondary depositional complexes. D) Schematic diagram showing dune-set,
 1902 sandsheet and interdune elements within an exclusively aeolian depositional
 1903 system. E) Scatter plot showing the relationship between the thickness and length
 1904 of dune-set, sandsheet and interdune elements. F) Probability density function
 1905 showing the thickness of dune set, sandsheet and interdune architectural
 1906 elements. G) Schematic diagram illustrating how DASA can be filtered for various
 1907 spatio-temporal characteristics. H-I) Box-and-whisker plots showing the thickness
 1908 distributions of interdune architectural elements from (H) different supercontinental
 1909 settings and (I) basin settings. The Pangaeen supercontinental setting is
 1910 highlighted with a red box; this particular spatio-temporal setting is interrogated
 1911 further in parts K and L. J) Schematic diagram illustrating the texture and facies of
 1912 interdune elements. K) Proportion of dry, damp and wet interdune architectural
 1913 elements in Pangaeen supercontinental settings only. L) Proportions of different
 1914 facies elements within dry, damp, and wet interdune elements in Pangaeen
 1915 supercontinental settings.

1916 **Table Captions**

- 1917 1. Case study names, locations and associated references of the modern aeolian
 1918 systems included in DASA.
- 1919 2. Case study names, locations and associated references of the ancient aeolian
 1920 systems included in DASA.

1921 3. Depositional-complex types used in DASA for the classification of overall
1922 depositional setting. Each depositional complex can be used as a primary or
1923 secondary complex-type descriptor.

1924 4. Examples of DASA sub-environment and architectural-element types for the
1925 classification of architectural and geomorphic elements; only the aeolian
1926 architectural and geomorphic elements discussed in this article are included here.

1927 5. Examples of DASA facies types for the classification of facies units.

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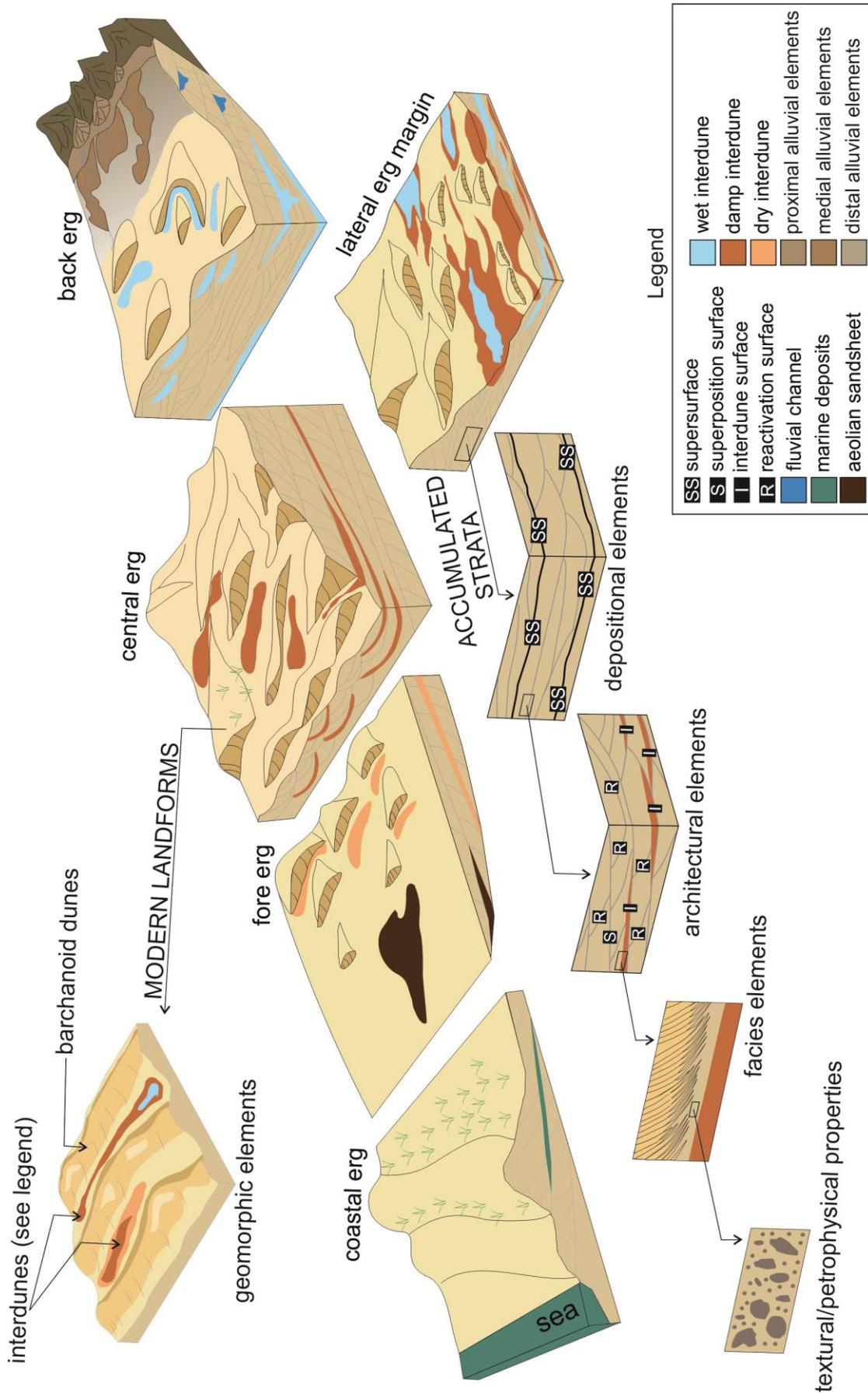
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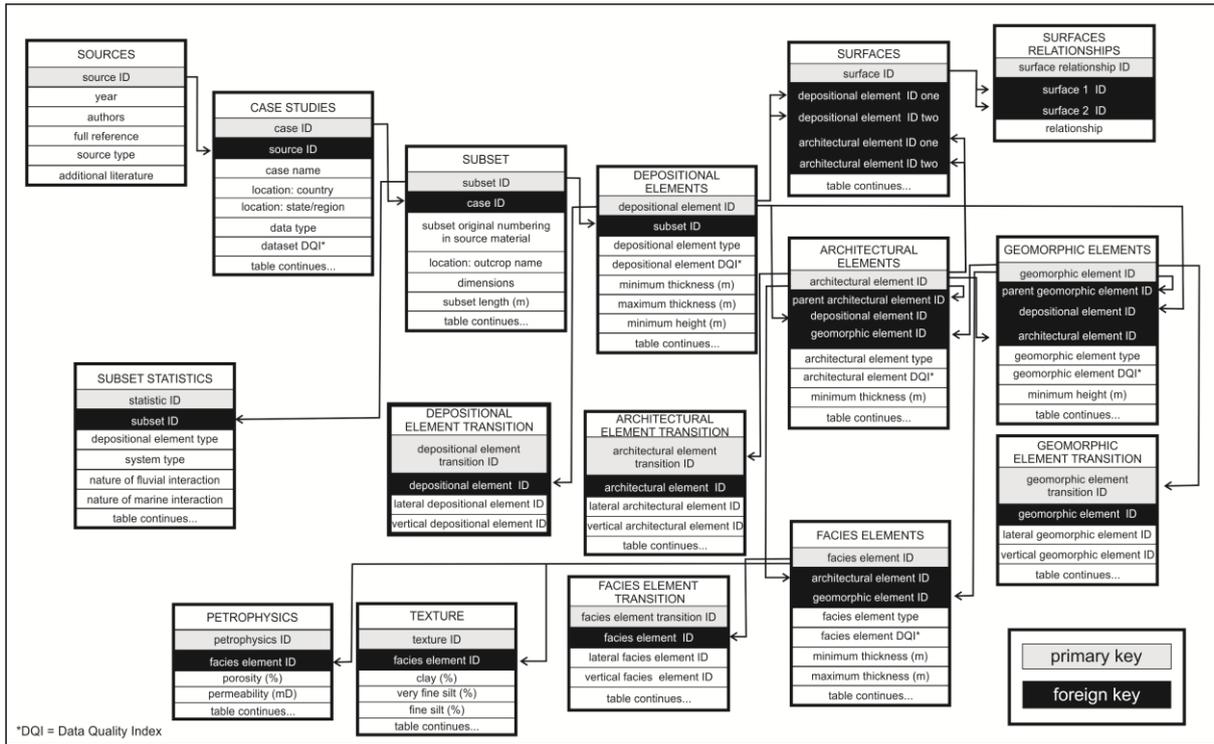
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1947 Figure 2



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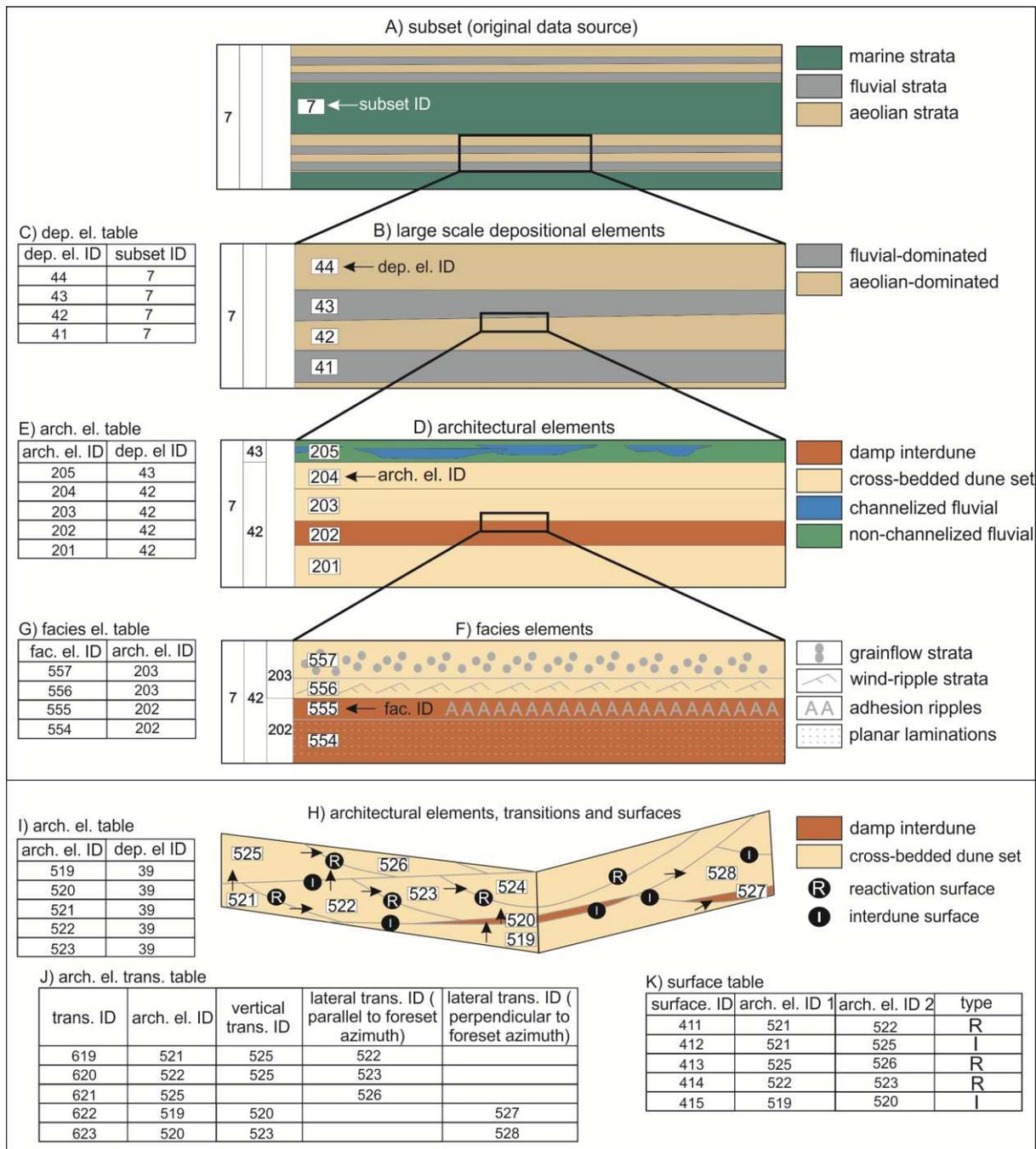
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1963 Figure 3



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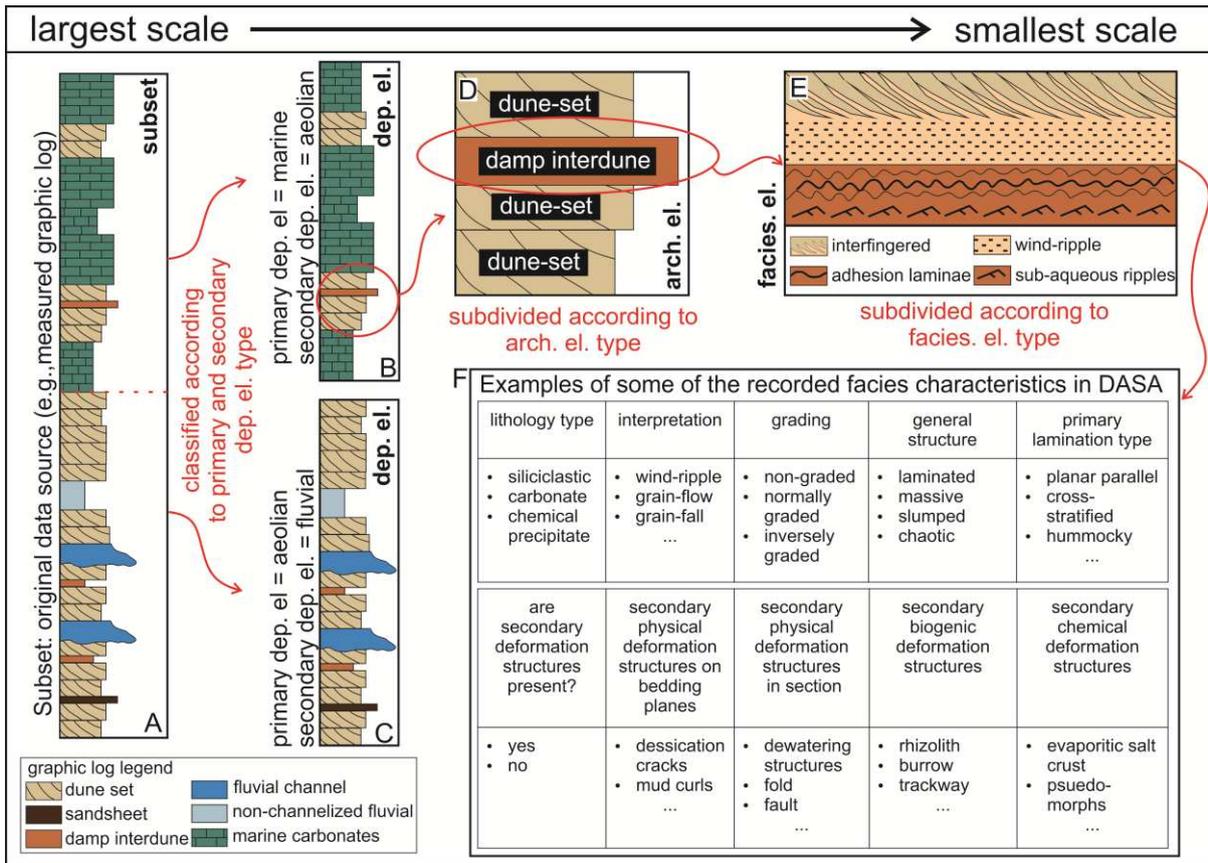
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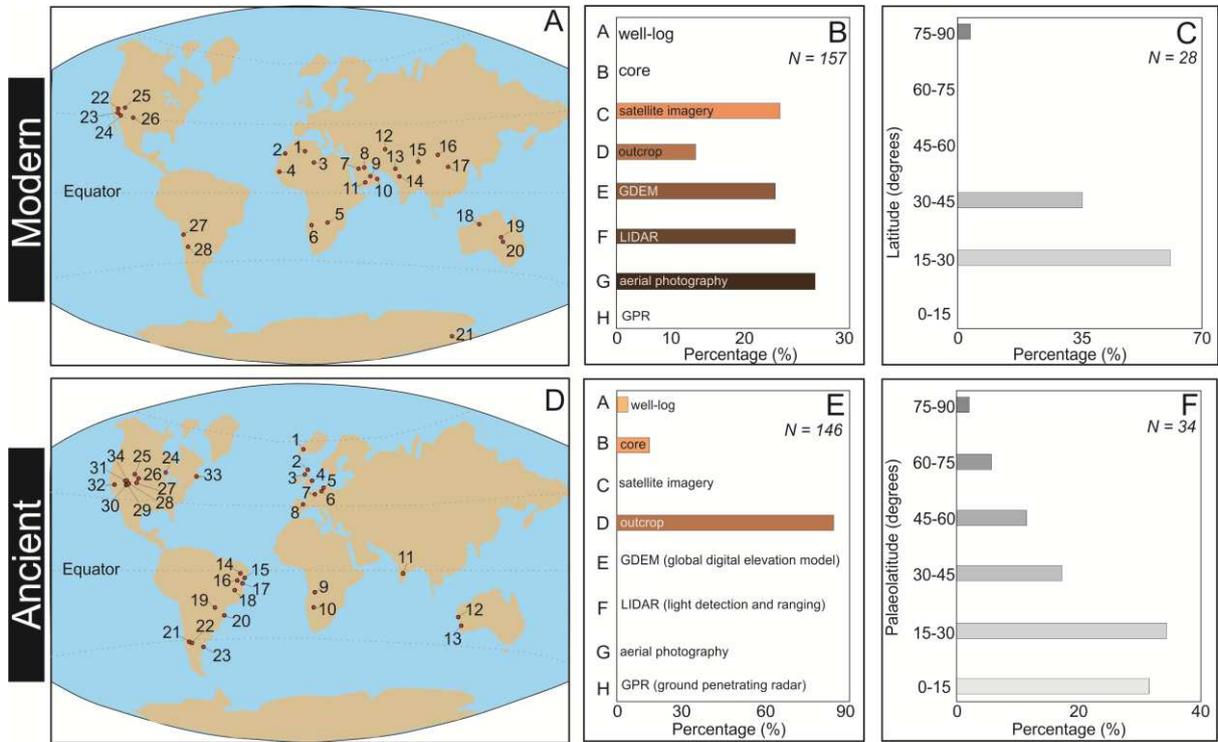
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1971 Figure 4



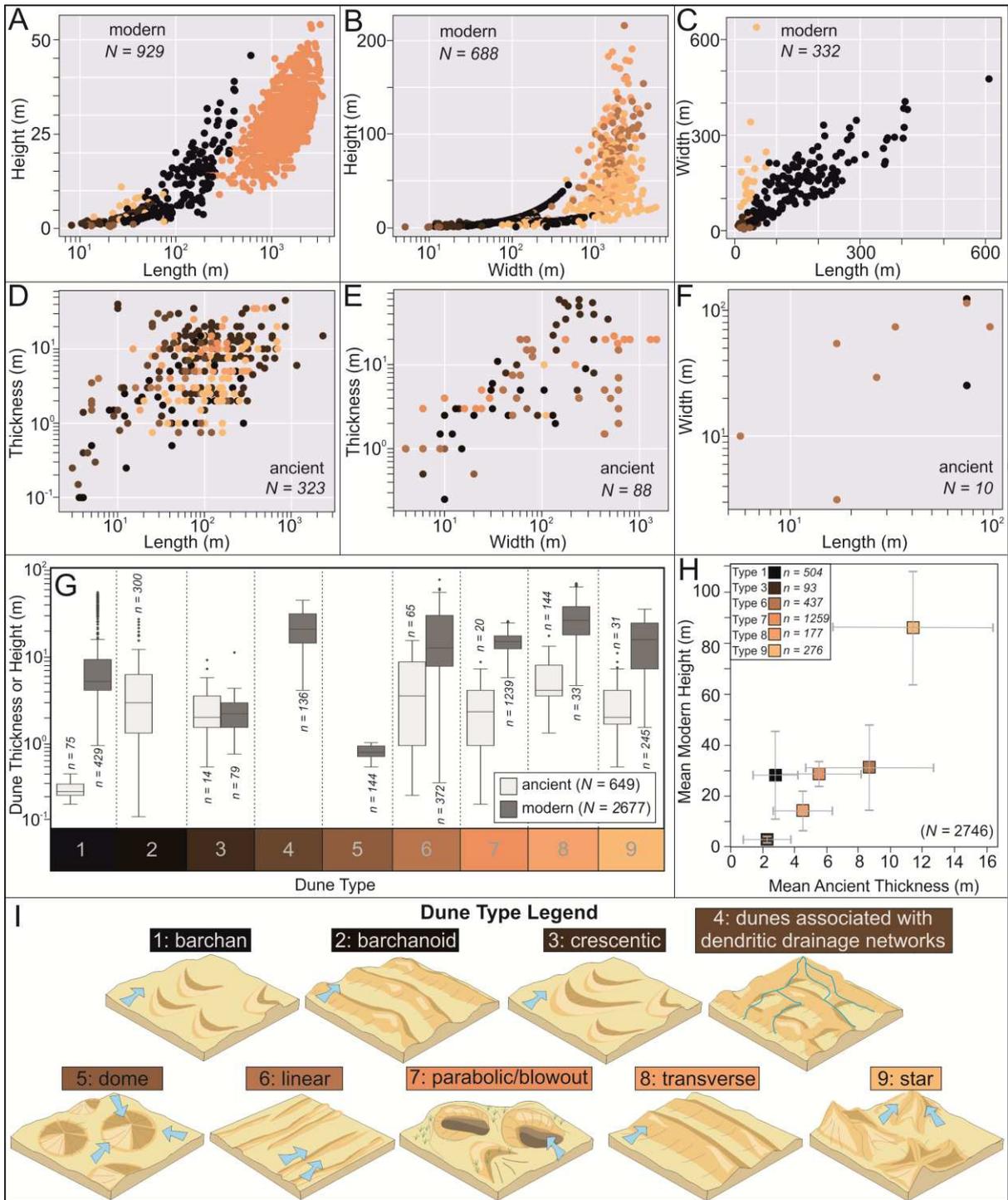
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1973 Figure 5



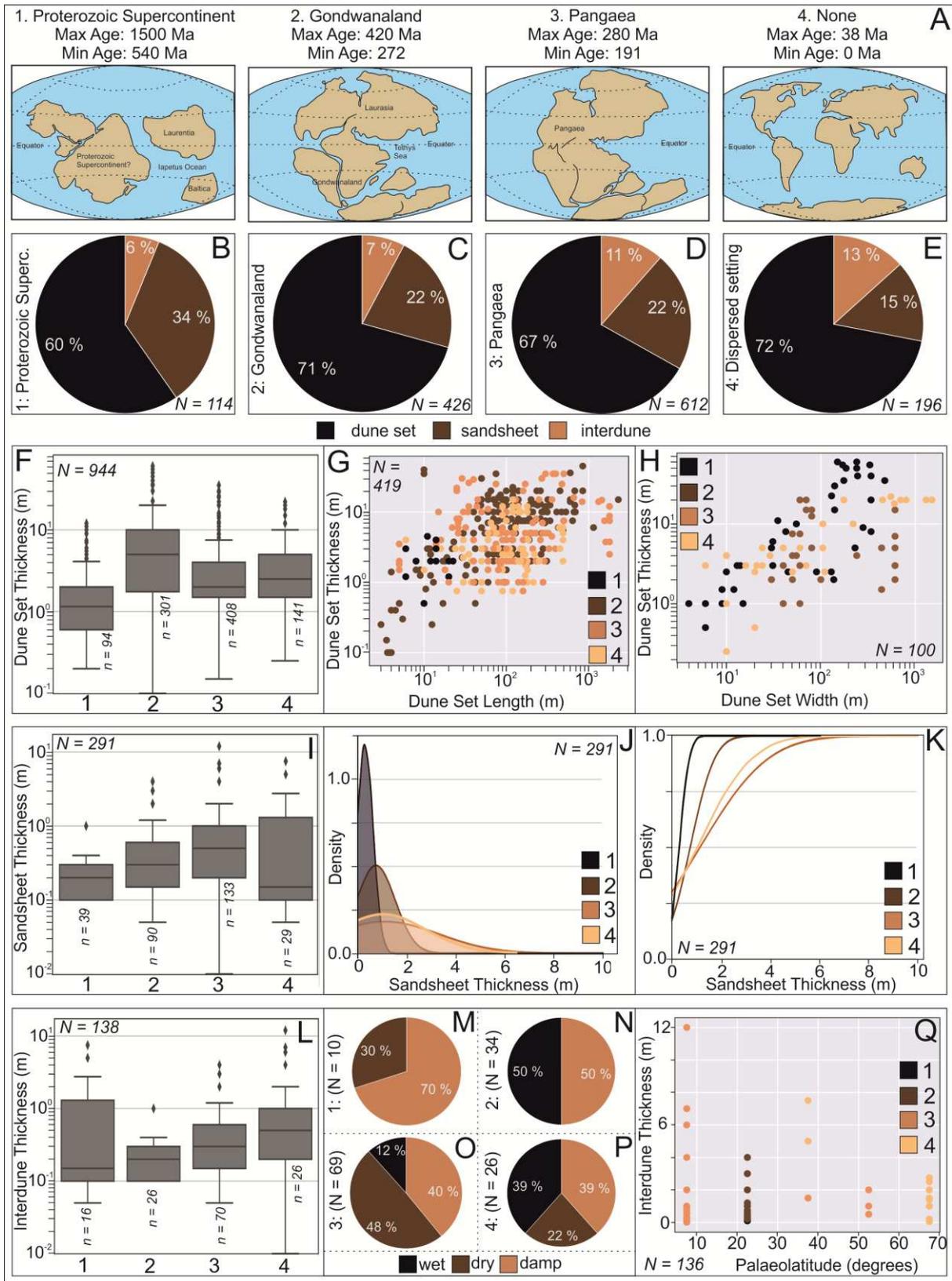
1974

1975 Figure 6



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1981 Figure 7

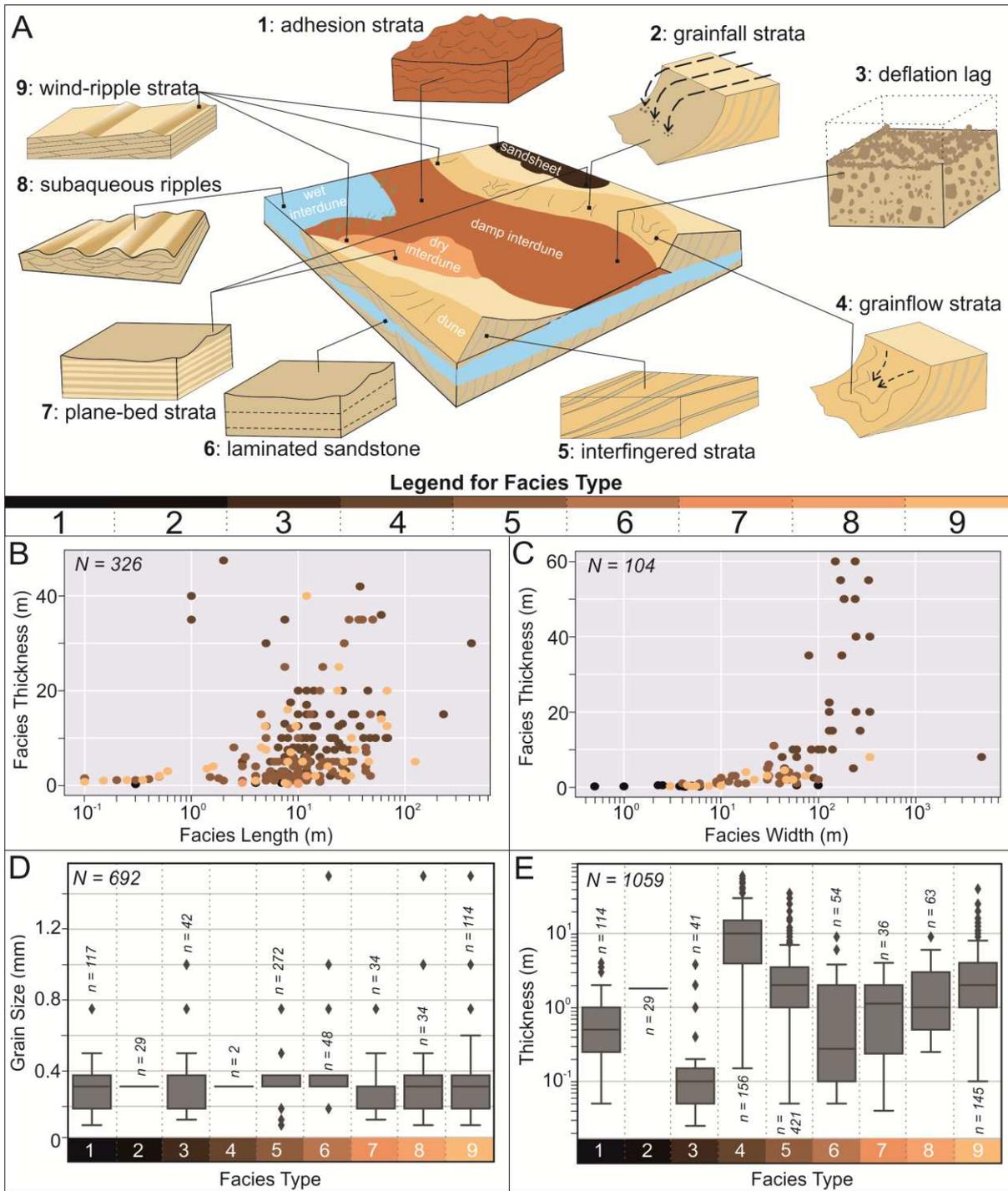


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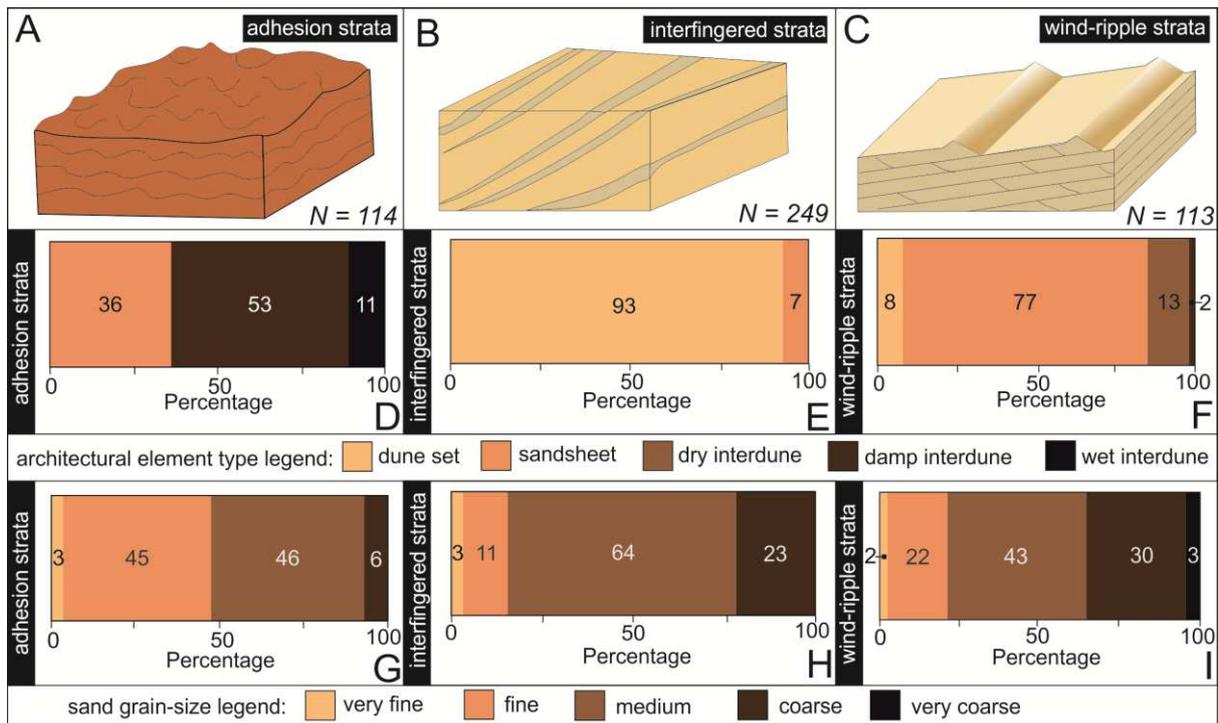
1984

1985 Figure 8



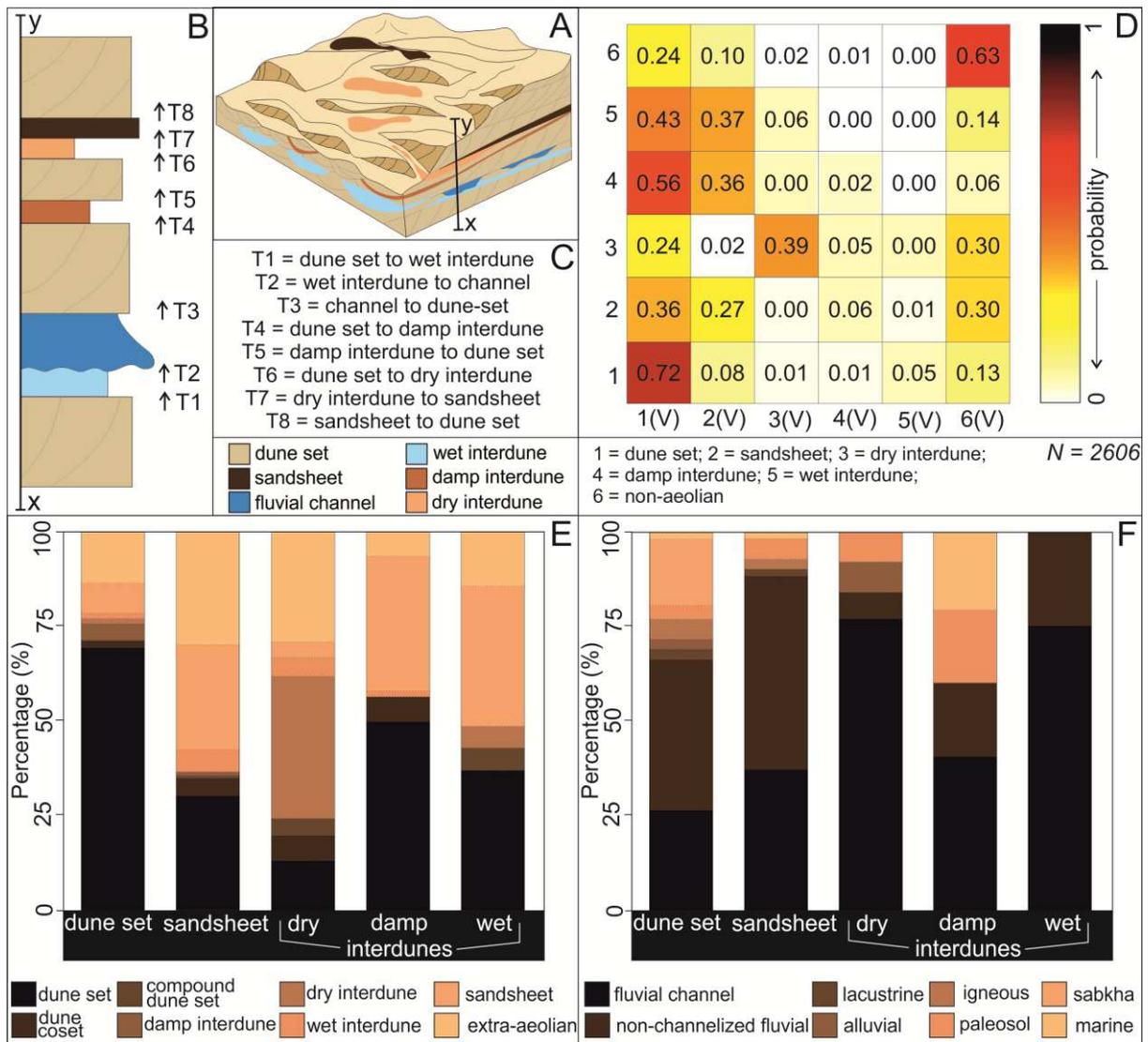
1986
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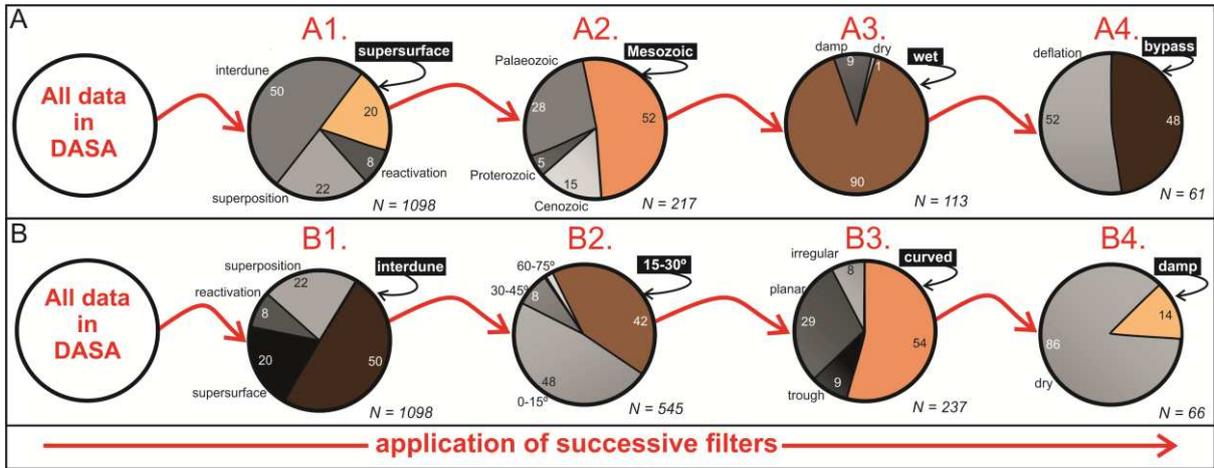
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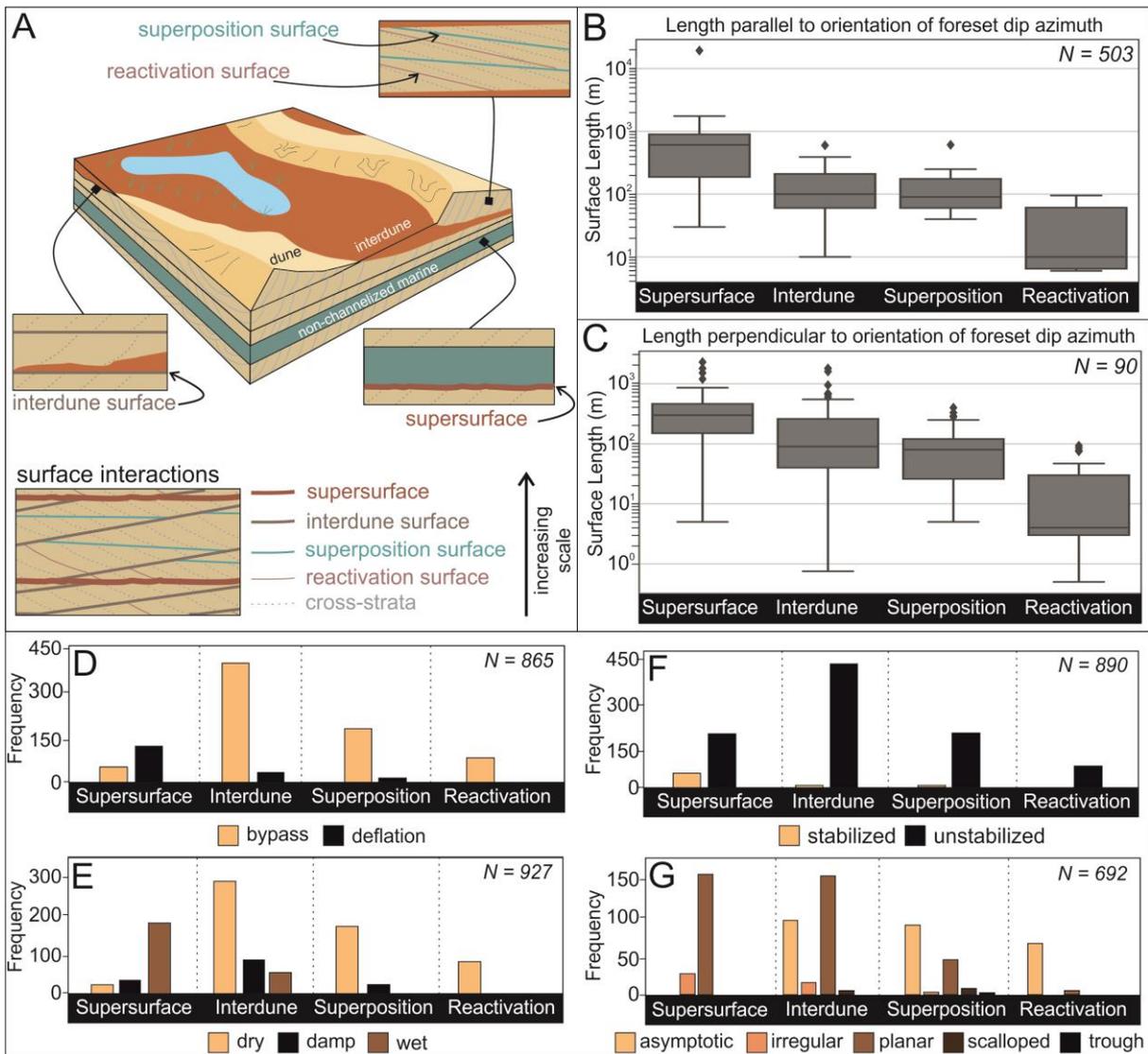
2020 Figure 11

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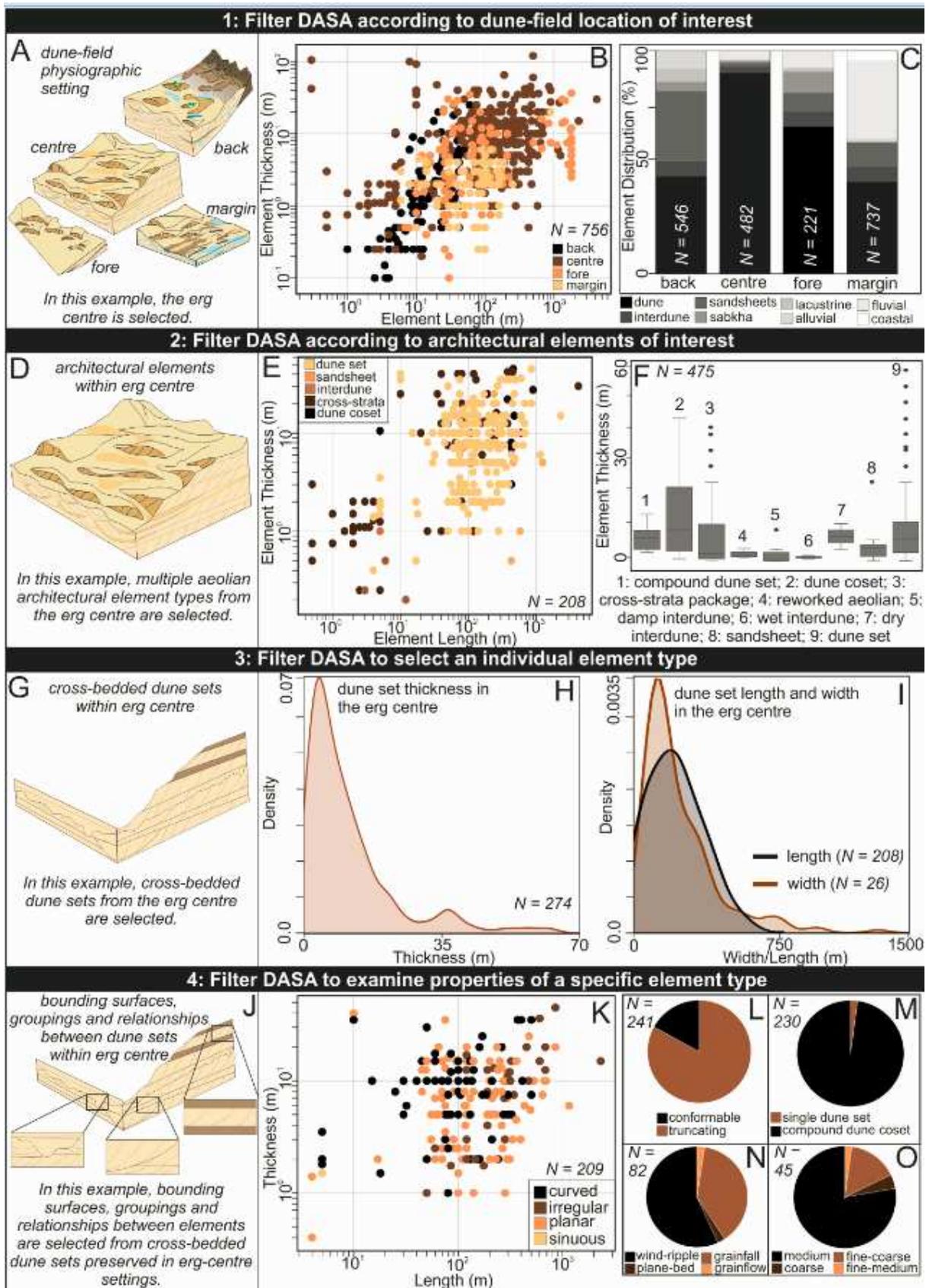
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2023 Figure 12



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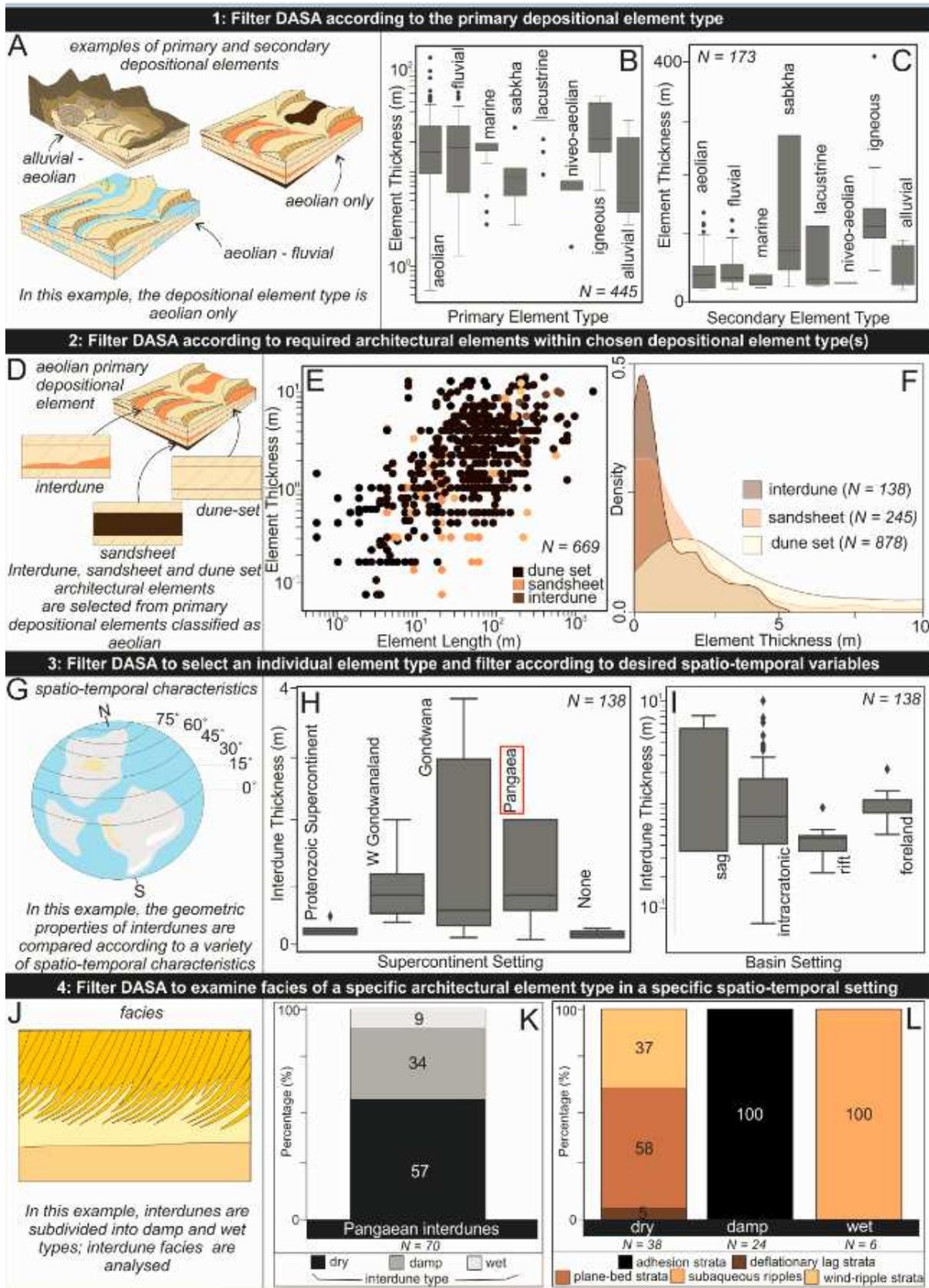
2025 Figure 13



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2028 Figure 14



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2031 Table 1

Case Number	Case Study Name	Location	Reference(s)
1	Grand Erg Oriental	Algeria, Tunisia	McKee (1979); Al-Masrahy and Mountney (2015); Telbisz and Kesler (2018)
2	Atlantic Sahara	Morocco	Elbelrhiti et al. (2008)
3	Idhan Murzuk	Libya	Al-Masrahy and Mountney (2015)
4	El Djouf	Mauritania, W Africa	Al-Masrahy and Mountney (2015)
5	Kalahari Desert	Botswana, Namibia, South Africa	McKee (1979); Kalahari (1988)
6	Namib Desert	Angola, Namibia, South Africa	McKee (1979); Lancaster (2009); White et al. (2011); Al-Masrahy and Mountney (2015); White et al. (2015)
7	An Nafud	Saudi Arabia	McKee (1979);
8	Western Desert	Egypt	Hamdan et al. (2016)
9	Persian Gulf	United Arab Emirates	McKee (1979);
10	Wahiba Sands	Oman	Al-Masrahy and Mountney (2015)
11	Rub' Al Kali	Saudi Arabia, Oman, United Arab Emirates, Yemen	McKee (1979); Al-Masrahy and Mountney (2013); Al-Masrahy and Mountney (2015);
12	Karakum	Turkmenistan	McKee (1979);
13	Kharan Desert	Pakistan	Al-Masrahy and Mountney (2015)

14	Thar Desert	India, Pakistan	McKee (1979); Bhadra et al. (2019)
15	Taklamakan Desert	Xinjiang, China	McKee (1979); Dong et al. (2000)
16	Gobi Desert	China, Mongolia	McKee (1979); Al-Masrahy and Mountney (2015)
17	Mu Us Desert	China	Al-Masrahy and Mountney (2015)
18	Great Sandy Desert	Australia	Wasson and Hyde (1983)
19	Simpson Desert	Australia	McKee (1979); Nanson and Price (1995); Al-Masrahy and Mountney (2015)
20	Strzelecki Desert	Australia	Wasson and Hyde (1983); Bishop (1997)
21	Victoria Valley	Antarctica	Bourke et al. (2005)
22	Colorado Desert	California, USA	Long and Sharp (1964); Bishop (1997)
23	Algodones Dunes	USA, Mexico	McKee (1979);
24	Sonora Desert (Gran Desierto)	Mexico	McKee (1979);
25	Navajo Indian Reservation	Arizona, USA	McKee (1979);
26	White Sands	New Mexico, USA	McKee (1979); Baitis et al. (2014); Al-Masrahy and Mountney (2015)
27	Atacama Desert	Chile, Peru	Finkel (1959)
28	Monte Desert	Argentina	Al-Masrahy and Mountney (2015)

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2034 Table 2

Case Number	Case Study Name	Location	Reference(s)
1	Eriksfjord Formation	Greenland	Clemmensen (1988)
2	Hopeman Sandstone	Scotland, UK	Clemmensen (1987)
3	Arran Red Beds	Isle of Arran, Scotland, UK	Clemmensen and Abrahamsen (1983)
4	Sherwood Sandstone	UK (Onshore and Offshore England and Northern Ireland)	Cowan (1993); Meadows and Beach (1993)
5	Rotliegendes Sandstone	Germany, Poland, Denmark, Baltic Sea, Netherlands	Ellis (1993); Newell (2001)
6	Boxtel Formation	Netherlands, Germany, Denmark, Poland	Schokker and Koster (2004)
7	Sable de Fontainebleau Formation	France	Cojan and Thiry (1992)
8	Escorihuela Formation	NE Spain	Liesa et al. (2016)
9	Etjo Formation	Namibia	Mountney and Howell (2000)
10	Tsondab Sandstone	Namibia	Kocurek et al. (1999)
11	Egalapenta Formation	India	Biswas (2005); Dasgupta et al. (2005)
12	Tumblagooda Formation	Australia	Trewin (1993)
13	Tamala Limestone	Australia	Semeniuk and Glassford (1988)
14	Sao Sebastiao Formation	Brazil	Formolo Ferronato et al. (2019)
15	Sergi Formation	Brazil	Scherer et al. (2007)
16	Mangabeira Formation	Brazil	Ballico et al. (2017)
17	Caldeirao Formation	Brazil	Jones et al. (2015)

18	Bandeirinha Formation	Brazil	Simplicio and Basilici (2015)
19	Guara Formation	Brazil	Scherer and Lavina (2005)
20	Piramboia Formation	Brazil	Dias and Scherer (2008)
21	Huitrin Formation	Argentina	Stromback et al. (2005)
22	Agrio Formation	Argentina	Veiga et al. (2002)
23	Rio Negro Formation	Argentina	Zavala and Frieje (2001)
24	Copper Habor Formation	Michigan, USA	Taylor and Middleton (1990)
25	Chugwater Formation	Wyoming, USA	Irmen and Vondra (2000)
26	Arikaree Formation	Wyoming, Nebraska, USA	Bart (1977)
27	Ingleside Formation	Colorado, Wyoming, USA	Pike and Sweet (2018)
28	Lower Cutler Beds	Utah, USA	Jordan and Mounney (2010)
29	Cedar Mesa Sandstone	Utah, Colorado, New Mexico, Arizona, USA	Loope (1985); Mounney and Jagger (2004)
30	Navajo Sandstone	Nevada, Arizona, Colorado, Utah, USA	Loope and Rowe (2003)
31	Entrada Sandstone	Wyoming, Utah, Arizona, New Mexico, Texas, USA	Crabaugh and Kocurek (1993); Benan and Kocurek (2000); Kocurek and Day (2018);
32	Big Bear Formation	California, USA	Stewart (2005)
33	Wolfville Formation	Nova Scotia, Canada	Leleu and Hartley (2018)

34	Page Sandstone	Arizona, Utah, Wyoming, USA	Jones and Blakey (1997); Kocurek et al. (1992)
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2035 Table 3

Depositional Complexes	Description
Aeolian	Deposits arising from, or relating to, the action of wind.
Niveo-Aeolian	Deposits composed of mixed aeolian and snow deposits, typically found in cold-climate settings (Koster and Dijkmans, 1988; McKenna-Neuman, 1990).
Fluvial	Deposits arising from or relating to the action of streams and rivers.
Marine	Deposits arising from or relating to the action of the sea.
Alluvial	Deposits arising from, or relating to the action of streams and sediment gravity-flow processes (cf. Melton, 1965).
Lacustrine	Deposits arising from or relating to accumulation in perennial lakes.
Sabkha/Playa Lake	Sabkhas and playa lakes describe low-relief flats where evaporites, and in some cases carbonates, accumulate. The terms sabkha and playa lake were originally used to describe coastal and inland settings, respectively (Evans, et al., 1964; Purser and Evans, 1973); however, the terms are now used interchangeably.
Igneous	Deposits relating to intrusive or extrusive volcanic activity.
Other	Any depositional element that differs in origin from those above.

2036 Table 4

Architectural or Geomorphic Element Type	Description
Dune (A/G)	Dunes are large (wavelengths of 5–250 m; Wilson, 1971, 1972) masses of wind-blown sand, typically found in desert and coastal environments (McKee; 1979). Dunes are classified further according to dune type.
Megabedform or Draa (A/G)	Megabedforms or Draas are very large (wavelengths of 500–5000 m and heights >50 m; Wilson, 1971, 1972) bed forms that are compound or complex in form (<i>sensu</i> McKee, 1979) where they support the development of superimposed dune-scale bed forms.
Cross-strata package (A)	Packages of aeolian stratification (typically composed of wind-ripple, grainflow and grainfall strata; Hunter 1977, 1981); form parts of dune sets; packages of cross-strata are typically separated by reactivation surfaces (Brookfield, 1977; Kocurek, 1996).

Dune set (A)	Dune-sets form the fundamental unit of deposition of an aeolian sand dune; dune-sets are formed of packages of cross-strata (Sorby, 1859; Allen, 1963; Rubin and Hunter 1982; Chrintz and Clemmensen, 1993); if dune sets migrate over each other, cross-stratified packages are truncated, delineating sets that are bounded by erosional surfaces (Brookfield, 1977; Kocurek, 1996).
Dune coset (A)	Two or more genetically related dune sets that occur in vertical succession; both the coset and its contained sets are separated by bounding surfaces (Brookfield, 1977; Kocurek, 1996).
Dune compound set (A)	A specialized class of coset wherein the contained sets record the migration of formative bed forms of a <i>common type</i> , for example where dunes migrate over the flanks of a parent megabedform (draa) which is itself migrating to leave an accumulation; both the compound set and its contained sets are separated by bounding surfaces (Brookfield, 1977; Kocurek, 1996).
Sandsheet (A/G)	Sandsheet deposits are low-relief accumulations of aeolian sediment in areas where dunes are generally absent (Kocurek and Nielsen, 1986; Brookfield, 1992; Rodríguez-López et al., 2012); can include low-relief bedforms such as zibar.
Interdune (undifferentiated) (A/G)	Interdune deposits are formed in the low-relief, flat, or gently sloping areas between dunes; neighbouring dunes are separated by interdunes; commonly referred to as the interdune corridors, interdune areas, or interdune hollows (Hummel and Kocurek, 1984).
Dry interdune (A/G)	Dry interdunes are characterized by deposits that accumulate on a substrate where the water table is well below the ground surface, such that sedimentation is not controlled by and is largely not influenced by the effects of moisture (Fryberger et al., 1990).
Damp interdune (A/G)	Damp interdunes are characterized by deposits that accumulate on a substrate where the water table is close to the ground surface, such that sedimentation is influenced by the presence of moisture (Fryberger et al., 1988; Lancaster and Teller, 1988; Kocurek et al., 1992).
Wet interdune (A/G)	Wet interdunes are characterized by deposits that accumulate on a substrate where the water table is elevated above the ground surface such that the interdune is episodically or continuously flooded with water (Kocurek and Havholm, 1993; Loope et al., 1995; García-Hidalgo et al., 2002).

2037 Table 5

Facies Element Type	Description
Wind-ripple strata	Wind-ripple lamination forms when wind-blown, saltating grains strike sand-grains obliquely and propel other grains forward (Bagnold, 1941; Hunter, 1977). The foreset laminae of wind-ripple strata are occasionally preserved (rippleform laminae), however, the internal laminae of wind-ripple strata are often indistinguishable due to grain size uniformity (translatent wind-ripple stratification; Hunter, 1977). In DASA, wind-ripples are subdivided into

	subcritically, critically and supercritically climbing ripple forms (<i>sensu</i> Hunter, 1977).
Grainflow strata	Grainflow strata form where a dune slipface undergoes gravitational collapse (Hunter, 1977; Mountney, 2006b; Bristow and Mountney, 2013). Grainflow deposits are typically erosionally based and are devoid of internal structure. Grainflow strata typically form discrete tongues or wide sheets of inclined strata on the lee-slope of dunes, which wedge-out towards the base of the dune; individual grainflow strata may be indistinguishable, resulting in amalgamated grainflow units (Howell and Mountney, 2001).
Grainfall strata	Grainfall strata are gravity-driven deposits that occur when the wind transports saltating clouds of grains beyond a dune brink; grains settle onto the upper portions of lee slopes as wind transport capacities reduce in the lee-side depressions (Nickling et al., 2002). Grainfall laminae are typically thin (<1 mm), drape existing topography, else may have a wedge-shaped geometry; grainfall lamination is generally composed of sand and silt or (rarely) clay sized grains (Hunter, 1977).
Interfingered strata	Cross-bedded strata are pervasive in aeolian dune sands and form through recurrent sedimentation on lee-slopes. Alternating processes of deposition give rise to intercalated (interfingering) packages of wind-ripple, grainflow and grainfall strata (Hunter, 1977; Hunter, 1981). Planes of stratification record the former shape and location of the lee-slope (Kocurek and Dott, 1981; Fryberger and Schenk, 1981). This composite facies type is used only in cases where it is not possible to differentiate individual wind-ripple, grainflow and grainfall facies elements.
Adhesion strata	Adhesion strata results from the adhesion of moving grains to a damp surface, such as a damp interdune (Hummel and Kocurek, 1984). Adhesion strata typically are low relief (several mm in height) and exhibit sub-horizontal structures with irregular surfaces. In DASA, adhesion strata can be further subdivided into adhesion plane beds, adhesion ripples (Kocurek and Fielder, 1982) and adhesion warts (Olsen et al., 1989), where appropriate.
Plane-bed strata	Plane-bed lamination forms when wind velocities are too high to form ripples (Hunter 1977, 1980). Plane-bed lamination is composed of (sub)horizontally laminated sand, which typically dips at angles of between 0 and 15° (Pye, 2009). Plane-bed laminae are typically millimetre-scale, with sharp or gradational contacts (e.g., Clemmensen and Abrahamsen, 1983) and form sets typically up to 100 mm (Pye, 2009).
Subaqueous ripple strata	Subaqueous ripple lamination is generated by tractional processes and are produced by the action of waves or currents on a sediment surface (Allen, 1978).

2038 Table Captions

2039 Table 1: Modern case-studies included in DASA

2040 Table 2: Ancient case-studies included in DASA

2041 Table 3: Depositional complex types used in DASA for the classification of depositional
2042 settings. Each depositional complex type can be used as a primary or secondary
2043 complex type descriptor.

2044 Table 4: Examples of DASA sub-environment and architectural-element types for the
2045 classification of architectural and geomorphic elements; only the aeolian architectural
2046 and geomorphic elements discussed in this article are included here. A full account of
2047 all types of architectural and geomorphic elements included in DASA is available in
2048 the Supplementary Information.

2049 Table 5: Examples of DASA facies types for the classification of facies elements; only
2050 the facies elements discussed in this article are included here. A full account of all
2051 DASA facies types is available in the Supplementary Information.