OLIVER WAKEFIELD & ED HOUGH

Lithofacies impacts on deformation bands within the Sherwood Sandstone principal aquifer

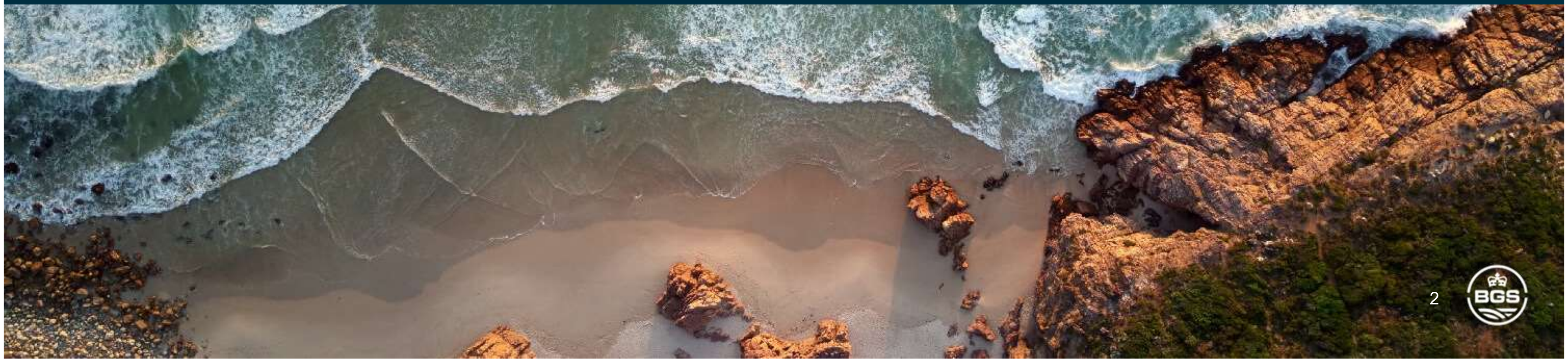
British Geological Survey

CONTENTS

- Sherwood Sandstone Group
- Deformation Bands

] **rationale** (for the two items above)

- Mixed aeolian-fluvial succession – Helsby Hill
- Implications for aeolian systems
- Food for thought…

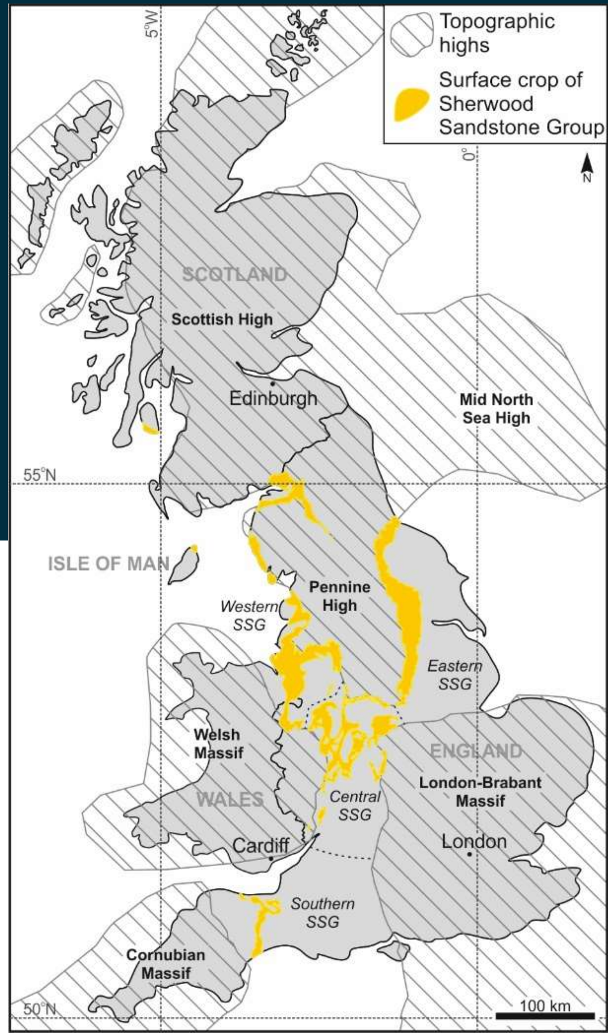


INTRO

Sherwood Sandstone

- Sandstone–rich succession
- Triassic aged
- Regional variations in thickness
- Semi-arid; with fluvial & aeolian affinity – stratigraphy is largely based on the dominance of fluvial/aeolian processes

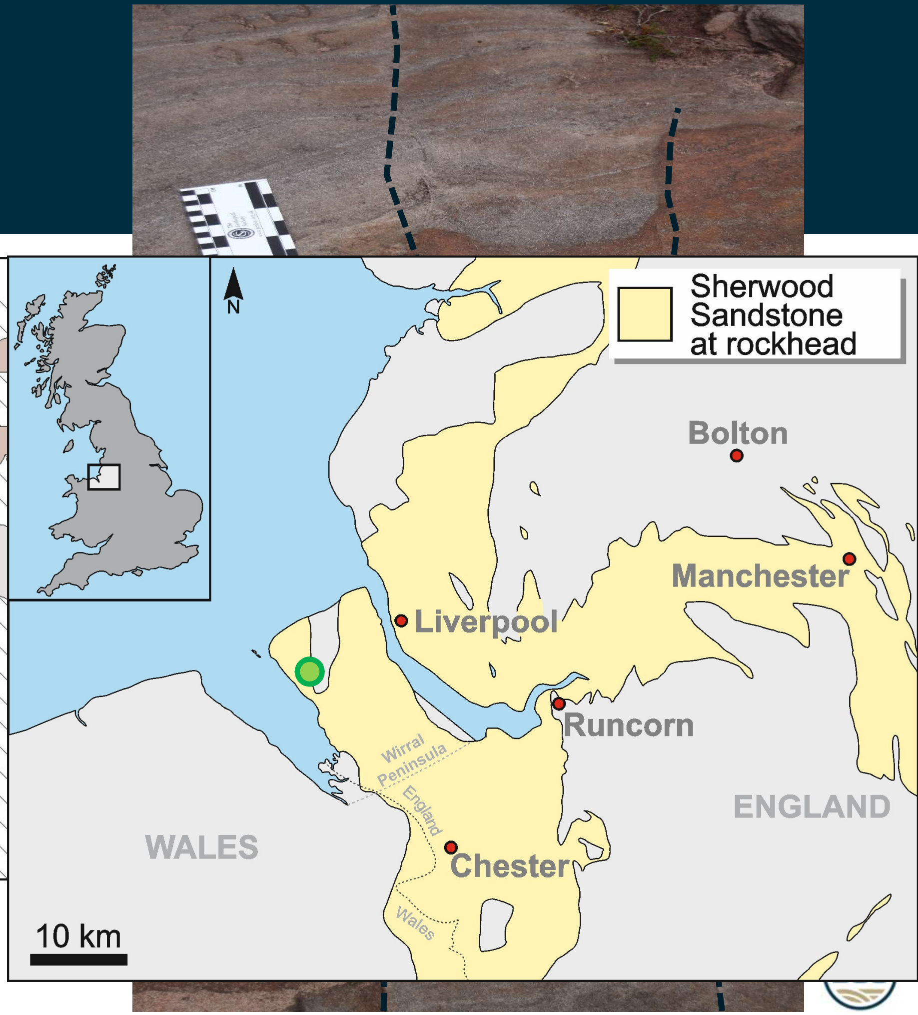
- Designated principal aquifer by the Environment Agency
- At rockhead/very shallow across most of the Midlands
- Oil & Gas producing

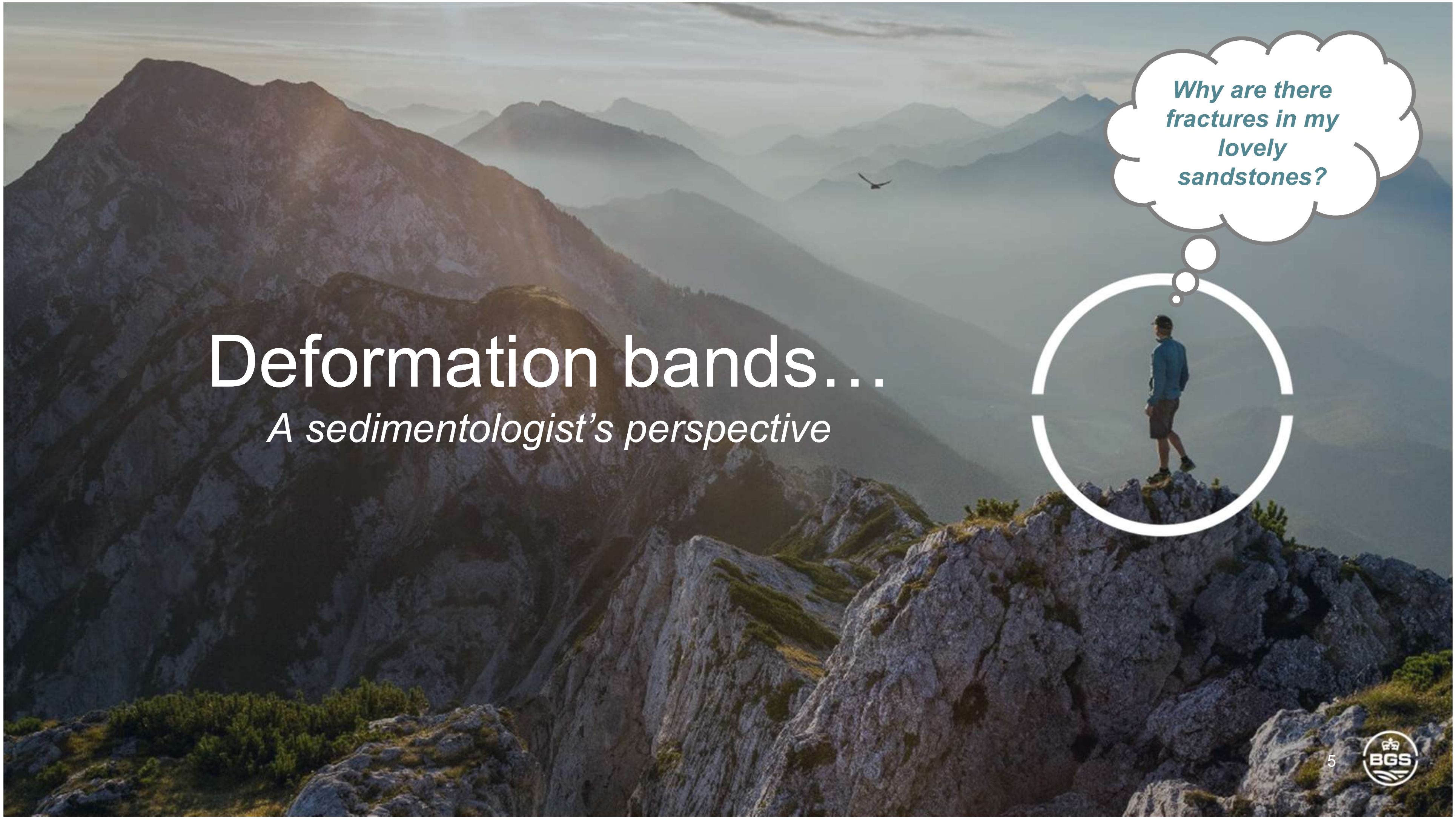


INTRO

Sherwood Sandstone

Thurstaston Common, Wirral

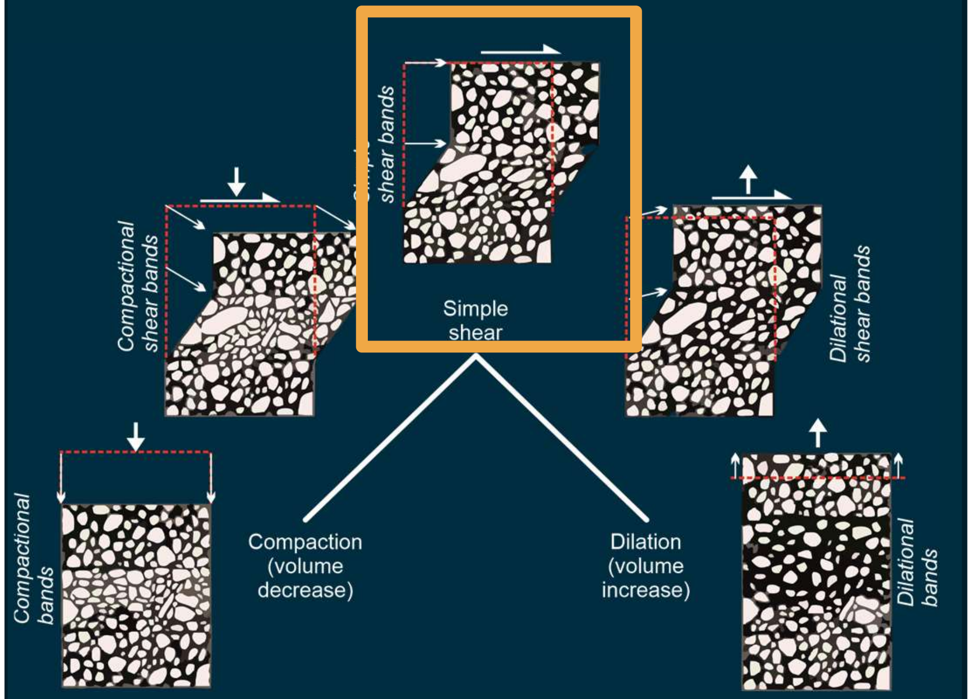



Why are there fractures in my lovely sandstones?
Deformation bands…
A sedimentologist's perspective
5
BGS


A
1 cm
B
1 cm
C

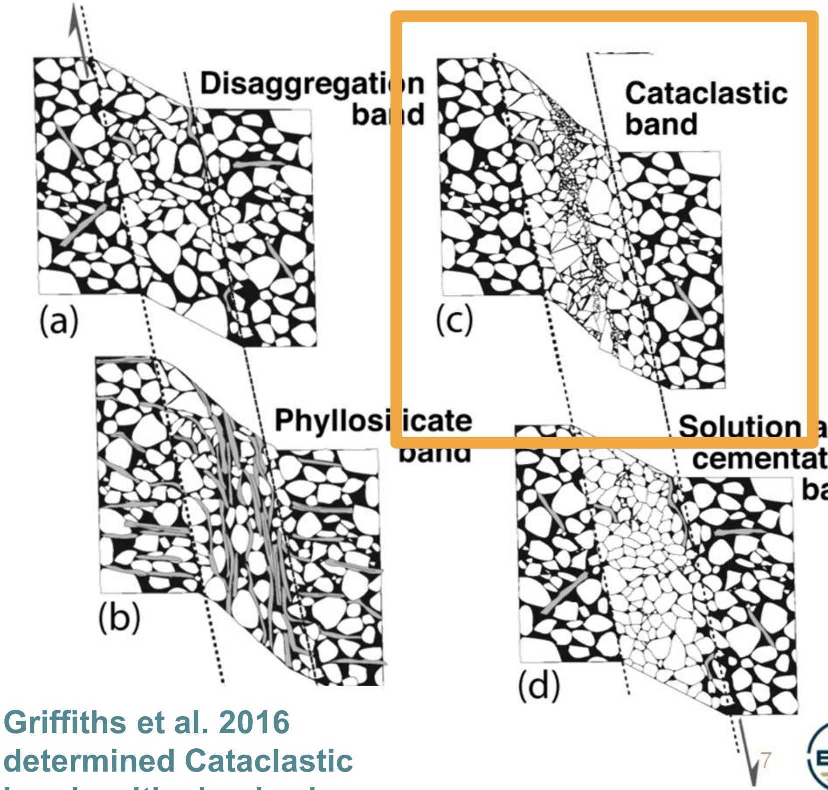
Introduction Deformation Bands

KINEMATICALLY



Figures from Fossen *et al*. 2007

DEFORMATION MECHANISM



Griffiths et al. 2016 determined Cataclastic bands with simple shear

RATIONALE

Deformation Bands

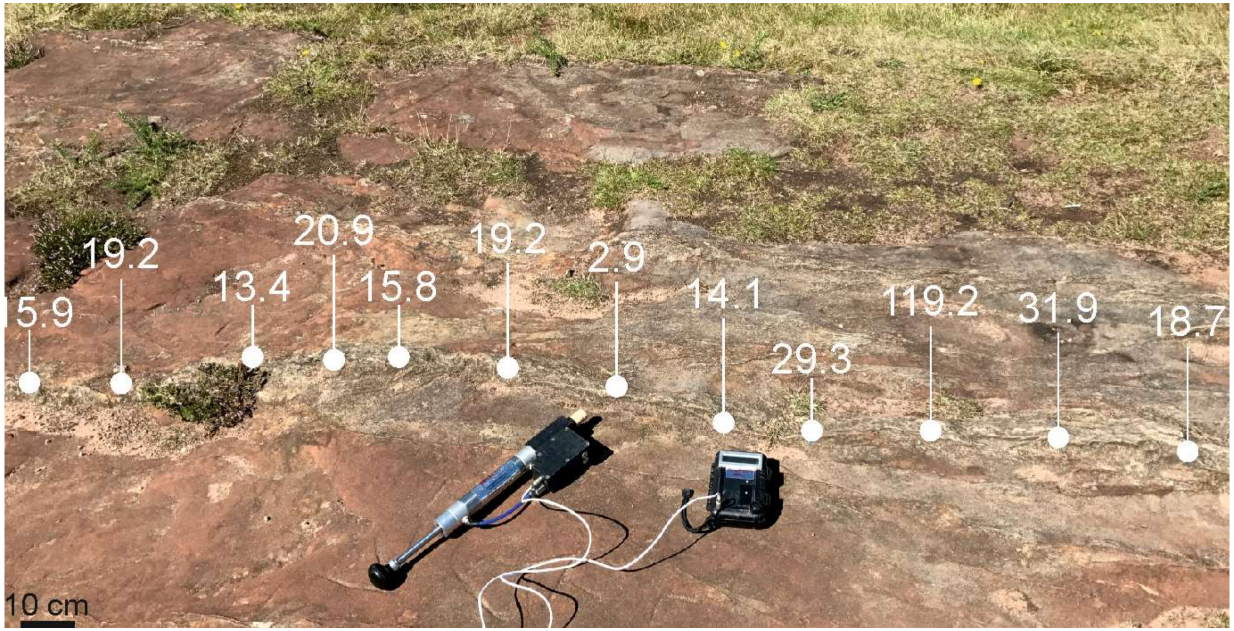
- Sub-seismic - often occur in fault damage zones
- Very commonly permeability reducing features – with variation along bands
- Complex to simple geometries

- 27 prominent papers on deformation bands in the field outcrop
- Of these only two (~7%) aren't in aeolian successions*

Is this a selection bias?

Reference	Host sucession	Depositional system
Antonellini et al. (1994)	Chinle Formation (Utah, USA) Wingate Sandstone Formation (Utah, USA) Kayenta Formations (Utah, USA)	Mixed fluvial, aeolian, lacustrine & palustrine Aeolian dunefield Aeolian dunefield
Aydin (1978)	Entrada Sandstone Formation (Utah, USA) Navajo Sandstone Formation (Utah, USA)	Aeolian; sabkha & dunefield Aeolian sand dune system
Cashman & Cashman (2000)	Savage Creek Marine Terrace (California, USA)	Variable littoral to shallow marine
Draganits et al. (2005)	Muth Formation (NW Himalayas)	Wave-dominated barrier island system
Edwards et al. (1993)	Hopeman Sandstone Formation (Moray Firth, UK) Burghead Sandstone Formation (Moray Firth, UK)	Aeolian dunefield (with minor fluvial incursions) Fluvial
Fossen (2010)	Entrada Sandstone Formation (Utah, USA) Navajo Sandstone Formation (Utah, USA)	Aeolian; sabkha & dunefield Aeolian dunefield
Fossen & Bale (2007)	Entrada Sandstone Formation (Utah, USA) Navajo Sandstone Formation (Utah, USA) Gullfaks Field [Brent Group, Cook Formation & Statfjord Formation] (North Sea)	Aeolian; sabkha & dunefield Aeolian dunefield Deltaic, shallow-marine & fluvial (Brent Group), Shallow-marine (Cook Formation), deltaplain (Statfjord Formation)
Fowles & Burley (1994)	Penrith Sandstone Formation (Vale of Eden & Dumfries, UK)	Aeolian dunefield with fringing alluvial fans
Griffiths et al. (2016)	Sherwood Sandstone (Thurstaston, UK)	Mixed aeolian-fluviall (semi-arid)
Hodson et al. (2016)	Moab Tongue Member [Curtis Formation] (Utah, USA)	Aeolian dunefield
Johansen & Fossen (2008)	Carmel Formation (Utah, USA) Entrada Sandstone Formation (Utah, USA)	Aeolian; sabkha & dunefield Shallow-marine to littoral
Johansen et al. (2005)	Moab Member [Entrada Sandstone Formation] (Utah, USA)	Aeolian; sabkha & dunefield
Main et al. (2000)	Hopeman Sandstone (Lossiemouth, Scotland)	Aeolian system (possibly wet)*
Mollema & Antonellini (1996)	Navajo Sandstone Formation (Utah, USA)	Aeolian dunefield
Parnell et al. (2004)	Jeanne D'Arc Formation (Newfoundland, Canada) Upper Old Red Sandstone (Caithness, Scotland) Elgol Sandstone Formation (Skye, Scotland)	Fluvial braidplain deposits Aeolian dunefield Deltaic
Parry et al. (2004)	Navajo Sandstone Formation (Utah, USA)	Aeolian dunefield
Raduha et al. (2016)	Entrada Sandstone Formation (Utah, USA)	Aeolian; sabkha & dunefield
Rotevatn et al. (2013)	Quartier de l'Etang quarry (Provence, France)	Deltaic and beach systems
Schueller et al. (2013)	Nubian Sandstone (Sinai, Egypt) Entrada Sandstone Formation (Utah, USA) Navajo Sandstone Formation (Utah, USA)	Fluvial Aeolian; sabkha & dunefield Aeolian dunefield
Schueller et al. (2013)	Aztec Sandstone (Nevada, USA)	Aeolian dunefield
Skurtveit et al. (2015)	Navajo Sandstone Formation (Utah, USA) Page Formations (Utah, USA)	Aeolian dunefield Aeolian dunefield
Sternlof et al.(2006)	Aztec Sandstone (Nevada, USA)	Aeolian dunefield
Taylor & Pollard (2000)	Aztec Sandstone (Nevada, USA)	Aeolian dunefield
Tindall & Davis (2003)	Navajo Sandstone Formation (Utah, USA)	Aeolian dunefield
Torabi & Fossen (2009)	Brent Group (Huldra Field, North Sea) Entrada Sandstone Formation (Utah, USA) Nubian Sandstone (Sinai, Egypt)	Deltaic, shallow-marine & fluvial Aeolian; sabkha & dunefield Fluvial
Torabi et al. (2008)	Navajo Sandstone Formation (Utah, USA) Entrada Sandstone Formation (Utah, USA) Nubian Sandstone (Sinai, Egypt)	Aeolian dunefield Aeolian; sabkha & dunefield Fluvial
Zuluaga et al. (2014)	Navajo Sandstone Formation (Utah, USA)	Aeolian dunefield

In-situ testing



- Non-destructive testing using a mini-permeameter
- Results likely overexaggerated due to surface position & weathering….
- ..however, results are inline with other published works

All 91 permeability readings on deformation bands were less than host rock
~50% were ≥3 orders of magnitude less permeable than the host rock

Factors known linked to the formation of deformation:

- grain size
- grain sorting
- grain/clast composition (mineralogy)
- grain/clast roundness
- porosity

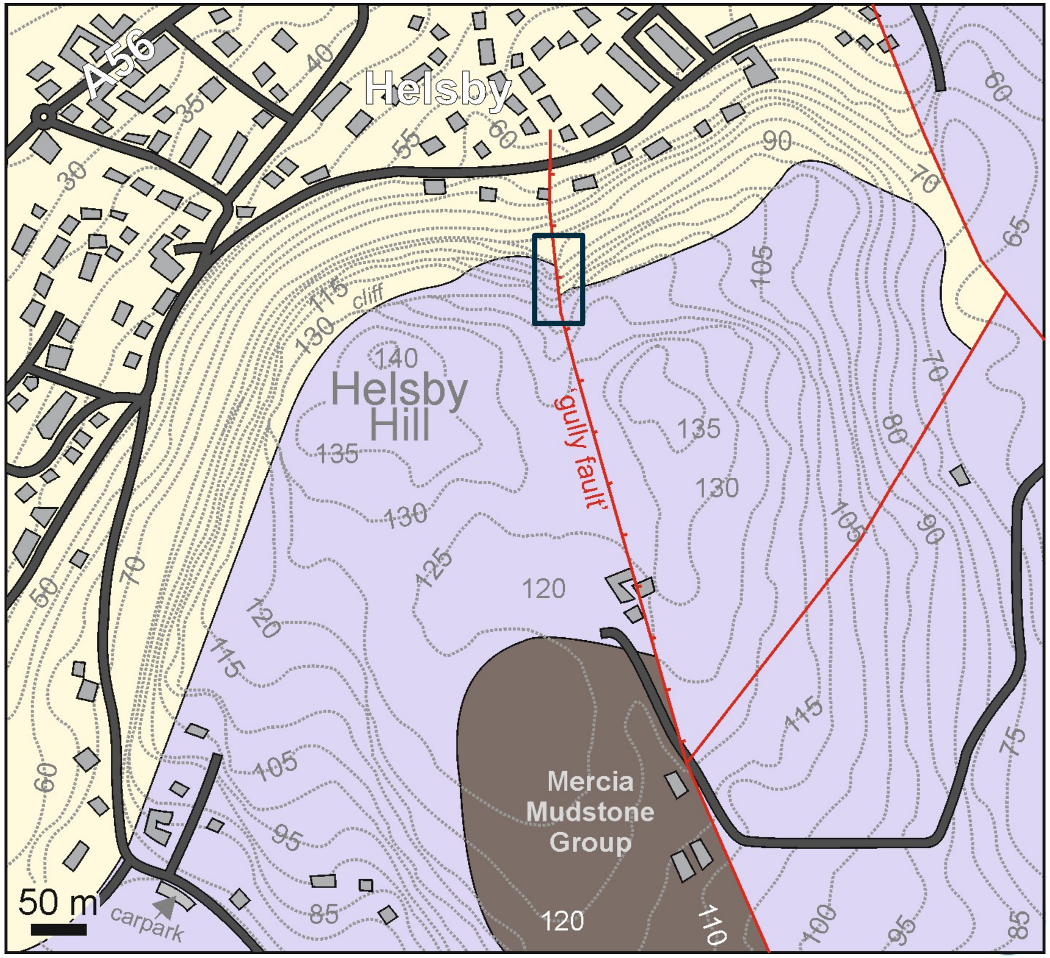
Primary Sedimentological

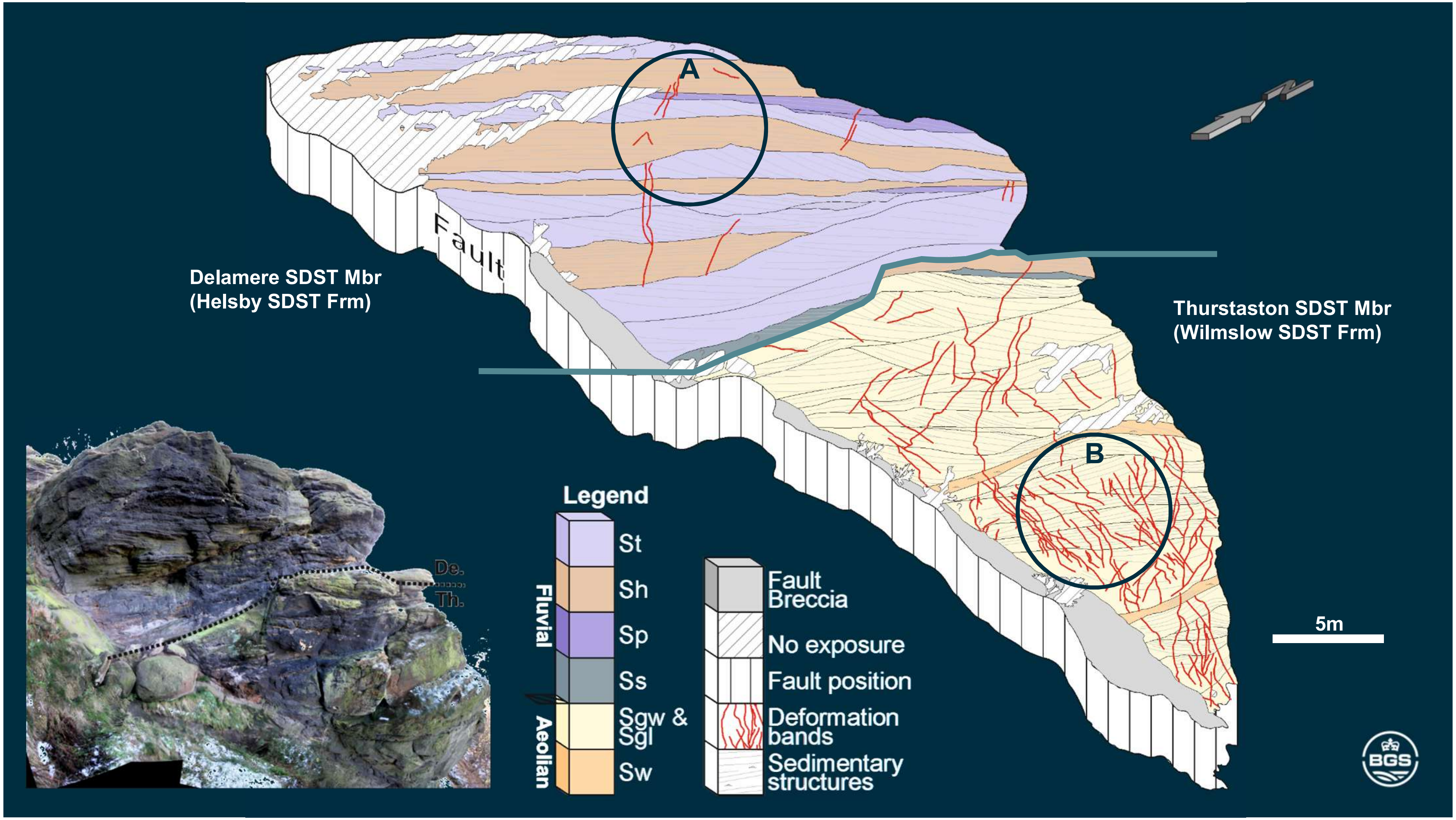
- ~~burial depth~~
- ~~lithification~~
- ~~amount and duration of stress~~
- ~~pressure exerted by porefluids during deformation~~

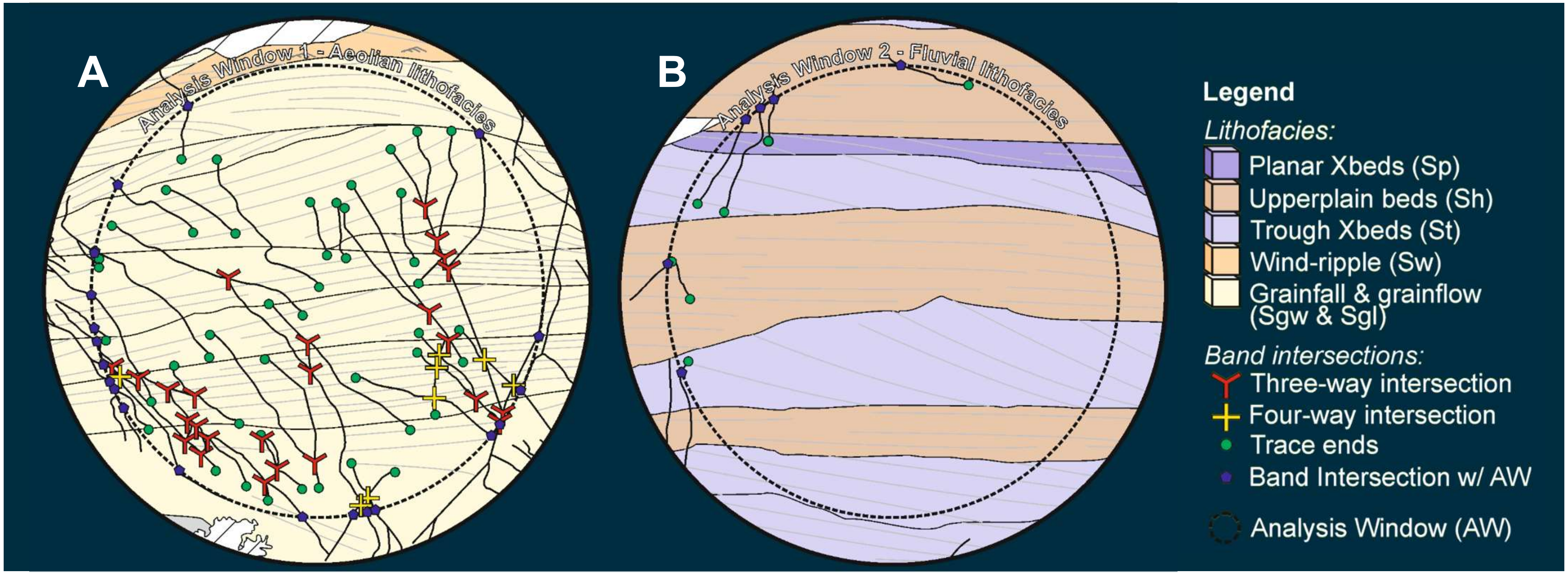
Secondary *'Stuff'*

CASE STUDY

Helsby Hill



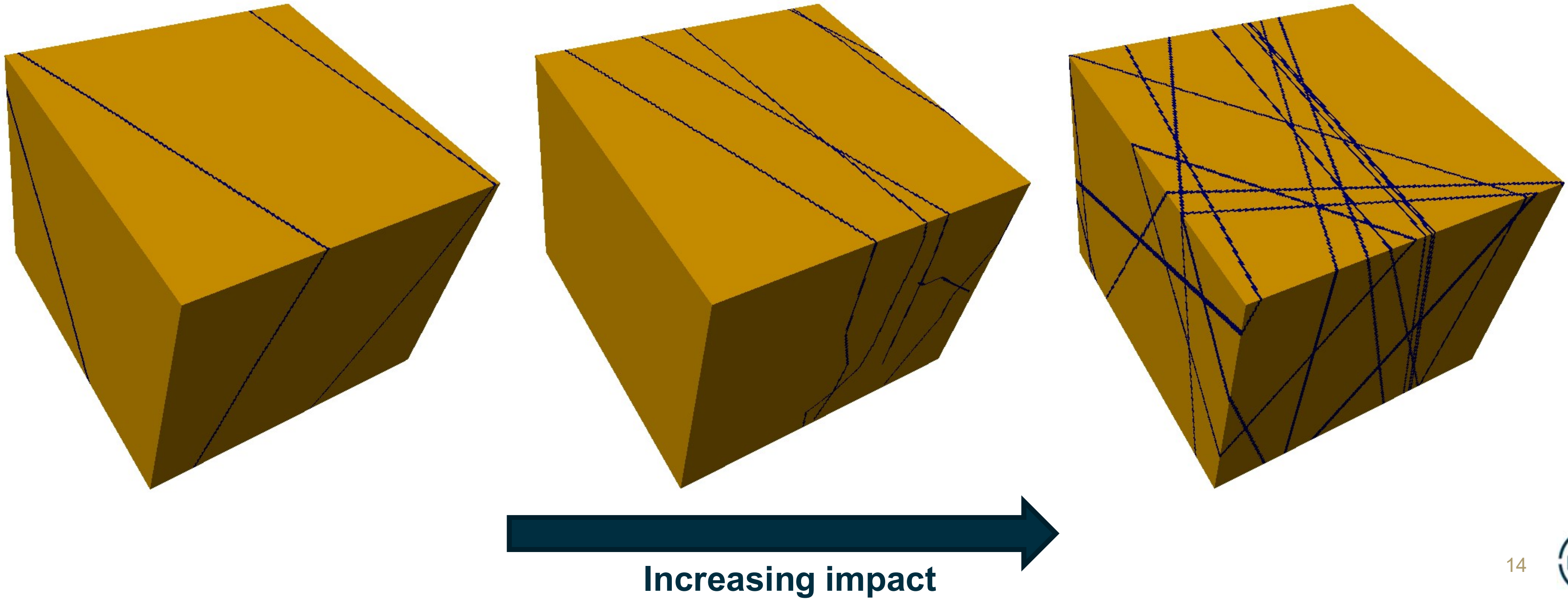

A
B
Fault
Delamere SDST Mbr
(Helsby SDST Frm)
Thurstaston SDST Mbr
(Wilmslow SDST Frm)
De.
Th.
Legend
Fluvial
Aeolian
St
Sh
Sp
Ss
Sgw & Sgl
Sw
Fault Breccia
No exposure
Fault position
Deformation bands
Sedimentary structures
5m
BGS



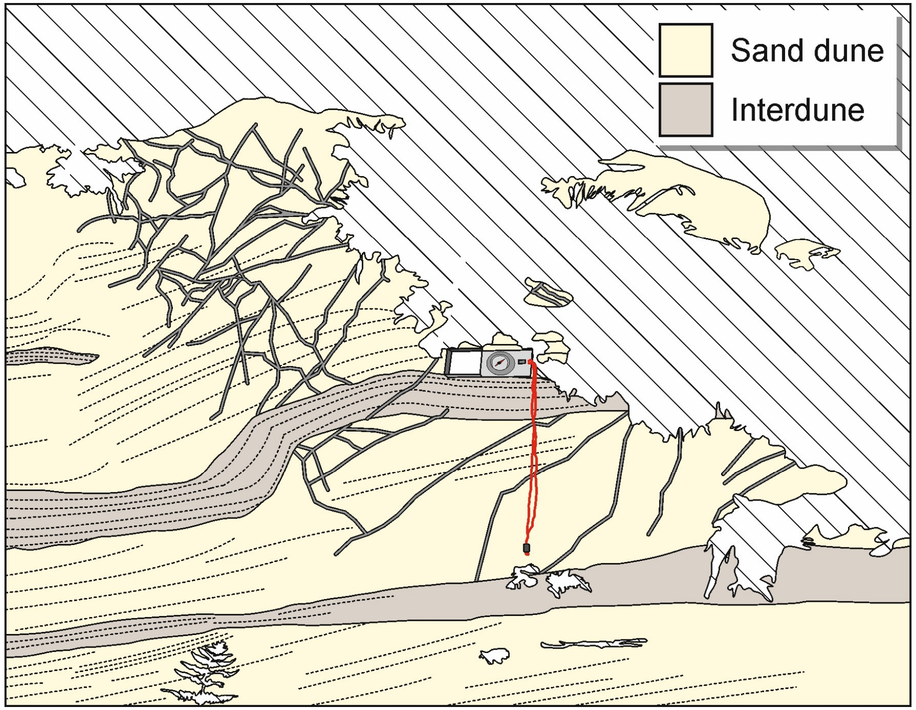
	Analysis Window 1 - Aeolian	Analysis Window 2 - Fluvial
Constituent lithofacies	Sgw & Sgl	Sp, Sh & St
Deformation band frequency	46	7
Deformation band Σ length in AW	51.28 m (168.24 ft)	3.62 m (11.88 ft)
Mean deformation band length	1.11 m (3.36 ft)	0.52 m (1.7 ft)
Deformation band intensity	2.61 m/m^2 (0.8 ft/ft^2)	0.18 m/m^2 (0.06 ft/ft^2)
Deformation band trace ends	70	7
Density estimator	1.79	0.2

Impact of deformation bands

Not just the frequency of deformation bands that's important



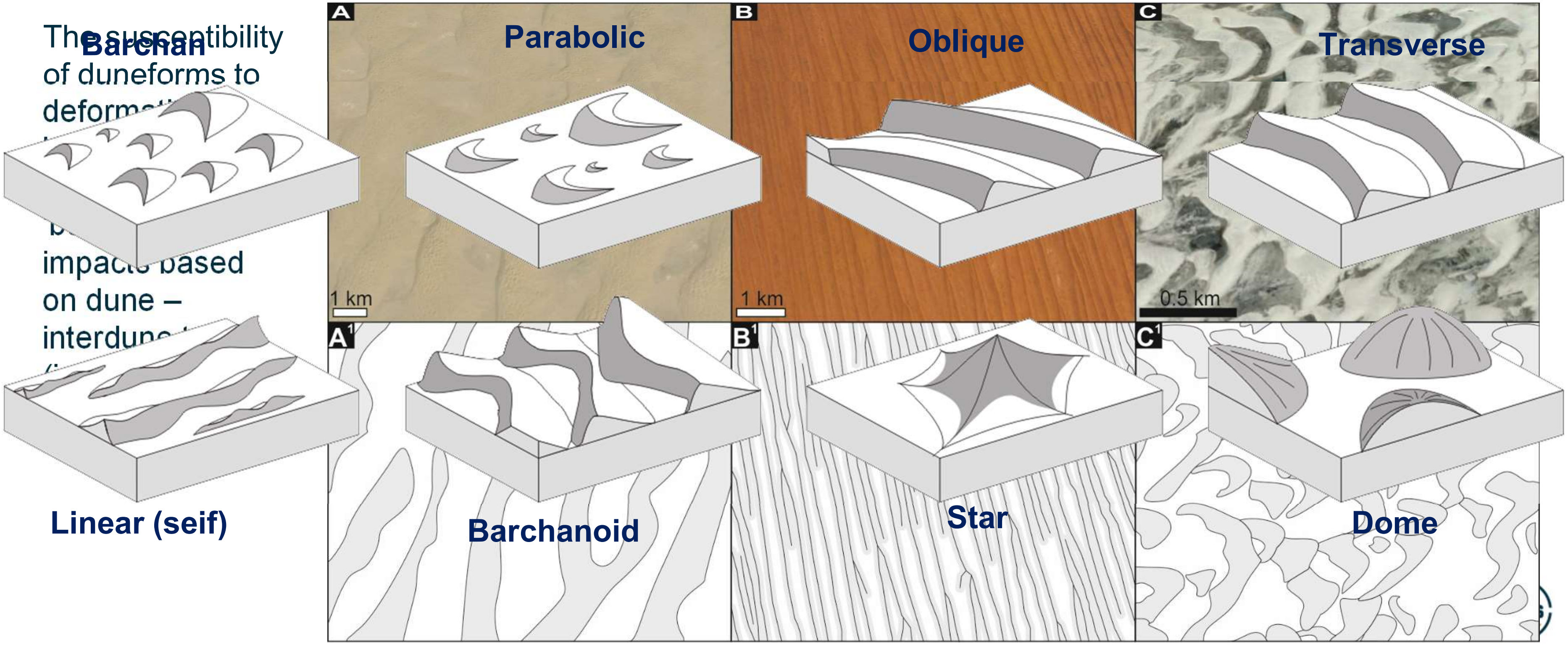
Dune vs. Interdune



AEOLIAN LITHOFACIES

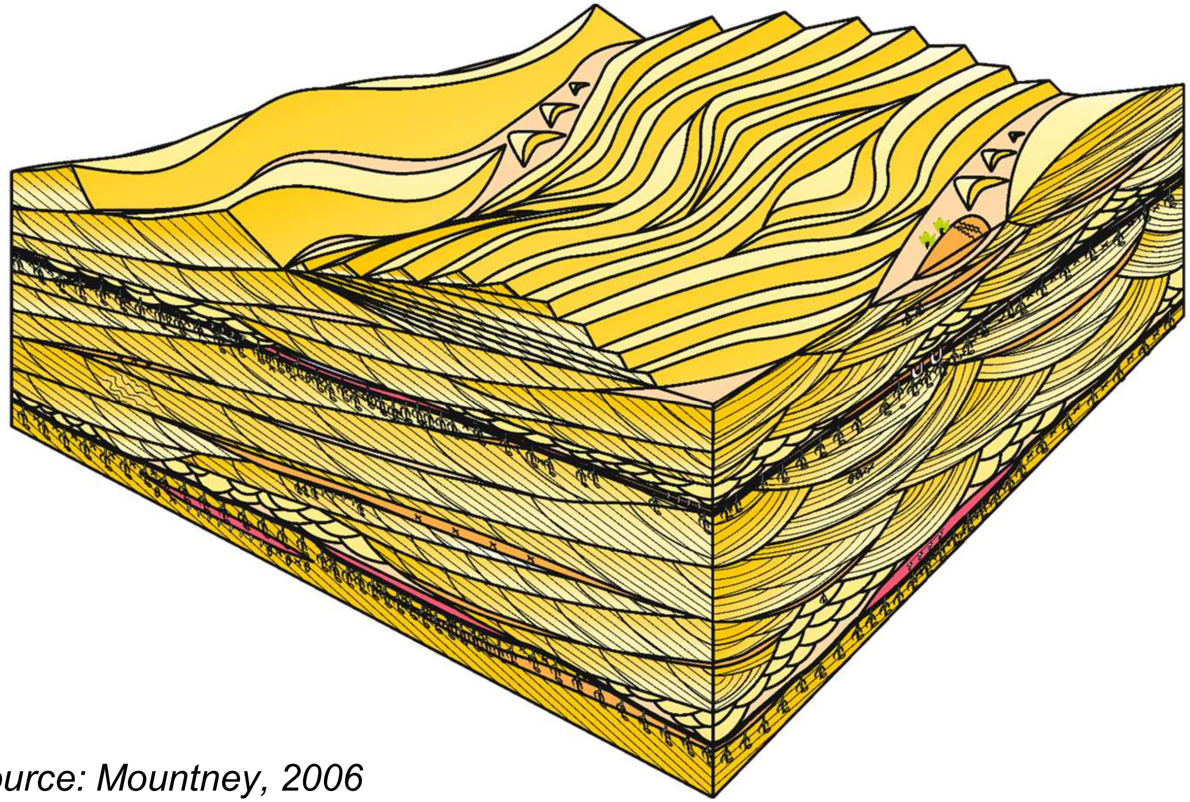
Dune vs. Interdune

The susceptibility
of duneforms to
deform
impacts based
on dune –
interdun



AEOLIAN LITHOFACIES

Dune vs. Interdune



Source: Mountney, 2006

- Bedforms & interdunes occur at a variety of scales
- Variation occurs spatially & temporally
- Interdune composition can also be highly variably

AEOLIAN LITHOFACIES

Dune vs. Interdune

- Aeolian lithofacies hosted >90% bands
- Sedimentology of aeolian systems is likely important to deformation band **formation** & **impacts**
- Deformation bands >12 mm thick were on average 1 to 2 orders of magnitude longer than those <12 mm
- Observed transition to 'open fractures' when passing between aeolian to fluvial lithofacies types
- The presence of deformation bands may be beneficial

Wakefield OJW., Hough E., Hennissen JAI., Thompson J., Catherine C., Parkes D. (*in press*) Lithofacies control on the formation of deformation bands: an example from the Sherwood Sandstone Group (Induan–Anisian, Lower Triassic) in western England. **AAPG Bulletin**, DOI:10.1306/02032218027.

FOOD FOR THOUGHT….

Human vs. Geological timescale