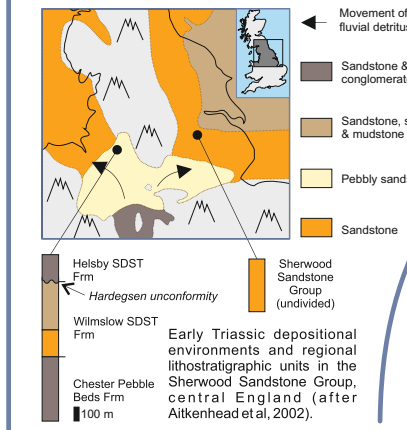
British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

Impacts of Regional Allogenic Forcing on a Single Depositional System: Example From the Sherwood Sandstone Group, UK

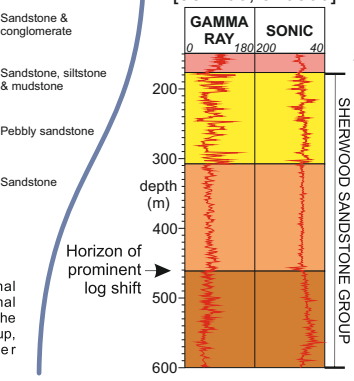
Oliver Wakefield[1], Ed Hough[1], Joanna Thompson[1], Jan Hennissen[1], Catherine Cripps[1]
1 - British Geological Survey, Keyworth, Nottingam, NG12 5GG, UK.

Introduction

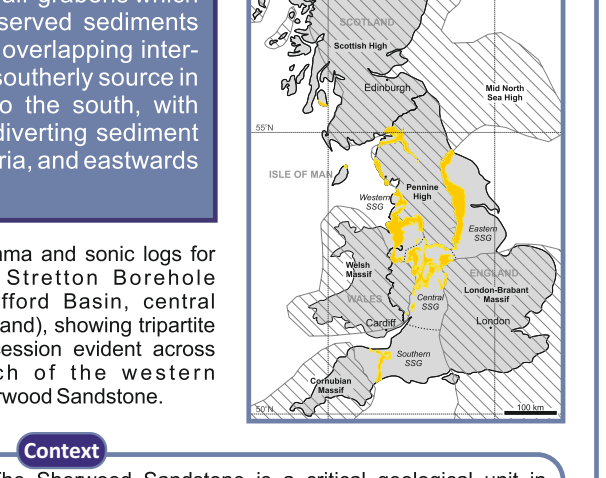
The Sherwood Sandstone Group is late Permian to Mid-Triassic (Ladinian) in age. The Early Triassic in Britain was characterised by rifting and extension related to the break-up of Pangea, with thick accumulations of arenaceous sediments developing in a series of actively subsiding linked half-grabens which fringed the local palaeo-high of the Pennines. Locally, preserved sediments reach over 1000 m in some depocentres, with younger units overlapping inter-basinal highs. Regional-scale depositional models suggest a southerly source in the Variscan foldbelt some few hundreds of kilometres to the south, with northwards draining rivers bifurcated by the Pennine High, diverting sediment westwards towards the Cheshire Basin, Lancashire and Cumbria, and eastwards to the Needwood Bain and the East-Midlands Shelf.



Early Triassic depositional environments and regional lithostratigraphic units in the Sherwood Sandstone Group, central England (after Aitkenhead et al, 2002).



Gamma and sonic logs for the Stretton Borehole (Stafford Basin, central England), showing tripartite succession evident across much of the western Sherwood Sandstone.



Context

The Sherwood Sandstone is a critical geological unit in Britain. It is the 2nd most important groundwater aquifer in England, and is a reservoir to hydrocarbon fields both onshore and offshore. Its close spatial relationship with the Coal Measures and proximity to major urban areas including Birmingham and Manchester has led to localised contamination. As such, an understanding of petrophysical properties of the group is relevant to many disciplines.

Lithostratigraphy Challenge

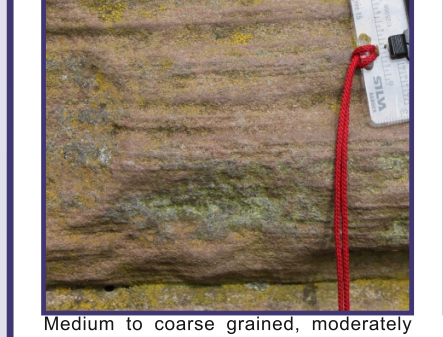
The classification of the Sherwood Sandstone is largely based on lithostratigraphy, due to an absence of age-diagnostic fossils. Historically, this succession has been split by using gross differences in composition and character (e.g. pebble content and degree of cementation). However, whilst this approach is successful in areas of lithological variability and good outcrop exposure, *and can to some extent be confirmed by borehole cores and logs*, it is difficult to apply where variations are more subtle, or outcrop and cores are not available.

The Sherwood Sandstone Group exhibits considerable facies variation to the west of the Pennines (Cheshire and East Irish Sea basins). In many areas, the group can be divided into a tripartite succession comprising a lower fluviatile unit, a middle unit that is predominantly eolian (becoming more so in distal areas), and an upper unit of mixed eolian and fluvial facies which have a complex spatial relationship. In this succession, major erosive bounding surfaces may represent significant time-gaps. Whilst this subdivision can be made across much of central and north-west England, correlations in the north-east (East Midlands Shelf and Cleveland Basin) are difficult to establish and the group remains undivided in the east.

Facies

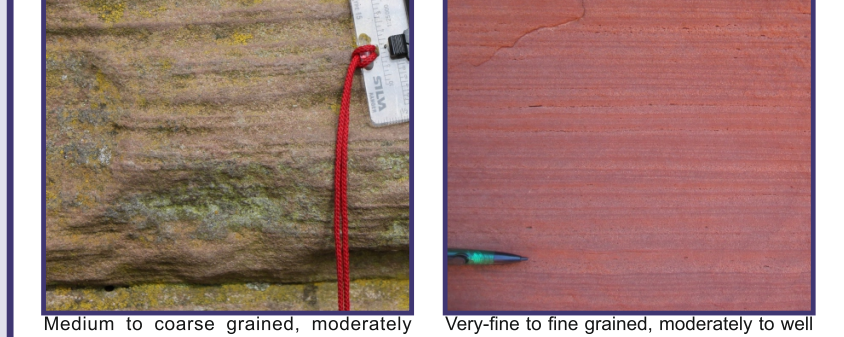
Twelve principle lithofacies are identified within the Sherwood Sandstone. Indicative photographs of each of the lithofacies is presented below. An understanding of the types and arrangement of lithofacies is important for a number of applied reasons. Crucially the original depositional processes are also responsible for providing the basic initial properties of the lithified material. As such, this is likely to influence any post-depositional diagenetic process which the material is subjected to (e.g. structural or diagenetic etc). It is therefore imperative that a baseline understanding which may impact the arrangement and character of lithofacies is established in order to further an understanding of reservoir conditions.

Upper plain beds



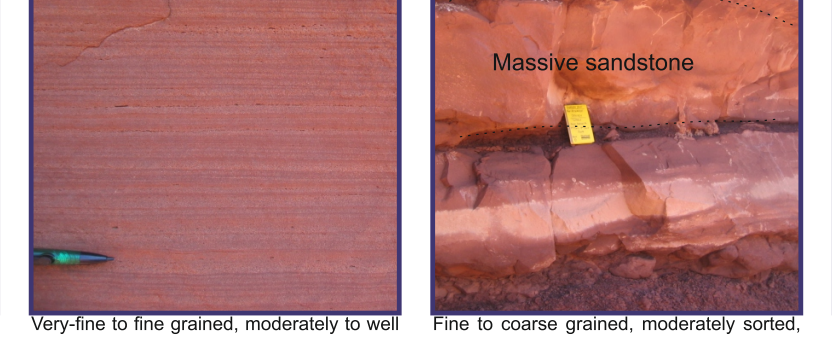
Medium to coarse grained, moderately sorted, sub- to well-rounded, sandstone arranged in horizontal sets, primary current lineation common.

Horz. lam. SDST



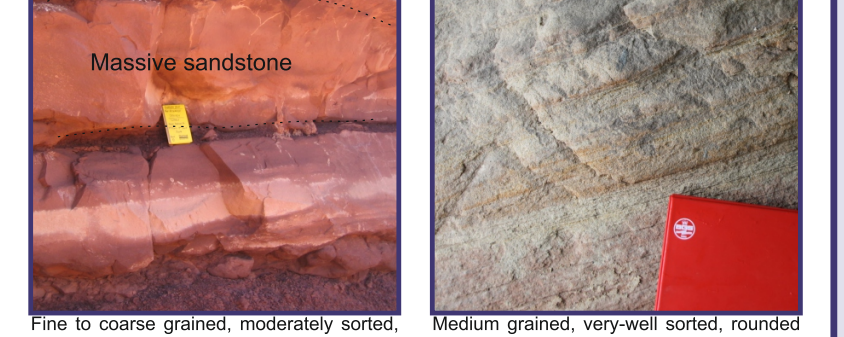
Very-fine to fine grained, moderately to well sorted, moderately rounded, sandstone. Contains fine-scale horizontal lamination.

Massive SDST



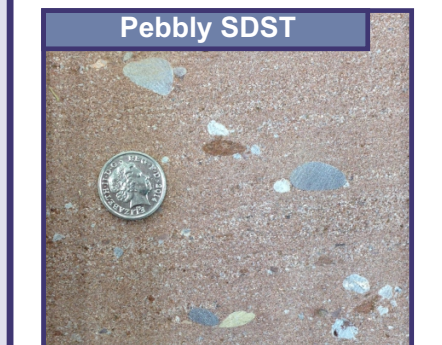
Fine to coarse grained, moderately sorted, sub-angular to sub-rounded, massive (structureless) sandstone.

Grainflow strata



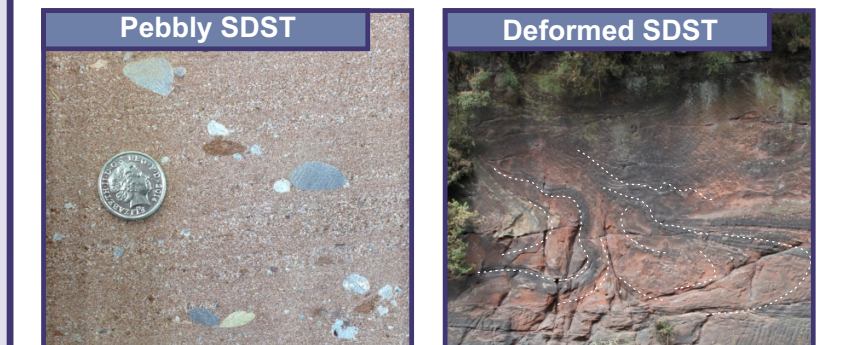
Medium grained, very-well sorted, rounded sandstones. Can show minor inverse grading with each unit. Intimately associated with grainfall strata facies.

Pebbly SDST



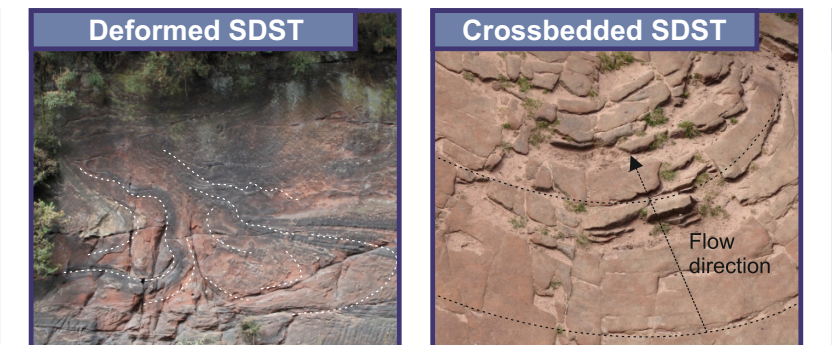
Fine to very coarse grained, poorly sorted, sub-angular to sub-rounded, pebbly sandstone. Can be normally graded to 'massive'.

Deformed SDST



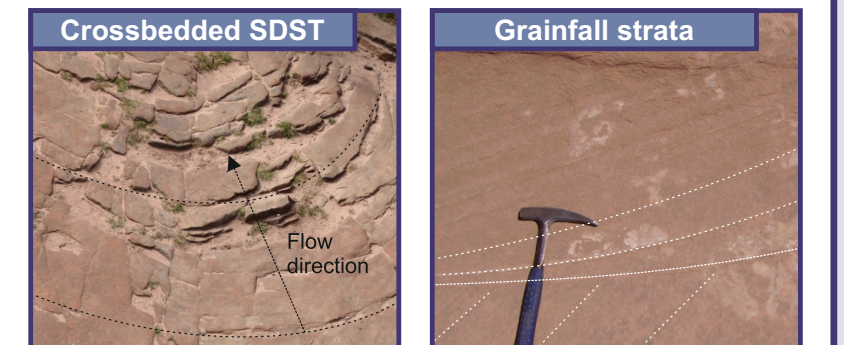
Medium to coarse grained, moderately sorted, sub- to well-rounded, sandstone containing convolute and contorted bedding.

Crossbedded SDST



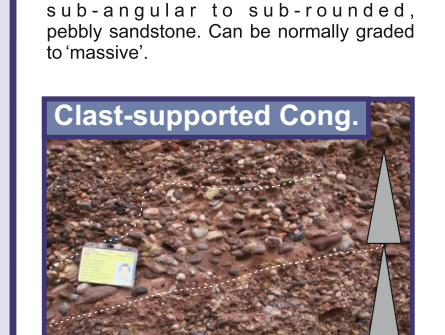
Fine to coarse grained, moderately sorted, sub-angular to sub-rounded, sandstone. Arranged in stacked cosets of planar- and trough-crossbedding.

Grainfall strata



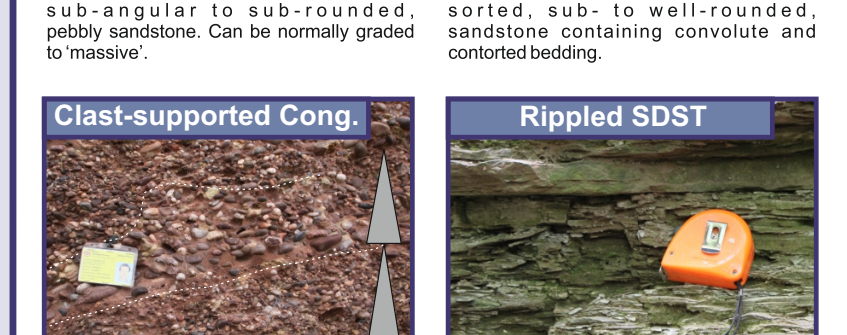
Fine to medium grained, very-well sorted, rounded sandstones. Intimately associated with grainflow strata facies.

Clast-supported Cong.



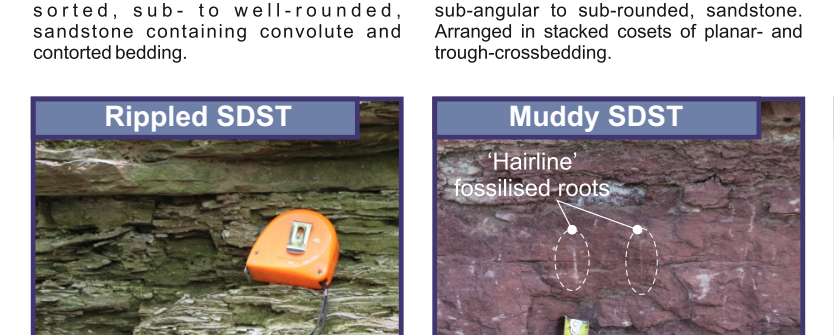
Poorly sorted, sub-rounded to rounded conglomerate. Clast-supported with a fine to medium sandstone matrix. May have normal to inverse grading.

Rippled SDST



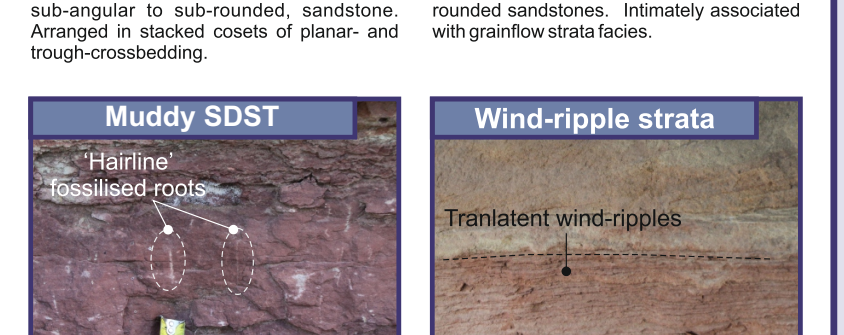
Very fine to medium grained, moderately sorted, sub-angular to sub-rounded sandstone. Arranged in sets of wave or current ripples.

Muddy SDST



Very fine to medium, muddy, poorly sorted, sub-rounded to sub-angular sandstone. Commonly has crude horizontal bedding, may also contain fossilised rootlets.

Wind-ripple strata



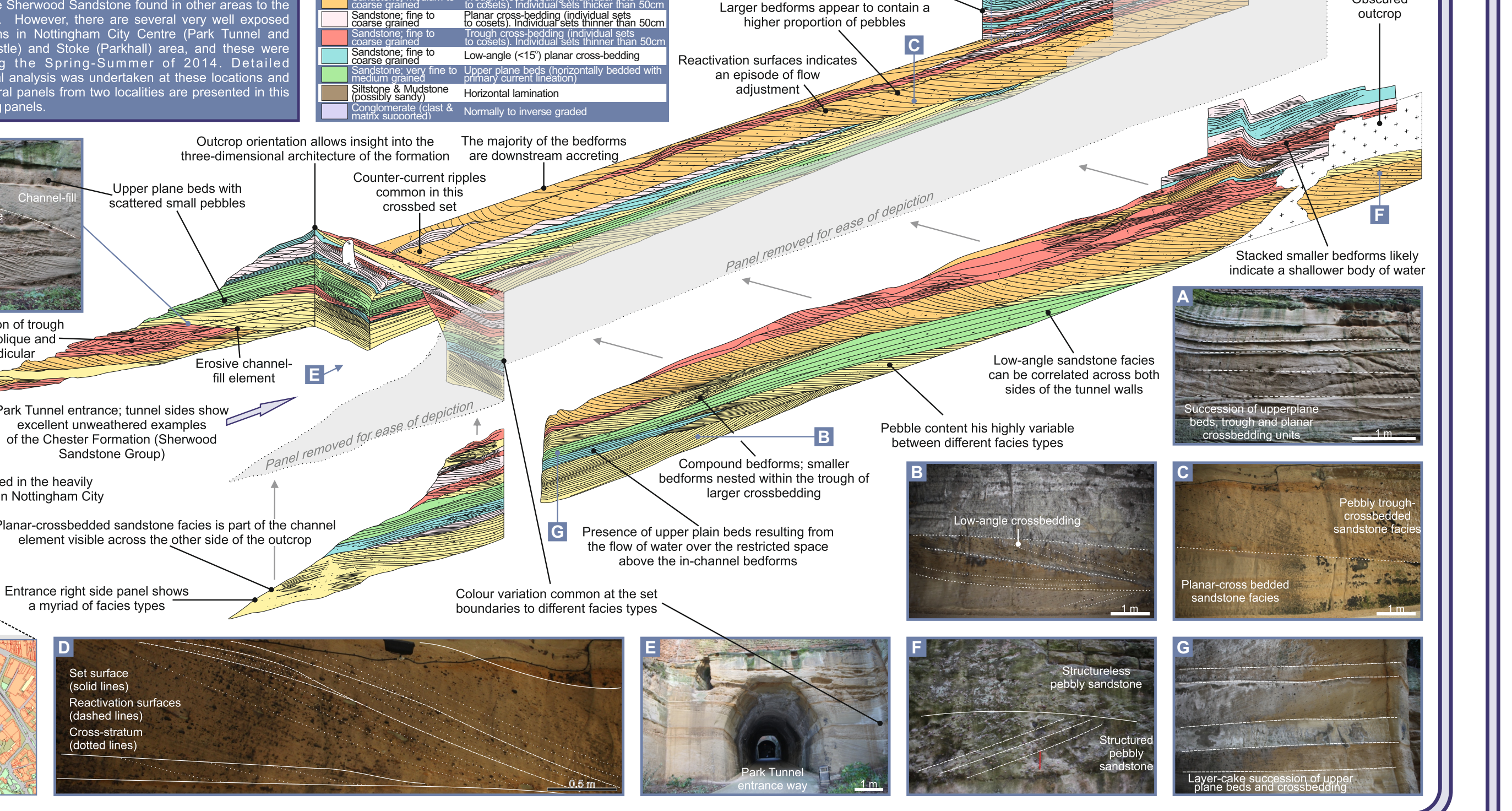
Fine to medium grained, very-well sorted, rounded sandstones. Contains fine ripple lamination or translatent strata.

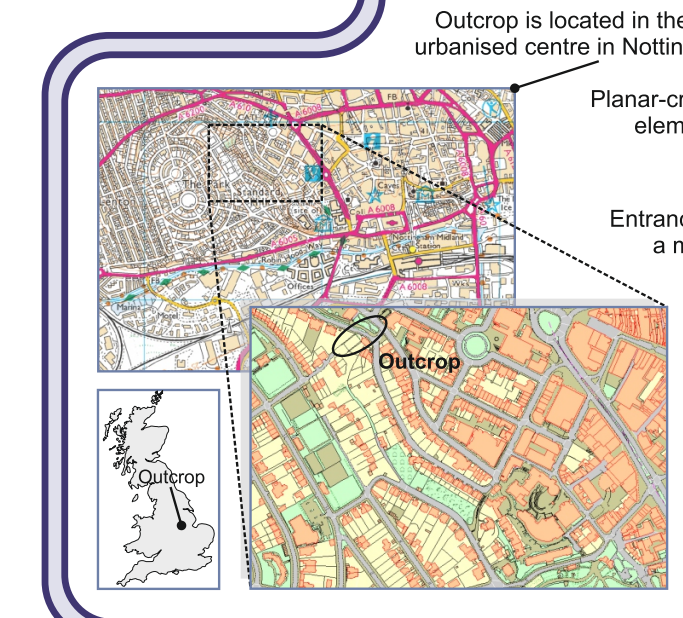
Architectural Panel: Park Tunnel

Architectural Panel Data

The Sherwood Sandstone Group of the Needwood Basin in outcrop has fairly limited exposure between Nottingham and Stoke compared to the Sherwood Sandstone found in other areas to the North and East. However, there are several very well exposed outcrop locations in Nottingham City Centre (Park Tunnel and Nottingham Castle) and Stoke (Parkhall) area, and these were visited during the Spring-Summer of 2014. Detailed sedimentological analysis was undertaken at these locations and three architectural panels from two localities are presented in this and the following panels.

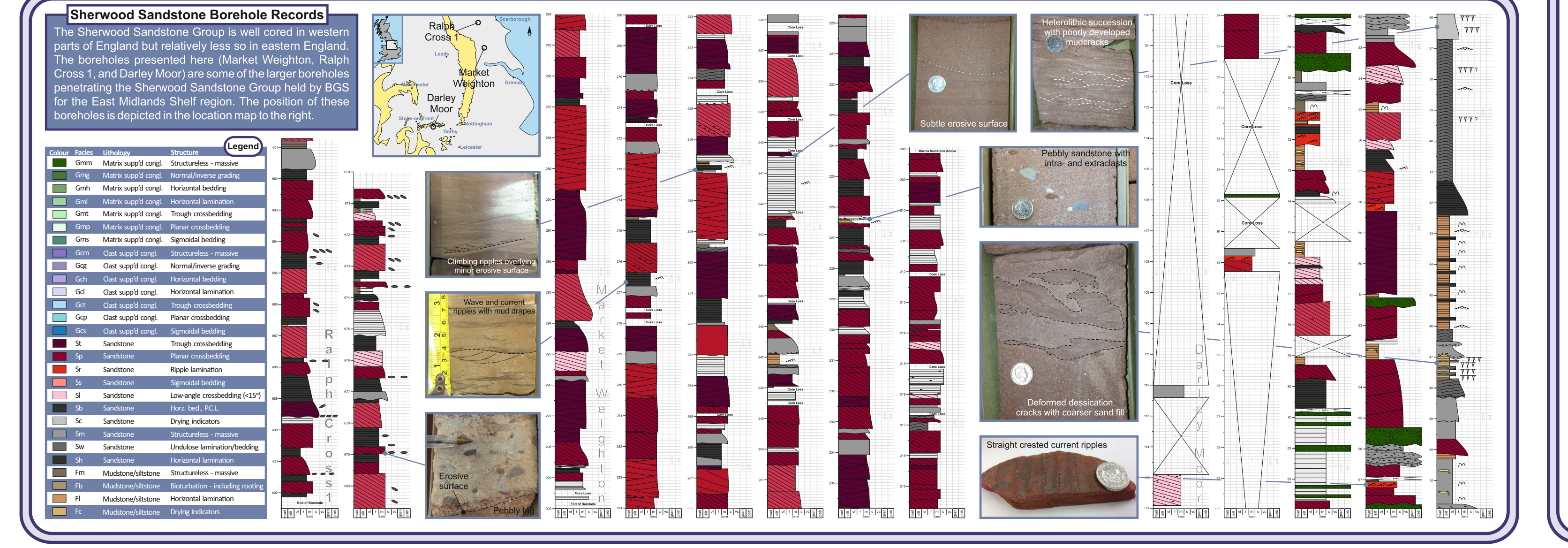
Legend	
Sandstone; medium to very coarse grained	Structureless (massive)
Sandstone; medium to coarse grained	Planar cross-bedding (individual sets to cosets). Individual sets thicker than 50cm
Sandstone; medium to coarse grained	Trough cross-bedding (individual sets to cosets). Individual sets thinner than 50cm
Sandstone; fine to coarse grained	Planar cross-bedding (individual sets to cosets). Individual sets thinner than 50cm
Sandstone; fine to coarse grained	Trough cross-bedding (individual sets to cosets). Individual sets thinner than 50cm
Sandstone; fine to coarse grained	Low-angle (<15°) planar cross-bedding
Sandstone; very fine to medium grained	Upper plane beds (horizontally bedded with primary current lineation)
Siltstone & Mudstone (possibly sandy)	Horizontal lamination
Conglomerate (clast & matrix supported)	Normally to inverse graded


Marked reduction in bedform size in upper portion of the succession
N
A
Larger bedforms appear to contain a higher proportion of pebbles
C
Obscured outcrop
Reactivation surfaces indicates an episode of flow adjustment
Outcrop orientation allows insight into the three-dimensional architecture of the formation
The majority of the bedforms are downstream accreting
Channel-fill
Margins of erosive channel element
0.5 m
Upper plane beds with scattered small pebbles
Counter-current ripples common in this crossbed set
Panel removed for ease of depiction
F
Stacked smaller bedforms likely indicate a shallower body of water
Chaotic succession of trough cross sets cut oblique and near perpendicular
Erosive channel-fill element
E
1 m
Park Tunnel entrance; tunnel sides show excellent unweathered examples of the Chester Formation (Sherwood Sandstone Group)
Panel removed for ease of depiction
Low-angle sandstone facies can be correlated across both sides of the tunnel walls
Succession of upperplane beds, trough and planar crossbedding units
1 m
Pebble content his highly variable between different facies types
B
Compound bedforms; smaller bedforms nested within the trough of larger crossbedding
Outcrop is located in the heavily urbanised centre in Nottingham City
Planar-crossbedded sandstone facies is part of the channel element visible across the other side of the outcrop
G
Presence of upper plain beds resulting from the flow of water over the restricted space above the in-channel bedforms
Low-angle crossbedding
Pebbly trough-crossbedded sandstone facies
Planar-cross bedded sandstone facies
Entrance right side panel shows
Colour variation common at the set



Borehole Records

Sherwood Sandstone B

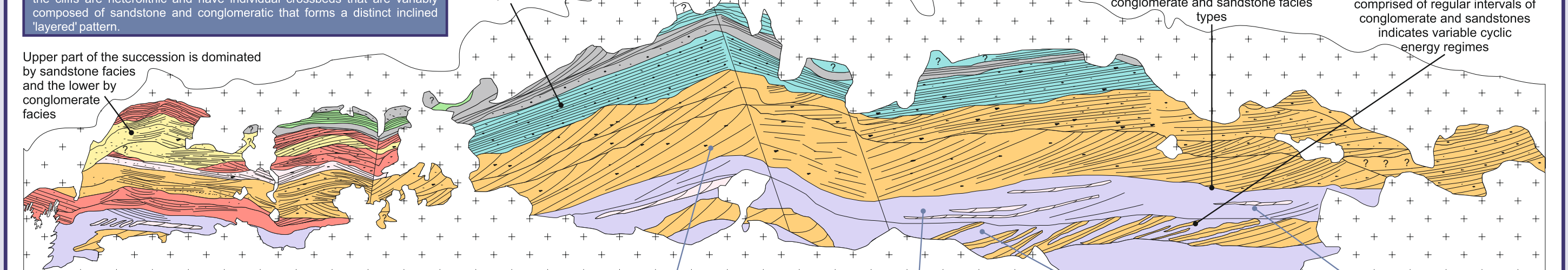


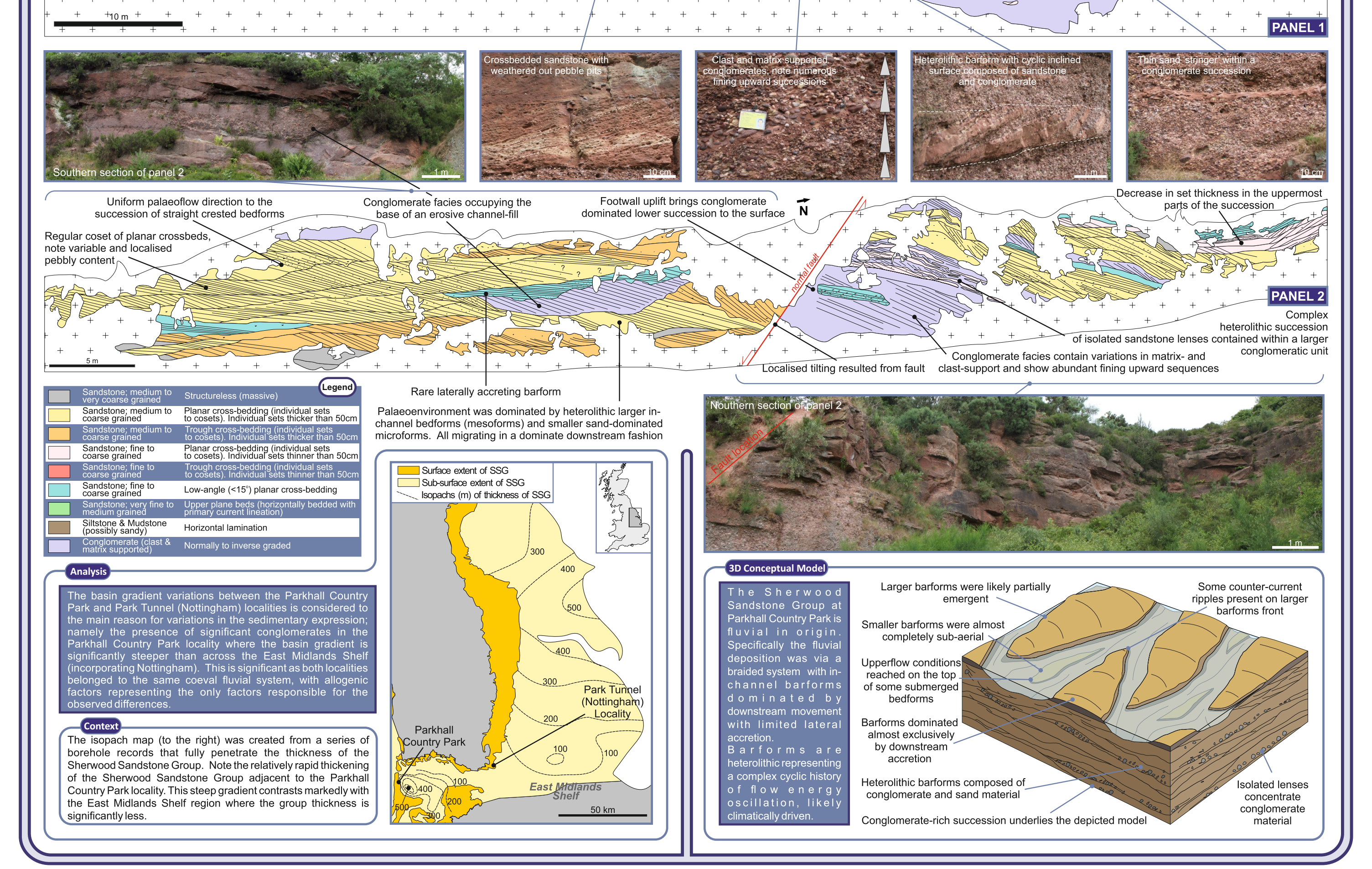
Architectural Panel: Parkhall Country Park

Parkhall Country Park

The outcrop of the Sherwood Sandstone at Parkhall Country Park (Hulme Quarry) has previously been studies by other authors. The outcrop at Park Hall is situated on the site of a now discussed quarry. There are numerous small exposes of the Sherwood Sandstone; the largest and best exposure is a line of cliff sections (up to 10 m high) that together form a 'u' shape that allows a parallel and perpendicular to flow insight. The Sherwood Sandstone in the Cliff Section contains markedly more and larger pebbles. In the exposed cliff approximately 20 – 35% of the section is comprised of conglomerates. These conglomerates are primarily restricted to the lower half of the cliffs, the upper part is dominated by sandstone and in places pebbly sandstone. This marked discrimination in the presence of both sandstone and conglomerates in the sections is indicative of either: i) a strong and abrupt change in flow conditions, or ii) a switch/depletion in the sediment supply away from coarse pebble material. Equally, both criteria could also be responsible collectively. Downstream accreting barforms identified in section are in the lower half of the cliffs are heterolithic and have individual crossbeds that are variably composed of sandstone and conglomerate that forms a distinct inclined 'layered' pattern.

Photograph of panel 1

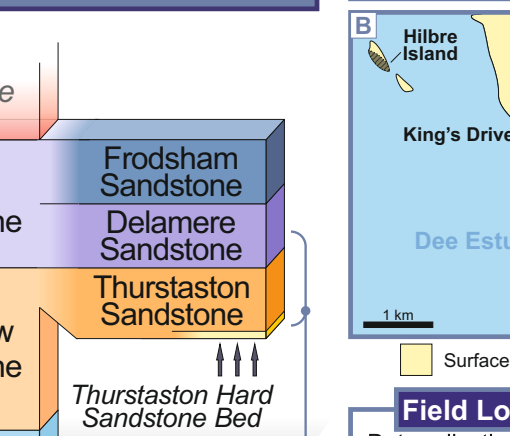

Upper part of the succession is dominated by sandstone facies and the lower by conglomerate facies
Pebbly sandstone
Heterolithic succession comprised of conglomerate and sandstone facies types
Heterolithic barform with crossbeds comprised of regular intervals of conglomerate and sandstones indicates variable cyclic energy regimes
10 m
PANEL 1

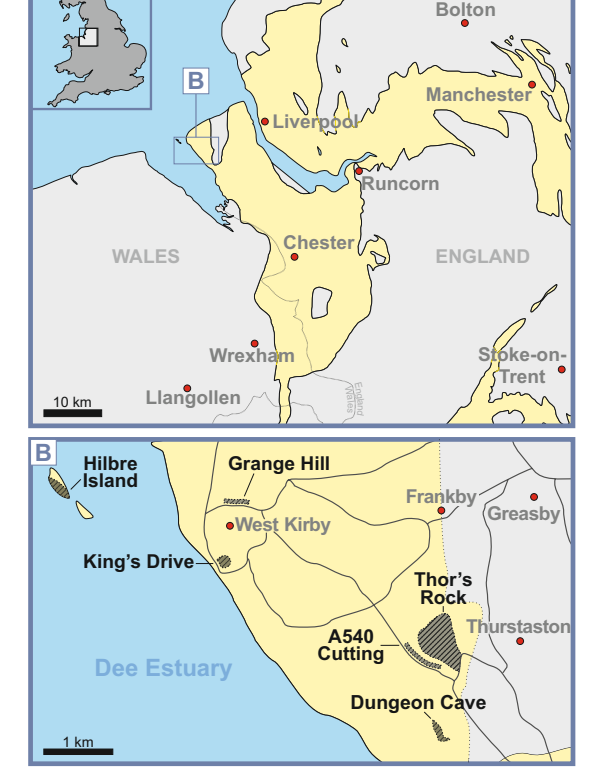

Crossbedded sandstone with weathered out pebble pits
Clast and matrix supported conglomerates, note numerous fining upward successions
Heterolithic barform with cyclic inclined surface composed of sandstone and conglomerate
Thin sand 'stringer' within a conglomerate succession

Deformation Bands

Deformation Bands

The porosity and permeability of a clastic body of rock are controlled by a combination of primary sedimentological processes and any secondary diagenetic and/or structural controls. The resultant porosity and permeability properties are of great importance to a number of industries notably in the extractive sector. This is especially important when reservoir sandbodies are the subject of porosity and permeability reducing processes. Despite the identification of deformation bands from examples around the world and the findings that they can indeed effect reservoir quality there still exist gaps in our knowledge relating to: i) potential effects of facies variation on deformation band formation and, ii) characterising the geometries and different styles of deformation band; this is further compounded by the fact that deformation bands occur at a sub-seismic resolution scale, posing considerable risk.



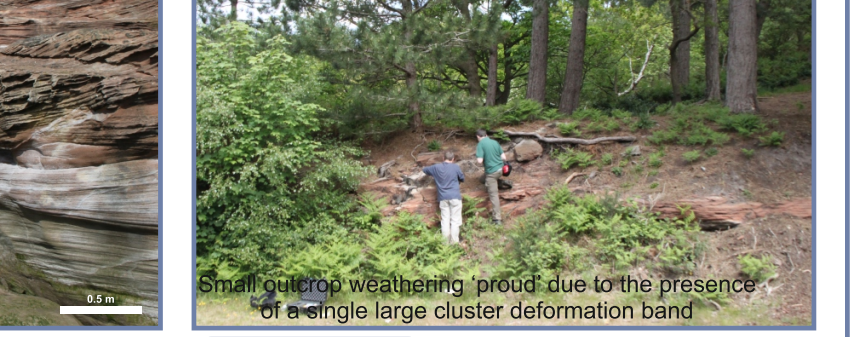


Field Localities

Data collection was undertaken at Localities of the Sherwood Sandstone Group in the Wirral, (western England). The six localities include well-exposed cliff sections all selected based on the presence of deformation bands.

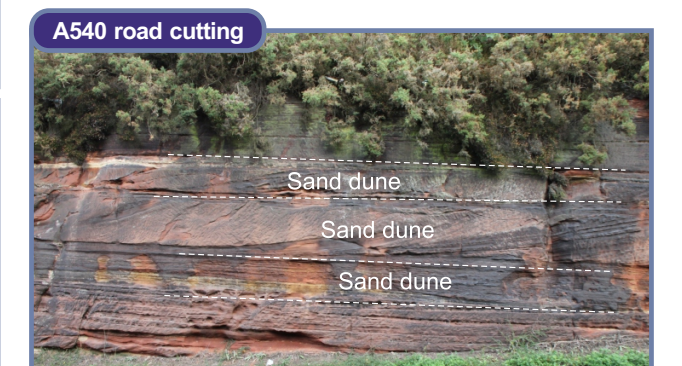
Hilbre Island

King's Drive



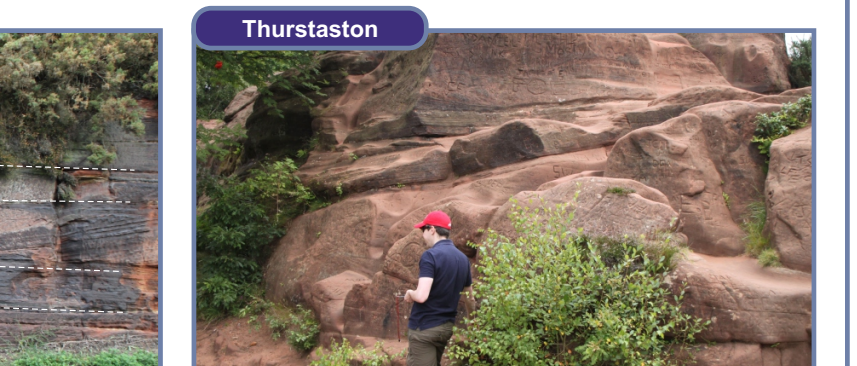
Small outcrop weathering 'proud' due to the presence of a single large cluster deformation band

A540 road cutting



Stacked eolian duneforms

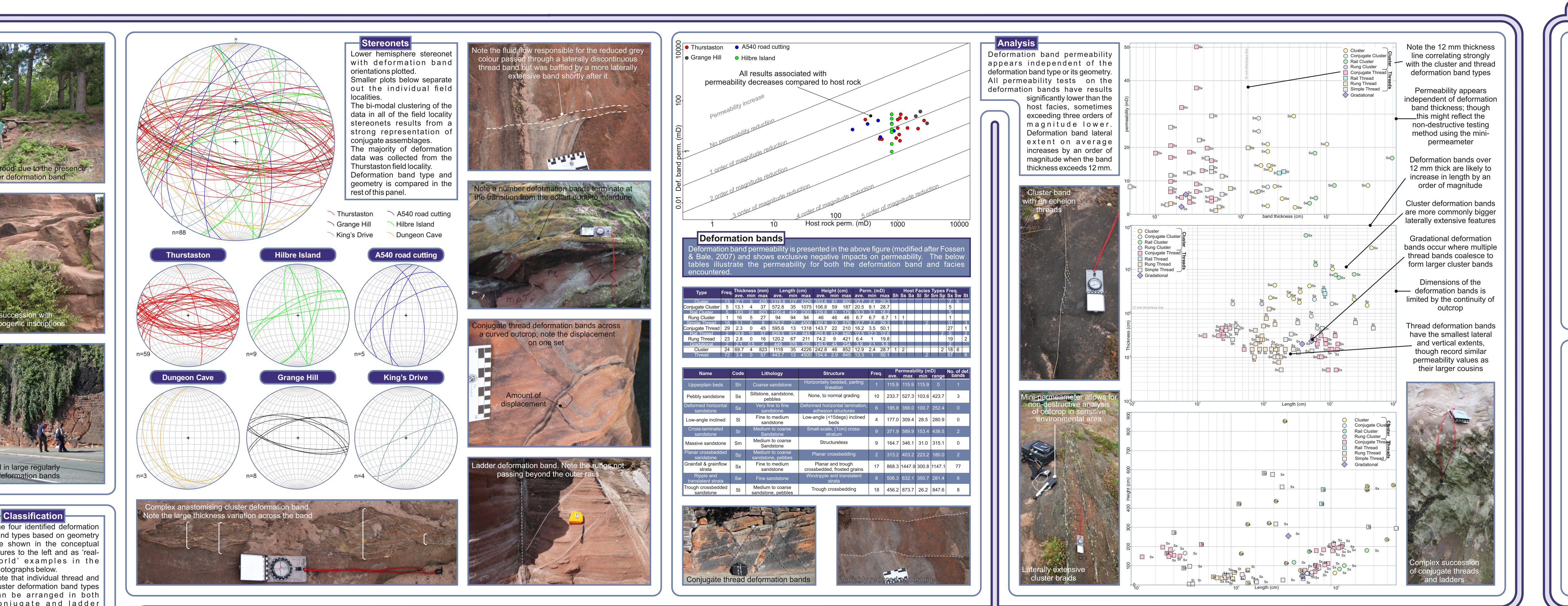
Thurstaston



Large eolian succession with abundant anthropogenic inscriptions

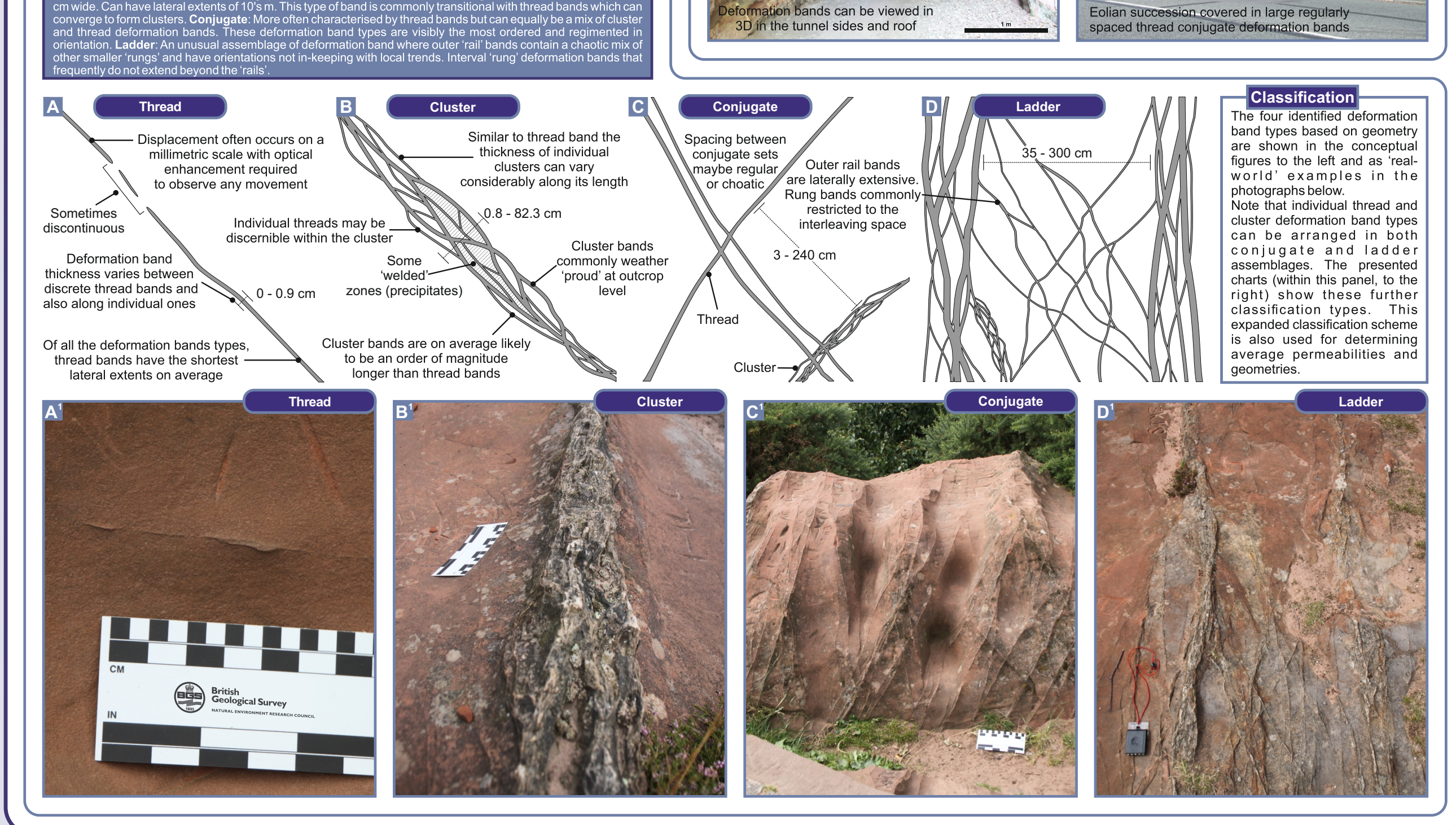
Deformation bands can be viewed in 3D in the tunnel sides and roof

Eolian succession covered in large regularly spaced thread conjugate deformation bands

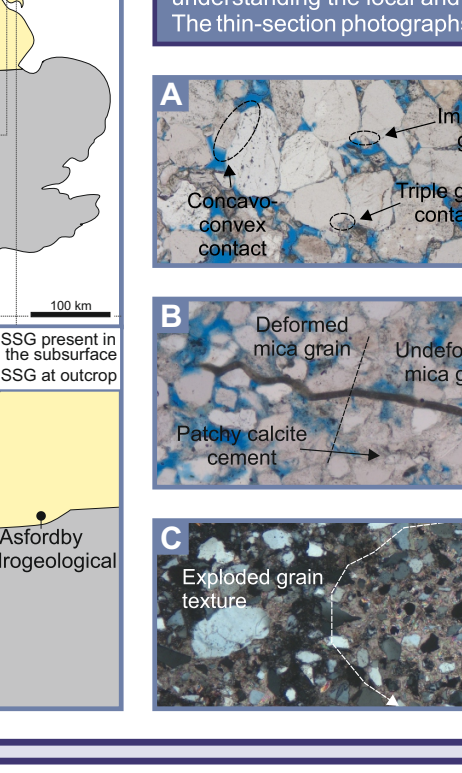


Deformation Band Styles

Four styles of deformation band are recognised and illustrated below (conceptual and photographic examples). **Thread**: The most frequent deformation band type recognised, often the thinnest and most laterally restricted type. Can often be discontinuous with small gaps in the deformation band. **Cluster**: Larger deformation band upto 10's cm wide. Can have lateral extents of 10's m. This type of band is commonly transitional with thread bands which can converge to form clusters. **Conjugate**: More often characterised by thread bands but can equally be a mix of cluster and thread deformation bands. These deformation band types are visibly the most ordered and regimented in orientation. **Ladder**: An unusual assemblage of deformation band where outer 'rail' bands contain a chaotic mix of other smaller 'rungs' and have orientations not in-keeping with local trends. Interval 'rung' deformation bands that frequently do not extend beyond the 'rails'.

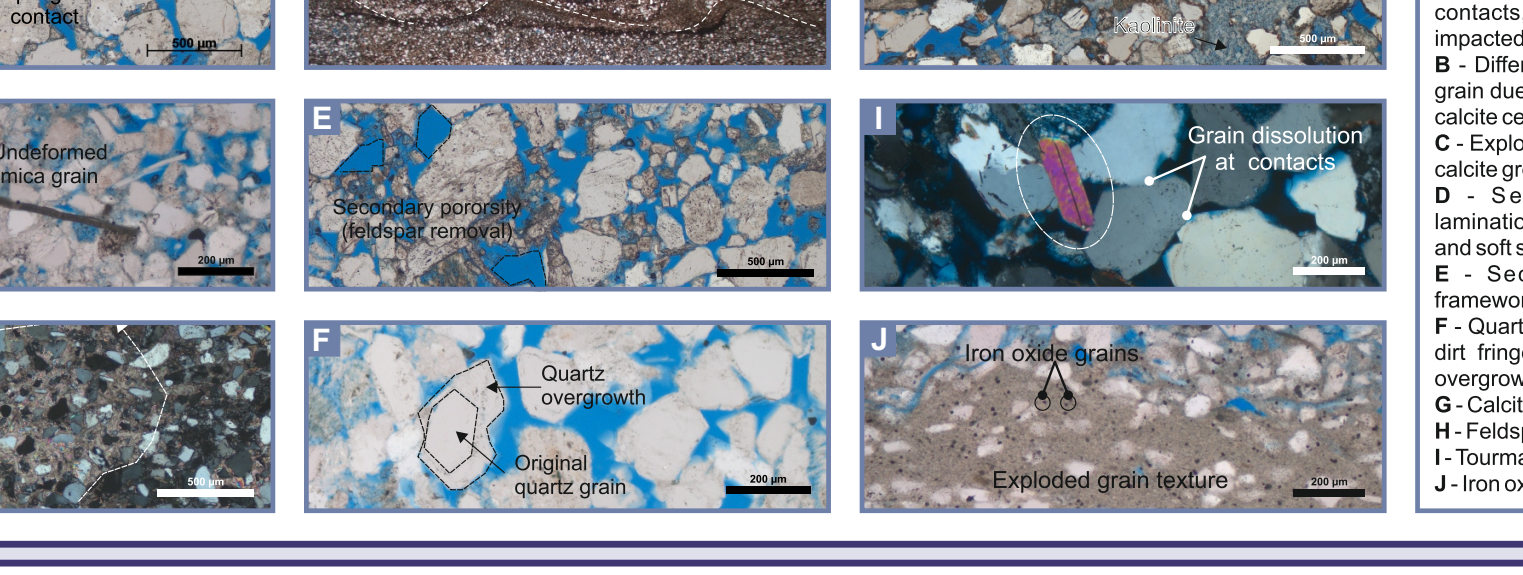

Thread
Cluster
Conjugate
Ladder
Conjugate thread deformation bands
Laterally extensive cluster braids
Complex succession of conjugate threads and ladders

Diagenesis



Diagenesis vs. lithofacies

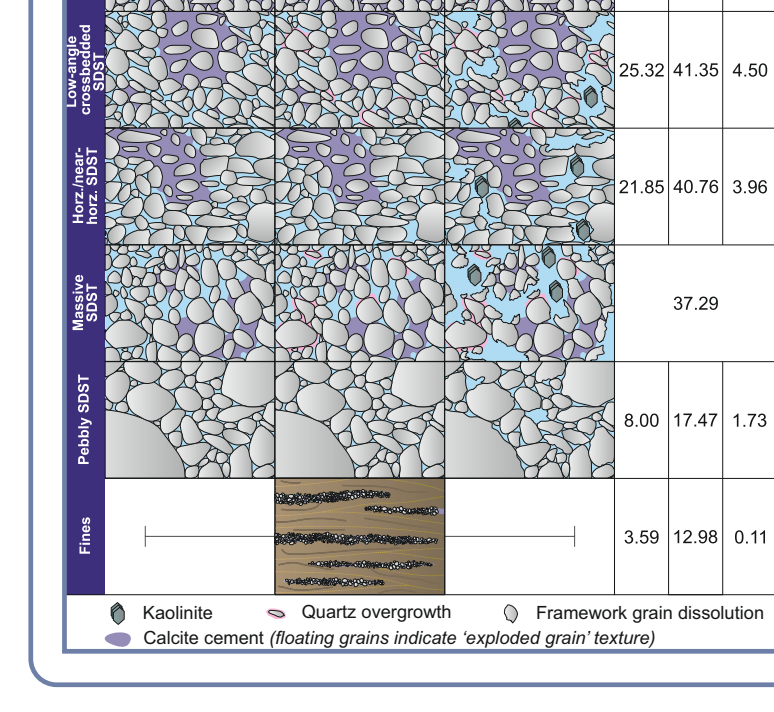
The Sherwood Sandstone of the Needwood Basin is a heterogeneous fluvial sandstone which has been subject to a complicated diagenetic history in post deposition. To better understand this diagenetic history five borehole cores were analysed. Relationships between diagenesis and primary depositional processes (lithofacies) were explored. The results of this study are important to understanding the local and more regional properties of the group with regard to aspects of fluid flow. The thin-section photographs below illustrate some of the findings.



Diagenetic features

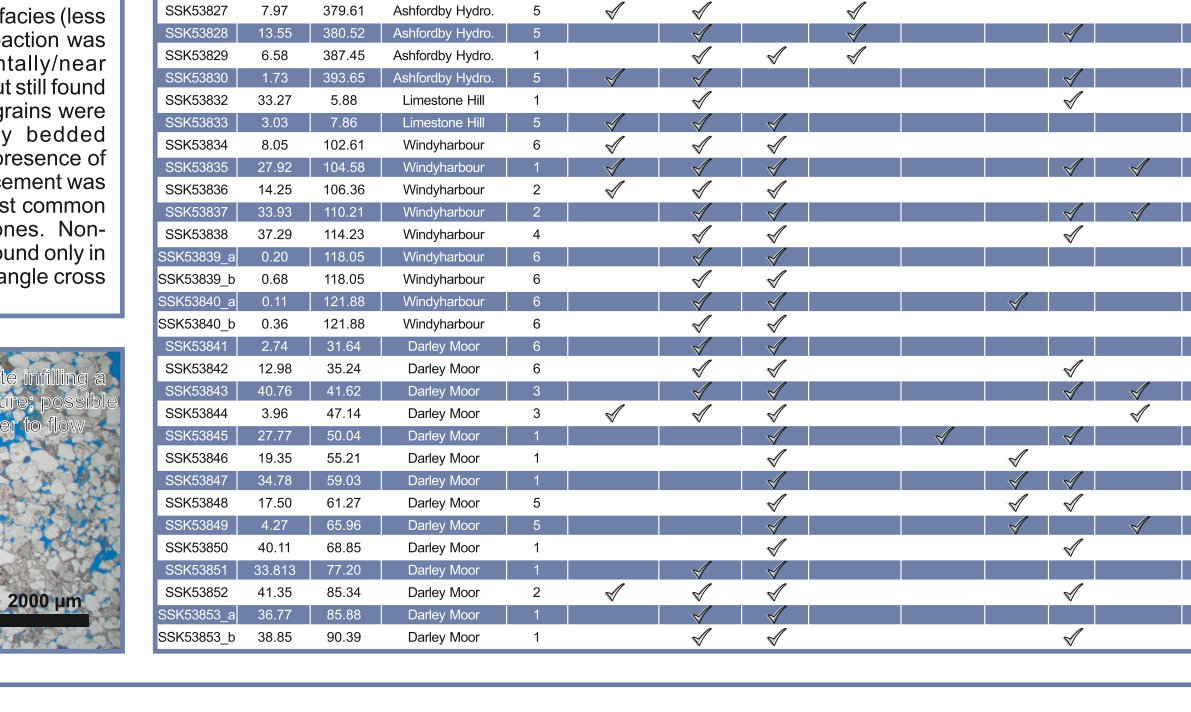
A total of 30 samples were taken from 5 borehole cores, all of which are held at the National Geological Repository at the BGS in Nottingham. Sample collection was conducted to incorporate the complete facies suite present in each borehole. From these samples a variety of diagenetic features were seen:

A - Textures representing different levels of compaction during burial: long grain contacts, concavo-convex contacts, triple grain contacts and impacted grains.
B - Differential compaction of a mica grain due to presence of eodiagenetic calcite cement.
C - Exploded grain texture suggesting calcite growth prior to burial.
D - Sedimentary structures: laminations, cross bedding, ripples and soft sediment deformation.
E - Secondary porosity due to framework dissolution.
F - Quartz overgrowths enclosing thin dirt fringe, thick dirt fringes prevent overgrowth formation.
G - Calcite replacement by dolomite.
H - Feldspar replacement by kaolinite.
I - Tourmaline grain.
J - Iron oxide grains.



Facies control on diagenesis

Quartz overgrowths were found in the massive sandstone sample and in half of all cross bedded and low-angle cross bedded sandstones. Framework grain dissolution was least common in muddy facies (less susceptible to dissolving). Compaction was slightly less likely in horizontally/near horizontally bedded sandstone but still found in 2/3rds of samples. Exploded grains were most common in horizontally bedded sandstones, this ties in with the presence of calcite cement. Although calcite cement was found in all lithofacies, it was most common in horizontally bedded sandstones. Non-dolocrete dolomite cement was found only in a small number of cross and low angle cross bedded sandstones.

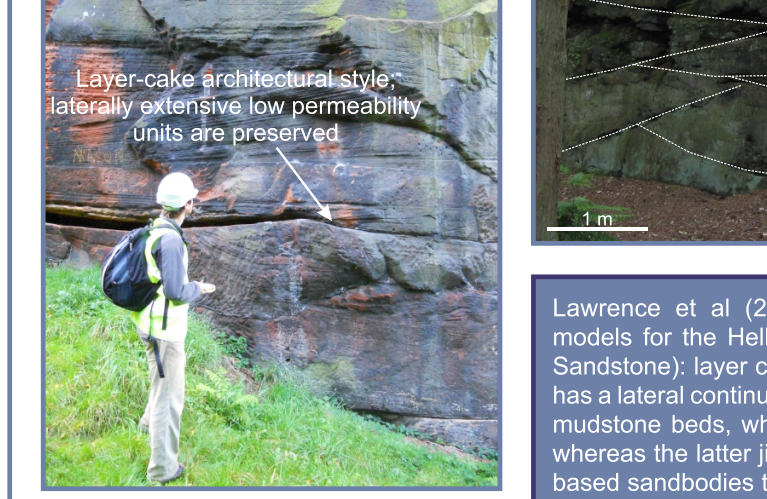

Sample
Porosity %
Sample depth (m)
Borehole
Facies code
Dolocrete/calcrete
Kaolinite
Cement
Calcite
Iron oxide
Dolomite
Baryte
FGD
Exploded
Quartz overgrowth
Comp.
Pyrite
Ashbourne 1
Ashfordby Hydro.
Limestone Hill
Windyharbour
Darley Moor

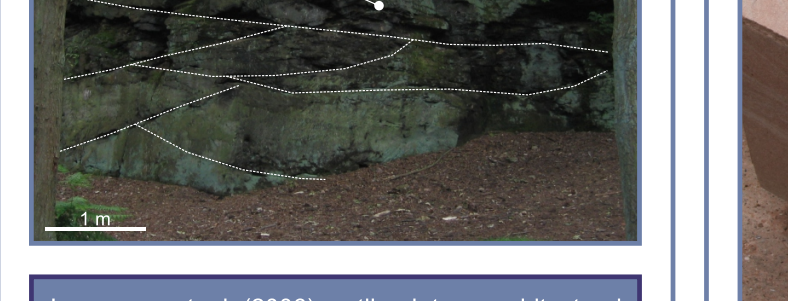
Porosity

The jPOR method (Grove and Jerram, 2011) was used to estimate porosity. This method uses a macro in ImageJ freeware (Schindelin et al., 2015) to analyse the proportion of blue colour in the scanned thin section image derived from blue epoxy resin impregnated prior to sectioning.
Porosity correlates negatively with depth, with the very deepest samples (350m+) having porosities no higher than 21% compared to shallower boreholes that can exceed 40%. This is likely to be due to the circulation of meteoric water in shallower samples removing susceptible minerals (such as carbonate cements) by dissolution, and thus increasing secondary porosity.
The highest porosities are found in the cross bedded sandstones and massive sandstones (this lithofacies is restricted to one sample and so cannot be said to be representative) which reflects the clean nature of these sandstones. The lowest porosities are found in muddy facies. Conglomerates also display generally low porosities; a combination of low porosity clasts, poor sorting and cementation. Horizontally bedded and low-angle crossbedded sandstones both have a wide variety of porosity values which reflects the level of cementation and framework grain dissolution both of which are dependent on past fluid flow.
The presence or absence of different cements had varying impacts on porosity. Calcite or dolocrete presence reduced pore volume by 17.5%. Patchy calcite cement did not appear to impact on porosity. Iron oxide cement reduced pore volume by 8% and most significantly, barite reduced pore volume by 23%.

Application and Rationale

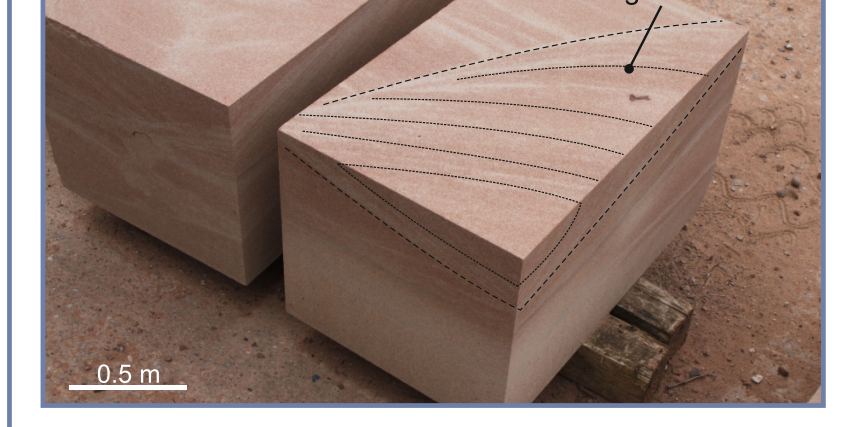
Outcrop Studies 1

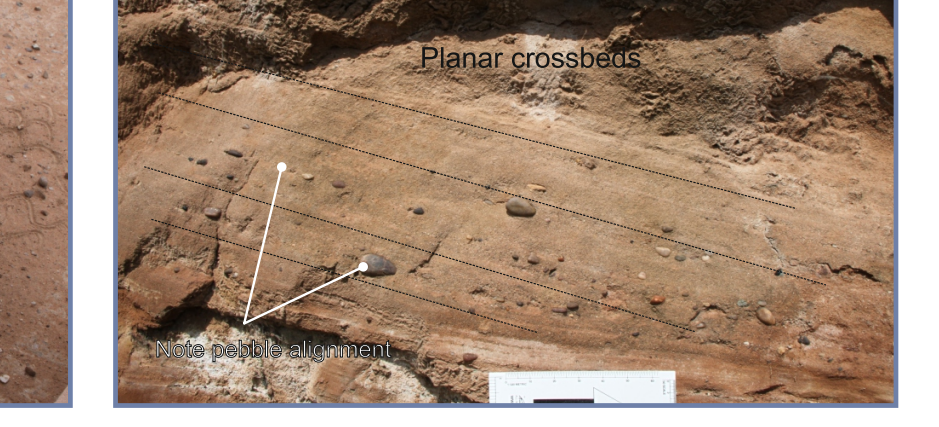

Layer-cake architectural style; laterally extensive low permeability units are preserved


Jigsaw sandbody geometry- downcutting at bases of major sandbodies removes underlying laterally continuous 'marker' horizons
1 m

Lawrence et al (2006) outlined two architectural models for the Helby Sandstone (upper Sherwood Sandstone): layer cake and jigsaw-type. The former has a lateral continuity to units, including subordinate mudstone beds, which may provide baffles to flow, whereas the latter jigsaw-type is typified by erosive-based sandbodies that down-cut through underlying mudstone beds and does not typically preserve laterally extensive low-permeability units. The distinction between layercake and jigsaw architectural styles is relevant when considering that in some instances, lateral dispersion of contaminants, hydrocarbons or water is fracture controlled (Chen et al., 2012) hence, maybe more relevant in layercake architectural styles. Contaminant migration in the unsaturated zone is particularly relevant to predicting pollution pathways in urban and peri-urban settings due to the concentration of industry in those areas where the Sherwood Sandstone is at or near the surface (rockhead).

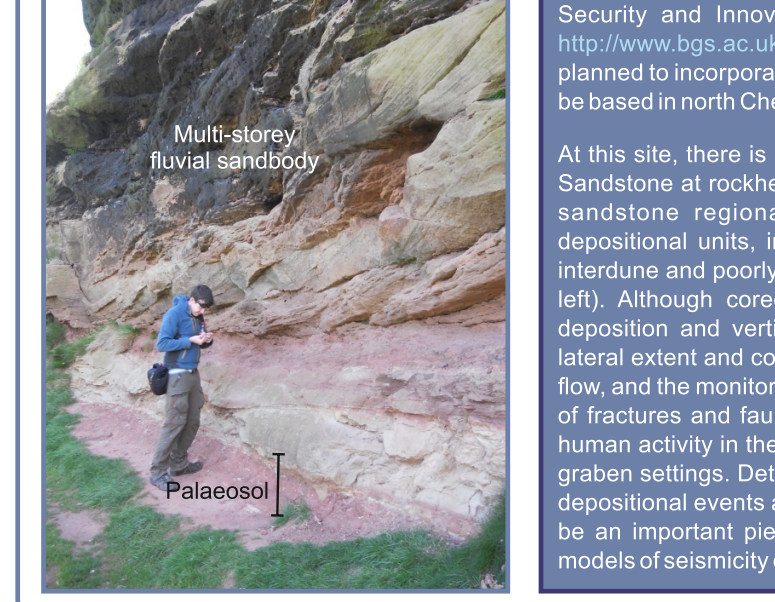
Primary Depositional Influence On Flow


Building stones from the Sherwood Sandstone
Individual trough crossbed
0.5 m



Bedrock heterogeneity in terms of bed character, composition and lateral and vertical extents in terrestrial sedimentary environments is partly influenced by changes in depositional facies, which can be significant on scales as little as 20 cm (Hitchmough et al., 2006). As groundwater flow (and that of constituent contaminants, if present) will preferentially concentrate along zones of higher permeability, and may indeed pond, resting on top of units of lower permeability (Lawrence et al., 2006), an understanding of depositional processes and hierarchy is relevant to contaminant management strategies. This natural variability is often beyond the resolution of many models which often consider the aquifer as isotropic at the scale of the modelled volume. In many settings, primary deposition influences the permeability and hydraulic conductivity of the reservoir, therefore having a direct impact on fluid flow, with all 'large bedding plane discontinuities' in the Sherwood Sandstone from Cheshire in one study being considered transmissive to flow (Hitchmough et al., 2006). The influence of depositional environment has an obvious effect on intergranular flow, but it is also a factor in the development of certain styles of fracture that impede flow. The relationship in 3D of this heterogeneity (controlled by the interplay between different depositional environments) is a key input parameter to groundwater conceptual models, where an understanding of groundwater flow, and the controls on the rate and direction of flow are relevant to aquifer management strategies, the mitigation of pollution (Allen et al., 2013) and the modelling strategy itself (Chen et al., 2012).

Understanding The Sub-surface



There are currently several subsurface survey and monitoring projects under development in the UK. These are designed to monitor changes that occur in response to human activities such as hydraulic fracturing, the development of geothermal schemes, or Carbon Capture and Storage (CCS). The Energy Security and Innovation Observing System for the Subsurface (ESIOS; http://www.bgs.ac.uk/research/energy/ESIOS/home.html), is a scheme that is planned to incorporate a group of research facilities, the first of which is likely to be based in north Cheshire, in the north-western part of the UK.

At this site, there is a significant thickness (200 – over 1000 m) of Sherwood Sandstone at rockhead that is fractured and faulted, and in common with the sandstone regionally, comprises both eolian- and fluvial-dominated depositional units, including fluvial channel (lateral accretion), eolian dune, interdune and poorly developed colonized (palaeosol) surfaces (see image to left). Although cored intervals of sandstone are available to quantify the deposition and vertical variations present, questions remain regarding the lateral extent and compositional variability of sandbodies, and their impact on flow, and the monitoring of flow, through the sandstone. Understanding the role of fractures and faults will also be critical to gaining an appreciation of how human activity in the subsurface may impact a principal aquifer in linked half-graben settings. Detailed outcrop studies describing the relationship between depositional events and facies from localities close to the proposed facility will be an important piece of baseline input data from which detailed flow and models of seismicity can be generated.

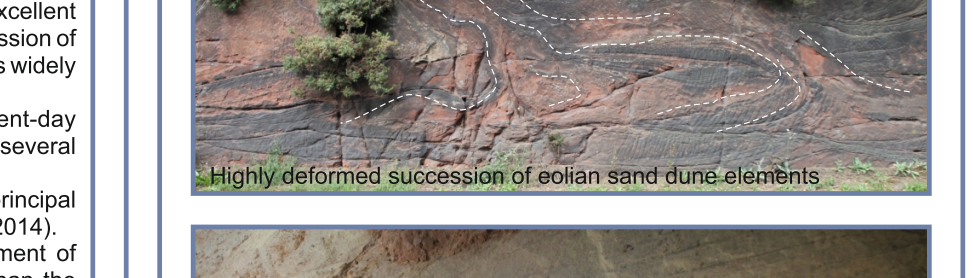
Depositional Physical Properties

The Sherwood Sandstone is relatively well-exposed throughout its crop. Zones of better-cemented strata commonly form positive topographical features, such as the prominent range of hills extending southwards from Frodsham and Helsby in Cheshire, NW England, and Cannock Chase in the English Midlands. These better-cemented intervals are commonly fluvial in origin and have been extensively quarried, giving excellent exposures with faces that are often perpendicular to one another, giving an impression of 3D structure. However, eolian units are typically poorer cemented and were not as widely quarried. This gives a bias of outcrop in favour of fluvial units.
Links between primary deposition in the Sherwood Sandstone and present-day petrophysical and hydrogeological characteristics have been the subject of several studies (e.g., Bouch et al., 2006; Beach et al., 1997; Griffiths et al., 2016).
It has been recognised that facies associated grainsize variations were a principal controlling influence on reservoir properties (along with compaction) (Grant et al. 2014).
Due to bed-plane discontinuities, Hitchmough et al (2006) reported development of significant anisotropic permeability, being 23 times greater in the horizontal than the vertical, justifying the need to inform reservoir and aquifer models with data derived from outcrop in addition to vertically cored sections.

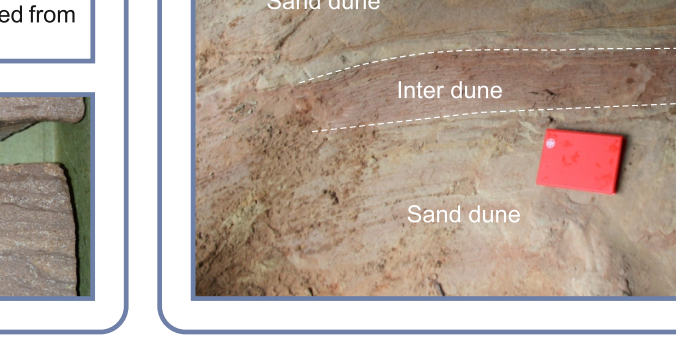
Bimodal coarse and fine sandstone

Inter-laminations of mudstone, siltstone and sandstone

Outcrop Studies 2



Highly deformed succession of eolian sand dune elements



Depositional Heterogeneity

Characterisation of sandstone reservoirs can proceed with the identification and mapping of features identifiable on the seismic scale (typically 10 - 20 m). However, there is significant and marked variation in lithology and petrophysical properties at the sub-seismic scale due to changes in depositional setting that give rise to marked lithological variability; this is clearly seen at an exposure from the upper part of the Sherwood Sandstone at Styrrup Quarry, Runcorn, Cheshire, NW England. Here, exposed with damp and rare wet interdune units, pr… the interaction with a shallow, fluctuating water table (… Thompson, 2002).

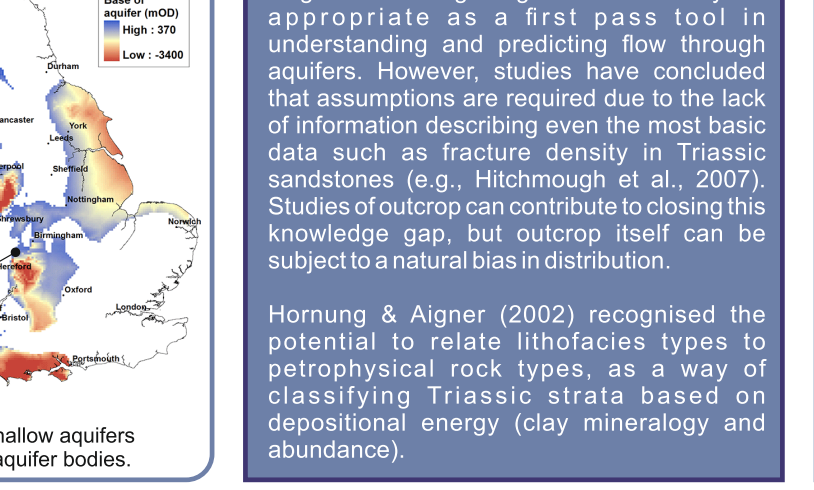
The recognition that lithological variation can … development of diagenetic cements and the style, … amount of fractures has been discussed by many … Shipton & Cowie, 2003; Hough et al., 2006; Griffith… This is of particular relevance to the identification and understanding of features relevant to reservoir quality at the sub-seismic scale, as the scale of individual element-bounding … in the Sherwood Sandstone (a mixed eolian-fluvial sandstone that accumulated in a terrestrial setting) often less than 2 m, with many published examples of depositional heterogeneity at a similar scale (e.g., Wakefield et al., 2015; Bouch et al., 2006; Newell, 2006; Hornung & Aigner, 2002).

… provide information concerning the vertical thickness variation of sandbodies and vertical sedimentological relationships, outcrop studies are required to confirm lateral compositional and structural heterogentity and the scales of variability (seismic data is often compromised as many relevant features are below the typical seismic scale, or of insufficient contrast to be imaged).

Flowpaths Within The Sherwood Sandstone

The Sherwood Sandstone is a dual porosity aquifer that primarily accommodates flow by matrix (intergranular) flow and to a lesser extent fracture flow (Allen et al., 1997; Lawrence et al., 2006). The amount of fracture flow remains largely unknown (Bloomfield et al., 2006), although may be important in certain settings (e.g., where non-aqueous phase liquids are travelling through an aquifer; Lawrence et al., 2006). Allen et al (1997) reported matrix intergranular permeability and porosity values as 0.1 – 10 md-1, and 15 – 30%; Lawrence et al (2006) quote 35% as the maximum porosity. Fracture flow proceeds via bedding (lamination, bounding surfaces), joints and faults (Allen, 1998), with deformation bands impeding flow. Bloomfield et al (2006) called for a better understanding of sedimentary architecture and how this influences the hydraulic conductivity of different sandstone lithofacies.

Triassic Aquifers



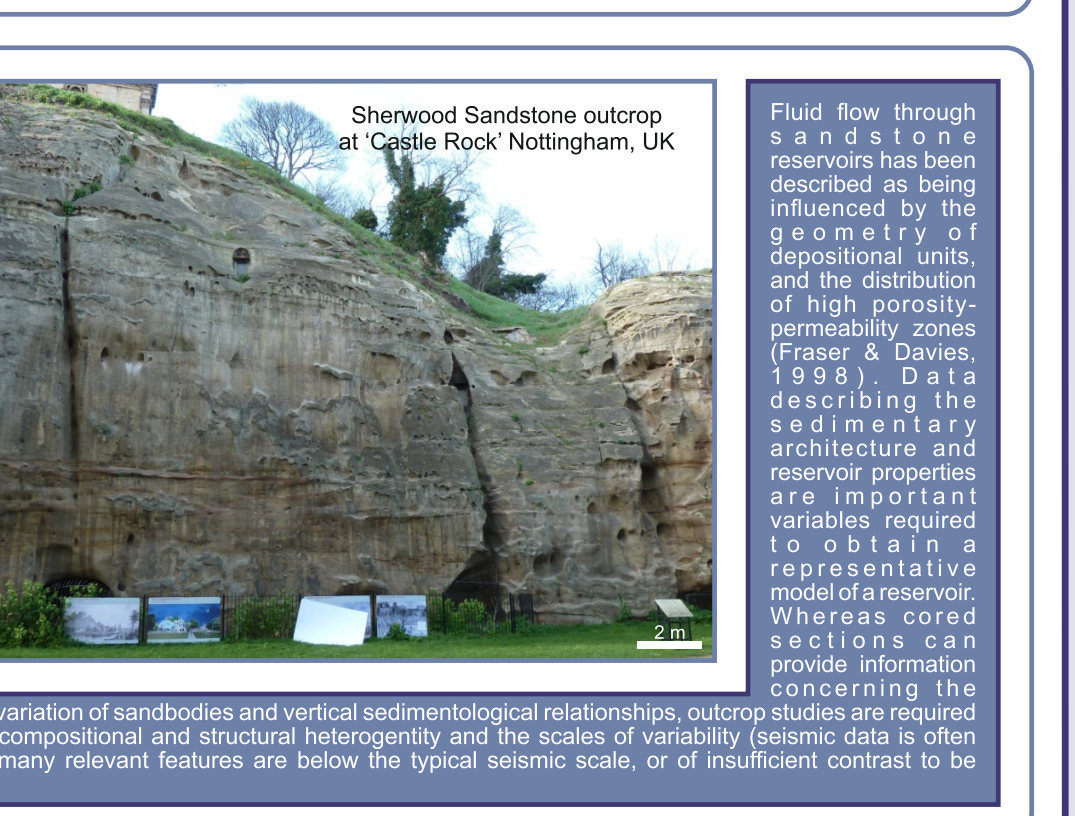
Blue areas indicate shallow aquifers
Red indicate deeper aquifer bodies.

Aquifer Properties

Regional scale geological models may be appropriate as a first pass tool in understanding and predicting flow through aquifers. However, studies have concluded that assumptions are required due to the lack of information describing even the most basic data such as fracture density in Triassic sandstones (e.g., Hitchmough et al., 2007). Studies of outcrop can contribute to closing this knowledge gap, but outcrop itself can be subject to a natural bias in distribution.

Hornung & Aigner (2002) recognised the potential to relate lithofacies types to petrophysical rock types, as a way of classifying Triassic strata based on depositional energy (clay mineralogy and abundance).

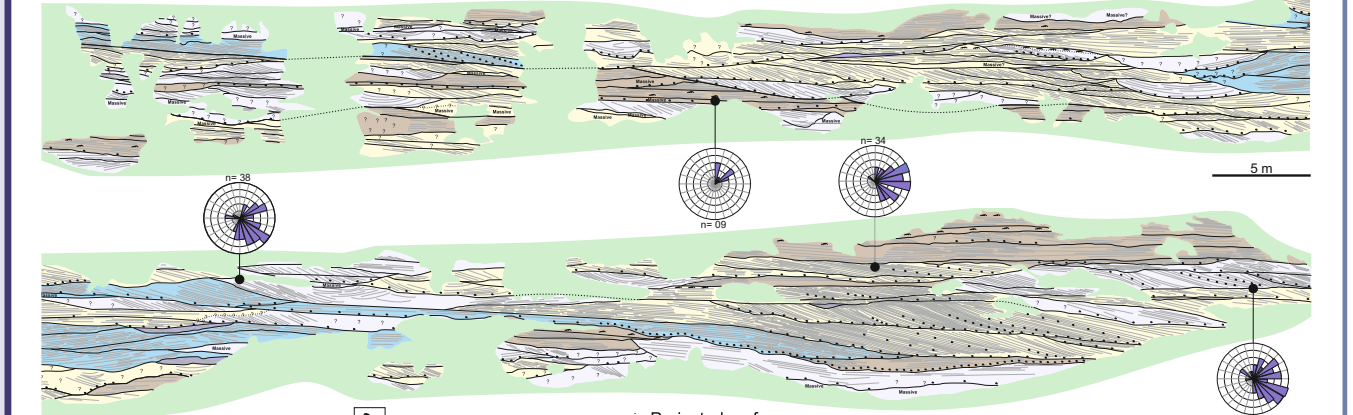
Mobile digital microscope used in-situ

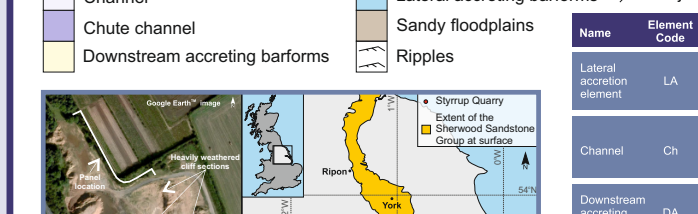


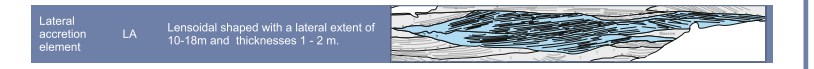
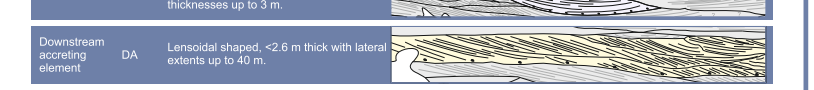
Sherwood Sandstone outcrop at 'Castle Rock' Nottingham, UK

Fluid flow through sandstone reservoirs has been described as being influenced by the geometry of depositional units,

Styrrup Quarry





Name	Element Code	Description	
Lateral accretion element	LA	Lensoidal shaped with a lateral extent of 10-18m and thicknesses 1 - 2 m.	
Channel	Ch	Erosively based 'u' shaped element. Lateral extents of up to 20 m and thicknesses up to 3 m.	
Downstream accreting element	DA	Lensoidal shaped, <2.6 m thick with lateral extents up to 40 m.	
Chute channel	Cch	Smaller erosively based channel feature; 1.2 - 2.6 m wide with a thickness ~0.5 m.	
Sandy floodplain	SF	Discontinuous tabular shape, thicknesses up to 3 m and lateral extents of up to 20 m.	

This panel provides the first modern sedimentological interpretation of the SSG in east England. The outcrop at Styrrup Quarry allows contrasts to be made with the style and expression of the Sherwood Sandstone between eastern and western England. Specifically, this highlights differences around the variation in fluvial discharge (between lowstand and highstand) and the absence of eolian facies types. It is interpreted that these differences relate to discharge variations between ephemeral and perennial systems with a perennial model proposed for Styrrup Quarry. This model draws upon inferences of additional water input from more local areas, likely topographic uplands of the London-Brabant and Pennine Highs which supplement the primary source of the Variscan Mountains in France with additional water.

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oliverw@bgs.ac.uk
http://www.bgs.ac.uk
☎ +44 (0) 115 936 3169