Quantifying the Impact of Geological Heterogeneity on Hydrocarbon Recovery in Marginal Aeolian Reservoirs*

Samantha Taggart[1], Gary Hampson[1], and Matthew Jackson[1]

Search and Discovery Article #40344 (2008)
Posted October 9, 2008

*Adapted from oral presentation AAPG Convention, San Antonio, TX, April 20-23, 2008

[1]Earth Science and Engineering, Imperial College London, London, United Kingdom (samantha.taggart@ic.ac.uk)

Abstract

The Permian Rotliegend gas play of the UK Southern North Sea consists of aeolian sandstones that pass distally into evaporite-rich lacustrine claystones. Previous development of the southern North Sea Basin has focused on high-quality aeolian sandstones. However, as these are now maturing, focus has shifted to exploring the potential of more heterogeneous, marginal reservoirs (so-called “feather-edge” play). Vertical and lateral heterogeneity within these marginal reservoirs poses a high risk to their successful development, as a result of low permeability stratigraphic units acting as potential barriers to flow.

The well-exposed Page (aeolian/sabkha) and Cedar Mesa (aeolian/fluvial) sandstones in southern Utah are analogous to elements of the marginal Rotliegend play and have been studied at outcrop to investigate sedimentologic heterogeneity at reservoir and inter-well scales. Measured sections and fence panels from the outcrop analogs have enabled the lateral extent and connectivity of different sandbodies to be mapped in three dimensions. 3D reservoir models of each outcrop analog have been constructed to create an accurate realization of facies architecture. Subsurface rock and fluid property data have been used to populate these outcrop-based models. Simulation of dry gas production from the models provides improved understanding of the way in which heterogeneity affects fluid flow patterns, reservoir behaviour, and potential development of Rotliegend “feather-edge” reservoirs.

NATURAL ENVIRONMENT RESEARCH COUNCIL

ConocoPhillips

Quantifying the Impact of Geological Heterogeneity on Hydrocarbon Recovery in Marginal Aeolian Reservoirs

Samantha Taggart, Gary Hampson & Matthew Jackson

Imperial College London

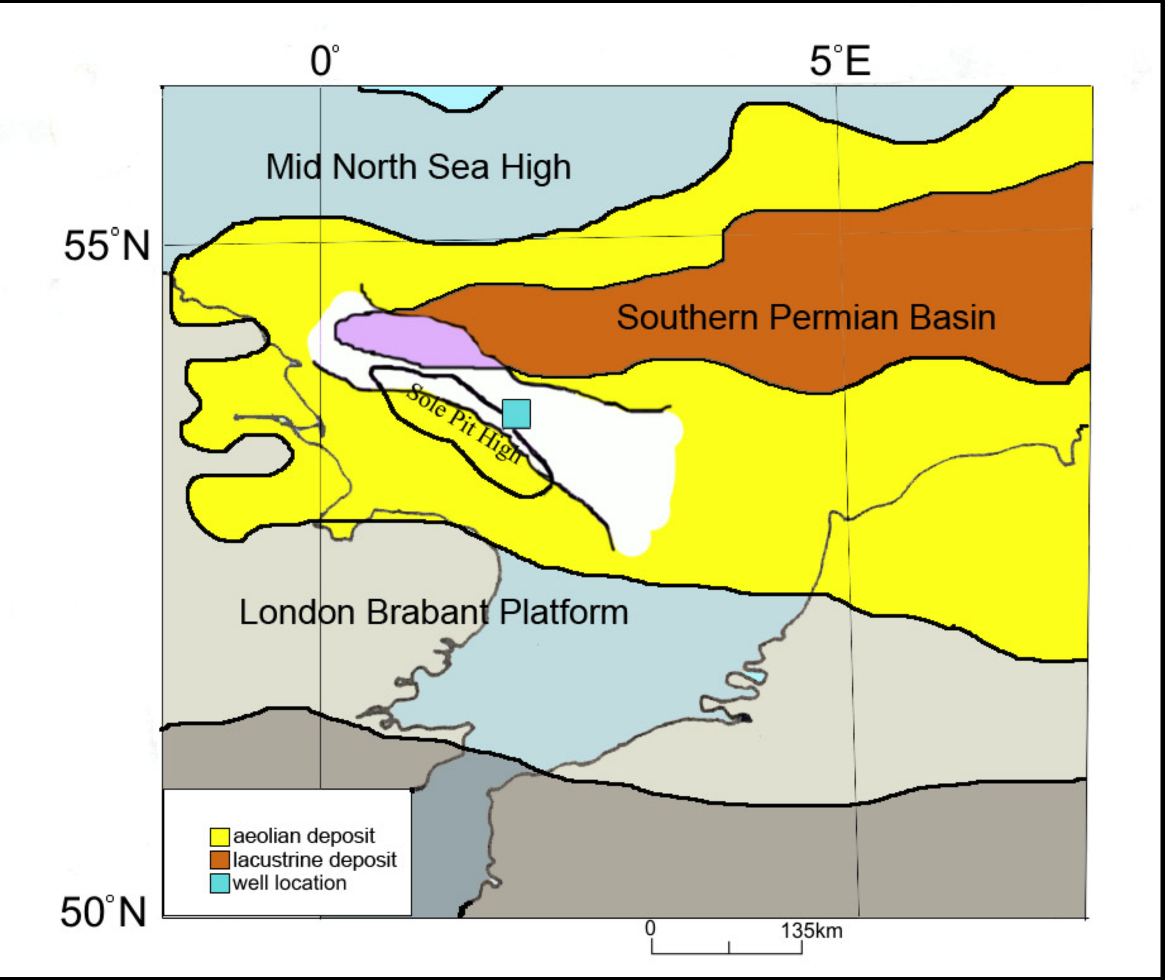
Project Aim

- Characterise and quantify reservoir properties and fluid flow dynamics of marginal aeolian facies found within Rotliegend gas fields of UK SNS

Project Overview

- Heterogeneity found within marginal aeolian reservoirs can have a pronounced impact on production
- Understanding the lateral and vertical heterogeneity between wells is key to building a geological model that will accurately reflect the subsurface geology and therefore produce viable results
- Using outcrop analogues the interactions typical of such deposits can be studied to help provide further understanding

Part 1: Subsurface Overview



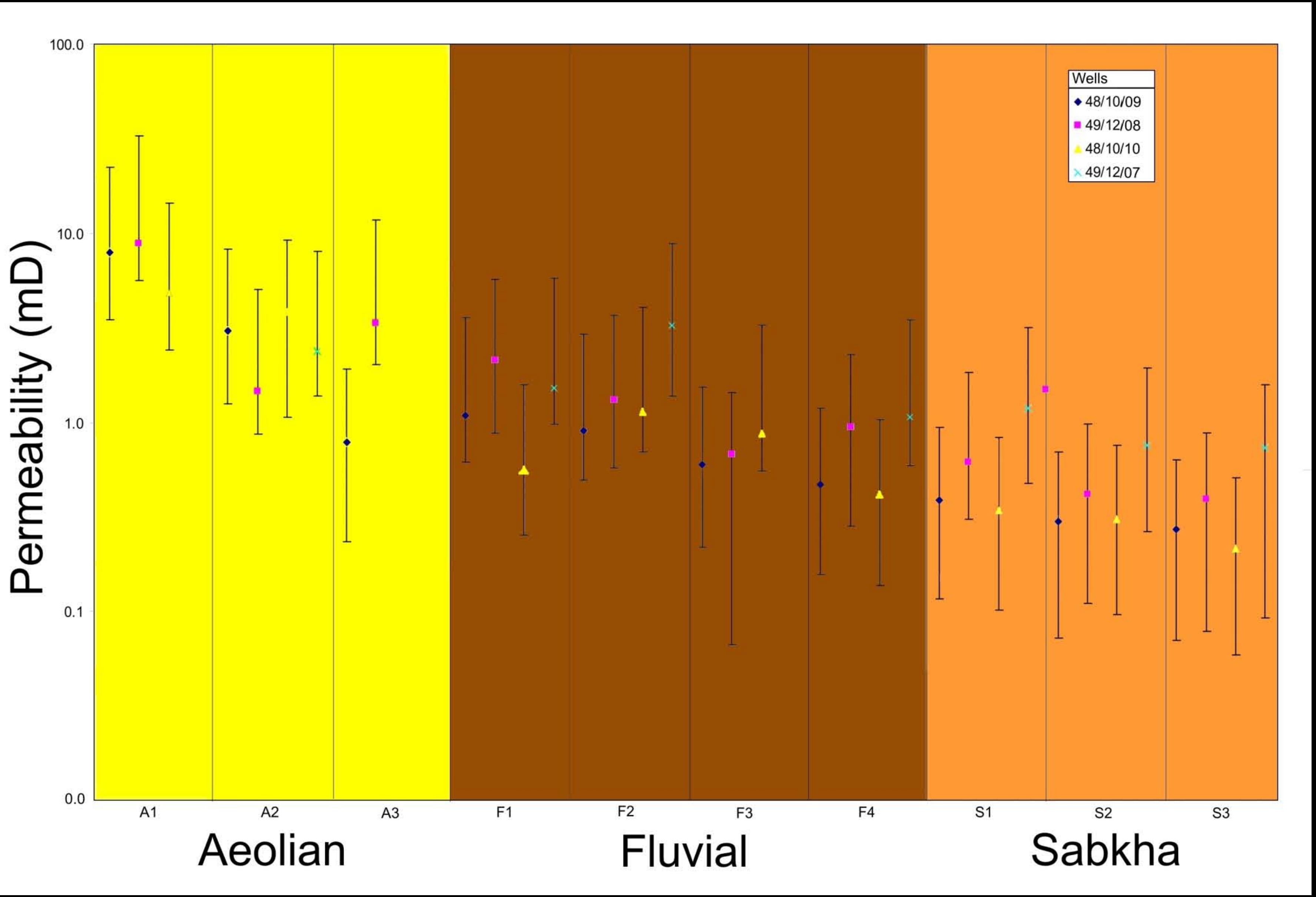
after (Ziegler, 1990)

- Cores logged to identify facies present within feather-edge play
- Quantitative data from wells have been compared to determine key rock properties for each facies

Facies

Facies Association	Facies	Lithology	Sedimentary Structures	Average Permeability (mD)
Aeolian	*A1*	medium grained sand	Steeply dipping grainfall and grainflow laminae-dip can exceed 25°.	8.4
	A2	fine to medium grained sand	Grainfall and grainflow laminae (shallower angle of dip) and wind ripple laminations.	2.7
	A3	fine to medium grained sand	Destratified sand.	2.1
Fluvial	*F1*	fine to medium grained sand	Structureless sand.	1.3
	F2	fine to medium grained sand	Laminated sands with dewatering structures.	1.6
	F3	sand with polylithic clasts	Conglomeratic with rip up clasts at base.	0.7
	F4	mud to fine grained sand	Mud rich planar and ripple laminated.	0.7
Sabkha	*S1*	>80% fine to coarse grained sand	Brecciated and distorted wavy bedding. Dewatering structures.	0.6
	S2	20-80% very fine to fine grained sand		0.4
	S3	>80% silt and mud	Planar silt and mud laminae as well as structures seen in S1 and S2.	0.4

Permeability Comparison of Facies

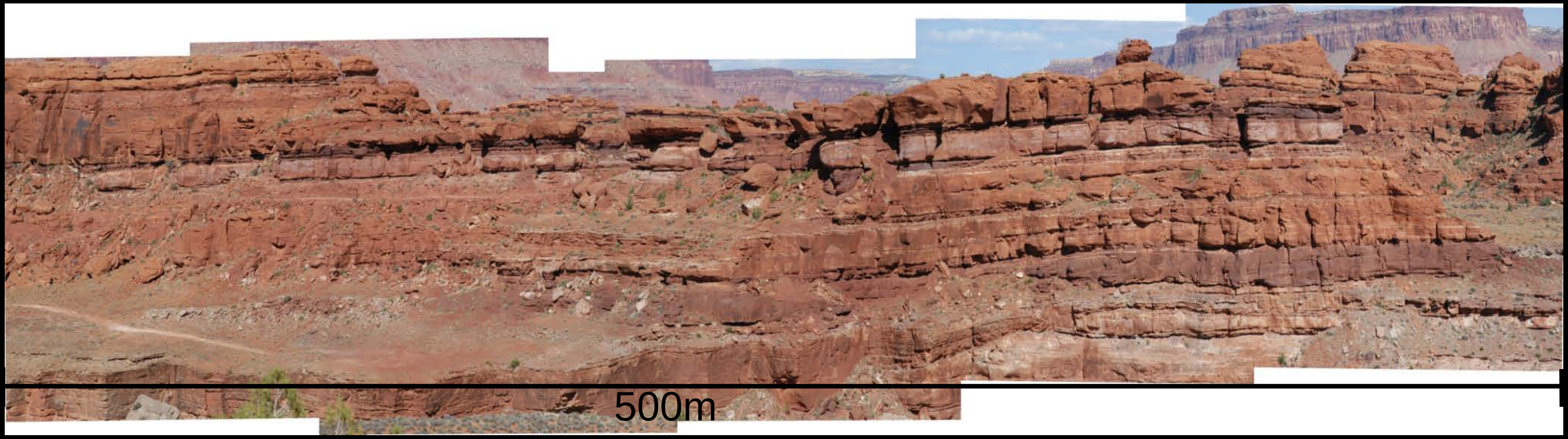


Part 2: Outcrop Analogue Overview

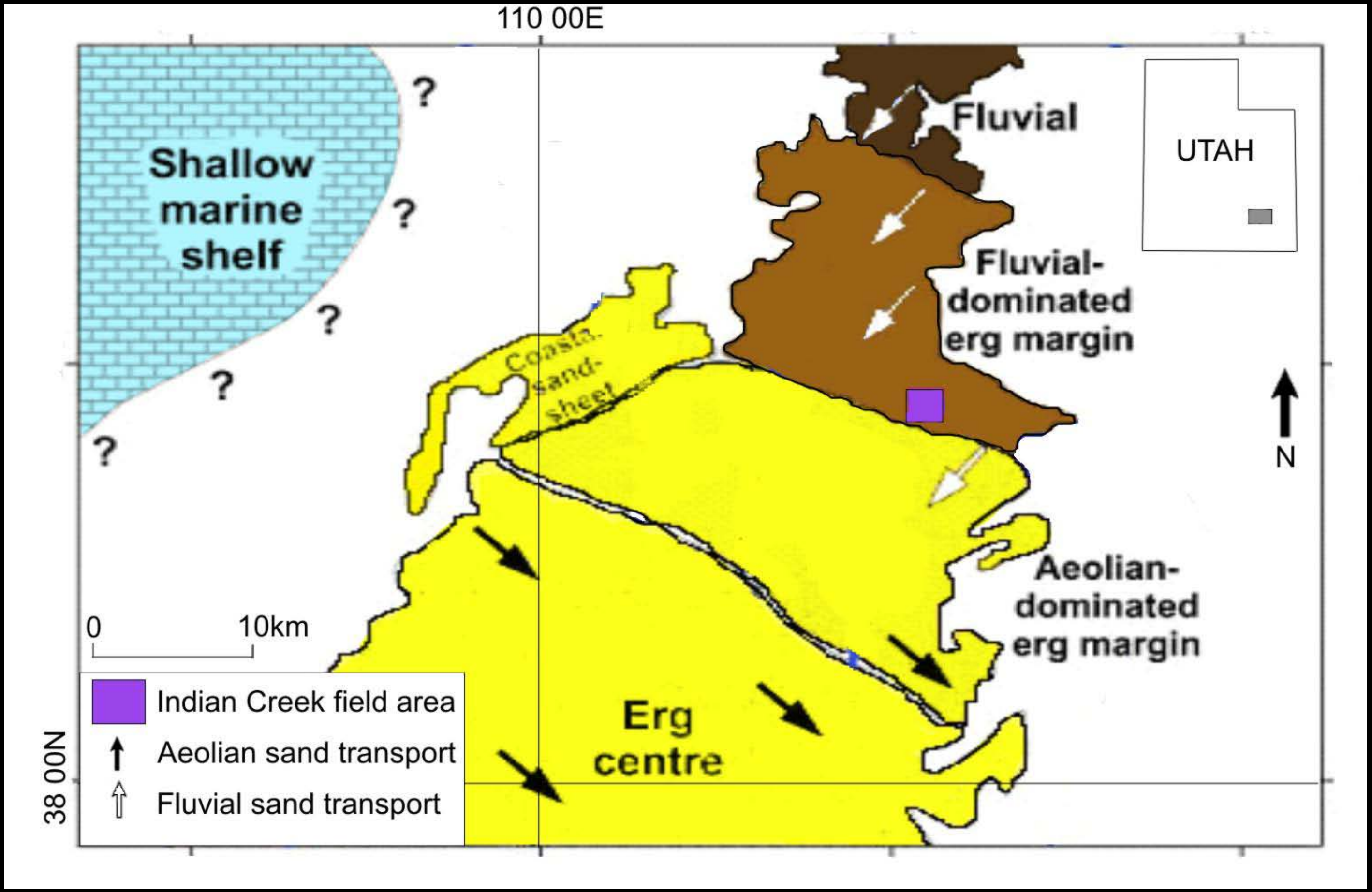
- 3D outcrop models provide improved understanding of lateral and vertical heterogeneity at inter-well scale
- 2 outcrop areas, SE Utah. Exposure almost continuous.
  – Cedar Mesa Sandstone, Indian Creek (aeolian/fluvial)
  – Page Sandstone, Escalante (aeolian/sabkha)

Indian Creek

- Dominantly aeolian with fluvial interdune deposits
- Similar facies seen in subsurface core
- No sabkha present



Indian Creek: Environmental Setting

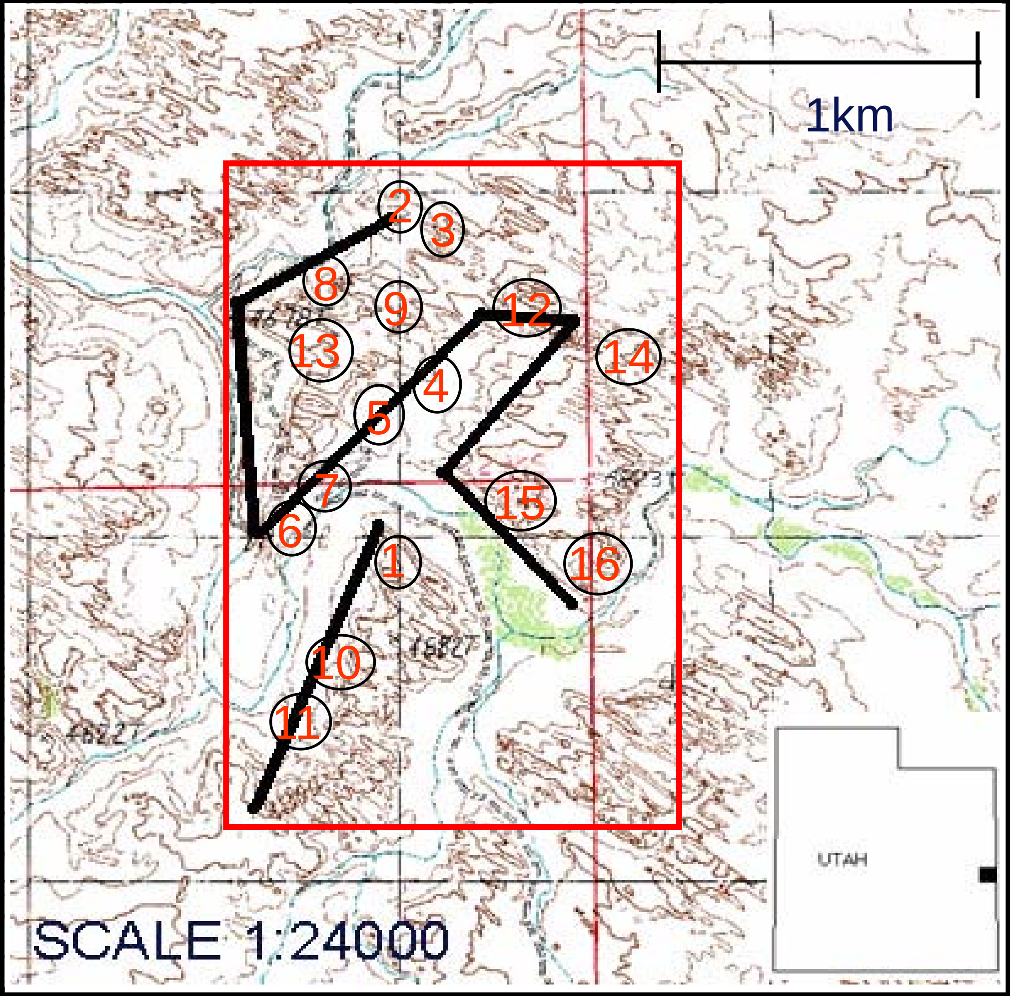


(after Mountney & Jagger, 2004)

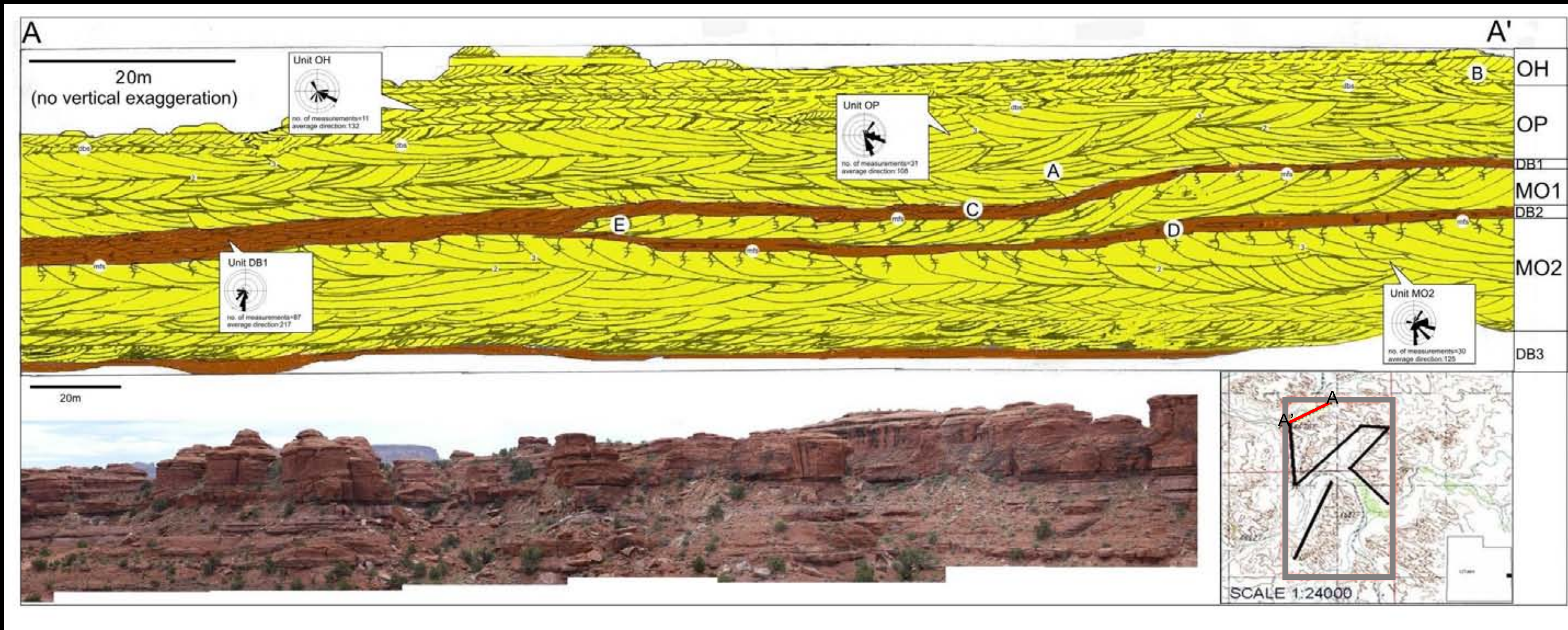
- Transition from dry aeolian erg through to fluvially dominated erg margin (Indian Creek)
- Fluvial dominated erg margin partitioned by flood supersurfaces formed when interdune areas experienced fluvial flooding

Indian Creek: Data Collection

- 3D exposure
- Logs (16)
- Fence Panels (11)
- Area: 700m*1700m

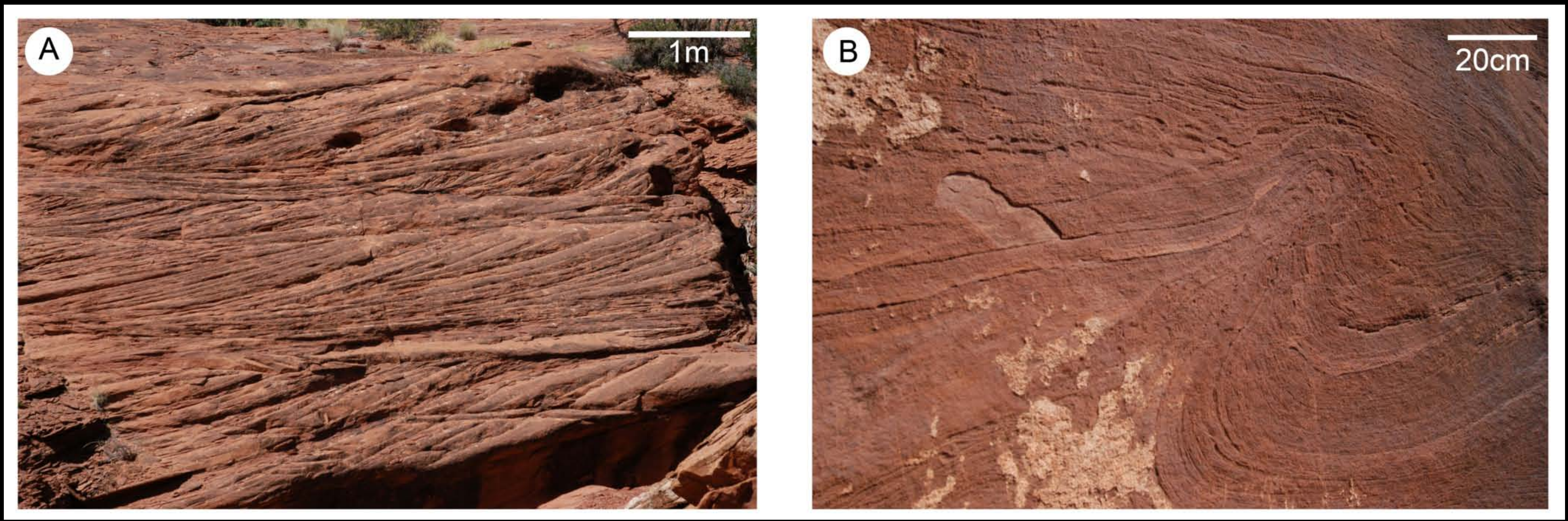


Indian Creek: Fence Panels



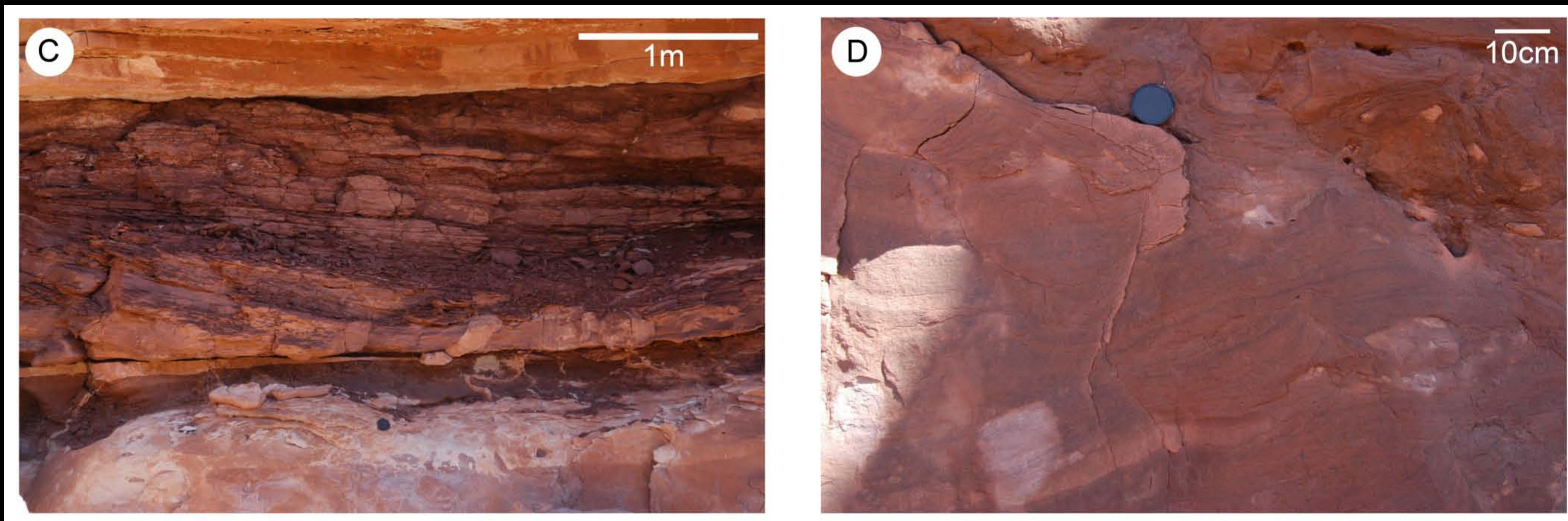
- 3D lateral and vertical heterogeneity
- Baffles to flow
- Incorporate into 3D model along with subsurface data

Indian Creek: Stratigraphic Units



A. Small scale trough cross-bedded dune sets (unit OP)
B. Soft sediment deformation (unit OH)

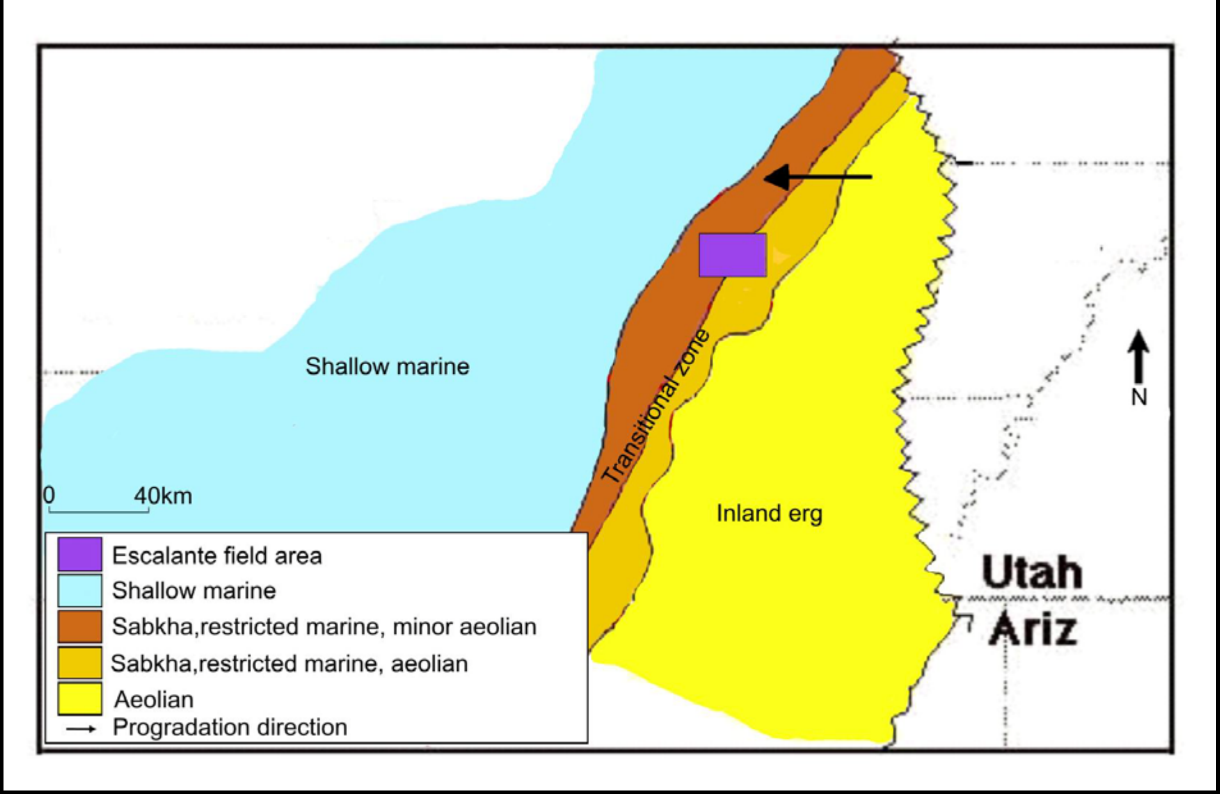
Indian Creek: Stratigraphic Units



C. Fluvial channel (unit DB1)

D. Small scale soft sediment deformation and water escape features (unit DB2)

Escalante: Environmental Setting

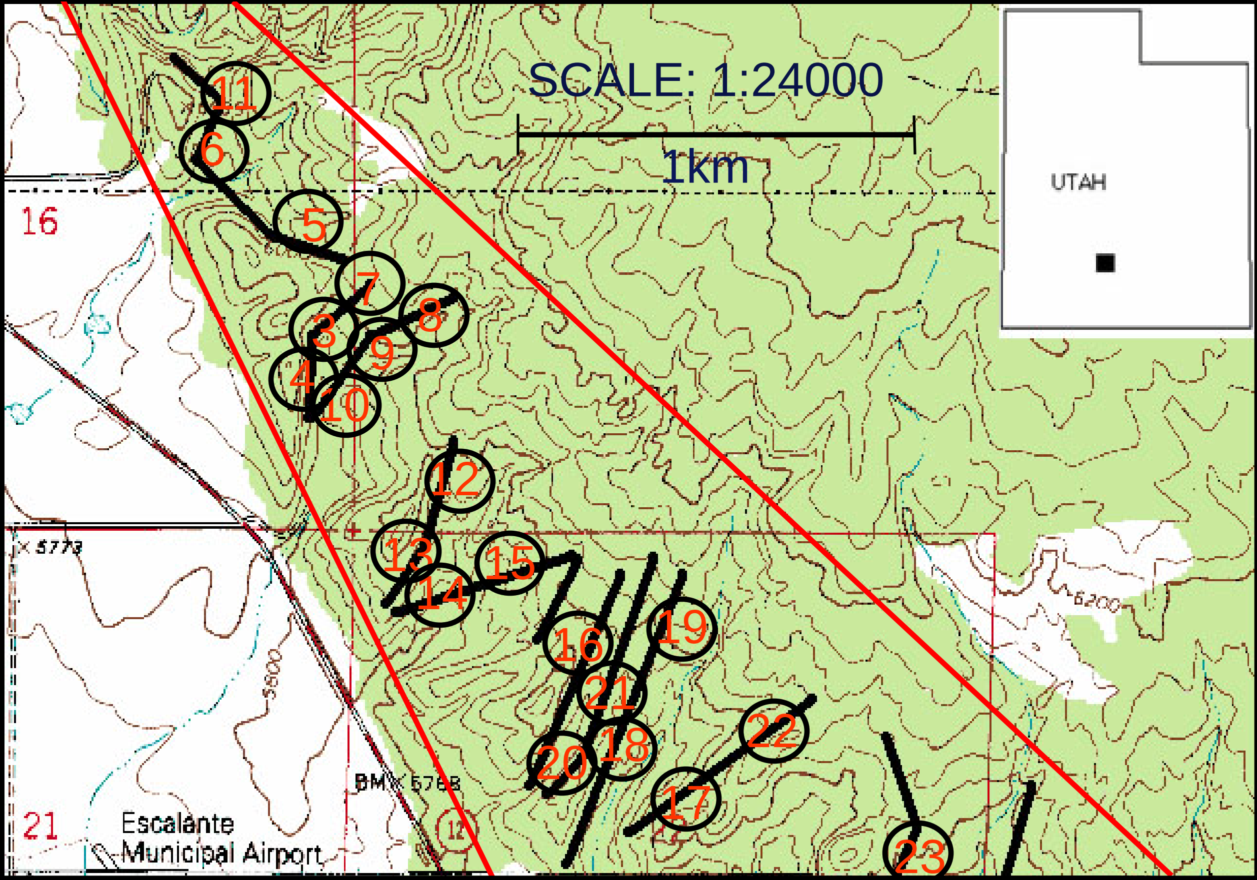


Escalante environmental setting. Location of field area indicated by box (after Blakey et al.(http://jan.ucc.nau.edu/~rcb7/Page.html))

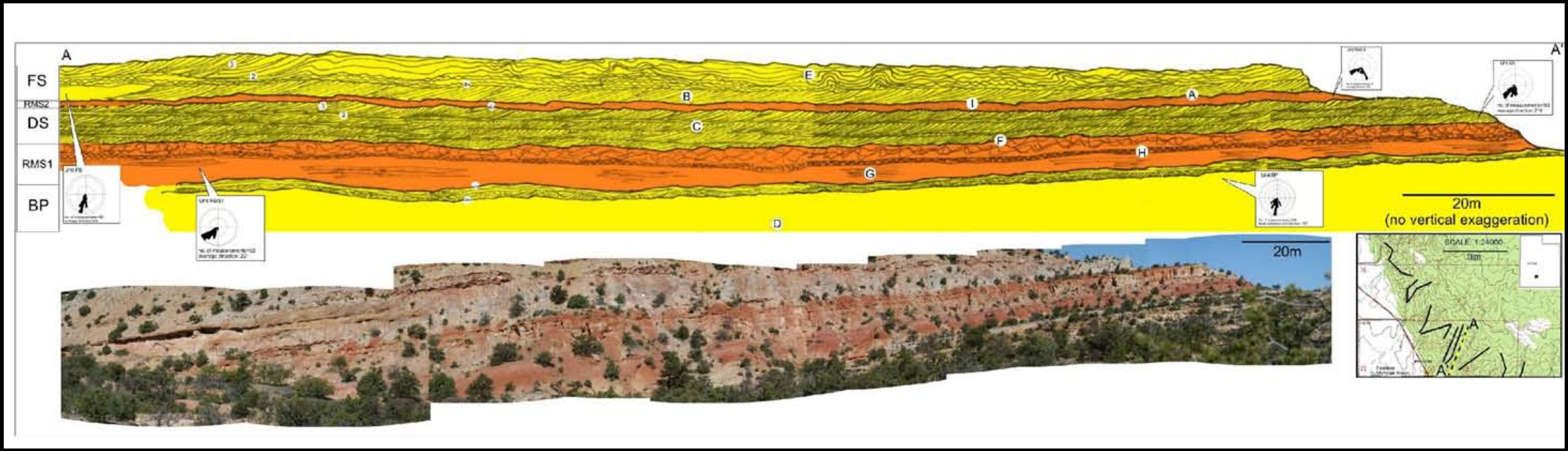
- Coastal erg with crossbedded sandstone and flat to wavy bedded sabkha
- Series of marine flooding events. Raised water table and truncated aeolian accumulation (supersurfaces)

Escalante: Data Collection

- Logs (23)
- Fence Panels (13)
- Area: 4.25km*1km

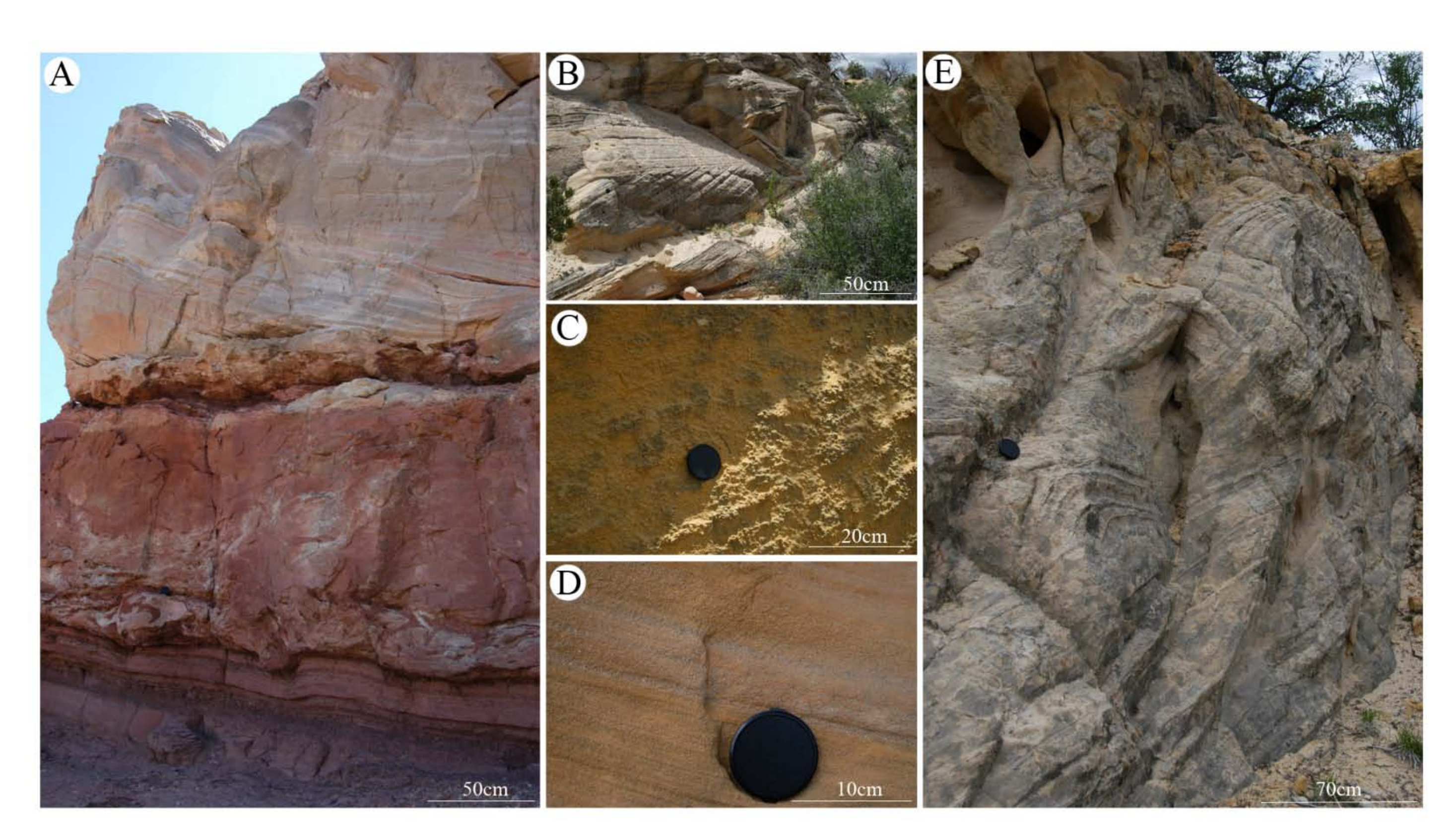


Escalante: Fence Panels



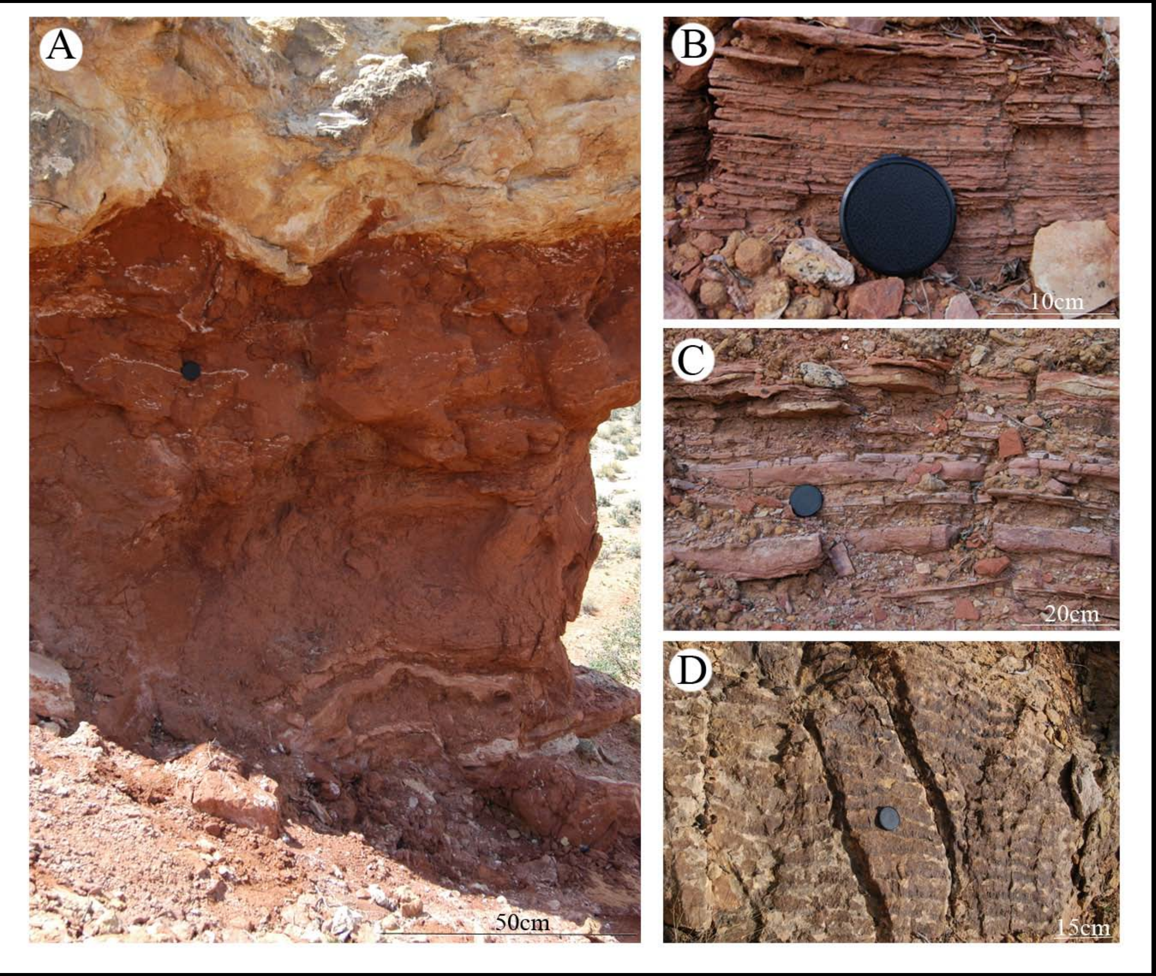
- Facies architecture heterogeneous vertically with less variation laterally

Escalante: Stratigraphic Units



A. Soft sediment deformed sand infilling desiccation cracks on the surface of unit RMS1.
B. Planar cross-beds within FS unit.
C. Diagenesis forming yellow nodules typical of DS unit.
D. Grainfall and grainflow laminae observed within BP.
E. Deposition of unit FS when water table high resulting in soft sediment deformation.

Escalante: Stratigraphic Units



A. Desiccation cracks (unit RMS1) infilled by unit DS.
B. Silty sabkha.
C. Preserved sand beds within sabkha.
D. Wave ripple casts in unit RMS2.

Part 3: Modelling

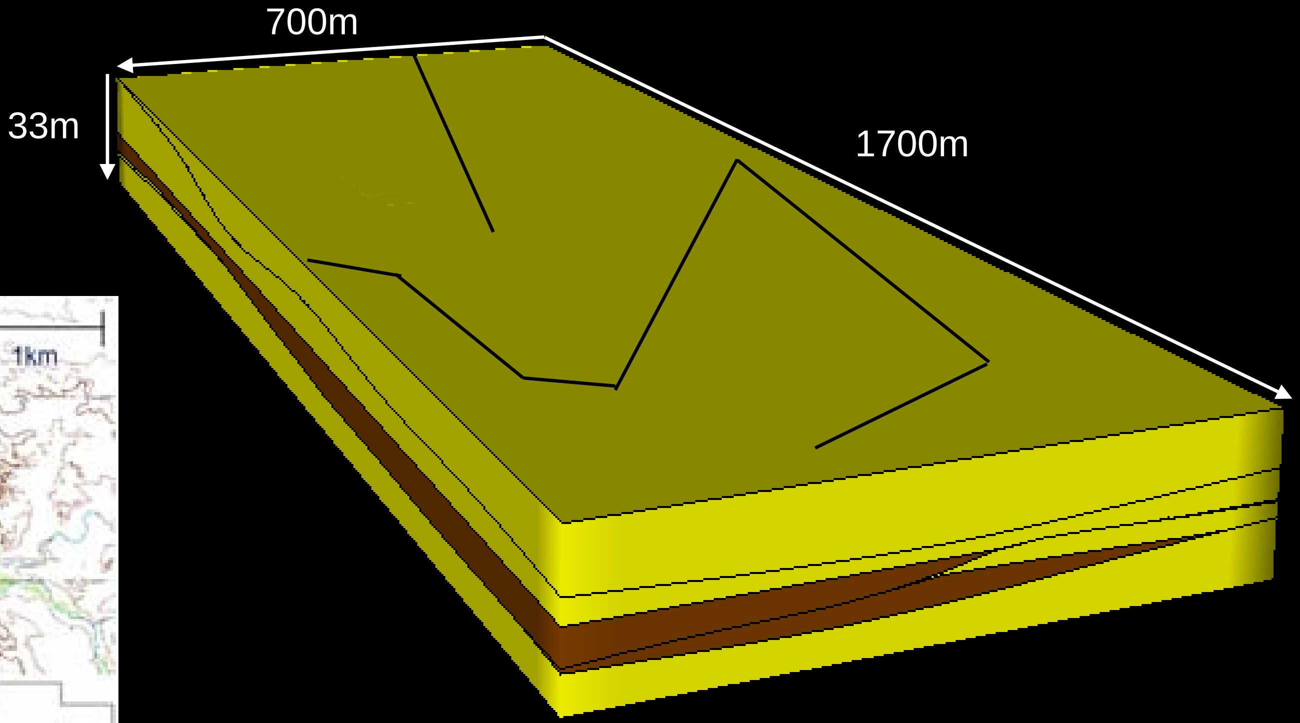
- Construction of 3D geological models directly from outcrop data and quantitative subsurface data

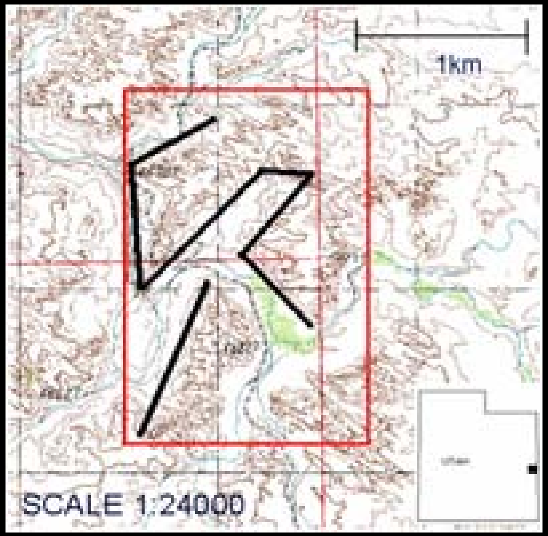
- Initial model construction has involved constructing surfaces that represent individual stratigraphic units

- A stratigraphic surface for each outcrop has been flattened to create a datum surface from which all other surfaces have been measured

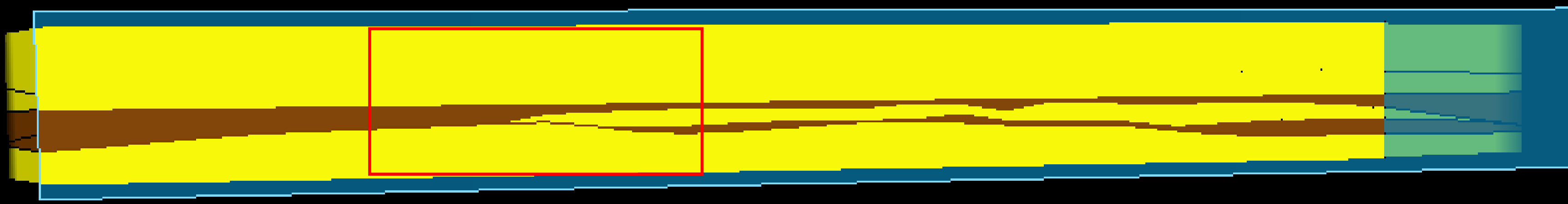
Indian creek

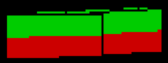
- Outcrop model incorporates six stratigraphic units (MO2 to OH)
- Geometry of bounding surfaces captured
- 3D geological heterogeneity well constrained

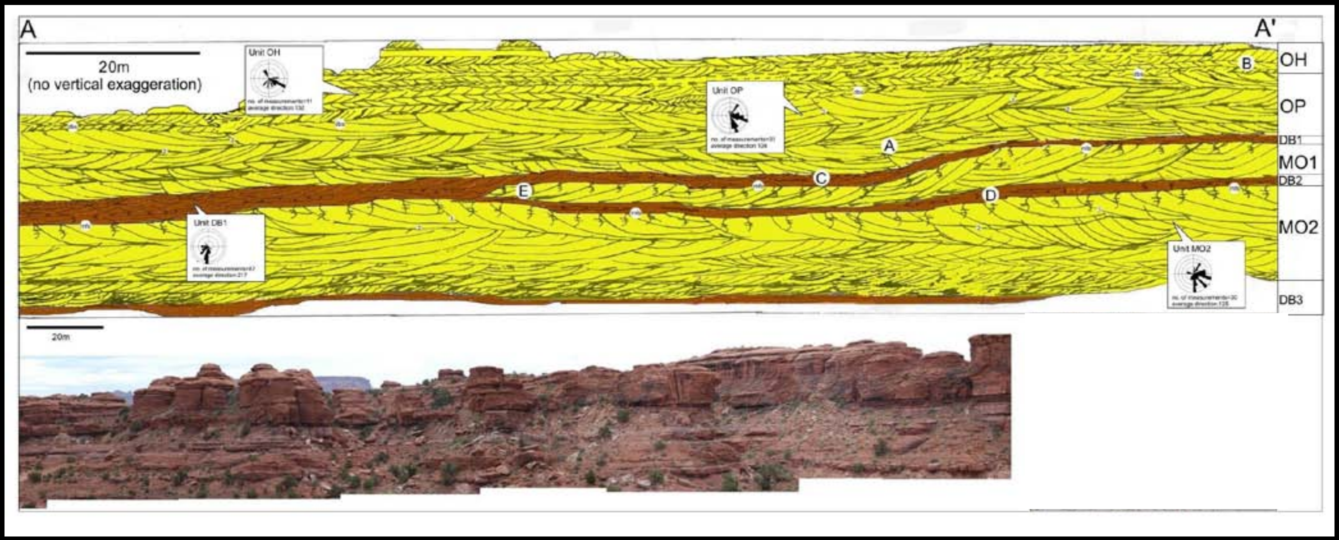


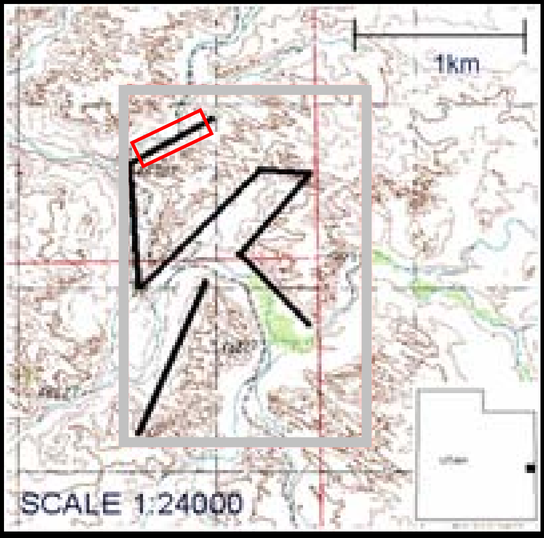


Indian creek



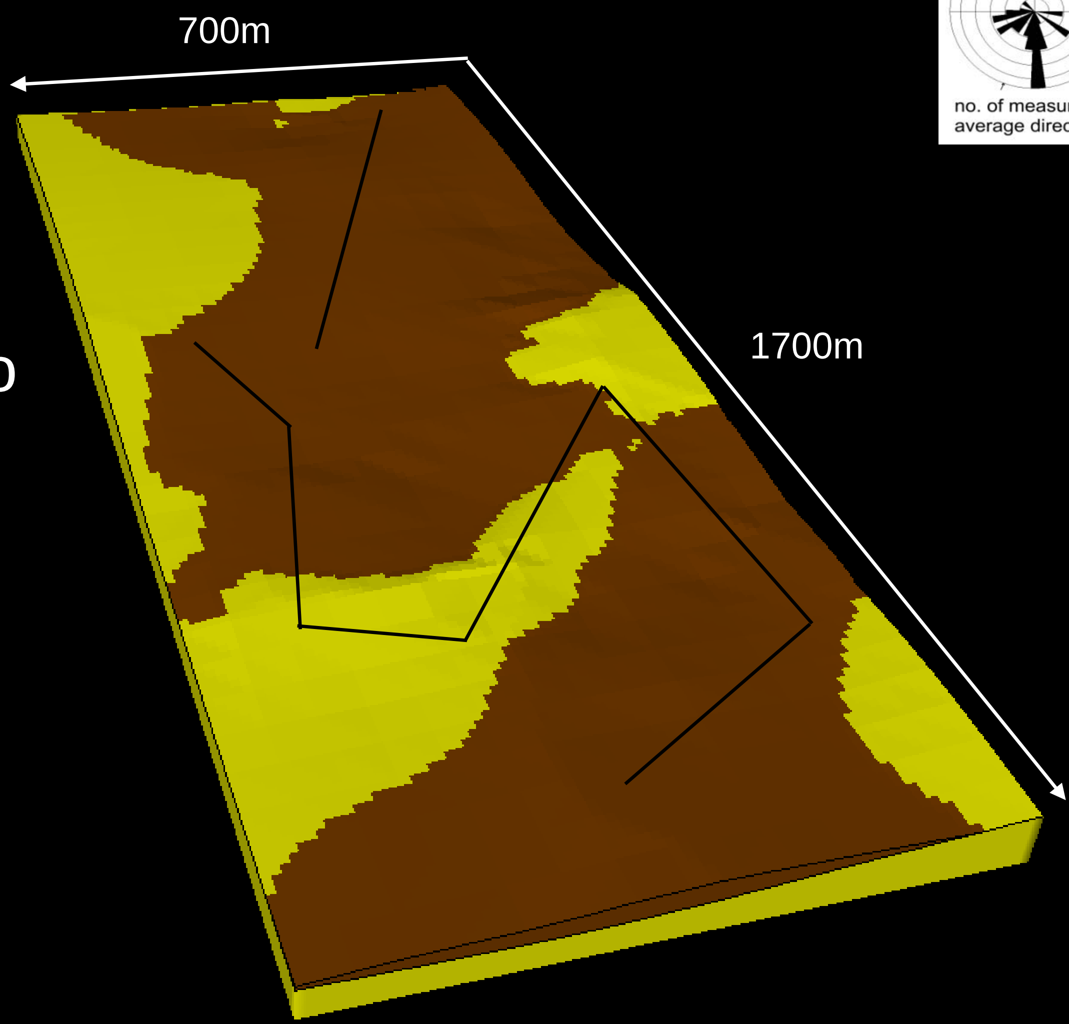


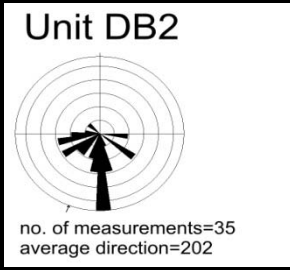


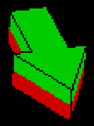


Indian Creek: Interpretation of surfaces

- Fluvial Unit DB2
- Channels flow preferentially through interdune areas and erode into underlying aeolian deposits

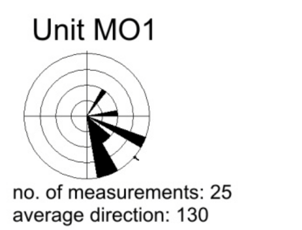


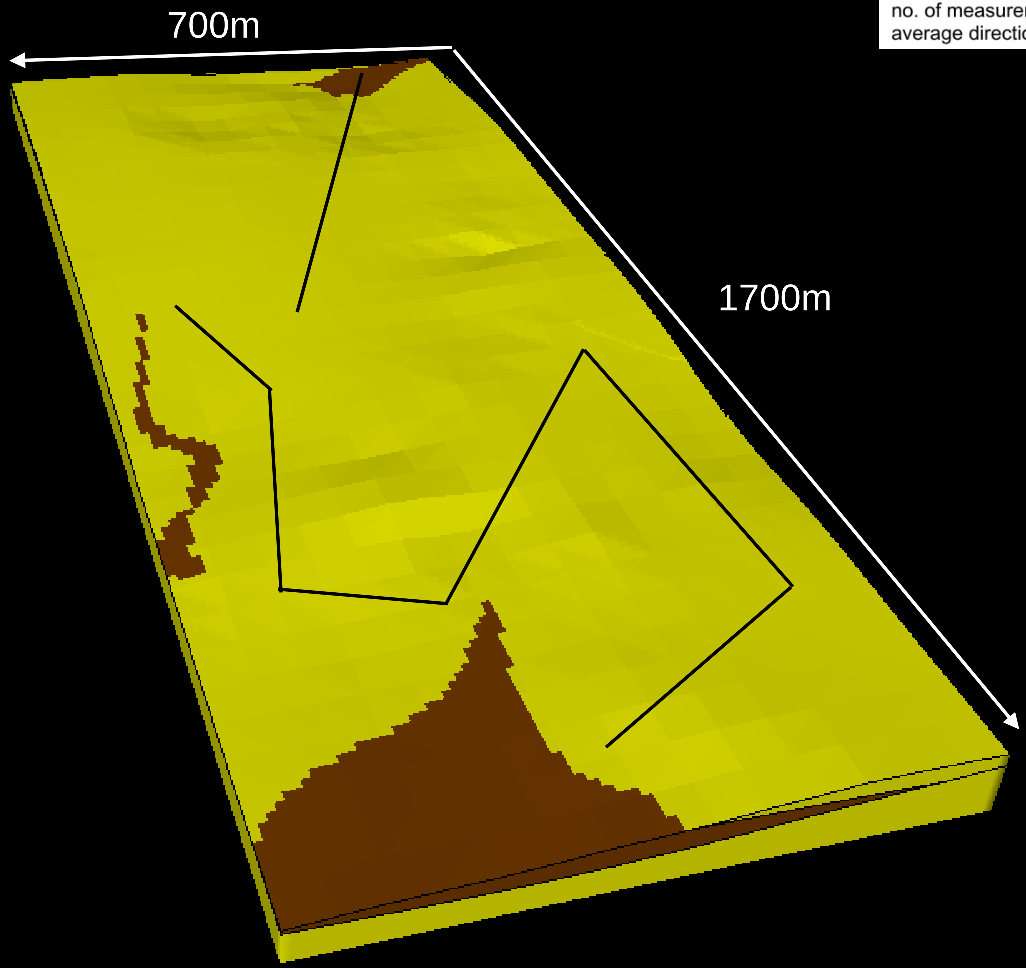


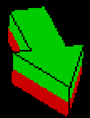


Indian Creek: Interpretation of surfaces

- Aeolian Unit MO1
- Pinch outs where fluvial channels have eroded

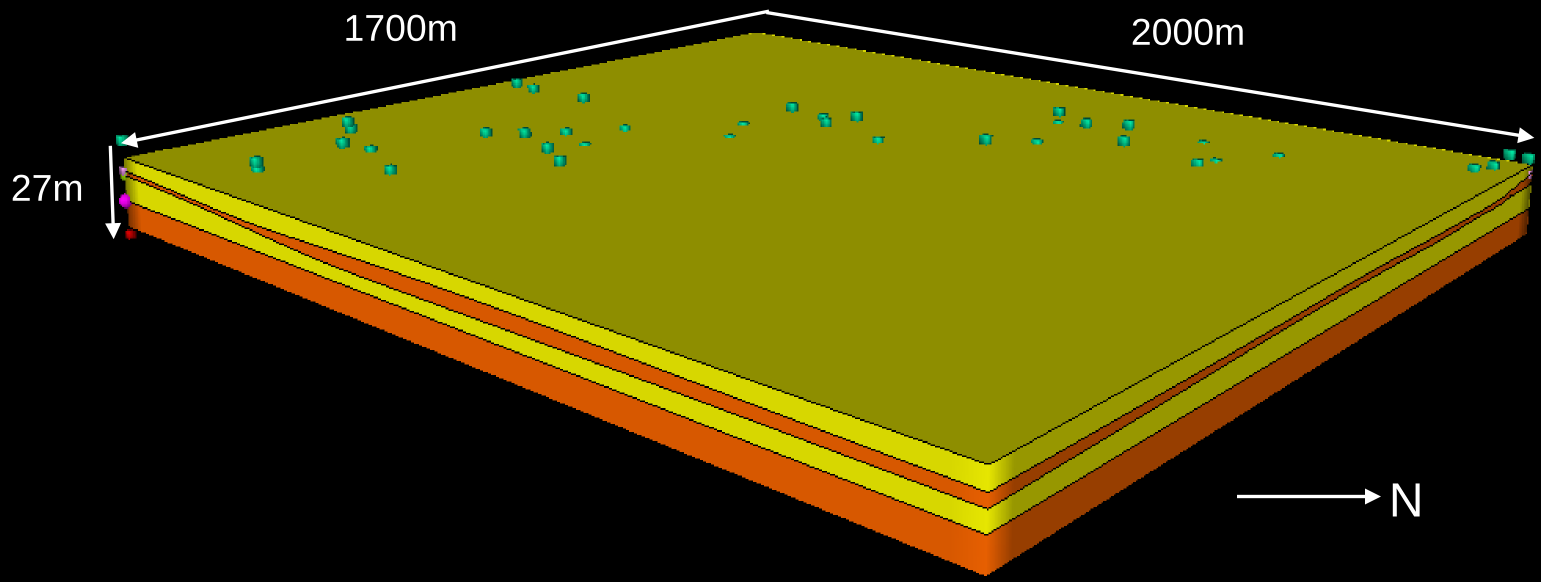




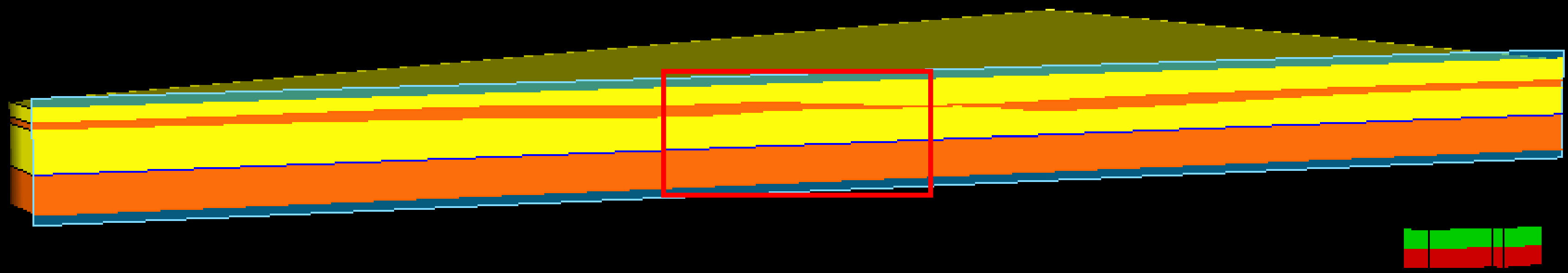


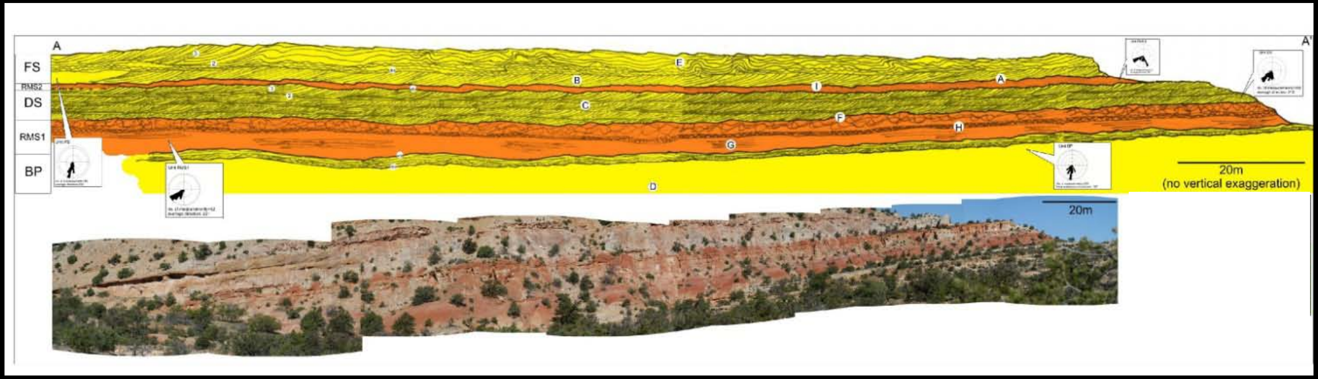
Escalante

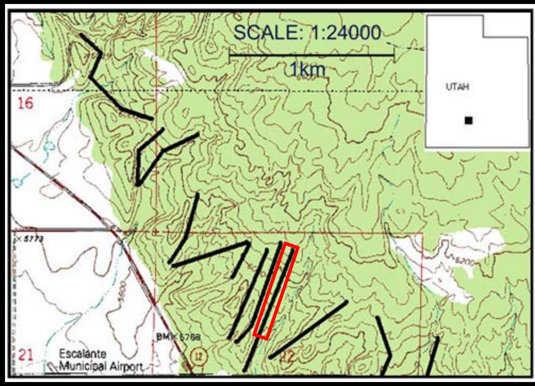
- Outcrop model appears "layercake"
- Aeolian and sabkha facies associations occur across the extent of the model with no pinchouts and little thickness variation



Escalante



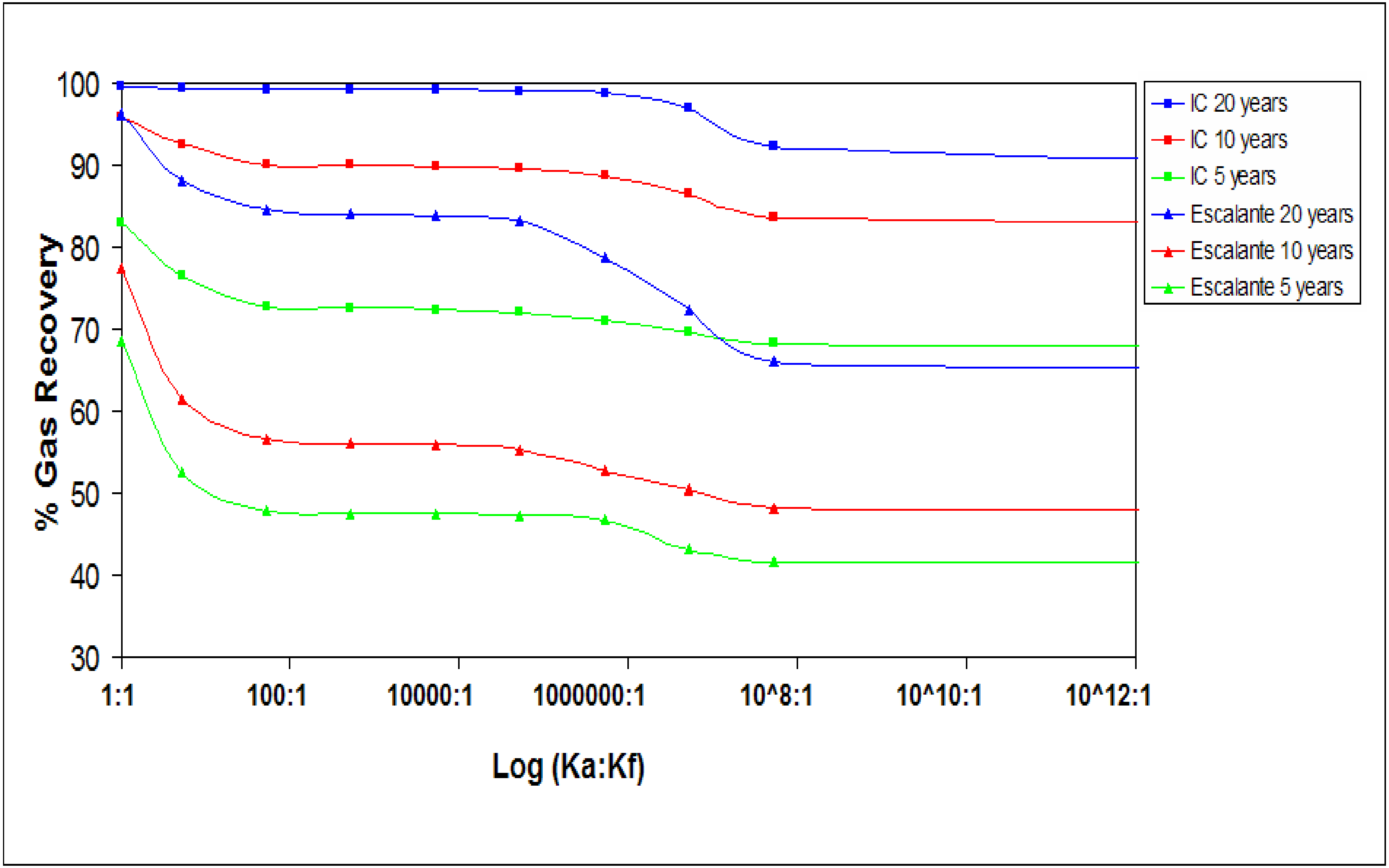

A
A'
FS
RMS2
DS
RMS1
BP
20m
(no vertical exaggeration)
20m


SCALE: 1:24000
1km
UTAH
16
21
22
Escalante
Municipal Airport
BM 5768

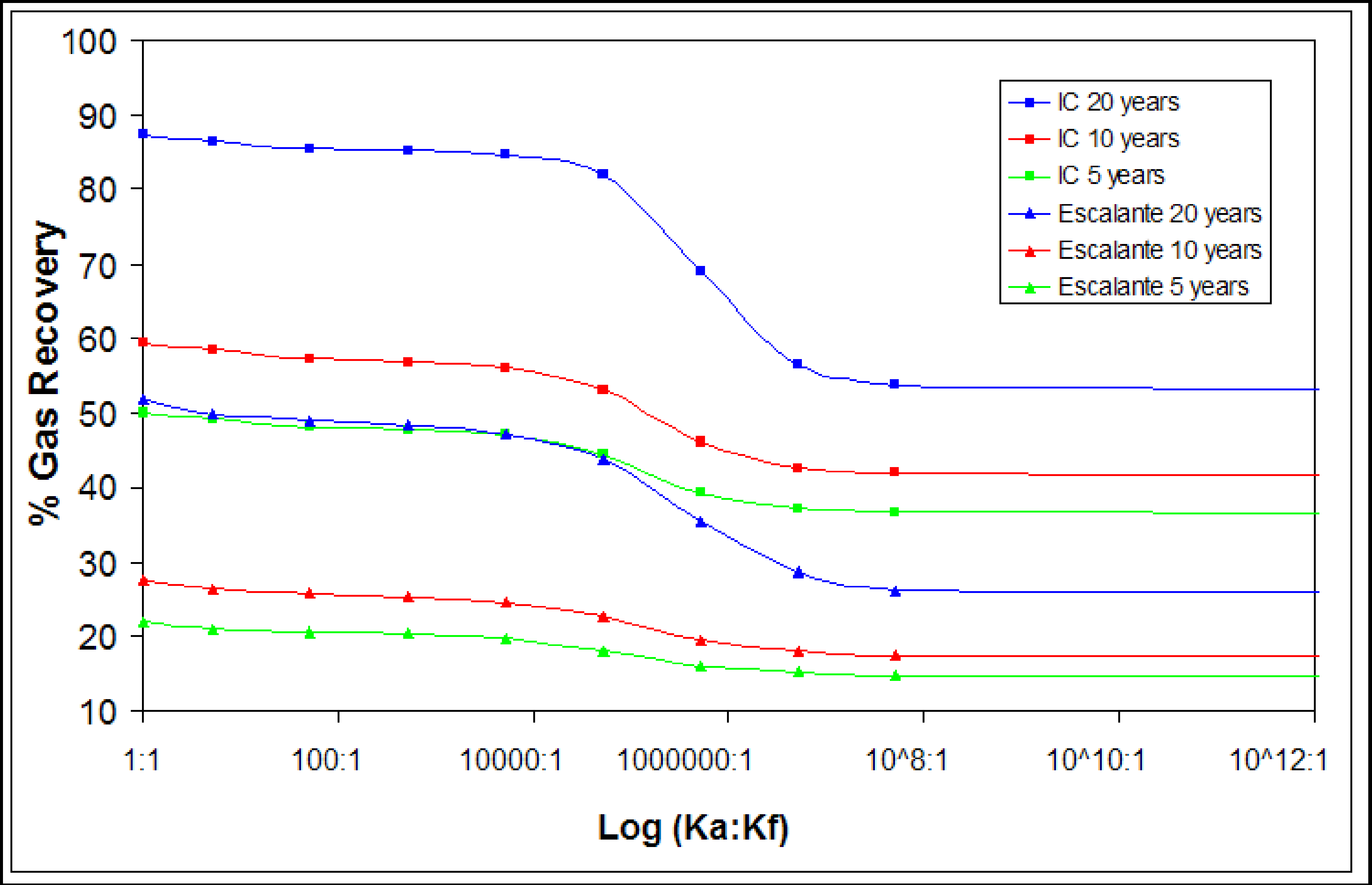
Model Summary

- Aeolian, fluvial and sabkha stratigraphic units have been modelled; capture key geometries
- Extrapolation between data points has been based on geological interpretation of the environment at the time of deposition
- Aeolian dune forms can be identified
- Fluvial units show channel forms which pass erosively through predominantly interdune areas of the underlying aeolian units
- Pinch-outs across the area can be seen where aeolian units have been eroded by fluvial channels
- Sabkha deposits are seen to be extensive laterally over the study area

Simulations: Vertical Well



Simulations: Horizontal Well



Summary

- Quantitative data from marginal aeolian outcrop analogues have been collected to investigate facies architecture

- Vertical and lateral heterogeneity observed within the two marginal aeolian settings has been modelled in 3D

- 3D models provide an improved understanding of the effect of heterogeneity within marginal reservoirs

Subsurface Applications for Industry

- Dimensions from these outcrop analogues have been incorporated into a model of an active reservoir within the UK SNS

- The updated geological model has been simulated in order to match it to observed production data

- Outcrop derived data provides better match for production data

References

Blakey, R.C., et al., Studies of Middle Jurassic Page Sandstone: Web. http://jan.ucc.nau.edu/~rcb7/Page.html Accessed 10-02-2008.

Mountney, N.P., and A. Jagger, 2004, Stratigraphic evolution of an erg margin aeolian system: The Permian Cedar Mesa Sandstone, SE Utah, USA: Sedimentology, v. 51, p.713-743. doi:10.1111/j.1365-3091.2004.00646.x

Ziegler, A.M., 1990, Phytogeographic patterns and continental configurations during the Permian period, *in* McKerrow, W.S., and C.R. Scotese, eds., Palaeozoic Palaeogeography and Biogeography: Geological Society (London) Memoir 12, p. 363-377.