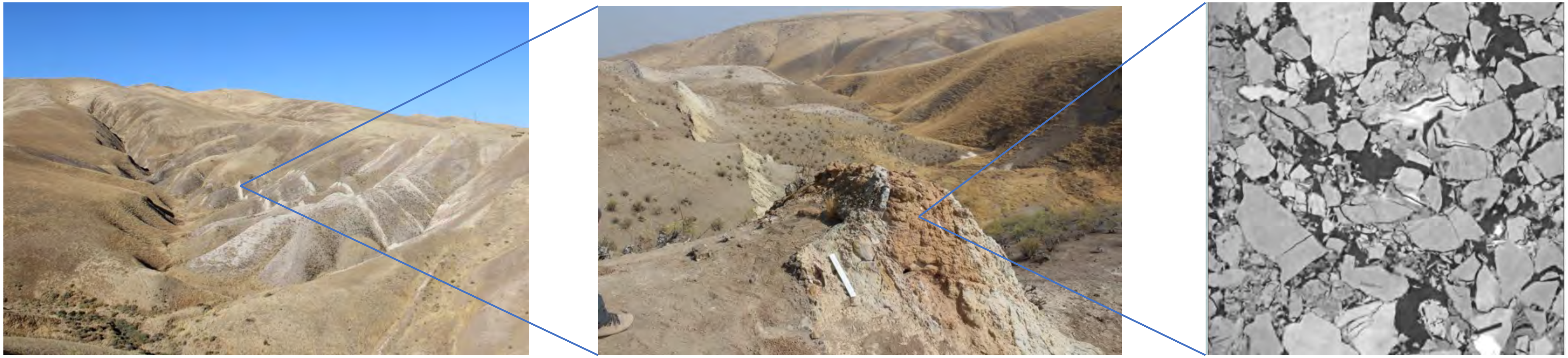
Ocean and Earth Science,
National Oceanography Centre
Southampton

STEMM-CCS

Underground CO_2 Storage Assurance

The Assessment of Onshore Geological Analogues of Fluid-Escape Structures

Ben Callow



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University of Southampton

Thank you to the 'CCUS' Research Community

- STEMM-CCS
- CHIMNEY
- CarbFix
- ACT-DETECT
- GAS-RIP

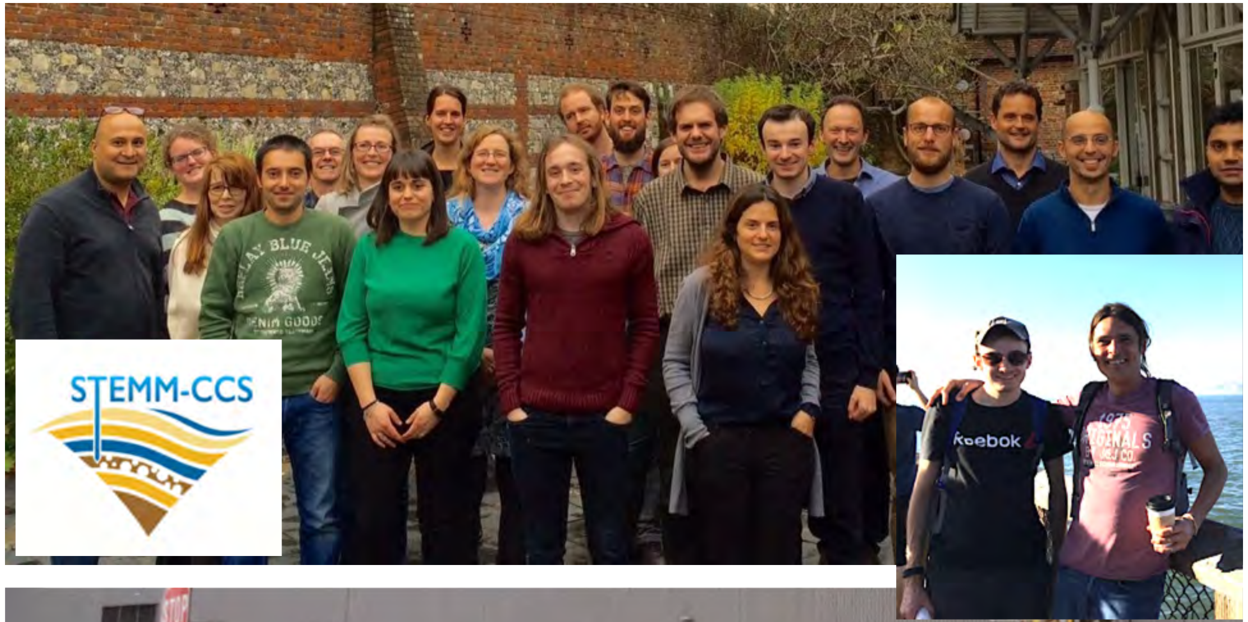
- IEAGHG
- UKCCSRC
- SIRG

DETECT
INTEGRATED GEOLOGICAL CO_2 LEAKAGE RISK ASSESSMENT

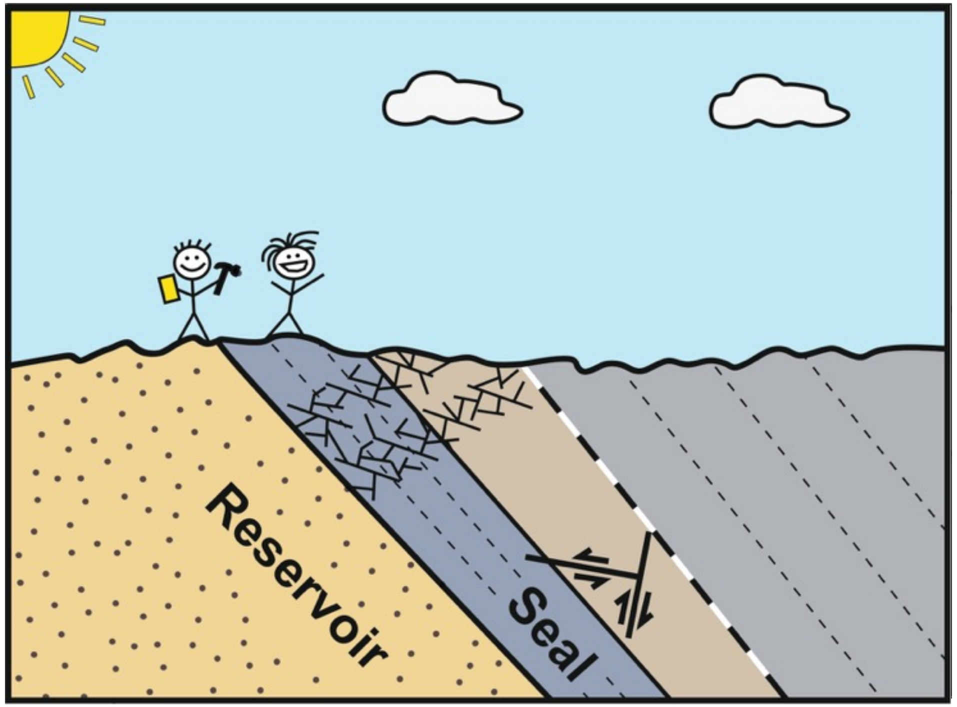
carbfix

GAS RIP
Geomechanical Assessment of CO_2 Storage Reservoir Integrity Post-closure

SIRG
Sand Injection Research Group

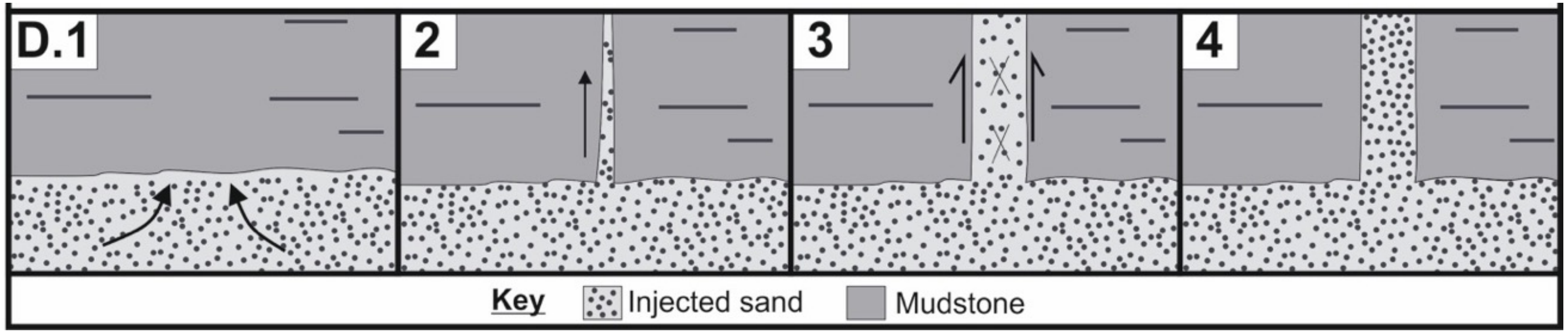


OVERVIEW: CO_2 LEAKAGE PATHWAYS IN THE SUBSURFACE:

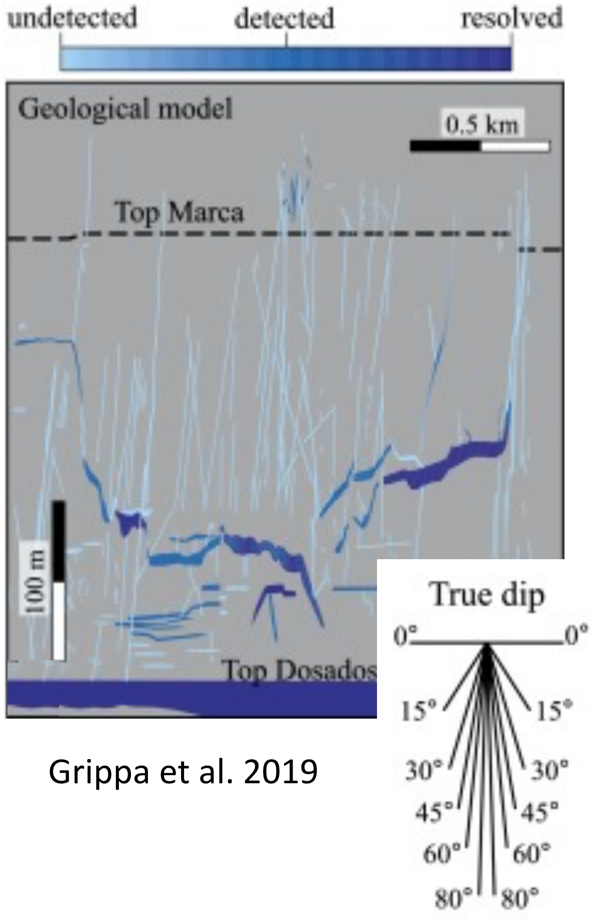


1. Faults
2. Drilling wells
3. Fluid-escape structures:
   - Sandstone intrusions
   - Seep structures

Fluid-escape structures currently poorly understood…



Adapted from Cobain et al. 2015



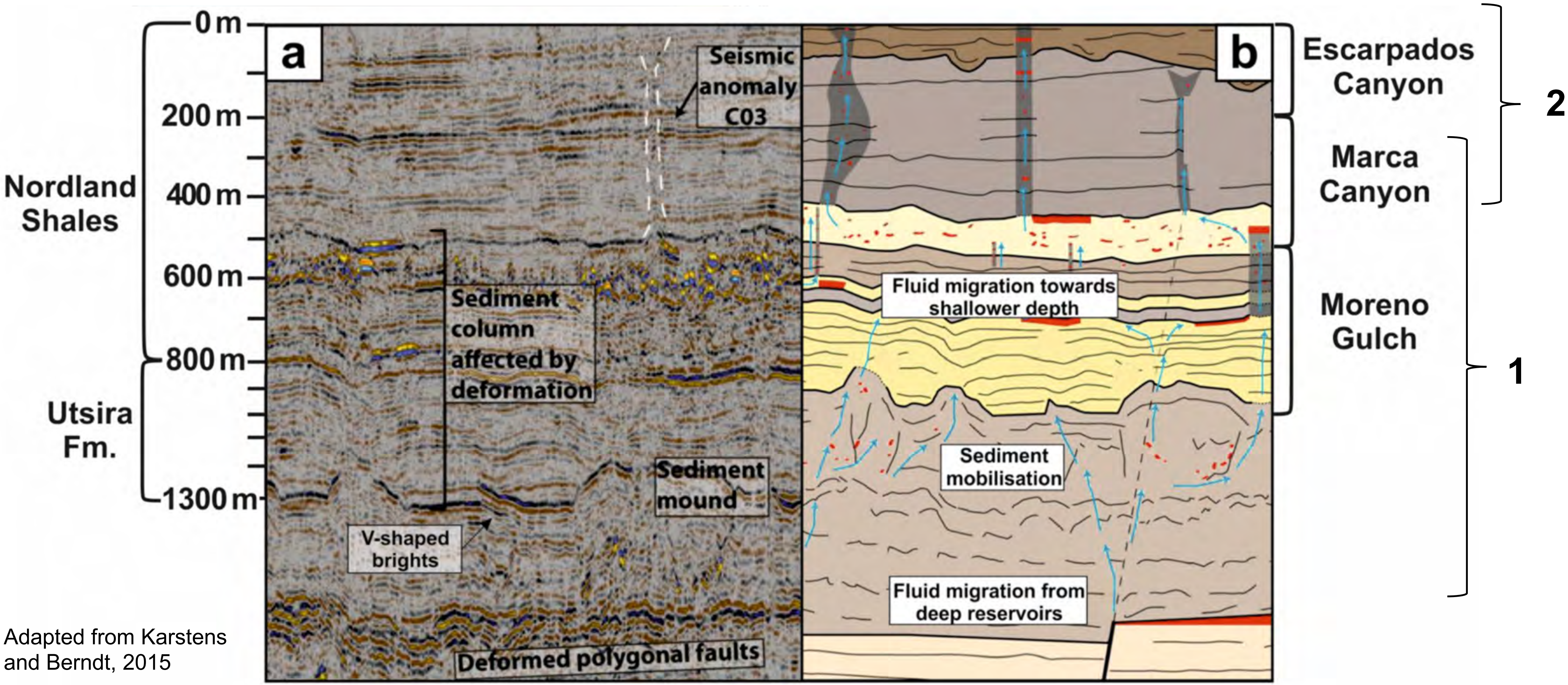
Grippa et al. 2019

Sub-vertical structures are difficult to image using seismic reflection

AIMS & OBJECTIVES

1. Highlight the geographical abundance of fluid-escape systems observed in the North Sea.
2. Description of fieldwork in the Panoche Hills, California – An onshore geological analogue of fluid-escape.
3. Quantify the temporal evolution of porosity-permeability - From when active fluid flow was occurring, to present day.
4. Implications for safe and permanent CO_2 storage

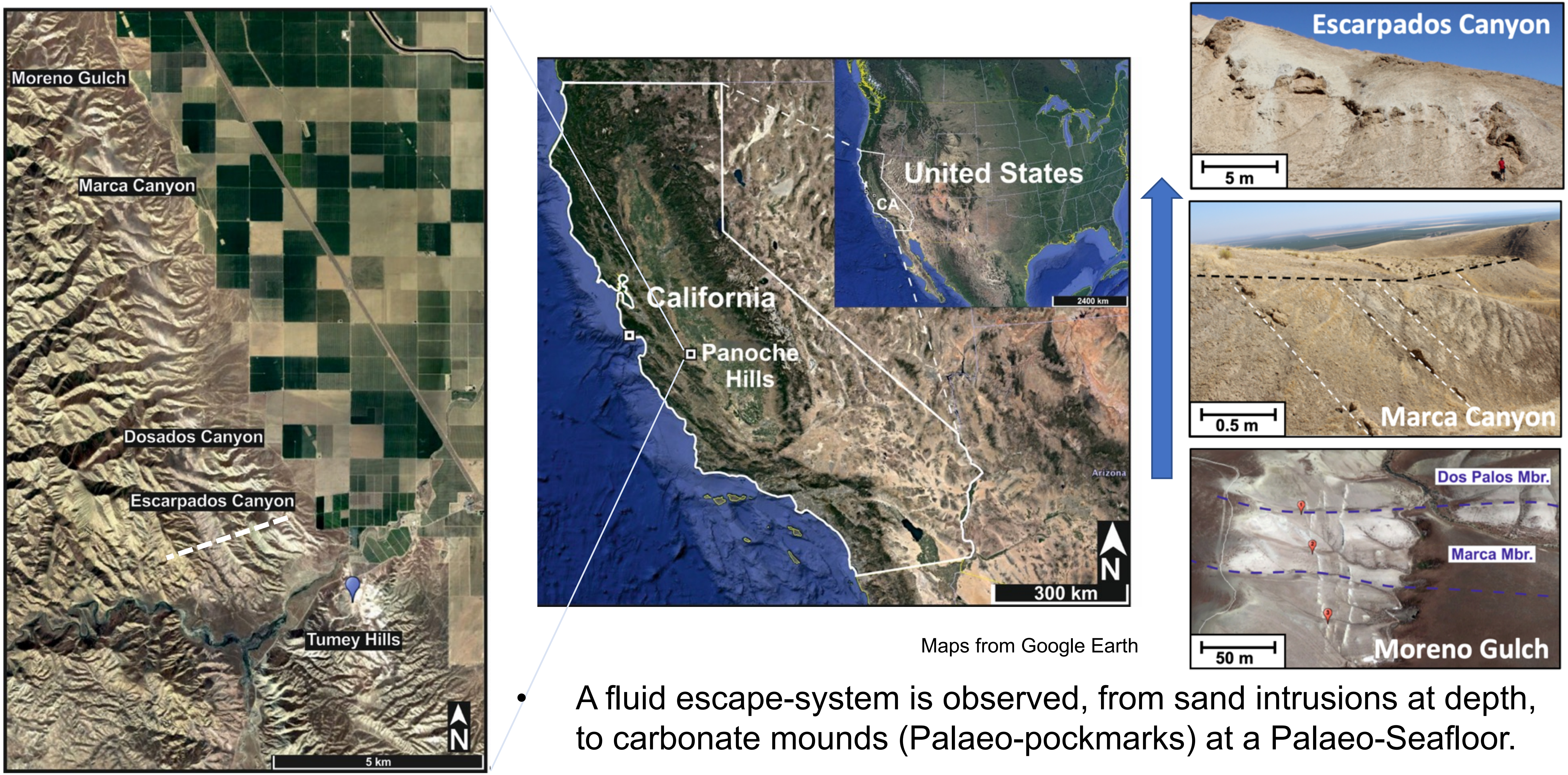
FLUID-ESCAPE SYSTEMS IN THE NORTH SEA



Adapted from Karstens and Berndt, 2015

1. Sediment remobilisation at depth
2. Seep structures in the shallow sub-surface

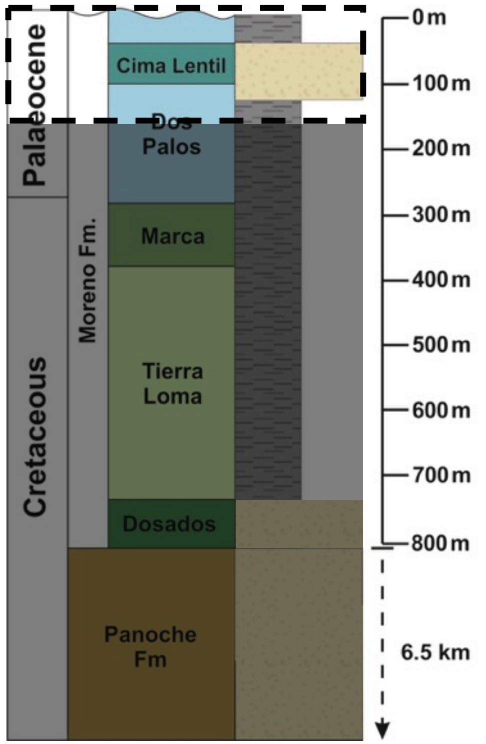
FLUID-ESCAPE SYSTEM



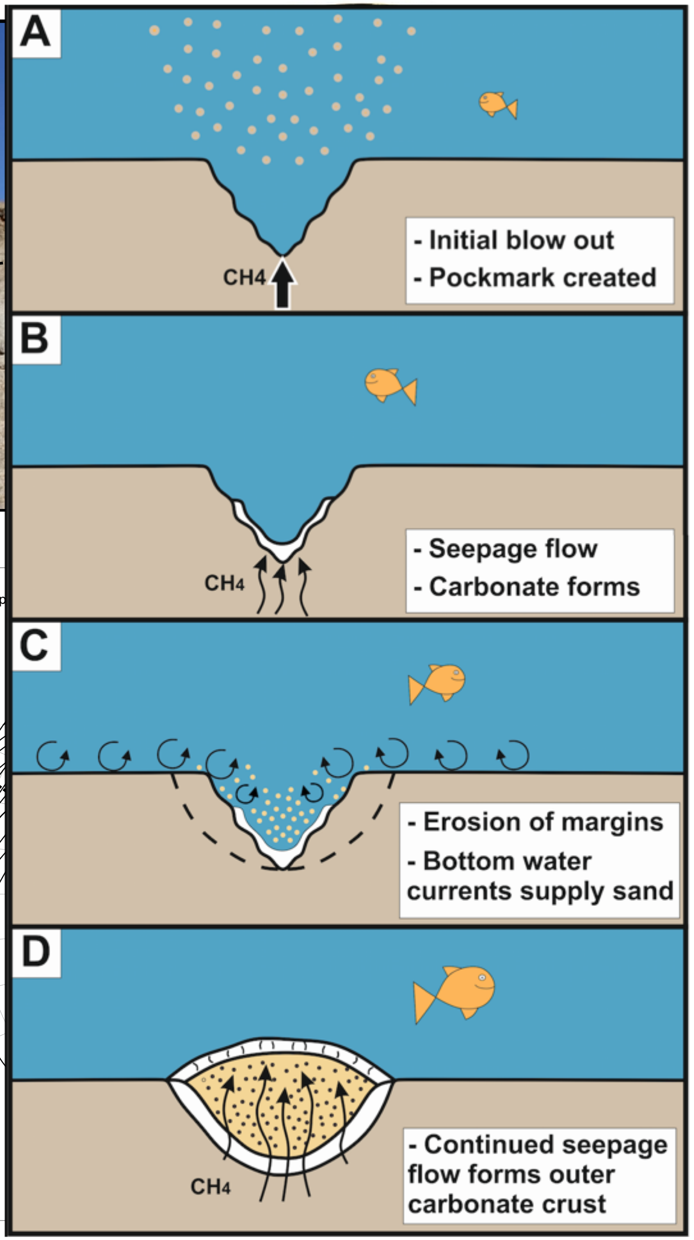
Maps from Google Earth

- A fluid escape-system is observed, from sand intrusions at depth, to carbonate mounds (Palaeo-pockmarks) at a Palaeo-Seafloor.

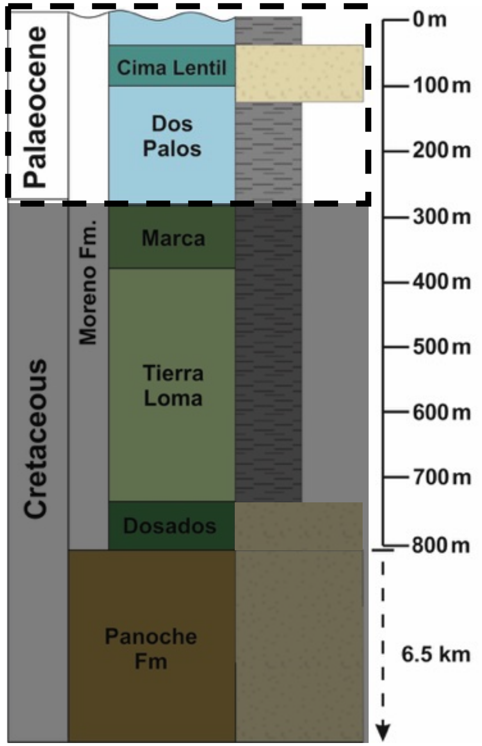
ESCARPADOS CANYON

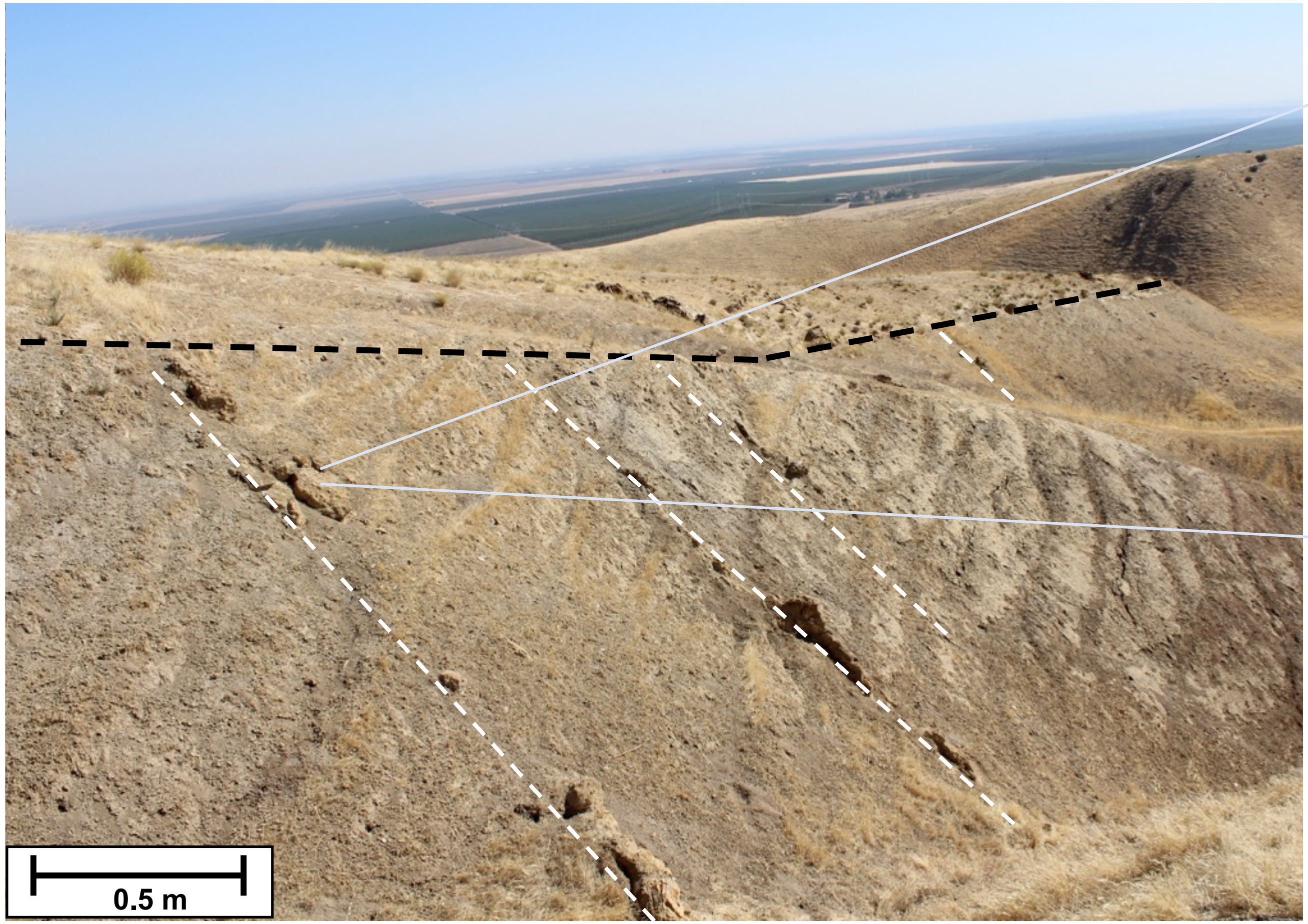


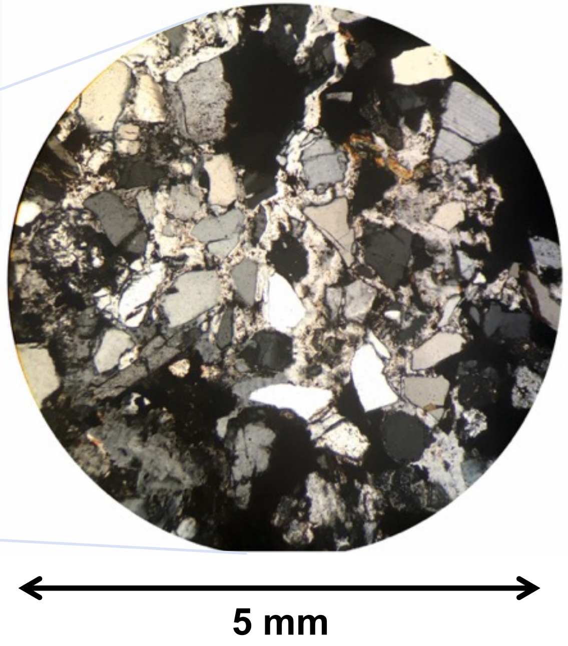
- Carbonate mounds used to be along one main horizon.
- Represents the Palaeo-seafloor
- Carbonates have formed from oxidation of methane at the seafloor
- Interpreted as Palaeo-pockmarks



MARCA CANYON

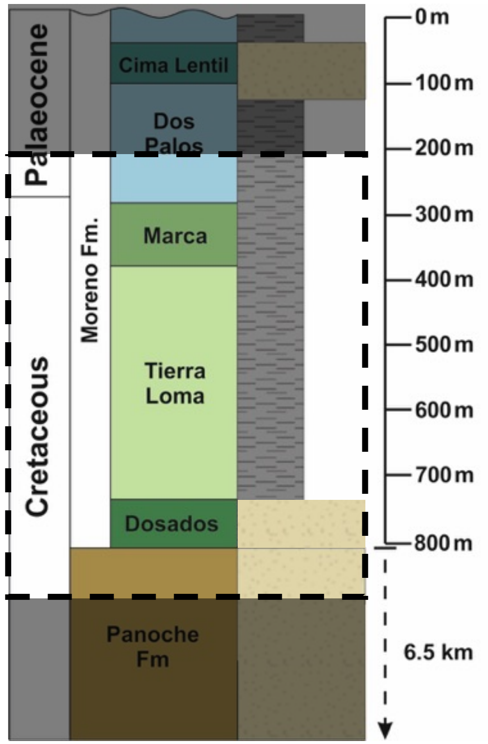


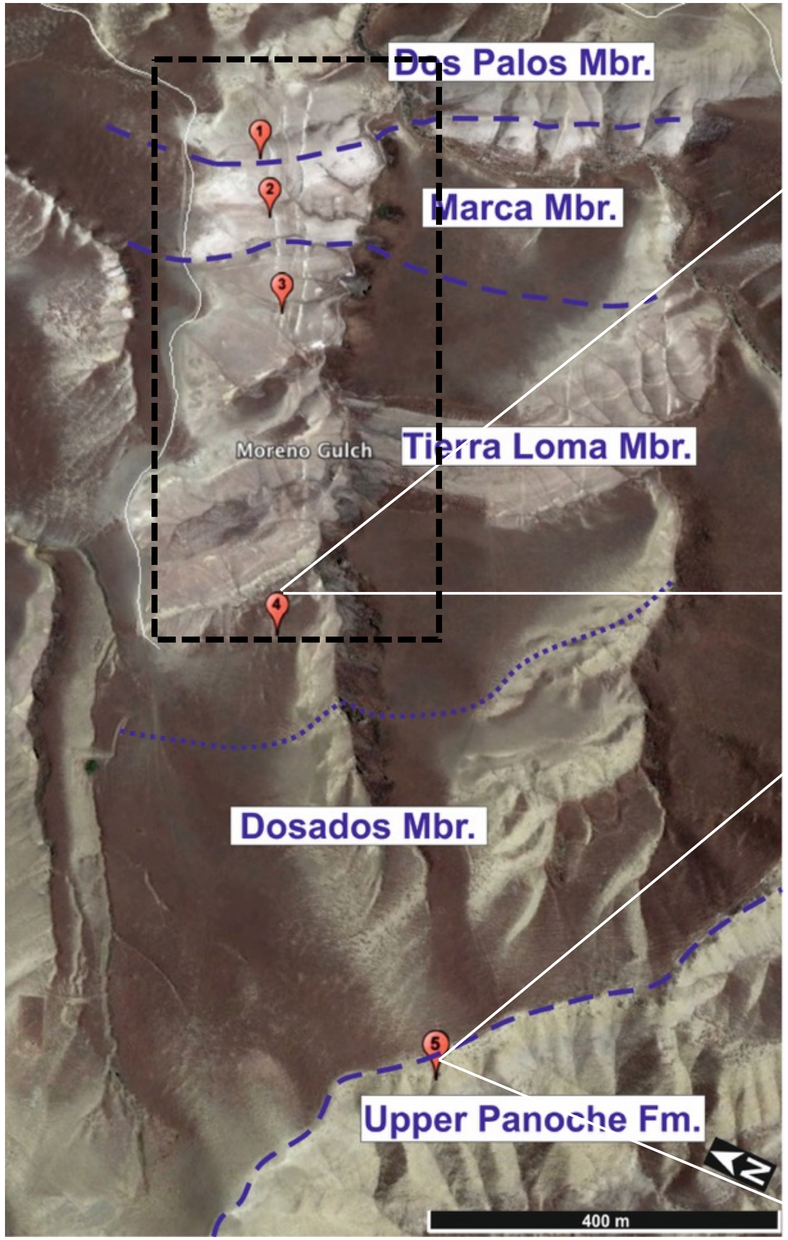




- Sandstone dykes intruding and terminating at carbonate mounds – Seep carbonates.
- Dykes are carbonate cemented – Carbonate reduces porosity-permeability.

MORENO GULCH

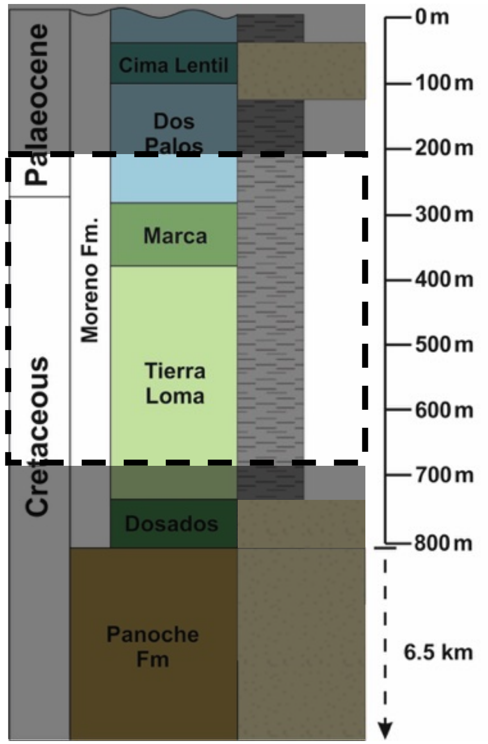




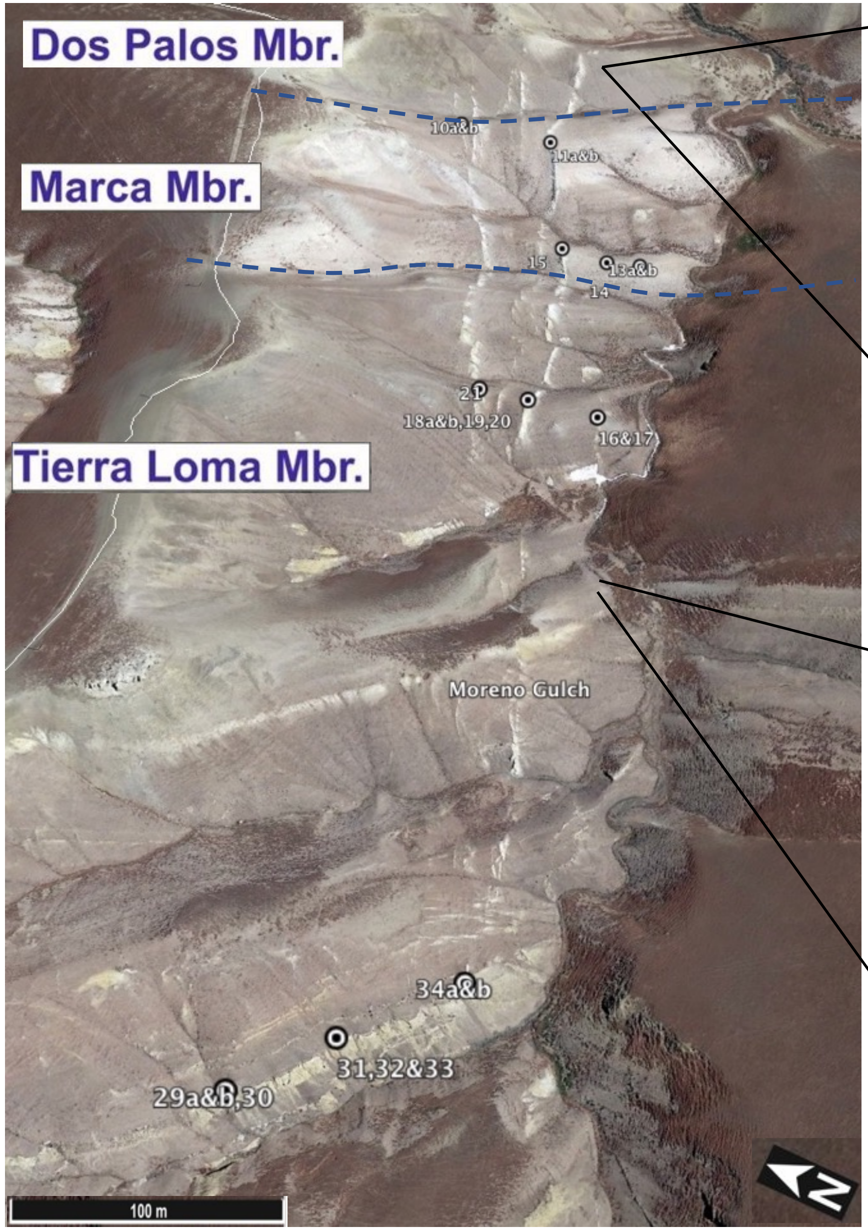
- Sandstone sills are orientated parallel to mudstone beds

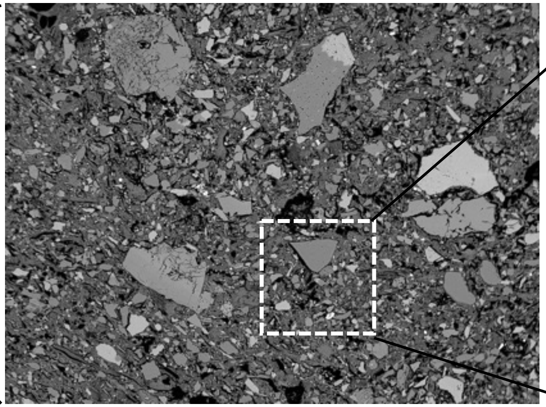
- The sand intrusions are sourced from older depositional sand units

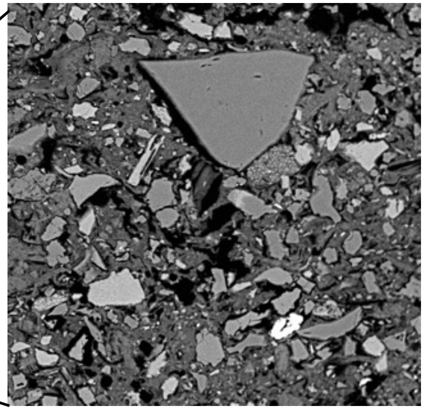
MORENO GULCH



- 600 m of vertical exposure
- Sandstone dyke intrusions orientated perpendicular to bedding.

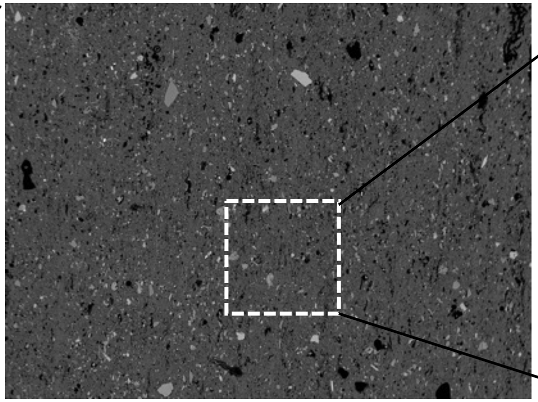


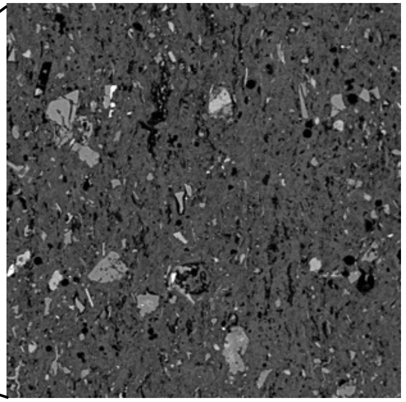




1.5 mm

- Siltstone – Upper slope / shelf-edge facies

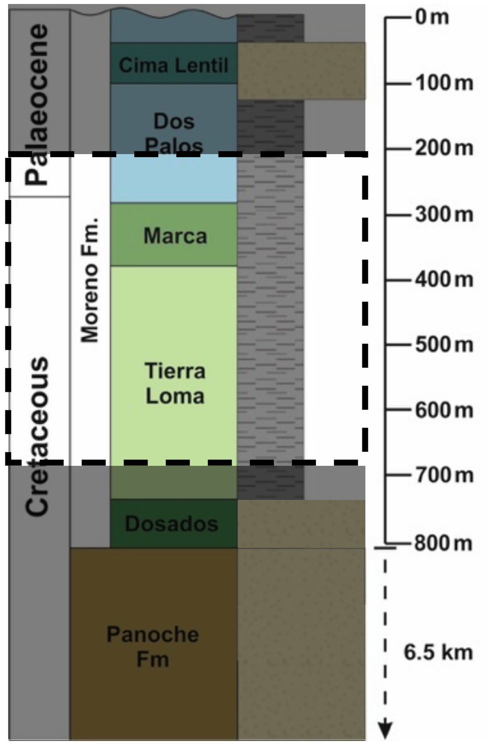


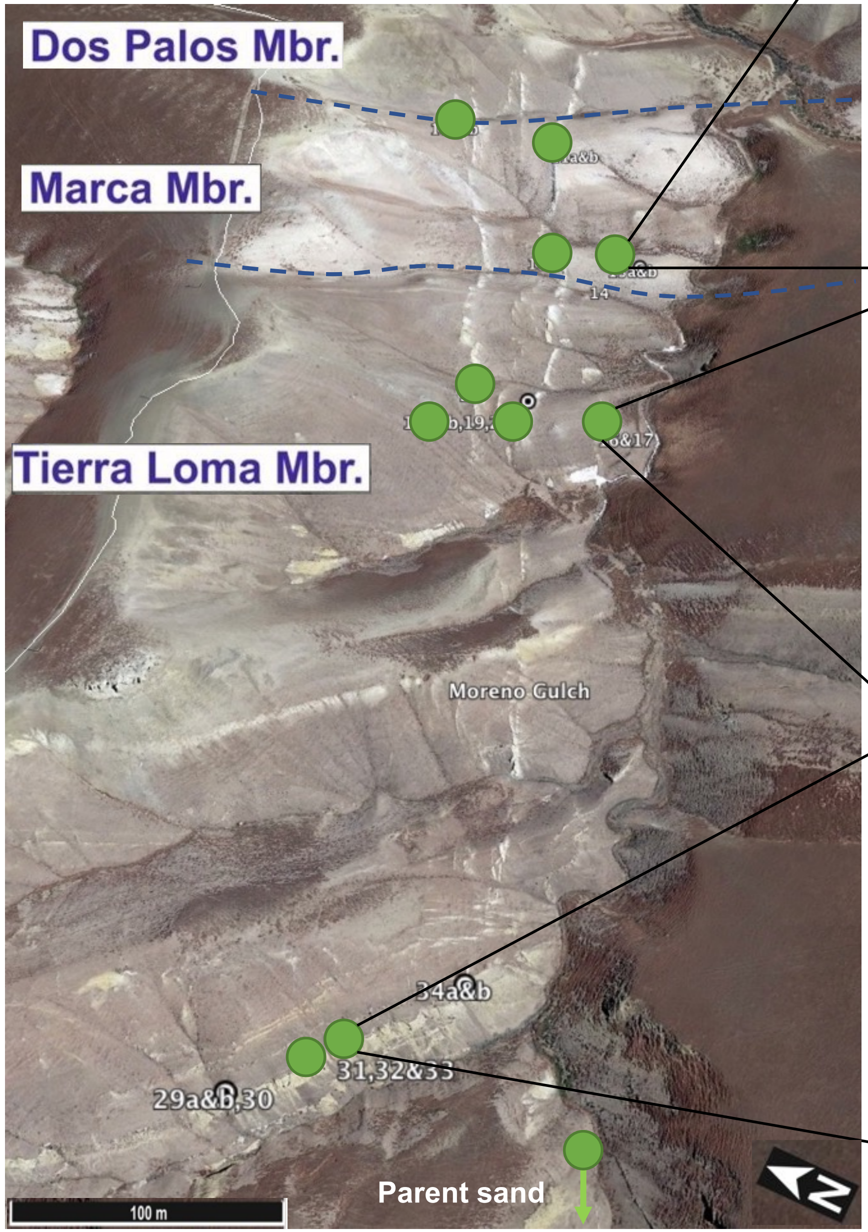


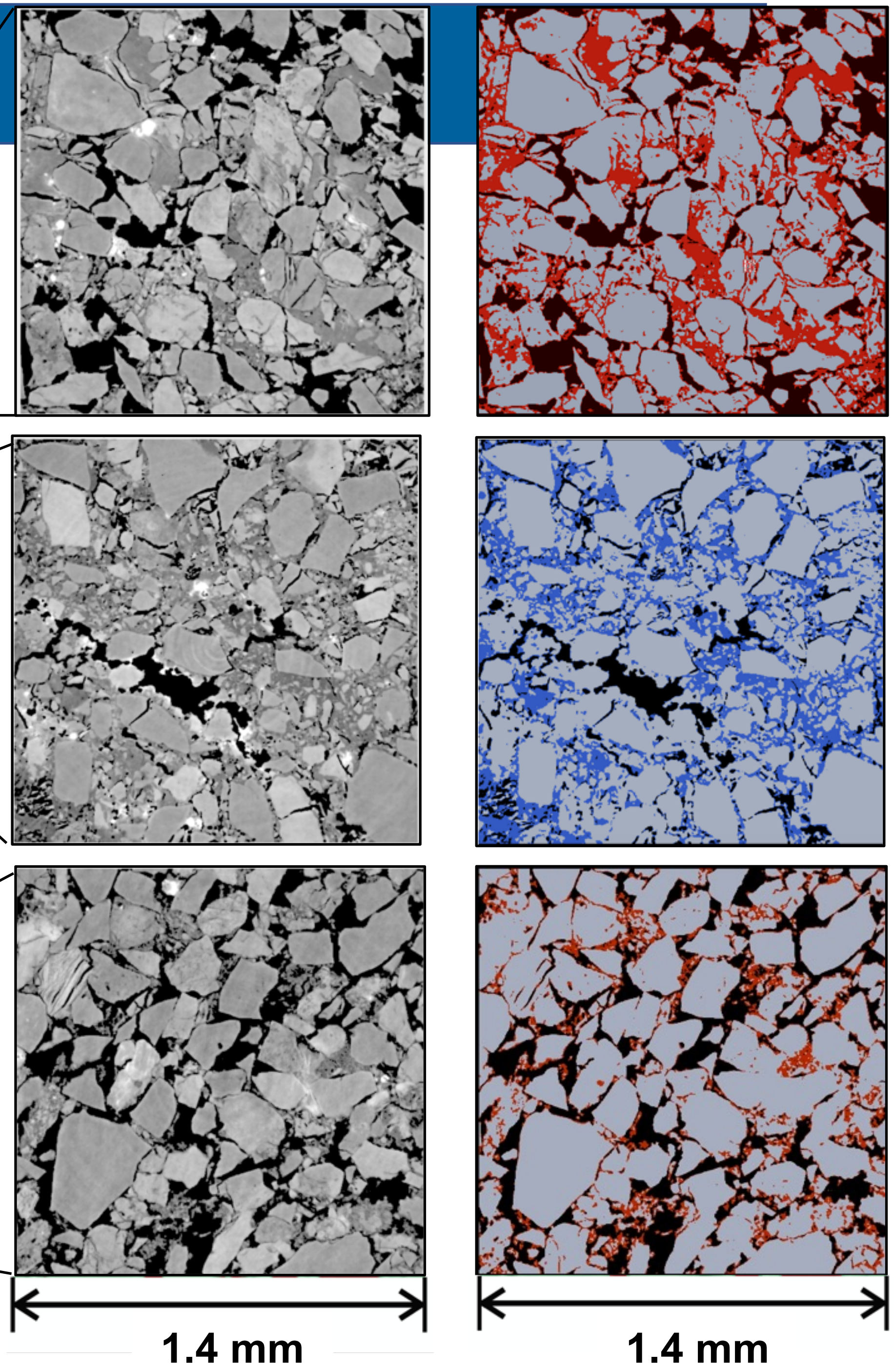
1.5 mm

- Siliceous mudstone – Lower-mid slope facies

MORENO GULCH

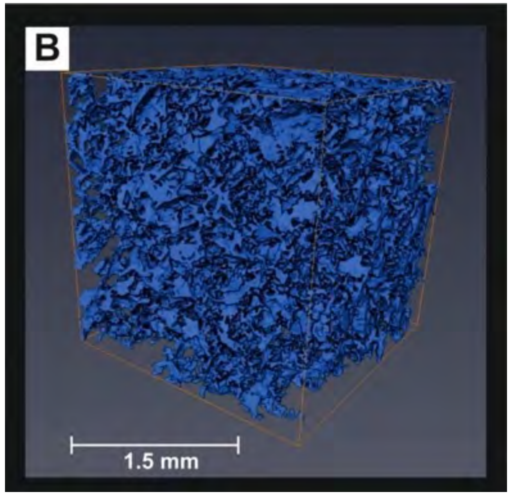


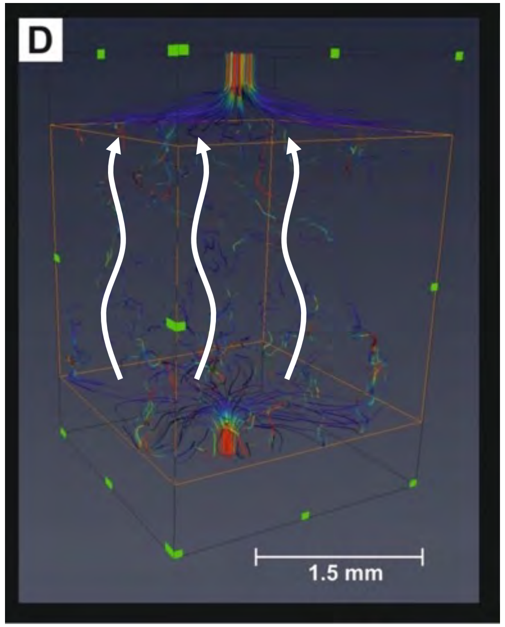


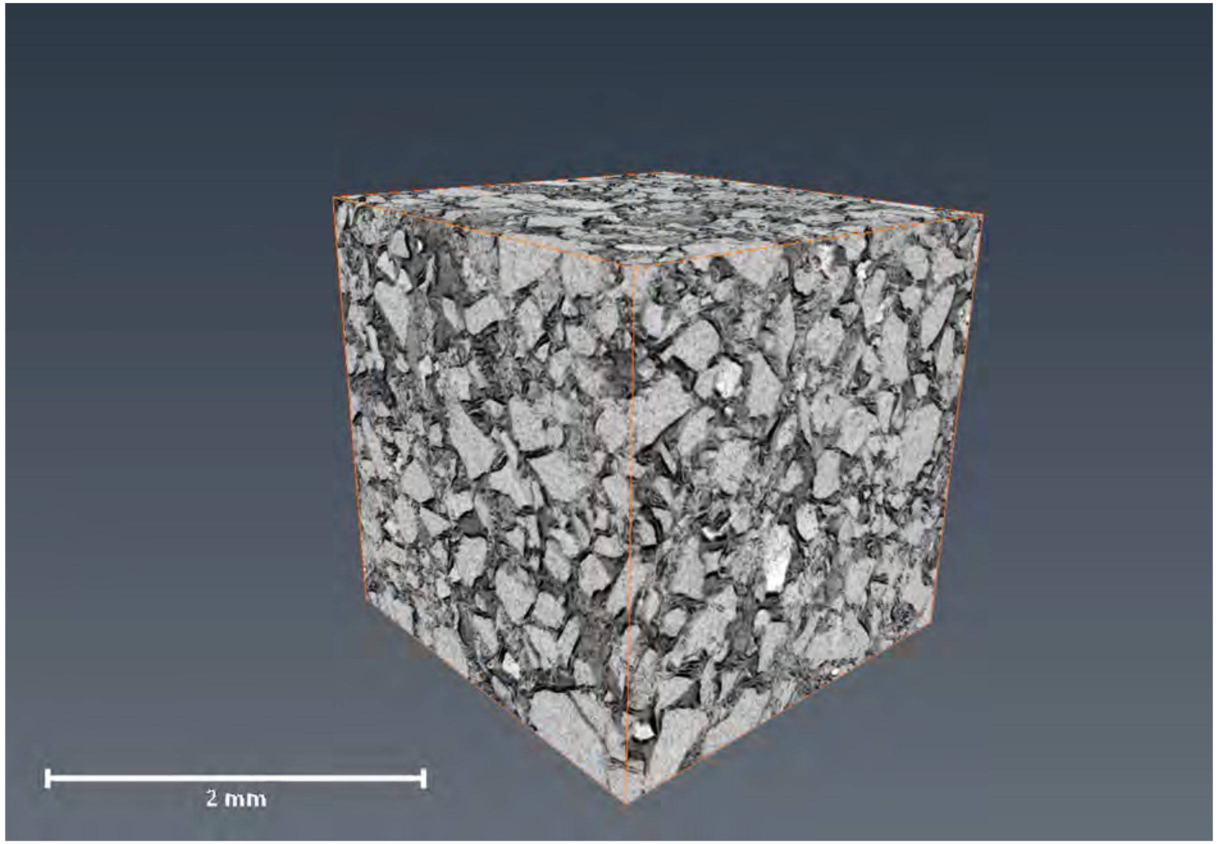


- Samples collected at a range of stratigraphic depths.
- Silica cement derived from host mudstones.

METHOD – 3D X-RAY MICRO-CT

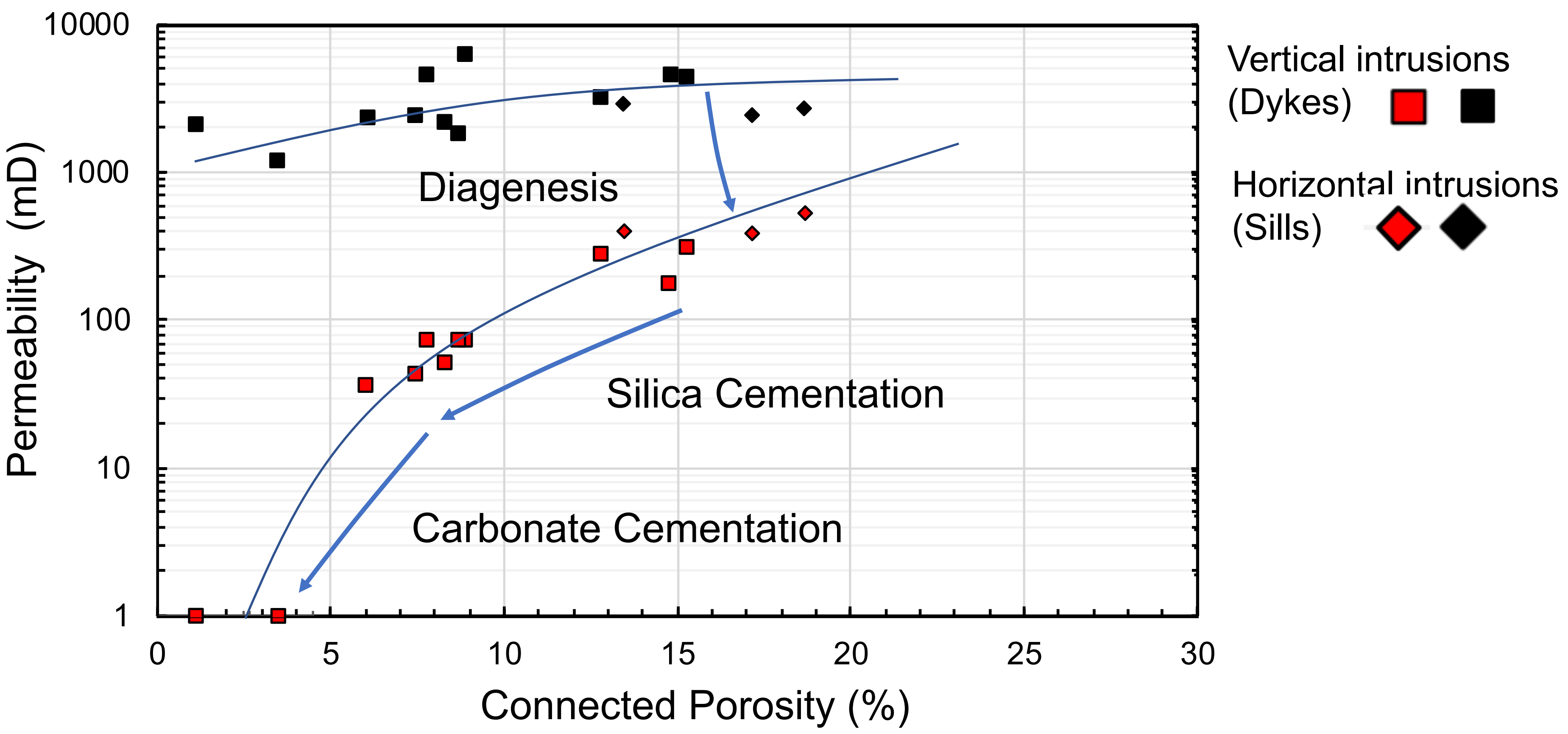


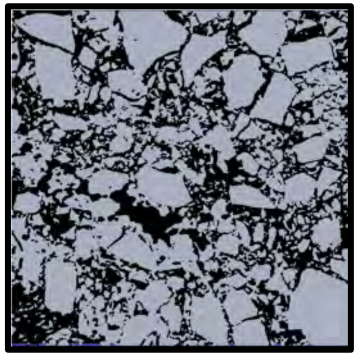




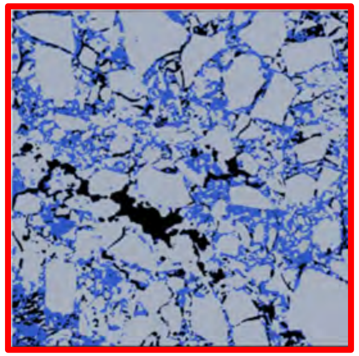
- Absolute permeability simulation
- Callow et al. 2020 – '*Optimal X-ray micro-CT image based methods for quantification of porosity and permeability in sandstone*' – in review (GJI)

RESULTS – POROSITY-PERMEABILITY

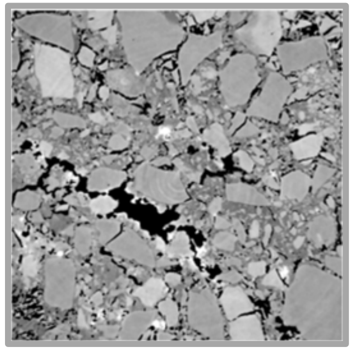




Cement & Clay Removed



Silica cementation



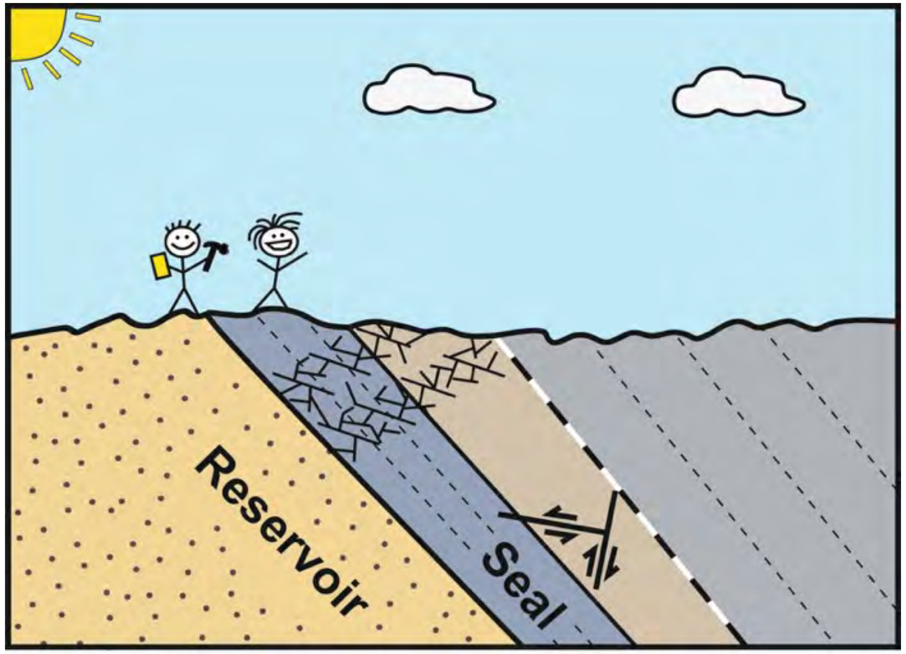
- Average permeability of sand intrusions from Alba & Balder fields ~2400 mD
- The effects of sediment consolidation and cementation must be considered…

CONCLUSIONS

1. Fluid-escape systems are widely observed in the North Sea. Analogues are used to improve our understanding.
2. Porosity-Permeability of fluid-escape systems are significantly effected by silica and carbonate (MDAC) cementation.
3. Constraining the presence and timing of cementation is crucial for accurate site characterisation and risk evaluation.
4. Fluid pathways appear to reduce in permeability and re-seal through time, which has positive implications for long-term safe and permanent CO_2 storage.

Take home message

"Geological analogues can be used to improve our understanding of the formation and permeability of fluid-escape structures"



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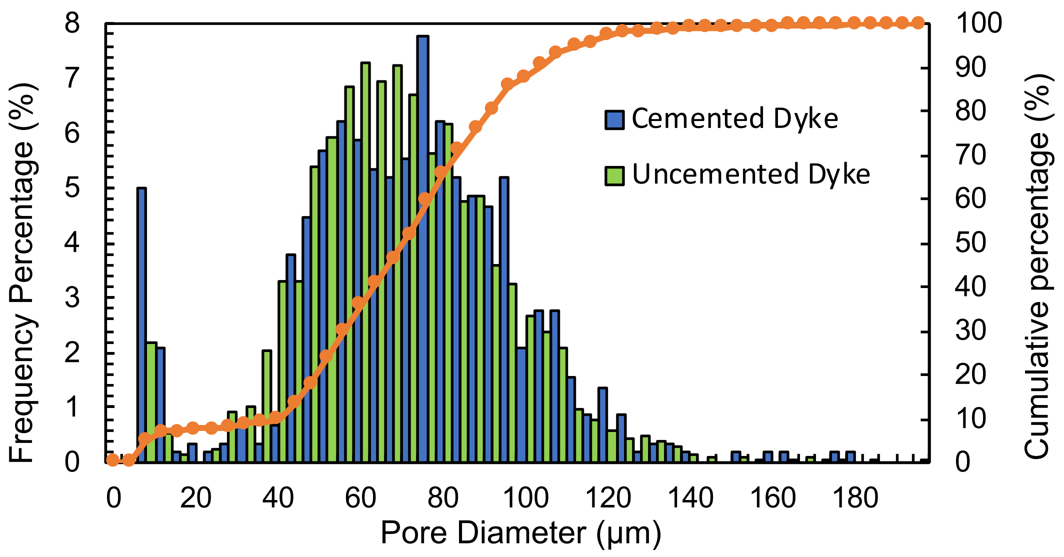
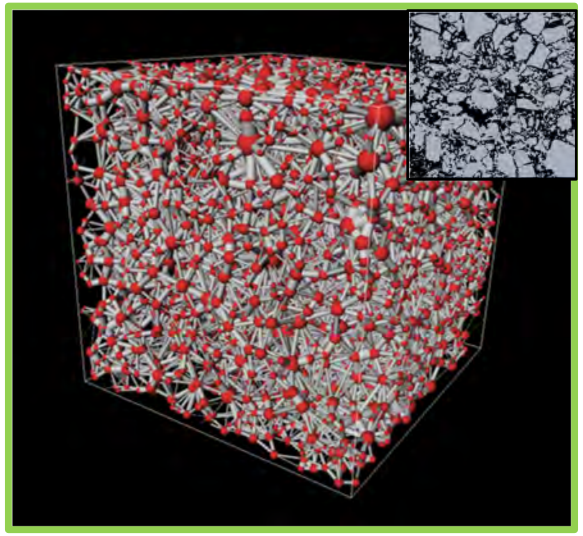
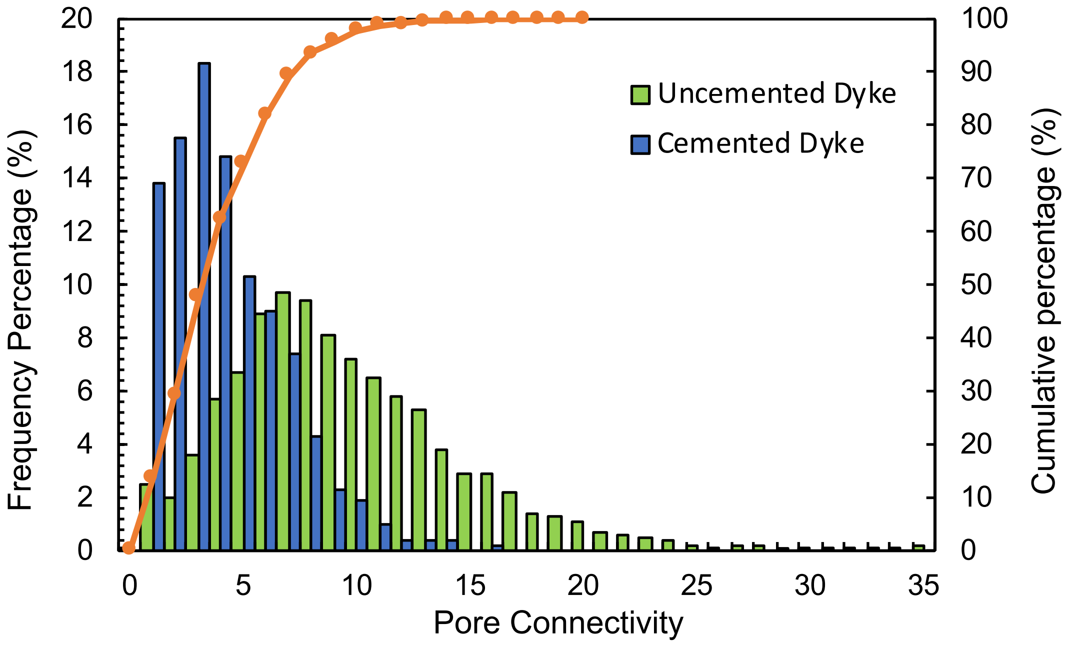
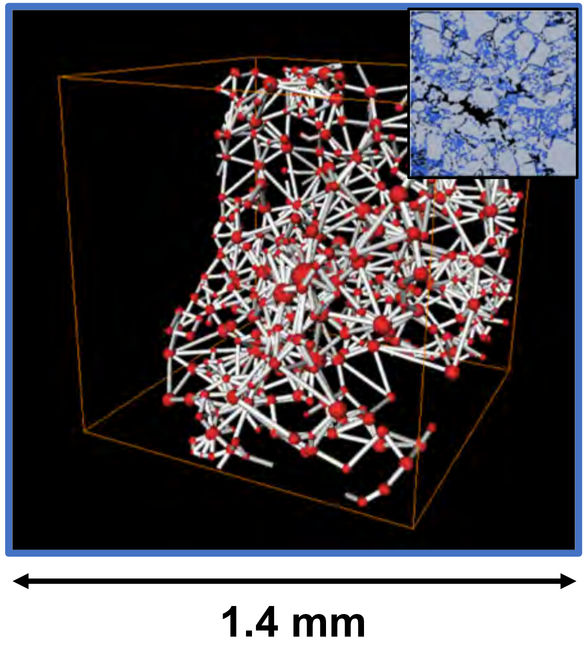
RESULTS – PORE STATISTICS









- Pores infilled with silica cement
- Cementation causes reduced pore connectivity