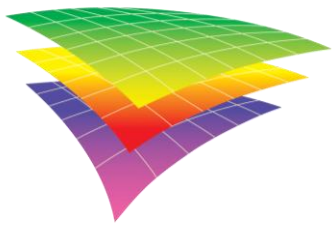
Characterising and understanding fractures, karstification, and surface fissures: processes and implications for geothermal reservoir development

Susie Daniels, R E Holdsworth,
N Narayan , R R Jones, J G Gluyas

18th April 2018



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Characterising and unde… fractures, karst… surface fi… i… …ermal …velopment

Learnings about karst from fractured oil and gas reservoirs

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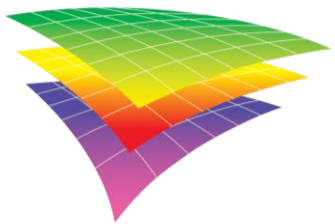

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Fracture Data to Predictive Models: Oil industry

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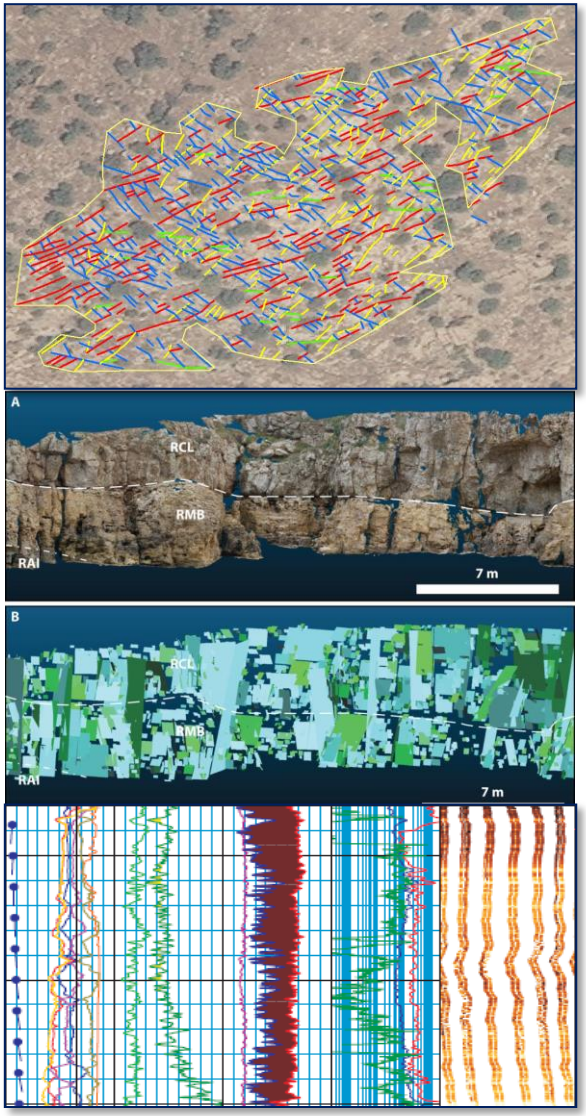
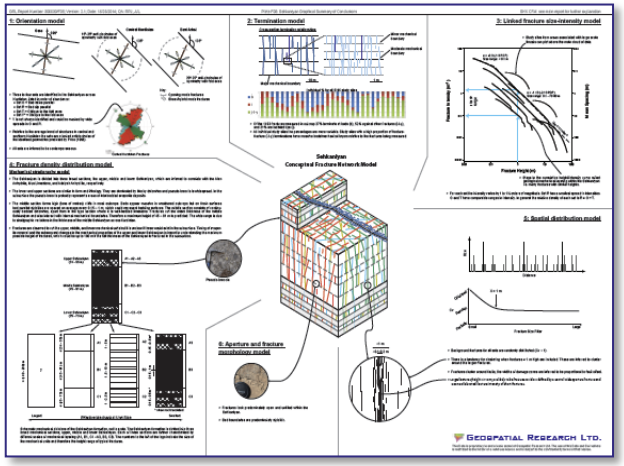
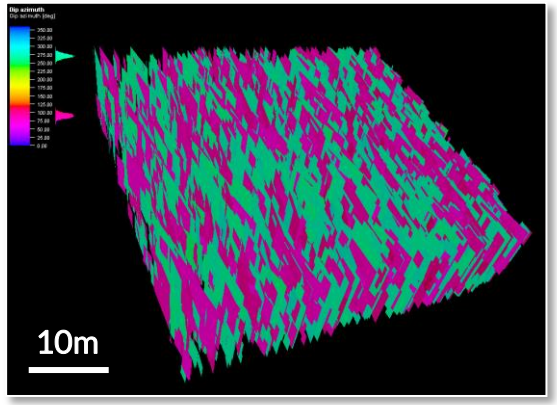
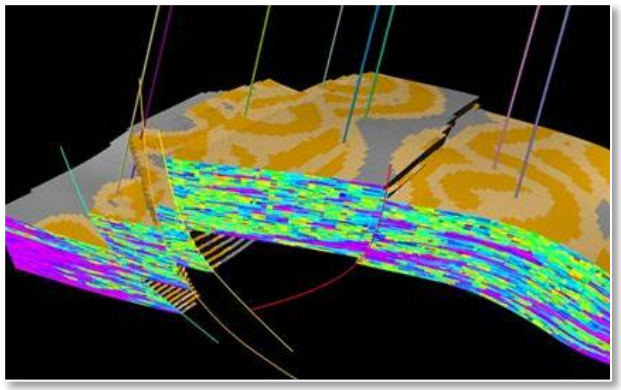


1. Fracture Characterisation (fieldwork, satellite imagery, sub-surface data)

- GRL have expertise characterising fractures in oil industry (e.g. fractured carbonates, basement, shales)

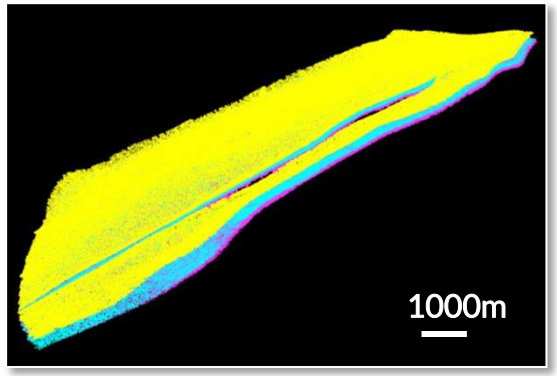






From https://dwyoga7.wordpress.com/2014/07/18/sketsa-geologi/

2. Conceptual Fracture Model (per fm./package/unit) + Structural Framework Model



3. 1D & Full-field Fracture Network Models

OUTLINE : From fractures to karst

- Characterising permeability within karst reservoirs
  - (relevance for example for Ultra Deep Geothermal projects of Netherlands)

- The importance of recognising the setting / process of karstification
  - case study from basement hosted oil accumulation

- Work to identify the setting of Carboniferous limestone karsts across the UK

Flow rates link to permeability

- Within karst the 'permeability architecture' can be complex
  - Matrix permeability
  - Fracture permeability
  - Void / fill permeability within cavities

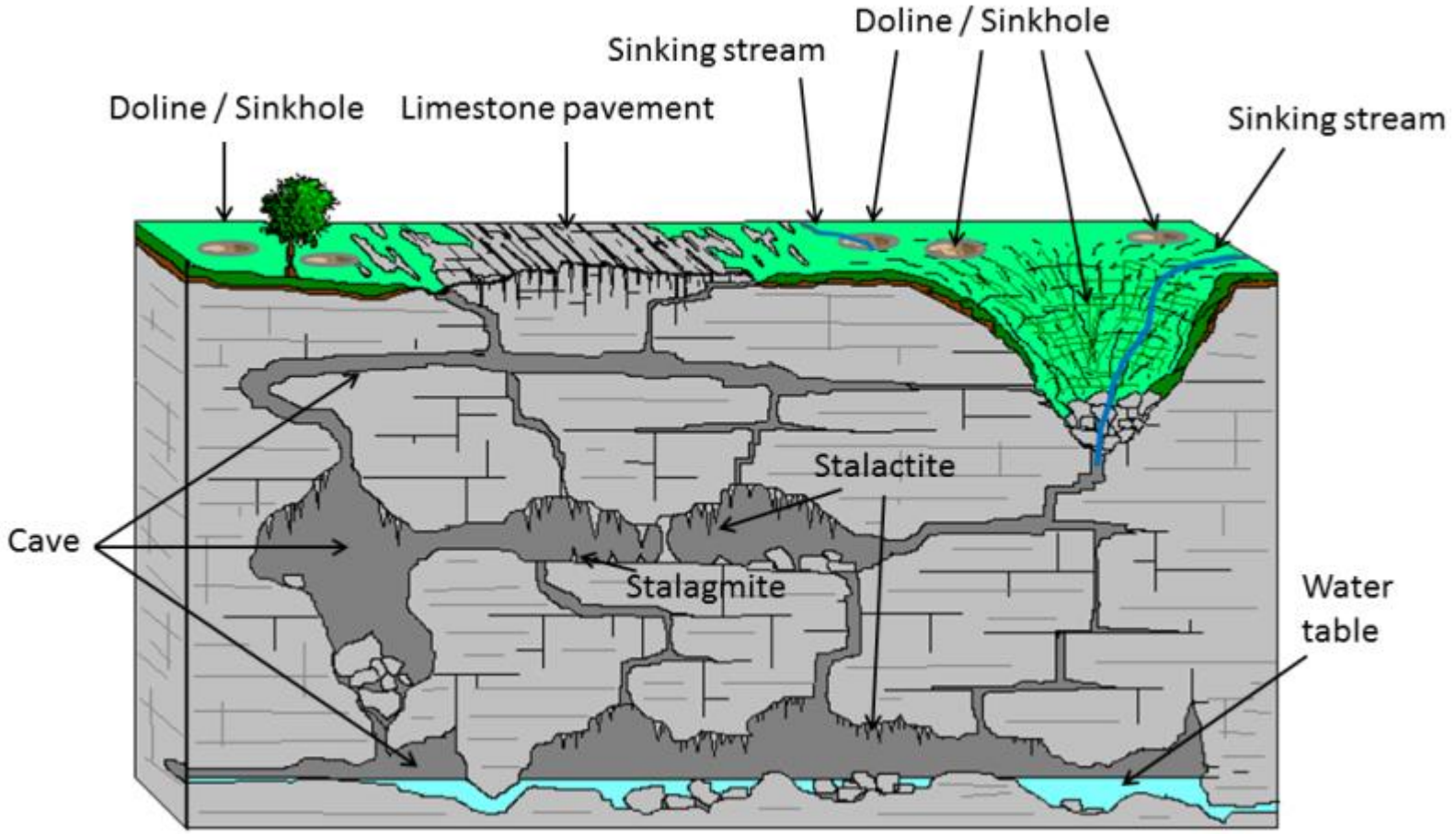


Image from Geological Survey of Ireland

Characterising fracture permeabilities

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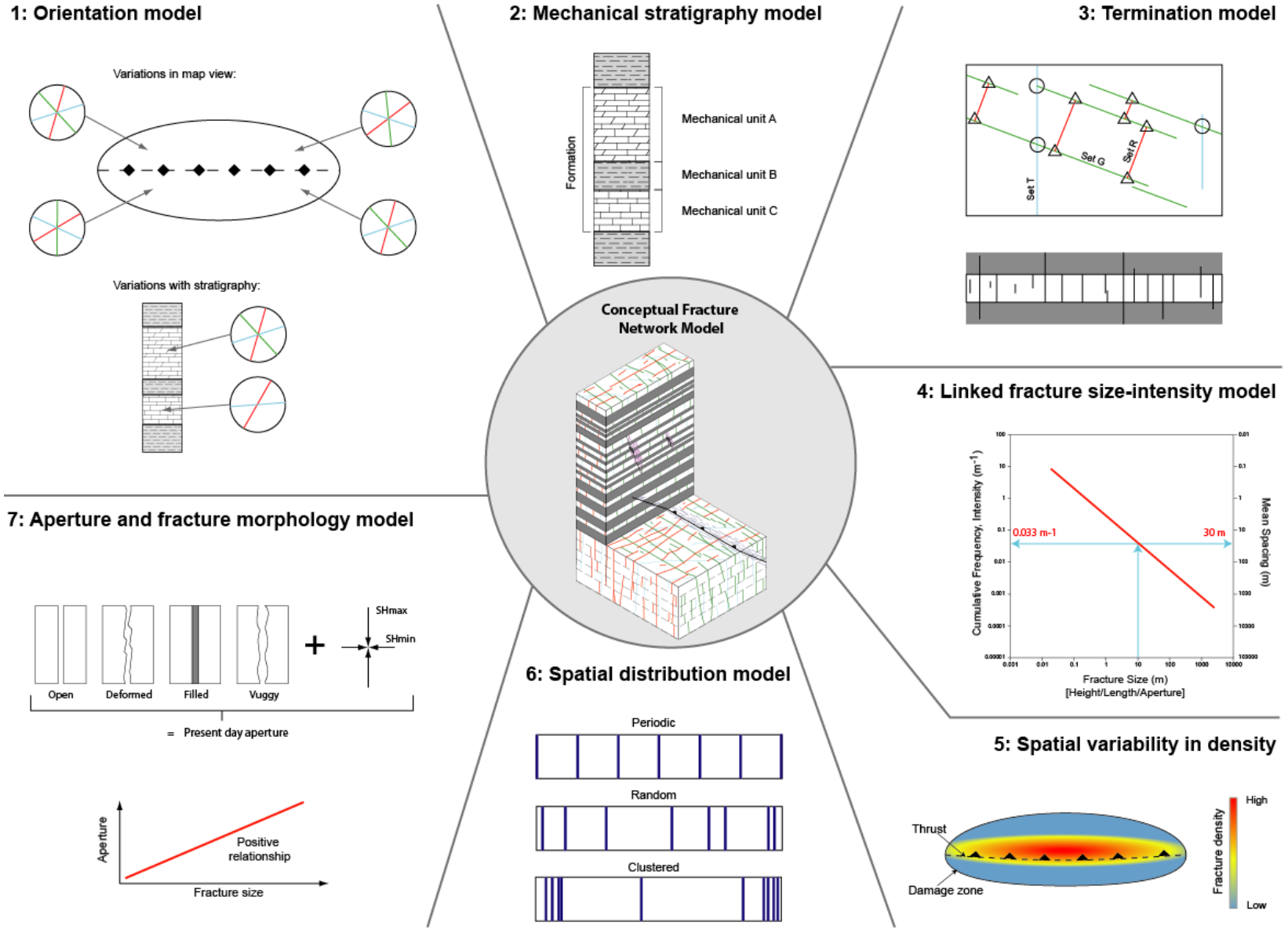

- Using both outcrop and subsurface data with careful application to the subsurface

Characterising karst cavities / fill

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Components that can be characterised:

- Quantification of karst network : directionality, percent cavity, morphology, volumes, dimensions and spatial distribution
- Analysis of geometrical connectivity, correlation with proven flow
- Evaluation of genetic link between karst bodies and pre-existing fracture network
- Characterisation of background fracture network, fault related fracturing and geometry and spatial relationship of karst bodies

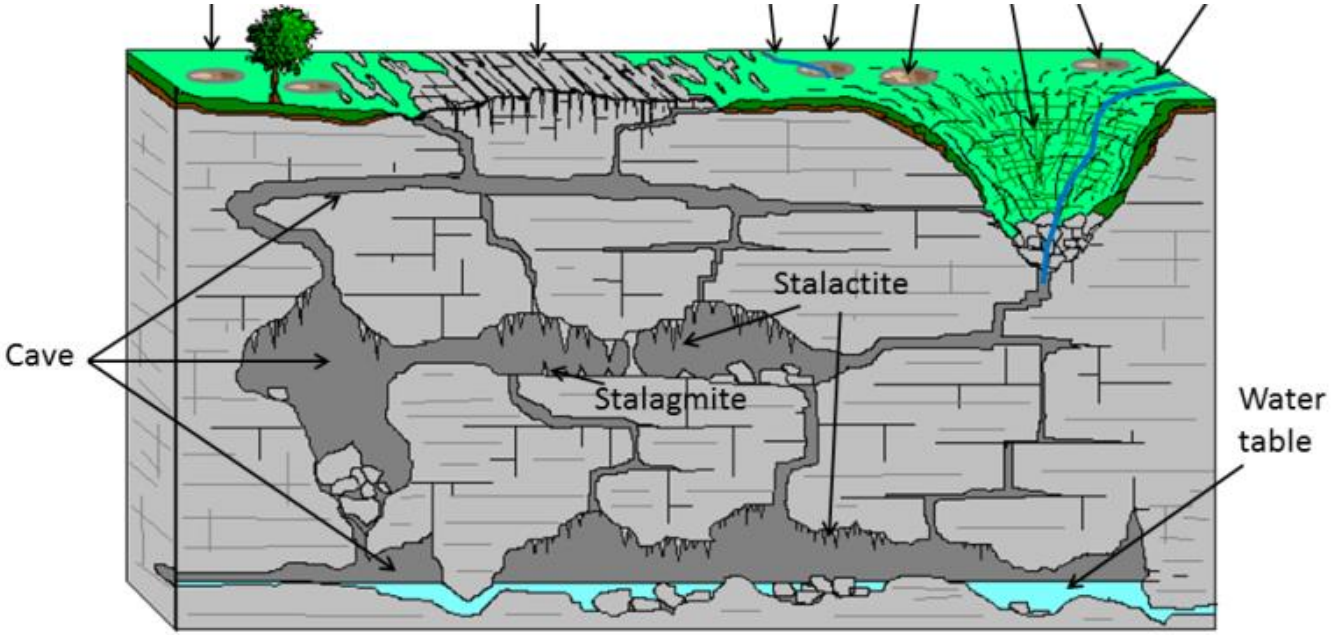


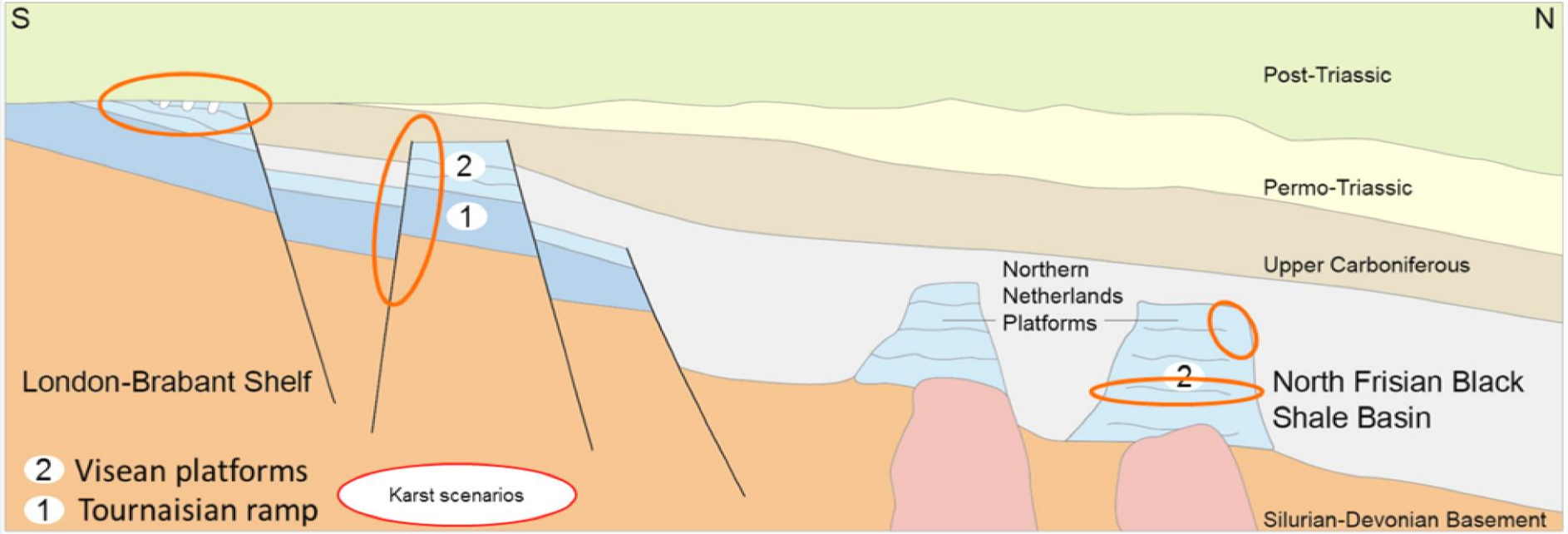
Image from Loucks 1999

Dinantian carbonates & their settings

- Evidence for karst
- Varied karstic scenarios

Dinantian platform carbonates at present

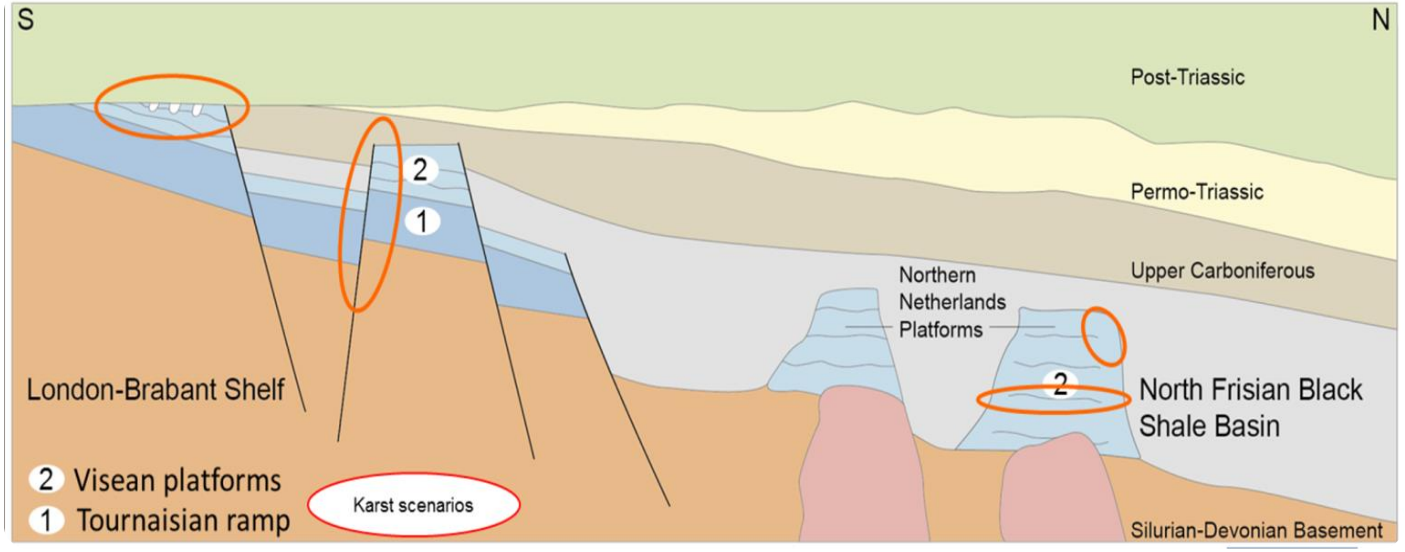
Differences in build-ups, diagenesis, fracturing, Z / T / p, stresses, etc.



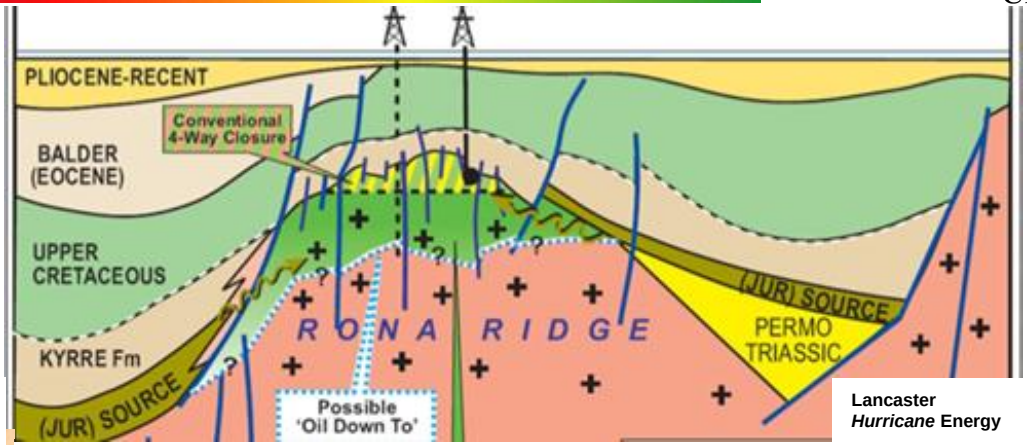
https://www.ebn.nl/wp-content/uploads/2017/12/Dinantian-Carbonates-are-hot.pdf

Various karst settings

- Different karst scenarios
  - Surficial (meteoric)
    - Syn-depositional tropical karst (platform collapse during lowstands / mixing of fresh and marine waters / exposure time)
    - Post depositional karst on exhumation (fractures conduit)
  - Subsurface (hydrothermal)
    - Deep / shallow
- Faults in any setting
- Genetic link between fractures and karst
- CASE STUDY: Karst and associated similar deposits e.g. fault related 'karst' in fractured basement (i.e. not actual karst, isolating rift-related deposits)



e.g. Fractured basement, Bob Holdsworth et al

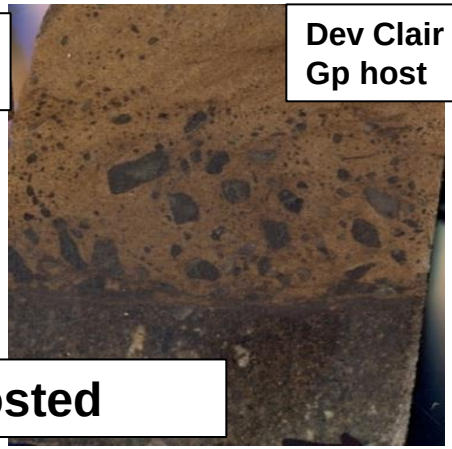


Lancaster *Hurricane* Energy

https://www.nationalgeographic.org/encyclopedia/rift-valley/

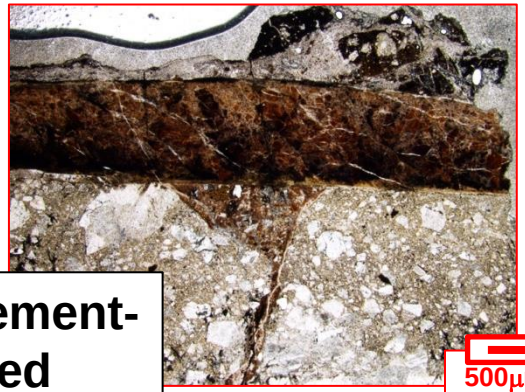
All cores 100mm wide

Jur Rona Sst host



Dev Clair Gp host

Cover-hosted



Basement-hosted

Dev Clair Gp host

- Karst-like deposits related to rifting only, not dissolution

Implications for fault-related karst

As well as dissolution faulting will influence karst by

- Stress differential at time of forming
  - Orientations of fractures
  - Dimensions of fractures
  - Dimensions of voids
- Connectivity of fractures

➢ **It is important to understand the karstification process for the reservoir…**

➢ **…Or to understand what we don't know about the setting (to define the possible range of predicted reservoir properties)**

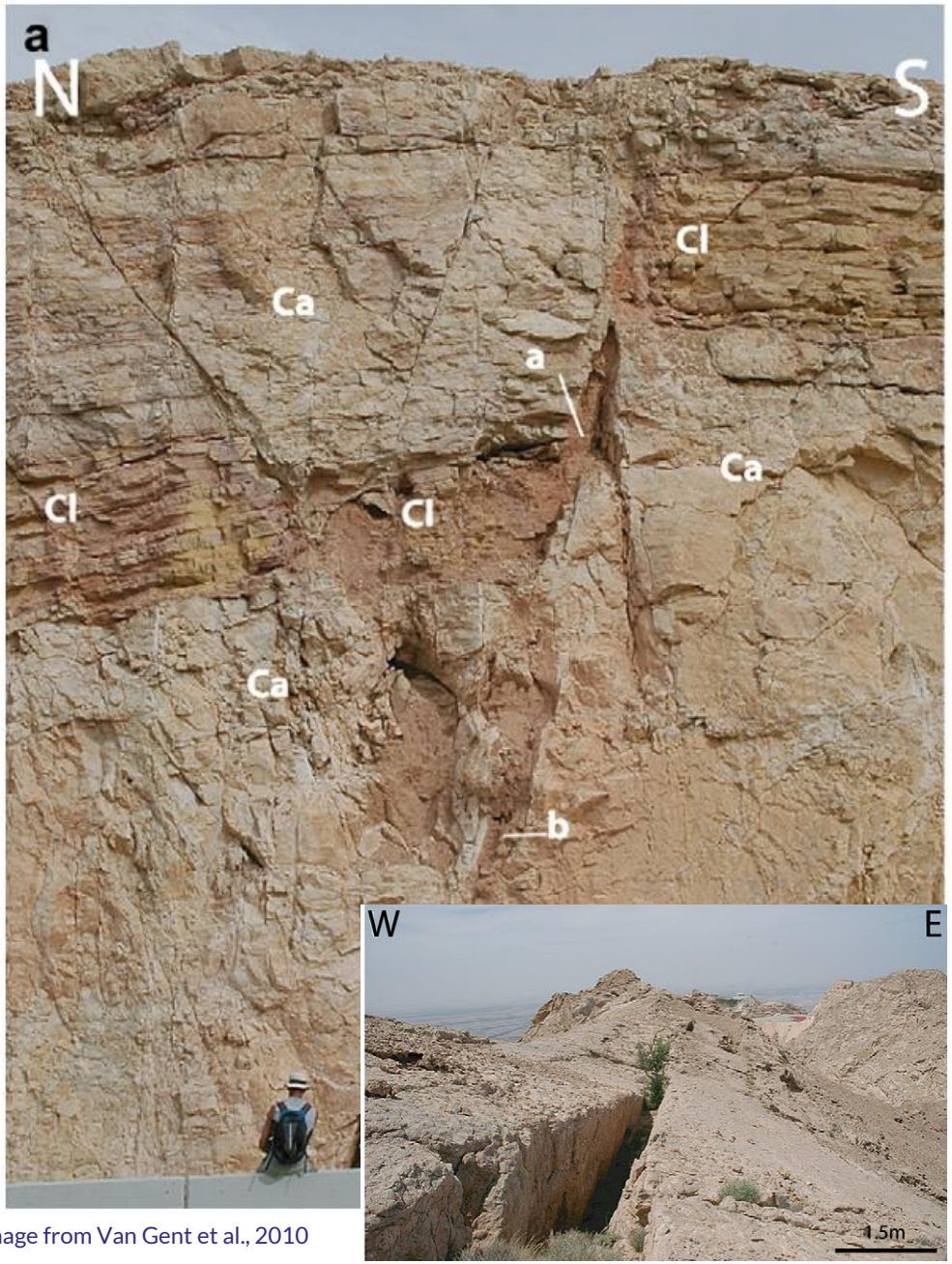
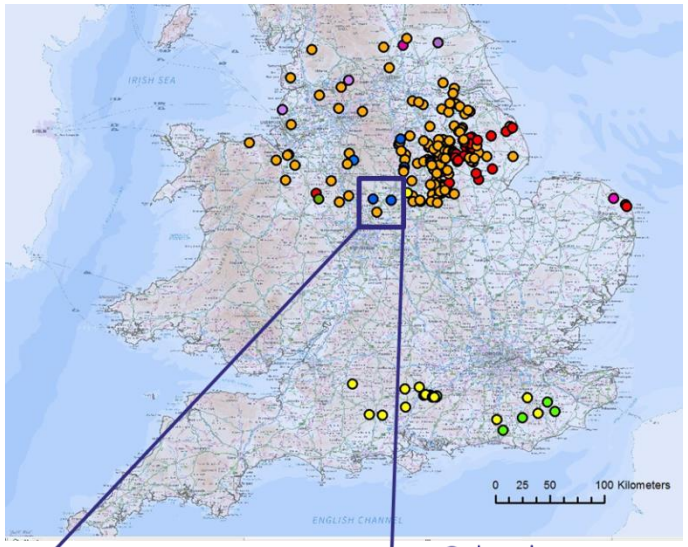
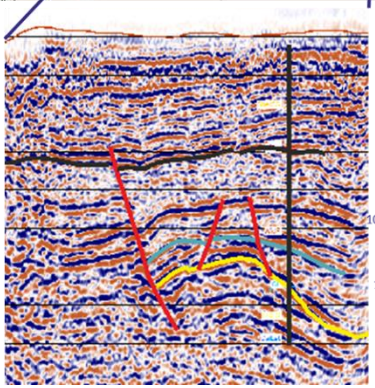


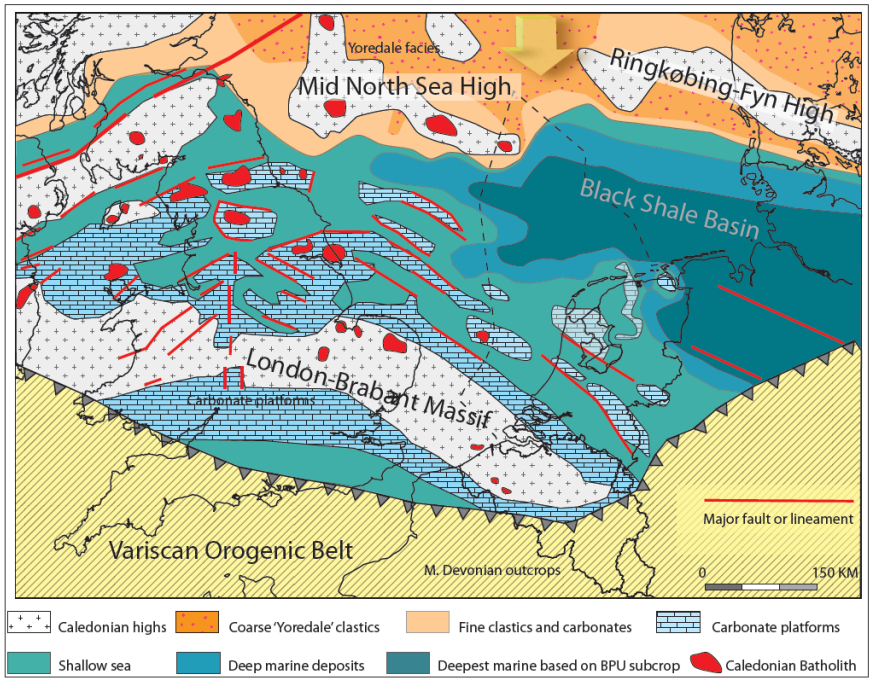
Image from Van Gent et al., 2010

N.Narayan (J Gluyas): The unconformity in the UK

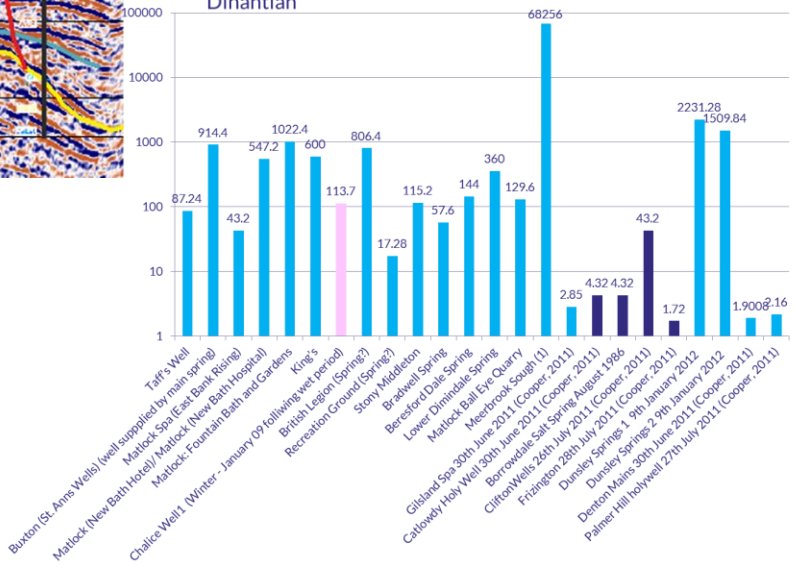




- Jurassic
- Triassic
- Coal Measures
- Namurian
- Lower Carboniferous/ Dinantian



Mississippian palaeogeography
Van Hulten , 2012



- Well & seismic mapping of the supercrop above Dinantian limestone: composite unconformity, some associated faulting
- Inference of timing of unconformity and hence conditions of unconformity
- Natural flow rates across unconformity & core studies
- Geothermometry analysis of spring waters to determine reservoir temperature.

Summary & Next step

Had quick look at

- how could characterise properties that impact permeability within karst analogues for the Dinantian carbonates
- the importance of understanding the details of the karstic process as much as possible to ensure most relevant application of analogue data
- techniques that have been applied to understand the nature of the unconformity at different locations across the UK (with respect to supercrop and flow rates)

Next steps:

- Nadia write up PhD
- Outcrop study of Dinantian karst, well constraining karstification conditions – Expressions of Interest