# Application of Pyrenean Fractured Carbonate Outcrops for Reservoir Characterisation*

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## Abstract

Fractured reservoirs such as tight carbonates, clastics and basements, are often highly heterogeneous in terms of open fracture distributions and connectivity, as well as hydrocarbon or fluid distributions. Working on sub-surface data without the benefits of relevant analog exposure and the application of geological principles based on field knowledge, can lead to mis-interpretation of well or seismic data as well as the results derived from techniques such as curvature analysis or seismic attribute analysis. This poster picks on some good-quality analog exposures in the Spanish Pyrenees to examine the following issues:

- The often major influence of mechanical stratigraphy on fracture distribution, connectivity and style.
- The problem of how to include sub-seismic scale fractures in reservoir models and meaningful simulations.
- The common assumption that faults and their damage zones are a good drilling target in fractured reservoirs.

## References Cited

Ramsay, J.G., 1967, Folding and fracturing in rocks: McGraw-Hill, New York, New York, 568, p.

Wennberg, O.P., M. Azizza., A.A.M. Aqrawi, E. Blanc, P. Brockbank, K.B. Lyslo, N. Pickard, L.D. Salem, and T. Svana, 2007, The Khaviz Anticline: an outcrop analog to giant fractured Asmari Formation reservoirs in SW Iran, *in* Geological Society, London, Special Publication 270, v. 1, p. 23-42.

# Application of Pyrenean Fractured Carbonate Outcrops for Reservoir Characterisation

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Lluis Ardevol i Oró

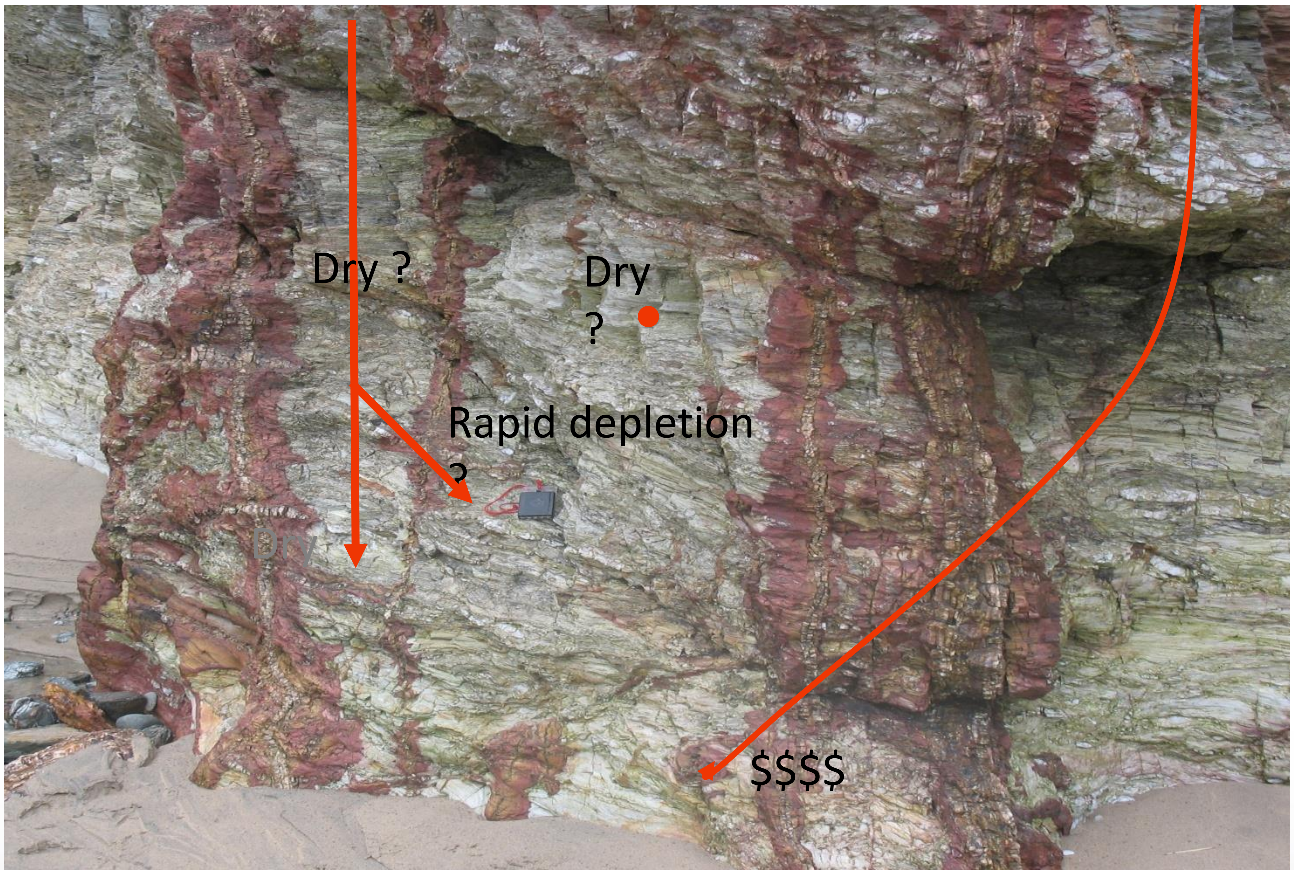
*This is an edited version of the slideset used in the talk, for download from the AAPG Conference site. Please contact Jon at [gutmanis@geoscience.co.uk](mailto:gutmanis@geoscience.co.uk) for more information*

AAPG European Regional Conference and Exhibition

Barcelona May 13 to 15 2014

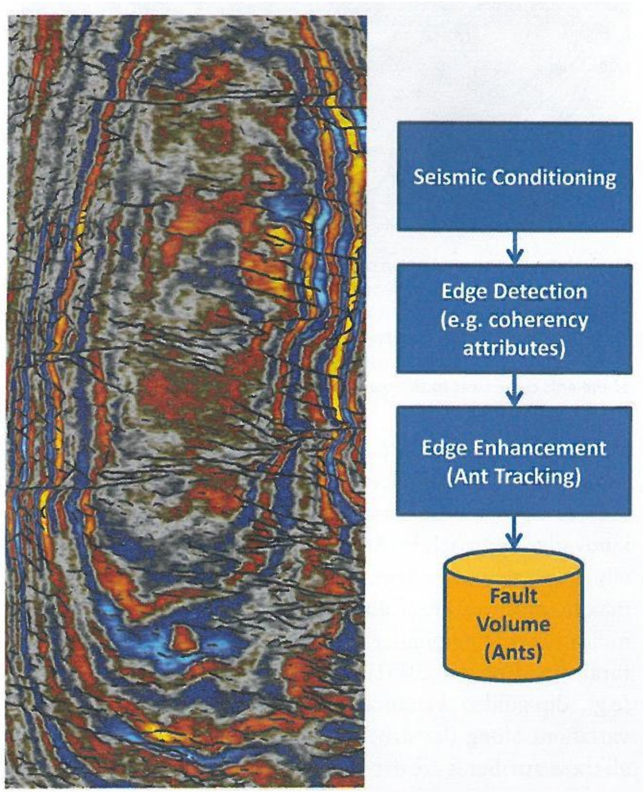
# Fractured Reservoirs are Challenging !

## Finding ‘Sweetspots’ and  Connected Volume

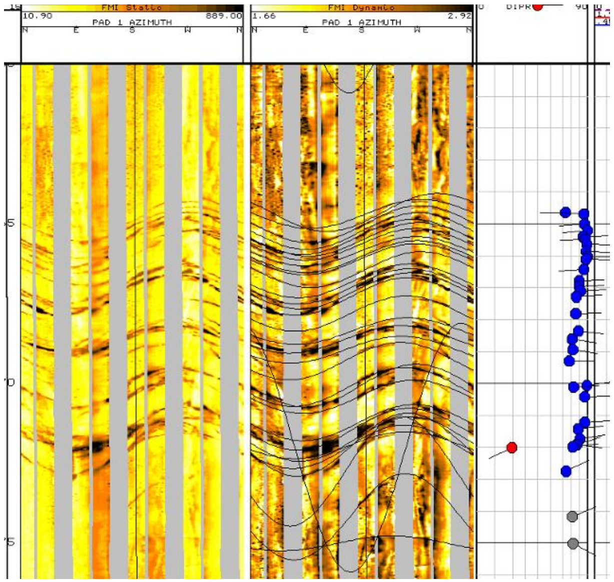



Fractures in Devonian mudstones with Fe-rich alteration haloes - Cornwall

# Typical Data Inputs for FRC

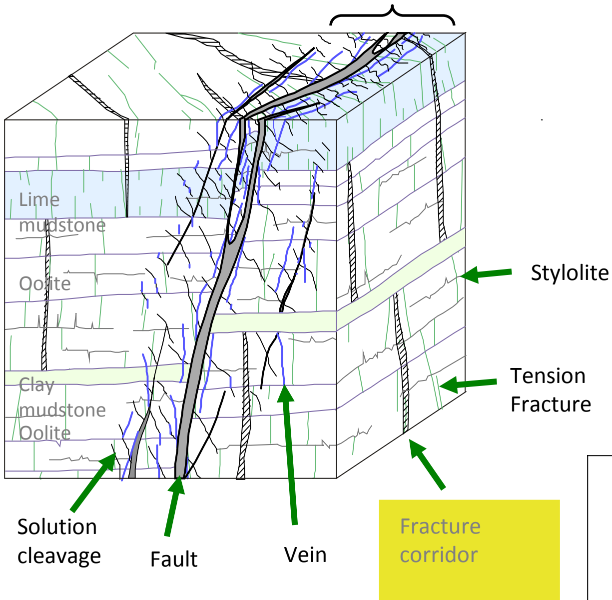



The 'seismic gap'

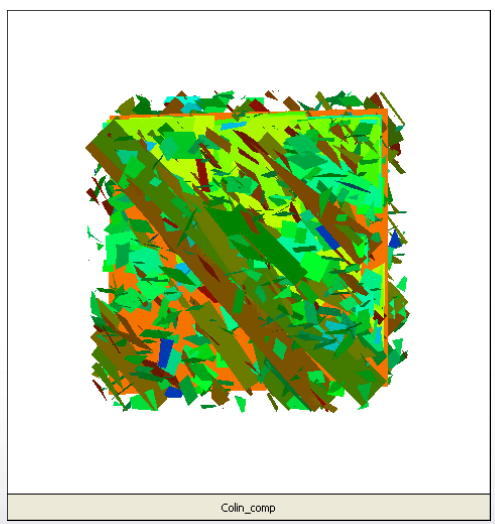


# Modelling the Fracture Component

## Geology for the RE's !

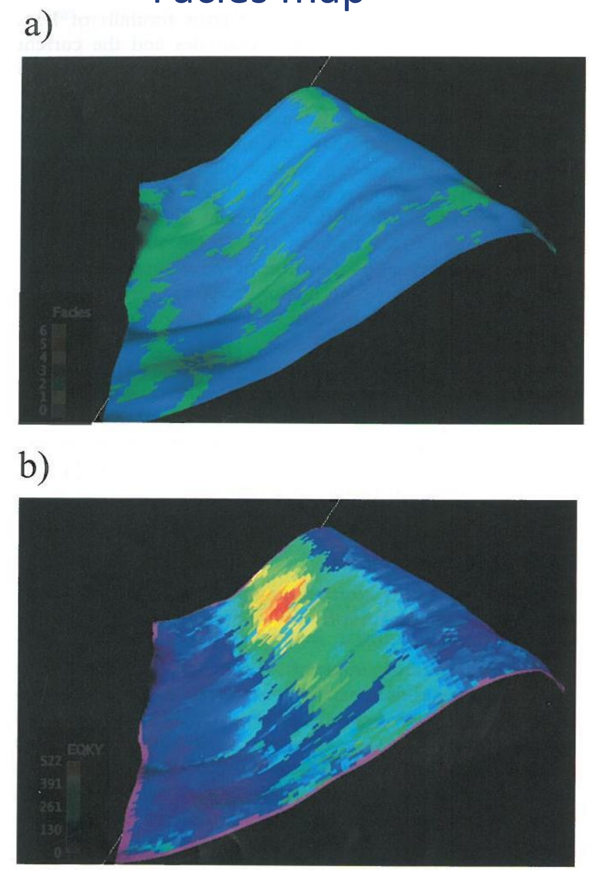



Conceptual




DFN

Facies map




Fracture permeability map

Wennberg et al 2007

GeoScience

# Objectives and Overview

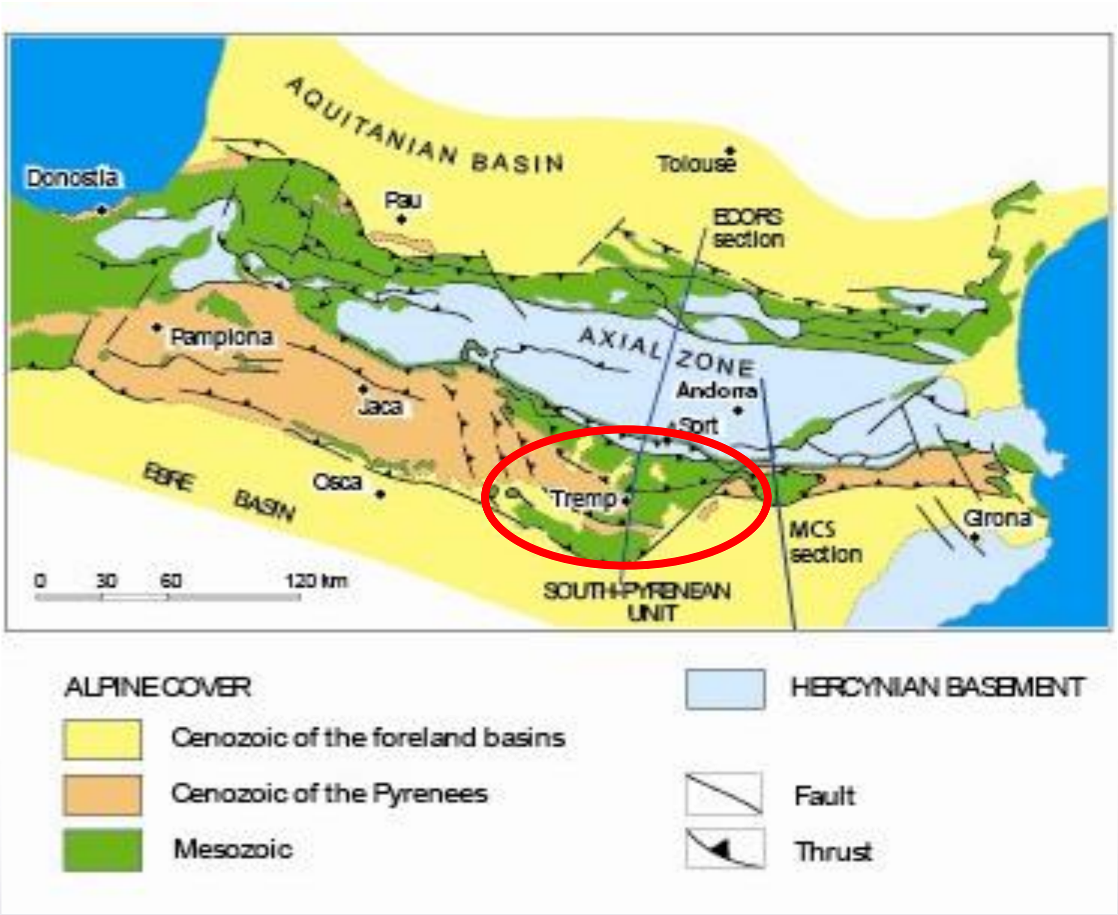
- To illustrate how outcrop can help us
  - with seismic and well data interpretation
  - understanding outputs from ‘back box’ softwares and techniques

- Look at some (related) issues:
  1. How litho-mechanical units influence fracturing
  2. How the outcrop can help model the sub-seismic volume

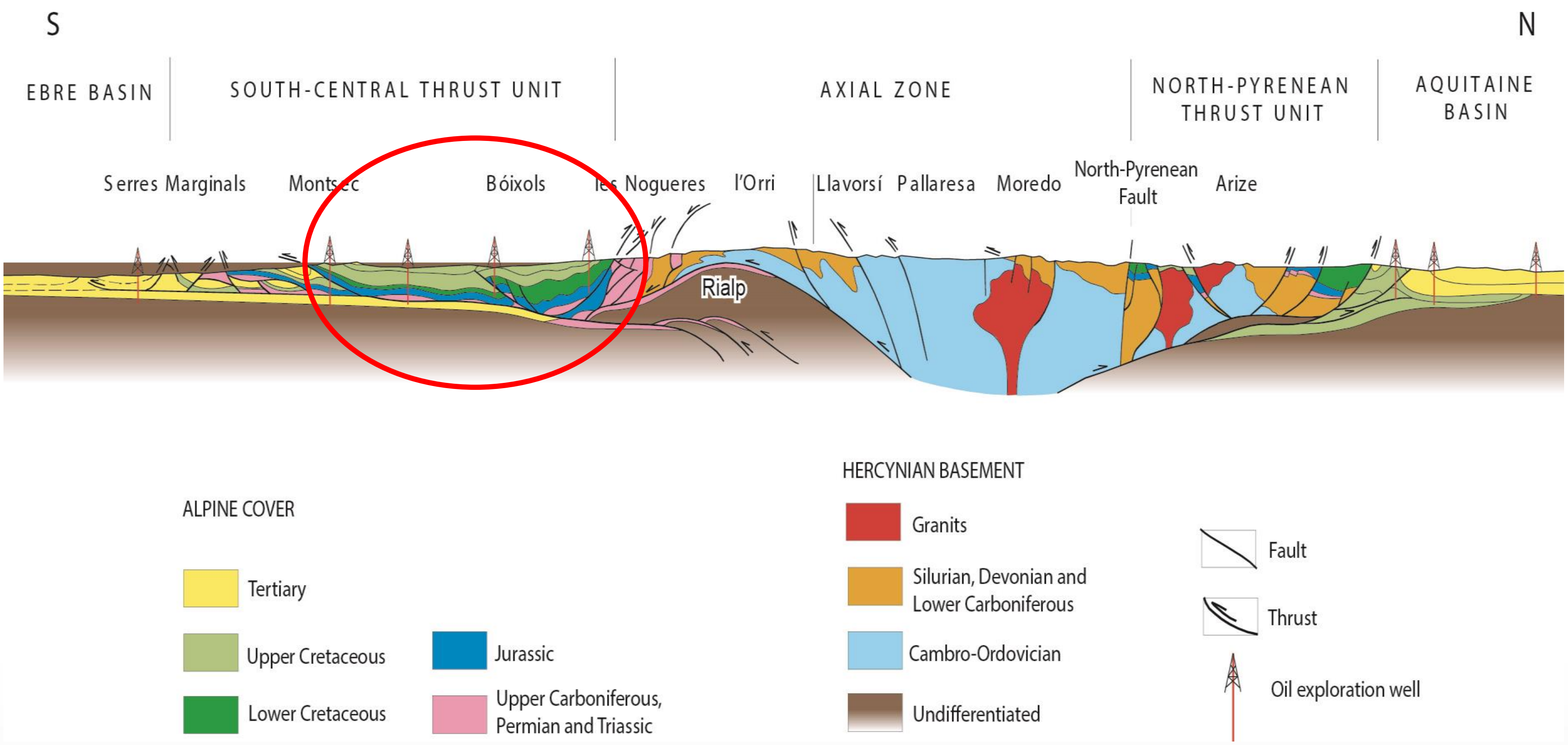
- Using some outcrops in the Tremp region of the south-central Pyrenees
  - Integration of outcrop and sub-surface data

# Regional Geology for the Outcrop Locations

## South-central Thrust Unit

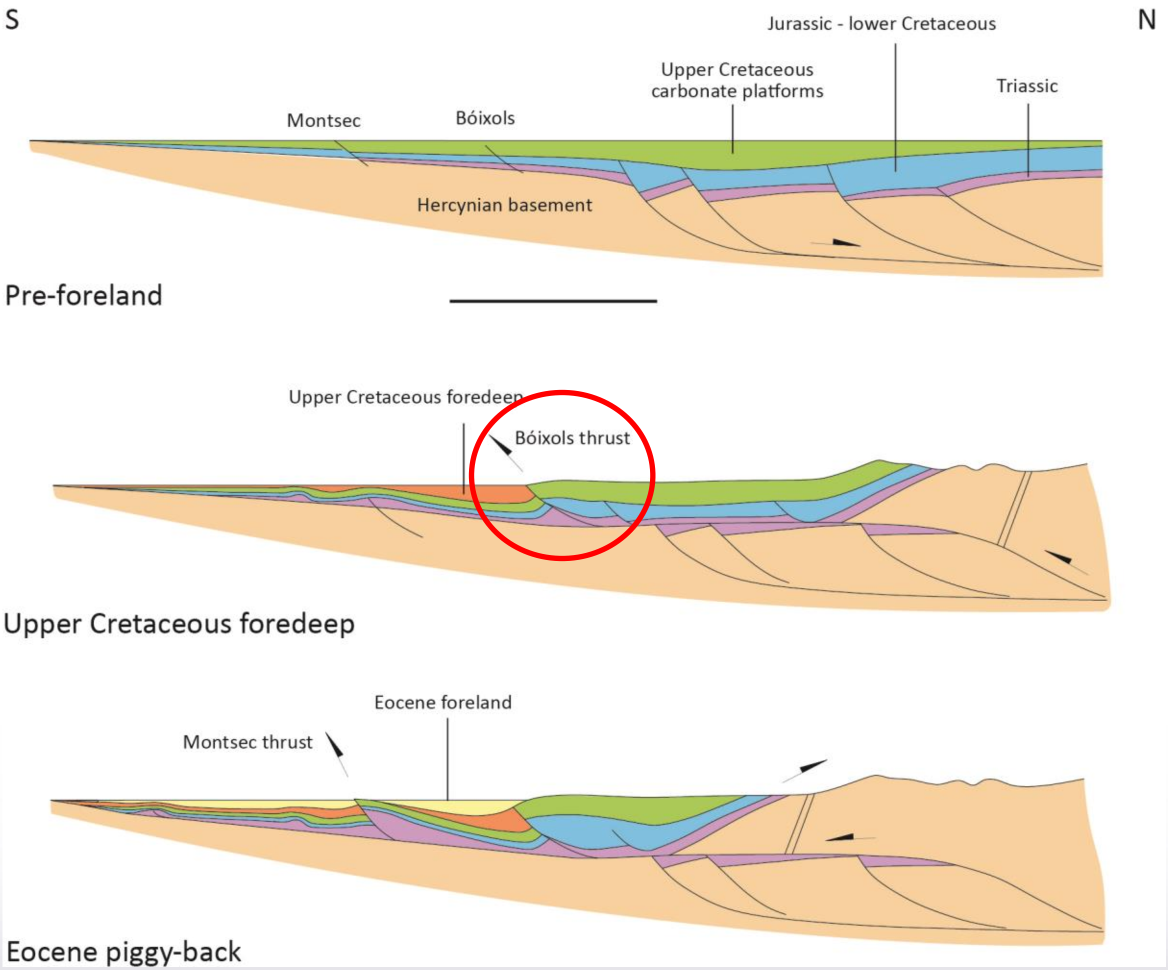


# Regional Geology for the Outcrop Locations



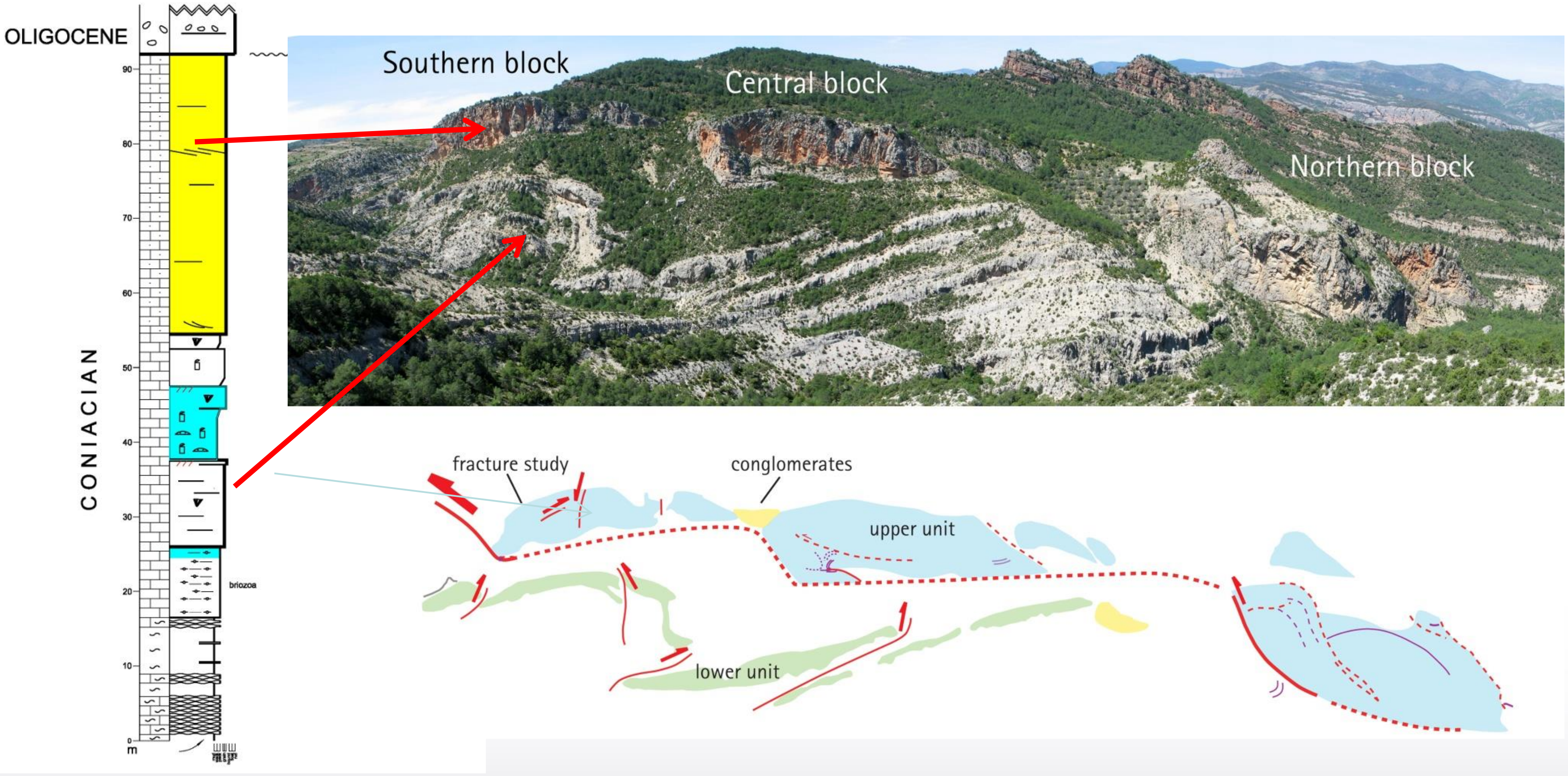
# Regional Geology for the Outcrop Locations

## South Central Thrust Sheets



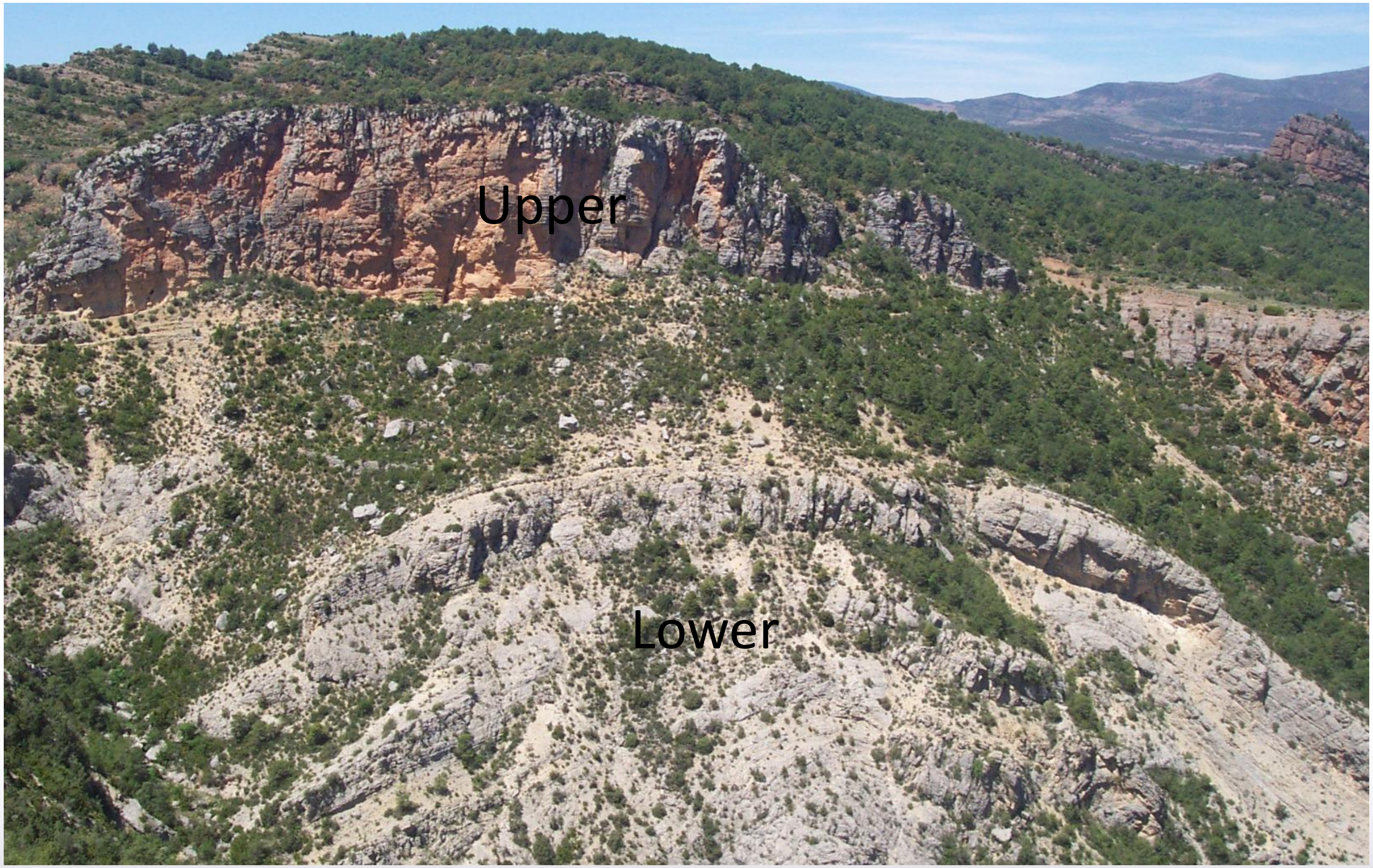
# 1. Mechanical Control on Fracturing

## Location A



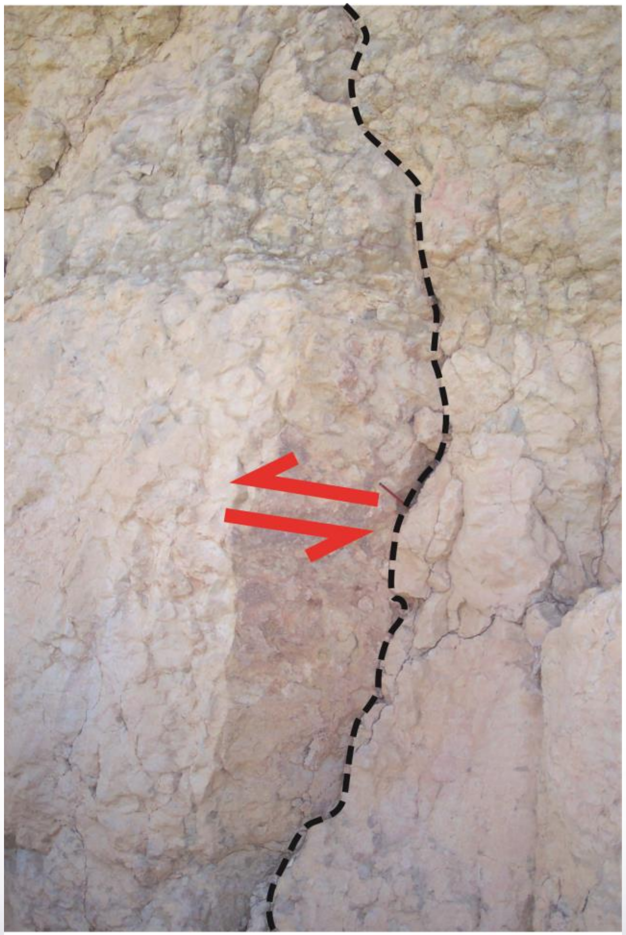
# 1. Mechanical Control on Fracturing

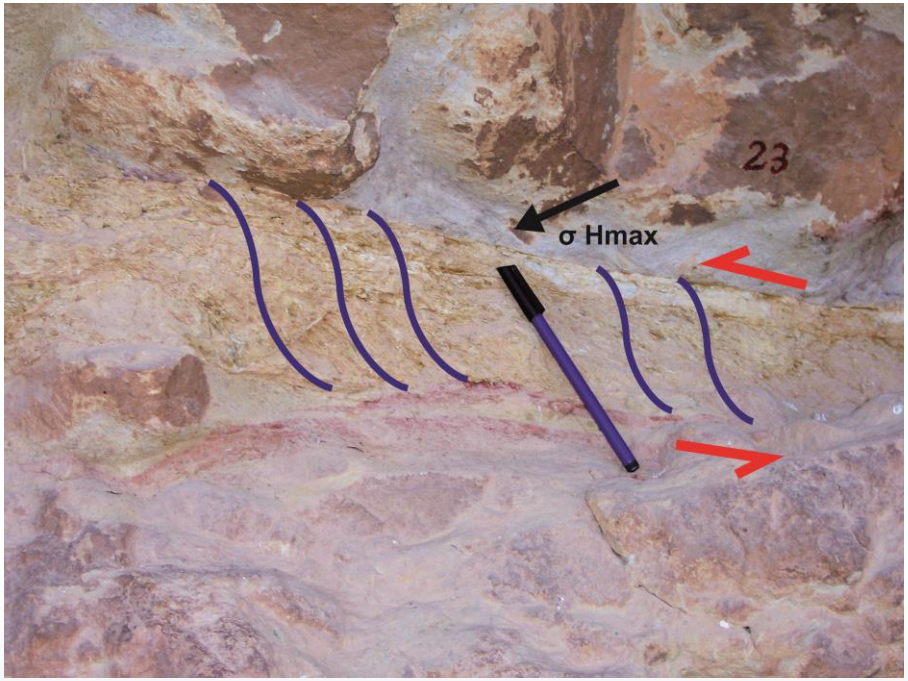
## Southern block



# 1. Mechanical Control on Fracturing

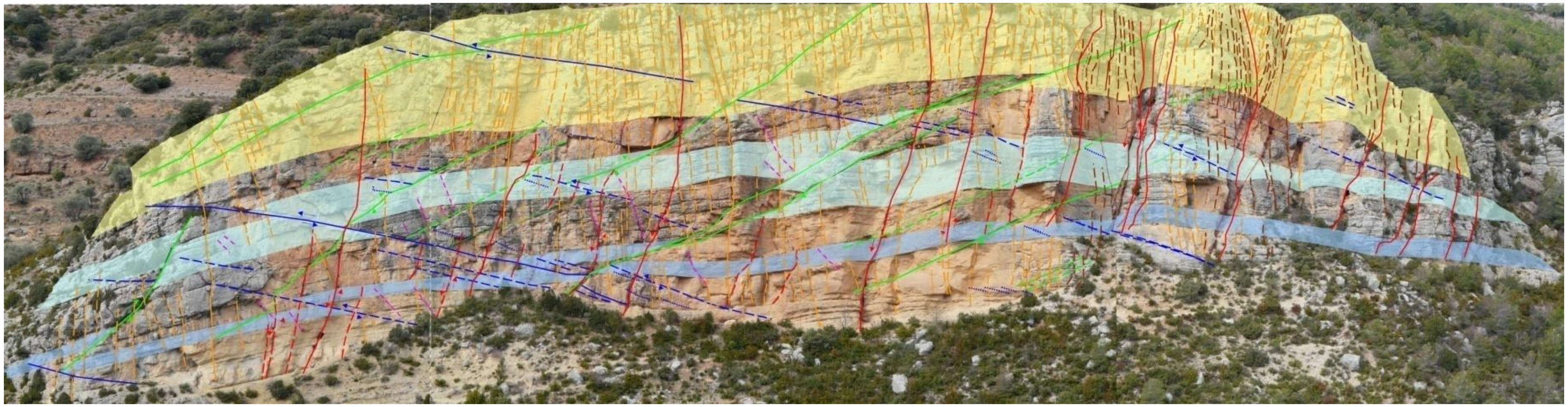
## Southern block - UPPER





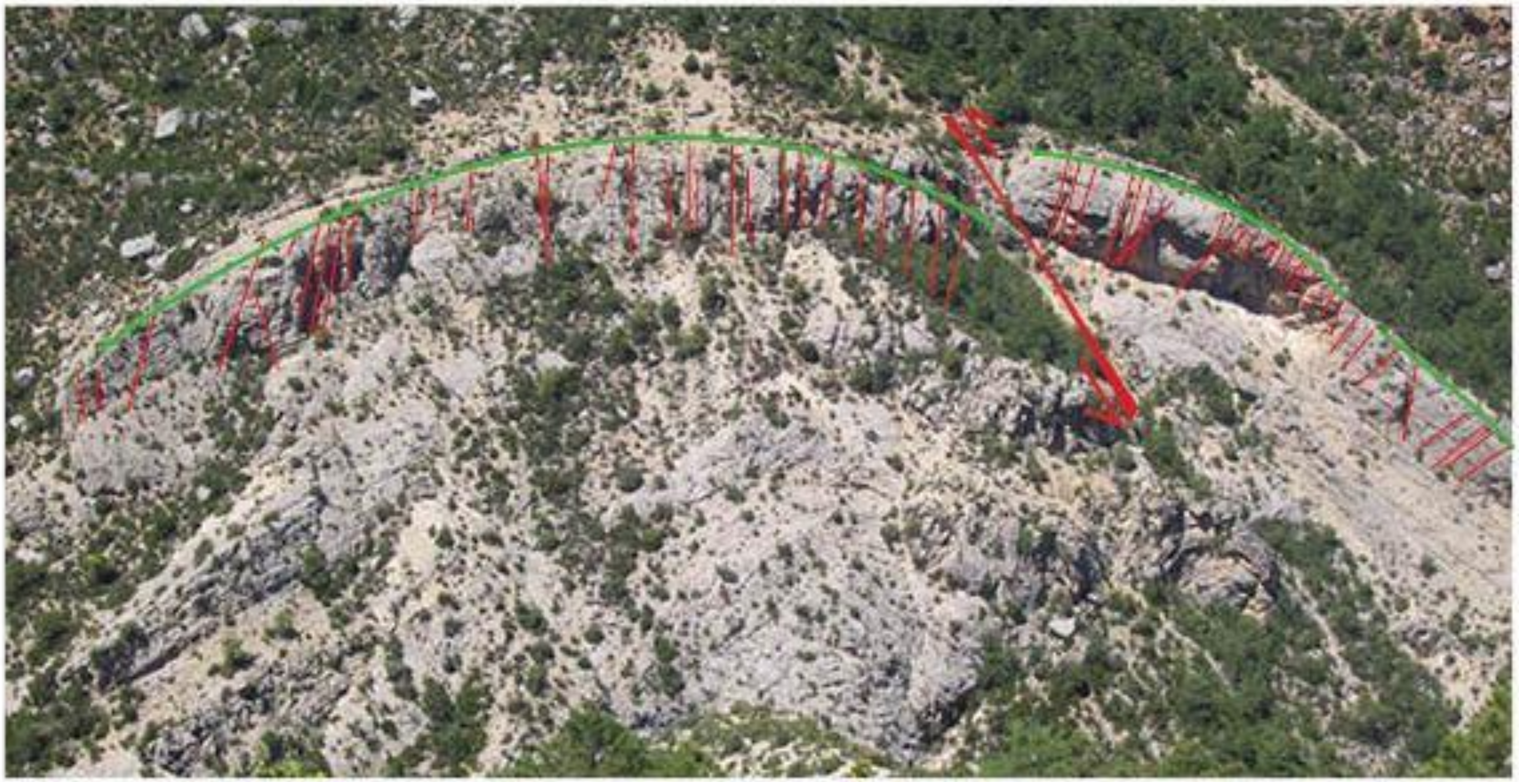
# 1. Mechanical Control on Fracturing

## Southern block - UPPER



# 1. Mechanical Control on Fracturing

Southern block - LOWER



# Applying the Outcrop Knowledge: A Project Example

•*In-situ* stress profile built from density logs (Sv), log-based strength estimates calibrated with LOT's and rock testing (Shmin), and drilling records (Shmax)

•Formation boundaries in blue: Cretaceous carbonates to Triassic mixed carbonate/evaporites sequence

•Fracture count from borehole image log analysis in the vertical blue column

•Close correlation between rock strength variations, stress, fracture count and fracture orientation

*The picture of in situ stress variation with depth in a Zagros exploration well that was shown here in the talk is confidential and not included in this pdf.*

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*Or 00441326 211070 for more information*

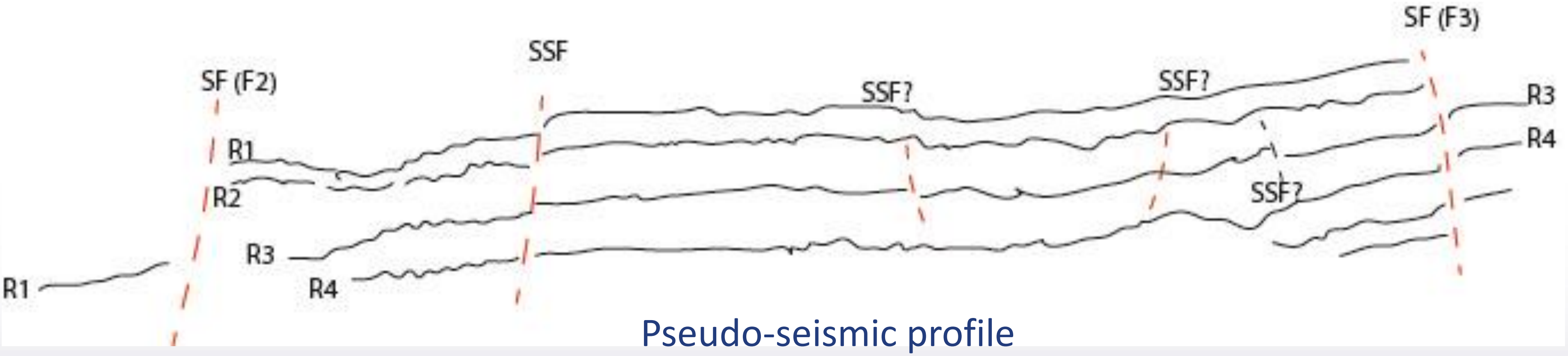
Shmax

Sv

Shmin

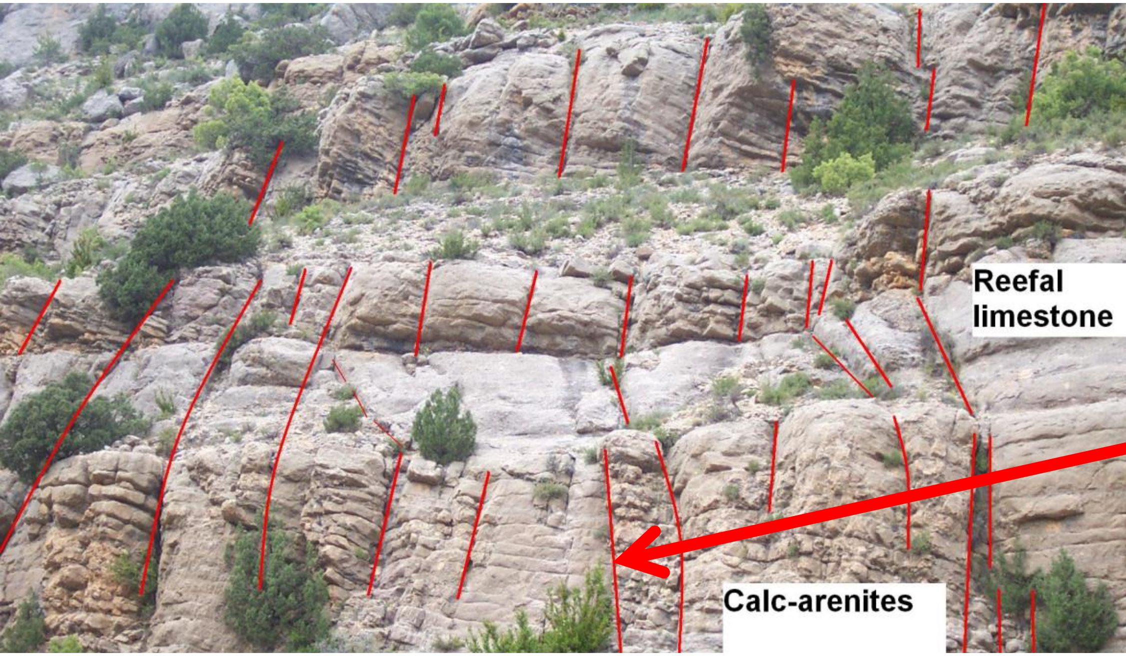
# 2. Investigating the Sub-Seismic Domain Location B

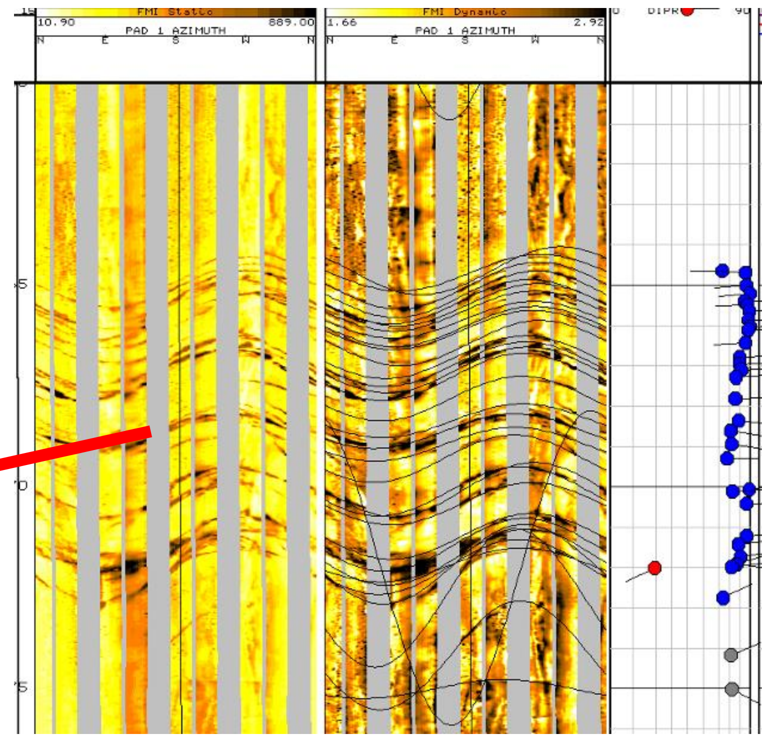

Interfingering Coniacian reefal carbonates and calc-arenites

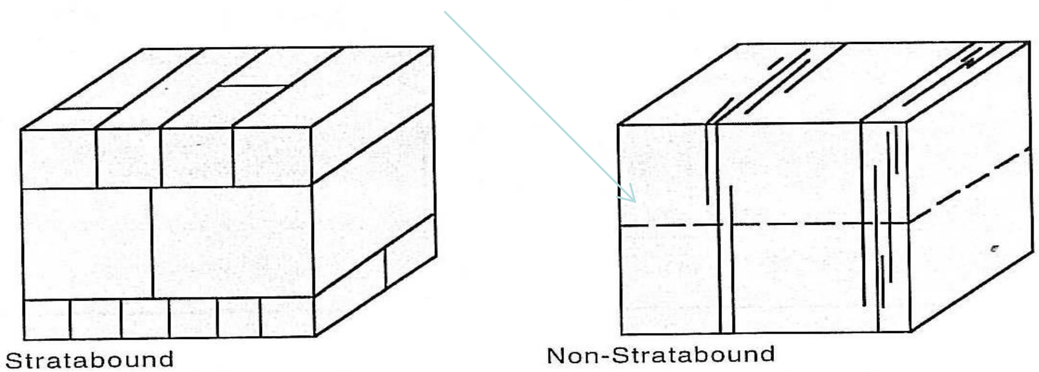



Pseudo-seismic profile

# 2. Investigating the Sub-Seismic Domain



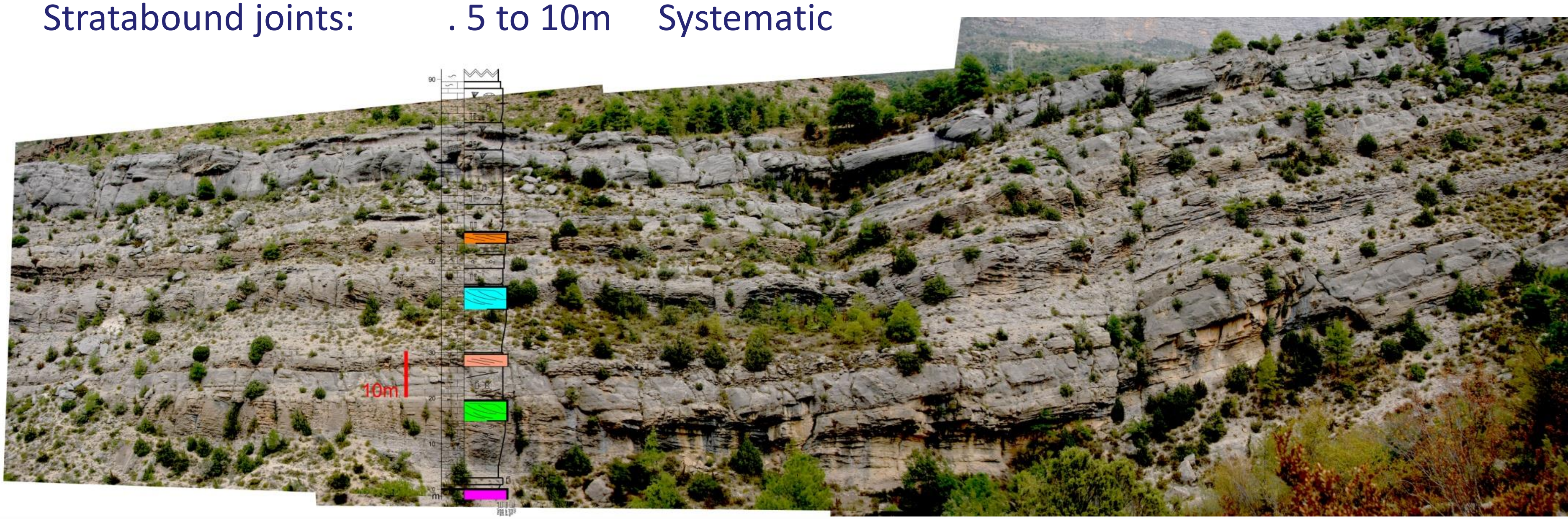



A hierarchy of fractures

# 2. Investigating the Sub-Seismic Domain

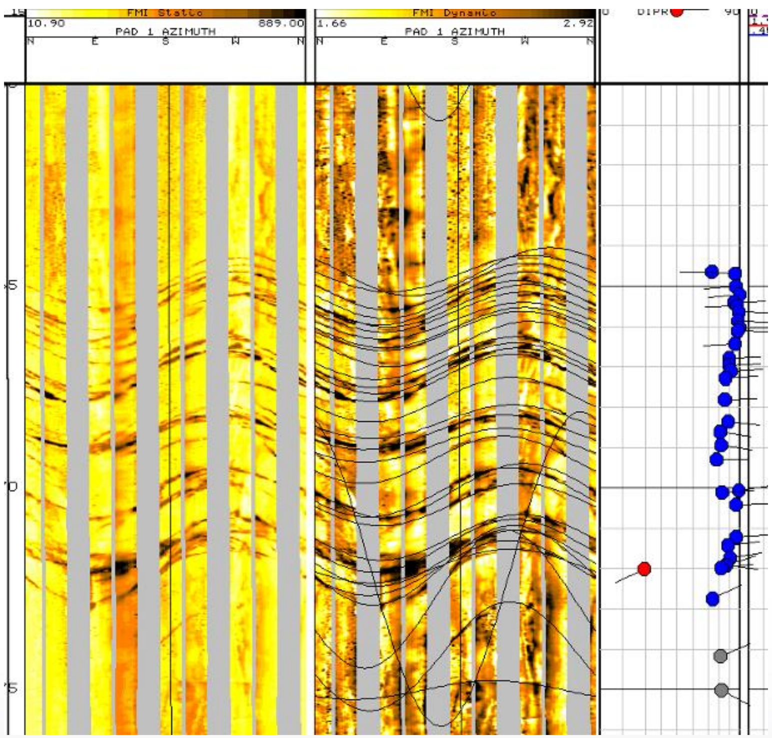
## Spacing Data and Grid Cell Size

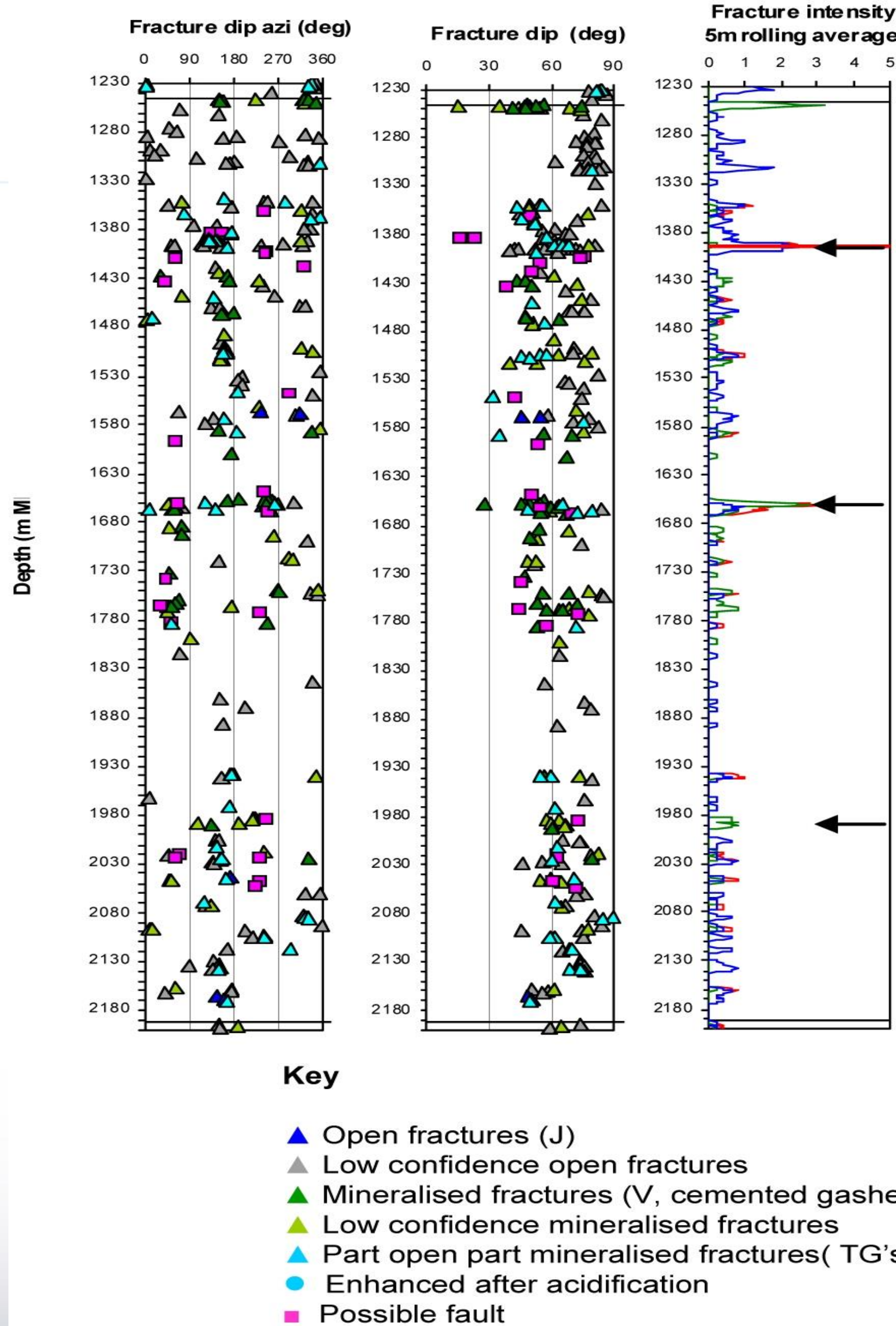
| | | | |
|---|---|---|---|
| Seismic scale faults: | ~500 to 1000m | May be clustered |
| Sub-seismic faults: | ~100 to 250m | Clustered |
| Fracture corridors: | 10 to 100m | Clustered |
| Stratabound joints: | . 5 to 10m | Systematic |




Lengths and heights can also be defined

# 2. Investigating the Sub-Seismic Domain

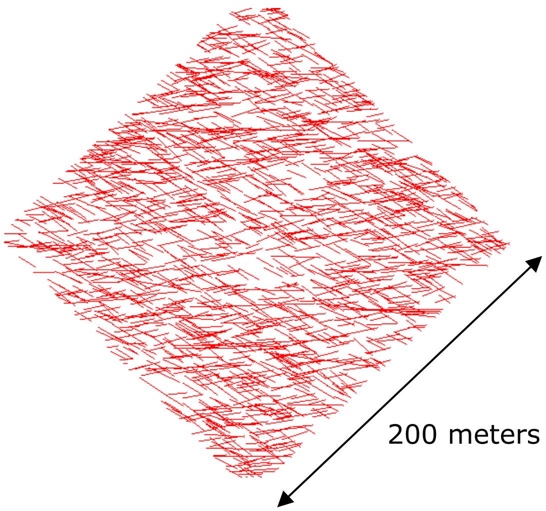


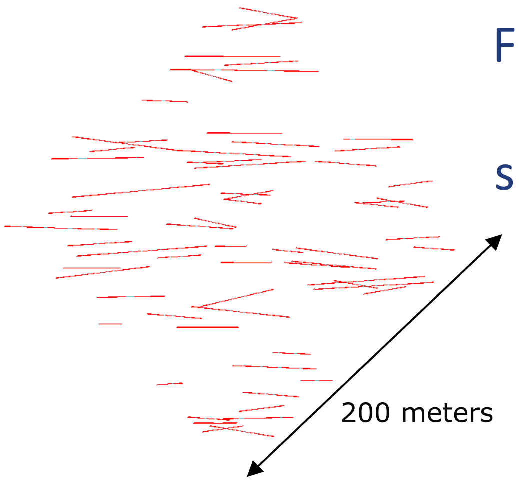



# 2. Applying the Outcrop Knowledge

## A Project Example

Systematic joints



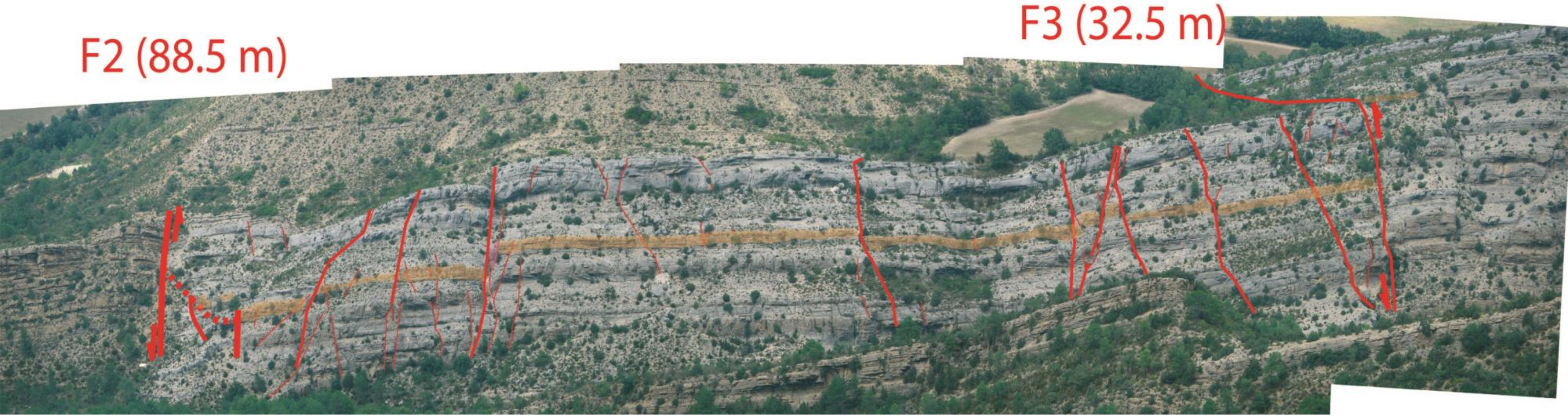

Fracture corridors and sub-seismic faults

- GoCad ▶ Petrel ▶ Eclipse
- Stochastic fracture realisations were generated to predict fracture-network permeabilities for reservoir simulation

Courteousy of Steve Gross (Chevron)

# 2. Applying the Outcrop Knowledge

## Select Appropriate Modelling Strategy




K multipliers for the bigger features and leave background out ?

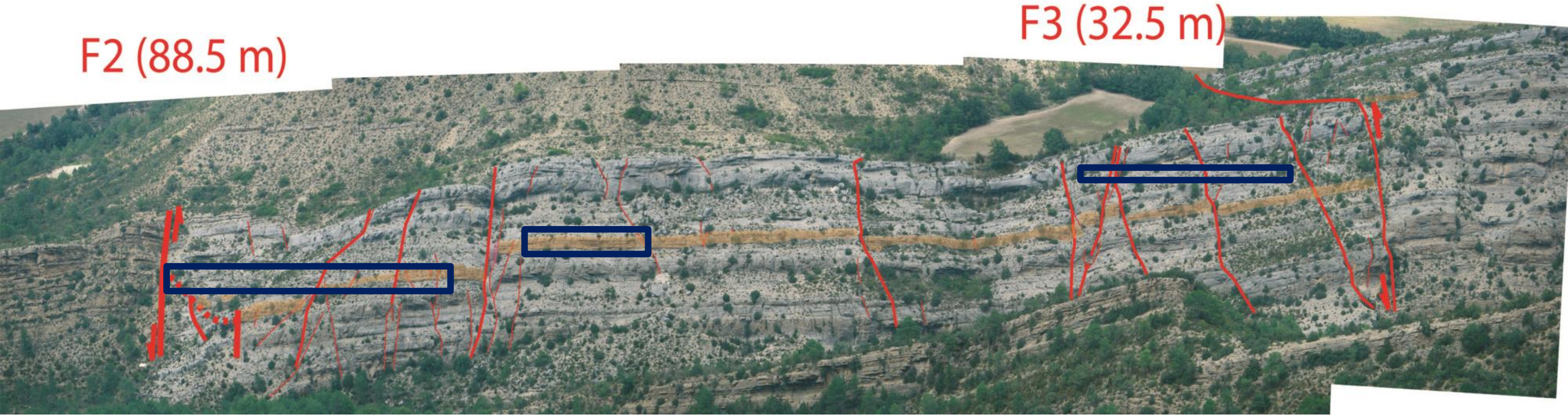
Or what grid cell size to capture heterogeneity range but not make the model slow ?

# 2. Applying the Outcrop Knowledge

## K modifiers at faults

# 2. Applying the Outcrop Knowledge

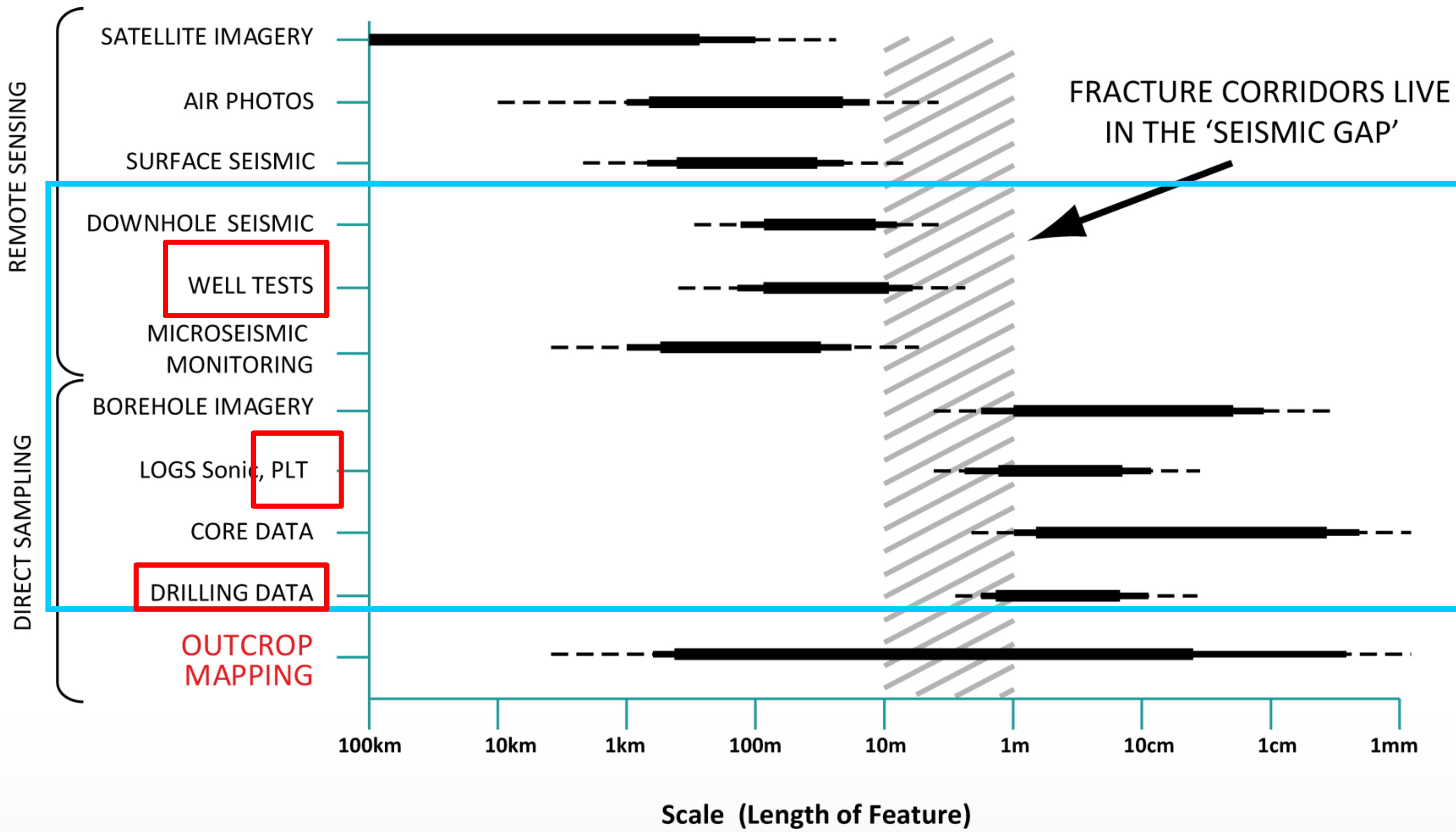
## Appropriate grid cell size




What grid cell size to capture heterogeneity
but not make the model slow........2 m x 50m....2m  x 100m ?

# In Conclusion

## Derive Fracture Parameters, Concepts, Templates



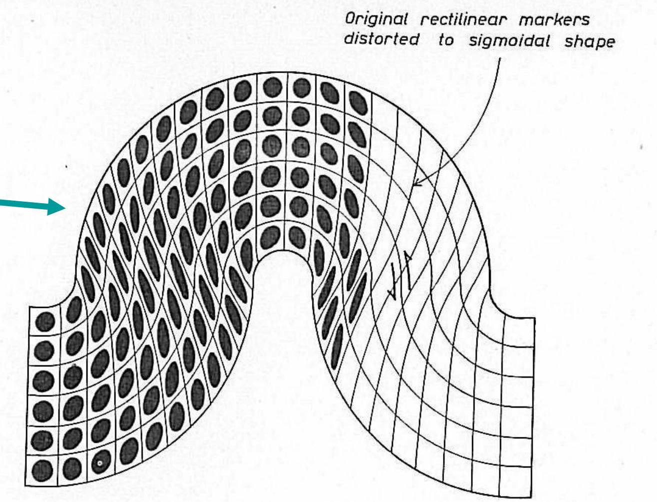

Reservoir Characterisation Data : Scales of Observation

# In Conclusion

## Test Software-Generated Results

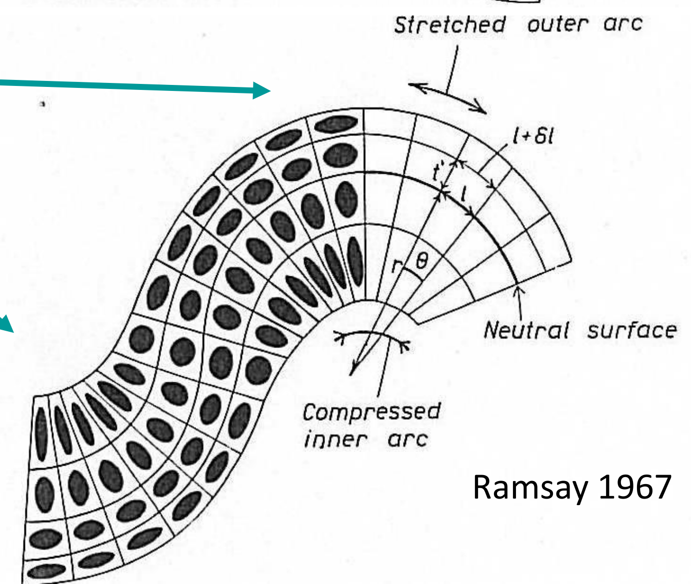
Flexural slip & flow folding:

highest strains are in fold limbs




Tangential longitudinal folding:

highest strains on fold hinges




Ramsay 1967

Plus lithomechanical properties affect deformation

# Thanks

## Have fun fieldwork (and safe) but expect the unexpected......

Lluis at work

A chopping board made from
400 Ma volcanic tuffs, NW England