Application of Pyrenean Fractured Carbonate Outcrops for Reservoir Characterisation

Edited Version for AAPG Website

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geoplay

AAPG Europe: Fractured Reservoirs: Geological, Geophysical and Engineering Tools to Crack Them

Catania Sicily, April 16-17 2015

Objectives and Overview

- To illustrate how outcrop can help us:
    1. with seismic and well data interpretation: can we close the ‘seismic gap’ ?
    2. understanding outputs from ‘black box’ softwares and techniques

- Using two related issues:
    1. how litho-mechanical units influence fracturing
    2. how the outcrop can help model the sub-seismic volume

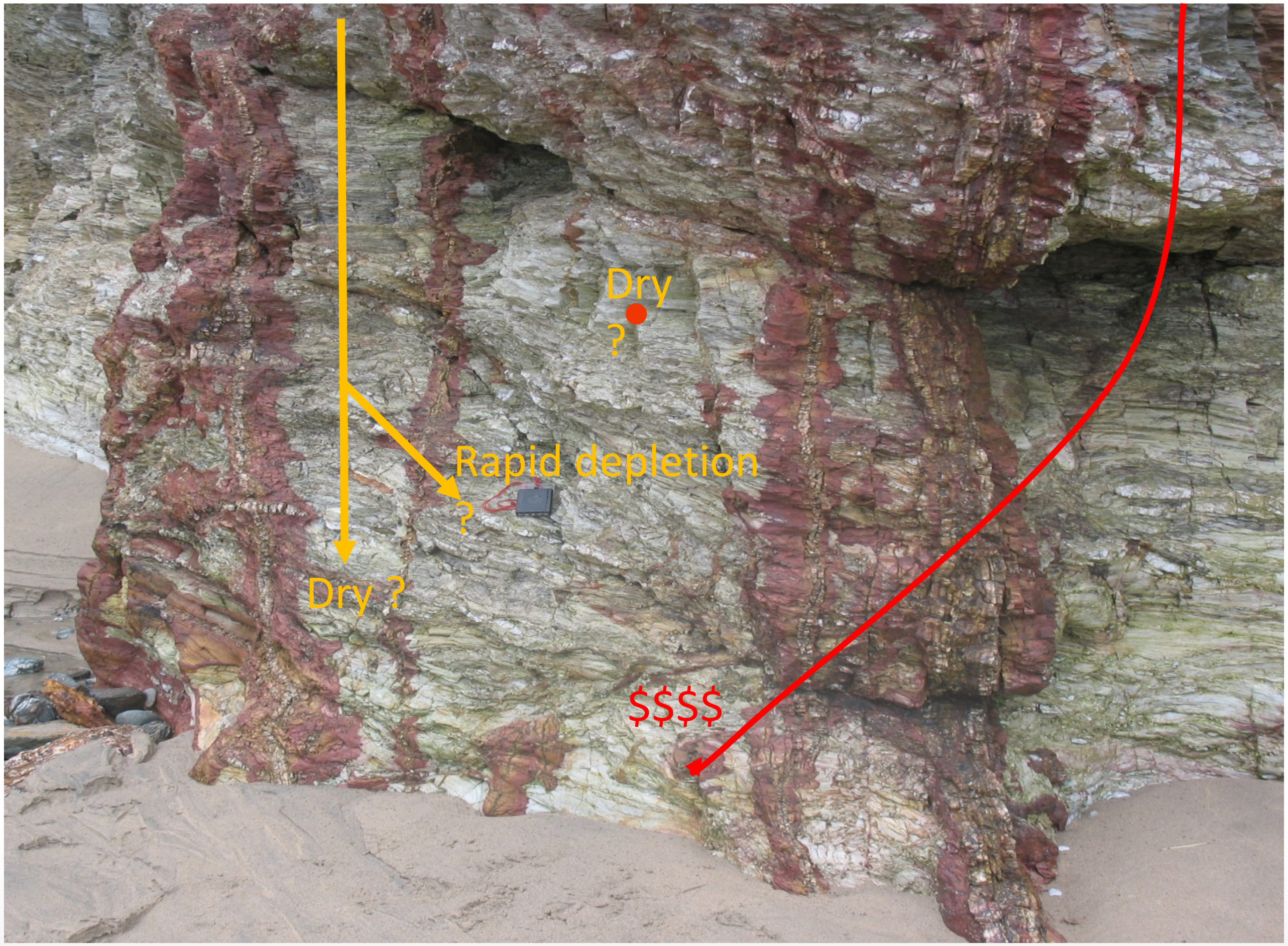
- Using some outcrops in the Tremp region of the south-central Pyrenees

Heterogeneity

Finding Fracture Sweetspots + Connected Volume

Heterogeneity

Finding Fracture Sweetspots + Connected Volume

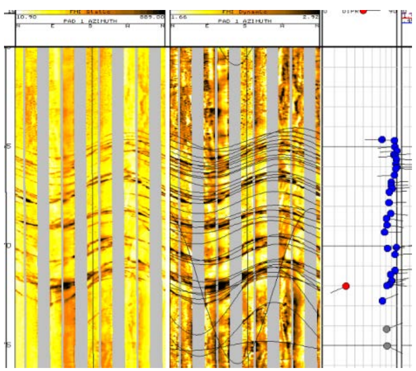


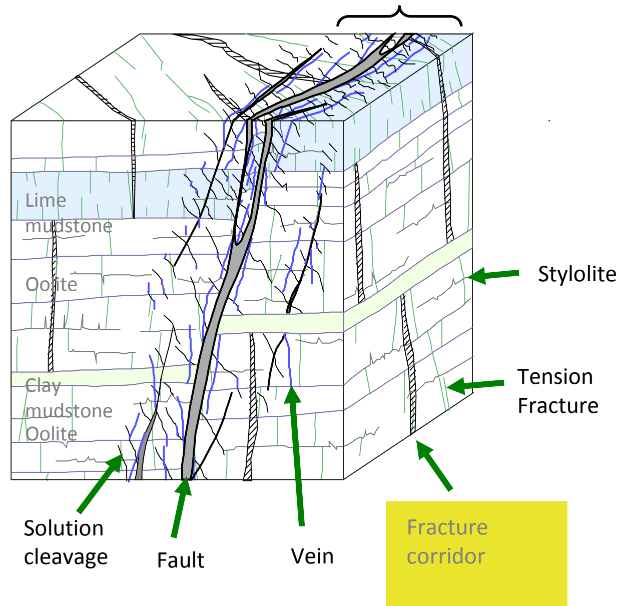
Fault damage zone fractures in Devonian marine mudstones with Fe-rich alteration haloes – Cornwall, UK

Modelling the Fracture Component

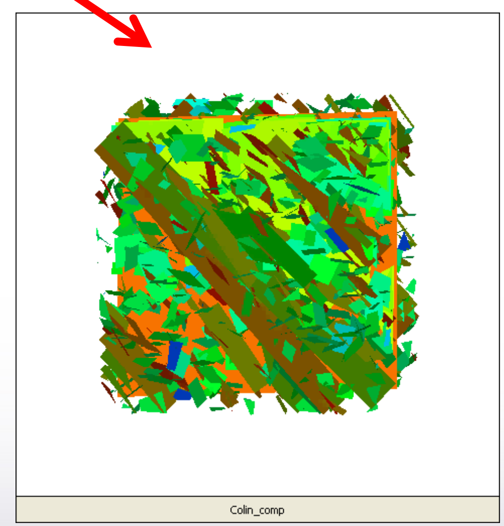
Geology for the RE's

Conceptual





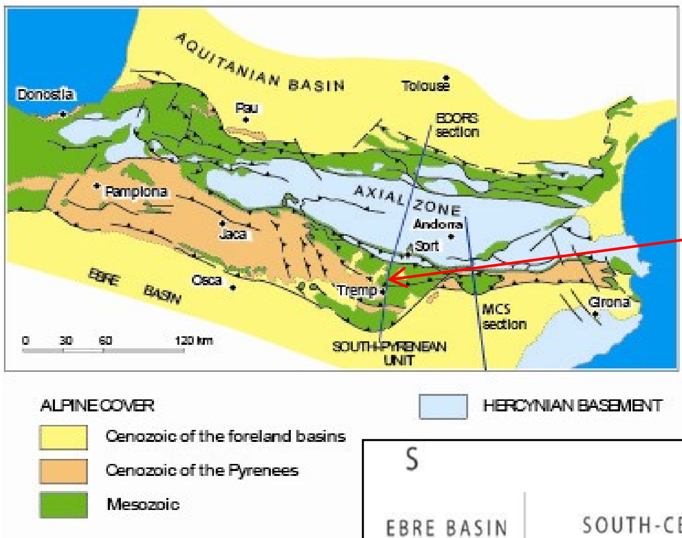
DFN



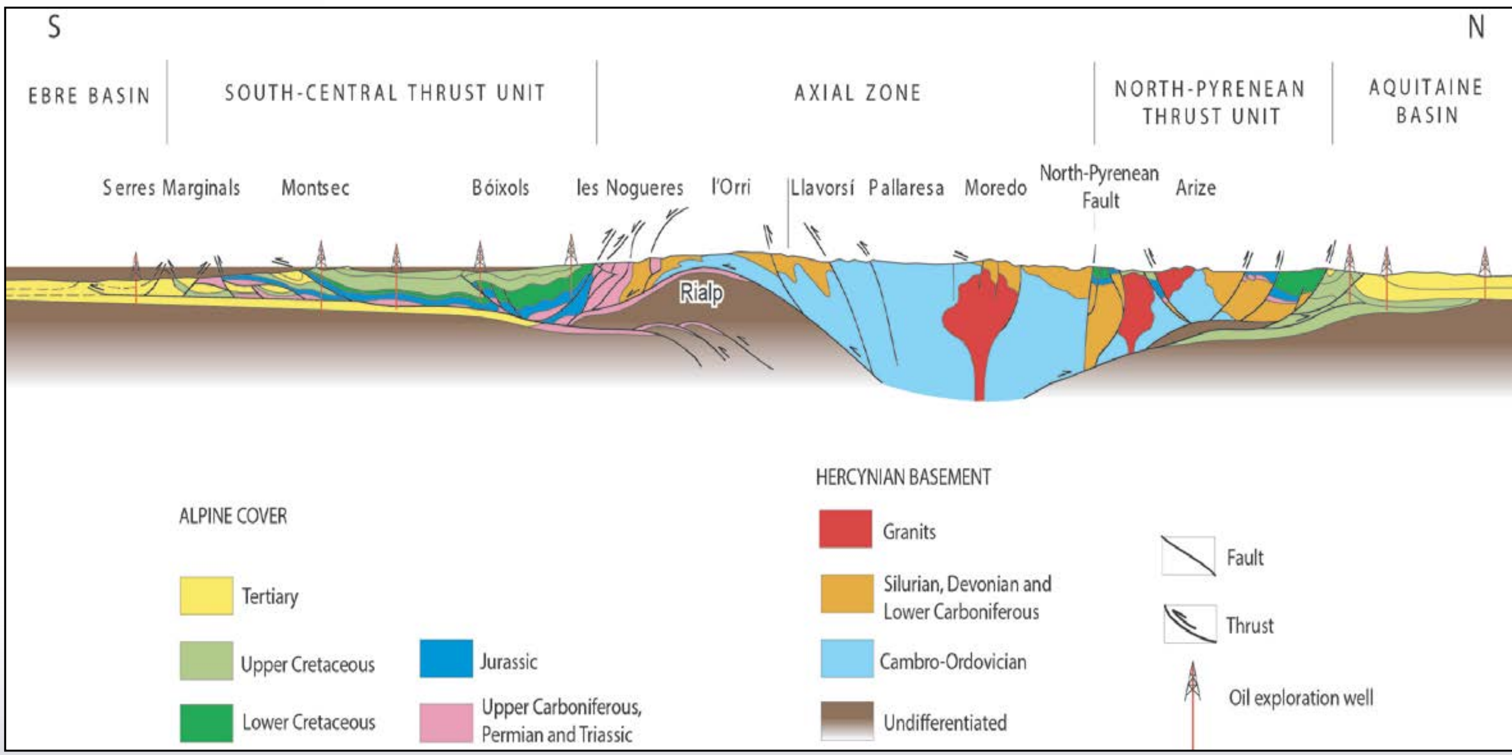
Colin_comp.avi

Regional Geology

Pyrenees South-central Thrust Unit

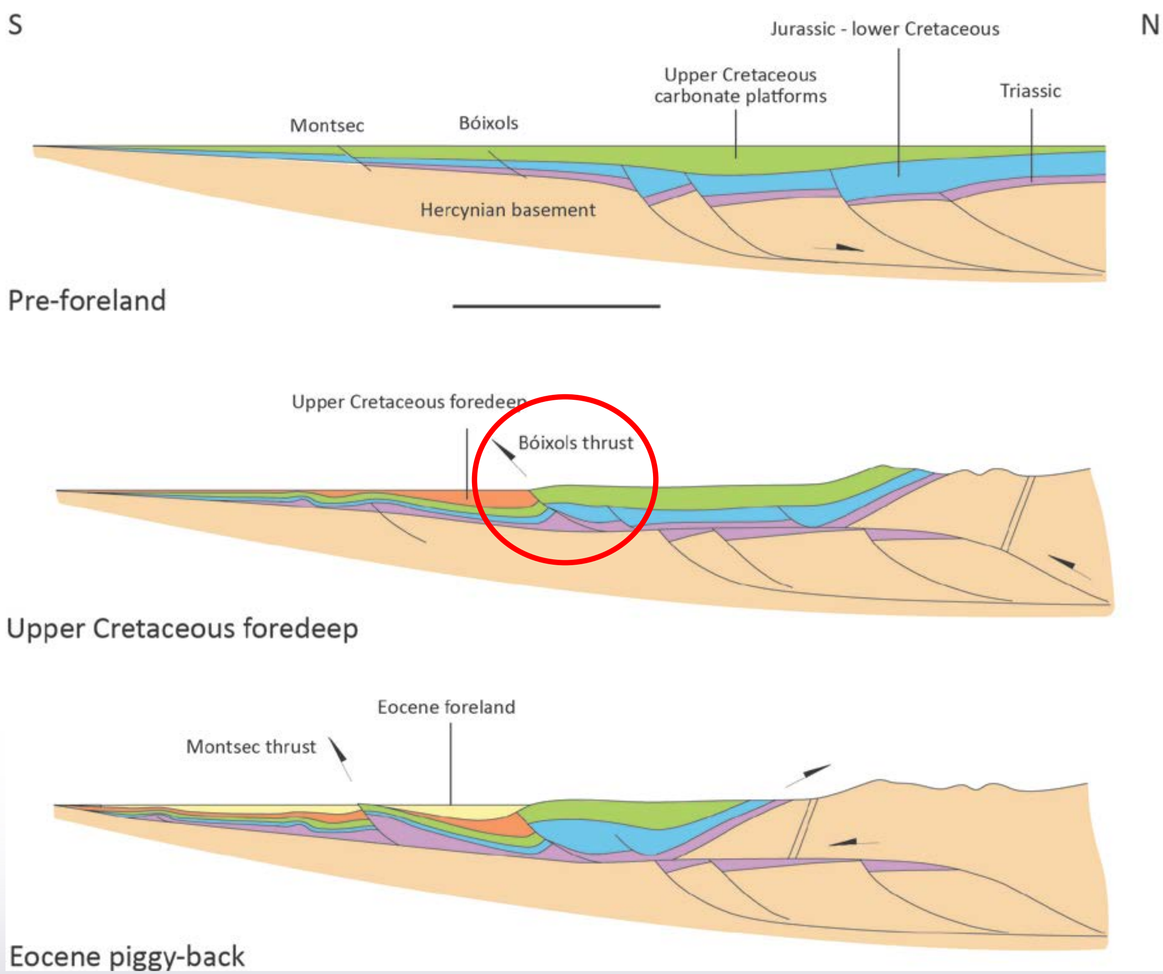


Tremp

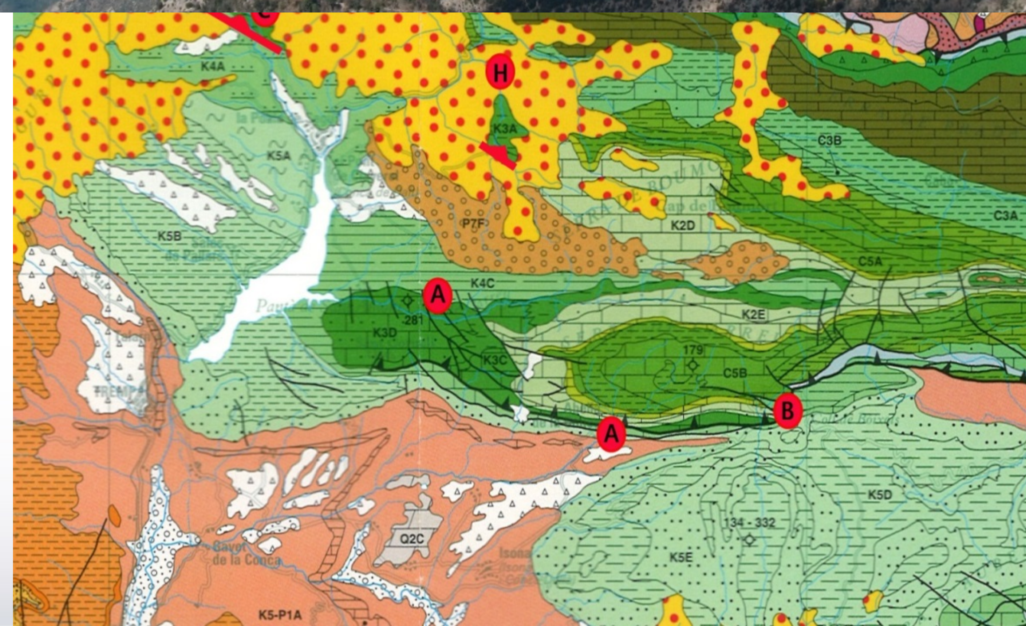


Regional Geology for the Outcrop Locations

South Central Thrust Sheets



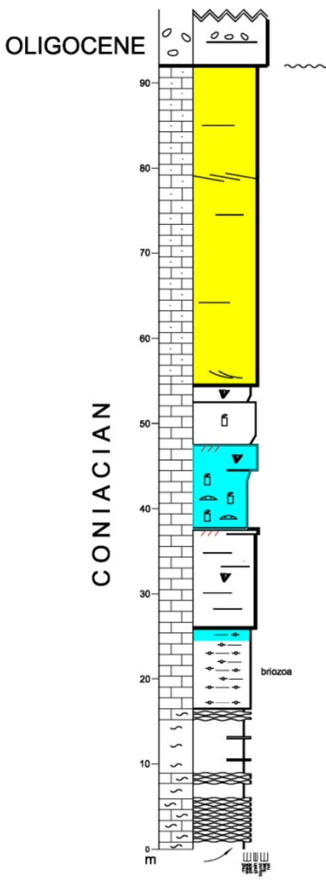
Outcrop Locations Hortoneda and Aramunt

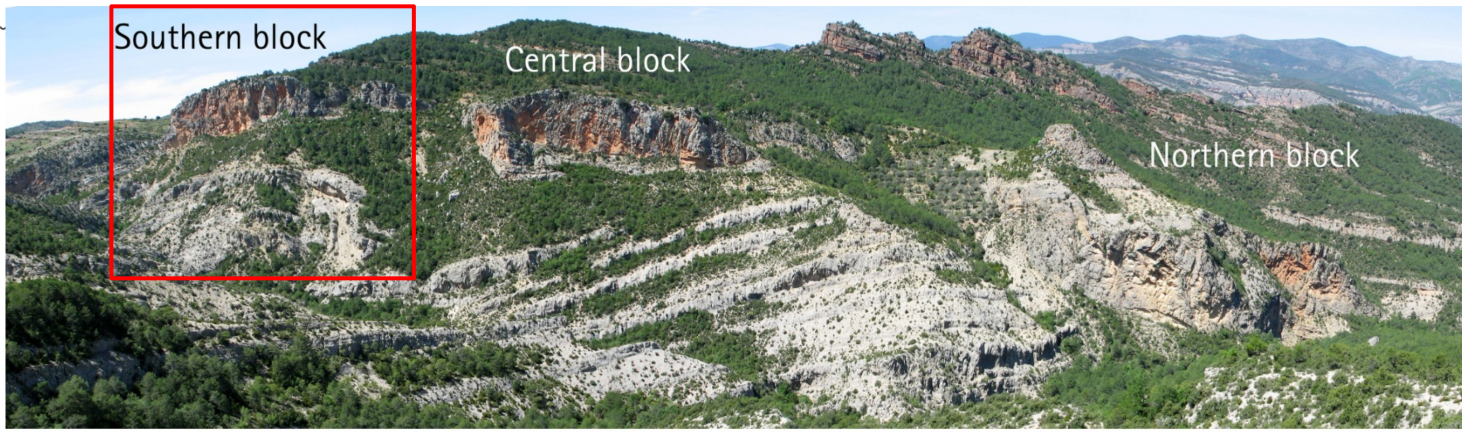


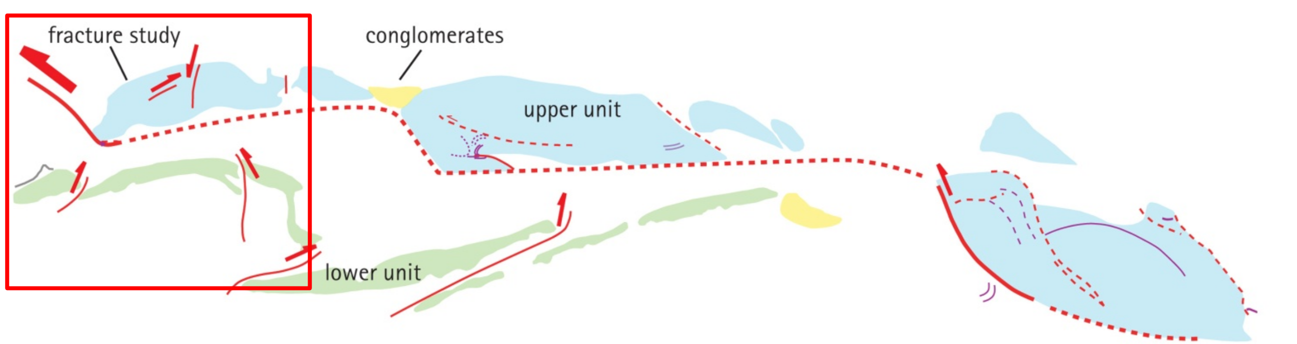
5 km

1. Litho-mechanical Control on Fracturing

Location H







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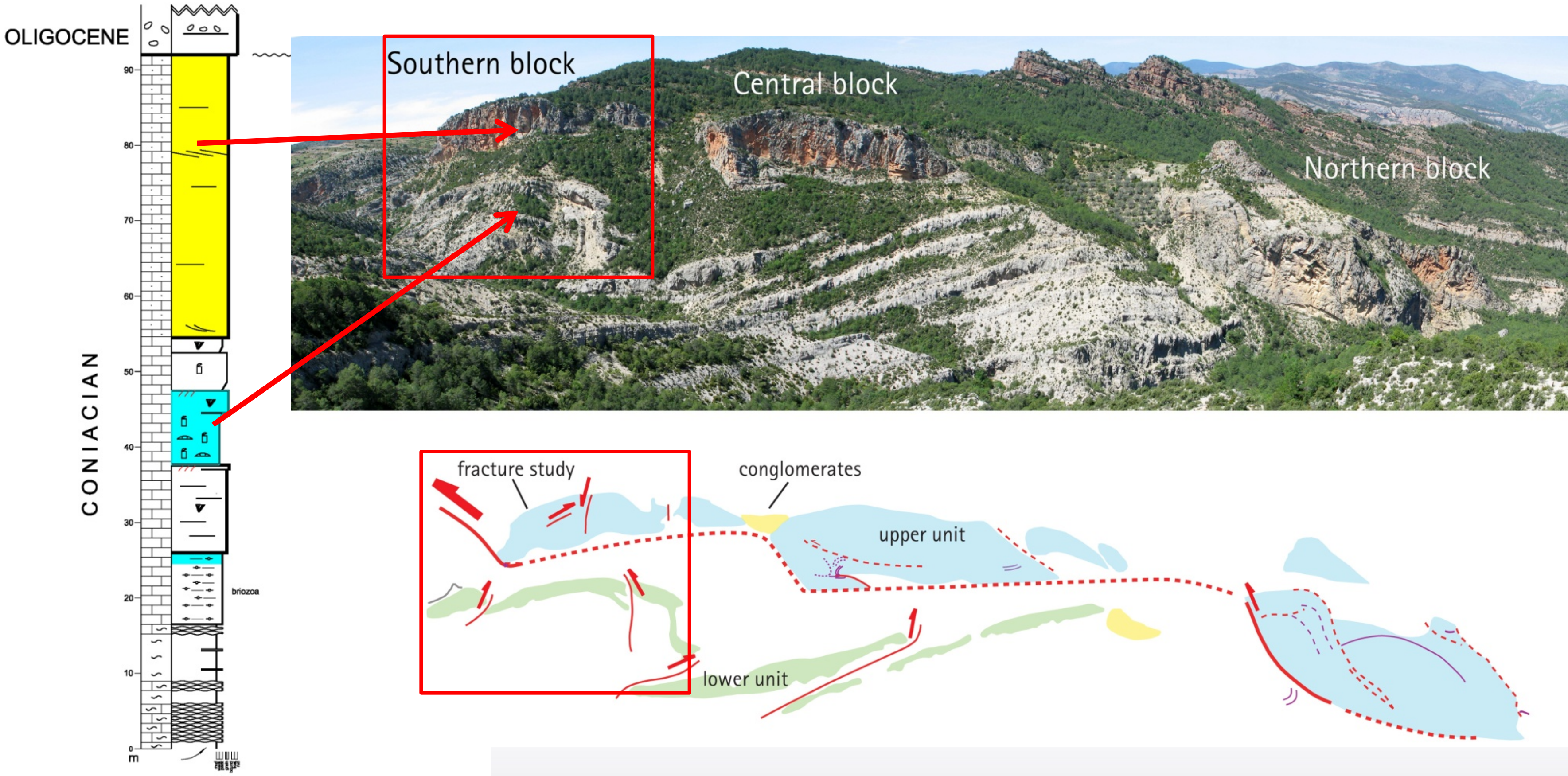
Litho-mechanical Control on Fracturing

Location H



Mechanical Control on Fracturing

Southern block

Mechanical Control on Fracturing

Upper Block – Massive Nodular Limestone

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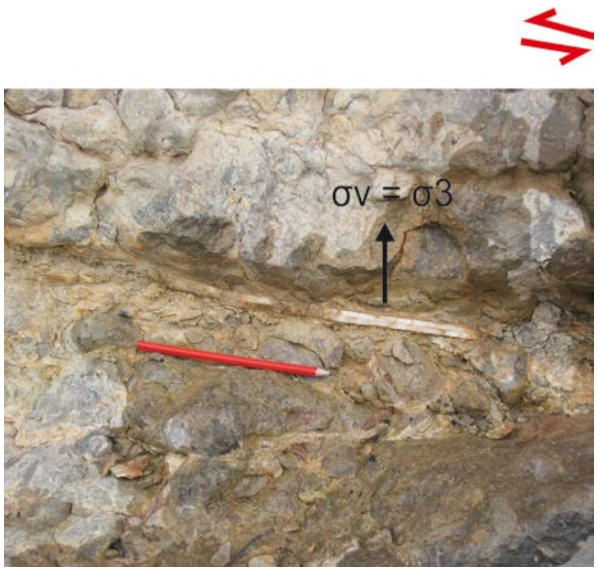
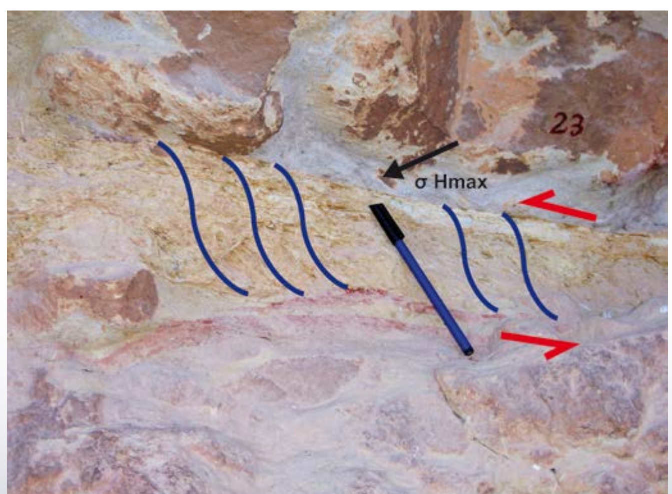
Fracture Paragenesis

Upper Carbonate Block



1. Low angle calcite veins indicating early vertical extension

2. Gently N and S-dipping shear zones indicating lateral shortening

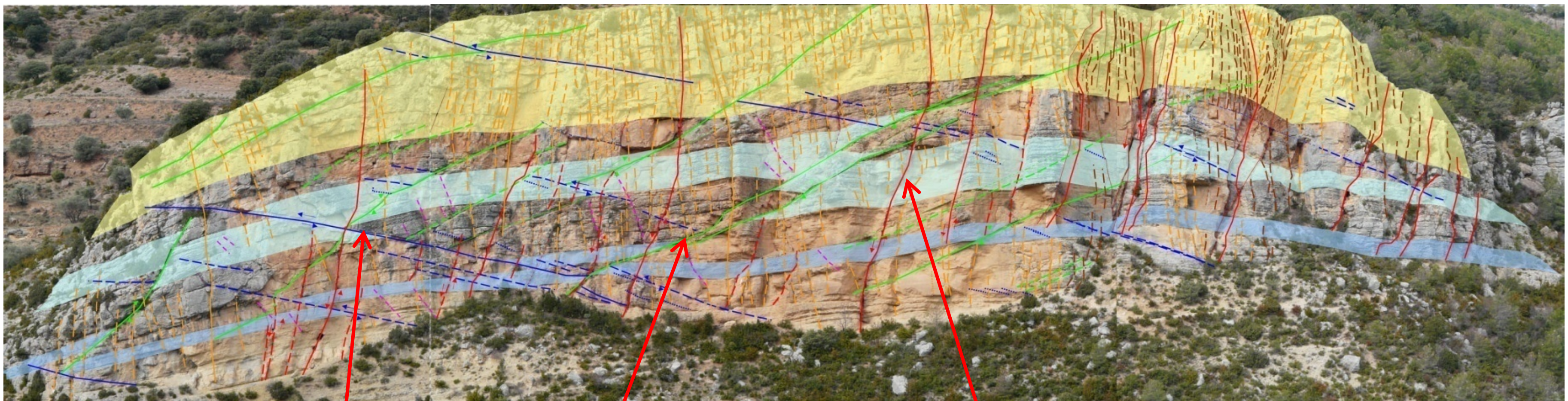


3. Sub-vertical extensional and shea joints indicating late tectonic ‘relaxation’

Fracture Paragenesis

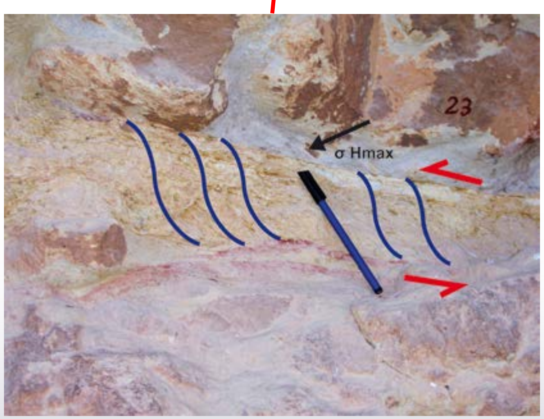
Upper Carbonate

~8% shortening



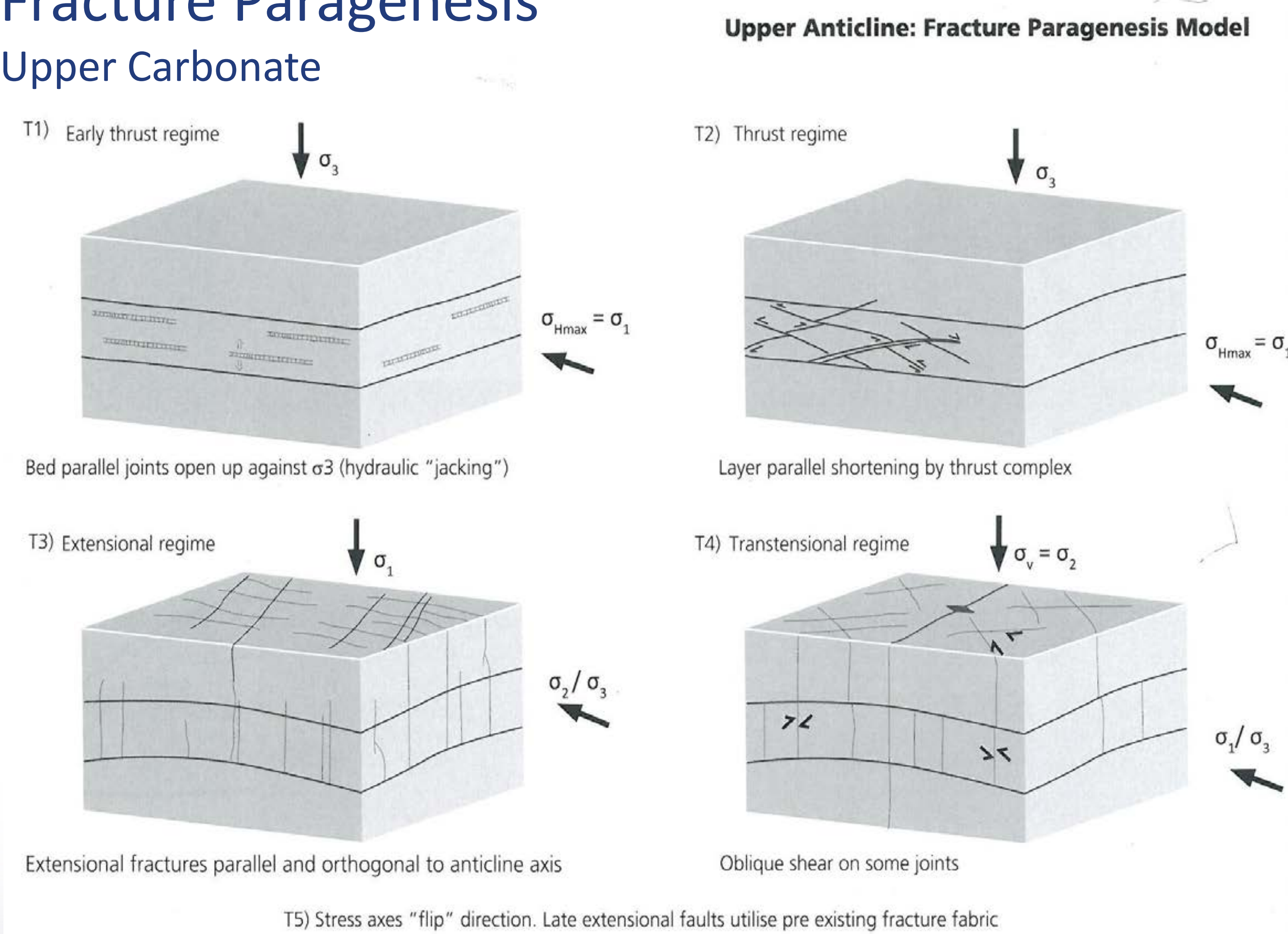
Top to the north

Top to the south thrusts



Fracture Paragenesis

Upper Carbonate

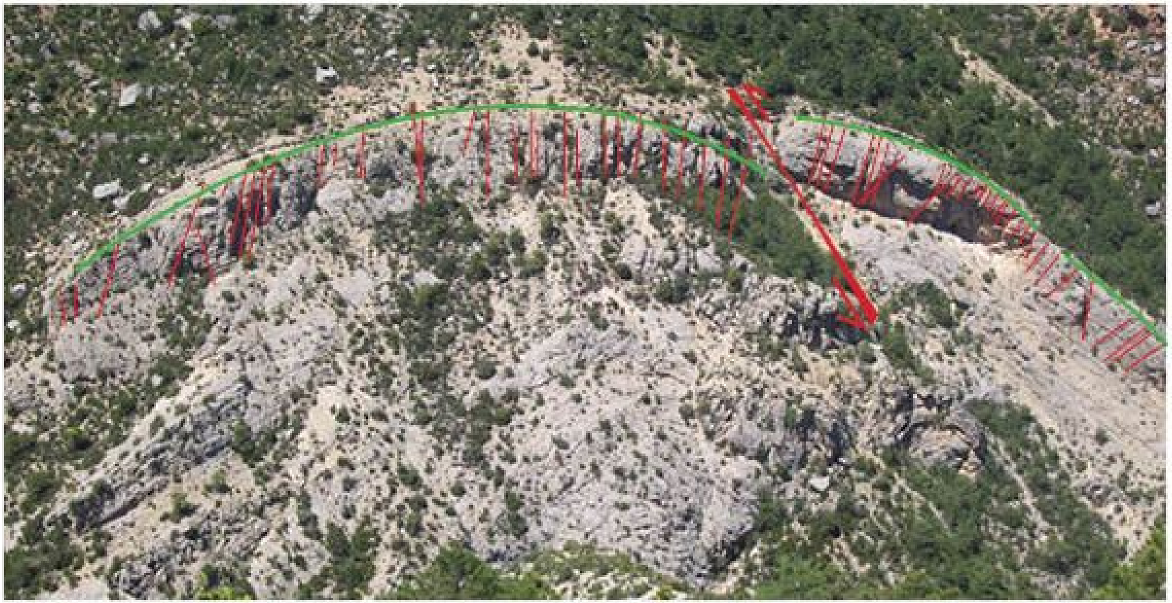


Mechanical Control on Fracturing

Lower Layered Carbonate

More classical axial planar fracture cleavage fanning around the fold, with limb shortening by a thrust

~15% shortening



Application to the Sub-Surface

A Project Example: Middle East Well

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

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

- Fracture count from borehole image log analysis in the far right column

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.

Please contact Jon at

gutmanis@geoscience.co.uk
Or 00441326 211070 for more information

Applying to Sub-Surface

A Project Example: Middle East Well

- Note good correlation between rock strength variations, differential stress and stress regime, and fracture count

- Fracture orientations also rotate with σHmax azimuth

- Inherited structure allows thrusting in a strike-slip stress regime

High $\sigma_1 - \sigma_3$, strike slip regime

Mainly low $\sigma_1 - \sigma_3$, normal regime

High $\sigma_1 - \sigma_3$, strike slip regime

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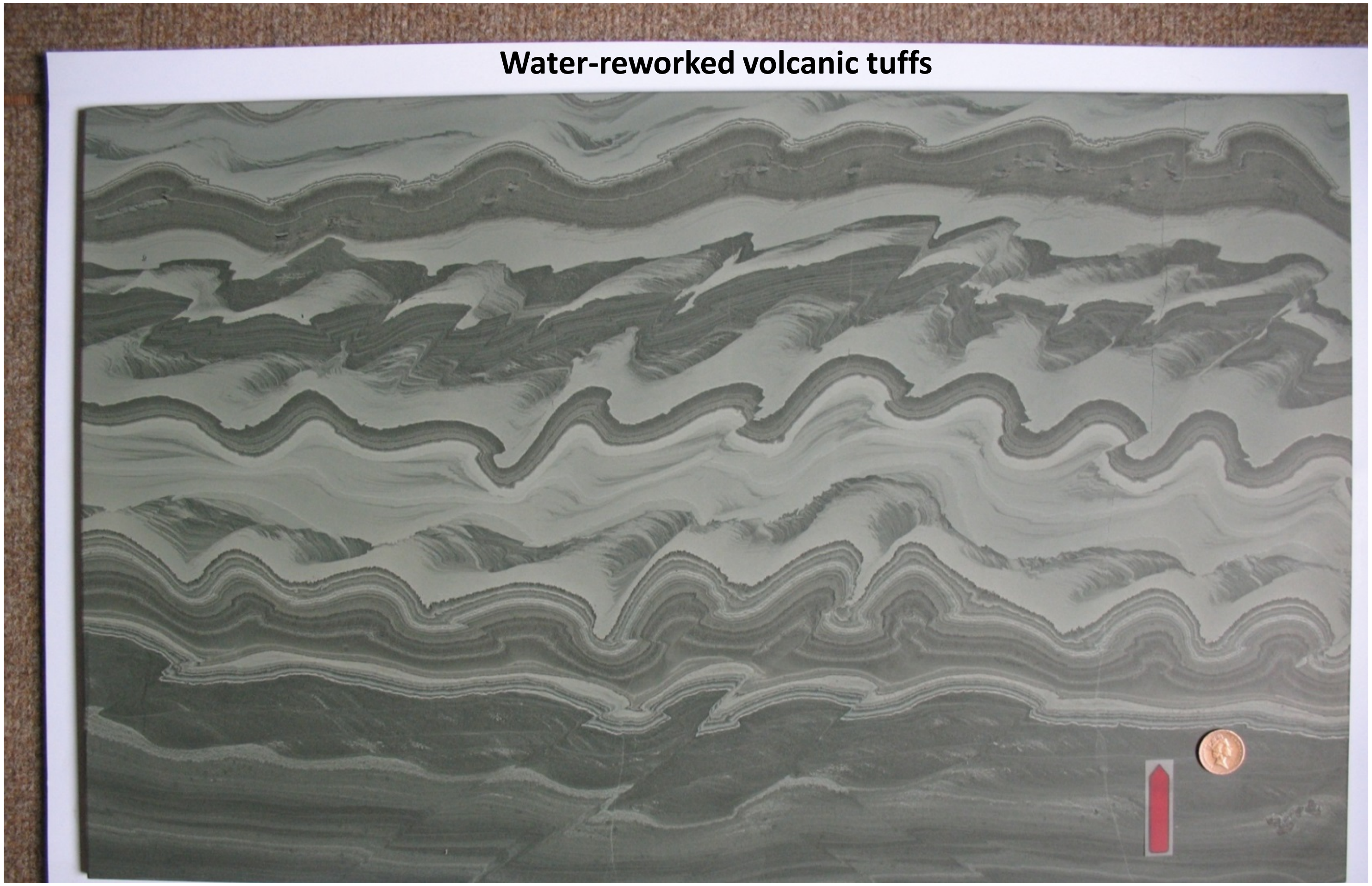
See Tavani et al JSG 2015 for a recent review of these issues

In Reality Most Folds are Hybrid and Complex



Mechanical contrasts and layer anisotropy have a major impact on folding

Folds are usually hybrid in reality - explains why universally consistent rules of fracture distribution are limited

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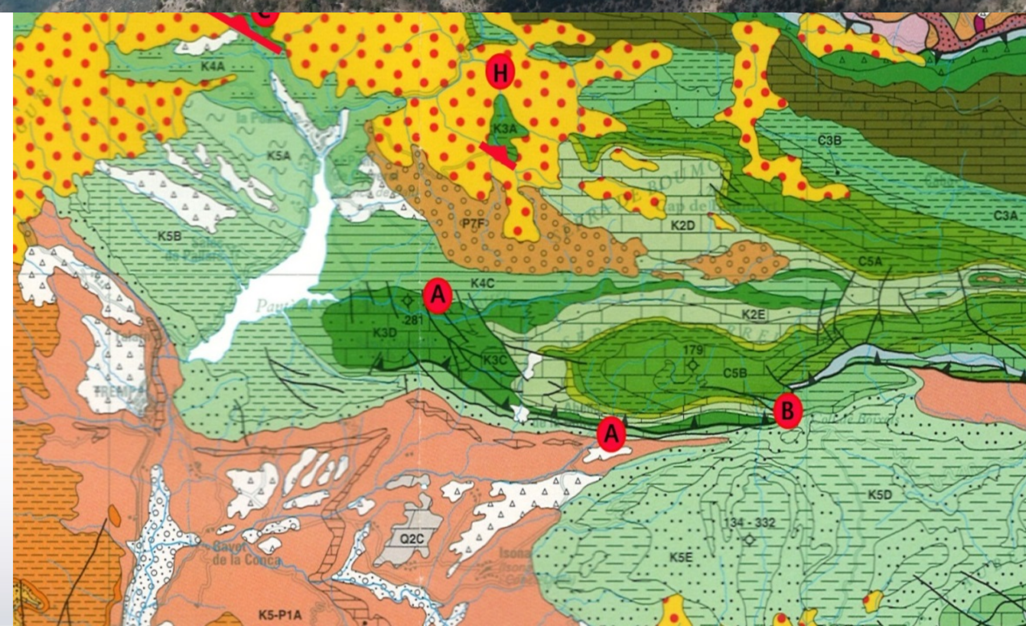
Outcrop Locations Hortoneda and Aramunt



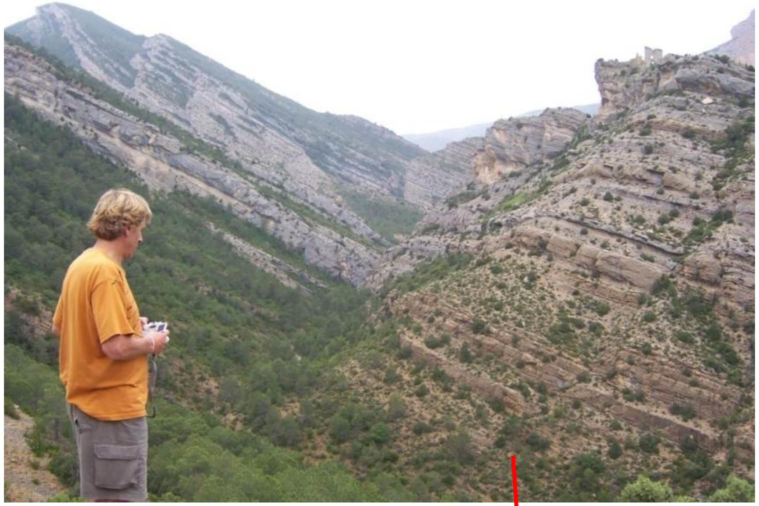
5 km

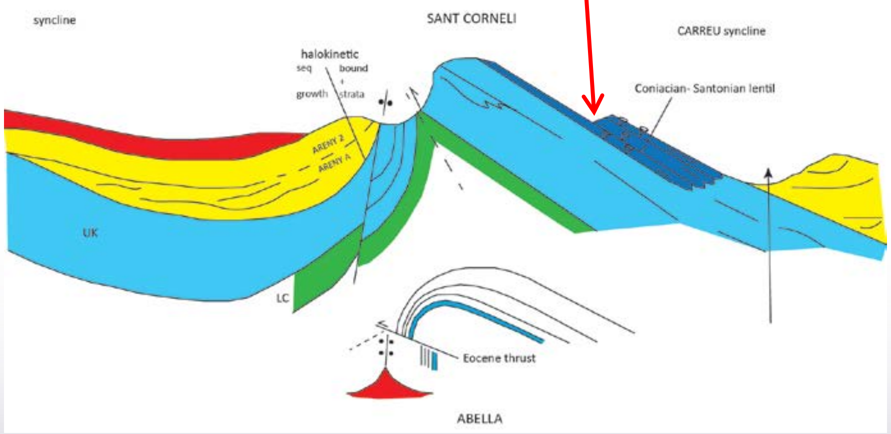
2. Investigating the Sub-Seismic Domain

Location A – Looking East

Interfingering Coniacian reefal carbonates , calc-arenites and marly limestones

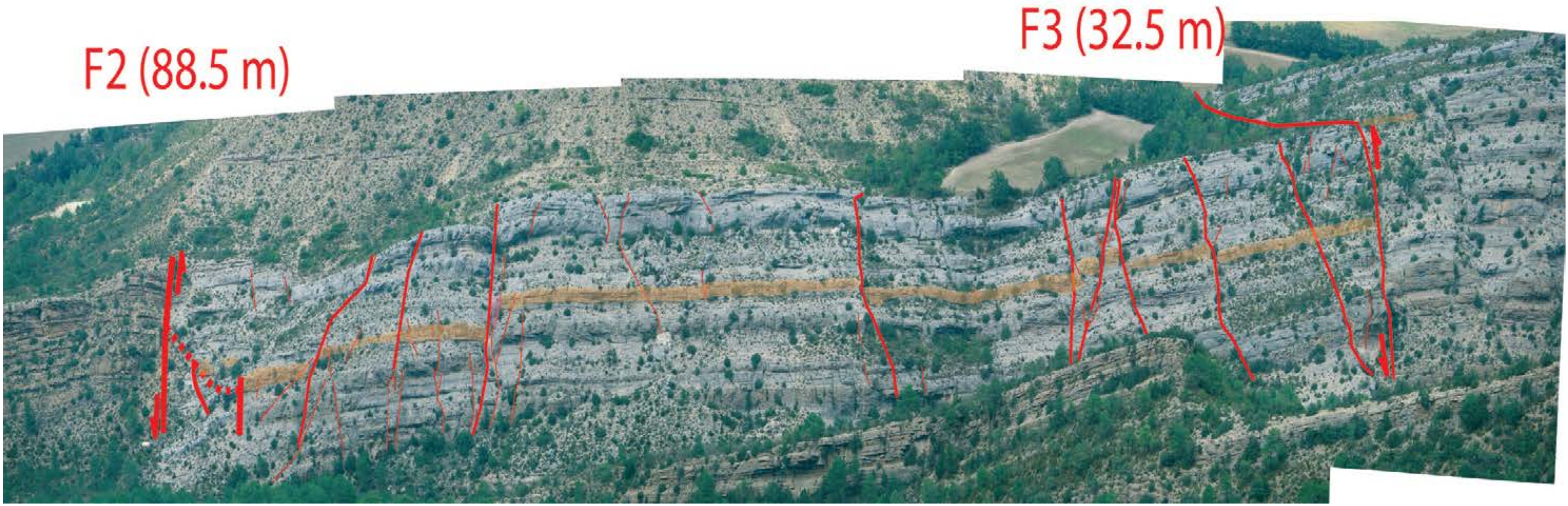
North dipping backlimb of St Corneli Anticline





Investigating the Sub-Seismic Domain

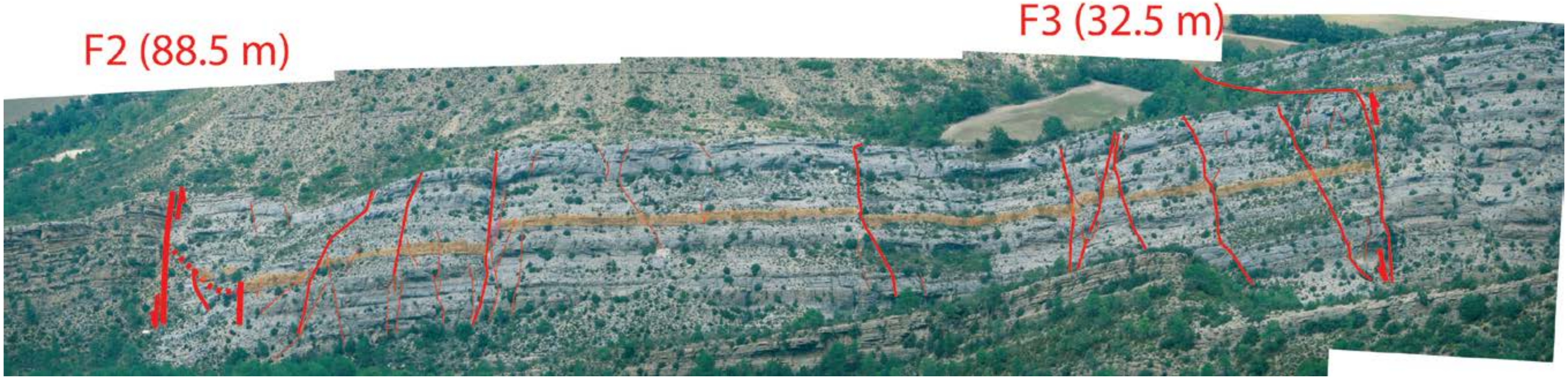
Looking North



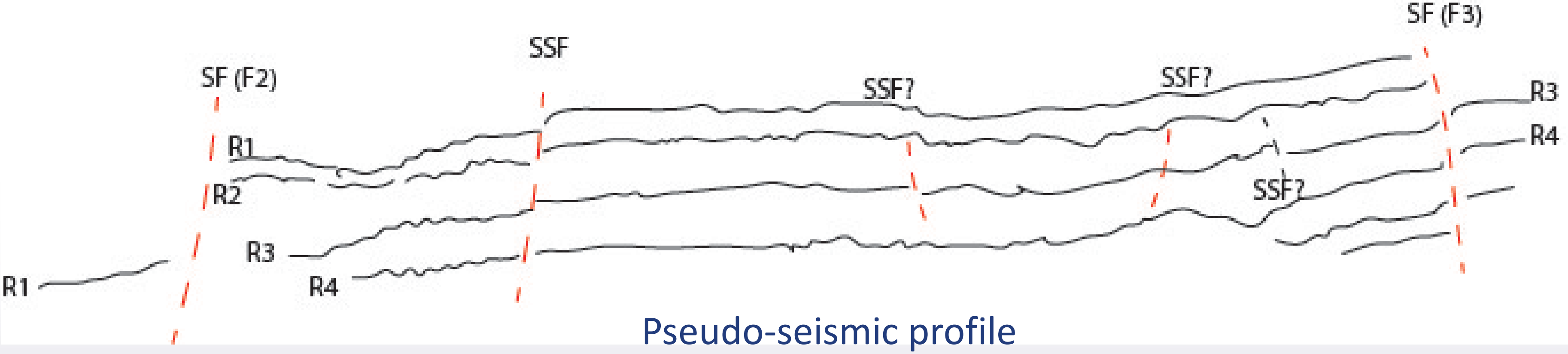
100m

Investigating the Sub-Seismic Domain

At the Very Limit of Seismic Resolution



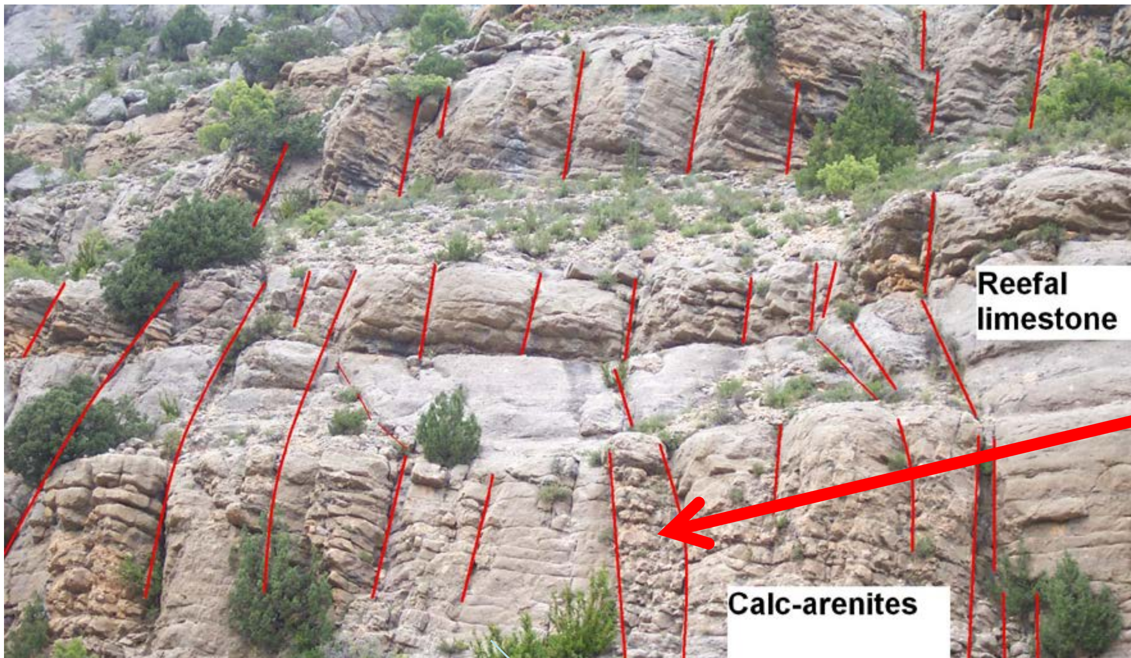
Interfingering Coniacian reefal carbonates and calc-arenites

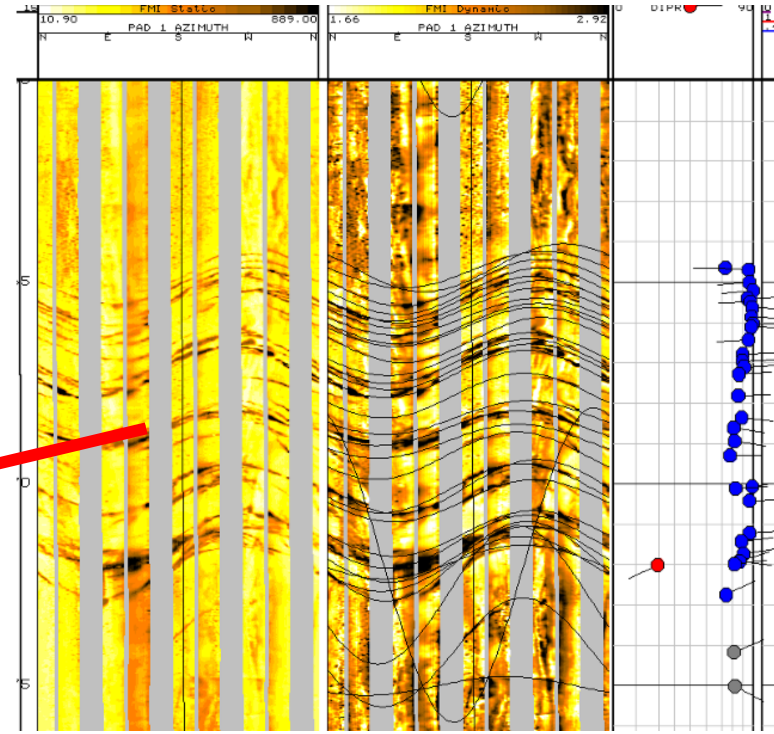


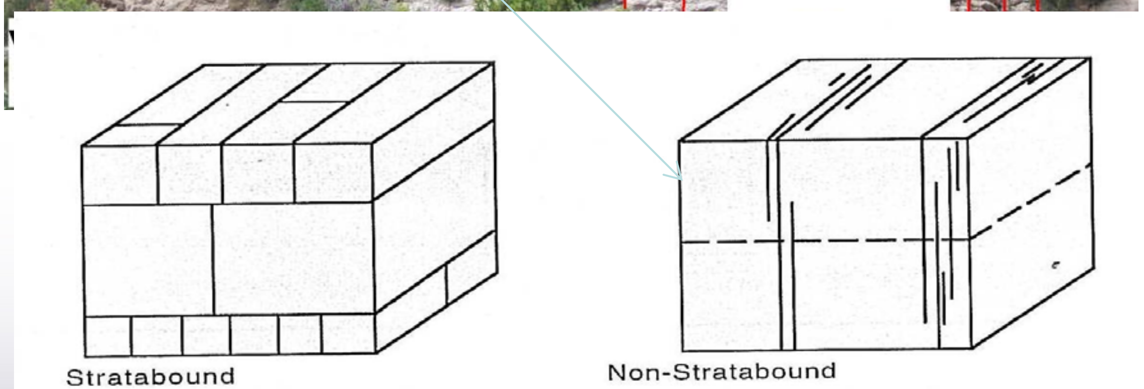
Pseudo-seismic profile

Going Sub-Seismic with the Drill Bit

Fracture Corridors and Joint Networks







A hierarchy of fractures

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Fracture Hierarchy

Spacing Data and Relationships to Lithologies

- Seismic scale faults:
  ~500 to 1000m Fairly regular spacing
- Sub-seismic faults:
  ~100 to 250m Clustered
- Fracture corridors:
  10 to 100m Clustered
- Stratabound joints:
  . 5 to 10m More systematic and regular

- Micro-scale fractures and variable matrix properties

Lengths, heights, sets, kinematics, timings can also be defined

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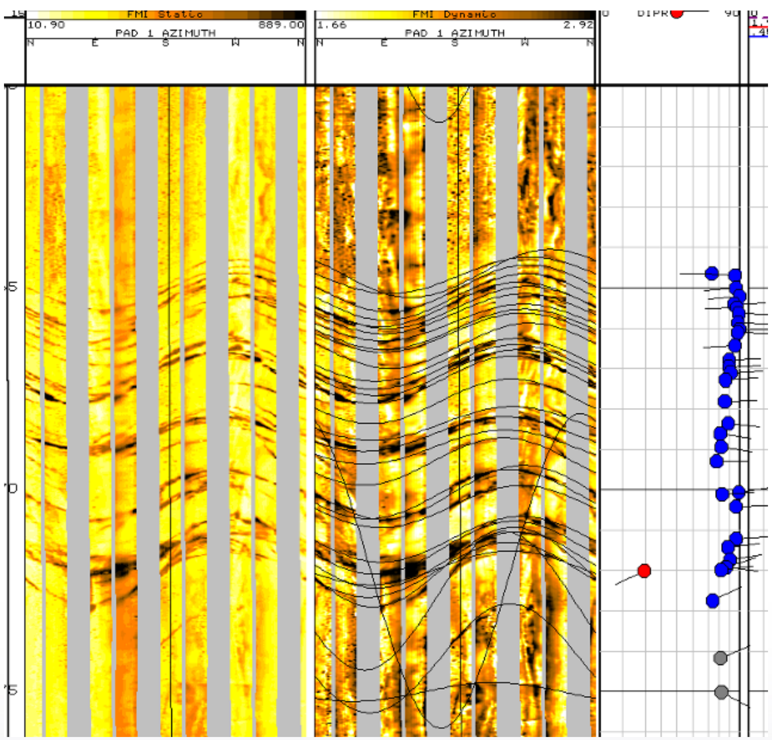
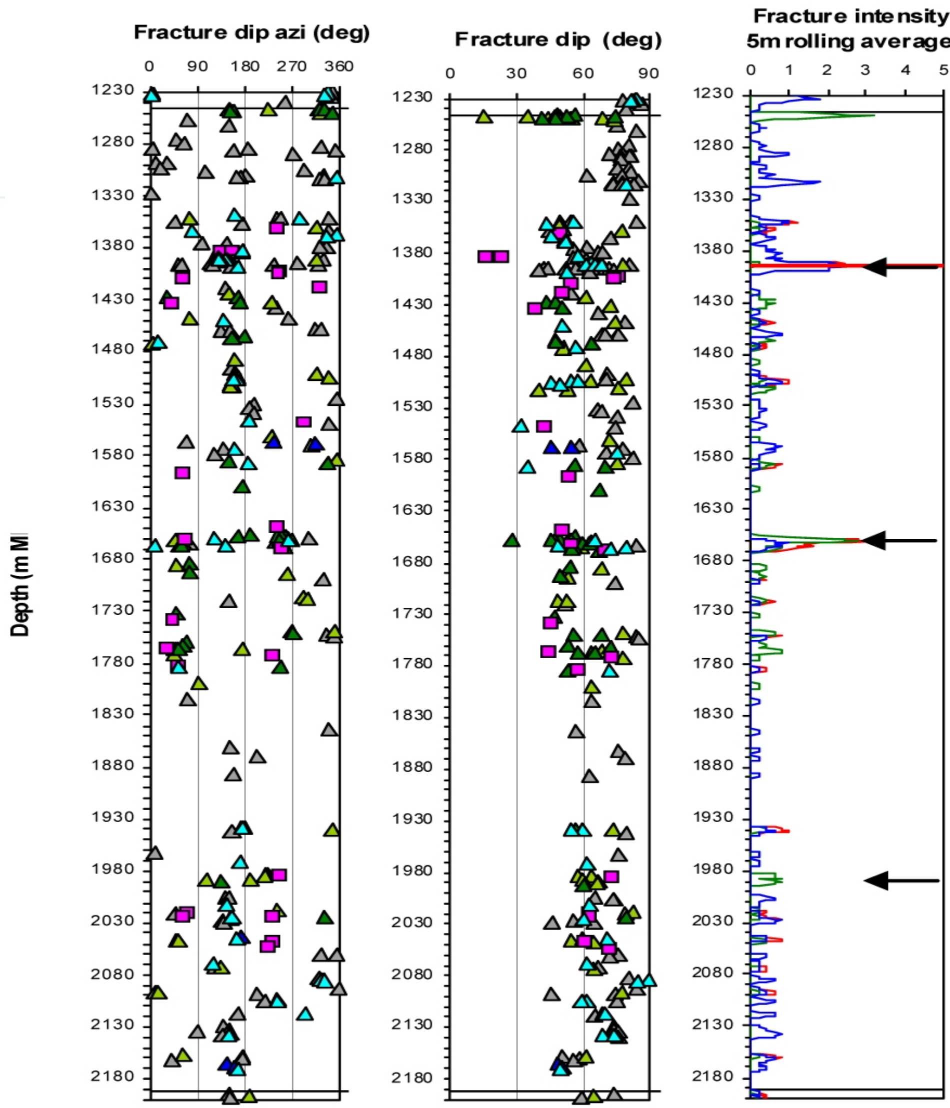
Application to the Sub-Surface

Interpretation of Image Logs



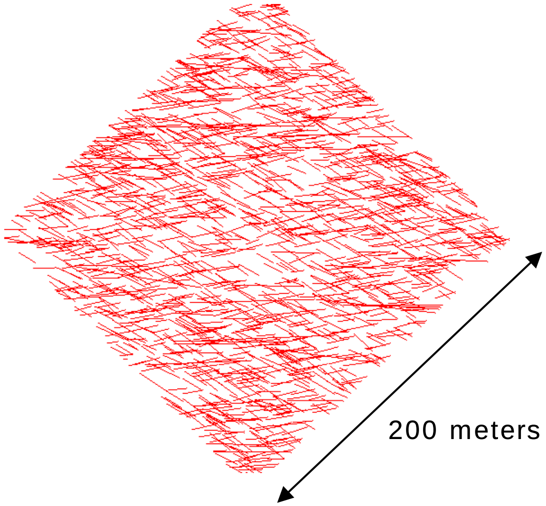


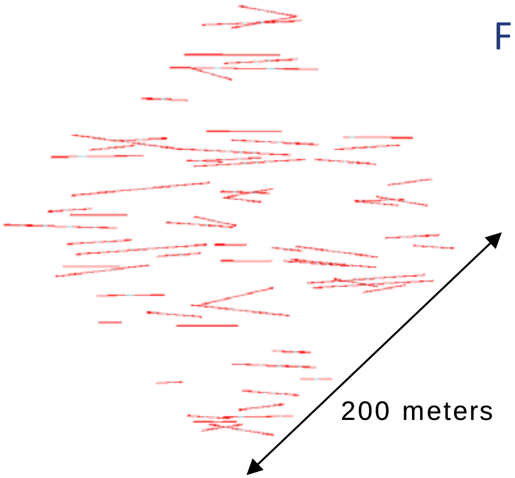
Key

- Open fractures (J)
- Low confidence open fractures
- Mineralised fractures (V, cemented gashe
- Low confidence mineralised fractures
- Part open part mineralised fractures(TG's
- Enhanced after acidification
- Possible fault

Application to the Sub-Surface
Static Fracture Models

Systematic joints





Fracture corridors and sub-seismic faults

- A Russian carbonate field modelled in GoCad ▶ Petrel ▶ Eclipse
- Stochastic fracture realisations were generated to predict fracture-network permeabilities for reservoir simulation

Courteousy of Steve Gross (Chevron)

Application to the Sub-Surface

Concepts and Parameters to Help Select Appropriate Modelling Strategy

Application to the Sub-Surface

Selection of Appropriate Modelling Strategy to Capture Heterogeneity

One approach: K multipliers for the bigger features/ domains and leave background out ?

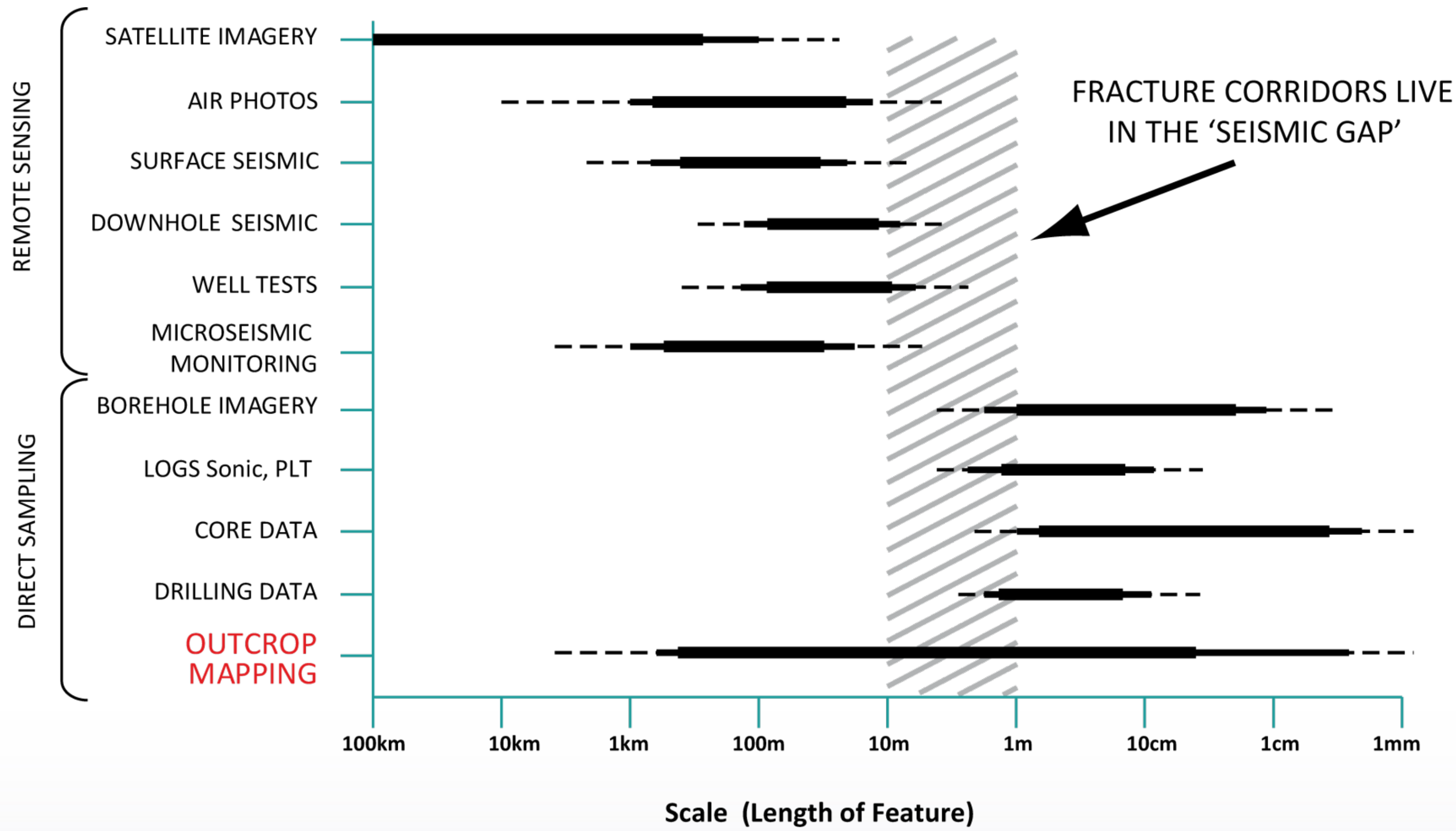
Application to the Sub-Surface

Selection of Appropriate Modelling Strategy to Capture Heterogeneity

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

In Conclusion

Derive Fracture Parameters, Concepts, Templates



Reservoir Characterisation Data : Scales of Observation

Thanks

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

Lluis Ardevol at work