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Comparison of Mechanical and Fracture Stratigraphy between Failed Seal Analouges

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INTRODUCTION

The presence of discontinuities in seal lithologies affects their mechanical and hydro-geologic properties. We examine the mechanical and fracture stratigraphy of failed Paleozoic and Mesozoic seal analogues in south-east Utah to understand the nature and distribution of fluid flow pathways in various seal lithologies. Outcrop surveys provide data for comparison between each locality to identify relationships between depositional composition, diagenesis, and loading history. These data characterize the distribution and morphology of open mode fractures, with changes in lithology and provide input for accurate quantitative subsurface geomechanical and fluid flow models.

METHODS

Outcrop

Measured stratigraphic sections -- detailed rock descriptions, identification of lithologic changes including grain size, bed thickness, & mineralogy

Scanlines - determine fracture distribution, morphology and interaction types

Rock strength and Permeability - field-derived compressive strength (N-type Schmidt hammer) and permeability (TinyPermII).

Petrography

XRD- mineralogic composition comparison between host and fractured rocks

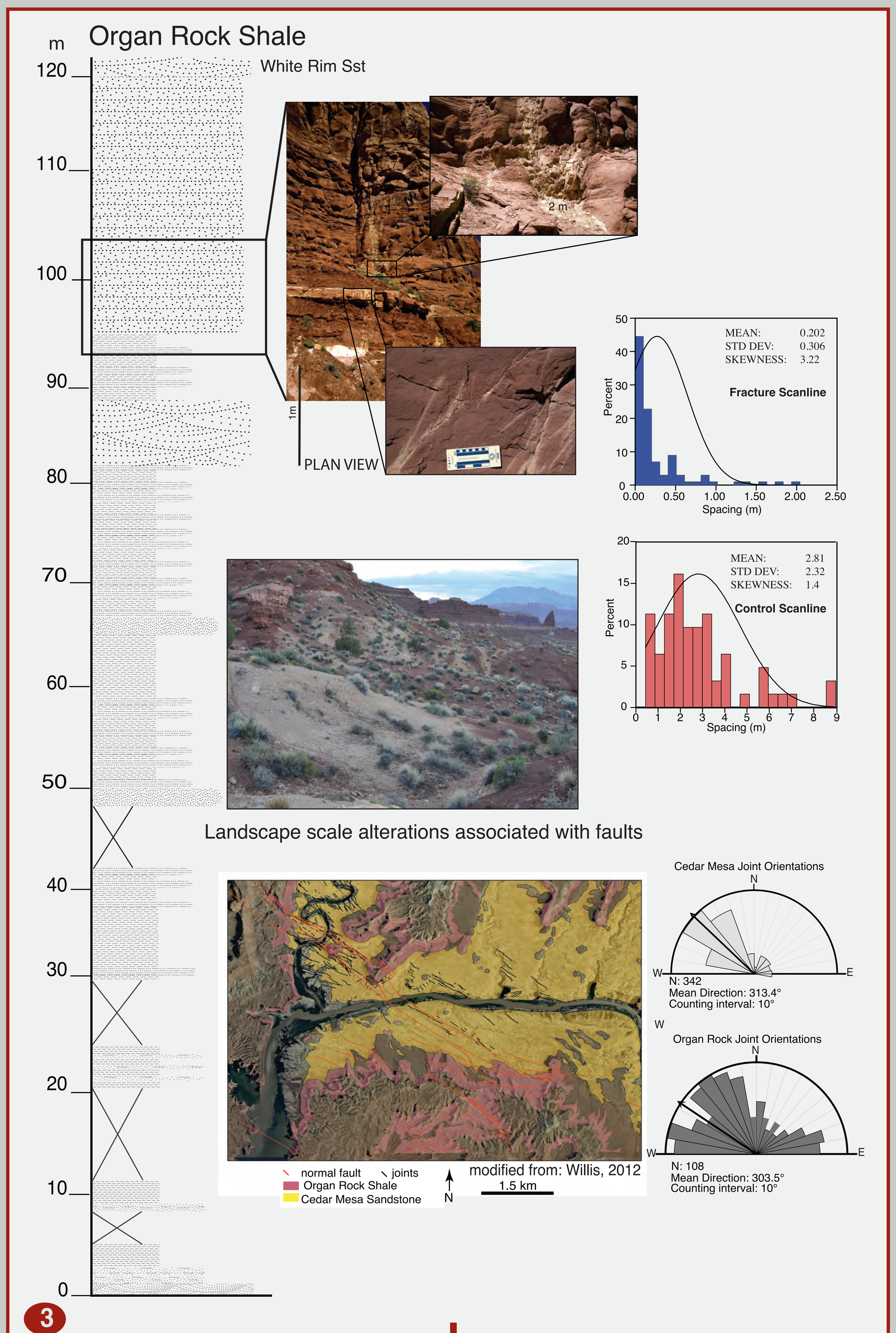
Thinsection - characterization of micro-structures and structural diagenesis

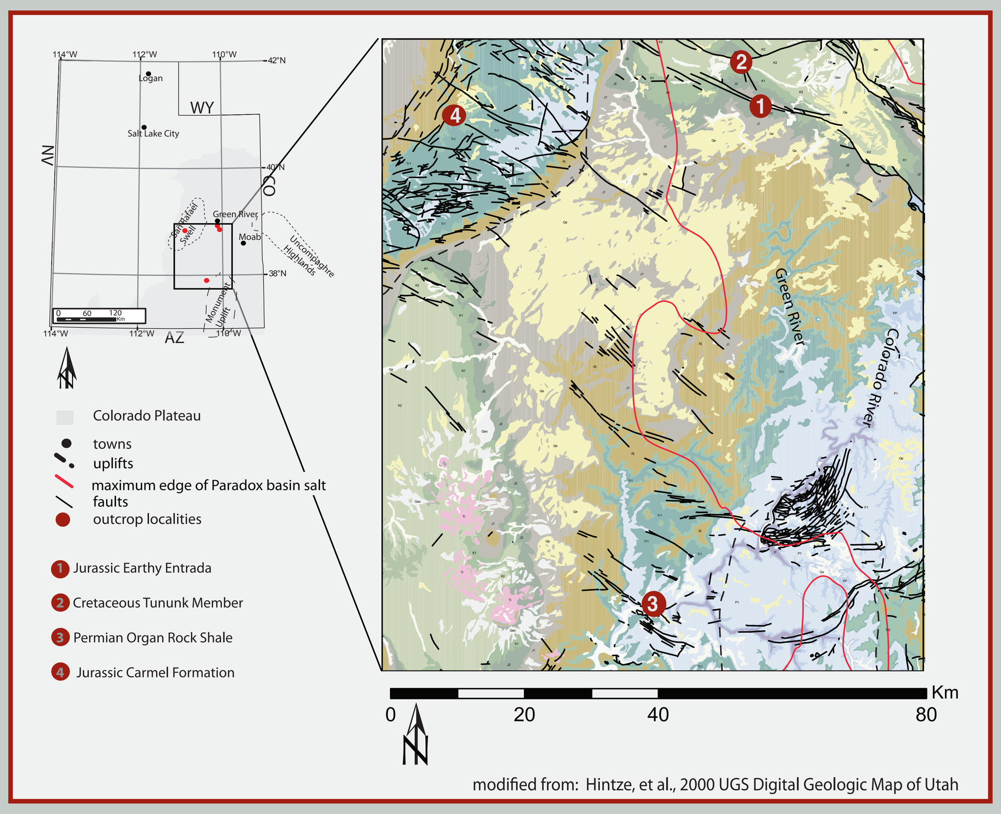
Theoretical

Burial History & Stress Evolution - burial histories merged with simple Mohr-Coulomb analysis to constrain Sv, SH, and Sh failure models through time

Mohr-Coulomb - stress changes & failure modeled through time where:

$C=0$ & $C=5$; $S_v=\sigma_1=\rho g z$, $\nu=0.25$, $S_H=S_h=\sigma_2=\sigma_3=(\nu/\nu-1)(P_p-S_v)+P_p$ (from Eaton, 1969)

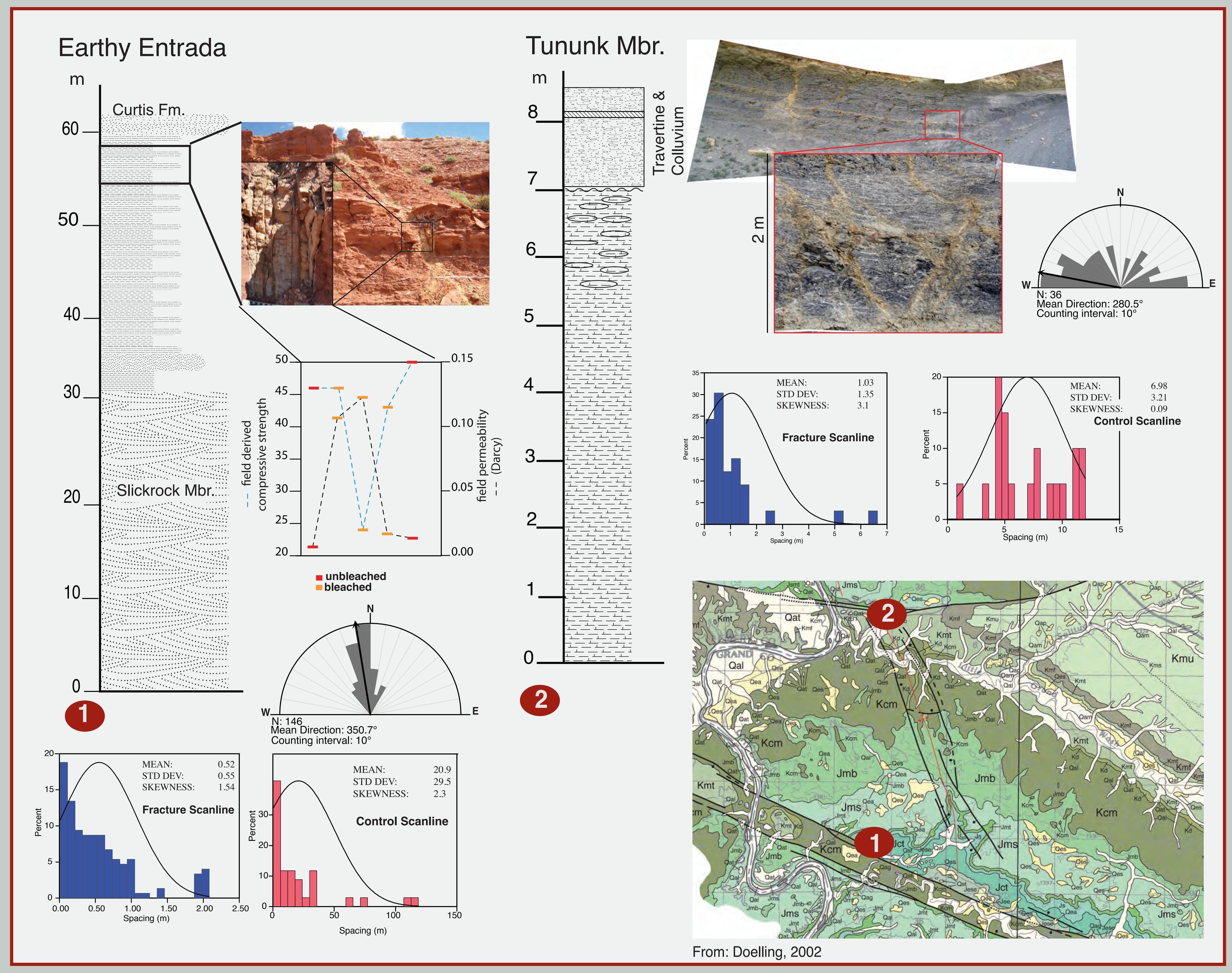


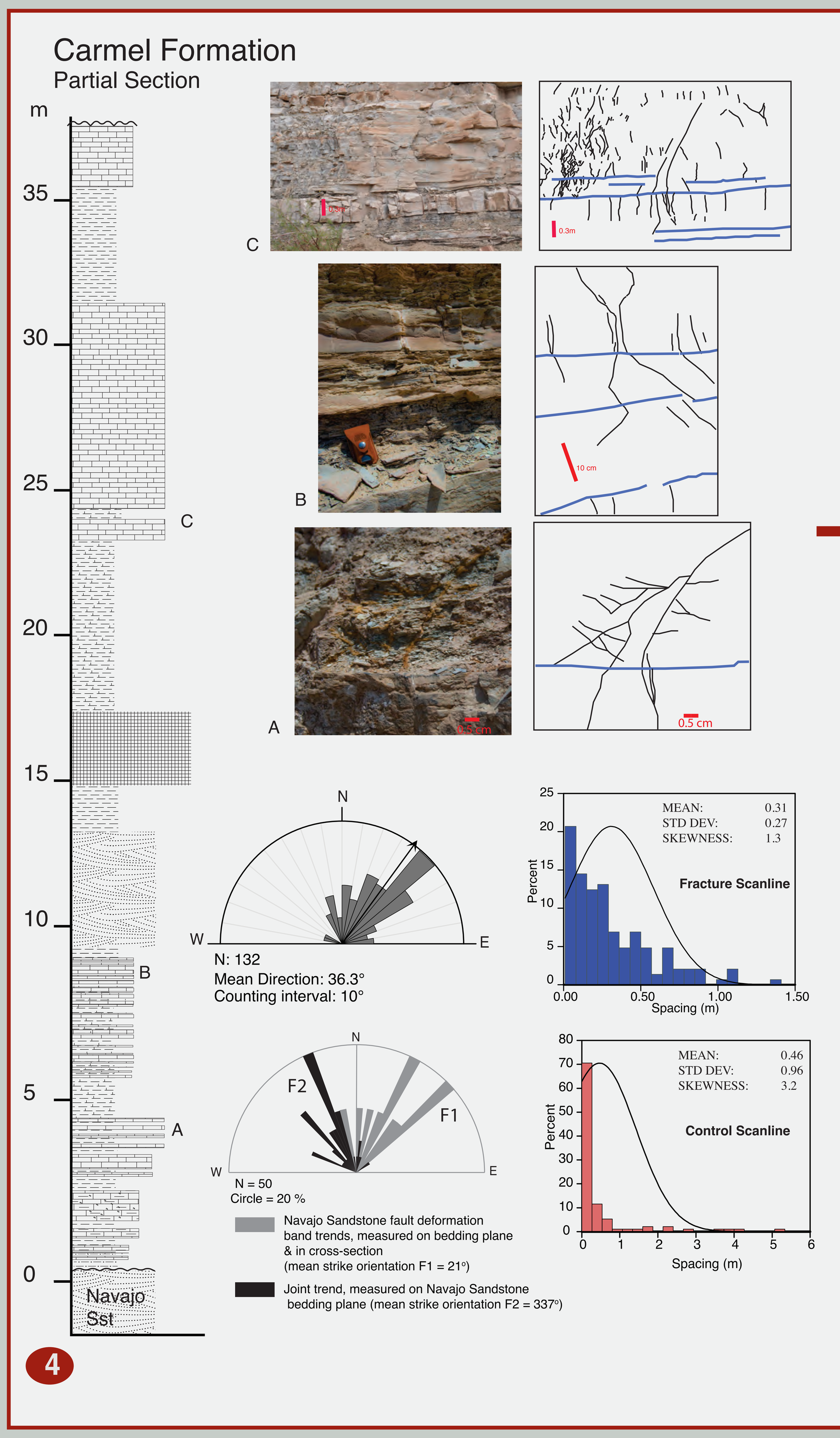


OUTCROP OBSERVATIONS

All localities show:

- evidence for mineralization and fluid flow in the subsurface
- mineralogic differences between host and fracture fill
- meso-scopic fault and fracture orientations which follow regional structural trends
- fracture spacing <0.25-0.5 fractures/meter
- fracture densities and morphology which vary with lithology and bed thickness





OUTCROP MECHANICAL STRATIGRAPHY: CARMEL FORMATION

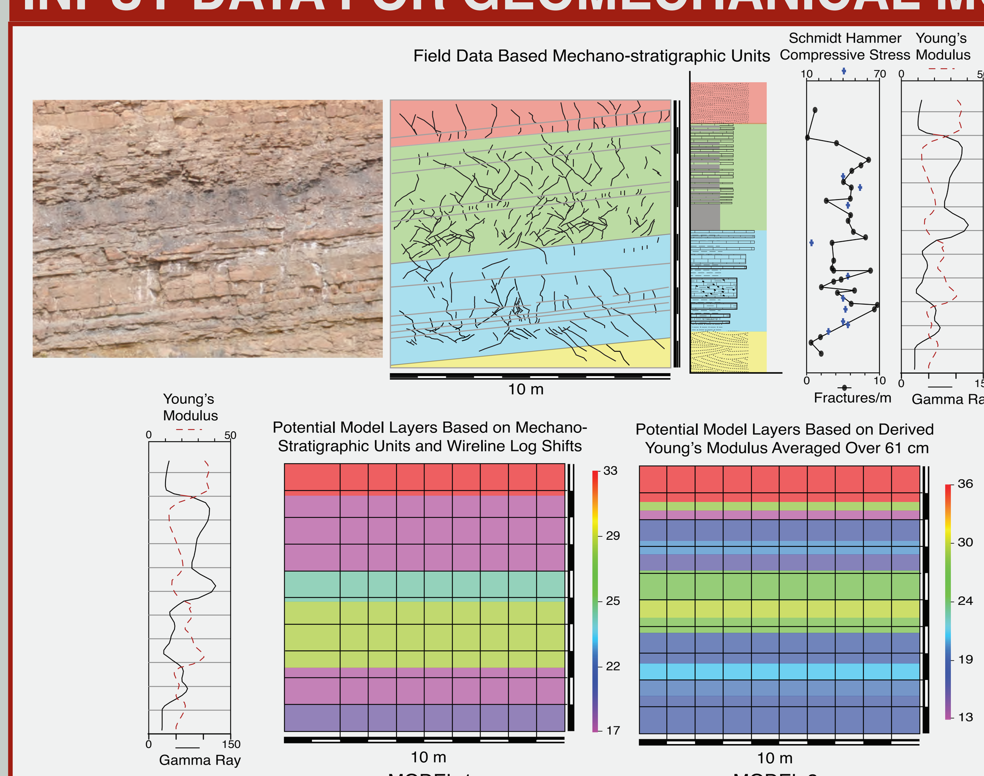
Using a modified rock mass ratings, (Bieniawski, 1989; Priest, 1993; Zhang, 2005), combined with quantitative stratigraphic analysis of fracture density distribution (Bertotti et al, 2007) we delineate mechanostratigraphic units.

Mechano-stratigraphic units have similar:

- bed thickness
- fracture density
- field derived permeability
- field derived compressive strength

From: Petrie, et al., in press

INPUT DATA FOR GEOMECHANICAL MODELING

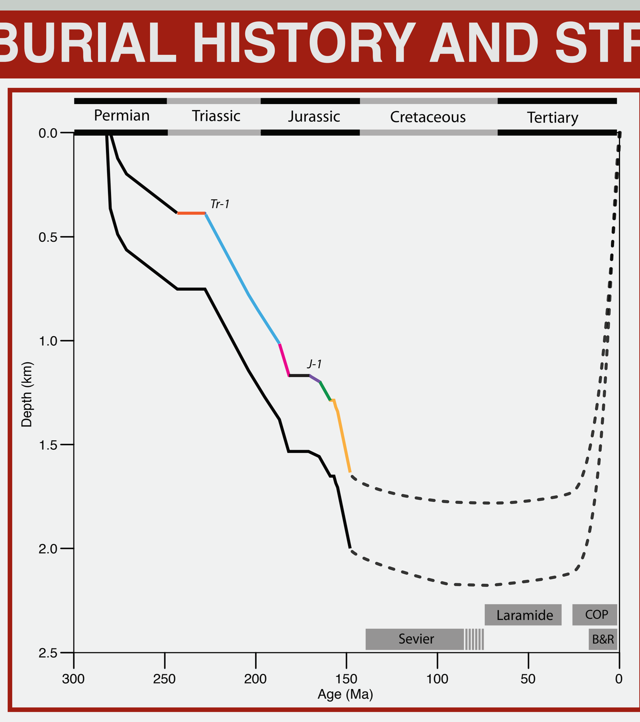


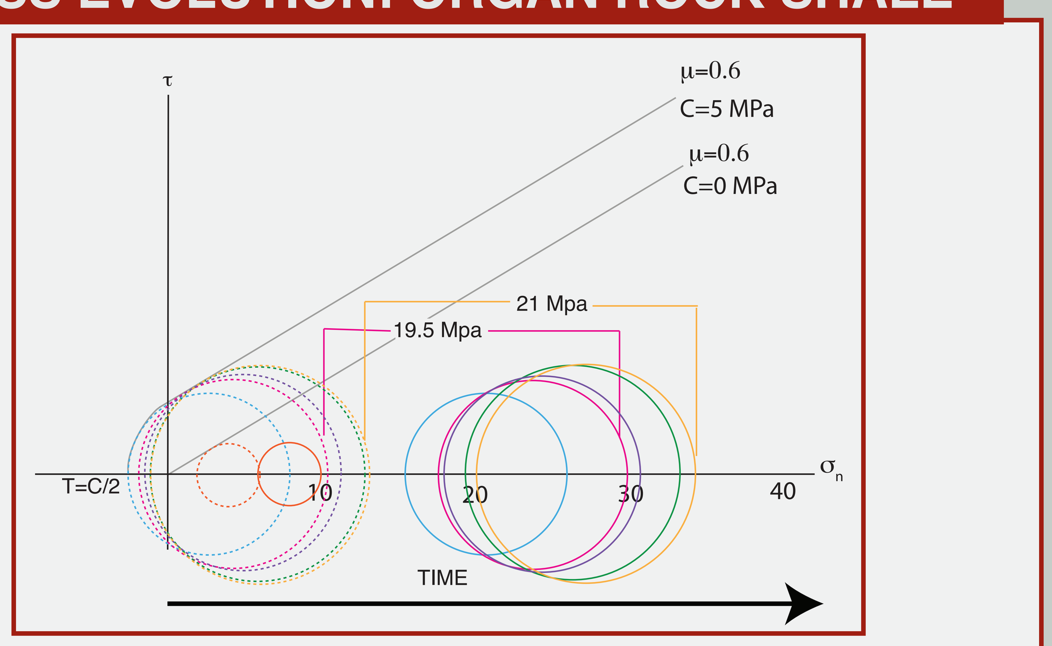
Estimates of dynamic Young's Modulus variability derived from wireline logs

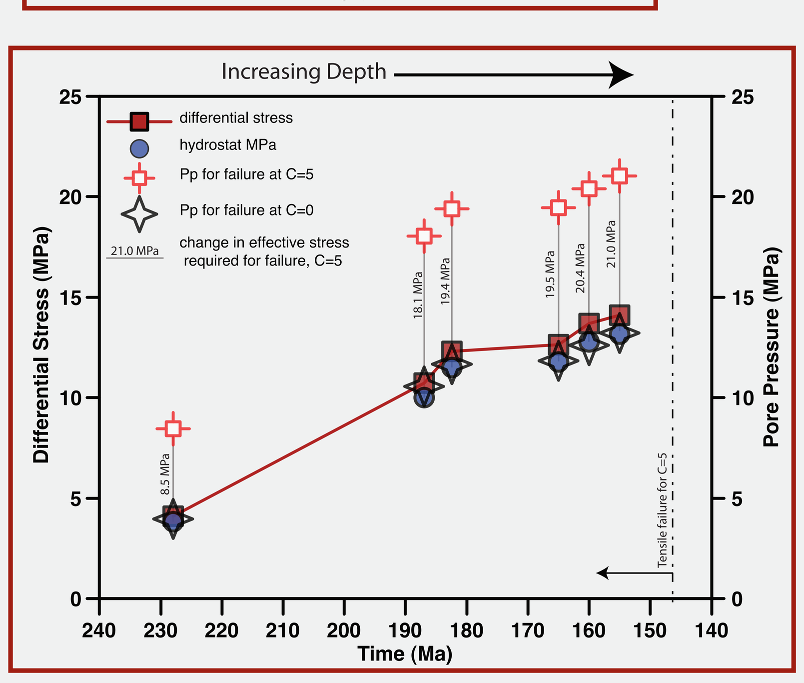
- Well-bore estimates of dynamic Young's Modulus show meter scale variability. (15-34 GPa)
- Field-based fracture density and compressive strength also show meter scale variability
- Variability in elastic moduli will be used in future geomechanical modeling

From: Petrie, et al., in press

BURIAL HISTORY AND STRESS EVOLUTION: ORGAN ROCK SHALE







Extensional fractures open by locally applied tectonic stress or by internal fluid pressure (see Laubach, 1988).

Fracture Formation:

1) response to thermoelastic contraction during exhumation
2) due to tectonic stress
3) hydraulic fractures due to overpressure at depth
4) a combination

Modeling stress history to maximum burial depth shows:

1) material with cohesive strength between 5-16 Mpa fails in tension
2) in a pervasively fractured crust - material with a cohesive strength of zero fails very near hydrostatic pressure
3) encountering pressures during burial can result in natural hydrofractures

CONCLUSIONS

Stratigraphic variability and resulting changes in mechanical properties influence the variability of fracture morphology and density over the cm to m scale.

Understanding fracture morphology in different seal types, across interfaces, and in various structural settings is key to understanding how seals respond to hydraulic failure.

Calculated variability in elastic moduli correlates to the mechano-stratigraphic variability observed in outcrop --- the variations in elastic moduli will be modeled to quantify their effects.

Overpressure during burial (lithostatic loading) can induce open-mode tensile failure that can effect future seal integrity: Are most seals fractured then re-cemented/re-sealed in some way?

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