Platform- to outcrop-Scale Fracture Patterns in an Atoll-Like Carbonate Platform: The Latemar Case Study (Dolomites, Italy)*

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Abstract

We present the first reconstruction of distributed fractures and causative stress and strain fields in atoll-like carbonate platforms on the basis of the outcropping Latemar platform (Dolomites, Italy), an analog for buried systems. We consider structural and sedimentological features ranging from platform- to layer scale.

The Middle Triassic Latemar platform is 3-5km across, 800m thick and is composed of a circular, well-bedded platform interior surrounded by a poorly organized slope with the local interposition of margin facies. Rocks in the Latemar are intensively fractured.

Using innovative data acquisition and processing tools we quantify the outcrop-scale geometry of fracture networks in the domains of the platform. We focus particularly on the poorly documented vertical distribution of fractures across the stratigraphy. We measured >5000 fractures.

Two fracture sets are found and have strikes constant from one domain to the other. Fractures in the platform slope are higher and have larger spacings than those of the platform interior. Here, bed thickness and bed interfaces exert a weak control on spacing and vertical distribution of fractures, and >50% of the fractures initiates or terminates inside the layers. Grainstone-dominated layers have the highest fracture density.

We apply finite element modeling to interpolate between data points and predict platform-scale stress and strain fields. The platform architecture is the primary input of the model. By changing i) boundary conditions (overburden and tectonic stresses) and ii) mechanic bulk properties of the composing domains we predict stress and strain distributions and type of fractures (opening vs. shear fractures).

Our preferred model is one which best fits i) the direction of fractures in the entire platform, ii) the spatial distribution of fracturing and, iii) the kind of fractures.

Fracture patterns in the Latemar are best modeled by applying an overburden of 1-2km and a significant tectonic stress parallel to the joints. The model predicts a platform interior that is mechanically softer than the margin and the slope. Such differences reflect platform properties during burial before full lithification. This is compatible with the parallelism between joints and the Neptunian and Middle Triassic volcanic dykes.

Building on the Latemar case study and using sensitivity analysis we predict fracture patterns affecting similar platforms subjected to different boundary conditions.

Reference

Narr, W., D.J. Fischer, P.M. Harris, T. Heidrick, B.T. Robertson, and K. Payrazyan, 2008, Understanding and predicting fractures at Tengiz – A giant, naturally fractured reservoir in the Caspian Basin of Kazakhstan: AAPG Search and Discovery article #20057, Web accessed 27 May 2011, http://www.searchanddiscovery.com/documents/2008/08041narr/index.htm

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Fundamental Controls on Flow in Carbonates

EM – Upstream Research Company

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- **all the members of the alliance**
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Fundamental Controls on Flow in Carbonates

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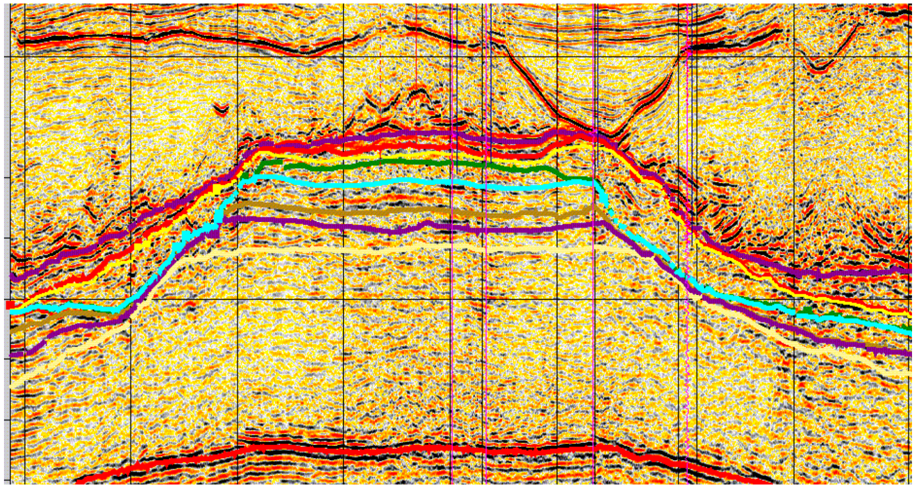
Predicting fracture patterns in atoll-like carbonate platforms

We want to predict:

- **distribution of fractured domains (how much and where)**
- **the position of fractures (stress and strain trajectories)**
- **fracture type**
- **fracture networks**

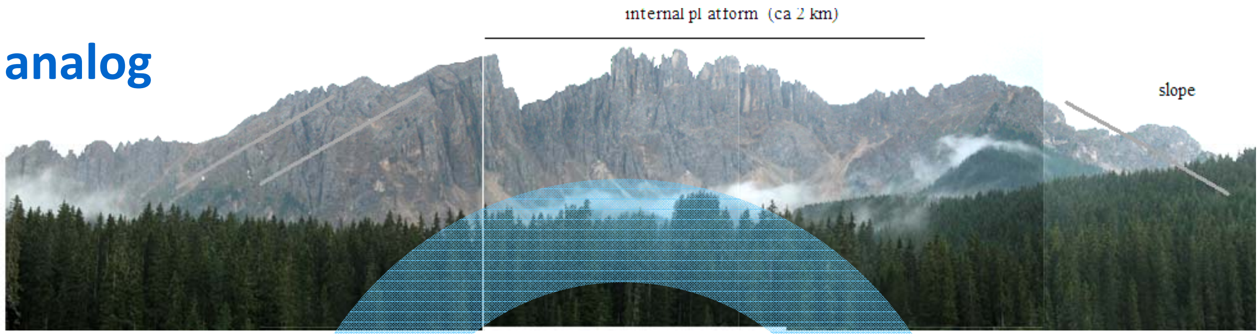
in atoll-like platforms they change

- **in space**
- **in time**

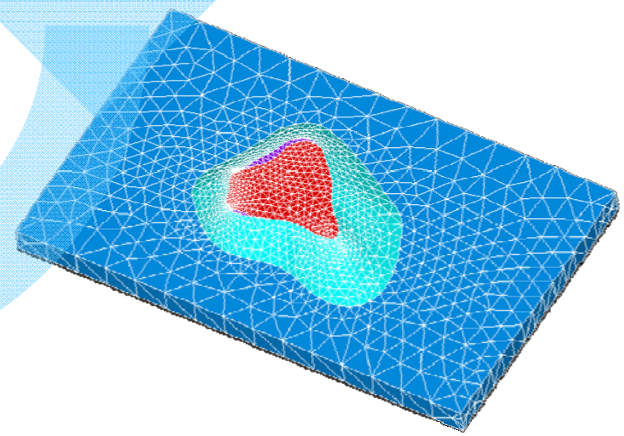


Narr et al. 2008

choose an analog



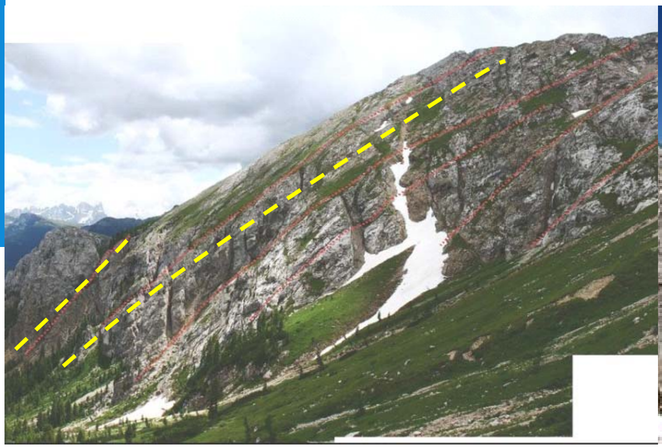
FEM to predict stress and strain

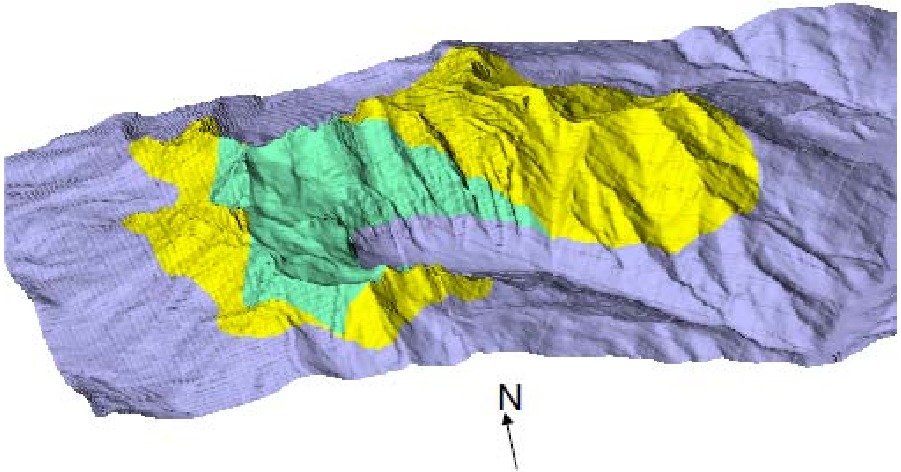


compare with fracture data

general rules

the Latemar, one of the world-class Triassic platforms in the Dolomites

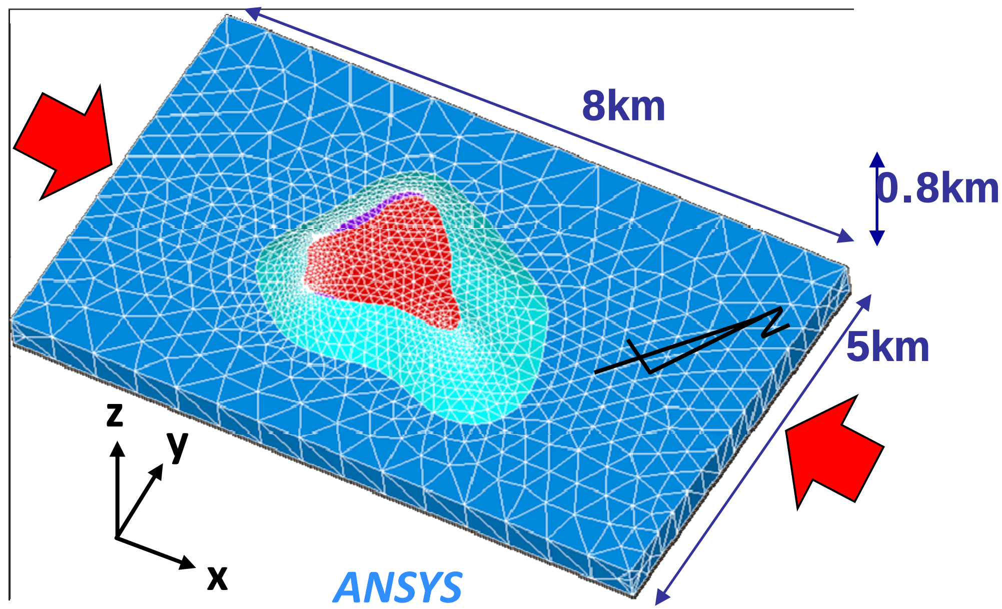




- a very well organized platform interior, with a variety of beddings
- a thin and discontinuous massif margin
- a massif, poorly structured slope

mechanic model

- 3 domains (interior, margin & slope)
- assembled in a simplified Latemar fashion
- elasto-plastic rheologies



We explore the role of

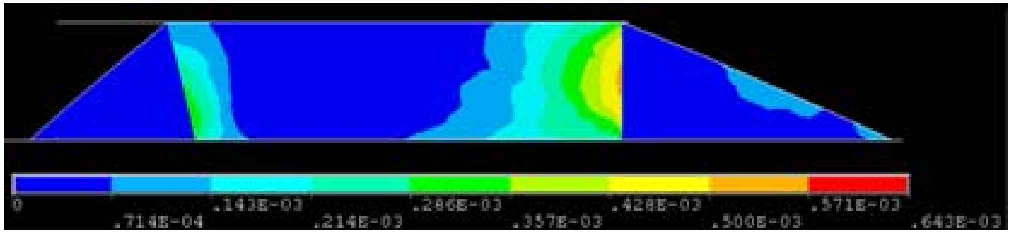
- Mechanical properties of the 3 domains
- Overburden
- Tectonic stresses

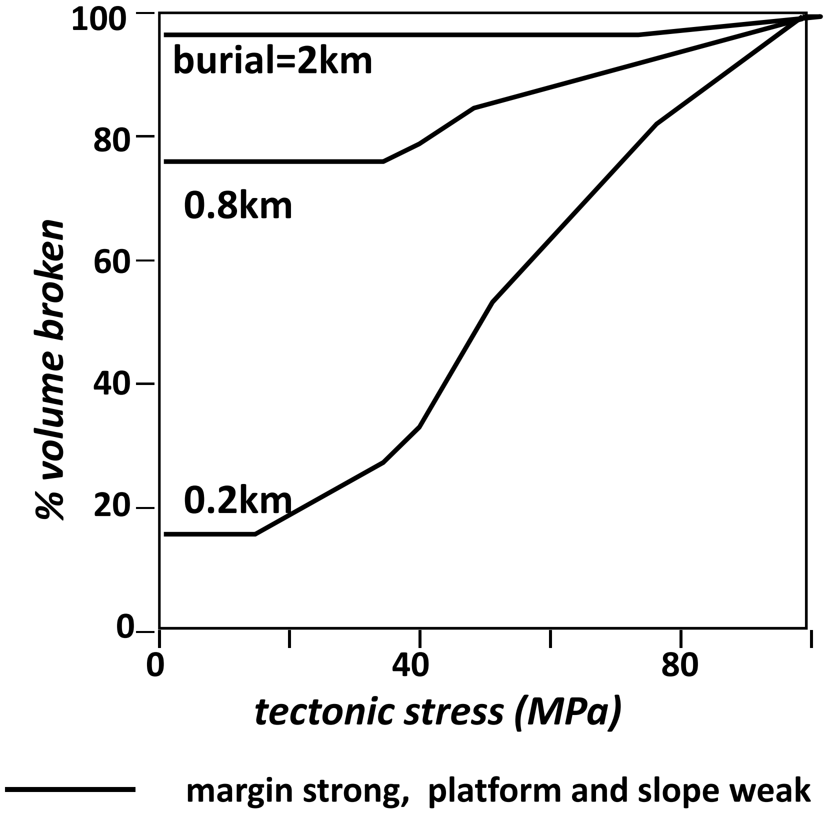
We predict

- fractured volume of the platform
- fracture types
- fracture directions

1) How much of the platform is broken? Where?

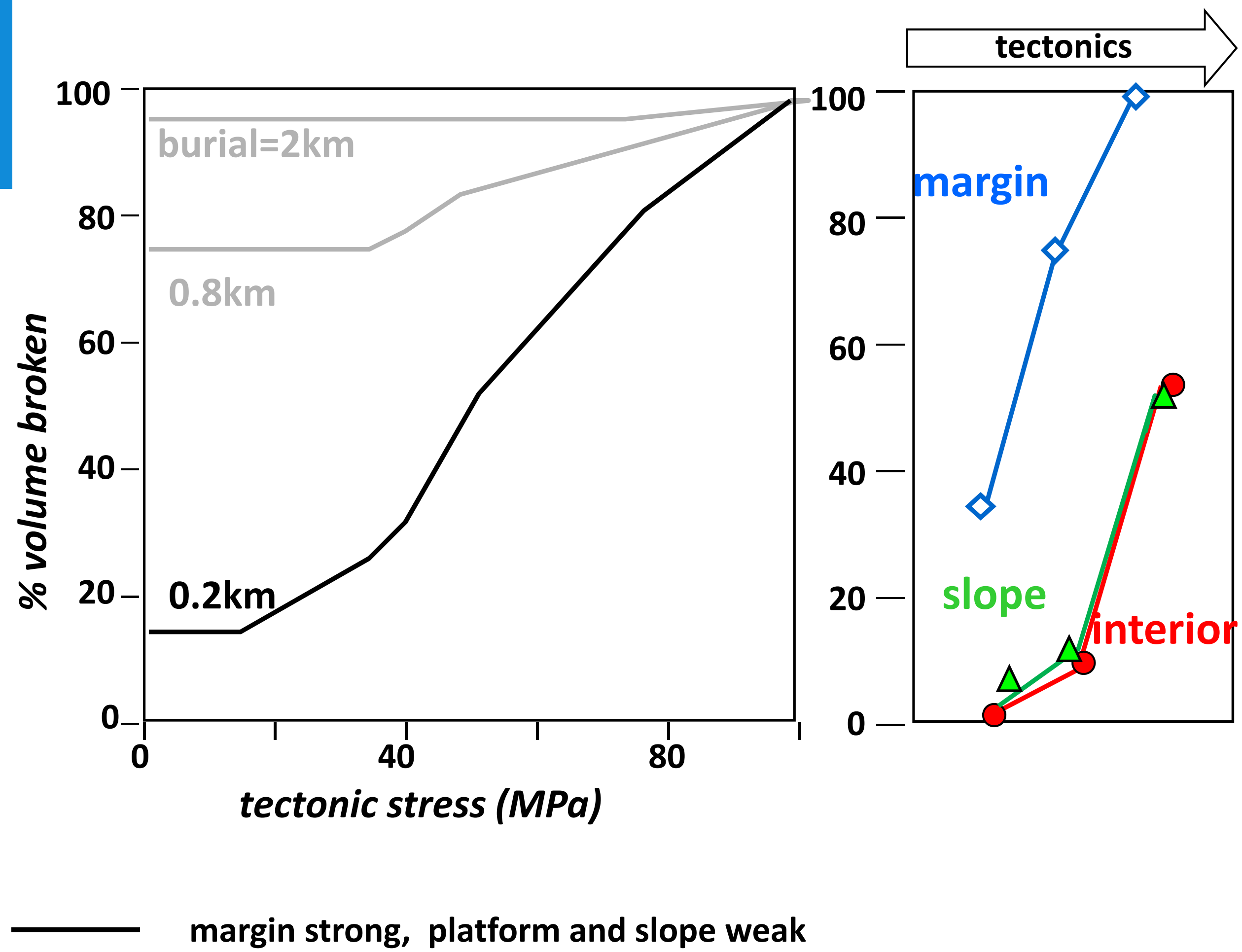
- overburden
- tectonic stresses
- mechanical properties





- gravity can fracture substantial parts of the platform
- tectonic stresses are only important at shallow depths

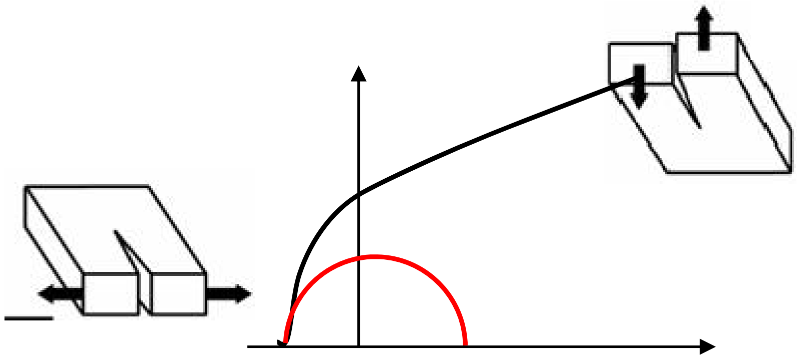
1) How much of the platform is broken? Where?



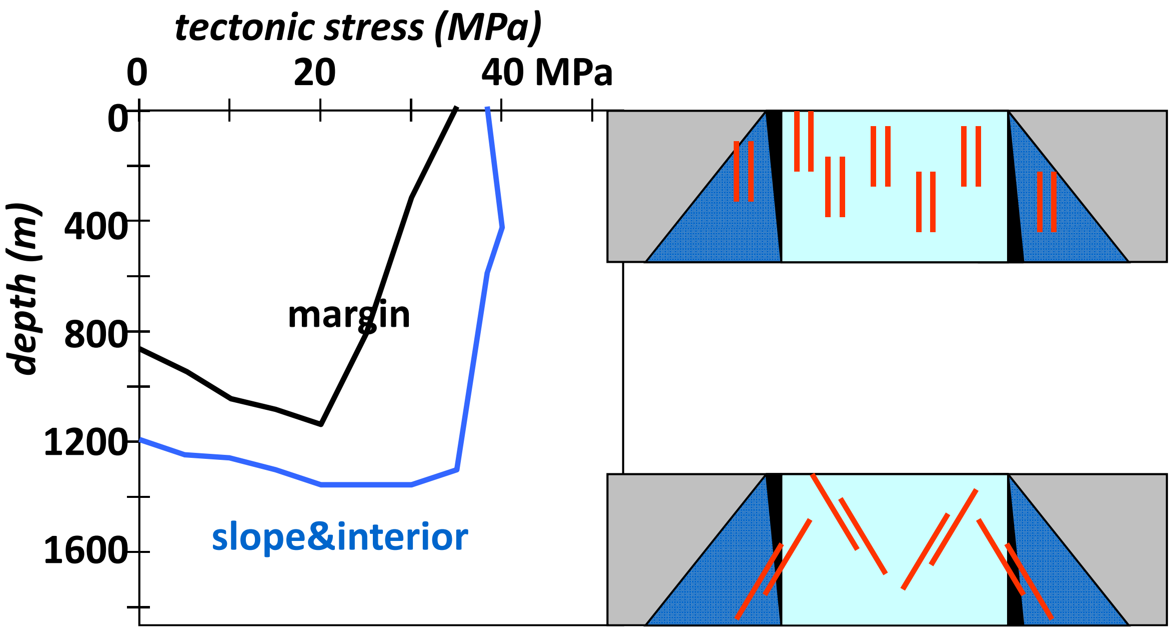
at 0.2km:

- 30% of the margin is broken by gravity
- slope and interior are increasingly fractured by tectonic stresses

2) What kind of fractures can we expect?



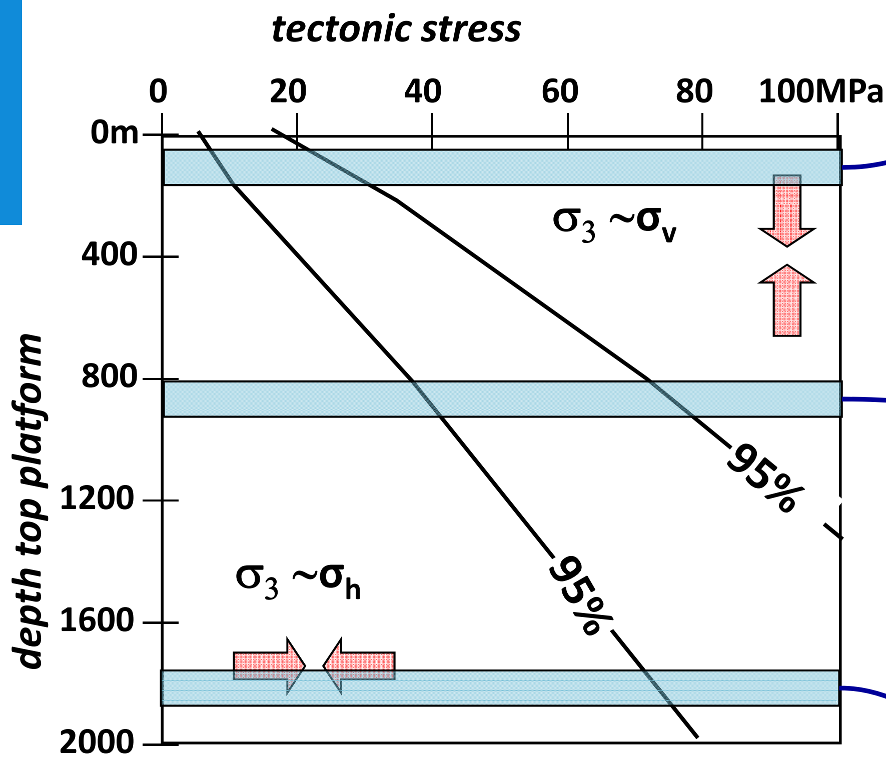
the boundary between mode I and mode II is at $\sigma_1 - \sigma_3 = 4T$



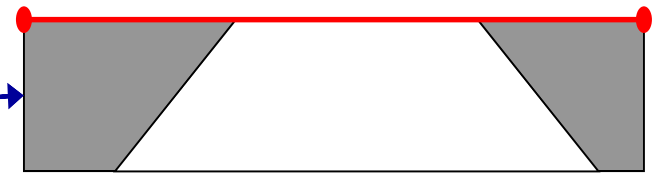
joints everywhere for tectonic stresses <20MPa

only shear fractures are predicted

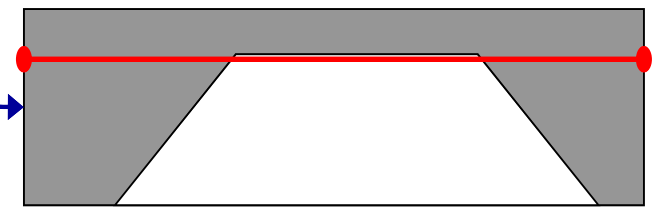
2) Horizontal and vertical stresses



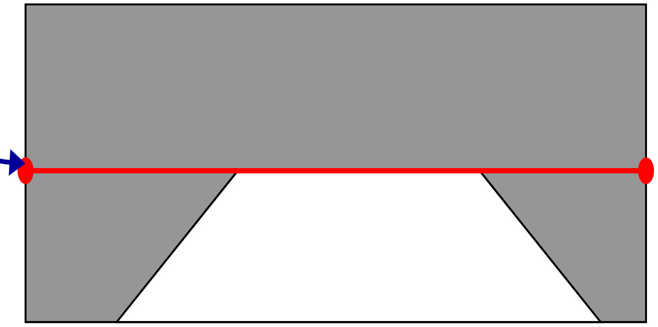
σ_3 is vertical through the platform for weak-to-normal tectonic stresses



σ_3 typically vertical



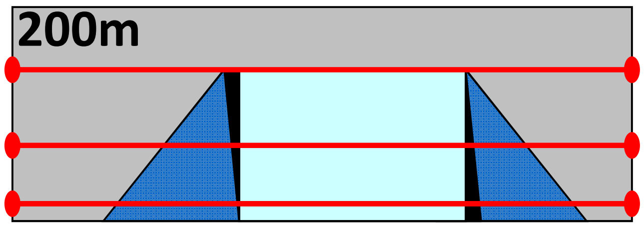
σ_3 horizontal for weak stresses



σ_3 horizontal throughout

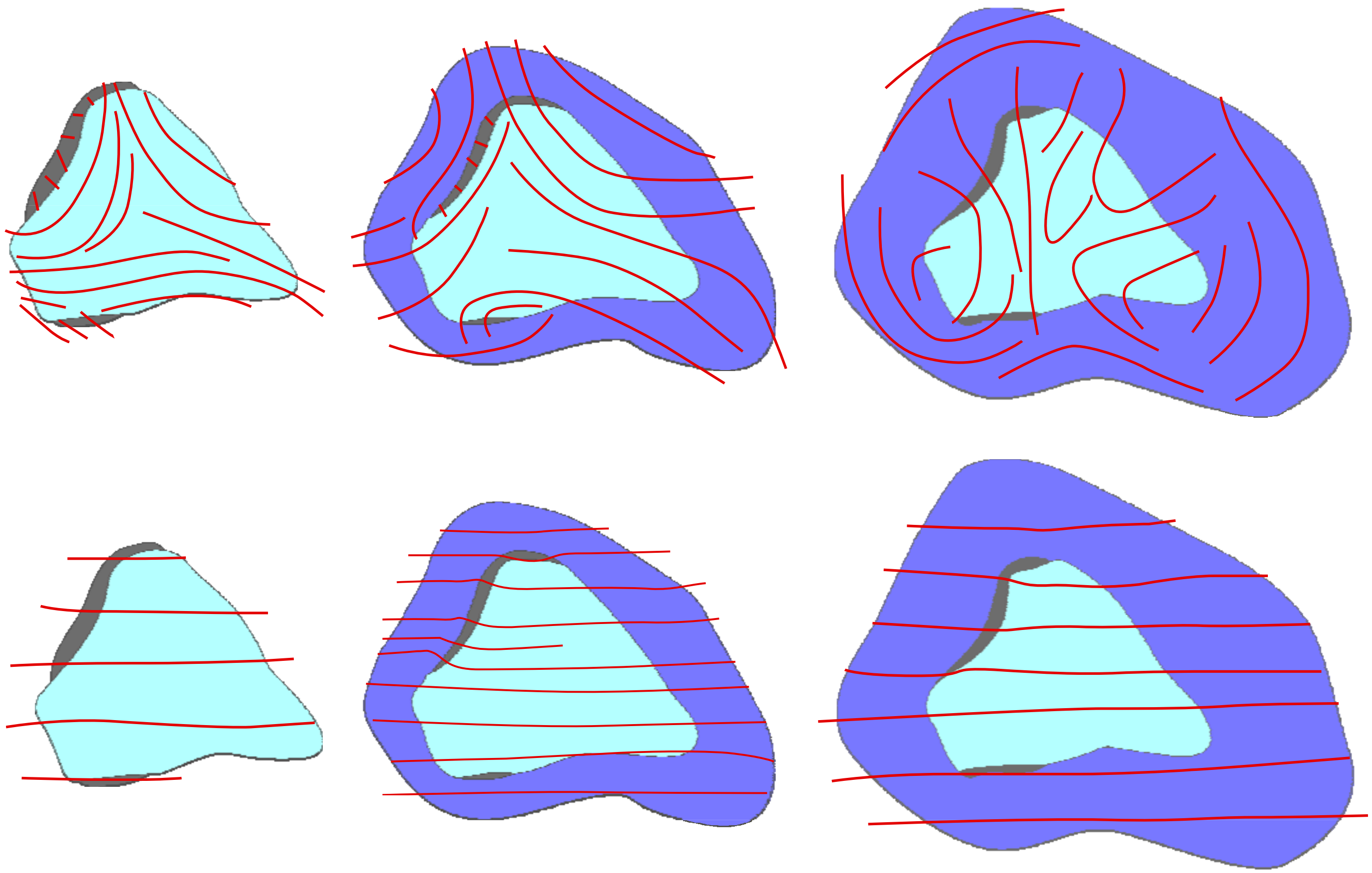
3) the map-view orientation of σ_3

Three sections at three depths in the platform



gravity only

+ tectonic



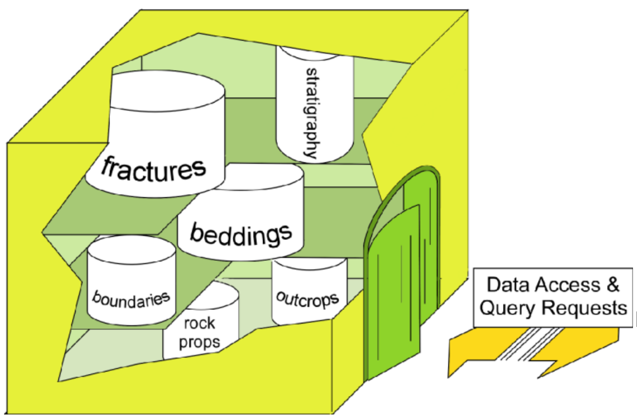
- fractures are perpendicular and parallel to platform boundaries
- differences with depth

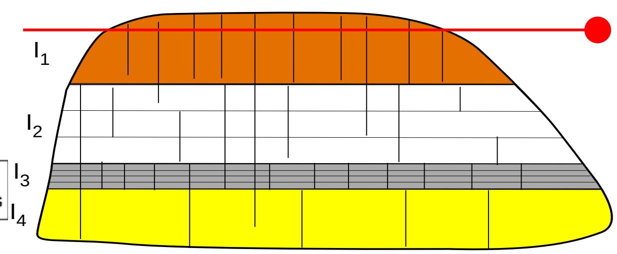
fractures are aligned with the tectonics stresses through the platform

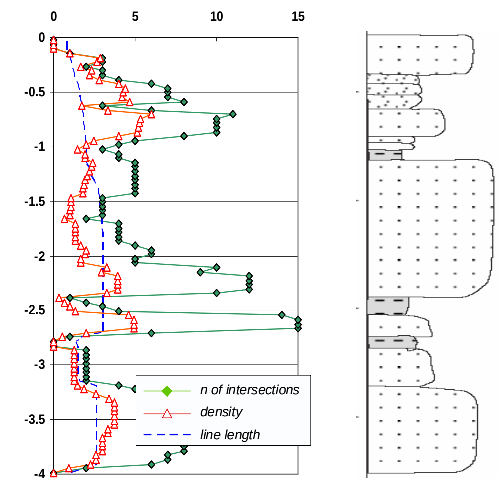
Latemar fracturing

DigiFract: digital data acquisition

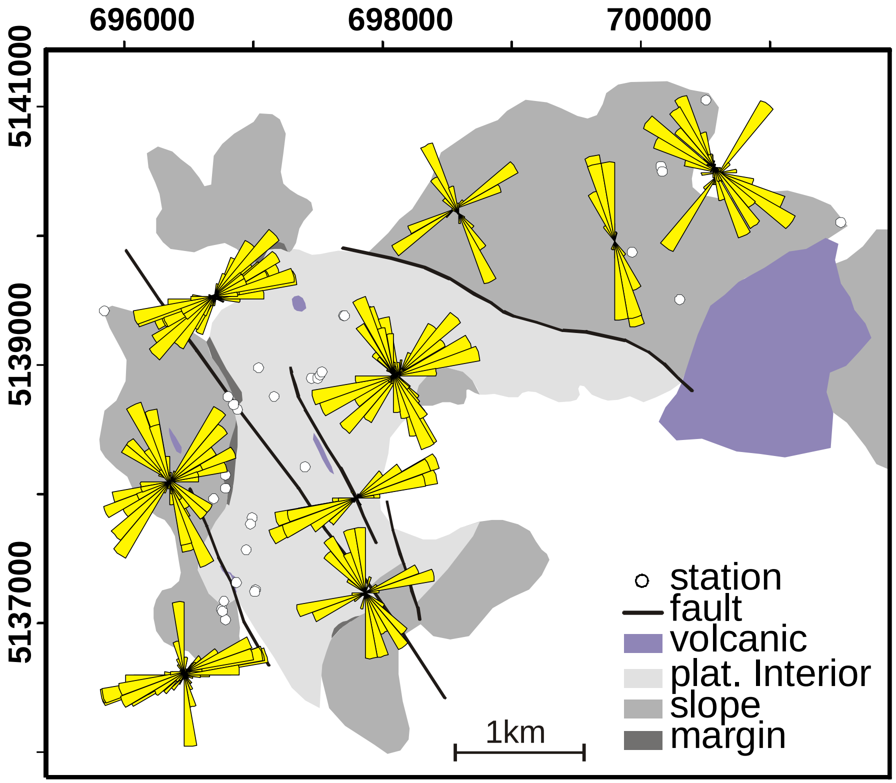
…..and processing





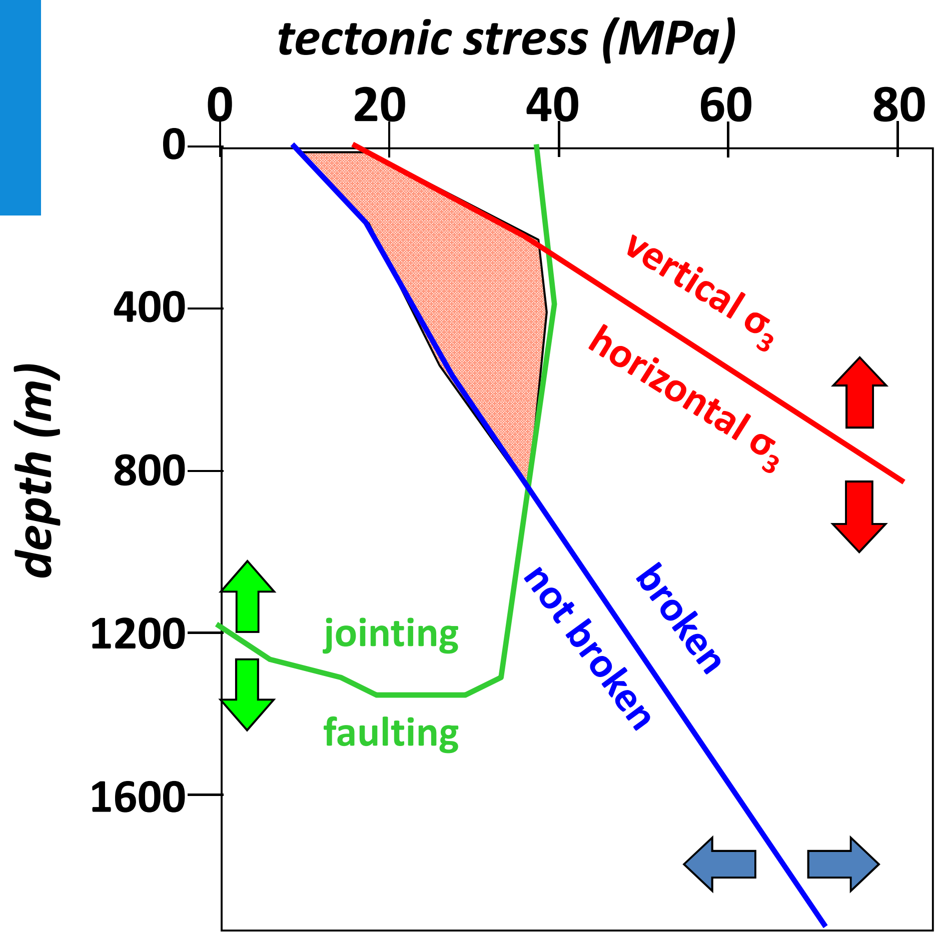


>1500 fractures (orientation, spacing, height, terminations) in the platform interior, margin and slope



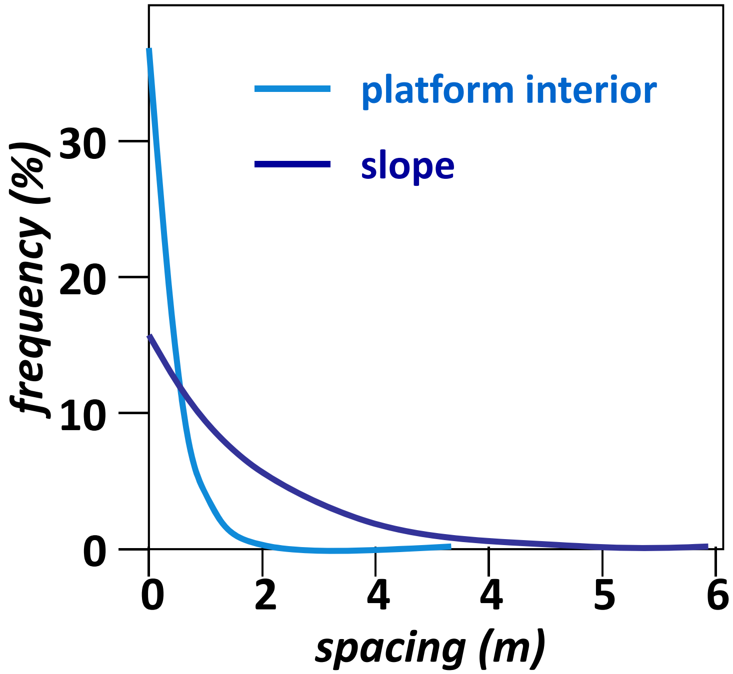
- the entire platform is broken
- mode I fractures throughout
- fractures have the same directions in all domains
- geometric characteristics change from one domain to the other

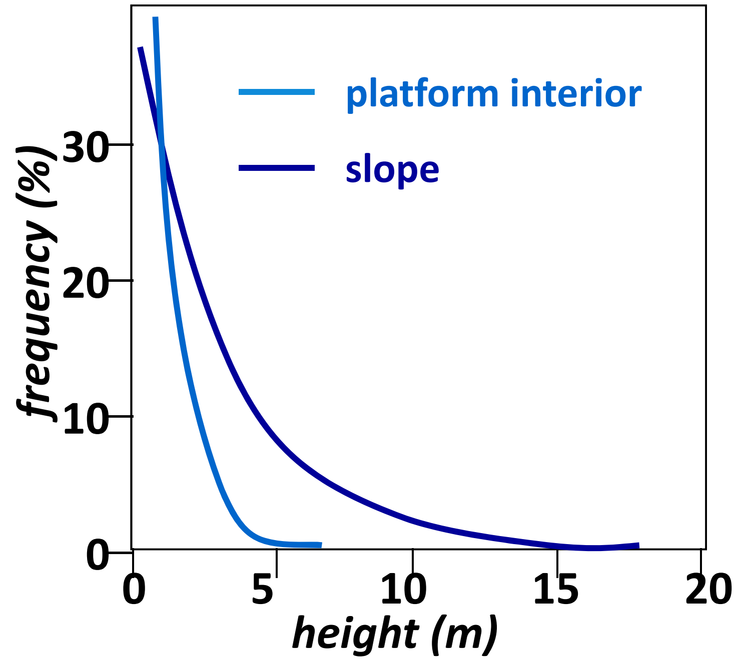
Conclusion 1: Latemar fracturing



Latemar fracturing took place within the uppermost several 100s m and in the presence of tectonic stress

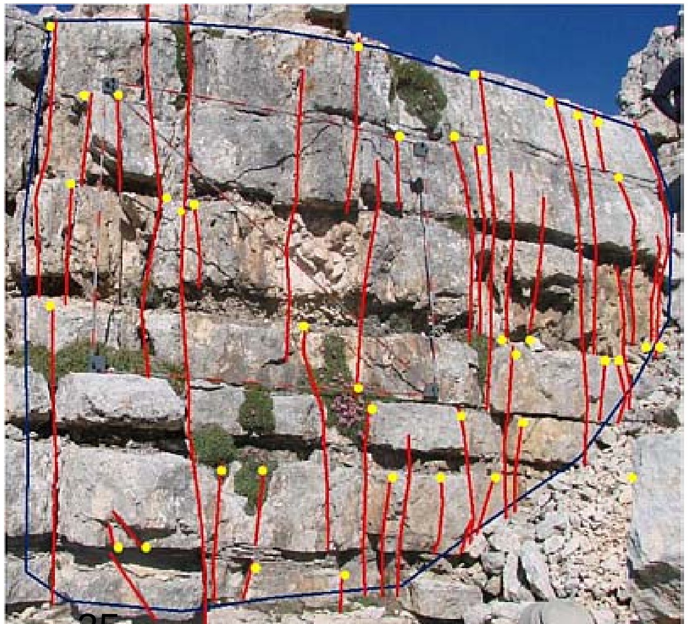
The fracture network

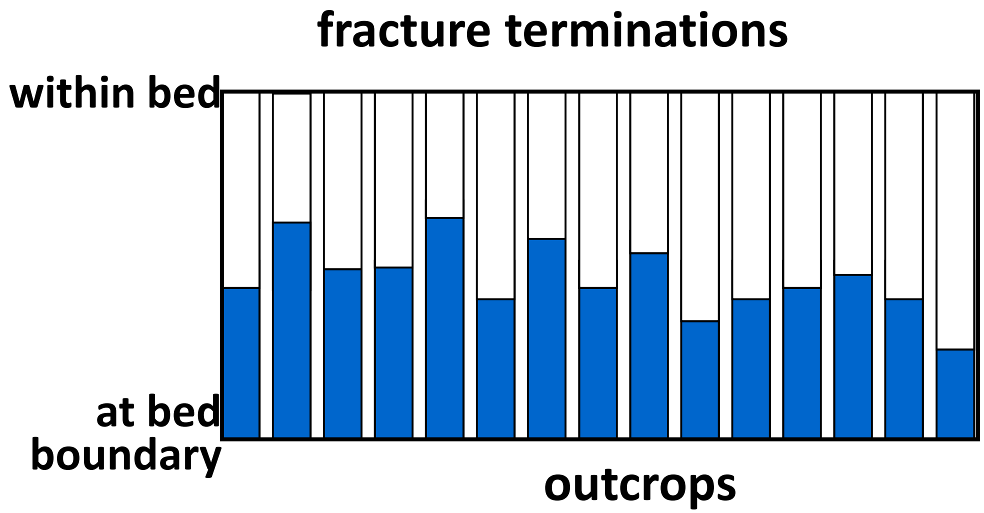


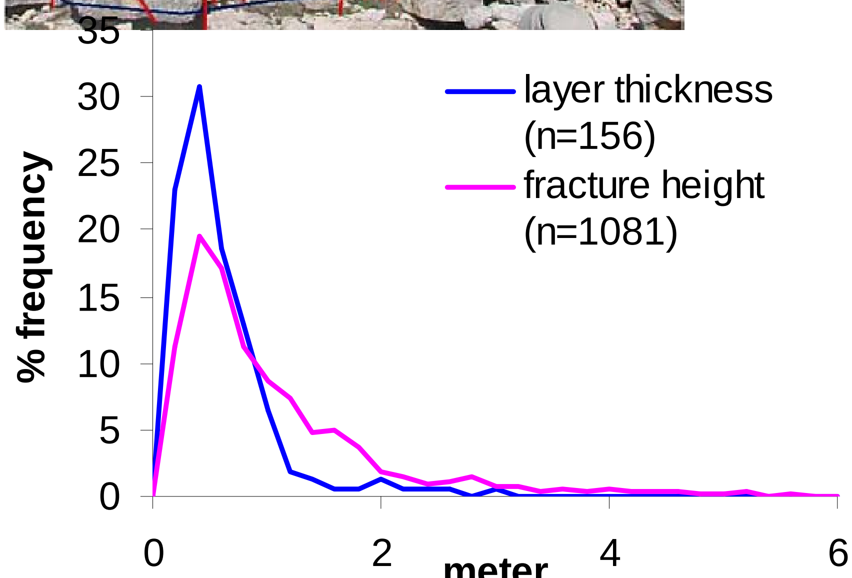


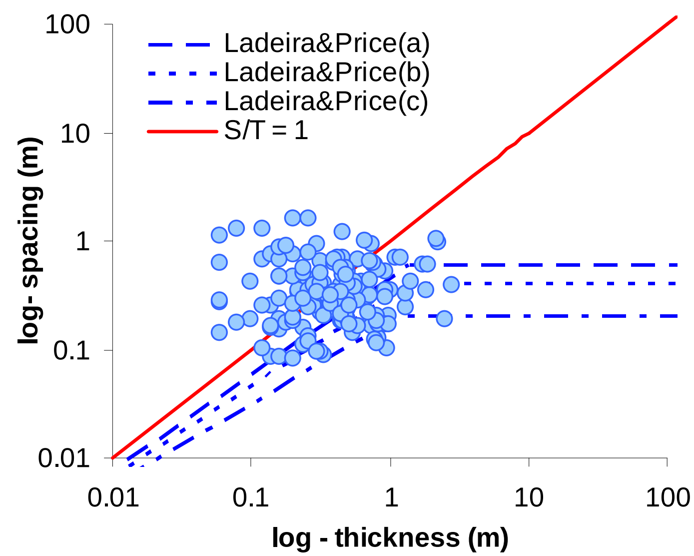
How do the different domains communicate?

Controlling factors in the platform interior



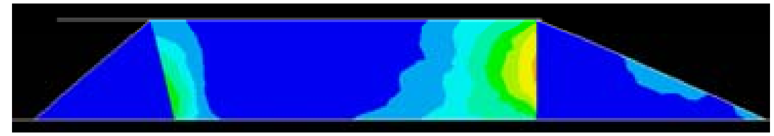




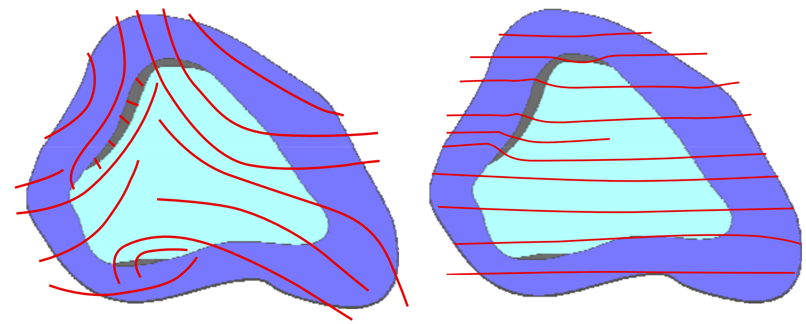


Conclusions (2): in general

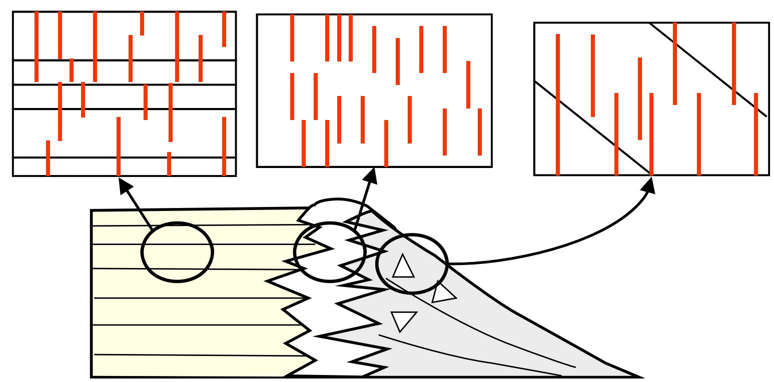
- gravity has a major role in fracturing the platform



- vertical joints form when tectonic stresses are weak to normal



- in gravity-alone, fractures are parallel or perpendicular to the margin. Sharp corners are important
- gentle tectonic stresses are enough to align fractures



- fracture stratigraphy is complex but can be quantified
- fracture characteristics differ from one domain to the other

Thank you