How Can We Use Tectonic Reactivation to Control Stress Distribution at Reservoir and Basin Scale? Learning from Paleopiezometry and Analogues*

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Abstract

Reactivation is a key tectonic process from several reasons. For operations, several applications based on the concept of critically stressed fractures have been developed in the last decade concerning reservoir management and seal integrity analysis. More fundamentally, the Byerlee law is still a reference that is used to control the mechanical behavior of the upper crust. It is generally used assuming that properly oriented planes of weakness are available in the rock mass and that therefore reactivation governs crustal strength. In addition, reactivation is studied at various scales from stress tensor inversion at small-scale to trap formation by basin scale fault reactivation. The objective of this presentation is to share some key learnings about reactivation and their consequences on our understanding of stress distribution. At small scale, reactivation can be directly observed as superimposed slickensides on faults or calcite twinning for example. These observations have been used to propose various methods to define paleo-stress. This point is discussed using recent results of paleo-stress history quantification from calcite twins with application to the evolution of the Appalachian foreland basin. At reservoir scale, we will demonstrate how the reactivation of fractures by folding can control the properties of fracture network. The chosen outcrop analogue shows striking similarities with what is expected for the stimulation of a pre-existing fracture network by hydraulic fracturing. This stresses the importance of reactivation at that scale. These successes at small scale have led to overestimate the role of reactivation. This will be demonstrated using analogue model of graben inversion by transpression. The proposed experiments reveal that the fault characteristics are not the key factor to explain the structural evolution of these models. In practice, at basin scale, the occurrence and geometry of decoupling layers (such as salt and overpressure shale) matters much more than reactivation. These examples reveal that during the past decade the study of reactivation has progressively shifted from large-scale tectonics to reservoir characterization. We advocate that it is time to revisit the large scale with the recent advances concerning paleopiezometry, taking into account properly the role of decoupling layers. This should lead to innovative achievements concerning the modeling of stress distribution.

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How Can We Use Tectonic Reactivation to Control Stress Distribution at Reservoir and Basin Scale?

Learning From Paleopiezometry and Analogues

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AAPG Annual Convention & Exhibition 2014

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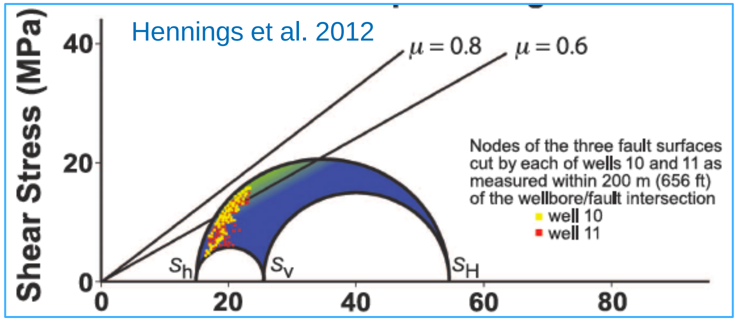
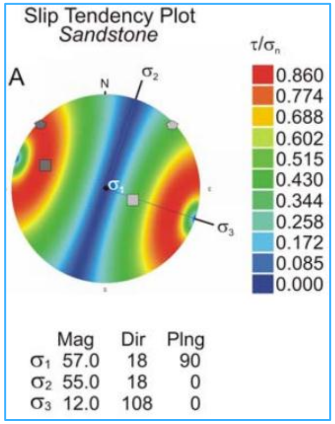
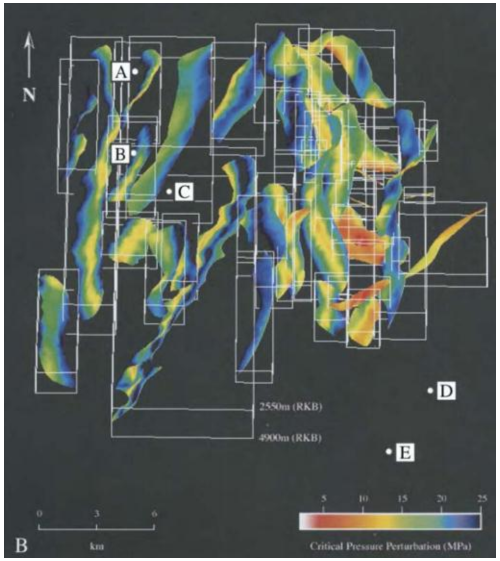
Introduction

- From the 90's, Morris, Zoback, GMI, Badleys …
  - "critically stressed fractures" + "Fault slip tendancy "

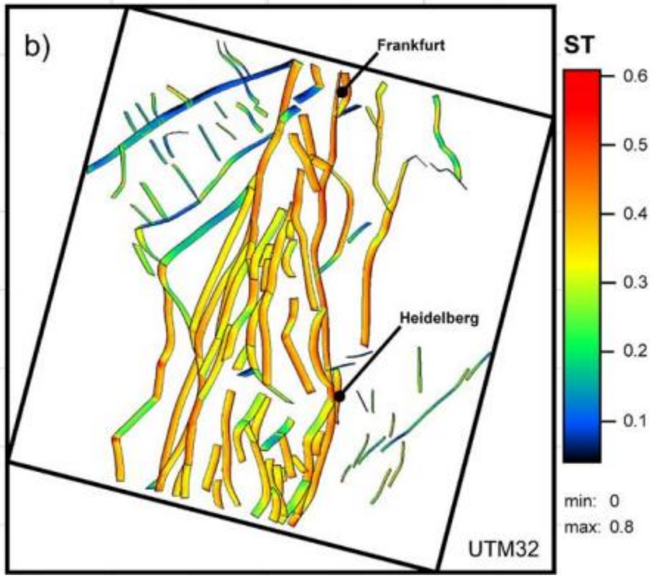




Moeck et al. 2009



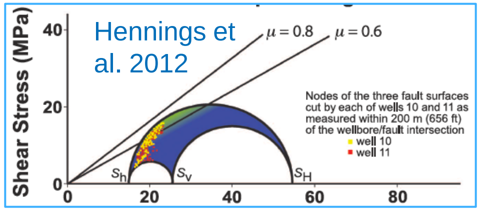
Wiprut & Zoback 2002



Beekman et al. 2010

Introduction

- **Reactivation is studied**
  - for fractured reservoir characterization
  - prospect ranking (sealing integrity)



- **Reactivation: a structure + a state of stress**

- **Outline of the talk from large to small scale**
  - Influence of structures: stress concentration matters
  - Reactivation vs creation of new structures
  - State of stress

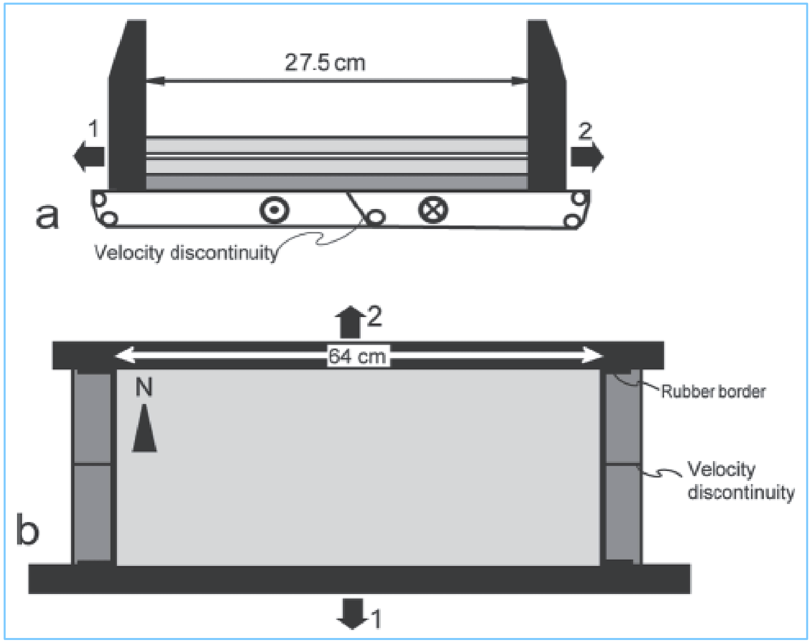
Reactivation at basin scale

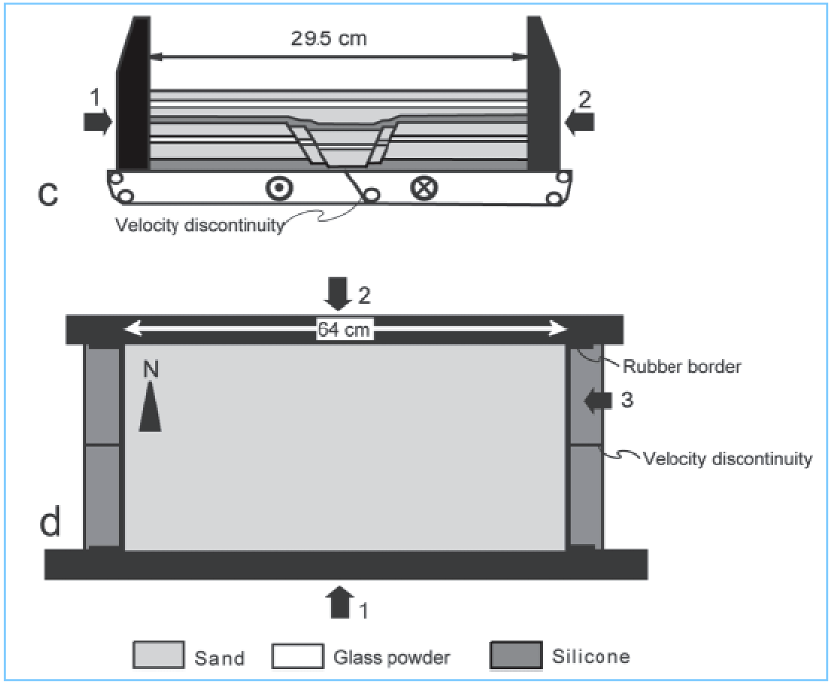
Role of decollement layer deformation

Example: Graben reactivation

- **A two phases experiment**

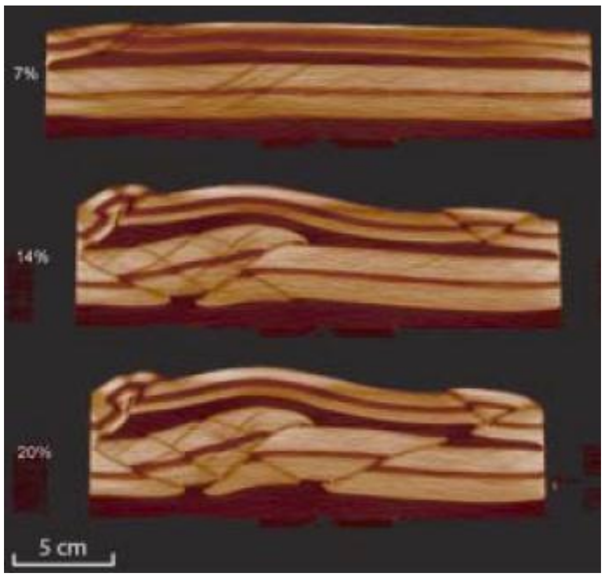
Mattioni et al. 2007

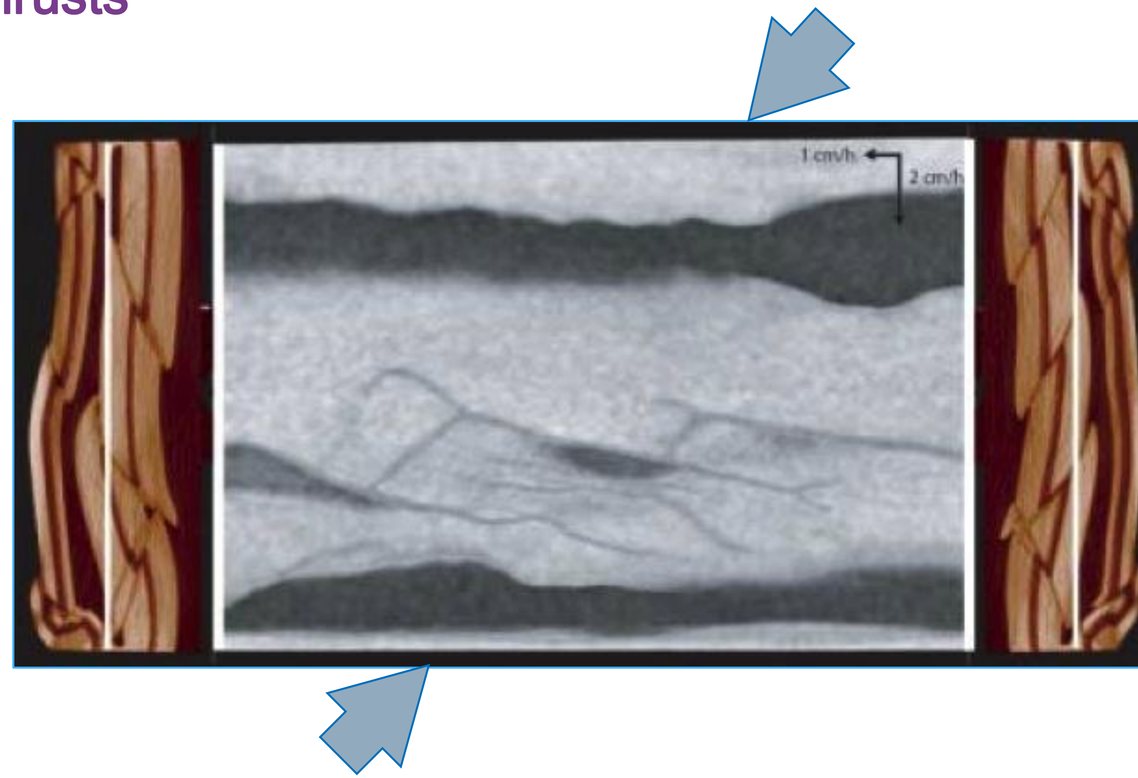




Example: Graben reactivation

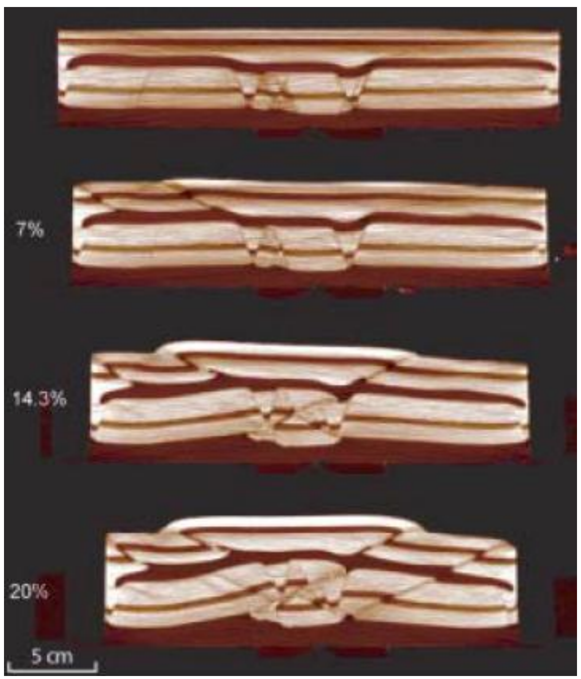
- Transpression of an undeformed section
  - Creation of oblique thrusts

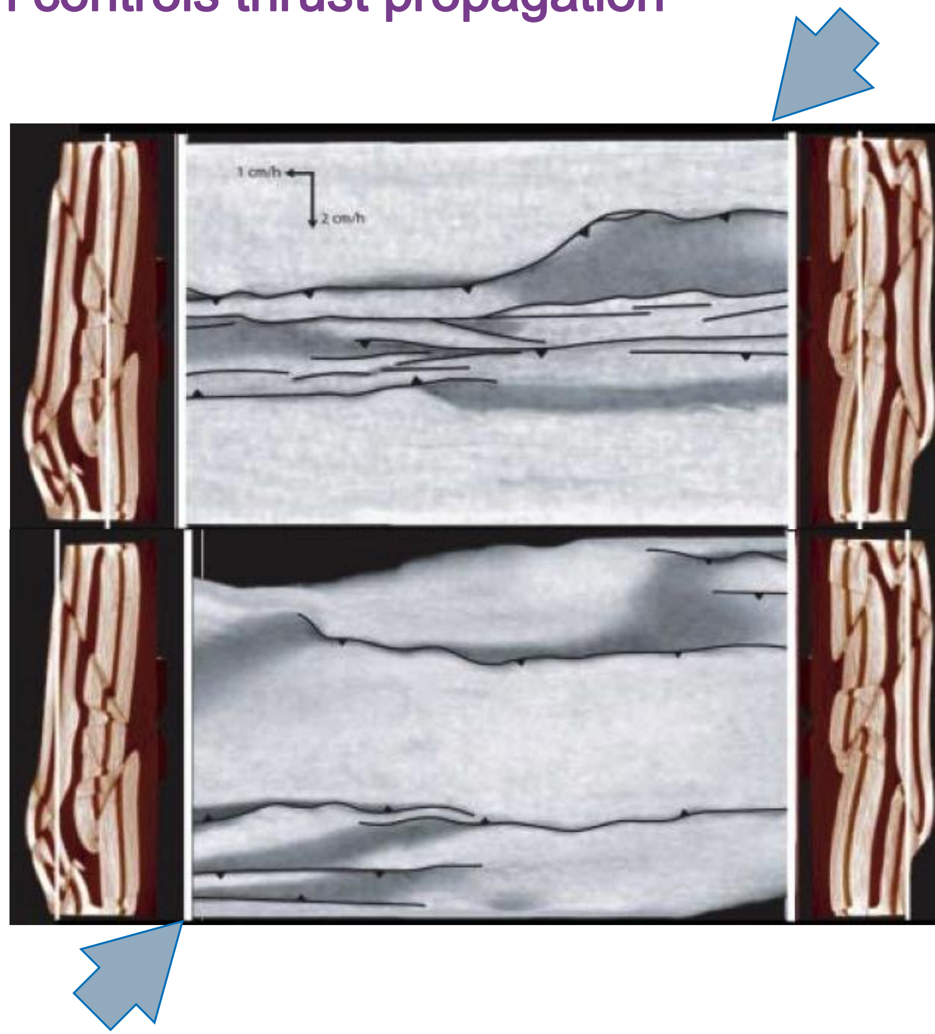




Example: Graben reactivation

- **Transpression of a graben**
  - **Decollement level deformation controls thrust propagation**
  - **But no reactivation**

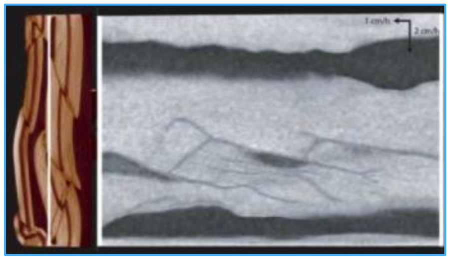


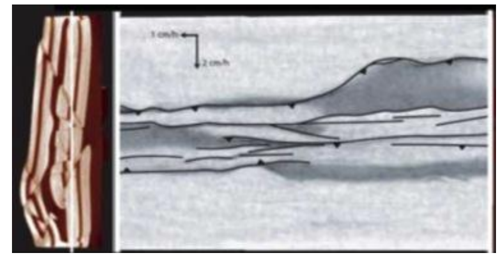


Example: Graben reactivation

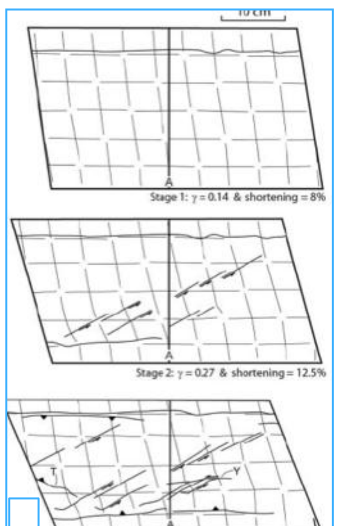
No pre-existing structure | Pre-existing structure

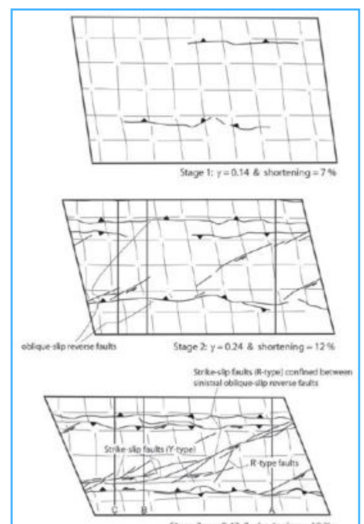
Weak strike slip





Strong strike slip





What have we learn?

- Knowning paleostress direction is important but not sufficient
- Fault properties is not necessarily the most important parameter
- Geometry of decoupling layer is one key

Reactivation of natural fracture network

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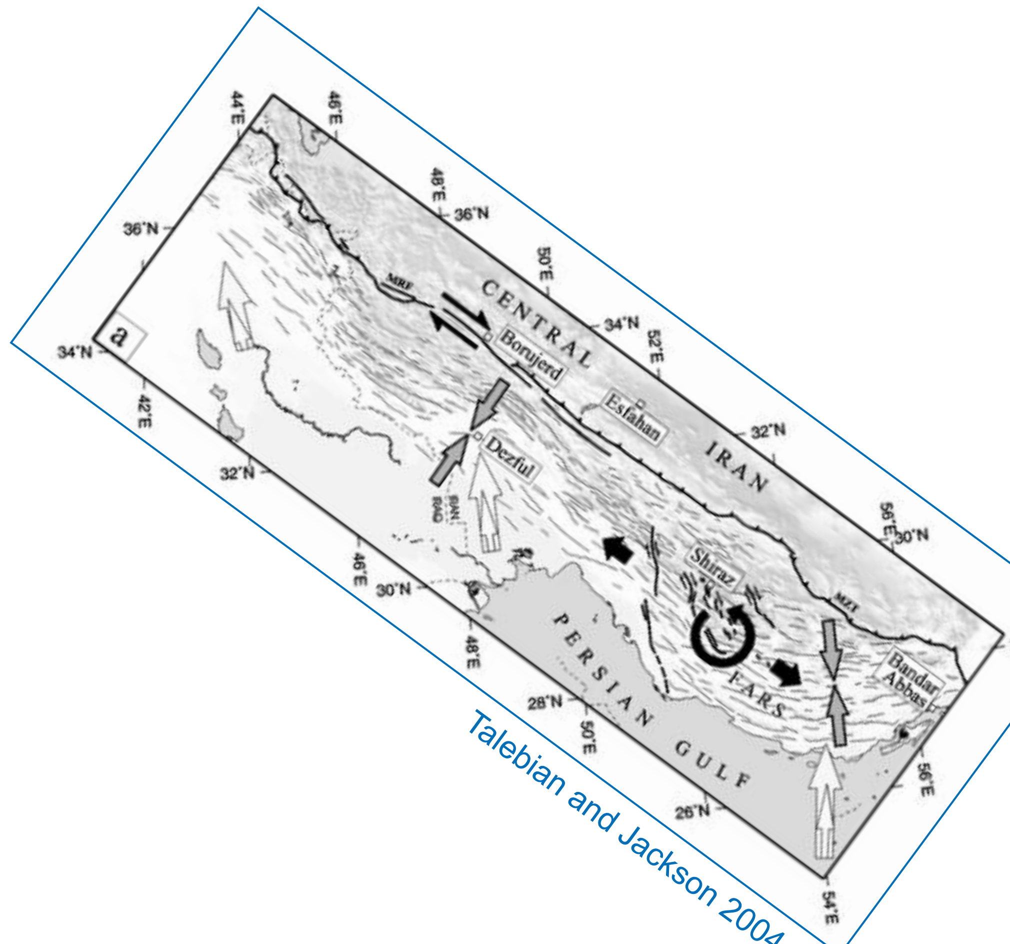
Example: Izeh zone, Zagros

- Reactivation at plate scale: Deformation Partionning
- Role of decollement layer at basin sale
- Impact at reservoir scale ?

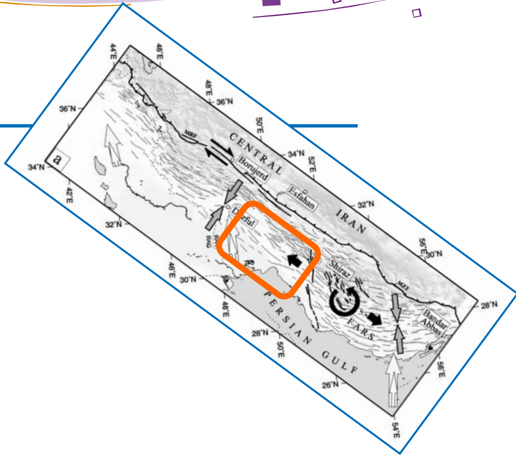
Sherkati et al. 2006

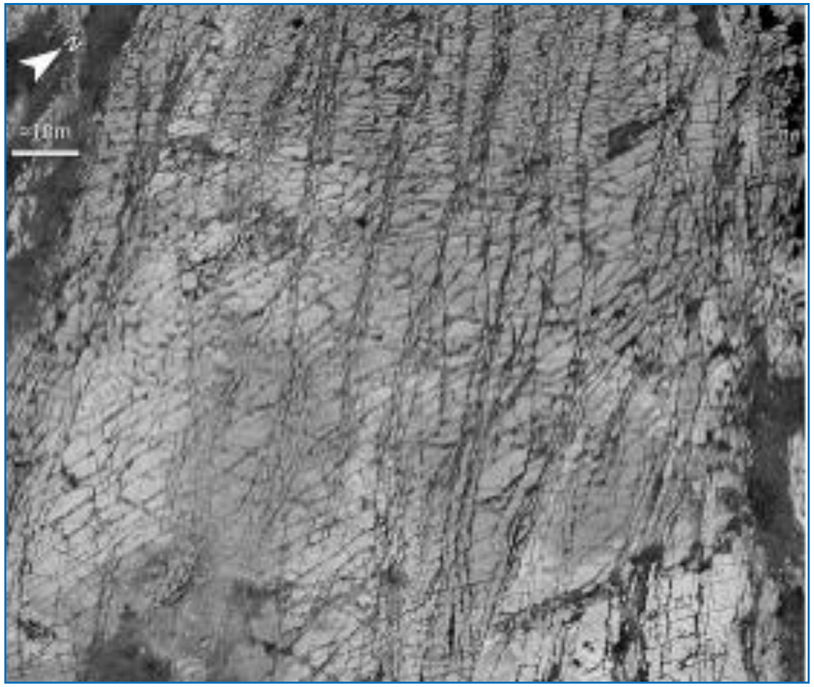


Talebian and Jackson 2004

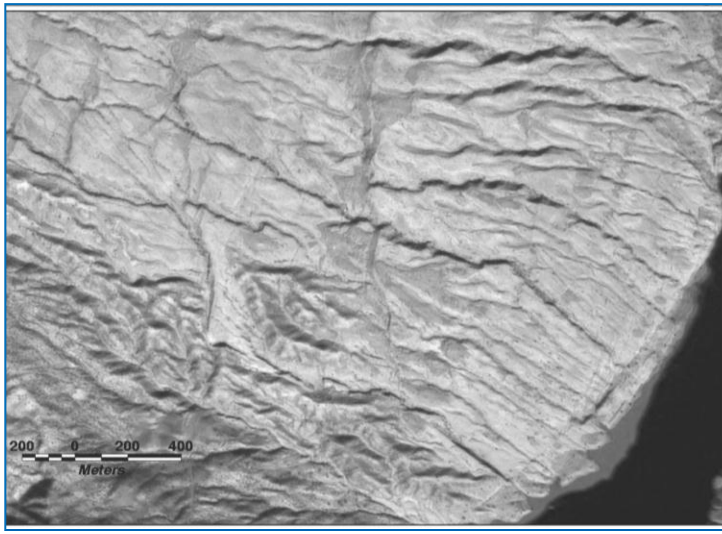
Reactivation and fracture growth

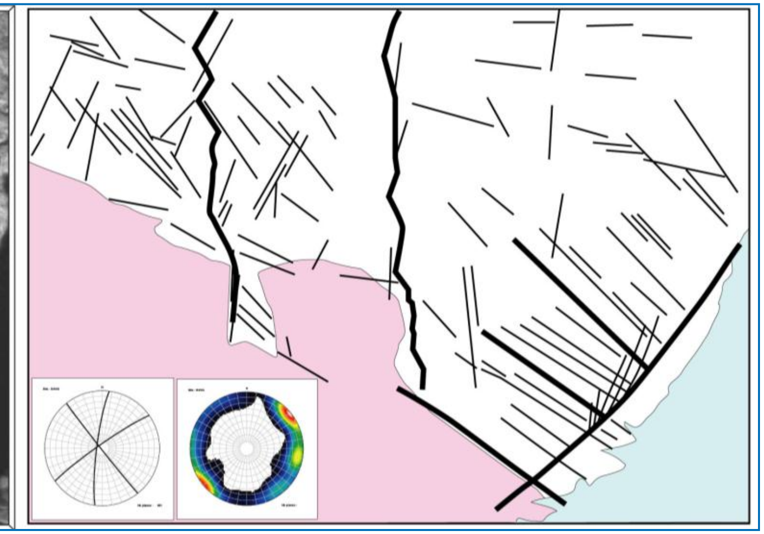
- **Fracture distribution**

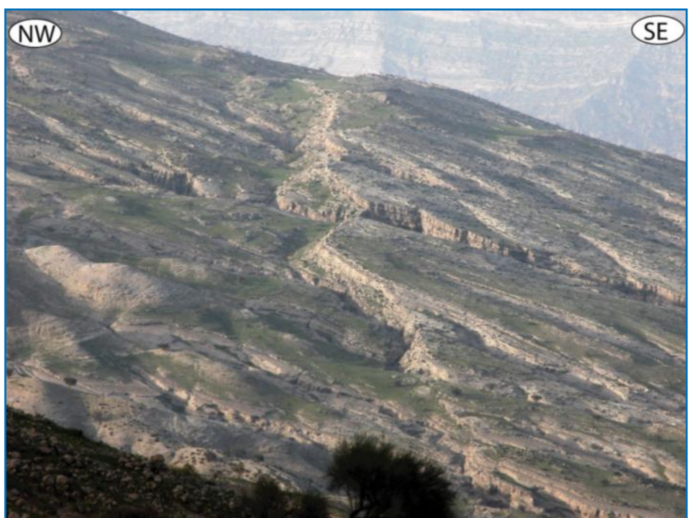




Reactivation and fracture growth

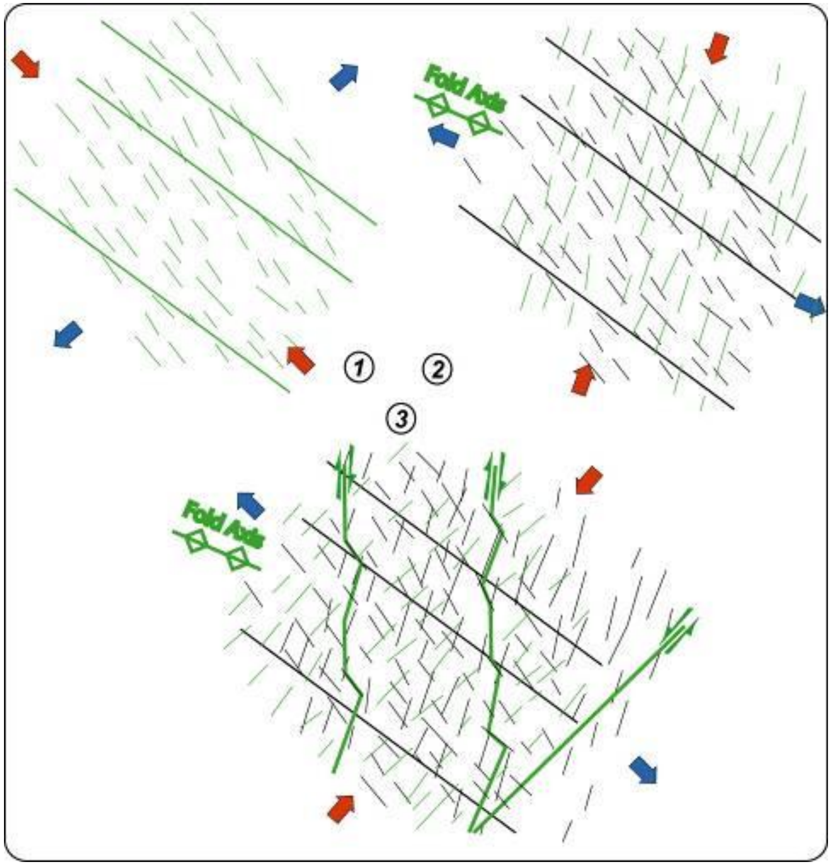






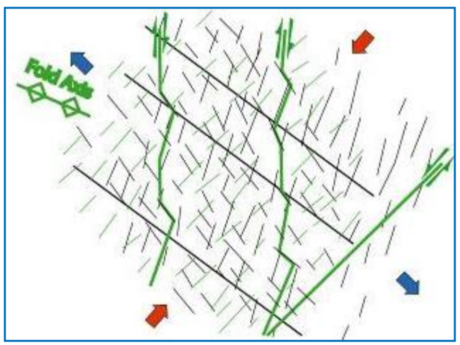
Reactivation and fracture growth

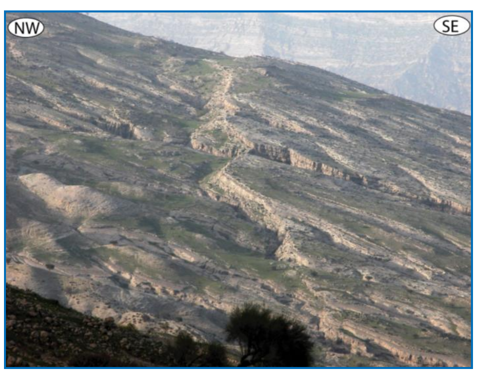
- **Proposed evolution**

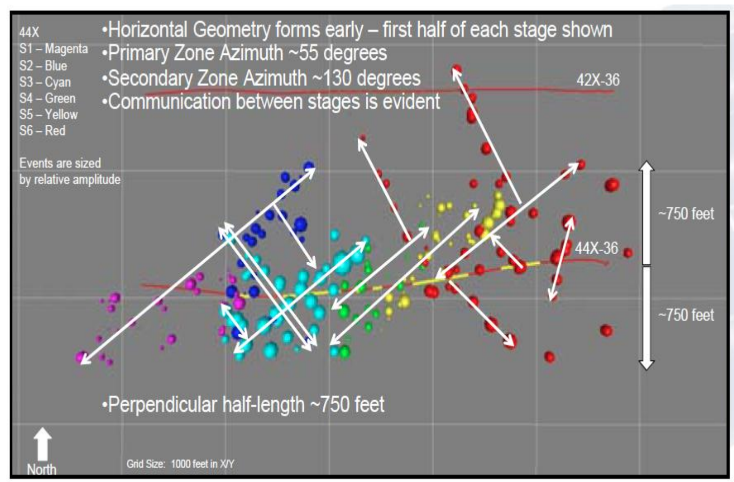


A source of inspiration for new plays? New tools?

- A reservoir scale
  - Prexisting fracture matters
  - A proper definition of paleostress and in-situ stress matter







Reactivation at microscale

Toward paleostress

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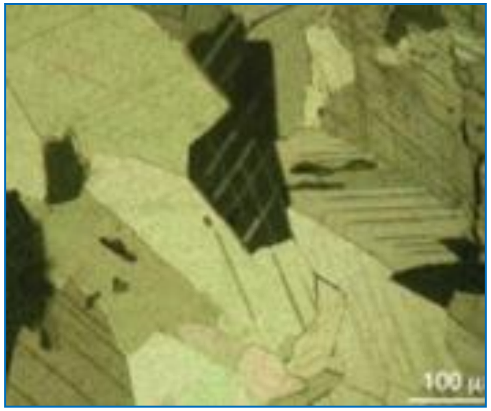
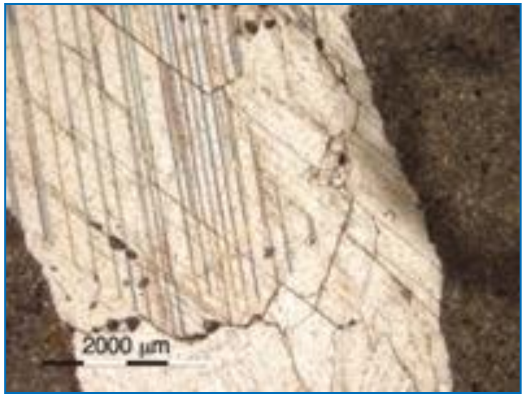
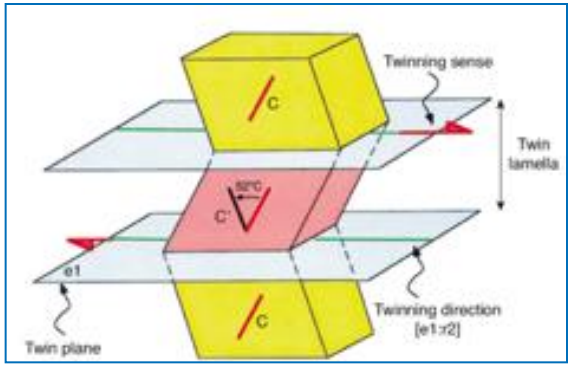
IFP Energies nouvelles

Exemple of reactivation at microscale

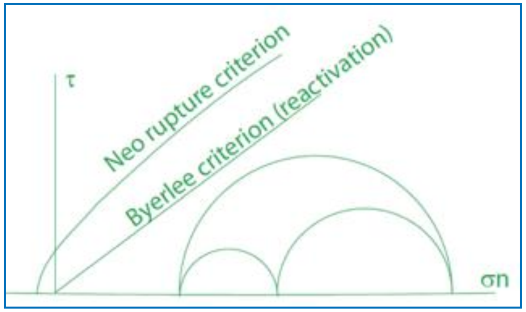
- **Calcite twins**



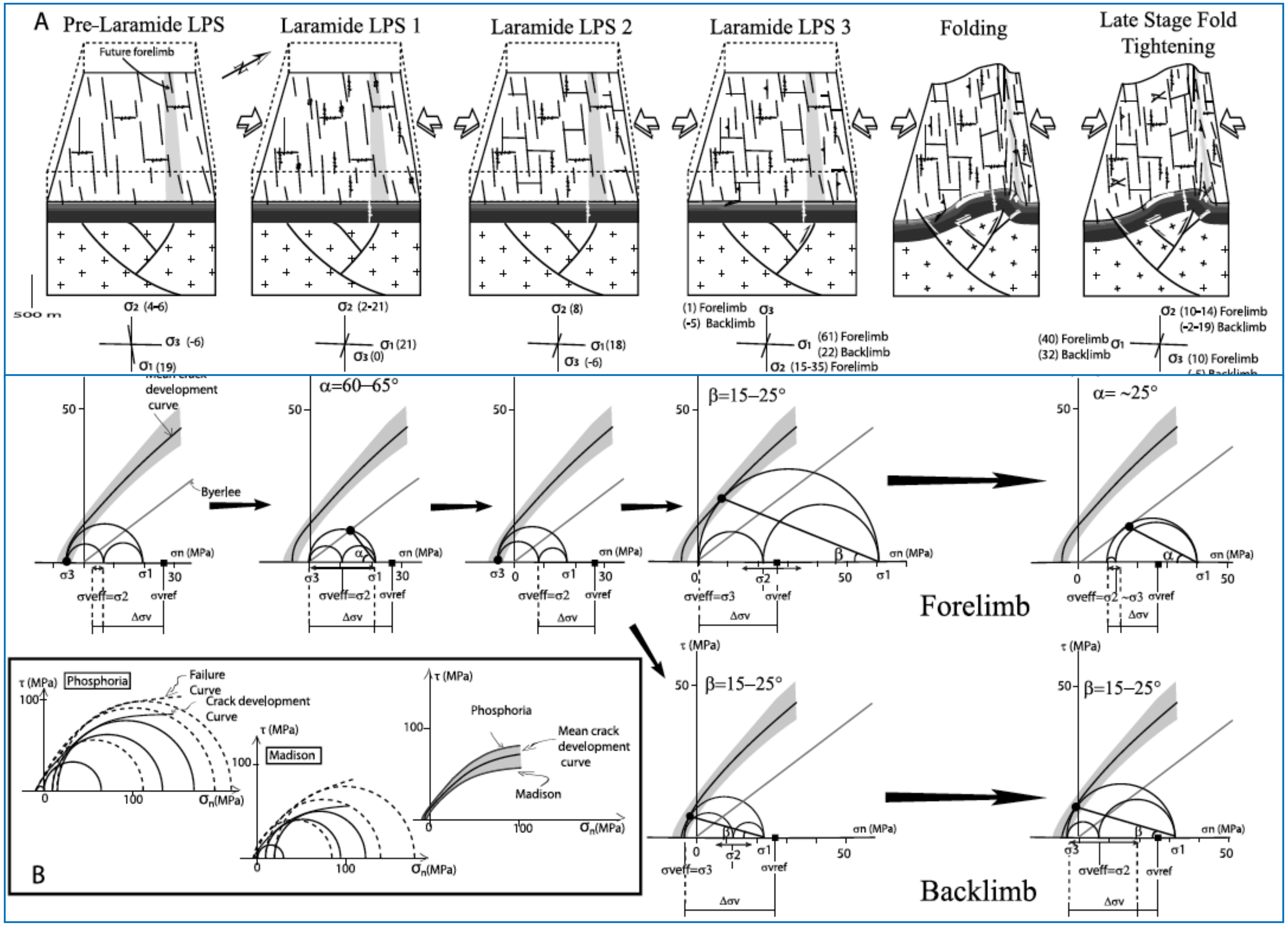




5 components from inversion



Example: sheep mountain



Amrouch et al., Tectonics 2010

Perspective

- Another exemple of :
  - early fracturing
  - the interest of studying interactions between a pre-existing structure and stress

- More systematic access to paleostress
  - Very promising results (can be used on cores)
  - Improvements in progress
    - Precision of the twinning threshold
    - Acquisition speed

Conclusion