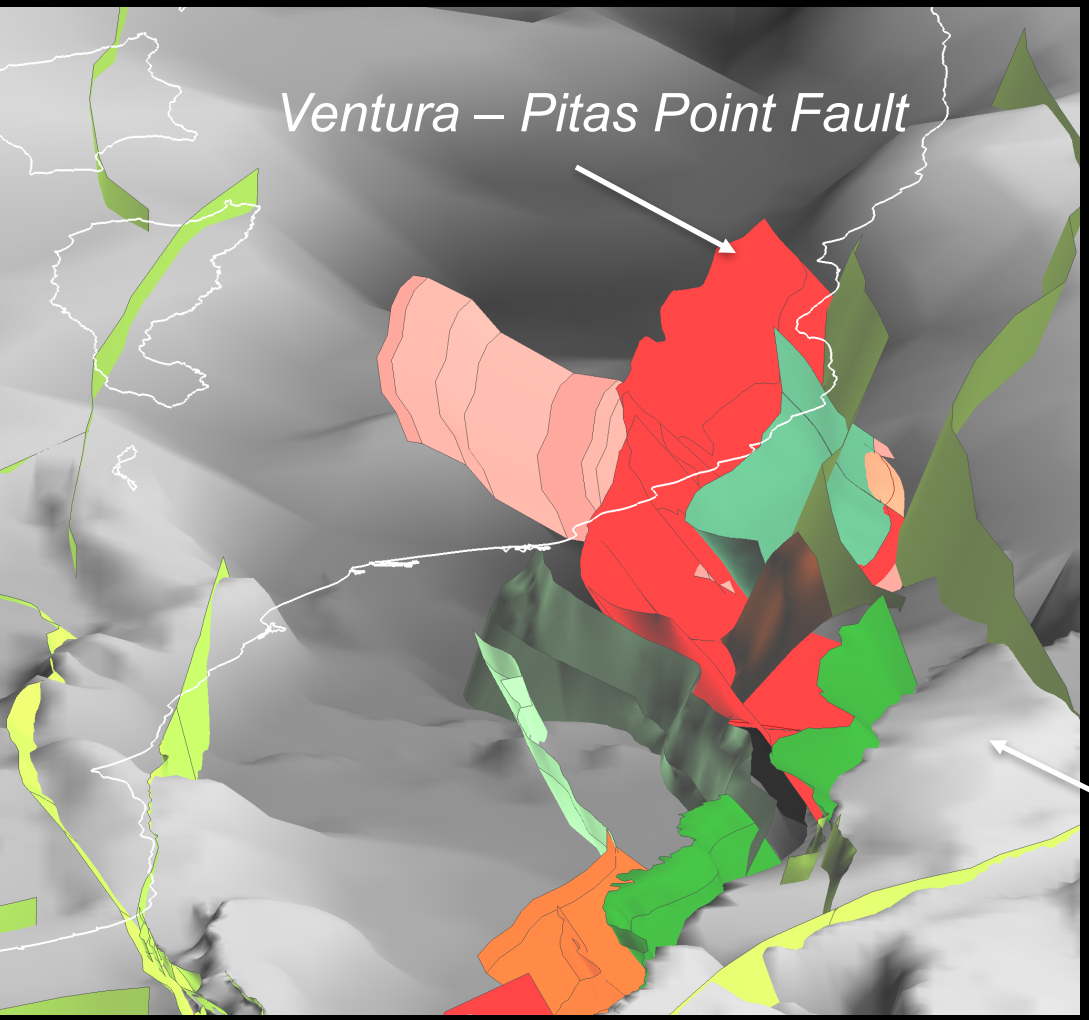
Constraints on the Geometry of the Ventura-Pitas Point Fault System at Depth & Implications for Hazards

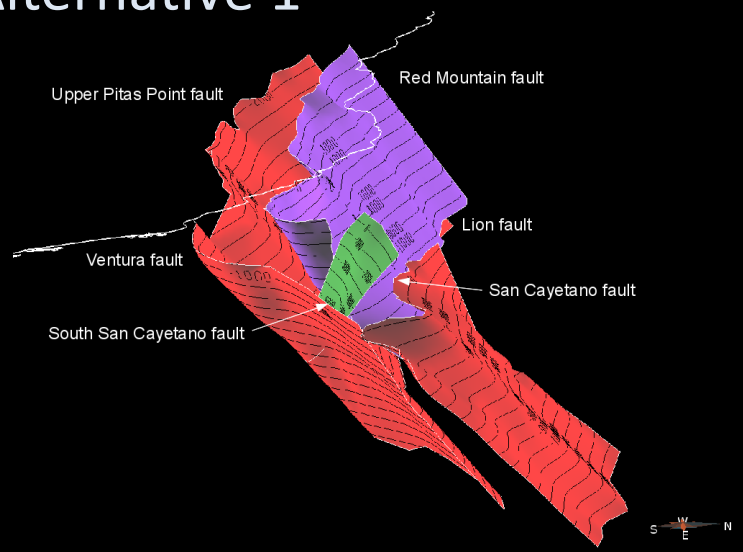


John H. Shaw

Michael Barrall, Reed Burgette, James F. Dolan, Eric Geist, Jessica Grenader, Thomas Gobel, William Hammond, Egill Hauksson, Judith A. Hubbard, Kaj Johnson, Yuval Levy, Lee McAuliffe, Scott Marshall, Craig Nicholson, David Oglesby, Andreas Plesch, Laura Reynolds, Thomas Rockwell, Kenny Ryan, Alex Simms, Christopher Sorlien, Carl Tape, Hong Kie Thio, and Steven Ward

Why does fault geometry at depth matter?

Alternative 1



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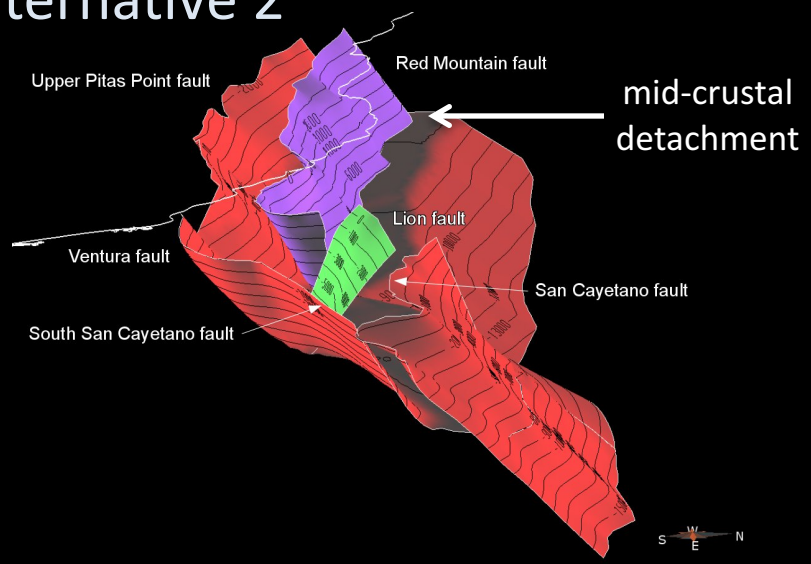


Determines size and location of the earthquake source

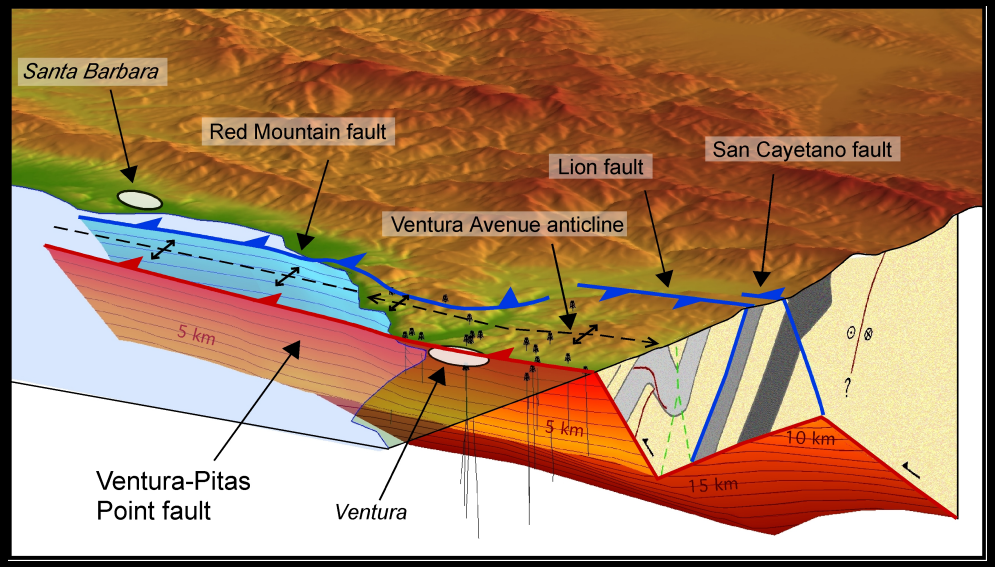
Impacts potential linkages with other fault systems

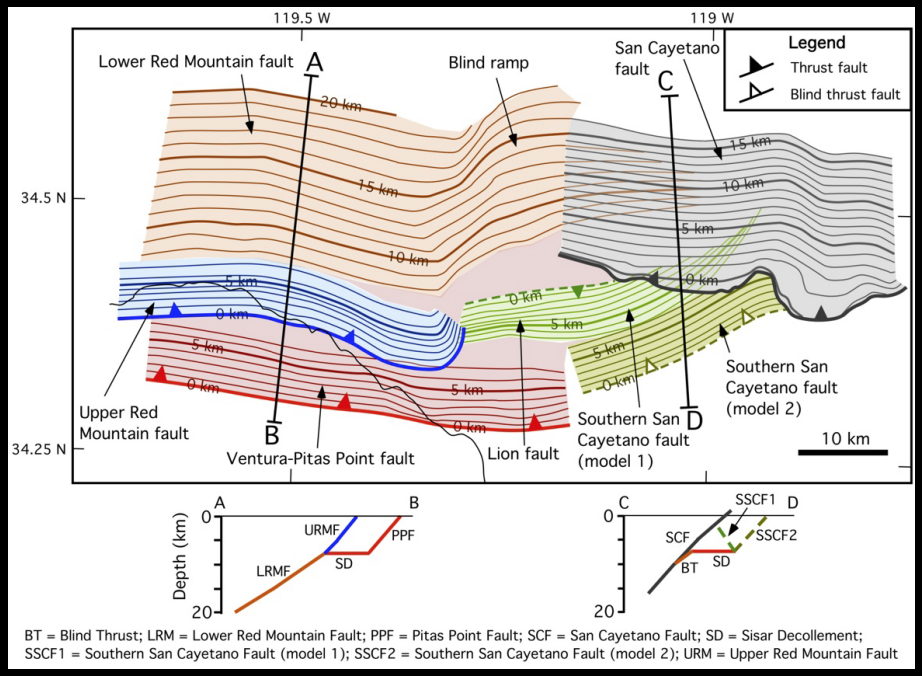
Influences how we ascribe deformation signatures (geologic or geodetic) to fault slip rates

Impacts dynamic rupture and wave propagation

….

Why does fault geometry at depth matter?





Hubbard et al., (2014, BSSA)

Determines size and location of the earthquake source

Impacts potential linkages with other fault systems

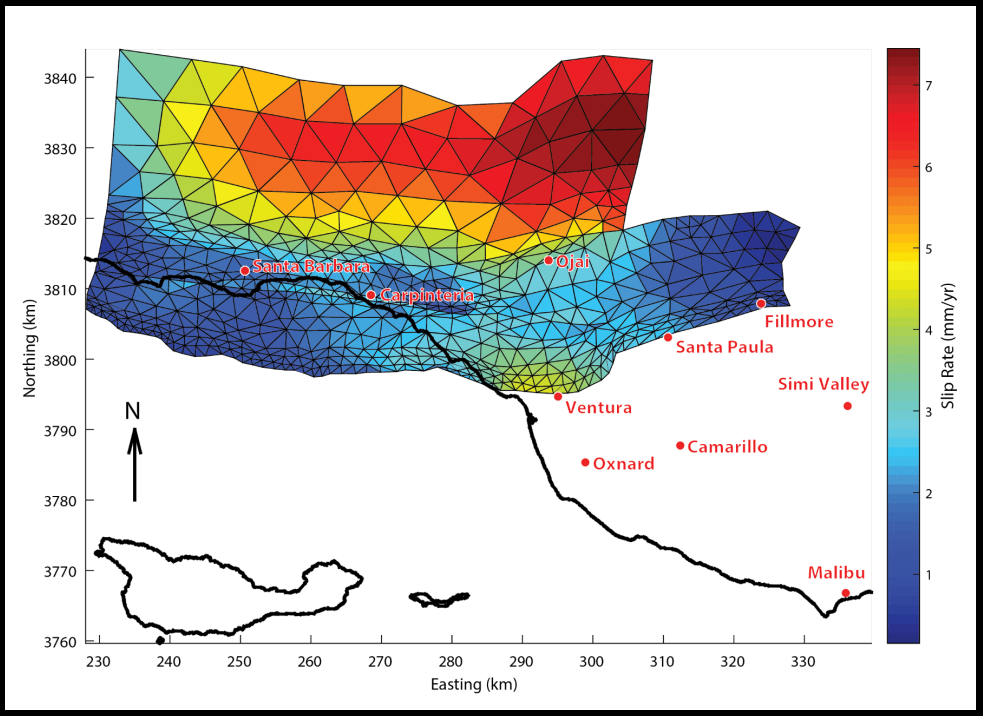
Influences how we ascribe deformation signatures (geologic or geodetic) to fault slip rates

Impacts dynamic rupture and wave propagation

….

Why does fault geometry at depth matter?

Marshall, Funning, & Owen, (2013)



- 3D Distribution of slip is complex
  - Slip rates are fast near coast where large paleo-uplift events have been found
  - Max slip is on lower ramp at depth, which agrees with Hubbard et al., (2014)

Determines size and location of the earthquake source

Impacts potential linkages with other fault systems

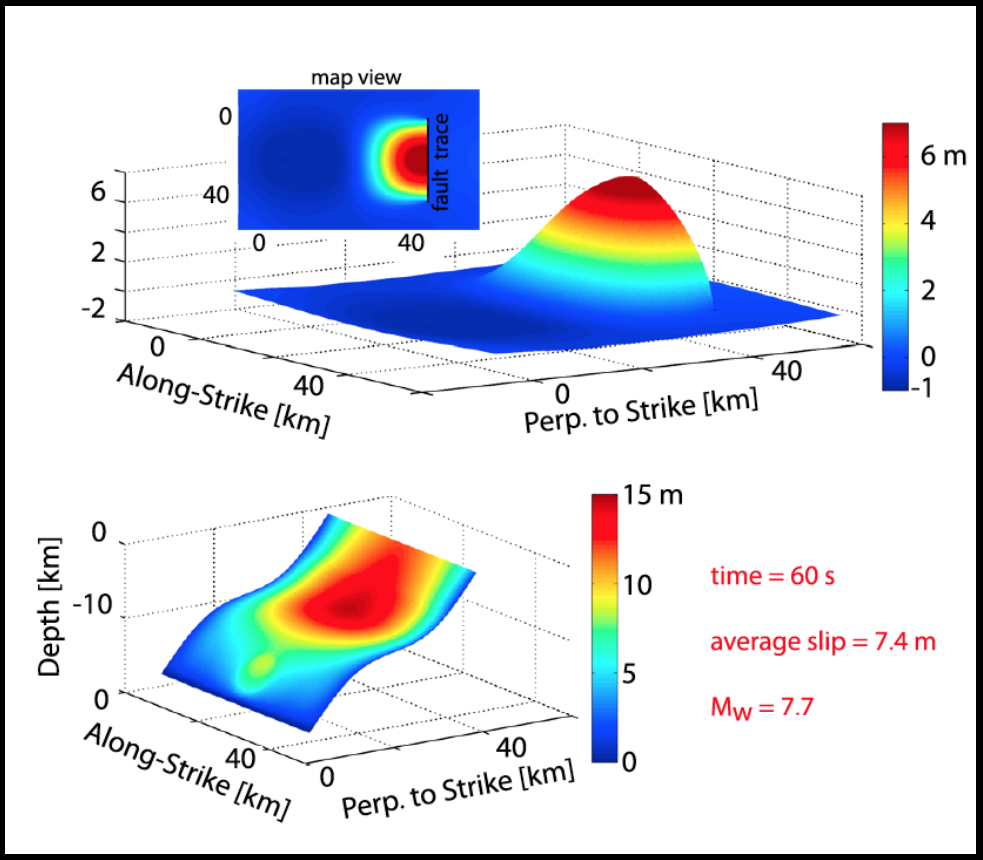
Influences how we ascribe deformation signatures (geologic or geodetic) to fault slip rates

Impacts dynamic rupture and wave propagation

….

Why does fault geometry at depth matter?

Ryan, K. J., E. L. Geist, M. Barall, and D. D. Oglesby (2015)



Determines size and location of the earthquake source

Impacts potential linkages with other fault systems

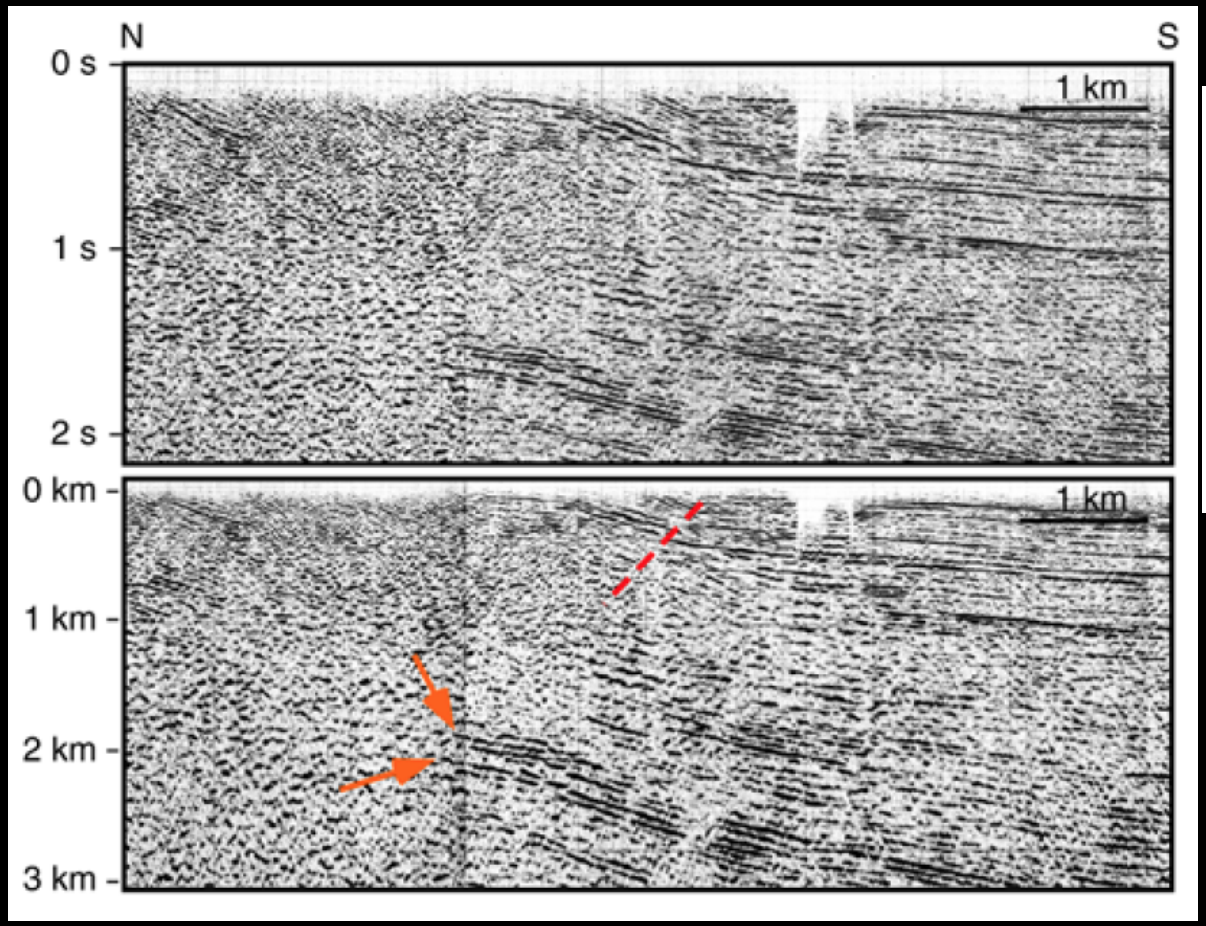
Influences how we ascribe deformation signatures (geologic or geodetic) to fault slip rates

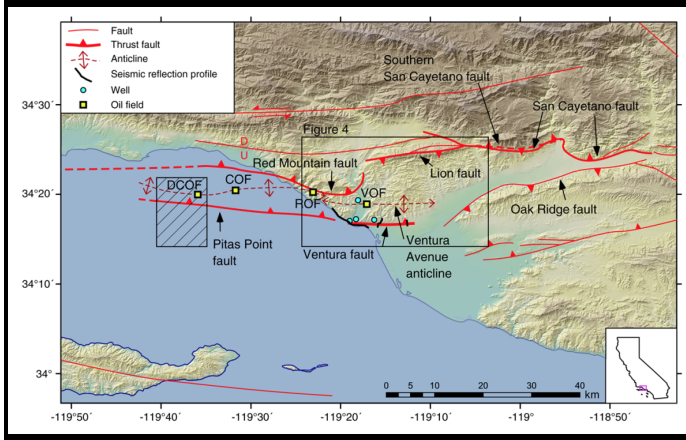
Impacts dynamic rupture and wave propagation (ground shaking & tsunami hazards)

….

Constraints on the shallow fault geometry

VB1 (Industry Line)

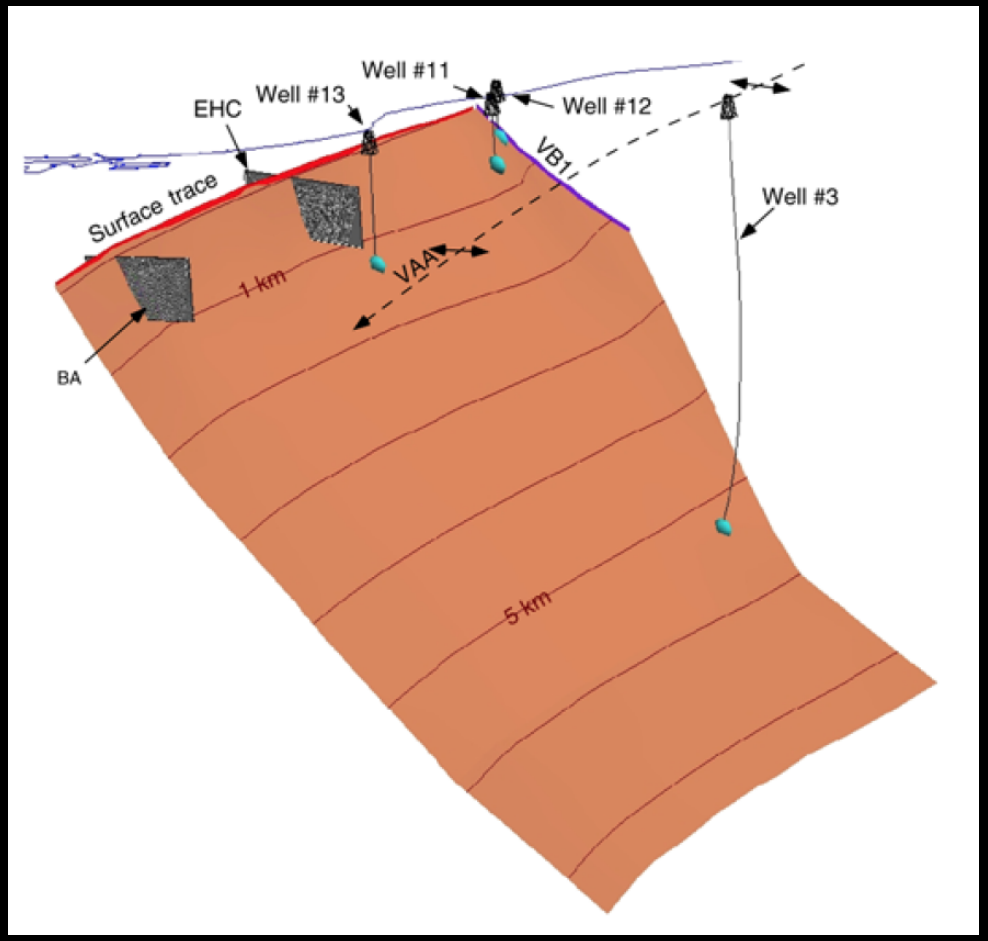




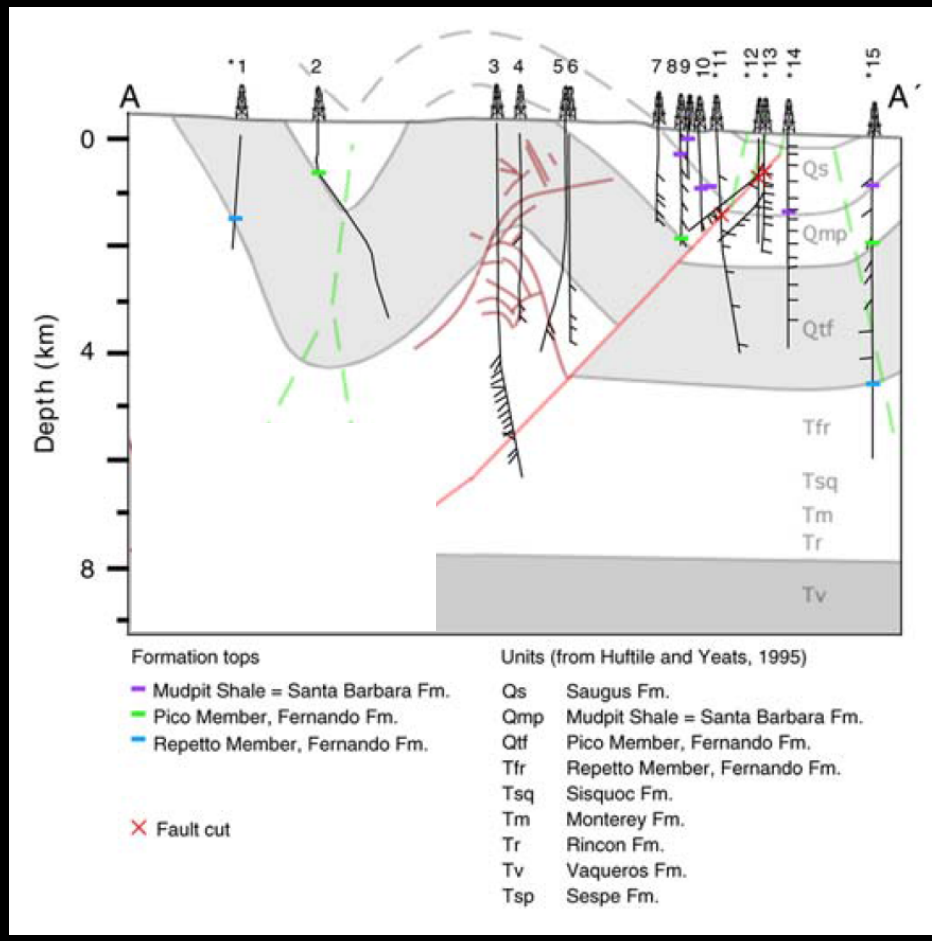
Hubbard et al., (2014)

Constraints on the shallow fault geometry

3D fault model



Geologic section



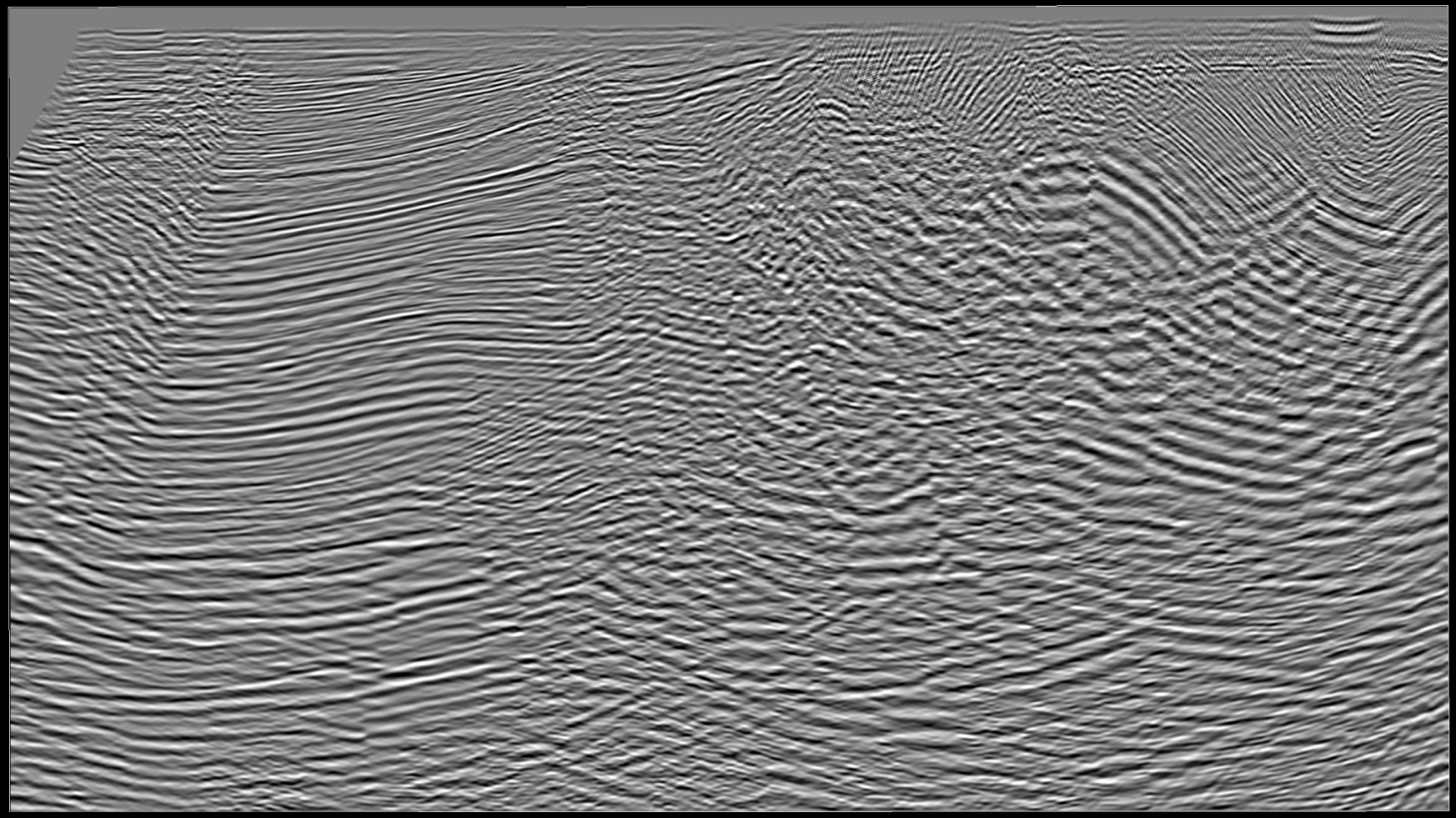
Hubbard et al., (2014)

Based on well and seismic constraints, the fault dips 45-55° N to a depth of about 6km.

This is generally consistent with offshore geometry represented by Sorlien, C. C., C. Nicholson, R. J. Behl, C. J. Marshall, and J. P. Kennett, (2014) and Sorlien, Nicholson, Kamerling, and Behl, (2015).

Lack of direct constraints on deep fault geometry

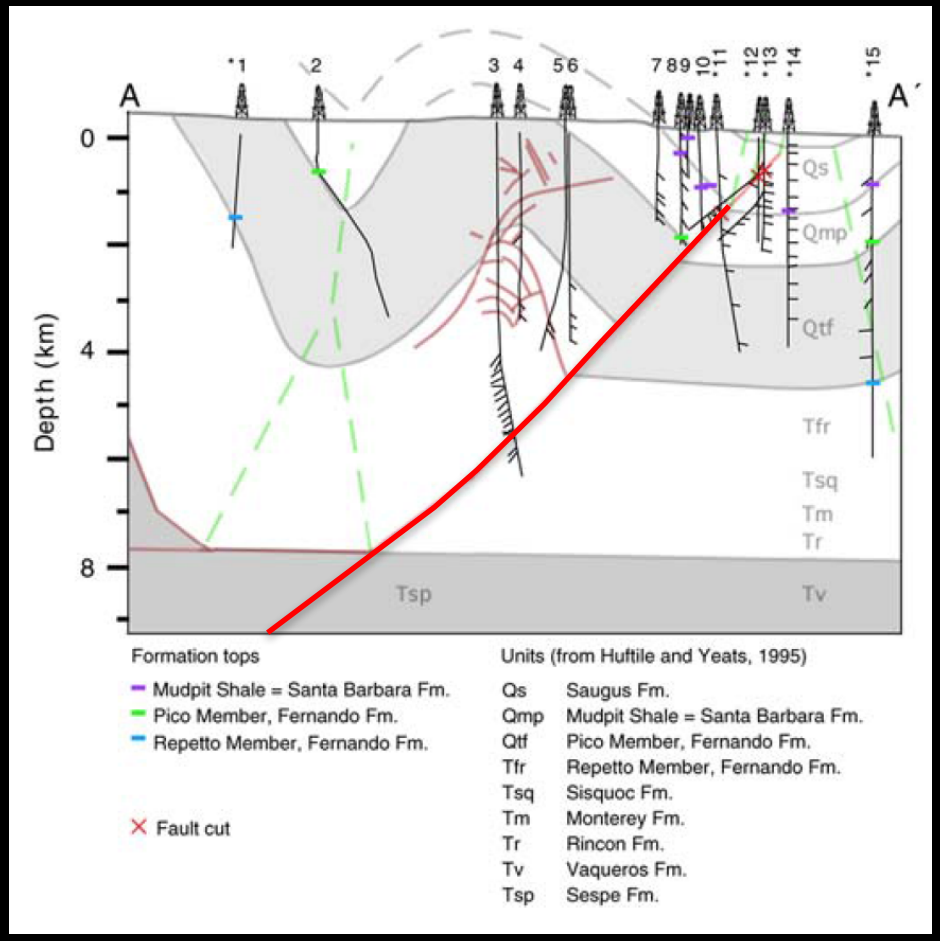
3D seismic



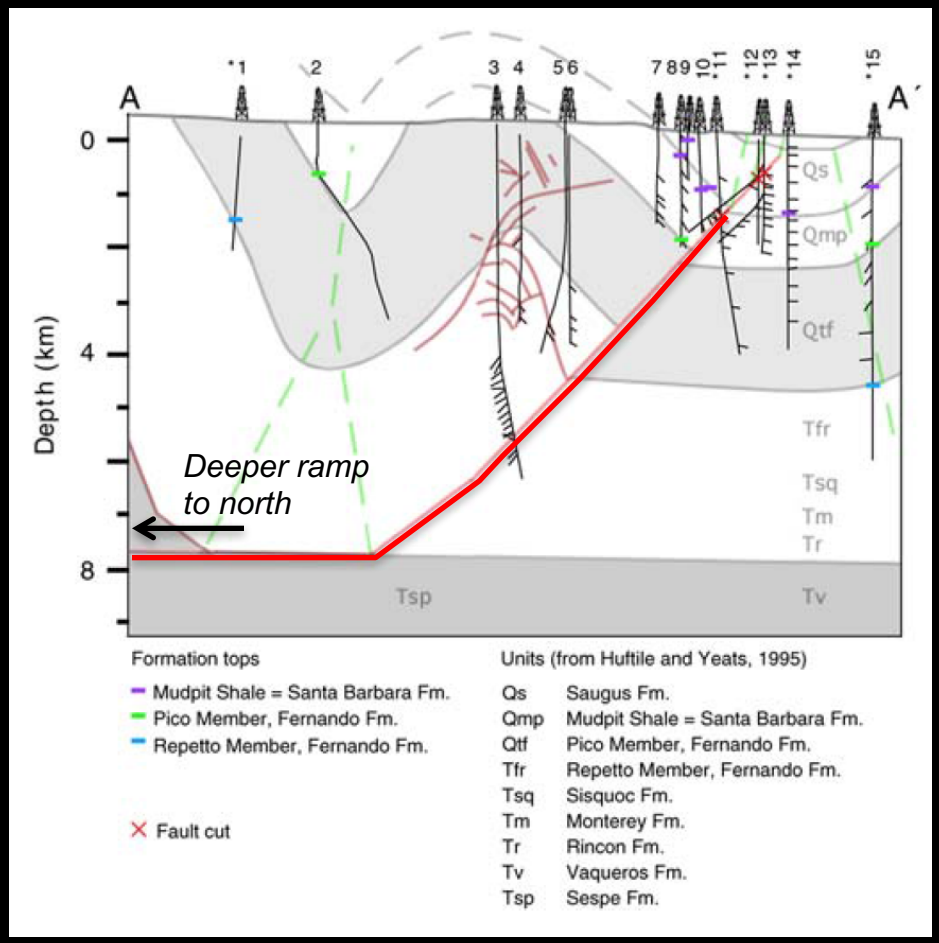
5s TWTT ≈ 7.5 km

Possible deep fault geometries

Planar fault



Mid-crustal detachment

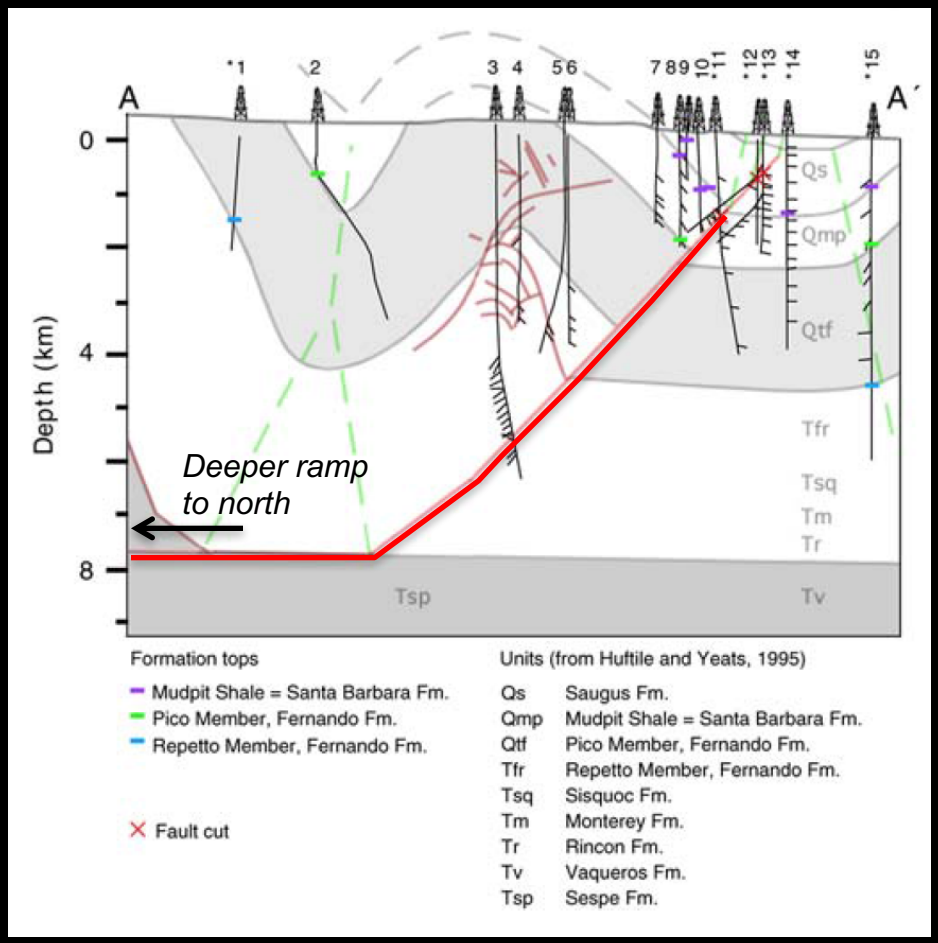


Hubbard et al., (2014)

Support for a mid-crustal detachment

- Presence of syncline defining north flank of Ventura and Dos Cuadras/Rincon folds

Mid-crustal detachment



Hubbard et al., (2014)

Support for a mid-crustal detachment

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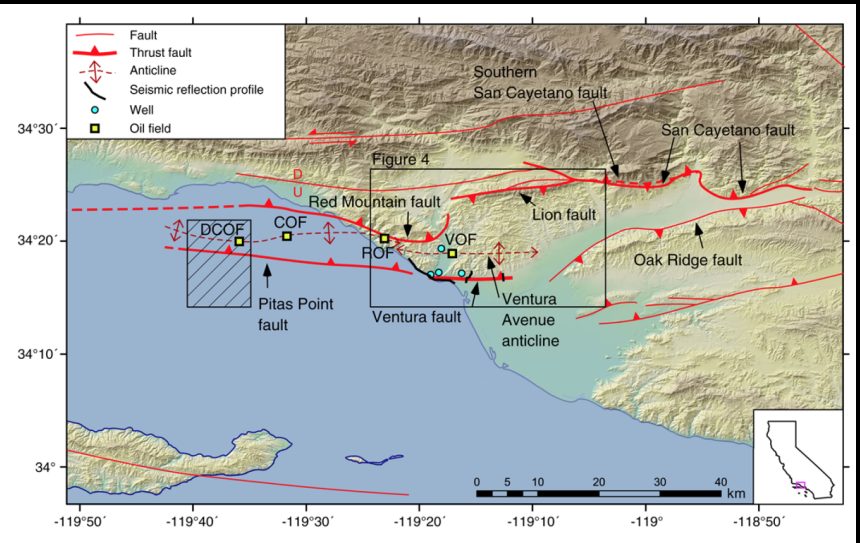
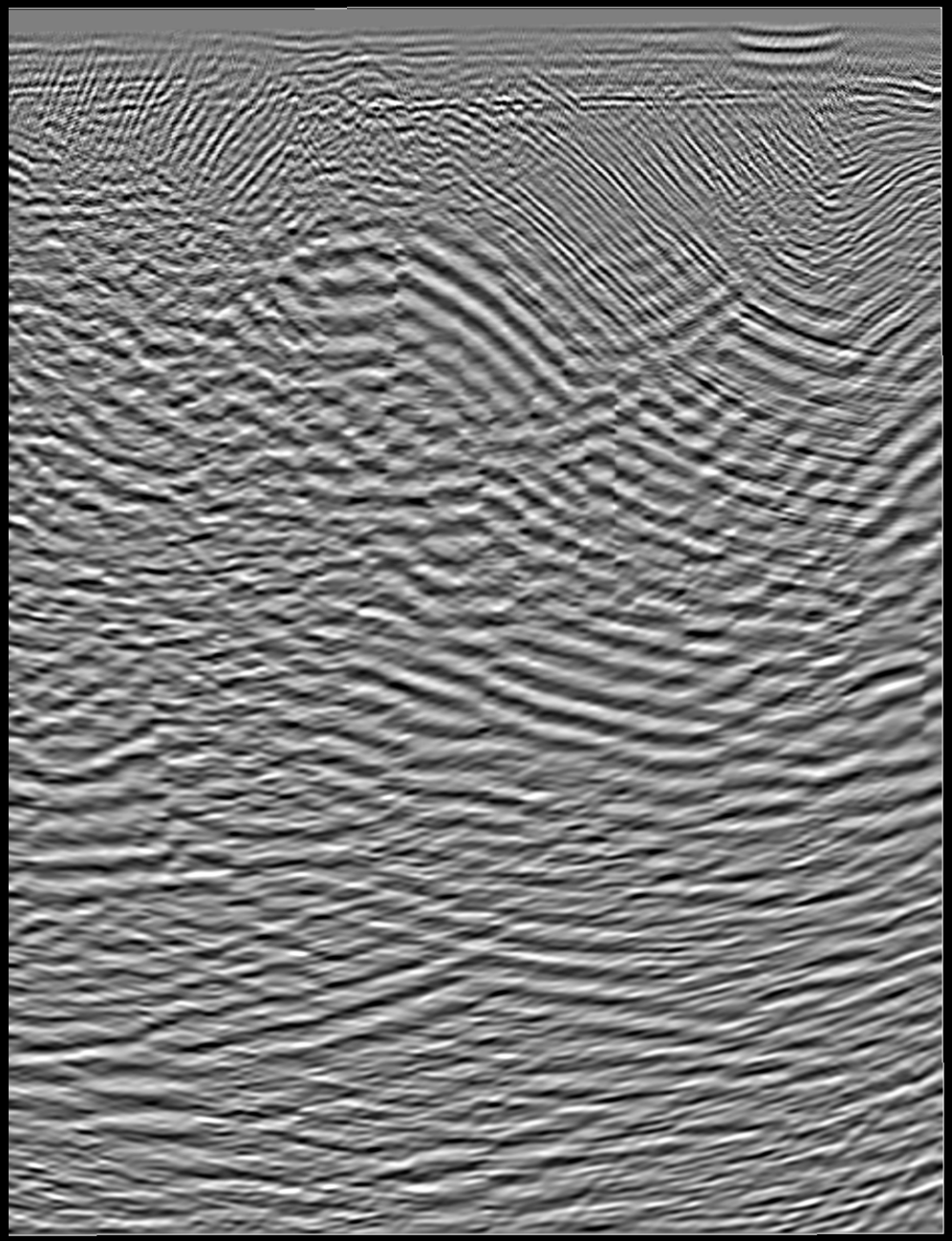


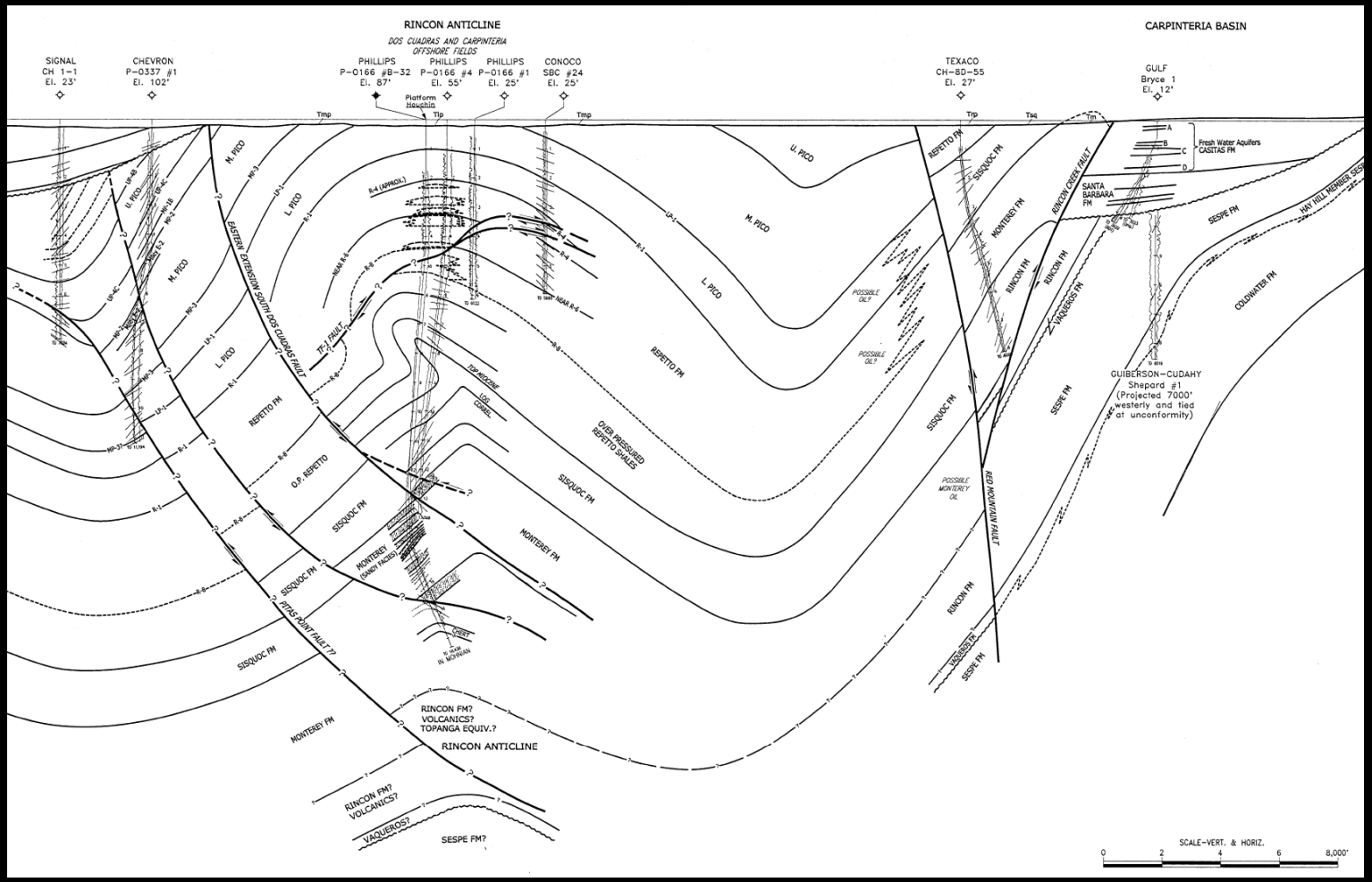
3D seismic



Support for a mid-crustal detachment

- Presence of syncline defining north flank of Ventura and Dos Cuadras/Rincon folds

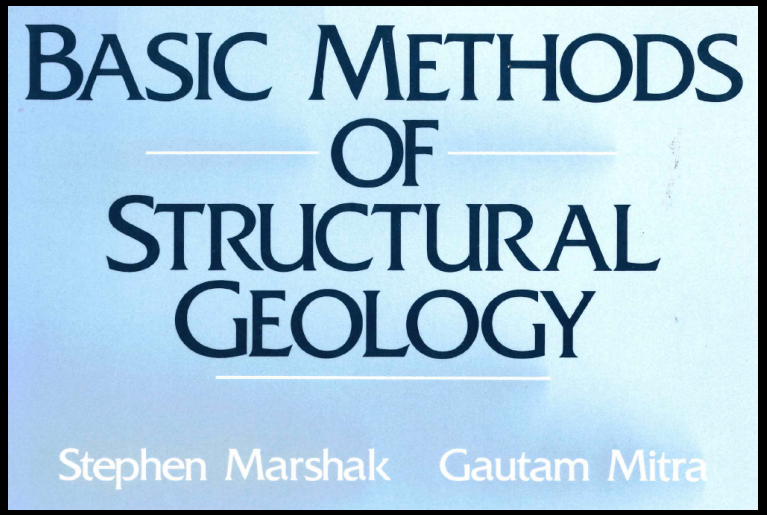
N



Redin et al., (2009; 1998)

Support for a mid-crustal detachment

- Presence of syncline defining north flank of Ventura and Dos Cuadras/Rincon folds



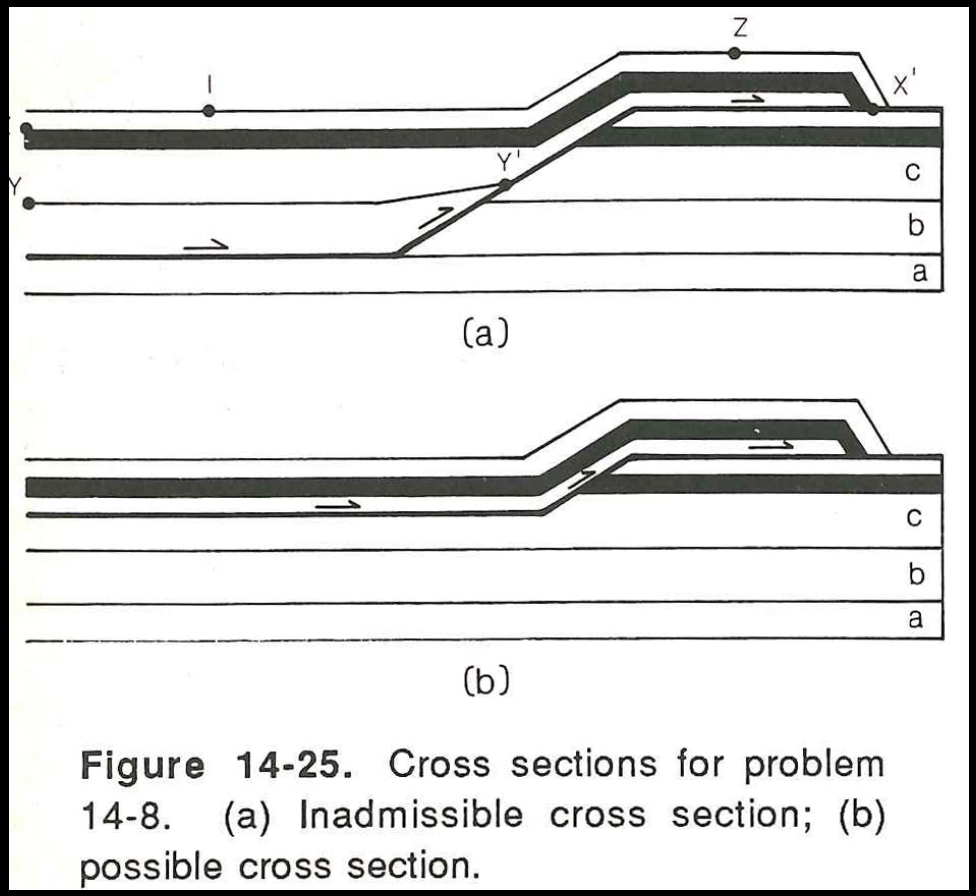


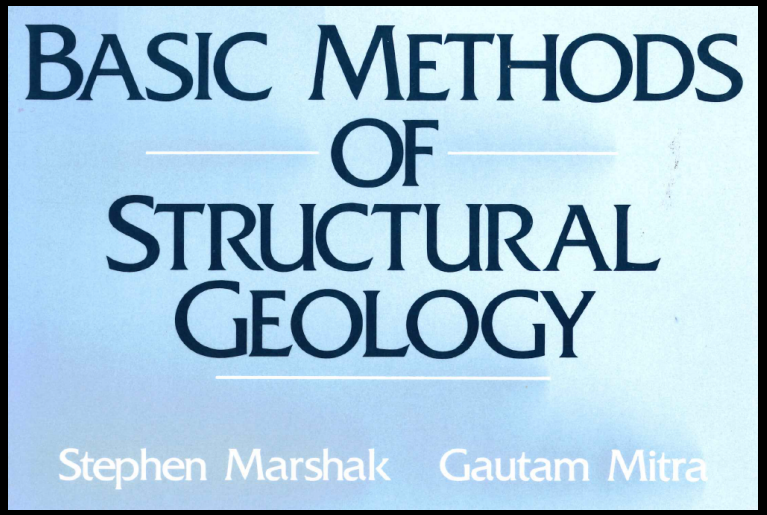
Figure 14-25. Cross sections for problem 14-8. (a) Inadmissible cross section; (b) possible cross section.

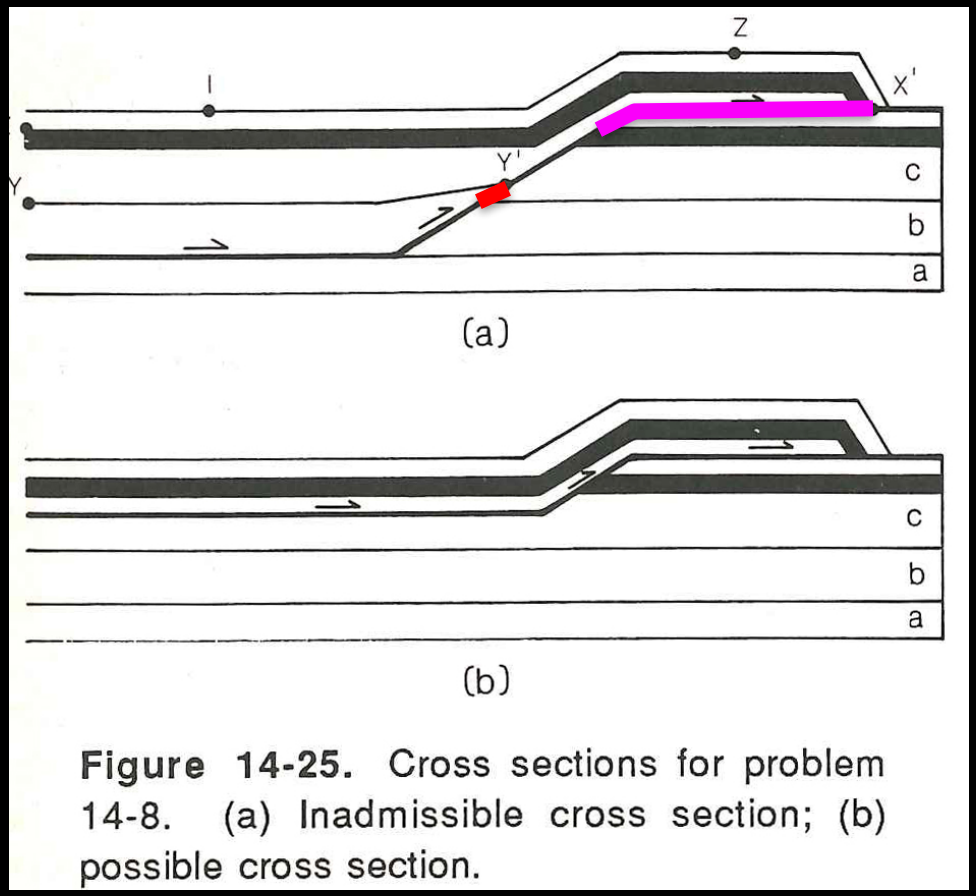
Marshak and Mitra (1988)

- Presence of syncline requires shallowing of fault
  - Note inconsistent slip of stratigraphic horizons in section a

Support for a mid-crustal detachment

- Presence of syncline defining north flank of Ventura and Dos Cuadras/Rincon folds





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Support for a mid-crustal detachment

- Presence of syncline defining north flank of Ventura and Dos Cuadras/Rincon folds

40% shortening

4% shortening

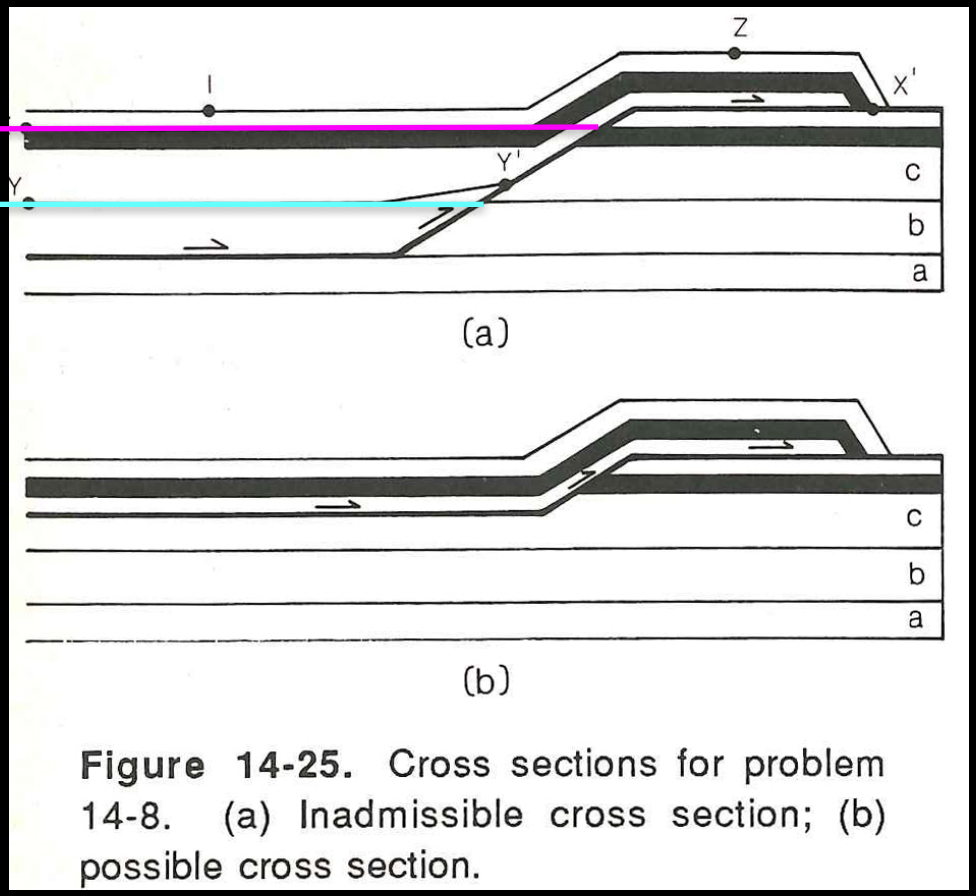


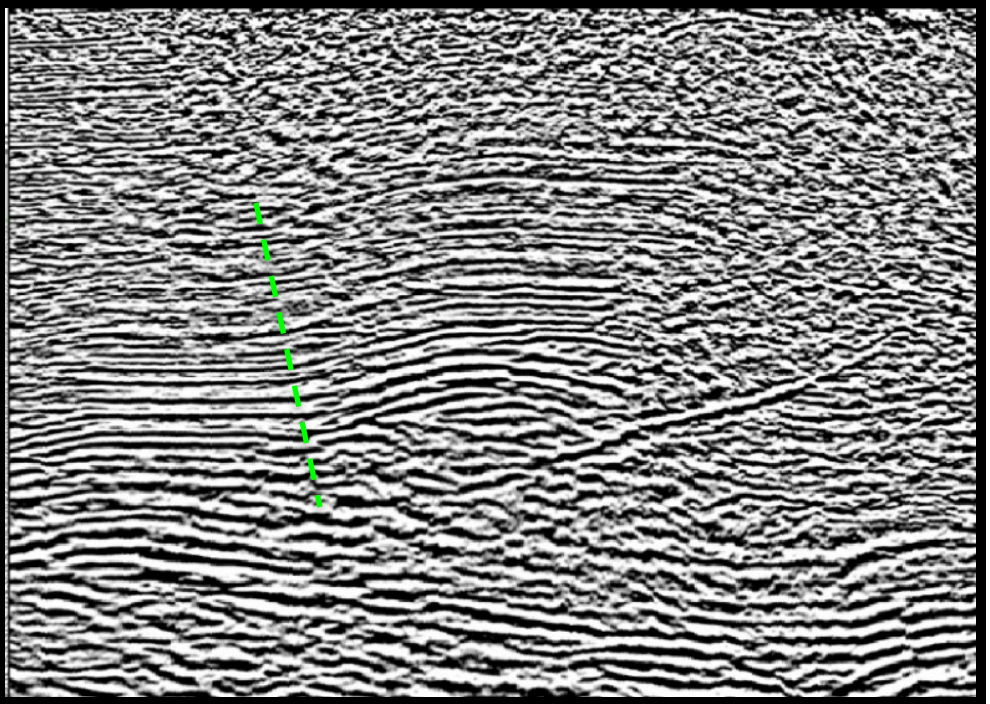
Figure 14-25. Cross sections for problem 14-8. (a) Inadmissible cross section; (b) possible cross section.

Marshak and Mitra (1988)

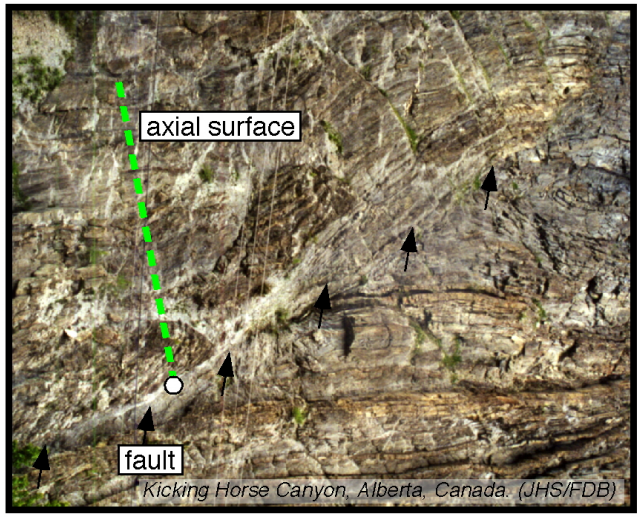
- Presence of syncline requires shallowing of fault
  - Note inconsistent slip of stratigraphic horizons in section a
  - Note inconsistent restored line lengths

Synclines and detachments

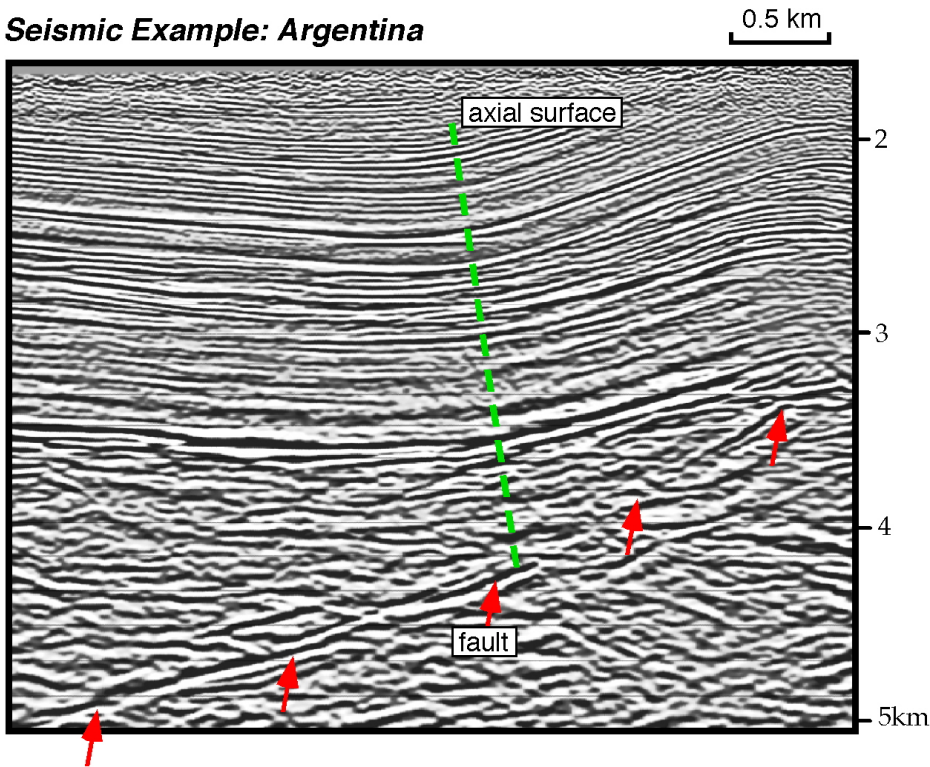
Seismic example: Sichuan basin



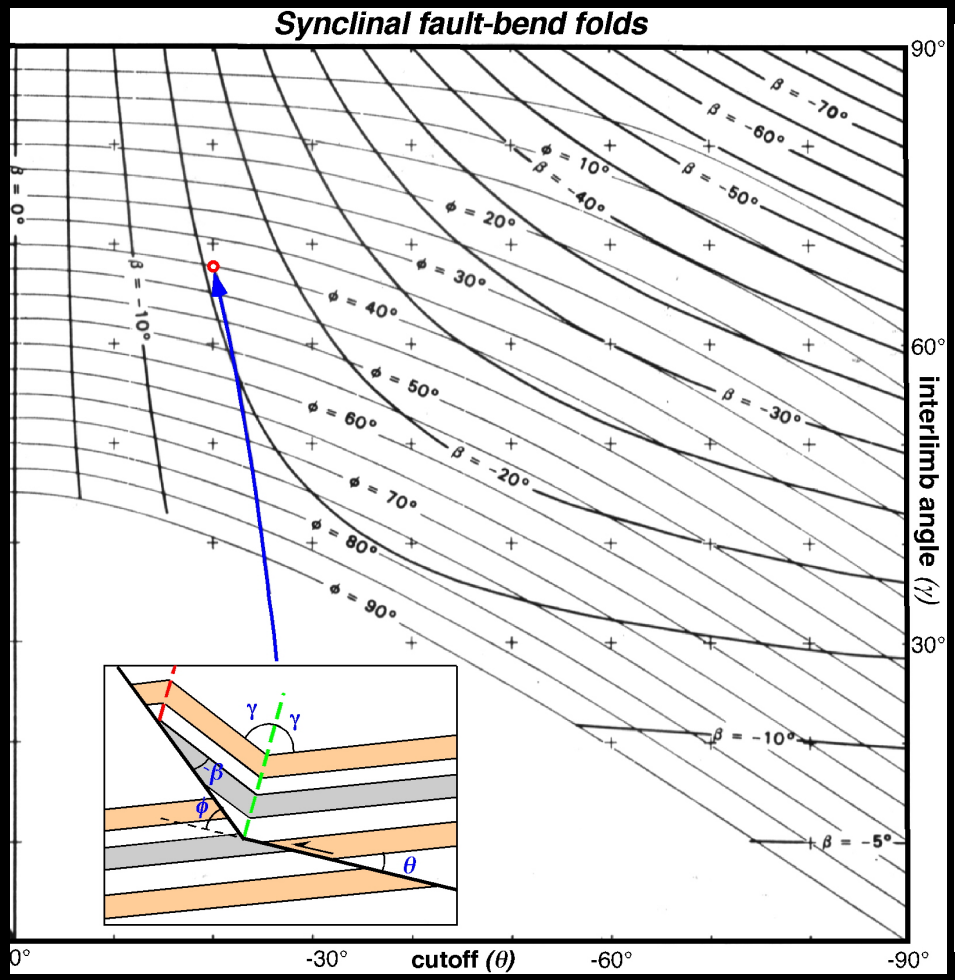
Field Example



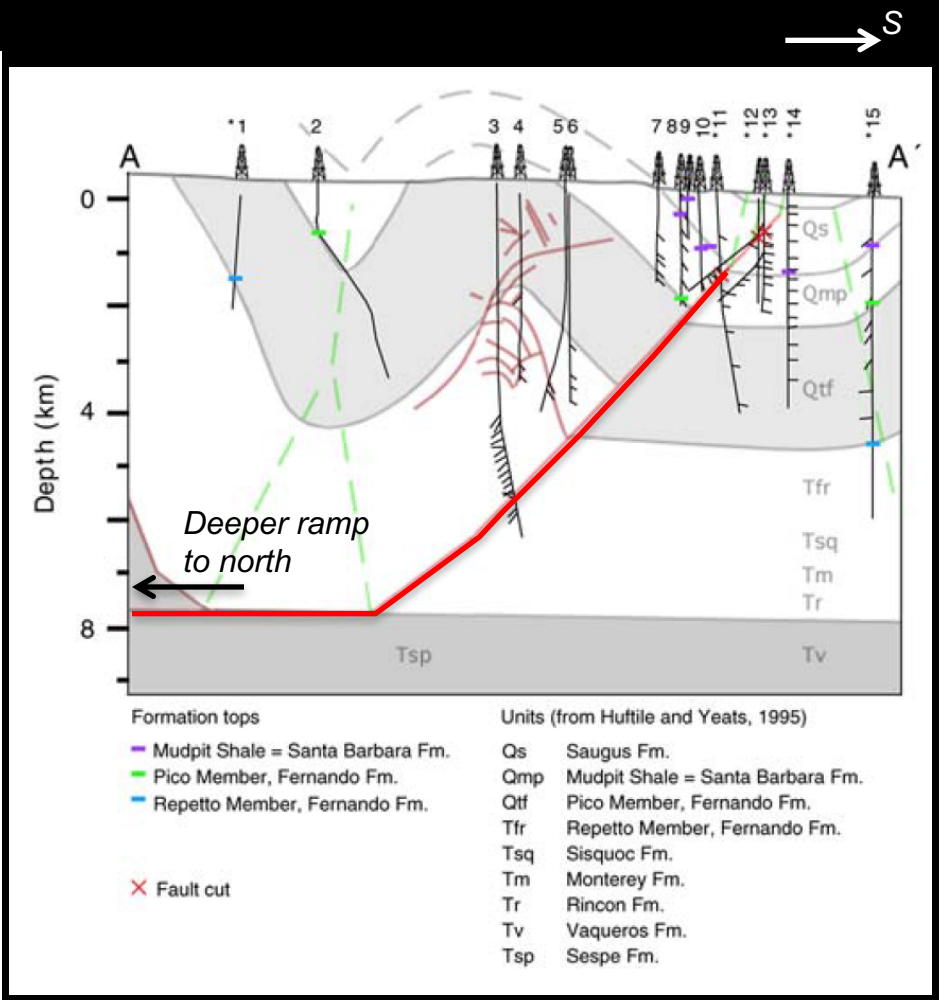
Seismic Example: Argentina



Synclines and fault bends

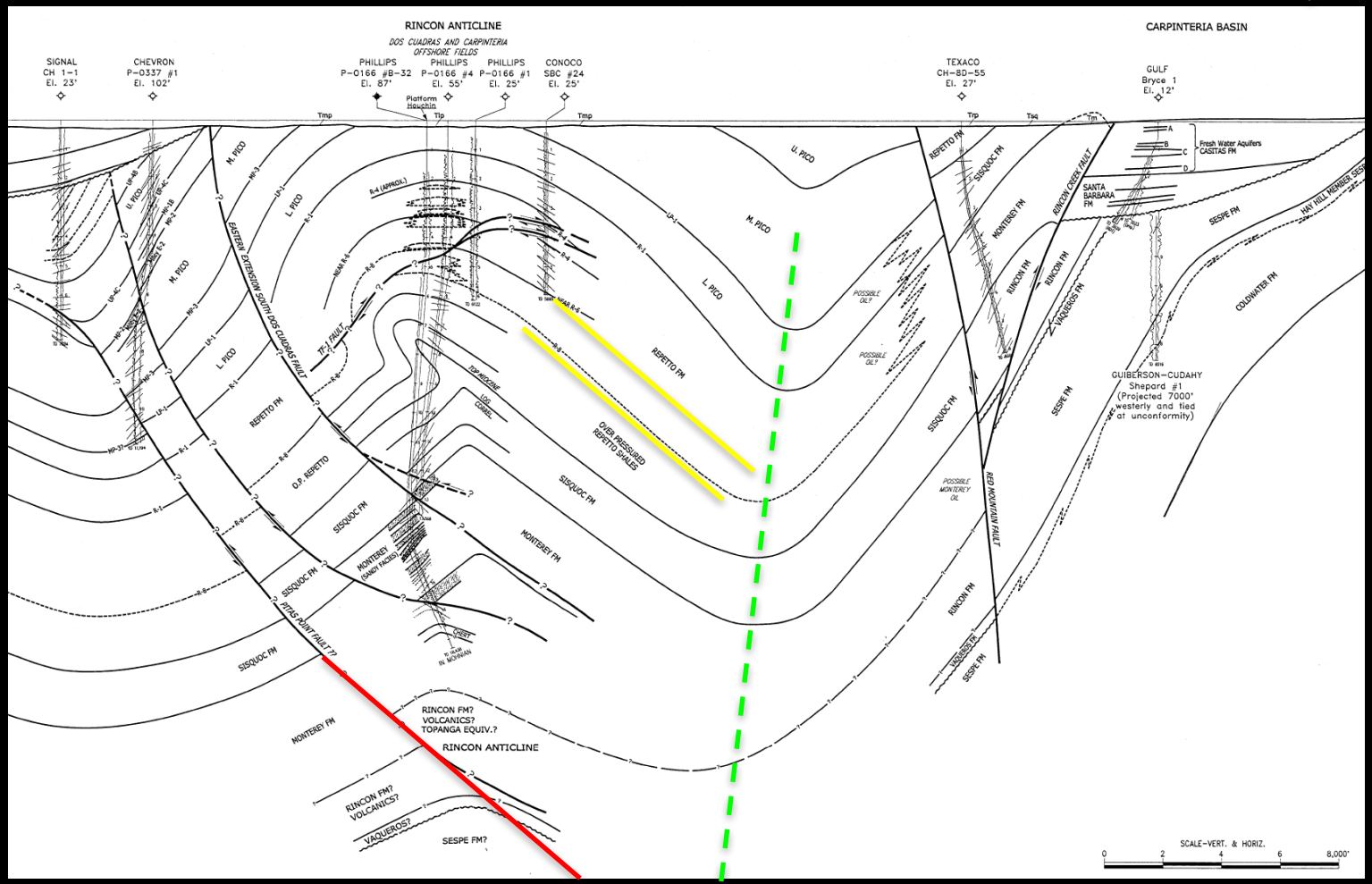


Suppe et al., (1983)



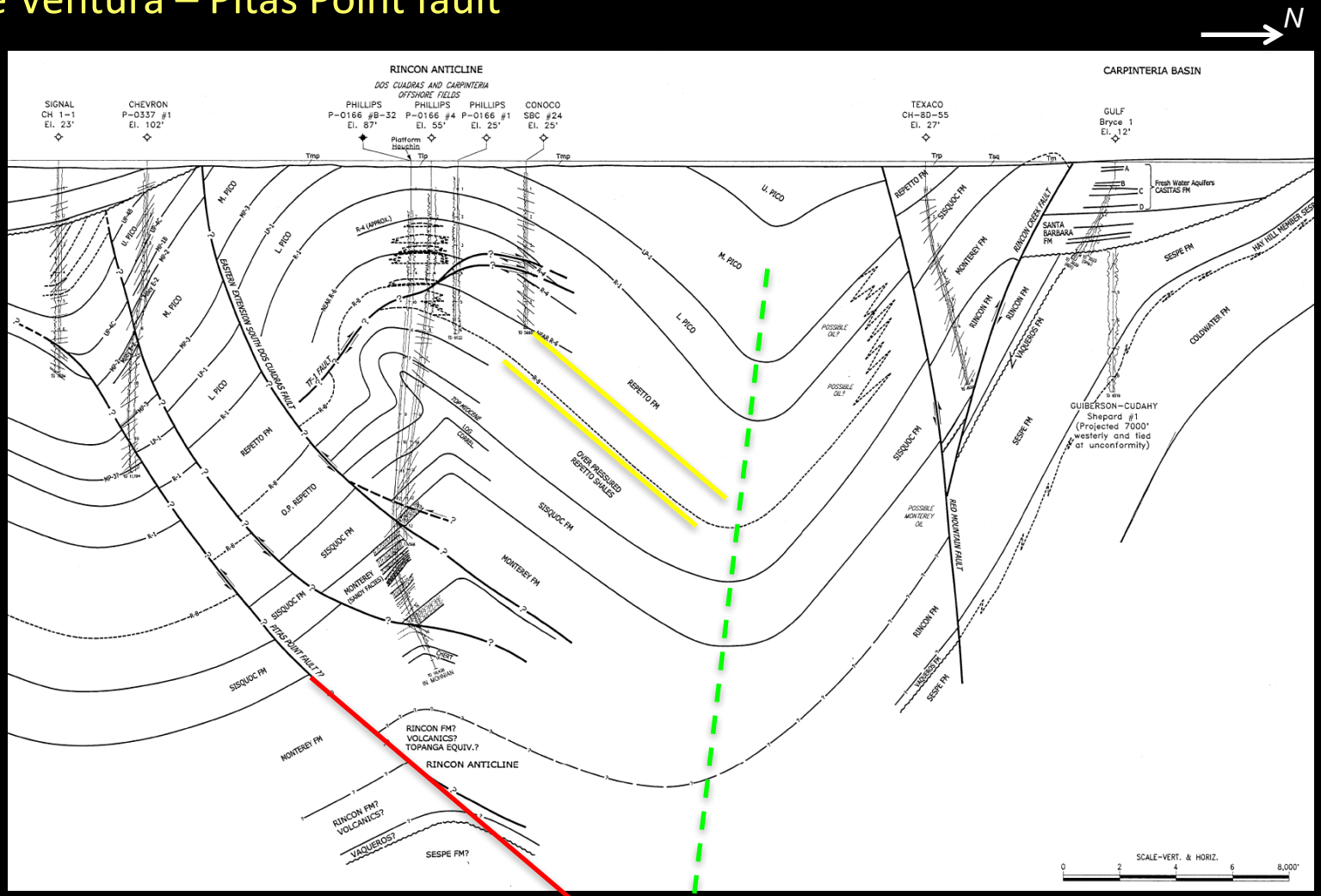
Hubbard et al., (2014)

Offshore Ventura – Pitas Point fault



Redin et al., (2009; 1998)

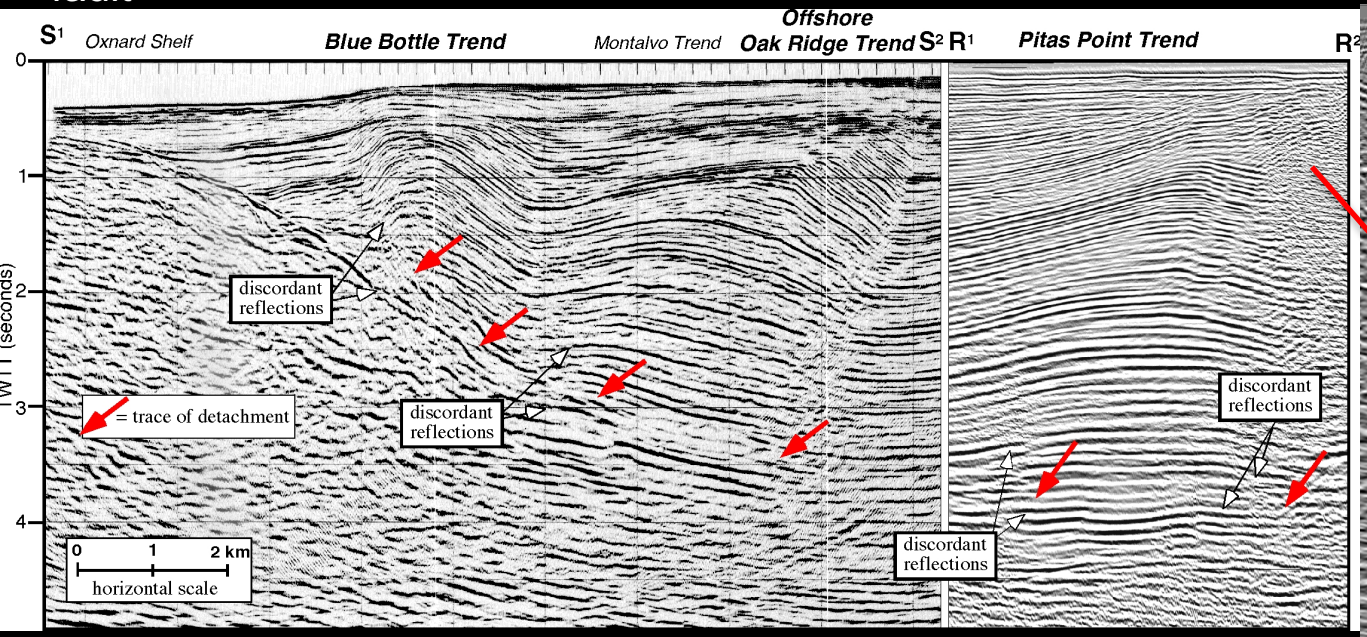
Offshore Ventura – Pitas Point fault

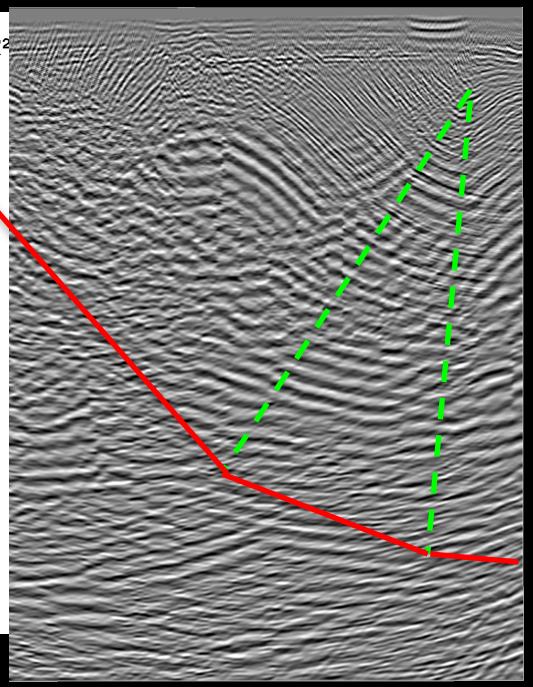


Redin et al., (2009; 1998)

Support for a mid-crustal detachment

- Presence of regional Miocene detachment level south of the Pitas Point fault





Shaw et al., (2014)

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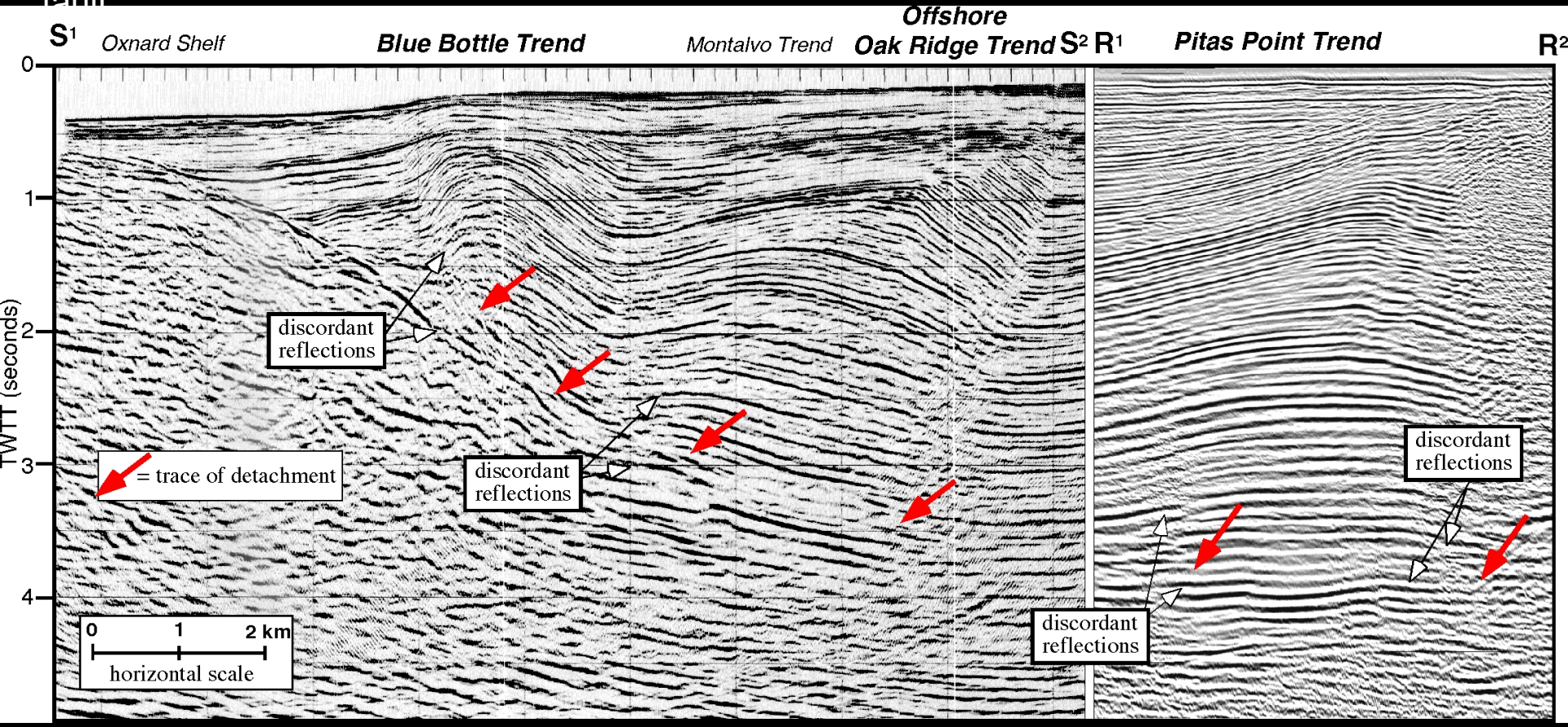

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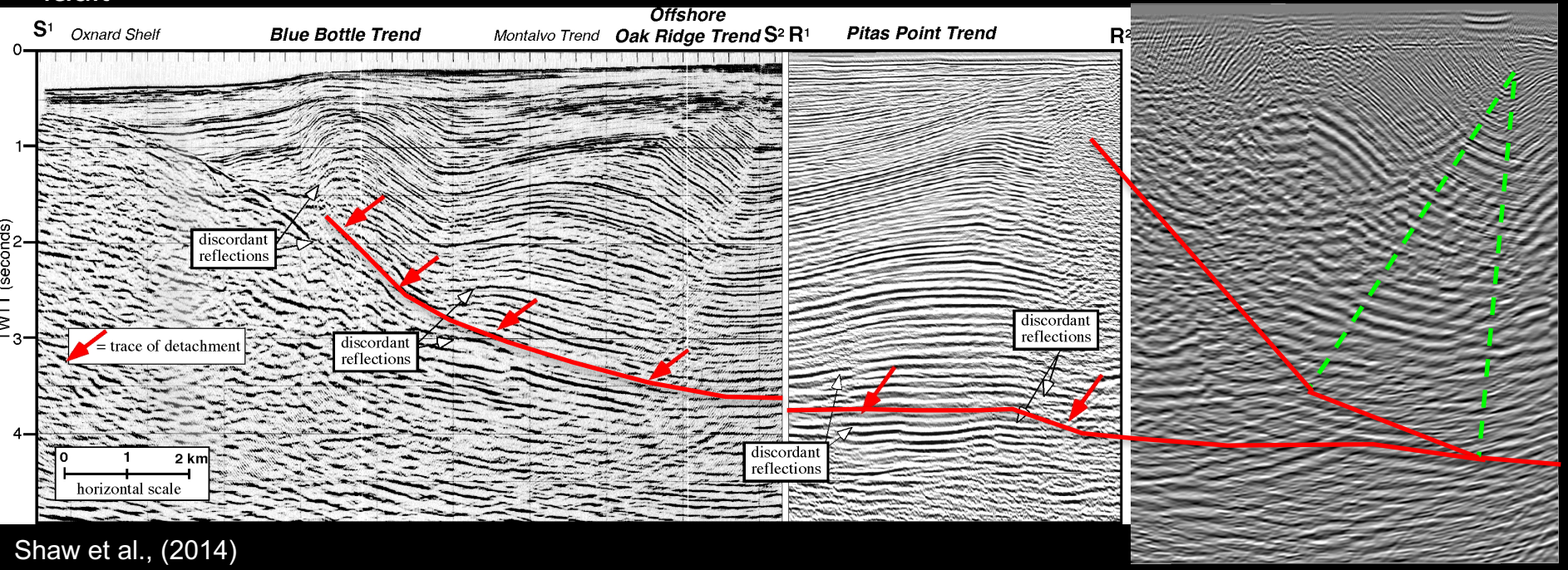
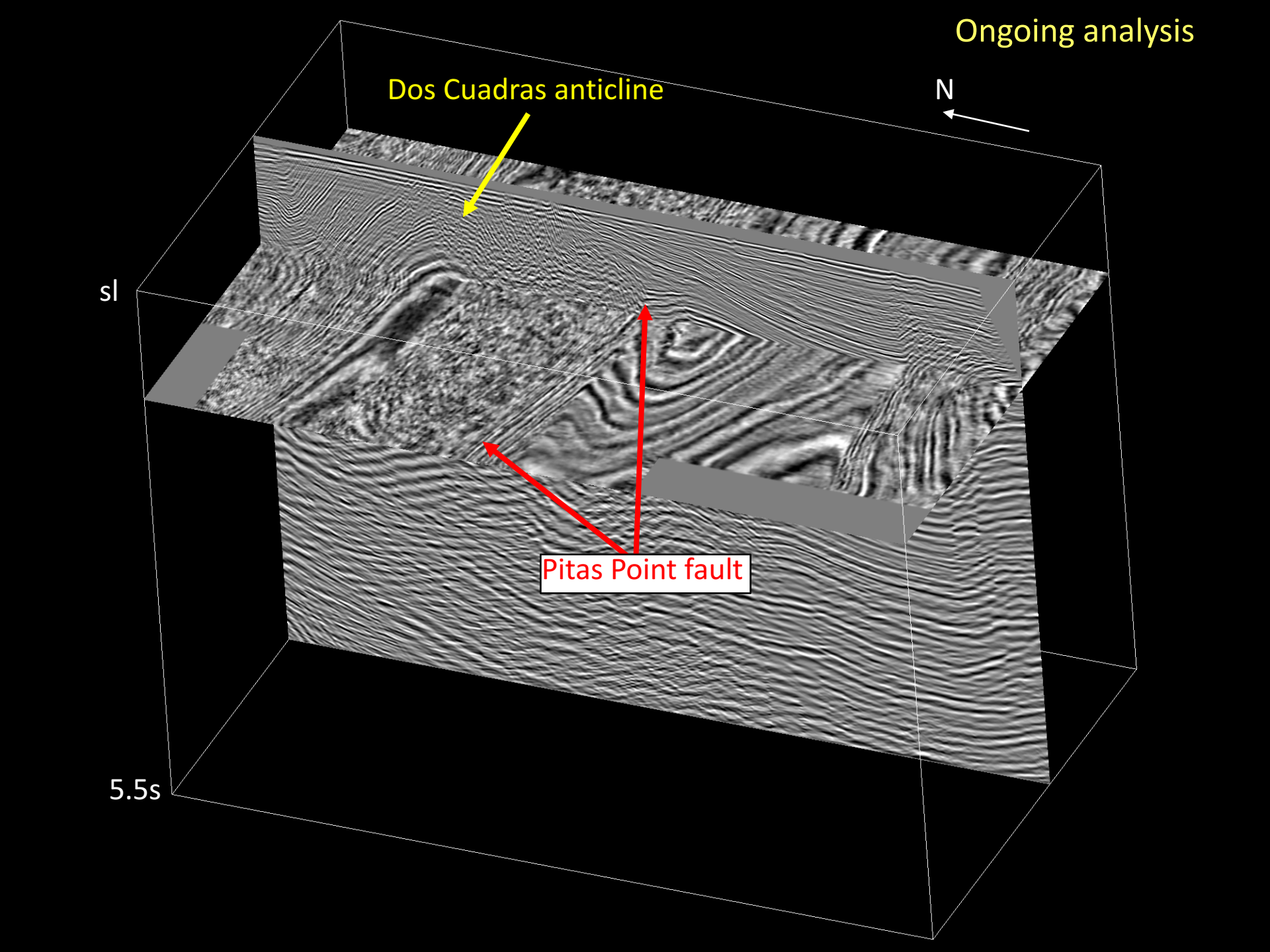
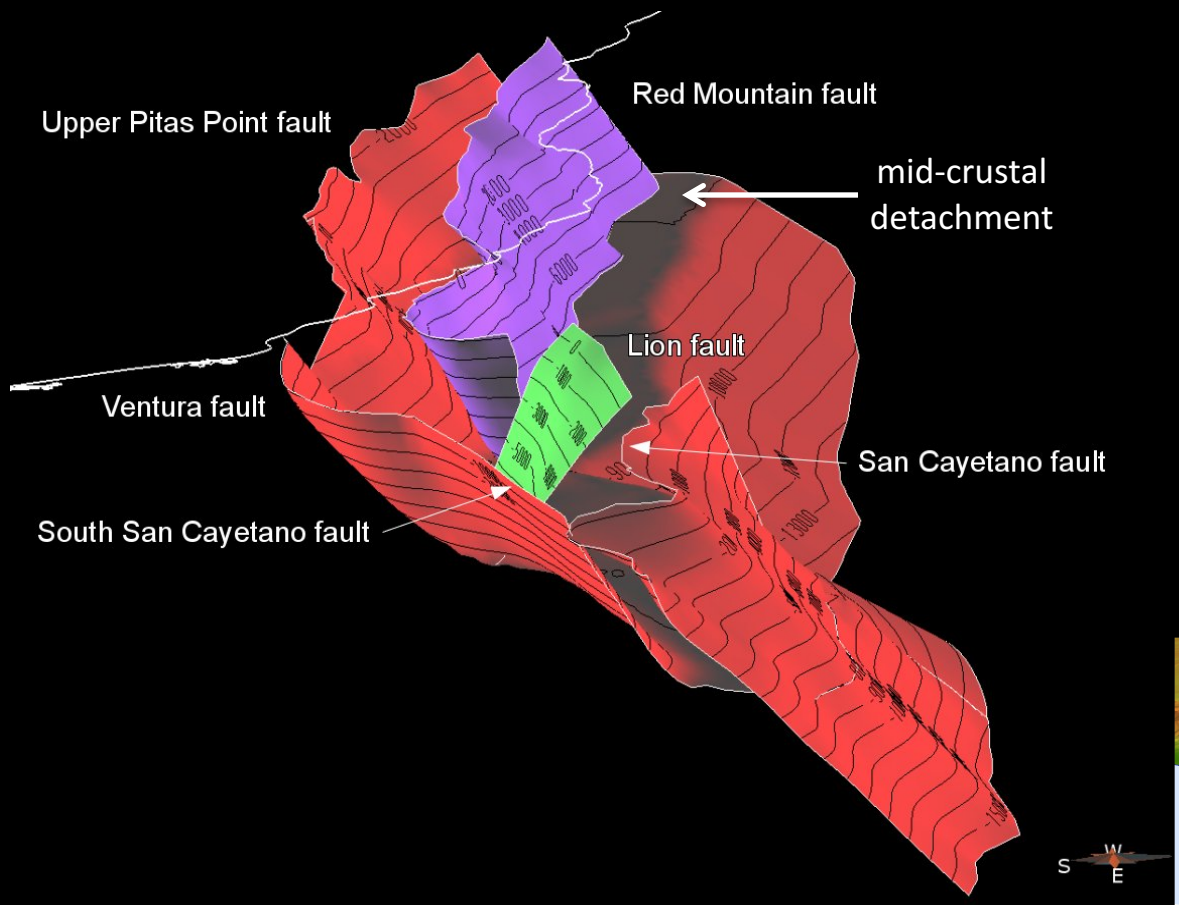


Shaw et al., (2014)

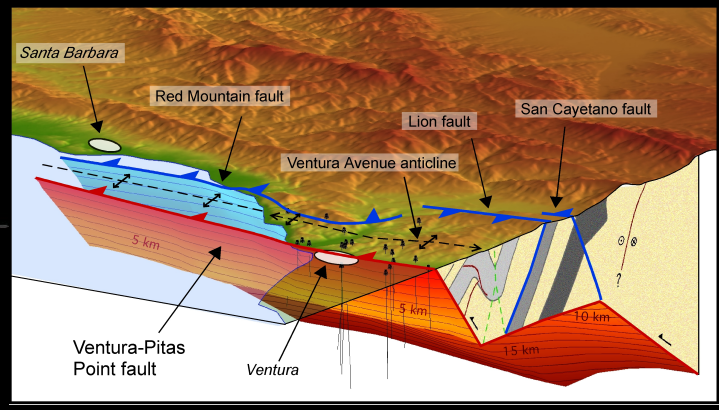

Ongoing analysis
Dos Cuadras anticline
N
sl
Pitas Point fault
5.5s

Constraints on the Geometry of the Ventura-Pitas Point Fault System at Depth & Implications for Hazards



We favor the presence of a mid-crustal detachment in the Ventura – Pitas Point fault, based on:

- structural balancing constraints
- presence of a regional Miocene detachment



Structural segmentation controlled the 2015 Mw 7.8 Gorkha earthquake rupture in Nepal

Hubbard et al., 2016

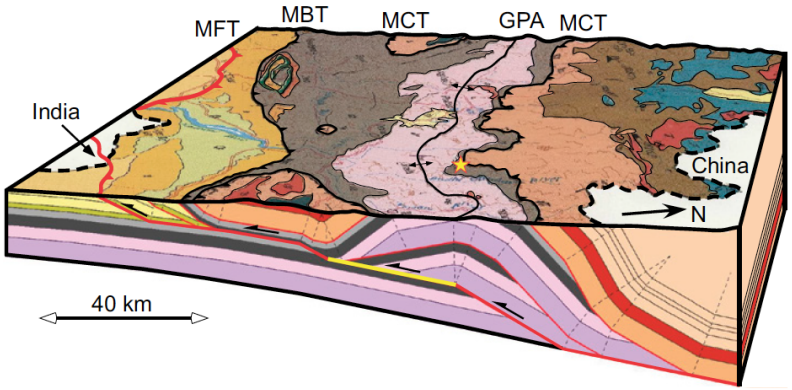


Figure 2. Block model of Nepal Himalaya, showing agreement of cross section (Fig. 1F) with surface geology (Geologic Map of Nepal [www.dmgnepal.gov.np/geology-of-nepal]). Yellow portion of Main Himalayan Thrust (MHT) corresponds to main-shock rupture patch of Gorkha earthquake. Yellow star shows surface projection of rupture initiation point (Avouac et al., 2015). Unit colors are same as in Figure 1. MCT—Main Central Thrust; MBT—Main Boundary Thrust; MFT—Main Frontal Thrust; GPA—Gorkha-Pokhara Anticlinorium.

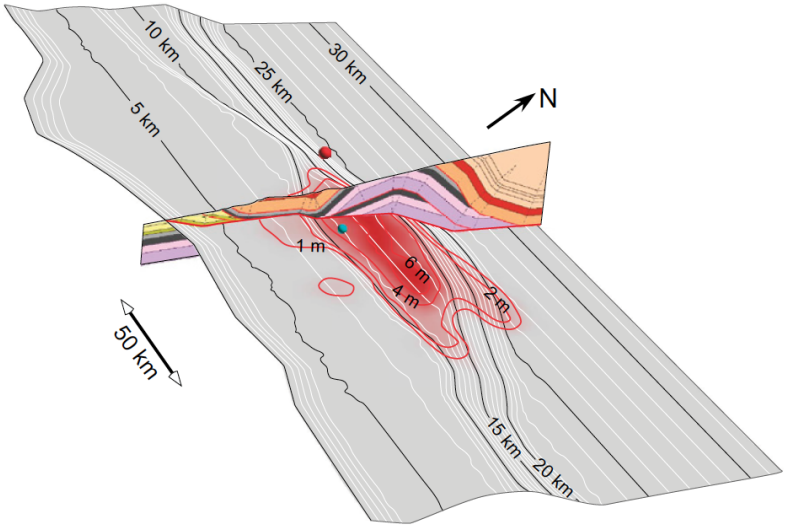


Figure 3. Perspective view of Main Himalayan Thrust. Black and white contours show depth below sea level to thrust surface. Red area and contours show slip amounts during Gorkha earthquake; red dot is hypocenter location (Avouac et al., 2015). Blue dot is Kathmandu. Cross section is same as Figure 1F.