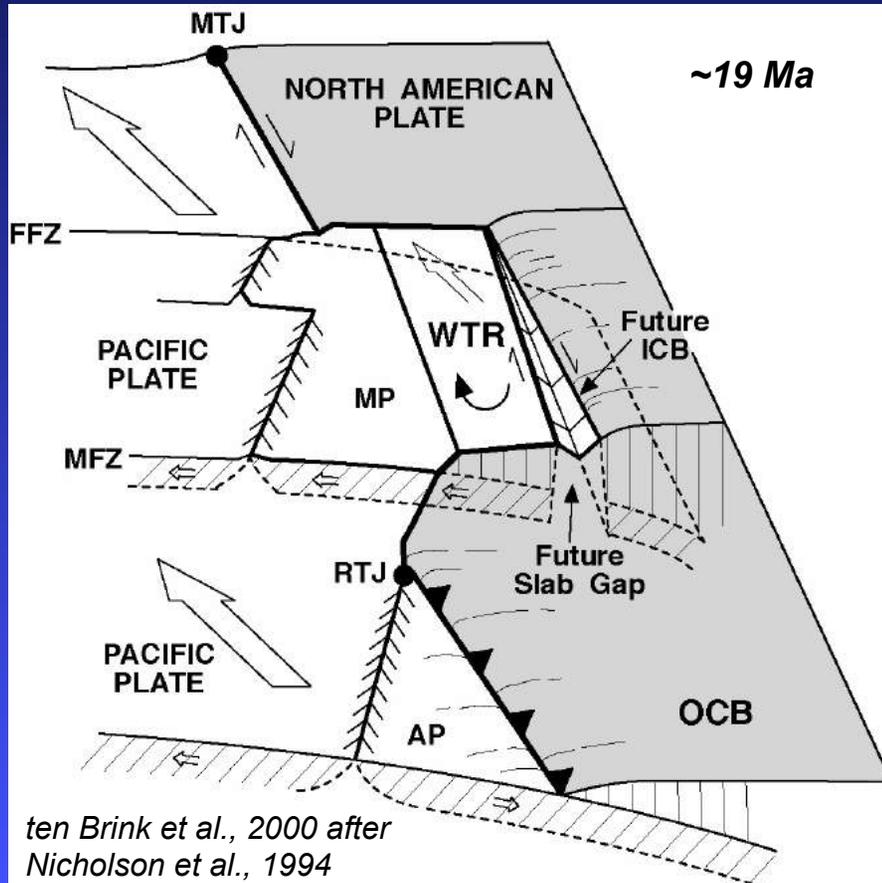


Tectonic Development of Southern California in 4D: Implications for Lithospheric Architecture and Strength Variations

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with animations from Tanya Atwater and Doug Wilson



- Importance of inherited structure
- **Absence of continental mantle**
- Presence of partially subducted microplates
- **Consequences of slab gaps or slab windows**
- Implications for mechanical layering, detachments and regional subsidence

SCEC Workshop on Establishing a Geologic Framework
in Southern California – June 8-9, 2016, Pomona, CA

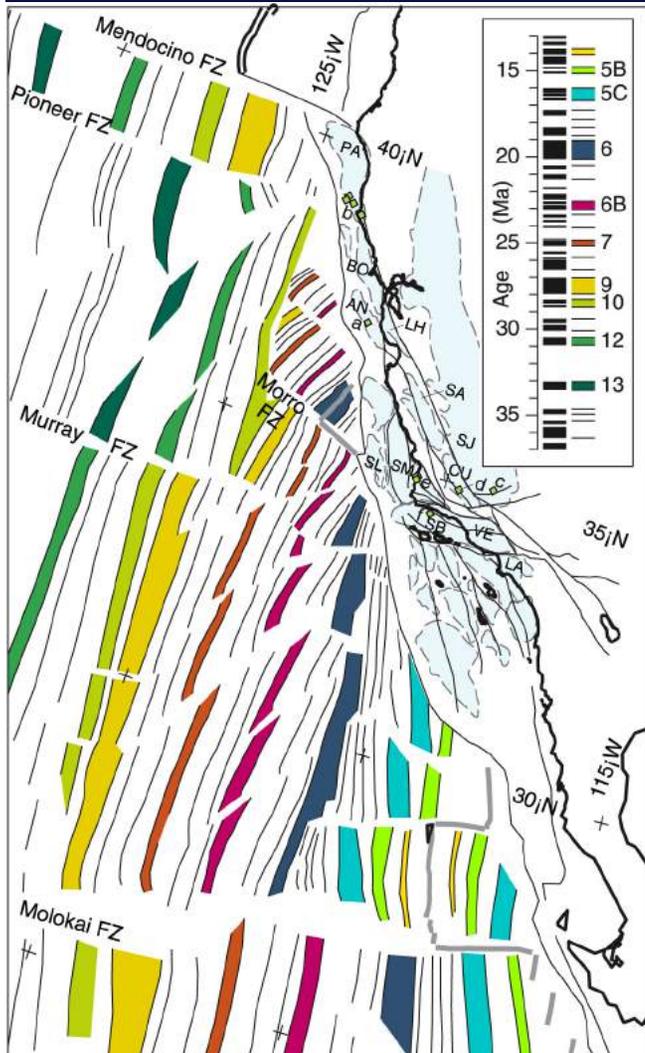
with research support from



Tectonic Map of North America and Magnetic Lineations of the Northeastern Pacific

(AAPG, 1992)

Timing of microplate capture or ridge subduction



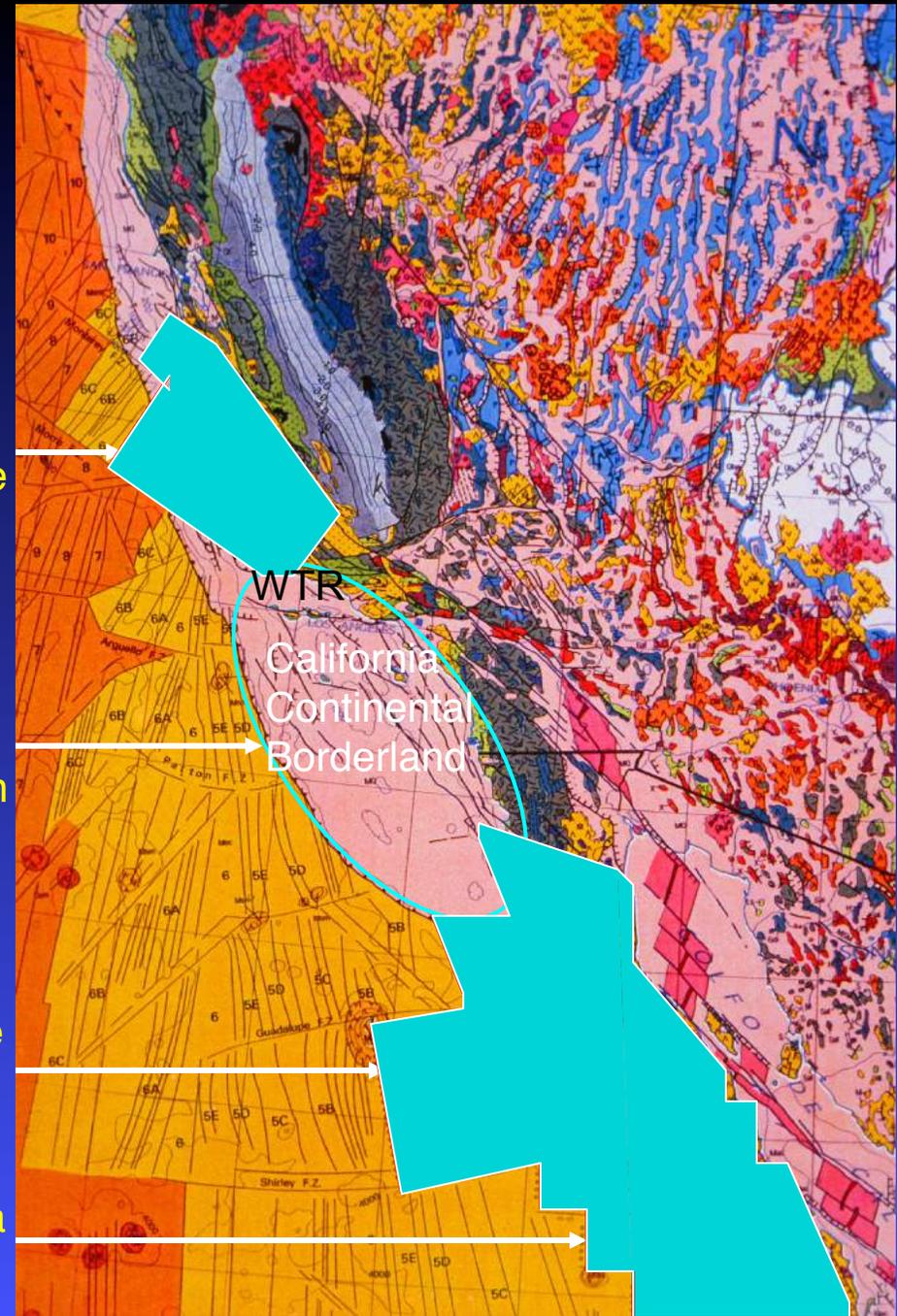
Wilson et al., 2005

Monterey Microplate
~19 Ma

Oblique Ridge Subduction
~19-15 Ma

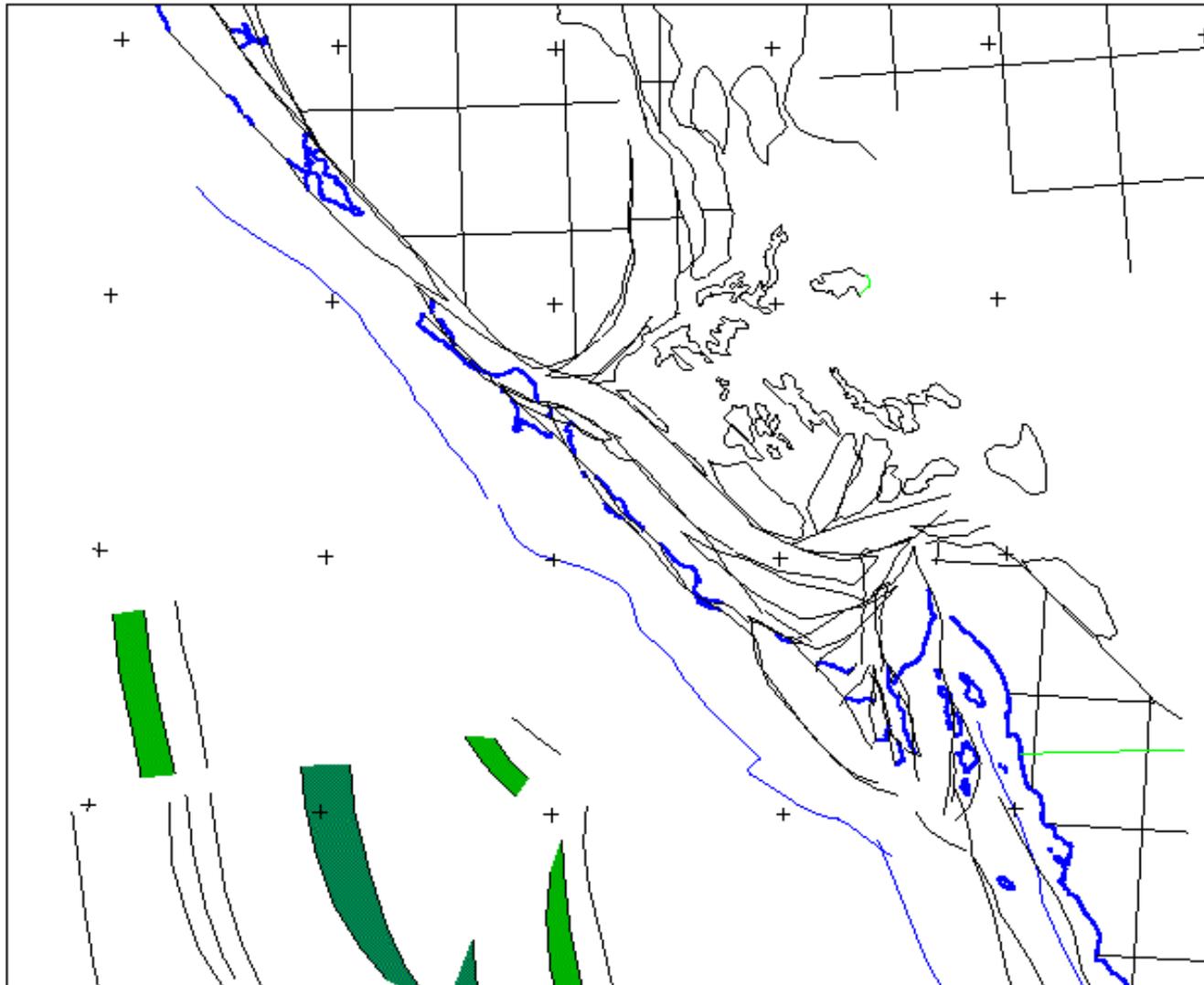
Guadalupe Microplate
~12 Ma

Magdalena Microplate
~12 Ma

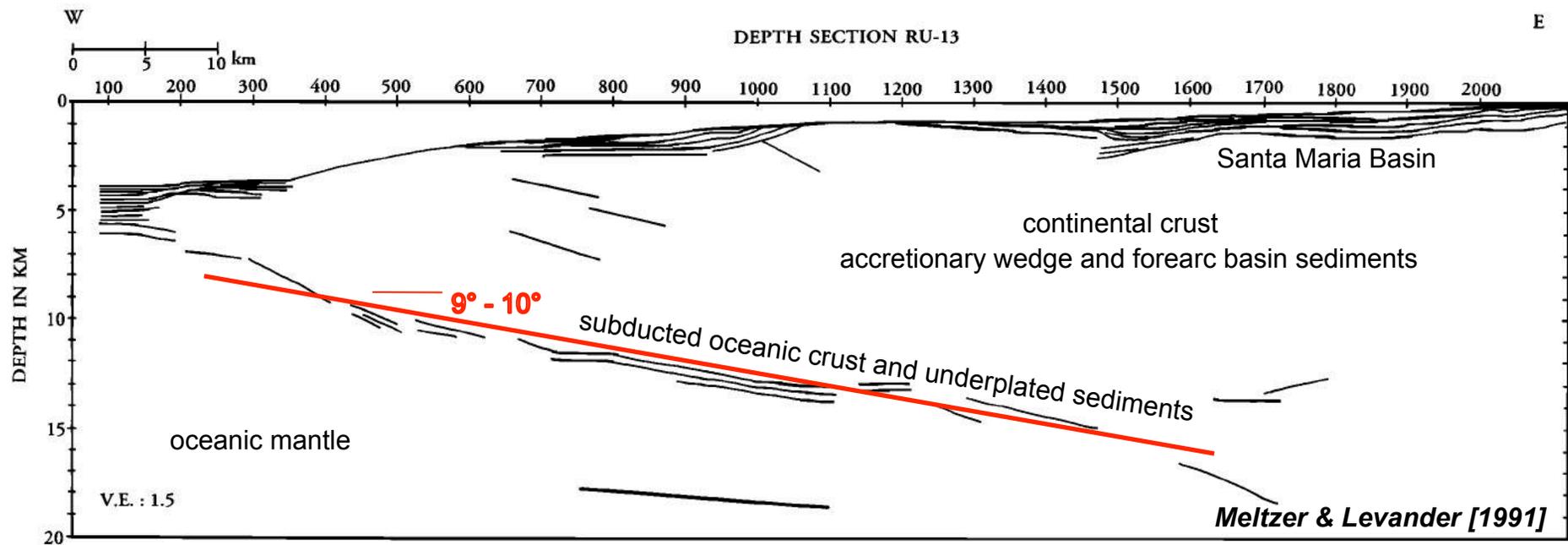


Wilson et al. Animation with Inferred Slab Windows
(Tectonics, 2005)

30.0 Ma



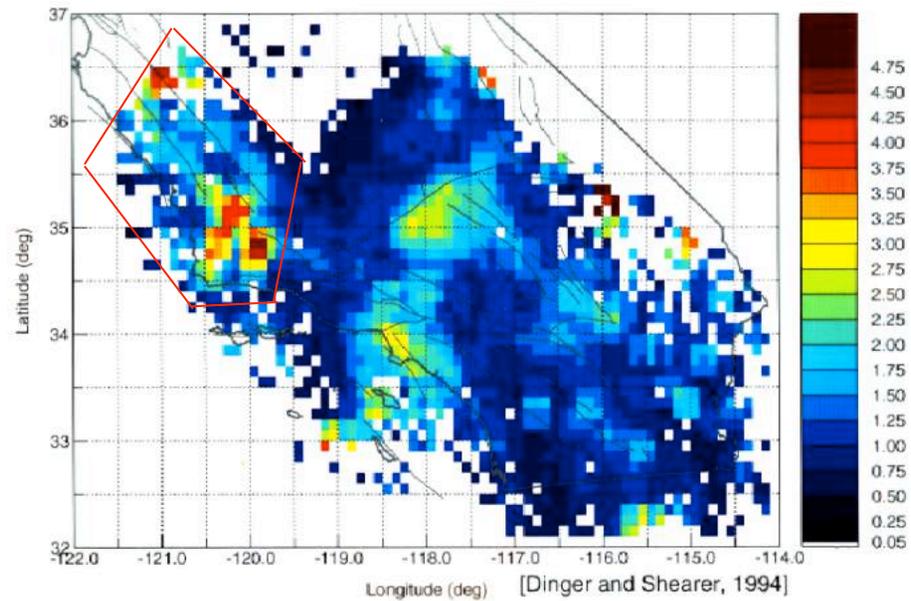
ftp://slicks.geol.ucsb.edu/pub/wilson/slabwin/volcs_slabwin_6.mov



Line drawing of multichannel seismic reflection line RU-13 across paleo-trench and offshore Santa Maria Basin [Meltzer & Levander, 1991]

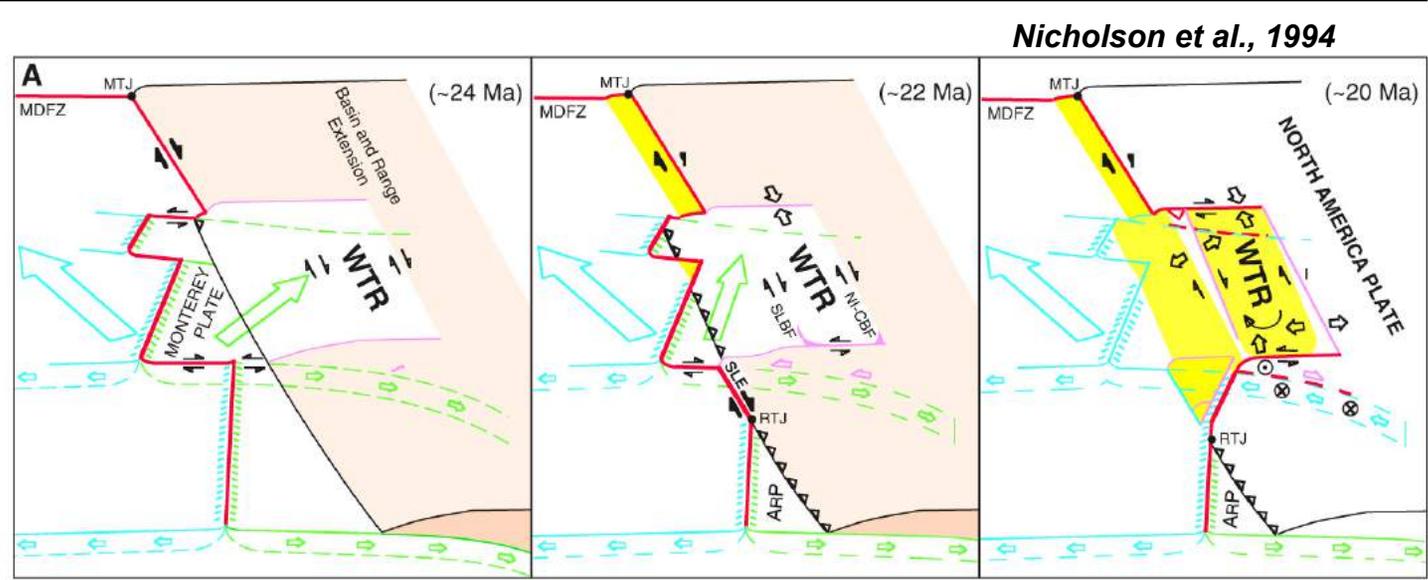
Anomalously high PmP/Pg amplitude ratios may signify top of subducted Monterey microplate [Dinger & Shearer, 1994]

PmP/Pg Amplitude Ratios

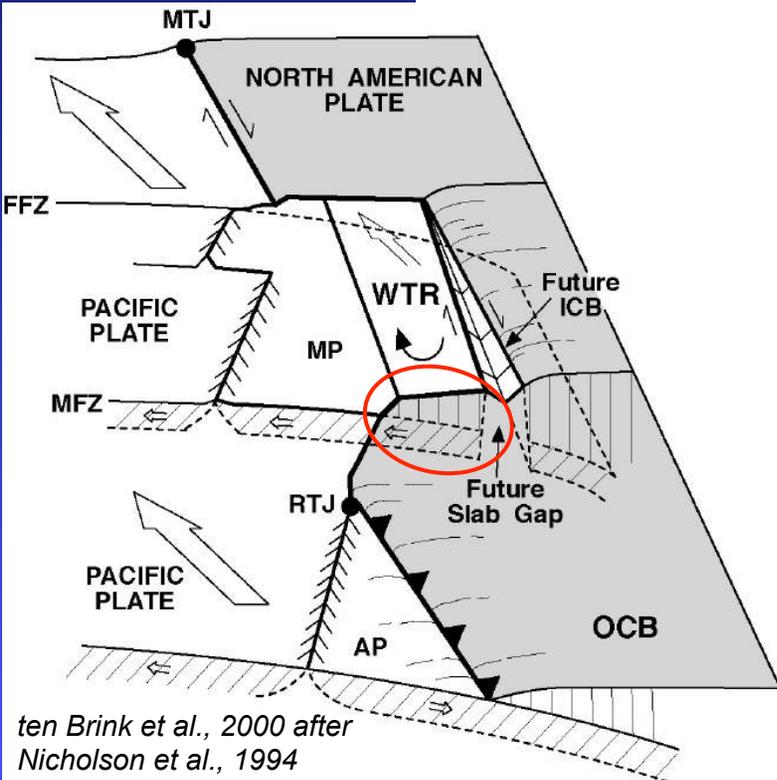


3D models for microplate capture initiating continental rifting and rotation of the WTR block.

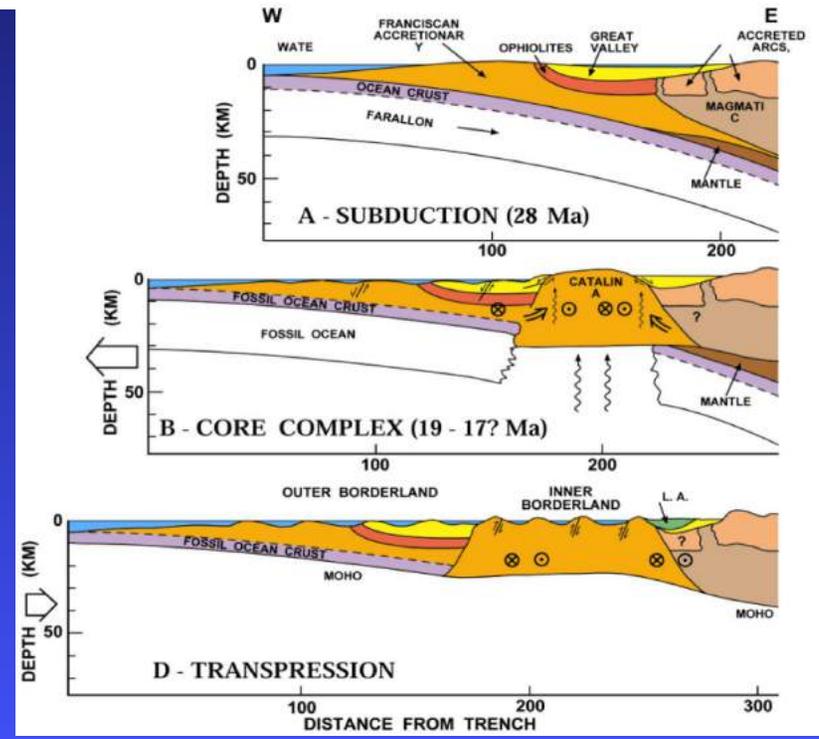
These models depend on the degree of coupling to partially subducted microplates development of a slab gap, and effects of spreading ridge subduction



Nicholson et al., 1994

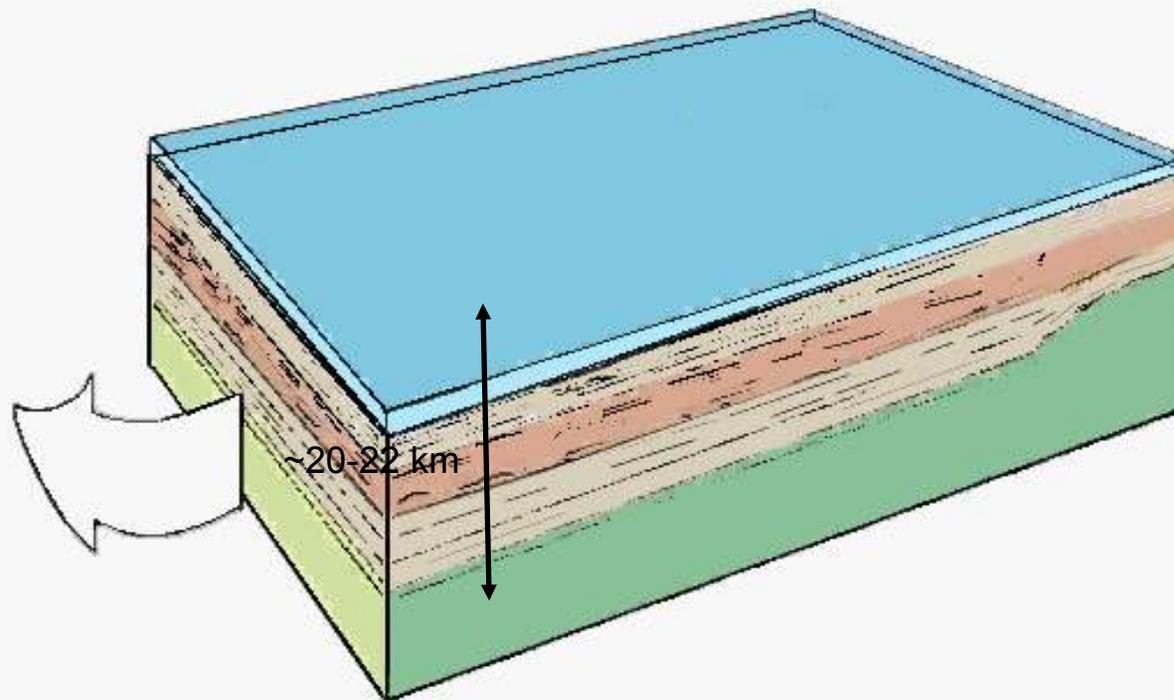


ten Brink et al., 2000 after Nicholson et al., 1994

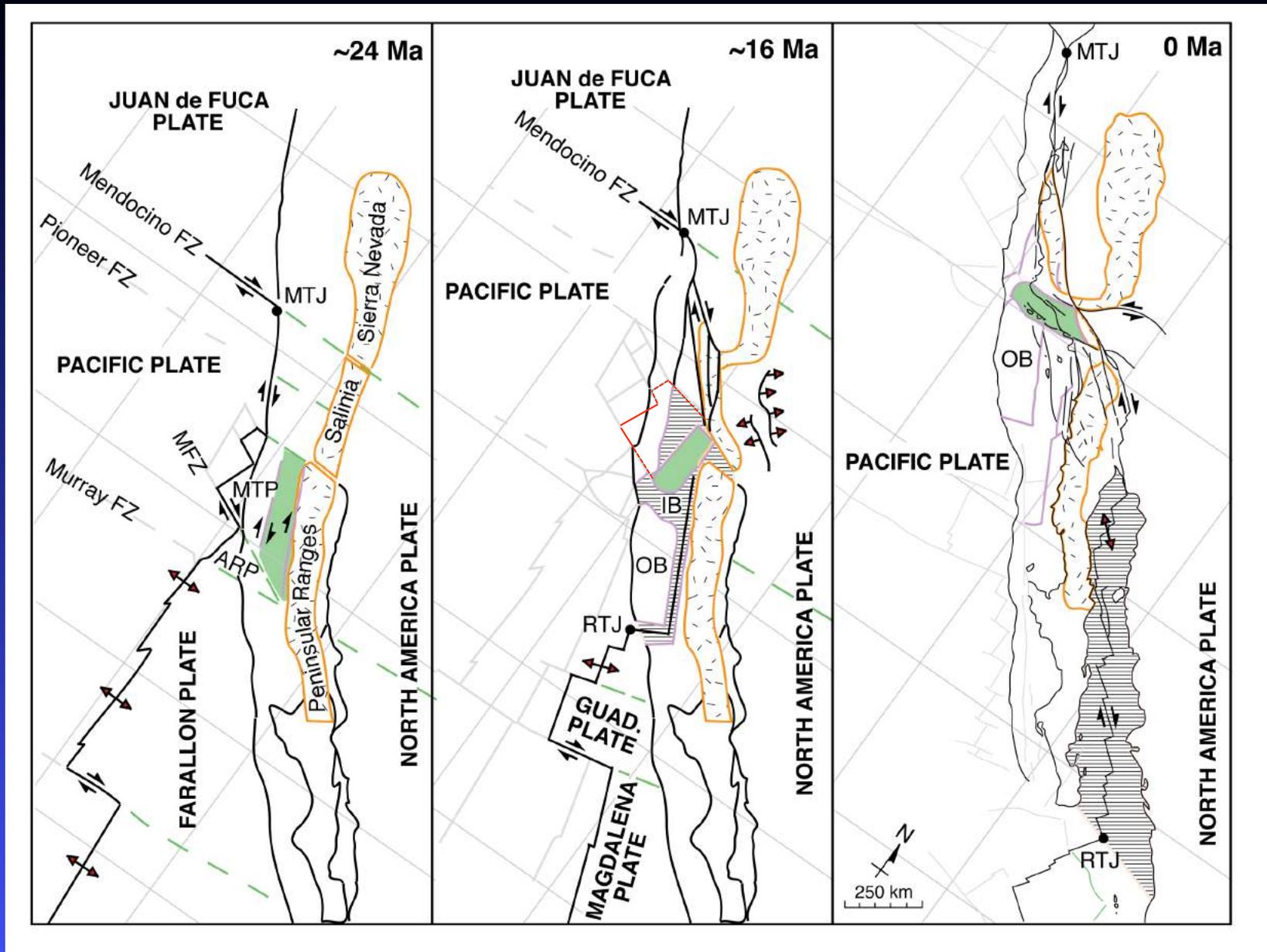


ten Brink et al., 2000 - Slap gap model

Tanya Atwater 3D Animation Rotation of Western Transverse Ranges block and exhumation of Catalina Schist basement



Abbreviated tectonic model for Pacific-North America plate interactions since 24 Ma [Nicholson et al., 1994]

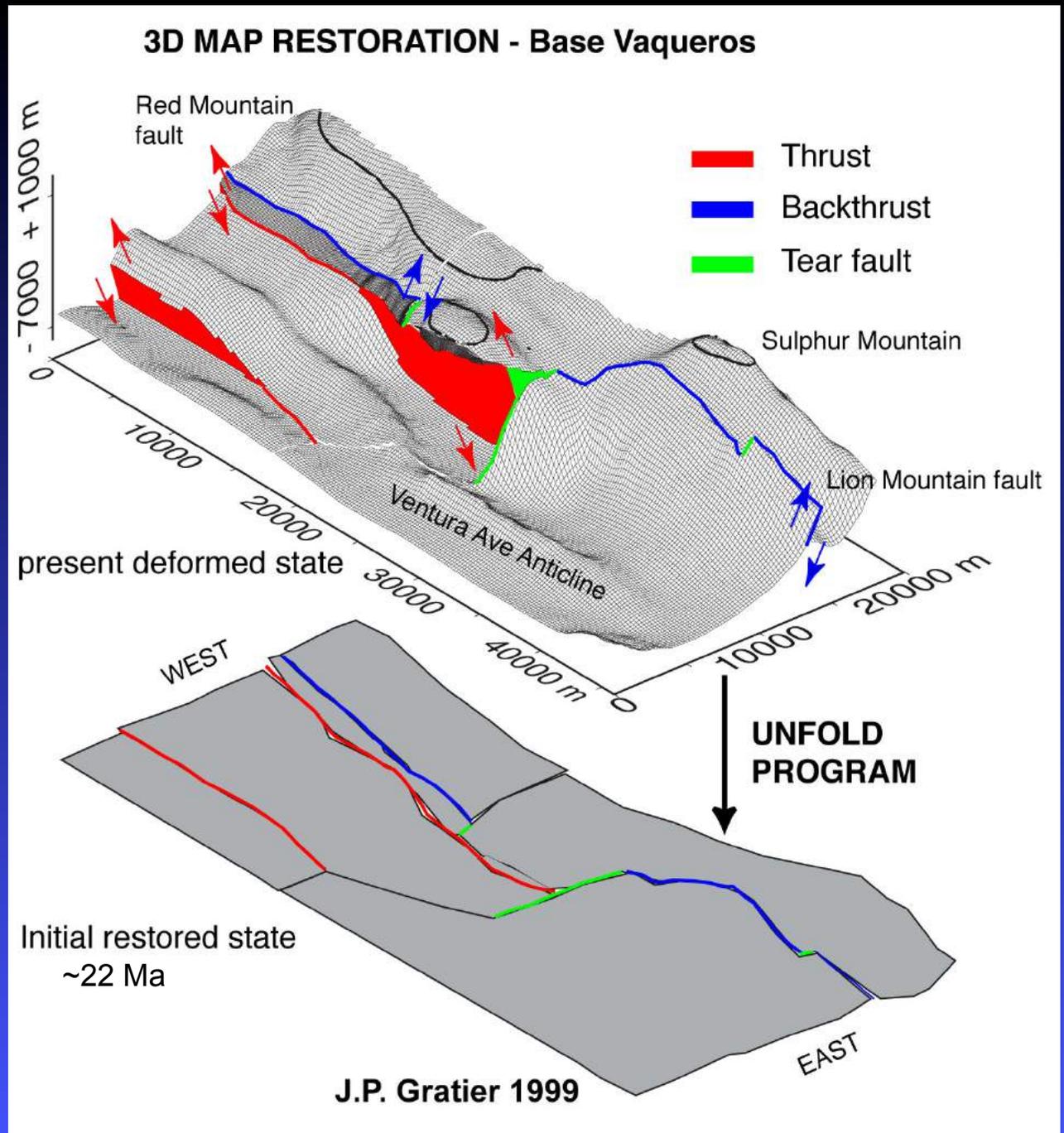


Green – rotating Western Transverse Ranges block; Hatched areas – regions of oblique rifting

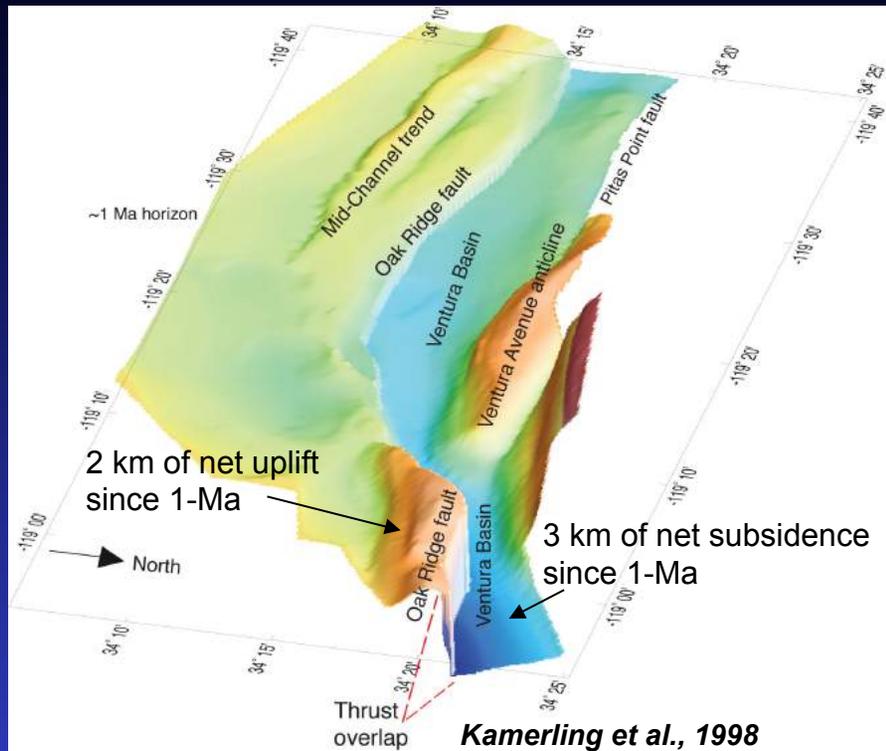
Base Vaqueros Formation (~22 Ma)

Vaqueros is a shallow-water sandstone deposited near sea-level

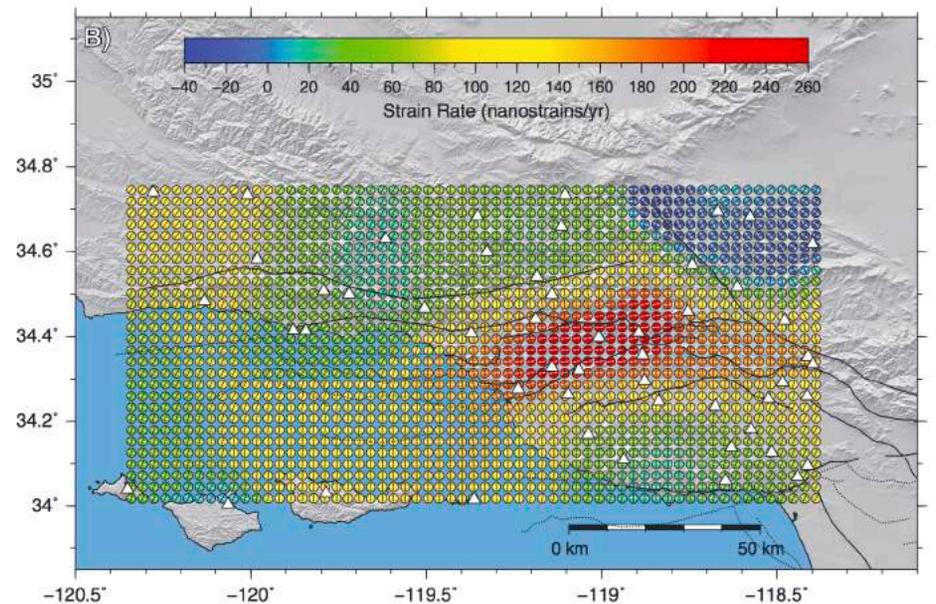
This reference horizon documents cumulative finite deformation – including folding, faulting, uplift and subsidence - since deposition, or prior to the initial rifting and rotation of the WTR block



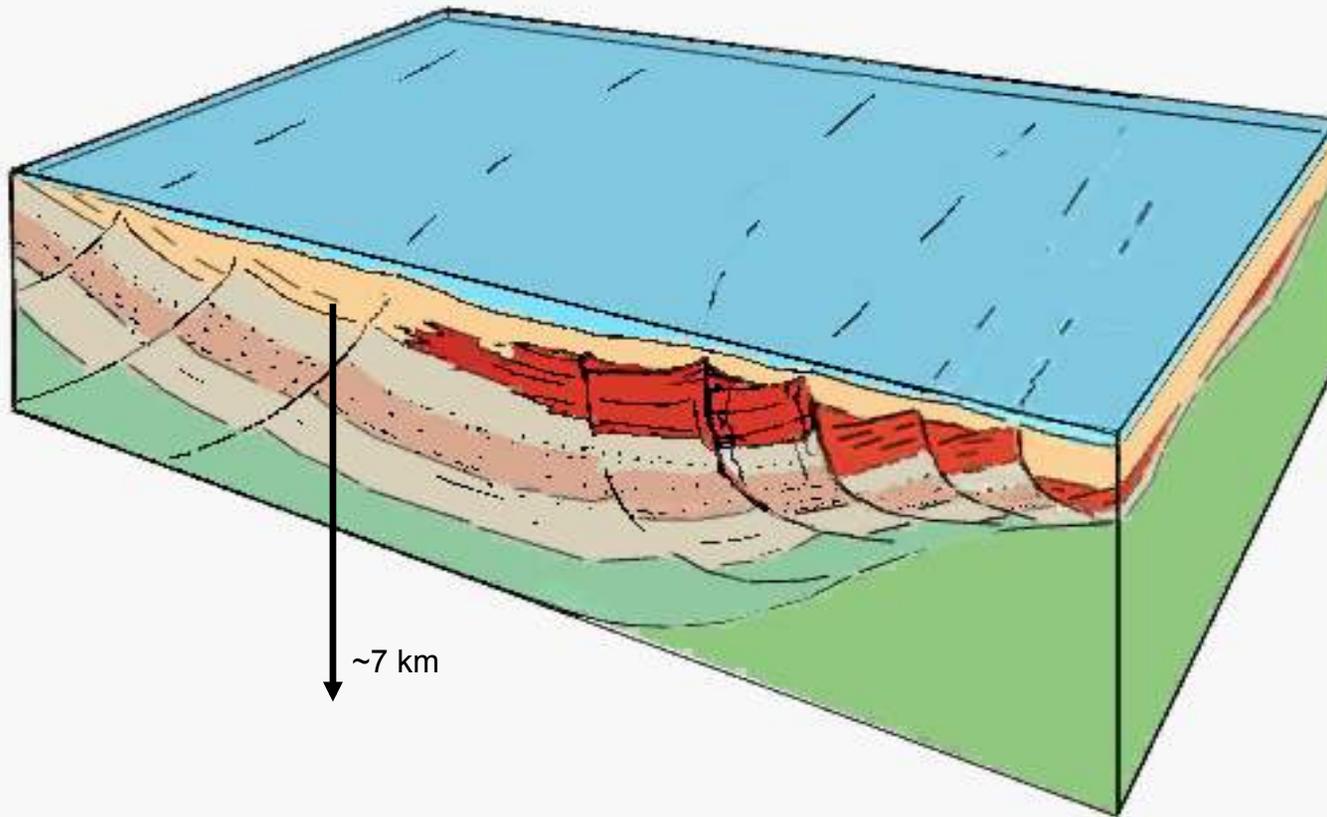
Deformed 1-Ma Stratigraphic Reference Horizon (Kamerling et al., 1998)



Maximum principal contraction rates within the Western Transverse Ranges as derived from corrected horizontal GPS velocities (Marshall et al., 2013)



Tanya Atwater Animation Shortening Across Ventura Basin



Conclusions

- Rheology and strength variations are strongly influenced by past tectonic developments and inherited tectonic structures.
- Southern California largely consists of relatively weak continental crust situated above either a slab window or partially subducted oceanic microplate.
- Various data sets can be used to help define the 3D geometry and thickness of the overriding continental crust and the areal extent, dip and 3D geometry of subducted microplate.
- Rotating blocks require basal tractions, distributed shear or possibly applied side-forces to drive rotation, and are detached at some structural level to allow rotation. WTR rotation was most likely driven initially by basal tractions along the paleo-subduction interface supplied by the underlying captured Monterey microplate moving with Pacific plate motion.
- Areas subject to ridge subduction or an underlying, developing slab window –such as the California Continental Borderland– often experienced initial uplift, volcanism and subsequent subsidence. In some areas, this subsidence is larger than predicted by simple 1D cooling models and sediment loading, suggesting significant lower crust/upper mantle components are also likely involved.
- As the WTR rotated off the underlying microplate and the plate boundary geometry became more transpressional after ~6 Ma, this oblique shortening was largely accommodated by regional subsidence. This subsidence continues today and appears to be mainly aseismic and non-elastic.
- This subsidence and the large components of non-elastic deformation involved, indicates that care must be taken when projecting geodetic data onto faults at depth as measured fault slip.
- Although several levels of detachment can and do exist within the WTR, the sustained subsidence precludes the presence of rigid, non-deforming footwall blocks and rigid, planar, non-deforming detachments, as these detachment surfaces must also deform and subside.
- Major litho-tectonic boundaries, such as the Outer Borderland Nicolas and Inner Borderland Catalina terrane boundary, are not always defined by active faults, indicating that other important litho-tectonic surfaces besides faults must be defined by the 3D Geologic Framework for the CRM.