Dynamics of Tear Faults in the Salt-Detached Systems of the Northern Gulf of Mexico*

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Abstract

The extensive salt in the Gulf of Mexico has resulted in a broad region of Neogene gravitational float connecting updip normal faults with downdip toe thrusts, all driven by gravitational sliding above the mobile substrate. Differential movement between various portions of the detached sedimentary cover has resulted in the development of numerous well-defined strike-slip tear faults. These tear faults are clearly imaged in seafloor bathymetry and their evolution can be studied in 3D seismic data. In general, these structures tend to interconnect between thicker salt bodies, which make up the weak points in the system. In the autochthonous salt system of the eastern GoM, where the underlying salt is thin or largely welded and the base-of-salt surface is relatively planar, these tear faults can form long linear trends with only minor jogs across local salt diapirs. Step-over zones of extensional pull-apart tend to provide conduits for escape of deeply buried salt. In the allochthonous salt system of the central GoM, where the underlying salt consists of a connected canopy and the base-of-salt surface is more irregular, the tear faults tend to exist as short segments separating minibasins sliding at different rates. In particular, when sliding minibasins ground out they tend to slow down, and tear faults of opposing vergence tend to form on either side as the adjacent minibasins continue downslope. Classic examples of grounded minibasins show these lateral tears to be matched by salt overthrusting from the north as the updip minibasin converges, and salt stretching to the south as the downdip minibasin pulls away. A range of structural styles associated with this spectrum of tear faults will be examined.

Selected References

Krueger, S.W. and N.T. Grant, *in press*, The growth history of toe thrusts of the Niger Delta and the role of pore pressure, *in* K. McClay, J. Shaw, and J. Suppe (editors), Thrust Fault-related Folding: AAPG Memoir 94, p. 1-34.

Krueger, S.W. and N.T. Grant, 2006, Evolution of fault-related folds in the contractional toe of the deepwater Niger Delta: AAPG Search and Discovery article #40201, Web accessed November 1, 2010, http://www.searchanddiscovery.net/documents/2006/06060krueger/index.htm?q=%2Btext%3Akrueger

Rowan, M.G., M.P.A. Jackson, and B.D. Trudgill, 1999, Salt-related fault families and fault welds in the northern Gulf of Mexico: AAPG Bulletin, v. 83/9, p. 1454-1484.

Website

USGS Landslide Manual, USGS Circular 1325, Web photo accessed September 27, 2010 (http://pubs.usgs.gov/circ/1325/pdf/Sections/Front.pdf)

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- Colleagues at Arco, COP and BP who have worked detachments and/or salt with me
- AGL Salt Consortium for advancing salt science for >20 yrs
- Bert Bally and Mark Rowan for useful discussions over the years
- USGS and NOAA for public domain geology and topography data
- BP for permission to present

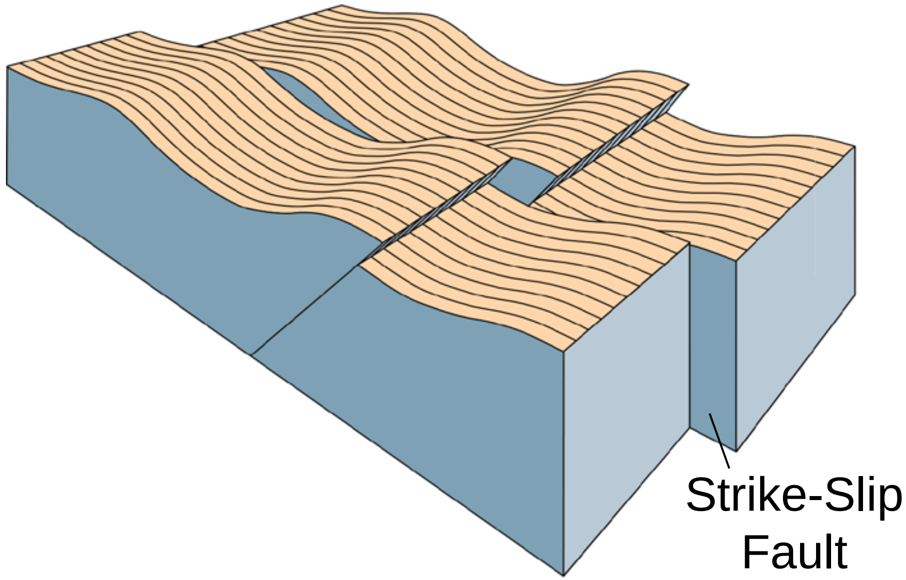
Key Messages

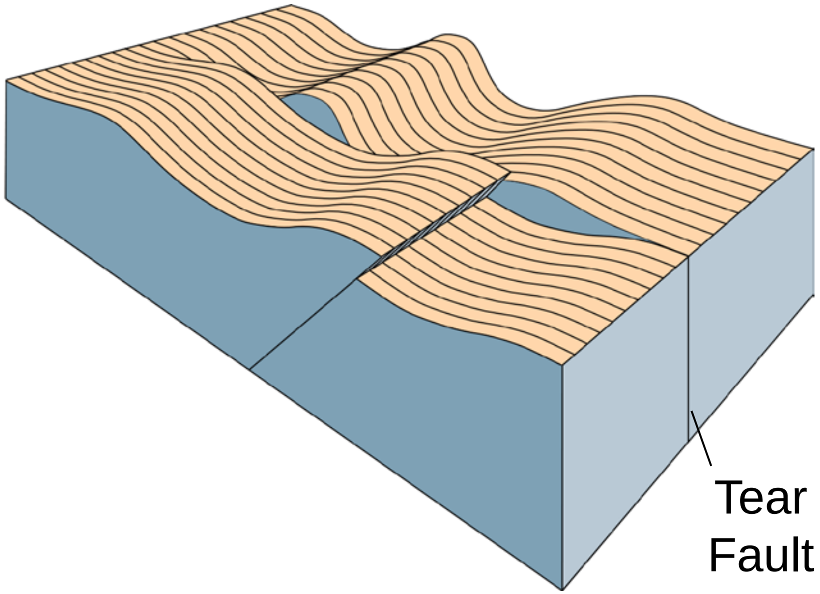
- The Northern GOM is a large gravitational float system
- Salt flows downhill and “puddles” at the base of slope
- Differential sliding in the cover leads to tear faults
- Deep tears tend to be long and linear, connecting salt feeders
- Shallow tears tend to be short and irregular, bounding minibasins
- “Inverse Landslides” can occur where minibasins ground out

Strike-Slip or Tear?

Strike-Slip Faults – Generally steep faults with a dominantly horizontal slip direction.

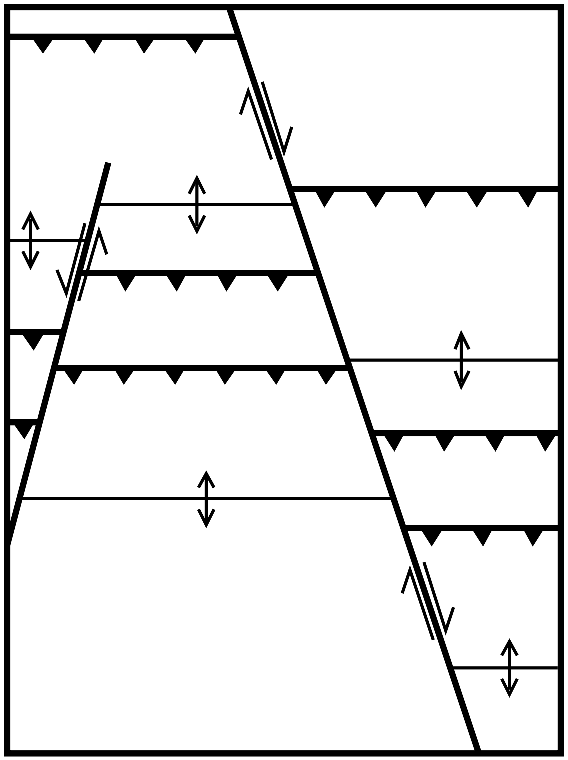
Tear Faults – Generally steep faults, sub-parallel to the transport direction in detached systems, which partition the strain between differentially deforming domains. (Can have a significant strike-slip component.)





Hybrid Cases

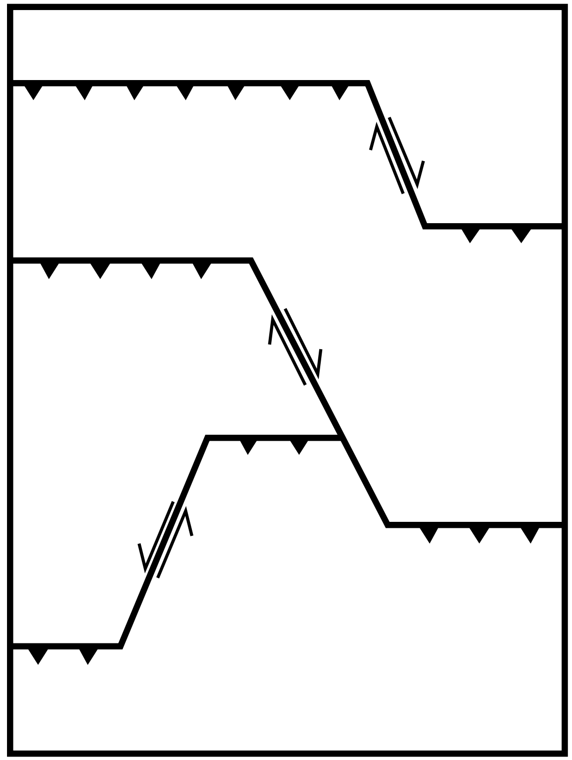
Strike-Slip Faults



Faults Post-Date Thrusts

Consistent Slip Sense and Magnitude

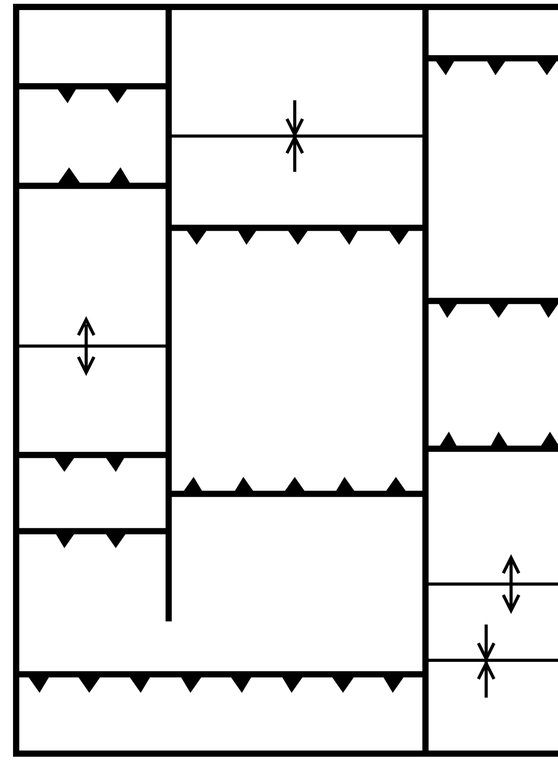
Transfer Faults



Faults Syntectonic

Consistent Slip Sense

Tear Faults

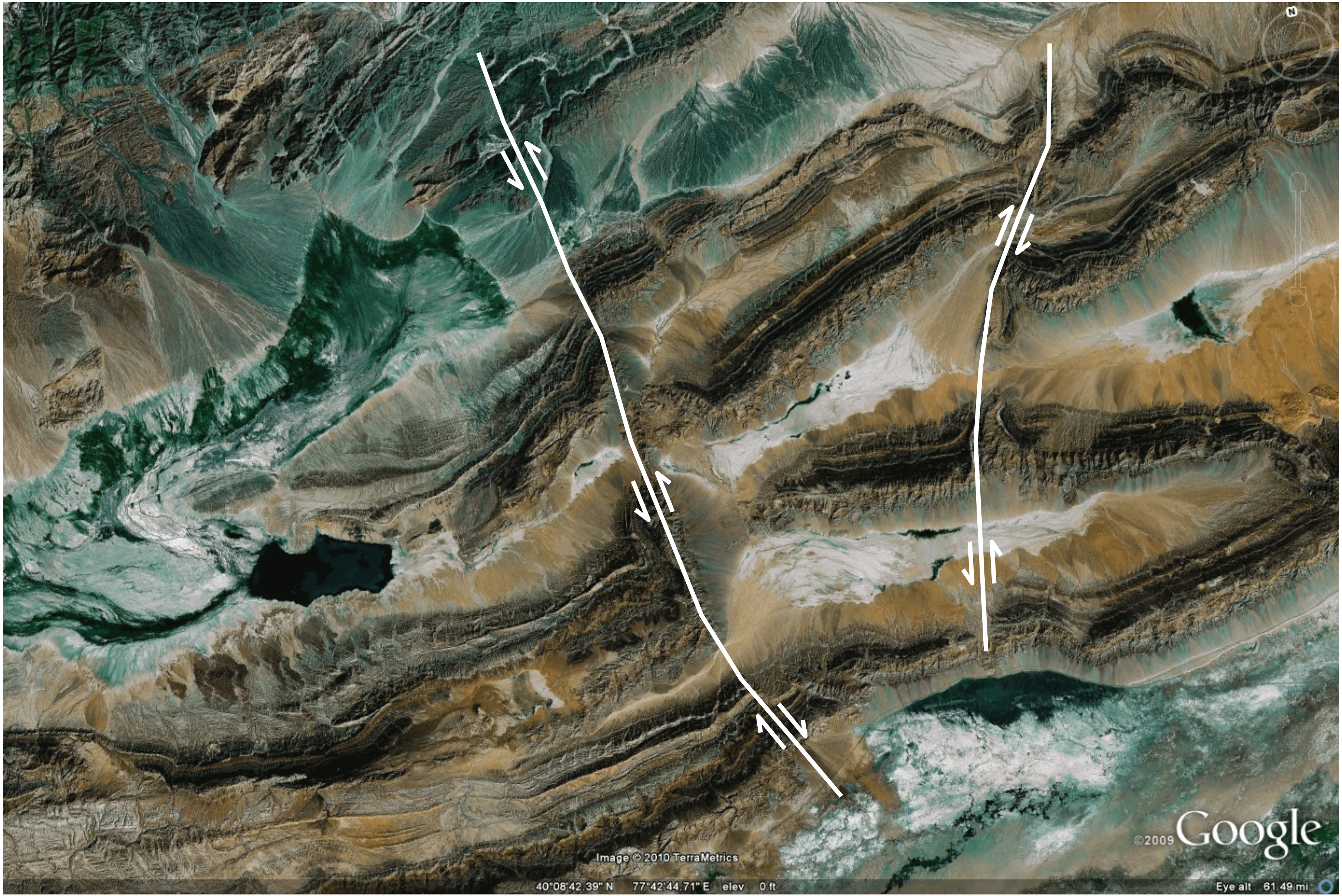


Faults Form Early

Variable Slip Sense and Magnitude

(after ARCO Strike-Slip Structural Styles Manual, by Krantz, 1991)

Tear Fault, NW Tarim Basin, China

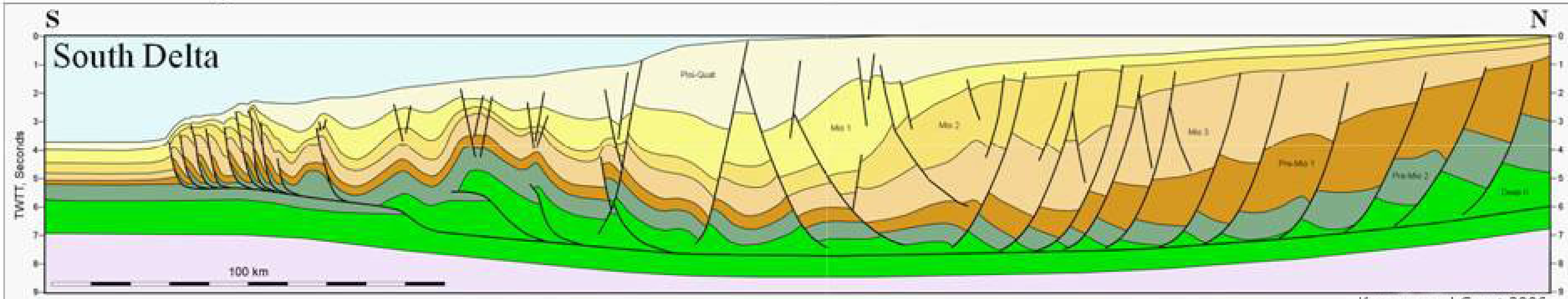


Kazerun Tear Fault, Zagros Foldbelt, Iran

Tear Fault, Saltillo, Mexico

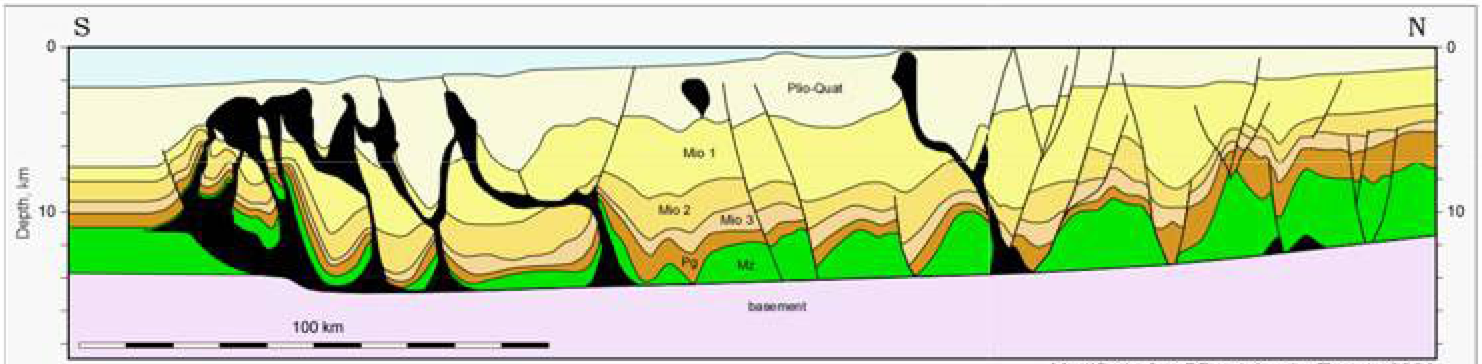
Gravitational Float Systems

Southern Niger Delta



Krueger and Grant 2006

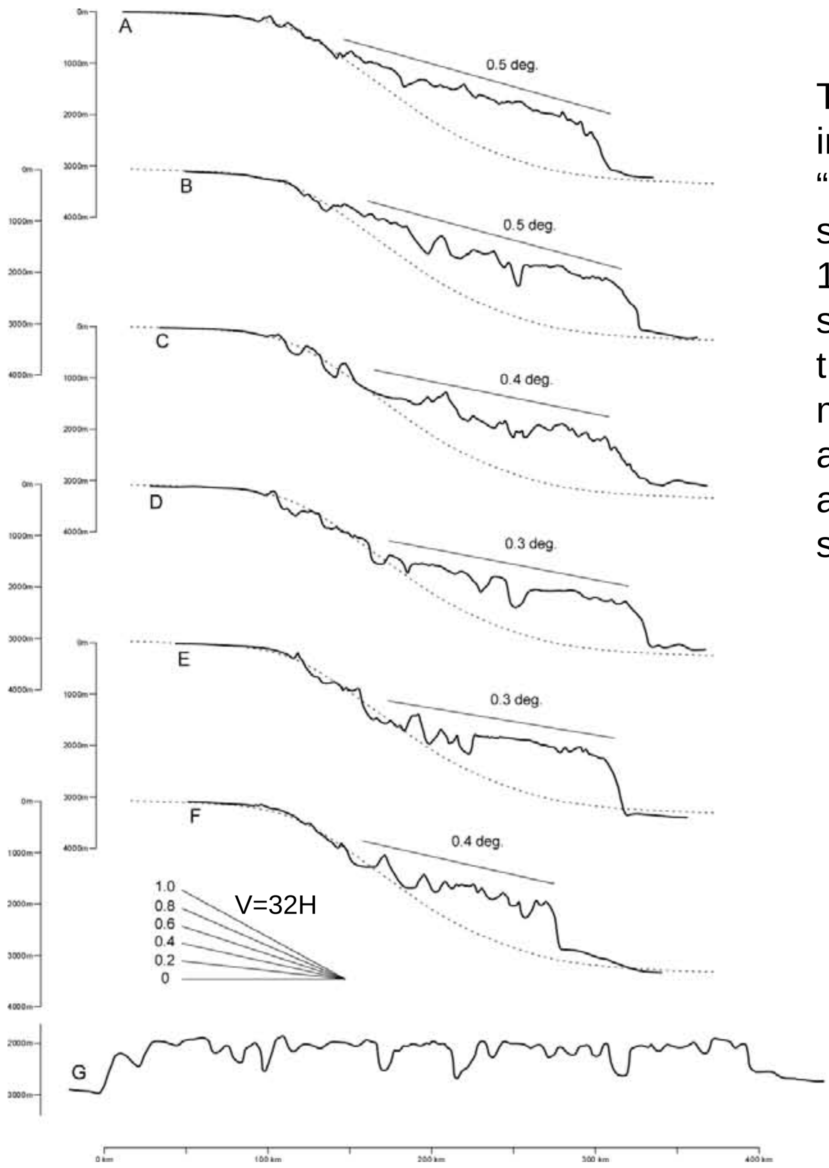
Eastern US Gulf of Mexico



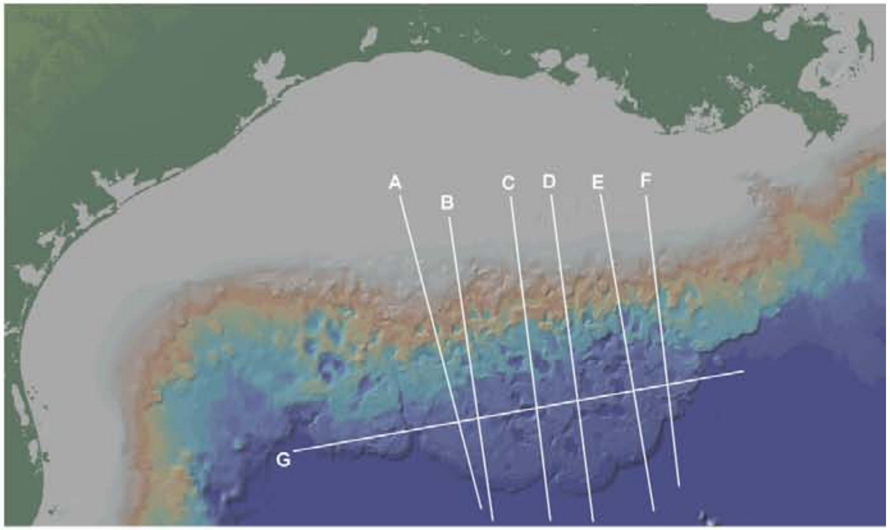
Modified after BP section by Turner, 2003

- Regional detachments (salt/mobile shale) on continental margins
- Driven by gravitational body forces rather than tectonics
- Paired extensional and contractional belts
- Downslope flow of mobile units common

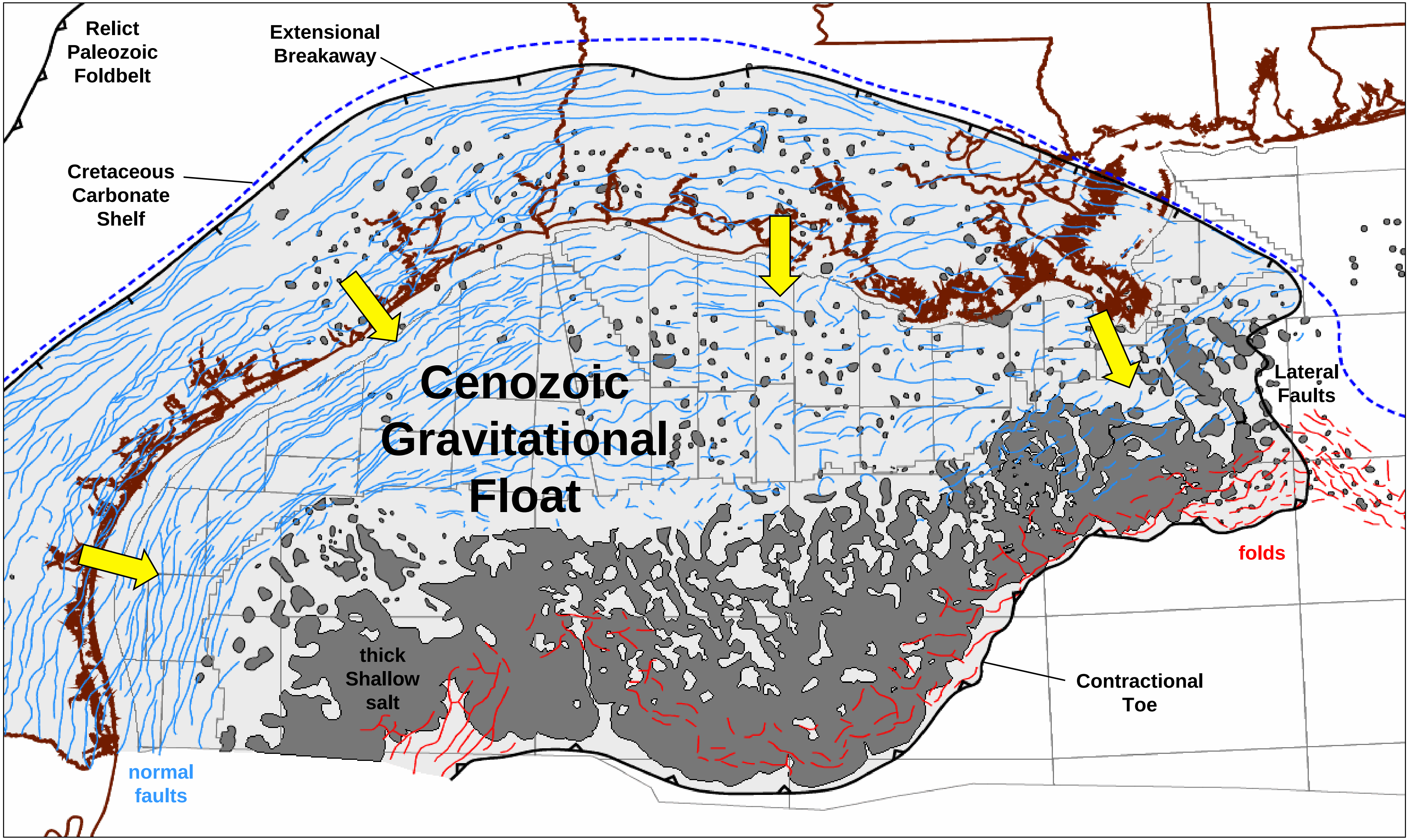
The Salt "Puddle" in the GOM



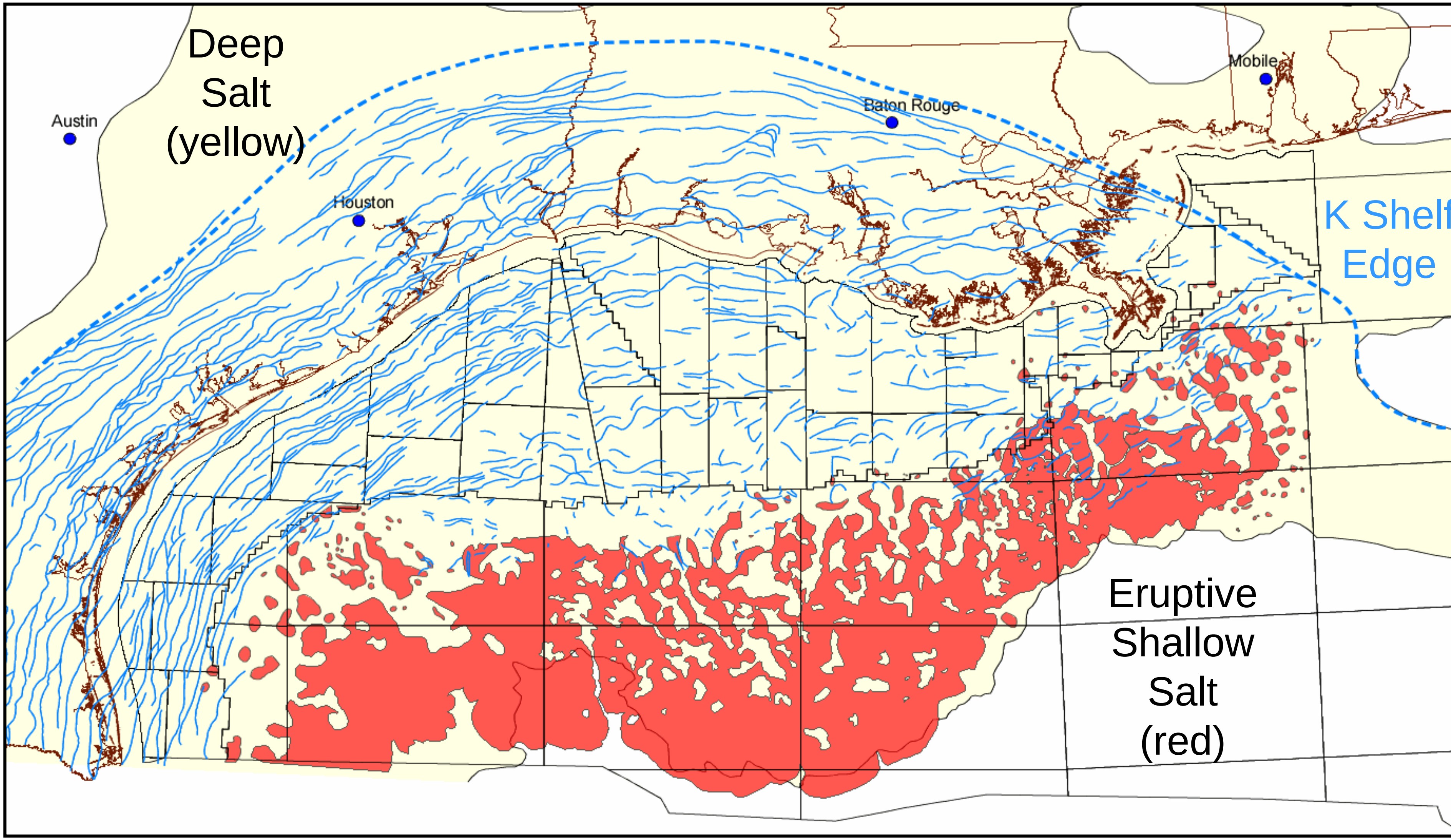
The allochthonous salt in the Gulf of Mexico behaves as an interconnected geologic fluid which flows downhill and "puddles" in deep water. Where there is massive salt the surface slope appears in a dynamic equilibrium of around 1/3 degree. In the more "vascular" potions of the system the surface slope can reach as high as ½ degree. Only where the salt is mostly grounded out can the surface slope be maintained at greater than ½ degree. This entire system advances as salt is squeezed out from beneath the advancing sedimentary load, with its natural depositional slope of upwards of 1 degree.



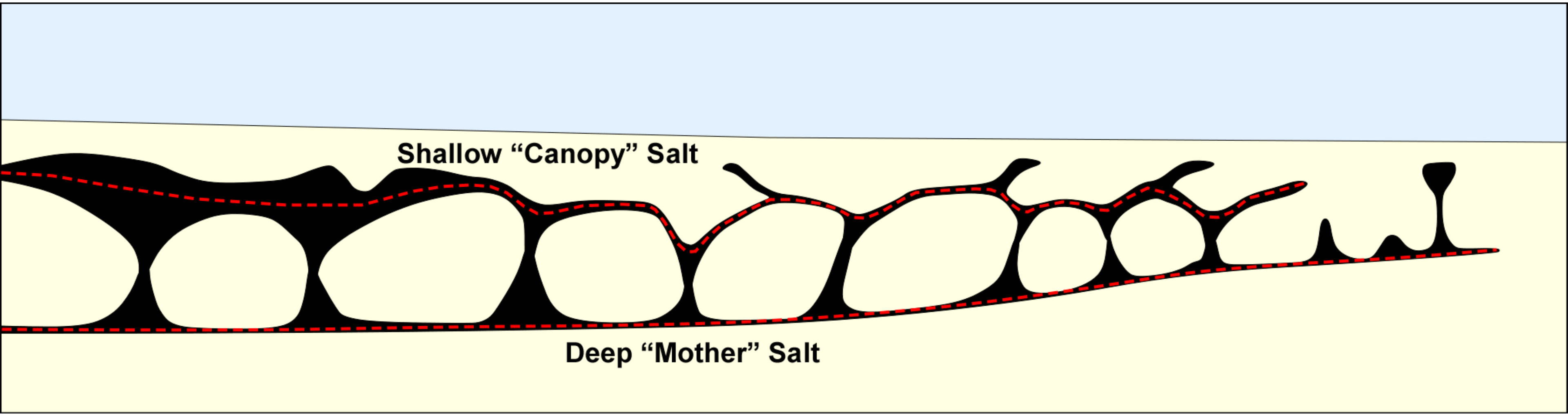
Gravitational Float, Northern Gulf of Mexico



Multi-Tiered Salt Detachment



Multi-Tiered Detachment Tears

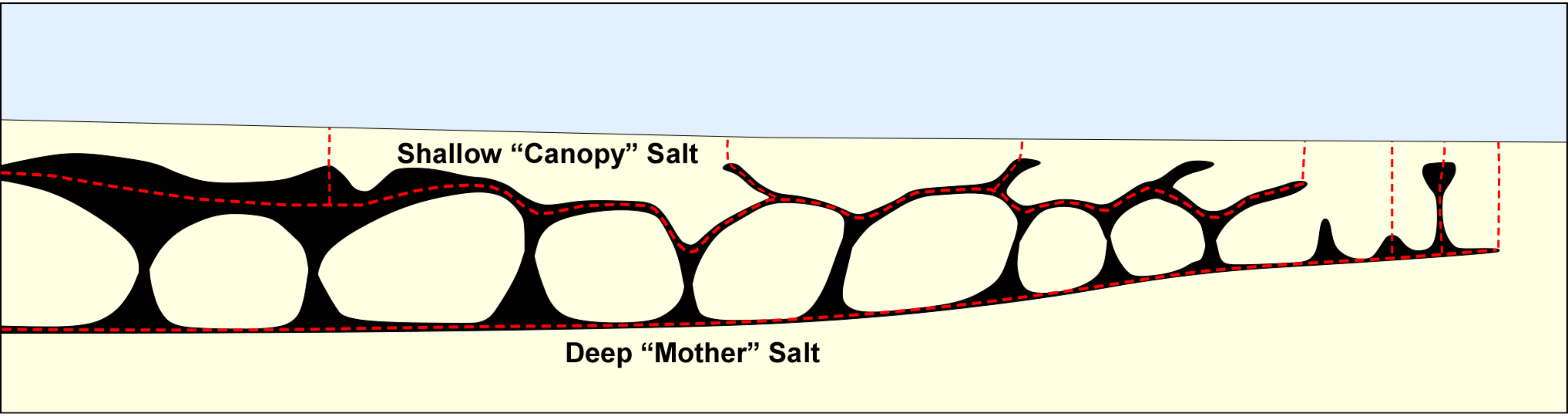


Multi-tiered salt presents two major detachment options:

- "Simple" detachment on the deep salt

- "Complex" detachment on the shallow salt

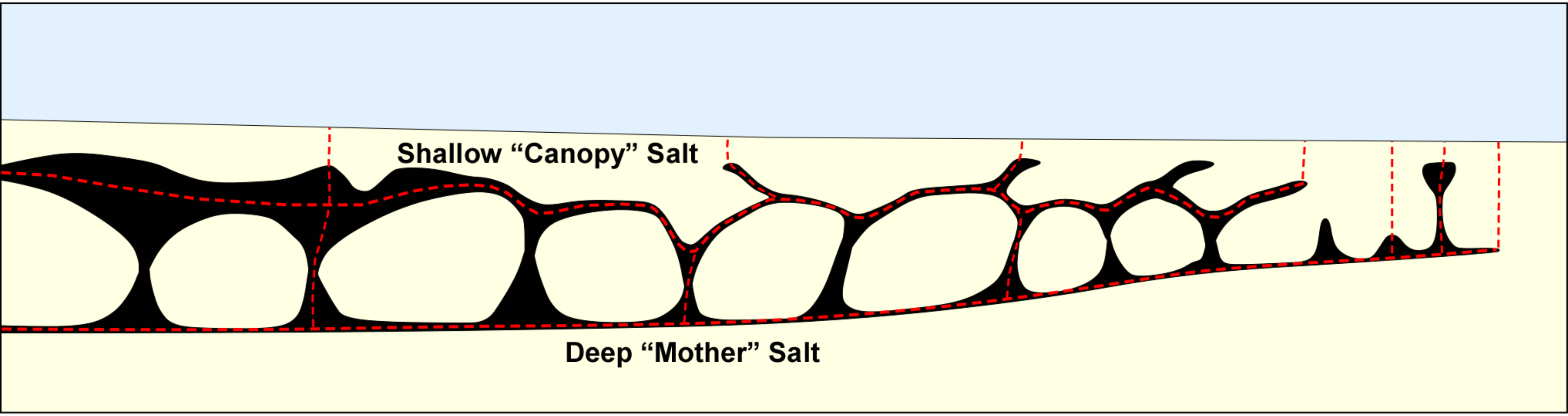
Multi-Tiered Detachment Tears



Tears above each detachment will seek minimum energy solutions:

- Thinnest "strong" sediments
- Thickest "weak" salt
- Detachment edges

Multi-Tiered Detachment Tears



If deep tears occur beneath the canopy, they will likely influence the shallow tears

Lateral Faults

(e.g. GOM Fault Families of Rowan et al., 1999)

The lateral tear fault boundaries between moving and stationary portions of detached systems

Class 1: Edges of deep or shallow sliding (multiple authors, 1995)
[Example – Roho Systems]

Class 2: Edges of stopped blocks (new)
[Example – Grounded Minibasins]

Landslide Analog For Detached Sliding

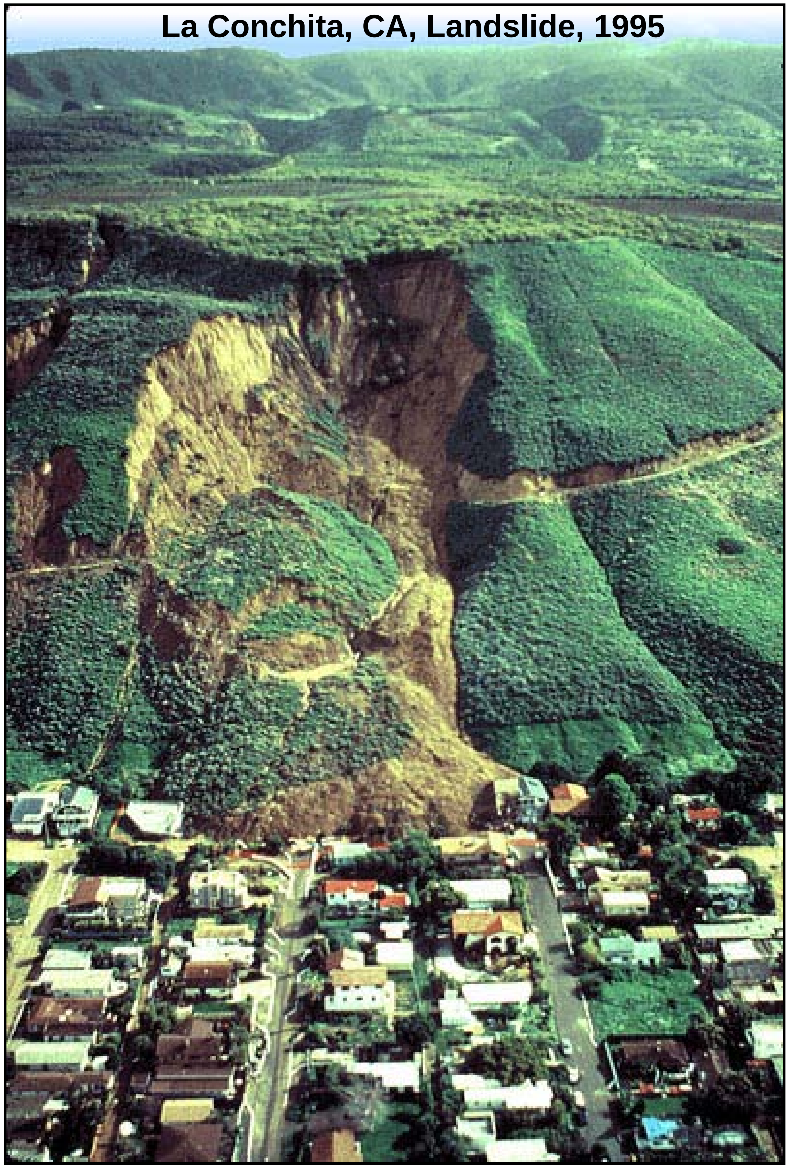
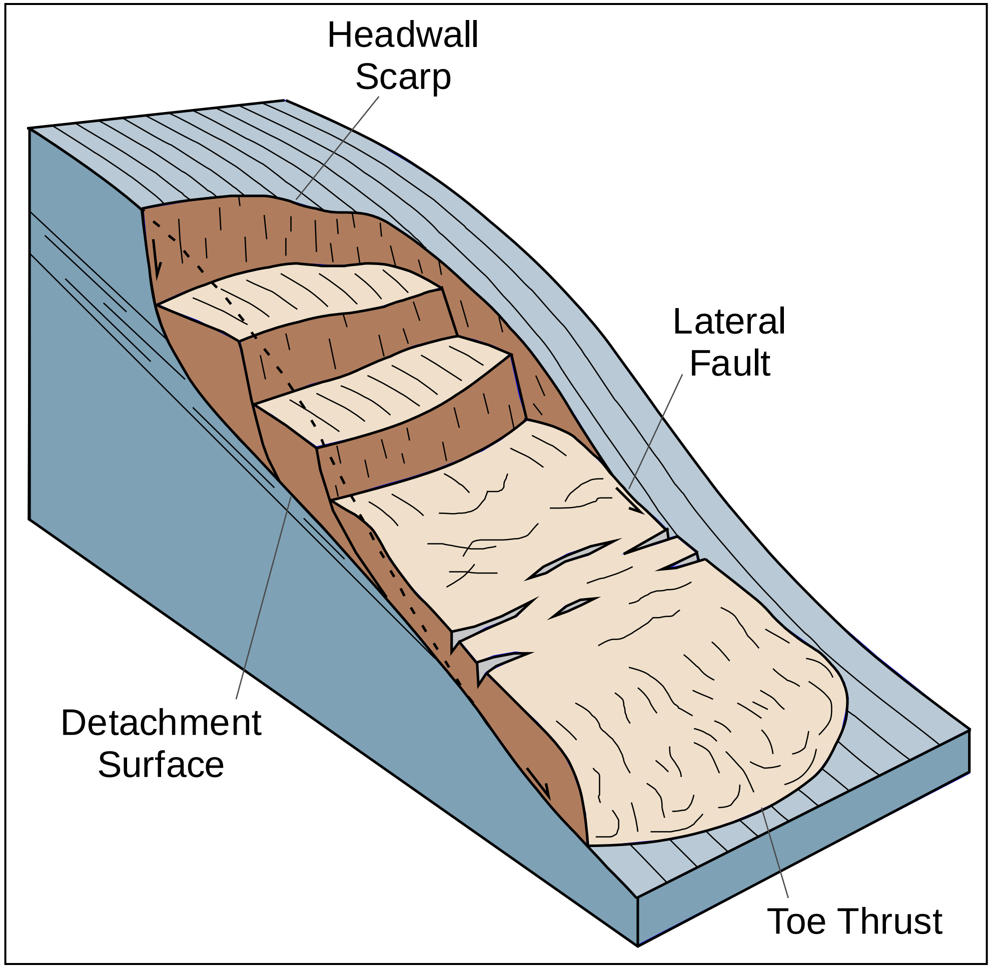
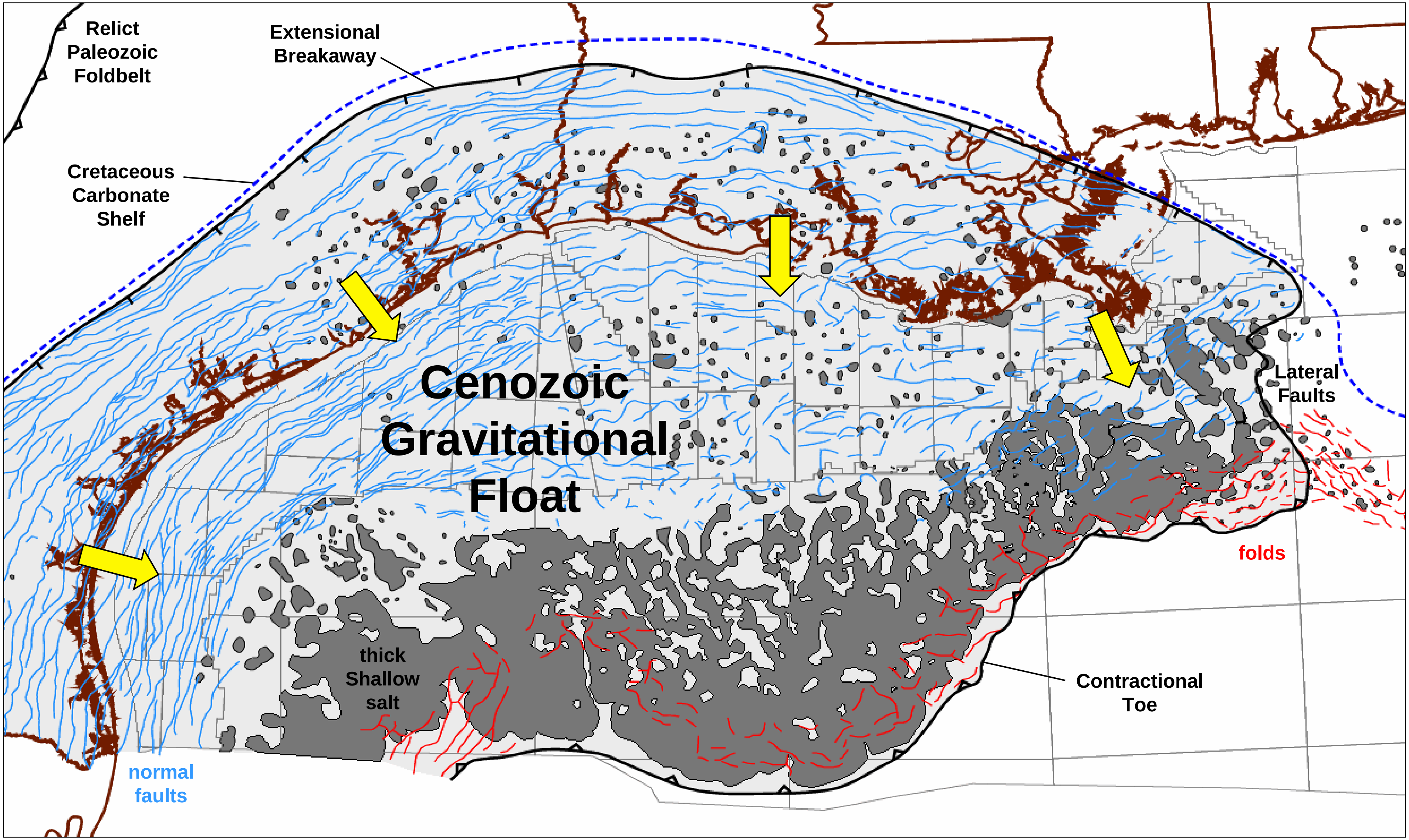


Photo source: USGS Landslide Manual, USGS Circular 1325

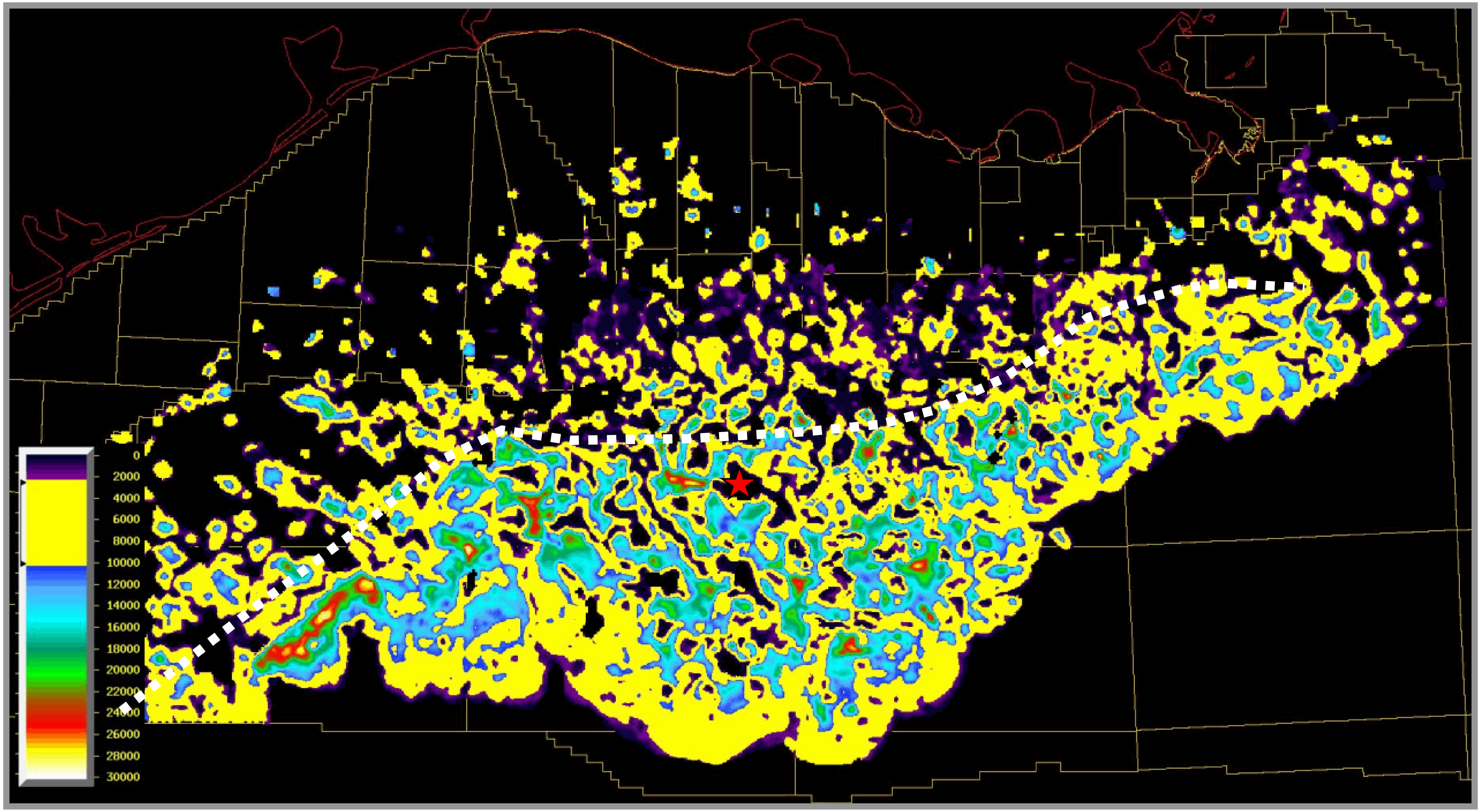
Downslope motion of a detached block inherently requires updip extension, downdip contraction, and lateral tear faults



Gravitational Float, Northern Gulf of Mexico



Prograding Expulsion of Salt



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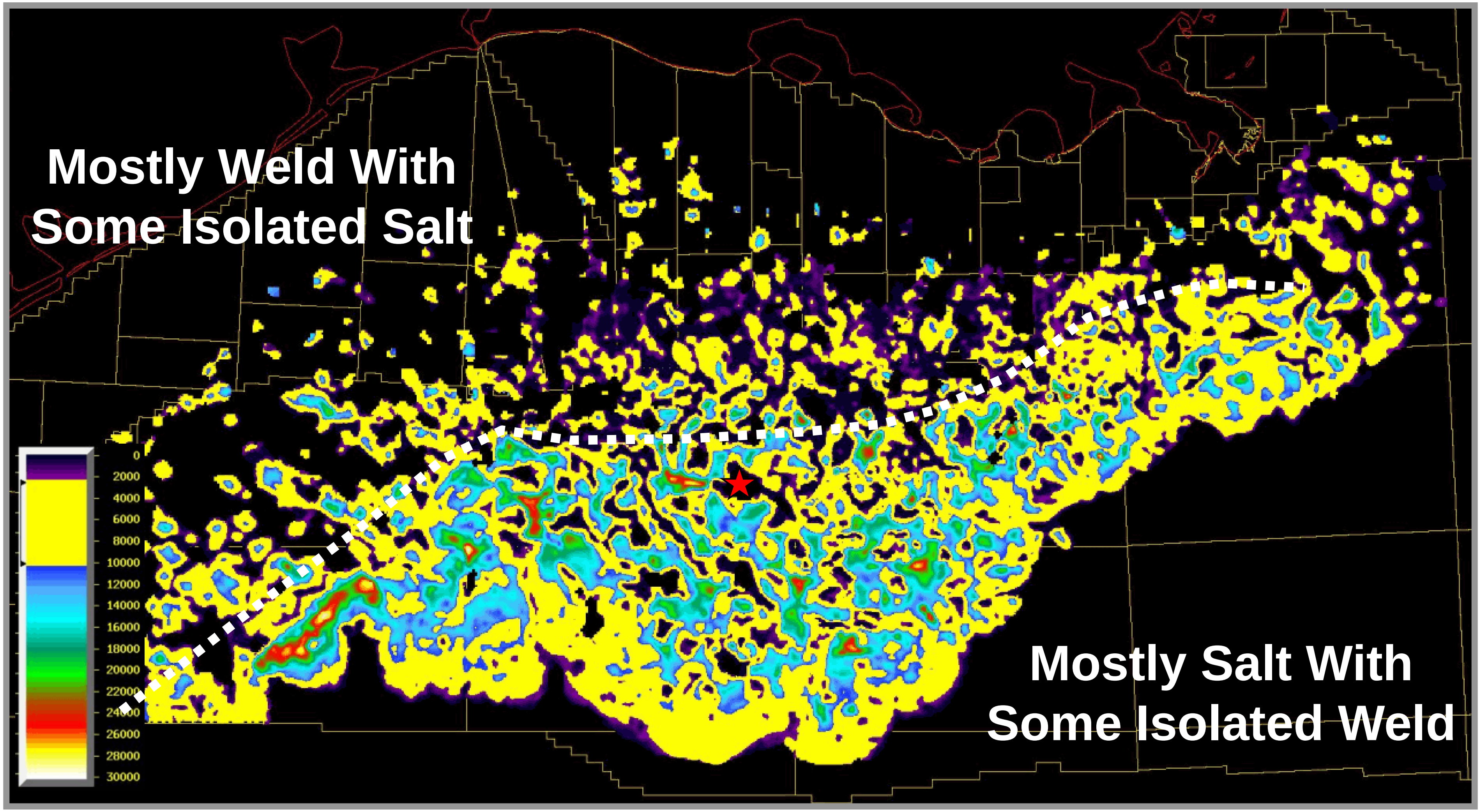
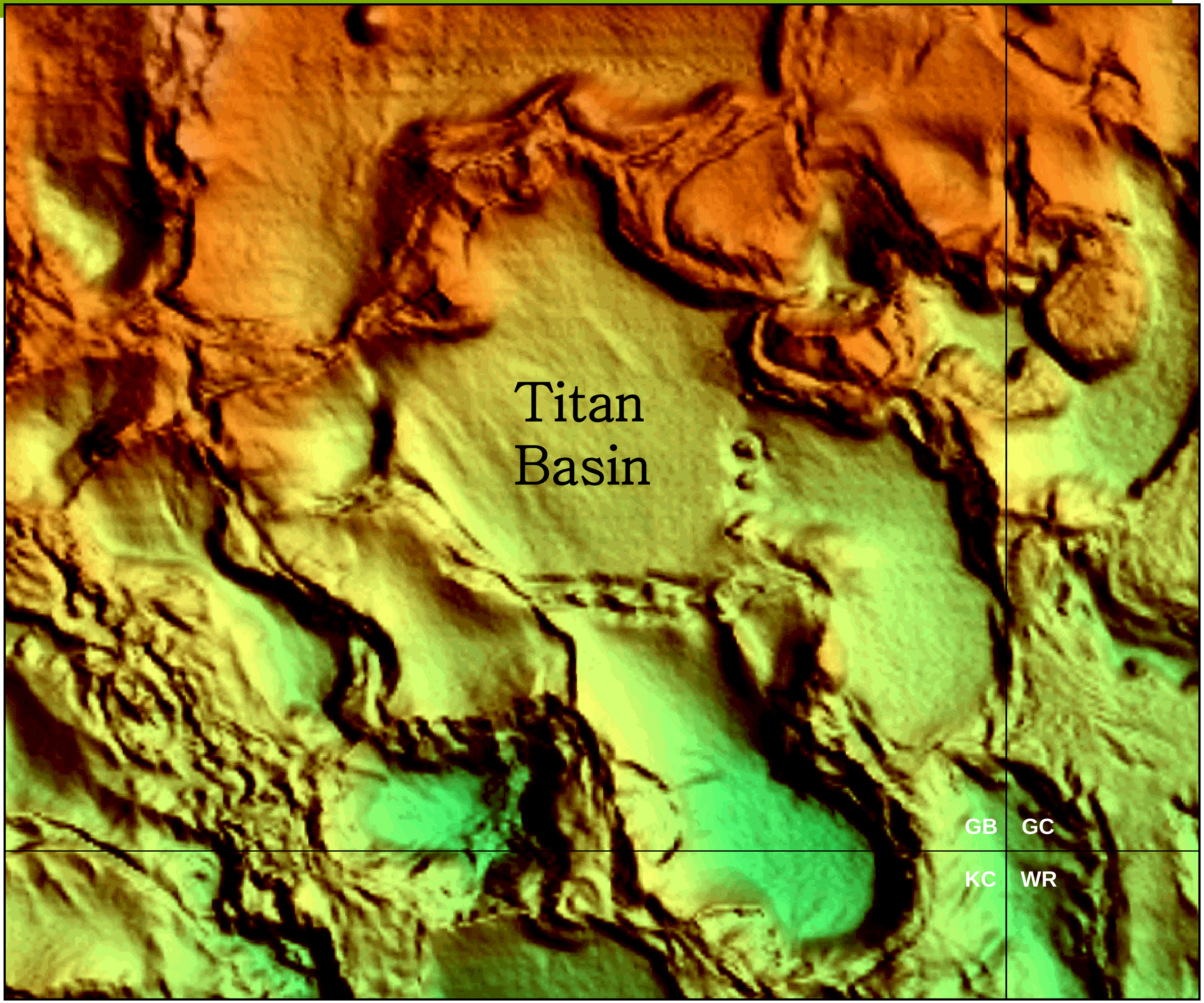


Grounded Minibasin Bounding Faults



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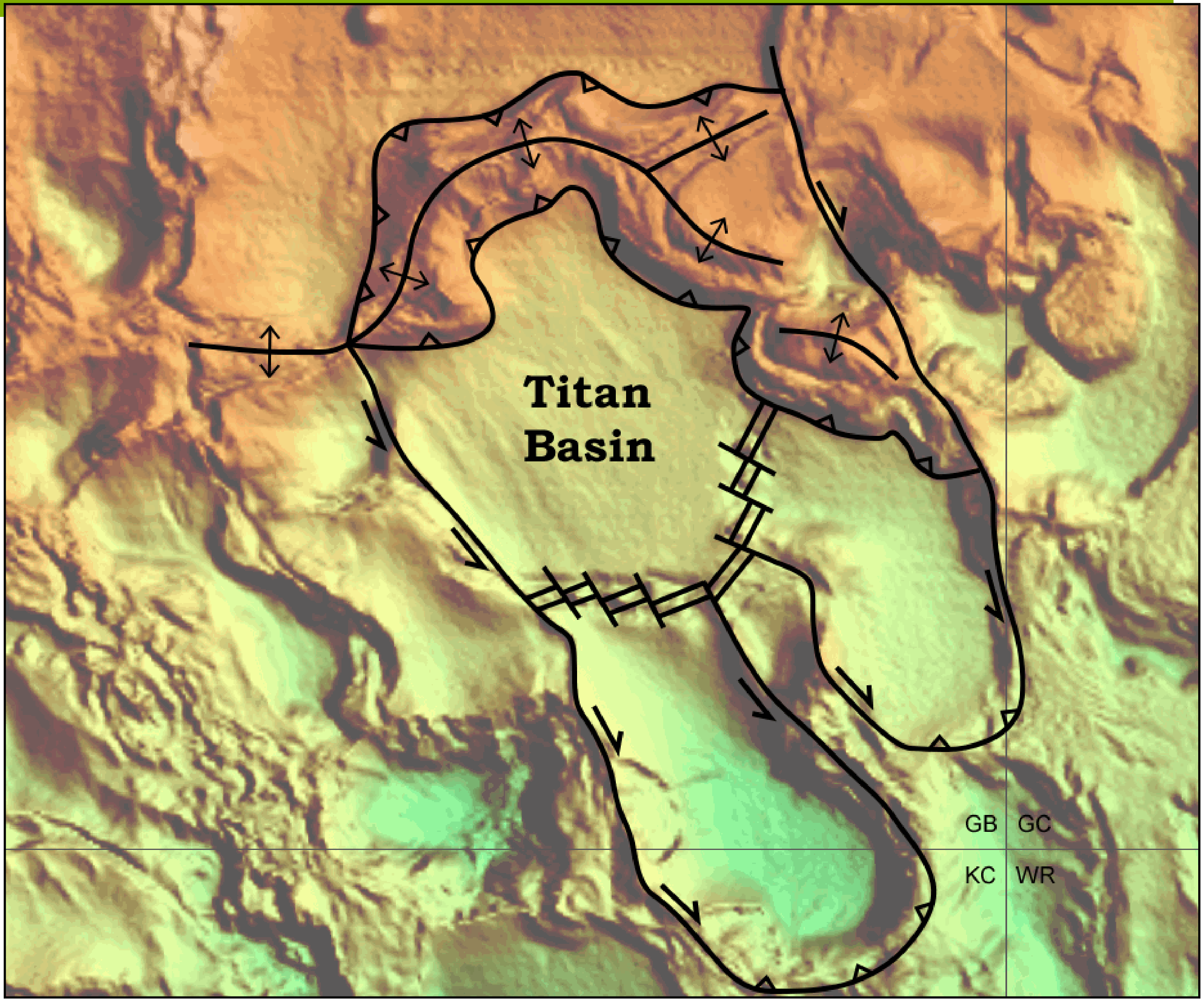
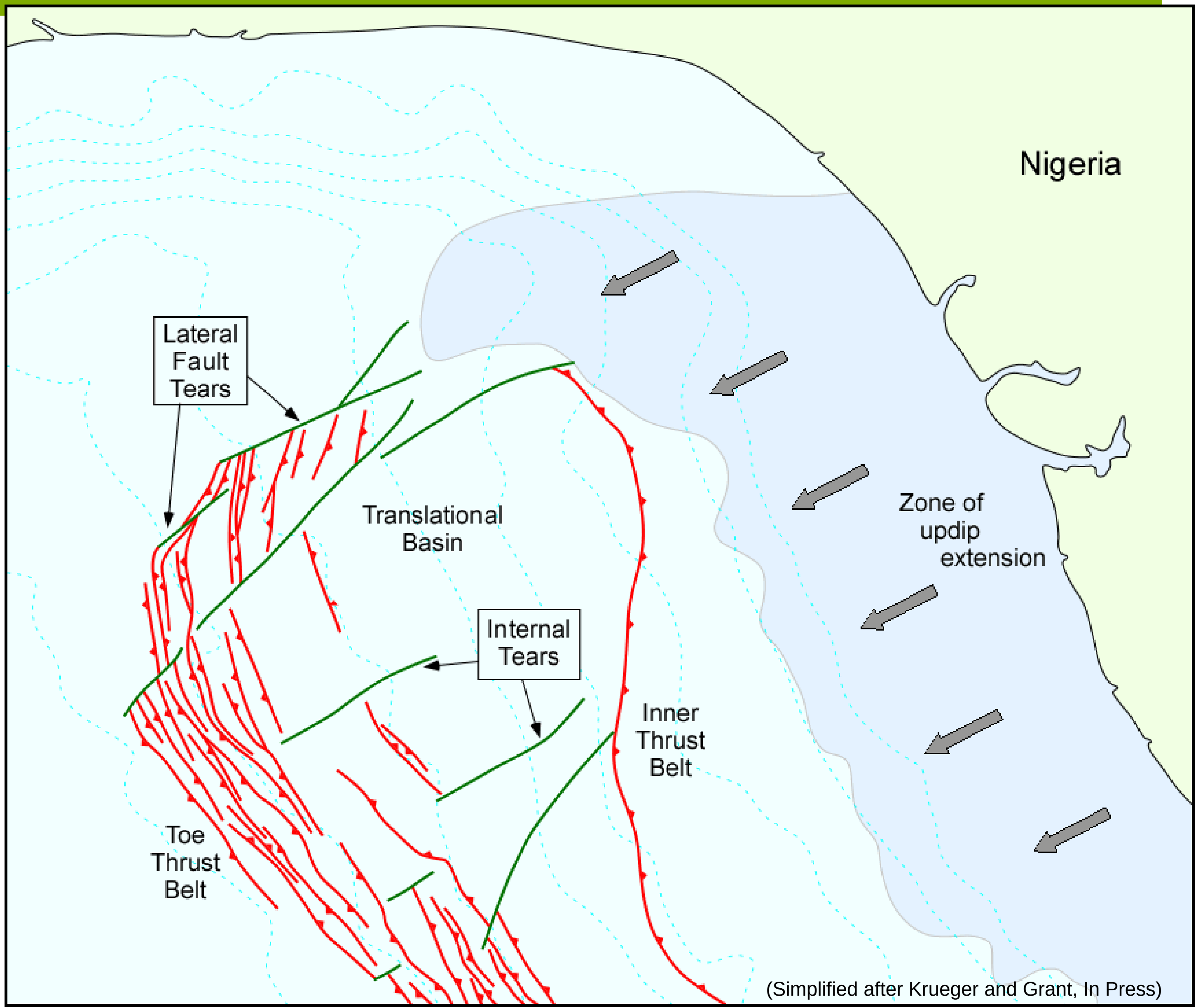


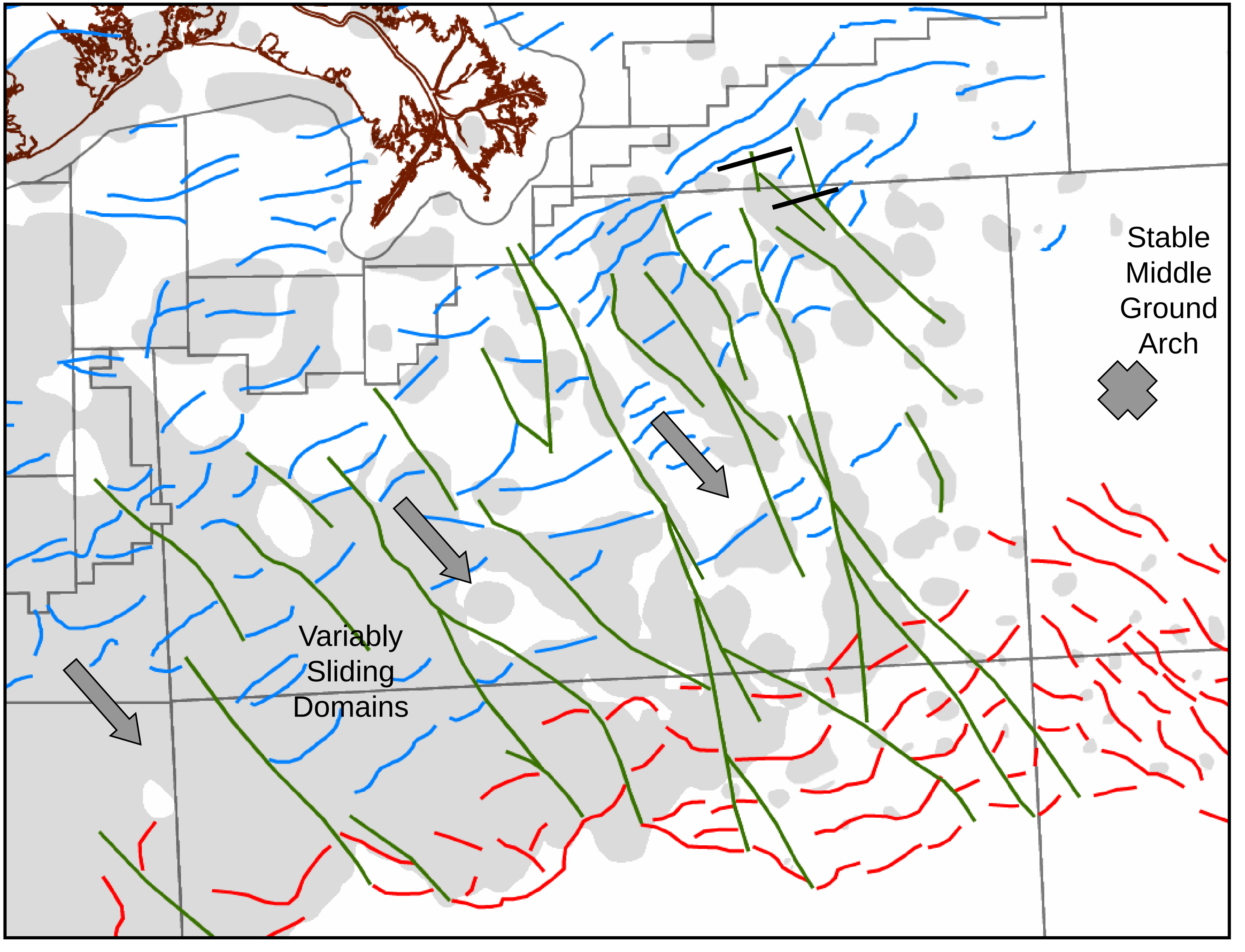
Internal Tear Faults

(Strike-slip boundaries between portions of detached systems sliding at different rates)

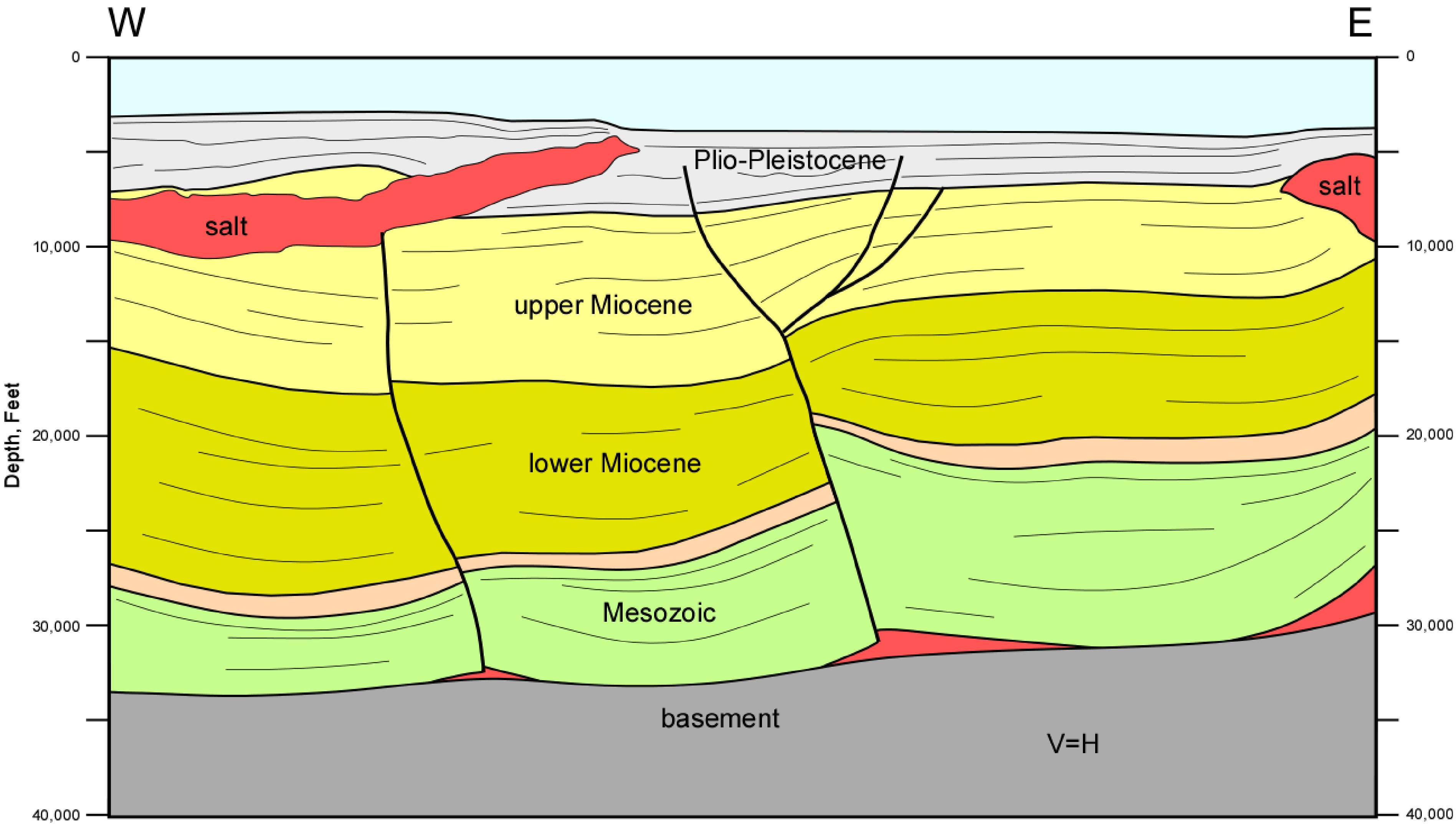
Tear Faults, Western Niger Delta



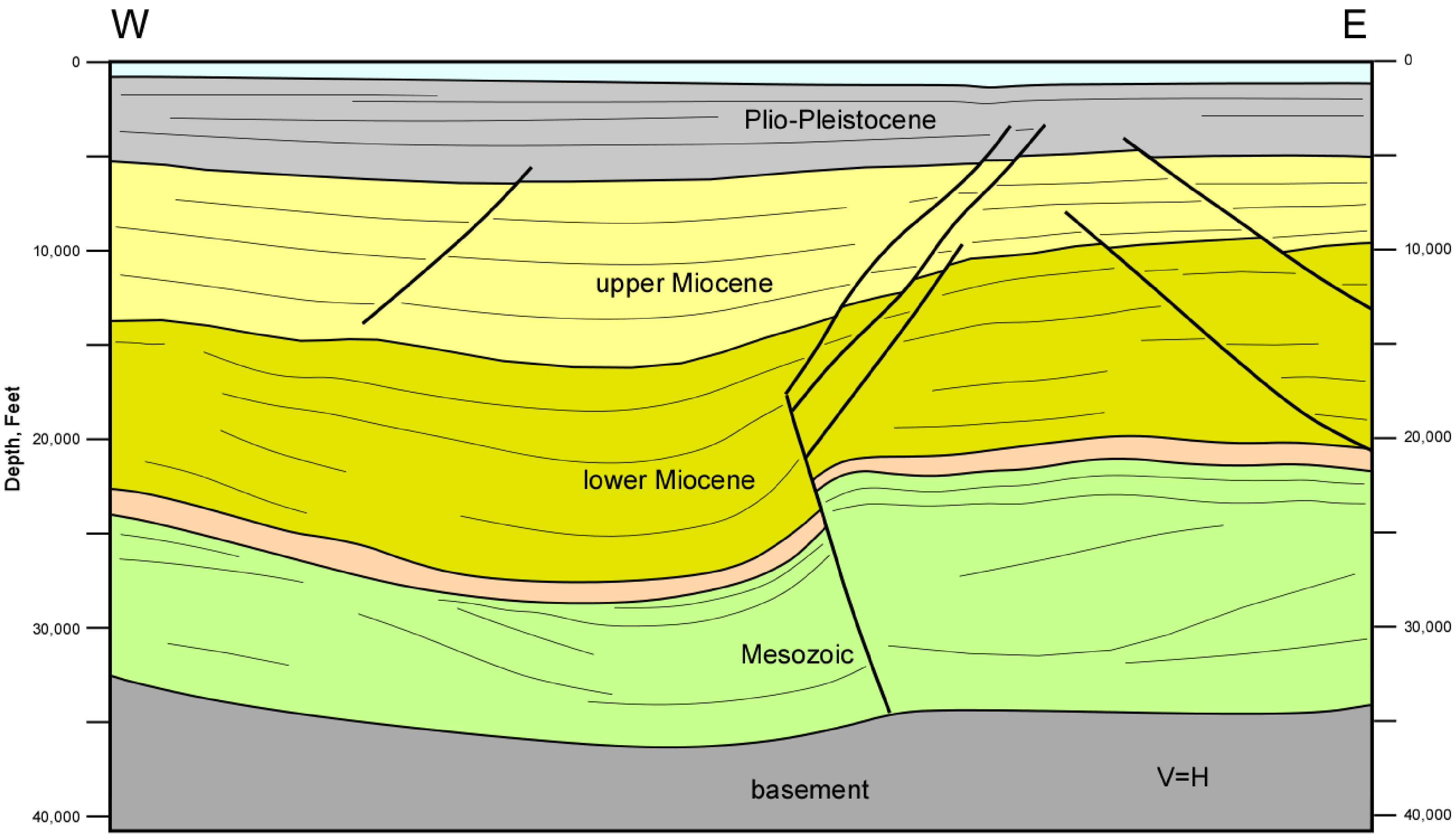
2nd Order Tears Above Deep Salt, EGOM



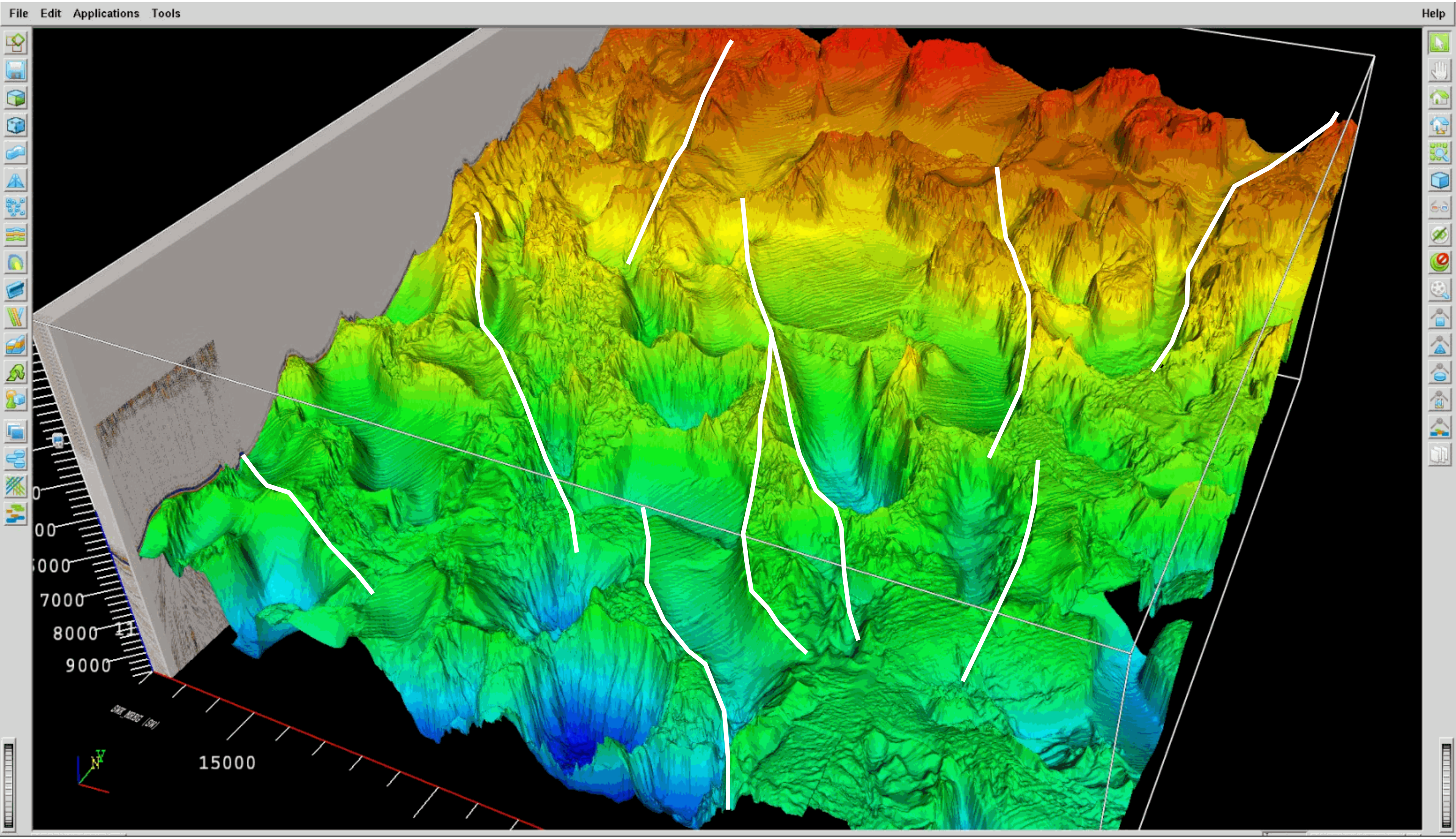
Strike-Slip Faults, NE Mississippi Canyon



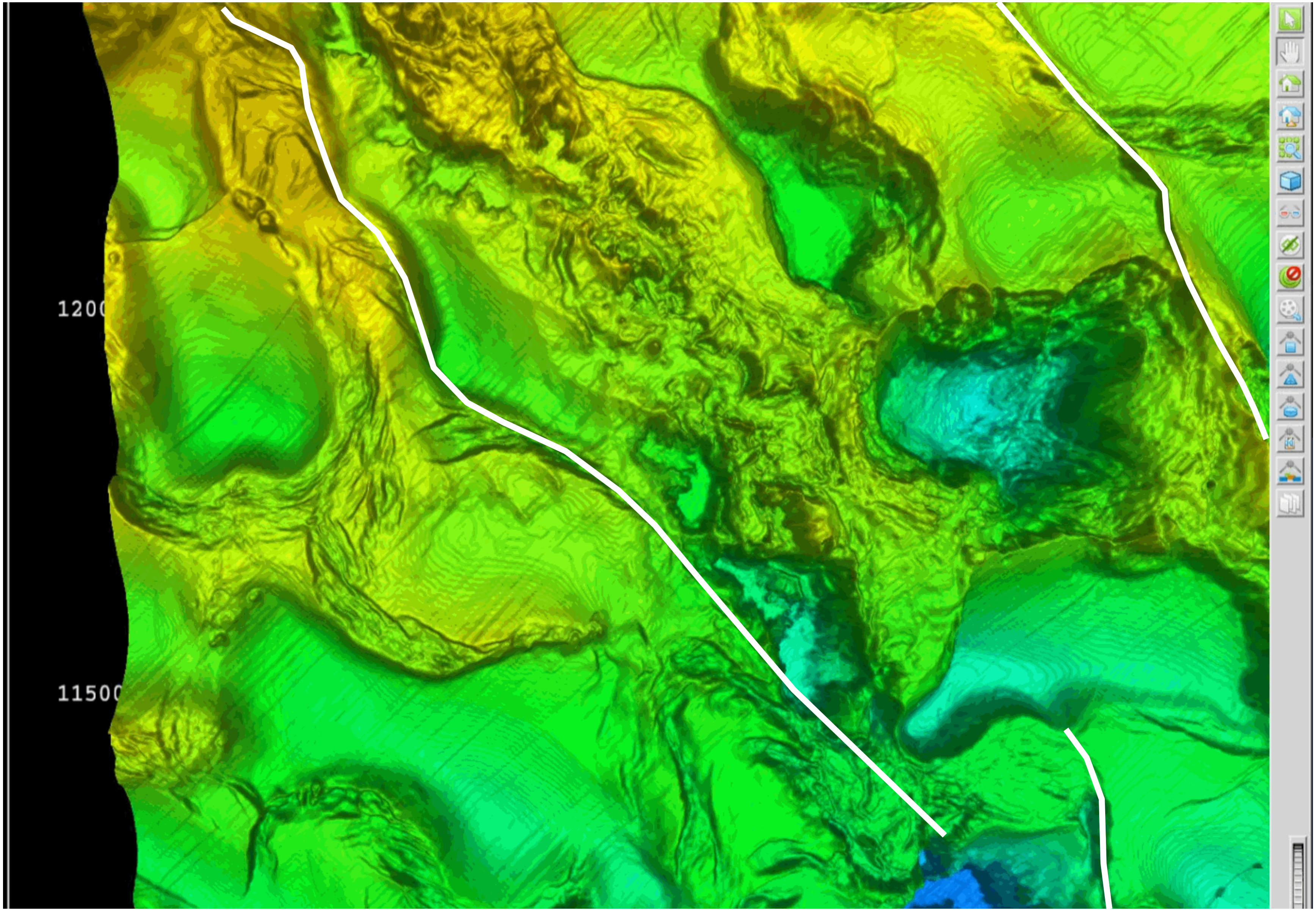
Strike-Slip Fault, Eastern Vioska Knoll



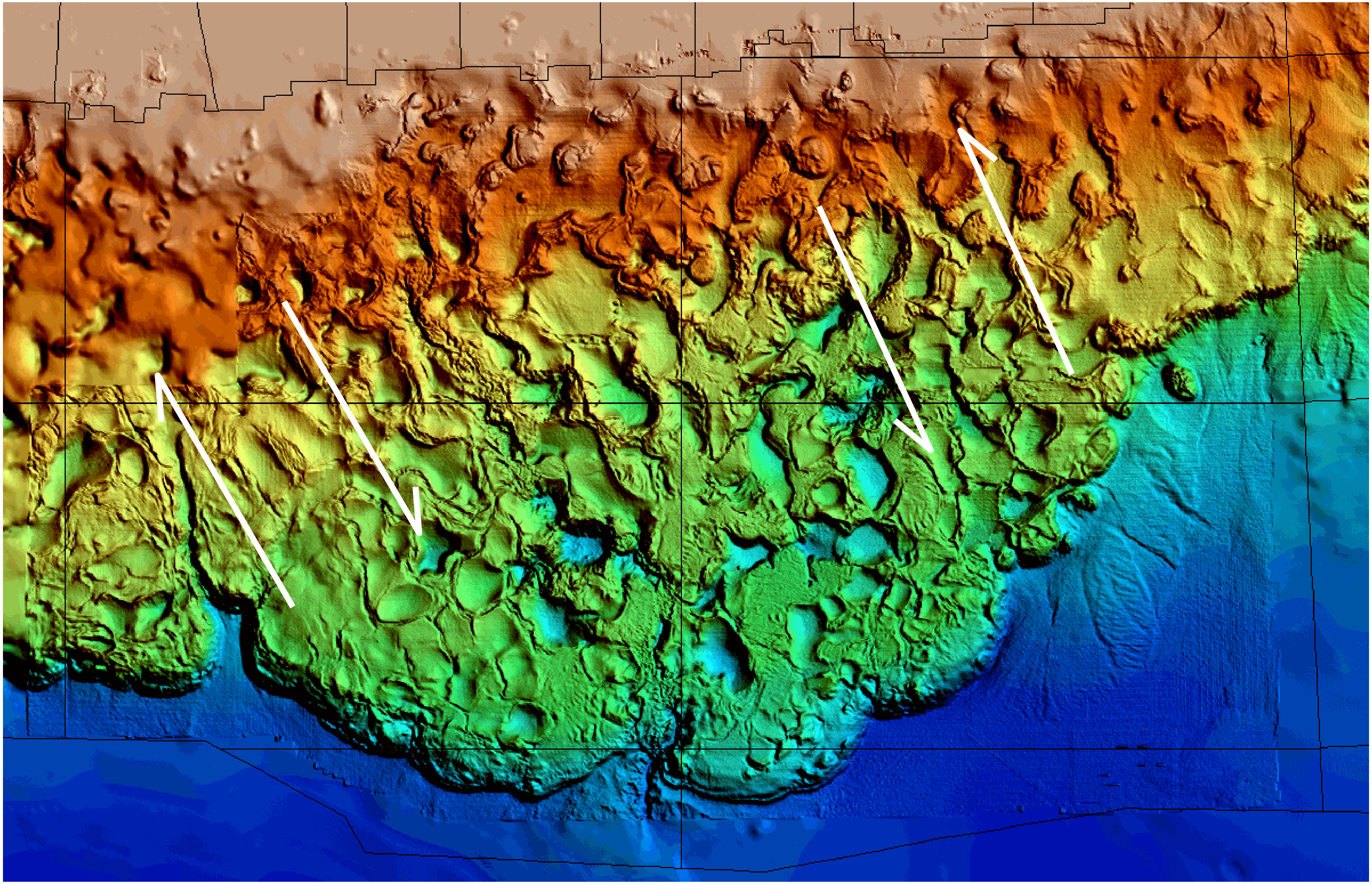
Tears Between Shallow Minibasins



Tear Offset of ~100Ka Bryant Canyon



Tear Faults at the Canopy Level



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Strike-Slip Fault, Bruin Bay, Alaska