

Jurassic-Cretaceous Tectonic Evolution of the Southeastern Gulf of Mexico, Constrains on the Style and Timing of Gulf of Mexico Rift-Drift Development*

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Abstract

The Southeastern Gulf of Mexico has been a seaway connecting the Gulf of Mexico with the Caribbean since the late Jurassic. Historical academic seismic data and the results of the DSDP Leg 77, collected in the 1980-81, was utilized to carry out detailed tectonic analysis and to help to understand how the evolution of this area is related to the opening of the Gulf of Mexico basin. Researchers agree that during the Late Triassic (?) to late Middle Jurassic continental extension phase, the stable Yucatan block rifted away from North America above a southward dipping crustal detachment. During the Callovian to Berriasian oceanic phase, however, to accommodate the newly formed oceanic crust in the Gulf of Mexico, the relatively stable Yucatan block rotated counterclockwise about 42° around a pole close to the Pinar del Rio Knoll, just north from the present day Cuba. Salt was deposited in the Gulf of Mexico in the Callovian to early Oxfordian (?) time above thinned continental and over the newly formed oceanic crust in the central Gulf. Lack of salt in both the oceanic and continental segments of the Southeastern Gulf of Mexico clearly indicates that the northern (oceanic) portion is younger than Callovian and that southern (continental) portion of the rift did not subside below sea level before the cessation of salt deposition in the Gulf of Mexico. Thus, the documented southward propagating rift in the Southeastern Gulf of Mexico, between Yucatan and Florida, fully developed only during the rotation of the Yucatan peninsula. In other words, the formation of the Southeastern Gulf of Mexico propagating rift and the formation of oceanic crust in the Gulf of Mexico are time equivalent. Based on the observed regional post-rift unconformity, dated in the DSDP Hole-535, the Yucatan block reached its current position is Upper Berriasian. Consequently, the Berriasian unconformity signals the completion of oceanic crust formation in the Gulf of Mexico.

Reference Cited

Pindell, J., R. Graham, and B. Horn, 2014, Rapid outer marginal collapse at the rift to drift transition of passive margin evolution, with a Gulf of Mexico case study: *Basin Res.*, v. 26, p. 701–725, doi:10.1111/bre.12059

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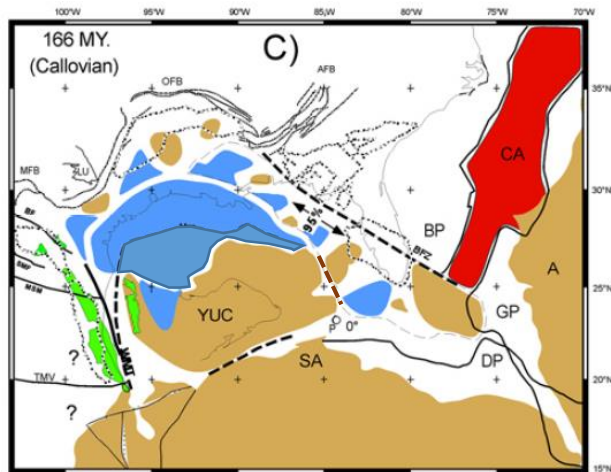
Richard T. Buffler (*Institute for Geophysics, the University of Texas at Austin*) rbuffler@gmail.com

Jurassic-Cretaceous tectonic evolution of the Southeastern Gulf of Mexico, constrains on the style and timing of Gulf of Mexico rift-drift development.

Acknowledgment:

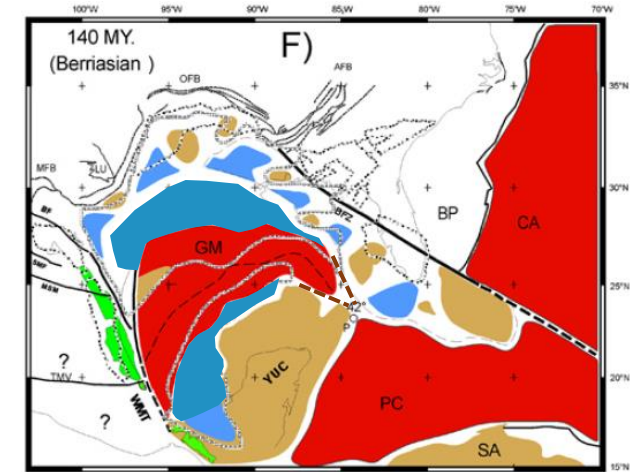
The authors are thankful to the Institute for Geophysics and to the Dynamic Group for their support of this research.

Without access to a unique combination of old academic and cutting edge modern seismic data our model would remain conceptual and poorly constrained.



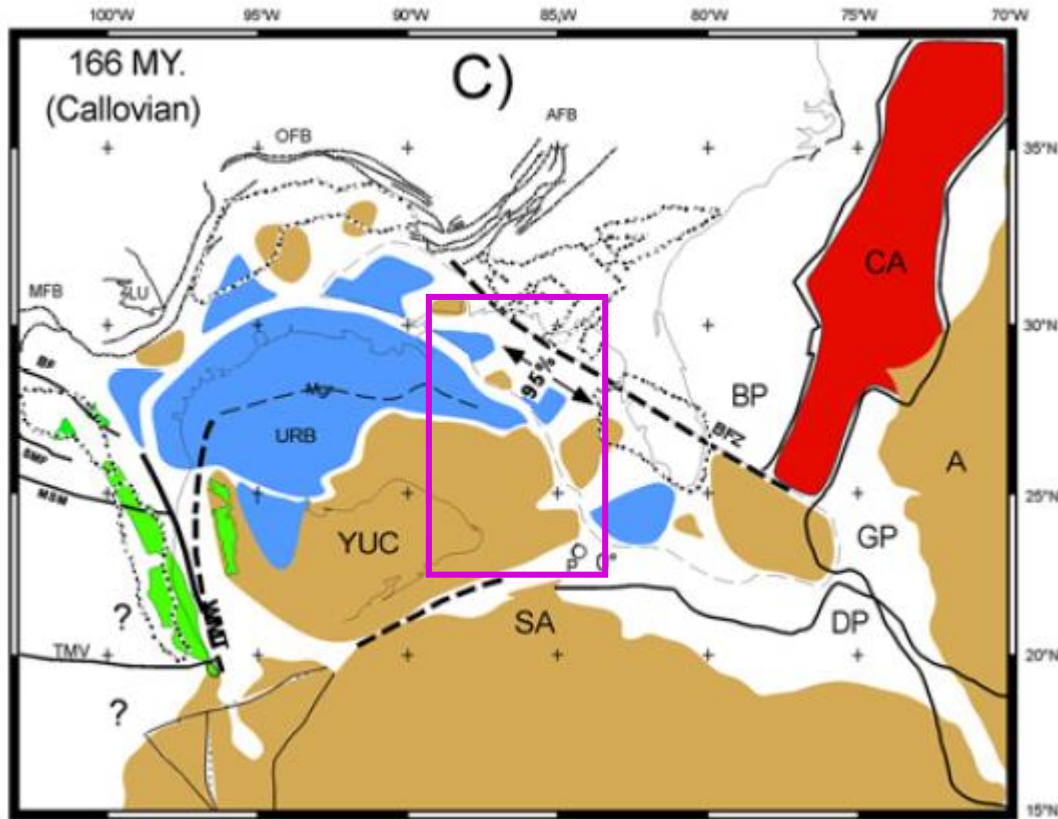
We wish to document that During the Upper Jurassic the SE-Gulf evolved as a southward propagating between the Yucatan and Florida blocks

Let's review the structural and stratigraphic evidences!

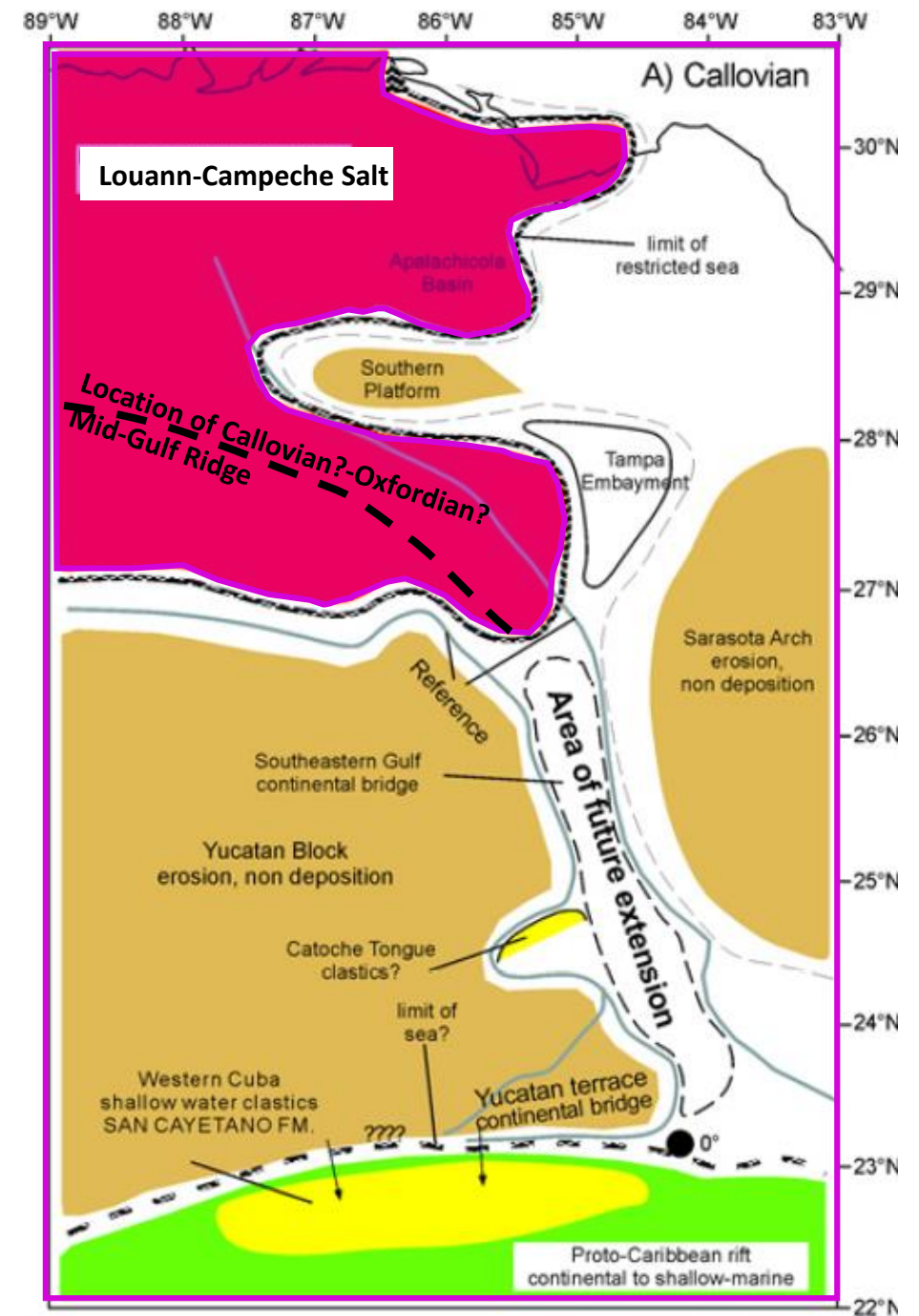


The Callovian was a turning point in the GOM evolution

- I. Central Atlantic is already partially opened
- II. Yucatan rifted away from the northern Gulf
- III. Gulf wide subsidence below paleo sea-level, Salt Deposition
- IV. Initiation of seafloor spreading in the Western Gulf?
- V. The SE-GOM remained an emergent land . Can we see the salt limit?

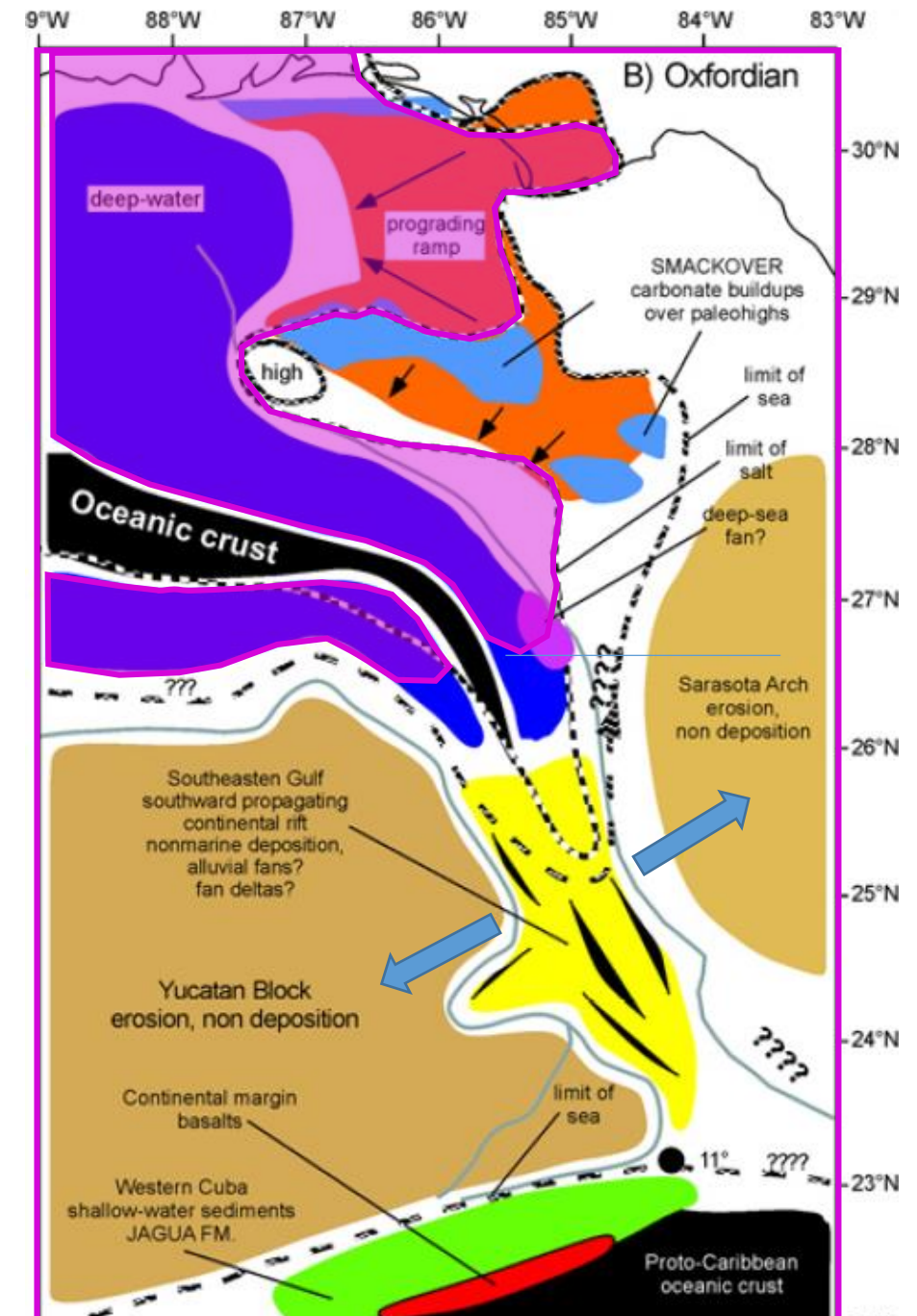
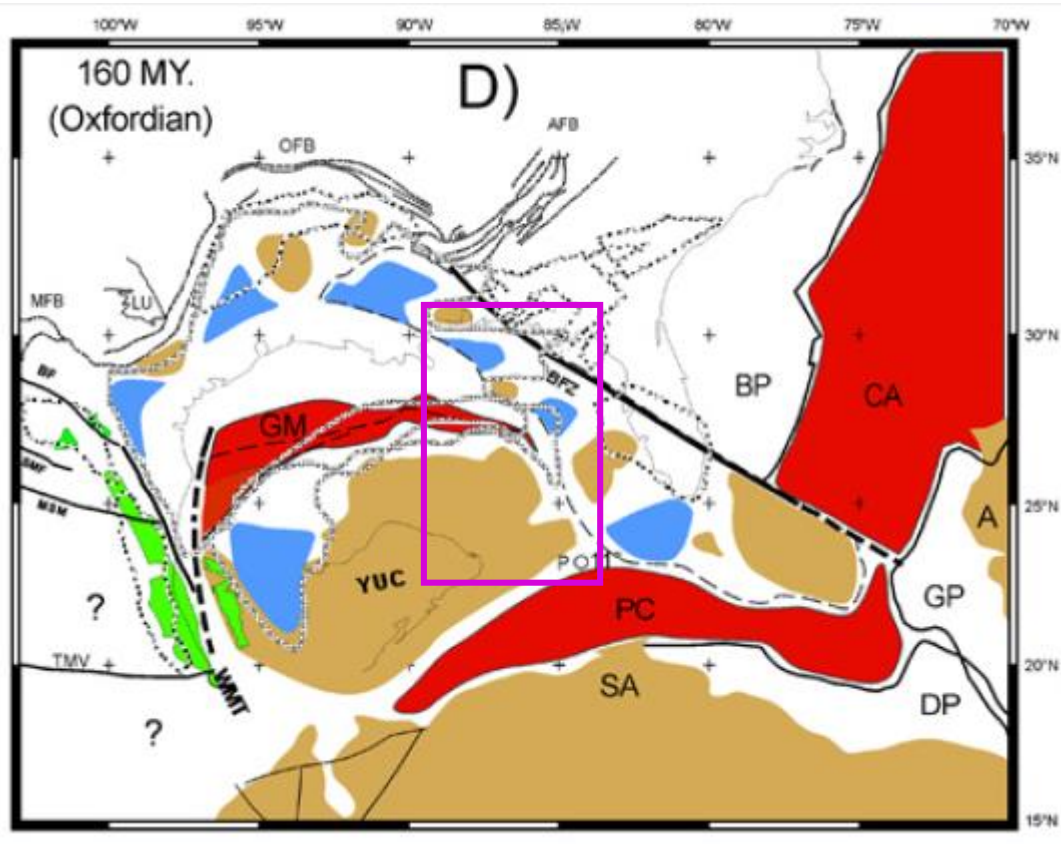


Western Cuba: shallow water clastic sedimentation



By the Oxfordian the Yucatan block rotated about 11° around a pole N of Cuba

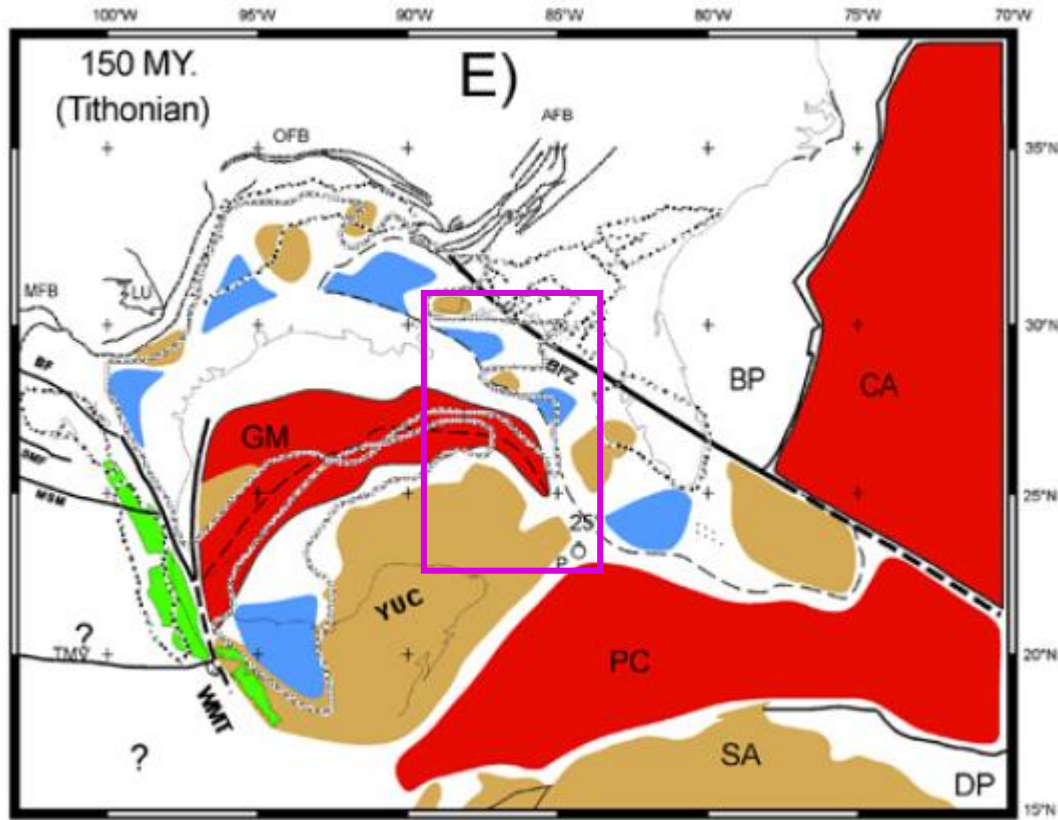
- I. The Mid-Gulf ridge propagated into the SEGOM
- II. The Luann and Campeche salt provinces got separated
- III. North of the pole an increasing amount of NE-SW extension was accommodated in continental rift setting



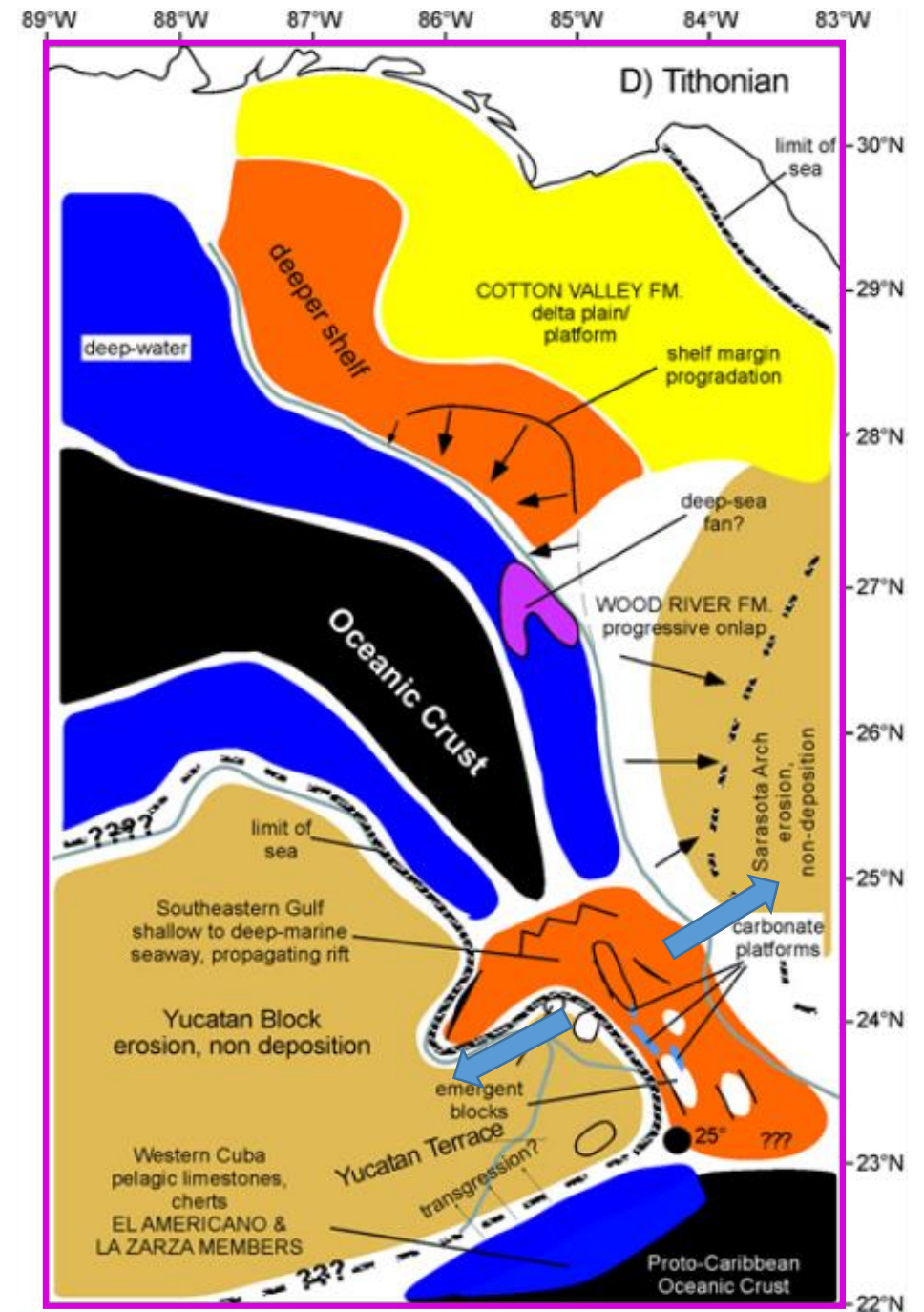
Western Cuba: shallow water sedimentation plus basaltic volcanism →

By the Tithonian the Yucatan block rotated about 25° around a pole N of Cuba

- The Mid-Gulf ridge propagated further into the SEGOM
- NE-SW extension continued in the southern segment
- Marine transgression reached the area. Possible carbonate deposition prevailed

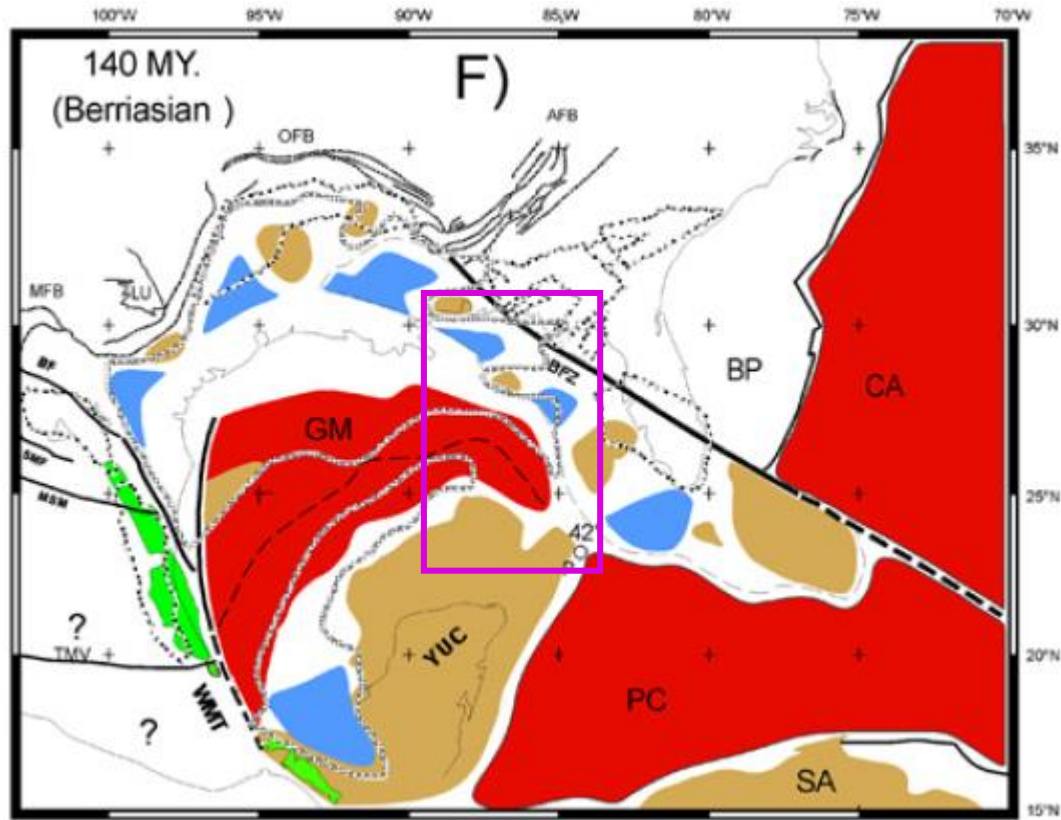


Western Cuba: deep water carbonates

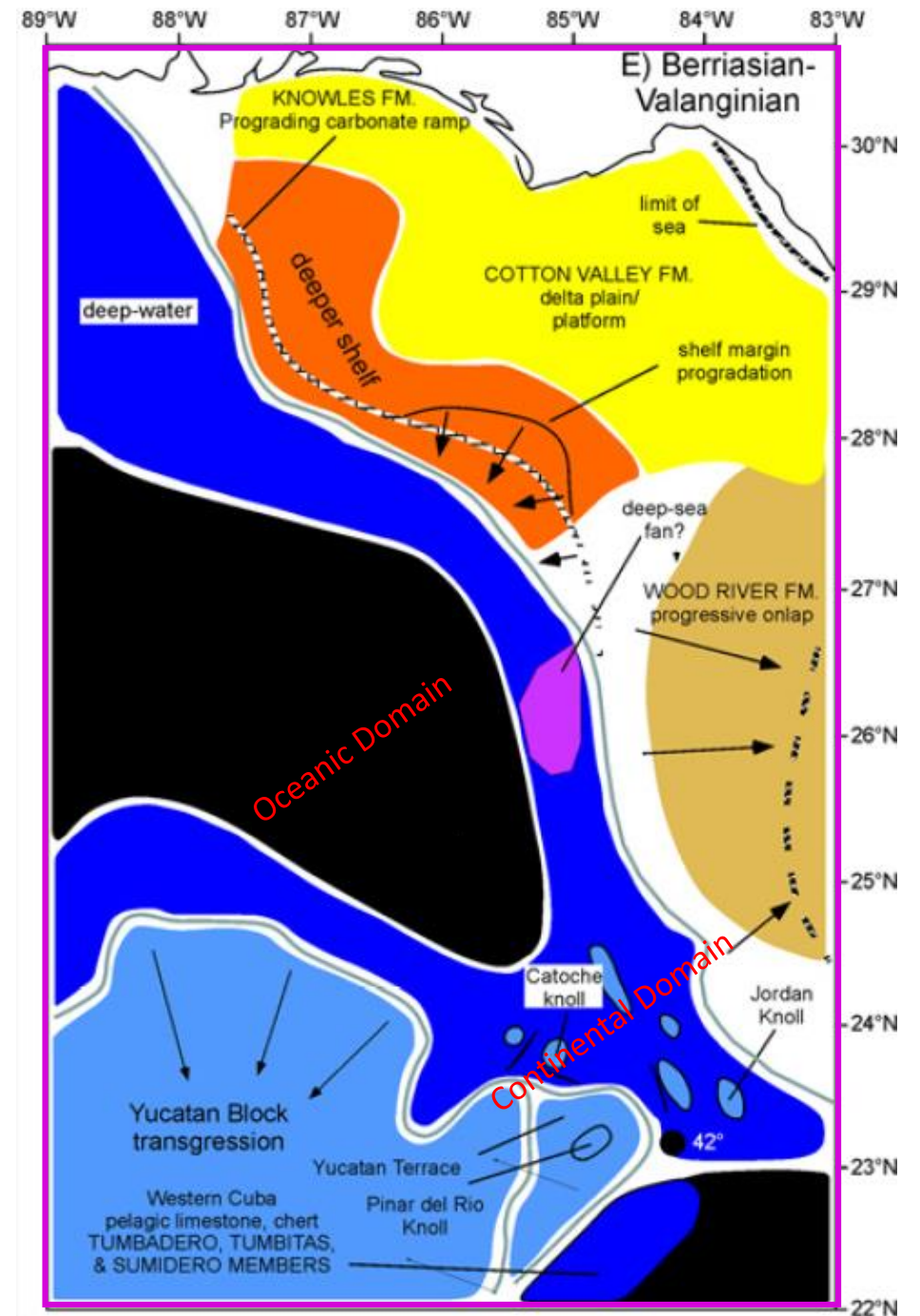


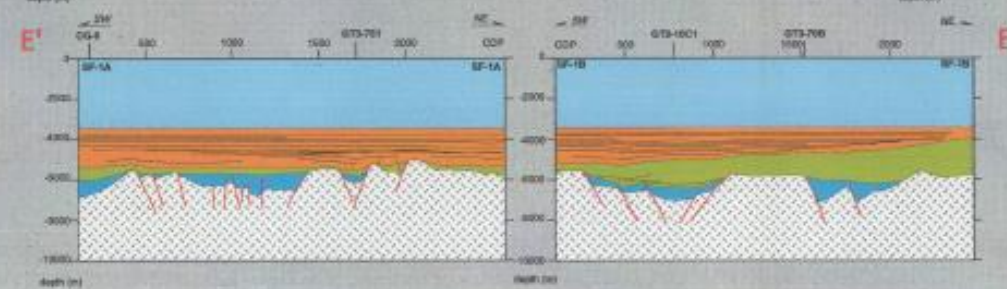
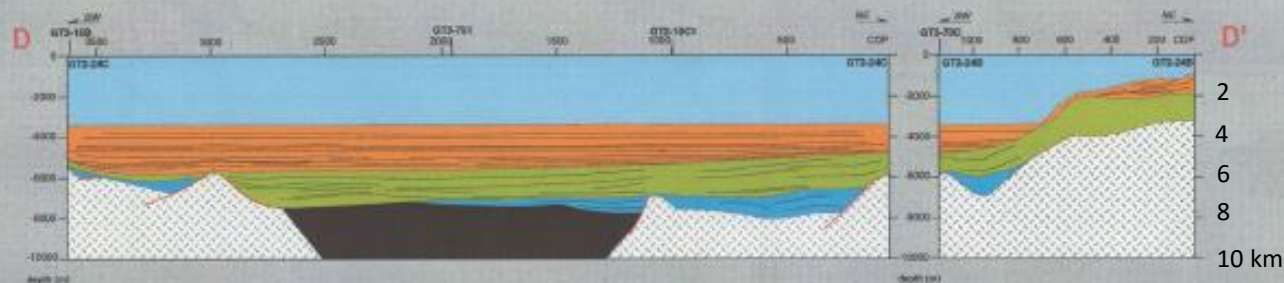
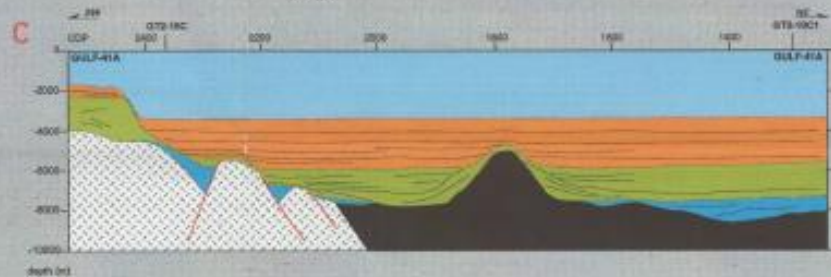
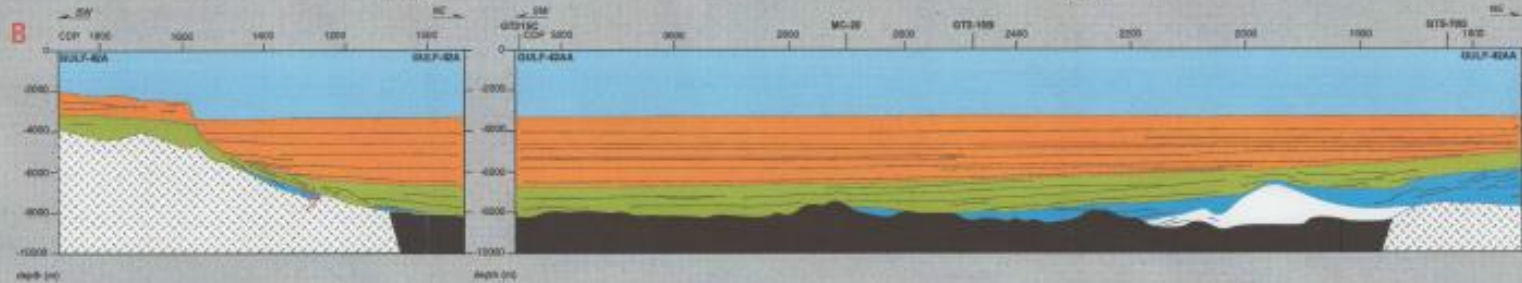
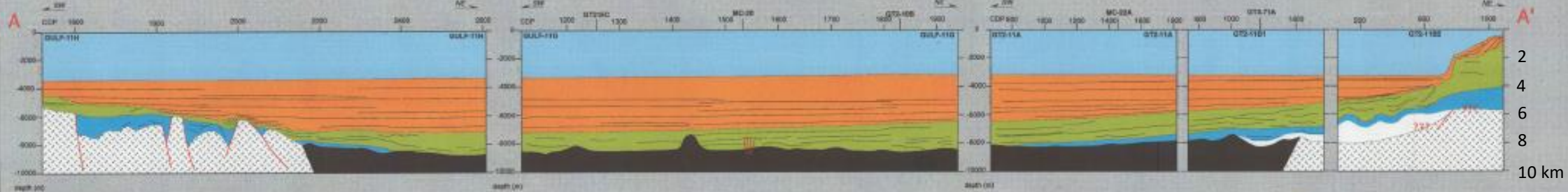
By the Berriasian the Yucatan block rotated about 42° around a pole N of Cuba

- Oceanic crust formation ceased in the GOM
- NE-SW extension/rifting stopped in the SEGOM
- Related Post-Rift Unconformity dated in DSDP well 535 constrain the end of oceanic crust formation in the Gulf



Western Cuba: deep water carbonates





ENCLASURE I.

SW-NE geological cross sections in the southeastern Gulf of Mexico. Based on depth converted interpretation of multichannel seismic data. Location of cross sections are marked by heavy red lines.

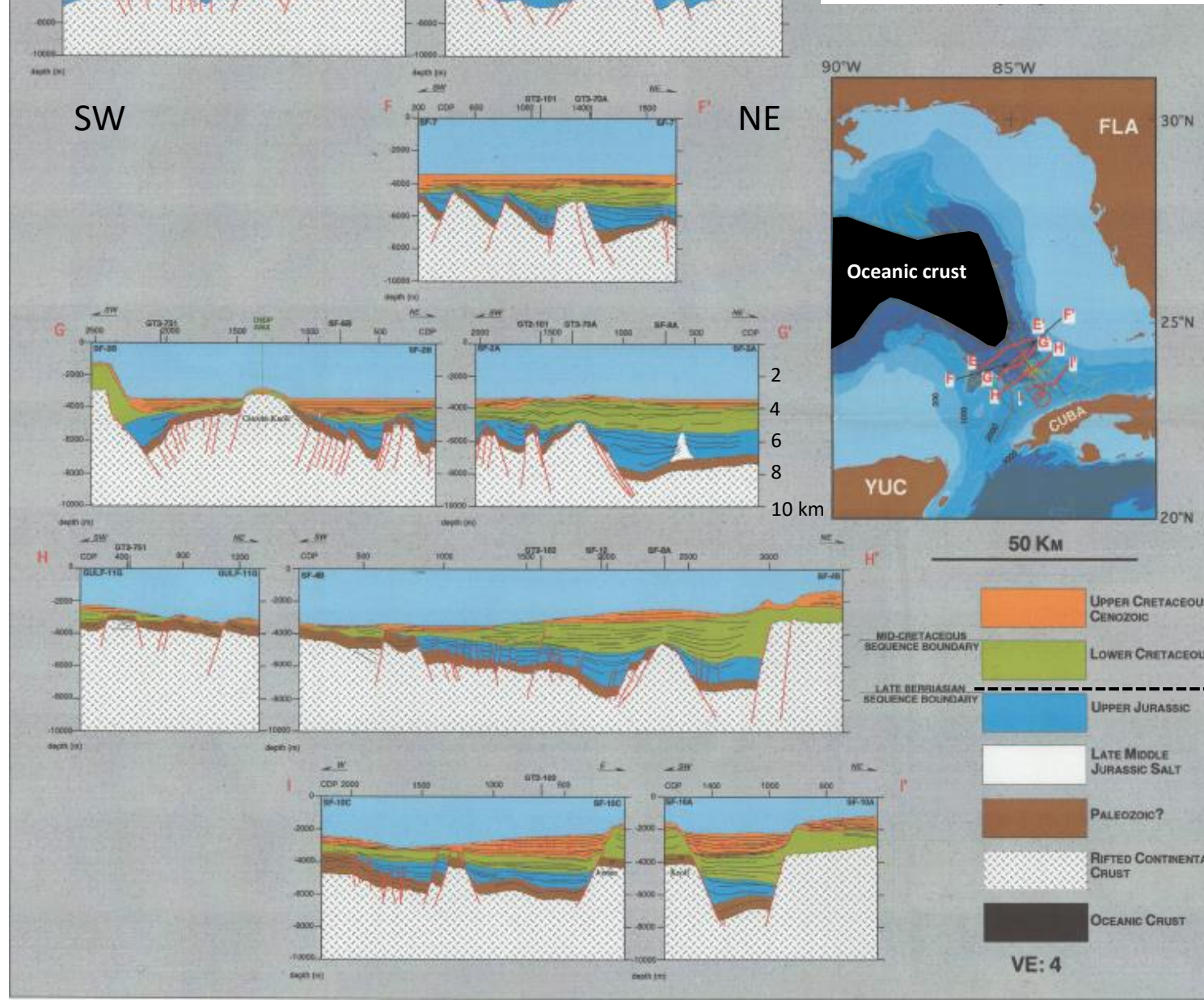


Seismic evidence for the propagating rift model in the SEGOM (oceanic domain)

Depth converted interpretation of historical academic and industry data

Seismic evidence for the propagating rift model in the SEGOM (continental domain)

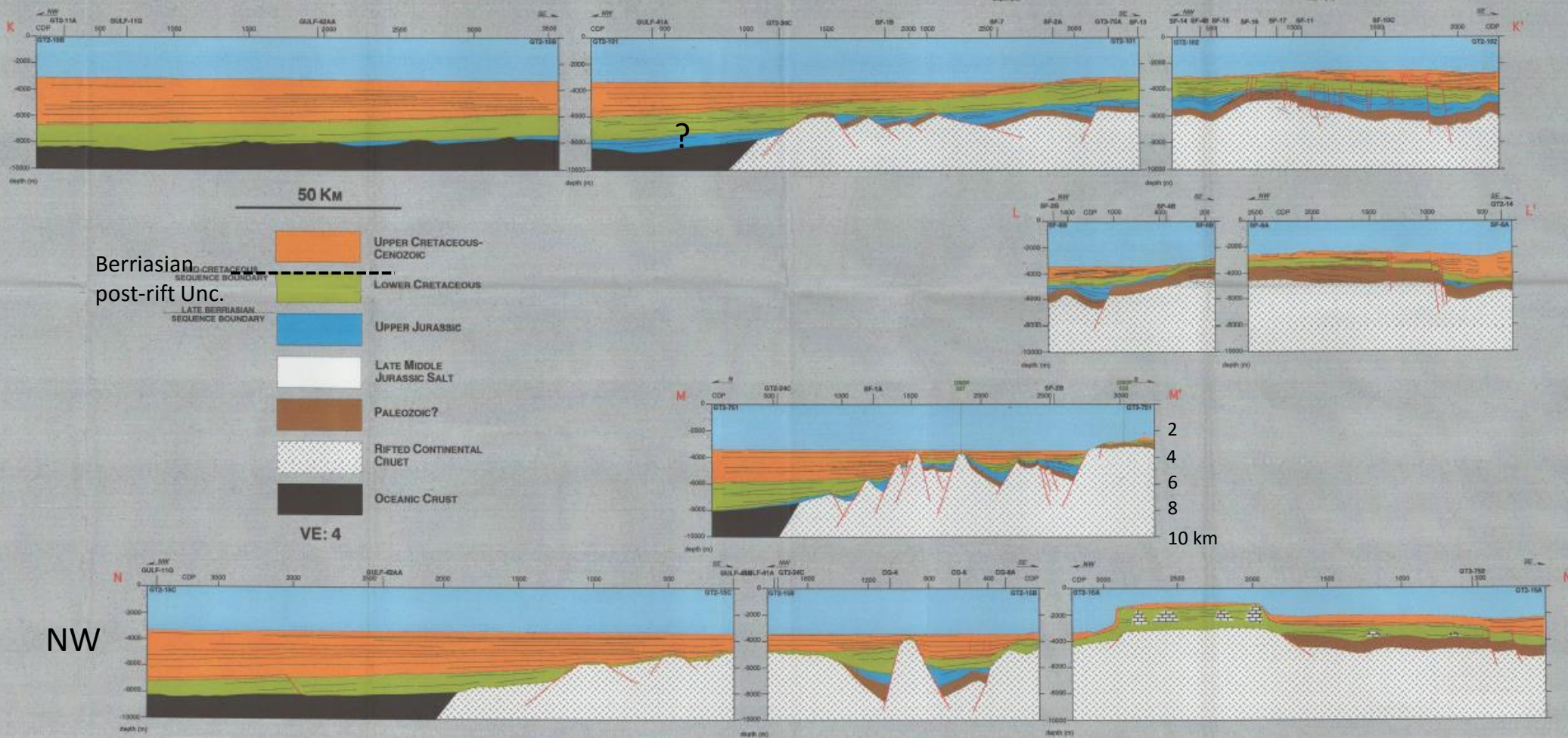
Depth converted interpretation of historical academic data



Berriasian post-rift Unc.

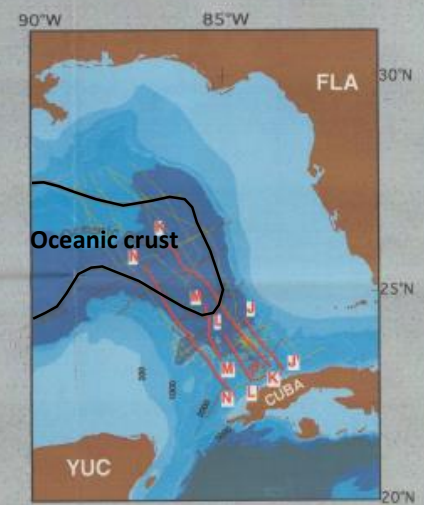
NW-SE view of the Continent-Ocean Transition

Depth converted interpretation of historical academic data



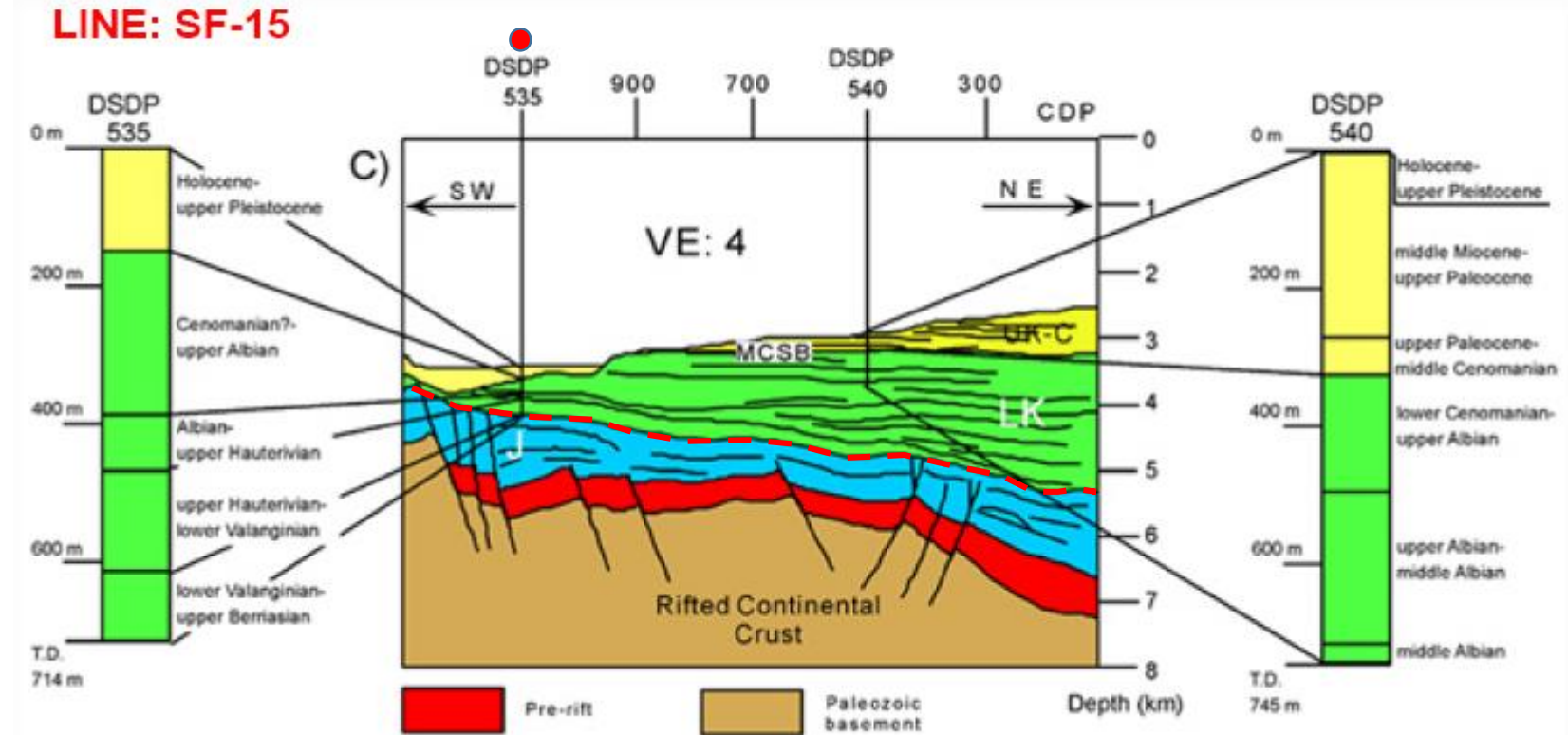
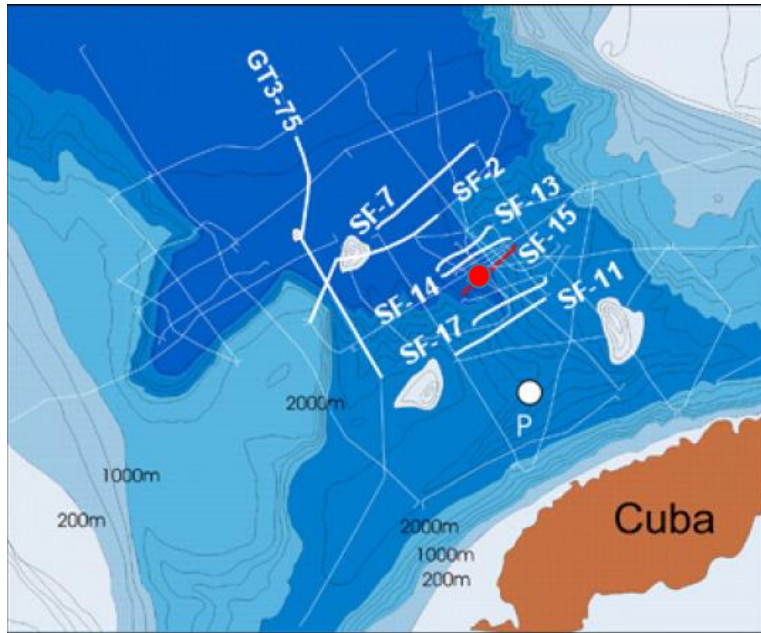
ENCLASURE III

NW-SE geological cross sections in the southeastern Gulf of Mexico. Based on depth converted interpretation of multichannel seismic data. Location of cross sections are marked by heavy red lines.



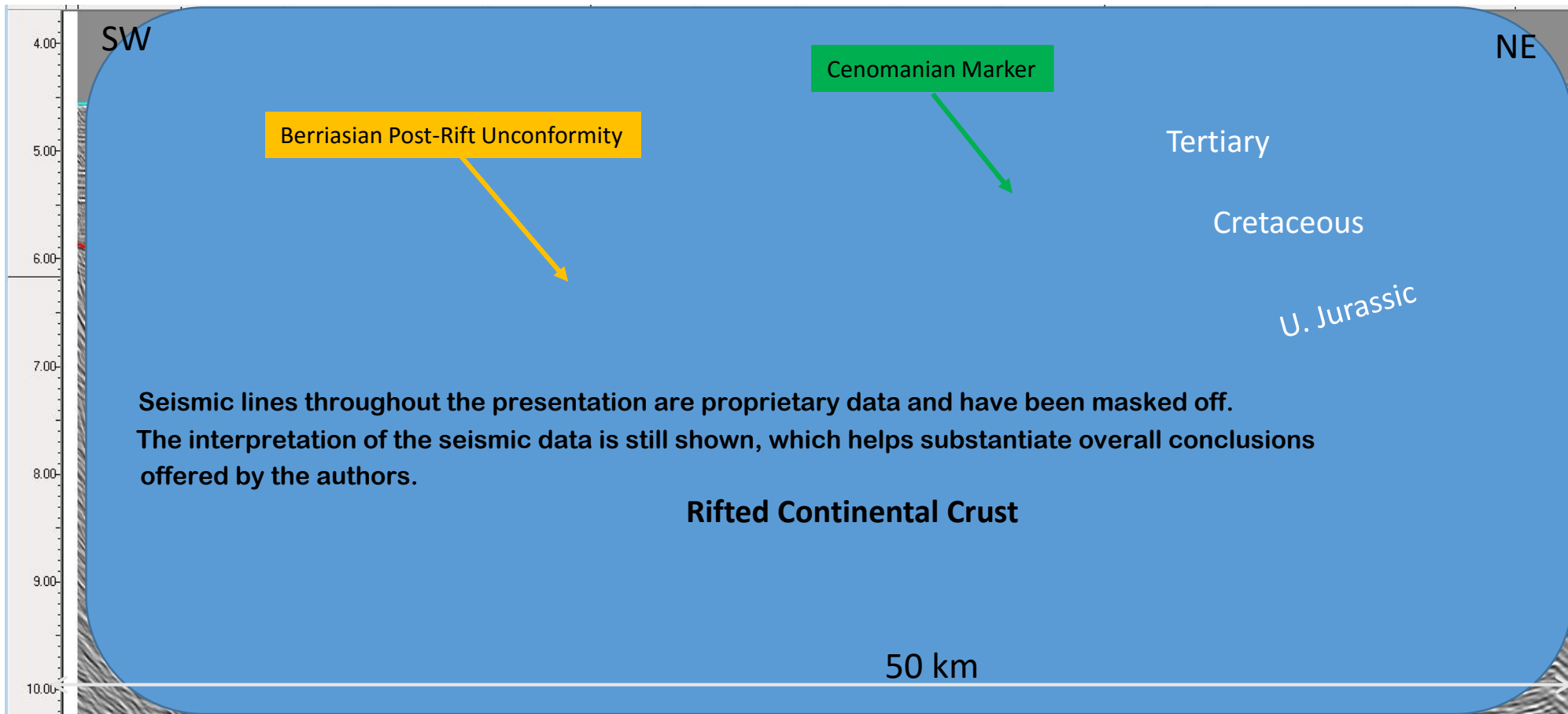
DSDP Hole 535 dates the post-rift unconformity as Late Berriasian in the SEGOM

Well encountered laminated bioturbated to massive limestones, marls, deposited in a deep-water setting.



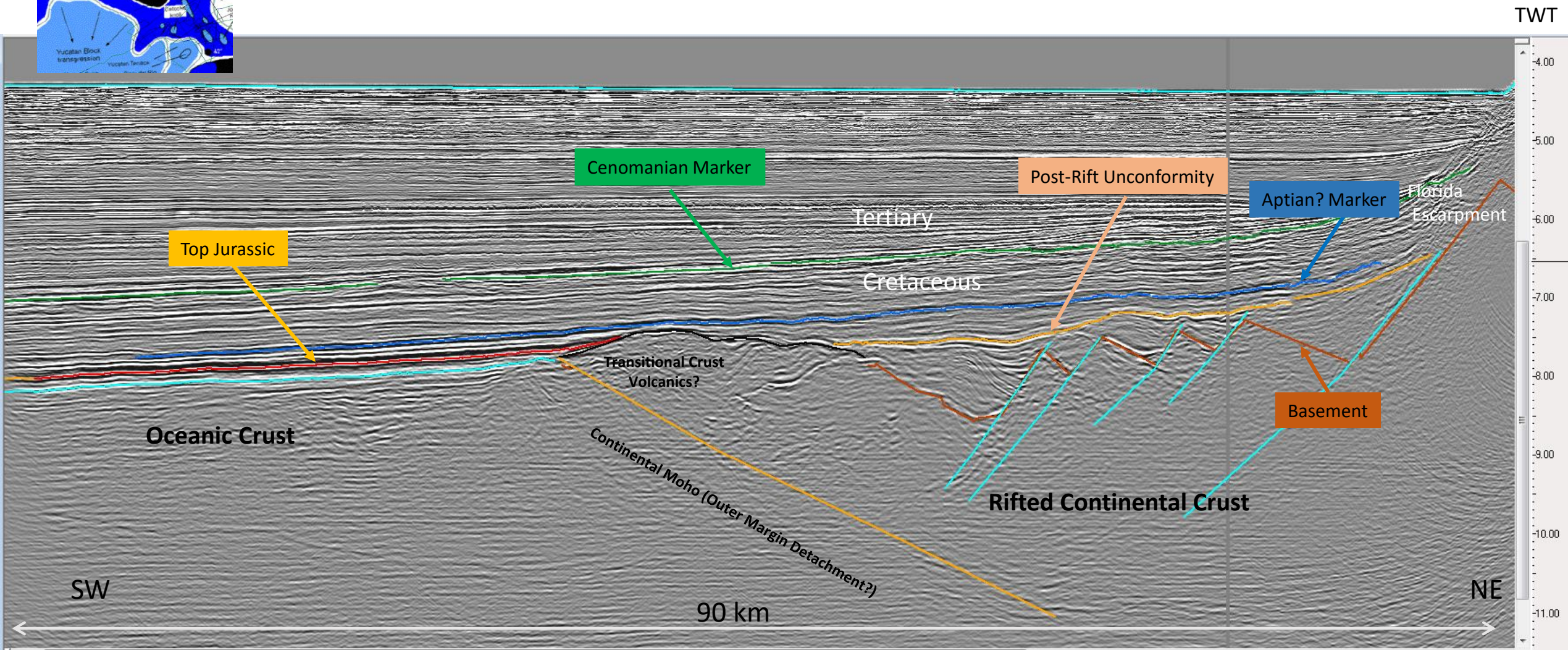
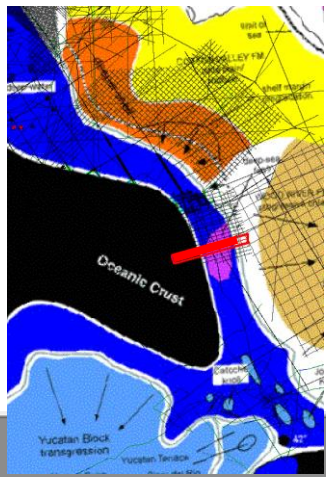
Modern PSTM seismic (SuperCache L-4800) clearly shows the “Top Berriasian” post-rift unconformity in continental domain of the SEGOM

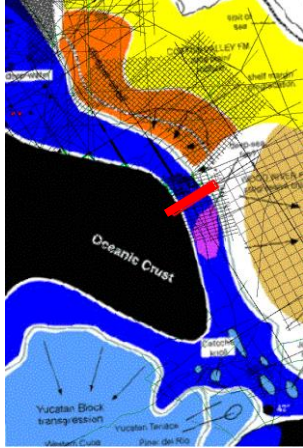
- Up-to 1 Sec (~2 km) Upper Jurassic deposited in a continental rift setting
- No salt deposition is observed
- Top Berriasian seals the rift-related structures, signals end of NE-SW extension in the area



South of the Tampa Embayment clear continent-ocean transition is observed (USGS PSTM data)

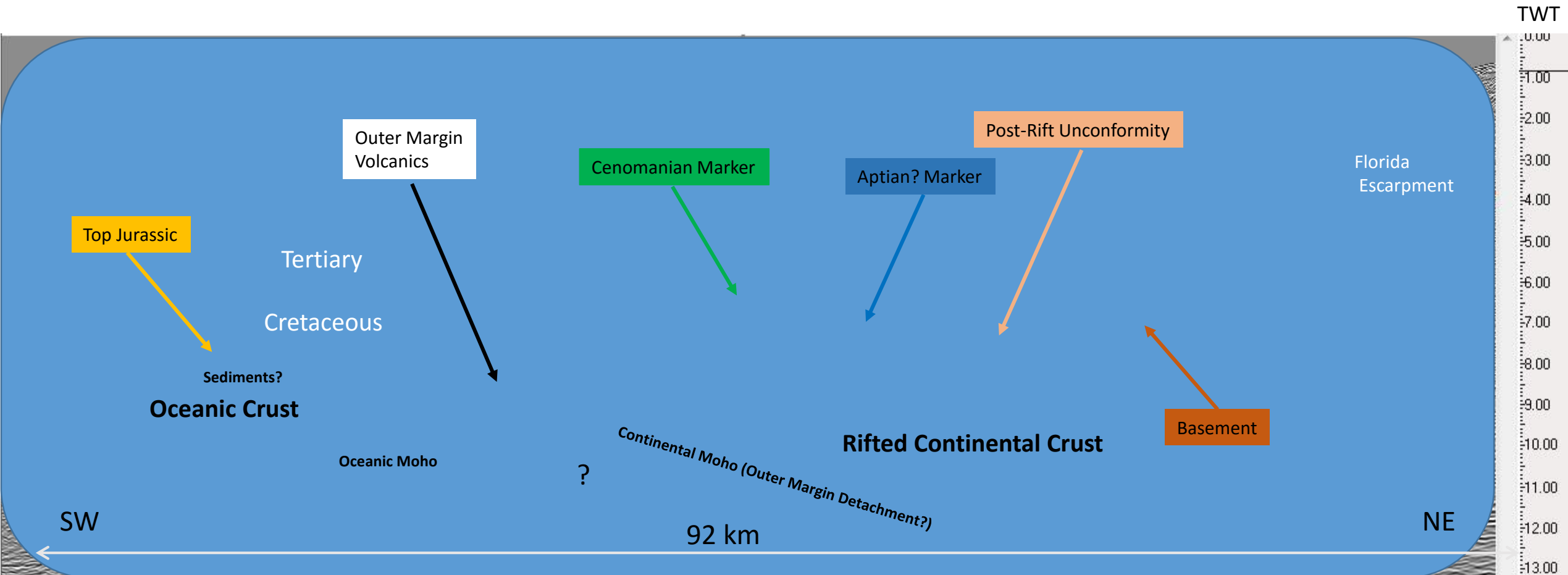
- Post Rift Unconformity is older here? (Kimmeridgian-Tithonian?)
- No salt deposition is observed
- Outer margin volcanism?
- Thin Jurassic over oceanic crust





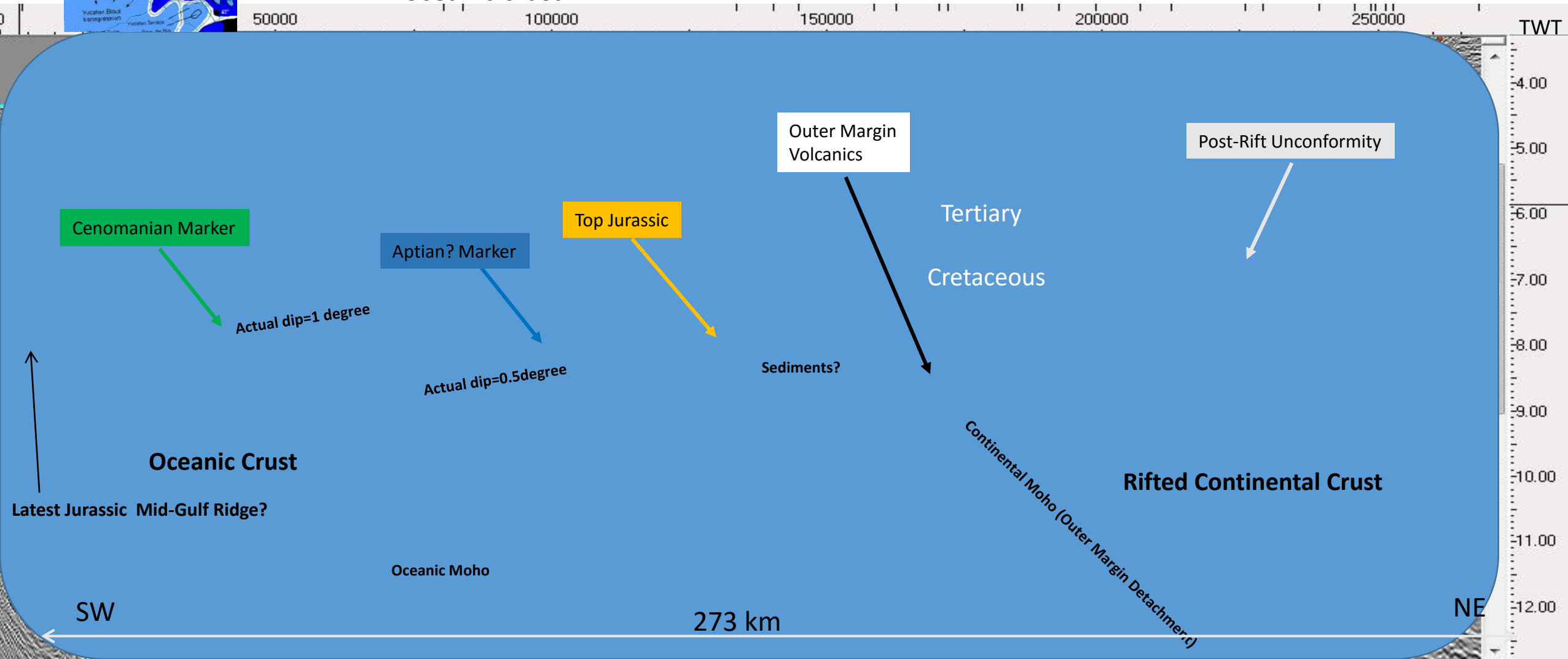
South of the Tampa Embayment on modern wide azimuth data the deep crustal features are well imaged (SuperCache PSTM L-3800)

- Post Rift Unconformity is older here (Kimmeridgian-Tithonian?)
- Outer margin volcanism is observed in frontal graben
- Thin Jurassic over oceanic crust.
- Post-Rift unconformity correlates below Top Jurassic marker.

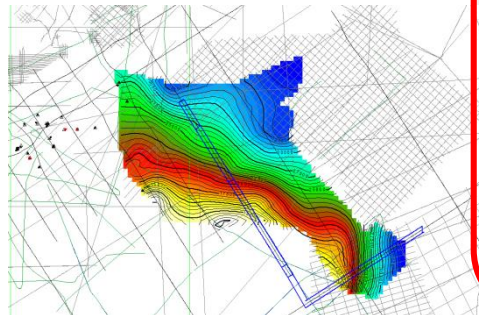
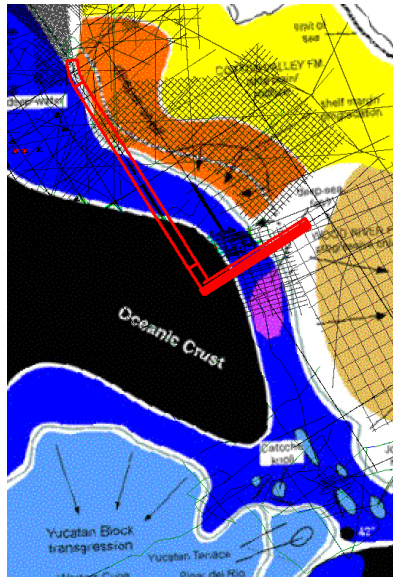
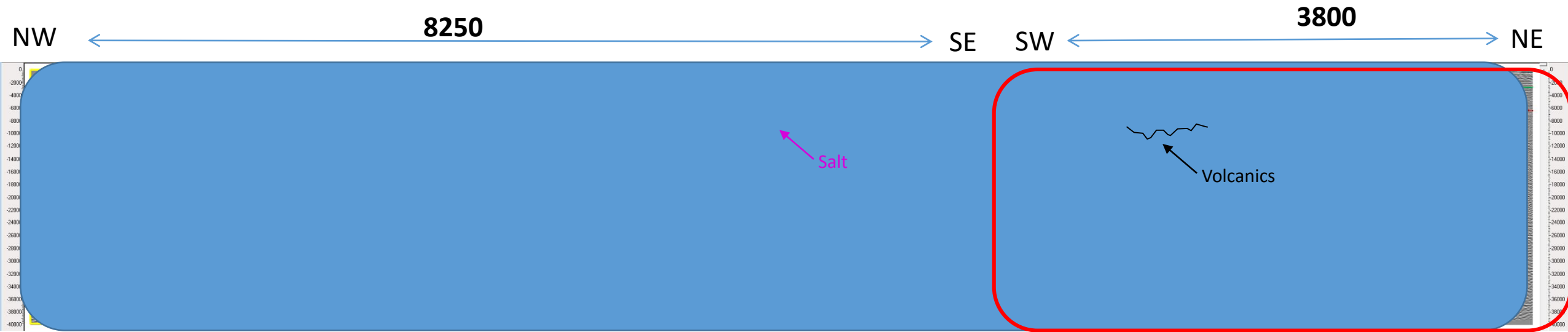


South of the Tampa Embayment the SuperCache PSTM L-3800 showing both the continental and oceanic domains

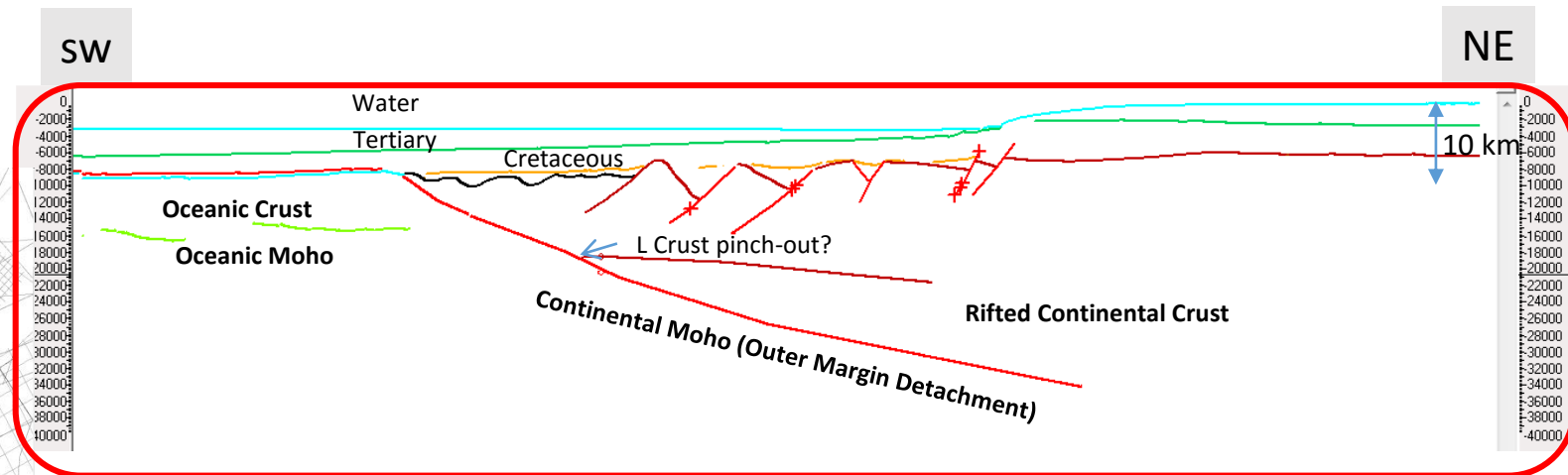
- Tilt of the Cenomanian Marker in the depth domain is ~ 1 degree
- We interpret that that Cretaceous markers onlap (rather than downlap) onto the oceanic crust
- This “onlap” relationship can only be used to determine the upper age (can’t be younger) of the oceanic crust



Composite SuperCache PSDM seismic line showing Crustal architecture and sedimentary record along the NW_SE and SW-NE lines (VE: 2)

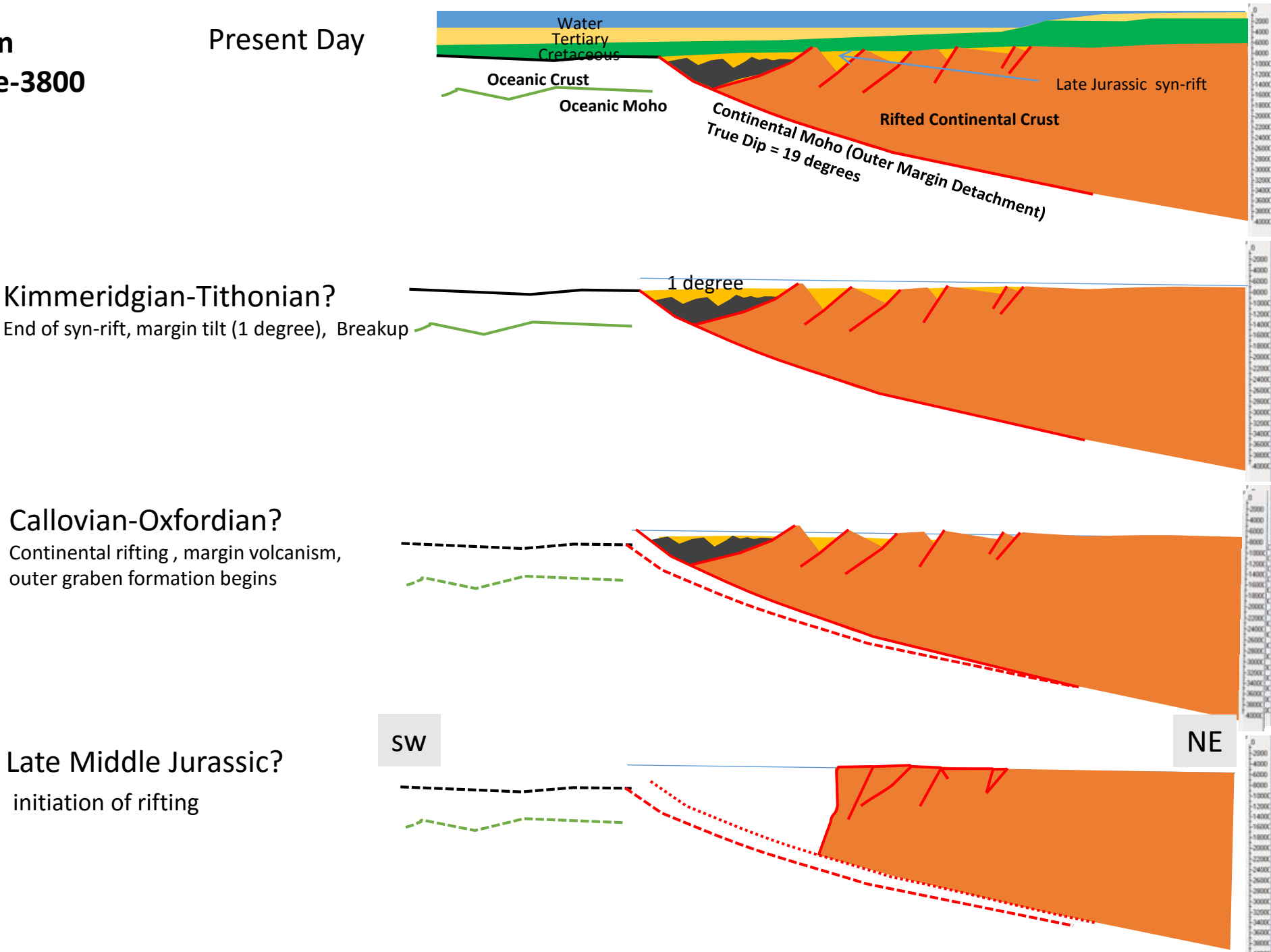


Moho Dip Map



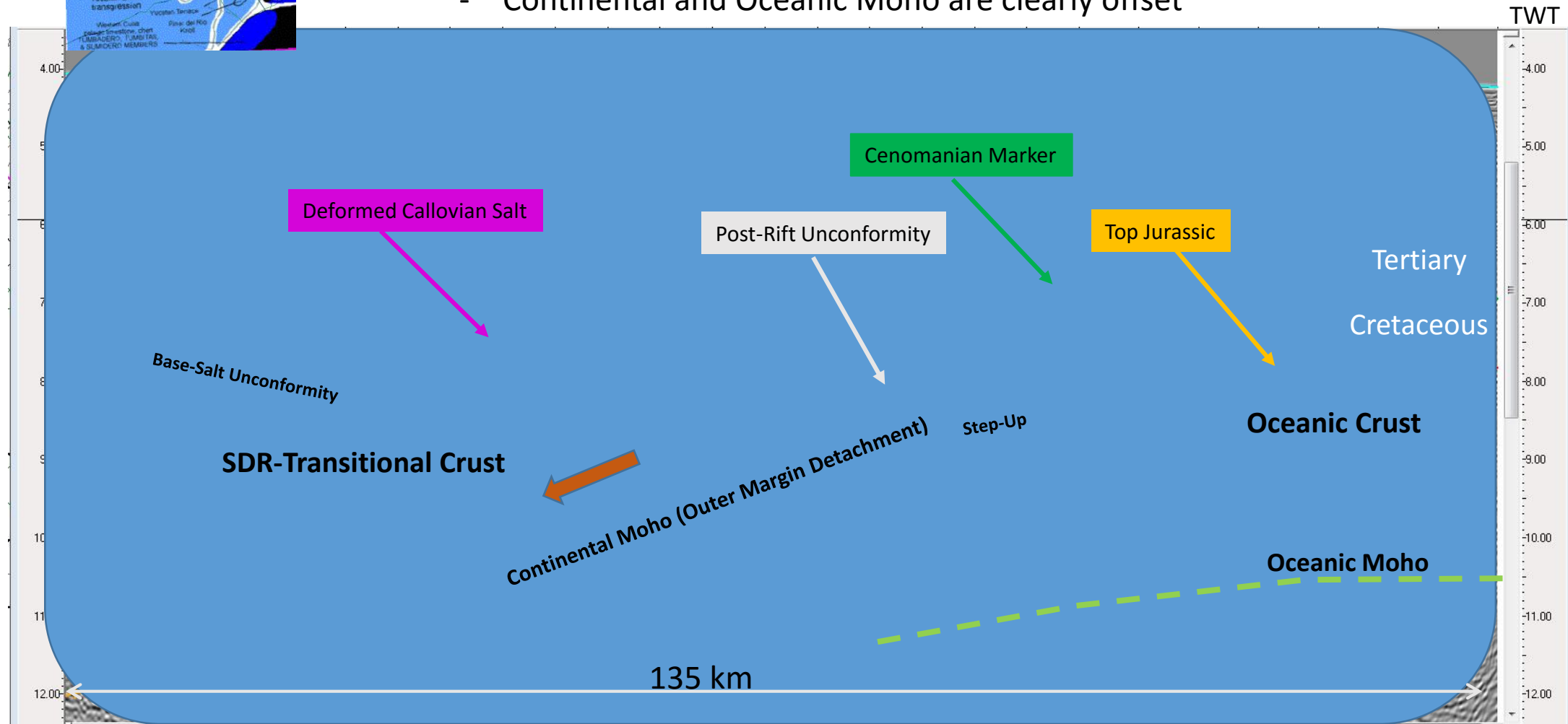
SW-NE Line-3800 cross section template (VE: 1)

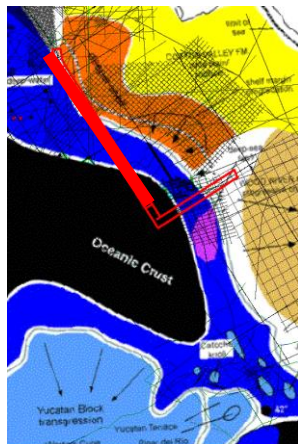
A) Schematic section
restoration of SW-NE Line-3800
to early rifting



Continent-Ocean transition North of the Tampa Embayment (SuperCach PSTM L-8250). Post-Rift Unconformity is the top of the Salt (Callovian-Oxfordian?)

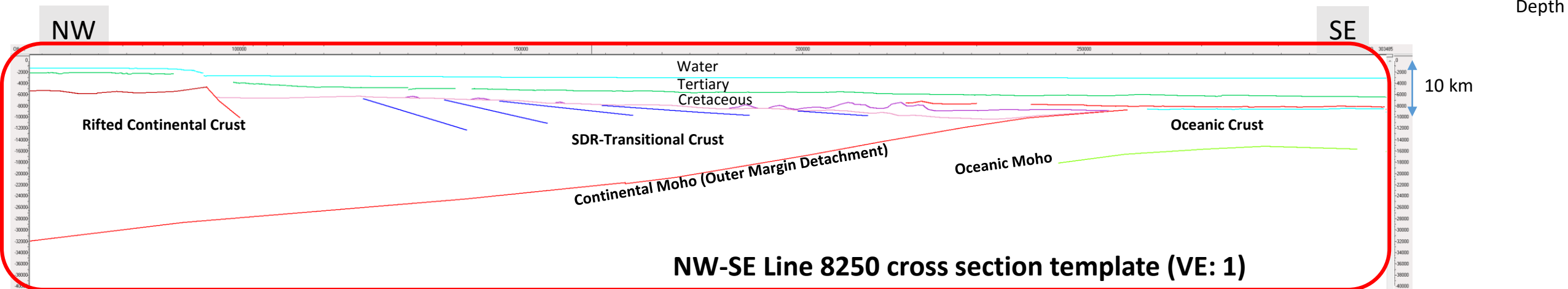
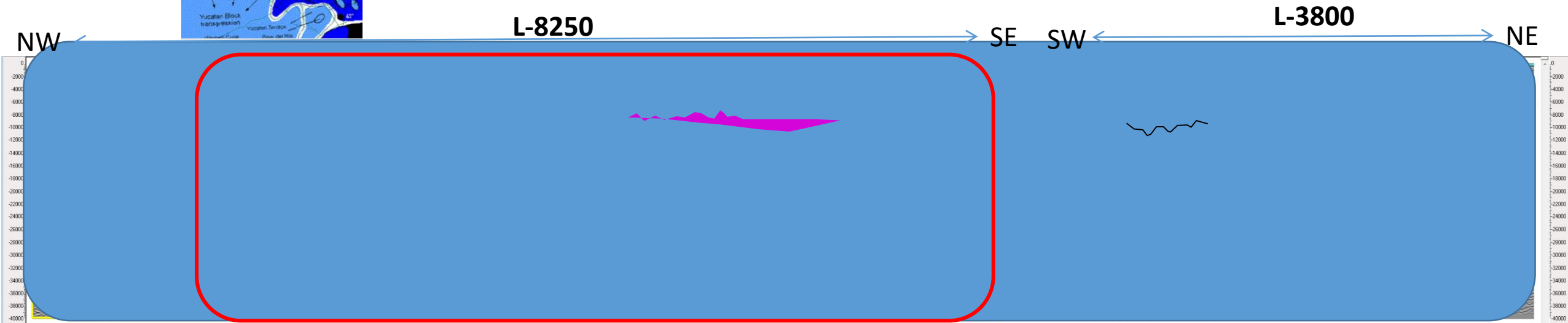
- Salt deposition occurred during the last phase of rifting and was likely directly deposited above unroofed mantle in the outer-margin collapse graben (Pindell, 2014)
- Outer-margin salt deformation (swelling and thrusting) mostly completed by the end Jurassic.
- Continental and Oceanic Moho are clearly offset





Composite SuperCache PSDM seismic line showing Crustal architecture and sedimentary record along the NW_SE and SW-NE lines (VE: 2)

- N Gulf: SDRs with variable dips, flat base-salt unconformity, salt deposition during last stage of rifting
- SE Gulf: Rotated fault blocks, lack of salt, continental margin volcanism, syn-rift section has younger sediments than salt.

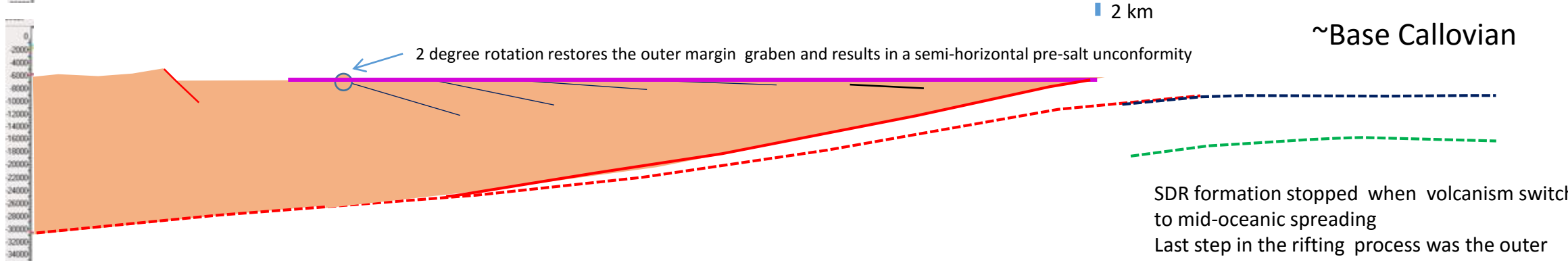
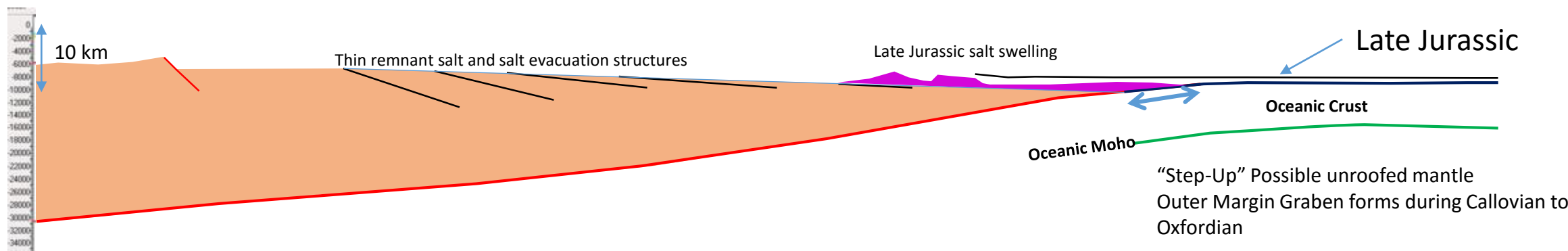
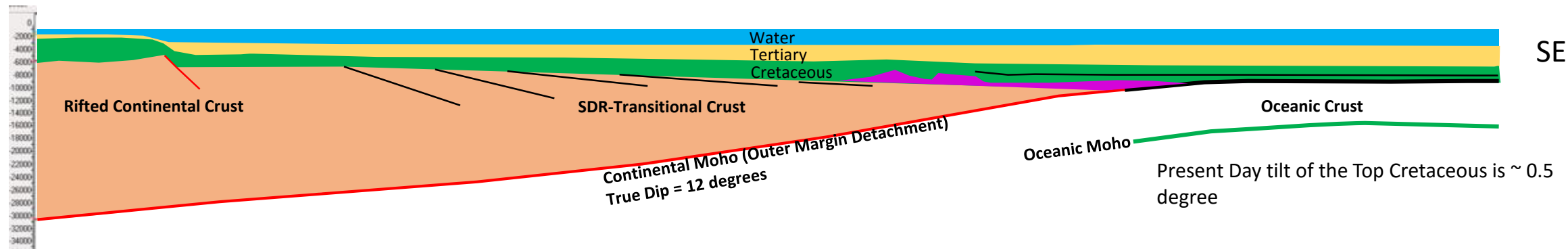


A) Schematic section restoration of NW-SE Line-8250 to late rifting

Present Day

NW

SE



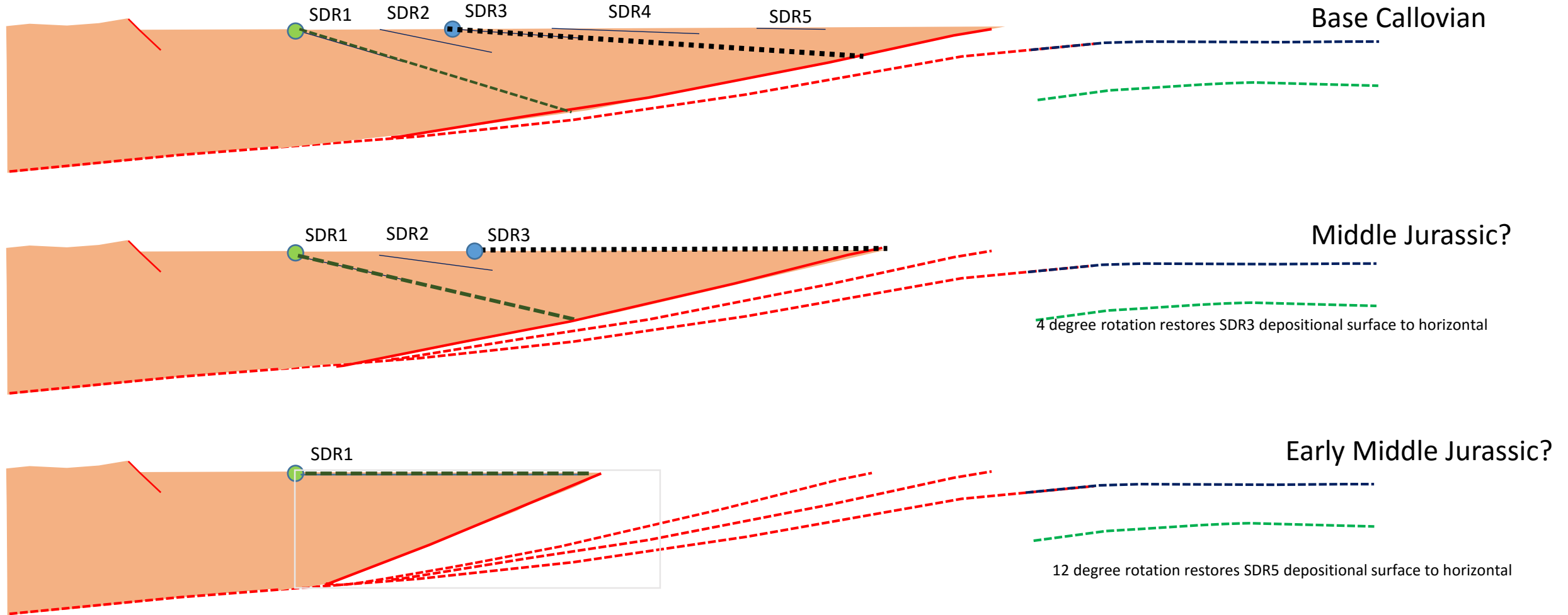
SDR formation stopped when volcanism switched to mid-oceanic spreading
 Last step in the rifting process was the outer margin graben formation.
 Since salt has also deposited in the outer margin graben, it has to be regarded as late syn-rift sediment in this location

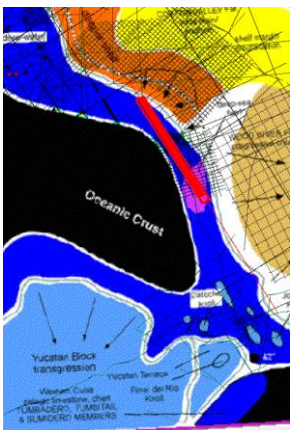
B) Schematic restoration of observed SDR events on the NW-SE Line-8250

- The underlying assumption is that SDRs are sub areal basalt flows
- Very large amount of “extension” has been accommodated during SDR formation

NW

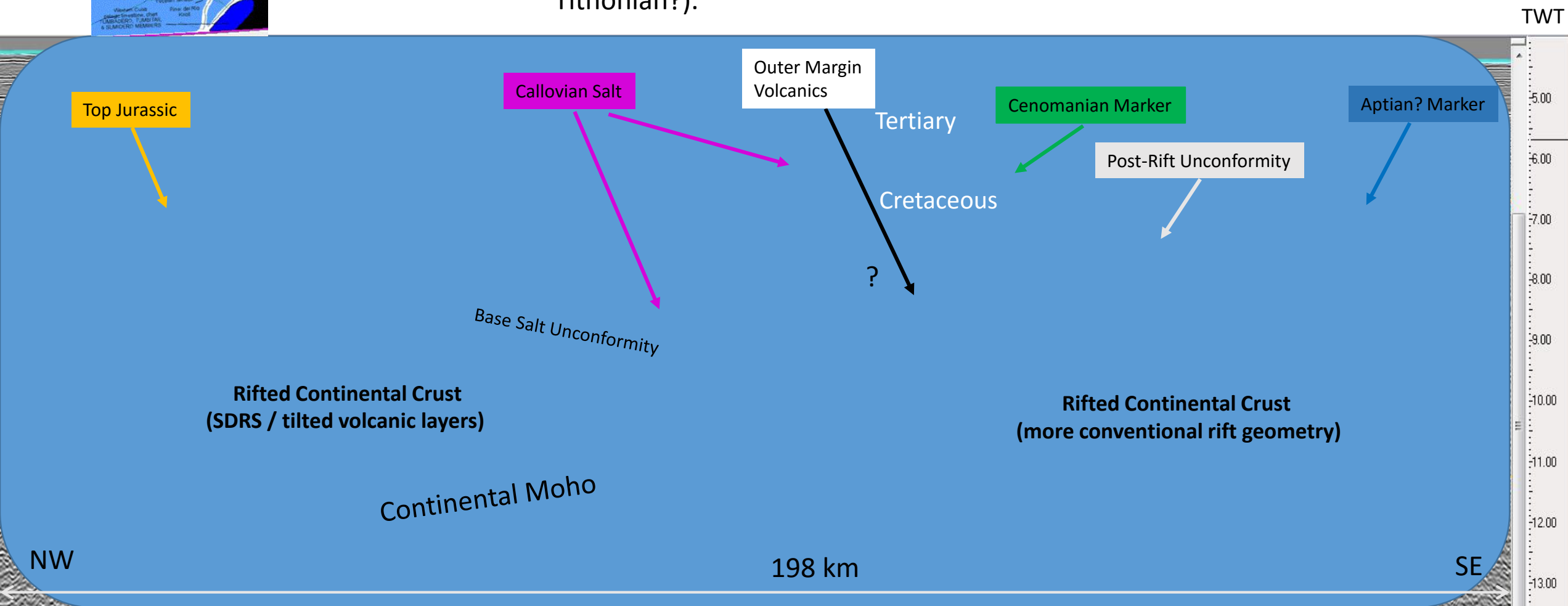
SE



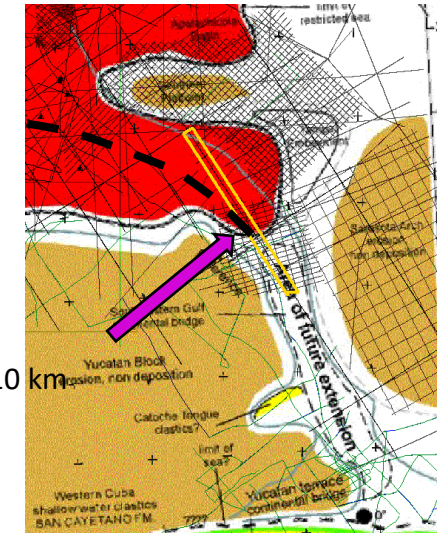


Edge of the salt basin at the southern entrance to the Tampa Embayment (SuperCache PSTM L-8450)

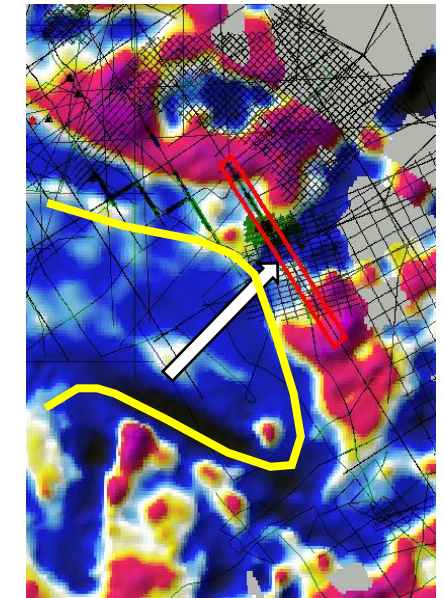
- Salt deposition north of and in the Tampa Embayment. Up-to a Second (~2 km) salt and un-faulted Upper Jurassic are observed.
- Salt pinches out against the S-flank of the Tampa Embayment
- Post Rift Unconformity south of Tampa Embayment is (Kimmeridgian?-Tithonian?).



- N Gulf: SDRs with variable dips, flat base salt unconformity, salt deposition during last stage of rifting
- SE Gulf: Rotated fault blocks, lack of salt, continental margin volcanism, syn-rift section is mainly post Callovian Upper Jurassic

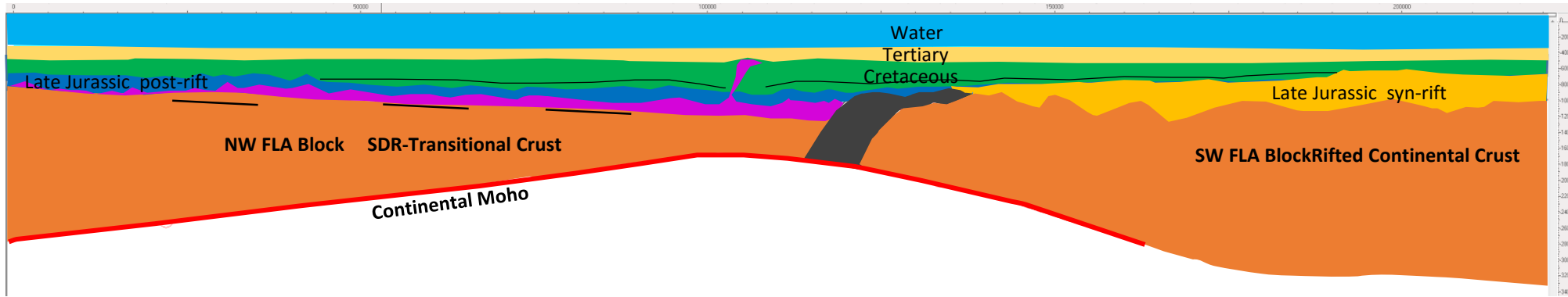


Callovian Restoration and salt deposition limit

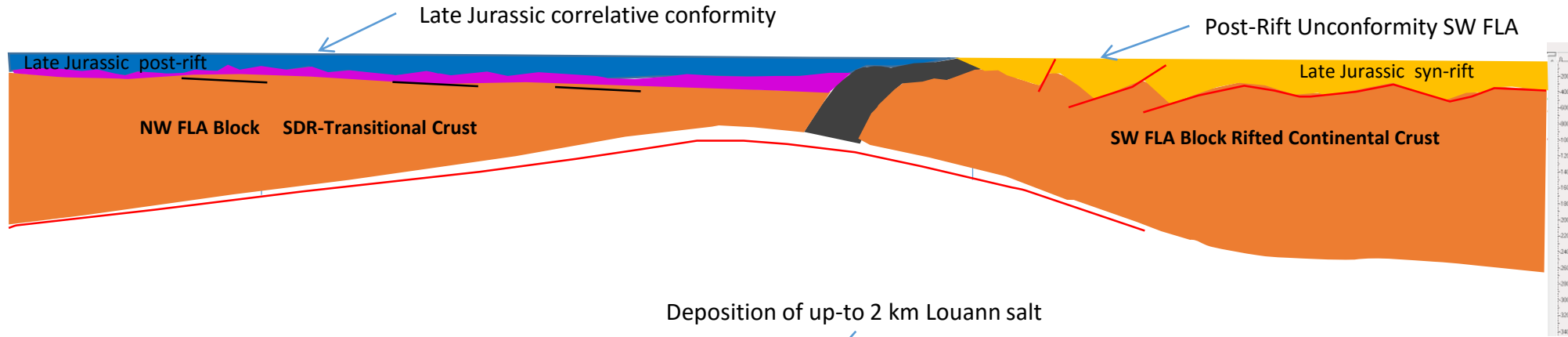


Magnetic Anomaly Map E-Gulf

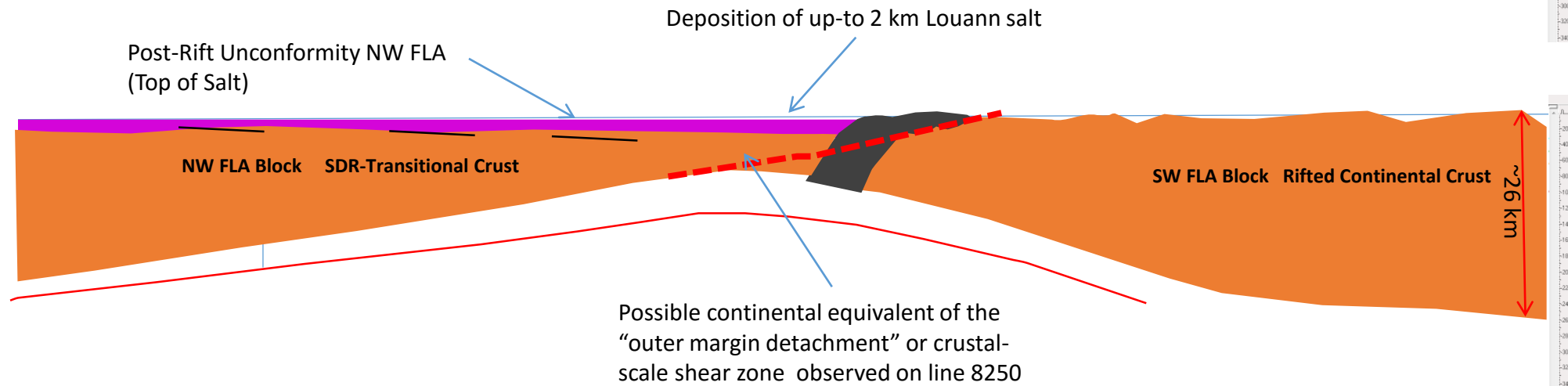
Schematic section restoration of NW-SE Line-8450



Present Day
Cretaceous thermal subsidence is largest over thinner crust



Kimmeridgian-Tithonian?
SW FLA: Continental rifting
NW FLA: post-rift basin fill, salt deformation



Callovian-Oxfordian?
SW FLA: Continental rifting begins
NW FLA: Late Rifting, continental margin volcanism, salt deposition

Summary: Eastern Gulf propagating rift evolution

- Restoration of NW-SE L-8250 (north of Tampa Embayment):
 - Wide area of “transitional” crust (Moho dips ~ 12 degrees), remained at or above paleo sea level till the Callovian
 - The roll of SDRs in the formation of “transitional crust” in the EGOM is non-trivial but may have accommodated a large amount of extension
 - Salt deposition coincided with the “outer-margin graben” formation and margin tilt
 - Salt represents the latest syn-rift sediments in the NE Gulf followed by **Oxfordian break-up in the NE Gulf**
- Restoration of NW-SE L-8450 (in front of Tampa Embayment):
 - Important structural boundary between the NW and SW Florida blocks is manifested by Callovian? igneous activity that separates the two blocks with different extensional timing and style.
 - The NW Block is underlain by an SDR-dominated crust which extended mainly during the Mid Jurassic in a NW-SE direction. The extension culminated in the Louann salt deposition.
 - The SW Block was rifted during the Upper Jurassic in response to a SW-NE directed extension as the Yucatan block rotated and the Gulf of Mexico oceanic crust propagated towards the SE.
- Restoration of the SW-NE Line-3800 (south of Tampa Embayment):
 - A relatively narrow rifted margin (Moho dip ~ 19 degrees)
 - Lack of well defined SDRs, but there is clear evidence for continental margin volcanism and block faulting
 - Outer-margin graben formation, margin tilt and subsidence below paleo-sea level occurred post Callovian. The age of the post-rift (break-up) unconformity is estimated to be **Kimmeridgian-Tithonian**
- Line-4800 SE GOM (continental extension only):
 - Large amount of SW-NE extension was accommodated in a continental rift setting. **Berriasian Post-rift unconformity in the SEGOM** signals the end of rifting (end of Yucatan rotation) and completion of oceanic crust formation in the GOM.

