AAPG VIRTUAL EVENTS
Latin America & Caribbean Region

CARIBBEAN 2021
TECHNICAL SYMPOSIUM · E&P SUMMIT

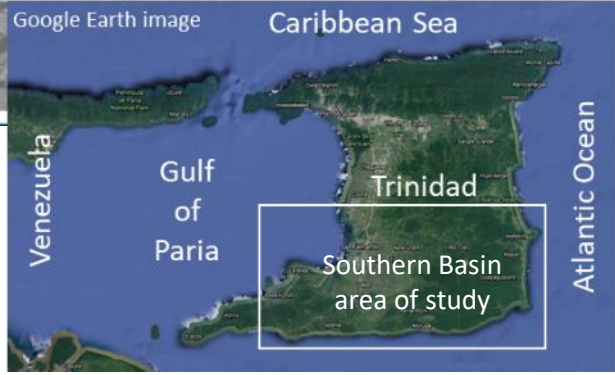
The Use of Tri-shear Forward Modeling Toward the Prediction of New Opportunities in Trinidad's Southern Basin

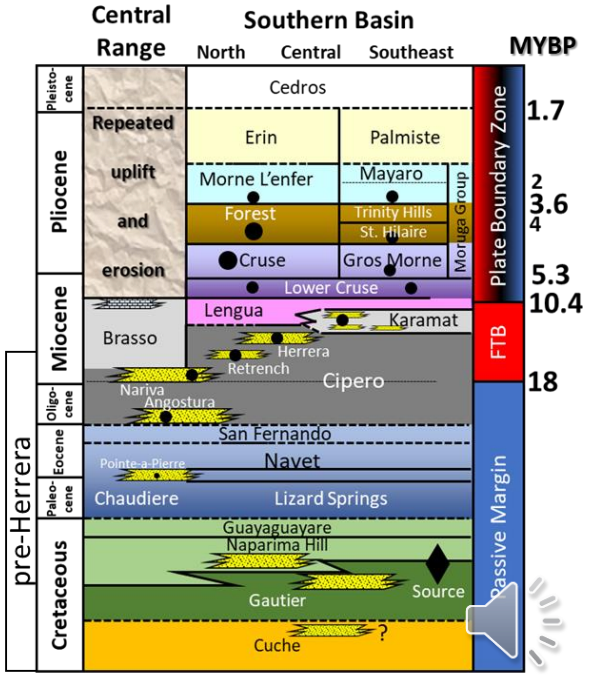
Leon Aden
Bifrost Energy

bifrost energy

Key Messages

- The structural complexity of Trinidad's Southern Basin has caused traditional modeling techniques to be inadequate for pre-drill structural precision
  - Contributor to exploration results within the pre-Herrera section
- Structural modeling is extremely powerful because it permits objective solutions, and needs to be a part of describing Trinidad's complex geology
  - Knock-on implications from model input
    - Vertical & lateral placement of structures & structural elements
    - Application can lead to a better understanding of seismic reflections
      - Improves pre-drill predictions of viable structures and their geometry
- Tri-shear forward modeling shown today highlights the potential to re-imagine Southern Basin opportunity identification
  - Out-of-sequence thrusting is common
  - Passive margin normal faulting, later inverted
  - Application in La Lune area yields intriguing results
    - Potential to expand its application across the Southern Basin

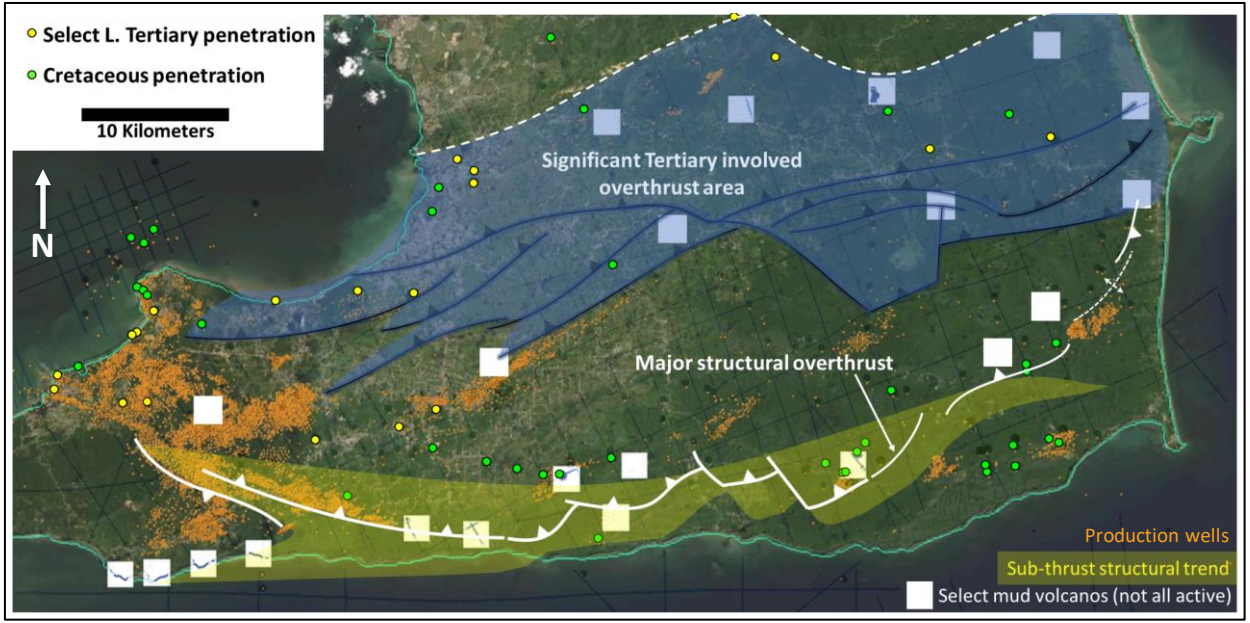




Modified from Bowman etal 2002

A Situation Analysis for pre-Herrera Exploration

- ~13,000 wells onshore & nearshore
  - ~2.5 billion bbls oil produced
- ~75 exploratory wells (in map area shown) in pre-Herrera section
  - 3 fields: combined EUR of ~75MBO
    - Some geographic bias, but understandable
    - Significant exploration effort…what caused past failures?
      - Tectonically stressed overburden*
      - Lack of reservoir*
      - Top seal compromised by mud diapirism and brittle shales**
      - Early initial structural timing with seal failure during subsequent events***
      - Inadequate precision in locating crests and steep limbs of compressional folds***



*not a focus of this talk **considered in this talk ***focus of this talk

Can Tri-shear Modeling Offer Improved Prediction for Southern Basin Exploration?

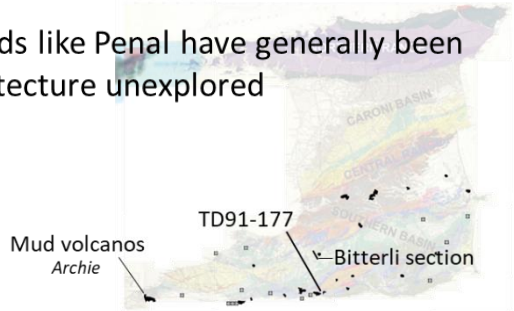
- The Penal area has long been used as an example of structural complexity in southern Trinidad
  - Interpreters have integrated wells, seismic, biostratigraphy, geochemistry, structure, and structural modeling, to derive their interpretations…

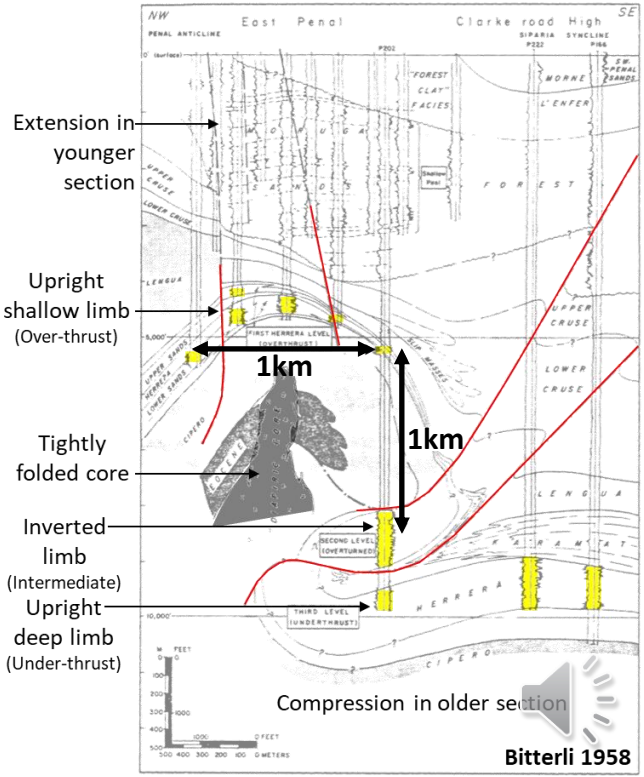
  …but limitations of seismic imaging associated with steep dips…

  …limitations of layer-parallel flexural slip deformation algorithms…

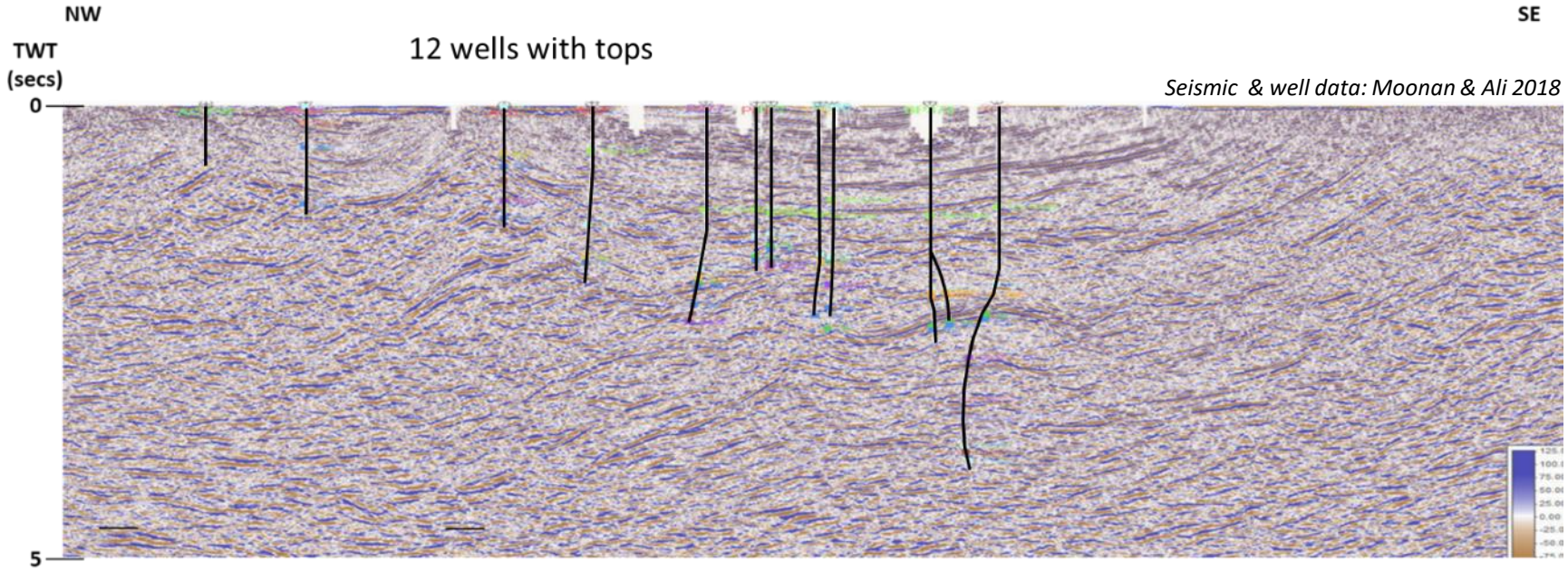
  …and multiple, over-printed deformation events create more complex interpretations in hindsight, but…

  …discovering the location and geometry of folds like Penal have generally been serendipitous, with significant structural architecture unexplored



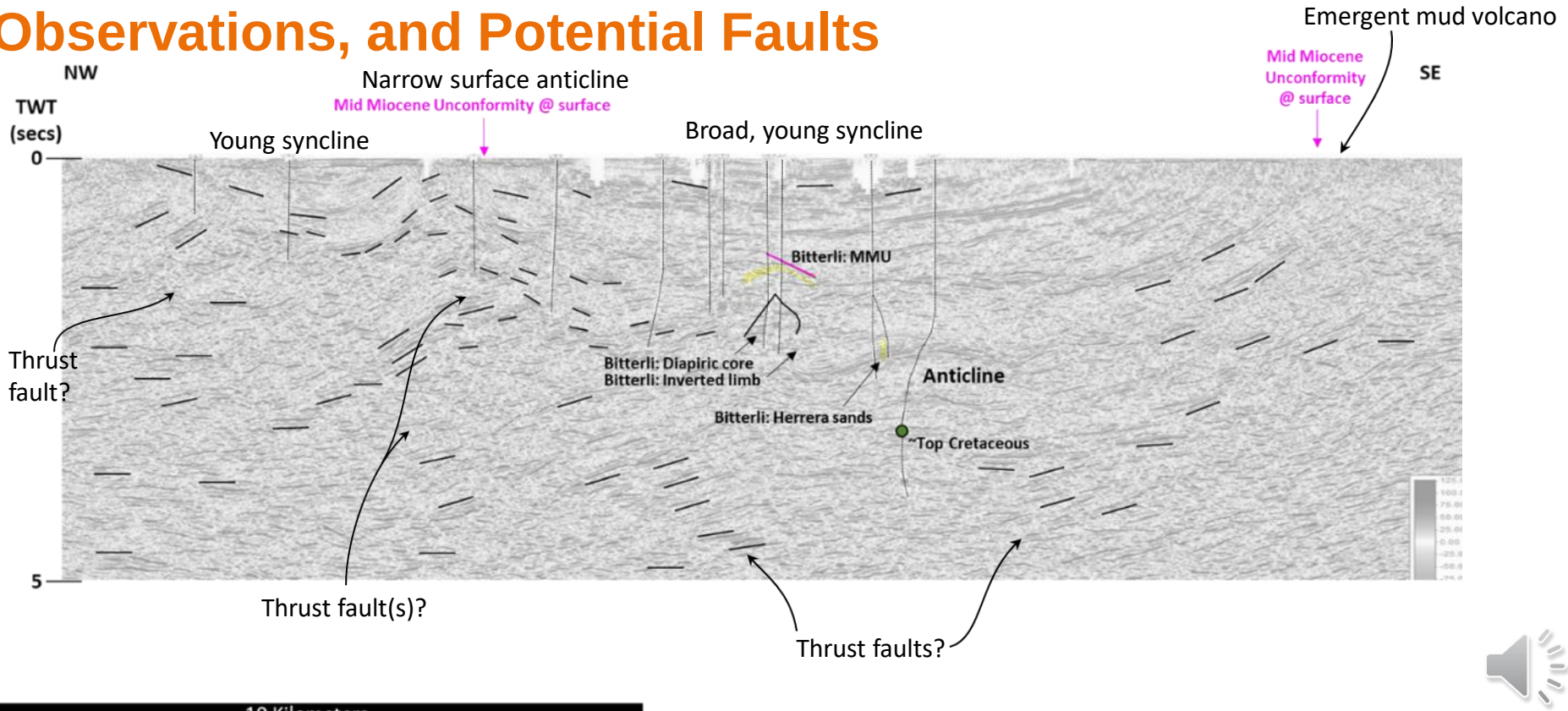


TD91-177: 2D Seismic and Wells

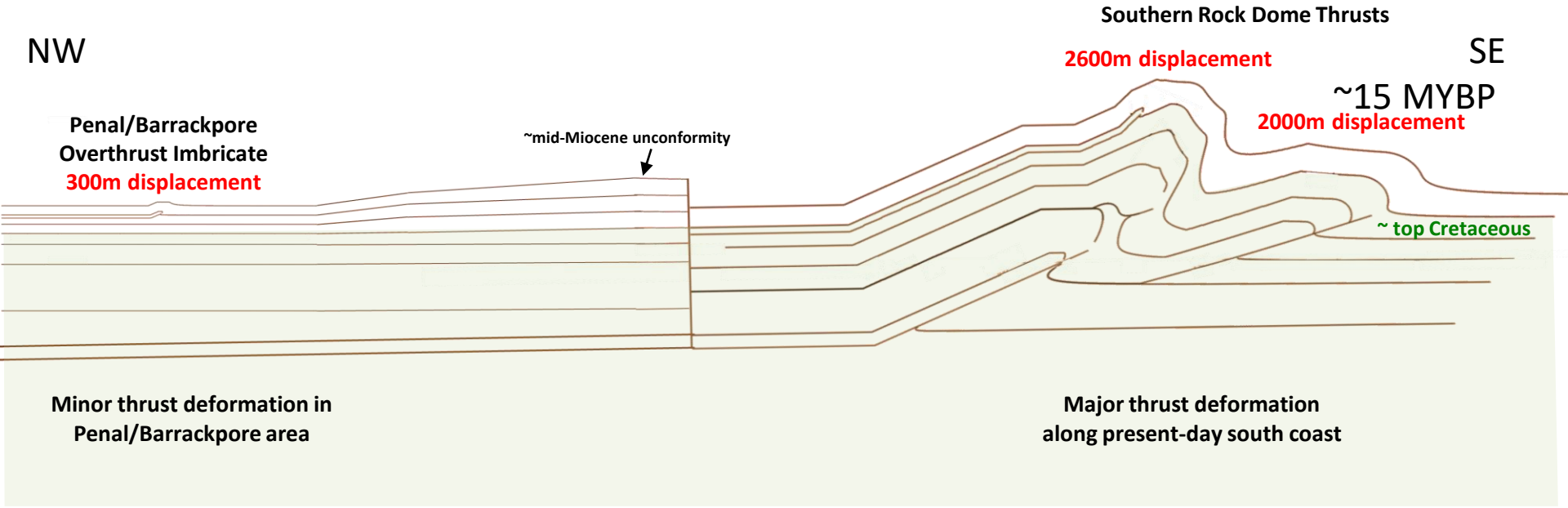


- **Good reflectivity** (for Trinidad 2D seismic), **and good well control** (to control placement of complex fold architecture) **traditionally make this a key line for Southern Basin structural analysis**
  - **To our knowledge, tri-shear forward modeling has not been previously published for any Trinidad line-of-section**

TD91-177: Geologic Elements, Seismic Observations, and Potential Faults

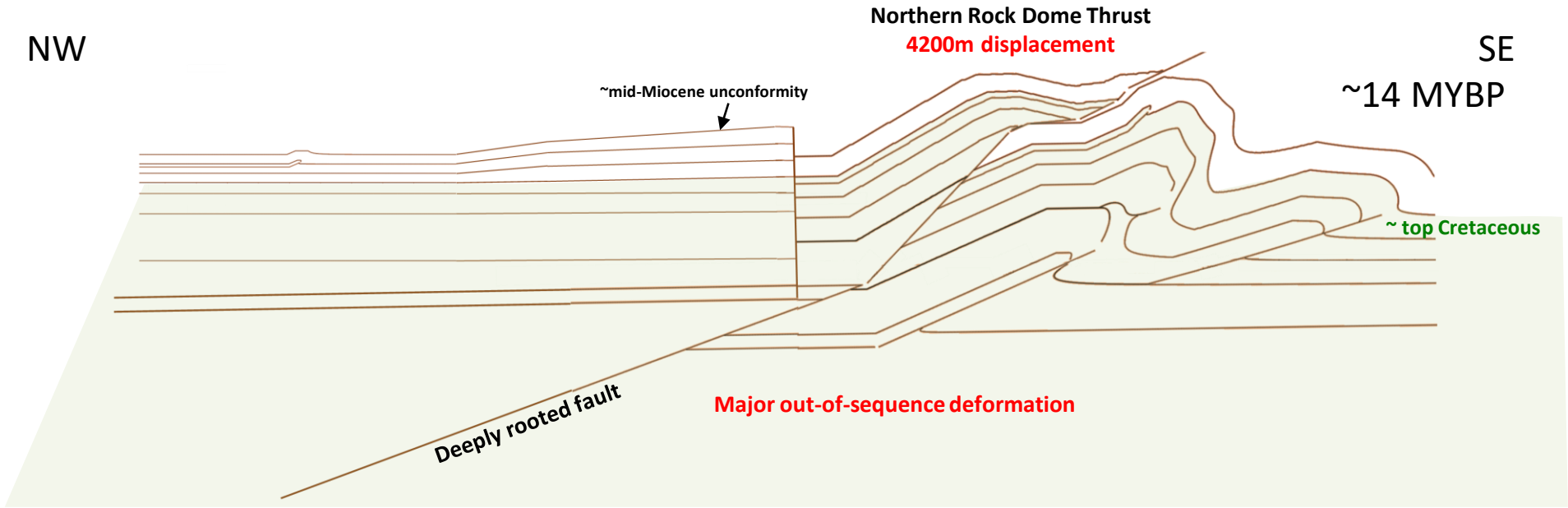


Forward Modeling of TD91-177
Southern Rock Dome Thrusting & Initiation of Penal / B'pore



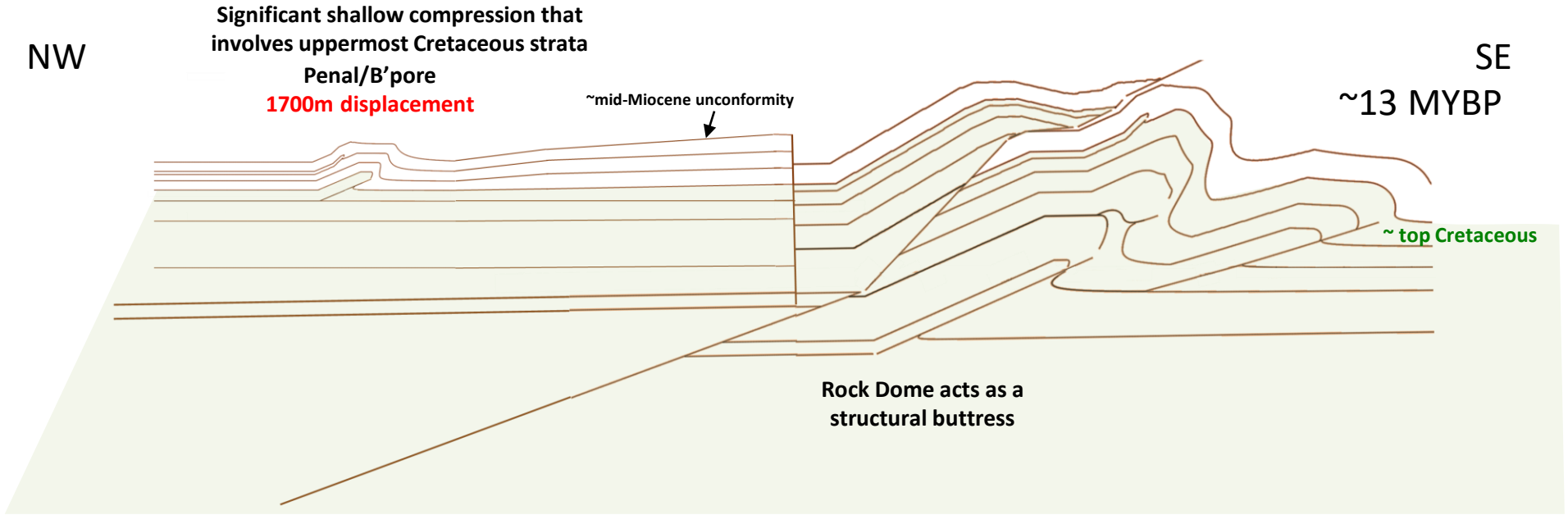
Model generated using Allmendinger's tri-shear code

Forward Modeling of TD91-177
Completion of Rock Dome Thrusting



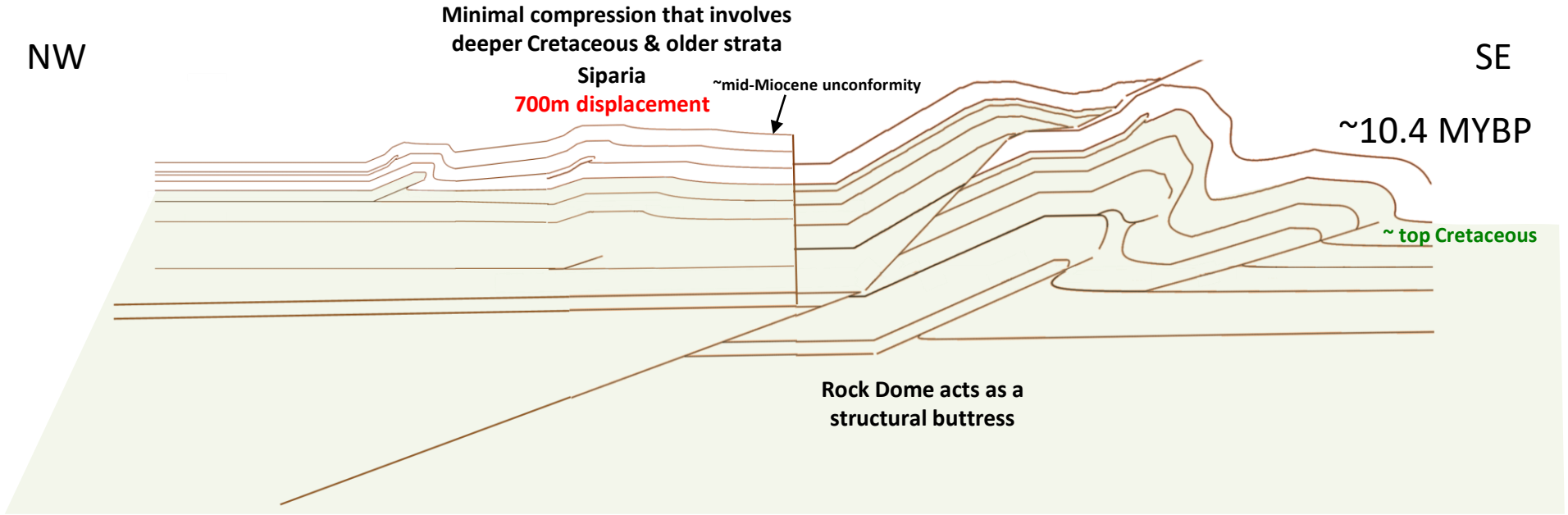
Model generated using Allmendinger's tri-shear code

Forward Modeling of TD91-177
Initial Development of Penal / B'pore Intermediate Limb



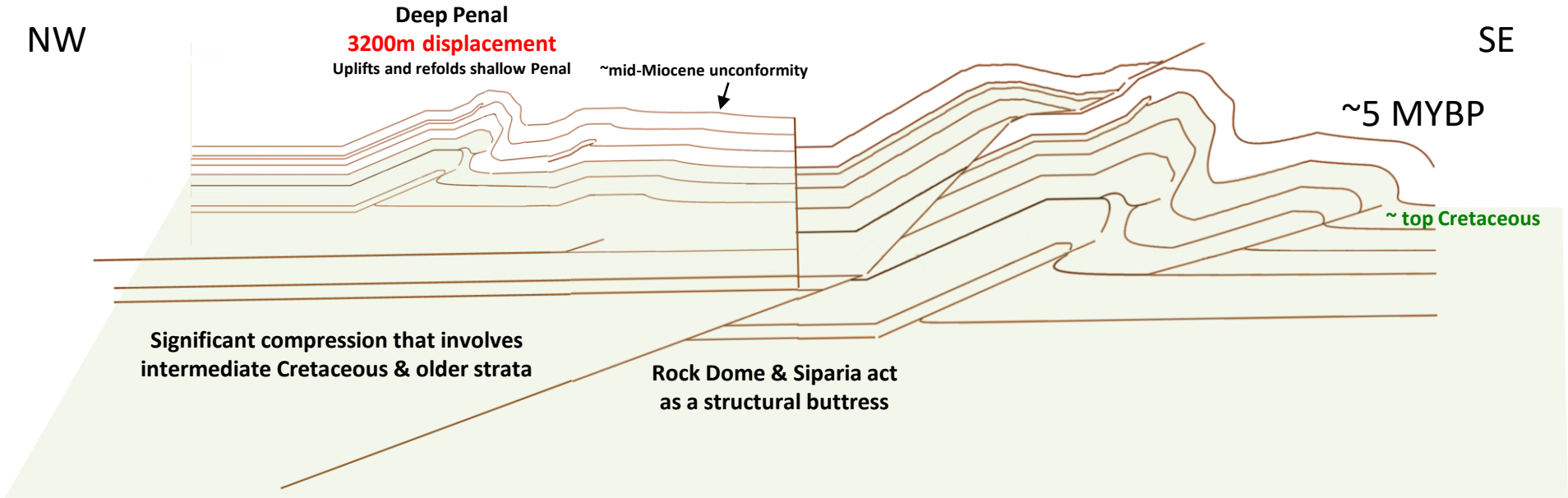
Model generated using Allmendinger's tri-shear code

Forward Modeling of TD91-177
Development of Penal / B'pore Underthrust (Siparia)



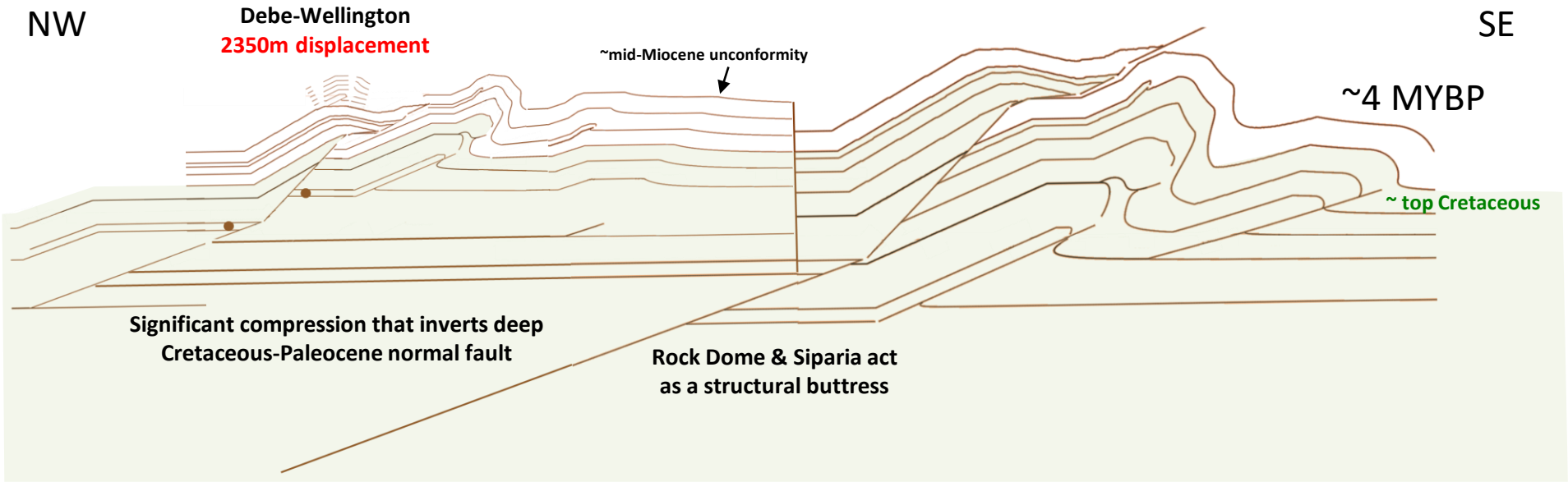
Model generated using Allmendinger's tri-shear code

Forward Modeling of TD91-177
Completion of Penal / B'pore Thrusting



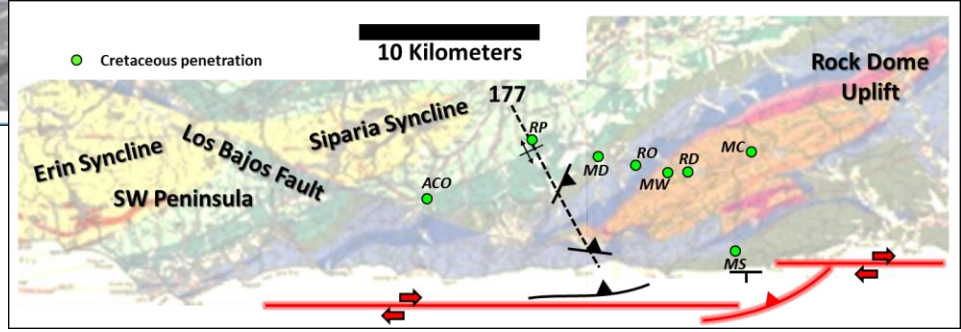
Model generated using Allmendinger's tri-shear code

Forward Modeling of TD91-177
Debe-Wellington Inversion



Model generated using Allmendinger's tri-shear code

Forward Modeling of TD91-177 South Coast Transpression



NW

SE

How does the well data within this area fit this model?

~mid-Miocene unconformity

Present-day

~ top Cretaceous

Transpression uplifts the greater Rock Dome area

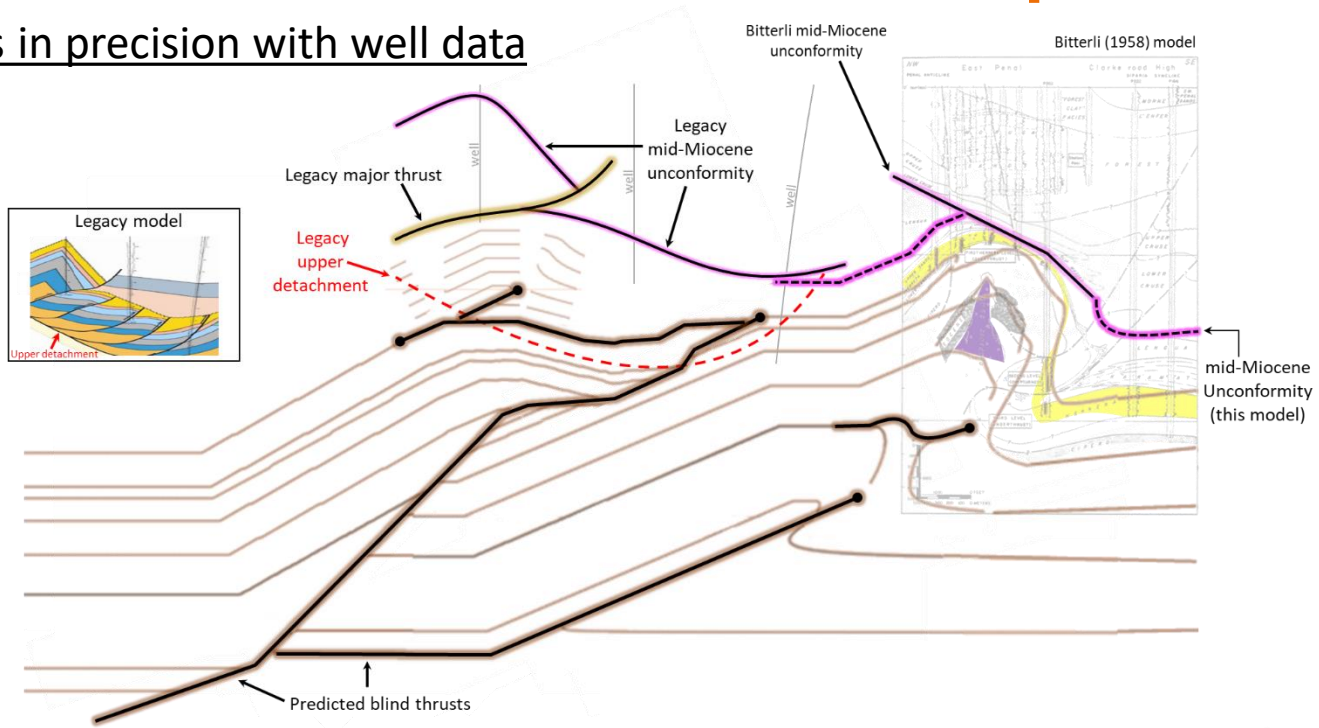
10 Kilometers

Penal / Barrackpore Area: Model to Well Comparison

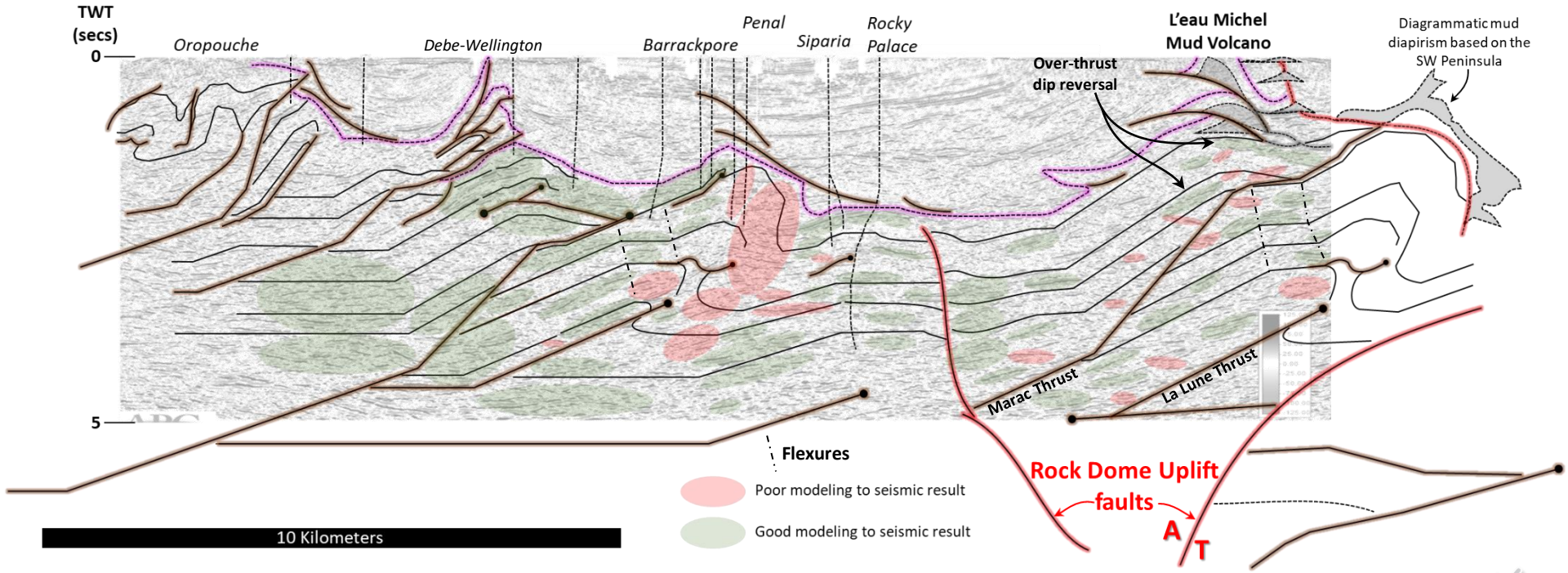
This forward model <u>succeeds in precision with well data</u>

Adds credibility to using it as a viable model for Trinidad's Southern Basin

Let's look at an extended model along line 177, and evaluate the model to seismic match…



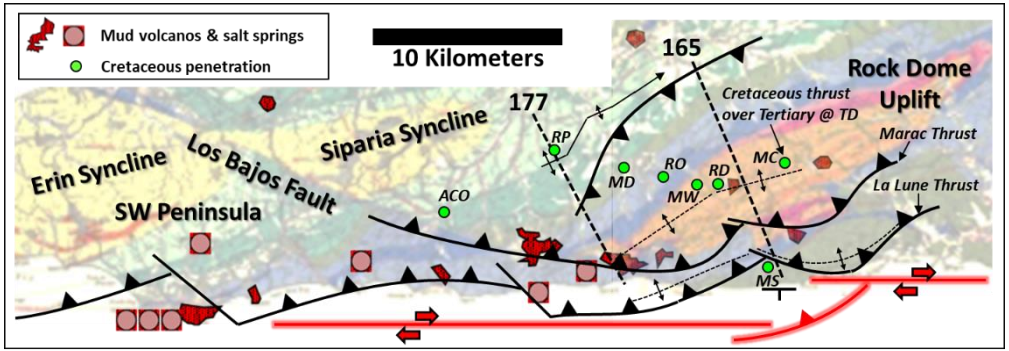
TD91-177: Model to Seismic Comparison

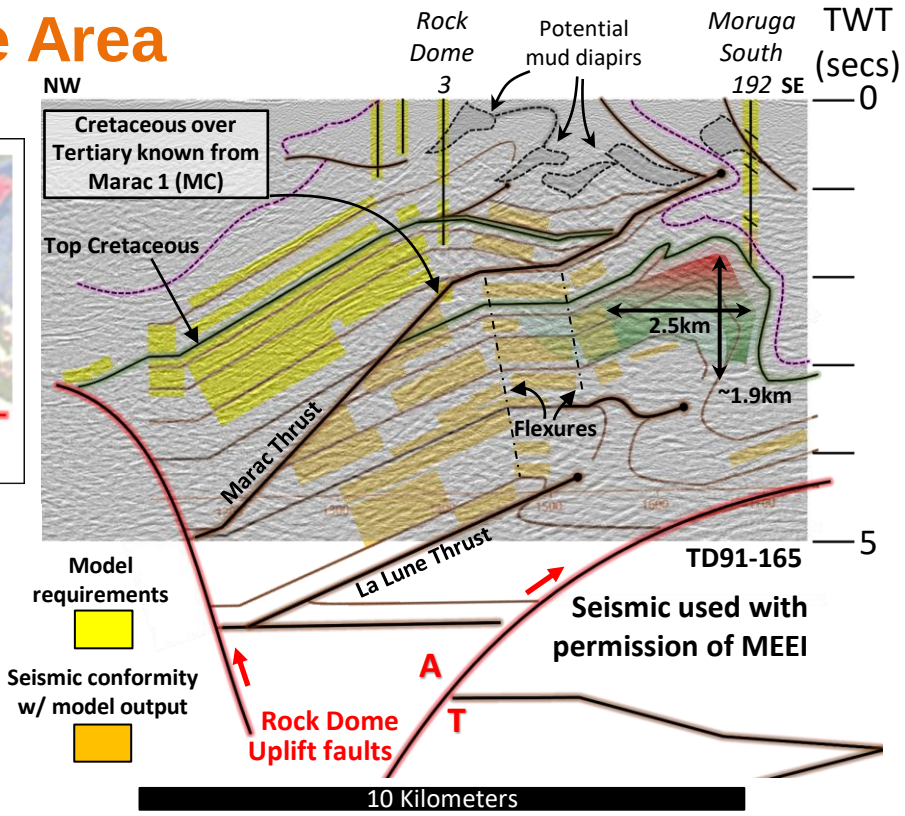


Elements of a Debe-Wellington/Penal-B'pore fault/fold set can be interpreted between Rock Dome Uplift faults
Can this be substantiated on adjacent seismic lines?

Model Application in Rock Dome Area

Trinidad Structural Elements





- Line 177 model imposed on Line 165; integrated with RD3 & MC well data
  - Model predicts the placement, tops, and fold geometry of La Lune structure
    - Very good fit with MS well data
    - Good seismic conformity of north limb (including flexures)
      - Model places fold position and dimensions

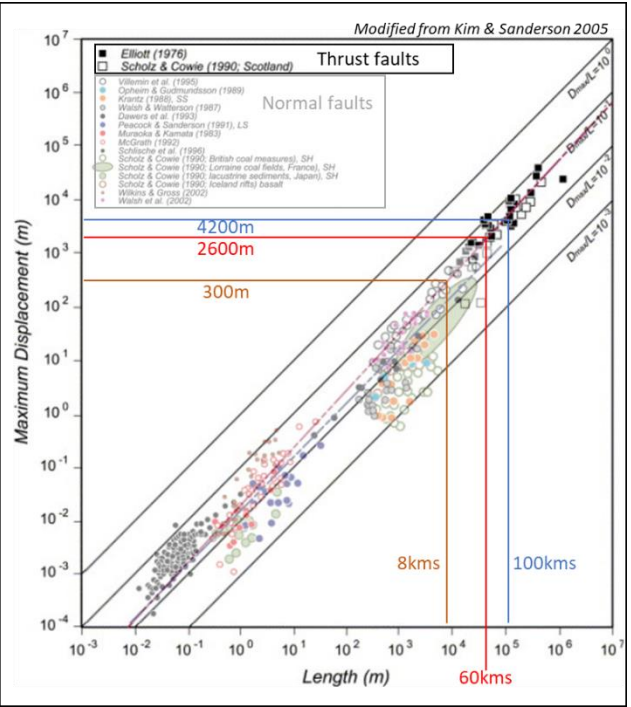
- RP, MD, RO, MW, and RD all penetrated Cretaceous clastic reservoirs
  - No clastic reservoir encountered @ MC (complete Cretaceous section) or MS (tagged top Cretaceous only)

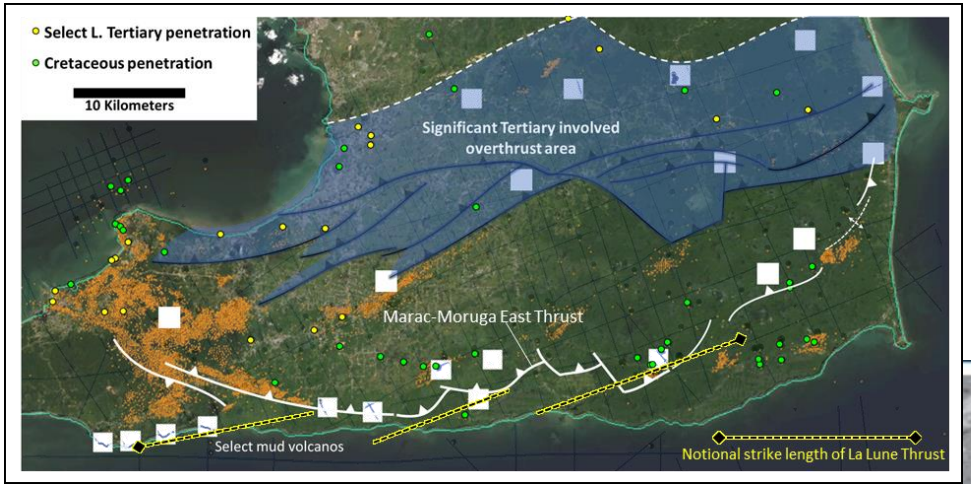
- A La Lune stratigraphic/structural opportunity exists, with some remaining reservoir and important diapiric seal risks

Takeaways for Southern Basin Exploration

- Comparing Trinidad's fault displacements with global analogs suggests many thrusts should have extensive strike length
  - Applying this tri-shear technique elsewhere in the Southern Basin suggests multiple underexplored thrust trends involving Trinidad's pre-Herrera section
    - Modeled geometry can "find" elements of predicted structures within the regional 2D seismic dataset, highlighting favorable closure areas
      - Looking for tri-shear geometry is a new use of existing seismic data, likely leading to new opportunities that marry structural targets with positive reservoir and seal relationships

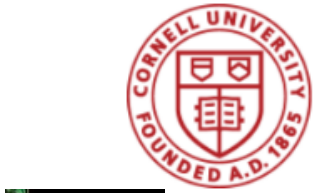
Global Fault Displacement *vs.* Length

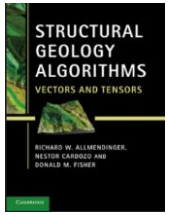


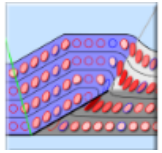


Acknowledgements

Trinidad Ministry of Energy and Energy Industries
(www.energy.gov.tt)

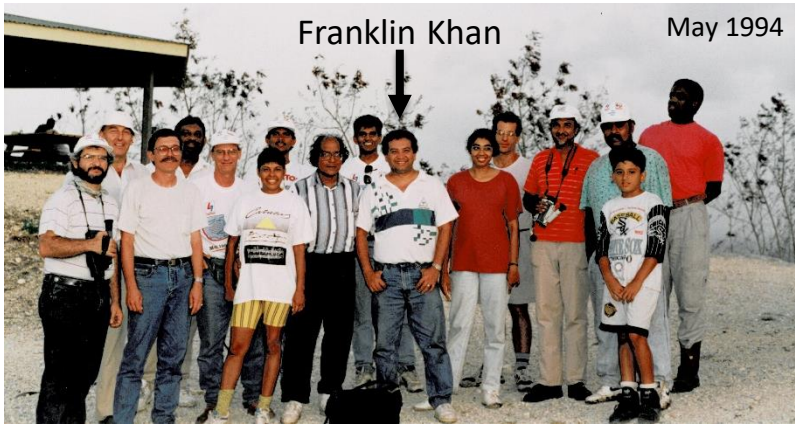






Fault/fold

Rick Allmendinger
(geo.cornell.edu/geology/faculty/RWA)



…and the many geoscientists who have worked the “graveyard of geological reputations”

IOWA

bifrost energy