New observations demand revisions of currently accepted tectonic models of the Gulf of Mexico

**Introduction**

- While most tectonic models agree that the initiation of the Gulf of Mexico began in the late Triassic with continental rifting and progressed to oceanic rifting around 160 Ma (e.g., Eddy et al., 2014; Snedden et al., 2014; Nguyen and Mann, 2016; Pindell et al., 2016), the original position of the Yucatan block and its subsequent journey are incredibly varied.

- The majority of published models restore the Western Yucatan margin to Texas-Louisiana as this provides a tight fit.

- We use potential fields and seismic data to identify geologic structures on the Yucatan and North America plate that were likely formed as conjugate margins to reconstruct the original position and motion of the Yucatan (from 200 to 137 Ma) to open the Gulf of Mexico.

**Tectonic features**

We applied a Bouguer correction to the original Free-Air Gravity grid from Sandwell et al. (2014), removed the regional trend and applied a high-pass filter to highlight shallow crustal structures. See Filina et al. (2020) for details on gravity reduction and filtering.

We have outlined the pre-salt basins and the regions of Seaward Dipping Reflectors (SDR) based on integration of potential fields and seismic data (Liu et al., 2019; Filina and Hartford, 2019).
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<table>
<thead>
<tr>
<th>Observation</th>
<th>Interpretation</th>
<th>Timing</th>
<th>Implication</th>
<th>Constraint</th>
<th>Reconstruction</th>
</tr>
</thead>
<tbody>
<tr>
<td>SDRs</td>
<td>Evidence of magmatic activity during continental rifting stage (Eddy et al., 2014; Liu et al., 2019; Filina and Hartford, 2019)</td>
<td>SDRs ~ 190 Ma (per DSDP well 535A, Buffler et al., 1984)</td>
<td>Magmatic burst during the last stage of the continental rifting and marks the end of extensive magmatism</td>
<td>The SDRs on the Yucatan block and on the North American margin should be near each other once reconstructed</td>
<td>187 Ma</td>
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<td>Presalt sedimentary basins (marginal rifts)</td>
<td>The syn-rift sediments before the deposition of salt at ~ 169 Ma (Pindell et al., 2019)</td>
<td>From ~ 190 to ~ 169 Ma, most likely deposited in the sag formed due to cooling at the end of the SDR magmatism</td>
<td>Local subsidence and accumulation of up to 5 km thick sediments (Williams-Rojas et al., 2012; Miranda et al., 2014) indicate lack of magmatic activity</td>
<td>Known to be in the eastern GOM (Sounders et al., 2017; Liu et al., 2019) and in the southern GOM (e.g. OReilly et al., 2017), so should be aligned once restored</td>
<td>175 Ma</td>
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<td>Outer Trough Zone of significant thickening of Jurassic strata in the Northern Yucatan</td>
<td>Evidence of uncontrolled flow of salt with the Jurassic overburden (Hudec and Norton, 2019)</td>
<td>~ 169 – ~160 Ma Post-salt continental stretching (Hudec et al., 2013)</td>
<td>Interpreted as exhumation of lower continental crust (Filina and Hartford, 2019) suggesting no magmatism immediately before oceanic spreading</td>
<td>May not have a conjugate structure as was developed in amagmatic settings and may be asymmetric; Initial oceanic spreading likely to be ultra-slow</td>
<td>160 Ma</td>
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<td>Phase 1 of oceanic spreading</td>
<td>Ultra-slow (0.9 cm/yr, Filina et al., 2020) spreading producing thin and uniform oceanic crust (~ 5 km; Christeson et al., 2014)</td>
<td>~ 160 – ~ 150 Ma (ages from Snedden et al., 2014)</td>
<td>Rotation of the Yucatan around the nearby pole produces E-W spreading centers, low availability of magmatic material</td>
<td>The E-W ridges from Yucatan and North America should be adjacent during reconstruction</td>
<td>150 Ma</td>
</tr>
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<td>Phase 2 of oceanic spreading</td>
<td>Slow (1.1 cm/yr, Filina et al., 2020) spreading resulting in thicker (up to 9 km) and layered crust (Eddy et al., 2018)</td>
<td>~ 150 – ~ 137 Ma (end of spreading is from Snedden et al., 2014)</td>
<td>Final separation of Yucatan from North America allows southward migration of the Yucatan block; Increase in magma supply</td>
<td>All oceanic crust should be formed by ~ 137 Ma</td>
<td>130 Ma</td>
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Additional Observations

1. GUMBO experiment images thinned and intruded continental crust with multiple magmatic additions (Christeson et al., 2014, Eddy et al., 2014 and 2018; Van Avendonk et al., 2015). This contradicts to tectonic models that propose the oceanic crust underlies all offshore of the basin (Lundin and Dore, 2017) and the ones proposing the presence of exhumed mantle (Kneller and Johnson, 2011; Pindell et al., 2016; Mingeuz et al., 2020)

2. The OCB for line GUMBO 2 is near the Sigsbee escarpment (Eddy et al., 2018; Filina, 2019) – this contradicts to many models reconstructing Yucatan to Texas-Louisiana margin (Eddy et al., 2014; Pindell et al., 2016; Nguyen and Mann, 2016) as they will end up with a wide overlap of continental crust.

3. All the recent models map the spreading center based on gravity data of Sandwell et al. (2014). The oceanic crust to the north of the spreading center is much wider than the southern one. This asymmetry is challenging to restore with a single spreading episode (Hudec et al., 2013; Nguyen and Mann, 2016).

Conclusions

- Temporal variability of magmatic regime during basin formation:
  - CAMP (~200 Ma) presumably responsible for the observed SDRs
  - Ultra-slow amagmatic spreading during the initial stage of the GOM opening ~160 Ma
  - Major ridge reorganization (~150 Ma) associated with increased magmatic supply.

- These variations in magmatic regime combined with apparent mismatches in geological geoscopes on “conjugate” margins call for some revisions of the currently accepted tectonic models for the GOM.

- We propose new locations of the Yucatan crustal block at 190 through 150 Ma that take into account geological observations listed in the Table on page 2.

Model Comparison

A. Model of Eddy et al., 2014
B. This study

Figures A and B show tectonic reconstruction at 190 Ma; see symbology on page 1. Figure A reconstructed using the model from Eddy et al., 2014, resulting in significant overlap of continental crust. Figure B is our reconstruction with both SDRs and pre-salt conjugate.

References

Nguyen, L. C., and P. Mann. 2018. Gravity and magnetic constraints on the Jurassic opening of the oceanic Gulf of Mexico and the location and tectonic history of the Western Transverse fault along the eastern continental margin of Mexico. Interpretation, v. 6, no. 4, p. SE25-SC55.
Sanford, A. L., Geiger, K. Roderups, and P. Hargraves, 2016, The Deformalization of Pre-Salt Lenses Blocks in the Deep OIiophere Campeche-Yucatán Basin: AAPG Annual Convention and Exhibition, Calgary, Alberta, Canada, Search and Discovery Article #048847