Continental Breakup and Formation of Rifted Margins: The Gulf of Mexico as a Natural Laboratory

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Identifying Theme: Rifted Margins

Rifted continental margins capture the full pre-rift through post-rift process of continental breakup. As such, studying rifted continental margins should be a central focus of the MARGINS Successor Program (Stern and Klemperer, 2008). Based on four workshops held during the past year (GSA Southeast Section and Annual Meetings, AGU Fall Meeting, and Workshop for Earthscope Science Plan meeting), we argue on behalf of >100 participants that the Gulf of Mexico (GOM) is an ideal place for such studies (Fig. 1). The GOM formed during a brief (~25 m.y.) period in Late Jurassic time when Pangea broke up to form the Tethys seaway (Dickinson, 2009). Rifting exploited the Paleozoic Ouachita orogenic belt in the northern Gulf, which formed during the final stages of assembly of Pangea, and on the west involved an extensive Mesozoic magmatic arc system formed by subduction along the western North American plate boundary (Torres et al., 1999; Barboza-Gudiño et al., 2008). Prior events include formation of a segmented south Laurentian rift and transform margin during the Cambrian, which followed the trend of the Mesoproterozoic Grenville orogenic belt (Mosher 1998). During rifting, Yucatan separated from Texas-Louisiana and slid south along the Tehuatepec transform (Marton and Buffler, 1994) allowing variations on the Yucatan margin to be compared with those of the NW Gulf.

The GOM basin presents several opportunities to study fundamental processes associated with continental breakup. We briefly outline 8 of these opportunities:

1) **Tectonic Inheritance.** Rift style and location are strongly influenced by preexisting lithospheric fabric, with continental breakup commonly occurring along the trend of the last orogen (Dunbar and Sawyer, 1989; Thomas, 2006). The GOM provides an opportunity to study the influence of two end-member cases: a "soft" collisional orogen in the central and eastern Gulf (eastern Ouachitas - thin-skinned deformation and minimal syn-orogenic telescoping of the crust, which results in relatively shallow mantle and a strong lithosphere), and a "hard" collision in the western Gulf (western Ouachitas - thick skinned deformation and a great deal of crustal telescoping, which generates both thick crust and a lithospheric weakness (Harry and Londono, 2004). In the GOM, we can evaluate how these two tectonic fabrics affect subsequent rifting under similar lithologies, thermal conditions, and extension rates.

2) **Rift Segmentation.** What controls whether transitional crust is broad (among the broadest in the world in the eastern GOM) or narrow (as in the western GOM)? How do along-strike variations in the nature of transitional crust and lithosphere segmentation impact the subsidence history and thermal evolution of the GOM margins? Rifted margins also vary from magma-rich (volcanic rifted margins, e.g. Norway) to magma poor (e.g. Iberia). Such variations are inferred along strike in the central Gulf of Mexico, from magma-rich beneath the Texas Gulf Coast (Mickus et al., 2009) to magma-poor beneath Louisiana-Mississippi (Harry and Londono, 2004). Do magma supply variations control the width of transitional crust, or do these variations reflect control by inherited tectonic fabrics? Although much of the syn-rift magmatic evidence in the GOM is deeply buried under late Mesozoic and younger sediments, a possibly unique opportunity to examine the GOM rift magmatic record is presented by xenoliths recovered from salt diapirs, some of which contain 160 Ma syn-rift alkalic lavas (Ren et al., 2009) picked up from underlying rift-related lavas.

3) **Mantle Fabrics.** What is the nature of mantle lithosphere and how does this change from continent, across the transitional crust, and into the center of the basin? Mantle xenoliths from central Texas (Young and Lee, 2009) indicate that the mantle lithosphere here is composed of slightly depleted spinel peridotite. Limited studies indicate strong, margin-parallel shear-wave splitting beneath the Texas Gulf coastal plain (Gao et al., 2008). Do the shear wave studies reflect crystal orientations developed during Jurassic rifting, or are they remnants of older events (e.g., the Ouachita orogeny)? This question speaks to how long mantle fabrics are preserved, and to whether orogeny or rifting may dominate mantle fabrics. Shear wave splitting beneath oceanic crust is generally perpendicular to the spreading ridge; because the spreading ridge is thought to have trended ~E-W, associated mantle fabrics would be oriented ~N-S, perpendicular to that observed beneath the coastal plain. How does the transition from rift-parallel to rift-normal fabric occur, and what does this signify about lithospheric evolution beneath the rift?

4) **Lithospheric Reactivation.** The Gulf coastal plain was magmatically and tectonically reactivated after the Jurassic, as revealed by Cretaceous low-degree asthenospheric melts (Griffin et al., 2010) and ongoing faulting. The landward extent of Cenozoic faulting and Cretaceous magmatism is generally associated with the landward limit of the Louann Salt. Is this reactivation a result of regional or plate-scale stresses? Local salt movement and/or eustatic rebound?

5) **Sedimentation, Eustasy, and Coastal Subsidence.** Sediments accumulated around the GOM range up to 18 km in thickness and are among the thickest of any continental margin. The NW GOM receives an extraordinary load of sediments from rivers draining southern Canada and the continental U.S. from east of the Rockies to west of the Appalachians as well as eastern central Mexico. This presents an opportunity to study source to sink depositional systems at a continental scale over a wide range of depositional environments, how rift architecture controls subsidence and thus sediment accumulation, and how sedimentation influences rift margin evolution. Evolution of this thick sedimentary section is also reflected in migration of the GOM shoreline. Position of the shoreline records the interplay between eustasy, sediment supply, tectonic subsidence and flexure. Understanding these variables has broad societal implications, from possible coastal flooding associated with sea level rise, to predictions of relative subsidence in important population centers like New Orleans.

6) **Salt Tectonics.** The GOM provides an ideal opportunity to study the connections between active faulting and salt movement on the scale of the coastal plain to continental slope, as well as more detailed studies of salt tectonic movements in environments ranging from shallow burial near the landward pinchout, deep burial beneath the shelf, and extrusion onto the abyssal plain. The GOM basin also provides world-class examples of a variety of salt tectonic styles (salt domes, ridges, welds, minibasins, etc.).

7) **Fluid Evolution and Migration**. The GOM is a factory for generating a wide variety of fluids: CO_2, brines, and a wide range of hydrocarbons. These are generated in different ways, including mantle flux (CO_2), sediment compaction (brines), biologic activity (biogenic methane), and diagentic/metamorphic reactions (fresh water, oil, thermogenic methane). The GOM provides an opportunity for understanding how these fluids form, migrate, and interact.

8) **Synergies**: The MARGINS successor program provides a timely opportunity to advance understanding of rifted margins in collaboration with other NSF initiatives as well as industry. These include EARTHSCOPE, which will conduct onshore broadband seismic, GPS, and magnetotelluric studies adjacent to rifted margins of the U.S. in the next decade; the Computational Infrastructure for Geodynamics (CIG), which provides computational tools to examine geodynamic problems related to continental breakup; and the Oceans Observatory Initiative, which will install a wide range of seafloor sensors. Participation by the hydrocarbon industry also is likely and should be encouraged. We expect that the MARGINS Successor Program will continue to stress geoscientific studies that cross the shoreline and will be well-positioned to lead the effort to study GOM evolution.

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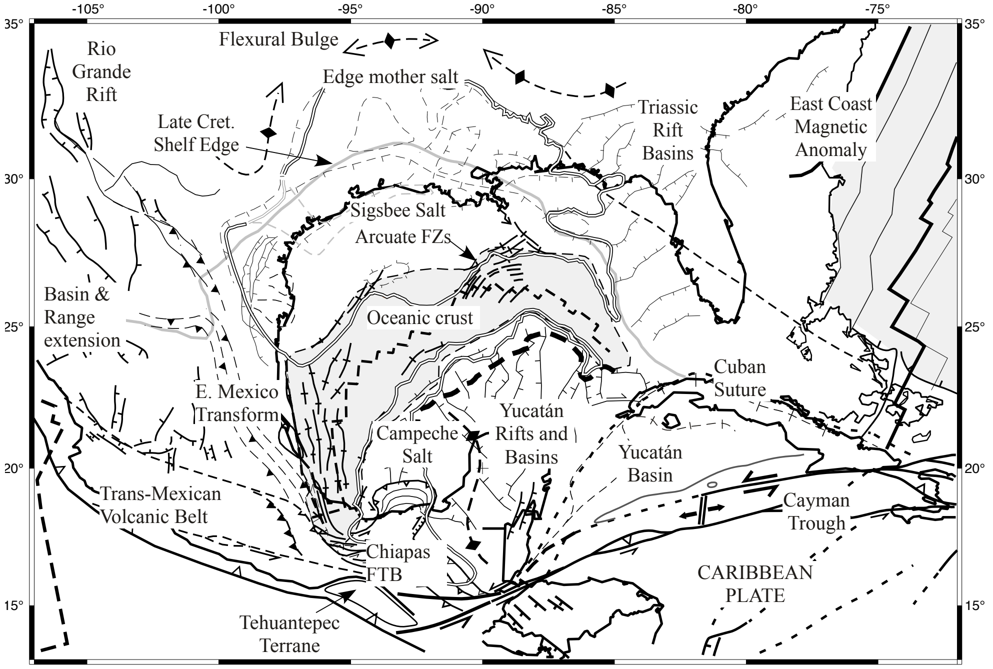

Fig. 1. Present day tectonic map of the Gulf of Mexico region (Pindell and Kennan, in press 2010).