The Gulf of Mexico and the southern margin of Laurentia

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Mickus et al. (2009; p. 387 in this issue of *Geology*) call fresh attention to the origin of the Gulf of Mexico, and particularly to the geodynamic processes that formed its rifted margin north of the oceanic crust forming its central expanse. I cannot hide my sympathy for the perspectives of the paper, for my co-authorship of recent abstracts would betray me (Stern et al., 2008; Dickinson et al., 2009; Stern and Dickinson, 2009).

The nature of the Gulf of Mexico (Fig. 1) is important to understand for several reasons: (1) it is a prime exemplar of a so-called small ocean basin floored by oceanic crust that is not contiguous with the oceanic crust beneath the world's principal oceans (Atlantic, Indian, and Pacific); (2) its formation was the last geotectonic step in delineating the southern margin of Laurentia, the Precambrian core of North America; and (3) sediment prisms flanking it are host to one of the world's great petroleum provinces.

The history of the Gulf of Mexico as an oceanic basin is a challenge to reconstruct because its flanks are so well masked by the thick sediment prisms that make it such a rich hydrocarbon resource, and there are no decipherable seafloor magnetic anomalies preserved within its interior to indicate directly the geometry of its opening. An important message of Mickus et al. (2009) is that modern geophysical techniques and analytical methods now give us potential leverage on the anatomy of the Gulf of Mexico that we could not gain in the past.

The prime focus of Mickus et al. is on the provocative interpretation that the northern flank of the Gulf of Mexico in Texas is a volcanic rifted margin, a geotectonic setting that has spawned whole books of commentary (Menzies et al., 2002) but has not previously been envisioned for the Gulf Coast. Tagging rifted margins as either volcanic or amagmatic is just a convenient way of labeling two end members of what is actually a spectrum of geotectonic behavior during continental rifting. Indeed, Mickus et al. suggest from their geophysical analysis that the Gulf margin grades eastward from a volcanic rifted margin in central Texas to an amagmatic rifted margin in Louisiana and beyond. They note, moreover, that the Gulf margin southward from Texas along the east coast of Mexico is a transform margin, yet another variant of a continent-ocean interface. Even so, introducing the concept of a volcanic rifted margin into the current picture of the Gulf of Mexico seems a crucial step, provided it is correct, toward understanding Gulf geodynamics. Mickus et al. draw out some of the implications of the idea.

From knowledge that the crust beneath the interior of the Gulf has an oceanic profile and lies beneath a water depth appropriate for Mesozoic seafloor, and that the Gulf is bounded on all sides by passive continental margins lacking subduction zones, we know that the Gulf is still surrounded by the continental blocks that separated to allow the oceanic center of the Gulf to form. The kinematics of Gulf opening were nevertheless uncertain for several decades after the advent of the theory of plate tectonics.

The central issue was the geometry of motion of the Yúcatan-Campeche block (Fig. 1) in pulling away from Texas. When one restores the pre-drift configuration of the Atlantic realm by backtracking Atlantic seafloor magnetic anomalies, Venezuela is shoved up quite close to Texas (Dickinson and Lawton, 2001a), and the Yúcatan-Campeche block must somehow fit between the restored margins of North and South America. One outdated approach to restoration was to assume that the Yúcatan-Campeche block pulled away from North America with the same motion vector as adjacent South America, and was simply left stranded behind when the two continents fully separated, but this assumption yields a highly unlikely pre-drift position for the Yúcatan-Campeche block spanning the Rio Grande embayment of southwest Texas and northeast Mexico. A more satisfactory initial position for the Yucatán-Campeche block, with a re-entrant in its margin draped around the Llano projection of Laurentia in central Texas (Fig. 1), is achieved by understanding that the Yúcatan-Campeche block rotated 42° clockwise while pulling away from Texas, leaving the oceanic Gulf of Mexico in its wake (Pindell and Dewey, 1982; Marton and Buffler, 1994). This geometry of opening is supported by paleomagnetic data from the Chiapas massif near the southwest corner of Yúcatan (Molina-Garza et al., 1992).

Once the motion of the Yúcatan-Campeche block is divorced from the motion of South America, the geodynamic impulse for opening the Gulf of Mexico is no longer fully apparent. Opening of the Gulf during the interval 160–140 Ma ago (Bird et al., 2005) coincided with Nazas arc magmatism in northeastern Mexico (Barboza-Gudino et al., 1999), meaning that the Gulf of Mexico was in a backarc paleogeographic position during Gulf seafloor spreading. This geotectonic setting opens the door to regarding the Gulf geodynamically as a backarc basin as well (Stern and Dickinson, 2009). As noted by Mickus et al. (2009), the northwestern corner of the Gulf at the north end of the Tehuantepec paleotransform connected seamlessly with the backarc Border rift system (Dickinson and Lawton, 2001b) extending in aulacogen-like fashion for ~1500 km into the continental block.

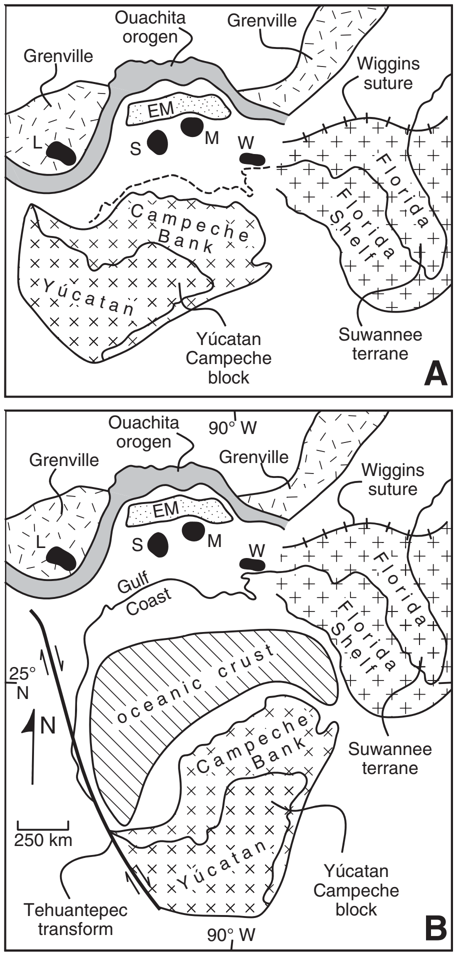

Figure 1. Pre-rift (A) and post-drift (B) configurations of the Gulf of Mexico region. EM—Eagle Mills rift basins. Uplifts (surface and subsurface): L—Llano; M—Monroe; S—Sabine; W—Wiggins.

Mesozoic continental rifting during the breakup of Pangea was just the last phase in the delineation of the southern margin of Laurentia.

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Earlier geotectonic events of signal importance included: (1) Proterozoic collisional orogeny along the Grenville belt during the assembly of Rodinia (Mosher et al., 2008), (2) the rifting away of the Argentine Precordillera (Thomas and Astini, 1996) in early Paleozoic time to form the passive pre-Ouachita margin of southern Laurentia (Thomas, 1991), and (3) late Paleozoic suturing of Gondwana to Laurentia along the Ouachita orogen during the assembly of Pangea (Viele and Thomas, 1989).

In common with the structures associated with Mesozoic rifting in the Gulf of Mexico, most of those precursor geotectonic elements of the southern Laurentian continental margin are buried under Mesozoic–Cenozoic sediment cover (e.g., Keller and Hatcher, 1999). Along the eastern and western margins of Laurentia, the Appalachian and Cordilleran orogens expose rock assemblages for direct observation along essentially the full lengths of those two continental margins. West of the Appalachian-Ouachita syntaxis, however, only ~20% of the length of the Ouachita orogen is exposed at the surface in Oklahoma–Arkansas and the Marathon region of west Texas, and little more than 10% of the southern Laurentian continuation of the disrupted Grenville orogen is exposed in the Llano uplift of central Texas and isolated ranges farther west. All else is hidden from view and intractable to traditional methods of geological study.

The southern Laurentian margin in the subsurface of Texas and adjoining areas is thus still a genuine frontier of geoscience. At long last we finally have the geophysical tools to explore it in detail. A successful program of study will require geoscientists in academia and industry to pool their respective resources in close collaboration, and that is a goal toward which we should all strive.

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