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Marine seismic refraction data from the northern Gulf of Mexico provide new constraints on continental rifting and tectonic evolution of the North American margin

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The Gulf of Mexico (GoM) formed by continental rifting and seafloor spreading during the breakup of Pangea as the Yucatán block rotated southward from North America. The effects of magmatism and mechanisms of rifting are poorly constrained by available geophysical data. We examine new marine seismic refraction data from the northern GoM in an attempt to better understand the regional crustal structure and shed new light on the early evolution of this restricted ocean basin. We present results from two of the four seismic profiles collected by the 2010 GUMBO cruise (GUlf of Mexico Basin Opening). On both GUMBO Line 2 and Line 3, ocean-bottom seismometers at 10-12 km spacing recorded 150 m spaced airgun shots. Instruments from GUMBO 3 record offsets >100 km, whereas typical GUMBO 2 offsets are shorter (50-80 km), limited by attenuation of compressional waves by complex salt structures. We use travel-times from long-offset reflections and refractions to image seismic velocities in the sediments, crystalline crust, and upper mantle using a tomographic inversion. GUMBO Line 3 extends from offshore Alabama through the De Soto Canyon towards the central GoM. We interpret velocities >5.0 km/s in the sediment layer landward of the Florida Escarpment as a Lower Cretaceous carbonate platform. Seaward of the Florida Escarpment, crystalline crust (5.5 – 7.5 km/s) thins significantly from 25 km to 7 km across a narrow, ~100 km-wide necking zone. Multi-channel seismic (MCS) reflection data coincident to GUMBO 3 display possible seaward-dipping reflectors within this zone of crustal thinning. A deep, localized region of anomalously high seismic velocities (>7.5 km/s) underlies thick crystalline crust at the landward end of GUMBO 3, exceeding the velocities of continental lower crust in the eastern US. We interpret this region to be under-plating and/or infiltration of asthenospheric melts, common at volcanic rifted margins. The seaward end of GUMBO 3 is interpreted as mafic ocean crust produced by normal seafloor-spreading on the basis of high crustal velocities (6.0-7.5 km/s), a consistent crustal thickness (~7 km), and minor lateral velocity variations.

GUMBO Line 2 extends from offshore Louisiana southward across the Sigsbee Escarpment. We find a massive (15-20 km) sediment package with noticeable lateral heterogeneities that we attribute to salt tectonics. We do not recover a sharp velocity contrast between the deepest sediments and the uppermost crystalline crust, and therefore we assign the top of basement to a 6.0 km/s velocity contour, which agrees well with coincident MCS data. GUMBO 2 crust thins slightly from north to south, but varies greatly in thickness from 3 – 10 km with seismic velocities between 6.0 – 8.0 km/s. We interpret the entirety of GUMBO 2 as oceanic crust formed by slow seafloor-spreading. This result substantially increases the amount of ocean crust interpreted in the GoM, and we invoke a ridge jump to explain the asymmetry in oceanic crust between North America and the Yucatán peninsula. We further suggest that the effects of heat and asthenospheric melt were more impactful and prolonged in the eastern GoM than in the west, infiltrating and weakening the thick continental crust at GUMBO 3 and producing a sharp transition from a volcanic rifted margin to ocean ridge basalt production. Although our velocity models do not show a rifted margin beneath the western GoM, ocean crustal thickness variations suggest an overall lower melt supply and more slow-spreading crust than in the East. Proximity of the eastern GoM to the likely origin of Central Atlantic Magmatic Province volcanism (CAMP) as well as mid-ocean ridge basalt production in the Atlantic Ocean may explain differences in melt supply and seafloor-spreading.

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