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Pangea breakup: Mexico, Gulf of Mexico, and Central Atlantic Ocean

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Summary

Late Triassic breakup of the super-continent of Pangea (ca. 230 Ma) preceded the final assembly of Mexico, the birth of the Gulf of Mexico, and the formation of the Central Atlantic Ocean. Extensional rifting in passive margins essentially stops once new oceanic lithosphere is created. Therefore closing ocean basins along geomagnetic isochrons is an objective method for analyzing reconstructed continental margins. New finite-difference rotation poles define relative motions between North America and Residual Gondwana (Afro-Arabia and South America) for geomagnetic isochrons M0 (124.6 Ma or Early Aptian), M25 (154.1 Ma or Kimmeridgian), and particularly M40 (165.1 Ma or Late Bathonian) (Gradstein et al., 2004), which lies within the Jurassic Magnetic Quiet Zone (JMQZ) (Figure 1).

Method

The method of calculating finite-difference rotation poles was similar to that described by Engebretson et al. (1984), which minimized the sum of the squared errors between rotated control points located at intersections of identified geomagnetic Chrons and fracture zones. Three pairs of control points located at the intersections of the Atlantis, Kane, and Fifteen-Twenty Fracture Zones with Chrons M0, M25 and M40, on both flanks of the Central Atlantic, were used for each of the three finite-difference pole calculations (Table 1).

Chron	Age (Ma)	Latitude	Longitude	Rotation angle
M0	124.6	66.70ºN	18.55ºW	54.23º
M25	154.1	66.10ºN	16.40ºW	65.83º
M40	165.1	65.50ºN	15.30ºW	71.76º

Table 1
Finite rotation poles for North America relative to Africa

Interpretation

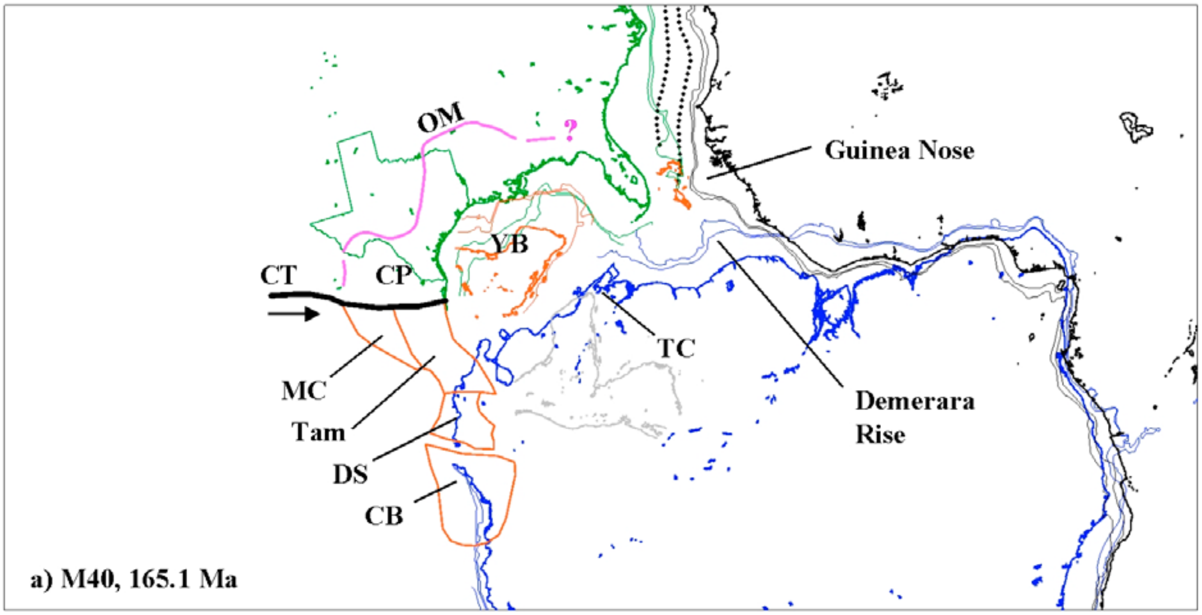
Interpretation of Jurassic Magnetic Quiet Zone (JMQZ) Chrons indicates that two ridge jumps occurred in the Central Atlantic shortly after seafloor spreading began: a ~90 km eastward jump at about 170 Ma (see Vogt et al., 1971), and a ~35 km jump to the west at about 160 Ma (Bird, 2004). These ridge jumps could have coincided with North American – Gondwana plate reorganizations including rifting of the Yucatan block away from North America and seafloor spreading in the Gulf of Mexico.

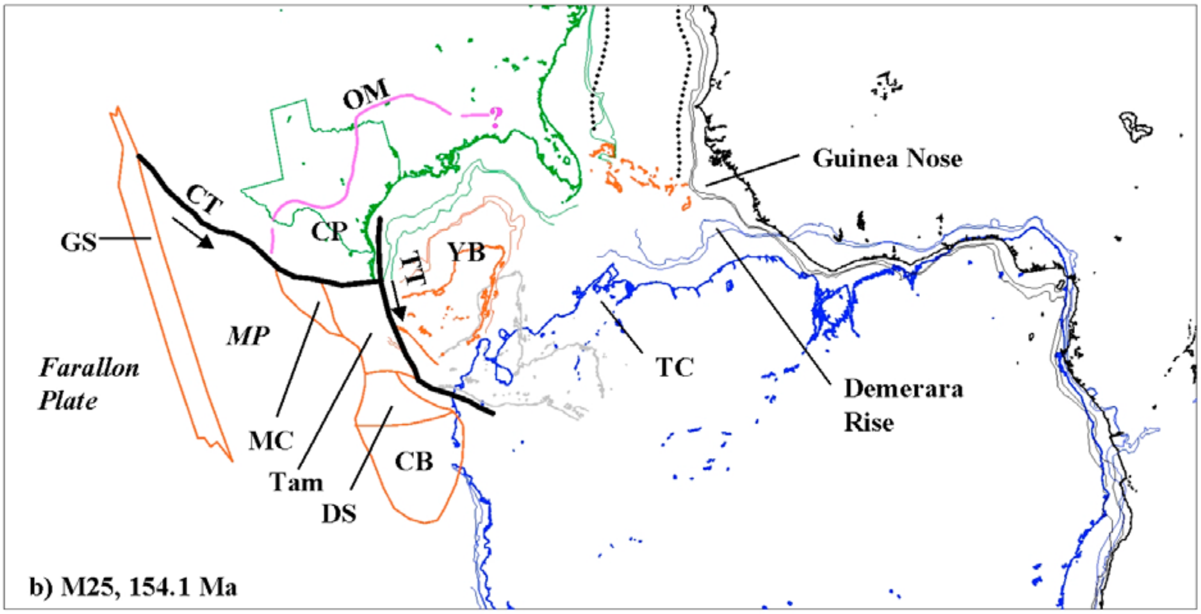
Our closest North American/Gondwana fit (Figure 1a) illustrates final closure that requires: 1) rotating the Yucatan block over 40º clockwise from its present position to close the Gulf of Mexico, 2) that the southern edge of the Florida shelf was contiguous with the Demerara Rise of South America and the Guinea Nose of Africa as suggested by Pindell and Dewey (1982), 3) that final closure requires SSE motion of North America relative to Africa, at a high angle to post-M40 fracture zones trends, and 4) that the Bahaman Island chain must have formed while the Central Atlantic was opening supporting the idea that the islands overlie a hotspot track, as was first suggested by Dietz (1973), That track is now recognized to be that of the Early Jurassic Central Atlantic Magmatic Province (CAMP) mantle plume that initially erupted at ~200 Ma (Marzoli et al., 1999).

We depict in Figure 1 the results of Dickinson and Lawton (2001) who reported that the Gondwanan Coahuila crustal block, which consists of the southern half of Texas and the northeastern corner of Mexico, was accreted onto Laurentia during the Permian along the Ouachita-Marathon suture. Farther south, and separated by the northwest oriented Coahuila Transform fault, the Gondwanan Tampico, Del Sur, Yucatan-Chiapas, and Chortis blocks form the eastern half of Mexico. As Pangea began to breakup the Mezcalera Plate was consumed by the advancing Farallon Plate west of the Gondwanan terranes and south of the Coahuila Transform. Formation of this western half of Mexico began with an Upper Triassic subduction complex was followed much later (ca. 120 Ma) by the accretion of the Guerrero Superterrane, which is an oceanic arc complex.

From M40 to M25 (165.1 Ma to 154.1 Ma) the Yucatan block appears to have rotated ~22º counterclockwise while extensive salt was deposited on extended continental crust (Figure 1b). The block was rotated about a pole located presently at 24ºN, 81.5ºW (Hall and Najmuddin, 1994). This rotation requires a north-south oriented Transform fault offshore eastern Mexico (Marton and Buffler, 1994; Pindell, 1994). By M0 (124.6 Ma) the Gulf of Mexico appears to have been completely formed after another 20º of counterclockwise rotation and seafloor spreading (Figure 1c). Prominent basement features defined by integrating seismic refraction and gravity data are interpreted to be hotspot tracks that were created by a single mantle plume beneath the Gulf of Mexico as the ocean floor was produced (Bird et al., 2005a). The second ridge jump in the Central Atlantic at ca. 160 Ma roughly coincides with the initiation of Yucatan block rotation and the formation of

Pangea breakup





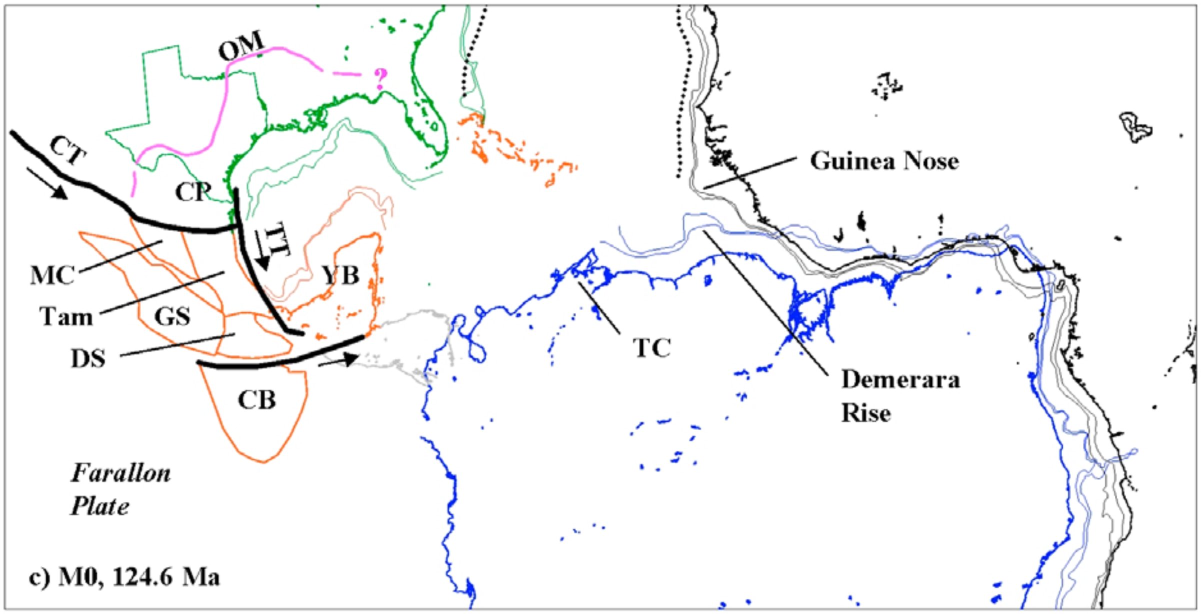


Figure 1. Formation of Mexico, Gulf of Mexico and the Central Atlantic Ocean after Pangea breakup: a) M40 (165.1 Ma), b) M25 (154.1 Ma), and c) M0 (124.6 Ma). Present western and northern coastlines of South America (west of TC) have been used for ease of geographic reference. Jurassic and Cretaceous coastlines in those regions, although poorly known, were certainly very different. North America (green) and South America (blue) are relative to Africa (black); South America - Africa closest fit position for M40 and M25, and for M0 as South America drifted away from Africa, after Bird et al., (2005b); and present-day Yucatan and Chortis blocks relative to North America are light gray. One km and two km isobaths, and estimated positions of abandoned Central Atlantic seafloor spreading centers (dotted lines), are plotted. Mexico crustal blocks (red), Ouachita - Marathon Suture (OM, magenta), and transform faults (heavy black) are modified after Dickinson and Lawton (2001). Bahaman Islands (red) may overlie seamounts produced by the Central Atlantic Magmatic Province mantle plume. CB = Chortis block, CP = Coahuila Platform, CT = Coahuila Transform, DS = Del Sur block, GS = Guerrero Superterrane, MC = Mesa Central Triassic subduction complex, MP = Mezcalara Plate, Tam = Tampico block, TC = “Trinidad corner”, TT = Tehuantepec Transform, and YB = Yucatan block.

the Gulf of Mexico (Buffler and Thomas, 1994; Burke, 1988; Dunbar and Sawyer, 1987; Hall and Najmuddin, 1994; Marton and Buffler, 1994; Pindell, 1994; Ross and Scotese, 1988; Salvador, 1991). We interpret the westward ridge jump in the Central Atlantic at ~160 Ma to be linked to the clearing by the Florida Shelf of the “Trinidad corner” on the north coast of South America (Figure 1a). That change, which made room for the Gulf of Mexico to open, was coeval with the onset of Yucatan block rotation.

Conclusion

Major events in the Middle Triassic to Early Cretaceous tectonic evolution of Mexico, the Gulf of Mexico, and the Central Atlantic Ocean are summarized in Table 2. Pangean break-up events between 230 Ma (Mid-Triassic) and 120 Ma (late-Early Cretaceous) established the large-scale structures of Mexico, the Gulf of Mexico, and the Central Atlantic (Figure 1, Table 2). The temporally and spatially well-defined plate rotations reported here provide the necessary regional framework for more locally focused analyses such as those of geologic structures and depositional systems.

Pangea breakup

230 Ma	Pangea breakup began: collapse of the Appalachians and Ouachitas
230 to 164 Ma	Mesa Central Subduction complex began to form as the Mezcalera Plate is consumed by the Farallon Plate; Gondwanan crustal blocks south of the Coahuila Transform are displaced eastward; extension of the Coahuila block toward the southeast, and stretching of the Yucatan block
200 Ma	CAMP plume erupts
180 Ma	Seafloor spreading began in the Central Atlantic (Withjack, 1998)
170 Ma	Eastward ridge jump in the Central Atlantic (abandoning African lithosphere on the western flank)
160 Ma	Westward ridge jump in the Central Atlantic (abandoning North American lithosphere on the eastern flank)
~160 Ma	Yucatan block began to rotate away from North America, 24º counterclockwise continental extension
~150 Ma	Seafloor spreading in the Gulf of Mexico, 20º counterclockwise rotation of the Yucatan block
~140 Ma	Gulf of Mexico formation was complete
~126 Ma	South America began separating from Africa
120 Ma	Guerrero Superterrane was accreted onto western Mexico

Table 2
Chronology of tectonic events.

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