Kinematic reconstruction of the central US and conjugate northwest African margin

Harm Van Avendonk, Lawrence Lawver, and Ian Norton
University of Texas Institute for Geophysics, Austin TX.
E-mail: harm@ig.utexas.edu

Summary: The Early Jurassic margin of the East Coast of the U.S. is an excellent location to study the interaction between extension, mantle flow, and magmatism during continental breakup, because the crustal structure and stratigraphy of the subsiding margin are fairly well preserved. Modern geophysical tools such as those available on the R/V *Marcus Langseth* and arrays of land and ocean-bottom seismometers will allow us to image the deep structure better than before. Our understanding of the thermal state of the lithosphere during rifting and the magma flux in the young ocean basin depend on estimates of the oldest spreading rates. In this paper we review some constraints on the early opening history, and we present a plate reconstruction for the Central Atlantic. From this compilation we estimate that the Early Jurassic seafloor spreading half rate may have been as low as 5.5 mm/yr, if the Blake Spur magnetic anomaly (BSMA) was the result of an eastward ridge jump as suggested by *Vogt* [1973]. If this model is correct, a ~250 km wide ocean basin with two conjugate volcanic margins lies off the eastern seaboard of the U.S. If it is incorrect, initial seafloor spreading was highly asymmetric in the Atlantic for the first 30 million years [*Labails et al.*, 2010].

An interpretation of the Mesozoic and Cenozoic seafloor spreading magnetic anomalies allows for a fit of eastern North and South America, Europe and Africa [*Klitgord and Schouten*, 1986] by mid-Jurassic time (175 Ma, using the scale of *Gee and Kent* [2007]). This reconstruction is straightforward to anomaly M25 (153 Ma), but spreading rates during early opening of the central Atlantic (in the Jurassic Quite Zone) are unconstrained [*Vogt*, 1973], so the onset of seafloor spreading is uncertain. On the other hand, on-land geological and geophysical data [*Marzoli et al.*, 2011; *Schlische et al.*, 2003] allow for a relatively short period of rifting and CAMP magmatism around the Triassic-Jurassic boundary (200 Ma) in the northeastern US, by which time extension in rift basins in the southeastern US had already ceased.

The major magnetic anomalies along the central Atlantic margins may provide a time line for the initial opening of the Atlantic. The large negative Brunswick magnetic anomaly (BMA) has been interpreted as a rift-related feature in the southeast Georgia Embayment [*Lizarralde et al.*, 1994] though its landward continuation must be an Alleghanian structure [*McBride and Nelson*, 1988]. The large positive (350 nT) East Coast magnetic anomaly (ECMA) probably marks the continent-ocean transition zone on the American plate [*Austin et al.*, 1990; *Grow and Markl*, 1977], just as the weaker West-African Coast magnetic anomaly (WACMA) does on the conjugate margin [*Roussel and Liger*, 1983]. *Sahabi et al.* [2004] have dated the WACMA (and therefore also the ECMA) at 195 Ma (Figure 1a).

Since there is not a clear African counterpart to the ~50 nT positive BSMA, *Vogt* [1973] suggested it represents a sliver of West-African margin crust that was left on the American plate after the spreading center jumped east. This would also explain why the distance between ECMA and M25 is much wider than the distance between WACMA and M25 at the African side. In fact, M25 lies right between BSMA and WACMA at 153 Ma (Figure 1c), which may imply that the new spreading center parted these two anomalies. If we assume that the spreading half rate between M25 and M21 (18.5 mm/yr) is an acceptable average half rate between BSMA and M25, we obtain an approximate age of 173 Ma for the ridge jump to BSMA/WACMA, which is consistent with the age of Callovian (163 Ma) sediments drilled at DSDP Site 534 on Outer Blake Ridge [*Sheridan et al.*, 1982] east of the BSMA. Since the BSMA does not extend north of the New England seamounts, the ridge jump would have to be limited to the same distance. An important implication of the ridge jump hypothesis is that seafloor spreading between ECMA and BSMA (250 km over 22 Myr) occurred at a very low half rate of 5.5 mm/yr.

As an alternative to *Vogt's* [1973] ridge jump, *Labails et al.* [2010] suggested that all magnetic anomalies west of the Mid-Atlantic Ridge (MAR) have a counterpart on the east flank, though some of these would have to be much weaker in amplitude. More importantly, this model requires a much larger spreading half-rate on the North American margin than at the conjugate African margin prior to M25 because the distance from ECMA to M25 is much larger than from WACMA to M25. *Labails et al.* [2010] attribute this long-lived (~30 Myr) discrepancy to higher temperatures under the African continent.

In this paper we focus on *Vogt's* [1973] original hypothesis, and we develop a kinematic model that uses our best dates for the mentioned magnetic anomalies. To reconcile the opening of the Gulf of Mexico and the central Atlantic we must assume that the basement of the Bahamas and Blake Plateau is either (presumably stretched) continental crust or younger igneous rock. The original position of Florida is uncertain because of the possible existence of a major transform boundary [*Klitgord et al.*, 1984], and because of the early extension in the South Georgia Basin [*Salvador*, 1987]. To avoid a gap between North America, South America, and Africa in a reconstruction of Pangaea around 200 Ma, it helps to consider the Bahamas Platform and Blake Plateau as extended fragments of continental crust, though there is no good geophysical evidence for their origin yet. In Figure 1 we present three time frames from a global plate reconstruction using the oceanic magnetic and tectonic database of the UTIG PLATES project to illustrate the opening of the central Atlantic.

Future studies of the U.S. eastern seaboard may address the relationship between magmatism and rifting during continental breakup. The nature and timing of CAMP suggest that small-scale convection in response to continental rifting was responsible for the production of thick volcanic wedges at the eastern U.S. and northwest African margins [*Holbrook and Kelemen*, 1993; *McHone*, 2000]. Alternatively, a plume may have set the breakup of Pangaea in motion [*Wilson*, 1997], though there is no strong evidence for it. Either way, the early spreading history was unusual as it may have been asymmetric [*Labails et al.*, 2010] or very slow (this study).

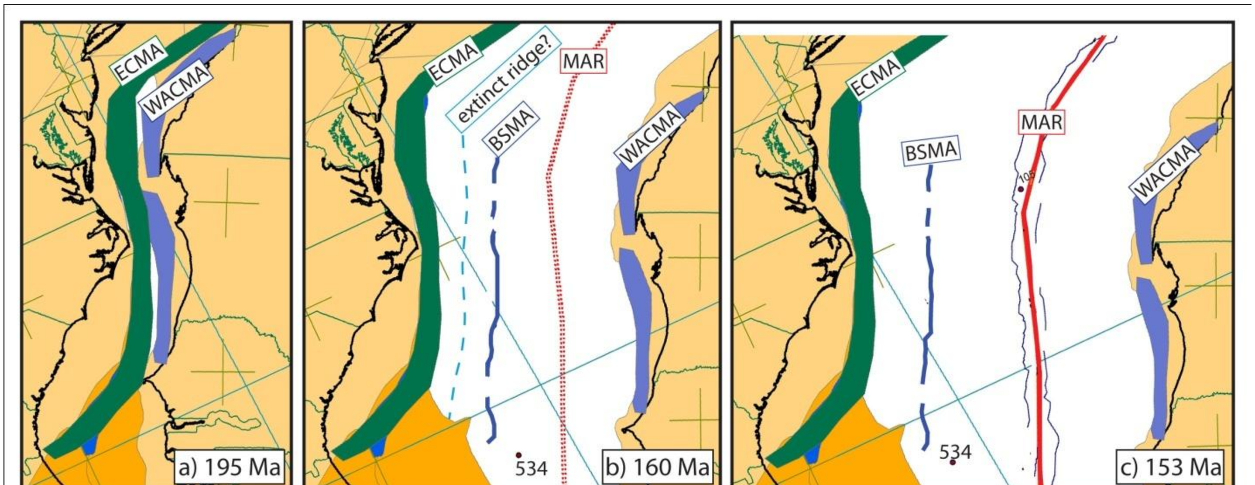

Figure 1. Plate reconstructions of the central Atlantic region. a) Onset of seafloor spreading. b) At roughly 173 Ma the spreading ridge jumped just east of the BSMA. c) Reconstruction at approximate age of M25. Note that the MAR here is equidistant between BSMA and WACMA.

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