# Some new thoughts on the early opening of the South Atlantic Ocean

**Colin Reeves**

Earthworks BV, Delft, The Netherlands
reeves.earth@planet.nl

## Introduction

One of the persuasive features of global tectonics is its simplicity. Inevitably there are local complications but it is unwise to lose sight of the big picture and much discretion should be exercised before local detail is used to revise the big picture. The latest data on the structure of the South Atlantic Ocean have been used – particularly the DNSC08 global gravity data (Figure 1; Andersen and Knudsen, 2009) – in an attempt to resolve its evolution into a small number of distinct phases (Reeves, 2009).

It often appears to be the case that instantaneous Euler rotation poles are a close approximation to interval poles over prolonged periods of geological time. This leads to the ability to describe the development of large oceans with a small number of distinct interval poles. In the case of large features like the South Atlantic Ocean, over 7000 km of mid-ocean ridge now provides a ridge-push that must be one of the major players in tectonics globally. The inertia of such a system surely means that only events (probably remote events) at global scale are capable of disrupting the long-term dynamic equilibrium.

## Closing the Equatorial Atlantic

Figure 2 shows how well a single Euler interval pole (Pole 1) describes the opening of the South Atlantic back to about 80 Ma. Plotted in rectangular coordinates based on that Euler pole, the fracture zones lie parallel to lines of Euler latitude and the magnetic anomalies parallel to meridians of Euler longitude. Small deviations are evident but need not be considered here. Before about 80 Ma, however, the fracture zones follow a distinctly different direction.

Closing the South Atlantic back to about 80 Ma and fitting the earlier fracture zones to an Euler pole (Pole 2) indicates a similar longevity for the previous spreading regime (Figure 3). In the Equatorial Atlantic, however, a slightly different pole is indicated by the fracture zones. This is interpreted as the result of the partial closing of the Benue Trough in Nigeria in Santonian times (~84 Ma) as northwest Africa rotated slightly anti-clockwise with respect to sub-equatorial Africa, producing a Gulf of Guinea slightly more 'open' in pre-Santonian Africa compared to the present day.

Operating Pole 2 backwards in time closes NE Brazil against the Gulf of Guinea long before the more southerly parts of the ocean are closed, implying a need for more translation in the south and less in the north of the ocean. This can be achieved by an Euler pole closer to the Gulf of Guinea than Pole 2 but at a location still normal to the older sections of the South Atlantic fracture zones (Figure 4). The model achieves this using Pole 3, selected rather arbitrarily, closer to the Gulf of Guinea than Pole 2 but at a location still normal to the older sections of the fracture zones. Pole 3 is operated in the interval 107 to 124 Ma. Reality, if not geometrical simplicity, could be a more gradual retreat (in reverse time) of the pole from Pole 2 to Pole 3 in the interval from 80 to 124 Ma (Figure 5).

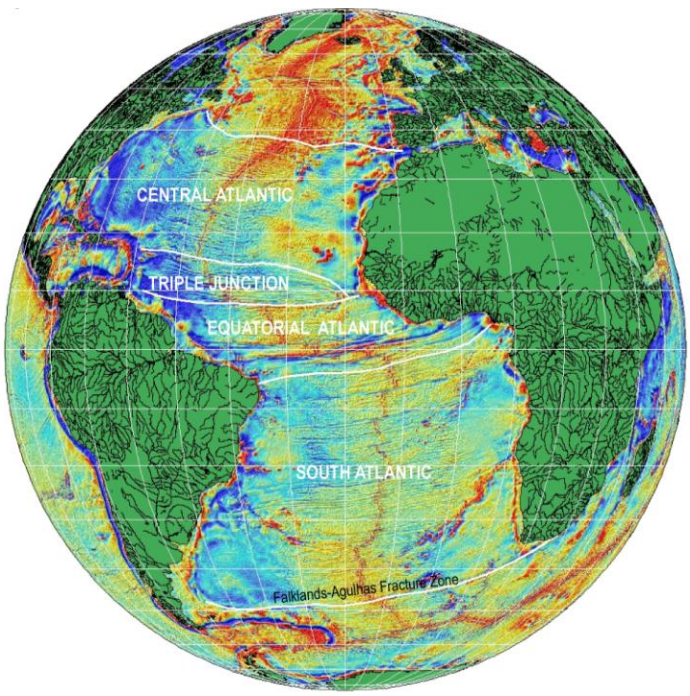


***Figure 1.*** *Features of the South Atlantic Ocean as seen in the DNSC08 gravity data.*

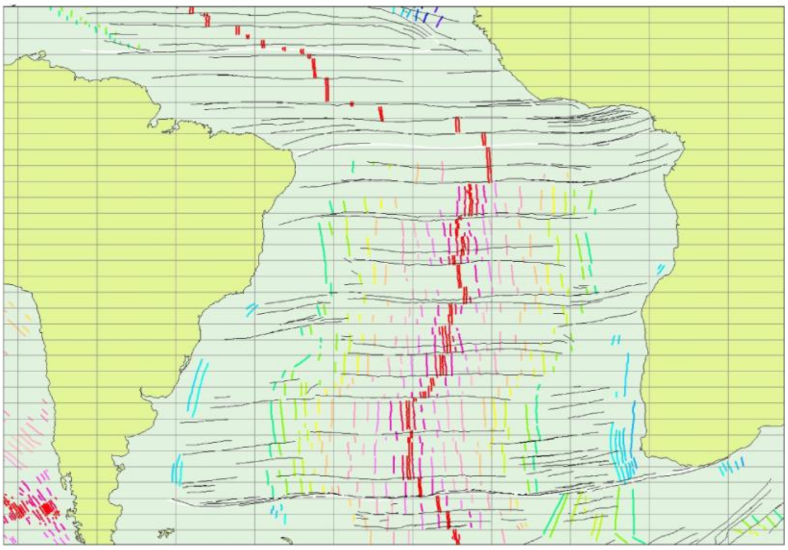

*__Figure 2.__ The present-day South Atlantic projected into rectangular coordinates based on an Euler pole (Pole 1) that fits the fracture zones and magnetic anomalies created since about 80 Ma. Note the absence of magnetic anomalies before about 80 Ma (green anomalies) and that parts of the fracture zones older than this have a distinctly different strike direction.*

**Closing the South Atlantic**

Going backwards further in time, South America becomes one with Northwest Africa and, by about 124 Ma, the Equatorial Atlantic is essentially closed (Figure 4). The South Atlantic is then reduced to a wedge tapering from a width of about 1000 km at the Falklands-Agulhas Fracture Zone (FAFZ) to almost nothing in the Gulf of Guinea. This remaining ocean can be closed by a pole (Pole 4) situated in Cameroon that the model operates in the interval 124 to 140 Ma approximately.

It should be noted that the recorded fracture zones in the south clearly follow the Pole 3 spreading direction until at least as far back as the time of the youngest M-series anomalies off Argentine / South Africa-Namibia, justifying the choice of 124 Ma as the time of regime change. In the southernmost Atlantic, just north of the FAFZ, the change from Pole 3 to Pole 4 implies a change in spreading direction of about 30 degrees azimuth during the transition period around 124 Ma and a significant tectonic event.

Before about 124 Ma, the earliest growth of the South Atlantic may be described as the ‘wedging apart’ of South America and Africa under the influence of the Tristan mantle plume with the rifting and crustal stretching process propagating northwards, penetrating deep into central parts of West Gondwana. The influence of a lesser plume (St Helena) may account for the bifurcation of this penetration at the present Gulf of Guinea with an eventual right-angle turn westwards of the successful Equatorial Atlantic rift/ocean system.

**The Falklands-Agulhas Fracture Zone**

The FAFZ is perhaps the most obvious southern limit to the tectonic South Atlantic ocean and invites visual correlation of South America with southern Africa on many world maps. This may be deceptive. The oldest parts of the FAFZ do ***not*** follow the direction predicted by Pole 4. But the Pole 4 direction *is* followed by (pre-) transforms mapped by Franke *et al.* (2007) off Argentina. Simple application of our model, while bringing a satisfactorily tight fit of the Precambrian of South America and Africa north of about the Walvis Ridge (Figure 6), does *not* close the North Falkland Escarpment with the Agulhas Fault; South America is more than 200 km too long for this to happen. Several authors have invented a multitude of extensional zones within the body of South America to explain away this discrepancy.

Here, a more conservative invention is proposed as follows. We suggest that the Maurice Ewing Bank is separated from the Falklands Plateau by a dextral strike-slip fault that shares the strike direction of the

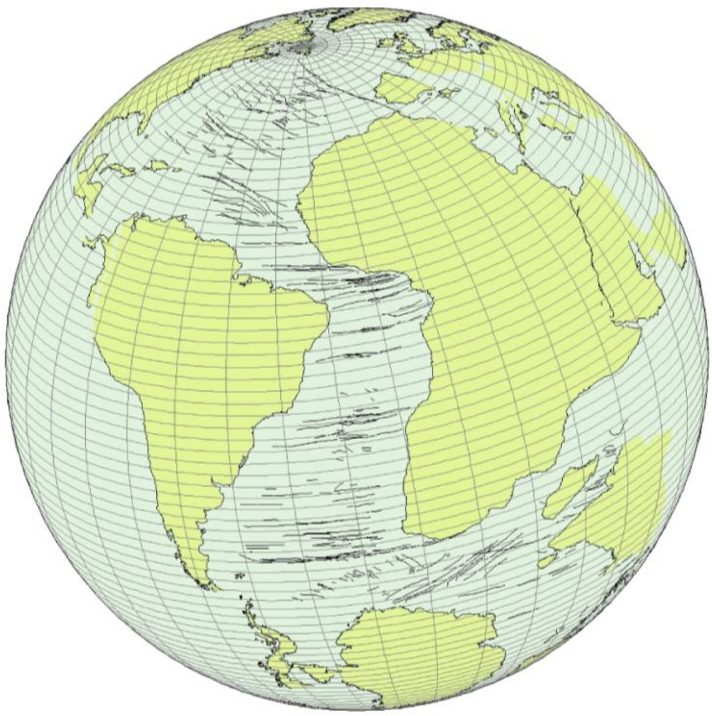

*__Figure 3.__ The South Atlantic at about 80 Ma. Older parts of the fracture zone system fit well to a single Euler pole (Pole 2) about which the latitude and longitude lines have been drawn.*

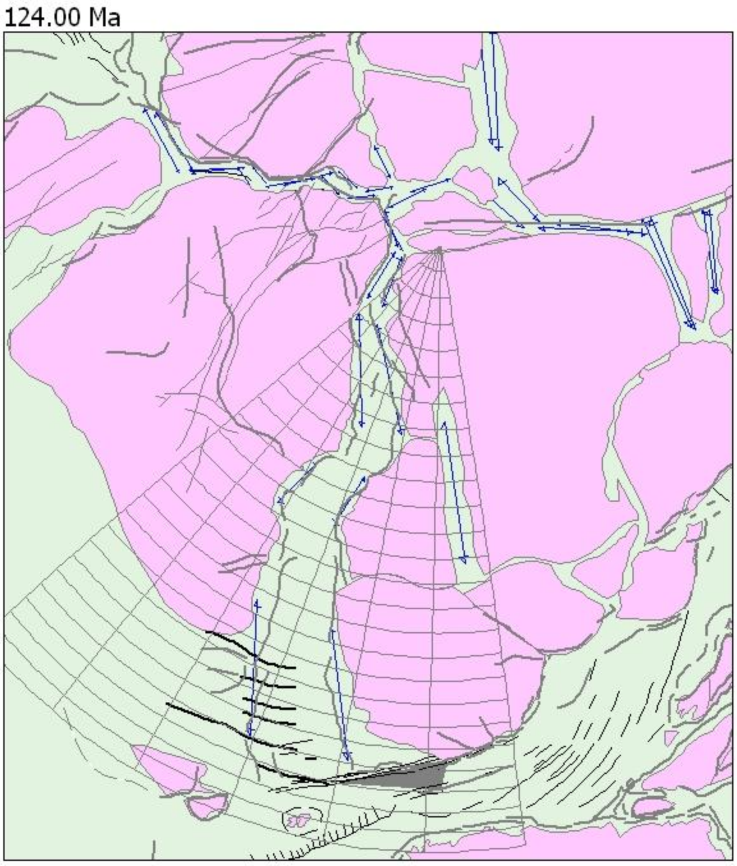


***Figure 4.*** *124 Ma. Areas that are considered to have behaved cratonically since the end of the Precambrian are shown in pink. Pre-transforms mapped off Argentina are shown as thick black lines, Maurice Ewing Bank as a grey triangle. The Euler pole (Pole 4,) indicated by Euler latitude and longitude lines, achieves South Atlantic closure back to 140 Ma. Double-headed arrows (blue) will be conjugate at this time.*

faults mapped in the Argentine offshore (Figure 4). If the Maurice Ewing Bank led a separate existence as a micro-plate in the time interval 140 to 124 Ma approximately and moved west against the Agulhas Fault less quickly than the rest of the Falklands Plateau, it would have reached its present position with respect to the latter and become stranded there at the time of the reorganization at ~124 Ma. If this were the case, the ocean immediately south of the Agulhas fault scarp of Africa and the coast-normal magnetic anomalies off the Natal coast would record only the westward motion of the Maurice Ewing Bank, not that of the whole Falklands Plateau or South America itself. Any relative motion of the Falklands Plateau against South America proposed by some authors along the Gastre Fault could have been completed much earlier, probably in the Jurassic. In the scenario proposed here, the North Falklands escarpment would only become part of the South America plate at about 124 Ma, after which time the growth of the FAFZ starts to follow the predictions of our model rather precisely.

### Factors further afield

The transition from a northward-propagating rift under the influence of the Tristan plume (and perhaps lesser input from the St Helena and Bouvet plumes, Pole 4 regime) to a more coast-normal oceanic spreading with input from ridge-push (Pole 3 regime) was certainly not instantaneous. A transition at about 124 Ma appears to fit with changes in the plate tectonic system around the Bouvet triple junction and east of Africa at about this time. Madagascar became part of the Africa plate and so, perhaps, did the Mozambique Rise as Antarctica – which it had previously followed – increasingly pursued a more westerly path with respect to Africa.

The rift in West and Central Africa is a product of the movement of Northwest Africa (with South America still more-or-less attached) with respect to sub-equatorial Africa. This rift system may well have undergone later reactivation and may itself have reactivated earlier rifts in some places, but its initial development was essentially completed in the period 140 to 124 Ma. The

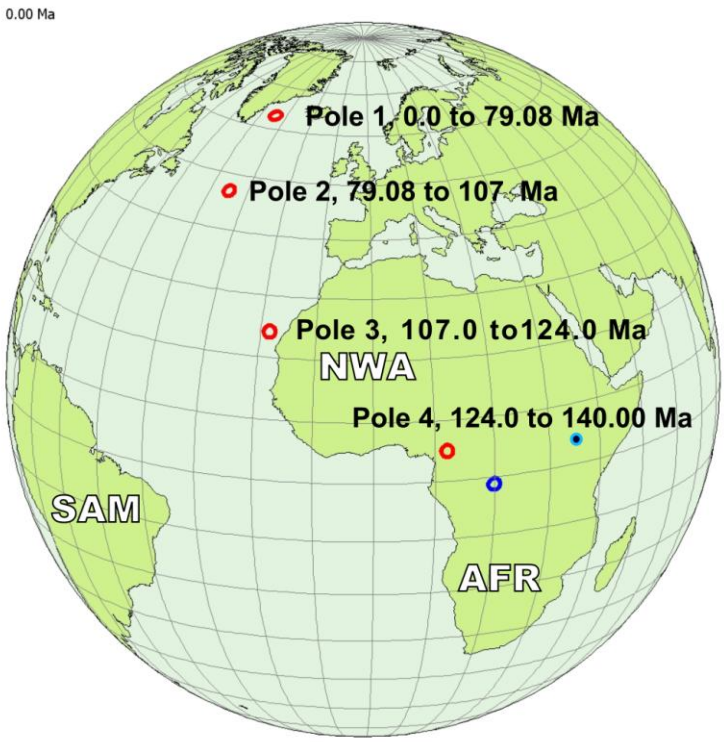


**Figure 5.** The locations of the four interval poles (present day Africa coordinates) used in Model CR10AALH to account for the opening of the South Atlantic Ocean.

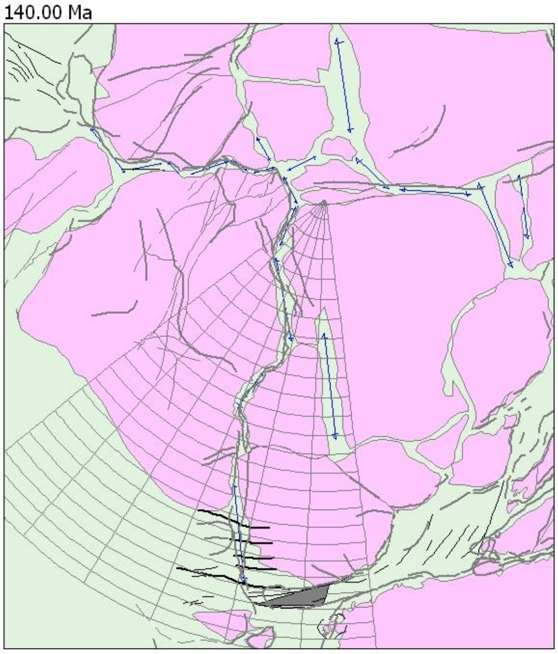


***Figure 6.*** *South Atlantic closed at 140 Ma. Maurice Ewing Bank shown in grey in its position against Africa and South America at this time. Earlier movement of fragments south of the Gastre-FAFZ is possible.*

subsequent partial closing of Nigeria's Benue trough in Santonian times has often been loosely attributed to the collision of Africa with Europe. This idea may be worth re-examination, particularly as this collision is still going on today. A more plausible and no less remote cause is the events at this time east of Africa where India ceased to follow the southward path of the remainder of East Gondwana and started its own independent northward motion. This represents a major change in plate tectonic activity on a global scale. The impact of the Marion plume to which this changed course of events is attributed, would tend to reverse the clockwise motion of north Africa with respect to the sub-equatorial parts of the continent.

The operation of the global tectonic model discussed here in the creation of the Atlantic Ocean west of Africa has been demonstrated in an animation in the colour scheme of the 2010 CGMW World Geological Map. This may be downloaded from: http://www.reeves.nl/upload/SouthAtlantic1.gif

A two-day workshop designed to impart a better 'feel' for the global-tectonic events in the vicinity of Africa through the Phanerozoic is also available on request. (http://www.reeves.nl/upload/AfricanGeodynamicsBrochure.pdf)

**Acknowledgements**

The support of Alan Smith and Lawrence Rush has been essential to the continuing use of the 'Atlas' software of Cambridge Paleomap Services Limited and is gratefully acknowledged. The author also appreciates useful discussions with Dieter Franke at BGR in Hannover. Suzanna Reeves selectively digitized features from the 2010 CGMW Geological Map of the World with permission.

**References**

Andersen, O.B., and Knudsen, P., 2009. DNSC08 mean sea surface and mean dynamic topography models. Journal of Geophysical Research, 114, C11001, doi:10.1029/2008JC005179, 2009.

Franke, D., Neben, S., Ladage, S., Schreckenberger, B., and Hinz, K., 2007. Margin segmentation and volcano-tectonic architecture along the volcanic margin off Argentina/Uruguay, South Atlantic. Marine Geology, 244, 46-67.

Reeves, C.V., 2009. Re-examining the evidence from plate-tectonics for the initiation of Africa's passive margins. Extended abstracts, GSH/PESGB meeting extended abstracts, London, 2009 September 9-10.