

The Role of Gravity and Aeromagnetic Data in Mapping Mega Gondwana Crustal Lineaments: the Argentina - Brazil – Algeria (ABA) Lineament

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Introduction

Satellite imaging of the Earth's surface is revealing many previously unrecognized tectonic features such as continental scale lineaments. The two examples, recognized by Guiraud et al., 2000 cutting North Africa, are shown in Figure 1 the Taoudenni lineament (white arrows) and the Tibesti lineament (red arrows). These lineaments have an expression in both the topography and exposed geology such that they can be traced with some reliability at satellite altitude. Other lineaments or fault zones can also be recognized (Figure 1) and have been proposed for Gondwana by Guiraud et al., 2000 and Reeves et al., 2004.

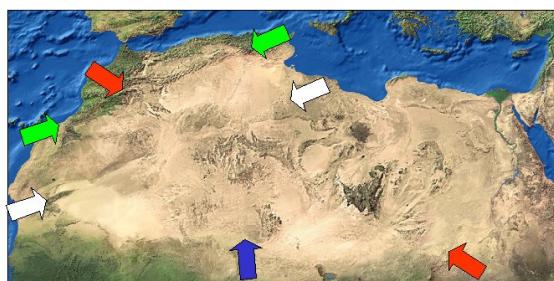


Figure 1: A Weather Satellite WSI composite image for North Africa clearly defining the Taoudenni lineament (white arrows), the Tibesti lineament (red), the Atlas Orogenic Belt (green) and Pan African lineaments (blue).

Imaging of terrestrial gravity and magnetic data on a continental scale is also a powerful means of identifying crustal tectonic lineaments. These lineaments do not necessarily have a clear surface expression, as the above examples, but have the advantage that they can be used in a more quantitatively sense to provide a simple chronology of events.

This study focuses on the south to north Argentina - Brazil – Algeria (or ABA) lineament. The full Gondwana extent of this ABA lineament has only been recognized from compilations of gravity and magnetic data for Africa and South America (Fairhead et al 1997; Fairhead and Maus, 2003) This contribution presents the geophysical evidence of the lineament's existence and the tectonic role it has played since the Palaeozoic in controlling basin evolution

along its length and particularly at its ends in Argentina and Algeria, the latter of which has three tectonic trends intersecting. The ABA lineament is also associated with significant sinistral shear movement, which helps to solve the plate reconstruction problem of the closure of the South Atlantic Ocean. This problem is explained in Figure 2.

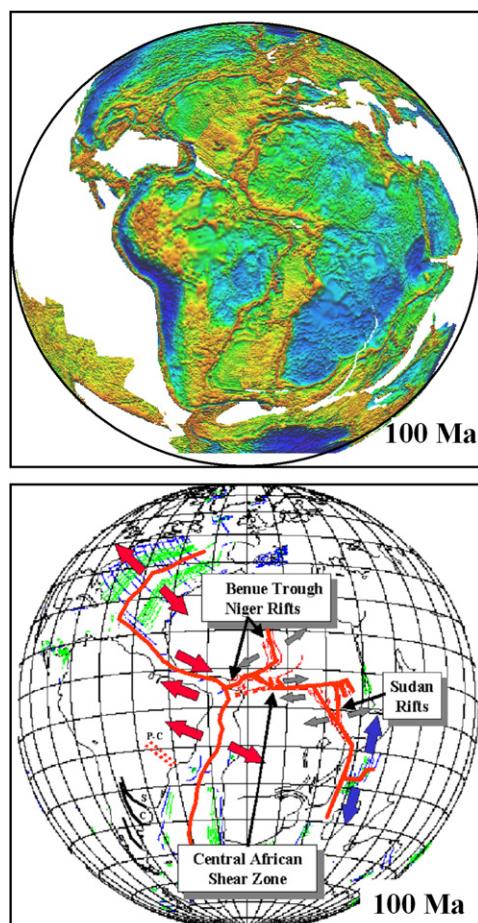


Figure 2: Reconstruction of the South Atlantic at 100 Ma showing gravity (upper) and tectonics (lower). Even when deformation within Africa is allowed for, it is not possible to close the South Atlantic Ocean at 130 Ma.

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Mapping Deformation in South America

Imaging the aeromagnetic data of Brazil (Figure 3A) reveals the location of a major SSW - NNE trending fracture zone called the Trans Brazilian Lineament (TBL), shown in white in Figure 3B. This lineament is a major suture zone 100's km wide that developed in Precambrian times and has been reactivated throughout time. The most recent movement was during the Mesozoic. It had sinistral shear displacement and has controlled the early Mesozoic basin formation in NE Brazil resulting in a number of basins shown in Figure 3B.

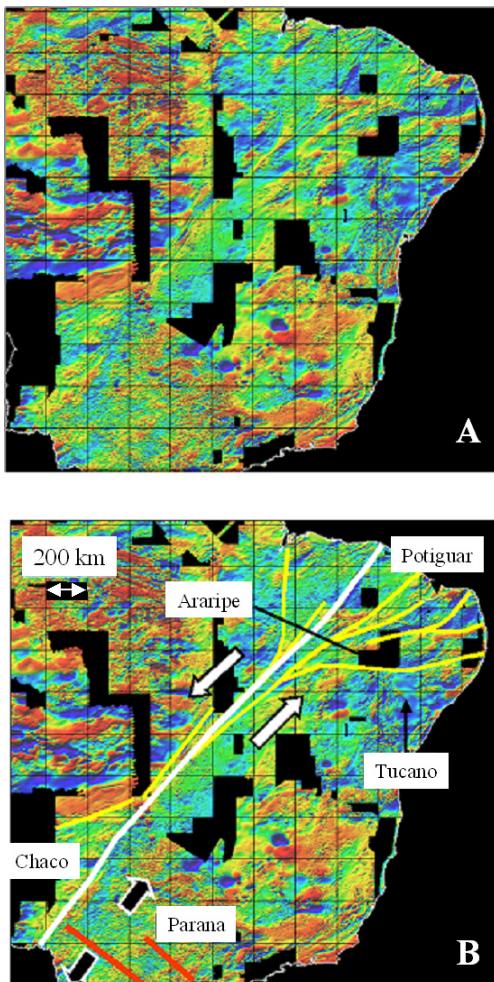


Figure 3: A) Aeromagnetic image of Brazil compiled by GETECH from CPRM and Petrobras data. B) Superposition of the Trans Brazilian Lineament (white) and 'flower' fractures in NE Brazil (yellow lines). These faults can be traced offshore and are truncated by the continental edge.

Southward extension: The Trans Brazilian Lineament (TBL) can be traced using aeromagnetic and gravity data southwards through Paraguay into northern Argentina. In southern Brazil and Paraguay, the TBL is associated with a linear zone of weak seismicity (Assumpcao, 1992) bordering the western edge of the Parana basin.

The continuation of the TBL south into Argentina is more difficult to determine due to the sparse coverage of potential field data. The tectonic model proposed in Figure 4 is the transforming of the sinistral shear movement of the TBL into SE trending extensional Salado and Colorado basins. This structural model provides a unifying model for the development of these late Palaeozoic and Mesozoic basins of Argentina and Brazil as well as the Parana-Chaco dyke injection zone (NW-SE red lines in Figure 3B). Detailed evaluation of the potential field data associated with the Parana – Chaco dyke swarm only supports extension rather than any dextral shear movement (this dextral movement was proposed earlier without any access to these data) as a means of having additional opening for the southern most South Atlantic Ocean.

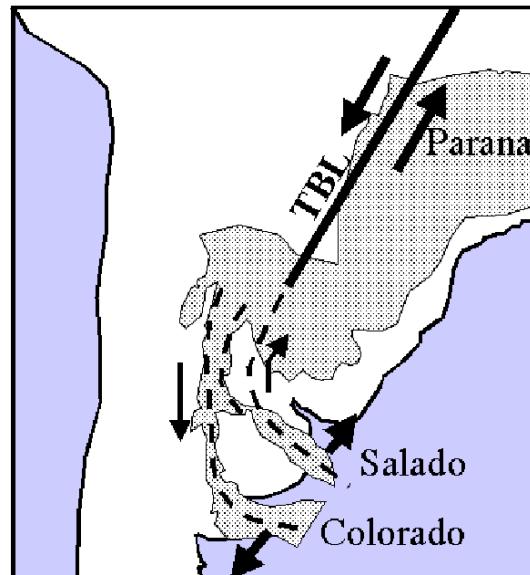


Figure 4: Simple tectonic model for northern Argentina dissipating the sinistral shear motion of the TBL into extensional Salado and Colorado basins.

The development of the Andes and sub-Andean basin system is also likely to have had a significant tectonic influence on the development of these Argentine basins, yet to be resolved. This lineament model is similar to the simple tectonic model proposed by Fairhead (1992) for the Central Africa shear/wrench zones (Figure 2), which

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transform into orthogonal extensional basins e.g.1 the NE trending Benue Trough with sinistral wrench motion transforms into the NNW trending Niger extensional rifts; e.g.2 the ENE trending Central African shear zone with dextral shear motion transforms into the SE trending Sudan extensional rifts.

Mapping the Deformation into Africa

The Trans-Brazilian Lineament can be traced from its magnetic signature across the continental shelf of northern Brazil before being truncated by the continent-ocean boundary (COB). This clearly implies an age and active phase prior to breakup of ~115 Ma. To determine its northern extension into Africa, the Equatorial Atlantic needs to be closed by bring West Africa back to its original position with respect to northern Brazil. Figure 5 does this. The TGL matches with its African counterpart called the Kandi fault zone in Benin.

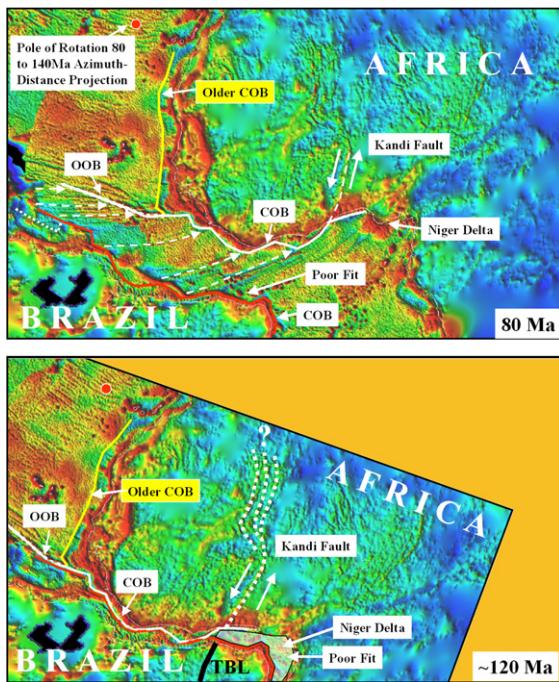


Figure 5: Closing of the Equatorial Atlantic. COB represents Continent-Ocean Boundary and OOB Ocean-Ocean Boundary. The conjugate position of the TBL with the Kandi Fault zone is shown.

It is interesting to note: in Figure 5 that at ~120Ma the continental margins, to the west of the TBL / Kandi fault zones have a tight plate reconstruction fit, so long as the Amazon cone and its older delta system are taken into consideration. In contrast, the continental margins to the

east of TBL / Kandi fault zones, i.e. the NE corner of Brazil and its conjugate part of Nigeria-Cameroun, have a poor (open) plate fit. This is due to the cumulative movement of all the shear/wrench and splay faults linking Brazil and Africa during the early breakup phase (see Figure 3B). The W-E trending Pernambuco fault, located immediately north of the Tucano basin (Figure 3B), is expressed on the African plate as the Foumban fault zone in Cameroon. To the north of the Pernambuco fault other splay faults, shown in Figure 3B, closely relate to the conjugate Benue Trough (Figure 2). The sum movement of all these structures has significantly affecting the shape of this conjugate margin. The implication of these movements is that the Equatorial Atlantic margins should not be used as a constraint for any reconstruction of the South Atlantic margins.

The Kandi fault zone can be traced north through Africa into Algeria using the gravity data (Figure 5) since the coverage of the aeromagnetic data is not as complete as one would like. In addition this region of Africa is close to the magnetic equator, thus tracking a S-N magnetic lineament would be difficult. Since this suture zone is several hundred kilometers wide it can never-the-less be identified in the CHAMP satellite magnetic data (Fairhead and Maus, 2003) as a negative Analytic Signal anomaly i.e. similar to the imaging of the TBL as a low susceptibility zone. In southern Algeria where the terrestrial aeromagnetic coverage is good, the S-N shear zone is clearly defined (Figure 6). The sinistral movement associated with this fault zone is confirmed within the central Saharan basin of Algeria by Guiraud and Alidou (1981).

Tectonic Importance of Lineaments

Since Mesozoic times the lineaments delineated in Africa (Figure 2) are associated with Gondwana plate breakup and have utilized earlier crustal weaknesses in their fracture propagation. As such they continue to be zones of crustal weakness and sites of sedimentary basin formation. These basins exhibit poly-phase basin development responding to the ever-changing plate tectonic stress patterns. This has been clearly demonstrated by Guiraud's studies of the West African interior rift basins (see Special Volume 213 of Tectonophysics 1992). The older lineaments identified in Figure 1 probably relate to similar tectonic processes. The advantage that gravity and magnetic imaging has over satellite optical/digital terrain imaging of these lineaments is the ability to use these data to determine the cross-cutting relationships and thus the sequence of tectonic events.

Convergence of Lineaments in Algeria: The lineaments shown in Figure 1 have profound influence on the development of sedimentary basins.

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Taoudenni Lineament: This ENE trending lineament in Mauritania and Mali (Figure 1), is Upper Proterozoic in age with Upper Proterozoic basins preserved. These basins are now being actively evaluated for their hydrocarbon potential. In Algeria the lineament appears to control the sedimentation during the Palaeozoic in the Saharan Platform and has been subsequently cross cut by the N-S zone of Pan African and Mesozoic fault structures. Further ENE in Libya it has been identified as a basement lineament from aeromagnetic data (Witte et al., 2007).

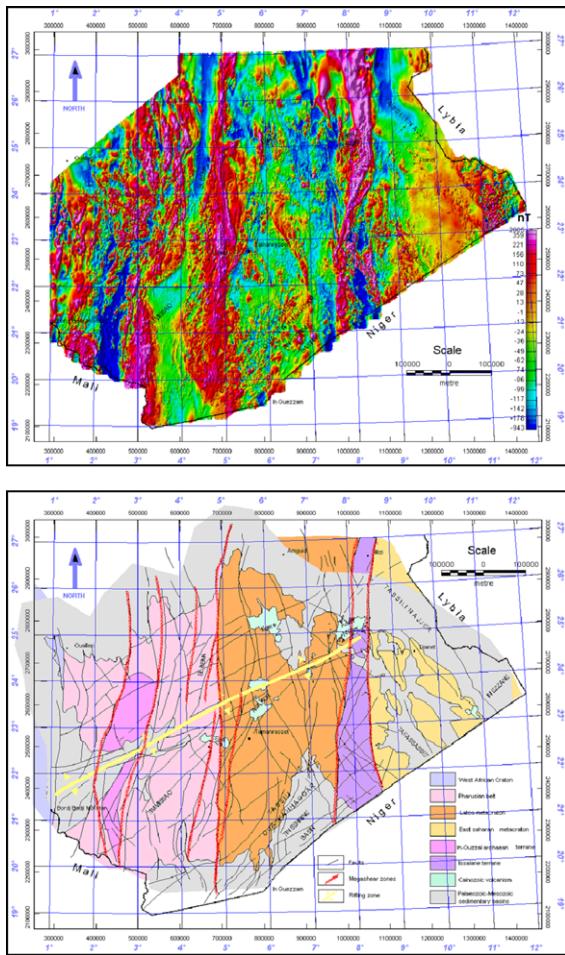


Figure 6: Aeromagnetic map of southern Algeria and its structural interpretation after Bournas et al. (2004)

Tibesti Lineament: This lineament is recognized at its NW end in the gravity field where it subdivides the Atlas Orogenic Belt into the Anti Atlas to the SW and Saharan Atlas to the NE. In Algeria it is disrupted, in a similar way to the Taoudenni lineament, by the S-N trending Pan Africa

and Mesozoic fault structures. The age of the Tibesti lineament is unknown but is likely to be older than the Pan African event.

How these lineaments relate more precisely to one another in Algeria will be the focus of Bournas et al (2007) SEG presentation.

Closing of the South Atlantic: Restoring the shear movement of the Trans Brazilian Lineament (TBL) back to ~130Ma (see Figure 7) requires dextral shear movement, estimated to be about 100 km, based on displacements estimated associated with the Central African Shear Zone (Figure 2). This amount of shear movement significant changes the geometry of the coastline and COB of NE Brazil. This plate restoration back to ~130 Ma (Figure 7) alone allows for a much tighter plate fit of the South Atlantic Ocean, due to the anti-clockwise rotation of the NE Brazilian. Because of the amount and complexity of deformation that has taken place in NE Brazil and in West Africa (Nigeria and Cameroon), the overall shape and geometry of the Equatorial and South Atlantic continental margins has changed significantly during continental breakup. Thus plate reconstruction of the South Atlantic Ocean should not use the Equatorial Atlantic margins as constraints. Currently plate tectonic reconstruction software do not generally allow the degree of fragmentation of Africa and South America that is needed and even if they did the amount and complexity the shear displacements, as illustrated in NE Brazil, can at best only be estimated.

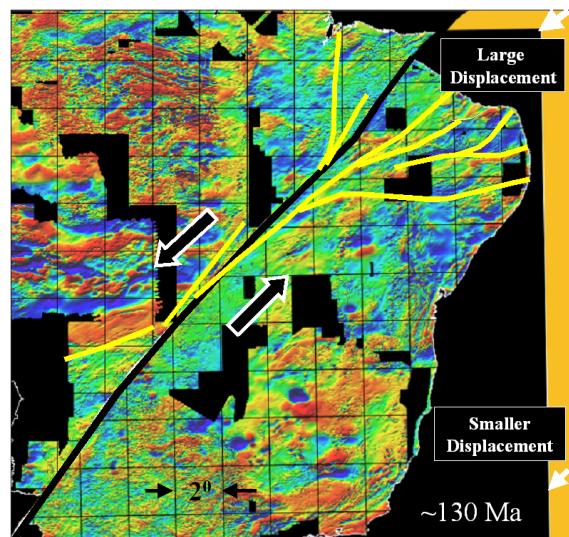


Figure 7: Restoring the position of eastern Brazil at ~130Ma using a dextral displacement of ~100 km. The 200 km graticule and orange frame indicates the sense of motion of eastern Brazil.