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Was the Iberian Plate moored to Africa during the Tertiary?

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One of the less constrained features in the Iberian tectonic evolution is the relative motion between the so-called Iberian Plate or Iberia and the African Plate. This is due mainly to the occurrence of compressive and distributive Neogene deformation along the old oceanic segment of this plate boundary, in the Atlantic depths, and to the superposition of the exotic terrane of Alboran, in the Mediterranean segment.

Flow-lines describing the Africa-Eurasia movement show clearly a sinistral displacement of Africa respect to Eurasia since the first stages of spreading in the central Atlantic up to sometime between anomalies M0 and 34 (120-83 Ma). With Iberia attached to Europe, this movement can be described as quasi-pure transform along the soutwestern part of Iberia (Azores-Algarve Basin) and oblique extension in the southeastern part (Betic margin). This plate arrangement resembles in certain aspects to a Gulf-of-California type of plate margin, open to the Ligurian Ocean ? with subordinate oblique extension in the complex Betic (South Iberian) Margin, characterised by internal basins and swells and unequal development of the Subbetic and Prebetic realms.

It is not clear the age of the end, or slow transition, of this sinistral transform movement that gave rise to overall convergence at the Africa-Europe plate boundary. This change occurred during a period of no magnetic reversals (Cretaceous Normal Superchron, CNS), thereafter the end of transform-related oblique extension in the South Iberian Margin remains imprecise. Short before this 120-80 Ma transitional period,

Iberia started to separate from North America during the 131-120 time span anomalies (M11 to M0) as a consequence of the northward propagation of the Atlantic spreading centre. This propagating rift, and asymmetric extension, may result in some differential motion between Europe and Iberia. Lately, with the onset of oceanic floor north of Iberia and sometime prior to anomaly 34 (83 Ma), the Iberian Plate is trained by and partially incorporated to Africa.

At this point the Africa-Iberia relative motion remains quite imprecise. At the longitude of Spain, the relative motion of Africa and Europe has been described as left lateral between anomalies 34 and 32-21 (83-46 Ma) and as N-S pure convergence between anomalies 21 and 5 (46-9 Ma). In this context, for the Africa- Iberia boundary one can envisage at least minor lateral motion during the latest Cretaceous and overall compression during the Paleogene and the Lower-Middle Miocene.

Within this gross model of relative movements, the type of boundary and the amount of translation across the Africa-Iberia interface are crucial for the understanding of the intraplate (or closely related to plate boundary) deformation, which now is expressed clearly in the topography of both Morocco and Spain-Portugal territories. In absence of a better resolution for the evolution of this ill-defined boundary new tectonic and palaeomagnetic data with the aim to constrain the model for the Africa-Iberia plate interrelation.

There is a general agreement between tectonic data and the plate model for the first stage (Jurassic Stage) of the Atlantic opening. Main transform-related features are evidenced in the Algarve (South Portuguese) Margin as witness of left-lateral motion between Africa and Iberia (Vegas *et al.* 2004). As above mentioned, oblique extension can account for the development of the Betic Margin, illustrating the en-echelon development of the intrabasinal configuration of the sedimentary highs. The disposition of other attendant intraplate rift zones, such the High Atlas ? right-lateral oblique extension ? and the Iberian Chain ? left-lateral oblique extension ? can also be explained as intracontinental stress transmission from this sinistral shear zone formed at the Africa-Iberia interface.

Plate reconstructions do authorise the continuation of this kind of motion, although with a substantial decrease in speed, until the Upper Cretaceous. In fact, sedimentation on the Algarve and Betic basins seems to have decreased during the Upper Cretaceous as a result of gradual cessation of the tectonic activity along the Iberia-Africa boundary.

A second tectonic stage initiates with the onset of convergence between Africa and Europe at the beginning of the Paleogene. This change in tectonic regime is recorded by the first stages of compressive deformation in the Pyrenees, where the *main* Africa-

Europe must be placed at the longitude of the Iberian Peninsula.

Although the most part of convergence ought to be assumed along this plate boundary, some *intraplate* deformation must be considered. Thereafter the Triassic-Jurassic rifts underwent a process of inversion, which culminated in the formation of the Atlasic and Iberian systems. Moreover the convergence was accommodated in several sub-parallel basement uplifts, or *plis-de-fond*, in the Variscan massifs of both the Iberian Peninsula and northern Africa. It is generally accepted that the final uplift of these intraplate chains postdates the collision in the Pyrenees and thereafter one can relate this *distributed* intraplate deformation to the Pyrenean orogen, the main source for stress transmission from the Iberia-Europe plate-boundary, in fact the Africa-Europe boundary during this tectonic regime. This regular pattern of intraplate deformation is coherent with a broad zone of accommodation of the convergence in the *lower plate*, i.e. the great African Plate plus the Iberian promontory. Inside this lower plate, deformation is localized along the previous stretched zones, the Mesozoic basins, as well as along other fault zones inherited either from the Variscan deformation or from the successive stages of the opening of the Atlantic. From this intraplate pattern, a solid attachment of Iberia to Africa can be inferred.

As for the direction of plate convergence, or slip vector, at the longitude of Iberia, intraplate structures are coherent with a 000 to 010 direction of the Africa-Europe slip-vector defined for the Early Eocene-Late Tortonian time span (50-9 Ma). Since then, at the longitude of the Iberian Peninsula, the direction of the Africa-Europe convergence changes to 130-140 and thereafter some reactivation of compressive structures can be expected. For this *neotectonic stage* a certain degree of lithospheric coupling between Africa and Iberia is also needed.

In this tectonic scenario, the overthrusting of the Alboran terrane onto the margins of the Africa-Iberia Mesozoic boundary does not contribute essentially to the accommodation of the overall Africa-Eurasia convergence. Only the thin-skinned foreland fold-and-thrust belt formed in the eastern part of the Betics (the Prebetic) seems to be congruent with the initiation of the *neotectonic* (9 Ma to Present) intraplate deformation.

Recent paleomagnetic studies on rocks of two Lower Jurassic great dolerite dykes of Spain-Portugal and Morocco, Plasencia-Messejana and Foum Zguid, show that no substantial latitudinal motion has occurred between the African and Iberian plates since the last 200 Ma, the age of the intrusion of the dykes. This is inferred from the fact that the rocks of both dykes yield an identical paleomagnetic pole. This precludes any latitudinal motion between them since the earliest Jurassic. The tectonic consequences this paleomagnetic study indicate that the Mesozoic Africa-Iberia rela-

tive motion must be purely longitudinal, since this kind of motion cannot be detected because of the geocentric axial dipole nature of the geomagnetic field. This agree with the transform-like motion along a roughly E-W plate-boundary. On the contrary, a significant north south directed convergence, and hence a substantial latitudinal motion, must be discarded. Indeed, there is a good concordance between the APW paths of Africa and Iberia for the Tertiary, indicating that since the Eocene no important relative motion, in the paleomagnetic sense, has occurred at the Africa-Iberia boundary.

All the above exposed data indicate that boundary stresses responsible for the intraplate deformation of Iberia, inasmuch from Eocene up to Middle-Upper Miocene, must be referred to the Iberia-Europe interface, the Pyrenean border. The remaining slow convergence, initiated at 9 Ma, seems to be very distributed over a wide area ? between the Anti-Atlas and the Pyrenees ? and causes the formation of the new Africa-Iberia frontier, in fact a not fully-fledged compressive plate boundary.