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Tectonic and geodynamic significance of paleomagnetic rotations in the Iberian Chain, Spain

Significado tectónico y geodinámico de las rotaciones paleomagnéticas en la Cadena Ibérica, España

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RESUMEN

Las evidencias obtenidas en calizas del Jurásico Superior de la Cadena Ibérica sobre (a) una componente magnética secundaria (cretácica) diferente de la magnetización primaria y (b) rotaciones locales de eje vertical de ambas componentes, delimitan en parte la historia evolutiva del movimiento de la Placa Ibérica e implican una reconsideración del concepto de "Iberia estable". La coexistencia de sitios rotados y no rotados apoya además un modelo tectónico de convergencia oblicua con relaciones diferenciales entre cobertera y basamento.

ABSTRACT

Evidence from Late Jurassic limestones of the central Iberian Chain for (a) a secondary (Cretaceous) magnetic component different in declination by some 15° (clockwise) from the direction of the primary magnetization, and for (b) local vertical-axis rotations of both these components, provides additional constraints on the history of motion of the Iberian Plate and implies a reconsideration of the concept of «stable Iberia». Moreover, the coexistence of rotated and non-rotated sites across the Iberian Chain supports a tectonic model of intraplate oblique convergence and differential cover-to-basement relationships.

Key words: *Palaeomagnetic rotations, opening of the Bay of Biscay, oblique convergence, Iberian Chain.*

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Introduction

A recent palaeomagnetic study on Jurassic (Oxfordian) limestones from the central Iberian Chain has shown local *in situ* vertical-axis rotations (Juarez, 1994; Juarez *et al.*, 1995 and in prep.). In particular, such rotations have been detected in samples from sites Aguatón and Pozuel del Campo (N of Teruel; fig. 1), where they affect both the primary (P) and a distictive secondary (S) component. At the sites of Tosos, Moneva, Anquela del Pedregal, Alustante, Griegos and Frías de Albarracín (N and S of the axial zone of the range (Fig. 1), on the other hand, measured palaeodeclinations of the P component, around 320°-330°, are broadly consistent with the presumed Late Jurassic direction for the Iberian Peninsula. The S component, always with normal polarity and with declinations in the range of 335°-345°, thus seems to represent an (?Early) Cretaceous remagnetization. The angular difference between both components, scattering around 15°, is similar in either group of sites.

The existence of differential rotations between sites across the Iberian Chain calls for a redefinition of «stable Iberia», i.e that part of the Iberian Peninsula not affected by perceptible internal deformation and therefore suitable for paleopole determinations. Furthermore, a plausible interpretation of the origin of the S component, of its angular difference with the P component and of the particular tectonic setting of rotated and non-rotated localities, may assist in the understanding of the intraplate evolution and the kinematic history of the Iberian Peninsula. All these points are briefly addressed in this note.

Tectonic setting of rotated and non-rotated sites in the Iberian Chain

The *in situ* palaeomagnetic rotations determined at sites Aguatón and Pozuel del Campo must be causally related to the Eocene to Early Miocene regional compressive/transpressive tectonism, as bth the P and S components pass the fold test (Juarez 1994). Intraplate compression and oblique tectonic inversion originated in stress transfer from the collisional Pyrenean border. In such a tectonic context, the coexistence of rotated and non-rotated domains in the central Iberian Chain points to differential cover-to-basement relationships. Accordingly, the unrotated Tosos and Moneva sites (located NE of the axial zone of the chain) would belong to a cover panel detached and dragged as a whole along the Armillas-Fonfría Fault (Fig. 1), a dextral basement fault studied

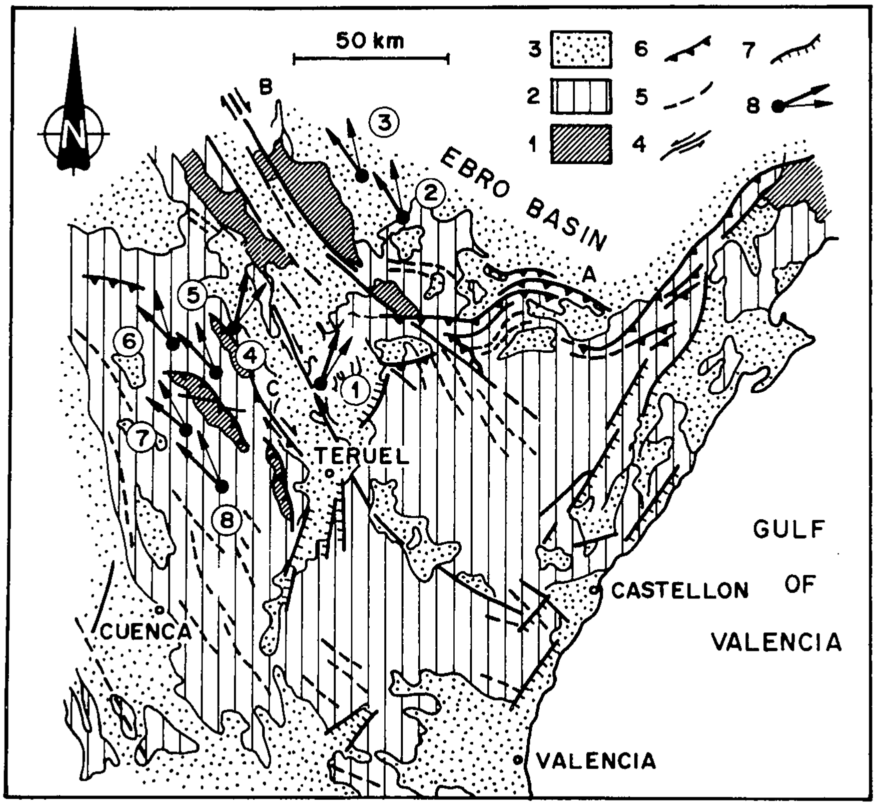

Fig. 1.- Geological sketch and location of palaeomagnetic sites in the central Iberian Chain. 1. Hercynian basement; 2. Mesozoic cover; 3. Tertiary basins; 4. strike-slip faults; 5. anticlines and monoclines; 6. thrusts; 7. normal faults; 8. relative positions and azimuth of P (bold arrow) and S components. A. Portalrubio thrust system; B. Armillas-Fonfría fault; C. Sierra Menera, Sierra Palomera and Ateca fault system. Encircled numbers: 1. Aguatón; 2. Moneva; 3. Tosos; 4. Pozuel del Campo; 5. Anquela del Pedregal; 6. Alustante; 7. Griegos; 8. Frías de Albarracín.

Fig. 1.- Esquema geológico y situación de los sitios paleomagnéticos en el centro de la Cadena Ibérica. 1. basamento hercínico; 2. cobertera mesozoica; 3. cuencas terciarias; 4. fallas en dirección; 5. anticlinales y monoclinales; 6. cabalgamientos; 7. fallas normales; 8. posiciones relativas y azimut de las componentes P (en trazo grueso) y S. A: sistema de cabalgamientos de Portalrubio; B: falla de Armillas-Fonfría; C: sistema de fallas de Sierra Menera, Sierra Palomera y Ateca. Números en círculos: 1. Aguatón; 2. Moneva; 3. Tosos; 4. Pozuel del Campo; 5. Anquela del Pedregal; 6. Alustante; 7. Griegos; 8. Frías de Albarracín.

in detail by Calvo Hernandez (1993). Oblique convergence was in part accommodated by cover folding, with axial traces at low angles to the shear direction (e.g. Tosos Anticline), and no significant *in situ* rotations. However, most of the dextral motion in the basement was taken up by a frontal thrust (Portalrubio thrust system; Fig. 1) that swings through 90° to join the Catalan Ranges. In contrast, sites Aguatón and Pozuel del Campo lie within the major dextral fault system that constitutes the «backbone» of the chain (Ateca, Sierra Palomera and Sierra Menera faults). There, oblique convergence caused basement uplifts and rupture of the cover in the form of positive flower structures, as well as in-line folds (Calvo Hernández, 1993). The *in situ* clockwise rotations are easily explained in this tectonic context. As far as the sites located SW of the axial strike-slip zone are concerned (Alustante, Anquela, Griegos and Frías; Fig. 1), by analogy with the situation observed to the NE, intraplate compressional stresses were accommodated through roughly NE-SW directed low-angle thrusting and folding, again without measurable vertical-axis rotations.

Geodynamic implications

The aximuthal difference established between the P and S magnetic components amounts to a 40-50% of the estimated total value of approximately 35° for the anti-clockwise rotation of Iberia relative to Europe since the latest Jurassic. A reliable dating of the remagnetization episode would thus provide important clues to a refined timing of the rotation of the Iberian Peninsula and, hence, help in settling the ongoing controversy concerning the early (essentially pre-Albian) kinematic evolution of the Bay of Biscay. Currently available paleomagnetic data from the study area do, however, not allow to fix this age adequately, so that an assessment has to be based on indirect evidence:

a) From a regional geological point of view, a Cretaceous thermal event, documented by low-grade metamorphism and an associated phase of ductile deformation (sinistral transpression; Gil Imaz and Pocoví Juan, 1994) in the NW part of the Iberian Chain (Cameros Massif, Sierra del Moncayo), obviously appears as the prime candidate for the acquisition of the S component. Radiometric dates of around 100 Ma and in the range between 108 and 86 Ma, obtained by Goldberg *et al.* (1989) and Casquet *et al.* (1992) respectively, assign this metamorphism to the Albian p.p. - Santonian interval (roughly coinciding with the younger half of the Cretaceous Normal Polarity Superchron, CQZ).

b) Alternatively, the time of partial remagnetization can be inferred by comparing the inherent magnetization direction with presumed original directions for the Cretaceous Period defined in other areas of stable Iberia. Following this approach, a fair coincidence shows up with the Aptian and Barremian-Aptian paleomagnetic directions reported by Galdeano *et al.* (1989) and Moreau *et al.* (1992) respectively, thus suggesting an age in the bracket of 130-120 Ma (? chrons M2N, M1N or oldest part of CQZ).

It is interesting at this point to check these two estimates against the results of recent kinematic analyses concerned with Iberia and the origin of the Bay of Biscay. Figure 2 is intended to summarize these data, along with some additional information relevant to the tectonic evolution of the N Iberian plate boundary and the NE plate interior. Our reconstruction of the Iberia-Europe relative motion (Fig. 2A) combines the work of Malod and Mauffret (1990), focussed on the Late Jurassic-Early Cretaceous (pre-M0) kinematics, with the detailed plate motion model derived by Srivastava *et al.* (1990; extended in Roest and Srivastava, 1991), from chron M0 to Present. We prefer such a combination to the full model developed by the latter

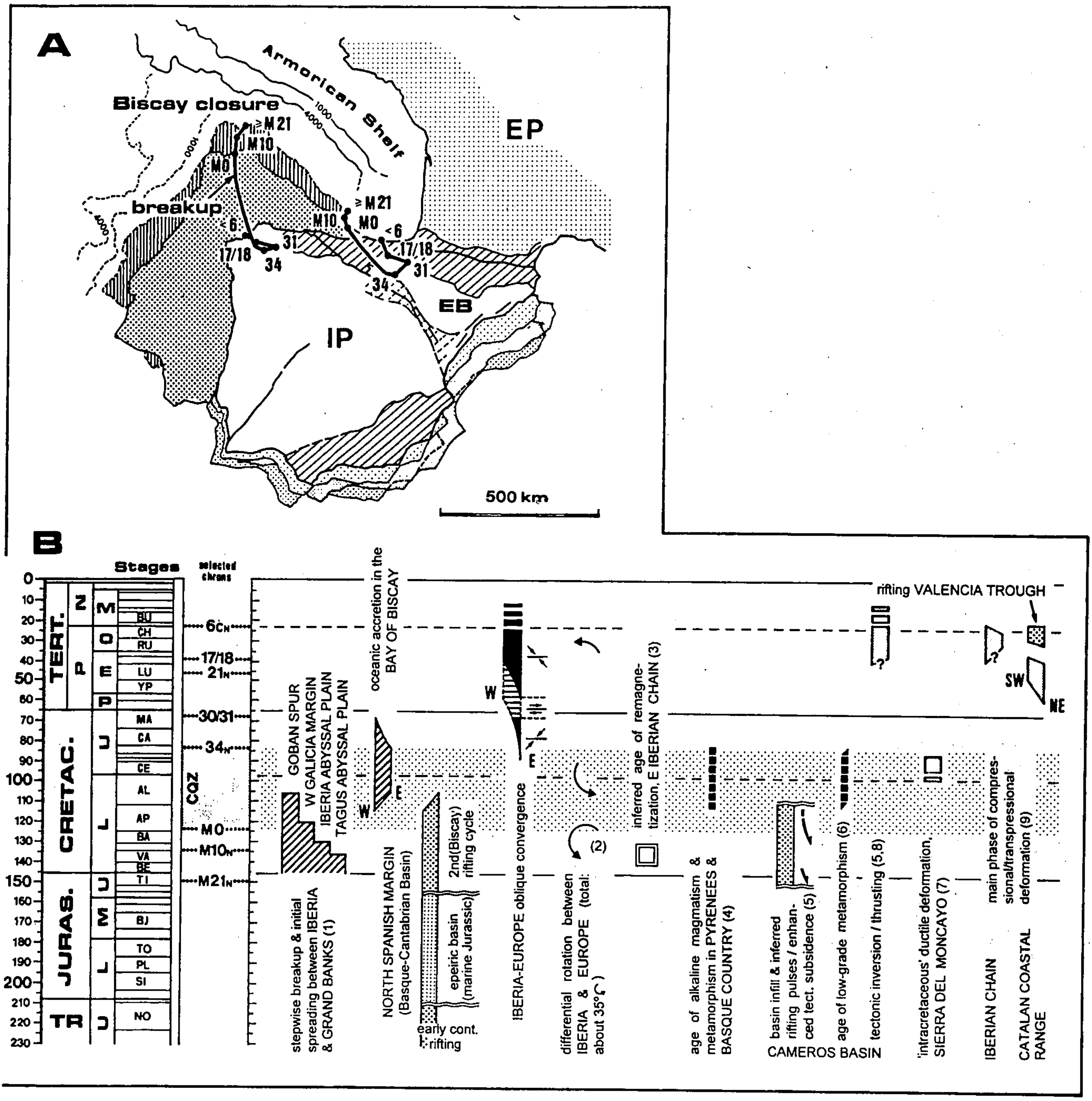

Fig. 2..- (A) Motion of the Iberian Plate with respect to Europe from Late Jurassic to Present, based on Malod and Mauffret (1990) for pre-Anomaly M0 (Early Aptian) kinematic evolution, and on Srivastava *et al.* (1990) and Roest and Srivastava (1991) later on. Flow lines depict motion paths for two localities on present-day North Spanish coast. EB: Ebro block.(B) Correlation of some major geological events. Chronostratigraphy and selected magnetostratigraphic data after Harland *et al.* (1989). CQZ: Cretaceous Magnetic Quiet Zone (Cretaceous Normal Polarity Superchron). (1) Whitmarsh *et al.* (1990), Pinheiro *et al.* (1992); (2) main phase of rotation (about close pole) according to Galdeano *et al.* (1989) and Moreau *et al.* (1992); (3) Moreau *et al.* (1992); (4) Montigny *et al.* (1986), Ancochea *et al.* (1992); (5) Mas *et al.* (1993); (6) Casquet *et al.* 1992), Goldberg *et al.* (1988); (7) Gil Imaz and Pocoví Juan (1994); (8) Casas Sainz (1993); (9) Guimerà (1984), Guimerà and Alvaro (1990).

Fig. 2.- (A) Movimiento de la Placa Ibérica respecto a Europa desde el Jurásico Superior; basado en Malod y Mauffret (1990) para la evolución cinemática pre-Anomalía MO (Aptiense Inferior) y en Srivastava et al. *(1990) y Roest y Srivastava (1991) para el período posterior. Las líneas de flujo describen el movimiento de dos localidades en la costa actual del norte dde España. EB: Bloque del Ebro. (B) Correlación de algunos eventos geológicos principales. Cronoestratigrafía y datos magnetoestratigráficos puntuales según Harland* et al. *(1989). CQZ: Zona de Calma Magnética cretácica (Supercrón cretácico de polaridad normal). (1) Whitmars* et al. *(1990), Pinheiro* et al. *(1992); (2) fase principal de rotación (alrededor de un polo próximo) según Galdeano* et al. *(1989) y Moreau* et al. *(1992); (3) Moreau* et al. *(1992); (4) Montigny* et al. *(1986), Ancochea* et al. *(1992); (5) Mas* et al. *(1993); (6) Casquet* et al. *(1992), Goldberg* et al. *(1988); (7) Gil Imaz y Pocoví Juan (1994); (8) Casas Sainz (1993); (9) Guimerà (1984), Guimerà y Álvaro (1990)*

authors, because of a better agreement with continental geological and geophysical data.

From figure 2 it readily appears that, relying on current North Atlantic plate reconstructions, a major part of the differential rotation between Iberia and Europe had to occur in connexion with oceanic accretion in the Bay of Biscay, whereas at best a 30% of the total amount was related with the Valanginian-Aptian stepwise north-ward propagation of the Atlantic Ridge along the W Iberian margin, and continental rifting in the Biscay area. This is in obvious contrast with the interpretation derived by Galdeano *et al.* (1989) and Moreau *et al.* (1992) from paleomagnetic work, according to which the main phase of rotation (27°±12°) would have taken place within the Hauterivian-Aptian interval, prior to spreading in the Bay of Biscay. Our estimate (b), implying a rotation in the order of 15° before 130-120 Ma (Barremian-early Aptian), clearly better accords with kinematic data, but still exceeds significantly model predictions. The contrary occurs with estimate (a), which predicts a rotation by the same amount between the Late Jurassic and some date within the Albian p.p.-Santonian interval (108-86 Ma; during Biscay spreading stage), unless the older limit of the interval and/or important variations in spreading rate were assumed.

No decisive arguments seem to exist so far in favour of one or the other interpretation of our results. However, regional geological data at hand collectively lead us (other than Moreau *et al.*, 1992; *cf.* Fig. 2B) to give preference to a causal relationship between remagnetization and the low-grade metamorphism occurring in the NW Iberian Chain (estimate (a)), disregarding the apparent incon-sistencies concerning the angular difference between the P and S magnetic components.

We further suggest a correlation of this metamorphism and related ductile shearing with the change in the Iberia-Europe relative motion to northeasterly directed convergence, shortly before anomaly 34 time (*cf.* Fig. 2A), and hence an early stage of shortening and oblique tectonic inversion in the previously rifted, thus weakened, crustal domain between «Iberia» and the Ebro Block. The main phase of deformation (dextral transpression) in the Iberian Chain seems, however, to be a consequence of the oblique convergence during the time interval between anomalies 17/18 and 6 (late Middle Eocene-Early Miocene). This intraplate oblique-convergent deformation was partitioned into strike-slip faulting and thrusting, the former involving localized block rotations and, therewith, *in situ* paleomagnetic rotations in the Mesozoic cover.

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