Sinistral transcurrent transpression at the Ossa-Morena Zone / Central-Iberian Zone boundary: the Portalegre-Esperança shear zone (Portugal)

Transcurrencía transpressiva sinestral en el límite entre las zonas de Ossa-Morena y Centro Ibérica: la zona de cizalla de Portalegre-Esperança (Portugal)

M. Francisco Pereira (*) and J. Brandão Silva (**)

(*) Departamento de Geociências, Centro de geofísica, Universidade de Évora. Apt 94, 7002 - 554 Évora Codex, Portugal ; mpereira@uevora.pt
(**) Departamento de Geologia, Faculdade Ciências Universidade de Lisboa. C2 - 5º Piso, 1700 Lisboa, Portugal; jbsilva@fc.ul.pt

RESUMEN

En el borde sur del Macizo Ibérico, al NE del Alentejo (Portugal) se ha reconocido la zona de cizalla varíscica de Portalegre-Esperança (PESZ). Esta zona incluye rocas del basamento de Ossa Morena del Proterozoico superior sobre las que reposa, discordante, una secuencia de rocas sedimentarias del Paleozoico Inferior de la Zona Centroibérica. El análisis estructural de la PESZ revela una compleja arquitectura tridimensional caracterizada por una foliación milonítica muy verticalizada, una lineación de estiramiento subhorizontal y simultánea una componente direccional (desgarre) y oblicua-direccional (inversa o normal) de sentido sinistrorso. Se ha interpretado como parte de un regimen de deformación transpresivo, en el que predomina una partición de la deformación y una dirección de transporte tectónico paralela al orógeno.

Key words: *Central-Iberian / Ossa-Morena zones boundary, transcurrent transpression, sinistral shearing, strain partitioning, upper crustal levels.*

Geogaceta, 29 (2001), 99-102
ISSN: 0213683X

Introduction

A field selected area located along a major tectonic boundary zone within the southern branch of the Ibero-Armorican Arc (IAA), in East Portugal was chose to present general observation on strain localization and partitioning processes as well as structural variation within a typical zone of ductile transpression. The IAA generated during regional transpressive tectonics (e.g. Dias and Ribeiro, 1994; Ribeiro *et al.*, 1995) represents a prominent segment of the Variscan fold belt in Western Europe that links the Iberian Massif to the Armorican Massif (Matte and Ribeiro, 1975; Brun and Burg, 1982). This work will focus on the southern margin of the Central-Iberian zone (CIZ) bound to the South by the Ossa-Morena zone (OMZ), where kinematics criteria for left-lateral transpressive tectonic evolution have been recognized (Sanderson *et al.*, 1991; Abalos, 1992; Pereira and Silva, 1995), also interpreted due to oblique extensional shearing (Azor *et al.*, 1994).

The aim of this paper is to describe and discuss the three-dimensional distribution of geometric and kinematics in a transpressional shear zone, the Portalegre-Esperança shear zone (PESZ) (Pereira, 1999), where strain partitioning with flattening, constriction and orogen-parallel transport are present.

The PESZ represents a major shear zone, developed under low-grade metamorphic conditions (Pereira *et al.*, 1997; Pereira, 1999). It is bound to the northeast by the Paleozoic CIZ basin north of the Alegrete fault, and to the southwest by the Upper Proterozoic OMZ basin south of the Mosteiros fault (Fig.1). Along the margin of the CIZ a Lower Paleozoic sequence that includes the southernmost occurrence of Armorican quartzites in the Iberian Massif, overlies the Upper Proterozoic basement rocks of the OMZ. The Upper Proterozoic-Lower Paleozoic stratigraphic record in the Portalegre-Esperança region includes from the bottom to top: i) an Upper Proterozoic basement (Mosteiros Formation of the Black Series; Gonçalves and Oliveira, 1986) consisting of a thick sedimentary sequence of low-grade metamorphic pelites, greywacke and cherts with intercalations of carbonates and bimodal volcanic rocks; ii) The Urra Formation (Gonçalves, 1971), a Cambrian and/or Ordovician sequence of volcaniclastic rocks which unconformable overlie the Mosteiros Formation; iii) the Armorican Quartzite a platform sequence with abundant quartzites, scarce interbedded pelites and basal conglomerates; iv) Llanvirnian black schist (Gonçalves and Peinador Fernandes, 1973), which include minor impure quartzites. The Portalegre Granite (466±12 Rb/Sr whole rock, Priem *et al.*, 1970) and the Carrascal Granite (Gonçalves and Peinador Fernandes, 1973) intruded this se-

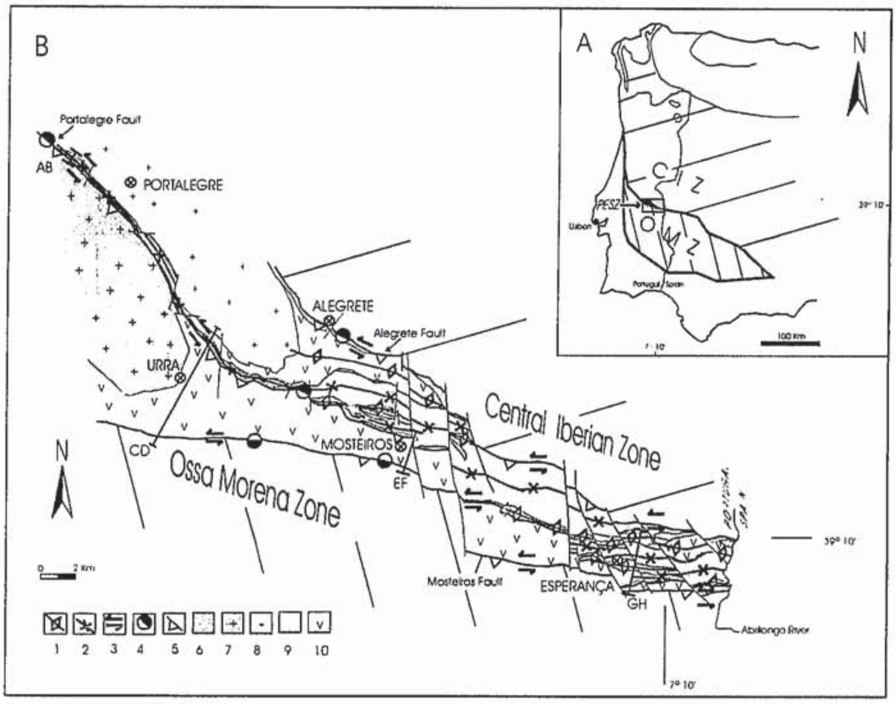

Fig. 1.- A - Geological sketch of the Portalegre-Esperança shear zone located at the Ossa-Morena (OMZ) / Central Iberian (CIZ) zones boundary. B - Schematic geological map of the Portalegre-Esperança shear zone. 1- F_k anticline; 2- F_k syncline; 3- sinistral major faults; 4- relative movement of blocks: black-downward, white-upward; 5- fault strike and dip directions; 6- Armorican quartzites; 7- Carrascal granite; 8- Portalegre granite; 9- Llanvirnian black slates; 10-Urra formation volcaniclastics rocks. A-B, C-D, E-F and G-H are the lines of the studied cross sections.

Fig. 1. A – Esbozo geológico de la localización de la zona de cisalla de Portalegre-Esperança en la frontera entre las zonas de Ossa-Morena (OMZ) y Centro Ibérica (CIZ). B – Mapa geológico esquemático de la zona de cisalla de Portalegre-Esperança. 1- F_k anticlinal; 2- F_k sinclinal; 3- fallas principales sinistras; 4- quartzitas Armoricanas; 5- granito de Carrascal; 6- granito de Portalegre; 7- esquistos negros del Llanvirn; 8-rocas volcanoclasticas de la formación deUrra. A-B, C-D, E-F y G-H representan la localización de los cortes geológicos estudiados.

quence and have been deformed during regional Variscan tectonics.

Structure of the Portalegre-Esperança shear zone

The geometry and kinematics of the Variscan structures that define the complex architecture of the PESZ have been studied in several transverses (cross-sections A-B, C-D, E-F and G-H, Fig. 1).

Major faults represent kilometric scale lineaments (Fig.2) along which shearing was preferentially accommodated: i) the Alegrete fault, located along the mechanical interface between the Armorican quartzite and the more pelitic stratigraphic units of the CIZ basin; ii) the Portalegre fault, located along the mechanical interface between the Armorican quartzite and the Urra formation volcaniclastics rocks; iii) the Mosteiros fault, located at the mechanical interface between the Urra formation volcaniclastics rocks and the Mosteiros formation meta-sediments and volcanics from the OMZ. With respect to these macrostructures, it is possible to observe that in the northwest sector, the Portalegre fault dips to southwest recording a reverse oblique sinistral sense of movement (Portalegre and Urra areas, Fig.2: cross-sections A-B and C-D). However, to the east (Louções area, Fig.2: cross-section G-H), it becomes steeper, close to vertical, with a strong sub-horizontal stretching lineation and left-lateral shear. The Mosteiros fault exhibits a geometry changes from southwest dipping with reverse oblique sinistral sense of movement in the Portalegre area (Fig.2: cross-section A-B), through a normal oblique sinistral displacement in the Mosteiros area (Fig.2: cross-section E-F). Further east, this fault becomes close to vertical, displays left lateral shear in the Esperança region (Louções area) changing to a northeast dip with sinistral oblique normal shear criteria in Spain (Albuquerque region).

Two main orders of folding belonging to the same kinematic event can be identified along the PESZ (Pereira *et al.*, 1997): kilometric folds (F_k) and decametric-metric folds (F_{dm}). F_k folds (Figs.2 and 3) which extend for more than 40 Km trending N45-65W, vergent to northeast in the Portalegre region and trending N75-85W, vergent to the north-northeast in the Esperança region. F_{dm} folds, commonly developed on F_k limbs, are associated with left-lateral shearing. These second order folds were generated as complex fold structures that were developed progressively in the hanging walls of imbricate faults characterized by a ramp-flat geometry or in relation to steeply dipping shear bands. On these structures there are several different fold-forming possibilities, which depend on the location of the thick quartzite beds with respect to the thin pelitic layers. Within narrow branching shear bands located in thin pelitic layers interbedded in the quartzite sequence, a strong shear band cleavage was developed related with strain concentration.

Discussion

Macro- and mesostructural analysis shows that folds with hinges that are oblique to parallel to the stretching lineation, are the main characteristic feature of the PESZ. Shear bands within the Armorican quartzite sequence develop preferentially within mechanically weak thin pelitic layers. These particular shearing concentration boundary conditions are generally linked to a viscosity contrast between quartzites and the less competent lithologies. In such cases, different rheological properties result in different response to deformation, leading to heterogeneous strain distribution and the development of buckling instabilities within the competent layers (Grujic and Mancktelow, 1995). Strain concentration in many natural settings is probably related to initial rheological heterogeneity along pre-existing structural or lithological discontinuities in the protolith (Schmid and Handy, 1990). Due to the concentration of simple shear strain in narrow bands, folds developed progressively as result of shortening normal to the stretching lineation, in more competent zones, in which the pure shear component predominated. The folds evolve by progressive deformation from gentle buckling to tight folding with steep limbs according with a tectonic transport sub-parallel to the trend of the PESZ.

The structural geometry in the PESZ is governed by heterogeneous strain distribution, leading to the development of lenses of weakly deformed rocks bounded by bands of intense shearing. This structural pattern is observed at all scales in the Armorican quartzites and associated quartz-felspatic rocks. In the Carrascal granite, narrow zones of mylonitization with intense grain-size reduction represent bands of high strain, located along contacts with Armorican quartzite. The Urra volcaniclastic rocks have developed a strong mylonitic fabric

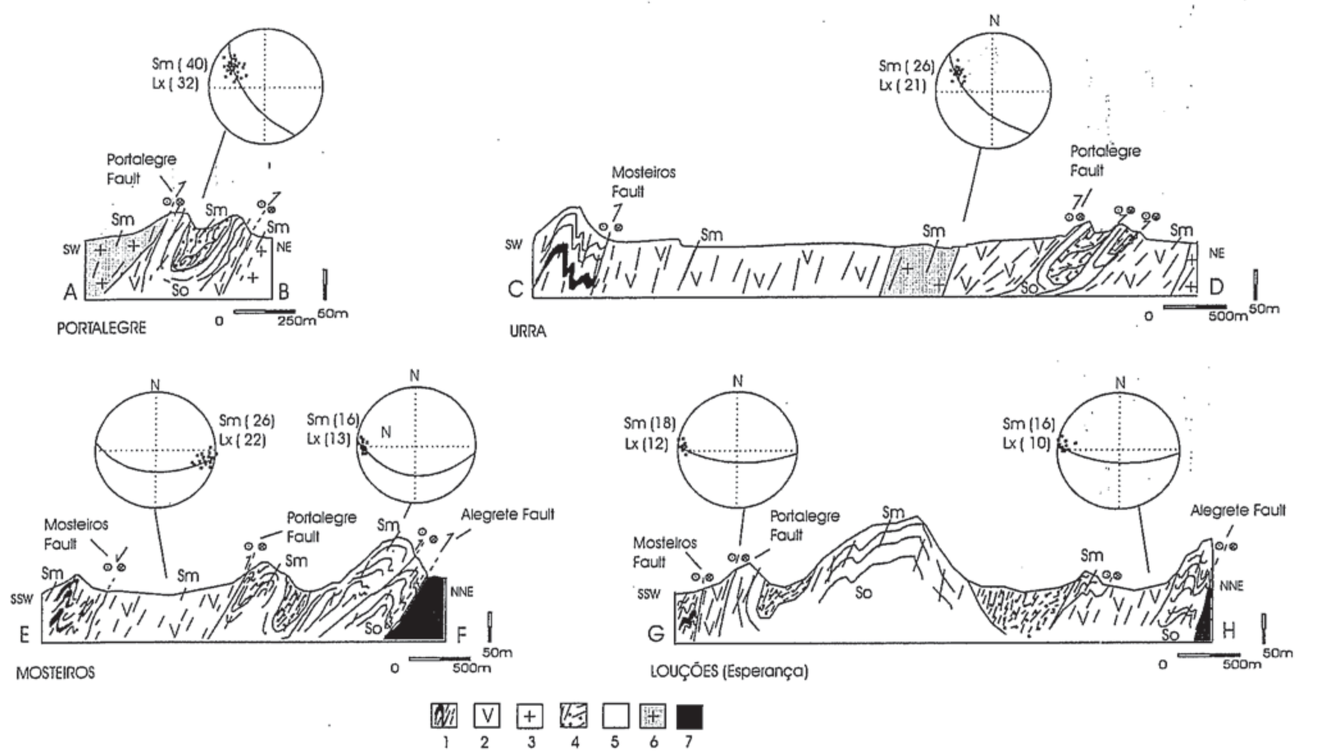

Fig. 2.- Schematic cross sections representing macroscale and mesoscale folds in different areas of the PESZ: A-B Portalegre, C-D Urra, E-F Mosteiros and G-H Louções (see figure 1 for location). Key: So, bedding; Sm, mylonitic foliation; 1, Black Series (Mosteiros formation); 2, Urra volcaniclastics rocks; 3, Portalegre granite; 4, Llanvirnian black slates; 5, Armorican quartzites; 6, Carrascal granite; 7, Silurian and Devonian sedimentary rocks; Stereoplots show the average orientation of the S-L fabric: stretching lineation (solid squares) and mylonitic foliation (solid line).

Fig. 2.- Mapa estructural esquemático de la zona de cisalla de Portalegre-Esperança. 1- movimiento relativo de los bloques: negro-descendiente, blanco-ascendiente; 2- componente sinistra de las fallas principales; 3- dirección y inclinación de las fallas; 4- (F_k) sinclinal kilométrico; 5- (F_k) anticlinal kilométrico. Cortes geológicos esquemáticos a representar dobramiento a las macro- e mesoscala en distintas áreas de la zona de cisalla de Portalegre-Esperança: A-B Portalegre, C-D Urra, E-F Mosteiros y G-H Louções. Clave: So, estratificación; Sm, foliación milonitica; 6, Serie Negra (formación de Mosteiros); 7, rocas volcanoclasticas de la formación de Urra; 8, granito de Portalegre; 9, esquistos negros del Llanvirnian; 10, quartzitas Armoricanas; 11, granito de Carrascal; 12, rocas sedimentarias Silúricas y Devónicas; Proyecciones estereográficas de la orientación media de lo fabric S-L: lineacíon de estiramiento (puntos negros) y foliación milonítica (línea a negro).

but, in some areas, these rocks are weakly deformed and primary structures and textures are still preserved.

Another important point, directly related to the main faults of the PESZ, is the fact that they are not continuous lineaments with the same geometric characteristics along their strike. The analogue experimental studies of Richard and Cobbold (1990) and Schreurs and Colleta (1998) are in good agreement with natural examples of continental transpressional tectonics, showing that sideways propagation at the tips of individual fault segments with increasing deformation induces geometrical modifications along the strike of lateral surfaces. Faults tend to link up with earlier formed lineaments and the result is a major anastomosing fault zone defining shear lenses (e.g. Schreurs and Colleta, 1998). For those examples, subvertical strike-slip faults could terminate by swinging into oblique-slip reverse or normal faults, as described in this work for the PESZ (Portalegre fault).

The stretching lineation related to the sinistral movement shows a peculiar variability along the PESZ trend, swinging gradually from west (Portalegre and Urra areas), with an oblique-slip thrust component (Fig2: cross-sections A-B and C-D), to an oblique-slip normal component in the center (Mosteiros area) (Fig.2: cross-section E-F), and a strike-slip component to the east (Louções area) (Fig.2: cross-section G-H). This variability can also be observed if we consider cross sections normal to the main trend of the zone (Fig.2: cross-section E-F).

Based on microstructural analysis it was possible to describe that Armorican quartzites display different aspects of intercrystalline deformation such as undulose extinction and lattice preferred orientation and evidence of recovery. These quartzites underwent dynamic recrystallization related to dislocation creep from regime 1 to the transition from regime 2 to regime 3 (Hirth & Tullis, 1992) suggesting that deformation took place under low-grade metamorphic conditions (~300°-350°C). Dynamic recrystallization is usually evident in a fabric characterized by large relic quartz grains with undulose extinction and subgrains with a shape-preferred orientation, surrounded by a matrix of new uniform small size grains with highly irregular boundaries. Analysis of deformation features in the Urra volcaniclastic rocks suggests intense sinistral shearing as indicates by asymmetrical pressure-shadows, recrystallization tails and rotation-induced fractures developed in porphyroclasts. Feldspar porphyroclasts have deformed by brittle fracturing and transformed to sericite. Quartz porphyroclasts are strongly flattened and experienced recovery and recrystallization processes (undulose extinction, subgrains and new recrystallized grains, in some cases mantled porphyroclasts structures). Elongated porphyroclasts banded recrystallized quartz ribbons and preferred orientation of phylossilicates defines the strong stretching lineation. Microstructural observations of quartz-feldspatic rocks (Urra volcaniclastics and Carrascal granite) suggest that deformation took place under low-grade metamorphic conditions (~300°-350°C), considering that quartz has deformed by dislocation creep and feldspar have developed brittle fracturing (e.g. Passchier and Throw, 1996).

In this paper, we have presented a description of different geometric and kinema-

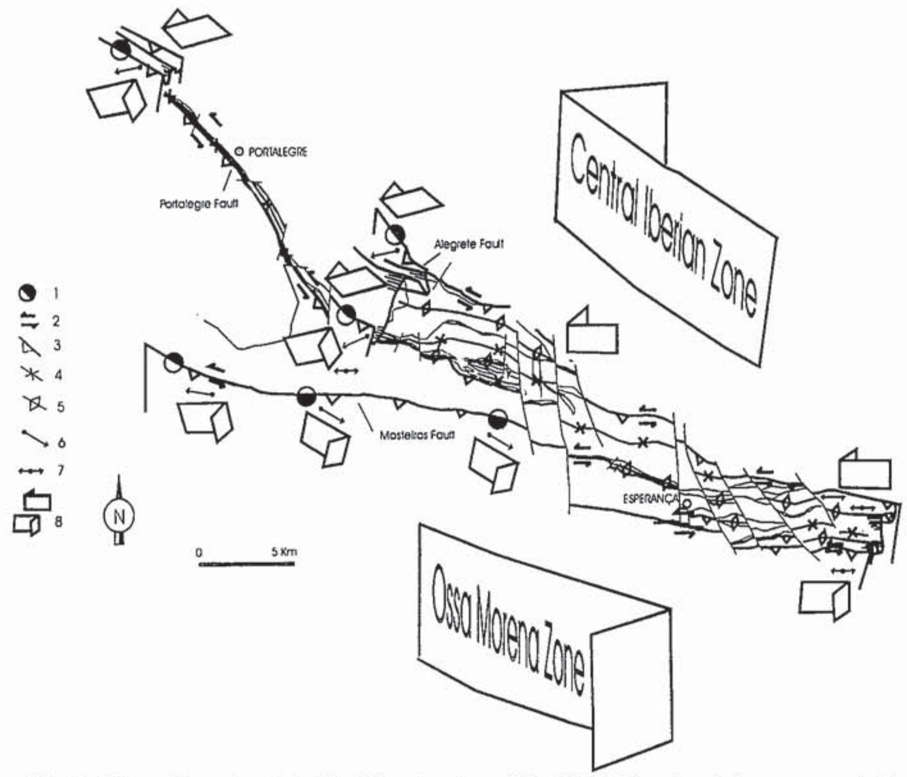

Fig. 3.- Three-dimensional sketch of the structure of the PESZ. Key: 1, relative movement of blocks: black-downward, white-upward; 2- sinistral component of major faults; 3- fault strike and dip directions; 4- F_k syncline; 5- F_k anticline; 6- stretching lineation; 7- subhorizontal stretching lineation; 8, transcurrent transpression component.

Fig. 3.- Esquema tridimensional de la estructura de la zona de cisalla de Portalegre-Esperança. Clave: 1, - movimiento relativo de los bloques: negro-descendiente, blanco-ascendiente; 2- componente sinistra de las fallas principales; 3- - dirección y inclinación de las fallas; 4- F_k sinclinal; 5- F_k anticlinal; 6- lineacíon de estiramiento; 7- lineacíon de estiramiento horizontal; 8, componente transcurrente transpression

tics characteristics related to the Paleozoic deformation of the PESZ. The discontinuous distribution pattern of these structural data suggests us that transpressive strain has been heterogeneously accommodated in space and probably in time, due to strain partitioning. This is supported by discrete occurrence along highly deformed shear bands within the transpressive zone, mainly localized along steep F_k limbs, where the quartzite layers are in contact with less competent lithologies (Urra volcaniclastics and/or Llandeilian-Llanvirnian black slates) or where more pelitic layers appear interbedded within the Armorican quartzite sequence. These shear bands belong to domains where simple shear predominates and separate domains where the pure shear component is the most relevant. It is also important to emphasize that the three-dimensional structural pattern reveals the coexistence, at the same exposure level, of simultaneous strike-slip and oblique-slip sinistral movements. These features are indicated systematic variations in lineation plunges parallel to the NW-SE trend of the zone, as well as to transversal variations normal to strike.

The PESZ is thus an example of a deformed region developed under a regime of sinistral transcurrent transpression. This ductile shear zone, where strain partitioning is present, is characterized by variations in stretching lineations plunges associated to a widespread mylonitic foliation, and fold axes trending subparallel to the orogen length and tectonic transport direction.

Data presented suggest that the PESZ should be considered as a Variscan sinistral transcurrent shear zone involving reactivation of pre-existing lower Paleozoic stratigraphic boundaries. The definition of the OMZ/CIZ depends on the geological period one is discussing. For example, the upper Proterozoic record is important to a discussion of the Cadomian Orogen. Instead, the lower Paleozoic unconformity is of major significance to interpret the earlier Variscan paleogeography. These two facts must be considered significant to the discussion of the present-day geometry in the context of the Variscan Orogeny major transcurrent transpression. Since the PESZ presents a prolonged geodynamic evolution during Paleozoic one cannot simplify the limit OMZ/CIZ as an overthrust of the OMZ onto the CIZ. The PESZ present-day geometry resulted from the penetrative shearing throughout the OMZ/CIZ transition zone, which overturned and obliterated a regional lower Paleozoic paleogeographic boundary.

Acknowledgements

Financial support was given by JNICT research projects: REDIBER: PBICT/P/CTA/2113/95 and TECTIBER: PRAXIS/2/2.1/CTA/353/94.

References

Abalos, B. (1992): III Cong.Geol.España, Salamanca, Simposios 2: 325-335

Azor, A., Gonzalez Lodeiro, F., Martinez Poyatos, D. and Simancas, J.F. (1994): *Geol.Rundschau* 83: 377-387

Brun, J.P. and Burg, J.P. (1982): *Earth Planet Sci Letters* 61: 319-322

Dias, R. and Ribeiro, A. (1994): *Jour. Struct Geol* 16: 1543-1554

Gonçalves, F. (1971): *Mem Serv Geol Portugal* 18: 1-62

Gonçalves, F. and Peinador Fernandes, A. (1973): Carta Geologica de Portugal 1/50 000, 32-B. Serv Geol Portugal

Gonçalves, F. and Oliveira, V. (1986): *Mem Acad Cienc Lisboa* 34: 1-35

Grujic, D. and Mancktelow, N.S. (1995): *Jour. Struct Geol* 17: 279-291

Hirth, G. and Tullis, J. (1992): *Journ Struct Geol* 14 (2): 145-159

Matte, P. and Ribeiro, A. (1975): *CR Acad Sci Paris* D 280: 2825-2828

Passchier, C.W. and Trouw, R.A.J. (1996): In *Microtectonics*. Springer, Berlin Heidelberg. New York, pp 1-289

Pereira, M.F. and Silva, J.B. (1995): *XIII Reun Geol Oest Penins, Ann IGCP* 319, Salamanca, 135-139

Pereira, M.F., Silva, J.B., Ribeiro, C. and Mateus, A. (1997): XIV *Reun Geol Oest Penins*, Ann PICG 376, Vila Real, 181-187

Pereira, M.F. (1999): Tese de Doutoramento, Univ Evora, pp 1-115

Priem, H.N.A, Boelrijk, N.A.I.M., Verschure, R.H, Hebeda, E.H and Verdurmen, E.A.T (1970): *Eclog Geol Helvet* 63(1): 255-274

Ribeiro, A, Dias, R. and Silva, J.B. (1995): *Geod Acta*, Paris 8 (4): 173-184

Richard, P. and Cobbold, P. (1990): *Annales Tectonicae* 8: 41-50

Sanderson, D.J, Roberts, S., McGowan, J.A. and Gumiel, P. (1991): *Jour Geol. Soc (London)* 148: 893-898

Schmid, S.M. and Handy, M.R. (1991): In Muller DW, McKenzie JA and Weissut H (eds). Controversies in Modern Geology. Evolution of Geological theories in Sedimentology, Earth History and Tectonics, Acad Press pp 340-361.