The geometry and kinematics of enclaves in sheared migmatites from the Evora Massif, Ossa-Morena Zone (Portugal)

La geometría y cinemática de enclaves en migmatitas cizalladas del Macizo de Évora, Zona de Ossa-Morena (Portugal).

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ABSTRACT

In the Montemor-o-Novo high-grade metamorphic terraines of western Ossa-Morena Zone (Portugal), sheared migmatites display a wide variety of distinct mesoscopic structures. Relationships of leucosome-melanosome layering and rotated enclaves allowed determination in which direction the tectonic movement occurred. We proposed non-coaxial progressive deformation to explain how the fabric elements moved during D2 sinistral shearing.

Key words: *Sheared migmatites, Serie Negra, Montemor-o-Novo metamorphic terrains, Évora Massif, Ossa-Morena Zone.*

RESUMEN

Las migmatitas cizalladas de los terrenos de alto grado metamórfico de Montemor-o-Novo, que afloran en los dominios occidentales de la Zona de Ossa-Morena (Portugal), presentan distintas estructuras mesoscópicas. Las relaciones entre lo bandeado migmatítico (leucosoma-neosoma) y los enclaves rodados han permitido la determinacíon de la direccíon del movimiento tectónico desarollado. Se propone la deformacíon progressiva no-coaxial para explicar el movimiento de los elementos de la fábrica durante la actuacíon del regímen de cizalla sinistral.

Palabras clave: *Migmatitas cizalladas, enclaves, Sucesión Finiproterozoica de la Serie Negra, terrenos metamórficos, Montemor-o-Novo, Macizo de Évora, Zona de Ossa-Morena.*

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Introduction

In shear zones a large number of sense-of-shear indicators are recognised from the fabric of deformed rocks. Most of these indicators were described and studied in detail using microscope techniques (Bouchez et al., 1983; Simpson and Schmid, 1983; Passchier and Trouw, 1996). Rigid porphyroclasts and their dynamically recrystallized mantles which form delta-type or sigma-type symmetry systems (Passchier and Simpson, 1986) are fabric elements generally available in such deformed zones. At high metamorphic grade, rocks mainly deformed in a ductile manner (Passchier et al., 1991) can include fragments of relatively strong material (enclaves), which are potential shear sense markers. For the Montemor-o-Novo region we document the occurrence of rotated enclaves in sheared migmatites from the Evora Massif (Carvalhosa, 1983), and use their geometrical and kinematic characteristics (Pereira, 2000) to determin in which direction the relative movement occurred, and how the fabric elements moved during shearing. The term enclave is used as a non-genetic term to describe fragments of rock that resisted migmatization (resisters) or residual material from which mobile material has been extracted (restites) (Shelley, 1997).

Geological setting

The study area covers a short section of the Almansor River with high-grade metamorphic rocks (Gonçalves, 1983) from the Evora Massif (Carvalhosa, 1983) included in the Beja-Aracena Domain (Apalategui et al., 1990) or the Montemor-Ficalho Sector (Oliveira et al., 1991), of the Ossa-Morena Zone (OMZ). Dominating this mapped area is the southeastern end of the elongate northwest-trending foliated tonalite, which shows a gradual contact with migmatites (Fig.1). Migmatites are characterised by a well-developed foliation (S2) that reflect tectonothermal transposition of an earlier tectonic fabric (S1) preserved on the Neoproterozoic country rocks. The evolution of this high-grade metamorphism developed on the Neoproterozoic Serie Negra succession (Carvalhosa, 1965) representing the Montemor-o-Novo high-grade metamorphic terrains has been explained by a plate-tectonic model, involving subduction and collision along the southern suture zone of the western European Variscan belt (Ribeiro et al., 1990). Geochronological works accomplished so far are insuficient to enable the dating of tectono-metamorphic events. Some authors (Carvalhosa, 1983; Gonçalves and Carvalhosa, 1993-1994; Carvalhosa and Zbyszewski, 1994) conclude from field evidences that this high-grade metamorphism was related to the Variscan orogenic events, which took place between the Middle Devonian and the Carboniferous, like some Spanish examples such as the Lora del Rio and Valuengo (Apraiz, 1998) and the Aracena (Bard, 1969) metamorphic core

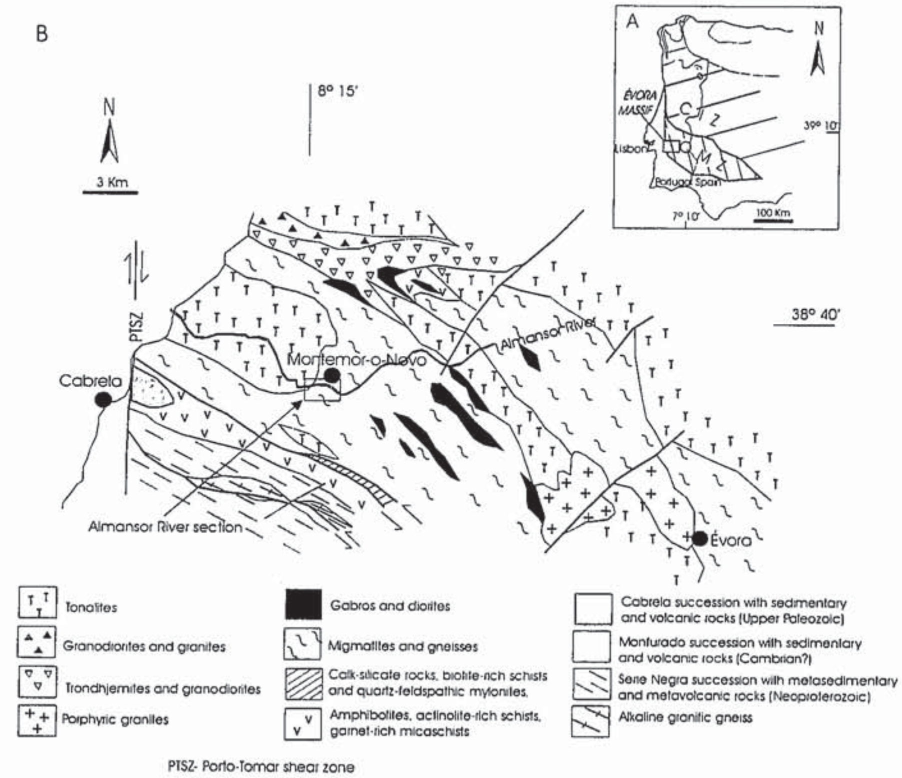

Fig. 1.- A:Geological sketch of the Évora Massif located at the Ossa-Morena (OMZ). B: Schematic geological map of the Montemor-o-Novo high-grade metamorphic terrains showing the distribution of the migmatized Neoproterozoic Serie Negra rocks and the localization of the Almansor river section.

Fig. 1.- A: Esbozo geológico con la situación del Macizo de Évora en la Zona de Ossa-Morena (OMZ). B: Mapa geológico esquemático de los terrenos de alto-grado metamórfico de Montemor-o-Novo con la distribución de las rocas migmatizadas de la sucesíon Finiproterozoica de la Serie Negra y localización de lo sector del río Almansor.

complexes. However, there is an alternative view which admit that deformation/metamorphism and pluton emplacement will represent Cadomian events (Eguiluz et al., 1997,2000) like some Neoproterozoic-Early Cambrian age for high-temperature/low-pressure tectonothermal occurrences from the northern and central OMZ sectors: the Mina Afortunada (Abalos and Eguiluz, 1992; Ordoñes-Casado, 1998) and the Olivenza-Monestério (Eguiluz, 1987; Eguiluz and Abalos, 1992; Ordoñes-Casado, 1998) anatectic gneiss domes.

Field relations

A restricted outcrop of migmatites, which gradually pass into the Montemor-o-Novo tonalite, was studied 200 meters to the southwest of the city of Montemor-o-Novo (Fig.1). Migmatites from the Almansor river section display a wide variety of structures. Figure 2 summarizes the spatial relationships of structures, leucosome (quartz + microcline + plagioclase ± biotite ± muscovite ± sericite ± cordierite and zircon) -melanosome (biotite + plagioclase + quartz + sillimanite + garnet ± chlorite) layering, black quartzites (quartz + graphite ± biotite ± opaques), biotite-rich paragneisses (plagioclase + biotite + k-feldspar + quartz + garnet + sillimanite ± opaques ± chlorite) and amphibolitic (horneblende + actinolite + plagioclase ± biotite ± quartz ± opaques ± chlorite) enclaves. The southern limit is dominated by

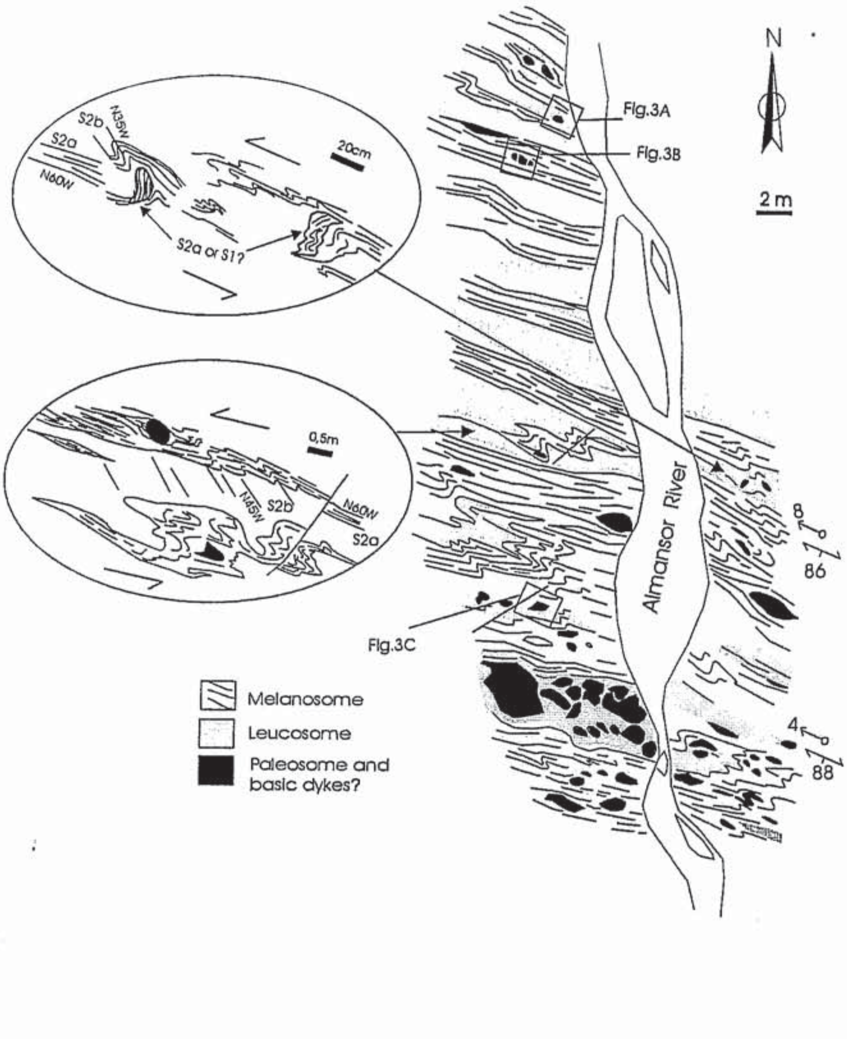

Fig. 2. – Schematic structural map of the Almansor river section with the migmatites from the Montemor-o-Novo High-grade metamorphic terrains. The southern limit is dominated by metatexites containing approximately 30-40% enclaves, which show a gradual contact with diatexites at North.

Fig. 2. – Esbozo estructural de las migmatitas de los terrenos de alto-grado metamórfico de Montemor-o-Novo en la seccíon del rio Almansor.

metatexites containing approximately 30-40% enclaves, which show a gradual contact with tonalites through a diatexite band. Metatexites show stromatic (banded) structure where the neosomes form light and dark layers in the paleosome generally parallel to the foliation S2. In pegmatoid leucosomes, pinch and swell structures are common indicating layer parallel extension. The heterogeneous texture in diatexites appears as light and dark streaks of more or less elongated shapes typical of schilieren structure. In the vicinity of the tonalite these migmatites look rather magmatic since paleosome and neosome can no longer be separated, defining a nebulitic structure. The structure is dominated by a melanosome-leucosome layering parallel to a steeply dipping N55-60W-trending foliation (S2a), which contains shallow-dipping stretching lineation (L2) defined by aligned growth of biotite and minor sillimanite. This planar fabric is disturbed by tight to isoclinal asymmetric F2a folds indicative of sinistral sense of shear. Axial surfaces of intrafolial isoclinal folds (F2a) are locally parallel to S2a. Superimposed F2b folds possess an axial planar N30-40W-trending foliation (S2b) and vergence to NW. Restricted fragments occur as boudins or dismembered fold hinges of melanosome in a ductile matrix of the leucosome. Foliation S2 in the enclosing migmatites typically wraps around the relatively rigid mafic bodies. Boudin necks are generally filled with pockets of locally derived or migrated partial melt (Fig. 3.B).

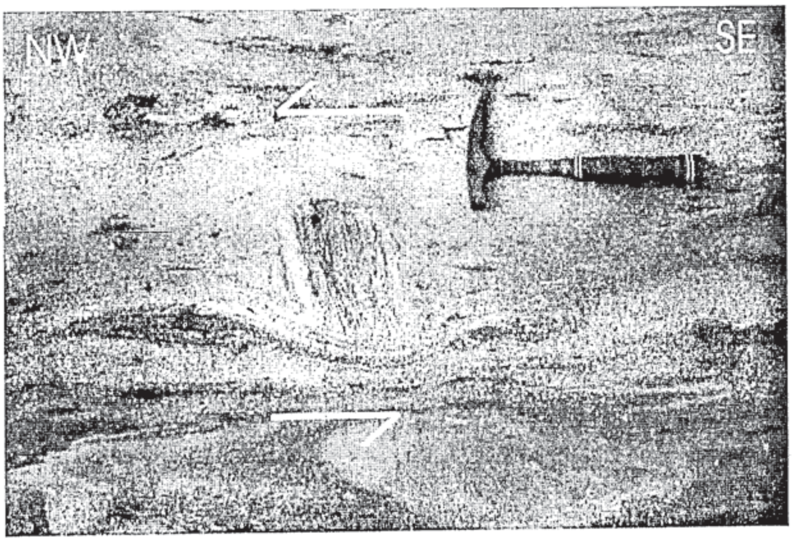

Figure 3.A

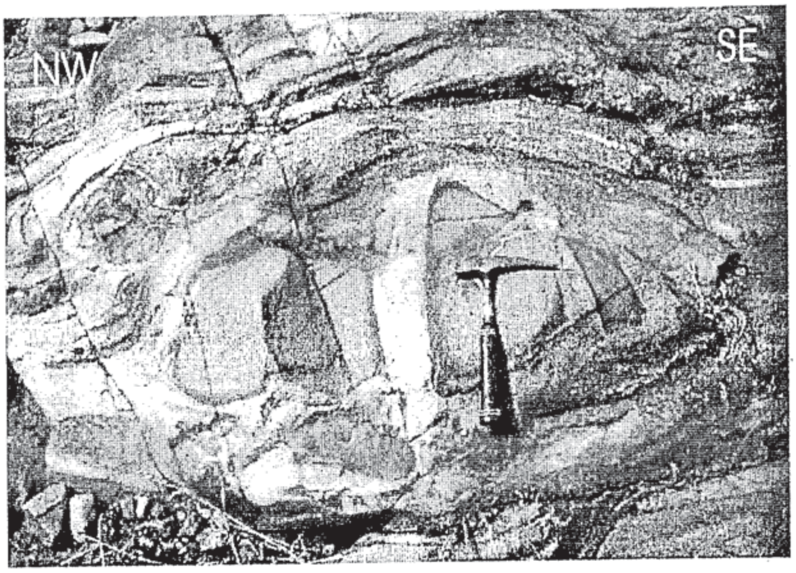

Figure 3.B

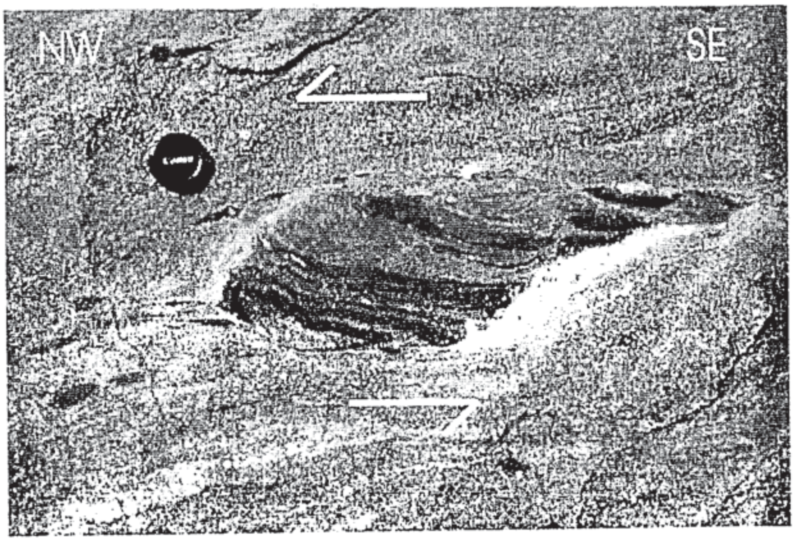

Figure 3.C

Fig. 3.- Migmatites from the Almansor River (Montemor-o-Novo). A- Asymmetrical tails of leucosome around a melanosome enclave; Sinistral shear sense is given by delta-type symmetry; (horizontal surface). B- Layer parallel extension of an amphibolitic enclave; (horizontal surface). C- The tails of leucosome on a paleosome enclave with sigma-type symmetry indicating sinistral shear sense; (horizontal surface).

Fig. 3.- Migmatitas del rio Almansor (Montemor-o-Novo). A- Fotografía de colas asimétricas de leucosoma de un enclave de melanosoma; se observa el desarrollo de sistemas do tipo-delta como criterio de cisalla sinistra; (superficie horizontal); B- Fotografía de un enclave anfibolítico boudinado paralelamente al bandeado migmatítico y a la dirección de extensión. C- Fotografía donde se observan colas de leucosoma en un enclave de paleosoma indicando un sistema do tipo-sigma indicando cisalla sinistra; (superficie horizontal).

Discussion

Kinematically, the data are consistent with migmatization during layer-normal shortening and layer-parallel to slightly oblique extension. Leucosome layers are folded with variable wavelengths and amplitudes showing uniform orientation of axial planes. Folds may form on melanocratic layers indicating the relative sinistral sense of movement. The effects of progressive deformation, visible in the Almansor river section, leads to changes in the migmatites S2 fabric. Some enclaves may deformed passively to became elongated parallel to S2 or may rotate and various types of foliations develop (Fig. 2). Paleosome and neosome layers or dykes become folded or boudinaged or just flattened and rotated into a new orientation. The non-coaxial nature of the flow can be determined from: 1) the geometry of rigid objects in the migmatites where the distribution of recrystallized minerals, forming the tails of enclaves is asymmetrical, include δ-type (Fig. 3.A) or σ-type (Fig. 3.C) symmetries; 2) the orientation of folded, folded-boudinaged metamorphic and tectonic layering. Some enclaves are interpreted as result of boudinaged isoclinal (rootless) folds in intense shearing bands. The planar fabric enclosed in this kind of enclaves S2a was probably formed during the early stages of D2 shearing that evolve to the late superimposed S2b. Boudins and folds have developed synchronously in melanosome layers due to strong competence contrast. F2 folds have formed by buckling of competent melanosome layers and by rotation of layers segments in response to non-coaxial flow. There are also evidences for a post-kinematic feldspathization during which feldspar phenoblasts grew independently of the structure caused by shearing related to metatexis and diatexis. D1 structures are interpreted as been preserved in some previously foliated enclaves of black quartzites indicating that the migmatites formed from the surrounding already deformed and metamorphosed Neoproterozoic Serie Negra succession.

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References

Abalos, B. and Eguiluz,B. (1992): *C.R. Acad.Sci.France*, 314, 691-698

Apalategui, O., Eguiluz, L. and Quesada, C. (1990): In Pre-Mesozoic Geology of Iberia, R.D.Dallmeyer and E. Martinez-Garcia (eds), Springer-Verlag, 399-409

Apraiz, A. (1998): Tesis Doctoral, Univ. Pais Vasco, 1-575

Bard, J.P. (1969): Ph.D.Thesis, Univ Montpellier, 1-397

Barros, A., Carvalhosa, A., Galopim de Carvalho, A M. and Matos Alves, C.A (1969): Carta Geológica Portugal 1:50,000, 40-A Évora, IGM

Bouchez, J.L., Lister, G.S. and Nicolas, A (1983): Geol. Runds., 72: 401-419

Carvalhosa, A. (1965): Mem. Serv. Geol. Portugal, 2:1-130

Carvalhosa, A. (1983): Com. Serv. Geol. Portugal, 69 (2), 201-208

Carvalhosa, A (1999): Carta Geológica Portugal 1:50,000, 36-C Arraiolos, IGM

Carvalhosa, A and Zbyszewski, G. (1994): Carta Geológica Portugal 1:50,000, 35-D Montemor-o-Novo, IGM

Eguiluz,L., Gil Ibarguchi, J.I., Abalos, B. and Apraiz, A. (2000): *GSA Bull.*, 112 (9), 1398-1413

Eguiluz, L. (1987): Tesis Doctoral, Univ. Pais Vasco, 1-694

Eguiluz, L. and Abalos, B. (1992): Prec. Res., 56, 113-137

Gonçalves, F. (1983): Com. Serv. Geol. Portugal, 69 (2), 269-273

Gonçalves, F. and Carvalhosa, A. (1993-1994): Mem. Acad. Ciênc. Lisboa, 34, 1-35

Oliveira, J.T, Vitor Oliveira and Piçarra, J.M. (1991): Cuad. Lab. Xeol. Laxe, 16, 221-250

Ordóñez-Casado, B. (1998): PhD thesis, ETH Zurich: 1-235

Passchier, C.W., and Simpson, C. (1986): J. Struct. Geol., 8, 831-843

Passchier, C.W., Myers, J.S. and Kroner, A. (1991): Field Geology of high-grade gneiss terrains, Springer-Verlag, 1-150

Passchier, C.W. and Trown, R.A.J. (1996): Microtectonics, Springer, 1-289

Pereira, M.F. (2000): 6ª Conf. Anual GGET, Évora, 33-34

Ribeiro, A., Quesada, C. and Dallmeyer, R.D. (1990): In Pre-Mesozoic Geology of Iberia, R.D.Dallmeyer and E. Martinez-Garcia (eds), Springer-Verlag, 399-409

Shelley, D. (1997): Igneous and metamorphic rocks under microscope, Chapman & Hall, 1-445

Silva, J.B., Simpson, C. and Schmid, S.M. (1983): GSA Bull., 94, 1281-1288