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).

M.Francisco Pereira (1), J.Brandão Silva (2)

(1) Departamento de Geociências / Centro de Geociências, Universidade de Évora, Ap.94, 7000-654 Évora Codex, Portugal; mpereira@uevora.pt
(2) Departamento de Geologia, Faculdade de Ciências Universidade de Lisboa, C2-SP, 1700 Lisboa, Portugal; jbsilva@flo.ul.pt

ABSTRACT

In the Montemor-o-Novo high-grade metamorphic terrains of western Ossa-Morena Zone (Portugal), sheared migmatites display a wide variety of distinct mesoscopic structures. Relationships of leucosome-metasomate 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 domíniocos occidentales de la Zona de Ossa-Morena (Portugal), presentan distintas estructuras mesométricas. Las relaciones entre el bandeo migmatítico (leucosoma-nisosoma) y los enclaves rotados han permitido la determinación de la dirección del movimiento tectónico desarrollado. Se propone la deformación progresiva no-coaxial para explicar el movimiento de los elementos de la fábrica durante la actuación del régimen 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 determine 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 (resistate) or residual material from which mobile material has been extracted (restite) (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 platetectonic model, involving subduction and collision along the southern suture zone of the western European Variscan belt (Ribeiro et al., 1990). Geochemical works accomplished so far are insufficient 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 (Apruz, 1998) and the Aracena (Bard, 1969) metamorphic core.
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; Ordoñez-Casado, 1998) and the Olivenza-Monestério (Eguiluz, 1987; Eguiluz and Abalos, 1992; Ordoñez-Casado, 1998) anatetic 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 amphibolite (boudinblend ± actinolite + plagioclase ± biotite ± quartz ± opaques ± chlorite) enclaves. The southern limit is dominated by

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: Esquema geológico a la situación del Mucoto de Évora en la Zona de Ossa-Morena (OMZ). B: Mapa geológico esquemático de las terrazas de alto grado metamórfico de Montemor-o-Novo con la distribución de las rocas migmatizadas de la cuenca delinproterozoica de la Serie Negra y localización del río 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 schillieren 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).

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 amphiboleitic 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 río Almansor (Montemor-o-Novo). A- Fotografía de colas asténtricas de leucosaoma en un enclave de melanosoma; se observa el desarrollo de sistemas de tipo-delta como criterio de círculo sinistras; (superficie horizontal); B- Fotografía de un enclave anfibolítico boudinado paralelamente al boudino migmatítico y a la dirección de extensión. C- Fotografía donde se observan colas de leucosaoma en un enclave de paleosaoma indicando un sistema de eje-sigma indicando círculo sinistras; (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. Foliation s may form on melanoocratic layers indicating the relative sinistral sense of movement. The effects of progressive deformation, visible in the Almancor river section, leads to changes in the migmatites S2 fabric. Some enclaves may deform passively to become elongated parallel to S2 or may rotate and various types of foliations develop (Fig. 2). Paleosome and neoformed 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 S-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 feldsparsization during which feldspar phenoblasts grew independently of the structure caused by shearing related to metatexis and dinetaxis. 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 successions.

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