Preliminary thermobarometric data from the Ouguela and Contenda-Barragem do Caia Units: Coimbra-Cordoba shear zone (Northeast Alentejo, Portugal)

**Datos termobarométricos preliminares de las unidades de Ouguela y Contenda-Barragem do Caia: zona de cizalla Coimbra-Córdoba (Alentejo Nororiental, Portugal)**

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**ABSTRACT**

The Coimbra-Cordoba shear zone comprises different tectonic units with a complex metamorphic evolution. In the Northeast Alentejo (Portugal) some of these units contain mineral parageneses of high-temperature/intermediate-pressure metamorphism, which were subsequently retrogressed to low-temperature/low-pressure conditions. Detailed microstructural studies show that the relationships between metamorphic assemblages and deformation stages in these rocks relate to strong shearing. In this preliminary study conventional geothermobarometrical techniques performed on rocks with appropriate mineral assemblages allows us to determine the P-T conditions near the metamorphic peak of two major rock units: (1) garnet-bearing leucocratic gneisses from the Ouguela Unit (600-700°C and 7-9 kbar), and (2) garnet-rich amphibolites (~550-600°C and 8-10 kbar) and garnet-rich amphibolitic boudins (650-700°C and 8.5-9.5 kbar) associated with calc-silicate rocks from the Contenda-Barragem do Caia Unit. These P-T determinations suggest that the rocks from Northeast Alentejo were buried to lower crustal depths of ~25-35 km consistent with the high-grade metamorphism (upper amphibolite facies) deduced from the relict mineral assemblages. Later, during the uplift and exhumation the rocks experienced strong retrogression in the greenschist-facies.

**Key words:** P-T data, garnet-rich tectonites, Ouguela Unit, Contenda-Barragem do Caia Unit, Coimbra-Cordoba shear zone, Ossa-Morena Zone

**RESUMEN**

Dos unidades tectónicas mayores incluidas en la zona de cizalla Coimbra-Córdoba muestran, en la región del Alentejo nororiental, una compleja evolución metamórfica que llega a alcanzar condiciones de alta temperatura y presión media-alta durante el máximo metamórfico. El análisis microestructural de la región indica que, en un proceso controlado por una zona de cizalla paralela al orógeno, la mayoría de las estructuras están asociadas a un fuerte proceso de cizallamiento en el que los últimos estadios evolutivos tienen lugar bajo condiciones retro metamórficas. En un estudio preliminar sobre las condiciones del pico metamórfico alcanzadas en estas unidades, se han aplicado técnicas geotermotermométricas, fundamentadas en la composición de los granates. Los resultados obtenidos son los siguientes: (1) gneises miloníticos cuarzofoldespáticos con granate de la Unidad de Ouguela (600-700°C y 7-9 kbar), y (2) anfibolitas ricas en granate (~550-600°C y 8-10 kbar) y boudines anfibolíticos ricos en granate (650-700°C y 8.5-9.5 kbar) asociados con rocas calcsilicatadas de la unidad de Barragem do Caia-Contenda.

**Palabras clave:** datos P-T, tectonitas con granate, Unidad de Ouguela, Unidad de Contenda-Barragem do Caia, zona de cizalla de Coimbra-Córdoba, Zona de Ossa-Morena

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**Introduction and Geological Setting**

The estimation of metamorphic P-T conditions, when used in conjunction with structural studies, is a powerful tool to gain insights into the tectonic evolution of orogenic belts. Thermal modelling of orogenic processes related to the heat distribution in active orogens, (including thermal conductivity, mantle heat-flow, crustal thickening, uplift and exhumation; e.g. England and Thompson, 1984; Thompson and England, 1984) has been successfully used to interpret the tectonic context of pressure (P) - temperature (T) data in ancient orogenic belts. In the case of deeply eroded orogens, where protoliths of many units are poorly known, mineral assemblages and P-T estimates provide essential data to characterise the tectonic evolution.

The Coimbra-Cordoba shear zone (CCSZ) represents a major structure of SW Iberia. It is located in the boundary
Fig. 1. - A: Geological sketch of the Coimbra-Cordoba shear zone (CCSZ) at the Ossa-Morena zone (OMZ) and Central-Iberian zone (CIZ) boundary. B: Schematic sketch of the CCSZ (including the high-grade Blastomylonitic corridor) portuguese sector at Northeast Alentejo, showing the location of the sampled areas: OUG - Ouguela leucocratic gneisses and CBC - Contenda-Barragem da Caia amphibolites.

Fig. 2. - Rim-to-rim compositional profiles in garnet from the Ouguela (OUG) and the Contenda-Barragem da Caia (CBC) tectonites.

Microstructural observations

The leucocratic gneisses from the OUG are tectonites with a strong S-L fabric. The typical mineralogical assemblage of these highly strained rocks is Qtz - Pl - Bt - Ms - Sgl - Gt - Zrn - Kfs + Chl ± Rz at Tur. Sillimanite occur as fibrolite within muscovite mica-fish, providing petrographic evidence for the prograde replacement reaction Ms + Qtz ® Sil + Kfs. Perithetic K-feldspar s-type porphyroclasts in an oblique foliated matrix of recrystallized quartz and fractured
Garnet-rich amphibolitic boudins within calc-silicate rocks of the CBC contain the Hbl – Pl – Grt – Opq – Spq – Qtz – Bt mineral assemblage. The shape preferred orientation grains of hornblende and plagioclase grains define foliation. Course grains of garnet are rimmed by a decompression corona of plagioclase or by biotite and quartz.

**Preliminary mineral chemistry and thermobarometric data**

In this study, thermobarometry was determined using conventional techniques based on garnet core-rim compositional variations and analyses of plagioclase and ferromagnesian minerals from matrix and reaction-rims of garnets. Mineral analyses were performed on a CAMEGA SX1000 electron microprobe at "Centre des Mésures Physiques" of the Clermont Ferrand University (France).

Rim-to-rim compositional variations in selected grains of garnets show significant differences between CBC and OUG samples (Fig. 2). Garnets from the CBC amphibolites show increase in Ca and Fe and decrease of Mn from the core to the rims, while the values of Mg and Fe/(Fe+Mg) remain unchanged. There are no significant differences on core-rim composition of garnets from the CBC amphibolitic boudins but they have slightly higher Mg-content consistent with decrease of Mn.

Garnets from the OUG leucocromatic gneisses show a core-to-rim increase in Fe, Mn and Fe/(Fe+Mg) and decrease in Mg and Ca. These patterns of zoning described above suggest that garnet compositional average was probably totally modified during retro-metamorphism (Tracy et al., 1976; Spear, 1989) and, as consequence, calculation of metamorphic temperature and pressure can only represent an approximation to peak metamorphism.

There are no significant differences in average compositions of plagioclase from the CBC amphibolites (An_{89-93}) whereas in the OUG leucocratic gneisses composition range from oligoclase to anorthoclase and sanidine (Fig. 5).

Hornblendes from the CBC amphibolites present flat Si and X_{Mg} zoning patterns (ranging from 0.42 to 0.56). Its chemical composition (Leake, 1978) ranges from tschermakite - hornblende-tschermakite to magnesio-hornblende in amphibolitic boudins associated with calc-silicate rocks and from hornblende-tschermakite to hornblende iron-tschermakite —
magnesio-hornblende in amphibolites intercalated with quartzites and micaschists (Fig.4).

P-T results for the different rocks studied indicate that the highest pressures were reached in the CBC garnet-rich amphibolites, with a core-rim variation from 10 kbar-600°C to 8 kbar-550°C. Temperature data were obtained by calibrations of different geothermometers: Grt-Anf (Perchuk, 1991), Anf-PI (Holland y Blundy, 1994) and Grt-Bt (Ferry y Spear, 1978; Perchuk, 1989). P data were determined by calibrations of Kohn and Spear (1990) Grt-Anf-PI geobarometer. Garnet amphibolite boudins in calc-silicate rocks from the same tectonic unit yield strongly consistent results under higher temperatures (8.5-9.5 kbar-650-700°C) using previous mentioned calibrations. Thermobarometric data from the OUG leucocratic gneisses show similar peak P-T conditions from 7 kbar-700°C down to 7 kbar-600°C (Fig.5). P-T data from these samples were obtained by calibrations of Grt-Bt geothermometer (Ferry y Spear, 1978; Perchuk, 1989; Williams y Grambling, 1990) and GASP geothermometer (Powell y Holland, 1988; Kozioł y Newton, 1989).

Discussion

This study suggests that the analysed mineral assemblages, from the two CCSZ tectonic units, typify intermediate-pressure amphibolite-facies metamorphism, variably retrogressed to greenschist-facies. P-T data characterize peak metamorphism exceeding 7 kbar and 600°C, with the highest P and T conditions being better preserved in the amphibolitic

Fig. 5.- P-T data from the Contenda-Barragem do Caia (CBC) amphibolite and amphibolitic boudin and from the Ouguela (OUG) leucocratic gneiss. See text for details about the thermobarometric methods employed.

Fig. 5.- Datos P-T obtenidos de las anfibolitas y boudines anfibolíticos de la unidad de Contenda-Barragem do Caia (CBC) y de los gneisess leucócraticos de Ouguela (OUG). Consultar el texto para mayor información sobre los métodos termobarométricos empleados.

boudins of calc-silicate rocks from the CBC. Petrographic observations indicate a later overprint by retrogression to lower- very low grade (~1-2 kbar-300-350°C). As noted by microstructural analysis, all samples are moderately to strongly foliated, with hornblende in the (CBC) and biotite-garnet in the (OUG) defining a gently plunging mineral and stretching lineation. Combined with the P-T data presented above, this observation suggest that both sinistral shearing and the retrograde reactions took place over a range of P-T conditions, beginning at or near the peak of metamorphism. From the P-T data presented one can admit that these metamorphic rocks were exhumed from 25-35 km depth due to wrench tectonism. This exhumation represents minor components of much larger sinistral transient displacements.

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