

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)

M. Francisco Pereira⁽¹⁾ y A. Apraiz⁽²⁾

⁽¹⁾Grupo Tectónica-Centro de Geofísica de Évora/Universidade de Évora, Apt.94, 7002-551 Évora, Portugal

⁽²⁾Dep. Geodinámica, Universidad del País Vasco, Apdo.644, 48080 Bilbao, España

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 retrometamórficas. En un estudio preliminar sobre las condiciones del pico metamórfico alcanzadas en estas unidades, se han aplicado técnicas geotermobarométricas, fundamentadas en la composición de los granates. Los resultados obtenidos son los siguientes: (1) gneises miloníticos cuarzofeldespáticos con granate de la Unidad de Ouguela (600-700°C y 7-9 kbar), y (2) anfíbolitas ricas en granate (~550-600°C y 8-10 kbar) y boudines anfíbólicos ricos en granate (650-700°C y 8.5-9.5 kbar) asociados con rocas calcosilicatadas 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 cisalla de Coimbra-Cordoba, Zona de Ossa-Morena

Geogaceta, 32 (2002), 123-126
ISSN:0213683X

Introduction and Geological Setting

The estimation of metamorphic P-T conditions, when used in conjunction with structural studies, is a powerful tool to gain insight in 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

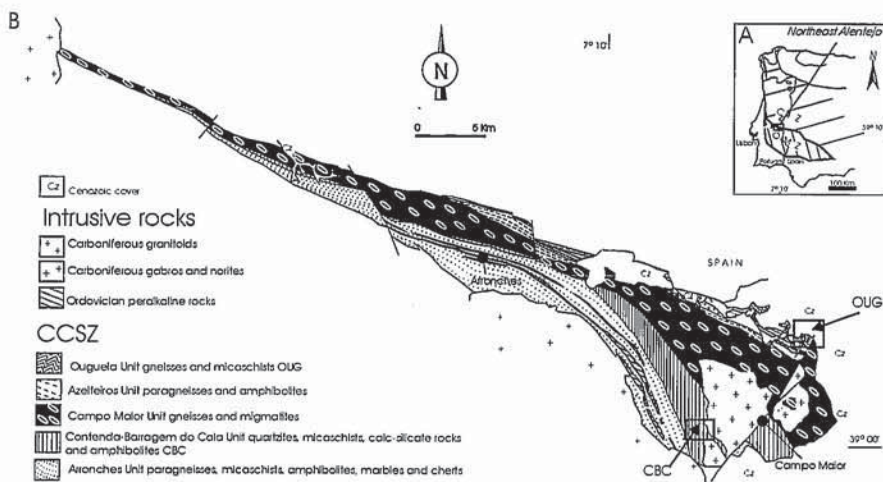


Fig. 1. - A- Geological sketch of the Coimbra-Cordoba shear zone (CCSZ) at the Ossa-Morena zone (OMZ) and Central-Iberian zone (CIZ) boundary. B - Schematic sketch of the CCSZ (including the high-grade Blastomylonitic corridor) portuguese sector at Northeast Alentejo, showing the location of the sampled areas: OUG - Ouguela leucocratic gneisses and CBC - Contenda-Barragem do Caia amphibolites.

Fig. 1.- A- Esquema geológico de la zona de cizalla Coimbra-Córdoba (CCSZ) en el límite entre la Zona de Ossa-Morena (OMZ) y la Zona Centroibérica (CIZ). B- Diagrama esquemático del sector portugués de la CCSZ en el Noreste de Alentejo con la ubicación de las áreas muestreadas: OUG- gneisses leucocráticos de Ouguela; CBC- anfíbolitas de la unidad Contenda-Barragem do Caia.

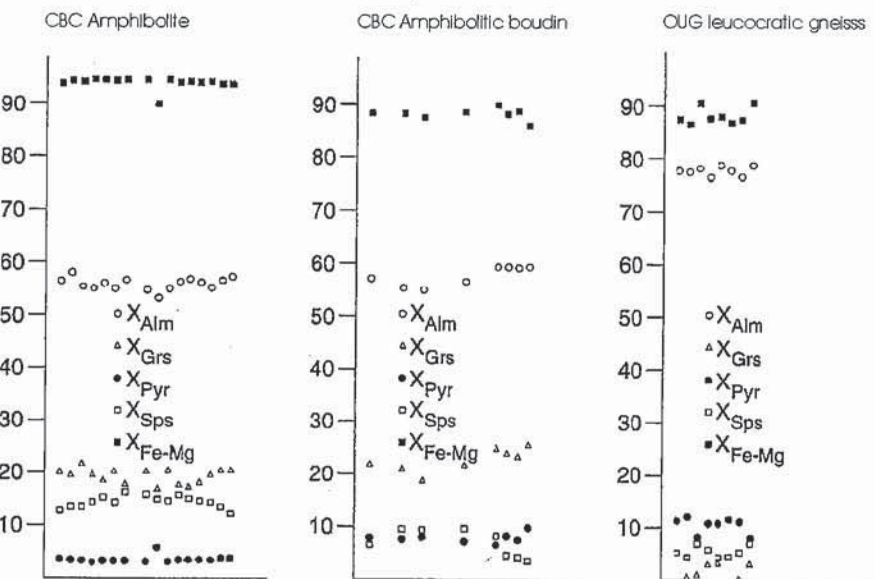


Fig. 2. - Rim-to-rim compositional profiles in garnet from the Ouguela (OUG) and the Contenda-Barragem do Caia (CBC) tectonites.

Fig. 2.- Perfiles composicionales de borde a borde en granates de las tectónicas de Ouguela (OUG) y de Contenda-Barragem do Caia (CBC).

between the Ossa-Morena and Central-Iberian Zones (Burg et al., 1981) of the Iberian Massif. It represents a deeply eroded orogenic segment which exhibit evidence of crustal-scale ductile wrenching developed after a period of crustal thickening, as pointed by the existence of a stack of different tectonic units (Abalos, 1990).

Independent of the controversy related with the age and relative importance of Cadomian and Variscan tectonother-

mal events (Abalos et al., 1993; Azor et al., 1993; Eguluz et al., 2000), this shear zone has been interpreted as a suture zone (Matte, 1986; Quesada and Munhá, 1990) notably after discovery of eclogite-facies rocks (Mata and Munhá, 1986; Eguluz et al., 1990).

Available P-T data from different tectonic units from the CCSZ Spanish sector depict a complex distribution of metamorphic facies within a NE-dipping pile of tectonic units (Abalos et al., 1991;

Abalos and Eguluz, 1992; Azor et al., 1994; Simancas et al., 2001). Abalos and Eguluz (1992) consider that the thermal peak of $720 \pm 30^\circ\text{C}$ occurred under pressures of 8 ± 0.5 kbar in the lowermost tectonic unit (Higuera de Llerena Gneiss) of the allochthonous stack, whilst in the overlying units peak temperatures of $670 \pm 30^\circ\text{C}$ were attained under 10 ± 0.5 kbar (in the lower Blastomylonitic migmatitic Gneisses) and >15 kbar (in the upper Eclogitic slice), thus resembling an inverted metamorphism configuration. Available geochronological data on metamorphism in the CCSZ are still scarce and subjected to controversial interpretations (Abalos et al., 1993; Azor et al., 1993; Eguluz et al., 2000; Simancas et al., 2001; Pereira and Silva, 2001).

It the CCSZ Portuguese sector of the Northeast Alentejo a division in different tectonic units similar to the proposed by Abalos and Eguluz (1992) was applied, mainly based upon detailed field and microtectonic studies (Pereira, 1999). The aim of this study is to unravel the P-T relationships from garnet-bearing metamorphic rocks of two CCSZ tectonic units, separated by an high-grade blastomylonitic corridor, the Campo Maior unit (Pereira, 1999), which is correlated with the Blastomylonitic migmatitic gneisses slice described by Abalos and Eguluz (1992) (Fig.1):

(1) The Ouguela Unit (OUG) that is composed of garnet-bearing leucocratic gneisses, sillimanite-biotite-rich gneisses and garnet-kyanite-rich micaschists, and crops out to the North of the high-grade blastomylonitic corridor (Campo Maior Unit).

(2) The Contenda-Barragem do Caia Unit (CBC), containing leucocratic gneisses and quartzites, garnet-rich amphibolites, micaschists and calc-silicate rocks with garnet-bearing amphibolite boudins, that outcrops to the South of the high-grade blastomylonitic corridor.

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 $\text{Qtz} - \text{Pl} - \text{Bt} - \text{Ms} - \text{Sil} - \text{Grt} - \text{Zrn} - \text{Kfs} - \text{Chl} \pm \text{Rt} \pm \text{Tur}$. Sillimanite occur as fibrolite within muscovite mica-fish, providing petrographic evidence for the prograde replacement reaction $\text{Ms} + \text{Qtz} @ \text{Sil} + \text{Kfs}$. Perthitic K-feldspar s-type porphyroclasts in an oblique foliated matrix of recrystallized quartz and fractured

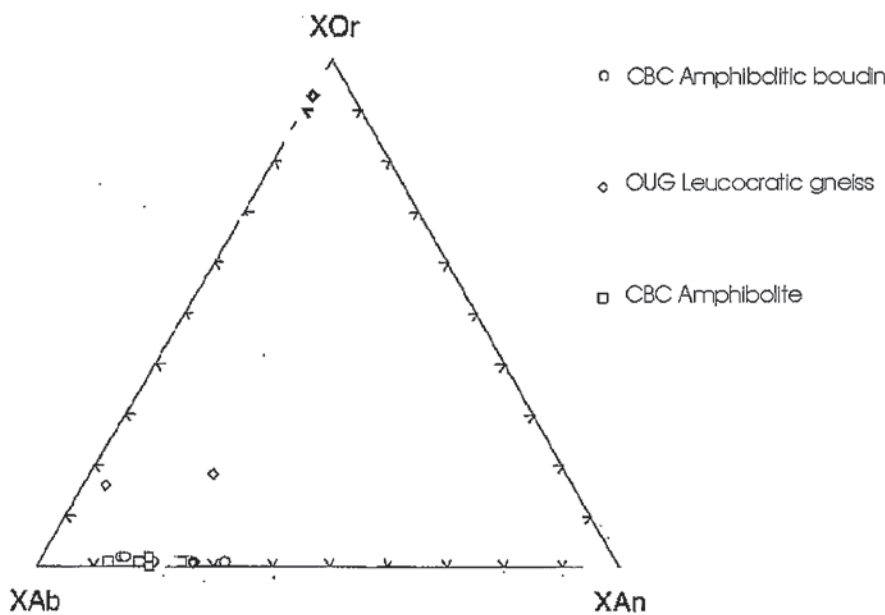
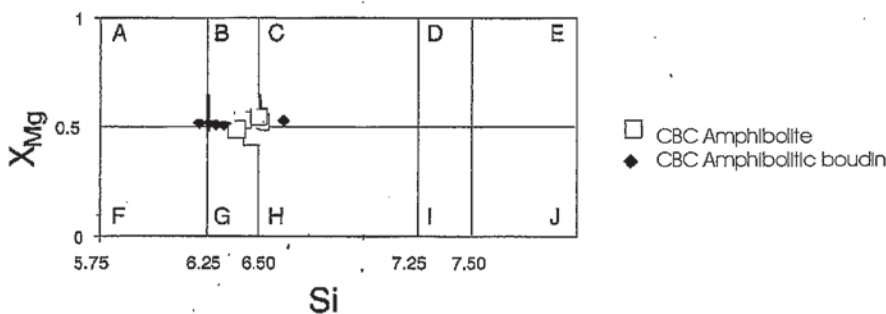


Fig. 3.- Or-Ab-Na plot for average compositions of plagioclase from the Ouguela (OUG) and the Contenda-Barragem do Caia (CBC) tectonites.

Fig. 3.- Diagrama Or-Ab-An para composiciones medias de plagioclasas en las tectonitas de Ouguela (OUG) y de Contenda-Barragem do Caia (CBC).



- A: Tschermakite
- B: Tschermakitic Hornblende
- C: Mg - Hornblende
- F: Fe - Tschermakite
- G: Fe - Tschermakitic-Hornblende
- H: Fe - Hornblende

Fig. 4.- Compositions of ferro-magnesian minerals (amphiboles) from the Contenda-Barragem do Caia (CBC) amphibolite and amphibolitic boudin. Field boundaries after Leake (1978).

Fig. 4.- Composición de los minerales ferromagnesianos (anfíboles) de las anfíbolitas y boudines anfíbolíticos de la unidad de Contenda-Barragem do Caia (CBC). Límites de composición según Leake (1978).

small grains of garnet with tails of biotite replaced by chlorite, suggest the occurrence of a generalised retrogression reaction during sinistral transcurrent shearing.

Retrograde reactions are also observed in the foliated garnet-bearing amphibolites of the CBC. These rocks

contain the assemblage Hbl - Pl - Opq - Grt - Bt - Qtz - Sph - Ep. Alternating layers rich in amphibole, biotite and opaques define the foliation, that wraps around garnet porphyroclasts. Garnets are partial or totally retrogressed to biotite, opaques and epidote. S-C planes define the sinistral sense of shear.

Garnet-rich amphibolitic boudins within calc-silicate rocks of the CBC contain the Hbl - Pl - Grt - Opq - Sph - Qtz - Bt mineral assemblage. The shape preferred orientation grains of hornblende and plagioclase grains define foliation. Coarse 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 CAMECA 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 unchangeable. 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 leucocratic 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_{10-35}) whereas in the OUG leucocratic gneisses composition range from oligoclase to anorthoclase and sanidine (Fig.3).

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 -

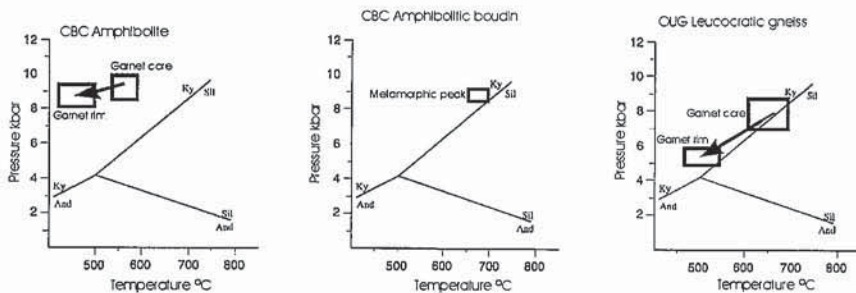


Fig. 5.- P-T data from the Contenda-Barragem do Caia (CBC) amphibolite and amphibolitic boudin and from the Oguuela (OUG) leucocratic gneiss. See text for details about the thermobarometric methods employed.

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

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-Pl (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-Pl geobarometer. Garnet amphibolitic 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 9 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; Koziol 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

boudins of calc-silicate rocks from the CBC. Petrographic observations indicate a later overprint by retrogression to low-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 transcurrent displacements.

Acknowledgements

Financial support was given by Geophysical Center of Évora/Tectonic Group budget for 2000-2002, Aecao Integrada Luso-Espanhola N° E-50/01, 2001-2002. Welthank C. Casquet (Univ. Complutense) for usefull reviews.

References

Abalos, B. (1990): Tesis Doctoral, Univ. Pais Vasco, 1-430
 Abalos, B., Eguiluz, L. (1992): C.R. Acad. Sci. Paris, 314, 691-698
 Abalos, B., Gil-Ibarguchi, J.I., Eguiluz, L. (1993): Tectonophysics, 217, 347-353
 Azor, A., Gonzalez-Lodeiro, F., Simancas, F. (1993): Tectonophysics, 217,

343-346
 Azor, A., Gonzalez-Lodeiro, F., Simancas, F. (1994): Tectonics, 13, 45-61
 Burg, J.P., Iglésias, M., Laurent, P.L., Matte, Ph., Ribeiro, A. (1981): Tectonophysics, 78, 161-177
 Eguiluz, L., Abalos, B., Ortega, L.A. (1990): Cuad. Lab. Xeol. Laxe, 15, 61-78
 Eguiluz, L., Abalos, B., Gil-Ibarguchi, J.I. (1990): Geogaceta, 7, 28-31
 Eguiluz, L., Gil-Ibarguchi, J.I., Abalos, B., Apraiz, A. (2000): Geol. Soc. Amer. Bull, 112 (9), 1398-1413
 England, P.C., Thompson, A.B. (1984): Jour. Petrol., 25 (4), 494-928
 Ferry, J.M., Spear, F.S. (1978): Contrib. Mineral. Petrol., 66, 113-117
 Holland, T.J.B., Blundy, J. (1994): Contrib. Mineral. Petrol., 116, 433-447
 Kohn, M.J., Spear, F.S. (1990): Am. Mineral., 75, 89-96.
 Koziol, A.H., Newton, R.C. (1989): Contrib. Mineral. Petrol., 103, 423-433
 Leake, B.E. (1978): Min. Mag., 42, 533-563
 Mata, J., Munhá, J.M. (1986): Bol. Soc. Geol. Portugal (Maleo), 2, 28
 Matte, Ph (1986): Tectonophysics, 126, 329-374
 Perchuk, L.L. (1989): In Evolution of Metamorphic Belts, J.S. Daly, R.A. Cliff and B.W.A. Yardley (eds), Geol. Soc. Spec. Pub., 43, 275-291
 Perchuk, L.L. (1991): In Progress in Metamorphic and Magmatic Petrology, L.L.Perchuk (eds), Cambridge, 93-111
 Pereira, M.F. (1999): Tesis Doctoral, Univ. Évora, Portugal, 1-115
 Pereira, M.F., Silva, J.B. (2001): Jour. Struct. Geol., 23, 835-837
 Powell, R., Holland, T.J.B. (1988): Jour. Metamorphic Geology, 3, 327-342
 Quesada, C., Munhá, J.M. (1990): In Pre-Mesozoic Geology of Iberia, R.D. Dallmeyer and E. Martinez-Garcia (eds), Springer-Verlag, 314-320
 Simancas, J.F., Martinez Poyatos, D., Expósito, I., Azor, A., Gonzalez Lodeiro, F. (2001): Tectonophysics, 332, 295-308
 Spear, F.S. (1989): In Evolution of Metamorphic Belts, J.S. Daly, R.A. Cliff and B.W.A. Yardley (eds), Geol.Soc. Spec. Pub., 43, 63-81
 Thompson, A.B., England, P.C. (1984): Jour. Petrol., 25, 929-955
 Tracy, R.J., Robinson, P., Thompson, A.B. (1976): Amer. Miner., 61, 762-775
 Williams, M.L., Grambling, J.A. (1990): Amer. Miner., 75, 886-908