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New data on tectono-metamorphic evolution of the Peri-Trasmontano domain (Schistose Domain) in Northeastern Portugal

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RESUMEN

Bajo el plano de cabalgamiento principal de Trás-os-Montes, en la región oriental del Complejo Alóctono de Morais, se ha identificado una unidad geológica portadora de andalucitas sin-tectónicas generadas por un metamorfismo térmico de baja presión. Este metamorfismo afecta esencialmente a las pizarras negras presentes en las diversas formaciones Neoproterozoico-Silúricas. Este tipo de metamorfismo térmico es fácilmente distinguible del metamorfismo asociado al plutonismo tardío / posterior a la tercera fase varisca ya que los primeros cristales de andalucita engloban la S1 y parcialmente la S2 varisca presentando rotación y boudinage sincrónicos con la segunda fase. Este metamorfismo sincinemático parece afectar solamente a las rocas del autóctono de la Zona Centro Ibérica y podría estar asociado fundamentalmente a fenómenos de extensión cortical, como los identificados en el Domo Gnéisico de Tormes. No obstante podría tener parcialmente un origen distinto, reflejando procesos de metamorfismo térmico de baja presión en zonas más internas del orógeno Varisco, habiéndose transportado algún retazo hasta las coordenadas actuales durante la imbricación tectónica de la segunda fase Varisca. La proximidad en la vertical de escasos cientos de metros entre las extructuras extensionales al Este y las compresivas al Oeste del sector estudiado, puede justificar la presencia de andalucitas pre y sin-S2, en dicha unidad tectono-metamórfica. Los criterios cinemáticos observados (parte superior hacia el SE) son coherentes con los descritos para las estructuras extensionales sinorogénicas variscas de regiones muy próximas al SE, sugiriendo una posible relación genética con dichos procesos de adelgazamiento cortical.

Palabras clave: Complejo de Morais, Dominio Esquistoso, Metamorfismo, Tectónica Varisca

Nuevos datos de la evolución tectono-metamórfica en el dominio Peri-Trasmontano (Dominio Esquistoso) del Nordeste de Portugal

ABSTRACT

Under the main Trás-os-Montes thrust plane, in the easternmost region of the Morais Allochthonous Complex, a geologic unit has been identified. It shows syn-tectonic S2-related andalusite blastesis, representative of low pressure thermal metamorphism. In the studied sector this metamorphism affects essentially the black slaty lithologies present in Neoproterozoic to Silurian formations. This kind of thermal metamorphism is easily distinguishable from the late to post S3 plutonic-related metamorphism, due to the existence of evidence of syn-kinematic mineral blastesis with rotation and boudinage, synchronously with S2 development. Syn-kinematic andalusite blastesis seems to affect only the autochthonous Central Iberian Zone rocks and it could be associated to crustal extensional phenomena like the ones identified in the Tormes Gneissic Dome. It is proposed that at least part of this andalusite blast generation could have a distinct origin, reflecting earlier low pressure thermal metamorphic events in inner Variscan orogen zones that were tectonically imbricated to present coordinates during the second Variscan phase. The vertical proximity of only a few hundred meters between extensional structures, to the East, and the compressive ones, to the West of the studied sector, could justify the presence of both pre- and syn-S2 andalusite blasts inside the above mentioned tectono-metamorphic unit. The kinematic criteria (top to SE) are consistent with the ones of the Variscan syn-orogenic extensional structures placed nearby to the SE, pointing to a possible genetic relation with those crustal thinning processes.

Key words: Metamorphism, Morais Complex, Schistose Domain, Variscan Tectonics

Introduction

The boundary between the Galicia-Trás-os-Montes (GTMZ) and Central Iberian (CIZ) zones of the Iberian Massif displays some eye-catching features in the eastern part of the Morais Allochthonous Complex. The most remarkable fact is the close proximity between the Variscan structures related to crustal thickening and the ones related to extension and developed in middle crustal levels. It is noteworthy that the lowest and more external Allochthonous Domain thrust structure (the Main Trás-os-Montes Thrust or MTMT according to Ribeiro *et al*., 1990), responsible for the stacking of the GTMZ exotic units over the CIZ, is only placed a few hundred metres above the detachment structures developed in the Tormes Gneiss Dome (TGD) during the Variscan extensional collapse (Escuder Viruete *et al.*, 1994).

New studies carried out in this area were focused specially in metamorphic and structural characteristics.

Previous works show that there is a direct relation between syn-S2 andalusite blastesis and the Variscan syn-orogenic extensional phenomena in nearby regions like the TGD (Escuder Viruete *et al.*, 1994 and Escuder Viruete, 1999). Evidence of these andalusite-rich units is described in this paper and supports the previous observations made by Escuder Viruete *et al.* (1994) and Escuder Viruete (1999). Nevertheless, some new details related to the andalusite blastesis lead to more accurate interpretation of the tectonothermal events undergone by this region during the Variscan orogeny.

Geologic outline

This region is characterized by the tectonic contact between two major structural units of the North Iberian Variscan segment: the allochthonous Galicia – Trás-os-Montes Zone (GTMZ) to the west, and the autochthonous Central Iberian Zone (CIZ) to the east (Figure 1). (Ribeiro *et al.,* 1990, Farias *et al.*, 1987 and Arenas *et al.*, 1988).

The GTMZ is composed by two domains which are, from bottom to top, the following: the Schistose Domain (SD) or Lower Allochthon (LA) and; the Upper Allochthonous Complex (UAC) represented in the studied area (Figure 1) by the Morais Allochthonous Complex (MAC) (Ribeiro *et al.* 1990, Arenas *et al.,* 2004, Martínez Catalán *et al.*, 2009, and references therein). The uppermost units of the GTMZ represent a set of superposed *nappe* folds and low angle imbricate thrusts, which were piled up in a piggy back thrust tectonic style during the Variscan Orogeny (Ribeiro *et al.,* 1990, Martínez Catalán *et al.*, 2003, Arenas *et al.,* 2004, Pereira, 2006, Gómez Barreiro *et al.*, 2007 and Martínez Catalán *et al.*, 2009). The UAC Domain is formed by stacked sheets that include continental and ophiolitic affinity slices. The present UAC exposure can be envisaged as mega-*klippen* preserved in the cores of the NW-SE trending Late Variscan synformal folds (Ribeiro *et al.,* 1990 and Díez Balda *et al.*, 1990). The UAC lithologies will not be described in this paper, because their lack of relevance for understanding the object of this study.

The Schistose Domain of GTMZ is made of Early Ordovician (Valverde-Vaquero *et al.*, 2005) and Silurian low grade metasediments and metavolcanics and Upper Devonian syn-orogenic deposits (González Clavijo, 2006, Martínez Catalán *et al.* 2008 and Martínez Catalán *et al.*, 2009). In the study region only Silurian metasediments were found (Pereira *et* al., 2006). They are represented by a sequence (from bottom to top) of black slates, small bodies of slates with pebbles, lidite and ampelite beds, followed upwards by grey stripped slates and psammites and finally by metagreywackes and slates with metasandstone beds and lidite olistoliths. In this area, Ribeiro (1974), Ribeiro *et al.* (1990) and Pereira *et al.* (2006) divided this domain in three stratigraphic units named, from bottom to top, Infraquartzite, Quartzite and Supraquartzite Formations. These units are respectively correlated with the Rábano Formation in Alcañices (González Clavijo, 2006) and with the Nogueira and Paraño Formations in Verín and Órdenes regions (Arenas *et al.*, 1988, Farias, 1990 and Arenas *et al.*, 2004). They exhibit a sedimentary style somewhat different from the typical Silurian autochthonous sequence observed in the CIZ (Farias *et al.*, 1987 and Rodrigues *et al.*, 2006a) even thought they belonged to the same continental passive margin. Recently, Rodrigues *et al.* (2006a, 2006b and 2006c) described west of the MAC the internal structure of the SD of the GTMZ. According to these authors the SD is composed by an Upper Parautochthon Domain (UPD), which includes a D1 cartographic-scale nappe fold system, and a Lower Parautochthon Domain (LPD) (or Subautochthon) characterized by a D2 imbricated thrust system (Rodrigues *et al.*, 2006a, 2006b and 2006c). The SD lowest D2 thrust is known as Main Trás-os-Montes Thrust (MTMT) (Ribeiro, 1974) and it is the first order regional fault that limits the GTMZ at its base. The SD (Figure 1) is therefore the lowest "thrust dominated" allochthonous Domain (Pereira, *et al.*, 2006).

The autochthonous CIZ is composed by Neoproterozoic to Silurian stratigraphic units, including Cambro-Ordovician magmatic Ollo de Sapo type units (Díez Montes, 2007 and Montero *et al.*, 2009), intruded by diverse pre, sin and late kinematic granitoids. In this area the autochthonous terrain includes, from bottom to top, the following formations:

- Laminated Phyllite Formation (Pereira *et al.*, 2006), composed of thin (millimetre to centimetre scale) layers of grey phyllites and metapsammites of Neoproterozoic to Cambrian age. It can be correlated with the Douro Group (Ribeiro, 1974, Escuder Viruete, 1999 and Pereira *et al.*, 2006) and with the Villalcampo Formation in Alcañices (Villar Alonso, 1990);
- Vale de Bojas Formation (Sá *et al*,. 2003, Sá, 2005

and Sá *et al.*, 2005), which is composed of black slates and grey psammites with orthoquartzite beds. This is correlated to the Capas de los Montes Formation in the "Ollo de Sapo" Domain of the CIZ (Díez Montes *et al.*, 2004 and Díez Montes, 2007) and with the Santa Eufémia Formation in Alcañices (Vacas and Martínez Catalán, 1987). Its age is Tremadoc-Lower Arenig;

- Marão Formation (Sá *et al*,. 2003, Sá, 2005 and Sá *et al.*, 2005), composed of orthoquartzite, impure quartzite and black slate beds of Middle to Upper Arenig age. This unit is also known as Armorican Quarzite Formation (Ribeiro, 1974, Gutiérrez Marco *et al.*, 1990 and Pereira *et al.* 2006) and it can be correlatated with the Peña Gorda Formation in Alcañices (Vacas and Martínez Catalán, 1987);
- Moncorvo Formation (Sá *et al*,. 2003, Sá, 2005 and Sá *et al.*, 2005), composed of a monotonous black slate sequence, and also known as Slaty Formation (Pereira *et al.* 2006). It can be correlated with the Luarca Slates (Gutiérrez Marco *et al.*, 1990, Díez Montes *et al.*, 2004 and Díez Montes, 2007) and with the Villaflor Formation in Alcañices (Vacas and Martínez Catalán, 1987);
- Santo Adrião Formation (Sá *et al*,. 2003, Sá, 2005 and Sá *et al.*, 2005), composed of foliated marbles and metabasic rocks of Lower Ashgill age (Upper Ordovician). This unit correlates with the "La Aquiana Limestone" in the Truchas Syncline (Barros Lorenzo, 1989, Martínez Catalán *et al.*, 1992);
- Finally, the Campanhó Formation (Pereira *et al.* 2006) culminates the Silurian sequence. It includes black slates, lidites, ampelites and ampelitic slates of Llandovery to Wenlock age. It can be correlated with the Manzanal del Barco Formation in Alcañices (Vacas and Martínez Catalán, 1987).

This sequence represents part of the northern sector of the relatively stable Gondwana margin, which suffered several extensional events during Cambro-Ordovician and Silurian times. This margin faced a collisional event during the Variscan Orogeny (Gutiérrez Marco, 1990, Rodríguez Alonso *et al.*, 2004, Martínez Catalán *et al.*, 2009) leading to the formation of the Late Carboniferous-Early Permian Pangaea Supercontinent.

To the S and SE of the studied area autochthonous higher grade rocks are exposed (micaschists, gneisses, migmatites) and are related to thermal doming during Variscan extension on the TGD (Escuder Viruete *et al.*, 1994 and Escuder Viruete, 1999).

It is possible to identify two main Variscan magmatic events, according to their relative timing with respect to the orogeny. The first event is syn-orogenic and is represented by magma bodies intruded synchronously with the generation of a S2 regional foliation (Escuder Viruete *et al.*, 1994, Escuder Viruete, 1999, Escuder Viruete *et al.*, 2004, Fernández-Suárez *et al.*, 2000, Martínez Catalán *et al.*, 2004a and Martínez Catalán *et al.*, 2009). The second event is composed by late to post-orogenic igneous rocks (syn to post-S3). This late magmatic event (Late Carboniferous-Permian) is possibly associated to tectonic relaxation and lithospheric delamination (Gutiérrez Alonso *et al.*, 2004, Gutiérrez Alonso *et al.,* 2008 and Martínez Catalán *et al.*, 2009) during the latest stages of the Pangaea's assembly.

The following section will describe the most important local geologic aspects and their respective macro, meso and microscale characteristics, which evidence a complex geologic history.

Local relevant Geologic aspects

The studied area (Figure 1A) is composed, from bottom to top, by: the CIZ Autochthonous metasediments and Late Variscan granitoids; the SD metasediments; and the MAC metasediments and metavolcanics. Located between the structurally upper zones of the CIZ and the lowermost part of the SD, an Ordovician to Silurian low metamorphic grade sequence was identified, overprinted by pre to syn-S2 thermal metamorphism (crossed pattern area in Figure 1B). This sequence comprises from bottom to top, the following lithologies (see Figures 1 and 2) limited by thrust planes:

- Greyish black, pyrite rich, Lower Ordovician slates (Vale de Bojas Formation);
- Upper Ordovician Santo Adrião Formation metabasics and foliated marbles;
- Silurian black, pyrite rich, slates and lidites (Campanhó Formation);
- Grey slates and psammites with pebbles (Infraquartzite, Quartzite and Supraquartzite Formations – Silurian).

This sequence usually shows an intense and gently dipping crenulation cleavage (S2) developed on a previous tectonic foliation (S1). Several phyllonitic bands, bearing an attitude sub parallel to S2, were observed inside this sequence. D3 cartographic scale upright folds with related NW-SE axial plane crenulation cleavage (S3) gently affect the preceding tectono-metamorphic fabrics (Figures 1, 3B and 4).

The autochthonous CIZ low grade metasediments, give rise to higher grade rocks towards the easternmost part of the studied area. All the rocks that

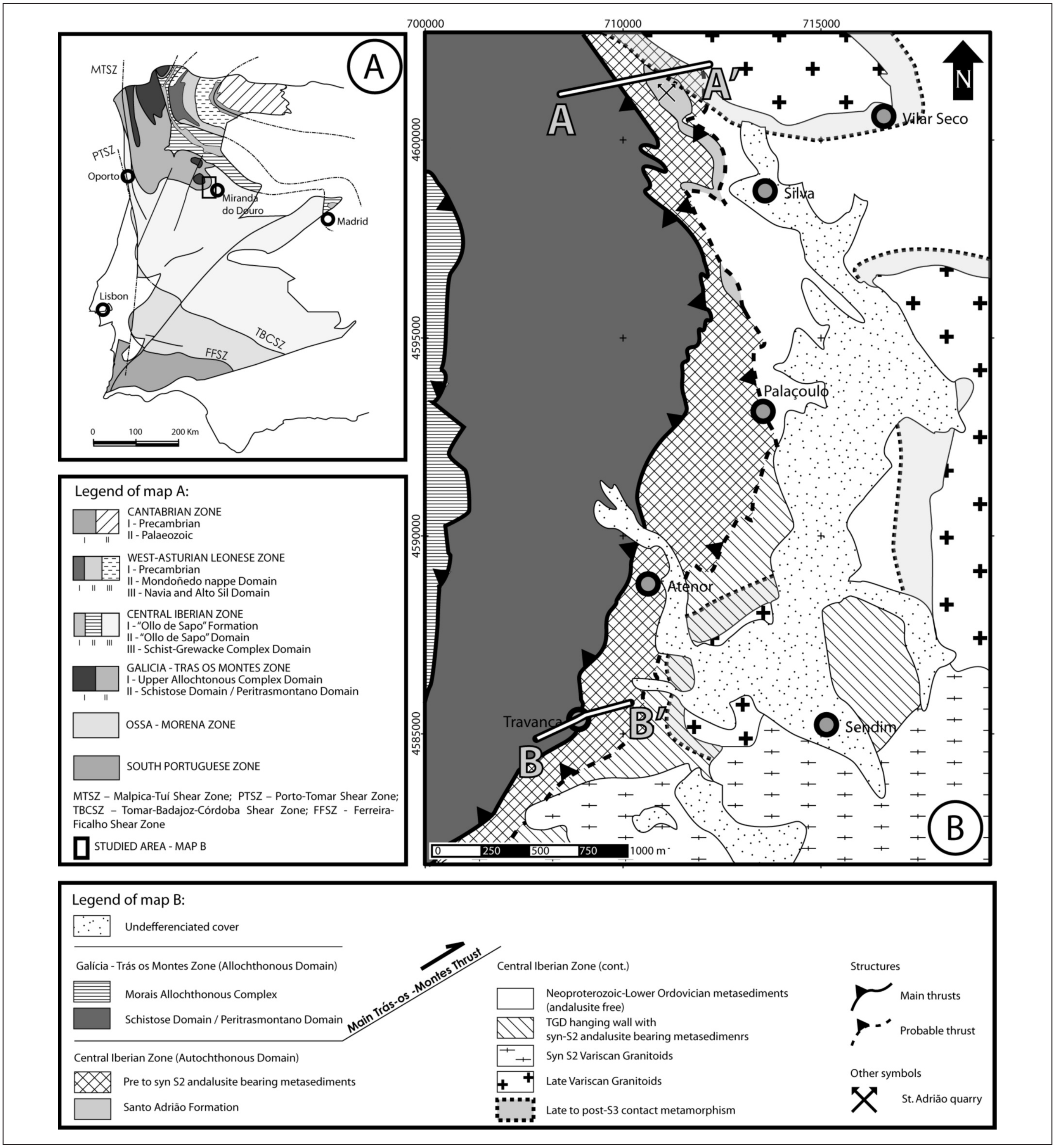

Figura 1. A: Localización geológica del área estudiada con los principales dominios geológicos del Macizo Ibérico. Adaptado de Julivert *et al.* (1972) y de Farias *et al.* (1987); B: Esquema intrepretativo basado en la "Carta Geológica de Portugal à escala 1:200.000, Folha 2" (2006) del INETI (Instituto Nacional de Enegenharia, Tecnologia e Inovação) (Pereira *et al.*, 2006) y localización de los cortes geológicos A-A' (Figura 2) y B-B' (Figura 4). Coordenadas: UTM, Datum Europeo-1950, huso 29ºN

Figure 1. A: Location of the studied area in a general map of the Iberian Massif showing the most important geologic domains. Adapted from Julivert et al. (1972) and Farias et al. (1987); B: Schematic intrepretation based on the INETI's (Instituto Nacional de Enegenharia, Tecnologia e Inovação) "Carta Geológica de Portugal à escala 1:200.000, Folha 2" (Pereira et al., 2006) with A-A' (Figure 2) and B-B' (Figure 4) cross-sections location. Coordinates: UTM, European Datum-1950, 29ºN

belong to the structurally lower part of the CIZ in this region, were abundantly intruded by diverse late to post-tectonic magmatic bodies and were affected by their respective contact metamorphism aureoles.

Thermal metamorphism evidences may be divided in two main types, depending on its timing in relation with the tectonic processes. The older metamorphic area bears, approximately, a N-S trend, cropping out as a rim around the SD and forming its relative footwall (Figure 1). This area displays pre and syn-S2 andalusite crystal growing, more developed in the most aluminous and graphitic host rocks, where blastesis of this mineral is favoured (Rubenach and Bell, 1988). In the same way as the MTMT is the upper limit of this unit, the TGD uppermost extensional detachment can be envisaged as its lower boundary. This thermally metamorphosed unit can be subdivided in two bodies. In the structurally higher, the andalusite porphyroblasts usually show pre-S2 cores, with S1 relicts and syn-S2 growing rims (Figure 3B). In the structurally lower part of this unit, only syn-S2 evidences were found (Figure 1 and Escuder Viruete, 1999). Local evidence of well developed mylonitic and phylonitic bands suggests that the limit between these two bodies is tectonic, but the importance of this structure has not been established yet.

The late contact metamorphic aureoles, related with late to post-D3 plutonism, show more regular shapes, bordering all late granitic bodies. It is easily distinguishable from the more precocious thermal events by the presence of static cordierite, biotite and andalusite blasts, which grow over the previous fabrics and metamorphic parageneses (Figure 1).

The Santo Adrião quarry area (Figure 1B) is one of the key points for the understanding of the local stratigraphy and tectonic evolution. The obtained cross-section and block diagram (Figures 2A and 2B), show that the most important D2 shear zones affects not only a specific stratigraphic limit but a thicker band that cuts through both the upper CIZ and the SD of the GTMZ. It is relevant to state that the pre to syn-S2 thermal metamorphism present on these rocks is most evident on the Ordovician and Silurian black slates that lay structurally below and above the Santo Adrião Formation (Sá *et al.*, 2003, Sá *et al.*, 2005).

Boudinage at several scales (parallel to stretching lineation - Ls) is observed in different open pits as represented on Figure 2B. This phenomenon is probably related to the intense top to SE, D2 ductile shearing at the base of the Santo Adrião Formation that induces stretching along a NW-SE direction.

Below and above the Santo Adrião Formation, it is possible to identify mylonitic bands (carbonated milonites and phyllonites, respectively), suggesting that in some cases some tectonic transport has involved this Formation, thus separating it from its relative autochthon.

Fabric description

Different tectonic and metamorphic fabrics associated to several tectonothermal pulses that affected this area during the Variscan orogenic cycle can be identified in the studied area. A relative chronologic sequence for the observed macro, meso and microscale geologic features is proposed in Table 1.

The studied rocks usually present syn to late S1 to early S2, low to middle greenschist metamorphic facies (chlorite zone), locally overprinted by a pre to syn-S2 andalusite/biotite/chloritoid thermal metamorphism, and by more recent andalusite/cordierite Late Variscan contact metamorphic aureoles.

The first andalusite generation (pre to syn-S2 foliation) (Table 1 and Figures 2 and 3), is representative of LP/LT-MT thermal metamorphism. Often, these early andalusite blasts, show internal zonation (Figures 3A and B), where S1 relicts are usually present in the mineral cores, and are substituted by S2 in the external rim. In most rocks, S1 foliation was fully overprinted by S2. In metapelites, S1 domains are usually smooth and parallel (see Paschier & Trouw, 1996 cleavage classification), easily distinctive from the anastomosing S2 crenulation cleavage. When S1 is transposed by S2, muscovite and oxide inclusions are preserved in the pre to syn-S2 andalusite, biotite and chloritoid blasts and in pressure shadows.

Extensional crenulation cleavage (ecc) domains developed on the phyllonite quartz ribbons (Figure 3C) indicating top to SE syn-S2 kinematics, longitudinally to the main Variscan orogen trend. A NW-SE preferred mineral lineation (Ls) is observed on S2 foliation planes. Thermal metamorphic porphyroblasts show top to SE rotation (asymmetric sigma and delta pressure shadows) and boudinage evidences, becoming sub-parallel to Ls.

Late Variscan shortening developed new open sub-vertical folds and related NW-SE steep crenulation cleavage (S3). A retrograde low grade metamorphism, within the chlorite zone, is contemporaneous to this shortening. This cleavage set is usually spaced and weak, contouring previous porphyroblasts (Figure 3B). In most cases, it crenulates the S2 foliation smoothly, being more pervasive in D3 fold hinge zones.

Late-Variscan (syn to post-D3) plutons intruded the area, especially in the CIZ. Nevertheless, towards the northern (Figures 1 and 2) and southern limits of the

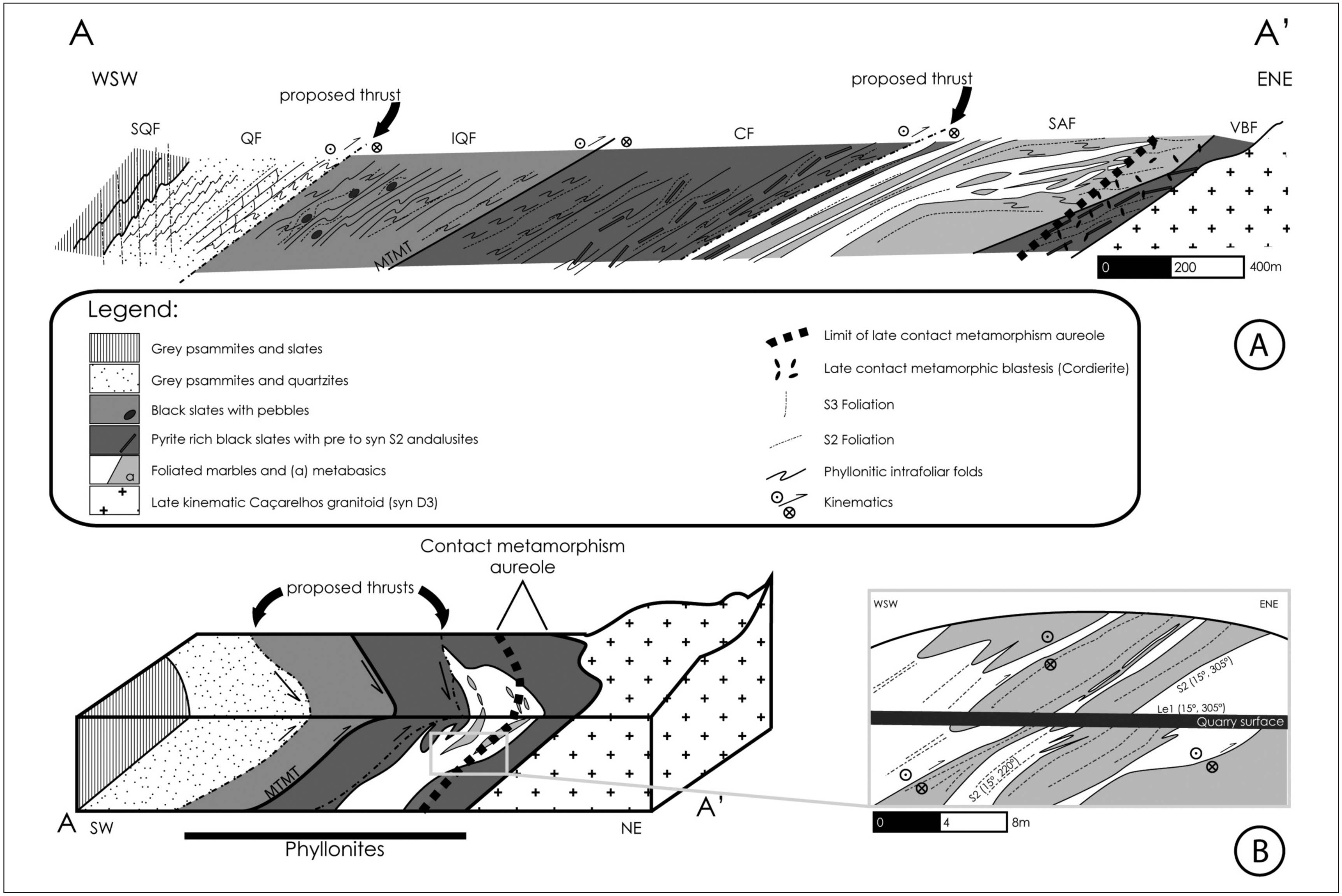

Figura 2. A) Corte geológico A-A' mostrando la disposición de las zonas de intensa filonitización con pliegues intrafoliares, las litologías afectadas por andalucita pre y sin-S2 y la aureola de metamorfismo de contacto provocada por la intrusión del granito tardi-cinemático de Caçarelhos; B) Bloque diagrama (izquierda) y corte geológico en las Minas de Santo Adrião (derecha) mostrando boudinage de los mármoles y de las metabasitas a lo largo de la dirección NW-SE (ver texto arriba). Abreviaturas: SQF –Formación Supracuarcítica; SQ – Formación Cuarcítica; IQ –Formación Infracuarcítica; CF – Formación de Campanhó; SAF – Formación de Santo Adrião; VBF – Formación de Vale de Bojas; MTMT – Cabalgamiento Principal de Trás-os-Montes

Figure 2. A) A-A' cross-section showing shear band disposition (phyllonites) with intrafolial folds, the lithologies affected by pre and syn-S2 andalusite blastesis and the contact metamorphic aureole associated with the late-kinematic Caçarelhos granite intrusion; B) Block diagram (left) and Minas Santo Adrião cross-section (right) exposing boudinage of marble and metabasic rocks along the NW-SE direction (see text above). Abbreviations: SQF – Supraquartzite Formation; SQ – Quartzite Formation; IQ – Infraquartzite Formation; CF – Campanhó Formation; SAF – Santo Adrião Formation; VBF – Vale de Bojas Formation; MTMT – Main Trás-os-Montes Thrust

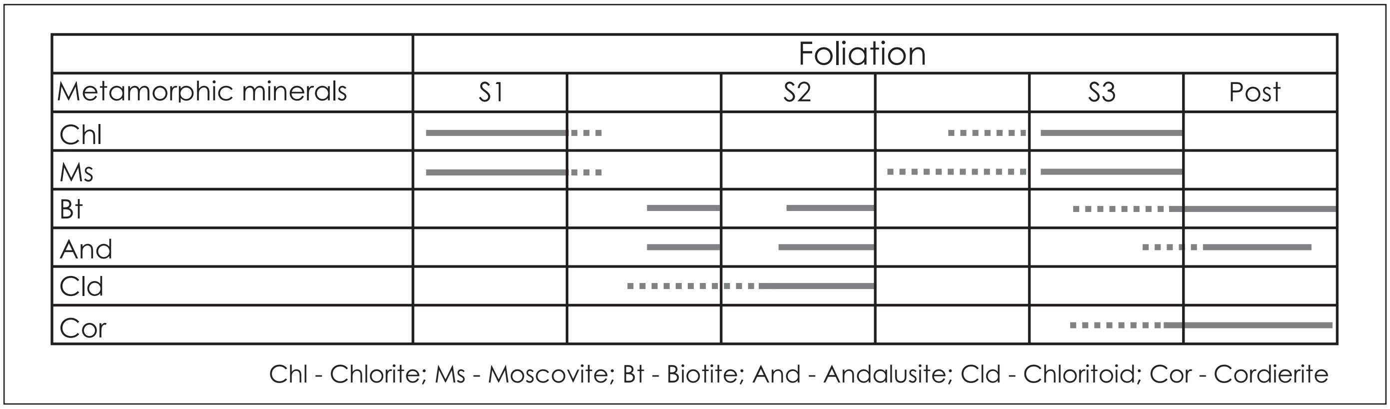

Tabla 1. Minerales índice metamórficos y su relación con las principales fábricas regionales. Estimado a partir de sus relaciones de crecimiento a meso y microescala
Table 1. Metamorphic index minerals and relation with the main regional foliations. Estimated from thin-section and mesoscale growth relations

studied area, some part of these intrusive bodies cut the earlier andalusite bearing rocks and locally superpose both thermal-metamorphic events, with new andalusite and cordierite (and more locally biotite) blastesis. This new mineral assembly shows no evidences of a later or coeval deformation event, and grows over the previously developed fabrics, being easily distinctive from previous andalusite generations.

Locally (Figure 4) it is possible to identify a set of late brittle shear zones, with top to SE kinematics, cutting the S3 Variscan cleavage, with a new centimetre-spaced S4 flat lying foliation. This brittle shear affects a small intrusive metagabbroic body and the lowermost part of its hanging wall (Figure 4).

Discussion and Conclusions

In the Variscan evolution of NW Iberia (GTMZ and CIZ) three main regional tectonic events have been traditionally identified, developing each one a regional tectonic foliation (Martínez Catalán *et al.*, 2004b). These events, as well as the metamorphic and magmatic phenomena related to the Variscan orogeny are diachronic, from the more internal parts of the Variscan Belt towards the external ones, as was stated by Dallmeyer *et al.*, (1997). The first and second phases are related to compression, resulting in thickening of the earth crust by folds and thrusts recumbent towards the external zones (Rodrigues *et al.*, 2006a, 2006b, 2006c and González Clavijo, 2006). As a result of this crustal thickening, a low grade Barrovian metamorphism was developed around the Morais Complex, in the CIZ (Escuder Viruete *et al.*, 2004), together with the first Variscan magmatic processes in the area (Dallmeyer *et al.*, 1997). Nevertheless, towards the end of D2, the crustal gravitational instability leads to a syn-orogenic extensional event focused mainly in the middle crustal levels; this episode created the TGD as established by Escuder Viruete (1999).This author describes a thermal metamorphic aureole in the lowermost part of the TGD hanging wall, as low metamorphic grade rocks came in proximity to the hotter lower crustal levels and associated decompression-related magmas.

The above described syn-S2 andalusite crystals and growth rims (around older post-S1 to pre-S2 crystal cores) can be easily related to this late Variscan extensional process (Figures 3A and 3B). They are clearly constrained by the later D3 shortening as the S3 postdates the diagnostic mineral growth (Figure 3B) as in the TGD (Escuder Viruete et al., 1994), to the SE, and the Ollo de Sapo Antiform (Díez Montes, 2007), to the N. The interpretation of the andalusite cores bearing only S1 relicts (Figure 3B) becomes less straightforward. An earlier start of the syn-orogenic extension seams quite unrealistic, as one very important part of the Variscan crustal thickening was attained by stacking of imbricated thrust units during D2. The existence of a younger thermal metamorphism aureole (post-S1 and pre-S2) could be supported by several data in this region and other nearby:

- in the Dallmeyer et al. (1997) compilation an inter D1/D2 magmatism is settled for this area;
- to the N, in the Alcañices Synform region, a remnant of a thermal metamorphic aureole was carried inside a D2 imbricate unit from the internal to the external zones of the orogen. The andalusite

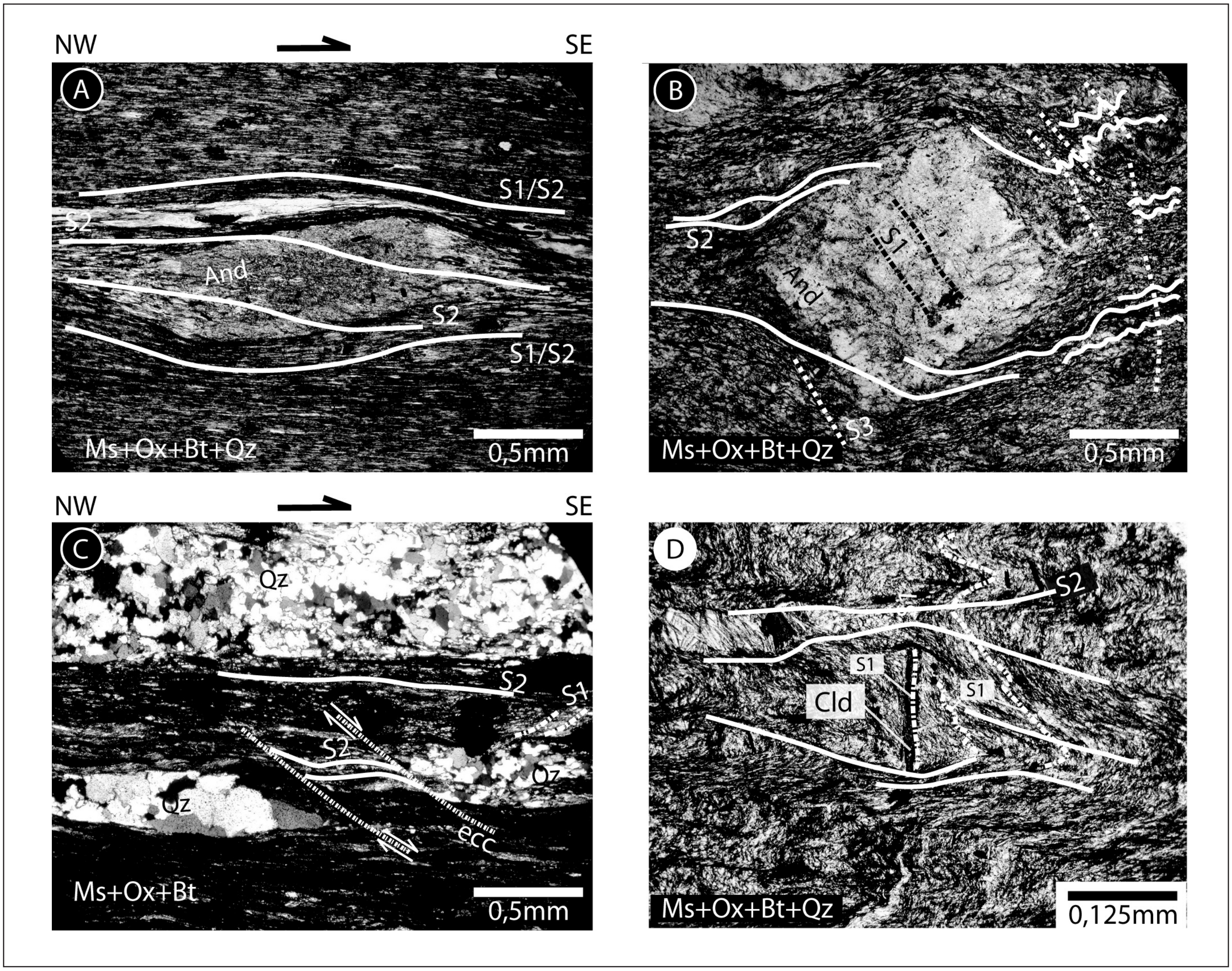

Figura 3. A) Porfiroblasto de andalucita sin-S2 (microfotografía con los nícoles paralelos) con rotación (patrón de inclusiones curvilíneo) y cuarzo recristalizado dinámicamente en las colas de presión asimétricas; B) Porfiroblasto de andalucita pre y sin-S2 (nicoles paralelos) con reliquias de S1 incluidas en el interior del cristal y S2 en los bordes recrecidos. Se observa la crenulación S3 de la foliación S2 en la cola de presión; C) Cintas de cuarzo recristalizadas dinámicamente en la foliación S2 afectadas por micro-cizallas extensionales (ecc) sintéticas, con cinemática que indica techo para el SE (nícoles cruzados); D) Crenulación S2 con blastesis contemporánea del cloritoide (Cld). El Cld incluye la foliación precoz S1. Se puede observar la microcrenulación de S1 en las colas de presión del Cld (nícoles paralelos). Abreviaturas: Ms – Moscovita; Ox – Óxidos/opacos; Bt – Biotita; Qz – Cuarzo; And – Andalucita; Cld – Cloritoide

Figure 3. A) Syn-S2 andalusite porphyroblast (microphotography with parallel nicols), showing rotation (curved inclusion pattern) and dynamically recrystallized quartz in asymmetric pressure shadows; B) Pre and syn-S2 andalusite porphyroblast (parallel nicols) with S1 relicts included inside the crystal and with S2 on the growing rim. S3 crenulation affects the S2 foliation in the pressure shadow; C) Dynamically recrystallized quartz ribbons and S2 cleavage affected by extensional crenulation cleavage microshears (ecc), evidencing a top to SE tectonic transport (crossed nicols); D) S2 crenulation cleavage with synchronous chloritoid (Cld) blastesis. The Cld show S1 relict inclusions. It is possible to observe S1 microcrenulation in the Cld pressure shadows (parallel nicols). Abbreviations: Ms – Moscovite; Ox – Oxides; Bt – Biotite; Qz – Quartz; And – Andalusite; Cld: Chloritoid

crystals display internal S1 foliation and are clearly surrounded by S2; asymmetric pressure tails and boudinage also evidenced pre-S2 growth (González Clavijo, 2006);

- the structural situation of the pre-S2 andalusite cores, at the top of a D2 shear band identified by mylonites and phyllonites below the MTMT (Figures 1 and 2) strongly suggests a structural environment similar to the Alcañices Synform, where several D2 stacked tectonic units have been

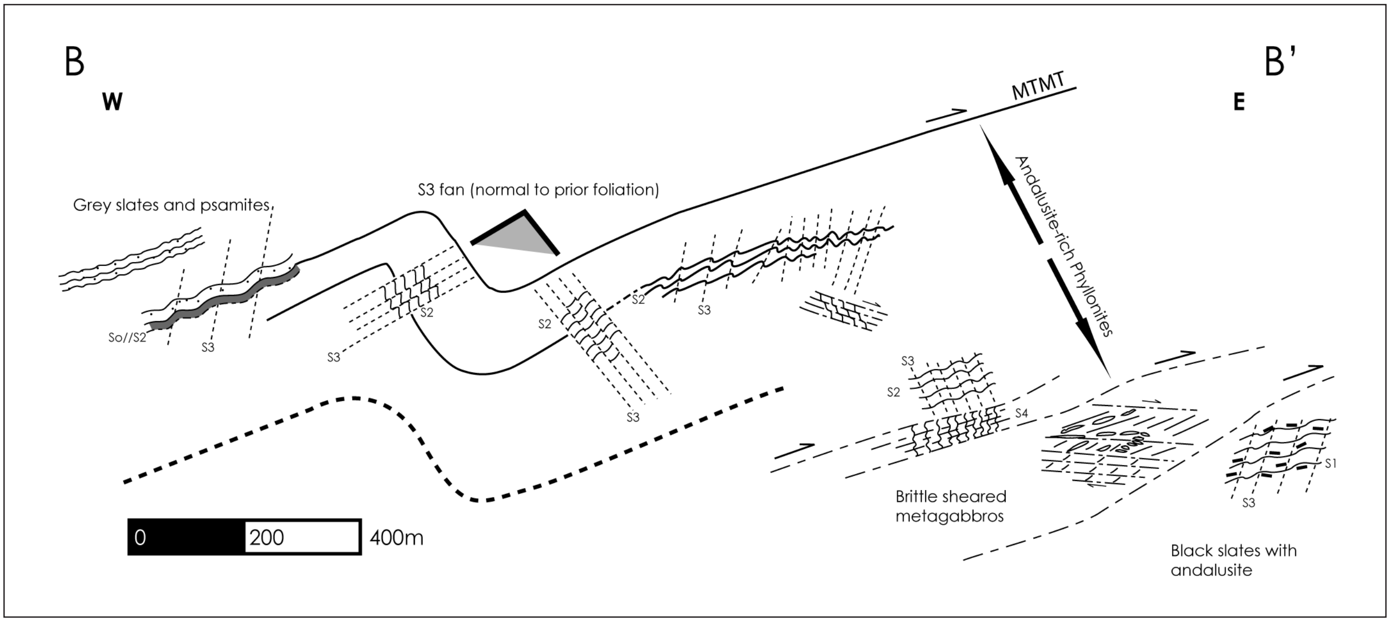

Figura 4. Corte geológico (A-A' en la figura 1). Se observan las relaciones de corte explicadas en el texto y la presencia de andalucitas pre a sin-S2 en las filonitas negras y en las pizarras negras a muro de los metagabros afectados por cizallas frágiles de bajo ángulo (S4?). Abreviaturas: MTMT – Cabalgamiento Principal de Trás-os-Montes

Figure 4. Geologic cross-section (A-A' in figure 1). It displays the crosscut relations explained in the text and the presence of pre to syn-S2 andalusite porphyroblasts in the black phyllonites and in the black slates in the footwall of metagabbros affected by low angle brittle shear bands (S4?). Abbreviations: MTMT – Main Trás-os-Montes Thrust

mapped in the upper part of the CIZ, under the lowermost GTMZ thrust (González Clavijo, 2006);

- the diachronic evolution of tectonomagmatic events stated by Dallmeyer et al. (1997) for the NW of the Iberian Massif supports the possibility of a pre-D2 magmatic body creating a thermal aureole in a relatively inner part of the orogen. The ongoing compression could transport part of this aureole to more external areas by thrusting at some earlier stage in D2. Lately, but still during D2, the NW-SE extensional processes described by Escuder Viruete (1996) for this region, bring the earlier aureole remnant in the environs of the thermal area of the TGD, thus growing the syn-S2 andalusite rims;
- late to post-D3 Variscan granitoid intrusion and related static thermal metamorphism partially overprinted both former thermal metamorphic subunits (Figure 1);
- late brittle shear bands were developed locally (Figure 4) leading to a new S4 foliation. This phenomenon is probably related to late to post orogenic fault reactivation during the latest Variscan extensional stages, driven by orogenic collapse (Martínez Catalán *et al.*, 2007 and Martínez Catalán *et al.*, 2009).

Complementary studies are presently underway aiming to a better perception of the Variscan evolution of this sector of the Iberian Massif.

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