



# Tectono-magmatic processes in the internal zones of the Variscan Orogen: the Tomiño area (NW Iberian Peninsula)

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**Abstract:** In the NW Iberian Variscan Belt we have surveyed a zone with an unusual development of late D<sub>3</sub> ductile structures (Tomiño area, Pontevedra). The rocks studied are mainly schists and granitoids. An early tectonic phase of folding (D<sub>1</sub>) was almost completely obliterated by a later one (D<sub>3</sub>). Syn-kinematic P-T estimations point to ~4 kbar and ~565 °C. These HT conditions and the abundance of granitic magmas would have imposed crustal weakening during the D<sub>3</sub> contractional event. Under this high heat flux, ductile D<sub>3</sub> structures were easily developed.

**Keywords:** tectonics, granitoid, variscan, Central-Iberian Zone, Iberian Massif.

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In internal orogenic environments tectonic processes are usually coupled with magmatism and metamorphism. These interrelations often generate diverse feedback relationships and complex rock-structure patterns (Solar *et al.*, 1998; Brown, 2007). Does magmatism control the type and style of tectonic activity? Is magmatism generated and focused in ascent conduits due to tectonic processes, or is, instead, tectonic deformation focused in zones with higher magmatic activity? In this work we deal with the causes of an uncommon strong development of late ductile structures (D<sub>3</sub> stage) in the internal zones of the Variscan Orogen of NW Iberia, thought to be influenced by contemporaneous magmatism. In the Tomiño area (SW Pontevedra province, NW Spain), a narrow N-S-trending belt of metasedimentary rocks crops out flanked by granitoids (Fig. 1). Rocks in this band, designated the Monteferro-El Rosal schistose band (MRSB), show strong synmetamorphic polyphasic deformation, produced during the Variscan orogeny. There are also some minor granitic bodies within the MRSB, and numerous granitic and aplitic-pegmatitic dykes of diverse size.

## Lithostratigraphy of the MRSB

The MRSB consists of an approximately 2000 m thick siliciclastic succession where six lithostratigraphic units have been differentiated, with likely ages ranging from Cambrian to Silurian (Toyos 1995, 2003). Their dominant lithologies are schist, mica-schist and metasandstones. Two main stratigraphic discontinuities can be observed in this succession, located at the bottom of Ordovician and near the Ordovician-Silurian boundary. These lithologies can be correlated with others from NW Portugal (Valongo anticline region), belonging to the Central-Iberian Zone (CIZ), and some of the upper units also bear a resemblance to lithologies from the Galicia-Trás-os-Montes Schistose Domain (GTMSD).

## Granitic rocks

In this area the igneous plutonic rocks are mainly peraluminous, Bt + Ms granitoids (see Kretz, 1983 for mineral abbreviations) that show diverse temporal

relationships (pre-, syn- and late-kinematic) with the main tectonic pulse (D<sub>3</sub>). The fabrics observed seem to be intermediate between magmatic and sub-solidus in the pre- and syn-kinematic granites, and magmat-

ic in the late-kinematic ones. A preliminary survey of their petrology and geochemistry is consistent with a grouping that follows an E-W spatial distribution pattern (Fig. 1):

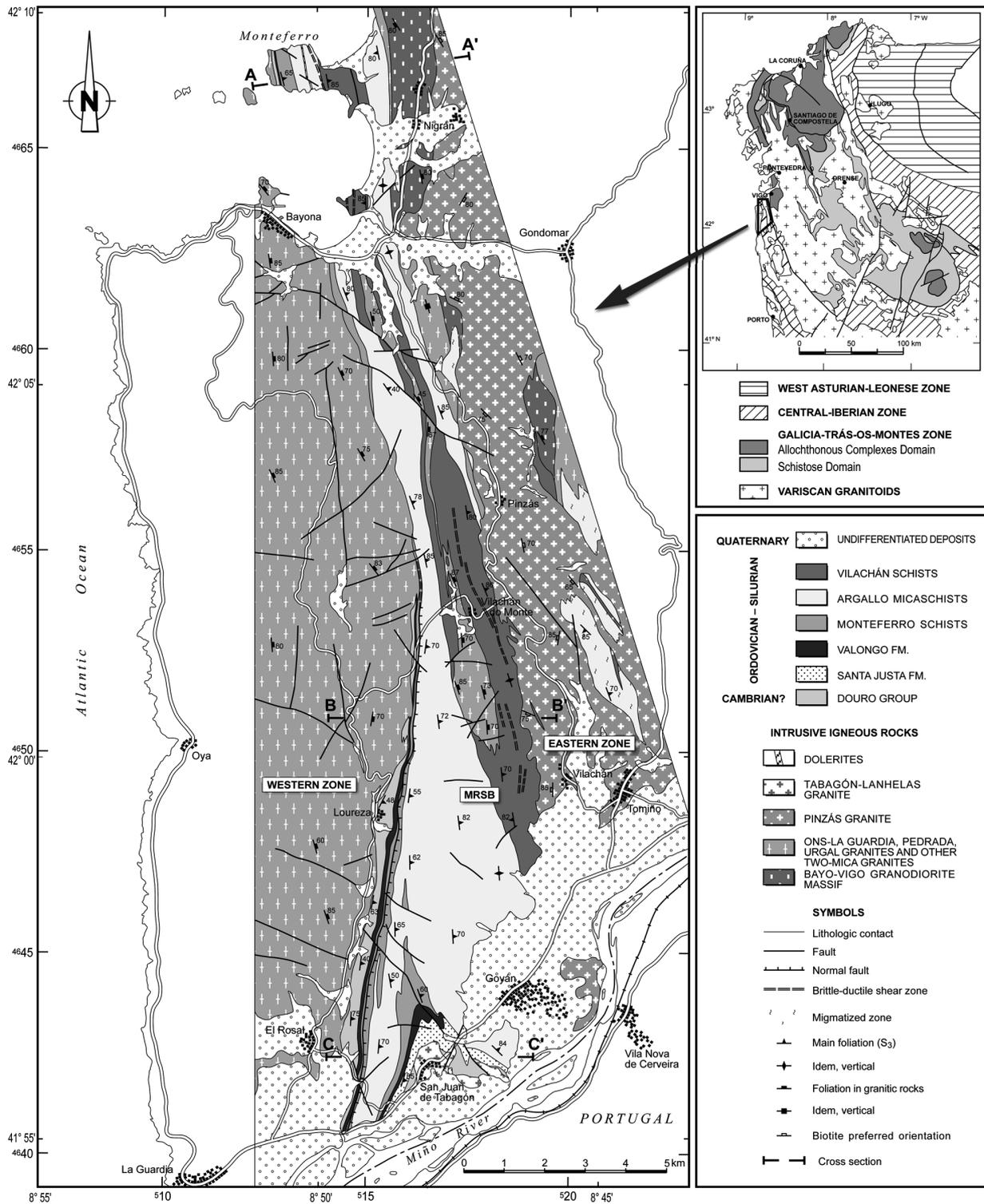


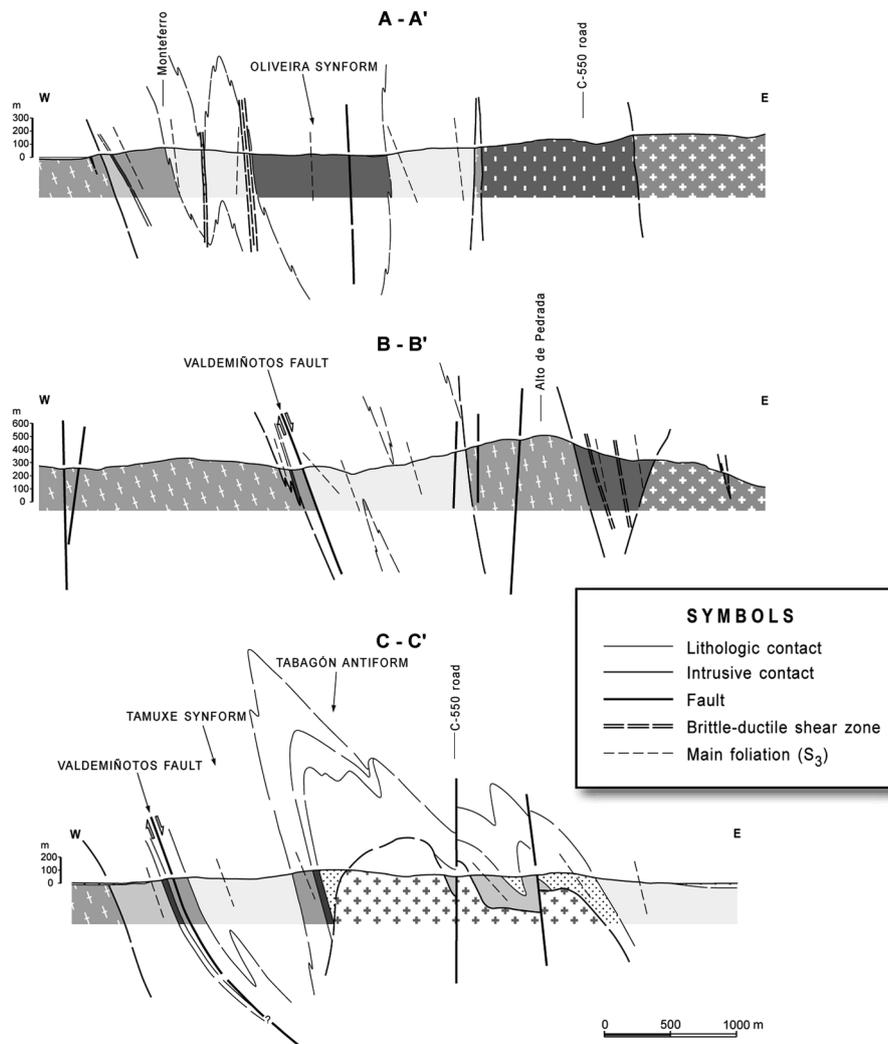
Figure 1. Geological map of the Tomiño Area.

a) Western zone intrusions are syn-kinematic two-mica granites of the Ons-La Guardia batholith (~310 Ma). They have N-S orientation with N-S steep Bt shape fabrics. Compositions are strongly peraluminous, especially in the more leucocratic granites. Other features of interest are the low  $P_2O_5$  contents and moderate  $Fe/(Fe+Mg)$  ratios.

b) Along the MRSB different types of intrusions occur: dykes, granitic sheets and plutons. Syn-kinematic dykes and sheet-like intrusions show a Bt shape fabric with a N-S trend and steeply dipping. An oval-shaped late- to post-kinematic pluton crops out to the south (Tabagón-Lanhelas Granite), with a more subtle Bt shape fabric following the pluton contacts. All these granitoids are strongly peraluminous two-mica granites. Some geochemical distinctive features are the high  $P_2O_5$  contents (0.3-0.4%) and also high  $Fe/(Mg+Fe)$  ratios.

Peraluminosity seems to decrease towards the most leucocratic granites.

c) The eastern zone shows greater abundance and variety of granitic rocks. The pre-kinematic Bayo-Vigo massif (~350 Ma) consists of Bt ± Ms granitoids which define a N-S-elongated intrusion (Gallastegui, 2005), showing a subvertical N-S foliation defined by alternating phyllosilicate and quartz-feldspar layers. Syn-kinematic two mica granites with sheet-like or dyke geometry crosscut the Bayo-Vigo massif. They show a steep N-S foliation, and in some locations S-C fabrics occur. The late- $D_3$  Pinzás batholith is formed by moderate peraluminous Bt ± Ms granitoids. The Bt crystals define a subtle N-S steeply dipping magmatic fabric, consistent with the shape of the intrusion. Some of these granites show a slight decrease of peraluminosity towards the most leucocratic terms.



**Figure 2.** Cross sections along the study area (see location and legend in figure 1).

## Structure of the MRSB

The structure of the MRSB is defined by different size folds formed during the  $D_1$  and  $D_3$  regional tectonic phases. Later events have developed brittle-ductile shear zones and fracture networks (Toyos, 1995). It is noticeable that the main structures were generated during the  $D_3$  deformation phase.

$D_1$  structures are quite scarce because most of them were obliterated by the later  $D_3$  event. At microscopic scale, a pre- $D_3$  fabric can sometimes be observed: in some samples, the  $D_3$  foliation ( $S_3$ ) is a crenulation cleavage of a previous  $S_1$ ; and there are also pre- to syn- $D_3$  porphyroblasts that include an internal foliation ( $S_1$ ) folded or forming high angles with the  $S_3$ . Only in a few locations is it possible to observe outcrop-scale, commonly isoclinal,  $D_1$  folds re-folded by  $D_3$  or crosscut by  $S_3$ . They are coaxial with the  $D_3$  later folds, defining Type 3 fold interference patterns (Ramsay, 1967), and have a vergence towards the west.

$D_3$  structures are mainly folds of different sizes with a penetrative axial plane foliation ( $S_3$ ), which is the dominant planar structure observed in the MRSB. First order folds have either subvertical axial planes or a slight vergence towards the west (Fig. 2). Minor folds have shapes of classes 1C and 2 (Ramsay, 1967). They are tight to isoclinal folds with straight hinge lines and variably plunging axes. The  $S_3$  is usually a continuous or zonal schistosity, but locally it can occur as a crenulation cleavage.

In the pre- and syn-kinematic granitoids the  $D_3$  event formed planar fabrics oriented subparallel to the MRSB foliation. Adjacent to the MRSB two main regional shear zones occur: La Guardia Shear Zone (López-Plaza and Martínez Catalán, 1987), in the western part, and the Malpica-Lamego Line (Llana-Fúnez, 2001; Llana-Fúnez and Marcos, 2001), to the east. These structures are mainly developed in granitic

rocks and show S-C fabrics. Dextral strike-slip movements in these bands are syn- to late- $D_3$ .

## P-T conditions

Pressure estimates have been obtained from the metamorphic assemblages in MRSB. The presence of the And + Bt ± St assemblage points to pressure conditions close to 4 kbar during the  $D_3$  event (Pattison and Vogl, 2005). The normative Qz-Ab-Or data from the syn- to late-kinematic leucogranites that intruded within the MRSB indicate that pressure of emplacement was between 3 and 5 kbar (Johannes and Holtz, 1996). Both sources of data seem to indicate a ~4 kbar estimate. Regarding temperature, previous thermometric data point to ~565±25 °C (Hébert, 1997). This estimation is coincident with the temperature established for the field of the And + Bt ± St assemblage (KFMASH system), thus adding further credibility to these temperature conditions during the  $D_3$  event.

## Discussion and conclusions

The abundance of pre-, syn- and late-tectonic intrusions within the study area is noticeable: magmatic/fluid veins, dykes, plutons and batholiths. This scenario, together with the P-T estimations, suggests an important heat flux located and sustained within this zone during the late orogenic contractional phase  $D_3$ . These factors would have produced crustal weakening and high ductile rock behaviour, as the  $D_3$  structures indicate. At the same time, magmatism appears to be controlled by regional structures with activity during the  $D_3$  stage.

A debated issue in this region is whether the MRSB belongs to the GTMSD allochthonous unit or to the autochthon of the CIZ. The lithostratigraphic and structural features of the study area show remarkable affinity with other areas of the CIZ from NW Portugal, leading it to be considered as part of this latter domain.

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