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# A new model for the Hercynian Orogen of Gondwanan France and Iberia: discussion

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## 1. Introduction

The study by Shelley and Bossière (2000) is an important contribution to the discussion concerning the Ibero–Armorican arc (IAA) generation model. This model comes as one of a sequence of previous ideas already published in several papers (Bard, 1971; Matte and Ribeiro, 1975; Lefort and Ribeiro, 1980; Ribeiro et al., 1980; Burg et al., 1981; Brun and Burg, 1982; Julivert, 1987; Ribeiro et al., 1990; Dias and Ribeiro, 1995; Ribeiro et al., 1995; Silva, 1997). A common feature of the interpretations in these papers is the great importance attributed to two major transcurrent faults: the dextral Porto–Tomar shear zone (PTSZ) and the sinistral Tomar–Badajoz–Cordoba shear zone (BCSZ), to explain the extension of the Iberian structures into the Armorican Massif in the form of trace the arcuate shape of the IAA.

The large-scale migration, rotation and accretion of microplates controlled by oblique interactions have been a matter of controversy since researchers applied different kinematic models to reconstruct such global tectonic movements. For example, Badham (1982) interpreted the Hercynides as the result of dextral interaction between Europe and Africa and considered the arcuate geometry of the IAA as a secondary structure. In contrast, Matte (1986) compared the present example of the Himalayas with the structures of the IAA in terms of an indentation of crustal fragments, and proposed the progressive development of the symmetrical outward lateral escape of blocks in France and Iberia. In this model, the indentor migration caused opposing strike-slip movements on either side represented by the major transcurrent faults of the Armorican Massif and the Iberian Massif. This geometry and kinematics were considered to be syngenetic with the formation of the arcuate structure of the IAA. However, the main geologic lines linking these western European Hercynian massifs through major shear zones are still questionable (e.g. Lefort, 1989).

In this comment we believe that the regional approach regarding the transcurrent faults of Hercynian Iberia (BCSZ and PTSZ) cannot be considered to be well established. In the following text we will comment on significant omissions concerning available work of the last decade and also focus our discussion on field data and the structural interpretation of Hercynian Iberia (Portugal and Spain).

## 2. Age constraints of the geodynamic evolution of the BCSZ: an Hercynian sinistral transcurrent fault superposed on the Cadomian arc of Iberia

The presence of a sinistral transcurrent transpressional regime of deformation in the BCSZ during the Hercynian is a well established fact (Burg et al., 1981).

There are a number of reasons to think that the main fabric developed in the BCSZ is Eohercynian–Hercynian justaposed on an earlier Cadomian arc structure (Upper Proterozoic–Lower Cambrian) and that the PTSZ represents a later Hercynian transcurrent fault.

In order to re-evaluate their recently proposed model for the Hercynian Orogen of Gondwanan France and Iberia, Shelley and Bossière (2000) need to consider recent data presented in the last decade by Iberian geologists.

### *2.1. The BCSZ comprises several tectonometamorphic Hercynian units*

Recent field data (Pereira, 1999) allowed a subdivision of the BCSZ into different tectonometamorphic units characterised by a well developed mylonitic S–L fabric with NW–SE trend and low-to-high-grade metamorphic conditions (Campo Maior unit migmatites give a protolith age of 465 ± 14 Ma and Carboniferous age for migmatization, 335 ± 14 Ma, SHRIMP U/Pb on zircons; Ordoñez-Casado,

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1999). Shear-sense criteria observed in BCSZ rocks indicate a transcurrent transpressional Hercynian deformation.

There is no consensus regarding this interpretation since some researchers interpret these subdivisions in different tectonometamorphic units as a result of a former Cadomian geodynamic evolution, later reactivated by Hercynian deformation under low–medium grade metamorphic conditions (Quesada, 1990; Abalos et al., 1991; Abalos and Eguiluz, 1992; Eguiluz and Abalos, 1992; Abalos et al., 1993) related to an important uplift during late Paleozoic sinistral transpression (Quesada and Dallmeyer, 1994). Other researchers think that the principal tectonometamorphic evolution of the BCSZ caused by the Cadomian orogeny does not seem to be well established (Azor et al., 1995). These two opposing interpretations are mainly related to the discussion of radiometric ages for the high-pressure, high-temperature metamorphism preserved in some eclogitic facies included in high-grade BCSZ tectonometamorphic units (e.g. Abalos et al., 1993; Azor et al., 1993). However, field data indicate that the BCSZ had a progressive polyphase tectonometamorphic evolution where a definitive interpretation of the age of the eclogites is not possible.

It is clear that the regional setting is more compatible with a Cadomian suture zone. It is possible to identify Upper Proterozoic synorogenic basins, Upper Proterozoic–Lower Cambrian transition calk-alkaline volcanism, dioritic plutons, anatectic granodiorites and migmatitic cores associated with high-temperature/low-pressure metamorphism (e.g. Eguiluz et al., 1995, 1999) overlain by Lower Cambrian sedimentary peri-Gondwanan basins.

Despite the scarcity of suture related igneous activity and stratigraphic records in the Paleozoic, recent radiometric ages from high pressure rocks from the BCSZ give Carboniferous age (340 ± 13 Ma SHRIMP U/Pb on zircons; Ordoñez-Casado, 1998) for eclogitization.

### *2.2. Late-Hercynian granitoid intrusives cross-cutting the BCSZ tectonometamorphic Hercynian units*

Granitoid bodies (Alpalhão–Pedroches batholit and Monforte–Sta.Eulália massif) that intruded at the end of the Carboniferous (~295 ± 15 Ma K/Ar whole rock; Bellon et al., 1979) give rise to contact metamorphism of the earlier deformed and metamorphosed BCSZ units. This represents the upper age constraint for the ductile transcurrent deformation associated with this major shear zone.

The late-Hercynian igneous activity occurred after deposition of Carboniferous basins (Dúrico–Beirão trench, Peñarroya and Matachel basins), localised in the vicinity or within the BCSZ, controlled by transcurrent transtension during the late stages of Hercynian deformation.

### *2.3. Lower Paleozoic peralkaline and alkaline intrusives included in the BCSZ tectonometamorphic Hercynian units cross-cut an earlier Cadomian tectonic fabric*

Ordovician and Silurian intrusions represented by the Northeast Alentejo peralkaline rocks in Portugal (Gonçalves, 1971; Pereira et al., 1997) as the Cevadais orthogneiss with a protolith age of 482 ± 16 Ma (U/Pb on zircon; Lancelot and Allegret, 1982) or 480 ± 37 Ma (Rb/Sr whole rock; Priem et al., 1970) are included in the BCSZ tectonometamorphic Hercynian units. These Lower Paleozoic rocks have been correlated in Spain with the peralkaline orthogneiss of Almendralejo–Aceuchal (475 ± 11 Ma, Rb/Sr whole rock; Garcia Casquero et al., 1985) intensely deformed and thermally-overprinted during Upper Paleozoic sinistral ductile shearing (334 ± 6 Ma, $^{40}Ar/^{39}Ar$ biotite; Schäfer, 1990).

The pre-Hercynian igneous group intrudes into a previously deformed and metamorphosed Cadomian basement. This is supported by the occurrence of orthogneiss apophyses cross-cutting a previous foliation also preserved in xenoliths inside the principal orthogneiss mass.

Some authors interpreted these structural relationships between pre-Hercynian granitoids and the previous deformed and metamorphosed country rocks as evidence for the existence of a major subdivision of the BCSZ in several Cadomian tectonometamorphic units which were overprinted under low-to-medium metamorphism conditions by Hercynian transcurrent tectonic displacements (Abalos, 1990; Abalos and Eguiluz, 1992). On the contrary, Azor et al. (1993, 1995) think that the main tectonometamorphic evolution of the BCSZ is Hercynian, and argued against the formation of this blastomylonitic belt in the Cadomian orogeny.

In our opinion, based mainly on data from the Portuguese sector of the BCSZ (Pereira, 1999), the Cadomian tectonometamorphic evolution is not well-preserved within the blastomylonitic belt as a consequence of the intense Paleozoic metamorphism (reaching high-grade conditions). Meanwhile, at the borders of the BCSZ where the Hercynian metamorphism is weak, it is possible to characterise the Cadomian tectonostratigraphic evolution as representing one of the main evolutionary geodynamic stages of this particular poly-tectonometamorphic sector of the OMZ.

## 3. The Porto–Tomar shear zone: a late-Hercynian dextral transcurrent fault of Iberia

At the north-western cartographic extension of the BCSZ in the Tomar region, the mylonitic fabric associated with the sinistral sense of shear, and which developed under high-to-low-grade metamorphic conditions, is cross-cut by an intrusive granitoid body (Martinchel–Tramagal granite). This intrusive body was deformed under low-grade metamorphic conditions associated with dextral shear sense, which gives support to the proposition that the PTSZ is a later transcurrent fault relative to the BCSZ.

Another example is in the Porto region, where north–south dextral shear movement was described (Ribeiro et al., 1980) superimposed on an earlier blastomylonitic fabric, and cross-cut by post-tectonic intrusives (Madalena–Lavadores granites and Castelo do Queijo granites of Upper Carboniferous age, 306 Ma, Rb/Sr biotite; Mendes, 1967–1968).

## 4. Conclusions

The assertion of a master fault status to the PTSZ and relatively minor importance to the BCSZ, probably representing bookshelf movements (Shelley and Bossière, 2000), seems to be a misinterpretation.

Field investigations in Iberia in the last decade demonstrates that the BCSZ is a major Eohercynian–Hercynian sinistral transcurrent fault overprinting a Cadomian arc localised at a convergent margin of Gondwana. The PTSZ is also a very important transcurrent fault with an evolutionary history during Carboniferous times that cuts and displaces the former complex BCSZ.

The most recent events related to Upper Paleozoic tectonics include the development of Upper Devonian–Carboniferous high-pressure, high-temperature metamorphism (Ordoñez-Casado, 1998) and Late Carboniferous retrogression (Quesada and Dallmeyer, 1994).

Along the Tomar–Porto region, the BCSZ units can be recognised. Where the two transcurrent faults diverge, field relations show that north–south dextral shearing affected an earlier northwest–southeast blastomylonitic belt, which exhibits sinistral transcurrent movement. Therefore the PTSZ cannot be interpreted as the major transcurrent fault of Gondwanan Iberia.

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