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Thick-skinned inter-plate and intra-plate tectonics in NW and SW Iberia

Tectónica do tipo "thick-skinned" em zonas de intraplaca e interplaca no NW e SW da Ibéria

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ABSTRACT: In the Abrantes area of the Ossa Morena Zone the NW tip of the Tomar-Badajoz-Cordoba Shear Zone (TBCSZ) stops against the Porto-Tomar-Ferreira do Alentejo Shear Zone (PTFASZ). Basement nappes of Cadomian age were thrust to the NE during the Variscan orogeny. Low intermediate pressure granulites contrast with high pressure eclogite Cadomian assemblages in the axial zone of TBCZ where we infer the presence of a Cadomian suture. It is proposed that the intra-plate basement nappe system of OMZ is connected via the PTFA paleotransform to the basement nappes of the NW Iberia inter-plate transported suture system.

KEYWORDS: Variscides, Iberia, Basement nappes, Cadomian.

RESUMO: Na área de Abrantes (Zona Ossa Morena), o extremo NW da Zona de Cisalhamento de Tomar-Badajoz-Córdoba termina contra a Zona de Cisalhamento Porto-Tomar-Ferreira do Alentejo. Mantos de carreamento de soco Cadomiano foram transportados para NE durante a orogenia Varisca; granulitos de pressão intermédia/baixa contrastam com associações cadomianas de alta pressão na zona axial da ZCTBC, devido à presença de uma sutura Cadomiana. O sistema intraplacas de mantos de soco da ZOM é conectado via a paleotransformante PTFA com os mantos de soco do sistema interplacas da sutura transportada do NW Ibérico.

PALAVRAS-CHAVE: Variscides, Ibéria, Mantos de soco, Cadomiano.

1. INTRODUCTION

In a previous review (Ribeiro *et al*., 2009), we supported the view that the internal Zones of the Iberian Variscides are characterized by the presence of thick-skinned Variscan thrust and transpressive tectonics involving Cadomian basement and Paleozoic cover, producing basement

nappes and basement axial zones in the core of flower structures. The NE boundary domain of Ossa Morena Zone (OMZ), thrusted on top of the Central Iberian Zone (CIZ), confirms this model based on both geochronological data (Henriques *et al*., 2009) and indirect stratigraphic, tectonic and petrological inferences.

We will examine first thick-skinned intra-plate tectonics in SW Iberia and second, its implications for the thick-skinned inter-plate tectonics in NW Iberia (Vera *et al*., 2004; Dias *et al*., 2006).

2. GEOLOGICAL SETTING

The studied area is located in the Abrantes (W-central Portugal) region of the Ossa Morena Zone, where the NW tip of the Tomar-Badajoz-Cordoba Shear Zone (TBCSZ) stops against the Porto-Tomar-Ferreira do Alentejo Shear Zone (PTFASZ). The TBCSZ is a WNW-ESE sinistral transpressive intra-plate Variscan flower structure, whereas the PTFASZ is N-S dextral paleotransform during the Variscan Wilson cycle in SW Iberia.

3. RESULTS AND DISCUSSION

The NE branch of the TBCSZ (with top to NE sense of thrusting), is characterized by the following tectonic units, from top to bottom:

- Paleozoic cover: Bimodal volcanics, marbles and meta-arkoses, metamorphosed under greenschist facies (and displaying a minor thrust at the base), inferred to be of Lower Paleozoic age by stratigraphic correlation with other sectors dated as Cambrian to Silurian in the Ossa Morena Zone.
- Cadomian intermediate crust: low/intermediate pressure (~ 4 - 7 kb) retrograded granulites, including a mafic (meta-gabbroic) component that yielded metamorphic zircons dated at 539±3 Ma (Henriques *et al*., 2009).
- Cadomian upper crust: granitic gneisses, yielding prismatic, oscillatory-zoned, igneous zircons dated at 570 Ma and 540±5 Ma metamorphic monazites (Henriques *et al*., 2009).
- Cadomian volcano-sedimentary sequences: Greenschist facies black phyllites and greywackes, intercalated with black chert beds and bimodal metavolcanics ("Série Negra"), which are correlated with the Neoproterozoic sequences of the Ibero-Armorican Massif.

All the tectonic units are separated by top to NE thrusts, operating under ductile conditions in the upper units and under a brittle regime in the lower units; thus, inverting the inherited Cadomian crust below the basal *décollement* of Palaeozoic cover. These tectonic units belong to the Ossa-Morena Zone and were transported towards NE, on top of the (very low-grade) Central-Iberian Zone relative autochthon (Ediacarian/Cambrian to Lower Devonian). The amount of the NE thrust displacement within the granulite basement nappe is considerable, at least 5 to 10 km; this is based on the presence of imbricated mafic and intermediate composition (both retrograded into the amphibolite facies), in the SW Bioucas and in the NE Olalhas klippen, resting on top of the lower-grade poly-metamorphic Cadomian assemblages.

The axial zone of the TBCSZ flower structure exposed high grade metamorphic rocks, particularly high grade gneisses including eclogite lenses (Mata & Munhá, 1986). The high-pressure metamorphism did affect neither the Lower Paleozoic peralkaline to peraluminous magmatic rocks (orthogneisses) nor the Paleozoic cover (re-crystallized under low-P amphibolite to greenschist facies (Romão *et al*., 2008; Romão *et al*., submitted) These relationships support a poly-cyclic model, with exhumation of Cadomian basement in the axial zone during the Variscan thermo-metamorphic cycle imprinted in the Paleozoic lithotypes. Recent U/Pb geochronology (Pereira *et al*., 2009) supports this model, yielding metamorphic zircon 550-640 ages in the high-grade gneisses, (including inherited zircons of Mesoproterozoic, Paleoproterozoic and Archean

ages), Lower Paleozoic magmatic zircons from rift-related intrusions and retrogradation and partial melting during the Variscan orogeny. This geodynamic setting contrasts with the NE branch of the TBCSZ because intermediate to low pressure granulites in the NE branch are replaced by high pressure eclogites, granulites and gneisses in the Axial Zone, suggesting a gradient to an higher pressure metamorphic regime towards the SW.

3. CONCLUSIONS

We conclude that the data presented above demonstrates a poly-cyclic orogenic evolution in SW Iberia TBCSZ represents a Cadomian suture, evolving under a high pressure metamorphic regime generated inside a subduction/colision orogen; this suture has been reactivated as an intracontinental rift during ~~t~~ lower Paleozoic times and as a transpressive intra-plate flower structure during the Upper Paleozoic convergent regime inside the Iberian plate that includes the OMZ and CIZ.

The presence of Cadomian basement in SW Iberia requires ~~a~~ reappraisal of the geochronological data on NW Iberia. We supported the view (Ribeiro *et al*., 2007; 2009; and references there in) that the continental Allochtonous Terrane (CAT) is also a basement nappe of probable Cadomian age, transported more than 200 km from its root zone in the Armorica Plate.

From top to bottom we find:

- Paleozoic cover (Cambrian age?) represented by the Lagoa and Ordenes schists and metagreywacke sequences; the lower contact with the underlying orthogneisses unit is sharp and of unknown nature (extensional detachment or unconformity?). Mafic dykes, intrude (across this contact) both schists and underlying orthogneisses.

- Cambrian upper crust is represented by orthogneisses in the Lagoa and Ordenes massifs; these gneisses are cut by mafic intrusions probably synchronous with 500 Ma gabbros (that intrude CAT high-P granulitic lower crust) such as in Monte Castelo, Ordennes Massif (Abatti *et al*., 1999) and Conlelas, Bragança Massif. In the Sabor valley (1 km to NNE of Reimondes Bridge) the mafic dykes (0.5 m wide on average) are only slightly stretched to NNW-SSE during D_1 Variscan deformation, with top to SSE shearing in both the Lagoa schists and gneisses. Mafic dikes show centimeter wide chilled margins; indicating that they were emplaced in brittle conditions, when the gneissic country rock was cooled after ductile shearing (with top to W; absent in the Paleozoic cover), probably during a Cadomian orogeny.

- CAT units are represented by high pressure granulites, eclogites and paragneisses restricted to small duplexes in the Morais and Ordennes Massifs but forming most of the Bragança and Cabo Ortegal basement klippe. These units represent Cadomian subducted ocean and continental lower crusts that subsequently underwent underplating at 500 Ma by ~~of~~ the mafic/ultramafic suite of Monte Castelo and Conlelas. The overall metamorphic PT conditions of the poly-cyclic Cadomian rocks and the mono-cyclic Variscan rocks (Marques *et al*., 1996) clearly require a reappraisal of the available geochronological data.

We conclude that field relations on the Lagoa gneisses and schists represent a typical basement cover relationship and given the Variscan geodynamics context the age of the basement is Cadomian, including possible relicts of previous cycles. The high-pressure poly-cyclic rocks in the Axial Zone of the TBCSZ, suggest the presence of a Cadomian orogen, reworked by the Variscan Wilson cycle and including possible relicts of previous Precambrian cycles.

The geodynamic setting of NW Iberia is typical of inter-plate thick-skinned thrusting by closure of the Paleotethys ocean between Iberia and Armorica (Ribeiro *et al*., 2007 and references there in). Indeed, obducted ophiolite complexes (~400 Ma) occur bellow which are not present (during the Variscan Wilson cycle) between CIZ and OMZ. Given the similarities between the Lower Paleozoic magmatism both in OMZ and in the Lower Allochtonous Complex of the NW Iberia and its position (below the ophiolitic nappes), we must consider that these

could represent the Paleozoic cover of the basement nappes of the NE OMZ described above, with centripetal vergence around the Ibero-Armorican Arc. If this is the case the dextral N-S PTFASZ would connect the intra-plate thick-skinned thrust system of the OMZ-CIZ boundary with the inter-plate thick-skinned thrust system of NW Iberia; the Paleotethys ocean in the Armorican NW Iberia traverse will be transferred or stopped against the PTFASZ paleotransform separating Iberia on the E side from the Finisterra plate on the W side. The reconstitution of Cadomian orogen before the Variscan cycle stimulate the search for Cadomian (and other Precambrian relicts?), inside Finisterra and its possible connection with the Léon Terrane (Sintubin, 2009) between Armorican and Avalonia SW England).

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References

Abati, J., G. Dunning, R. Arenas, F. Díaz Garcia, P. González Quadra, J. Martínez Catalán, and P. Andonaegui (1999) – Early Ordovician orogenic event in Galicia (NW Spain): evidence from U/Pb ages in the uppermost unit of the Ordenes Complex. *Earth and Planet. Sci. Lett.*, 165, pp. 213-228.

Dias, R., Araújo, A., Terrinha, P. & Kullberg J. C. (2006) – *Geologia de Portugal no contexto da Ibéria*. Univ. Évora, Portugal, 418 p.

Henriques, S. A., Dunning, G. R., Ribeiro, M. L., Neiva, A. M. & Romão, J. (2009) – *Ediacaran Gneisses along the Ossa-MorenaCentral Iberian Zone boundary, Portugal; their distribution, character, age and metamorphic history*. The Geological Society of America, Annual Meeting, Abstracts with programs, 41, 7, 270 p.

Mata, J.& Munhá (1986) – Geodynamic significance of high-grade metamorphic rocks from Degolados-Campo Maior (Tomar-Badajoz-Cordoba Shear Zone). Abstract, Maleo, Vol. 2, nº 13, p. 28. *Sociedade Geológica de Portugal*. Lisboa.

Marques, F. O., A. Ribeiro, and J. Munhá (1996) – Geodynamic evolution of the Continental Allochthonous Terrane (CAT) of the Bragança Nappe Complex, NE Portugal. *Tectonics*, 15, pp. 747-762.

Pereira, M.F., Silva, J.B:, Drost, K., Chichorro, M. & Apraiz, A (2009) – Relative timing of the transcurrent displacements in northern Gondwana: U-Pb laser ablation ICP-MS zircon and monazite geochronology of gneisses and sheared granites from the western Iberian Massif (Portugal). *Gondwana Research*, doi: 10.1016/j.gr.

Ribeiro, A., Pereira, E., Fonseca, P., Mateus, A., Araújo, A., Munhá, J., Romão, J. & Rodrigues, J. F. (2009) – Mechanics of thick-skinned Variscan overprinting of Cadomian basement (Iberian Variscides). *C. R. Geosciences*, Paris, 341, pp. 127-139.

Ribeiro, A., Munhá, J., Dias, R., Mateus, A., Pereira, E., Ribeiro, L., Fonseca, P., Araújo, A., Oliveira, T., Romão, J., Chaminé, H., Coke, C. & Pedro, J. (2007) – Geodynamic evolution of SW Europe Variscides. *Tectonics*, 26, TC6009.

Romão, J., Ribeiro, A., Dias R., Pereira, E., Munhá, T., Mateus, A. & Araújo, A. (2008) – *Interplate versus intraplate strike-slip deformed belts: examples from SW Iberia Variscides*. Extended Abstract, International Meeting of Young Researchers Structural Geological and Tectonics (YORSGET 08-OVIEDO), pp.203-206.

Romão, J., Ribeiro, A., Munhá, J., Mateus, A., Araújo, A. & Dias, R. (submitted) – Accommodation of shortening components in transpression regimes: Tomar-Badajóz-Córdoba Shear Zone the example (SW Iberian Variscides). *Society Geologic of London*.

Sintubin, M., Berwouts, I., Muchez, P. & van Noorden, M. (2009) – *"Bretonian" contraction-dominated deformation in Central Armorica caused by the docking of the Léon microcontinental Block at the southern margin of the Rheic Ocean*. Oroclines, Delamination, Relations & Effects, IGCP, 497-574, pp. 277-279.

Vera, J. A. (2004) - *Geologia de España*, SGE-IGME, Madrid, España, 890 p.