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Interactive comment on "Deciphering the metamorphic evolution of the Pulo do Lobo metasedimentary belt (SW Iberian Variscides)" *by* Irene Pérez-Cáceres et al.

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1. General comments This paper constitutes a very well-documented study of the characteristics of phyllosilicates and organic matter in pelitic samples collected along two sections across the Pulo do Lobo "belt", a critical unit to understand the so-called SW Iberia Variscan suture. The goal and approach are to be applauded and the paper deserves publication. That said, I find the results to be incomplete, mainly because the short number of samples in just two sections located near the eastern end of a belt that is much larger, wider and better exposed in its central and western parts in Portugal. The conclusions are supported by the data presented but I would like to see results

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from other sections and from other rock types, for instance the metamafic rocks that are only marginally mentioned. One of the conclusions reached by the authors is that there is in no evidence for HP metamorphic conditions in their samples. Fair enough! But surprisingly they have not attempted to analyze samples in the vicinity of the only reference to possible HP relics published so far (Rubio Pascual et al., 2013). I recognize the interest of the data presented and recommend publication but at the same time I insist that the authors should enlarge the scope of their research as suggested above. Also with a general character, I find the paper to present only the authors' interpretation of the SW Iberia Variscan orogen. This is evidenced by many references to the first author's papers and those of her group, hiding other controversial (to the authors' minds) interpretations behind the general statement "and references therein". This would be fine if they did not derived conclusions that have profound geodynamic implications. Consensus is far from being reached on the geodynamic evolution of this part of the Variscan orogen, and the authors' model is just one of many. In this respect, the entire "Section 2: Geological setting" is rather disappointing. Potential readers would welcome a discussion of the various models proposed, at least on those aspects that are later discussed in the paper.

2. Specific comments References cited in the comments below and not included in the paper are listed at the end of this section. A) Lines 150-152: The authors should follow consistent criteria to describe the subdivision of the South Portuguese Zone (SPZ). As written, they are mixing structural and stratigraphic criteria (Pulo do Lobo and Iberian Pyrire belts are structural units whereas the Carboniferous flysch refers to a stratigraphic unit). My recommendation is to use a first order structural division of the entire SPZ, not only of the units exposed in Spain, and eventually a reference to the stratigraphy of each of them. Flysch units occur in all structural divisions and those present in the Pulo do Lobo belt are not Carboniferous but Late Devonian (Famennian) in age, at least in part. B) Section 2.1. Pulo do Lobo Belt. The authors refer in this section to only a part of the stratigraphic units described in the Pulo do Lobo Belt in Spain. In my opinion they should refer to all the stratigraphic divisions that crop out

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in both Spain and Portugal. By the way, I am respecting in this review the term “belt”, as a simply descriptive word, despite this unit has been referred to with other more genetic terms (zone, terrane). A critical review of this topic would be appreciated by potential readers, mainly if the Pulo do Lobo belt is thought to occur in the vicinity of a major suture zone between Laurussia (Avalonia) and Gondwana, as inferred in section 2. C) Lines 181-191: The paleontologically-based Famennian age of the Santa Iria formation is disputed on the basis of younger detrital zircon ages. See below the discussion in point (v) of comment D. Most authors would agree that the Santa Iria formation was only affected by the 3rd regional foliation (a pressure/solution type). See Braid et al., 2010 and Quesada et al., 2019 for description and further references. D) Lines 197-213: Biased and incomplete description of the mafic rocks in the Pulo do Lobo belt and their possible interpretation. The authors are referred to the chapter by Quesada et al., 2019 for a more complete description. The following points deserve special attention: i) On lines 199-200 the authors write “interpreted as a tectonic mélange (the so-called Peramora Mélange; Fig. 1b-c; Apalategui et al., 1983; Eden, 1991; Dahn et al., 2014)”. The term Peramora mélange was first introduced by Eden, 1991 in his thesis; therefore the reference to Apalategui et al., 1983 is inappropriate here. ii) In addition to the tectonic nature of the imbrication of the mafic rocks with Pulo do Lobo schists as well as internally, those authors also recognized the sedimentary nature of the Peramora mélange, which consists of both mafic matrix and mafic and sedimentary clasts (from mm-to m-scale, lenticular to sigmoidal-equidimensional in shape). Mafic clasts include basalts, dolerites and gabbros, some of the latter preserving the original igneous textures and no pervasive cleavage, although all the rocks in the mélange are retrogressed to greenschist facies conditions. iii) MORB-like metamafic rocks also occur in the Portuguese extension of the Pulo do Lobo belt, namely along the Trindade-Alfarrobeira strip, which are intersected by the Alfarrobeira drill core (see Ferreira and Oliveira in Quesada et al., 2019). There, a more coherent metamafic package is imbricated with minor Pulo do Lobo schist as well as internally. Individual metamafic horses reach up to decametric thicknesses (the interpretation as a tectonic

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mélange seems plausible here!). iv) The rocks referred to above are not the only igneous rocks present in the Pulo do Lobo belt. Especially relevant to this discussion paper is, the ca. 354 Ma calcalkaline, subduction-related gabbro component of the Gil Márquez pluton (Gladney et al., 2014; Braid et al., 2018). These rocks are unfoliated and intruded Pulo do Lobo belt rocks (but not the Santa Iria formation) after the first two phases of cleavage development recorded in these rocks (presumably S1 and S2 in the discussed paper). The arc signature of the gabbros indicates that subduction was still active in this part of the orogen at ca. 354 and that the Pulo do Lobo belt was located in the upper plate. These data supports the interpretation of the belt as part of an accretionary prism. v) The youngest U-Pb zircon ages (mostly LA-ICPMS data)obtained from the metamafic igneous rocks are taken as representing maximum crystallization ages, implying that their emplacement must postdate deposition of the oldest metasedimentary rocks in the belt, therefore, they must be intrusive. Several problems arise, though. First, these young ages occur in both matrix and clasts of the mafic mélange as well as in the metasediments, the palynomorph-derived Devonian age of which is not disputed by the authors (the only exception being the Santa Iria formation, whose age is also disputed). Second, the metamafic rocks (at least the matrix) are also deformed by the same three folding events recorded in the metasediments. Third, intrusion of the ca. 354 Ma (also an LA-ICPMS age) unfoliated gabbro of the Gil Márquez pluton postdates the first two cleavages in the host rocks. All these data make it likely that a partial rejuvenation of the U-Pb system in zircons may have taken place, as already interpreted by Dahn et al., 2014. This rejuvenation may have been related to: i) subsequent syn-collisional slab breakoff (ca. 345-335 Ma) events, interpreted by Braid et al., 2018 on the basis of the ages and geochemical signatures of the main felsic components of the Gil Márquez pluton, which also intrude the Santa Iria Flysch, ii) a lithospheric delamination and mantle replacement event (ca. 316 Ma), interpreted by Dupuis et al., 2014 to account for the emplacement across SW Iberia of a swarm of mafic dikes with MORB signatures; and iii) a combination of those two or other processes not recognized as yet. vi) Mississippian magmatic rocks occur in profusion

across SW Iberia (from the Iberian Pyrite Belt in the SPZ, through the Pulo do Lobo belt, the OMZ and also the southern part of the CIZ). They occur however in rather different paleogeographic and paleotectonic environments that probably did not occupy the present-day relative positions in the Mississippian, mainly if the otherwise unknown but surely significant displacements during the left-lateral subduction/collision orogenesis are taken into account. Assuming that all these igneous rocks developed in response to a single event seems rather speculative. vii) The authors refer to "Peramora Olistostrome, Pérez-Cáceres et al., 2015", which is in fragant contradiction with their previous interpretation of the Peramora málange as a tectonic one (line 199). E) Line 219: Please specify formation names F) Lines 240-241: assuming that detrital micas are "generally larger than 2 μm" seems an oversimplification that might lead to misinterpretations. At smaller grain sizes it is not a simple task distinguishing syn-kinematic neoblasts from mechanically rotated detrital grains that may preserve a record of previous events under the prevailing very low- to low-grade metamorphic conditions. G) Line 467: The age attribution of S1 to the Devonian and S2 to the Carboniferous is arbitrary. Both cleavages formed prior to intrusion of the ca. 354 Ma gabbro of the Gil Márquez pluton (see Gladney et al., 2014; Braid et al., 2018). In addition, Braid et al., 2010 demonstrated that both cleavages and associated folds developed under a similar strain regime dominated by sinistral transpression, and suggested that they formed during a process of progressive deformation culminating in exhumation. Thus, S1 may have formed at certain depths during progressive burial, whereas S2 would have developed during subsequent exhumation. This interpretation would be in agreement with the metamorphic evolution described in this discussion paper. The problem in the authors' age attribution may reside is their interpretation of the youngest detrital zircons in the Santa Iria formation as maximum depositional ages, a point discussed by Dahn et al., 2014 and Oliveira et al., in Quesada et al., 2019, who interpret those younger ages to be the result of a process of partial lead loss (see point (v) in comment D). A discussion on this topic would be appreciated. H) Lines 487-489: There is ample consensus that the Santa iria formation is only affected by the 3rd deformation event,

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with similar geometrical and kinematic characteristics throughout the area and different to those of D1 sand D2 (see Braid et al., 2010 and Quesada et al., 2019 for description and further references) . I) Lines 516-519: Samples PLB 93 (and aso PLB 91) appears to have been collected (lousy precision in Fig. 1) near to the contact with the Peramora mélange or within one of the metasedimentary horses imbricated with it. There, apart from the mafic sedimentary mélange (Peramora mélange s. str. or Peramora olistostrome sensu Pérez-Cáceres et al., 2015) and Pulo do Lobo schist imbricates there exists a swarm of late mafic dikes (those with MORB signature dated at ca. 316 Ma by Dupuis et al., 2014). These are beautifully exposed along the Alcalaboza river where they intrude the Peramora málange and imbricated Pulo do Lobo schist, and hand specimens of these basaltic rocks are hard to distinguish from unfoliated metamafic rocks of the clasts of the mélange. If the increase in T described by the authors was related to the emplacement of the dikes, those samples should not be considered further. J) Lines 542-544: Biotite was reported by Apalategui et al., 1983 and Braid et al., 2010, among others, in rocks belonging to the Pulo do Lobo and Ribeira de Limas formations. Reference to those works should be given, and discussed if the authors believe that biotite is not paragenetic with the other phyllosilicates. If biotite is a part of the syn-kinematic paragenesis, which I think is, then the following discussion in this paragraph should be reconsidered. K) Line 566 and section 5.3: The attribution to the "middle/upper Carboniferous" of this event is not supported by undisputable data. In addition, I am confused on the relationship between deformation and metamorphic events (D1-D2-D3 and M1-M2, in the authors' terminology). In the lack of reliable thermochronologic data I would like to see a clear statement on this issue. If as the authors state, and everybody agree!, the Santa Iria formation is unconformable on the previously deformed lower sequences, then the latter must have been exhumed prior to deposition of the former. Therefore, every metamorphic evidence supporting temperatures >300°C must relate to the burial of the Pulo do Lobo and Ribeira de Limas formations, that is, pre-late Famennian. L) Lines 609-613. I wonder why the authors have not tried to collect and analyze samples of metasedimentary rocks in the area

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where those pseudomorphs were reported. It would have been worthwhile! M) Lines 616-623: Where has S3/D3 (lines 178 and 191) gone? What is its role in the story? N) Lines 638-641: The lack (or poor preservation) of HP characteristics may have an explanation in various well-documented processes: i) the predominant sinistral strike-slip regime of the deformation in this part of the orogen (large lateral displacements vs. little burial); ii) thermal overprint and re-equilibration after accretion to the upper plate as suggested by intrusion of the calkalkaline arc-related gabbros at ca. 354 Ma; iii) thermal overprint and re-equilibration during subsequent emplacement of late- to post-kinematic igneous rocks (e.g. Sierra Norte Batholith); etc.

References cited in the comments but not in the paper - Braid JA, Murphy JB, Quesada C, Gladney ER, Dupuis N (2018) Progressive magmatism and evolution of the Variscan suture in southern Iberia. Int J Earth Sci (Geol Runds) 107: 971–983. - Dupuis NE, Braid JA, Murphy JB, Quesada C, McFarlane CRM (2014) Changing mantle sources in a suture zone in the heart of Pangea: implications for collisional tectonics during the waning stages of ocean closure. Int J Earth Sci (Geol Runds) 103: 1403-1414. - Gladney ER, Braid JA, Murphy JB, Quesada C, McFarlane CRM (2014) U-Pb geochronology and petrology of the late Paleozoic Gil Márquez pluton: Magmatism in the Variscan suture zone, southern Iberia, during continental collision and the amalgamation of Pangea. Int J Earth Sci (Geol Runds) 103:1433–1451. Quesada C., Braid JA, Fernandes P, Ferreira P, Jorge RS, Matos JX, Murphy JB, Oliveira JT, Pedro J, Pereira, Z (2019) SW Iberia Variscan Suture Zone: Oceanic Affinity Units. In: Quesada C and Oliveira JT (Eds), The Geology of Iberia: A Geodynamic Approach, v. 2: 131-171. Springer Regional Geology Reviews.

3. Technical corrections Lines 99-100: Insert “to” between “allows” and “know” Line 129: Write “At present” instead of “Actually” Line 134: Write “that” between “shearing” and “occurred” Line 221: write “non-altered” instead of “not altered” Line 539: write “grains” instead of gains”

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