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Reply to Comment on “The Late Devonian Variscan suture of the Iberian Massif: A correlation of high-pressure belts in NW and SW Iberia”

Rubén Díez Fernández*, Ricardo Arenas

Departamento de Petrología y Geoquímica e Instituto de Geociencias (UCM, CSIC), Universidad Complutense de Madrid, 28040 Madrid, Spain

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ABSTRACT

The existence of a large allochthonous nappe pile emplaced onto the hinterland of the Iberian Massif and covering most of the basement of NW and SW Iberia proposed by Díez Fernández and Arenas has been called into question on the basis of structural, geophysical, and regional data from SW Iberia. The discussion provided here is based on a revision of the fundamentals of the Variscan geology of NW Iberia and on a more detailed presentation of the geology of SW Iberia. Our counterarguments reveal the reasoning of Simancas et al. against the verisimilitude of the large allochthonous pile as inconclusive, incomplete, or erroneous in some cases. Therefore, we maintain that our structural correlation and its implications remain fully valid for the case of the Iberian Massif.

1. Introduction

The existence of a huge allochthonous tectonic pile that covered most of the hinterland of the Variscan orogen has been recently proposed by Díez Fernández and Arenas (2015). Tracing of this allochthonous ensemble is possible through the structural correlation of the three Late Devonian high-P / low- to intermediate-T metamorphic belts that crop out in NW and SW Iberia, all of which are interpreted as dismembered counterparts of a single suture. This structural correlation has been considered “untenable” for the case of the Iberian Massif by Simancas et al., who have argued against its verisimilitude on the grounds of “structural and kinematic flaws of this hypothesis.”

First, we would like to thank the attention and consideration given to our proposal by a reputed research group that has contributed to a best understanding of the Iberian Massif. We really appreciate their comments on our work, as sharing opinion on a fundamental subject for the geology of Western Europe is a constructive way to solve the Variscan orogen puzzle. However, comments by Simancas et al. are built on a series of misunderstandings about the geology of NW Iberia and an incomplete presentation of the regional geology of SW Iberia. Here we will give a summary of the main tectonometamorphic features of the geology of NW Iberia that may help to clarify some of the basics of the allochthonous complexes of the Iberian Massif. Then we will give specific answers to the comments from Simancas et al. by bringing a more detailed vision of the geology of SW Iberia under discussion.

After careful reading and evaluation of their arguments, we think none of them invalidate in any way our correlation and structural interpretation. It is just the opposite. They are reinforced since we find no solid reasoning against our ideas, and everything that has been commented is here refuted by clear counterarguments. To our surprise, comments by Simancas et al. acknowledge the paleogeographic implications derived from our structural correlation and accept the proposed terrane correlation between NW and SW Iberia, which is a main objective of our work.

2. The Variscan orogen in NW Iberia: structural and geochronological synthesis

A rootless oceanic suture of Variscan age is preserved in NW Iberia. The suture is defined by ophiolitic units that occur within an allochthonous tectonic pile resting on top of what is usually referred to as the Parautochthon and Autochthon of the Iberian Massif. The set of far-travelled terranes can be divided in three main constituents, from bottom to top: the basal, ophiolitic, and upper allochthonous units (Martínez Catalán et al., 2009). The basal and upper allochthonous units represent pieces of peri-Gondwanan continental crust (Abati et al., 1999; Albert et al., 2015; Arenas et al., 1995, 1997; Díez Fernández et al., 2010; Fernández-Suárez et al., 2003; Fuenlabrada et al., 2010, 2012; Martínez Catalán et al., 1996), whereas the ophiolitic

* Corresponding author at: Facultad de Geología, Departamento de Petrología y Geoquímica e Instituto de Geociencias (UCM, CSIC), Universidad Complutense de Madrid, C/ José Antonio Novais, no 2, 28040 Madrid, Spain. Tel.: +34 913944904; fax: +34 915442535.

E-mail addresses: georuben@usal.es (R.D. Fernández), arenas@geo.ucm.es (R. Arenas).

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units account for oceanic and transitional crust occurring in the peri-Gondwanan realm (Arenas et al., 2007b, 2014b; Díaz García et al., 1999; Sánchez Martínez et al., 2007, 2011, 2012). These ophiolites can be grouped according to their Cambrian–Ordovician (500–475 Ma) or Devonian (395 Ma) age as well as to their relative structural position when they appear in contact (Arenas et al., 2007a).

The oldest Variscan deformation registered in NW Iberia is Early Devonian (400–395 Ma) and consists of a high-P/high-T metamorphic belt that occurs along the lower structural sections of the upper allochthonous units (Fernández-Suárez et al., 2007; Ordóñez Casado et al., 2001). The mafic and ultramafic protoliths of the Devonian ophiolites indicate extensional activity affecting the peri-Gondwana realm in the Middle Devonian (395 Ma; Arenas et al., 2014a). Exhumation of the high-P/high-T metamorphic rocks of the upper allochthonous units was assisted by extensional detachments during the Late Devonian (Gómez Barreiro et al., 2007), and both these faults and former Variscan fabrics were bent into an east-verging train of recumbent folds during the Late Devonian and lower Carboniferous (Albert et al., 2012; Dallmeyer et al., 1997; Gómez Barreiro et al., 2007; Marcos et al., 1984; Peucat et al., 1990).

The Variscan accretion of the ophiolitic units under the upper allochthonous units took place from the Middle to the Late Devonian (390–365 Ma; Peucat et al., 1990; Dallmeyer et al., 1997) and is coincident (somewhat older) with the subduction of the basal allochthonous units under the ophiolitic and upper allochthonous units in Late Devonian times (370 Ma; Abati et al., 2010). The emplacement of the whole allochthonous set onto its relative autochthon was carried out by a large-scale ductile thrust (Lalín–Forcarei thrust; Martínez Catalán et al., 1996) in Carboniferous times (~340 Ma; Dallmeyer et al., 1997). This specific structure and its equivalents across the Iberian Massif are the ones responsible for the allochthonous nature of the ensemble made of the basal, ophiolitic, and upper units. This is one of the basics of the geology of NW Iberia and as such, it has fundamental implications for the recognition of equivalent far-travelled terranes throughout the Variscan orogen: the allochthonous terranes experienced a number of early Variscan phases of deformation (as old as Early Devonian) before being juxtaposed onto their relative autochthon in the Carboniferous.

Simancas et al. state that “transpression-related deformational features are totally absent in the Allochthonous Complex of NW Iberia, where a tectonic scenario of frontal collision seems appropriate.” Such assertion does not consider any of the advances made in the geology of NW Iberia during the last decades. A transpressional setting for the Variscan orogeny recorded in NW Iberia has been proposed for the case of Early Devonian continental subduction (Ábalos et al., 2003), the opening of a pull-apart basin in the Middle Devonian (Arenas et al., 2014a), a second continental subduction in the Late Devonian (Díez Fernández et al., 2012a), the early Carboniferous exhumation of the high-P rocks formed in the Late Devonian subduction (Díez Fernández and Martínez Catalán, 2012), the development of a tectonic mélange in the frontal part of the allochthonous complexes (Arenas et al., 2009), the gravitational collapse of the orogenic crust after maximum crustal thickening (Díez Fernández et al., 2012b), and for the intracontinental deformation during the late stages of Variscan convergence (Martínez Catalán, 2011). In our opinion, NW and SW Iberia are much more alike than previously thought, as in both regions a component of strike-slip shearing played a role during almost the whole Variscan convergence. However, the bearing of tangential deformation and orthogonal shortening across the orogen seems well established for the case of NW Iberia, whereas it may have been underestimated in its SW section.

3. A closer view into the geology of SW Iberia

Before we proceed with specific answers to the main “flaws” pointed out by Simancas et al. (see Sections 3.1–3.8), it is necessary to clarify one of the assertions that has been wrongly attributed to our previous work. The huge allochthonous nappe was not “emplaced in Late Devonian time onto the Gondwana margin.” The overriding of that previously structured nappe pile is Carboniferous (Viséan; see Section 2). Late Devonian is the putative age of the high-P metamorphism that characterizes the three high-P metamorphic belts that have been correlated across the Iberian Massif by Díez Fernández and Arenas.

3.1. The Devonian structure of the Ossa–Morena Zone (I)

Simancas et al. maintain that the SW-vergent km-scale recumbent folds and thrusts that dominate the internal structure of the low- to intermediate-grade sections of the Ossa–Morena Zone (OMZ) are “incompatible with the eastward-directed emplacement” of the allochthonous complexes “unless the entire OMZ is considered a huge backthrust.” Interestingly, the authors both expose the apparent “flaw” and provide a potential justification to support our correlation. However, for the sake of precision, it is important to highlight that the emplacement of the allochthonous ensemble (as constrained in NW Iberia) occurred in the Carboniferous, whereas the SW-vergent structures mentioned by Simancas et al. are Devonian (Expósito et al., 2002). In fact, with all data at hand, the age of such SW-directed recumbent folding in the OMZ can be constrained to the Early Devonian, as indicated by the palynological content found in discordant strata resting on top of those folds (Expósito Ramos, 2005; Pereira et al., 1999). In the light of this, we find no actual kinematic incompatibility since we are dealing with geological processes of different age.

A special case should be made for the SW-vergent folds that affect some sections of the Late Devonian high-P metamorphic belt that occurs in SW Iberia, close to the southern boundary of the OMZ (Cubito–Moura Unit; Ponce et al., 2012). These folds have similar trend and asymmetry to the Early Devonian folds mentioned above, and based on these coincidences they have been assumed as coeval. A careful revision of available data indicates otherwise. In the Cubito–Moura Unit, these folds affect a penetrative foliation formed during the exhumation of this unit after a high-P metamorphic event. Dating of the latter in other units located along the same high-P metamorphic belt has yielded Late Devonian ages (~370 Ma; Moita et al., 2005). A reference age for the initial exhumation of this high-P belt is 358 Ma (Rosas et al., 2008). Both ages allow discarding the correlation between the SW-vergent folds affecting the Cubito–Moura Unit (probably Carboniferous) and the Early Devonian folds that occur elsewhere in the OMZ.

The cross section published by Díez Fernández and Arenas (2015) establishes that the units of the OMZ containing the Early Devonian recumbent structures are correlative with the upper allochthonous units of NW Iberia. In NW Iberia, this particular set of units recorded a series of phases of deformation during the Devonian, prior to their emplacement onto the Iberian Autochthon to the east in the Carboniferous (see Section 2).

3.2. The Devonian structure of the Ossa–Morena Zone (II)

Simancas et al. argue against the upright synformal structure of the OMZ by using, to our surprise, the Devonian recumbent structures of the OMZ as an argument. According to Expósito et al. (2002) (among others), the upright folds that occur in the OMZ bend the recumbent folds of Devonian age, such as the Monesterio Anticline. Therefore, the upright folded structure of the OMZ was acquired in the course of later Variscan contraction. In this regard, similar upright folds have been described and dated as late Carboniferous elsewhere in the Iberian Massif.

In agreement with Simancas et al., we think that the older phase of deformation is suitable for locating the deepest stratigraphic levels of a given region, but only if it is affected by one phase of deformation. Obviously, this is not the case of the OMZ. Similarly to what has been done for decades in NW Iberia, we consider that the primary phase of