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Interactive comment on "A first estimation of the contraction related to vertical axis rotation: the case of the Ibero-Armorican Arc formation" *by* Josep Maria Casas et al.

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Dear editor, Thank you very much for your comments, but unfortunately we are not able to access to the second referee's report. We can only read the post of M. Mattei (20 Sep 2020), and the one of the Anonymous Referee #1 (23 Sep 2020). So, we don't know the details of the second referee comments. Please, let us know how we can get to this report. 1) Concerning your comments, we like to explain further our reasons for not doing a discussion and critical reassessment of the paleomagnetic data set in our work: 1.1) This data set supports only one of the proposed models published that explain the origin of the Ibero-Armorican arc, that is the arc formed as a result

of the rotation about a vertical axis of an initial linear orogen. In our contribution we also present other different competing models, but we don't go into the geological arguments supporting the different proposals because our starting point is different. We focus on the deformation needed for those vertical axis rotations from the estimation of the amount of contraction (horizontal shortening) and the amount of surface of lost lithosphere needed assuming the Ibero-Armorican Arc was formed as an orocline or a secondary fold. 1.2) The coherence between the available paleomagnetic data for the region and any proposed model is a main point. But, as explained above, paleomagnetic data should be considered, as well as any other data that can be significant in an orogen scale. On the contrary, most paleomagnetic analyses have not considered the regional-deformational implications of huge rotations around a vertical axis at the scale analysed. So, in our opinion if we follow your suggestion the relationship between paleomagnetic and regional geological studies usually is not well balanced. The latter ones have to discuss and consider the palomagnetic data, but the former ones usually do not take into account the regional implication of their proposals. 1.3) As stated, in our paper we deal with this point and conclude that the deformation needed for those vertical axis rotations is not found. Then, a contradiction appears that should not be solved by considering only one type of data. This should be one of the main conclusions of our work. 1.4) Some points concerning the internal coherence of the paleomagnetic data that have been already published previously (Casas and Murphy, 2018). We included a brief summary in the response to the M. Mattei's comments: It should be noted that the paleomagnetic data are not easy to interpret. Some of the involved rocks in the southern arm of the arc have not provided interpretable results, and in the other hand the results obtained differ in both branches of the arc. The paleomagnetic results are quite different in the northern branch of the arc, in the core of the arc (Cantabrian zone) and in the southern (western) arm of the arc. In the northern branch, a ca. 25° clockwise rotation is proposed by Pastor-Galán et al.(2015b) to form the arc. In the central area, a post-Variscan folding and pre-orocline formation re-magnetization suggests that the arc formation is due to late Kasimovian-Moscovian-

Gzhelian rotation linked to an important reactivation of previously formed N-S oriented structures and the formation of radial folds and E-W oriented thrusts in the core of the arc (Weil et al. 200, 2001, 2010, 2012 and 2013). However, the results of the southern arm are more difficult to interpret. According to Pastor-Galán et al (2015a, 2016 and 2017) and Fernández Lozano et al. (2016) paleomagnetic declination vectors exhibit a wide dispersion, ranging from 60°(Fernández Lozano et al.2016) to 90° (Pastor-Galán et al. 2017). Moreover, results obtained differ, depending on the type of analysed lithologies. These authors attribute the results to a re-magnetization synchronous with the formation of the arc (Late Kasimovian-Early Permian). This interpretation has some important consequences: a) it implies that re-magnetization processes were active for a long time interval (ca. 13 my, 310-297 Ma) in the southern branch of the arc, b) it implies a different timing for the re-magnetization in the northern arm and in the core (previous to the arc formation), compared to the southern arm (synchronous with the arc formation), and c) it imposes a different kinematics for the formation of the arc, as in its northern arm the arc form as a result of 25° clockwise rotation, whereas in the southern arm a counter-clockwise rotation ranging from 70-90° is required (Pastor-Galán et al. 2015a, 2016 and 2017; Fernández Lozano etal. 2016). A closer view of the paleomagnetic results suggests that although this dispersion exists, when the data are considered grouped in their sites, the dispersion may be minimized. For instance, in Fig. 6 of Pastor-Galán et al (2017) the dispersion of the mean values of the sites is around 40°. Moreover, the deviation of the mean value of all the obtained vectors (138°/12.5°) from the Early Permian reference declination orientation (158°) is only ca. 20°(Figs. 8 and 12, Pastor-Galán et al. 2017). In our opinion the most important point is that the paleomagnetic results of this southern arm are not in accordance with regional geology data. Proposed counter-clockwise vertical axis rotations ranging from 70-90° implies shortening of several hundreds of kilometres and internal deformation in the southern arm of the arc to acquire an iso-clinal fold geometry from an initial arc formed by tangential longitudinal strain (Weil et al. 2013). However, as we discuss in our contribution, no structures related to these deformations are described,

the re-magnetization is post-Variscan folding (Pastor-Galán et al. 2015a, 2016), and these areas are characterized by simple structures with open upright folds and gently plunging fold axes (Pastor-Galán et al.2016). Such simple structural arrangement allows Pastor-Galán et al. (2017) to discard structural complexities as the main source of scatter of the declination vectors in the southern arm of the arc. As stated, it should be noted, however, that the discrepancy between regional structure and paleomagnetic data is not discussed in paleomagnetic papers dealing with the southern arm of the arc. As our starting point is different, from regional geology data, we cannot use paleomagnetic data that are not in accordance with the regional data to constrain our proposed reconstruction. We are conscious that a detailed discussion of the points outlined above is beyond the scope of this paper. We think that a detailed discussion of the various aspects of this complex geology is a matter for a paper by itself.. 2) We agree with the Anonymous Referee #1 that the manuscript may be improved following some of his suggestions. 2.1) To the best of our knowledge, “progressive arc” models have not been invoked for the formation of the Ibero-Armorican arc at the scale of the orogen. Maybe the most similar could be the indentor model, which is thought to originate a progressive deformation in the indented plate. We will consider this point in the revised version of the manuscript. In the same way, we will reorganise the Introduction in order to clarify which is the main problem we would like to address. 2.2) Concerning his comment about the method we use: “these estimations are very, very rough and are not presented rigorously”, we have to say that we present a first estimation of this contraction. As far as we know, nobody has tried this approach before. The proposed geometry of the Variscan Arc is at the scale of hundreds of kilometers, defined by the boundaries between the Variscan zones in Iberia. The only markers that can be used to estimate its deformation at that hecto-kilometric scale are those boundaries. Deformation at smaller scales should be consistent to this analysis, if a secondary arc is to be accepted. Our analysis is not, then, an oversimplification. 2.3) Moreover, we think that our conclusion is that the deformation observed from structures at smaller scales than that of the arc is far less than the one needed to explain its formation from a previous linear orogen, and even we found some inconsistences on the proposed age of the arc development. So, the statement that "this rough estimation . . . should be accompanied by more precise estimations which include not only the type of structures and the shortening due to each set of structures, but also the timing of these latter" should be asked to the authors who proposed that the Variscan Arc is secondary. 2.4) Concerning the surface measurement methods, we would like to precise that in order to estimate the amount of surface of lost lithosphere needed –assuming the Ibero-Armorican Arc was formed as an orocline or a secondary fold forming as a result of strike-slip faulting–, the original maps were escalated in a CAD environment (Microstation®). The boundaries of the lost area were defined comparing the WALZ-CZ boundary previous and after the arc formation, and assuming an arcuate path to the line tips during deformation. The areas bounded between these three lines were measured using the CAD tool for this purpose and rounded to 103 km2. In this estimation, the values of lost lithospheric surface should be considered as minimum, as it is assumed that there is no change in the position of the fold hinge during its development. 2.5) In a general way, we agree that the Geological Setting is hard to read for anyone not familiar with the complex geology of the Iberian Massif. We will try to make it more clear and readable in the new version and also to improve the location of the localities and case studies not localized in the figures. In the same sense, we will rewrite and reorganize the manuscript in order to expose our ideas in a more clear way. Thank you again for your comments and we await your decision considering our comments in order to submit the revised version in the due time. Sincerely yours, On behalf of the co-authors,

Josep Maria Casas

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