Response to reviews and comments on the MS: **"Evolution of the Iberian Massif as deduced from its crustal thickness and geometry of a mid-crustal (Conrad) discontinuity"**, by Ayarza et al.

Ahead, we provide answers to the comments on our paper presented by reviewer 1.

Reviewer 1: Anonymous

> …..however, the main goal of the paper is not clearly stated. The authors reprocessed 6 profiles though finally interpret 7 of them. About 6 reflection profiles, many of these data were already well documented and published (e.g. Simancas et al., 2013, Ehsan et al., 2014, etc.) documenting lots of details in the sections and interpretation and providing much more constraints than in the submitted manuscript. In the submitted manuscript, the authors show final reprocessed data, however, they do not provide any comparison with the previous results, they do not document the improvements or differences. So that, there is not clear evidence what is new in their submitted interpretation.

The goal of the paper is to provide a joint interpretation of all the seismic datasets acquired in the Iberian Massif. Up to date, they have been thoroughly interpreted individually, as the reviewer points out. However, there are features that need to be re-interpreted as the most recent models for the evolution of the Iberian Massif emphasize the importance of late orogenic extension in the configuration of the orogeny and its later reactivation during the Alpine Orogeny. This effect can be evaluated from the geometry of a mid-crustal discontinuity and that of the Moho. The upper crust interpretation has not significantly varied. Those features that were previously correlated with upper crustal faults and thrusts remain unmodified. It is just finally, in this paper, we stablish a correlation between this orogeny scale mid-crustal discontinuity and the Conrad discontinuity, thus providing a new definition regarding what this discontinuity might represent. According to the above, the introduction will be modified.

> Also, in the interpretation, they discuss details that are not constrained by the data in such a way. They also mention wide-angle data, but they do not provide velocity profiles though they convert TWT into depths which makes the interpretation less credible.

The details that are not constrained by the data, like the direction of movement of thrusts and faults, have been previously integrated with surface geology, interpreted and published. This is known by the reviewer, as acknowledge in the second paragraph of the comments, partially reproduced above, in the first "squared" comment. In our text, we provide cites of all the previous interpretations of the seismic profiles we present. It is not efficient to "...discuss details that are not constrained by the data..." since data are published elsewhere and references are provided. However, and also in relation with comments by the second reviewer, we will include in this version cross sections at the top of the seismic profiles to facilitate upper crustal correlations between geology and seismics. We will also refer to cites more often. Migration velocities presented in figure 2 and are calculated from wide-angle data and those are the ones used for depth conversion. This information will be added to the paper

> From Figs. 3-8, showing seismic sections and their interpretation, it is not clear how the interpretation is constrained, the interpretation is not correlated with geology, motion along lines

(red arrows) is not documented, red dashed lines are not explained and do not correlate with the data, black lines termed Main lithological boundaries are not attributed to these lithologies, sometimes they are not constrained by the data (see e.g. line (d) in Fig. 3, bottom black line in Fig. 4b, line (c) in Fig. 4b, lines (b) in Fig. 5, numerous (a) lines in Fig. 8. Labelling of reflectors (a,b,c etc…) is not explained in figure captions and also sometimes does not correlated with the data. Interpretation is not the same for all profiles, see e.g. interpretation of data in Fig. 8 vs Fig. 7.

As stated above, cross-sections are going to be added on top of seismic sections, and cites of the papers where the interpretation is made will be included in the figure captions. The red dashed lines are referred in the legend of figures as "Geometry of attribute analysis boundaries". Attribute analysis is one of the routines applied during reprocessing of the profiles, as explained in section 3.2: Processing of datasets, lines 277-283, and described in two references cited (Chopra and Alexeev, 2005; Taner and Sheriff, 1997). However, we acknowledge that the non-specialized reader may ignore what these routines do, so that a brief explanation will be added. Finally, red dashed lines are expected to discriminate between different types of crust (lithologies) at a large scale. Even though sometimes they do not have exactly the same geometry as reflections, we prefer keeping them as they often add constraints to the interpretation.

Line d in figure 3 marks the top of the lower crust. Bottom black line in figure 4b is constrained in the southern part of the figure, which provides a lower crustal thickness. The rest is extrapolated from the geometry of the upper crust and previous publications. C in figure 4b is constrained by reflectivity at ~3 s TWT and surface geology. Lines b in figure 5 feature high reflectivity and their identification is straightforward. Finally, 'a' lines in figure 8 are well observed. Anyway, we will revise the identified reflections on the light of the cross-sections we are going to add. Finally, labelling description will be also included in the figure captions. In addition, we will change the name of the labels so the same features have always the same label (e.g., Moho_m)

According to two final figures and discussion, the authors seem to focus on two major discontinuities in the Iberian Massif – the Moho and the mid-crustal discontinuity. However, in my opinion, they are not well documented/constrained by the data at some parts (see, e.g., the bottom line in Fig. 4 in the N marked with "?" which does not seem to be justified by the data; or strong reflectors (d) at depths ~30-35 km in Fig. 6 considered by the authors as reflectors in the mantle with anomalously shallow Moho at depth 22km which may have natural also different explanation) and thus the interpretation might not be correct

As explained above, bottom black line in figure 4b is constrained in the southern part of the figure, which already provides a lower crustal thickness. The rest is extrapolated from the geometry of the upper crust and previous publications. Also the stack indicates that the geometry is similar to the one depicted but migration blurs the final image. There is an entire paper devoted to reflections d (Ayarza et al., 2004), where these have been modeled in 3D. Their origin and interpretation play no role in the scope of this paper as they are 3D alpine features coming from the southward subduction of the oceanic crust of the Bay of Biscay. Of course, their origin might be different. But the only published model, so far, is that of Ayarza t al. (2004).

The mid-crustal discontinuity is also discussed in relation to outdated term Conrad discontinuity, however, there is no comparison with velocity profiles which would help to discuss its genealogy.

One of the points of the paper is to define the nature of the Conrad discontinuity as we observe it in an orogeny scale profile, with zones previously belonging to two supercontinenets (Gondwana and Laurussia). Velocity profiles derived from wide angle data are going to be included in some of the sections to help on this interpretation

Figures: Tectonic setting is missing, seismic sections are poorly labelled, explanation of figures and labels is not provided in figure captions but only in text, geology is not provided in sections for comparison and references.

Captions presently explain the content of the figures, without describing their main features and geological interpretation. For description and interpretation, the reader is referred to the text in an implicit way, that is, without adding the classical "See text for explanation" tag. However, cross sections will be added on top of the profiles. Labelling will be modified to make it more coherent regarding the whole of figures and will be included in the figure captions.

Fig 1 needs reworking since there are difficulties to see profiles on top of tectonic structure. The geology is very detailed but the tectonic structure that is essential for the goal of this paper is not visible clearly from this figure.

The main problem to see the tectonic structure in Figure 1 is the granitoids, but they are important as indicators of deep crustal processes. So, the figure will be duplicated (parts a and b), leaving the structure in one map and the granitoids in the other. The seismic lines will be highlighted changing their color if necessary.

Fig. 1: Tectonic zones referred in the text many times are not seen from Fig. 1

References to tectonic zones in the text will be revised and depending on their importance, removed, added in the figure or referred to their publication

Figs. 3-8 – Moho labelling should be provided in all Figs. 3-8; labels for individual horizons/reflectors should be provided in figure captions.

Moho labelling will be included in every figure. Furthermore, reflector labels will be included in figure captions and will be modified so they represent the same features in every profile.

Figs. 3-8 in Legend – Geometry of attribute analysis boundaries – not clear what it means, it needs to be explained.

More details about the attribute analysis will be given in the text

Fig. 3: I do not see subhorizontal reflector (e) extending through the whole section justified by the data.

Certainly reflector e is only well constrained in the stack. In the migrated section is only visible between CDP's 1000 and 2000. We will mark the rest with a dashed line and refer to the publication where the stack was interpreted

Fig. 3: Moho at 14.5s TWT -> from Fig. 3 I can see the depth of ~40km, so what is correct?

Depth conversion has been made using the migration velocities, which have been extracted from coincident or neighboring wide angle data. In the ESCIN-1 dataset, the migration velocity is 5600 m/s. So 14.5 s TWT converts to 40.6 km. The same criteria applies to the rest of the profiles

Fig. 4: I do not see (b,c) structures interpreted in the section constrained by the data

b reflections clearly offset sediments from the Duero Basin and c reflection can be identified from CDP 1000 to 500 above 7 s TWT. Certainly it loses reflectivity after migration but it can be followed and interpreted also, when compared with the published stack. Reference to this publication will be added in the description

Fig. 4: It is not clear how the arrows are derived

Cites and cross sections will be added so the sense of movement interpreted from the reflections is clear. But, this is an area affected by Alpine compressional tectonics, and the main faults are identified on surface.

Fig. 4: I do not see the bottom line in the N marked with "?"justified by the data. How is it constrained? And is this Moho? If not, where is it?

Yes, that reflection represents the Moho and, it is constrained by reflectivity at the southern part of the profile (which provides a lower crustal thickness). The rest is extrapolated from the geometry of the upper crust and previous publications based on the stack image

Fig. 6: How can the authors derive the red arrows from the reflection data?

In general, we derived them from the knowledge of the surface geology, the geometry of reflections and also assumed results from previous publications, and cross sections will be included in the figures to ease the reader the understanding of these features. In the case of this figure, the sense is not clear, as the reflections are deep and cannot be correlated to structures at the surface. It images a part of the Variscan crust that was subjected to compression and thickening followed by very important extension. So, the most probable late-Variscan motion is to the west, and the possibility of reactivation of early crustal-scale thrusts should not be ruled out. The text has already a discussion regarding this issue (lines 429-437).

Fig. 6: the Moho is located at around 9 s TWT (~27 km), the shallowest identified so far in the Iberian Massif -> from Fig. 6 I can see strong reflector (c) at ~9s TWT, however, its depth is stated at 21-24 km. This seems to be very shallow if this is the Moho. This needs to be explained.

The ESCIN3-2 line is an offshore profile sampling sedimentary basins and featuring a thin crust. Thus, the migration velocity, derived from neighboring wide angle data is low: 5.2 km/s (Fig. 2), which implies that 8-9 s TWT convert to 20.8-23.4 km

Fig. 6: strong reflectors (d) at depths ~30-35 km considered by the authors as reflectors in the mantle with anomalously shallow Moho at depth 22 km above. How can the authors distinguish what is the crust and what is the mantle? Cannot the (d) reflector at depths of ~30-35km represent the crust/mantle boundary? This needs to be explained.

Yes, indeed. The narrow, sub-horizontal and highly reflective band between 8-9 s in ESCIN-3.2 is the continuation of the profile ESCIN 3.3 lower crust. Accordingly, the one strongly dipping to the W could be the continuation of another reflective band found in ESCIN-3.3 between 10-12 s and interpreted as a partial (only the basement) crustal duplication: the underthrusting of the Cantabrian Zone basement. We have explained this structure in several publications (e.g., Ayarza et al., 1998). The deep west-dipping reflections on Fig. 6 would be the continuation into de mantle of this partial crustal duplication. Considering the reviewers opinion, we will priorize this interpretation over the one provided in the first version of the paper and we will add a more thorough discussion, together with the pertinent references

Fig. 7: Red dashed lines – not clear what they represent and how they are related to the initial normal incidence data.

These lines represent the boundaries of the attribute analysis and roughly represent different types of crust/lithologies. More information about the attribute analysis is going to be added

Fig. 7: fairly transparent upper crust -> I do not see fairly transparent upper crust throughout the whole section, it might be transparent in certain parts (e.g. around 6000-7000 CDP), however it exhibits variations aside. Also previous interpretations (Ehsan et al., 2014) show reflections in the upper crust along this section.

The upper crust in this section is fairly transparent when compared with the IBERSEIS section. The reason is the abundance of vertical folds affecting little impedance contrast layers (lines….). Also, the existence of granitoids decreases reflectivity. However, it is true that reflectivity exists. Furthermore, reviewer 2 pointed out that the upper crust is certainly quite transparent. Nevertheless, we will rephrase the main description of this part of the sections

Fig. 8: I am surprised by the level of interpretation presented in Fig. 8 compared to e.g. Fig. 7. Are the data that much different? I cannot see so many reflectors from section in fig. 8, on the other hand, I can see more structure in the upper crust in section of fig. 7 (see also my comment above).

IBERSEIS shows the most reflective upper crust of the Iberian Massif so far. Also, the quality and continuity of the surface outcrops allows interpretation to reach deeper levels. Again, we will rephrase some of the sentences used in the description of these two profiles.

Fig. 8: red circles are not explained.

Symbols with red circles show possible fault motion, as indicated in the legend. In this case, they indicate sinistral wrench motion. Of course, we ignore the real motion of the fault traced on the profile, and the symbols only try to represent in some way the generalized sinistral transcurrence at the boundary between Ossa-Morena and South Portuguese zones. They can be deleted or further details can be added in the figure caption.

The authors include non-reprocessed profile CIMDEF in their final interpretations (see Fig. 9 and 10), however, they do not provide references nor even discuss this profile in respect to differences in the interpretation methods. Since the results along this profile were achieved from different data and methods, comparison of results in this respect is crutial.

Indeed, more details about this dataset will be added. At the time of the submission of this paper, the CIMDEF dataset was under minor revision but it is now published. So now, cites referring to its publication will be added. However, keep in mind that this is not a vertical incidence profile but it has been obtained by interferometry of natural source data (noise). These type of data is geared to show sub-horizontal reflections and thus, time migration does not help in the interpretation. Authors publishing that dataset have not deliberately migrated it and neither have us. Its resolution is also lower (2.5-4 Hz) so CIMDEF is just used to constrain the depth and geometry of the mid-crustal detachment and the Moho in the area where a vertical incidence gap exists.

Geology section is very long and comprehensive, however, it does not give the generalised overview of tectonic setting that is necessary for the goal of the paper (if it is the Moho and mid-crustal discontinuity).

Does the reviewer refer to the Geological Setting section? We will include more information that can be useful in the understanding of the Moho depth according to geology. But the discovery of the mid-crustal detachment has been only possible after the analysis of vertical incidence sections so we cannot include it in the geological setting

192-198 – This para does not fit the overall text on tectonics.

Again, does the reviewer refer to the Geological Setting section? There, an overview of the tectonics of the Iberian Massif is done between lines 66-99, and the Carboniferous extension and mafic intrusions are mentioned on lines 82-87. Furthermore, the IRB is probably one of the most outstanding features identified in the seismic data of the Iberian Massif. Although including seismic data interpretation in the Tectonics section is not desirable, the implications of this body in the support of the Early Carboniferous extension mnade us to include it, and we prefer to keep it.

299,338 – Is the migration velocity same for all profiles? And why there is chosen this value of 5600m/s?

Figure 2 shows the migration velocities for every profile. They are different and have been chosen in relation with the wide angle velocities of overlapping or neighboring profiles.

Pfs ESCIN 3.3., 3.2., ALCUDIA and IBERSEIS do not state any migration velocity. It should be included

Figure 2 includes the migration velocity of every seismic line presented. We will include this information in figure captions too.

264-283 processing of datasets – This chapter does not state, which data are to be processed and interpreted. This should be included.

We will include that

326 – Moho at 14.5s TWT -> from Fig. 3 I can see the depth of ~40km, so what is correct?

Depth conversion velocity is the migration velocity, which is based on wide angle data. In this case v=5600 m/s so the conversion is correct

424 – the Moho is located at around 9 s TWT (~27 km), the shallowest identified so far in the Iberian Massif -> from Fig. 6 I can see strong reflector (c) at ~9s TWT, however, its depth is at 21-24 km. This seems to be very shallow if this is the Moho. I can also see strong reflectors (d) beneath termed subcrustal reflectors. They are at depths of ~30-35km. How can the authors distinguish what is crust and what is the mantle? Cannot the (d) reflector at depths of ~30-35km represent the crust/mantle boundary?

As it has been discussed elsewhere, depth conversion velocity is the migration velocity, which is 5.2 km/s for this profile. In addition, an as it has been discussed above, the high dipping features somehow represent a complex Alpine crust-mantle boundary (mantle-oceanic crust-mantle sequence) imaged in 3D, i.e, located to the N of the profile. As stated above, there is an entire paper devoted to reflections 'd' (Ayarza et al., 2004), where these have been modeled in 3D. Their origin and interpretation play no role in the scope of this paper as they are 3D alpine features coming from the southward subduction of the oceanic crust of the Bay of Biscay. Therefore, we consider that, other than citing the corresponding papers, there is no point in extending the information regarding those features.

448 – fairly transparent upper crust -> I do not see fairly transparent upper crust throughout the whole section, it might be transparent in certain parts (e.g. around 6000-7000 CDP), however it exhibits variations aside. Also previous interpretations (Ehsan et al., 2014) show reflections in the upper crust along this section.

In fact, that upper crust is very transparent as it is composed mostly of vertical folds affecting little reflective lithologies. Reflectivity is associated to few existing contrast between metasediments, granites and a suture zone. Furthermore, the second reviwer acknowledges that the upper crust in very transparent in general in the shown sections.

There too many references (over 100, some of them are local in Spain and not accessible for broad readership) – needs elimination and restriction to only the most relevant ones.

Some non-essential references of local character will be removed

43 – reference in missing

We will add it

104, 139 cropping out -> outcropping

We will change it

328, 696, 799, … and many other times – related with –> related to

We will change it

709 – underplating

We will change it

1425 – sample interval -> sample rate

We will change it

1425 – sample rate is missing

It will be added

1417-1425 – migration velocity is missing - stated only in text

It will be added

1429-1452 – migration velocity is missing

It will be added

Fig. 9 – profile CIMDEF is not interpreted – reference is missing

It will be added

Fig. 10 – what is the lilac dashed line?

Yes, our mistake. It is an intra-lower crust highly reflective feature, tentatively related with the extension by-product. It will be explain in the figure.

Fig. 10 – profile CIMDEF is not re-interpreted, it is already published, however, reference is missing

This profile was under review at the time of the submission. Now, that it is accepted, the reference will be added

Reference to figures needs to be unified throughout the manuscript. Sometimes they are referred as Fig., sometimes as Figure, sometimes as figure. It needs to be unified.

When in parenthesis we use Fig. Along the text figure or Figure depending if there is a period before. We will check every case and correct them.