Reviewer 1: Dr. Antonio Casas

The paper by Olaiz et al presents a recopilation of a large quantityt of data, that will contribute to the understanding of the recent or rather present-day tectonics of Iberia (whether greater or not, I think that the term greater could be kept for the sector limited by the ancient plate boundaries, let's say the mid-Atlantic ridge on one side an Sicily-Calabria on the other). The selection of data is good and therefore I think that the discussion and conclusions presented are well founded on these data. The presentation is of very good quality, and all in all the paper will contribute to the knowledge of this particular sector, sometimes with controversial interpretations, of the European-African plate boundary. My only remarks are related to formal issues. These include the use of toponyms that are of common knowledge for the researchers who work in the Iberian plate, but not for the rest. I do not know in which way they could be made undestandable (and localized for the whole scientific community. Maybe a table with the location of the different features referred to in the text or their location in the map. Another possibility is to reduce the number of geographical/geological names but this is not so good a solution, in my opinion. Other minor issues are related to the use of Tertiary for Cenozoic of some gramatical or typographic errors (suggests in line 165, Gorring instead of Gorringe, etc…). I also suggest the authors to revise carefully the use of subscripts because sometimes the names of the stress axes and other variables are difficult to distinguish within the text.

Dear Dr. Casas,

Thank you for your insightful comments. We appreciate your suggestions, which have significantly improved the manuscript.

We have reviewed the subscripts through the manuscript, and some typos that you have recognized.

In figure 1 we have added numbers to the faults for easier recognition. The numbers have been used in the text and in the tectonics zones summary.

Kind regards,

Antonio

The manuscript "Seismo-tectonics of Greater Iberia: An updated review" provides a comprehensive analysis of the seismo-tectonic characteristics and stress regimes in the Iberian Peninsula, based on an extensive compilation of 542 moment tensor focal mechanisms. The study employs various methodologies, including focal mechanism classification, stress inversion techniques, and Slip Model analyses to assess contemporary tectonic deformations and stress distributions. In conclusion, this updated review enhances knowledge about seismo-tectonics in Iberia by providing detailed insights into active stress regimes and their implications for seismic risk assessment in this geologically complex region.

This is an up to date seismic contribution to stress distribution in the Iberian peninsula and worth to be published.

I have annotated the manuscript by pen, hopefully the author can decipher my hand writing. Of course, there are some flaws, typos and use of "poor" english. Interestingly the quality varies during the manuscript, seems like different chapter have been writing by individual authors, and nor "stream-lining" has been carried out. This is a pity! As the quality of data and illustrations are excellent and clear.

Dear Dr. Reicherter,

We greatly appreciate your valuable review and your kind words. Your suggestions have improved significantly the quality of the original manuscript. We have implemented your comments in the original document.

Please, find below our responses in red

Best regards,

Antonio Olaiz

Some more general comments:

"Greater Iberia" - is not existing. It´s short Iberia or Iberian Peninsula. Avoid that term. Iberia has 4 nations since more than 300 years, and nobody refers to Spain as "Smaller Iberia".

Rock units are upper and lower, time (ages) is Early and Late. Correct this throughout the ms.

Sorry, but according to the international chronostratigraphic chart, the correct terms for age are lower, middle, and upper. (www.stratigraphy.org)

The introduction and objective chapter (1) needs to be re-written in terms of plate tectonics the review and status are sometimes not correct. Partly Iberia is considered as an individual plate (line 38), sometimes African Plate is Nubian Plate and v.v. It should be consistent. Done (yellow labelled). If I wrote "ref" a reference is missing. The introduction needs a clear separation of plate tectonics and stresses induced by different sources.

Done. The new Introduction separates Iberian Peninsula from the Iberian microplate and plate-related stresses from those with a more local origin:

1 Introduction and objectives

The Iberian Peninsula, and the former Iberian microplate, shows evidence of an intense and distributed Alpine deformation that occurred over geologic time scales (de Vicente and Vegas, 2009) (Fig. 1). After the Variscan orogeny, and during the Mesozoic, numerous extensional structures developed, in which thick sedimentary deposits accumulated, with one exception, on the Iberian Massif to the west. At the northern edge of the Iberian microplate, this extension even reached the stage of oceanic crust generation (Montadert et al., 1971; Nirrengarten et al., 2018; Sibuet et al., 2004), albeit during a very short time (Aptian-Albian) (Srivastava et al., 1990). According to tectonic reconstructions, the Iberian microplate moved independently relative to Africa and Eurasia until it collided with Eurasia to form the Cantabrian-Pyrenean Orogen. From the beginning of the Eocene, the Iberian microplate underwent significant compression, not only at its northern border, where an incipient subduction zone was located (Gallastegui and Pulgar, 2002; Fernandez-Viejo et al., 2012), but also in its interior.

The result of Alpine compression in the interior of the Iberian microplate was the inversion of the Mesozoic aulacogen of the Iberian Basin (Iberian Chain, IC), and the development of a series of ranges characterized by crustal thickening along the Iberian Massif, including the Spanish-Portuguese Central System (SPCS). This set of intra-plate ranges can also be considered as an incipient and aborted orogen (de Vicente et al., 2022). It has also been suggested that the Iberian microplate accommodated shortening by forming lithospheric folds (Cloetingh et al., 2002). Accompanying these large thrusts, major strike-slip faults and deformation belts were activated at the crustal scale, such as the South ("Castilian") and North ("Aragonese") Branches of the IC, and the Messejana-Plasencia fault (more than 500 km long), which nucleated on an end-Triassic basic dyke related to the Central Atlantic Magmatic Province (Cebriá et al., 2003; Villamor, 2002; de Vicente et al., 2021). The age of the main deformation event for these fault systems is Oligocene to Lower Miocene. However, in the westernmost sector, the SPCS and the left-lateral strike-slip faults of Regua and Vilariça display significant deformation during the Middle to Upper Miocene. They are still considered active structures (Cabral, 2012).

Today, extensional structures dominate the easternmost part of the Iberian Peninsula, dating back to the Upper Miocene, due to back-arc extension related to a subduction zone located below Corsica and Sardinia, which were initially part of the Iberian microplate (van Hinsbergen et al., 2014). A very recent normal faulting stress regime, unrelated to plate tectonics, also affects the Pyrenees, where a post-orogenic collapse process has been suggested (Asensio et al., 2012). Thus, the active plate boundary would have migrated from the north, when Iberia was an independent microplate, to the south of the Iberian Peninsula (Terceira Ridge - Gloria Fault – Alboran - Tell Atlas), when Iberia became a part of the Eurasian Plate, where the emplacement of the Alboran Domain and the subduction of the southern edge of the Iberian Peninsula, have produced a diffuse plate boundary that encompasses the Betics, where shortenings and extensions occur almost simultaneously. In the complex deformation setting of the Cenozoic and neotectonic periods, it is not surprising that the present tectonic stresses in the Iberian Peninsula exhibit significant variations in both the stress regime and the orientation of the principal stress axes (de Vicente et al., 2008) over relatively small areas.

The estimation of earthquake focal mechanisms in recent years, performed by seismic institutions in Spain and Portugal (IGN, IAG and IPMA), has generated a large amount of information that adds to scientific publications resulting from different projects, such as TopoIberia (e.g. Matos et al., 2018; Martín et al., 2015), or significant earthquake crisis (e.g. Cesca et al., 2021; Villaseñor et al., 2020).

In this study, we will exclusively use well-fitted moment tensor focal mechanisms to study the contemporary deformation pattern in the Iberian Peninsula. We analyse the rupture characteristics of focal mechanisms populations for defined tectonic subareas and use the Slip Model described by Reches (1983) and de Vicente (1988) to assess which of the two nodal planes was the rupture plane. This information, along with the focal mechanism populations, is then used to perform a stress inversion to determine the orientation of the maximum horizontal stress (SHmax) and the tectonic stress regime. We also derive the SHmax orientation from the individual focal mechanism and integrate these results with those from the stress inversion into a revised dataset for the World Stress Map project, based on borehole logs, overcoring measurements, and geological stress indicators.

References

Fernández-Viejo, G., Álvarez Pulgar, J., Gallastegui, J and Quintana, L. The fossil accretionary wedge of the Bay of Biscay: Critical wedge analysis on depth-

migrated seismic sections and geodynamical implications. Journal of Geology, vol. 120, n.º 3, pp. 315-31, https://doi.org/10.1086/664789., 2012

Martín, R., Stich, D., Morales, J and Mancilla F.: Moment tensor solutions for the Iberain-Maghreb region during the IberArray deployment (2009-2013). Tectonophysics, 663, 261-274, [Dataset] https://doi.org/10.1016/j.tecto.2015.08.012, 2015.

Montadert, L., B. Damotte, J. P. Fail, J. R. Delteil, and P. Valéry, Structure géologique de la plaine abyssale du Golfe de Gascogne, in Histoire Structurale du Golfe de Gascogne, edited by J. Debysier, X. Le Pichon, and M. Montadert, VI.14.1-VI.14.42, Technip, París, 1971.

Nirrengarten, M., Manatschal, G., Tugend, J., Kusznir, N. and Sauter, D. Kinematic Evolution of the Southern North Atlantic: Implications for the Formation of Hyperextended Rift Systems. Tectonics, https://doi.org/10.1002/2017TC004495., 2018

Sibuet, J. C., Srivastava, S. P. and Spakman, W. Pyrenean orogeny and plate kinematics. J. Geophys. Res. 109:B08104, doi:10.1029/2003JV002514., 2004

Srivastava, S. P., Roest, W. R., Kovacs, L. C., Oakey, G., Levesque, S., Verhoef, J. and Macnab, R. Motion of Iberia since the Late Jurassic: Results from detailed aeromagnetic measurements in the Newfoundland Basin, Tectonophysics, 184, 229 – 260, https://doi.org/10.1016/0040-1951(90)90442-B 1990

Line 39: compression in Iberia started as early as Late Cretaceous (there is an old paper by - sorry by myself- Reicherter and Pletsch, 2000, Terra Nova, already discussing this)

Ok. We have added:

A pronounced change in the tectonic framework has been suggested to have occurred around 84 Ma, when an incipient collision between the Iberian microplate and Africa may have begun (Reicherter and Pletsch, 2000).

Reicherter, K.R. and Pletsch, T.K. Evidence for a synchronous Circum-Iberian subsidence event and its relation to the African-Iberian plate convergence in the Late Cretaceous. Terra Nova 12, 141-147, https://doi.org/10.1046/j.1365-3121.2000.123276.x 2002

Line 61: seismic institutions? Better Seismic Obsersatories or Geophysical Institutes...

Done, we changed to Geophysical Institutes

Line 69: SHmax should be written consistently in the ms.

Done. We changed to S_{hmax}

Fig.1. Some structures are missing, Gafarillos Fault? Palomares Fault is cutting the Carboneras (better: the Carboneras Fault is ending at the Palomares). Why difference between Post-Orogenic and Late Miocene extension? It is basically in the Betics identical?

We have added the names of the cited faults in the manuscript according to Reviewer 1

Post-orogenic extension is related to the Pyrenees, whereas Late Miocene extension is due to different causes, discussed in the text

Line 99: 30 km focal depth means in the oceanic realm --> it is in the mantle lithosphere?

Yes. It is written: The events are shallower than the Moho proposed by Diaz et al. (2016), except for some events located in oceanic crust (depth < 30 km), where the rheology of the upper mantle may be assumed to be similar to that of the crust.

Line 116: please sort like the description before...

Done. We have changed to: Conversely, when we deal with stresses, we use thrusting stress regime, strike-slip stress regime, and normal faulting stress regime.

Figure 3: what about the gaps, in Mallorca or central Spain.

We have implemented a search radius of 150 km, which may determine lacks in the final interpolation.

We have included “Search radius 150 km” in the figure caption.

4 Tectonic zonation chapter: this can be organized better, some descriptions are missing

We have reviewed the text and including Granada Basin that was missing.

Table 4 and 5: descriptions are varying? Why?

Tables 4 and 5 summarize the results of different approaches. We have homogenized including Betics > 20 km

Popultaion Betics >20 km was missing in the Supplementary material. Now is included.

Line 394: In 5.5 El Camp Fault was already mentioned in 5.3? Reduce redudancy.

The Camp fault can be considered as belonging to both the western Valencia trough and the northern Catalan coastal range. Moreover, it has the importance of having been one of the first faults studied with palaeoseismological methods in Iberia. We believe that it is not redundant to mention it in both cases.

Line 420: sentence incomplete

Completed

Line 484 and others: N070°E-N090°E is rather bulky, why not N070-090°E much simpler and easy, and please consistent throughout the manuscript.

Done

Line 499: I find the SVT here a bit displaced in your listing? It does not fit here.

We have listed the areas roughly from N to S, so SVT is explained here.

Line 589: confusion 5.14 was already called WAA? Should be Granada Basin?

It is true. Corrected

Chapter 5.15: I was wondering if the authors ignore geological work done? My own (sorry again, but this was the reason I reviewed the ms) work from 2005 (Reicherter and Peters Tectonophysics) already describes radial extension and a recent stress field including active faults. What about the Arenas de Rey earthquake 1884? This paragraph can be improved significantly. The intrabasinal deformation is compared with the margins of the GB different. Also the Jabaloy et al paper has not been considered. I know the paper are "old" but according to your new data, they already mentioned several facts.

We have added: extensional basin within the orogen, which is dominated by the presence of NW-SE normal faults related to radial extension (Reicherter and Peters, 2005).

Reicherter, K.R. and Peters, G. Neotectonic evolution of the Central Betic Cordilleras (Southern Spain). Tectonophysics 405,191-212. https://doi.org/10.1016/j.tecto.2005.05.022, 2005

Line 739: remnant effect of the slab? This should be expleaind better and reference is missing? Is this really mechanically possible? Why 20 km depth? The earthquakes there (Malaga region) are usually much deeper? Is there mid-crustal detachment?

It is written: likely influenced by the remnant effect of the slab (Gea et al., 2023). In this paper, the remnant effect of the slab is explained.

the 20 km division is for comparison with the results of Ruiz-Constán et al. (2012)

Line 832: "As it can been seen in Fig....." this is really poor English, and degrades the quality of the manuscript. This refers to the entire chapter 7 Discussion, please consider a re-writing, as the quality does not meet international standards.

Rewritten: As shown in Fig. Discussion. All the text has been reviewed.

Line 966 It should be chapter 8 Conclusions, not 7...

Sorry, yes.

Fig. 15 - this is not an Alpine tectonic map of Iberia.... It is a map of recent stress in Iberia, please change text (Line 945) accordingly.

Done

I didn´t check the references for completeness, this is editors work. Supplementary maps are very nice, but directly outline the problems: where there is no earthquake .... and especially for the GB I have major doubts, as marginal faults do not appear as seismically active.

I hope this review helps improving the manuscript, if you cannot decipher my hand-writing in the ms, let me know. Good luck.

Aachen, 25/3/2025 Prof. Klaus Reicherter

Reviewer 3

The manuscript by Olaiz et al. offers valuable insights into the seismotectonics of greater Iberia. The authors have compiled and analysed over 500 focal mechanism solutions to enhance the understanding of the region's active tectonics. While there are some typos and inconsistencies in acronym usage (e.g., SHmax) and figure references (e.g., "Fig." vs. "Figure"), these are minor issues likely to be addressed during the production stage. Overall, the manuscript is well-organized but would benefit from an additional round of English editing. Therefore, I recommend publication pending minor revision.

Dear Reviewer,

We sincerely value your feedback. Your suggestions will greatly enhance the manuscript.

Please, find below our comments written in red.

Best regards,

Antonio Olaiz

Some general comments

A clearer explanation of the database would be helpful, particularly regarding how the authors identified and handled duplicate entries. While the highest %DC is mentioned, additional detail on the process would improve clarity.

During the compilation and merge of different databases, the date and origin time format was standardized. When two or more events share the same date, the time is reviewed. If the time also matches, the coordinates are analysed to confirm that it is the same event. Finally, the %DC is compared, and only the higher value is retained.

I feel the depth parameter was not thoroughly discussed across the different sections. For example, were there any observed changes in stress regime with depth? Also, I wasn't sure how depth was accounted for in Figure 3; was the map created using focal mechanism data? If so, how did you generate a map considering that focal mechanisms come from varying depths?

In this approach, we assume that the type of stress is uniform throughout the entire seismogenic crust. With two exceptions: The focal mechanisms in the Atlantic offshore, which, being only five in number, we have included mechanisms at mantle depths. The solution is very congruent. In the Western Betics population, where evidence of a vertical slab is present, we have considered two subpopulations: those above and below 20 km.

A clearer explanation on your 're-evaluation' for other stress data (inferred from WSM) would be great. Also, I think WSM has lots of stress inferred from focal mechanics solutions for this region. So, how did you deal with it as you also have a new comprehensive database of FMS.

We will update and expand the text accordingly including a minor update of the quality assignment of the Iberia data set which does not affect any of the results. The latter is only a technical issue to be consistent with the new release of the World Stress Map (WSM) database 2025 (Heidbach et al., 2025) and the WSM technical report TR 25-01 where the latest update of the WSM quality ranking has been published very recently (Rajabi et al., 2025). The Iberia dataset has been integrated into the WSM database release 2025 with these slight changes that we will also adopt in the manuscript.

Technically we started with the compilation of stress data records from the WSM database release 2016 in the area between 15°W – 5°E and 34°N – 45°N and re-evaluated each data record. For the sub-dataset of single focal mechanisms (FMS data records), we compiled a completely new dataset (see chapter 2 of the manuscript). This was necessary as the WSM cannot look into regional details. This is an agreement with the WSM policy encouraging regional studies (special study areas) that are more precise in the data assessment. If such a special study area is reported the dataset is replaced in the global WSM compilation. This has been done e.g. for Iceland (Ziegler et al., 2016) and more recently for Taiwan (Heidbach et al., 2022). These special study areas are also explained in the WSM TR 25-01 (Rajabi et al., 2025) and our study is one of these.

The completely new compilation resulted in 542 data records with robust focal mechanisms. These were used in two ways: First, determined from the nodal plane of each focal mechanism the P-, T-, and B-axes and applied the WSM guidelines to derive from these the S_{Hmax} orientation and the stress regime and assigned the data quality following the WSM quality ranking scheme (see WSM TR 25-01 of Rajabi et al., 2025). Secondly, we use these focal mechanisms for a formal stress inversion (FMF) that resulted in 24 FMF data records (see Tab. 5 of the manuscript).

For all other stress indicator types in the WSM from borehole data (BO, DIF, HF), overcoring measurements (OC) and geological fault slip analysis (GFI), we checked for each data record if the information needed to assign a data quality is provided and correctly taken from the original literature. We then re-assigned the data quality according to the latest WSM quality ranking scheme 2025 (now published in the aforementioned WSM TR 25-01). We also checked the literature for new data records in the regional of interest and added these to the compilation.

This new compilation of FMS data records from earthquake focal mechanism (n=542), new FMF data records (n=24, this study) and the new assessment of all old data records according to the up-to-date quality assignment resulted in average in a decrease of data records with higher quality, but we now have a consistent and robust dataset. This decrease is a typical result of other special study areas since lots of data records haven't been touched partly for 30 years when the first major WSM database was released in 1992, but progress in knowledge how to interpret data more robust results typically in a downgrading the quality following the up-to-date WSM quality ranking scheme.

References

Heidbach, O., Liang, W.-T., Morawietz, S., von Specht, S., and Ma, K.-F.: Stress Map of Taiwan 2022, GFZ German Research Centre for Geosciences, Potsdam, 10.5880/wsm.Taiwan2022, 2022.

Heidbach, O., Rajabi, M., Di Giacomo, D., Harris, J., Lammers, S., Morawietz, S., Pierdominici, S., Reiter, K., von Specht, S., Storchak, D., and Ziegler, M. O.: World Stress Map Database Release 2025, GFZ Data Services [dataset], 10.5880/WSM.2025.001, 2025.

Rajabi, M., Lammers, S., and Heidbach, O.: WSM database description and guidelines for analysis of horizontal stress orientation from borehole logging, GFZ Helmholtz Centre for Geosciences, Potsdam, WSM TR 25-01, 118, 10.48440/WSM.2025.001, 2025.
Ziegler, M. O., Rajabi, M., Heidbach, O., Hersir, G. P., Ágústsson, K., Árnadóttir, S., and Zang, A.: The stress pattern of Iceland, Tectonophys., 674, 101-113, 10.1016/j.tecto.2016.02.008, 2016.

A supplement (or appendix) consisting of the details of 542 focal mechanics solutions would be great.

Following journal guidelines, a Zenodo repository has been created, including the complete and referenced database at https://doi.org/10.5281/zenodo.14326528.

The text in the data availability chapter has been modified to be more comprehensive.

Supplementary material includes the focal mechanism compiled and the calculated for this study is available at a Zenodo repository (https://doi.org/10.5281/zenodo.14326528). A database encompassing both the results of this study and vintage data from World Stress Map, is standardized in accordance with World Stress Map guidelines and accessible at https://doi.org/10.5281/zenodo.14326528.

Detailed comments

Line 90: use Geofon (GFZ-Potsdam) instead of GFZ-Potsdam.
Done
Line 99: Maybe show the Moho depth of the study area as a map?
It is drawn in the cited reference: Diaz et al., 2016.
Line 113: It needs a sentence or two to explain what the Reches (1992) methos is known for and why did you prefer this method?
Done
This approach enables iterative testing of various friction coefficients, validated by angular criteria established by SLIP and PAM, as detailed in the subsequent section. The methodology has been recently revised and implemented in MATLAB (Busetti et al., 2014; Wetzler et al., 2021).

Line 115: thrust or thrusting?
Thrusting. Done
Line 115-117: What about stress orientation?
We have added "and stress-strain orientations"
Why both 3.1 (line 118) and 3.2 (185) have the same title (i.e., kinematic analysis)?
Sorry. We changed to 3.1 Kinematic analysis. Composite focal mechanism
And 3.2 Kinematic analysis. Slip model
Line 185 to 190 needs at least reference as you are providing some info from the literature.
The provided references (Reches, 1983; de Vicente et al., 1988) give this information.
Figure 3: What particular depth this map has been prepared for?
We answered that question in the second comment.
Line 763: change 'inver-sions' with 'inversions'.
Done

Figure 9: I see lots of SHmax orientations inferred from FMSs on this map. It would be great to clarify if there are new FMSs (based on your database) or if they were in the WSM database?

The map includes both orientations, the new obtained in this study and the previous included in the WSM database. It is hard to represent both using different symbols. However, the database is available at https://doi.org/10.5281/zenodo.14326528.

Figure 15: it would be great to add a background (e.g., topography) and some names on the map for those who are not familiar with the area.

This is what we initially did, with the map in Fig. 1 blurred. Other reviewers suggested that we better make the background white. We believe that simultaneous viewing of the two figures yields better results.