Answer to Anonymous Referee #2 (https://doi.org/10.5194/egusphere-2022-708-RC2):

Thank you for accepting to be a referee, and the time spent to review this manuscript. We appreciate the comments. We have updated our manuscript accordingly and hope to answer the questions satisfactory, in the following. Where we references to manuscript lines, these are the lines in the new, revised manuscript.

The main comments are how to evaluate the uncertainty of your clustering? Where do the uncertainties come from, and how large? For example, in Figure 4 (second panel), the whole area was identified as sed-A within profile 250-350 km for all depths, it is not clear if MT method/the resistivity does not have enough resolution to identify the resistivity change along the depth axis?

The uncertainty of the clustering is determined within the probabilistic Gaussian mixture modeling algorithm. GMM is a soft clustering approach, meaning that for each data point the probability for each defined cluster is determined and then the cluster with the highest probability is assigned to the data point (cf. l. 266ff.). We visualized the probability of the assigned cluster with a colour saturation in figures 3, 4, and 5. We slightly modified the figures, by including only three ranges of certainty: above 90%, between 60 and 90%, and below 60%, which are thus better distinguishable by the symbol saturation in figures 3, 4, and 5. We believe, this improves the direct visibility of model areas with larger clustering uncertainty. For example in figure 3b at the intersection of clusters at density 2600-2800 kg m^{-3} and el. Resistivity $2 \cdot 10^1$ - 10^2 Ωm; or in figure 5, bottom panel, profile kilometre 30 – 70. For this second example of the mantle cluster assignment along profile P3, we discuss the cluster uncertainty in l. 620ff., stating that interpretations in the northern part of our models should be mostly disregarded.

To clearly state that the posterior probability is a measure for uncertainty, we changed the sentence in l. 271f.

In the following figure (Fig. 1 in this reply), we have also depicted the distribution of the probability for each of the 11 clusters. The distribution shows mostly a dominant high certainty (<90%) except for the manually defined cluster “cru-D2”. In our opinion, this only emphasizes the importance to isolate this cluster manually and distinguish it from the more clearly defined cluster cru-D, representing magmatic underplating below Walvis Ridge.

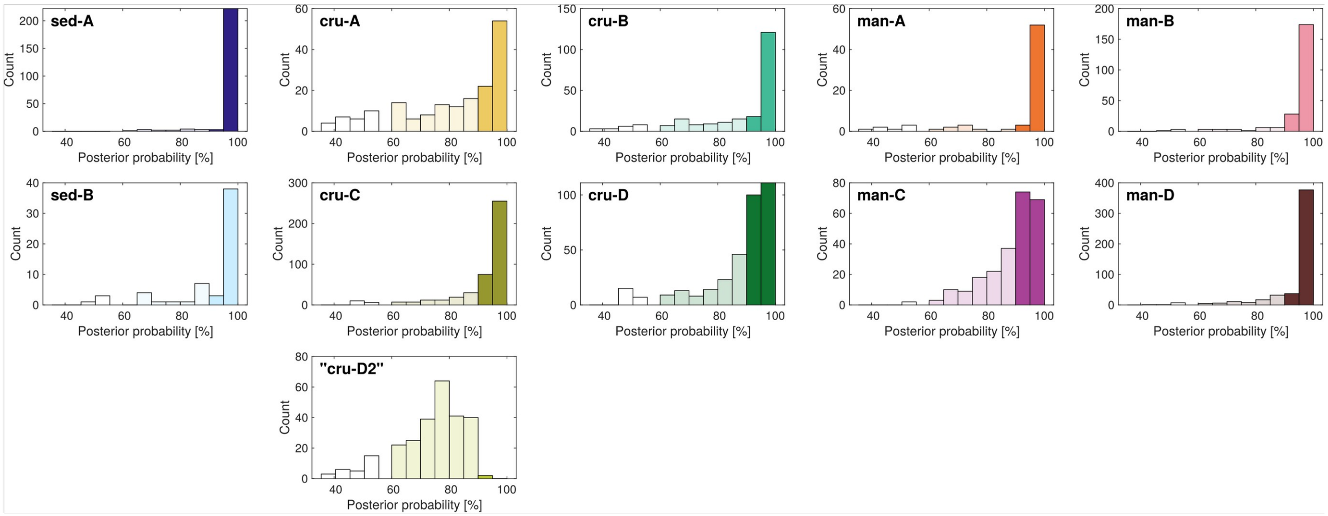

Figure 1: *Representation of cluster certainty. It shows the distribution of the Gaussian mixture model's posterior probability for each cluster. Binning is fixed between the minimum in all probabilities (35%) and 100% in steps of 5%.*

<u>Concerning cluster sed-A and the lack of vertical differentiation:</u> In Figure 2, we present the AIC and BIC criteria for the determination of the number of needed clusters. For the sediment domain (Fig. 2a), the curve is generally less smooth than for the other two domains, which complicates the decision process for the number of clusters. Therefore, we also tested clustering with three assigned sediment domain clusters. The additional third cluster mainly moved the transitional zone between the lower and higher resistivity clusters and did not add a spatially confined, thus lithologically interpretable cluster (see Fig. 2A and 3A in this reply). Additionally, the certainty, i.e. posterior probability of the assigned clusters, decreased with the addition of a third cluster (see Fig. 2A in this reply, less saturated symbols).

In another attempt, which we did not include in the final manuscript, we have added seismic velocity as a third parameter in the clustering algorithm (Fig. 2B, 2C, and 3B in this reply). We used the available velocity models by Fromm et al. (2017) and Planert et al. (2017). The inclusion of seismic velocity in the clustering with three sediment domain clusters resulted in a clear vertical separation of the lower resistivity sediment cluster (Fig. 2B and 3B in this reply). We interpreted this differentiation do result from the increasing compression with depth, and therefore increasing seismic velocity of marine sediments. Figure 2B in this reply shows that the electrical resistivity and density values of these vertically separated clusters (here, sed-A and sed-B) are in the same ranges. This indicates that the resolution of our resistivity and density models are insufficient to resolve the parameter change due to increasing compression. Nevertheless, for our differentiation in lithological or tectonic units, this effect of mere compaction is insignificant, which is why we have refrained from including it in the final manuscript. For the Crustal- and Mantle domains, this effect was even stronger, which can be attributed to the general structure of seismic velocity models, which are usually built as gradient models with strictly increasing velocity with depth.

We added a brief statement about the effects of the inclusion of a third sediment domain cluster in our manuscript (l. 307ff.).

We hope this explanation of our additional clustering tests helps to understand our reasoning for the two evaluated sediment clusters in the final manuscript, and the neglecting of the three parameter clustering including seismic velocity.

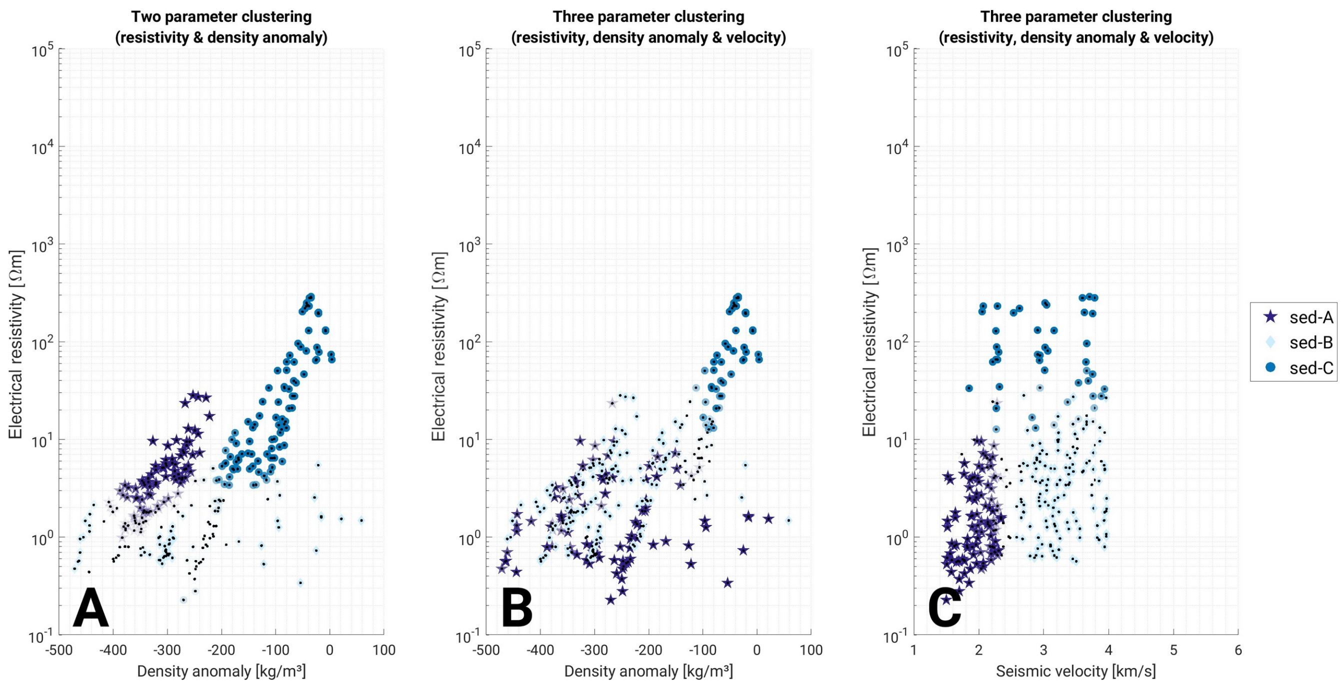

Figure 2: *Cross-plots of electrical resistivity and density anomaly (A and B), and electrical resistivity and seismic velocity (C) and their identified clusters for the sediment domain. The analyses generated three sediment domain clusters, compared to the 2 clusters presented in the final manuscript. Additionally, plots B and C show the results for a clustering of the three parameters electrical resistivity, density, and seismic velocity. Note that in this figure, density is depicted as an anomaly of a background density of 2800 kg m*$^{-3}$*. For absolute density as it is depicted in the final manuscript, one simply adds those 2800. These results were not included in the final manuscript and therefore only serve as an explanation for our reasoning to not include them.*

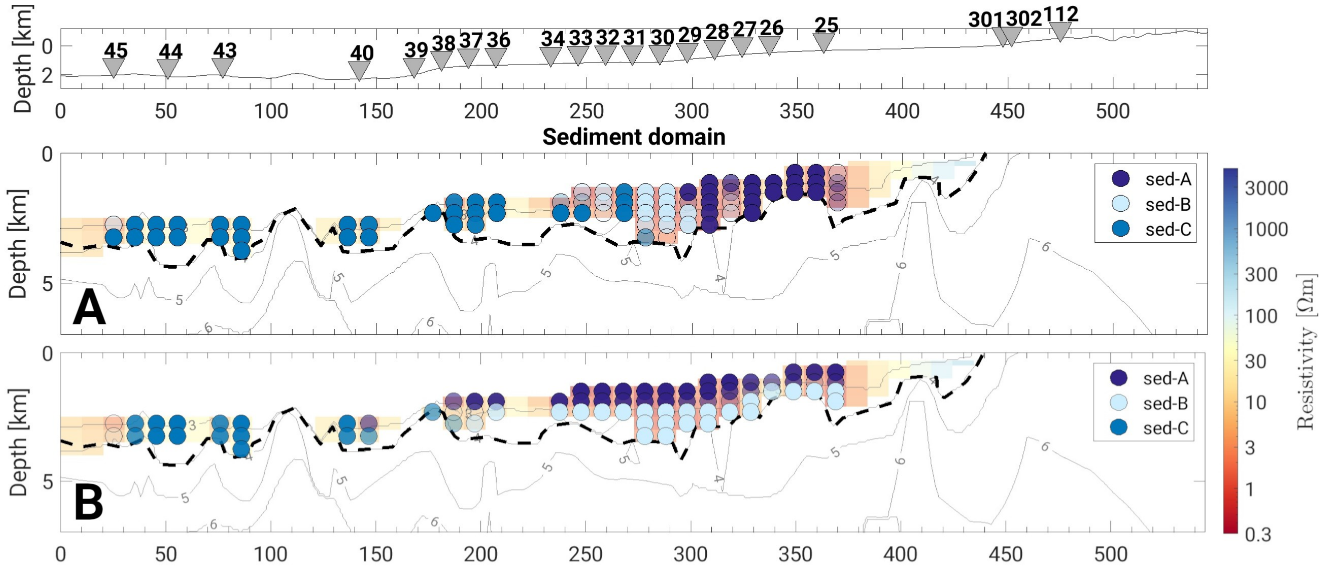

Figure 3: *Vertical section along profile P100 through the 3D electrical resistivity model overlaid with parameter clusters. Top panel shows topography, and location of MT stations. Second panel (A): Results for sediment domain and two parameter (electrical resistivity and density) clustering. Third panel (B): Results for sediment domain and three parameter (electrical resistivity, density, and seismic velocity) clustering. Colour saturation of circles is proportional to posterior probability of the Gaussian mixture model. Less saturated circles depict decreased certainty of the cluster classification. These results were not included in the final manuscript and therefore only serve as an explanation for our reasoning to not include them.*

In Figure 6, how does the electrical conductance distribute for other clusters?

We have only included electrical conductance values for the shown three clusters, because they are the clusters summarizing the upper model conductive anomalies above 10 km. In MT inversion, it is often difficult to resolve both parameters electrical conductivity and thickness for shallow layers, whereas the total conductance of a layer may be resolved with relatively high accuracy (Kaufmann et al., 2014; Weidelt, 1985). This is due to the limited high frequency signal, especially in marine MT studies where the high frequency content of the source signal is filtered by the water column. For the deeper and more resistive structures, we assume that we can ambiguity concerning electrical resistivity and thickness of anomalies is less pronounced.

Page 1, Line 27-30, About the end-member of passive margins, the volcanic or non-volcanic, or called magma-poor or magma-rich margins, Authors need to mention a form between the volcanic and non-volcanic margins, an intermediary form margin in the world.

Thank you, for pointing out this lacking information. We have added a sentence and the proposed references to our manuscript (l. 32 ff.) and clarified, that the described magma-poor and magma-dominated margins are only the end members of margin classification (l. 28).

Page 2, Line 36-37, it requires reference here to explain "margin formation and mantle plume-lithosphere interaction."

We have added five exemplary references (l. 53f.).

Page 2, Line 57, the title "Geological Setting: Phases of the geodynamic evolution of the Namibian passive continental margin" is too long and it requires delete the redundant words after geological setting.

We have followed the referee's suggestion for the Results-part title and included the "*Phases of the geodynamic evolution of the Namibian passive continental margin"* as a subtitle. We believe, that the descriptive subtitles help guiding the readers.

Page 5, Line 100-103, needs to add reference here

We have added four references connecting decompression melting with rifting lithosphere (l. 125 f.). References for the features a) intrusive magmatic bodies, b) magmatic dykes and sills, and c) continental flood basalts (CFB), are included in the following paragraphs, where we present examples for each of the features.

Page 5, In this section "Phase 2: Arrival of magmatism", Authors need to add Figure 1 after some text to show the "Kaoko Belt" or intrusive bodies, dyke and sills, and the location of "Tristan mantle plume".

We added the reference to Figure 1 (l. 139) and altered the map inlay of Figure 1 to show the present day location of the Tristan hotspot and the corresponding hotspot track.

Page 5, Line 123"2.3 Phase 3: Transition from rifting to continental breakup", I think this title is questionable, why authors separate the rifting process from continental breakup? This process is not continuous?

Yes, we agree, that the transition from rifting to continental break-up is a continuous process.

We have observed that in literature, authors often describe a stringent COB (continent-ocean boundary), which is presented as a line feature. As mentioned in l. 150ff., we believe that this distinct definition of a boundary is prone to false interpretations, and the transition should be rather viewed as a zone. This zone may present differently at different margins, but similar processes are responsible for the associated structures. Therefore, we compiled a specific sub-section describing this "transition from rift to drift". This phrase has been used similarly by e.g. Bertotti et al. (1993); Jagoutz et al. (2007); and Nielsen and Hopper (2004).

We changed the second sentence of this paragraph, to clearly state that the rift to drift transition is a continuous process (l. 151).

Page 8, Line 196, please simply describe the gravity inversion method and tools used in this manuscript.

We have added basic information about the applied inversion code and forward engines in l. 215ff. Additionally, we added a reference at the proposed line to the previous publication Franz et al. (2021), where the technical details of this joint inversion are described in much detail (l. 238).

We refrained from describing the joint inversion details here, because it has been covered extensively in the mentioned previous publication.

Page 8, Line 222-226, the method discussion needs move to discussion part.

We believe, that this part is important as a motivation why we utilized the GMM clustering method. We do not discuss our particular clustering here, but describe the general benefits of this approach.

In in discussion in l. 620ff. we pick up on this benefit: the clustering results north of Walvis Ridge have generally lower posterior probability. There, the soft clustering approach helps to identify areas of less certainty. Consequently, we mostly refrain from interpreting anomalies there (l. 623f.).

Page 10, the title "Results: Identified clusters of characteristic physical parameter values and -relationships and their spatial correlation" is too long. The title "Identified clusters of characteristic physical parameter values and -relationships and their spatial correlation" can be as a sub-title.

We have followed the referee's suggestion and included the "*Identified clusters of characteristic physical parameter values and -relationships and their spatial correlation*" as a subtitle. We believe, that the descriptive subtitles help guiding the readers.

Page 15, Line 357, the title "Discussion...." is also too long.

We have followed the referee's suggestion for the Results-part title and included the *"Link between the identified physical parameter clusters, passive margin evolutionary phases, and associated crustal types"* as a subtitle. We believe, that the descriptive subtitles help guiding the readers.

Page 23, the conclusion part, Line 608-613, please remove to the discussion part.

This paragraph summarizes the work we presented in this manuscript, justifies our results by mentioning the agreement with independent seismic results, and states how these results can be useful for future research. It follows the discussion and we would like to leave it in the manuscript as a concluding statement.

<u>Figures</u>

In Figure 1, add the location of the "Tristan mantle plume"

We altered the map inlay of Figure 1 to show the present day location of the Tristan hotspot and the corresponding hotspot track. We do not display the supposed location during break-up at the Namibian margin, because it is subject to discussion (cf. l. 670ff.).

In Figure 2, add the letter A, B and C for separated small figures. The labeled AIC/BIC mark above the three small figures.

Figure two was changed according to the referee's suggestions.

References in this response:

Bertotti, G., Picotti, V., Bernoulli, D., and Castellarin, A.: From rifting to drifting: tectonic evolution of the South-Alpine upper crust from the Triassic to the Early Cretaceous, Sedimentary Geology, 86, 53–76, 10.1016/0037-0738(93)90133-P, 1993.

Franz, G., Moorkamp, M., Jegen, M., Berndt, C., and Rabbel, W.: Comparison of Different Coupling Methods for Joint Inversion of Geophysical Data: A Case Study for the Namibian Continental Margin, Journal of Geophysical Research: Solid Earth, 126, 1–28, 10.1029/2021jb022092, 2021.

Fromm, T., Jokat, W., Ryberg, T., Behrmann, J. H., Haberland, C., and Weber, M.: The onset of Walvis Ridge: Plume influence at the continental margin, Tectonophysics, 716, 90–107, 10.1016/j.tecto.2017.03.011, 2017.

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Kaufman, A., Alekseev, D., and Oristaglio, M.: Principles of Magnetotellurics, pp. 377–415, 10.1016/B978-0-444-53829-1.00011-3, 2014.

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Planert, L., Behrmann, J., Jokat, W., Fromm, T., Ryberg, T., Weber, M., and Haberland, C.: The wide-angle seismic image of a complex rifted margin, offshore North Namibia: Implications for the tectonics of continental breakup, Tectonophysics, 716, 130–148, 10.1016/j.tecto.2016.06.024, 2017.

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