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Interactive comment on "Bayesian geological and geophysical data fusion for the construction and uncertainty quantification of 3D geological models" *by* Hugo K. H. Olierook et al.

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Reviewer #3:

The manuscript entitled "Bayesian geological and geophysical data fusion for the construction and uncertainty quantification of 3D geological models" presents an interesting approach for integrating geophysical and geological observations into a probabilistic modelling approach of subsurface. Joining the gap between geological and geophysical inversion of subsurface has been a long-standing problematics and this study takes one step toward this objective. Being from the geological side of this problematic my main observations are that the geological description of the subsurface that

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Discussion paper

is used in this study remains relatively simple (probably for sake of parsimony, as required by inversion problems). I would not place this remark as a criticism for this study but rather as an acknowledgment that further research is needed for improving the parameterisation of geological models. This study has the merit of showing the interest of coupling geophysical and geological inversion. Therefore, I find it valuable for the community and I would recommend accepting it for publication provided some minor revisions.

We thank the reviewer for their detailed review of our manuscript. Please find attached a zip file containing comments to all reviewers, a manuscript with track changes and a clean manuscript with all changes incorporated.

2 Specific comments: The parameterisation consist of a Gaussian process with an RBF interpolation of depth map of the geological contacts. You should better discuss the limitations of this approach on the geometry of the contacts. At least it cannot reproduce multiz structured, but it would also have limitations for vertical or sub vertical contacts. As you mentioned in the introduction Obsidian was designed for basins, ie. With layers being roughly horizontal. Isn't it limiting the sampling and more generally the applicability of the method to other geological regions? The description of this geological parameterisation was apparently supposed to be supported by fig. 3 but several reference to this figure in page 6 line 1 and 10 are apparently not pointing at the right thing. The user-defined control points of the Gaussian process are not show as expected. In addition, it would be interesting to show the prior distribution for the parameters describing the depth of the geological interface, which has apparently been omitted. AGREE. We agree that the 2.5-D approach used by Obsidian has limitations when applied to more complex geologies, which we now highlight in more detail in the discussion. We anticipate that many of these insights will carry over to more complex 3-D modeling methods such as the implicit surface approach used by GemPy (de la Varga et al, 2018); future work will combine advanced sampling methods like Obsidian's with sophisticated parametrizations of geological structure like GemPy's. We

have also included mention of the prior distribution for the depth to the geological contact, which was very permissive âĂŤ a Gaussian with standard deviation 5 km at each control point. Thus while the 2.5-D parametrization with RBF kernel for the interface is restrictive, any further assumptions about depth to contact were by design uninformative. This is unrealistic when trying to reproduce a well-studied area in detail, but could be useful when formulating initial models in areas about which little is known." You chose to ignore some lithologies based on their smaller cover of the surface. What is the mag sus and density of these formations? They are ignored (because barely seen on surface) but are they going to affect the magnetic and gravity field?

AGREE. This was poorly worded before. We have now added to section 3.1: “Only the two volumetrically-major units are modelled in this study as the other units appear primarily near the surface (Johnson et al., 2011), and are also present only in areas smaller than our model can resolve (see next paragraph). Resolving finer-scale features is out of the scope of this contribution.”

I think you should clarify the way you introduce and discuss you probabilistic approach of the lithological observations. Unless there are arguments for taking particular care with these observations, they seem to me to be rather hard constraints as compared to gravity and magnetic responses. Of course, observations could be misinterpreted, but unless the two discussed units are very similar, you would not need chemical analysis or dating to assign them to one or the other group. On the other hand, gravity and magnetic field are by nature ambiguous.

AGREE. We have overhauled our methods section to make this significantly clearer.

Why are the high probability areas that outcrop in the middle of the modelled region so different between fig 9b and 10a? On 9b it looks roughly circular whereas it has a crescent shape on 10a.

This is just a distortion in the 3D model. The actual modelled area is circular.

Please refer to the annotated manuscript for more detailed comments and corrections. We have made minor changes as recommended by the reviewer's attachment.

Please also note the supplement to this comment:
https://www.solid-earth-discuss.net/se-2019-4/se-2019-4-AC3-supplement.zip

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