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Interactive comment on "Subsurface structures of a quick-clay sliding prone area revealed using land-river reflection seismic data and hydrogeological modelling" *by* Silvia Salas-Romero et al.

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We thank A. Booth for the critical and useful comments. We have addressed all the specific comments in our revised manuscript, as detailed below.

(A. Booth Referee #2) This is an ambitious paper that shows the strengths of combining multiple data sources together. As the authors point out in the introduction, the analysis is highly multi- disciplinary and multi-methodological, and the hydrological modelling draws on a di- verse set of data. Having less expertise in hydrological modelling, most

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of my comments pertain to the treatment of the geophysical data and the general format of the paper.

(Authors) We thank the reviewer for his comments, which have been very useful for improving our manuscript. We hope the general format of the manuscript (length and structure) is improved after this revision.

(A. Booth Referee #2) a) At times, it seems a little lengthy. An aspect of this is the length of some of the paragraphs (Section 4.1, for example, is a monster which spans Pages 8 and 9!); break these up a bit to improve the appreciation of your process.

(Authors) We agree with the reviewer and have reworked different sections and moved figures to the supplementary material for improving the readability.

(A. Booth Referee #2) b) Sometimes the interpretation of the seismic data is also over-long, but also over- interpreted. I list some specific examples below (Points 13-16), but the key point is that not all of the seismic observations appear to have significance in the model – so I think you should restrict the discussion of the interpretation to the most relevant parameters. A full interpretation could go into supplementary material, although (see below) I'd suggest that some of this is over-interpreted anyway.

(Authors) We followed this advice and reduced the interpretation section. Some of the figures are now included in the supplementary material.

(A. Booth Referee #2) With such streamlining, the objectives of your paper will be more understandable and its significance therefore more appreciable.

(Authors) We thank for the comments and hope that the objectives of the manuscript are now clearer.

(A. Booth Referee #2) Title. This indicates that you reveal subsurface structures with modelling, but I'm not sure this is what you mean. Presumably, the structures you image in the geophysical data help constrain the model? A title like "Hydrological modelling of a quick-clay vulnerable area, constrained with geophysical data" would be

more informative?

(Authors) We thank the reviewer for the suggestion. We agree to change the title to 'Hydrogeological modelling of a quick-clay vulnerable area, constrained with geophysical data'.

(A. Booth Referee #2) Abstract. For all the numerical analysis in your paper, the abstract contains no numbers. Can you add some in? e.g., some highlights from the geophysical dataset, and some of the hydrological parameters you use and model?

(Authors) We have added some numerical information to the abstract.

(A. Booth Referee #2) P1L24: "sensitive" – to what? Makes it sound a bit like they are emotional!

(Authors) This type of clays is usually described using this geotechnical terminology.

(A. Booth Referee #2) P2L4: Explain the terminology "sensitivity higher than 50"... Is there a unit or a reference system here?

(Authors) The definition of sensitivity is given in this page in line 3. It is the ratio of the undrained undisturbed shear strength to the remoulded shear strength, thus there is no unit.

(A. Booth Referee #2) P2L7: Surely there's no need to separate "geotechnics, geophysics or geology" out? Aren't they're all "geoscience"?

(Authors) We agree with the reviewer and have modified the sentence for using only the geoscience term.

(A. Booth Referee #2) Section 2.1 (and throughout): You variously refer to your seismic lines by number, or by the source acquisition method. I found this very confusing, trying to remember what method was used on what line, and would prefer that you stick to the numerical reference throughout. The table usefully informs what source was used anyway.

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(Authors) We checked the text and kept the numerical reference when mentioning the seismic lines.

(A. Booth Referee #2) P5L25: No need to say “reflected sound waves”: if they are transmitted as sound waves, they’ll come back as sound waves!

(Authors) The sentence has been modified.

(A. Booth Referee #2) P6L16: What velocity from the 800-4000 m/s range did you settle on? It doesn’t seem to be listed anywhere.

(Authors) For lines 2–2b, 6 and 7 we used 1400 m/s in the first 150 m depth and 1800 m/s from 150 m depth to the end of the section. So the velocity changed gradually within this range. This information has been added to the text for these lines, and also for the wireless part in line 5–5b (1300 m/s in the first 75 m depth and 3100 m/s from 75 m depth to the end of the profile).

(A. Booth Referee #2) P7L3: Why the different mute definition for the wireless data?

(Authors) We used a different mute function for the wireless data than for the cabled data because the first option (top mute filter based on the picked first breaks) did not work so well as for the other lines and the cabled part of line 5–5b. Then we tested the surgical mute which worked better for the wireless data.

(A. Booth Referee #2) P7L23: What is this absolute value of error with respect to? Give it as a fraction of the typical target depth?

(Authors) We modified the sentence and now it is: ‘This value was justified based on the available borehole data for depth calibration. An error on the order of 1-3 m depth can still be expected, which corresponds to e.g. a 1.3-4% error for a target depth of 75 m’.

(A. Booth Referee #2) P7L25: To help with the interpretation, it might be worth tabulating the expected response of the different geologies you interpret in each geophysical

dataset. Even just listing the range of seismic velocities and resistivities you might expect would help your data description.

(Authors) We thank the reviewer for this interesting suggestion. A table listing seismic velocities and resistivities for every material has been added to the manuscript.

(A. Booth Referee #2) P8L5: Are you implying that the borehole is 0.02 m, or 0.02 *km* away from the seismic line? If it really is 0.02 m, then it hardly seems worth reporting this, and you could just say that the borehole lies on the seismic line.

(Authors) We modified the text and now we include the sentence 'the borehole lies on the seismic line'.

(A. Booth Referee #2) P8L7: The interpreted faults are not really clear, and it seems an over-interpretation particularly since refraction static corrections were not applied. Could near-surface anomalies be the origin of the discontinuities and misalignments that you claim? In any case are the faults and damage zones critical to your model? It seems to me that you could be much more tentative in interpreting them, without damaging any parameter in your model.

(Authors) We agree with the reviewer; the discontinuous reflectivity might be related to near-surface anomalies. For avoiding over-interpretation of the seismic data, we re-evaluated all the sections and removed F features where no geological evidence or other evidence was clear.

(A. Booth Referee #2) P8L8: You don't get a lot of reliable ray coverage in the refraction tomography to really talk about the velocities below reflection B1. I agree that your velocities above this horizon are likely reliable, and you do point out that they have velocities consistent with coarse-grained, saturated sediment. However, in general, I find the resistivity data (Figure 5d, Figure 6e) to provide the much more compelling evidence of a bedrock underburden.

(Authors) We reworked the text for making clearer the information given by the P-wave

refraction tomography velocities in lines 2–2b and 5–5b.

(A. Booth Referee #2) P9L2: On what grounds do you interpret a kinematic response from the seismic data? You see dipping horizons, but I don't see how you can say that this represents a slip surface.

(Authors) We interpreted that the sediments seem disturbed below the landslide scar, apparently moving towards the river (we have modified the sentence). It is only an interpretation, we do not specify that there is a slip surface.

(A. Booth Referee #2) P9L6: I would suggest that it is beyond the capability of travel-time inversion to resolve boulders, as you claim here. I might expect that they could appear as diffractions in the seismic section, or high-resistivity anomalies, but I don't believe that the tomography would be sensitive to them. Furthermore, this over-interpretation doesn't actually appear to influence any parameterisation of your model, so the paper wouldn't be damaged if you said that your tomography has some unexplained velocity artefacts.

(Authors) We followed the reviewer's advice and modified the text accordingly.

(A. Booth Referee #2) P11L20: You suggest that the seismic data shows a higher-resolution delineation of the bedrock/sediment contact, but you wouldn't be able to make this interpretation if it wasn't for the sum total of your datasets! It therefore seems unnecessary to make this assertion when you draw on inferences from all of your data – it doesn't matter which is best! Indeed, this whole section could be considered for removal as it's not clear to me that you are presenting a different hypothesis to one that has been previously postulated. It will always be the case that the use of multiple data sources leads to an improved interpretation.

(Authors) We have reworked this part of the Discussion and removed several parts as the reviewer suggests.

(A. Booth Referee #2) In the interpretation of Figure 9, you correctly point out in the

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main text that you are prone to mistaking multiples for genuine reflections. You appear to avoid multiples, except (potentially) for the interpretation between âĹij800-2500 m in Figure 9b. Can you be sure that this hasn't been misinterpreted? Also, the inset figures here add very little: the data look very fuzzy, so much so that the logs don't appear to correlate with anything at all.

(Authors) After careful consideration we removed this channel from the interpretation. We removed the inset figures too.

(A. Booth Referee #2) There are potentially too many figures in the paper, and 12 and 13 could be ear- marked for removal as they're not very clear partly because of the limited quality of the seismic data. Could they be moved into supplementary material instead? Equally, once the interpretation is streamlined, I don't think that all the seismic lines need to be included.

(Authors) We followed this advice and now figures 12 and 13 are included the supplementary materials. We have also moved the figures corresponding to lines 6 and 7, and the single-channel river seismic data to the supplementary material.

(A. Booth Referee #2) Some figure captions need to be reduced in length, typically those relating to the seismic lines (Figures 5,6,8).

(Authors) The length of the captions has been reduced.

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