Author Response RC1 - Multiphysics property prediction from hyperspectral drill core data

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We thank the reviewers for their constructive feedback. Please find a full set of responses, including a revised manuscript and record of the corresponding changes with the changed line numbers in the attached pdf file.

Sincerely,
Akshay Kamath and authors

Reviewer Comment 1

Dear Andres Ortega Lucero & Steven Micklethwaite,

We thank you for your time and effort reviewing the submitted manuscript, and are pleased that you appreciated our results. We have incorporated your suggestions into the revised manuscript, as detailed in the following pages. Please note that to facilitate the evaluation of our revision, the page and line numbers of the reviewers' comments refer to the originally submitted manuscript while page and line numbers of our responses refer to our revised manuscript.

Kindest regards,
Akshay Kamath, Samuel Thiele, Moritz Kirsch and Richard Gloaguen

Q) Does the paper address relevant scientific questions within the scope of SE?

Yes, it does. The exploration of new methodologies based on hyperspectral data that allow the prediction of petrophysical properties beyond the mineral-mapping traditional approach is highly relevant within the earth sciences.

We are glad the reviewer finds the work interesting, and agree completely.

Q) Does the paper present novel concepts, ideas, tools, or data?

The paper presents a novel processing workflow to predict petrophysical properties from hyperspectral core data.

It might be worth the authors reading and possibly citing the PhD thesis from Rocio Vargas Soto, which achieves similar things using hyperspectral imaging to extract comminution properties (https://espace.library.uq.edu.au/view/UQ:c0c45d3)

The PhD thesis mentioned by the reviewer sounds very interesting but is not publicly accessible and therefore can not be cited. The author did not publish in scientific journals.

Q) Are substantial conclusions reached?

They are substantial as part of a broader development to see if we can use hyperspectral data to extract petrophysical properties.

Agreed. Our contribution is a first-step, but hopefully a useful one.

Q) Are the scientific methods and assumptions valid and clearly outlined?

The methodology is clearly covered, discussing the data acquisition, co-registration and processing. However:

a. In section 3.1 “Hyperspectral data acquisition”, although is mentioned that the details of the dataset can be found in a previous work from “Thiele et al. (2024)” it would be worthy to mention the spectral resolution and/or number of bands in each spectral region (VNIR-SWIR, MWIR, and LWIR). It will allow to better understand the further section 3.4 “Spectral processing”, specially when it is mentioned that the first and last 10 bands of the MWIR and LWIR data were removed. Similarly, in section 3.8, reference is made to the relevance of the spectral sampling resolution for the configuration of the convolutional neural network model.
b. In section 3.3, "Data Co-registration," the spatial resolution of the slowness and hyperspectral data is mentioned. It may also be useful for the authors to include the spatial resolution of the density and gamma-ray properties to provide a clearer understanding of the downsampling method
c. The first heading in Fig 4 only references SWIR, however in the text in section 3.6 the heading in described as VNIR-SWIR. Can you please update the figure?

The reviewers are correct, and the paper could benefit from a more in-depth section on the hyperspectral dataset. In accordance, the section has been updated from L3.16 as follows:

"These sensors capture a broad range of hyperspectral data across different spectral regions: with the AisaFENIX sensor capturing 450 bands in the visible-near to short-wave infrared (VNIR-SWIR; 380–2500 nm) with an average spectral sampling resolution of 3.5 nm for the VNIR and 5.5 nm for the SWIR, the SPECIM FX50 sensor capturing 308 bands in the mid-wave infrared (MWIR; 2700–5300 nm) with an average sampling resolution of 8.4 nm, and the AisaOWL sensor capturing 103 bands in the long-wave infrared (LWIR; 7700–12300 nm) with an average sampling resolution of 45 nm."

For the second point, we have added the sampling resolutions of the density and gamma-ray logs, starting from L4.21:

"Specifically, a thin-plate spline kernel and a different number of nearest neighbours for the slowness, density (with a sampling resolution of 2 cm), and gamma-ray (with a sampling resolution of 5 cm) logs ..."

For the third point, Figure 4 has been updated to have VNIR-SWIR as the title of the first head.

Q) Are the results sufficient to support the interpretations and conclusions?

Yes, they are. The interpretations and conclusions are based on the model's performance in

predicting each petrophysical property.

Q) Is the description of experiments and calculations sufficiently complete and precise to allow their reproduction by fellow scientists (traceability of results)?

Yes, it's well described, and the inclusion of the Shapley analysis provides insights into how the model is learning, which gives confidence in generalizing the model to other experiments

Q) Do the authors give proper credit to related work and clearly indicate their own new/original contribution?

Check

Q) Does the title clearly reflect the contents of the paper?

Check

Q) Does the abstract provide a concise and complete summary?

Check

Q) Is the overall presentation well structured and clear?

It is well-structured. The paper presents a clear methodology for data acquisition, processing and analysis.

Q) Is the language fluent and precise?

Check; Lines 254 onwards: Slightly convoluted sentence. REWRITE "This indicates that there is a sensitivity to the fundamental mechanical and petrophysical properties of the rock, and it suggests that the model could be generalised on more diverse data."

The sentence has been restructured (with minor changes to avoid repetition) at L10.19:

"The model appears to be sensitive to the fundamental mechanical and petrophysical properties of the rock, which suggests that it could be generalised on more diverse data."

Q) Are mathematical formulae, symbols, abbreviations, and units correctly defined and used?

Check

Q) Should any parts of the paper (text, formulae, figures, tables) be clarified, reduced, combined, or eliminated?

The paper is extremely well-written and there is no text to be eliminated, reduced or combined. The paper could benefit from adding more detail on the data used, rather than simply referencing Thiele et. Al 2024 as mentioned above.

We agree with the reviewer and have made the necessary additions.

It may also be useful for the authors to be slightly more explicit about the challenge of generalisation in the paper. In line 250, the authors address this problem by discussing the implications of the results from the Shapley analysis. However, for readers who do not have much knowledge about CNNs it may be useful to add the following sentence at the beginning of the paragraph:

"A common challenge for deep learning models based on CNNs is whether or not they can be generalised. In this study, training and applying the model to 3 drill cores from the same geological sequence does not mean that similar results could be attained in different geological sequences. However, given the results from our Shapley value analysis, we suggest ... "

Additional clarification about the problems with generalisation has been added as suggested on L10.13:

"A common challenge for deep learning models based on CNNs is whether or not they can be generalised. In this study, training and testing the model on three drill cores from the same stratigraphic sequence does not mean that similar results could be attained in different regions. However, given..."

Q) Are the number and quality of references appropriate?

Check

Q) Is the amount and quality of supplementary material appropriate?

Check