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Interactive comment on "How can geologic decision making under uncertainty be improved?" *by* Cristina G. Wilson et al.

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OVERVIEW COMMENTARY

This manuscript represents a valuable contribution to the geological literature applying established psychological understanding of decision-making to the interpretation of uncertain geological information. I support its publication in Solid Earth as a means to highlight this field of research to geological interpreters in various sub-disciplines.

My overview comments below highlight some observations that are intended to provide an alternative perspective to the authors that may contribute to some improvements, though actions are not expected on all points. I would be pleased to discuss any of my comments further with the authors.

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Throughout the manuscript the term decision-making is used in various ways. There may be benefit in clarifying the type of judgement (is it primarily subject to aleatory or epistemic uncertainty) and the sensitivity of the final outcome to that decision. This may allow clearer suggestion of which biases / debiasing strategies are most significant for that case. Furthermore this may add weight to your overall argument, identifying (in-line with past work) that higher impact (more summative) decisions, may be more vulnerable to significant impacts of human bias (Begg, Welsh, & Bratvold, 2014).

The case studies are well-written and demonstrative of discussed principles. The description of the geological issue could be shortened, while discussion of the psychological perspective and suitability of a particular approach to address the identified psychological issues raised should be enhanced.

Throughout the manuscript there are a number of comments regarding implementation of IT and AI solutions. These comments should be justified with expansion on the specific aspect of human bias or decision-making uncertainty that is being addressed, linking the comments back to the theme of the manuscript. Without this justification, the comments are slightly redundant and detract from the overall message.

DETAILED COMMENTARY

P. 1; ln. 1-16: Suggest the abstract should be broken into paragraphs, though perhaps this is a formatting error within the manuscript submission process (?).

P. 2; ln.11: Repetition of preservation / exposure issues from ln. 8-9.

P.3 ln. 7: Are there any further comments to be made on biases that have not already been considered in the geological literature? Is there value in future work on these themes?

P. 3; ln. 18: May benefit from clarification of how 'maximising the utility of a decision' relates to a problem where your aim is to best characterise a system, rather than maximise or minimise an individual parameter such as volume or cost.

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P. 3; ln. 14: It may be useful to define decision-making and discriminate between decisions at different levels, i.e. calculation of individual parameters versus overall interpretations, throughout the manuscript. In the latter elements this would enable more seamless reference back to earlier points of discussion.

P. 3; ln. 15: Normative decision models. Though the current examples are clear for a non-specialist reader, may benefit from direct relationship of these principles to a geoscience problem featuring a sparse and irregularly sampled time series (less common with the normal economic and financial examples).

P. 4; ln. 3: Completely agree with the direction of your argument here, however it remains ambiguous, geoscientists can make optimal choices, however it may be worth noting that an optimal choice may be consideration of multi-scenario interpretations (common in the hydrocarbons industry).

P. 5; ln. 18: Perhaps this line could be framed as a description of what is to follow, rather than a continued description of the intuitive and deliberative causes.

P. 7; ln. 4: Arguably, students may have an advantage in some of these settings as they may have more recently experienced a broader range of geological settings and applications.

P. 8; ln. 10: Great to see this highlighted, however are the experts addressing epistemic or aleatory uncertainty in this exercise? The prediction of the range of variability could indicate that this would be an aleatory uncertainty, unless guided by an underlying epistemic uncertainty in the interpreted mechanism of corrosion.

P. 9; ln. 28: Multi-scenario modelling is common in some sub-disciplines, making the general application of this statement to the whole discipline of geology inaccurate.

P. 11; ln. 34: Which models are referred to here (i.e. mental, geological, risk-models)?

P11; ln. 13-16: Personal opinion: This highlights the importance of sensitivity analysis, adding a sensitivity analysis to the end of any workflow providing immediate feedback

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to the practitioner (/learner).

P.12; ln. 20: Much of the uncertainty training available to industry focusses on understanding probability and raises awareness of bias in this context. In reality this is normally coupled with training in a structured workflow, potentially negating the implications of Fischoff's description despite its broader relevance.

P. 12; ln. 22: Depending on the location of this box, a definition of choice architecture and nudging may be required.

P. 12; ln. 30: The description of choice architecture should be clarified with a more concise description.

P. 13; ln. 7: Suggested that this paragraph be broken up.

P. 13; ln. 20: A comment or citation with regards to standardisation of workflows in petroleum engineering would be well placed here.

P. 14; ln. 35: Check for the plurality of data.

P. 14; ln. 37: Could a steeper line also indicate a simpler problem?

P. 16; ln. 9-11: On expert elicitation, it may be useful provide examples of how statistical approaches could be used to guide appropriate filtering and averaging of expert opinions (e.g. Aspinall, 2010).

P. 17; ln. 6: Considering this section; the principle advantage to this approach seems to be the reduction in cognitive load on the geoscientist during acquisition freeing up time for field location interpretation and potentially making a more uniform/complete dataset. Reading this section, I felt the psychological advantage was slightly disjointed compared to the psychological challenges (including bias) discussed earlier in the manuscript. A sentence framing the issue in line with the intuitive / deliberative thinking (P. 4; ln. 15) may provide a route to achieving this?

P. 19; ln. 16: Could the sub-titles of the case studies be altered slightly to indicate

their psychological significance. e.g. Case study 2: Automation as a tool to allow more deliberative thinking. Case study 2: A nudge to verify fault interpretation.

P. 19; ln. 21: The analysis/interpretation of seismic volumes is inherently 3D, even if visualisation is in 2D. Methods such as 3D geobody extraction, geometric attribute analysis or horizon extractions are commonly employed and 3D in both analysis and visualisation. Description of the geological technique could potentially be summarised, allowing further discussion of the psychological challenges to be addressed.

P. 20; ln 19: Nice example of using nudges to influence workflow decision. Again, description of the geological technique could potentially be summarised, allowing further discussion of the psychological challenges to be addressed.

REFERENCES

Aspinall, W. (2010). A route to more tractable expert advice. Nature, 463(January), 294–295.

Begg, S. H., Welsh, M. B., & Bratvold, R. B. (2014). Uncertainty vs. variability: What's the difference and why is it important? In SPE Hydrocarbon Economics and Evaluation Symposium. Houston, Texas: Society of Petroleum Engineers.

Bentley, M., & Smith, S. (2008). Scenario-based reservoir modelling: the need for more determinism and less anchoring. Geological Society, London, Special Publications, 309(1), 145–159.

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