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Conceptual Bias in Faults

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Summary

Conceptual bias in geoscience is unescapable. Fault-related bias is common in seismic interpretations, in regionally-based perspectives and in communications we use. Such bias can impact many existing and emerging projects in which fluid-injection schemes are being planned; unexpected out-of-zone fluid flow and unwanted earthquakes has environmental and socio-economic consequences. The effects of bias can be reduced by our continuous awareness, due diligence, and nuancing our wording. This benefits project risk analyses, planning and mitigation.

Introduction

Conceptual bias – as used in here – is a general term referring to any bias that arises due to errors from faulty logic, assumptions or misguided beliefs. It may lead to incorrect conclusions from observed data or statistical tests, or lead to inaccurate interpretations and models. Therefore, it can impact project risk analyses, commercial evaluations and decision making. Negligence can also be an unwelcome result from bias.

When looking at the existing and emerging Energy sectors, it is important to be aware of bias:

- the Western world is experiencing exponential growth in the number of sequestration schemes, geothermal projects, and self-proclaimed technical experts
- a workforce is being redeployed from petroleum exploration into new energies
- the global reach of unfiltered social media

Below are four examples showing how conceptual bias is present in the structural geology realm.

(1) The Same Fault, yet Different

In a structural geology workshop that I once organized, participants were asked to interpret a seismic section (Figure 1). The main structural features were observed and interpreted by all; in contrast, a range of interpretations was given for the upward extent of faults and for the linkages of faults. The result of this basic exercise reiterated that 'conceptual uncertainty is inherent in seismic interpretation' (Bond et al., 2007).

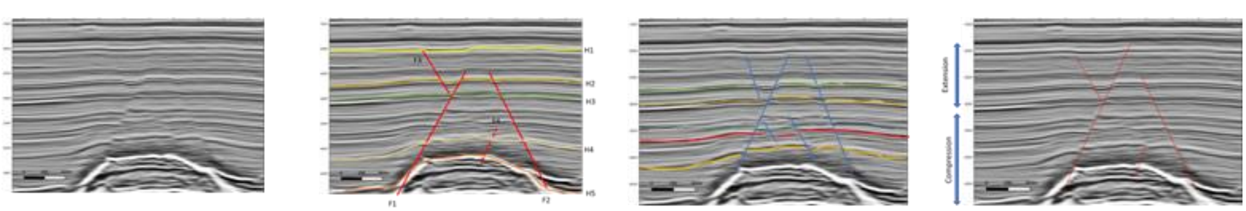

Figure 1: [left] uninterpreted seismic section; [others] three selected interpretations showing an inherent discrepancy in both method and interpretation results based on the same input (n=43).

To expand the exercise, recognizing the difference between data, observation, interpretation, and maps & models is important in understanding where bias comes into play. Using Figure 2, the number of assumptions and possible scenarios increase when going from left to right. In quantifying words: data (facts) are agreed upon by most people; observations are agreed upon by many people; interpretations are agreed upon by several people, and models (representations) are agreed upon by some.

Figure 2 – schematic linkage

The number of scenarios at each step is influenced by data quality, data quantity, parameter uncertainty and the amount of white space; but also, available literature, legacy interpretations, and project time available.

It can be of concern when alternate interpretations or models are being suppressed, for example when addressing project risks and uncertainties. It is not uncommon to see fiery disputes over tectonic models, seismic migration processes or seismic velocity models.

It can also be of concern when conceptual models are being taken as factual, especially in areas where observations or interpretations are scarce. Take for example the impact of clay diapir models in relation to seismic imaging and interpretation.

(2) The Nuance of Wording

Whether a glass is half-filled or half-empty addresses the same observation, but it yields a different meaning. With the words that you choose, you can bias people's minds and you can influence people's decisions (Barry, 2022). Many skilled authors know how to manipulate words and sentence structures. Conversely, not everyone is a wordsmith or a master in a specific language. Hence, there is misunderstanding and bias in wording and/or the interpretation thereof.

Consider the following examples:

- The title of several papers: "*The tectonic model of* …"; so, there is only one model?
- A post on social media: "*During the CCS process, CO_2 is injected into the subsurface of a suitable reservoir, where it will remain permanently trapped. Forever*." This is quite certain.
- A reply to a proposed model: "*No, you're wrong!*"; effectively preventing debate.
  Perhaps *"The likelihood of your scenario is low"* is more inviting to a conversation.

There are many more examples; I am sure you can think of a few. Some wording is done on purpose, and some is lost in translation; yet, there is nuance in wording that we need to be mindful.

(3) The Nuance of Graphics

Maps, models and cross sections can also influence people's minds. For example, changing the line style of contacts can show interpretation certainty: a solid line denotes 'most likely present', a dashed line 'likely present', and a dotted line 'inferred' (Figure 1b). Such qualifiers appear to be less common in interpretations and on final products (maps, cross sections, models) in recent history, which could lead to misrepresentation or misinterpretation.

A few considerations: First, was it the intention of the author to qualify certainty? Some graphics are intended to be conceptual only, which may not require contacts to be qualified. Second, interpretations, maps, models and cross sections are being created using powerful modeling software. At the interpretation stage, contact qualifiers can still be applied, but at subsequent mapping & modeling stages, contacts are rendered uniform throughout. It is possible to re-introduce qualifiers after the modeling is done, by re-introducing contacts as polygons and splitting them up. Such detailed work can be time consuming and not all authors will perform this step.
Last, how does the reader 'read' the image? Will the figure caption be read, or is the diagram taken out of its original context, for example on social media, where first movers tend to be heard. In this instance, similarities with the 'broken telephone game' arise.

(4) a Matter of Perspective

A picture can become clear if you can look at it from different angles. In petroleum exploration, we are looking for prospects in which fluids have stayed; in CCS-projects, we are looking for prospects in which fluids will stay. So when evaluating fault-bound prospects, we should not only look at fault seal, but also at fault leakage.

In the North Sea basin in the 1990's, across-fault fluid flow became widely accepted as the fault seal/leakage mechanism (a.o. Yielding, 2002). A myriad of research, software packages, and publications emanated from Western Europe in the following decades, all assuming this mechanism at its foundation. The same region is now at the forefront of many CCS-projects, many publications are flourishing, most of which focus only on the existing correlation.

But, across-fault fluid flow is not the only component to address in fault seal/leakage. Faults in basins that undergo rapid migration and fluid fill appear to dip seal; despite seeps along the surface trace of the faults, which indicate dip leakage (Skerlec, 1999). Such traps have a 'fluid valve' and are associated with fault reactivation and fault-parallel fluid flow. This mechanism is demonstrated in a.o. the Gulf of Mexico (Finkbeiner et al., 2001), the South China Sea (Brem, in preparation), but also in the North Sea (Wiprut & Zoback, 2002). It can even be shown using a fractured showerhead!

Interestingly, the fault-parallel fluid flow model is not widely accepted among geologists as a fault seal mechanism. Furthermore, the underlying workflow is not part of many geological software packages.

Conclusion:

Conceptual bias in geoscience is unescapable. A few examples on fault-related bias are shown herein. The effects of bias can be reduced by our continuous awareness, due diligence, and nuancing our communications.

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