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Uncertainty in Seismic Interpretation: The Use of Forward Modelling to Help Structural Understanding in Deep Water Fold Thrust Belts

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Seismic interpretation is a key element in an exploration workflow. However, the uncertainty in a geological model resulting from a seismic interpretation is not systematically assessed as part of a normal exploration workflow. This is despite seismic data, and hence its interpretation, having an inherent uncertainty. Recent work has shown that the range of interpretations applied by professional geoscientists to a single 2D synthetic seismic line resulted in contrasting tectonic models i.e. compressional, extensional, strike-slip… (Bond et al., 2007). The application of these competing conceptual models to the interpretation exercise highlights the under-constrained nature of the exercise data, common across the geosciences, and the uncertainty in seismic interpretation. For any under-constrained problem there is not a unique solution and analogues and models need to be used to aid understanding.

For better imaged seismic data sets, constrained by additional knowledge of the tectonic setting and/or local analogues, the uncertainty in seismic interpretation may fall more into the realm of the precision of fault or horizon placement. However, in all seismic datasets there are areas that are poorly imaged. The ‘steep’ limb of thrust structures often lie in such poorly imaged areas and can be difficult to interpret. For these badly imaged areas it is possible to draw ‘sausages’ that define the X, Y, Z space of uncertainty in fault location or steep limb angle.

Uncertainty ‘sausages’ acknowledge that interpretational uncertainty exists but do not provide any clues as to the range of conceptual structural models that may have created the structure. That is despite the potential to use the normally better imaged hanging wall geometry to help constrain the range of applicable models. Sharing interpretations, knowledge and analogue information, is important for understanding this range of conceptual uncertainty for a given dataset. Using examples of thrust structures from the Virtual Seismic Atlas (VSA) we have created multiple conceptual models of thrust fault generation for a deep water fold thrust belt setting i.e. fault propagation fold versus trishear. The models created span a range of possible concepts that affect not only fault position and hanging wall geometry, but also the mechanics of the structural evolution.

Using a well-imaged deep water fold thrust structure as an example, we have forward-modelled potential end member concepts for its structural evolution. As well as creating forward modelled scenarios that geometrically match the observed seismic structure in the hanging wall we have mapped the strain accumulated during the forward modelling. The mapped strain has been used to assess the impact of model choice, or structural evolution, on the potential locations of sub-seismic deformation. The results show that the chosen model is likely to have implications not only on fault or horizon placement but on parameters important for exploration decisions such as reservoir compartmentalisation, hydrocarbon volume and permeability. In the case study chosen the seismic imaging is of a quality that the forward modelled geometries and strain maps can be compared directly with the well-imaged faults, folds and associated "sub-seismic" deformation. In this case the best-fitting forward model and it structural evolution may be used as an analogue for similar, but less well imaged structures elsewhere. We argue that the question is not whether we can quantify the uncertainty in seismic interpretation, but the impact of this uncertainty on the key decision making parameters.

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Reference

Bond, C.E., Gibbs, A.D., Shipton, Z.K., and Jones S. (2007). What do you think this is? 'Conceptual Uncertainty' in geoscience interpretation. GSA Today, v17, 4-10. doi:10.1130/GSAT01710A.1