P07

Fault Seal Risk Volumes - Assessing Uncertainty in Prospect and Field Development

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SUMMARY

Fault seals can be both beneficial and/or detrimental to the generation of traps and the economic extraction of hydrocarbons from reservoirs. From exploration to development, the resolution at which fault behaviour needs to be understood varies, as does the data available to determine that behaviour. In this contribution we present new methods for mapping the potential seal risk of a spatially variable stratigraphic sequence. Both exploration and production scenarios are investigated and probabilities for different seal types from juxtaposition to membrane seals are calculated and mapped. Where more data is available (in production settings) permeability retardation or enhancement risk can be mapped over the reservoir area and through the stratigraphic volume. Risk mapping allows rapid assessment of fault-related reservoir compartmentalisation, which is often critical in more complex structural settings. Risk map interpretations can then be used to generate new faults in the grid that better honour likely layer connections while honouring the information gathered from the dynamic data. Overall the technique allows for a better understanding of the uncertainty due to faulting and hence a greater ability to focus potential new data acquisition, to direct further interpretation and to rapidly generate multiple realistic scenarios to mitigate these risks.

Fault seals can impact both trap generation and economic hydrocarbon extraction. The resolution required to characterise fault behaviour and the data available will vary between exploration and development settings. During exploration, the identification of structures capable of supporting relatively large columns is a key aim; alternatively, for production, defining the potentially baffling nature of intra-reservoir faults may be critical. In both arenas, determining the sealing nature of the sequence is the primary aim for fault seal studies. In addition, it is also important to assess the impact of a similar structure in different locations (Tveranger *et al.*, 2008). Potentially risky structures could, if defined, be targeted for further interpretation or data acquisition. This first-order risk assessment is not routinely undertaken because of spatial variations in stratigraphy and fault throw. Lateral variations in these systems generate both sealing and leaky windows, which can vary along strike.
We present new methods to map potential seal risk in a spatially variable stratigraphic sequence. For exploration cases the results are returned as a percentage likelihood of a seal, non-seal (intra-reservoir juxtaposition), or cross-fault communication potential. For production cases the results are returned as the likelihood of permeability retardation or enhancement. Risk volumes are generated using supplied stratigraphic geocellular volumes and the results can be displayed as maps, sections or volumes that colour code the potential effect of a fault on a sequence. This provides an effective and intuitive means of defining seal risk and potential compartmentalisation (Jolley *et al*., 2007) within a reservoir sequence (e.g. Figure 1c). In addition to risk mapping, tools have been developed to create new faults within geocellular volumes so that additional structures can be incorporated into fluid flow simulation with the correct set of cross-fault permeability connections.

Risk mapping methodology

Cross-fault juxtaposition can affect trapping and communication in reservoirs. The juxtaposition of permeable and impermeable units across a fault will retard fluid flow, although this depends on both the stratigraphy and structural geometry. For a given stratigraphy the impact of a fault with a given throw can be readily determined. Self-reservoir juxtaposition occurs if the throw is less than the reservoir thickness at that location. Figure 1(a) shows a progressively offset sand unit. In this case the fault seal risk is easy to define, as self-juxtaposition of the sand occurs until the reservoir is completely offset and until this occurs the probability of self-juxtaposition is 100%. If either the sand thickness or throw changes spatially then the probability of self-juxtaposition will vary; this is the simplest form of spatial seal risking.

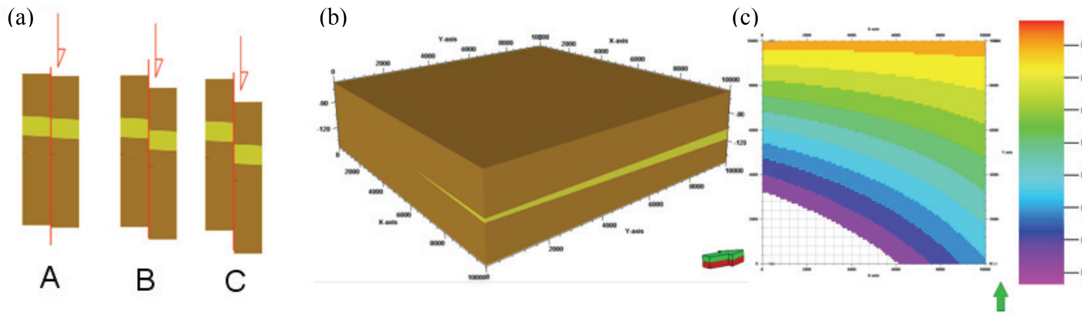

Figure 1 *(a) Stratigraphic column showing sequential offset of a sand package. Sealing only becomes effective at total offset. (b) Stratigraphic model with a thinning sand unit surrounded by shales. (c) Risk map for the thinning sand slab for intra-reservoir juxtaposition.*

Figure 1(b) shows a sand thinning within a shale package. A fault in the SW may completely offset the reservoir; however, as the sand unit thickens to the N the probability of reservoir self-juxtaposition increases for the same throw. The probability map (Figure 1c) shows that for the reservoir unit, a fault with 0–15m throw is most likely to offset the reservoir in the SW of the area (probabilities below 50%), whereas reservoir self-juxtaposition is more likely in the N and NE (as the sand thickness approaches the maximum fault throw).

Multiple stacked reservoirs

Stacked reservoirs with complex juxtaposition seals are common in many petroleum systems. Predicting the impact of faulting for a given throw range in a stacked sand sequence may be critical to prospect evaluation. The methodology described above can be also used for more complex examples. Figure 2(a) shows three sands laterally varying in a reservoir model. Figure 2(b) shows the likelihood of juxtaposition of the middle and lower reservoirs. Figure 2(c) incorporates both membrane and juxtaposition seals; in this case the probability of a seal assuming that a 20% shale gouge ratio (SGR) is sufficient to form a capillary seal for a specified column height and fluid properties is shown.

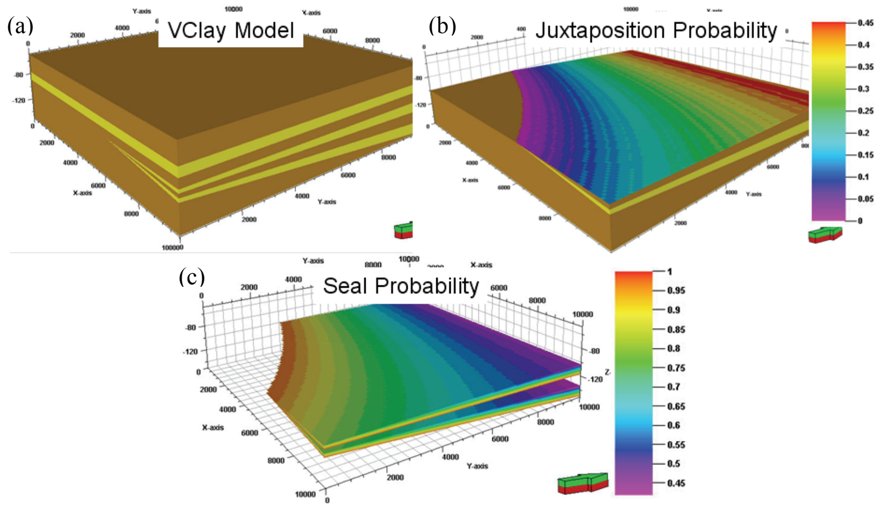

Figure 2 *(a) Laterally varying sand model. (b) Probability of juxtaposing middle with lower reservoir sands for a 0–30m throw fault. (c) Seal risk assuming a 20% SGR and reservoir:reservoir juxtaposition control the cross-fault flow potential (0–30m throw fault).*

This technique has also been applied to more complex cases with highly complex stratigraphies and geometries.

Conclusions

Fault seal risk mapping in 3D geocellular volumes rapidly identifies high seal risk areas, helping to target further interpretation and to quantify uncertainty. This approach rapidly defines likely trap sites or potential compartmentalisation for exploration and areas of transmissibility retardation or enhancement within the reservoir due to faulting for production. This information can then be used to validate existing faults or potentially create new ones in the grid that better honour both likely layer connections and dynamic data. The techniques presented here provide an effective platform for rapid risk mitigation through the quantification of fault-related uncertainty.

References

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