Outcrop-Based Reservoir Models: Fieldwork-derived Numerical Laboratories to Constrain and Mitigate Subsurface Uncertainty

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Abstract

Reservoir characterization is an exercise in constraining uncertainty that arises from sparse sampling of the subsurface by widely spaced wells at length scales below seismic resolution. Outcrop analogs are an invaluable complement to well and seismic data in this context, because they provide qualitative concepts and quantitative spatial data to guide interpretations of lithology distribution in inter-well volumes. However, analog-driven interpretations of reservoir architecture are not straightforward to compare with dynamic data that describe fluid flow during production – the acid test of any interpretation of reservoir geology. The value of outcrop reservoir analogs is most fully realised when they are used to construct outcrop-based reservoir models that enable explicit predictions of flow patterns in a form that can be compared with routine reservoir-monitoring data.

This presentation will draw on an inventory of integrated, inter-disciplinary studies that have developed tools, methods and applications of such outcrop-based reservoir models, using examples from shallow-marine siliciclastic reservoir analogs. The critical elements required to relate outcrop observations to predictions of reservoir flow behavior include:

1. careful selection of outcrop analogs that match key aspects of the target subsurface reservoir;
2. characterization of outcrops that allow pseudo-3D architectural relationships to be constrained at appropriate length scales;
3. appreciation of the limitations and uncertainties in interpretation of the outcrop analog dataset;
4. use of modeling tools and methods that accurately capture observed geometric and spatial relationships;
5. an experimental approach to model design and use, which enables uncertainty in geologic interpretation to be investigated;
6. direct flow simulation of the outcrop-based reservoir models; and
7. extraction of proxies for reservoir-monitoring data from flow simulations.

The goals of this approach are to identify which geologic heterogeneities exert most impact on fluid flow in the reservoir, to relate these heterogeneities to characteristic flow patterns, and to identify monitoring signals that allow these flow patterns to be identified and mitigated in the reservoir. Fieldwork is the essential starting point for this holistic approach to reservoir characterization and modeling.