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Identification, Upscaling and Modeling Strategy for Multi-Scale Fracture Networks in Variable Lithology Reservoirs

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SUMMARY

Modelling of multi-scale fracture and fault networks is highly uncertain, relying typically on a range of parameters (size, shape, flow properties, connectivity, spacing, orientation) with individually large or sometimes unknown ranges which are very difficult to quantify. Analog data can be used, but resulting models are often unsuitable for well placement or detailed production monitoring in fields under development.

Borehole image data are critical in the static (geological) description of the fracture network, but in the absence of dynamic information (e.g. mud losses while drilling, PLT, production, long-term well test) the relative contribution of fractures and fracture networks is speculative. This study highlights the challenges of building a hierarchical description of fractures and connected conduits in a sour gas reservoir which has not started production. In addition, constraining dynamic behaviour is hampered by extreme operational limitations (only short duration well tests and production logging is not feasible).

This case study describes a workflow for characterising fault / fracture networks in the pronounced mechanically layered Arab Formation (Late Jurassic) reservoirs of onshore UAE.

Introduction

Modelling of multi-scale fracture and fault networks is highly uncertain, relying typically on a range of parameters (size, shape, spacing, orientation, aperture, degree of fill, connectivity) with individually large or sometimes unknown ranges which are very difficult to quantify. Analogue data can be used, but resulting models are often unsuitable for well placement or detailed production monitoring in fields under development.

Borehole image data are critical in the static (geological) description of the fracture network, but in the absence of dynamic information (production, long-term well test, PLT) the relative contribution of fractures and fracture networks is speculative. This study highlights the challenges of building a hierarchical description of fractures and connected conduits in a sour gas reservoir which has not started production. In addition, constraining dynamic behaviour is hampered by extreme operational limitations (only short duration well tests and production logging is not feasible).

This case study describes a workflow for characterising fault / fracture networks in the Arab Formation (Late Jurassic) reservoirs of onshore UAE, underlying the regionally extensive Hith Formation (anhydrite) top-seal. The Lower Arab comprises a 250-300ft thick succession of tight lime mudstones with thin bioclast-rich layers, abundant stylolites and layer-bound fractures. This is overlain by a mechanically weaker 60-100ft oolitic grainstone unit. The overlying upper Arab Formation (180-250ft thick) is an alternating sequence of thin dolomitic limestones and bedded anhydrites.

Methodology

The initial challenge was to accurately describe the different scales of fractures from borehole images calibrated with core data and seismic. The different imaging tools (wireline & LWD), drilling conditions and wellbore trajectory resulted in variable expression of features on image logs. Early on, it became apparent that the majority of fractures in the lower Arab mudstones are short, layer-bound and emanating from stylolites.

The presence of regional, conjugate shear-fracture zones (vertically continuous across reservoirs) is known from nearby fields, but poor seismic quality hampered their recognition. Potentially conductive shear-fracture zones were initially searched for on image logs in the upper Arab grainstones, where layer-bound fractures are uncommon. Criteria such as orientation, clustering, dip anomalies and openhole log responses were used to extract features that could be validated at seismic scale. These zones may be fluid-conductive, cemented or mixed. On seismic data they are expressed as lineaments with varying degrees of confidence and continuity.

A third structural element, reverse faults parallel to the anticline, is much clearer on seismic but more subtle on borehole image logs. However, larger segments could be seismically mapped with higher confidence and calibrated with images and core as mainly resistive (cemented) features, potentially locally segmenting the field.

Conclusions

The various scales of fractures clearly require different modelling strategies. Layer-bound fracture and stylolite networks, whilst very striking on borehole images, are vertically discontinuous and can be modelled using modified matrix properties with permeability anisotropy reflecting their strong preferred orientation.

Shear fracture clusters appear to be randomly spaced throughout the field with certain preferred directions (conjugate sets), although some features cluster at a larger scale forming more continuous corridors. The latter can be modelled deterministically, although their dynamic impact is still uncertain (local barriers/baffles, conduits or both).

Larger reverse faults can be deterministically mapped and assigned properties (mainly local barriers / baffles) which may impair horizontal and vertical flow due to their lower angle dips (ca. <45deg). Sub-seismic scale smaller features clustering around larger reverse faults can be represented by local (area-specific) transmissibility modifiers.

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