Challenges in Building and Calibrating Mechanical Earth Models in Complex Tight-Gas Reservoirs for Hydraulic Fracture Optimization Projects

Sawsan S. Al Sadi[1], German D. Merletti[1], Peter Armitage[1], Safa Al Breiki[1]

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Abstract

Tight-gas sandstones are low-permeability, gas-bearing reservoirs that require hydraulic fracture stimulations to produce wells at economic rates. The giant Khazzan-Ghazeer gas field located in the Sultanate of Oman contains two main Paleozoic reservoirs, the Barik and Miqrat. There are two main challenges related to the stimulation of the Barik reservoir. The first one is related to the reservoir configuration that can prevent a single-stage hydraulic fracture from propagating evenly away from the borehole. The second challenge consists of controlling the hydraulic fracture (HF) growth when initiated in good quality reservoirs in the proximity of a gas-water contact (GWC). Mechanical Earth Models (MEM) are critical for fracture modeling and optimization to determine the optimum stimulation design. This study describes the workflow applied to build a robust MEM for the Barik and its calibration after each fracture treatment with a thorough description of sources of errors that could lead to inaccurate stress profiles and misleading HF geometries.

An Elastic Horizontal Strain model is utilized to build the MEM that uses core tests, wireline logs and pressure decline analysis from injection tests on sandstones and encasing shales. Pseudo-static rock mechanical properties are obtained by single-stage triaxial compression tests. These discrete pseudo-static properties are correlated to their equivalent dynamic properties that are computed from high-frequency wireline acoustic logs. Overburden stress is calculated using integrated bulk density log from the surface to the depth of Barik reservoir. Pore pressure is directly measured using wireline formation testing tools. Wireline MicroFracs delivering layer-by-layer closure stress and Diagnostic Fracture Injection Tests (DFIT) performed over gross interbedded lithologies are used to assess minimum horizontal stress.

There are multiple pitfalls that could potentially compromise the accuracy of the MEM. Quality controlling the input data that go into the MEM calculations is the first step to prevent the inaccuracy of the generated stresses. For example, using bulk density in the overburden stress calculations without correction for washouts, or using poorly processed compressional and shear acoustic logs in the dynamic properties' estimation, or the inclusion of unreliable core plug measurements for deriving dynamic-to-pseudo static property functions. All can introduce errors to closure models if not properly quality controlled leading to wrong hydraulic fracture geometries. The MEM is dynamically calibrated by history matching the modeled net pressure with the recorded net pressure. Up to 70m difference in hydraulic fracture length between poorly- and fully calibrated MEM in the Barik reservoir has been observed.

This technical work demonstrates the value of building robust mechanical earth models (MEM) for stimulating and increasing the productivity of tight-gas reservoirs. Special emphasis is put on describing multiple sources of misleading data that can potentially compromise the accuracy of MEM. We successfully overcame the challenge posed by heterogenous reservoir stacking patterns and we provided evidence supporting the

need for one or two additional fracture stages. We also built confidence to limit the fracture propagation into undesirable water- bearing layers, therefore maximizing the productivity of gas-bearing intervals.