Geomechanics Aided Solution to Support Drilling and Completion of Dadaş Unconventional Reservoirs, SE -Türkiye

Fethi Bensenouci[1], Ahmet Ergün Mengen[1], Canalp Özkul[1], Artem Orlov[1], Kirill Ezhov[1], Mehmed Ekrem Yazaroğlu[1], İsmail Ömer Yılmaz[2]
[1]Exploration Department, Türkiye Petrolleri Anonim Ortaklığı (TPAO), Ankara / Türkiye
[2]Department of Geological Engineering, Middle East Technical University, Ankara / Türkiye

INTRODUCTION

Exploring unconventional reservoirs is known to be technically and economically challenging from drilling to reservoir evaluation and stimulation. In order to develop unconventional reservoirs, oil companies have to drill and stimulate high number of wells which makes geomechanics studies crucial to provide necessary insights for successful operations. Dadaş Silurian shale, located in SE- Türkiye, are being explored as unconventional reservoir by the TPAO for decades. Numerous problems related to formations instability and or pore pressure have been reported while drilling these formations. Hydraulic fracturing completed in some wells turned out to be also very challenging in various intervals. Considering these different problems, a geomechanics study is completed at different scales in Dadaş field to help improving, in the short term, hydraulic fracturing operations and provide solutions for drilling optimization to limit drilling-related non-productive time and bad hole conditions.

METHODS

The study starts by collecting all relevant and available data that can be used as input in geomechanical parameters calculations or help to calibrate the obtained results. Then, the collected data is reviewed, classified and corrected when required. The lack of data like shear slowness logs is tackled using rock physics. Rock properties are calculated using wireline logs and calibrated with mechanical core tests. Pore pressure calculation is predicted using Eaton and Bowers methods, calibrated by drilling events and hydraulic fracturing results. Vertical stresses are calculated based on bulk density, whereas horizontal stresses calculation is done using a poro-elastic model. Considering the 1D modeling limitations e.g. effects of geological attributes such as: non-horizontal horizons, faults, fractures and evolution of stresses away from the wellbore wall, it was decided to complete the study with an advanced 3D geomechanical modelling. The 3D model offer a solution that provides stresses in magnitudes and directions computed over the whole field or reservoir. The 3D modeling integrates 1D data and 3D seismic inversion results available in one block of Dadaş field. The main tools used for this study are Techlog™ for 1D modelling and Petrel™ with VISAGE™ for 3D modeling.

RESULTS

After a data audit including core analysis, daily drilling reports (DDR) review and wireline logs QC, 12 post-drill 1D Geomechan-ics models known also as 1D MEMs (for Mechanical Earth Models) are completed to provide, in a low Turnaround Time, necessary data for hydraulic fracturing design. Elastic properties and rock strength parameters are found to vary with depth and rock mineralogy. Rock properties calculated along the studied sections show some similarities with Vacca Muerta shale in Argentina. However, more mechanical lab tests are still needed to complete better the characterization of the mechanical properties of Dadaş shale. Pore pressure in the different wells show some lateral variability in Dadaş-I member even within one block. Overall, we see that pore pressure gradients tend to increase toward the center of basin. This parameter will be subject to further investigation after receiving additional data from the current operations. Horizontal stresses calculations show vertical and lateral heterogeneities over the field. The minimum horizontal stress gradient ranges from 0.75 psi/ft to 1.1 psi/ft, with a stress regime varying from normal to strike/slip and, locally, reverse (Figure 1). The maximum horizontal stress calculation is validated with wellbore stability analysis. Sensitivity analysis of wellbore stability with respect to hole deviation and azimuth is completed at selected depths in Dadaş-I member. This analysis aims at defining the most stable azimuth for planned horizontal sections; however the results do not show high sensitivity on borehole direction for deviation angles close to 90°. In that case drilling toward the minimum horizontal stress direction is recommended. The 1D geomechanics results are integrated with petrophysics outputs to select and rank the wells candidate for fracking operations and also to define the best perforation intervals for each well. The 1D results are also used as inputs in the 3D modelling phase.

A 3D geomechanical model is completed based on the most complete structural model available for the reservoir, including geological attributes, seismic, pore pressure field and spatial grid. It aims at calculating rock properties and in-situ stresses at 3D scale over a field or a block. In this study, rock properties are populated within a structural model in Dadaş by integrating 1D MEMs, acoustic impedance and VpVs ratio from seismic inversion in depth domain. In-situ stresses are calculated in the pre-production condition using the finite element simulator VISAGE, calibrated with 1D stress profiles and closure pressures from hydraulic fracturing. The final 3D stress results capture well enough the heterogeneity noticed at well scales. Limited variation of stresses magnitudes and orientations is noticed near the major faults acting as discontinuities within the field. Also, the impact of the faults in the field is different between the ones striking E-W and those striking NNE-SSW. The combination of 3D in-situ stresses and 3D rock properties allows the calculation of 3D wellbore stability parameters, an important tool in drilling designs. The 3D analysis provides also additional attributes to investigate the best future wells locations in the field (Figure 2) and to support the natural fracture modeling (DFN). Finally in-situ stresses are used as input in a discontinuity stability analysis to define the most critically stressed natural fractures and faults. The combinations of all these attributes will help to define the best locations of the future wells.

CONCLUSION

For the first time in Dadaş field, a multi-scale Geomechanics study is completed to support decision making during the exploration phase. The post-drill 1D Geomechanics integrated with Petrophysics allows to select the well candidates for the hydraulic fracturing campaign and also to define the perforation intervals. Rock properties calculated at well scale show vertical variability related to mineralogy but low lateral heterogeneity in the same facies. Regarding pore pressure and horizontal stresses slightly higher lateral variability is noticed. By combining 1D rock properties and seismic inversion results, rock properties are populated within a structural model obtained from 3D seismic and stresses are calculated using finite element code. Stress magnitudes are calibrated with 1D profiles at well scale and closure pressures. The 3D model is able to capture the stress heterogeneity seen between the wells. The 3D results are used to provide more attributes like Fracture Gradient, Breakdown gradients, Stress Anisotropy, Brittleness… to support new prospect locations identification. The 3D results are also used to model natural fractures network within the studied block. As way forward, the integration of stresses, natural fractures network and reservoir properties will be integrated in a Two-way Coupling Geomechanical model to estimate the impact of reservoir depletion on fracture porosity and permeability and on production forecast.

Keywords: Dadaş shale, Multi-scale Geomechanics