Natural Fracture Modeling in Unconventional Dadaş-1 Member for 3D Seismic Survey: Case Study, Turkey

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OBJECTIVE AND SCOPE

Traditional description of unconventional reservoir like any natural fracture reservoirs relies heavily on quality and analysis of image logs and core data at discrete well locations. These data provide high vertical resolution information but soon becomes challenging to use and propagate away from the borehole. The presented modeling process is generally based on pure stochastic workflow that tries to achieve realistic 3D model of fractured reservoir by matching the well information, in-situ stress and capture inter-well heterogeneity using 3D seismic data. This workflow has been tested on unconventional natural fracture reservoir in Diyarbakir basin where late Silurian – lower Devonian age Dadas-1 organic rich shale member exhibits both low porosity and extremely low matrix permeability. Acting as one of the main source rocks in SE Turkey, it represents a self-sourced unconventional play. The interpretation of image logs and core samples reveals clusters of fractures suggesting a naturally fracture reservoir type 1. This study aims at using an integrated approach spanning from seismic interpretation to image log data analysis and 3D geomechanics to develop a discrete fracture network model (DFN) and to provide new insights into distribution of hydrocarbons since fractures is solely responsible for making this reservoir producible(Figure 1). In addition, a derived DFN model offers an opportunity to improve a reservoir modeling (static and dynamic), to provide the basis for design of an optimum well placement, stimulation, completion, production and could serve as a guide on how to improve the seismic acquisition/resolution to highlight valuable fracture zones.

METHODS, PROCEDURES, PROCESS

This integrated study uses borehole image log data acquired in the Dadas-1 member interval of 3 exploration wells: A, B and C, 3D seismic volume and 3D geomechanical model. Fracture modeling was performed using a fracture modeling software that calculates fracture permeability, porosity and matrix block size on 3D reservoir grids by constructing the DFN model. The main steps of the workflow were: 1). to use previously interpreted image log data and classify the natural fractures by fracture sets using dip azimuth distribution. The wellbore fracture data is dominantly striking in E-W and N-S directions with a large number having a high (> 60 degree) dip angle. Important to note is that the statistical likelihood of intersecting high (>50 degree) angled fractures is reduced by drilling vertical wells, suggesting that the vertical wells used in this study may be underestimating the true fracture density; 2) evaluate possible fracture drivers, defined as any 3D properties that can be sensitive to or capture directly fracture intensity information in the inter-well space. The fracture drivers used in our workflow are various post-stack seismic attributes: Variance, Curvature, Chaos, Ant-Tracking, Sweetness and etc. All tested seismic attributes are used as input to a multi-scale statistical correlation analysis where previously derived 1D intensity logs using image logs were matched. Because seismic domain comes with inherent resolution limitations compared to borehole data the fracture intensity logs were generated with different window filter size to evaluate the best scaling factor for optimizing correlation with the seismic domain. The best fracture drivers for the total intensity log before splitting on sets appear to be 3D Curvature (≈0.66 correlation factor), Chaos (≈0.43 correlation factor) and flatness (≈0.55). These 3 seismic cubes supervised by interpreted intensity values at well locations were used to derive 3D fracture intensity cube (or 3D fracture driver). The QC crossplot between interpreted and predicted intensity logs shows correlation value 0.88; 3) to review this analysis in the context of the seismic structural interpretation and regional tectonic framework. Since the fracture distribution and density relate to the tectonic features (faults), Ant-tracking 3D seismic attribute was used to derive seismically resolved faults/fractures. All captured by Ant-tracking discontinuities were split into two tectonic sets based in the strike direction and relationship to tectonic events: Set-1 fault polygons in black that have West-East orientation and formed during 1st tectonic event and Set-2 fault polygons in red that striking in North-South and formed during 2nd tectonic period (Figure 2); 4) to employ 3D geomechanical model to determine the likelihood of natural fractures undergoing tensile reactivation. This model does not consider variables such as fracture plane roughness, cementation, pressure variation, or the possibility of crystal bridging, which has been shown to enable fractures to remain open and permeable albeit not preferentially aligned with $\sigma 1$. Importantly, all fracture types (conductive, partially conductive and resistive) were used for the modeling. Natural fractures in shale, as weak planes of mechanical heterogeneity, can reactive and widen the treatment zone, affect propagation and intensity of artificial fractures. Even the cemented fractures, i.e. mineral veins, can considerably contribute to efficient hydraulic fracture treatment, because of the weak chemical bond between the fracture-filling minerals and their wall rocks that can be easily broken apart.

RESULTS, OBSERVATIONS, CONCLUSIONS

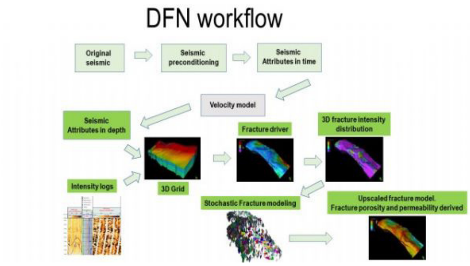
The analysis of natural fracture orientation, dip, aperture together with petrophysical data, seismic interpretation, paleo- and current stress regimes enable to build a 3D discrete fracture model, predict their occurrence in the Dadas-1 interval and used this output for dynamic reservoir modeling (Figure 3). Adopting the reasonable assumption that lateral heterogeneity of the fracture network is related to the major tectonic events, the seismic attribute analysis together with regional geology reveals two major sets of fractures: strike in ESE-WNW that relate to the first extensional tectonic event and the second with a strike NNE-SSW after paleo-stress rotation from E-W to N-S. Application of 3D geomechanical model reveals that not all fractures should be considered as point of weakness for the future fracking campaign. Only natural discontinuities that are favorably oriented to in-situ stress more likely to be critically stressed and hydraulically conductive. The result of this interpretation were used to predict hydrocarbon flowing zones (in the absence of PLT data). Accordingly, the selection of testing intervals on the basis of the highest density of fractures only is not a valid approach to determine prospective zones. From the structural point of view, in the current strike-slip/compressional regime, the fracture direction is the main control to hydrocarbon flow with the best contribution coming from natural fractures oriented close to the present day maximum horizontal stress.

NOVEL/ADDITIVE INFORMATION

The novel aspect of this project is the multi-scale approach rooted in seismic interpretation, detailed fault imaging and interpretation combined with attribute analysis, image log analysis combined together with 3D geomechanical model to determine the orientation of flow contributing fractures for optimizing well testing and design.

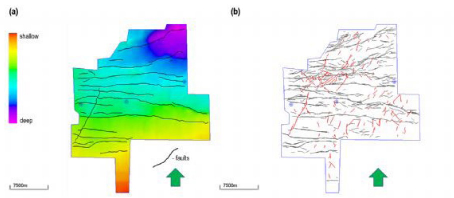
Keywords: Unconventional resources, fracture modeling

Figure 1



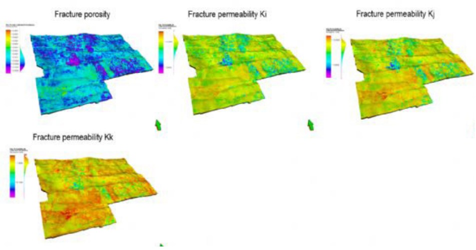
Discrete Natural fracture model (DFN) workflow

Figure 2



(a) The Top Dadas-1 structural map in depth and seismically interpreted fault polygons; (b) Fault polygons extracted from the Ant-Tracking seismic attribute. The polygons in black color are associated with the 1st tectonic event and the polygons in red color with the 2nd tectonic even

Figure 3



Derived from DFN model the fracture porosity and fracture permeability maps for unconventional reservoir of Dadas-1 member