3-D Geomechanical Restoration as a Tool for Fractured Reservoir Characterization: Example From the Permian Basin

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Abstract

Understanding the geologic factors affecting reservoir performance is critically important for operations in unconventional fields. In this study, we apply a 3D geomechanical restoration method to identify structural components that influence production and water cut from the Devonian Thirtyone Formation in a mature gas field within the Permian Basin of West Texas. The Thirtyone reservoir serves as a viable test case because it is a brittle chert with characteristics of a fractured reservoir. We integrate this technique with geologic and geophysical datasets indicating natural rock strains to assess the impact of deformation on reservoir performance. Well log and 3D seismic interpretations within the Atoka-Basement interval suggest the major structures are primarily anticlinal fault-bend folds, with the top of the Ellenburger serving as the upper detachment. However, in one area, a prominent fault-propagation fold soles into this detachment. We perform 3D restorations to model the strain patterns these structures experienced during fold growth. The strain tensor is calculated at each node of the volumetric mesh, which we use to analyze strain patterns across the study area. Moreover, we generate a semblance volume from 3D seismic to serve as a proxy for natural rock strain. After extracting semblance onto stratigraphic surfaces, we map linear low-semblance features that correspond to small, secondary faults imaged in seismic but are not represented in the volumetric restorations. To assess whether our restoration tool accurately captures natural strain patterns – and thus, can be reliably used for reservoir characterization – we evaluate strain-semblance correlations across the entire field, over individual structures, and along distinct deviated well paths. Our results suggest moderate-strong, negative strain-semblance correlations, with greater strain corresponding to lower semblance. Given this consistent correlation, we explore the ability of these restorations to predict subtle strain signatures associated with secondary faults not represented in the models. We document where these secondary faults and associated strains likely impact cumulative production, water cut, and thus, permeable reservoir pathways. Our results indicate that 3D geomechanical restorations have the potential to aid reservoir characterizations, and in turn guide future development operations in cases where deformation plays a role in defining reservoir performance.

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