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Using seismic inversion to predict geomechanical well behavior: a case study from the Permian Basin

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Summary

The *in-situ* stress and elastic rock properties are first order controls on fracture stimulation behavior and consequently production. These properties can be well understood post drill. However, knowledge prior to drilling provides the opportunity to optimize well planning, including location and landing depth. Seismic inversion can be used to estimate the rock elastic properties, which can be used to estimate the *in-situ* stress state based on well calibration. A 1D well based model was built for a well in the Permian Basin, which predicted variations in induced fractures observed in image logs acquired in the well. This model was applied to a 3D elastic property volume derived from a joint facies and impedance inversion using rock physics models. The inversion result was then used to predict the mechanical behavior of a well 20 miles away from the original location. The prediction match the observed variation in induced fractures observed in image logs at the offset well location, validating the use of inversion coupled with 1D geomechanics to predict well behavior pre-drill.

Introduction

Production in unconventional reservoirs is controlled by the *in-situ* rock properties and the behaviour of the hydraulic fracture stimulation. The induced fracture behaviour is controlled by the *in-situ* stress state and the elastic rock properties. By understanding the variation in elastic properties and *in-situ* stresses pre-drill can facilitate optimal well planning including well location and landing zone, as well as potential completion strategies. This paper demonstrates a workflow and example demonstrating how the integration of seismic inversion with 1D geomechanical models can be used to predict well behaviour at offset locations.

Method

A coupled geomechanical and seismic inversion workflow has been developed. The workflow consists of building a calibrated 1D geomechanical model at the well locations using elastic log data and the poro-elastic equations (Plum et. al., 2000)). The 1D model is then up-scaled to seismic resolution to assess the feasibility of utilizing properties derived from a seismic inversion. An innovative pre-stack facies-based seismic inversion process (Kemper & Gunning, 2014), capable of producing physical estimates of impedances and density, is used to invert the seismic dataset for facies and elastic properties. The geomechanical model is then applied to elastic properties derived from the inversion to build a 3D geomechanical model.

Examples

The workflow has been tested on a dataset from the Wolfcamp formation in the Permian Basin. The dataset included compressional and shear sonic logs, plus a multi-mineral petrophysical interpretation from six wells. A detailed rock physics study was undertaken to QC the sonic log data and to understand the relationship between mineralogy and elastic properties. This provided the foundation for both the subsequent geomechanical analysis and seismic inversion.

The correlation between inverted elastic properties and up-scaled log data was considered very good. After applying the geomechanical model to 3D elastic properties derived from the inversion, a zone of low fracture initiation pressure and high stress anisotropy was identified at Well A. This zone correlates with an interval where a high concentration of drilling-induced tensile failures are observed on an FMI image log. While the zone of low fracture initiation pressure is observed to extend laterally from Well A, the predicted initiation pressure increases to background levels in the vicinity of Well B. Image log data from Well B shows no evidence of drilling induced tensile failures within the laterally equivalent interval. These observations from image logs provide independent validation of the 3D geomechanical model.

Conclusions

The results can be used to understand fracture behavior - including stress anisotropy, initiation pressures, fracture barriers, and potential height growth – at any potential well location within the data volume.

Acknowledgements

References

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