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Seismic Inversion for Engineering Applications in Unconventional Reservoirs

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Summary

Economic production from unconventional reservoirs requires increasing the surface area in contact with the reservoir via hydraulic fracturing. Important to the design of efficient hydraulic fractures is knowledge of the orientation and magnitude of principal stresses, geomechanical rock properties, and the density and orientation of any natural fractures. The use of seismic AVOAz (Amplitude Variation with Offset and Azimuth) inversion to determine fracture density and orientation as well as horizontal stress anisotropy and the orientation of the principal stresses is illustrated using examples from the Middle East and North America. An example is shown of using the results of seismic AVOAz inversion calibrated to geomechanical measurements on cores, to build a 3D MEM (Mechanical Earth Model) for an area in North America. The variation in principal stresses over the area is evaluated using the Finite Element Method. Computed stresses are found to be consistent with variability in production over the area and show stress rotations near faults in agreement with microseismic data.

Introduction

Economic production from unconventional reservoirs requires increasing the surface area in contact with the reservoir via hydraulic fracturing. Important to the design of efficient hydraulic fractures is knowledge of the orientation and magnitude of principal stresses, geomechanical rock properties, and the density and orientation of any natural fractures. This presentation describes a workflow that enables the use of wide-azimuth seismic data for characterizing the in-situ stress, stress anisotropy, geomechanical properties, and the density and orientation of natural fractures. An essential component of this workflow is the use of seismic AVOAz (Amplitude Variation with Offset and Azimuth) inversion to determine fracture density and orientation as well as horizontal stress anisotropy and the orientation of the principal stresses. The workflow is illustrated using examples from the Middle East and North America. An example is shown of using the results of seismic AVOAz inversion, calibrated to geomechanical measurements on cores, to build a 3D MEM (Mechanical Earth Model) for an area in North America. The variation in principal stresses over the area is evaluated using the Finite Element Method. Computed stresses are found to be consistent with variability in production over the area, and show stress rotations near faults in agreement with microseismic data.

Method

Economic production from unconventional formations requires good Reservoir Quality (RQ), representing the multiple properties defining reservoir potential, and good Completion Quality (CQ), representing the multiple properties defining the potential for creating and sustaining a large surface area in contact with the reservoir (Suarez-Rivera et al., 2011). Since unconventional reservoirs are often heterogeneous, reliable predrill methods to determine the spatial variation in RQ and CQ are required to optimally locate wells in such reservoirs. Because of the low permeability of unconventional reservoirs, economic production requires increasing the surface area in contact with the reservoir via hydraulic fracturing. Important to the design of efficient hydraulic fractures, are knowledge of the orientation and magnitude of principal stresses, geomechanical rock properties, and the density and orientation of any natural fractures. The workflow used to determine in-situ stress, stress anisotropy, geomechanical properties, and the density and orientation of natural fractures in unconventional reservoirs is shown in figure 1. An essential component of this workflow is the use of seismic AVOAz (Amplitude Variation with Offset and Azimuth) inversion (Bachrach et al., 2013). During the presentation, this workflow will be illustrated using examples from the Middle East and North America.

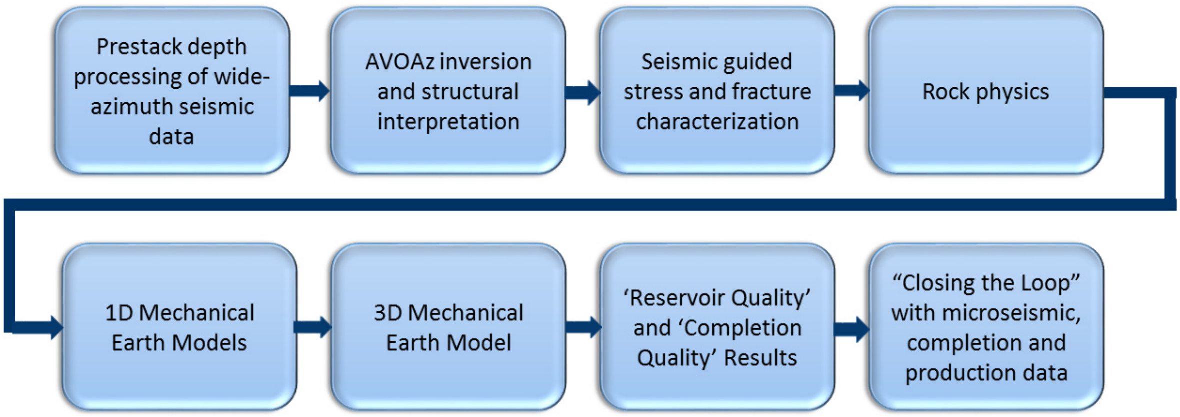

Figure 1 *Workflow used to determine in-situ stress, stress anisotropy, geomechanical properties, and the density and orientation of natural fractures in unconventional reservoirs.*

Conclusion

Although unconventional reservoirs are heterogeneous, the heterogeneity in reservoir and completion quality can be investigated pre-drill using wide-azimuth seismic data. Characterization of in-situ stress and natural fractures, needed to model the propagation of hydraulic fractures, requires AVOAz inversion of wide-azimuth prestack depth migrated seismic data. This enables optimization of well location, borehole trajectory, well spacing, and the design of hydraulic fractures, before a well is drilled.

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References

Bachrach, R., Sayers, C.M., Dasgupta, S., Silva, J. and Volterrani, S. [2013]. Recent advances in the characterization of unconventional reservoirs with wide-azimuth seismic data. SPE 168764.

Suarez-Rivera, R., Deenadayalu, C., Chertov, M., Hartanto, R.N., Gathogo, P. and Kunjir, R. [2011]. Improving Horizontal Completions on Heterogeneous Tight Shales. CSUG/SPE-146998.