SEISMIC AVO INVERSION TECHNIQUES FOR EXPLORATION OF THE COOPER BASIN UNCONVENTIONAL PLAYS

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Papers

Paper 1: Cooke, D., S. Tyiasning, and H. A. Khair, 2016, Unexpected behaviors of stimulated fractures in the high-stress Cooper Basin: The Leading Edge, **35**, no. 1,78-84.

Conference paper: Cooke, D., and S. W. Tyiasning, Quantifying the reliability of three-term AVO, SEG Technical Program Expanded Abstracts 2013. 383-387.

Paper 2: Tyiasning, S., and D. Cooke, 2015, A comparison of competing amplitude variation with offset techniques applied to tight gas sand exploration in the Cooper Basin of Australia: Interpretation, **3**, no. 3,SZ15-SZ26.

Paper 3: Tyiasning, S., and D. Cooke, 2016, *(in-press)* Anisotropy signatures in the Cooper Basin of Australia: stress vs. fractures: Interpretation.

Paper 4: Tyiasning, S., D. Merzlikin, D. Cooke, and S. Fomel, 2016, A comparison of diffraction imaging to incoherence and curvature: The Leading Edge, **35**, no. 1,86-89.

Paper 5: Tyiasning, S., and D. Cooke, 2016, *(will be submitted to Interpretation)* Impact of pore pressure versus fluid saturation on elastic properties in Murteree Shale of the Cooper Basin: Interpretation.

Declaration

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Statement of Authors Contributions

This research is summarised in the papers that constitute this thesis was undertaken within the GeoFrac research group at the Australian School of Petroleum, and collaboration with the Texas Consortium for Computation Seismology (TCCS) at the University of Texas at Austin. The GeoFrac research group consists of several PhD students, research staff and lecturers who collaborate across a wide range of seismic AVO, stress, geomechanics, structural geology and fracture stimulation issues. Hence, all the papers presented are co-authored and detailed statements of relative contribution are summarised below and endorsed by the co-authors.

Abstract

This thesis is comprised of six topics, each of which complements the knowledge of exploration challenges and applicable seismic AVO inversion techniques for Cooper Basin unconventional reservoirs. The first topic discusses unexpected fracture stimulation treatment behaviors that may relate to the Cooper Basin's high tectonic stress and overpressure. This study analyzes the Cooper Basin in-situ stress, rock strength and pore pressure, which are compared with image logs interpretation of natural fractures and borehole breakouts.

Topic two presents a sensitivity analysis of three-term AVO inversion and provides knowledge on the reliability of the inversion results. This analysis uses stochastic forward modelling of random noise and various source-receiver offsets followed by AVO inversion. Bayesian probability is used to quantify how increases in signal-to-noise ratio and far offset distances influence the reliability of inversion results. This example used a single set of rock properties, where measurements of seismic signal have been 'normalized' in attempts to make these results applicable to all reservoirs. This analysis presents some limitations with performing AVO inversion that are helpful for deciding suitable inversion types for the available data set.

A major challenge in the Cooper Basin is mapping thin fluvial tight gas sand bodies that are difficult to interpret on seismic data due to strong reflections from adjacent Permian coals. This is not the common AVO problem of distinguishing between coal and gas sand, but a more difficult class-I AVO problem of mapping fluvial sands beneath a sheet coal that varies in thickness. Topic three provides a solution of using Poisson's ratio attribute calculated from extended elastic impedance (EEI) technique and a rotation of near and far

partial stacks. Noise sensitivity and tuning analyses on these techniques also show advantages and disadvantages associated with each technique.

Seismic data from the Cooper Basin exhibits azimuthal anisotropy in both AVO and HTI interval velocity (derived from migration velocity analysis). Topic four investigates if anisotropy is caused by fractures or by the Cooper Basin's large difference between minimum and maximum horizontal stress. This study compares both migration velocity anisotropy and AVO anisotropy extracted from a high-quality 3D survey to a 'ground truth' of dipole sonic logs, borehole breakout and fractures interpreted from image logs. The results suggest that stress is the dominant cause of the HTI anisotropy observed in the seismic data.

Topic five evaluates alternative (non-AVO) techniques for mapping natural fractures; diffraction imaging and common seismic attributes such as incoherence and curvature. These techniques are applied to a Cooper Basin data set and the results are analyzed on their ability in detecting subtle features (small faults, fractures and channel-edges) and their resolution (vertical and spatial).

The final topic in this thesis investigates the ability of rock properties to detect the presence of overpressure, a topic that adds further complexity to advances in shale gas exploration in the Cooper basin. Results show that while overpressure can and does impact rock properties in the Cooper Basin, variations in gas saturation have a similar and stronger impact. Separation of the overpressure signature and the saturation signature is problematic.

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