STRUCTURAL PERMEABILITY IN AUSTRALIAN SEDIMENTARY BASINS

by

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Abstract

Declining conventional hydrocarbon reserves coupled with technological advances and growing energy demands have triggered a shift in exploration of energy-rich Australian basins, with a progressive focus on unconventional energy sources, such as coal seam gas, shale gas and enhanced geothermal systems. Unconventional play viability is often heavily dependent on the presence of secondary permeability due to interconnected natural fractures, as they commonly exert a prime control over total permeability due to low primary permeabilities. The structural permeability of the Northern Perth, South Australian Otway, and Northern Carnarvon basins are characterised using an integrated approach combining geophysical wellbore logs, seismic attribute analysis and detailed structural descriptions of core and outcrop. Integration of these methods allows for the identification of faults and fractures over a range of scales, providing crucial permeability information. New stress orientation data is also interpreted, and allows for stress-based predictions of fracture reactivation to be made.

This study represents the first attempt at generating a database of fracture properties for Australian sedimentary basins through the combination of several methodologies, and addresses three significant scientific questions: 1) What are the main factors controlling fracture reactivation in Australian basins? 2) Can 3D seismic attributes be used to identify natural fractures in the subsurface beyond the wellbore? And, 3) Are electrically conductive fractures in image logs actually open to fluid flow?

This study demonstrates that distinct correlations exist between natural structural fabrics identified in 3D seismic attribute analysis and the natural fractures identified through interpretation of electrical resistivity image logs from petroleum wells, and supports the supposition that similar features at different scales are being identified. Fracture reactivation within the studied basins, in particular the Otway and Carnarvon basins, shows that fracture reactivation can become complex, and depend not only on the in-situ stress regime but also fracture fills, as well as local and regional structures. Natural fractures identified on image logs as being electrically conductive are generally assumed to be hydraulically conductive. However, Otway Basin core shows open fractures are rarer than image logs indicate, and this is likely due to the presence of fracture filling siderite. Siderite is an iron-carbonate mineral that may cause fractures to appear hydraulically conductive on image logs.

The techniques outlined herein represent an effective method by which potential structural permeability can be assessed on a regional scale with various levels of data availability. This is demonstrated in several case studies of Australian sedimentary basins featuring varying datasets. Basin-wide structural permeability is constrained using a variety of data, ranging from predominantly using image logs supported by 3D seismic, to performing a basin-wide assessment using image logs, 3D seismic, core, and outcrop studies.

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Thesis Declaration

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Statement of Author's Contribution

The research summarised in the papers that constitute this thesis was undertaken within the Seismic, Structure & Stress (S^3) Research Group at the Australian School of Petroleum (consisting of Dr. Simon P. Holford, Dr. Rosalind C. King, Dr. Khalid Amrouch, Dr. Stijn Glorie, Prof. Alan Collins, and numerous honours and PhD students) and with external collaborators at BP Petroleum (Dr. Guillaume Backé), Ikon Science (Dr. Scott Mildren), and the South Australian Centre for Geothermal Energy Research (Prof. Martin Hand). Hence all the papers presented herein are co-authored by either members of this research group and/or external collaborators. Detailed statements of their relative contribution are included prior to each publication. These are endorsed by the co-authors.

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