Structural Permeability in Australian Sedimentary Basins

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ABSTRACT

Declining conventional hydrocarbon reserves have triggered a shift in exploration of energy-rich Australian basins towards unconventional sources, such as coal seam and shale gas, as well as thermal energy from enhanced geothermal systems (EGS). Unconventional play and EGS viability often depends on secondary permeability due to interconnected natural fractures that commonly exert a prime control over absolute permeability due to degraded primary permeability. Structural permeability of the Northern Perth, South Australian Otway, and Northern Carnarvon basins are characterised via an integrated approach combining geophysical wellbore logs, seismic attribute analysis and detailed structural descriptions of core and outcrop. Integration of these methods allows for identification of faults and fractures at a range of scales, providing crucial permeability information. This study raises 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 fractures in the subsurface beyond the wellbore? 3) Are electrically conductive fractures in image logs actually open to fluid flow? We demonstrate distinct correlations between aligned natural structures identified in 3D seismic attribute analysis and natural fractures identified through interpretation of electrical resistivity image logs, implying that similar features at different scales are being identified. Fracture reactivation within the basins, in particular the Otway and Carnarvon basins, is demonstrated to be complex, depending not only on the in-situ stress regime but also fracture fills and pre-existing local and regional structures. Natural fractures identified on image logs as being electrically conductive are generally assumed to be hydraulically conductive. However, core from the Otway Basin shows open fractures are rarer than image logs indicate, likely due to the presence of fracture filling siderite, an iron-carbonate that may cause fractures to appear hydraulically conductive on image logs. The techniques demonstrated in several case studies represent an effective method for assessing regional structural permeability with various levels of data availability. Basin-wide structural permeability is constrained using a variety of data, ranging from predominantly image logs supported by 3D seismic, to performing a basin-wide assessment using image logs, 3D seismic, core, and outcrop studies.