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Remote Sensing of Subsurface Fractures in the Otway Basin, South Australia

Adam Bailey (1), Rosalind King (2), Simon Holford (1), and Martin Hand (3)

(1) Australian School of Petroleum, University of Adelaide, Adelaide, Australia (adam.bailey@adelaide.edu.au, simon.holford@adelaide.edu.au)), (2) School of Earth and Environmental Sciences, University of Adelaide, Adelaide, Australia (rosalind.king@adelaide.edu.au), (3) Institute of Minerals and Energy Resources (IMER), University of Adelaide, Adelaide, Australia (martin.hand@adelaide.edu.au)

A detailed understanding of naturally occurring fracture networks within the subsurface is becoming increasingly important to the energy sector, as the focus of exploration has expanded to include unconventional reservoirs such as coal seam gas, shale gas, tight gas, and engineered geothermal systems. Successful production from such reservoirs, where primary porosity and permeability is often negligible, is heavily reliant on structural permeability provided by naturally occurring and induced fracture networks, permeability, which is often not provided for through primary porosity and permeability.

In this study the Penola Trough, located within the onshore Otway Basin in South Australia, is presented as a case study for remotely detecting and defining subsurface fracture networks that may contribute to secondary permeability. This area is prospective for shale and tight gas and geothermal energy. The existence and nature of natural fractures is verified through an integrated analysis of geophysical logs (including wellbore image logs) and 3D seismic data.

Wellbore image logs from 11 petroleum wells within the Penola Trough were interpreted for both stress indicators and natural fractures. A total of 507 naturally occurring fractures were identified, striking approximately WNE-ESE. Fractures which are aligned in the in-situ stress field are optimally oriented for reactivation, and are hence likely to be open to fluid flow. Fractures are identifiable as being either resistive or conductive sinusoids on the resistivity image logs used in this study. Resistive fractures, of which 239 were identified, are considered to be cemented with electrically resistive cements (such as quartz or calcite) and thus closed to fluid flow. Conductive fractures, of which 268 were identified, are considered to be uncemented and open to fluid flow, and thus important to geothermal exploration. Fracture susceptibility diagrams constructed for the identified fractures illustrate that the conductive fractures are optimally oriented for reactivation in the present-day strike-slip fault regime, and so are likely to be open to fluid flow.

To gain an understanding of the broader extent of these natural fractures, it is necessary to analyse more regional 3D seismic data. It is well documented that fault and fracture networks like those generally observed in image logs lie well below seismic amplitude resolution, making them difficult to observe directly on amplitude data. However, seismic attributes can be calculated to provide some information on sub-seismic scale structural and stratigraphic features. Using the merged Balnaves/Haselgrove 3D seismic cube acquired over the Penola Trough, attribute maps of complex multi-trace dip-steered coherency and most positive curvature, among others, were used to document the presence of discontinuities within the seismic data which area likely to represent natural fractures, and to best constrain the likely extent of the fracture network which they form.

The resulting fracture network model displays relatively good connectivity surrounding structural features intersecting the studied horizons, although large areas lacking significant discontinuities are observed. These areas make it unlikely that the fracture network contributes to permeability on a basin-wide scale, though observed features are optimally oriented for reactivation under contemporary stress conditions and are thus likely to provide at least local increases in permeability.