PRESENT-DAY STRESS IN CENTRAL AND SOUTHEAST AUSTRALIAN SEDIMENTARY BASINS

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Abstract

This thesis consists of six published papers. The present-day stress tensor has been determined using petroleum well data in the Gippsland and Otway Basins in Southeast Australia (Papers 1 and 4) and the Cooper Basin in Central Australia (Paper 5). In the Gippsland Basin, the present-day stress regime is transitional between one of reverse and strike-slip faulting and the maximum horizontal stress (S_{Hmax}) is oriented ~139°N. The present-day stress regime in the Victorian sector of the Otway Basin is also transitional between one of reverse and strike-slip faulting and S_{Hmax} is oriented ~135°N. Horizontal stresses are lower in the South Australian sector of the Otway Basin where the stress regime is one of strike-slip faulting and S_{Hmax} is oriented ~124°N. The orientations of S_{Hmax} in Southeast Australia are consistent with focal mechanism solutions, neotectonic structures and modelling of plate-boundary forces (Paper 4).

Closure pressures from mini-frac injection tests are commonly used to determine the minimum horizontal stress (S_{hmin}) magnitude. However, in high stress basins such as the Cooper and Gippsland Basins, these pressures may not reliably yield S_{hmin} (Papers 2 and 5). In the Cooper Basin, high closure pressures (>18 MPa/km) were observed in tests where pressure-declines indicated complex hydraulic fracture growth. Closure pressures in these injections are unlikely to be representative of S_{hmin}. They are believed to reflect the normal stress incident on pre-existing planes of weakness that are exploited by hydraulic fluid during the mini-frac injection (Paper 5). Sub-horizontal fabrics that are open at the wellbore wall were observed on image logs in the Cooper and Gippsland Basins (Papers 2 and 5). This fabric is believed to be at least partially responsible for the

complex growth of hydraulic fractures observed in the Cooper Basin. The occurrence of these sub-horizontal fabrics and knowledge of rock strength have been used to constrain the magnitudes of S_{Hmax} and S_{hmin} independently of mini-frac injections in the Cooper and Gippsland Basins (Papers 2 and 5).

The present-day stress tensor is often quoted as a single gradient at a sedimentary basin- or petroleum field-scale. Image logs and mini-frac data from Central and Southeast Australia indicate significant stress differences between stratigraphic units (Papers 3 and 5). Finite element modelling of the stress distribution between interbedded sands and shales in the Gippsland Basin indicates that stress is 'partitioned' to 'hard' lithological units in high stress areas. This accounts for the observation that borehole breakout only occurs in hard, cemented sandstones in the Gippsland Basin (Paper 3). A generic 'mechanical stratigraphy' derived from knowledge of wellbore failure (from image logs), rock strength and rock properties in individual rock units in the Cooper Basin allows an approximation of the present-day stress-state to be made directly from image-logs for individual rock units prior to mini-frac injection (Paper 6). This is important for predicting and understanding hydraulic fracture growth and containment.

When considered together, the papers comprising this thesis provide significant new data on the orientation and magnitude of present-day stresses in Central and Southeast Australia. They also provide insight into the tectonic origin of those stresses and their distribution within sedimentary basins. In particular the papers develop and use new methods for constraining the present-day stress in regions of high tectonic stress. They

also discuss implications for problems in petroleum development including wellbore stability and hydraulic fracturing.

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Papers

Paper 3: Nelson, E. J., Hillis, R. R. & Mildren, S. D., 2006, Stress Partitioning and Wellbore Failure in the West Tuna Area, Gippsland Basin: *Exploration Geophysics*, **37,** 215–221.

Paper 4: Nelson, E. J., Hillis, R. R., Sandiford, M., Reynolds, S. D. & Mildren, S. D., 2006, The present-day state-of-stress in Southeast Australia: *Australian Petroleum Production and Exploration Association Journal*, **46**, 283–305.

Paper 5: Nelson, E. J., Chipperfield, S. T., Hillis, R., Gilbert, J., McGowen, J. & Mildren, S. D., 2007, The relationship between closure pressures from fluid injection tests and the minimum principal stress in strong rocks: *International Journal for Rock Mechanics and Mining Sciences*, **44,** 787–801.

Paper 6: Nelson, E. J., Chipperfield, S. T., Hillis, R., Gilbert, J. & McGowen, J., 2007, Using geological information to optimise stimulation practices in the Cooper Basin, Australia: *Petroleum Geoscience*, **13,** 3–16.

Declaration

This thesis contains no material which has been accepted for the award of any other degree or diploma in any university or other tertiary institution and, to the best of my knowledge and belief contains no material previously published or written by another person, except where due reference has been made in the text.

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Statement of Authors' Contributions

The research summarised in the papers that constitute this thesis was undertaken within the 'Stress Group' at the Australian School of Petroleum and with industry collaborators. The ASP 'Stress Group' comprises several PhD students and research staff who collaborate across a broad range of present-day stress-related issues. Hence all the papers presented herein are co-authored and detailed statements of relative contribution are summarised below and endorsed by the co-authors.

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