COMPRESSIONAL DEFORMATION AND EXHUMATION IN SEDIMENTARY BASINS AT 'PASSIVE' CONTINENTAL MARGINS, WITH IMPLICATIONS FOR HYDROCARBON EXPLORATION AND DEVELOPMENT

by

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“Throughout the coast of Brazil, and certainly for a considerable space inland, from the Rio Plata to Cape St. Roque, lat. 5°S, a distance of more than 2,000 geographical miles, wherever solid rocks occurs, it belongs to a granitic formation. The circumstance of this enormous area being thus constituted of materials, which almost every geologist believes to have been crystallized by the action of heat under pressure, gives rise to many curious reflections. Was this effect produced beneath the depth of a profound ocean? Or did a covering of strata formerly extend over it, which has since been removed? Can we believe that any power, acting for a time short of infinity, could have denuded the granite over so many thousand square leagues?”

—Charles Darwin, Bahia or San Salvador, Brazil,

29 February 1832 (Darwin, 1839, p. 12)

Abstract

There is growing recognition that extensive phases of compressional deformation and exhumation have interrupted the post-rift subsidence histories of some economically important 'passive' continental margins. Understanding the distribution, magnitude, chronology and causes of exhumation and compressional deformation at these margins can reduce exploration uncertainty. The Otway and Faroe-Shetland basins along the southern Australian margin and northwest European Atlantic 'passive' margins, respectively, provide ideal natural laboratories to further understand syn and post-rift compressional deformation, inversion and exhumation.

Post-Albian exhumation in the Otway Basin was quantified to be ~400-3600 m across the eastern and northern parts of basin using a new sonic transit time-depth trend, which represents normal compaction of volcaniclastic shales deposited within a fluvio-lacustrine environment – unlike any other such trends previously published. These estimates are consistent with those from complementary thermal, palynological and seismic datasets. Whilst the impacts of exhumation are well known for *conventional hydrocarbon systems*, this study is amongst the first to highlight the implications of exhumation on *unconventional hydrocarbon systems*, in particular related to petrographical and geomechanical rock properties.

Exhumation in the Otway Basin is mainly related to mid-Cretaceous and Neogene neotectonic compressional deformation and inversion episodes, with the latter strongly governed by the contemporary stress state. Using complementary geophysical datasets and considering lithological heterogeneity, basement fabrics and variations in structural style with depth – factors generally neglected in previous geomechanical-focused studies in this region – it is possible to better understand the relationship between neotectonic deformation and stress.

Comparisons between bulk crustal strain rates based on Neogene shortening estimates, and present-day strain rates of based on earthquake data and geological observations demonstrates that strain rates in the Otway Basin have declined since the onset of Neogene compressional deformation and exhumation. Neogene bulk crustal strain rates determined independently from shortening estimates and exhumation magnitudes yield similar results, suggesting that Neogene exhumation in the eastern Otway Basin can be accounted for solely by crustal shortening within a mildly compressional intraplate stress field, with ~30% of the total present-day strain rate accounted for by aseismic deformation.

In the central parts of the offshore Otway Basin, where there is very thick preserved Upper Cretaceous sequence and few indications of major post-Albian tectonic activity, significant and

previously unreported overpressures are examined. Pore pressure gradients exceed ~16 MPa/km within the fine-grained Upper Cretaceous Belfast and Flaxman formations, and are most likely due to a disequilibrium compaction associated with Pliocene burial by a proto-Murray River discharge.

Estimating exhumation in the Otway Basin using sonic log data provided consistent values with thermal-based techniques, indicating that heating can be related (in part) to deeper burial. However, this may not hold true in all basins. More than ~400m of post-Danian exhumation was quantified using sonic data along the Rona High in the Faroe-Shetland region where thermal history data indicates anomalous heating due to transient hot fluid flow and is problematic for exhumation analyses. This exhumation likely occurred during the Oligocene to Mid-Miocene in response to a major reorganisation of the northern North Atlantic spreading system.

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Declaration

I certify that this work 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. In addition, I certify that no part of this work will, in the future, be used in a submission for any other degree or diploma in any university or other tertiary institution without the prior approval of the University of Adelaide and where applicable, any partner institution responsible for the joint-award of this degree.

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David Ronald Tassone Date

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 (*Dr. Simon P. Holford*, *Dr. Rosalind King*, *Dr. Mark Tingay* and *Dr. Adrian K. Tuitt*) and with external collaborators at Geotrack International Pty. Ltd. (*Dr. Paul F. Green* and *Dr Ian R. Duddy*), the Brittish Geological Survey (*Dr. Martyn S. Stoker* and *Dr. Howard Johnson*), The University of Edinburgh (*Prof. John R. Underhill*) and the Deep Exploration Technologies CRC (*Prof. Richard R. Hillis*). Hence all the papers presented herein are co-authored by either members of this research group and/or external collaborators, and detailed statements of their relative contribution are summarised below and endorsed by the co-authors.

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This Thesis documents my research into '*Compressional deformation and exhumation in sedimentary basins at 'passive' continental margin, with implications for hydrocarbon exploration and development'*. It also documents the collaborative research I have fortunately been involved in with respect to this subject over the duration of my postgraduate studies at the Australian School of Petroleum, The University of Adelaide, as well as some of the opportunities to present my work I have been to privileged to experience. This research work would not have been possible without the continual support and encouragement of a number of people.

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