The University of Adelaide
Department of Geology and Geophysics

QUANTIFICATION OF EXHUMATION IN THE COOPER-EROMANGA BASINS, AUSTRALIA

Angelos Mavromatidis

June 1997

A thesis submitted to the University of Adelaide
in fulfilment of the requirements for the degree of
Doctor of Philosophy

CONTENTS

CHAPTER 3: RESULTS OF COMPACTION-BASED ANALYSIS OF EXHUMATION

CHAPTER 4: QUANTIFYING EXHUMATION USING VITRINITE REFLECTANCE

CHAPTER 5: EVIDENCE OF EXHUMATION FROM APATITE FISSION TRACK ANALYSIS AND FLUID INCLUSION HOMOGENIZATION TEMPERATURES

CHAPTER 6: COMPARISON OF EXHUMATION RESULTS FROM THE DIFFERENT METHODS AND INFERRED BURIAL/EXHUMATION HISTORIES FOR THE COOPER-EROMANGA BASINS

CHAPTER 7: STRUCTURAL FRAMEWORK AND TECTONIC MECHANISMS OF UPLIFT AND EROSION

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

Exhumation in the Cooper-Eromanga Basins of South Australia and Queensland has been quantified using the compaction methodology. The standard method of estimating exhumation based on the degree of overcompaction of a single shale unit has been modified, and twelve units, predominantly shales ranging in age from Cretaceous to Permian have been analysed, and the results from different units crossplotted. Furthermore, not only sonic log data, but also data from the other porosity logs (density and neutron) and the adjusted sonic log have been used to quantify exhumation. However, values from the sonic log data are considered the most reliable.

The results of the compaction analysis reveal that Late Cretaceous - Tertiary exhumation increases eastwards from the Patchawarra Trough, through the Gidgealpa-Merrimelia-Innamincka Trend and Nappamerri Trough into the Queensland sector of the basins. Maxima of approximately 1 km of Late Cretaceous - Tertiary exhumation occur north of the Jackson-Naccowlah area and near the north-eastern boundary of South Australia in the Morney and Curalle domes. In many wells the Permo-Triassic section of the Cooper Basin is more overcompacted than the Mesozoic section of the overlying Eromanga Basin. In such areas maximum burial-depth of the Cooper Basin sequence is believed to have been attained in Late Triassic - Early Jurassic times, prior to the deposition of the Eromanga Basin, and not to have been subsequently re-attained.

Vitrinite reflectance data were also modelled in order to investigate exhumation in the Cooper-Eromanga Basins. However, without independent information on the thermal history of the area, vitrinite reflectance data cannot uniquely reveal exhumation magnitudes, because any excess of reflectance above that consistent with current temperatures can be explored by a combination of higher palaeogeothermal gradients and/or exhumation from greater burial-depth. Nonetheless, vitrinite reflectance data do seem to require a relatively recent increase in geothermal gradients in the basins, and higher geothermal gradients during the deposition of the Cooper Basin sequence. Exhumation magnitudes indicated by such a geothermal gradient history are largely consistent with those derived from the compaction methodology.

Exhumation results based on apatite fission track analysis and fluid inclusion homogenization temperatures have also been compiled and although of limited coverage, these results are also broadly consistent with those based on compaction analysis.

Seismic reflection profiles indicate the compressive nature of the structural style associated with the major uplift events in the Cooper-Eromanga Basins. While a number of mechanisms may have driven regional Late Cretaceous - Tertiary exhumation, the two-layer lithospheric compression model is considered as the most complete explanation of uplift.

The study has major implications for hydrocarbon exploration in the basins. Regarding maturation levels, predicted maturation of source rocks will be greater for any given geothermal history if Late Cretaceous - Tertiary exhumation is incorporated in maturation modelling. Perhaps even more importantly, the excess of exhumation of the Cooper Basin sequence over the Eromanga Basin sequence suggests that Cooper Basin source rocks in some areas are unlikely to charge Eromanga Basin reservoirs because hydrocarbons would have been expelled from these source rocks in Late Triassic - Early Jurassic times, prior to the deposition of the Eromanga Basin.

The study has also implications for depth-conversion of seismic two-way-times because it helps quantify the (high) velocity anomalies associated with overcompaction. Exhumation values from this study can also be used to improve porosity predictions of reservoir units in undrilled targets.

STATEMENT

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.

If accepted for the award of the degree and, if applicable, I consent to the thesis being made available for photocopying and loan.

June 1997

ACKNOWLEDGEMENTS

This work was carried out while I was in receipt of an OPRS (Overseas Postgraduate Research Scholarship) award from the Australian Government and a scholarship from the University of Adelaide. I am grateful to my supervisor Dr. Richard Hillis who provided me constant support and encouragement to continue my studies during difficult times. It was he who first suggested applying the revised overcompaction technique using well log data from the Cooper-Eromanga Basins. I am grateful to my supervisor for his friendly guidance throughout my entire residence in Australia. I am also indebted for his careful and detailed corrections of drafts of this thesis. He also provided generous support for me to attend seminars and conferences, from which I gained useful information for my study.

I would like to thank Associate Prof. David McKirdy for his critical review of the vitrinite reflectance chapter. I am also indebted to Dr. Peter Tingate for reviewing the AFTA chapter and for his interest, encouragement and the discussions of the techniques and his invitation to give a seminar at the NCPGG (National Centre of Petroleum Geology & Geophysics) regarding the results of this thesis. Thanks to Prof. Reza Harami for his interest, comments and discussions on the project. I wish to extend my appreciation to fellow postgraduate student Rob Menpes for his discussions and assistance throughout the project. I would like to thank Ms Vivien Hope who as a university officer was always friendly and positive to my enquires. I wish to acknowledge Mr Tony Hill for his interest in the work, and his invitation to present the results of my research at MESA (Mines & Energy South Australia).

I am grateful to Santos Ltd. for access to their well log data and the computing facilities. More specifically, I wish to thank David Warner for discussions with his colleagues regarding the importance of the project and its implications for Santos' Ltd. exploration. I am grateful to David Hudson, Grant Jacquier and Paul Siffleet for the support in the use of software at Santos Ltd. Without these computer facilities, it would have been impossible to fulfil the aims of my study. Maris Zwigulis is also thanked for his 'curiosity' in discussing different aspects of this thesis during my research period.

I would like to acknowledge the moral support from my family in Greece. Despite not having seen them, during my studies in Australia, which made my and their life more difficult, they always encouraged me to continue and try to expand my knowledge. Last but certainly not least, I express many thanks to my partner Stephanie Eleftheriou for her moral and financial support. Her support was beyond thanks.

This thesis, particularly the well log, vitrinite reflectance and AFTA data, and seismic sections are published with the permission of the Santos Ltd. and the Cooper-Eromanga joint venture partners.