A revised chronostratigraphic framework for the Onshore Otway Basin, implications for understanding the early development of an intra-cratonic rift margin

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SUMMARY

This paper utilises modern reflection seismic data, surface geology and well information, including petrophysical/lithological characteristics and biostratigraphy. The aim is to construct a new chronostratigraphic framework for the Onshore Otway Basin, while answering unresolved questions about the basin's early rift history. These include the order in which individual depocentres were formed, the corresponding timing of deposition of laterally varying stratigraphic packages, and which units were confined to individual rift depocentres. The integration of stratigraphic correlations, petrophysical interpretation, drill-core descriptions, petrological/lithological analysis and biostratigraphy with interpreted seismic data resulted in the identification of at least two extra chronostratigraphic sequences. This study focused on high-resolution volumetric modelling of all stratigraphic sequences within the Otway rift system. Particular attention was paid to the Early Cretaceous stratigraphy following the identification and mapping of the two previously undocumented sedimentary sequences within the Victorian section of the basin. This led to a revised chronostratigraphic framework for the Onshore Otway Basin, which, in-turn, served to explain the relationship between fluvio-lacustrine sedimentation and tectonism during the early history of intercontinental rift systems.

Key words: Otway, Basin, intercontinental, fluvial lacustrine

INTRODUCTION

A number of studies have attempted to define the tectono-stratigraphic evolution of the Onshore Otway Basin; however, many of these were applied to specific depocentres. Those applied on a regional scale, such as Geary & Reid (1998), Norvick (2001), Boult & Hibbert (2002), Krassay (2004), Norvick (2005) and Hall & Keetley (2009), used selective regional seismic surveys and corresponding intersecting well data to make broad interpretations. However, due to the vast quantity of studies on specific depocentres and an apparent lack of agreement between South Australian and Victorian studies, differences in stratigraphic nomenclature and other inconsistencies still need to be resolved (Figure 1).

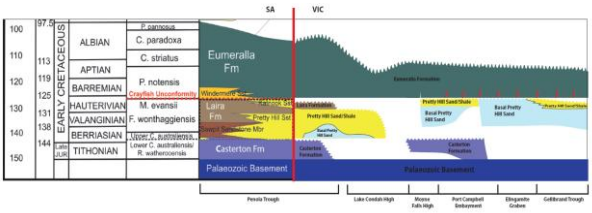

Figure 1 Comparison of stratigraphic frameworks between Camac & Boult (2009) and Parker (1995)

Detailed studies of the South Australian section of the Penola Trough have led to subdivision of the Pretty Hill Sandstone into various informal members, such as the Sawpit Shale, Sawpit Sandstone, Pretty Hill Sandstone and Katnook Sandstone (Figure 1), and has led to an improved understanding of the development of sedimentation style during the early development of the rift (Lovibond R. *et al.*, 1995; Camac & Boult, 2008). To date, these sub-divisions have not been officially correlated to stratigraphy within the Victorian section of the basin. This study attempts to address this inconsistency by developing a seamless geological model across South Australia and Victoria.

Previous studies attempted to analyse the relationship between tectonism and sedimentation within continental rifts (e.g. Schlische & Olsen, 1990; Prosser, 1993; Mcleod *et al.*, 2002) and propose or support the idea of a vertical transition from early fluvial, shallow-lake to deep-lake environments during a rift-phase (Lambaise, 1990; Lambiase & Bosworth, 1995). In contrast, the Crayfish Group of the Onshore Otway Basin appears to present a different vertical transition from early rift lakes, through high-energy fluvial sedimentation to flood-plain/low-energy fluvial environments. There are differences in the order of stacked facies types in continental basins around the world and those of the Otway Basin stratigraphy. This suggests that intercontinental basins are complex and that they are unlikely to fit a single universal model for sedimentation patterns.

A combination of data-types was analysed, including well information (petrophysical, lithological and biostratigraphic data), seismic interpretation from South Australia and an up-to-date dataset of two dimensional reflection seismic data (Figure 2) across the Victorian section of the basin.

METHOD AND RESULTS

Nineteen key wells that penetrated Early Cretaceous stratigraphy were selected along the Victorian section of the basin (Figure 4). All biostratigraphic interpretations from these wells were standardised to the Morgan *et al.* (1995) biozonation scheme, so that a consistent biostratigraphic framework and corresponding age control could be utilised. Drill-core was examined from eight of these wells, including Bus Swamp-1, Casterton-1, Heathfield-1, Mocamboro-11, Hawkesdale-1, Pretty Hill-1, Woolsthorpe-1, Garvoc-1 and Warrachbarrunah-2. A series of well correlation panels were then constructed along the dip and strike of each major depocentre (Figure 4 and Figure 5) in order to investigate whether a new stratigraphic framework could be developed for the Victorian section of the basin.

Two-dimensional time/depth seismic surveys were interpreted across the onshore, with detailed well correlations defining a new stratigraphic framework. This resulted in the regional mapping of six horizons within the Crayfish Group (including Top-Basement), two of which had not been recognised within the Victorian section of the basin prior to this study (Figure 2), namely, the Sawpit Shale and the Sawpit Sandstone. The interpreted sequences were then integrated into a 3D structural model.

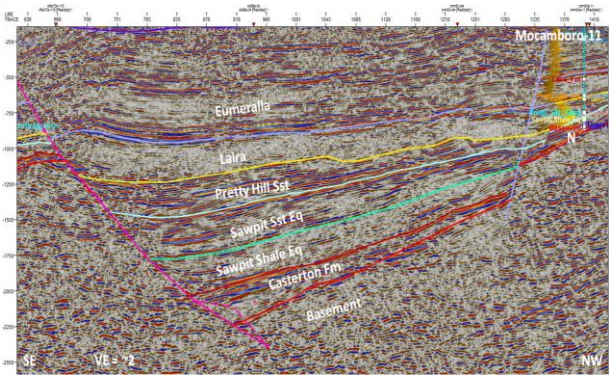

Figure 2 TWT Seismic interpretation of the Mocamboro Trough showing members of the Crayfish Group

Seismic facies were also identified, based on overall external geometry, reflection configuration, reflection continuity and amplitude. This allowed for the construction of a generalised chrono-stratigraphic framework for the Early Cretaceous sediments of the basin, as shown in Figure 6 and a three dimensional structural-stratigraphic model.

Results indicate that the Early Cretaceous sediments of the Onshore Otway Basin present a vertical and lateral transition from early-rift lakes (Casterton/Sawpit Shale equivalent), to high-energy fluvial sedimentation (Sawpit Sandstone) and flood-plain/low-energy fluvial environments (Laira Formation). Like most rift basins, these broad vertical and lateral changes in facies can be attributed to changes in subsidence rate and sediment supply during the early development of the basin. During early rifting the subsidence rate was rapid, allowing for the preferential deposition of lacustrine sediments of the Casterton Formation and Sawpit Shale Member. These sediments are generally confined to individual depocentres and formed a series of isolated, lacustrine environments from late Tithonian-Berriasian time. The subsidence rate began to reduce during the late Berriasian as dominantly fluvial sediments of the Sawpit Sandstone Member were deposited; during this time sediment supply exceeded available accommodation space and spilled into adjacent depocentres, forming a through-going fluvial environment that is likely to have sequentially filled each depocentre from west to east. Finally, during the Valanginian-Hauterivian, the subsidence rate began to increase again and comparatively fine-grained sediments of the Pretty Hill Formation and overlying Laira Formation were deposited. This may be due to fault-segment linkage within the depocentres and therefore a sudden increase in accommodation space relative to available sediment supply. The effect of fault-array evolution on sedimentation style is described by a number of studies (e.g. Gupta *et al.*, 1998). These relative changes in subsidence rate have been confirmed by structural restorations over each major depocentre, and subsequent calculation of cumulative subsidence of each major bounding fault from late Tithonian to late Barremian time, as shown in Figure 3 below.

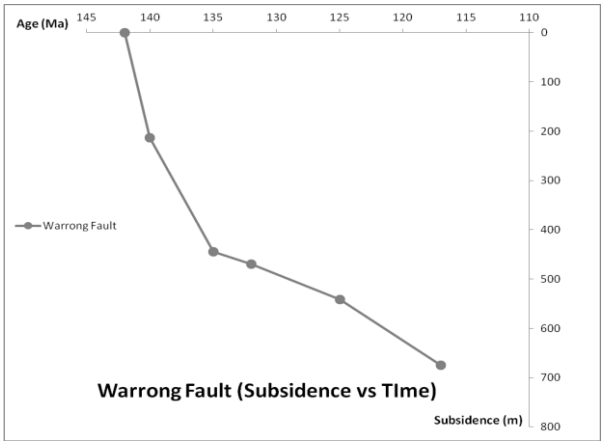

Figure 3 Cumulative displacement plot of the Warrong Fault, showing rapid subsidence from 142-135Ma during the deposition of the lacustrine sediments, slower displacement from 135-125Ma during the deposition of high energy fluvial sediments and finally a renewed increase in subsidence rate during the deposition of the flood-plain deposits of the Laira Fm (125-117Ma**)**

CONCLUSIONS

This study proposes that at least two sub-units exist within the previously undifferentiated Pretty Hill Sandstone within the Victorian section of the Otway Basin; these may be age-equivalents of the Sawpit Shale Member and Sawpit Sandstone Member as first described by Lovibond *et al.* (1995) in South Australia.

According to these results, the Early Cretaceous sediments of the Onshore Otway Basin present both a vertical and lateral transition from early-rift lakes, through high-energy fluvial sedimentation to flood-plain/low-energy fluvial environments. Like most rift basins, these broad vertical changes in facies types can be attributed to changes in subsidence rate and sediment supply controlled by regional tectonics during the early development of the basin. Analysing these changes develops our understanding of the factors controlling fluvio-lacustrine sedimentation in continental rifts.

REFERENCES

BOULT P. J. & HIBBURT J. E. 2002. *Petroleum Geology of South Australia* (2 edition) 1: Otway Basin South Australia. Department of Primary Industries and Resources. Petroleum Geology of South Australia Series, Vol. 1.

CAMAC B. A. & BOULT P. J. 2008. Introducing the Jacaranda Ridge Sandstone: A new play in the Penola Trough: Otway Basin, Australia. *PESA Eastern Australasian Basins Symposium III, Sydney, 14–17 September, 2008*, 95 - 108.

GEARY G. C. & REID I. S. A. 1998. Hydrocarbon prospectivity of the offshore eastern Otway Basin, Victoria for the 1998 Acreage Release. *Victorian Initiative for Minerals and Petroleum Report 55, Department of Natural Resources and Environment.*

GUPTA S., COWIE P. A., DAWERS N. H. & UNDERHILL J. R. 1998. A mechanism to explain rift-basin subsidence and stratigraphic patterns through fault-array evolution. *Geology* **26**, 595-598.

HALL M. & KEETLEY J. 2009. Otway Basin: stratigraphic and tectonic framework *GeoScience Victoria 3D Victoria Report 2. Department of Primary Industries*.

KRASSAY A. A., CATHRO D. L. & RYAN D. J. 2004. A regional tectonostratigraphic framework for the Otway Basin. *In, Boult, PJ, Johns, DR and Lang, SC (eds), Eastern Australasian Basins Symposium II, Petroleum Exploration Society of Australia, Special Publication, 97-116*.

LAMBAISE J. J. 1990. A model for tectonic control of lacustrine stratigraphic sequences in continental rift basins. *In:* Katz B. J. ed. *LACUSTRINE BASIN EXPLORATION - CASE STUDIES AND MODERN ANALOGS*, pp. 265 -276.

LAMBIASE J. J. & BOSWORTH W. 1995. Structural controls on sedimentation in continental rifts. *In: Hydrocarbon Habitat in Rift Basins*, pp. 117-144. **80** Geological Society of London, London.

LOVIBOND R., SUTILL R. J., SKINNER J. E. & N. A. A. 1995. The hydrocarbon potential of the Penola Trough, Otway Basin. *APEA Journal* **35**, 358 - 371.

MCLEOD A. E., UNDERHILL J. R., DAVIES S. R. & DAWERS N. H. 2002. The influence of fault array evolution on synrift sedimentation patterns: Controls on deposition in the Strathsprey-Brent-Stratfjord half graben, northern North Sea. *AAPG* **86**, 1061-1093.

MORGAN R. P., ALLEY N. F., ROWETT A. I. & WHITE M. R. 1995. Biostratigraphy (Chapter 6). In: Morton, J.G.G. and Drexel, J.F. (Eds.). *Petroleum Geology of South Australia.* 1: Otway Basin (Report 95/12) Mines and Energy South Australia, Adelaide, 95 - 102.

NORVICK M. S., SMITH M. A. & POWER M. R. 2001. The Plate Tectonic Evolution of Eastern Australasia Guided by the Stratigraphy of the Gippsland Basin. *Eastern Australian Basin Symposium* Special Publication 15-23.

NORVICK M. S. 2005. Plate tectonic reconstructions of Australia's southern margin. *Geoscience Australia Record 2005/07*

PARKER G. J. 1995. Early Cretaceous Stratigraphy Along The Northern Margin of The Otway Basin, Victoria, VIMP Report 23, . Melbourne, VIC.

PROSSER S. 1993. Rift-related linked depositional systems and their seismic expression. *In:* Williams G. D. & Dobb A. eds. *Tectonics and seismic sequence stratigraphy* pp. 35-66. **71** Geological Society Special Publication.

SCHLISCHE R. W. & OLSEN P. E. 1990. Quantatve filling model for continental extensional basins with applications to early Mesozoic rifts of eastern North America *Geology* 98, 135-155.

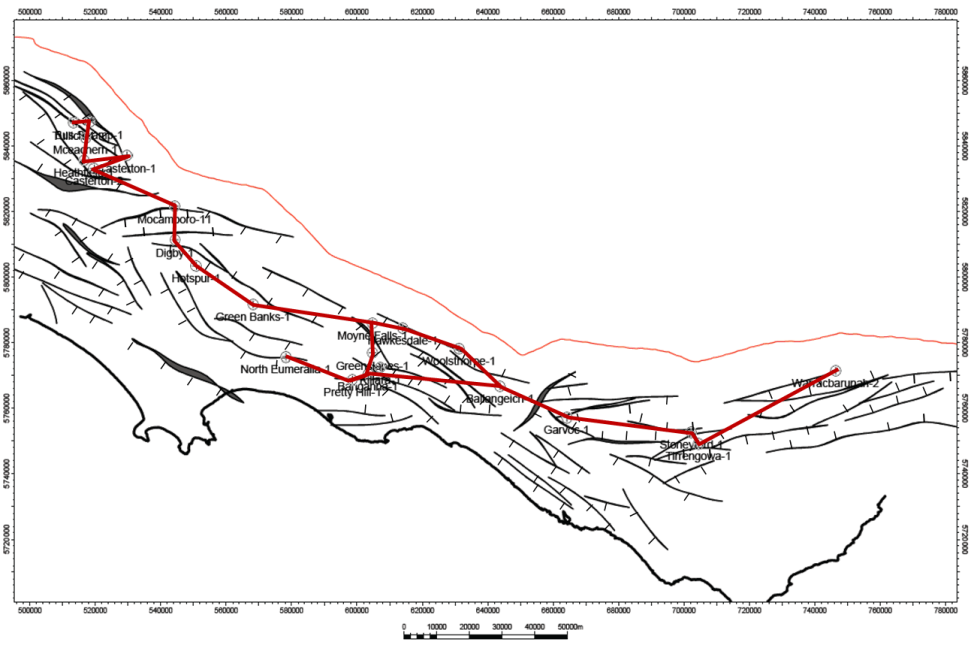

Figure 4 Location of well correlations conducted during this study

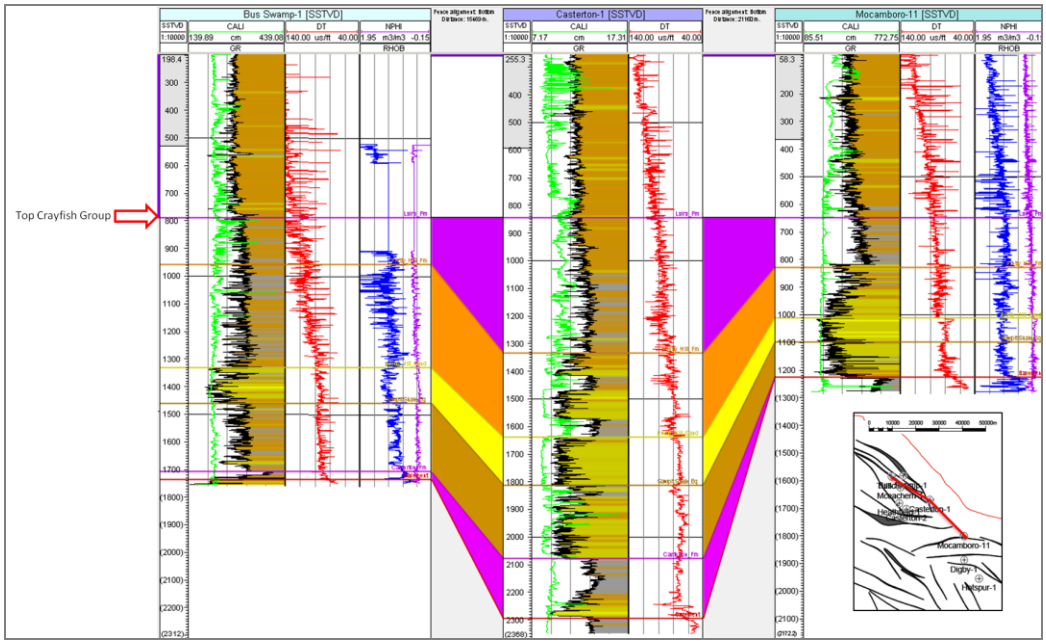

Figure 5 Well Correlation between Bus Swamp-1 and Mocamboro-11, showing all the major constituents of the Crayfish Group as interpreted by this study; Casterton Fm (light purple), Sawpit Shale equivalent (brown), Sawpit Sandstone equivalent (yellow), Pretty Hill Fm (orange), Laira Fm (dark purple). Note that the Sawpit Shale equivalent appears to contain lower gamma material in Casterton-1 and Mocamboro-11 compared to Bus Swamp-1. This is because these wells are situated in areas that were close to the potential sediment source during the time of the deposition of the Crayfish Group sediments

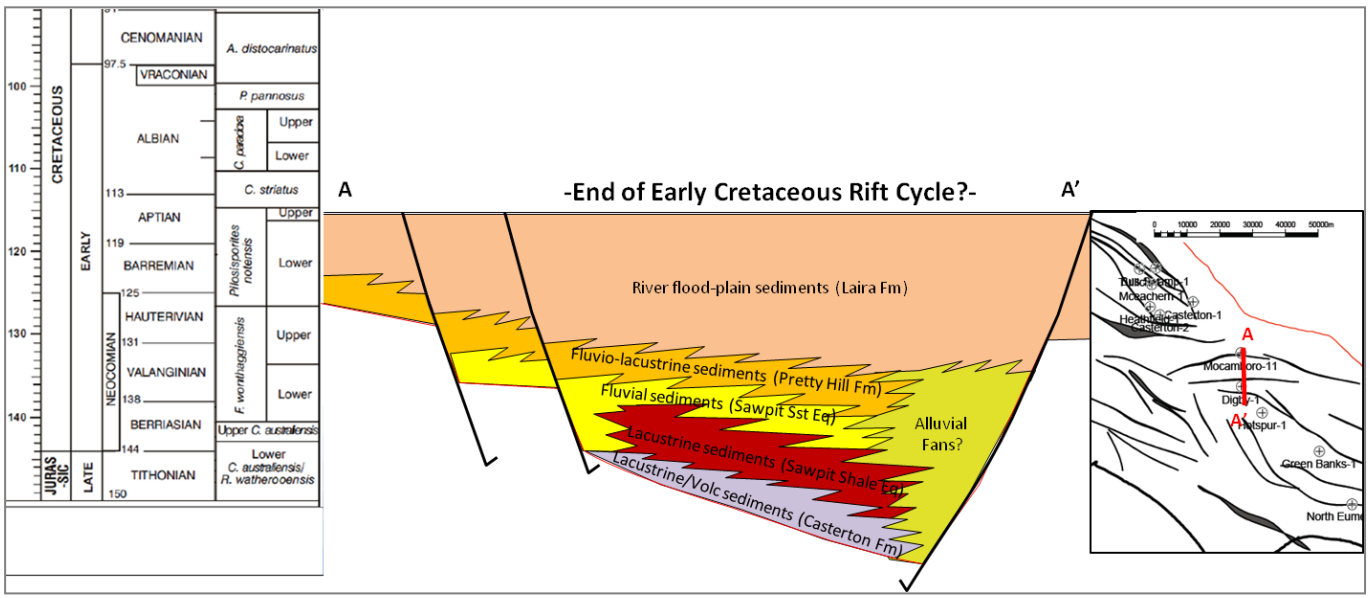

Figure 6 Generalised chronostratigraphic framework for the Early Cretaceous sediments of the Victorian section of the Onshore Otway Basin