Draft

2D modelling of a Palaeozoic glacimarine petroleum system, Tasmania Basin, Australia

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SUMMARY

The glacimarine Late Carboniferous to Late Permian Lower Parmeener Supergroup of the onshore Tasmania Basin contains potential source rocks in pyritic mudstones, Tasmanite Oil Shale and carbonaceous freshwater beds. An oil seep in southern Tasmania was sourced from the tasmanite. Potential reservoirs exist in freshwater sandstone, sealed by marine siltstone. The Upper Parmeener Supergroup of Triassic age contains sandstone and coals. During the mid Jurassic, thick (up to 600m) and extensive dolerite sills intruded into the basin. A tensional environment continued into the Cretaceous associated with Gondwana break-up (140Ma ~ 100Ma.). Block faulting was initiated at the beginning of the Tertiary.

This study involves petroleum system modelling in 2D section, simulated with PetroMod8.0. The work is based on an interpreted 2D seismic survey line and a regional structural history study. Stratigraphic and lithological data is derived from drill holes and outcrop data. The Jurassic igneous intrusion is set as a special event model.

The simulation result shows that all 3 Permian source rocks were effective, contributing different volumes of hydrocarbons. Jurassic dolerite intrusions affected petroleum system maturity and preservation. Different results obtained with different possible heat flows and structural histories demonstrate that they had a large control on hydrocarbon generation, migration, distribution and preservation. This study highlights aspects for further work especially the need for a greater understanding of palaeo- heat flow, but it shows that considerable hydrocarbon potential exists in the onshore Tasmania Basin.

Key words: petroleum system, modelling, Tasmania Basin, dolerite, Permian, Jurassic.

INTRODUCTION

The Tasmania Basin is composed of the Late Carboniferous-Late Triassic Parmeener Supergroup. The basal succession consists of 5-450m of tillite deposited unconformably on eroded highlands formed after Devonian deformation. The remainder of the Lower Parmeener Supergroup is mainly fossiliferous glacimarine siltstones, sandstones and limestones overlain conformably on the tills. The Lower Parmeener Supergroup thins to the southwest, northwest, northeast towards palaeo-land, and its southern and northern boundaries are presently offshore. The Upper Parmeener Supergroup consists of conformably overlying uppermost Permian and Upper Triassic terrestrial sandstones, siltstones and minor coal measures. The former widespread presence of 2-3km of Jurassic and Cretaceous sediments is suggested from apatite fission track studies but they have only been definitely found in a small graben in southern Tasmania. Tertiary fluvial and lacustrine deposits are found locally in graben such as the Longford Basin.

The Tasmania Basin was initiated by crustal extension with an axis trending approximately N-S. The tensional environment continued into the Cretaceous (Bendall *et al*, 2000) associated with Gondwana break-up. During the Early Jurassic (about 180 Ma), extensive and thick (up to 600m) dolerite sheets intruded into the Parmeener Supergroup from multi-feeder dykes. From the Early Cretaceous (130Ma), the basin uplifted rapidly (Kohn *et al*, 2002). A non-depositional or erosional environment extended to the beginning of the Tertiary when block faulting occurred followed by deposition in graben such as the Longford Basin.

The Gondwana Petroleum System 1 is identified in the Lower Parmeener Supergroup with glacimarine pyritic mudstone, Tasmanite Oil Shale, carbonaceous freshwater beds as potential source rock, with freshwater sandstone as potential reservoirs and with marine mudstone and siltstone as potential seals. Source rock maturity data indicates that the basin is generally immature in the north, but is mature through the main body of the basin (Reid, 2003). Oil seeps in outcrop, oil inclusions and gas show from drill holes suggest that hydrocarbon have been generated and expelled. Traps consisting of domes, anticlines and faults were formed probably during the Early Cretaceous (Bendall *et al,* 1991, 2000).

Based on recently acquired data, several models for a 2D section were constructed with software package PetroMod8.0. Jurassic dolerite intrusion is included as an event model in the model construction. Different possible event models were set to infer possible affects. Finite element simulation was conducted to simulate the petroleum system evolution process through the geology history in the section.

The simulation result shows the Parmeener Supergroup is an effective petroleum system. Jurassic dolerite intrusion has significantly affected petroleum system maturity and preservation. Different results attained with different possible models demonstrate that heat flow and structural history have a great control on hydrocarbon generation, migration and preservation. This study shows that more work on structural and heat flow history is needed for a better understanding of the petroleum system. However, the study shows that economic hydrocarbon deposits potentially exist in the onshore Tasmania Basin.

METHOD AND RESULTS

Petroleum system model construction

Based on an interpreted seismic survey line (Stacey, 2003) and recently acquired drill hole data and other available geological, geochemical and geophysical data, 2D section petroleum system models of the onshore Tasmania Basin were constructed and then simulated with PetroMod 8.1(Table 1), Figure 1.

Heat flow rate model:
Heat flow rate is evenly set along the section and change is considered during the Jurassic igneous intrusions (from 60 to 95 and then to 60 mW/m^2).

Structural history model:
Erosion, block faulting, uneven uplift, regional folding and fault transmissibility are considered through the geological history.

Igneous intrusion (dolerite sill) model:
The igneous intrusion model parameters are set as follow. Intrusion time 180 Ma, Intrusion temperature 1000C, Solidus temperature 950 C, Magma density 2500 kg/m^3, Magma heat capacity 0.7 kcal/kg/K), Crystallization heat 700 (MJ/m).

Simulation parameter and simulation results

Part of simulation results is showed as in figure 2, 3, 4.

1) All the source rocks may be effective for oil expulsion when they enter the mature zone.
2) Source rocks enter the oil window regionally as early as the Early Jurassic because of dolerite intrusion.
3) In the case where an eroded section above dolerite less than 1000m is assumed, the lower part of the Parmeener Supergroup did not enter the mature zone, while the upper part, closer to the dolerite sheets, may enter the over matured zone.
4) Dolerite (except near the surface) is a good seal both for oil and gas while the Woody Island and Bundella Fms are good seals only for oil.
5) Faulting time and fault zone transmissibility are key factors for oil accumulation and can affect regional maturation status.
6) Further studies are needed to refine palaeo-heat flow.
7) Traps may be formed in the Uint1 and Liffey Gp

CONCLUSIONS

The Parmeener Supergroup petroleum system contains good quality source rocks (mainly type I and type II kerogen), seal rocks (Ferntree and Bundella Fms for oil and dolerite for both oil and gas), reservoir rocks (Faulkner Gp), and maturation conditions. Intrusive Jurassic dolerite is a key factor in petroleum system evolution. It not only matured the source rock proximally but also sealed the distally expelled hydrocarbons. Cretaceous-Tertiary uplift and block faulting may have fractured the traps but the faults provide vertical migration conduits for the upper traps. The palaeo-heat flow rate determined the final maturation status of the source rocks and the generated hydrocarbon components. Structural and heat flow histories will need further study in order to achieve a better understanding of the Gondwana 1 Petroleum System. This study confirms that economic hydrocarbon potential exists in the onshore Tasmania Basin.

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Age (Ma)	Structural history	Burial history	Related properties	PS elements and related parameter
1.65-0	Deposit locally	(Quaternary)		
66-1.65	Volcanic deposit/Block faulting locally	(Tertiary)	Regional volcanic/terrestrial deposition	Local deposition or eroded overburden
140-66	Uplift	(Cretaceous)	Erosion	Eroded or non-deposition
200-140	Dolerite intrusion	Hiatus (Jurassic)	No deposit	Eroded or non-deposition
235-200	Deposition 175-0 local erosion	T2 (supposed eroded stratum)	Siltstone + sandstone	Eroded overburden
240-235	Deposition	T1	Siltstone + sandstone	Over burden
265-240	Deposition 18-0 locally erosion	Unit1 (Triassic)	Quartz sandstone	Reservoir
270-265	Deposition	Ferntree Fm	Mudstone	Seal
283-270	Deposition	Cascades Gp	Siltstone + limestone	Seal
286-283	Deposition	Liffey Gp	Sandstone + siltstone	Reservoir (4.1-14.9%, 0.4-8.8mD)
291-286	Deposition	Bundella	Shale/organic mudstone	Poor source rock (TOC 0.7 wt%, HI, 550)
293-291	Deposition	Woody Island Fm	Siltstone + shale	Source rock (TOC 1.5 wt %, type I-II, HI 550). Tasmanite:(TOC 2.5-68%, type I, HI 900 Ro<0.5 Tmax 450C)
300-293	Deposition	Basal tillite (Late Carboniferous)	Diamictite + conglomerates + sandstone	Under burden
310-300	Deposition	Pre-Permian unconformity	Limestone + dolomite? Deformed Devonian turbidites?	Eroded folded basement

Table 1. Related data and parameters used in petroleum system modelling onshore Tasmania Basin

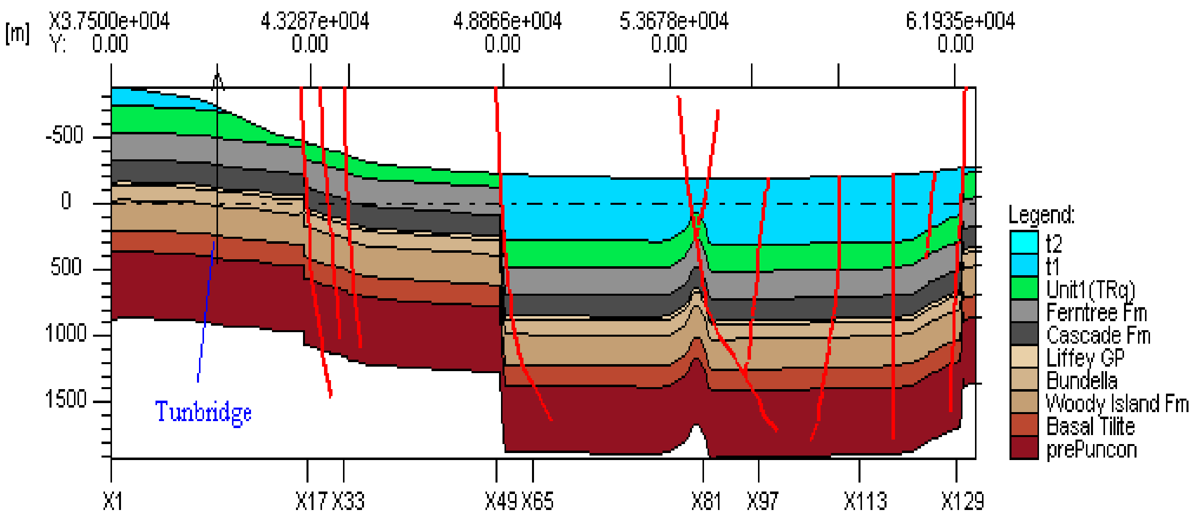

Figure 1. 2D cross section of petroleum system modelling onshore Tasmania Basin

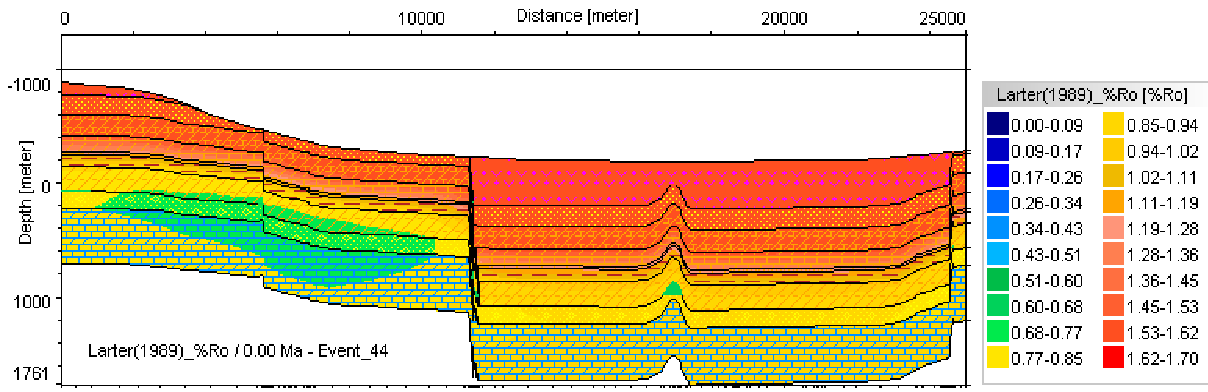

Figure 2. Present day maturation zone and hydrocarbon distribution. Uneven uplift. causing uneven maturation is shown.

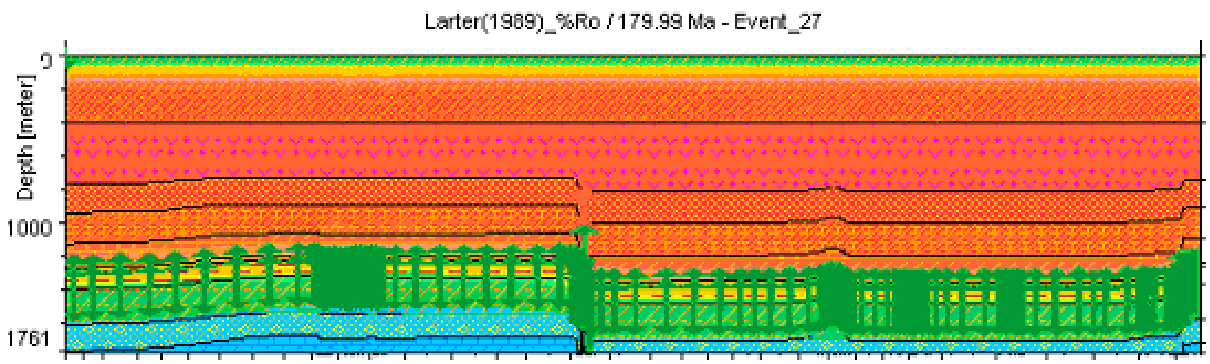

Figure 3. When eroded unit is set as 500m above dolerite then the source rock enters into oil window and expels hydrocarbons at 179.99 Ma. This is caused solely by dolerite intrusion. Green arrow shows oil migration vector while the red arrow shows gas migration vector.

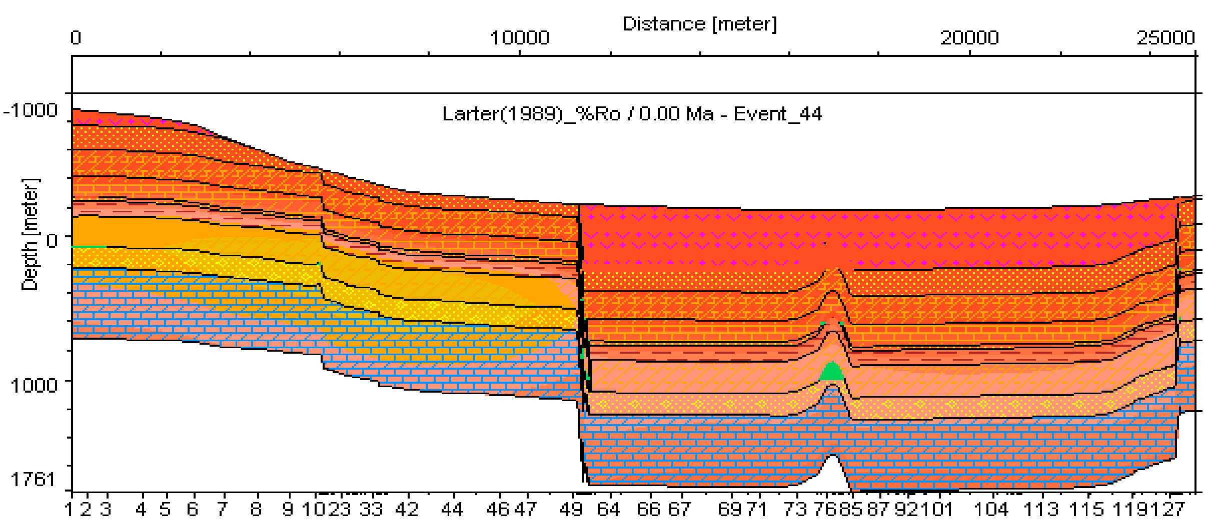

Figure 4. When heat flow rate is set higher during igneous intrusion (95 mW/m^2) and eroded unit set as 1000m, the main section enters the gas window but oil could still exist in deeper traps.