

CONTROLS ON HYDROCARBON GENERATION IN THE GONDWANAN TASMANIA BASIN

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Abstract

Recent studies show that the Gondwanan Petroleum System is present in the Late Carboniferous-Late Triassic onshore Tasmania Basin with mudstone and coal source rocks, sandstone reservoirs and siltstone seals. Maturation studies indicate that most of the basin is in the oil window. Hydrocarbon generation, expulsion and migration is indicated by oil seeps in outcrop, by oil inclusions in cores and gas shows from drill holes.

The onshore Tasmania Basin experienced successive extensional episodes, deposition from Permian to possibly Cretaceous, rapid uneven uplift and erosion from Early Cretaceous to Tertiary, block faulting and later regional deposition in the Tertiary. Its geological history is further complicated by the intrusion of up to 600m thick, extensive, Jurassic dolerite sheets.

We have constructed a 2D cross section petroleum system model, then simulated its evolution using PetroMod8.0 modelling package. The Jurassic dolerite intrusion is set as a special event model.

The study results show that the source rocks (Woody Island Fm inclusive of tasmanite, Liffey Gp) may be effective, contributing different volumes of hydrocarbons. Jurassic dolerite intrusion has affected petroleum system maturity and preservation dependant on its intrusion depth and position. Different results attained with different models of possible eroded thickness and heat flow rate change during igneous intrusion, demonstrate that heat flow and structural history have the strongest control on hydrocarbon generation, migration and preservation. Quantitative modelling confirms the hydrocarbon potential of the onshore Tasmania Basin.

Keywords: petroleum system, modelling, Tasmania Basin, Jurassic dolerite, Permian, igneous intrusion.

Introduction

Petroleum exploration history of Tasmania

Petroleum exploration started in the early 1890's, but was discouraged by a no-oil opinion from government geologists (Bacon 1996; Wilkinson 1991). This negative perception continues to the present. The Petroleum System Concept was introduced by Magoon and Dow (1991) and applied to Australian basins soon after (Bradshaw 1993). Based on the petroleum system concept and with new data from drilling,

geochemistry and geophysics, Bendall, et al (2000) reassessed the petroleum potential of the onshore Tasmania Basin with the conclusion that petroleum systems exist on shore Tasmania Basin and hydrocarbon discovery is possible.

Geology and geological history of onshore Tasmania Basin

The onshore Tasmania Basin is composed of the Late Carboniferous-Late Triassic Parmeener Supergroup (Reid et al, this volume). The basal succession consists of 0-450m of tillite deposited unconformably on eroded highlands formed after Devonian deformation. The remainder of the Lower Parmeener Supergroup is mainly fossiliferous glacial marine siltstones, sandstones and limestones. The Lower Parmeener Supergroup thins to the southwest, northwest, northeast towards palaeo-land, and its southern and northern boundaries are presently offshore. It is conformably overlain by Upper Parmeener Supergroup of uppermost Permian and Upper Triassic terrestrial sandstones, siltstones and minor coal measures. The former widespread presence of 2.5-4km of Jurassic and Cretaceous sediments is suggested from apatite fission track studies (O'Sullivan & Kohn 1997), 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 onshore 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 (Berry and Stacey, this volume).

Petroleum systems in the onshore Tasmania Basin

The Gondwana Petroleum System 1 is identified in the Lower Parmeener Supergroup. Glacial marine pyritic mudstone of the Woody Island/Quamby Fm, Tasmanite Oil Shale, and mid-Permian carbonaceous freshwater beds of the Liffey Group are potential source rocks, with freshwater sandstone of Liffey Group as potential reservoirs and with marine mudstone and siltstone of Cascade and Ferntree Fm 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 and Burrett, this volume). Oil seeps in outcrop, oil inclusions and gas shows from drill holes prove that hydrocarbons have been generated (Reid and Burrett, this volume). Traps consisting of domes, anticlines and faults were formed probably during the Early Cretaceous and Early Tertiary (Bendall *et al*, 1991, 2000).

Aims

Based on recently acquired data, several geology models for a 2D section were constructed using software package PetroMod8.0 to simulate the petroleum system process and to further identify and quantify the controlling factors hydrocarbon generation, migration, distribution and preservation in the Tasmania Basin.

Jurassic dolerite is extensively distributed in or near the petroleum system and is included as an event model in the model construction and simulation. Different possible heat flow and structural history event models were set in order to simulate possible affects.

The simulation results confirm that 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 large 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 accumulations potentially exist in the onshore Tasmania Basin.

Methods and data used

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 8.0(Table 1), Figure 1.

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

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 deposit or eroded overburden
140-66	Rising	(Cretaceous)	Erosion	Eroded or no deposit
200-140	Dolerite intrusion	Hiatus (Jurassic)	No deposit	Eroded or no deposit
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 stone)	Sandstone	Over burden
270-265	Deposition	Fern tree Fm	Calcareous 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) Source rock (TOC 3 wt%, HI 550)
291-286	Deposition	Bundella Fm	Shale	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).
300-293	Deposition	Basal tillite	Sandstone + conglomerates + diamictite	Underlying sequence (underburden)
310-300	Deposition	Pre Permian unconformity	Limestone + dolomite	Eroded folded basement

Heat flow tendency model

Heat flow rate is evenly set along the section and change is considered during the Jurassic igneous intrusions (from 60 to 100 and then back to 60 mW/m² again) in the alternative event models. Figure 2.

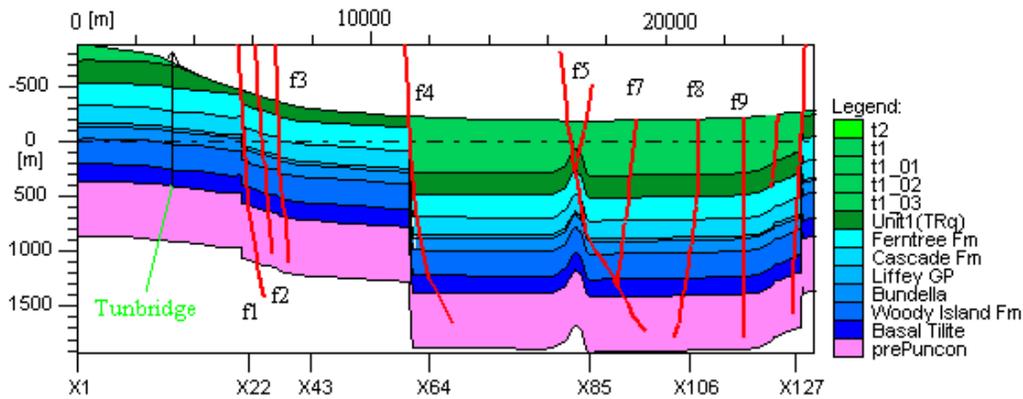


Figure 1. 2D cross section of the petroleum system modelling onshore Tasmania Basin

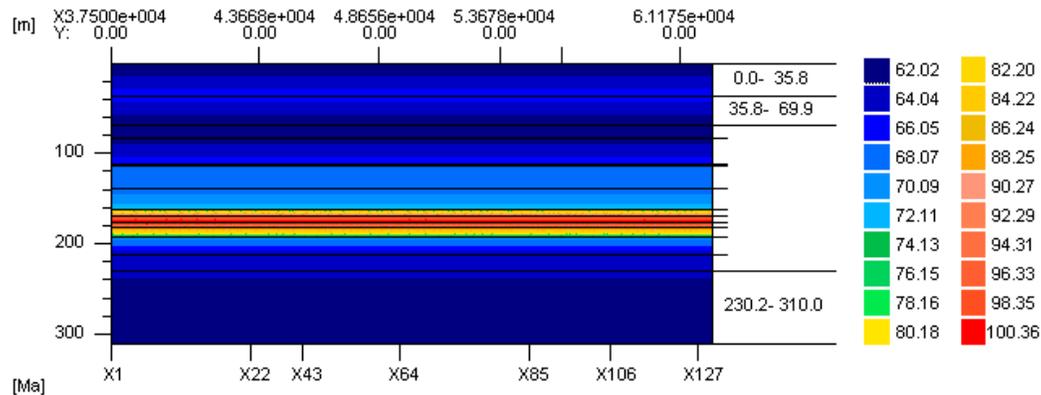


Figure 2. Heat flow trend assigned to the 2D section. The heat flow rate elevation is considered for igneous intrusion. Coloured boxes is the key of heat flow rate value in the unit of mW/m².

Structural history model

Erosion, block faulting, uneven uplift, regional folding and fault transmissibility are considered through the geological history. The reverse fault is simplified into a monocline as the software cannot simulate it. The eroded section (t2) thickness above the Triassic/Jurassic dolerite is set differently in different models.

Igneous intrusion (dolerite sill) model

The igneous intrusion event model parameters are set as follows mainly based on Leaman, (1975). Intrusion time is 180 Ma, Intrusion temperature is 1200 C, Solidus

temperature is 1100C, Magma density is 2600 kg/m³, Magma heat capacity is 0.7 kcal/kg/K, Crystallization heat is 700 MJ/m.

Results and analysis

Simulation results

Part of simulation results is shown as in Table 2 and Figure 3, 4, 5, 6, 7.

Model nm0101, nm 0102 show that if do not consider the igneous intrusion infection, take the heat flow rate as a constant of 60 mW/m² and take the erosion start from 130 ma (Early Cretaceous) then the source rock may get in oil zone. The accumulation is oil. But if just take the eroded unit as Triassic, and erosion start from 175 ma. Then the maturation time and expulsion time will be much earlier though the maturation status is still in oil zone. Table 2 and Figure 4.

Taken igneous intrusion effective but do not consider the heat flow rate change (model m131) then the effect of intrusion body contained thermal energy on maturation is demonstrated. Table 2 and Figure 3, 5.

Table 2. Events models used in PS models construction and simulation results:

<i>Event model name</i>	nm0102	nm0101	m101	m131	m132	m135	m50
Stratigraphy model							
Tertiary eroded thickness (km)	0	0	0	0	0	0	1
Triassic eroded thickness (km)			3	0.5	0.5	3	0.5
Eroded T, J, K thickness (km)	1.5	2					
Igneous intrusion	Not set	Not set	Not set	Set	Set	Set	Set
Heat flow model	df	df	df	df	hfl	hfl	hfl
Structural model	Not set	not set	not set	not set	not set	not set	
Faults name							f1, f4, f5
Faulting start age							At 140 Ma
Faults set open age (along)							since 140Ma
Paleo section							
Results model:							
Mature status today	just get in oil zone	All in oil zone	All in oil zone	Upper in wet gas zone, lower in oil zone	Most in wet gas zone, part oil zone	wet gas zone	Most wet gas zone, part oil zone
Oil expulsion age (Ma)	137 (just start)	187-136	225-210	180-171	190-198	225-210	180-171
Trapped HC	no oil accumulation in reservoir yet	oil	oil	wet gas in upper near dolerite trap, oil and gas in lower trap	wet gas in upper near dolerite trap, oil and gas in lower trap	wet gas in lower trap, few gas left in upper trap	less gas accumulated in lower trap

If taken heat flow rate changed during igneous intrusion (model m132, m135) then the source rock will matured much earlier but if the eroded thickness more than 3km then the igneous intrusion will not affect the maturation status obviously instead it will affect the generated hydrocarbon distribution. Table 2 and Figure 6.

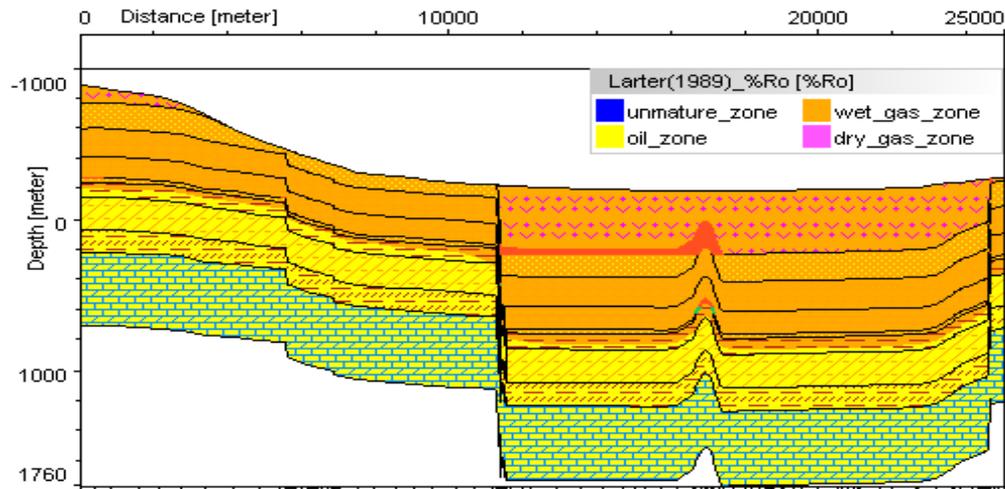


Figure 3. Model m131 simulation results showed present day maturation status and hydrocarbon distribution characters. Green is oil accumulation and red is gas.

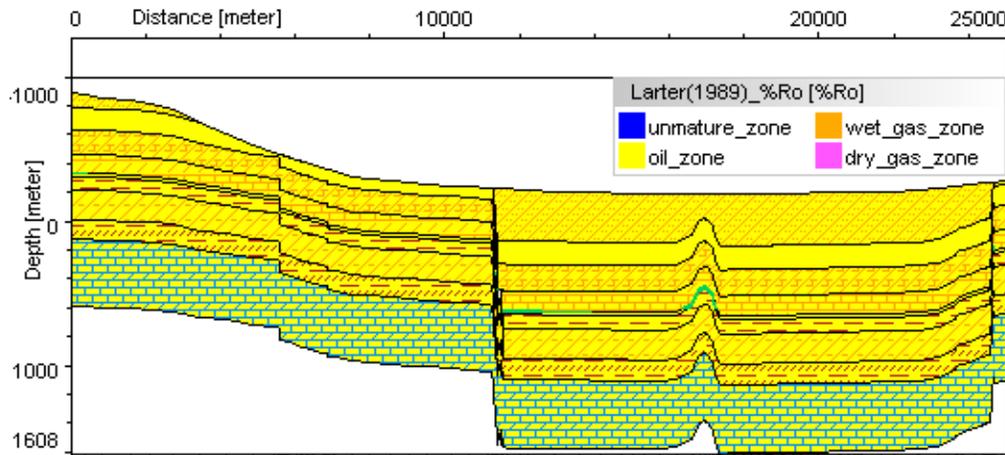


Figure 4. Model nm0101 simulation results showed present day maturation status and hydrocarbon distribution characters if the igneous intrusion effect is not considered. Green is oil accumulation and red is gas.

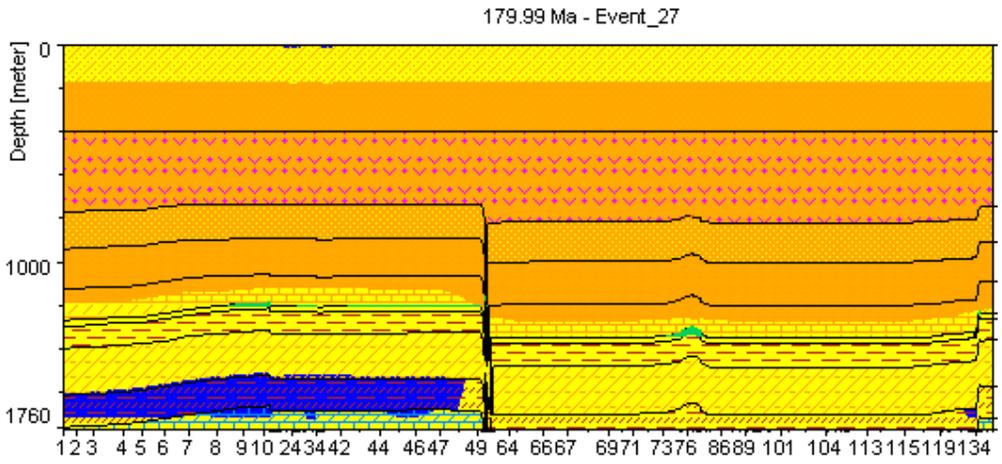


Figure 5. Mature status when igneous intruded while eroded section t2 is set as 500 meters thick and heat flow rate elevation during intrusion is not considered (model m131). The key is same as Figure 2.

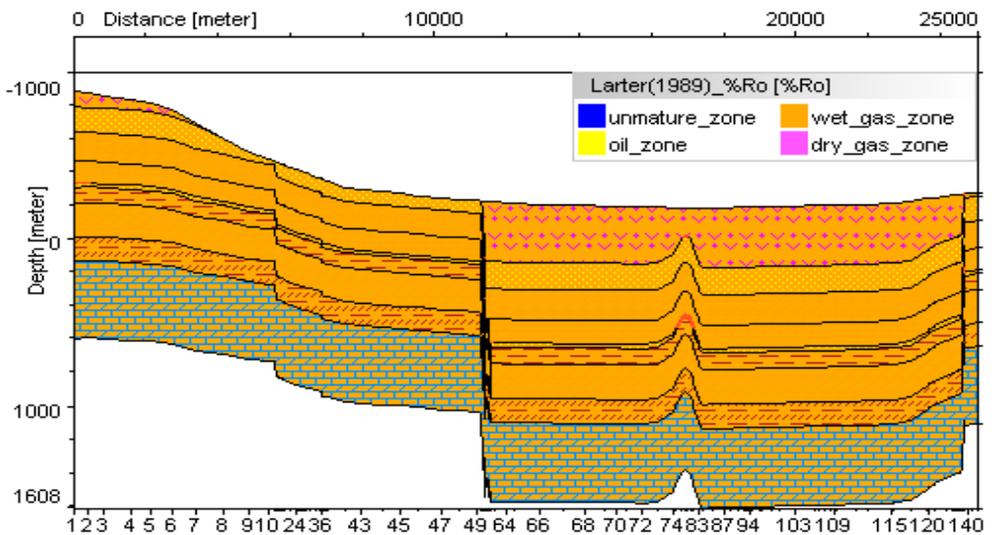


Figure 6. Model m135 simulation result. All in wet gas zone and little gas left in upper traps.

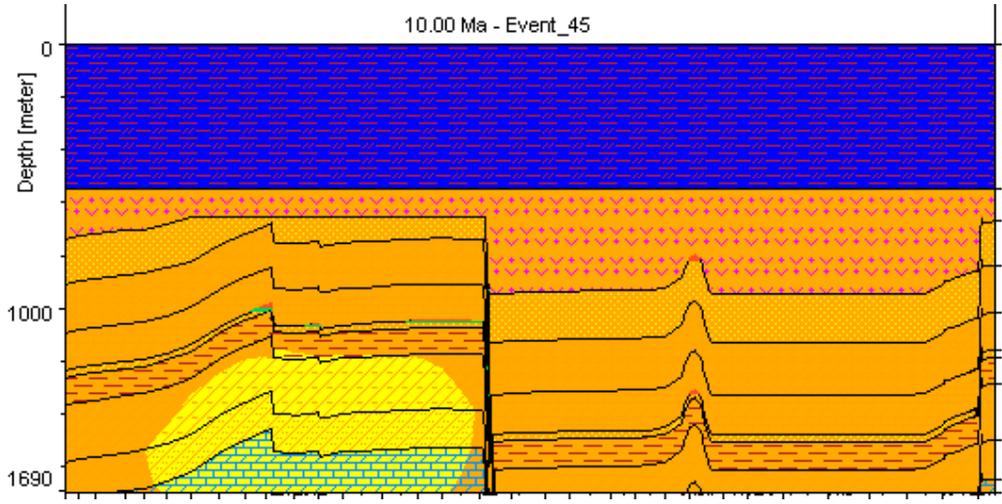


Figure 7. Model m50 shows that a 1km thick Tertiary deposition will not affect the source rocks maturation status. The accumulation amount is much reduced because of the leaching through the fault zone.

In model m50 structural history and possible Tertiary eroded deposit is simulated. Compared with m132 faulting event affected hydrocarbon accumulation and preservation largely. Tertiary deposition with lifted and eroded dolerite as basement does not affect the maturation status of the petroleum system. Table 2 and Figure 7.

From the simulation results, we can say that:

- 1) All the source rocks may be effective for oil expulsion when they enter the mature zone.
- 2) Maturation status may be heavily disturbed by igneous intrusion especially when the eroded unit are less and the erosion occurred early. In this case its role should be considered in the maturation assessment of the petroleum system.
- 3) Igneous intrusion could affect the maturation status of the petroleum system as well as the hydrocarbon distribution.
- 4) In the case where an eroded section above dolerite less than 1000m is assumed and heat flow rate elevation is not considered during igneous intrusion, the lower part of the Parmeener Supergroup may just enter the mature zone, while the upper part, closer to the dolerite sheets, has entered the gas zone. Correspondingly upper trap may contain more matured hydrocarbon than lower traps.
- 5) Faulting time and fault zone transmissibility are key factors for oil accumulation and can affect regional maturation status.
- 6) Palaeo-heat flow is another key factor for the petroleum system evolution. And further studies are needed to refine palaeo-heat flow.
- 7) Traps may be formed in the Lower Triassic Unit1 and in the 'middle' Permian Liffey Gp.
- 8) Hydrocarbon potential exists in the onshore Tasmania Basin.

Conclusions

The Parmeener Supergroup petroleum system contains source rocks (Woody Island Fm and Liffey Gp), seal rocks (Ferntree and Cascades Fms for oil and dolerite for both oil and gas), reservoir rocks (Liffey/Faulkner Gp), and appropriate 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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