Petroleum Systems Modelling: Charge Evaluation of the Eltham Area (PEP 51150), Onshore Taranaki Basin

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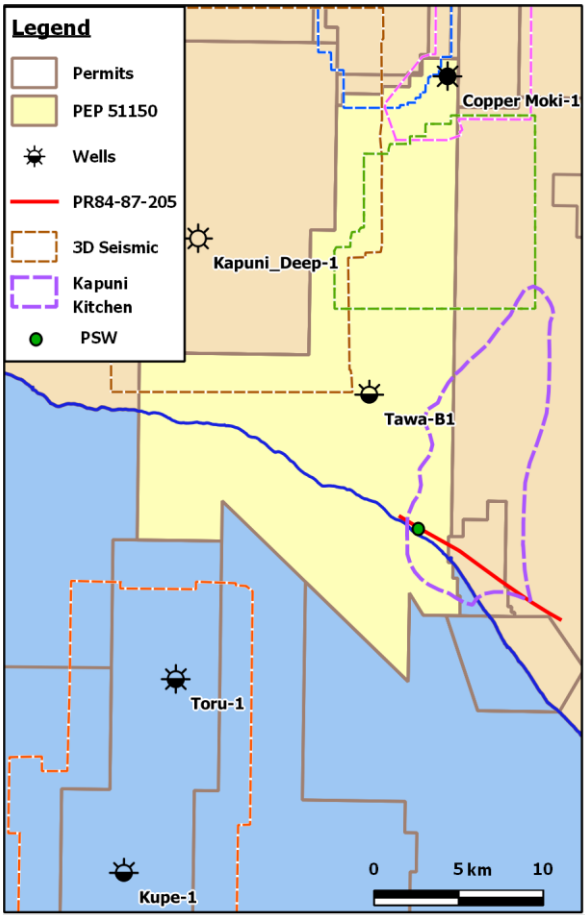
An understanding of basin evolution and the related petroleum system is an essential step in hydrocarbon exploration and exploitation. The Taranaki basin has been widely studied and modelled by GNS Science and independent researchers. Although the PEP 51150 area is covered by regional basin models, it has not been specifically modelled to understand the block's prospectivity. The main objective of this study is to answer questions with regard to generation and timing of hydrocarbon expulsion in the block. The model also helps us understand whether the source rock in this area is within the oil or gas generation window. Due to the paucity of calibration data in the deepest part of the study area, geochemical information from offset wells has been included in the model. The calibration wells were selected based on their proximity to the study area, and abundance and reliability of data. Wells included in the study were Toru-1 and Kupe-1 to the south, Kapuni Deep-1 to the north-west and Tawa-B1 within the permit area. A pseudo well was located in the deepest part of the block and modelled using input parameters and assumptions from the selected wells.

The petroleum systems modelling indicates that all the four source rock intervals: Rakopi, Farewell, Kaimiro and Mangahewa Formations are actively generating hydrocarbons. Within the deepest part of the permit the Farewell and Rakopi source rocks may have entered the gas window while the Kaimiro and Mangahewa Formation source rocks remain in the oil window. Assuming a transformation ratio threshold of 30%, the critical moment was attained in the Mid Miocene period. Some reservoir rocks were contemporaneously deposited during this period and may not have been properly sealed during migration.

Hydrocarbon migration is another risk element when assessing potential within this area. Faults are considered to play an important part in migration and thus targets proximal to faulting may have lower risk associated with charge. Understanding the migration path will be critical for future exploration activities

Introduction

The NZEC operated permit, PEP 51150 (Figure 1) is located within the onshore portion of the Taranaki Basin, which is a major Late Cretaceous to Recent hydrocarbon-bearing sedimentary basin located in the west of the North Island, New Zealand (King & Thrasher 1996). The Taranaki Basin has been widely studied and modelled by GNS Science and independent researchers (Hayward and Wood 1989, Kamp and Green 1990, Armstrong et al. 1996, Higgs et. al. 2007, Kroeger et. al. 2013). However, the PEP 51150 area has not been specifically modelled to understand the permit's prospectivity. Charge assessment is carried out specifically to understand the charge history and exploration risk associated with reservoir location, formation of structural and stratigraphic traps relative to the timing of hydrocarbon expulsion and migration.



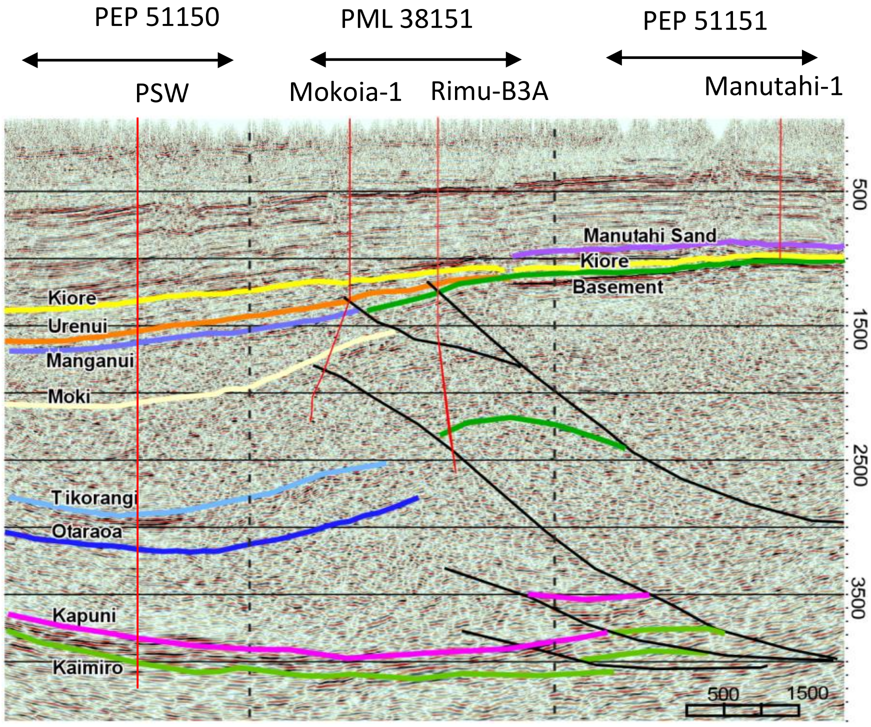


Figure 1: Location map of the Block PEP 51150 with Pseudo-well location (PSW) and a section showing interpreted seismic line PR84-87-205, wells and permit boundary

Model Inputs

A study of available published literature was used to collect stratigraphic information for the models. None of the wells penetrated Basement so calculated assumptions have been made for thickness and exhumation of formations beyond well total depths. The forward modelling relied on the assumptions of regional unconformities, especially the age and duration of erosion or non-deposition and the thickness of any eroded sediment. Forward modelling also relied on assumptions of bulk lithologies, geochemical parameters and kinetics. Generalized bulk lithologies were used for each formation/unit. Geochemical data in terms of Total Organic Carbon (TOC) and Hydrogen Index (HI) were used from publicly available ROCKEVAL data on respective source rock intervals and different kinetics were applied to check the effect on modelling.

Petroleum system modelling depends mainly on the boundary conditions which in turn rely on an understanding of paleogeography and paleotectonic events in the basin. The Taranaki Basin is very complex in this regards. However, there is a general agreement that the basin can be divided into three structural units separated by tectonic lineaments: Western stable platform, NE mobile belt and SE mobile belt.

The northern part of the basin is different to the south both structurally (Knox, 1982) and thermally (Pandey, 1981). The study area falls within the SE Mobile Belt. Care is taken to avoid the Tarata Thrust Zone as thrusting will increase the complications of the 1D model.

Paleowater depths have been ascertained from biostratigraphic studies undertaken by GNS at Kapuni Deep-1 and Kupe-1. These depths have been applied to the models where the paleowater depths are unknown. Sediment water interface temperature depends on the paleogeographic reconstruction of the basin and is used from the internal database of PetroMod depending on the present latitude. Tectonic phases affecting the basin are used to determine the heat flow history of the basin.

The geohistory of the study area is divided into three broad phases, active extension, passive margin subsidence and quiescence, and finally active compression and crustal thickening. From compiled works of various researchers, an agreement can be seen for Late Cretaceous-Paleocene extension, thermal sag and subsidence lasting until the Oligocene, then shortening in the Miocene that continues to the present day. Calibration data from the wells in the form of Vitrinite Reflectance and Bottom Hole Temperatures (BHT) were collected from public sources including core evaluation reports and well log headers respectively. As BHTs available have no time-since-circulation information, a simple correction is done by adding 18°C. (http://www.zetaware.com/utilities/bht/default.html)

Model Calibration

Due to the paucity of calibration data in the deepest part of the study area, bottomhole temperatures and vitrinite reflectance from offset wells have been included in the model. Calibration wells were selected based on proximity to the study area and, abundance and reliability of calibration data. The wells used include Toru-1 and Kupe-1 to the south, Kapuni Deep-1 (KD-1) to the north-west and Tawa-B1 within the permit.

Models were calibrated with available vitrinite reflectance and temperature values (Lowery, 1988 and well completion reports) as shown in Figure 2a, 2b, 2c, 2d and 2e. A reasonable calibration is obtained for the modelled wells.

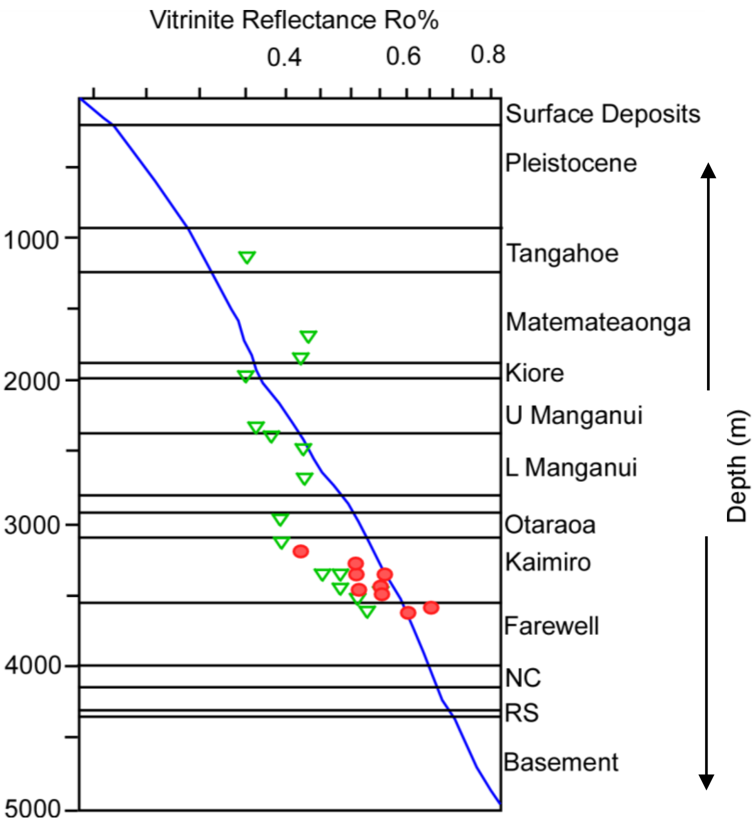


Figure 2a: Maturity calibration Kupe-1

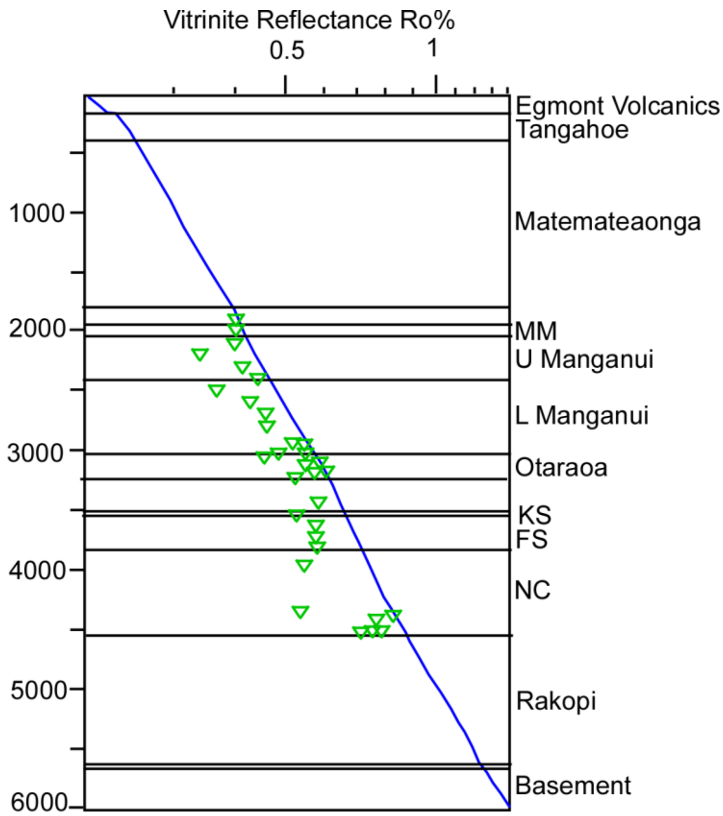


Figure 2b: Maturity calibration KD-1

(RS: Rakopi Source, NC: North Cape, (KS: Kaimiro Source, FS: Farewell Source MM: Mount Messenger)

▽ : VRo data from PR1341 ● : VRo data from Armstrong's thesis

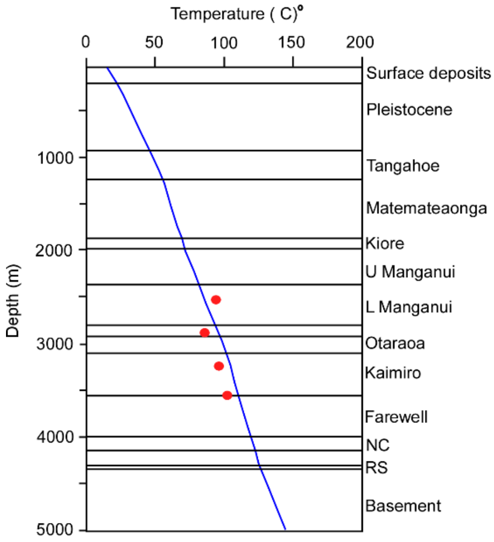


Figure 2c: Temp calibration Kupe-1

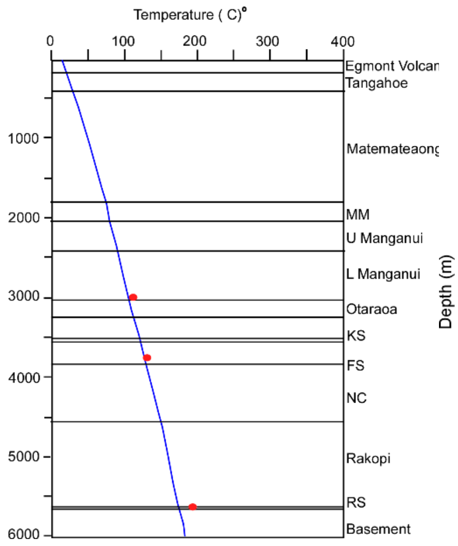


Figure 2d: Temp calibration KD-1

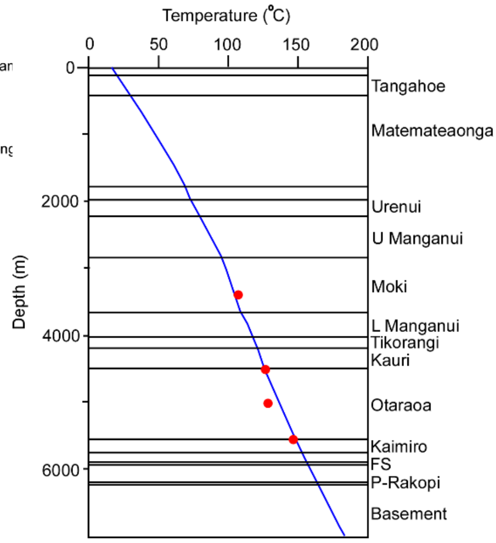


Figure 2e: Temp calibration Tawa-B1

Pseudo-well Location (PSW)

The calibrated model's boundary conditions were used to model a pseudo-well location in the deepest part of the basin. Seismic line PR84-87-205 was selected for this purpose and then interpreted and depth converted to obtain the formation tops for constructing the main layers of the model (Figure 1).

Model Results

Finally, Transformation Ratios (TR), which is the percentage of kerogen transformed into petroleum were obtained for the models (Table1). The TR in Tawa B1 area is encouraging. Here Rakopi source rocks started transforming in mid Miocene with current TR of approximately 70%. At the pseudo well location Rakopi source (RS) rocks show TR values of 87%, while Farewell source (FS) rocks shows TR of 78% and Kaimiro source (KS) rocks show TR of 70% (Figure 3a). An additional Mangahewa Source (MS) is present in Tawa-B1 and PSW where TR values of 51% and 49% respectively are achieved.

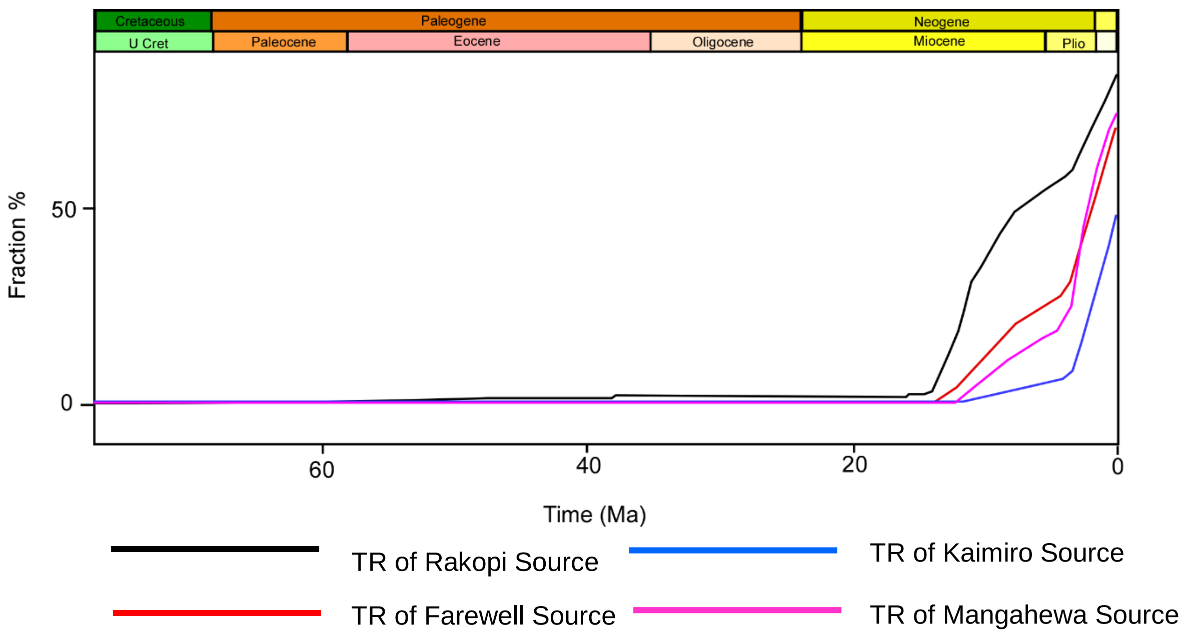


Figure 3a: Transformation Ratios of Rakopi, Farewell, Kaimiro and Mangahewa source rocks in PSW

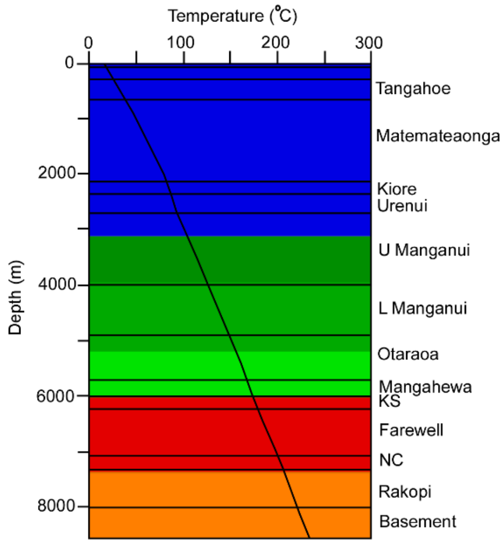


Figure 3b: Sweeny Burnham maturity index at PSW

Table1: TRs of source rocks as modelled in wells

Well	TR for Rakopi Source	TR for Farewell Source	TR for Kaimiro Source	TR for Mangahewa Source
Kupe-1	1.7%	0.9%	none	none
Toru-1	42%	24%	15%	none
KD-1	47%	4%	3%	none
Tawa-B1	70%	60%	55%	51%
PSW	87%	78%	70%	49%

Phase of Hydrocarbons

Based on vitrinite reflectance (Sweeney Burnham 1990 cited in PetroMod v11 SP3), maturities of source rocks (Rakopi, Farewell, Kaimiro) in the pseudo-well are in the gas window (Figure 3b) while Mangahewa source rock are in the oil window. However, in coals the effective oil window starts at higher maturities than the conventional oil window, and in addition extends to higher maturities (Petersen, 2004).

Conclusions

Results of the 1D basin model infer that all four Rakopi, Farewell, Kaimiro and Mangahewa source rock intervals are actively generating hydrocarbons. Within the deepest part of the permit at PSW the Farewell and Rakopi source rocks may have entered the gas window while the Kaimiro and Mangahewa Formation source rocks remain in the oil window. A petroleum systems event chart is shown in (Figure 4) where a critical moment is attained in the Mid Miocene. Hydrocarbon migration through faults and carrier beds was not modelled in this study as it is beyond the scope of 1D modelling but understanding the migration path will be critical for future exploration activities.

Inference from calibration wells:

1. Burial depth attained by source rock horizons in Kapuni Deep-1 is enough to generate hydrocarbons locally.
2. Although source rock horizons are present at the Kupe-1 location they were not buried deep enough to the optimum conditions for hydrocarbon generation.

Inference from wells in the permit area:

1. At the Tawa-B1 location Rakopi source rocks started generating hydrocarbons in the Mid Miocene and crossed the critical moment in the Late Miocene. All other source rocks attained critical moments in the Plio-Pleistocene. The major reservoir rocks namely Moki and Mount Messenger were deposited in Mid Miocene while Urenui was deposited in Late Miocene. Thus some of the generated oil has been trapped in stratigraphic and structural traps in these reservoirs if the faults and overlying mudstones acted as good seals.

2. At the PSW location all the source rocks started generating hydrocarbons in the Miocene and the critical moment for Rakopi source rocks was reached in the Middle Miocene. Some reservoir rocks were contemporaneously deposited during this period and may not have been properly sealed. This would have led to a loss of hydrocarbons either by migration to favourable structures or to the seafloor.

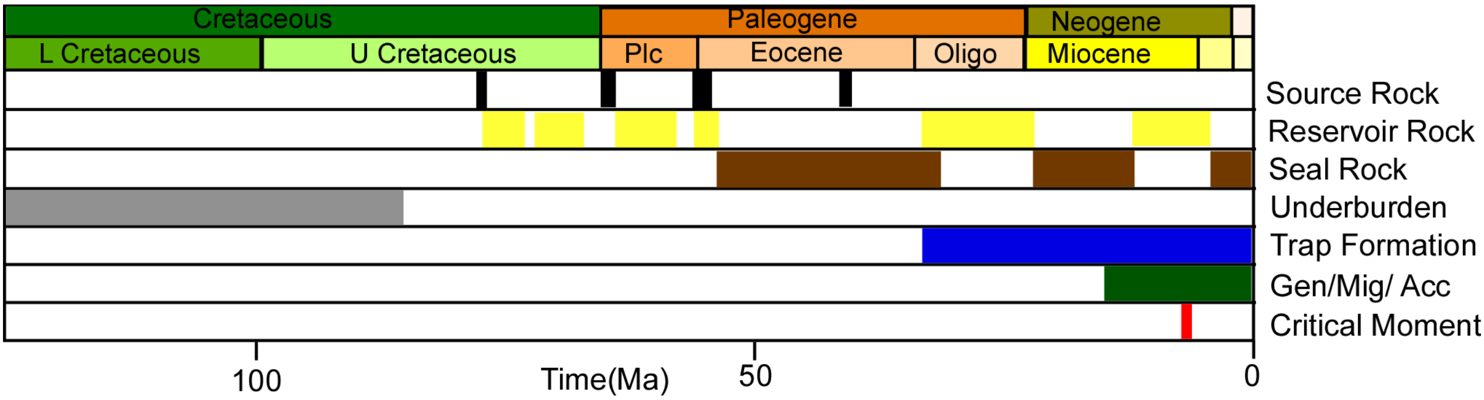


Figure 4: Petroleum System Event Chart

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