

THE CHARACTERISATION OF POTENTIAL HYDROCARBON-GENERATIVE SOURCE ROCKS IN THE NORTH TARANAKI BASIN BY GEOCHEMICAL BIOMARKERS

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Abstract

Over recent years, organic geochemical biomarker research has been carried out at Victoria University of Wellington with the view to characterising the sterane and triterpane biomarker components of the potential source rocks and produced hydrocarbons from wells of the onshore and offshore South Taranaki Basin area. The results from these studies have shown consistently that the hydrocarbons in this basin are of terrestrial origin, are probably sourced from the deep (about 5.5-6.5 km) Pakawau and Kapuni Group coals and shales, and have migrated to their present shallower reservoirs.

In the offshore North Taranaki basin however, the situation appears to be more complex.

This paper presents the results of a similar characterisation of the sterane, hopane and diterpane biomarkers of organic extracts from the formations encountered in the Awakino-1 and Turi-1 wells, drilled offshore in the North Taranaki basin.

Mature oil with a distinct terrestrial fingerprint, similar to that of the McKee field oil is encountered at a shallow depth (420m) in the Awakino-1 well, while at greater depths (2880m) the sediments show traces of a mature oil predominately of marine origin.

In the Turi-1 well traces of a moderately mature oil of mixed marine-terrestrial origin are present at shallow 396-406m and 790-799m depths. This oil has migrated into these formations. A more mature, similarly mixed marine-terrestrial oil, which could have been formed *in situ*, is present at greater depths of 3811-3814m and 4088-4090m.

It therefore appears that oil generation in the North Taranaki Basin is from various marine, mixed marine-terrestrial and terrestrial sources, whereas in the South Taranaki Basin the source is invariably terrestrial.

Introduction

Over recent years geochemical biomarker studies on the oils and condensates, and the possible source rocks of both the onshore and offshore areas of the South Taranaki Basin have been carried out. These have shown that the oils and condensates are predominately of terrestrial origin (Czochanska *et al.*, 1988; Johnston *et al.*, 1988), and that although they are usually reservoired in the mid-upper sands of the Kapuni Group or the Oligocene limestone, they have in fact been sourced from coals and also probably shales much deeper within the sequence. These coals are the Early Paleocene-Eocene Kapuni Group and the Late Cretaceous Pakawau Group and likely generation depths are 5-5.5 km., with subsequent migration of the hydrocarbons to their present shallower reservoirs. In general the biomarker data show that these terrestrial sediments have very similar source characteristics and increase progressively in maturity with increasing depth of burial (Collier and Johnston, 1991; Johnston *et al.*, 1988, 1990, 1991).

In the development history of the Taranaki Basin during the Paleocene, terrestrial conditions and accumulations prevailed in the south and east, while inner and outer shelf conditions prevailed in the north and west. The sedimentary sequences of significance to petroleum generation and exploration interest in the North Taranaki Basin are therefore primarily marine. (e.g. see King and Robinson, 1988; Geosearch, 1991). A geochemical study of the oil from the Kora structure, North Taranaki Basin, showed this oil to be distinct from the oils of the South Taranaki Basin and primarily of marine origin. The Kora oil is characterised by unusual concentrations of C₃₀ desmethyl and C₃₀ and C₃₁ methyl steranes (Reed, 1992, this volume). Generation is considered to have taken place in a marine source not yet encountered on drilling, and at a considerable depth corresponding to a present day burial depth of 5.2-5.4 km., consistent with that for generation from terrestrial sources in the South Taranaki Basin.

Although a number of wells have been drilled in the North Taranaki Basin, no commercial quantities of hydrocarbons have been encountered to date, and indeed there appear to be no oil or condensate samples available from the majority of these wells for geochemical analysis. Also to date, there have been no published geochemical biomarker studies on the sediments or potential source rocks encountered in the drilling of these wells.

This paper presents the results of the sterane, pentacyclic triterpane (hopane) and diterpane biomarkers extracted from the organic material contained in the various formations of the Awakino-1 and Turi-1 wells. As the wells have penetrated a number of different formations, both marine and terrestrial, the biomarker distributions are more complex than those of the South Taranaki Basin sediments.

Samples

The locations of the Awakino-1 and Turi-1 wells, drilled in the North Taranaki Basin are shown in Figure 1. The general stratigraphy of the Basin has been discussed in detail by King and Robinson, (1988); Geosearch (1991), and is therefore not repeated here.

The formations encountered in the drilling of these wells are given in Table 1. The sterane, hopane and diterpane biomarker distributions have been characterised for the organic material extracted from the formations identified by an asterisk (*) in Table 1. These biomarker distributions for the Awakino-1 well are shown in Figure 2, and for the Turi-1 well in Figures 3a and 3b. These biomarker data were kindly made available by NZ Oil and Gas Ltd.

The identification of the individual sterane, hopane and diterpane components are well established and the significance of the various biomarker components and ratios are now well known. These have been documented extensively elsewhere (e.g. Seifert and Moldowan, 1978, 1981; Philp, 1985; Johnston *et al.*, 1992, this volume), and therefore are also not repeated here.

Results and Discussion

Awakino-1 Well

The biomarker distributions of the Awakino-1 well show the organic material extracted from the Moki "B" sands at a depth of 420m, to be predominately terrestrial in nature and of a high level of maturity, equivalent to a vitrinite reflectance of about 0.95-1.0 %, similar to that of the South Taranaki Basin oils. The terrestrial nature is indicated by the abundance of the C_{29} steranes relative to C_{27} steranes, and also a similar abundance of C_{29} diasteranes. The presence of oleanane and C_{30} resins in the hopane biomarker distributions also support this conclusion (Figure 2). The equal proportions of C_{29} S and C_{29} R steranes, the predominance of C_{29} R,S BB steranes, the 60:40 ratio of $C_{31,32,33}$ S:R hopanes, and low moretane/hopane ratios confirm the relatively high level of maturity of this organic material. These results suggest the presence of a mature terrestrial oil, similar to that of the McKee oil, which has migrated into these sediments from a terrestrial source elsewhere deeper in the Basin. The presence of norhopanes in the sample indicate a considerable degree of biodegradation has taken place (Figure 2).

The deeper 2481m sample from the marine Turi Formation and the 2541m and 2880m samples from the terrestrial Maui Formation show a mixed marine-terrestrial character with a marine predominance. This is indicated by the the lesser C_{29} diasterane content and the increased C_{27} sterane content. The greater abundance of the R relative to the S epimer for both the C_{27} and C_{29} steranes, and the comparability of the $C_{31,32,33}$ S and R hopanes, indicate the hydrocarbons in the Turi Formation at 2481m and the Maui Formation at 2541m are of relatively low maturity. The presence of labdanes are also indicative of a terrestrial input. It is therefore likely that these extracts represent in situ organic material rather than migrated oil. The maturity level is equivalent to about a 0.55 % vitrinite reflectance (Figure 2).

Awakino-1			
Formation Name	Lithology	Age	Depth (m)
Manganui	Mudstone (Marine)	Mid Miocene	150-315
Moki B Sands*	Sandstone (Terrestrial)	Mid Miocene	315-1035
Manganui	Mudstone (Marine)	Mid Miocene	1035-1782
Taimana	Marl (Marine)	Early Miocene	1782-1915
Tikorangi	Limestone (Marine)	Oligocene	1915-2055
Otaraoa	Limestone (Marine)	Oligocene	2055-2347
Turi*	Mudstone (Marine)	Eocene	2347-2505
Maui*	Sandstone (Terrestrial)	Paleocene-Eocene	2502-2900 (TD)
Turi-1			
Formation Name	Lithology	Age	Depth (m)
Manganui*	Mudstone (Marine)	Mid Miocene	396-762
Mohakatino *	Volcanics (Terrestrial)	Mid Miocene	790-1329
Moki B Sands	Sandstone (Terrestrial)	Mid Miocene	1631-1677
Manganui*	Mudstone (Marine)	Mid Miocene	1686-2945
Taimana	Marl (Marine)Early	Miocene	2960-3055
Tikorangi	Limestone (Marine)	Oligocene	3070-3110
Otaraoa*	Limestone (Marine)	Oligocene	3125-3220
Turi*	Mudstone (Marine)	Eocene	3238-4090

Table 1: Formations encountered in the Awakino-1 and Turi-1 wells.

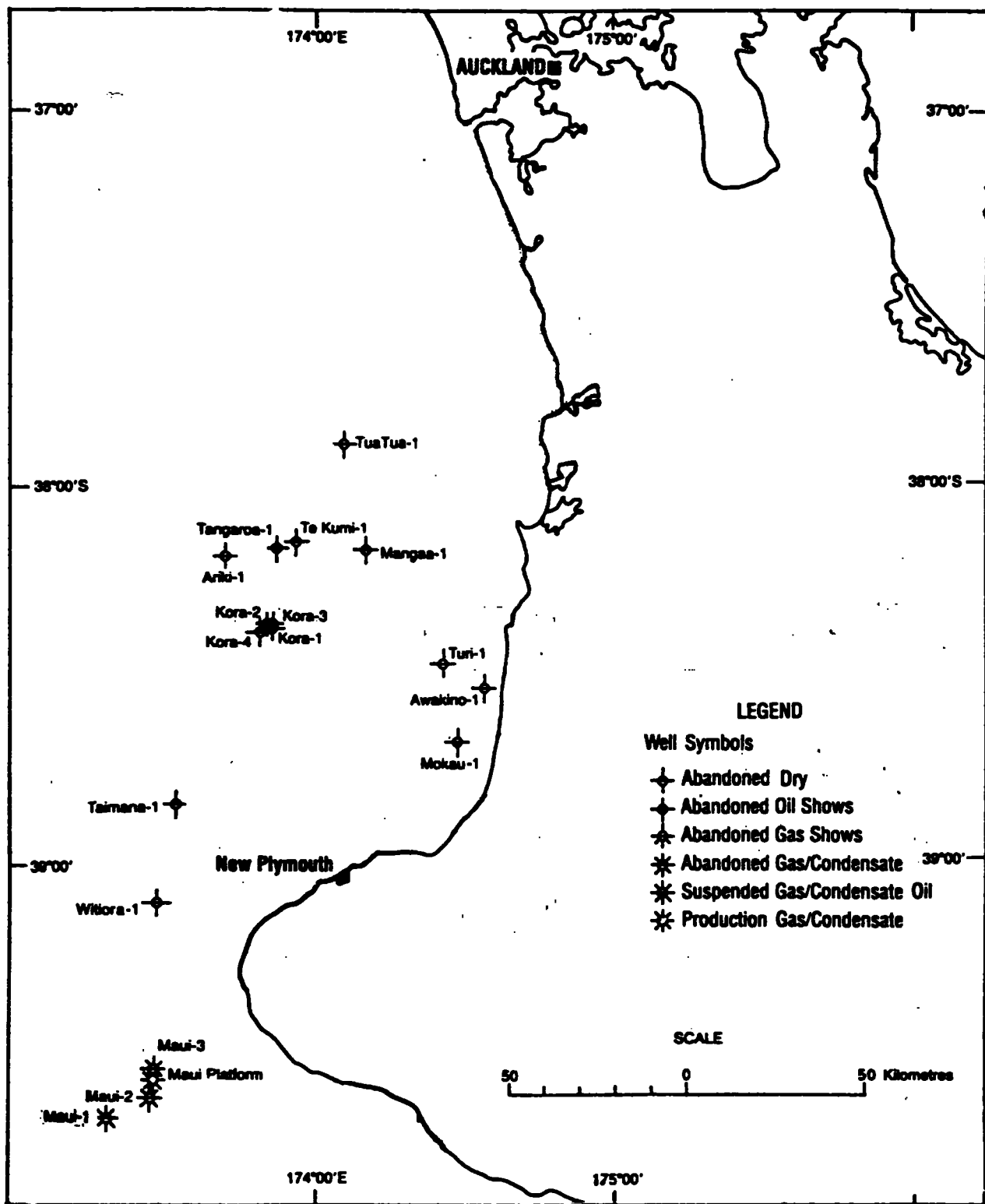


Figure 1: Map of the North Taranaki Basin area showing the location of the Awakino-1 and Turi-1 wells.

In contrast however, the organic material extracted from the slightly deeper 2880m sample from the terrestrial Maui Formation appears to be a mature marine oil. The similar abundance of the C_{29} R and S steranes, the increased abundance of the % C_{29} BB steranes, the 60:40 ratio of the $C_{31,32,33}$ S and R hopanes, and low moretane/hopane ratios suggests a high level of maturity, comparable to that of the terrestrial oil in the 420 m sample (Figure 2).

The presence of norhopanes shows some biodegradation of the organic matter has taken place in all the formations, but as noted above, this is most significant for the terrestrial oil in the shallow Moki "B" sands.

Turi-1 Well

The sterane, hopane and diterpane biomarker distributions for the 396-406 m sample from the Manganui formation and

Turi-1

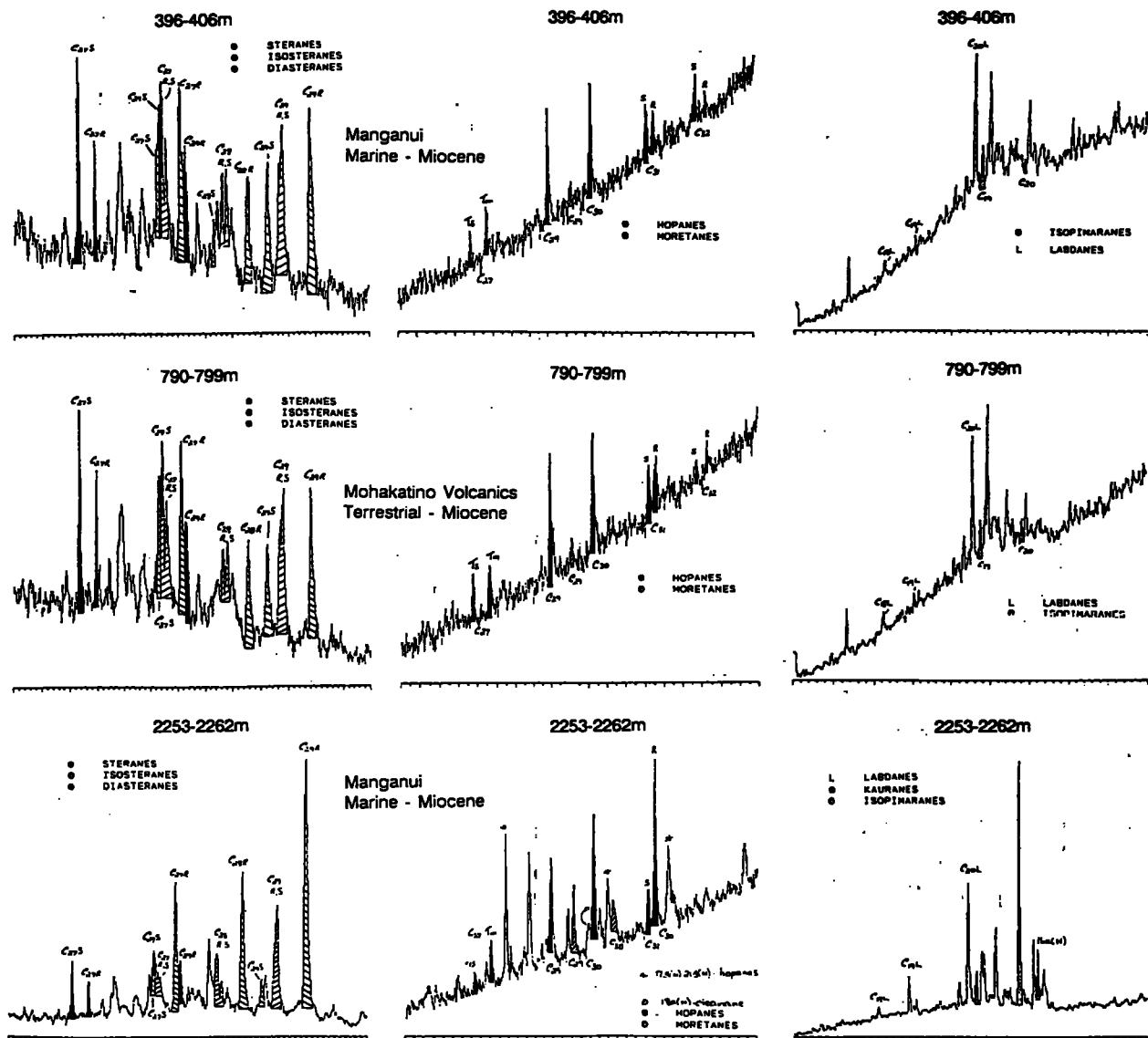


Figure 3a: Sterane, triterpane (hopane) and diterpane gcms mass fragmentograms for the organic material extracted from the particular formations at 396-406 m, 790-799 m and 2253-2262 m depths in the Turi-1 well.

The biomarkers of organic material extracted from the 2253-2262 m Manganui Formation sample, show this material to be of very low maturity and to have a predominant terrestrial character. The low maturity is indicated by the significant abundance of the R epimer relative to S for the C_{29} and C_{27} steranes, and also the occurrence of hopanes. The terrestrial nature is shown by the predominance of C_{29} steranes and diasteranes over their respective C_{27} counterparts, and also by the presence of oleanane and the abundance of labdane, kaurane and isopimarane diterpanes. This material presumably represents *in situ* organic matter in the formation and has a maturity level equivalent to about 0.3-0.4 % vitrinite reflectance (Figure 3a).

The organic material extracted from the sample at 3198-3230 m for the Otaraoa Formation has a greater marine character and is more mature, equivalent to a vitrinite reflectance of about 0.5-0.6 %. Some hopanes are still

present however. Also for the C_{27} and C_{29} steranes, the R epimer is in greater abundance than the S epimer, indicative of such a medium level of maturity. The diterpanes indicate a mixed marine-terrestrial character (Figure 3b).

The respective similarities in the sterane, hopane and diterpane distributions for the samples of the Turi Formation taken at 3811-3814 m and 4088-4090 m suggest the presence of a mixed marine-terrestrial oil in these sediments. The contribution of plant-derived organic material is indicated by the small amount of oleanane present in the 3811-3814 m sample and the labdane and isopimarane present in both samples. The deeper 4088-4090 m sample is slightly more mature than that of the 3811-3814 m sample. This is shown by the slightly greater ratio of C_{29} S to R steranes and the slightly smaller moretane/hopane ratio for the deeper sample. The maturity level for the 4088-4090m sample is equivalent to a vitrinite reflectance of about 0.95-1.0 % (Figure 3b).

Turi-1

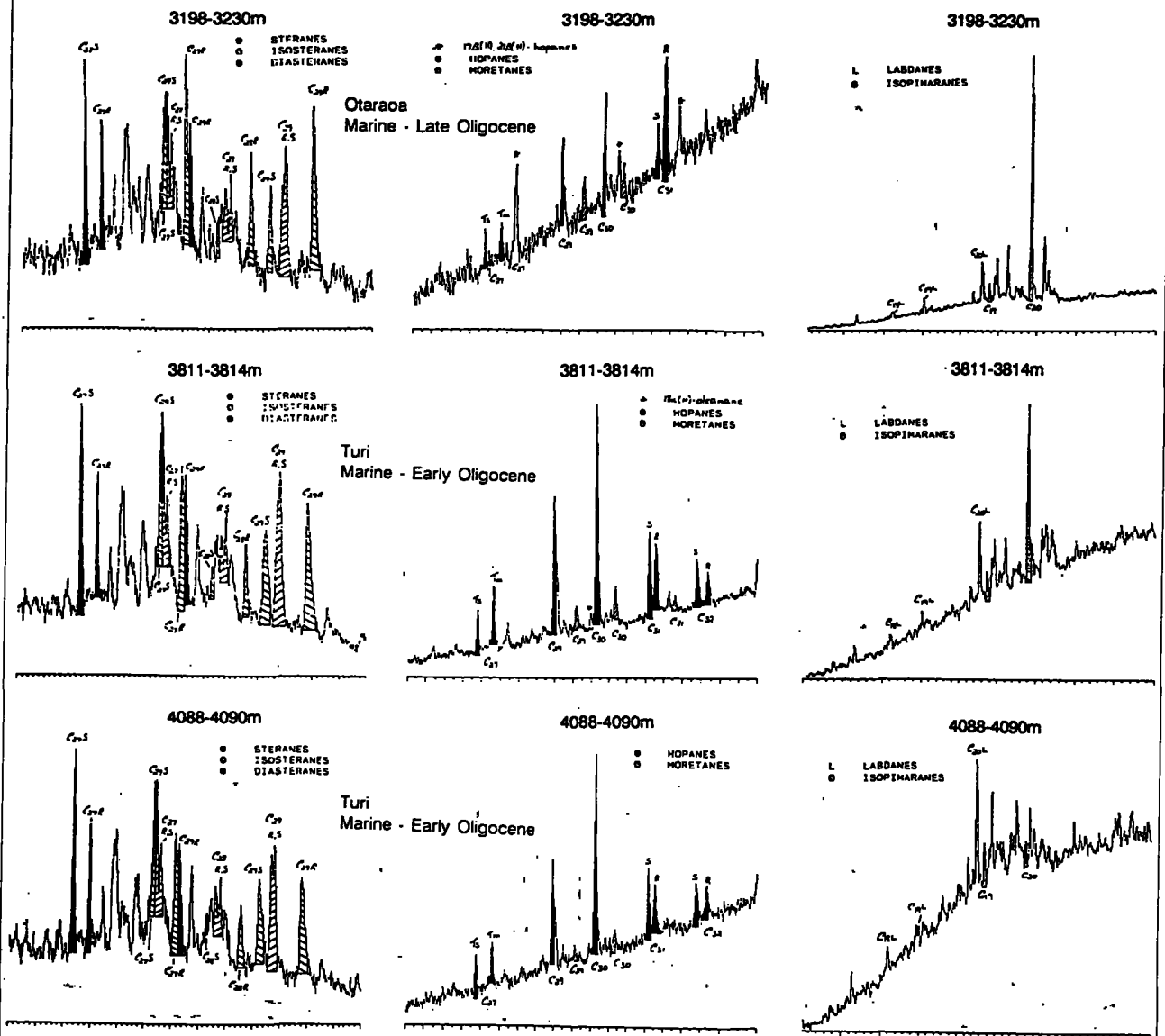


Figure 3b: Sterane, triterpane (hopane) and diterpane gcms mass fragmentograms for the organic material extracted from the particular formations at 3198-3230 m, 3811-3814 m and 4088-4090 m depths in the Turi-1 well.

Conclusion

From this study of the biomarker data for the Awakino-1 well, it is concluded that a mature terrestrial oil similar to the McKee oil, but somewhat biodegraded, has migrated into the shallow 420 m Moki "B" sands from a terrestrial source located elsewhere and much deeper in the Basin. It is possible this source may be close to the eastern margin of the basin and could be a common source for the oil traces observed here in the Moki "B" sands of the Awakino-1 well, and also for the oil of the McKee wells.

A mature and predominately marine oil is present in the deeper 2880 m Maui sands. As the level of maturity of this oil is significantly greater than that of the Maui Formation itself, it is suggested that this oil is also generated elsewhere in the Basin and has migrated into the Maui Formation.

For the Turi-1 well it appears that a mixed marine-terrestrial oil of a maturity equivalent to 0.7 %

vitrinite reflectance has migrated into the both the shallow 396-406 m sequence of the Manganui formation and the 790-799 m sequence of the Mohakatino Volcanics. This oil has not been generated within these formations, but again has migrated in from elsewhere in the Basin.

In addition, organic material with a mixed marine-terrestrial character, and a greater maturity, is present in the deeper 3811-3814 m and 4088-4090 m samples of the marine Turi Formation. The biomarker data show the organic material in these two deeper samples to be similar, with the maturity of the 4088-4090 m sample being slightly greater than that of the 3811-3814 m sample. It appears therefore that the organic material sampled here is *in situ* and represents a mature oil generated within the Turi Formation.

A comparison of the biomarker data for the deeper Turi Formation, Turi-1 well, with that for the deeper Maui Formation, Awakino-1 well, show the organic material

extracted from both these formations to be similar. This similarity could suggest that the Turi Formation may be the source for the oil present in the Maui Formation. However suitable timing for migration and appropriate migration pathways would have had to have existed for this argument to be plausible. The minor differences in the biomarkers could be attributed to the picking up of specific biomarker compounds along the migration pathway. The maturity level and the hopane distributions of this oil are significantly different to those of the less mature oil noted in the shallower Manganui and Mohakatino Formations of the Turi-1 well.

The oil traces encountered in both the Awakino-1 and Turi-1 wells do not show the abundance of C_{30} desmethyl and

C_{30} and C_{31} methyl steranes which are present in the oil from the Kora-1 well, and hence the source for the Kora-1 oil is different from those of the hydrocarbons in the Awakino-1 and Turi-1 wells.

No commercial quantities of oil were encountered in either the Awakino-1 or the Turi-1 wells.

In conclusion therefore it is apparent that the oil generation and migration history of the North Taranaki Basin is much more complex than that of the South Taranaki Basin. For the North Taranaki Basin it is likely that oil generation could have taken place in a number of mixed marine-terrestrial sources, as well as from terrestrial sources, whereas for the South Taranaki Basin generation is from terrestrial sources.

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