HIGHER-PLANT EVOLUTION DURING THE CRETACEOUS TO PALAEOGENE IN THE GIPPSLAND BASIN, AUSTRALIA

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Introduction

The Gippsland Basin is the most productive Australian hydrocarbon-bearing basin, with a Cretaceous–Neogene depositional sequence. The main hydrocarbon source rocks are restricted to the Cretaceous–Palaeogene Latrobe Group. Much is known about the stratigraphy, regional geology, hydrocarbon potential and petroleum biodegradation of the Gippsland Basin. However, limited research on biomarkers within the Latrobe Group has been publicly reported, especially in reconstruction of palaeo-vegetation and palaeoclimate changes from the Cretaceous to the Palaeogene (Jiang and George, 2018). In this study, 37 hydrocarbon source rocks including shales, coaly shales and coals from the Proteacidites asperopolus (P. asperopolus), Malvicipollis diversus (M. diversus), Lygistepollenites balmei (L. balmei), Forcipites longus (F. longus), and Tricolporetis lilliei (T. lilliei) palynological biozones (grouped by increasing age) were analysed using gas chromatography-mass spectrometry. Palaeoflora evolution is investigated by comparison of gymnosperm-derived and angiosperm-derived aliphatic and aromatic indices, including oleane relative abundance, the angiosperm/gymnosperm index (AGI), the higher plant index (HPI), and the higher plant parameter (HPP). In addition, we also compare the AGI of sediments from the Gippsland Basin and the Taranaki Basin, which formed due to the separation of Australia and Zealandia in the Upper Cretaceous and is comparable to some depositional units in the Gippsland Basin.

Results

A series of higher-plant-derived biomarkers was detected in Upper Cretaceous to Palaeogene Latrobe Group hydrocarbon source rocks, including bicyclic sesquiterpanes (such as drimane, homodrimane and 4β(H)-eudesmane), diterpanes (such as labdane, phylocladane, beyerane, isopimarane, rimuane and kaurane) and triterpanes (such as oleanane, 10β(H)-des-A-oleanane, 10β(H)-des-A-lupane and 10β(H)-des-A-ursane). Higher-plant-derived aromatics identified in the study area include alkynaphthalenes, cadalene, alkylphenanthenes, retene, simonellite, pyrene, perylene, fluoranthene and other oleanane-, ursane-, and lupane-type aromatic triterpenoids (such as tetrnor-ursa-1,3,5(10),6,8,11,13-heptaene and 1,2,9-trimethylpicene). The oleane index of the Upper Cretaceous samples averages 0.04 in the F. longus biozone and 0.08 in the T. lilliei biozone, while the Palaeogene samples have average OIs of 0.34, 0.11, 0.05 in the P. asperopolus, M. diversus, and L. balmei biozones, respectively. The HPI and HPP are in a range of 1.3–40.5 and 0.38–0.84 for the F. longus samples, and 0.41–24.9 and 0.36–0.79 for the T. lilliei samples. In contrast, the HPI and HPP of the P. asperopolus, M. diversus, and L. balmei samples range from 3.8–7.0 and 0.11–0.11, 3.8–5.0 and 0.06–0.23, 1.8–23.1 and 0.32–0.84, respectively.

Several variants on the AGI, calculated according to Killops et al. (1995) and Nakamura et al. (2010), are illustrated in Table 1. Different biozones exhibit slight differences in AGI. The average of these values generally display a tendency of an upward decrease from the T. lilliei to the L. balmei biozone, and then an upward increase to the P. asperopolus biozone, reflecting palaeofloral (angiosperm vs. gymnosperm) variation over time. The AGI proposed by Killops et al. (1995) in the Gippsland and Taranaki basins are different from each other at the same

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age. The AGI of the Upper Cretaceous hydrocarbon source rocks in the Gippsland Basin is slightly higher than those in the Taranaki Basin, but in general the Gippsland Basin has a lower AGI for the Palaeogene source rocks than corresponding sediments in the Taranaki Basin (figure not shown).

Summary

Diverse higher plant-derived biomarkers have been detected in the Upper Cretaceous–Palaeogene Latrobe Group hydrocarbon source rocks in the Gippsland Basin. Interpretation of aliphatic and aromatic sesqui-, di- and triterpenoids indicates that gymnosperms (e.g. Araucariaceae and Podocarpaceae) contributed more organic matter than angiosperms (e.g. Nothofagus, Ilex and Proteaceae) to the Upper Cretaceous palaeofloras in the Gippsland Basin. However, angiosperms gradually began to dominate the Palaeogene rainforests, especially with Nothofagus, Proteaceae and Euphorbiaceae. Analyses of the oleanane index and various AGIs, combined with previous studies, enables the inference that the palaeoclimate changed from warming to relative cooling and then back to warming again, over the time period from the T. lilliei biozone to the P. asperopolus biozone. This is consistent with palynological evidence and estimates of sea-surface temperature changes recorded in the Gippsland Basin (Wagstaff et al., 2006; Macphail, 2007).

Table 1 Different angiosperm/gymnosperm indices (AGI) calculated from Killops et al. (1995) and Nakamura et al. (2010) for Upper Cretaceous to Palaeogene sediments in the Gippsland Basin. The values are displayed as total range (average).

<table>
<thead>
<tr>
<th>Age</th>
<th>al-AGI</th>
<th>ar-AGI</th>
<th>ar-AGI(Ole)</th>
<th>ar-AGI(PAH)</th>
<th>AGI</th>
</tr>
</thead>
<tbody>
<tr>
<td>P. asperopolus</td>
<td>0.30–0.38</td>
<td>0.76–0.91</td>
<td>0.68–0.89</td>
<td>0.84–0.95</td>
<td>1.12–1.24</td>
</tr>
<tr>
<td>M. diversus</td>
<td>0.06–0.24</td>
<td>0.92–0.99</td>
<td>0.86–0.98</td>
<td>0.94–0.99</td>
<td>0.11–0.67</td>
</tr>
<tr>
<td>L. balmei</td>
<td>0.02–0.15</td>
<td>0.50–0.94</td>
<td>0.41–0.90</td>
<td>0.60–0.97</td>
<td>0.05–0.48</td>
</tr>
<tr>
<td>F. longus</td>
<td>0.01–0.09</td>
<td>0.39–0.9</td>
<td>0.26–0.88</td>
<td>0.76–0.95</td>
<td>0.03–0.24</td>
</tr>
<tr>
<td>T. lilliei</td>
<td>0.03–0.16</td>
<td>0.42–0.96</td>
<td>0.30–0.95</td>
<td>0.81–0.98</td>
<td>0.05–0.32</td>
</tr>
</tbody>
</table>

Note: ① is from Killops et al. (1995) and ② is from Nakamura et al. (2010).

References