# PETROLEUM GEOCHEMISTRY OF THE OTWAY BASIN AND THE SIGNIFICANCE OF COASTAL BITUMEN STRANDINGS ON ADJACENT SOUTHERN AUSTRALIAN BEACHES

**by**

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To my grandad, Alfred Partridge
for bicycles, dominoes and
wisdom - life is long

This work contains no material which has been accepted for the award of any other degree or diploma in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text.

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# Abstract

The stranding of crude oil on the beaches of southern Australia was first recorded approximately 150 years ago. This material, locally known as coastal bitumen, was used by the early maritime visitors and settlers to caulk their vessels and is the first recorded commercial use of crude oil in Australia. Historical records indicate that the greatest amount of coastal bitumen strands along the coasts of South Australia and western Victoria. The Otway Basin, which straddles part of this shoreline, is one of a series of basins located along the southern passive margin of the Australian continent. These basins formed during the Late Jurassic-Early Cretaceous in response to the rifting and final breakup of eastern Gondwanaland 95 million years ago. The circumstantial evidence of coastal bitumen, and the more recent discovery of offshore gas seeps, have been used to promote petroleum exploration in the Otway Basin. As a result, several small but commercial gas fields and numerous oil shows have been discovered. The moderate success of exploration in the Otway Basin may not be a true indication of its ultimate reserves, given that Australia's most prolific petroleum province, the Gippsland Basin, lies immediately to the east.

The aims of this study were twofold: to appraise the hydrocarbon potential of the western Otway Basin, and to identify the origin(s) of the coastal bitumen.

Source rocks were identified using an interdisciplinary approach which included wireline log interpretation, lithological descriptions, organic petrology (*viz.* maceral analysis, vitrinite reflectance) and organic geochemical analyses (*viz.* TOC and Rock-Eval pyrolysis). Oil-source rock and oil-oil correlations were attempted using carbon isotope mass spectrometry, gas chromatography and gas chromatography-mass spectrometry.

In the western Otway Basin the most important hydrocarbon plays occur within the Early Cretaceous Otway Group (Crayfish Subgroup and Eumeralla Formation). Terrigenous source rocks with potential to generate both oil and gas were identified in the lower Eumeralla Formation. The waxy paraffinic-naphthenic crude oils recovered from Windermere-1 and 2, Lindon-1 and Port Campbell-4 have biomarker signatures that are indicative of a terrestrial source to which conifer resins made a significant contribution. These oils have been correlated with coaly facies of the lower Eumeralla Formation. In the Crayfish Subgroup, lacustrine mudstones in the Pretty Hill Sandstone contain kerogen derived from a mixture of algal and biodegraded plant remains which appears to have generated significant volumes of gas (Katnook-Ladbroke Grove Gas Field; Troas-1) and minor quantities of oil (Sawpit-1).

Reservoir bitumens occur in the Pretty Hill Sandstone at Crayfish-A1 and Zema-1. These bitumens are unlike any other oil found within the Otway Basin. Their distinctive biomarker assemblage indicates that they were derived from algal and bacterial remains preserved in carbonate-evaporite sediments. Although no such source rocks have yet been penetrated by any exploration well, it is believed that they may be located within either the lower Crayfish Subgroup or the Casterton beds. These inferred source rocks are likely to be overmature in most areas of the western Otway Basin, precluding any significant future hydrocarbon generation. However, their required presence indicates that hydrocarbons were generated very early in the history of the basin.

A bimonthly survey documenting the stranding of coastal bitumen between Kangaroo Island, South Australia and Cape Otway, Victoria was carried out from September 1990 to September 1991. The physical characteristics of the coastal bitumens collected during this period enabled three categories of beached petroleum to be identified: waxy bitumen, asphaltite and oil slicks. Elemental, isotopic and biomarker analyses of representative samples confirmed that these three categories of petroleum are not geochemically related. Of extreme significance is the fact that they bear no resemblance to oil discoveries in the Otway Basin.

Waxy bitumens are the most common type of coastal bitumen, accounting for 90 % of the total beached petroleum. They represent the weathered remains of paraffinic-naphthenic crude oils which have low to moderate sulphur (0.1-2.6 %) contents. Their medium to low density (10-40 °API) ensures that they float in sea water. These waxy bitumens contain a unique association of source-specific biomarkers, notably botryococcane, oleanane, isomeric bicadinanes and 4-methyl steranes, which is not found in any indigenous Australian oils. The biological precursor of botryococcane is synthesized only by the freshwater green alga *Botryococcus* sp. and 4-methyl sterols are abundant in dinoflagellates. Oleanane originates from angiosperms which first appeared in the Late Cretaceous. High concentrations of bicadinane are derived from the resins (dammars) of the fossil angiosperm family *Dipterocarpaceae*. In terms of their biogeographic range, both extant and fossil dipterocarps are confined to the tropics of Southeast Asia, although their dammars have been found on South Australian beaches. Together, these biomarkers imply that the waxy bitumens were derived from Tertiary lacustrine source beds which were deposited at low palaeolatitudes. When the effects of extensive weathering and biodegradation are taken into account, the waxy bitumens are similar to bitumens stranded on the coasts of the Northern Territory and Western Australia, and to Tertiary crude oils produced from Sumatra. Hence, it has been deduced that the waxy bitumens originate from oil seeps within the Indonesian Archipelago. These crude oils are transported into southern Australian waters as flotsam by a complex system of surface ocean currents which include the South Equatorial Current, Leeuwin Current and West Wind Drift.

Asphaltite is the least common variety of coastal bitumen. These jet black bitumens are heavy (~ 8 °API) and characteristically exhibit deep desiccation cracks on their upper surface. The oldest asphaltite analysed in this study was collected before the year 1900 on Kangaroo Island, and the stranding of comparable samples continues to the present day. The asphaltites have a uniform aromatic-asphaltic composition and are rich in sulphur (S = 3-6 %). Their unimodal *n*-alkane distribution centred about $C_{15}$, the predominance of cholestane among their $C_{27}$-$C_{29}$ desmethyl steranes and the presence of dinosterane (a marine dinoflagellate biomarker) as the major $C_{30}$ 4-methyl sterane, highlight the marine source affinity of the asphaltites. The presence of rearranged steranes and hopanes indicates that their parent crude oils were generated from clay-rich sediments. The asphaltite samples are isotopically light ($\delta^{13}C_{sat}$ ~ -30.0 ‰; $\delta^{13}C_{arom}$ ~ -29.5 ‰) relative to the waxy bitumens. These depleted $\delta^{13}C$ values, combined with the presence of dinosterane and $C_{28}/C_{29}$ sterane ratios ranging from 0.7 to 1.2, suggests that their source rocks are of Mesozoic age. The South Australian and Victorian asphaltites are almost identical to asphaltic bitumen which strands on the west and south coasts of Tasmania. The biomarker geochemistry of the asphaltite was compared with those of many other Australian and non-Australian marine sediments and oils. However,

no matching signatures were found and so the source of the asphaltite could not be identified. Nevertheless, the long stranding history of the asphaltite suggests that it is a natural phenomenon.

A third group of ‘coastal bitumens’ represents stranded oil slicks. These films and sheets of liquid oil are of sporadic occurrence and have been linked to local maritime operations. The bitumens assigned to this category have variable geochemical signatures depending on the type of oil discharged; both refined and unrefined crude oils were among the samples collected. The majority of these crude oils originated from either Southeast Asia or the Middle East, the two main provinces from which oil is imported into Australia.

The stranding of coastal bitumen along the southern margin of Australia can be attributed to both natural and anthropogenic causes but not, as first suspected, to oil seepage from the offshore sector of the Otway Basin.

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"Love is temporary insanity curable by marriage"

Amba Bierce

But I'll wait and see.....

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