BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

RECORD

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Research Cruise Proposal

OFFSHORE OTWAY AND GIPPSLAND BASIN GEOCHEMISTRY

Project

BMR Fossil Fuels Project

Principal Investigators D.T.Heggie, G.W.O'Brien & T.G.Graham

Schedule: April/May, 1988

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1. SUMMARY

During April/ May 1988 the Bureau of Mineral Resources will conduct a 22 day geochemical research programme in the Otway and Gippsland Basins. This programme follows previous preliminary studies (January-February 1987) which examined the distribution and molecular composition of light hydrocarbon gases within deep water surficial sediments in the Otway Basin. The major thrust of the forthcoming cruise will be to obtain shallow water (continental shelf) geochemical data from both the Otway and Gippsland Basins, to test ideas generated from the previous programme, and, in particular, to integrate the results with inhouse BMR geohistory and maturation modelling studies. The objectives are, therefore:

1. To develop new information on source rocks, maturation, and hydrocarbon migration on the Mussel and Crayfish Platforms and Voluta Trough in the Otway Basin.

2. Specifically, to test the relationship between variations in source rock maturation (as indicated by well data and geohistory analyses) and the surface hydrocarbon gas composition and distribution within sediments from the Otway and Gippsland Basins.

The majority of the programme will be focussed on the Otway Basin, with the final 4-5 days of the cruise spent in the Gippsland Basin. Sampling will be carried out along previously shot BMR multi-channel seismic lines, and will consist of vibracoring in shallow water (<150m) and combinations of piston and gravity coring in deeper water.

In the Otway Basin, four key profiles will be sampled (see Fig.1). The two western profiles (A & B) run from the Crayfish Platform into the Volulta Trough, whereas the eastern profiles (C & D) run from the Mussel Platform into the central Voluta Trough. On all of these profiles the basal Early Cretaceous, considered the section with the best source potential, becomes progressively deeper buried (towards A" etc.), with maturity increasing from V_R =1.0-1.3 (peak oil generation) on the Platform margins to

overmature (V_R = 3.0-4.0) in the central Voluta Trough. Similarly, the Late Cretaceous sequences (eg. Belfast Mudstone), which are immature on the Platform margins, are ideally placed within the oil window in the central Voluta Trough. The molecular compositions of the thermogenic gases within the surface sediments along these profiles may thus provide important clues to the nature of the principal source horizons within the Otway Basin. For example, a dry gas signature in the central Voluta Trough would argue against a Late Cretaceous source, and support the contention that the Early Cretaceous is the major source horizon.

In addition to the above profiles, specific areas will be studied in detail. These include previously defined hydrocarbon anomalies and potential seafloor seeps off Port Douglas (see Fig.1).

The Gippsland Basin programme will consist principally of sampling from the southern shelf, through the Central Deep, and onto the Lakes Entrance Platform (see Fig.2). Latrobe Group source rocks vary from immature to overmature along this transect, and the objective is to determine whether this change in maturity is reflected in the composition of the surface hydrocarbon gases. The Gippsland programme will allow a comparison of the results obtained from a frontier exploration area, the Otway Basin, with those from a major oil/gas producing province.

In both the Otway and Gippsland Basins, high resolution seismic data will be collected over selected hydrocarbon anomalies, in order to better define near-surface structure, particularly faulting. This data will be acquired with either a 15 or 80 cubic inch water gun.

2. INTRODUCTION

Hydrocarbon gas measurements in recent marine sediments of continental margins can be used as a geochemical prospecting tool in the search for sub-seafloor petroleum accumulations. Light hydrocarbons (C1-C5) generated from organic-rich source rocks at depths of several kilometres (Hunt, 1984), or leaking through the cap rocks of gas-bearing petroleum reservoirs

(Leythaeuser et al., 1982), migrate upwards by diffusion through the water-saturated pore space of sediments and/or by effusion of a discrete gas phase along carrier beds and fracture systems associated with faults. Gas reaching the seafloor will be absorbed in surficial fine-grained sediments, occluded in early diagenetic carbonate minerals, or escape from the sediment to the overlying water column (as described for the Gulf of Mexico by Reitsema et al., 1978).

The interpretation of data on light hydrocarbons in marine sediments is complicated because the gases have two possible origins:

1. biogenic, i.e. produced in-situ by bacterial activity or,
2. thermogenic, i.e., produced via non-biological processes when organic rich source-rocks are buried and heated to temperatures of 60-150^{o}C.

Thermogenic (petroleum-related) hydrocarbons may be distinguished from biogenic (microbially-derived) gas on the basis of the relative abundance of the C1-C4 components (e.g. C1/C2+C3, and C2/C2:1) and the isotopic composition (del C-13 and del D) of the methane (Bernard et al., 1976, 1977; Brooks et al., 1979; Kvenvolden and Redden, 1980; Kvenvolden et al., 1981; Claypool and Kvenvolden 1983). Anomalous concentrations of thermogenic C1-C5 hydrocarbons in the upper 1-3 metres of fine-grained sediments on the continental shelf and slope are direct evidence of submarine seeps. Seeps or vents signify the existence of active source-rocks, or discrete petroleum accumulations, at depths of up to 5 km below the seafloor. Hydrocarbon seepage is favoured in areas where the continental margin is faulted and/or intruded by diapirs (Kvenvolden et al., 1981; Kvenvolden and Field 1981; Nelson et al., 1978; Anderson et al., 1983).

The offshore Otway Basin is, for a number of reasons, an interesting area to investigate thermogenic hydrocarbons in surface sediments. Firstly, submarine oil seeps occur in the area, as evidenced by the common bitumen strandings along the coastlines of South Australia and Victoria. Secondly, faulting does extend to the near-surface, particularly in the western Voluta Trough, and thus potential conduits for migrating hyrocarbons are present. Thirdly, the maturity of the potential source horizons, the Early and Late Cretaceous, vary markedly across the basin. Because of this variation, the composition of the surface gases may provide an indication of which sequence is the predominant contributor to the hydrocarbon "inventory". For these reasons, a preliminary geochemical sampling cruise was conducted in the Otway Basin in 1987. A total of 43 sites was occupied along 6 seismic profiles of the continental margin between southeastern South Australia and western Tasmania, in water depths ranging from 200 - 4000m. Sampling was not carried out on the continental shelf because the sediments were too sandy for gravity coring, and vibracoring was not an available technique.

Anomalous concentrations of thermogenic light hydrocarbons were identified at 9 locations (Fig.3), in water depths ranging from 450-2500m. Most of these anomalies lay over major faults which appear to be acting as conduits for thermogenic gas migrating upwards from Cretaceous source rocks (Fig.4). Several anomalies were not related to faulting, however, and may be explained by micro-seepage through cap rocks of potentially large gas accumulations within Cretaceous reservoirs. Both the total gas composition and concentration showed systematic variations across the basin. The highest gas concentrations were found in the western Otway Basin where the Tertiary sediment cover is relatively thin, and faulting apparently extends to the surface. In contrast, the lower concentrations were found to the east where Tertiary sediment cover is thicker and faulting generally does not extend above top Late Cretaceous. The thermogenic gases were dry, indicating generation from mature to overmature reservoirs, though the degree of "wetness" increased progressively from west to east across the basin. This variation in wetness across the basin may suggest that the Early Cretaceous is the principal hydrocarbon source of these hydrocarbons, since maturation modelling data show that the Early Cretaceous is markedly overmature in the western Otway, but in the late mature to condensate "window" on the Mussel Platform.

The present study aims to expand upon this earlier data set, and, in particular, to extend the sampling onto the continental shelf by use of a vibracorer. The three principal structural provinces in the Otway Basin, the Crayfish Platform, the Voluta Trough, and the Mussel Platform, will be investigated in detail, as will the areas transitional between the provinces (see Figs. 1&2). This data will then be integrated with BMR multi-channel seismic and geohistory modelling data, in order to better interpret the light hydrocarbon data. The total cruise length is 22 days, of which approximately 17 days will be spent in the Otway Basin. An additional 4-5 days will be spent in the Gippsland Basin, a major oil/gas producing province. This Gippsland programme will comprise a sampling leg from the southern platform, through the Central Deep, and onto the Lakes Entrance Platform.

3. GEOLOGY AND STRATIGRAPHY

The geology and stratigraphy of the offshore Otway Basin have been reviewed extensively elsewhere (see Williamson et al., 1987), and hence will not be repeated here. The sediments range in age from earliest Cretaceous to Neogene (Fig.5), though only the Cretaceous section has significant hydrocarbon potential in the offshore. The Early Cretaceous Otway Group is comprised of a terrestrial sequence of basal lacustrine to alluvial plain facies (Pretty Hill Sandstone) which is (?) unconformably overlain by volcanogenic alluvial plain sandstones, mudstones and shales (Eumeralla Formation). The Pretty Hill Sandstone is considered to have excellent reservoir (fluvial facies) and source (lacustrine facies) potential, with the impermeable Eumeralla Formation providing a widespread seal. Recent work by McKirdy et al. (1986) suggest that the lacustrine facies may have sourced many of the oil seeps observed along the coast.

The end of the Early Cretaceous was marked by a period of block faulting, uplift, and erosion and the basin became subdivided into three structural provinces, the Crayfish Platform, the Voluta Trough, and the Mussel Platform. The two platforms remained relatively shallow water depocentres during the Late Cretaceous and Tertiary, whereas rapid subsidence quickly established the Voluta Trough as a deep water depocentre, particularly in the Late Cretaceous. The earliest Late Cretaceous sediments in the basin belong to the Waarre Sandstone, which was deposited as a trangressive sand sheet as a marine transgression swept across the basin. With continued trangression, thick sequences of prodelta muds (Belfast Mudstone) were deposited within the Voluta Trough, whereas on the adjoining platforms, relatively sandy shallow water facies were deposited (Curdies-Paaratte Formations) (see Fig.6). Exposure and erosion occurred over much of the Otway Basin at the end of the Cretaceous, and consequently the Tertiary sediments unconformably overlie the Cretaceous. Tertiary sedimentation was limited on the Crayfish Platform and western Voluta trough, but thick in the central Voluta trough and Mussel Platform.

Faulting, which provides potential conduits for hydrocarbon migration, varies markedly in character across the basin. On the Crayfish Platform, faulting is largely restricted to the top Otway horizon, whereas in the western Voluta Trough, it extends well into the Tertiary, and in some instances, all the way to the seafloor. On the Mussel Platform, faulting only occasionally extends to the top Cretaceous horizon.

4. MATURATION MODELLING AND PREDICTED LIGHT HYDROCARBON SIGNATURES

The maturation history of the Crayfish Platform, Voluta Trough, and Mussel Platform are represented in Figs.7-9 by the Neptune#1, Voluta#1, and Pecten#1 geohistory diagrams, respectively. On the Crayfish Platform, the basal Early Cretaceous (Pretty Hill Sandstone) is now within the late mature to overmature "window", whereas the Late Cretaceous is immature. Any thermogenic hydrocarbons in this area have therefore almost certainly been generated within the Otway Group. Within the Voluta Trough, the basal Early Cretaceous is markedly overmature, whereas the Late Cretaceous is ideally placed within the oil window. A preponderance of dry hydrocarbons at this location would indicate that the Early Cretaceous is the principal source, whereas a "wet" gas signature would suggest that a Late Cretaceous source predominates. On the Mussel Platform, the basal Early Cretaceous is well placed within the present day oil window, whereas the Late Cretaceous is thermally immature. Hence relatively wet gas might be expected on the Mussel Platform.

5. PROGRAMME

The cruise programme is divided into 2 parts. The cruise begins at Portland on April 19 and ends at Port Welshpool on May 12. Approximately 16-17 days will be spent in the Otway Basin, with the remaining 4-5 days spent in the Gippsland basin. Four lines will be investigated in detail in the Otway Basin (Fig.1), whereas only one will be worked in Gippsland (Fig.10). The objectives in both basins are the same, namely to test the proposal that the light hydrocarbon signature in the surface sediments may provide an indication of source rock maturity at depth. As such, the sampling will encompass the principal structural features of both basins. Sampling will be conducted using vibracoring on the continental shelf and a combination of piston and gravity coring in deeper water. High resolution seismic will be collected over selected hydrocarbon anomalies, using either 15 or 80 cubic inch water guns.

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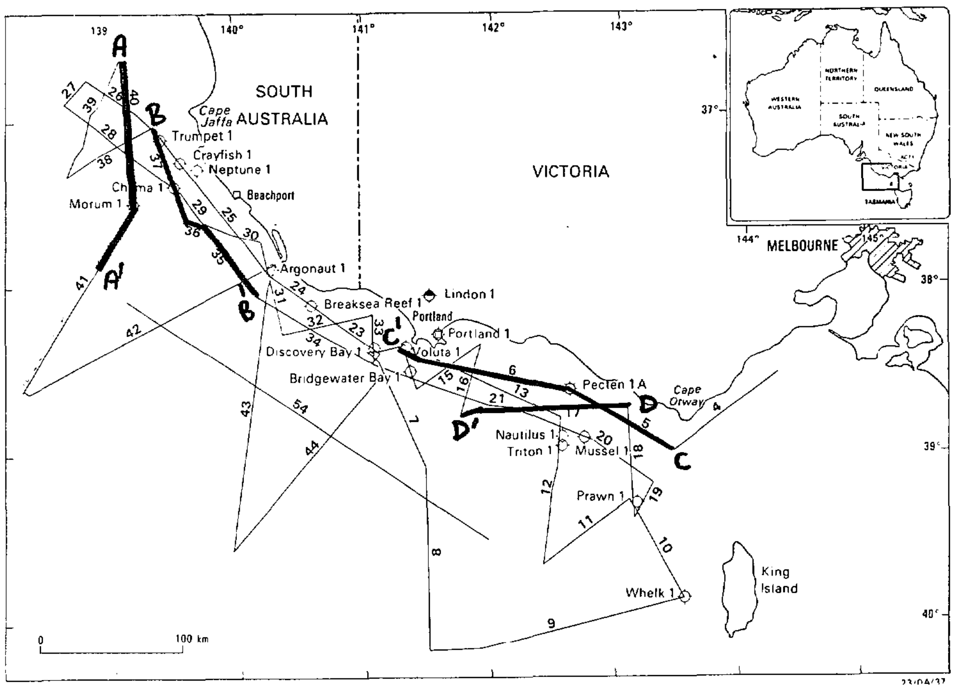

Fig. 1 Location of BMR 1985 multichannel seismic lines in the offshore Otway Basin and proposed geochemical sampling programme.

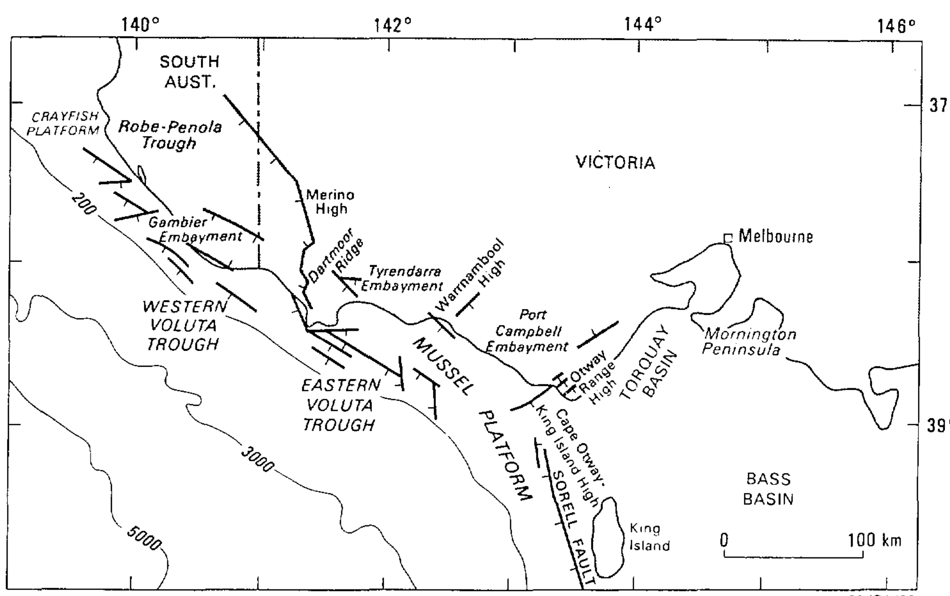

Fig. 2 Structural elements of the Offshore Otway Basin

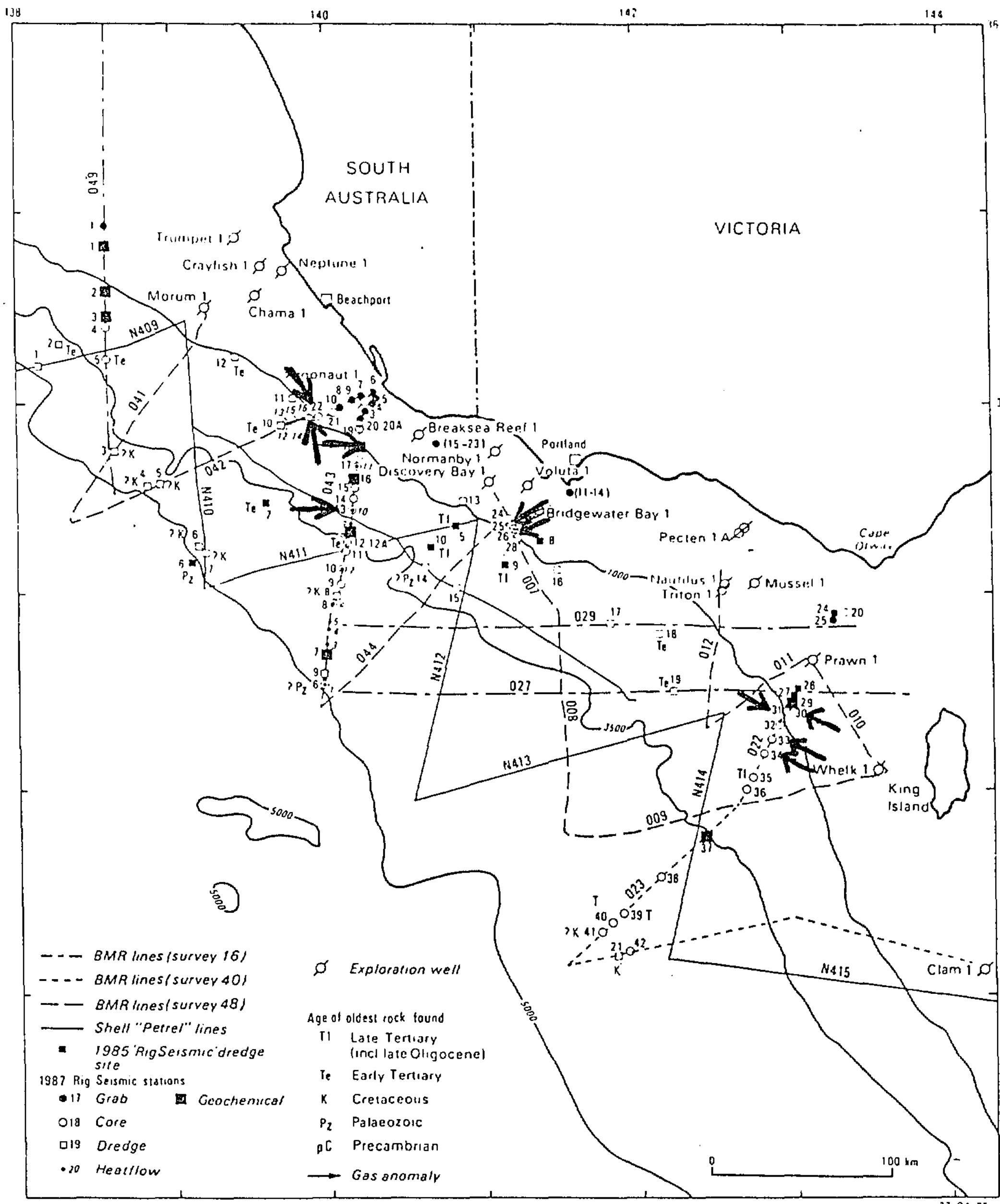

Fig. 3 Map showing locations of anomalous hydrocarbon concentrations detected in BMR cruise 67.

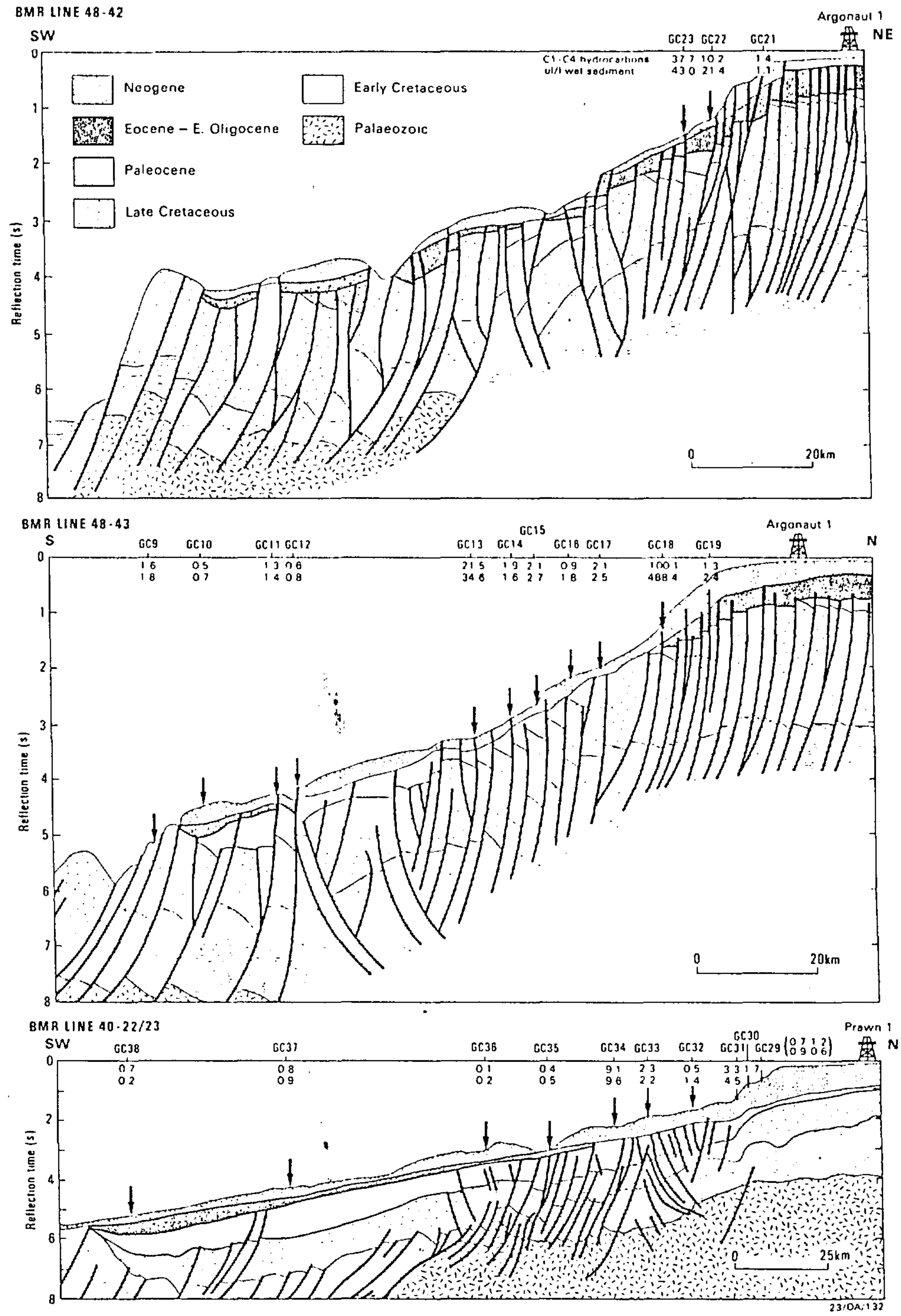

Fig. 4 Line drawing of BMR seismic lines 48/42, 48/43 and 40/22-23 with hydrocarbon values in surface sediments superimposed.

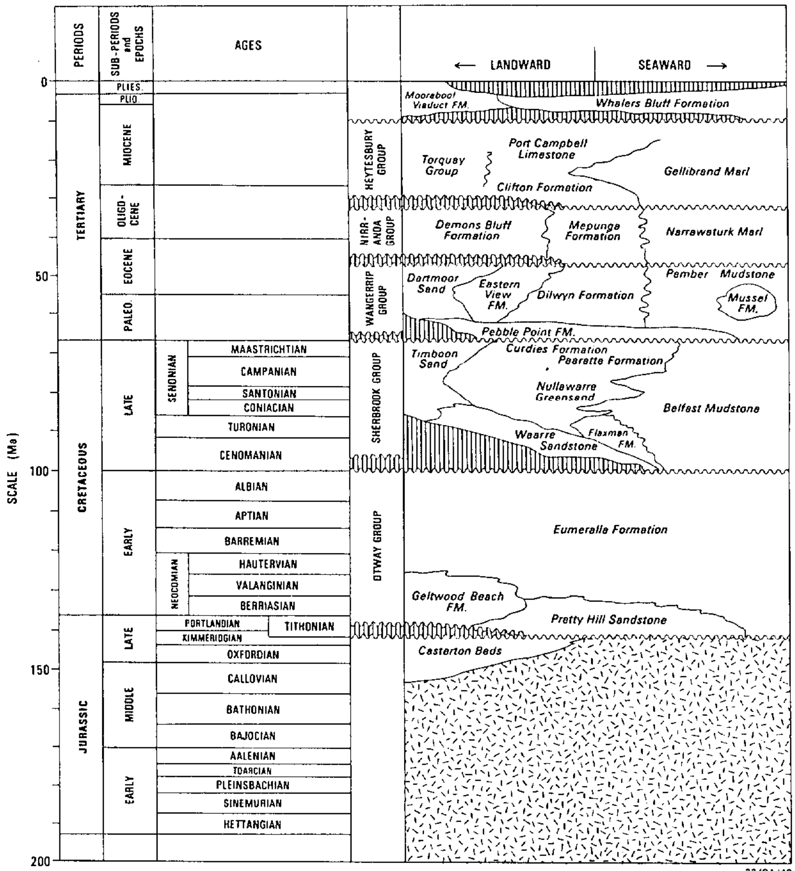

Fig. 5 Generalised stratigraphic section of the Otway Basin

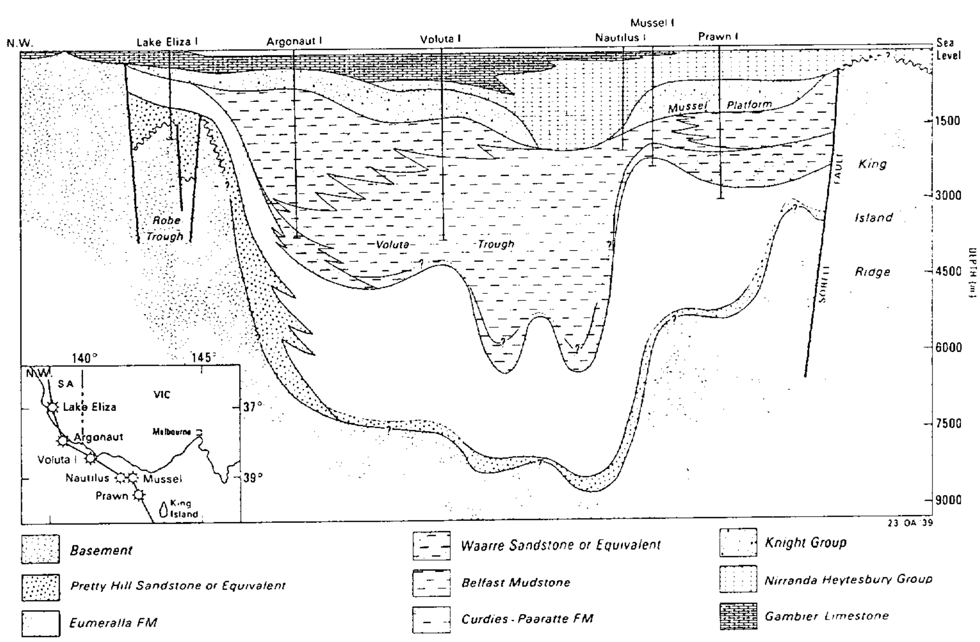

Fig. 6 Schematic cross section of the Offshore Otway Basin

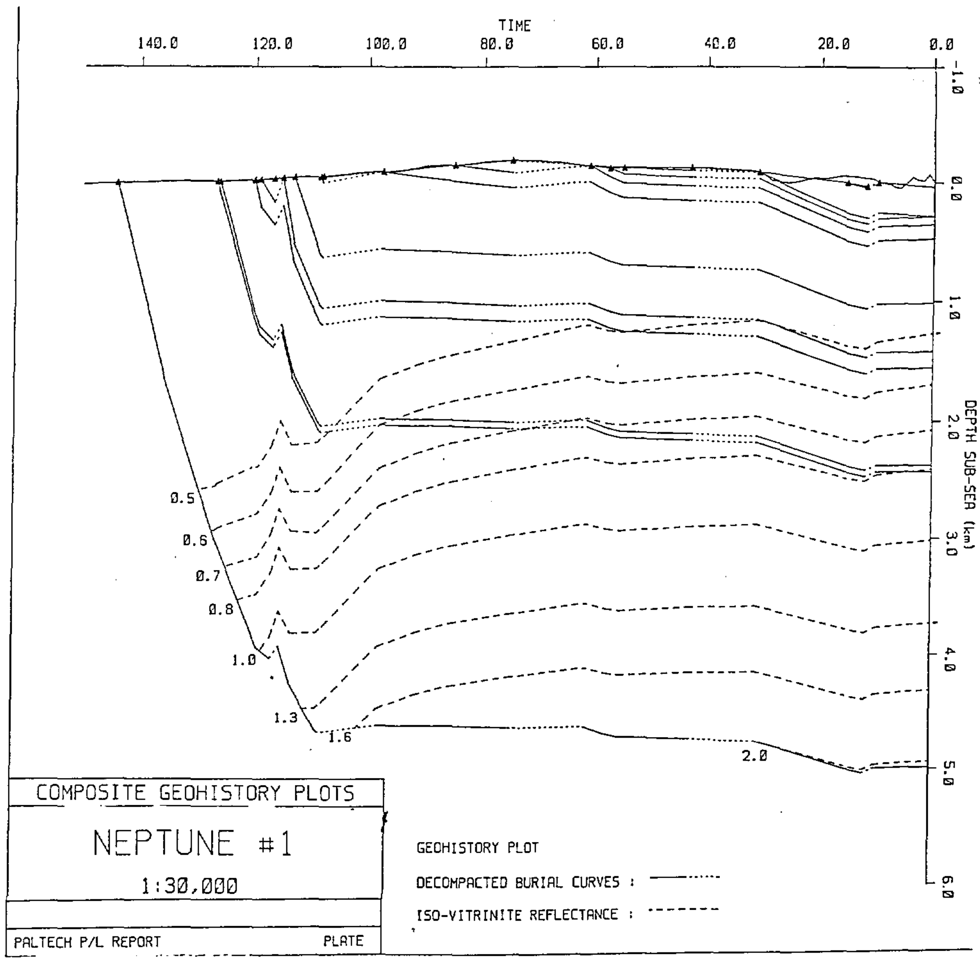

Fig. 7 Geohistory diagram for Neptune#1 well location on the Crayfish Platform.

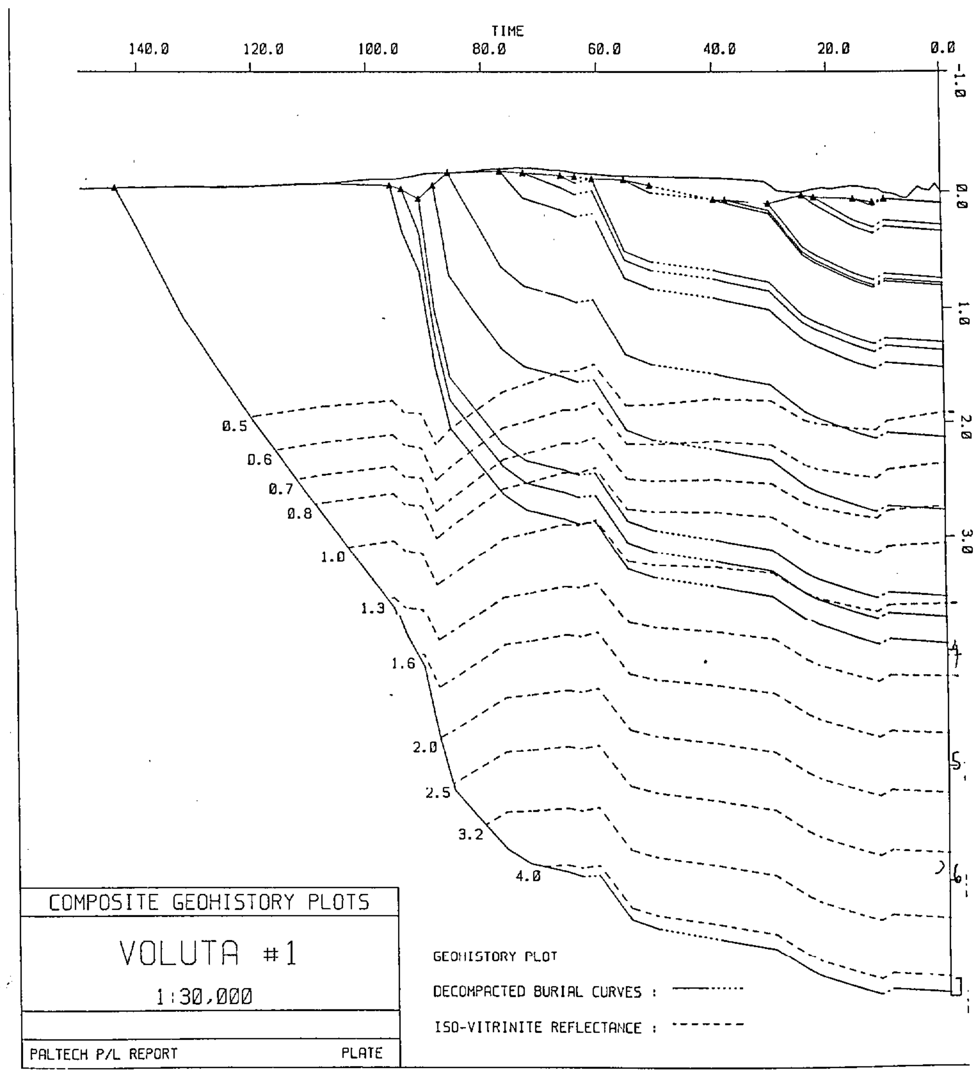

Fig. 8 Geohistory diagram for Voluta#1 well location in the Voluta Trough.

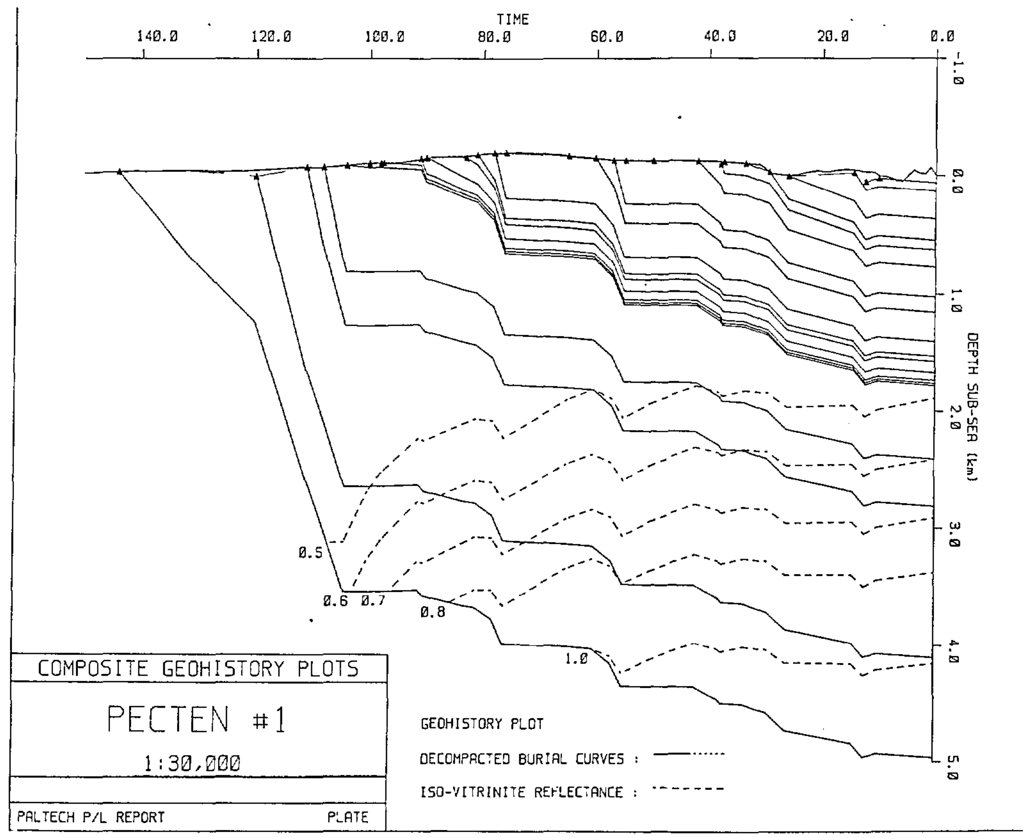

Fig. 9 Geohistory diagram for the Pecten#1 well location on the Mussel Platform.

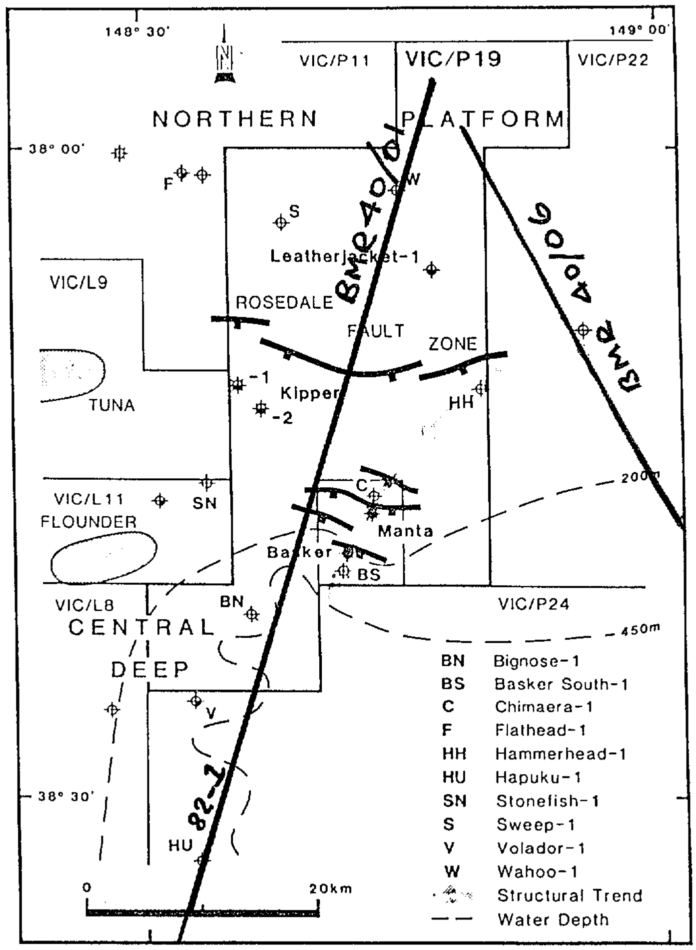

Fig. 10 Location map of proposed geochemical sampling line in the Gippsland Basin (BMR Line 82-1).