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THE GEOCHEMICAL CHARACTERIZATION OF CRUDE OIL FROM AUSTRALIA AND PAPUA NEW GUINEA

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The Geochemical Characterization of Crude Oils from Australia and Papua New Guinea*

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T.G. Powell[+] and D.M. McKirdy[+]

1 Controls on Crude Oil Composition

- a Introduction
- b Source
- c Heat
- d History of Migration
- e Flushing

2 Analysis of Oils

- a Introduction
- b Analytical Procedures

3 Geochemistry of Oils from Australia and Papua New Guinea

- a Southern Coastal Region
  - (i) Gippsland Basin
  - (ii) Otway Basin
- b Great Artesian Basin
  - (i) Bowen and Surat Basins
  - (ii) Galilee Basin
  - (iii) Cooper Basin
- c Central Intracratonic Region
  - (i) Amadeus Basin
- d North Western Region
  - (i) Canning Basin - Fitzroy Trough
- e Western Coastal Region

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+ Organic geochemists BMR

(i) Carnarvon Basin

(a) Barrow Sub-basin

(b) Dampier Sub-basin

(ii) Perth Basin

(a) North Dandaragan Trough

(b) Central Dandaragan Trough

(c) Vlaming Sub-basin

(d) Bunbury Trough

f Papua New Guinea

(i) Papuan Basin

4 Geochemical Classification of Oils from Australia and Papua New Guinea

5 Acknowledgements

6 References

CONTROLS ON CRUDE OIL COMPOSITION

INTRODUCTION

Petroleum is a complex mixture of hydrocarbons and other compounds, the composition of which is governed by the interaction of many geological processes e.g. sedimentation and decay of organic detritus, burial diagenesis (involving thermal alteration and catalytic activity), and migration etc. The relative importance of these processes in petroleum generation differs according to geological setting. Thus the nature of petroleum varies from one reservoir to another and no two crude oils will be identical in composition. Classification of petroleums on the basis of the various parameters which have determined their composition is therefore extremely difficult. Nevertheless considerable progress has been made in recent years towards understanding the geological controls of the composition of crude oils. These controls are the source of the oil, heat, the migration history of the oil, and the flushing effects of associated formation waters.

SOURCE

A number of authors (Hunt 1953, Barbat 1967, Evans, Rogers & Bailey, 1971) have demonstrated that oils vary in composition according to the nature of their sedimentary environment. Oils associated with clastic sequences have a medium gravity, a paraffinic or paraffinic-naphthenic composition and a low sulphur content. In contrast, petroleum occurring in carbonate and evaporite environments is considerably heavier, being aromatic-asphaltic in composition, and generally has a high sulphur content. Nitrogen-rich oils may well be drived from phosphatic source beds (Barbat, 1967).

Evidence accumulated in the last few years has indicated that the waxes and cuticles of leaves, spores, and pollen may constitute the source material for some petroleums. Oils with a high wax content are thought to be derived from the debris of higher plants (Hedberg, 1968). Brooks, Gould & Smith (1969b) suggested that high pristance to phytane ratios are indicative of a terrestial source.

A recent study of Australian high wax oils has demonstrated that in general they are characterized by high pristane to phytane ratios (Powell and McKirdy, 1973).

In Australia, the Gippsland oils and the gas-condensate of the Cooper Basin almost certainly originated from plant waxes and cuticles (Brooks, 1970; Brooks, Hesp & Rigby, 1971). Mathews, Burns & Johns, (1971) have shown that the hydrocarbon distribution of some Bowen-Surat Basin oils is not inconsistent with an origin in the non-marine Evergreen Formation.

HEAT

Modern theories of petroleum genesis require that petroleum hydrocarbons be formed from their organic precursors under the influence of increasing temperature, usually expressed in terms of geothermal gradient and depth of burial (Philippi, 1965). Prolonged thermal alteration results in the cracking of high molecular weight hydrocarbons and asphaltic materials, to produce an oil of higher API gravity (Barton, 1937; McNab et al, 1952; Louis & Tissot, 1967; Evans, Rogers & Bailey, 1971). At elevated temperatures petroleum liquids are ultimately destoryed leaving only dry gas (Landes, 1967; Brooks, Hesp and Rigby, 1971).

HISTORY OF MIGRATION

The composition of crude oils may alter during migration. Preferential absorption of asphaltic materials will lighten the oil (Silverman, 1965) and lead to modifications in Ni-V ratios (Al-Shahristani & Al-Atyia, 1972), but the nett effective change is quite small. More drastic alteration occurs where the physical constraints, in particular pressure, change. One such phenomenon, termed separation-migration (Silverman, 1965), requires the existence of two phases (liquid and vapour). Reduction of pressure can be induced by faulting and fracturing and may result in the preferential loss of the vapour phase. Should this happen under the new reservoir conditions the vapour reverts to a two phase system by retrograde condensation. As a result there is a progressive enrichment of low molecular weight hydrocarbons in the direction of transport, independently of any maturation. Alternatively, an increase in pressure due to greater depth of burial of the reservoir may cause de-asphalting of the crude and lead to the formation of a lighter oil (Evans, Rogers and Bailey, 1971).

FLUSHING

Invasion of the reservoir brines by meteoritic waters will remove light hydrocarbons roughly in proportion to their solubility in the under-saturated water flowing by the reservoir. The loss of the gasoline fractions lowers the API gravity of the oil (Barbat, 1967, Evans, Rogers & Bailey, 1971). Bacteria introduced to the reservoir in the moving water may initiate microbial degradation of the oil (Evans, Rogers & Bailey, 1971). Normal paraffins are preferentially removed. Where sulphate-reducing bacteria are involved the sulphur produced may react with the oil to form sulphur-rich oils and tars, or sulphur deposits (Evans, Rogers & Bailey, 1971).

ANALYSIS OF OILS

INTRODUCTION

For a particular oil it is extremely difficult to distinguish the effects of any one geological process unless detailed geochemical evidence is available (Rogers, Bailey & Evans, 1971). Consequently, a systematic study of the composition of Australian oils and condensates was undertaken. The analytical procedures outlined below are based on a scheme for the geochemical analysis of crude oils devised by Rogers, Bailey and Evans (1971). The results and discussion for each basin are set out in the same order as the basin geology is presented in this volume and the reader is referred to these sections for details of the geology.

PROCEDURES

The API gravities of the oils were measured according to method

IP 160/68. The sulphur analyses were carried out by the CSIRO Microanalytical Service. The exact pour points were not determined; rather distinctions were drawn as to whether the pour points fell above or below 50°F. Since the asphalt contents of Australian oils discovered to date are negligible, a pour point of greater than 50°F (Hedberg, 1968) was taken to indicate a high wax oil. Where the pour point falls between 30°F and 50°F, a cloud point of above 25°F for US Bureau of Mines distillation fraction 11, or a cloud point of above 95°F for fraction 15, was also used as evidence of high wax content (Hedberg, 1968). This additional information was obtained from US Bureau of Mines and company analyses. The wax content is given as high (H) or low (L). It was not measured in condensates (*) (Table 1).

Preliminary distillation was carried out according to method IP 24/55 and cuts were taken at intervals of 50°C. The specific gravity of each cut was measured and the data used to calculate US Bureau of Mines Correlation Indices (Smith, 1964). Values below 10 represent ultraparaffinic fractions; 10 to 20 - highly paraffinic; 20 to 30 - paraffinic; 30 to 40 - naphthenic; and above 40 - aromatic (Barbat, 1967). The divisions are somewhat arbitrary and the indices represent a series from paraffinic at low values to aromatic at high values. The naphthenic and aromatic fields overlap considerably. Nevertheless, the correlation curve (plot of correlation index against mean boiling point of the distillation fractions) provides a useful compositional profile of the crude oil.

The fractions boiling above 250°C were combined and the asphaltenes separated according to method IP 143/57. The asphaltene-free residue was then chromatographed on alumina by eluting successively with petroleum ether (40-70°C), benzene, and methanol to obtain the saturated hydrocarbons, aromatic hydrocarbons and oxygen, nitrogen and sulphur (ONS) compounds, respectively. The saturated hydrocarbons were analysed by gas chromatography using a 50 m x 0.25 mm ID capillary column coated with Apiezon L and nitrogen as carrier gas. The column was temperature programmed from 100°C to 250°C at 4°C per minute and held at 250°C until all the peaks had been eluted. N-alkanes, pristane, and phytane were identified by co-injection of authentic standards and by comparison of retention times with published data.

GEOCHEMISTRY OF AUSTRALIAN CRUDE OILS

SOUTHERN COASTAL REGION

Gippsland Basin

Crude oil and gas-condensate are produced from several fields in the off-shore Gippsland Basin. The characteristics of the oils and condensates are listed in Table 1 and the correlation curves are given in Fig. 1. The important features of the oils from this basin are their high wax content, paraffinic-naphthenic composition and high pristane to phytane ratios. The Halibut, Mackerel and Kingfish oils have very similar distillation yields and correlation indices. The high wax content and high pristane to phytane ratios (greater than 5) are indicative of a source from the debris of terrestrial plants (Hedberg, 1968; Brooks, Gould & Smith, 1969b; Powell & McKirdy, 1973). It is significant that the n-paraffins extracted from a coal at 2286 m in the Marlin AI well have an almost identical molecular distribution to those in the Kingfish oil (Brooks and Smith, 1969a). All these accumulations occur in the non-marine sediments of the Latrobe Group. Both the composition of the oils and their geological setting support a non-marine origin.

Otway Basin

Two non-commercial oil shows have been discovered in the predominantly non-marine Otway Group (Cretaceous) in the Otway Basin (Wopfner, Kenley and Thornton, 1971). The oils encountered in the Flaxmans and Port Campbell wells are similar in character to the oils from the Gippsland field in having a paraffinic base (Fig. 1). The wax content, pristane to phytane ratio, and gasoline yield are all high (Table 1). The composition of these oils is consistent with a non-marine source.

GREAT ARTESIAN BASIN

Bowen and Surat Basins

Oil and gas have been discovered in formations ranging from Devonian 'Basement ' to Lower Jurassic. Only the oils at Moonie, Alton and Conloi have proved commercial. Gas is produced from fields on the Roma Shelf. Five oil samples from the Roma Shelf and five from the Mimosa Syncline have been examined (Table 1). The features which characterize the majority of these oils are again high values for wax content, gasoline yield, and pristane to phytane ratio. The correlation curves (Fig. 2) indicate some divergence in composition, particularly in the lower boiling fractions. However, with the exception of the Conloi oil, the fractions boiling above 275°C are similar. The correlation indices for these fractions fall in the range 20-31, and the composition of the combined fractions boiling above 250°C is 77-85% saturated hydrocarbons, 7-15% aromatics, and 3-8% ONS compounds (Table 1). In the Conloi crude the fraction boiling above 250-300°C has a correlation index of 50, indicating a naphthenic-aromatic base, yet column chromatography reveals a composition similar to the other oils (83% saturated hydrocarbons, 10% aromatics, and 7% ONS compounds).

Gas chromatographic analysis shows that n-paraffins are the predominant hydrocarbons in all but the Conloi oil where they are totally missing. In addition, the Conloi crude is stripped of the light boiling fractions (below 200°C) (Table 1). A possible explanation for the anomalous composition of the Conloi oil is that water washing has removed the lighter hydrocarbons and bacteria have selectively metabolized the n-paraffins.

Considerable variation in the composition of the lighter boiling fractions exists in the samples from the Roma Shelf. However, the similarity of the higher boiling fractions suggests that the oils may have a common or related source. If this is so, the differences in composition of the lighter fractions must have arisen during migration. The Surat Basin is part of the larger hydrodynamically active Great Artesian Basin in which extensive secondary migration is likely to have occurred (Power and Devine, 1970; Conybeare, 1970).

The high pristane to phytane ratios and wax contents of the Bowen and Surat crudes (Conloi excepted) suggest a largely non-marine source.

Galilee Basin

An oil show was encountered in non-marine Permian clastic sediments in the Lake Galilee No. 1 well in the Galilee Basin. The oil has a very high wax content, a low yield of gasoline fractions (only 17% distils over below 200°C: Table 1) and a low pristane to phytane ratio. It is probably of non-marine origin. Powell and McKirdy (1973) have attributed its unusually low pristane to phytane ratio to a derivation from terrestrial organic material which has undergone little thermal alteration during burial diagenesis.

Cooper Basin

Both gas-condensate and oil discoveries have been made in the Cooper Basin: the gas-condensate forms the main commercial accumulations. All the hydrocarbon occurrences are within the non-marine Gidgealpa Formation of Permian age. The oils are paraffinic (Fig. 3), with high wax contents and high pristane to phytane ratios (Table 1). The condensates tend to be more naphthenic and have lower pristane to phytane ratios. These features may be due to maturation of hydrocarbons in the reservoir. Regional variations in the extent of organic maturation occur across the Cooper Basin. Thus in the Moomba area dry gas only is encountered in association with high rank coals (89.0% Carbon, dry ash-free), whereas at Gidgealpa and Toolachee gas-condensate occurs in association with slightly lower rank coals (85.5 - 86.6% C, D.A.F.: Brooks, Hesp and Rigby, 1971). There is little doubt that the hydrocarbons are of non-marine origin.

CENTRAL INTRACRATONIC REGION

Amadeus Basin

The Mereenie crude from the Amadeus Basin is of particular interest since it is the only Lower Palaeozoic oil so far found in Australia. The correlation indices show that the oil is highly paraffinic (Table 1). Gas chromatographic analysis of the saturated hydrocarbons separated from the fraction boiling above 250°C reveals that there is a marked odd carbon number predominance in the n-paraffin distribution below C_{20} (Fig. 4). A similar feature has been reported by Martin, Winters and Williams, (1963) in other Lower Palaeozoic crudes and is suggestive of an origin from the fats of micro-organisms. The low pristane to phytane ratio is consistent with an origin from the debris of aquatic organisms.

NORTH WESTERN REGION

Canning Basin - Fitzroy Trough

Only one oil show has been reported in the Fitzroy Trough. This was found in the Carboniferous Laurel Formation in the Meda No. 1 well. It is a highly paraffinic, high-wax oil. Despite a low pristane to phytane ratio its other features point to a non-marine source.

WESTERN COASTAL REGION

Carnarvon Basin

Barrow Sub-basin

Oil has been recovered from both Jurassic and Cretaceous formations but only that occurring in the Cretaceous at Barrow Island represents a significant commercial accumulation. The samples examined came from the Windalia 'Sand', the Muderong Greensand and three levels within the Barrow Group at Barrow Island (viz 2042 m, 1828 m and 1889 m in the Barrow No. 1 well). Oils from the Birdrong Sand (Cretaceous) in the Flinders Shoals No. 1 and Rough Range No. 1 wells, and from two levels within the Jurassic (viz 1737 m and 1798 m) in the Pasco No. 1 well, were also analysed.

The correlation curves (Fig. 5) indicate that with the exception of the Rough Range crude, the oils in the Barrow Sub-basin fall into two families. Those occurring in Cretaceous reservoirs are naphthenic-aromatic in composition, in contrast to the Jurassic oils, which are paraffinic-naphthenic and have a high wax content (Table 1). The difference between the two groups of oils lies mainly in their proportion of straight-chain paraffins (Fig. 6). Gas chromatograms of the saturated hydrocarbons isolated from the Jurassic oils are dominated by n-paraffins, although substantial amounts of naphthenic hydrocarbons are also present. The oils from Cretaceous reservoirs contain an extremely complex mixture of naphthenic hydrocarbons, with n-paraffins forming only a small proportion of the total.

The oil recovered from the Birdrong Sand in the Flinders Shoal No. 1 well is stripped of light hydrocarbons and has probably been water-washed in the reservoir. The Birdrong Sand is a prolific aquifer in the adjacent onshore area. The Muderong Shale and Gearle Siltstone, both marine formations, are considered to be the source for the Cretaceous oils (Parry, 1967). The Muderong Greensand member at Barrow Island yielded oil that is very similar to the Windalia crude (Fig. 5). Together, the low pristane to phytane ratios (Table 1) high correlation indices, and low wax content of the Cretaceous oils indicate a marine source.

The intermediate pristane to phytane ratios, paraffinic-naphthenic base and high wax content of the Jurassic oils in the Barrow Sub-basin suggests a mixed marine and terrestrial source in keeping with the marginal marine character of the Jurassic host sediments.

The oil from the Birdrong Sand in Rough Range No. 1 well is quite different in composition from the remaining oils in the Barrow Sub-basin. It is ultra-paraffinic and devoid of light boiling fractions. Its high wax content suggests a non-marine source.

Dampier Sub-basin

Gas/condensate and oil are known from Triassic, Jurassic and Cretaceous formations within the Dampier Sub-basin. Major gas/condensate discoveries (North Rankin, Goodwyn, and Rankin) have been made in Triassic sediments of the Rankin Trend. A thin oil column was encountered in the Rankin No. 1 well beneath the gas-condensate and a small amount of oil was recovered from the Toolonga Calcilutite in the North Rankin No. 1 well. Oil has also been discovered in the Eaglehawk No. 1 well in Triassic sediments on the Rankin Trend. Gas/condensate has also been found in the Barrow Group (Jurassic-Cretaceous) at the Angel location and a non-commercial oil discovery was made in the same group in the Legendre No. 1 well.

With the exception of the oil from Eaglehawk No. 1 well, the correlation curves (Fig 7) reveal a basic similarity in the composition of the oils and condensates from both the Barrow Group and Triassic reservoirs. The close resemblance of the condensates from the Rankin Trend and the Angel field is particularly striking and a common source is likely.

The Rankin Platform is an uplifted Triassic fault block overlain unconformably by Cretaceous sediments. To the southeast, a fault with up to 2400 m of throw separates it from a trough of Jurassic sediments (Kaye, Edmond and Challiner, 1972). Within this trough are located the Legendre structure and the Madeleine-Dampier anticlinal trend containing the Angel field. Chemical evidence suggests that hydrocarbons in these prospects have been generated from Jurassic sediments. Subsequent migration up dip led to accumulations in Triassic sands on the Rankin Platform, and also in sands of the Barrow Group at the Angel and Legendre locations. Jurassic sediments encountered at depth in the Madeleine No. 1 and Dampier No. 1 wells are excellent source rocks (Powell and McKirdy unpublished results). The mixed non-marine and marine nature of their organic matter is consistent with the intermediate pristane to phytane ratios (3.3 - 4.3) observed in the oils. The oils and condensates of Jurassic origin in the Dampier

Sub-basin are slightly more naphthenic than the Jurassic oils in the Barrow Sub-basin.

The small amount of oil recovered from the Toolonga Calcilutite in the North Rankin No.1 well and the oil which flowed from the Triassic in the Eaglehawk No. 1 well are very similar in composition. They are of the naphthenic type and as such strongly resemble the oils occurring in the Cretaceous at Barrow Island. The main difference is that the oils from North Rankin and Eaglehawk have a greater proportion of high boiling fractions (Table 1). If these oils have a Cretaceous source, the oil at Eaglehawk must have migrated into the Triassic sands from overlying Cretaceous sediments. Thus the division of oils into a paraffinic-naphthenic type with a Jurassic source and a naphthenic-aromatic type with a Cretaceous source seems to be a feature of both the Barrow and Dampier Sub-basins

Perth Basin

North Dandaragan Trough

Wells drilled in the area adjacent to the Dongara Saddle flowed both gas and oil from reservoirs ranging in age from Permian to Jurassic. Only the gas is commercial and it occurs in the Dongara, Mondarra and Yardarino fields. The main reservoirs are in the Yardarino Sandstone (Triassic), which in part rests unconformably on Permian sediments. An oil leg is present in each field. Minor oil has also been found within the Triassic Kockatea Shale in both the Mount Horner No.1 and North Erregulla No. 1 wells, and in the Jurassic Cockleshell Gully Formation in the Erregulla No. 1 well.

Correlation curves (Fig. 8) show that the oils and condensates are highly paraffinic and remarkably similar in composition. The corresponding pristane to phytane ratios are low and fall in the very narrow range 1.0 - 1.5 (Table 1). The API gravities of the oils also show little variation (34.6 - 37.6^{o}). All the oils are extremely waxy, being solid at room temperature.

Distillation data (Table 1) show that the oils from the Dongara, Mondarra, and Yardarino fields are stripped of light ends (i.e. fractions boiling below 200°C) compared to those oils from the remaining wells. The absence of low boiling components from the oils indicates that they are not in equilibrium with the overlying gas. This in turn could imply the oil and gas accumulated by separate events. Nevertheless, the similarity in the correlation curves and pristane to phytane ratios of the respective oils and condensates strongly suggests that they have a common or related source.

The waxy nature of these oils suggests a largely non-marine source but their pristane to phytane ratios are anomalously low. The relatively small yield of low boiling fractions, even in those oils which are not stripped of light ends, and the absence of naphthenic components show that the parent organic matter has suffered minimal thermal alteration. Low rank coals tend to have low pristane to phytane ratios (Brooks, Gould and Smith, 1969b). Thus the waxy nature of the oils in the northern Dandargan Trough, their lack of naphthenic components, low yield of light fractions, and low pristane to phytane ratios together indicate a source from terrestrial organic matter which has not undergone extensive diagenetic alteration.

The source for the oils in this area is probably the Kockatea Shale, since the oil in the Mount Horner No. 1 well occurs in sandstone lenses within the Kockatea Shale and is thought to be more or less *in situ*. The basal Triassic Yardarino Sandstone, the main reservoir, is overlain by the Kockatea Shale. As the Kockatea Shale is the likely source of the liquid hydrocarbons it is difficult to envisage two periods of generation and migration - one for the oil and another for the gas - from such a single source. Perhaps a more plausible explanation is that the oil was derived from the Kockatea Shale, whereas the dry gas originated in more highly altered Permian Coal Measures downdip of the present hydrocarbon accumulations and has mobilised the light fractions from the oils.

Central Dandaragan Trough

Gas/condensate is produced from the Gingin and Walyering fields which are approximately 22 km apart in the central Dandaragan Trough. Unconnected sands within the Cockleshell Gully Formation constitute the producing zones. Two samples from different levels within the Gingin field were compared with two samples from approximately equivalent stratigraphic intervals in the Walyering field. In each case the condensate from the greater depth contains the higher proportion of heavy hydrocarbons (Table 1). The correlation curves (Fig. 9) show that the samples from the equivalent horizons in each field are similar in composition, but that there are marked differences between the upper and lower levels within the same field. The pristane to phytane ratios of the two deeper condensates are similar (3.1 and 3.4). There is, however, an unexplained discrepancy in values for the shallow samples (5.5 and 2.8). The most likely source for these condensates is the Cockleshell Gully Formation itself. This formation was deposited in a marginal marine to continental environment (Jones and Pearson, 1972). Its condensates are paraffinic to naphthenic, and those from the deeper levels have a high wax content. All show intermediate pristane to phytane ratios which, in combination with other compositional data, indicate a mixed source.

Vlaming Sub-basin

Oil was recovered from the Gage Roads No. 1 well in the off-shore part of the Vlaming Sub-basin. It is a high-wax paraffinic oil with a high pristane to phytane ratio (Table 1). It is located in the continental Yarragadee Formation (Jurassic) and is undoubtedly of non-marine origin.

Bunbury Trough

A gas/condensate flow has been obtained from Upper Permian Coal Measures in the Whicher Range No. 1 well. The condensate is naphthenic and has an intermediate to high pristane to phytane ratio (Table 1).

PAPUA NEW GUINEA

Papuan Basin

The Uramu condensate was recovered from Miocene reef sediments in the off-shore part of the Papuan Basin. It is naphthenic to aromatic in composition and has a low pristane to phytane ratio in keeping with a marine origin. The remaining samples were obtained from onshore wells drilled in the Delta Region of Papua. The Bwata sample is an extremely light condensate. The Omati and Puri samples are characterized by a high wax content, paraffinic-naphthenic composition, and low to intermediate pristane to phytane ratios. They are probably derived from mixed marine and terrestrial source material.

GEOCHEMICAL CLASSIFICATION OF OILS FROM AUSTRALIA AND PAPUA NEW GUINEA

This geochemical survey of crude oils discovered within Australia and New Guinea has shown that they are mainly of paraffinic to naphthenic base and have low sulphur and asphalt values. High wax contents are also common. Notwithstanding their general similarity these crudes can be divided into three groups based on their composition and geological environment. These are (1) High wax and predominantly paraffinic oils and condensates with high pristane to phytane ratios (greater than 4.5) occurring in non-marine or deltaic sequences; (2) Paraffinic-naphthenic oils with intermediate pristane to phytane ratios (3.0 to 4.5) and occasionally a high wax content associated with near-shore marine clastic to deltaic sequences; (3) Low wax naphthenic oils with low pristane to phytane ratios (less than 3.0) associated with carbonates and euxinic shales. These categories are illustrated in Fig. 10 where the pristane to phytane ratios are plotted against the average correlation index of the 250 - 300°C distillation fractions.

The first category is by far the most prevalent and includes oils from the Gippsland, Otway, Bowen, Surat, Galilee, Cooper, Perth and Canning Basins. Variations in composition amongst these high-wax oils can be attributed to differences in the degree of maturation. Thus the oils from the northern Perth Basin are inmature, being highly paraffinic with low pristane to phytane ratios. Mature oils from the Gippsland, Bowen, and Surat Basins are paraffinic to naphthenic and have high pristane to phytane ratios. Condensates from the Cooper Basin tend to be slightly more naphthenic and probably represent an advanced stage of maturation.

Oils found in marginal marine sediments from the Papuan , Perth, and Carnarvon Basins fall into the second group. They are even more naphthenic and have intermediate pristane to phytane ratios.

The third category comprises the seven oils so far discovered in Australia which have a definite marine source. These are the oils derived from Cretaceous sediments in the Carnarvon Basin, the Uramu condensate from Papua, and the Mereenie oil from the Amadeus Basin. All but the Mereenie oil are naphthenic to aromatic in composition and each has a low pristane to phytane ratio.

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REFERENCES

Barbat, W.N., 1967 - Crude oil correlations and their role in exploration, Amer. Ass. Petrol. Geol. Bull., 52: 1255-1292.

Barton, D.C., 1937 - Evolution of Gulf Coast crude oil, Amer. Ass. Petrol. Geol. Bull., 21: 914-946.

Brooks, J.D., and Smith, J.W., 1969a - The diagenesis of plant lipids during the formation of coal petroleum and natural gas - II. Coalification and the formation of oil and gas in the Gippsland Basin, Geochim. Cosmochim. Acta, 33: 1183-1194.

Brooks, J.D., Gould, K., and Smith, J.W., 1969b - Isoprenoid hydrocarbons in coal and petroleum, Nature, 222: 257-259.

Brooks, J.D., 1970 - The use of coals as indicators of the occurrence of oil and gas, APEA J., 10 (2): 35-40.

Brooks, J.D., Hesp, W.R., and Rigby, D., 1971 - The natural conversion of oil to gas in sediments in the Cooper Basin, APEA J., 11 (1): 121-125.

Conybeare, C.E.B., 1970 - Solubility and mobility of petroleum under hydrodynamic conditions. Surat Basin, Queensland, J. Geol. Soc. Aust., 16: 667-681.

Evans, C.R., Rogers, M.A., and Bailey, N.J.L., 1971 - Evolution and alteration of petroleum in western Canada, Chem. Geol., 8: 147-170.

Hedberg, H.D., 1968 - Significance of high wax oils with respect to genesis of petroleum, Amer. Ass. Petrol. Geol. Bull., 52: 736-750.

Hunt, J.M., 1953 - Composition of crude oil and its relation to stratigraphy in Wyoming, Amer. Ass. Petrol. Geol. Bull., 37: 1837-1872.

Jones, D.K., and Pearson, 1972 - The tectonic elements of the Perth Basin, EPEA J., 12 (1): 17-22.

Kaye, P., Edmond, G.M., and Challinor, A., 1972 - The Rankin Trend Northwest Shelf, Western Australia, APEA J., 12 (1): 3-8.

Landes, K.K., 1967 - Eometamorphism and oil and gas in time and space. Amer. Assoc. Petrol. Geol. Bull., 51: 828-841.

Louis, M.C., and Tissot, R.P., 1967 - Influence de la temperature et de la pression sur la formation des hydrocarbures dans les argiles a'kerogene, Seventh World Petrol. Cong. Proc., 2: 57-60.

McNab, J.G., Smith, Jr., P.V., and Betts, R.L., 1952 - The evolution of petroleum, Indus and Eng. Chemistry, 44: 2556-2563.

Martin, R.L., Winters, J.C., and Williams, J.A., 1963 - Distribution n-paraffins in crude oils and their implications to the origin of oil, Nature, 199: 110-113.

Mathews, R.T., Burns, B.J., and Johns, R.B., 1971 - An approach to identification of source rocks, APEA J., 11 (1): 115-120.

Parry, J.C., 1967 - The Barrow Island Oilfield, APEA J., 7 (1): 130-133.

Philippi, G.T., 1965 - On the depth, time and mechanism of petroleum formation, Geochim. Cosmochim. Acta, 29: 1021-1049.

Powell, T.G., and McKirdy, D.M., 1973 - A relationship between pristane to phytane ratio, crude oil composition and geological environment in Australia, Nature, in press.

Power, P.E., and Devine, S.B., 1970 - Surat Basin, Australia - subsurface stratigraphy, history and petroleum. Amer. Ass. Petrol. Geol. Bull., 54: 2410-2437.

Rogers, M.A., Bailey, N.J.L., and Evans, C.R., 1971 - A plea for inclusion of basic sample information when reporting geochemical analyses of crude oils, Geochim. Cosmochim. Acta, 35: 632-636.

Al-Shahristani, H., and Al-Atyia, M.J., 1972 - Vertical migration of oil in Iraqui oil fields: Evidence based on vanadium and nickel concentrations, Geochim. Cosmochim. Acta, 36: 929-938.

Silverman, S.R., 1965 - Migration and segregation of oil and gas, in Fluids in Subsurface Environments (Ed. A. Young and G.E. Galley) Amer. Ass. Petrol. Geol. Mem., 4: 53-65.

Smith, H.M., 1964 - Hydrocarbon-type relationships of eastern and western hemisphere high sulphur oils, U.S. Bur. Min. Rep. Invest. 6542: 87 p.

Wopfner, H., Kenley, P.R., and Thornton, R.C.N., 1971 - Hydrocarbon occurrences and potential of the Otway Basin, in The Otway Basin of South Eastern Australia (Ed. H. Wopfner and J.G. Douglas), Spec. Bull. Geol. Surveys S. Aust. and Vic. 385-430.

Table 1 - Characteristics of Crude Oils from Australia and Papua New Guinea

BASIN	GIPPSLAND					OTWAY	
WELL OR FIELD	Barracouta	Halibut	Kingfish	Mackerel 3	Marlin A-1	Flaxmans 1	Port Campbell 4
DEPTH (metres)	2643-2679	~ 2346	~ 2286	2394	~ 1570	3304-3513	1789-1799
PRODUCING FORM.	Labrobe Gp	Latrobe Gp	Latrobe Gp	Latrobe Gp	Latrobe Gp	Otway Gp	Otway Gp
AGE	U. Cret.- Eocene	U. Cret.- Eocene	U. Cret.- Eocene	U. Cret.- Eocene	U. Cret.- Eocene	Cretaceous	Cretaceous
API Gravity	57.5	42.4	45.9	47.0	49.8	47.6	45.4
Sulphur %	nd	0.1	0.1	< 0.1	< 0.1	0.3	0.1
Wax	*	H	H	H	H	H	H
Distillation							
volume % < 100°C	18.0	10.5	10.0	11.0	8.5	2.0	6.5
100-200	54.0	27.0	31.0	27.0	40.0	61.5	34.5
200-280		18.0	18.5	16.0	32.0	22.0	20.5
280-340	28.0	19.0	18.0	16.0	19.5	14.5	24.0
> 340		26.5	22.5	30.0			14.5
US Bur. Mines							
Correlation Indices							
Fraction 100-150°C	12	19	18	24	18	28	14
150-200	12	23	21	26	19	23	15
200-250	14	28	24	27	17	20	16
250-300	nd	32	26	30	16	21	18
300-340	nd	31	26	25	nd	nd	18
Composition of combined Fractions > 250°C							
Saturates %	74.8	78.9	78.9	88.1	83.3	82.9	83.1
Aromatics %	8.2	14.6	11.9	9.1	5.0	10.9	9.5
Eluted ONS cpds %	16.9	6.4	9.0	2.6	11.6	6.0	7.3
Asphalt %	0.14	0.21	0.13	0.31	< 0.05	< 0.05	0.58
Pristane to Phytane Ratio	7.6	8.7	8.1	7.3	12.0	7.0	7.6

Table 1 (cont)

BASIN		BOWEN AND SURAT - MIMOSA SYNCLINE				- ROMA SHELF	
WELL OR FIELD	Alton 1	Cabawin 1	Conloi 1	Moonie 1	Wunger 1	Dirinda 1	Duarran 1
DEPTH (metres)	1847-1865	3026-3029	1314-1317	1770-1780	1915-1920	1219-1230	1225-1241
PRODUCING FORM	Evergreen	Kianga	Evergreen	Precipice Sst	Wandoan	Timbury Hills	Precipice Sst
AGE	Jurassic	Permian	Jurassic	Jurassic	Triassic	Devonian	Jurassic
API Gravity	43.2	46.5	28.7	37.8	45.9	47.3	37.3
Sulphur %	0.3	0.2	0.4	0.3	0.1	0.2	0.3
Wax	H	H	L	H	L	H	H
Distillation volume % < 100°C	5.0	10.5	0	4.0	0.0	10.0	5.0
100-200	30.0	41.5	9.5	20.0	40.0	39.0	31.5
200-280	27.5	21.5	38.5	25.0	38.0	22.0	21.5
280-340	26.0	25.5	27.4	30.0	21.5	19.0	42.0
> 340	11.5		24.5	21.0		10.0	
US Bur. Mines Correlation Indices							
100-150°C	22	22	nd	35	nd	16	46
150-200	22	24	34	33	18	17	46
200-250	21	27	41	31	19	19	40
250-300	21	28	47	27	20	24	32
300-340	22	29	53	25	nd	28	30
Composition of fractions > 250°C							
Saturates %	77.09	80.2	82.8	80.5	85.7	81.9	81.3
Aromatics %	12.8	15.3	10.0	14.2	7.2	13.5	11.9
Eluted ONS cpds %	10.04	4.4	7.1	5.2	6.9	4.4	6.6
Asphalt %	0.07	0.11	0.15	0.42	0.12	0.22	0.19
Pristane to Phytane Ratio	6.6	6.5	3.2	5.6	8.6	6.7	6.0

Table 1 (cont)

BASIN	BOWEN AND SURAT-ROMA SHELF			GALILEE	COOPER		
WELL OR FIELD	Richmond 1	Snake Creek 1	Sunny bank 2	Lake Galilee 1	Brolga 1	Chandos 1	Coonatie 1
DEPTH (metres)	1770-1780	1514-1548	2002-2009	2643-2678	2769-2798	2064	2839-2850
PRODUCING FORM	Precipice	Showground	Bandanna	un-named	Gidgealpa	un-named	Gidgealpa
AGE	Jurassic	Triassic	Permian	Permian	Permian	Permian	Permian
API Gravity	43.2	46.8	34.9	42.2	48.8	46.8	46.5
Sulphur %	< 0.1	0.3	0.1	< 0.1	nd	0.2	nd
Wax	H	H	H	H	*	H	*
Distillation volume % < 100°C	13.0	6.5	1.5	1.0	2.5	17.0	3.5
100-200	38.0	55.5	12.5	16.0	62.5	35.0	42.0
200-280	34.0	27.0	21.5	26.0	21.0	27.5	27.0
280-340	) 15.0	) 11.0	29.5	34.0	) 14.0	) 20.5	) 27.5
> 340	)	)	35.0	23.0	)	)	)
US Bur. Mines Correlation Indices 100-150°C	33	24	nd	nd	23	30	19
150-200	32	24	33	16	23	26	23
200-250	29	28	35	16	24	25	25
250-300	35	30	33	15	25	24	29
300-340	nd	nd	28	13	nd	nd	nd
Composition of fractions > 250°C Saturates %	80.5	82.6	81.9	90.4	83.8	87.5	82.4
Aromatics %	10.5	10.3	13.5	5.1	14.5	11.3	17.3
Eluted ONS cpds %	9.0	7.1	4.4	4.4	1.6	1.0	2.9
Asphalt %	< 0.05	0.10	0.11	0.16	< 0.05	0.06	< 0.05
Pristane to Phytane Ratio	8.2	7.0	6.4	2.0	7.3	6.6	3.1

Table 1 (cont)

BASIN	COOPER					AMADEUS	CANNING
WELL OR FIELD	Della 5A	Fly Lake 2	Gidgealpa 3	Toolachee 7	Yanpurra 1	E. Mereenie 4	Meda 1
DEPTH (metres)	1909-1951	2905-2914	2229-2234	2229-2245	2894-2928	~ 1600	1557-1564
PRODUCING FORM	Gidgealpa	Gidgealpa	Gidgealpa	Gidgealpa	Gidgealpa	Pacoota Sst	Laurel
AGE	Permian	Permian	Permian	Permian	Permian	Ordovician	Carboniferous
API Gravity	43.0	47.7	45.6	55.7	43.8	46.9	38.0
Sulphur %	nd	< 0.1	0.1	nd	< 0.1	< 0.1	nd
Wax	H	H	*	*	H	L	H
Distillation volume % < 100°C	0.0	14.0	0.0	16.0	3.0	13.0	0.0
100-200	30.0	36.5	80.0	56.0	36.0	32.0	24.0
200-280	40.0	19.5	)	17.5	27.0	24.0	23.5
280-340	)	11.0	) 20.0	)	19.0	26.0	20.5
> 340	) 30.0	19.0	)	) 15.0	15.0	5.0	32.0
US Bur. Mines Correlation Indices							
100-150°C	27	18	nd	19	14	15	14
150-200	28	22	25	17	17	17	14
200-250	25	24	29	15	19	19	17
250-300	27	30	nd	nd	23	23	21
300-340	nd	nd	nd	nd	17	21	23
Composition of fractions > 250°C							
Saturates %	83.6	74.6	87.2	91.2	81.1	84.8	74.0
Aromatics %	13.6	18.2	7.9	7.1	12.5	9.0	18.1
Eluted ONS cpds %	2.8	7.1	4.7	1.5	6.4	6.1	7.7
Asphalt %	< 0.05	0.05	0.12	< 0.05	0.65	0.13	< 0.05
Pristane to Phytane Ratio	4.0	7.3	nd	7.0	10.0	1.5	1.6

Table 1 (cont)

BASIN	CARNARVON - BARROW SUB-BASIN						
WELL OR FIELD	Barrow 15	Barrow 3	Barrow 1	Barrow 1	Barrow 1	Flinders Shoal 1	Pasco 1
DEPTH (metres)	~ 670	-	~ 1889	~2011	~2042	791-799	1759-1753
PRODUCING FORM	Windalia	Muderong	Barrow Gp	Barrow Gp	Barrow Gp	Birdrong	Barrow Gp
AGE	Cretaceous	Cretaceous	Jur. - Cret.	Jur. - Cret.	Jur.- Cret.	Cretaceous	Jur. - Cret.
API Gravity	35.3	32.1	41.7	39.8	38.3	22.9	40.2
Sulphur %	0.1	nd	nd	nd	0.2	nd	nd
Wax	L	L	H	H	H	L	H
Distillation volume % < 100°C	6.0	1.0	6.0	2.5	2.0	0.5	0.5
100-200	35.5	26.0	35.0	18.0	28.0	0.5	32.0
200-280	33.5	39.5	21.5	29.5	27.0	26.5	36.5
280-340	15.5	23.5	25.0	20.0	21.0	32.0	18.5
> 340	8.5	10.0	12.5	30.0	22.0	40.5	12.5
US Bur. Mines Correlation Indices							
100-150°C	27	28	26	25	24	nd	24
150-200	36	34	28	29	28	nd	24
200-250	48	47	32	31	30	45	26
250-300	63	55	36	32	36	52	31
300-340	65	56	33	33	33	54	32
Composition of fractions > 250°C							
Saturates %	68.2	77.2	79.2	82.9	80.9	77.3	80.6
Aromatics %	18.9	16.7	15.7	11.3	12.4	14.4	14.1
Eluted ONS cpds %	12.9	5.9	5.0	5.6	6.6	8.2	4.4
Asphalt %	0.19	0.07	0.02	0.05	0.05	0.23	0.05
Pristane to Phytane Ratio	2.8	3.1	3.3	3.5	3.5	1.8	3.4

Table 1 (cont)

BASIN	BARROW SUB-BASIN			CARNARVON - DAMPIER SUB-BASIN			
WELL OR FIELD	Pasco 1	Rough Range 1	Angel 1	Eaglehawk 1	Goodwyn 1	Legendre 1	N. Rankin 1
DEPTH (metres)	1825-1831	~1100	2734-2737	2750-2766	3146-3151	1894-1897	2572-2583
PRODUCING FORM	Barrow Gp	Birdrong	Barrow Gp	Mungaroo Beds	Mungaroo Beds	Barrow Gp	Toolonga Calcilutite
AGE	Jur. - Cret.	Cretaceous	Jur. - Cret.	Triassic	Triassic	Jur. - Cret.	Cretaceous
API Gravity	43.9	39.9	55.6	27.6	54.8	42.7	29.4
Sulphur %	nd	nd	nd	< 0.1	nd	0.2	nd
Wax	H	H	*	L	L	H	L
Distillation volume % < 100°C	2.0	2.5	28.0	0.0	15.0	10.0	2.5
100-200	39.0	0.5	47.0	12.0	52.5	40.0	19.5
200-280	26.5	14.0		40.0	23.5	24.5	32.0
280-340	15.0	42.0	15.0	33.5	9.0	16.5	24.0
> 340	18.0	41.0		14.5		9.0	24.0
US Bur. Mines Correlation Indices 100-150°C.	12	nd	21	nd	21	25	31
150-200	15	nd	25	nd	23	33	37
200-250	20	nd	32	46	28	36	50
250-300	28	8	nd	54	35	42	64
300-340	32	8	nd	58	nd	35	nd
Composition of fractions > 250°C Saturates %	80.0	86.8	84.5	72.1	85.7	73.6	73.0
Aromatics %	12.1	10.0	7.8	10.1	7.4	20.4	20.2
Eluted ONS cpds %	7.7	3.0	7.6	17.0	6.8	5.8	6.7
Asphalt %	< 0.05	0.36	< 0.05	0.81	< 0.05	0.36	0.33
Pristane to Phytane Ratio	3.5	5.3	4.3	1.7	4.0	3.3	2.3

Table 1 (cont)

BASIN	DAMPIER SUB-BASIN		PERTH BASIN - NORTH DANDARAGAN TROUGH				
WELL OR FIELD	N. Rankin 2	Rankin 1	Dongara 4	Dongara 14	Erregulla 1	Mondarra 1	Mondarra 3
DEPTH (metres)	~3200	2953	1718-1719	-	3173-3180	2688-2700	2835-2844
PRODUCING FORM	Mungaroo Beds	Mungaroo Beds	Yardarino Sst	Yardarino Sst	Cockleshell Gully	Yardarino Sst	Wagina Sst
AGE	Triassic	Triassic	Triassic	Triassic	Jurassic	Triassic	Permian
API Gravity	52.8	38.1	54.1	35.5	34.8	47.9	35.7
Sulphur %	nd	<0·1	nd	nd	<0·1	nd	nd
Wax	*	L	*	H	H	*	H
Distillation volume % < 100°C	21.0	2.5	2.0	2.5	3.0	0.5	2.5
100-200	50.0	17.5	68.0	4.5	12.0	36.5	2.5
200-280	17.5	27.5	)	16.0	13.0	40.5	8.0
280-340	)	28.0	) 30.0	15.0	22.0	)	9.0
> 340	) 11.5	24.5	)	62.0	50.0	) 22.5	78.0
US Bur. Mines Correlation Indices							
100-150°C	27	23	18	nd	nd	18	nd
150-200	30	26	16	nd	nd	17	nd
200-250	34	35	13	20	21	19	nd
250-300	nd	40	nd	17	21	15	19
300-340	nd	47	nd	16	18	13	14
Composition of fractions > 250°C							
Saturates %	82.5	75.2	96.5	76.7	73.9	93.5	91.6
Aromatics %	13.7	13.0	0.4	20.2	24.4	4.3	6.7
Eluted ONS cpds %	3.8	11.3	3.0	3.0	1.6	1.5	1.6
Asphalt %	< 0.05	< 0.05	< 0.05	< 0.05	0.05	< 0.05	0.05
Pristane to Phytane Ratio	3.7	4.0	1.1	1.2	1.1	1.3	1.1

Table 1 (cont)

BASIN	NORTH DANDARAGAN TROUGH			PERTH BASIN - CENTRAL DANDARAGAN TROUGH			
WELL OR FIELD	Mount Horner 1	Nth Erregulla 1	Yardarino 1	Gingin 1	Gingin 2	Walyering 1	Walyering 2
DEPTH (metres)	1484-1490	2918-2930	2237-2284	3864-3879	4255-4298	3368-3398	3981-3997
PRODUCING FORM	Kockatea	Kockatea	Wagina Sst	Cockleshell Gully	Cockleshell Gully	Cockleshell Gully	Cockleshell Gully
AGE	Triassic	Triassic	Permian	Jurassic	Jurassic	Jurassic	Jurassic
API Gravity	36.7	34.6	37.6	41.8	38.5	45.2	45.6
Sulphur %	<0.1	nd	0.4	nd	< 0.1	0.1	nd
Wax	H	H	H	*	H	*	*
Distillation volume % > 100°C	4.0	3.5	2.0	1.0	1.0	12.5	8.5
100-200	17.0	12.5	2.5	57.5	29.0	54.5	43.5
200-280	16.0	14.0	12.0	26.0	23.0	17.0	21.0
280-340	14.0	15.0	33.5	) 14.5	20.0	) 20.0	12.5
< 340	49.0	56.0	49.0	)	27.0	)	14.5
US Bur. Mines Correlation Indices							
100-150°C	15	nd	nd	34	22	32	25
150-200	15	nd	nd	36	23	37	27
200-250	17	22	nd	44	26	43	27
250-300	18	21	16	49	30	nd	30
300-340	18	16	15	nd	32	nd	29
Composition of fractions > 250°C							
Saturates %	70.9	73.9	85.1	83.3	72.6	86.3	79.3
Aromatics %	18.0	24.4	8.5	13.7	19.7	9.8	15.5
Eluted ONS cpds %	11.0	1.6	6.2	2.9	7.6	3.7	5.0
Asphalt %	0.31	0.05	0.05	0.05	0.08	0.05	0.30
Pristane to Phytane Ratio	1.2	1.1	1.0	5.5	3.1	2.8	3.4

Table 1 (cont)

BASIN	VLAMING SUB-BASIN	BUNBURY TROUGH	PAPUAN			
WELL OR FIELD	Gage Roads 1	Whicher Range 1	Bwata	Omati	Puri	Uramu 1A
DEPTH (metres)	1760-1769	4200-4204	1447-1605	~4105	2097-2301	1818-1888
PRODUCING FORM	Yarragadee	Un-named	Un-named	Un-named	'Taurim' Lst	Un-named
AGE	Jurassic	Permian		Jurassic	Miocene	Miocene
API Gravity	41.5	41.5	56.3	40.3	32.9	40.1
Sulphur %	0.1	0.1	nd	nd	0.1	0.6
Wax	H	*	*	H	H	*
Distillation						
volume % < 100°C	4.5	1.0	31.0	0.0	1.5	9.5
100-200	19.5	58.0	60.0	37.5	24.0	58.5
200-280	19.5	31.0	)	26.5	31.5	22.5
280-340	21.5	) 10.0	) 9.0	21.0	22.0	) 9.5
> 340	35.0	)	)	15.0	22.0	)
US Bur. Mines Correlation Indices						
100-150°C	13	32	24	27	22	40
150-200	19	31	26	29	23	48
200-250	25	42	nd	33	24	56
250-300	27	43	nd	34	30	nd
300-340	23	nd	nd	32	33	nd
Composition of fractions > 250°C						
Saturates %	81.2	83.2	nd	72.1	75.2	83.8
Aromatics %	12.1	12.6	nd	20.9	18.6	9.1
Eluted ONS cpds %	6.6	4.1	nd	7.0	6.3	6.9
Asphalt %	0.05	0.19	nd	0.11	0.12	0.13
Pristane to Phytane Ratio	5.0	5.3	nd	3.4	2.5	2.8

Fig. 1. Correlation curves for oils and condensates from the Gippsland and Otway Basins.

Fig. 2. Correlation curves for oils from the Bowen and Surat Basins.

Fig. 3. Correlation curves for oils and condensates from the Cooper Basin.

Fig. 4. Gas chromatogram of saturated hydrocarbons obtained from the Mereenie oil.

Fig. 5. Correlation curves for oils from the Barrow Sub-basin.

Fig. 6. Gas chomatograms of the saturated hydrocarbons obtained from the Barrow-Windalia and Barrow-Jurassic oils.

Fig. 7. Correlation curves for oils and condensates from the Dampier Sub-basin.

Fig. 8. Correlation curves for oils and condensates from the north Dandaragan Trough.

Fig. 9. Correlation curves for oils and condensates from the central Dandaragan Trough.

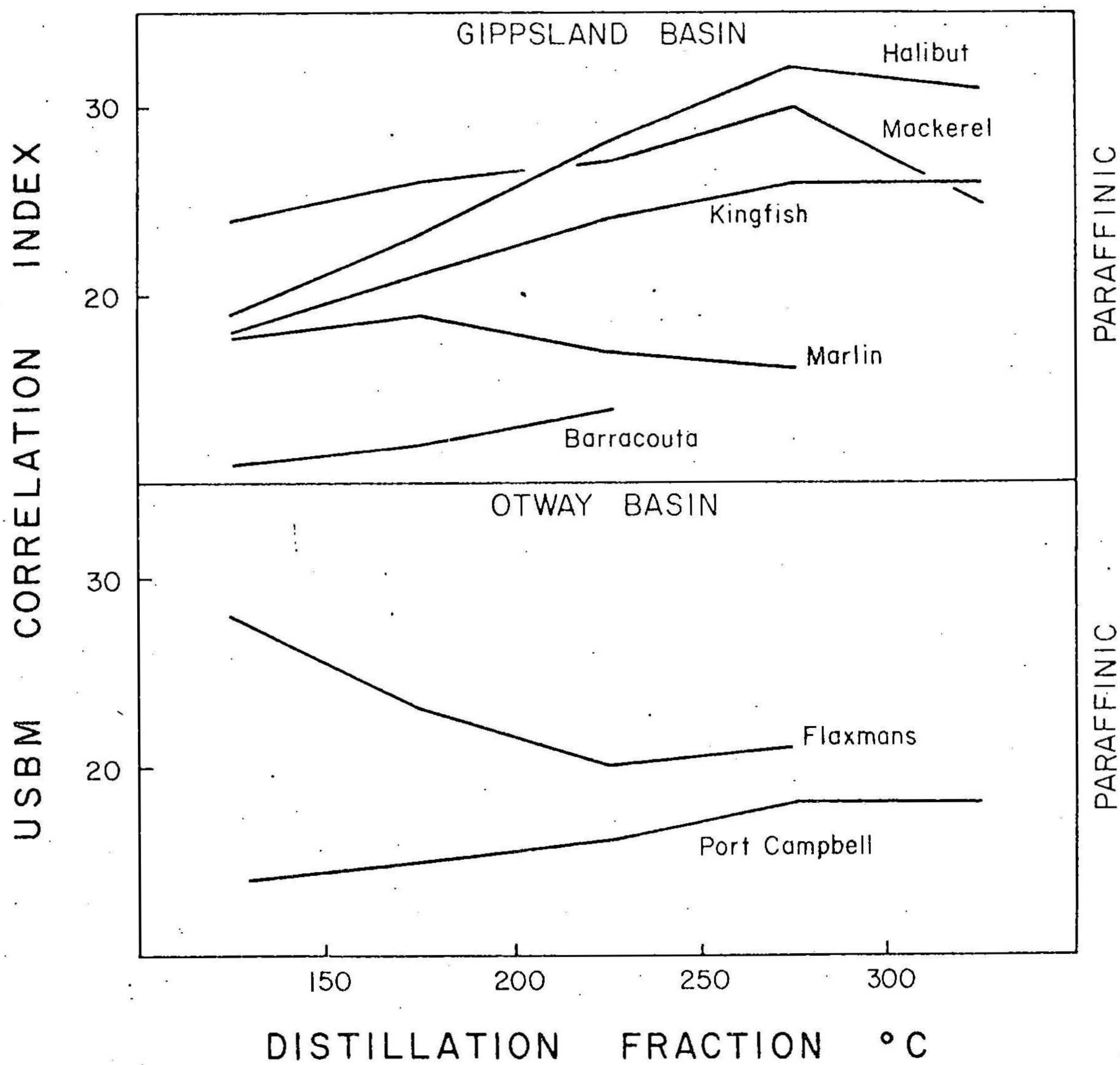
Fig.10. Relationship between pristane to phytane ratio and crude oil composition.

A. Paraffinic and paraffinic-naphthenic oils with a high wax content from non-marine clastic sequences.

B. Paraffinic-naphthenic oils occasionally with a high wax content from near-shore marine to deltaic sequences.

C. Low wax naphthenic oils associated with carbonates and black shales.

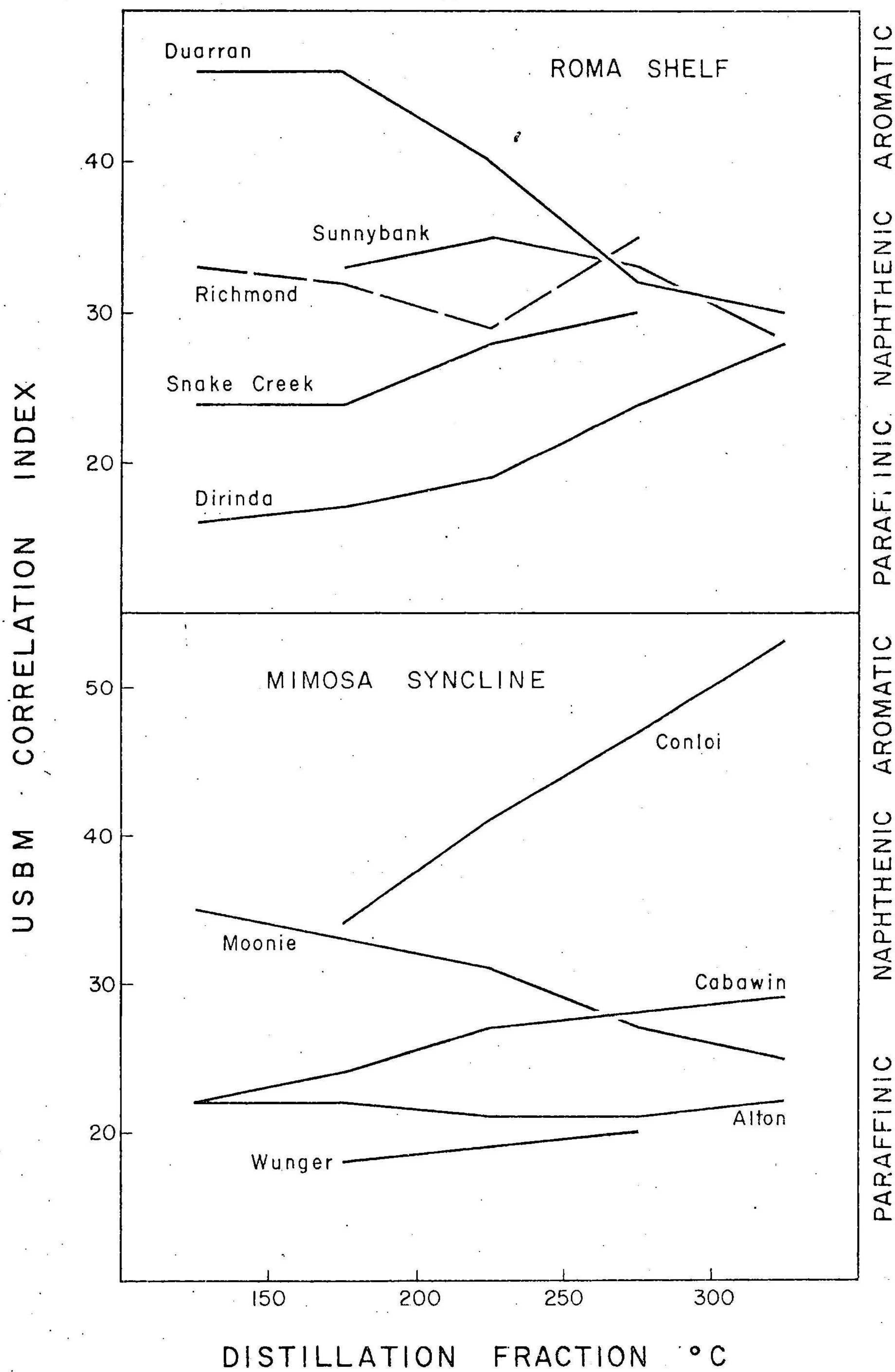
Fig. 1



GIPPSLAND BASIN
Halibut
Mackerel
Kingfish
Marlin
Barracouta
OTWAY BASIN
Flaxmans
Port Campbell
30
20
USBM CORRELATION INDEX
PARAFFINIC
PARAFFINIC
150
200
250
300
DISTILLATION FRACTION °C

XM - 66A

Fig. 2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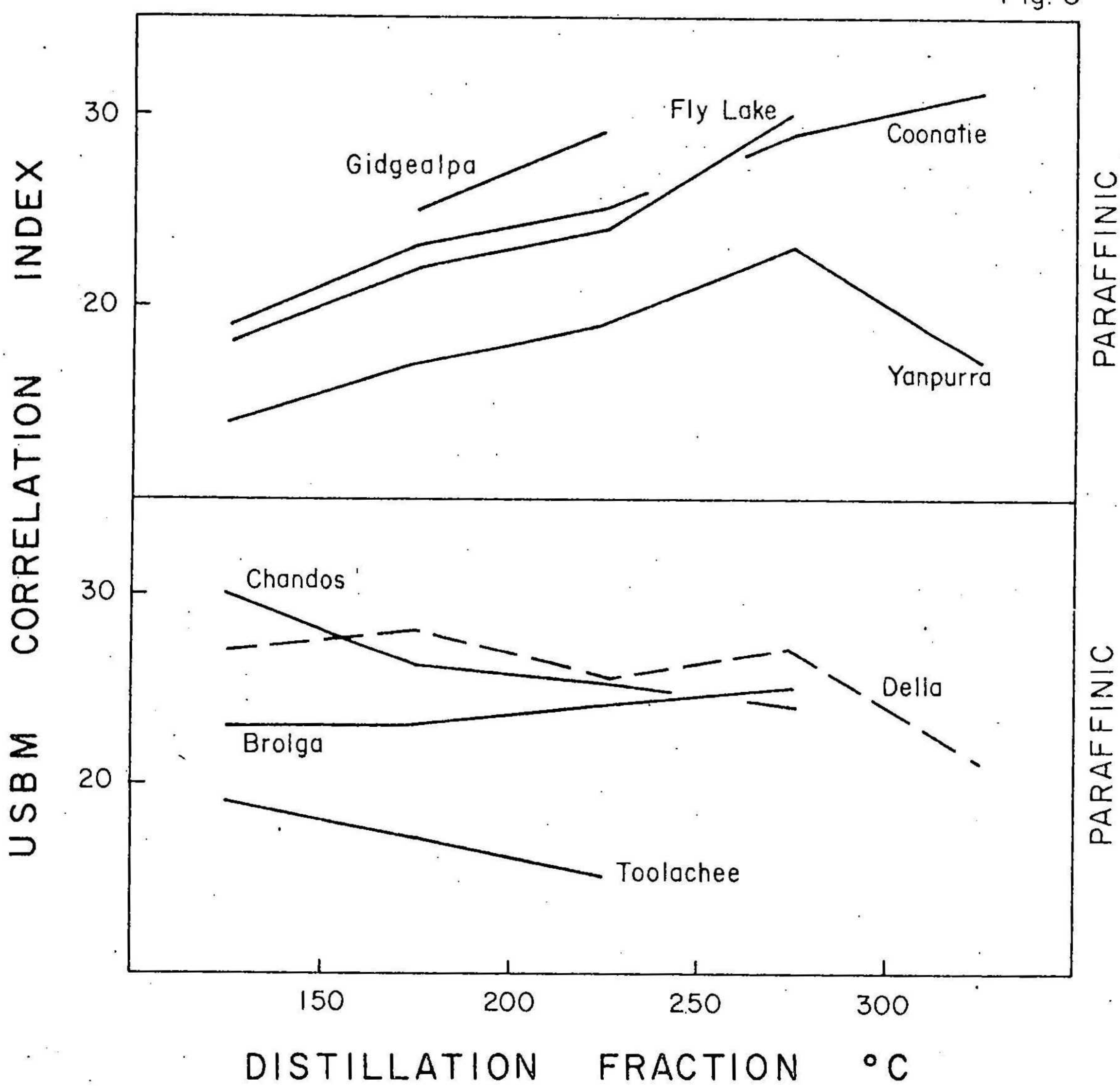
Sunnybank
Richmond
Snake Creek
Dirinda
MIMOSA SYNCLINE
Conloi
Moonie
Cabawin
Alton
Wunger
USBM CORRELATION INDEX
40
30
20
50
40
30
20
150
200
250
300
DISTILLATION FRACTION °C
PARAFFINIC NAPHTHENIC AROMATIC
PARAFFINIC NAPHTHENIC AROMATIC

XM-66B

Fig. 3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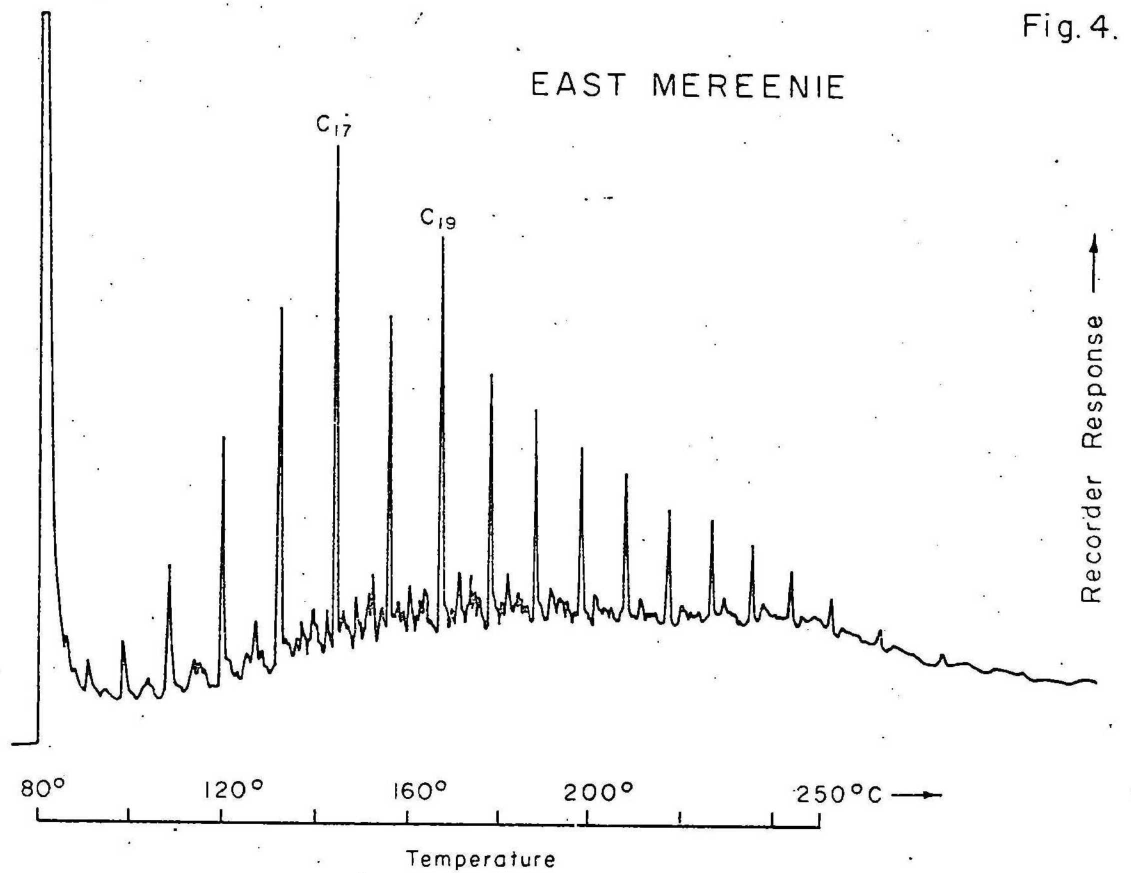
Fly Lake
Coonatie
Yanpurra
PARAFFINIC
30
20
Chandos
Della
Brolga
Toolachee
PARAFFINIC
150
200
250
300
DISTILLATION FRACTION °C

XM-66C

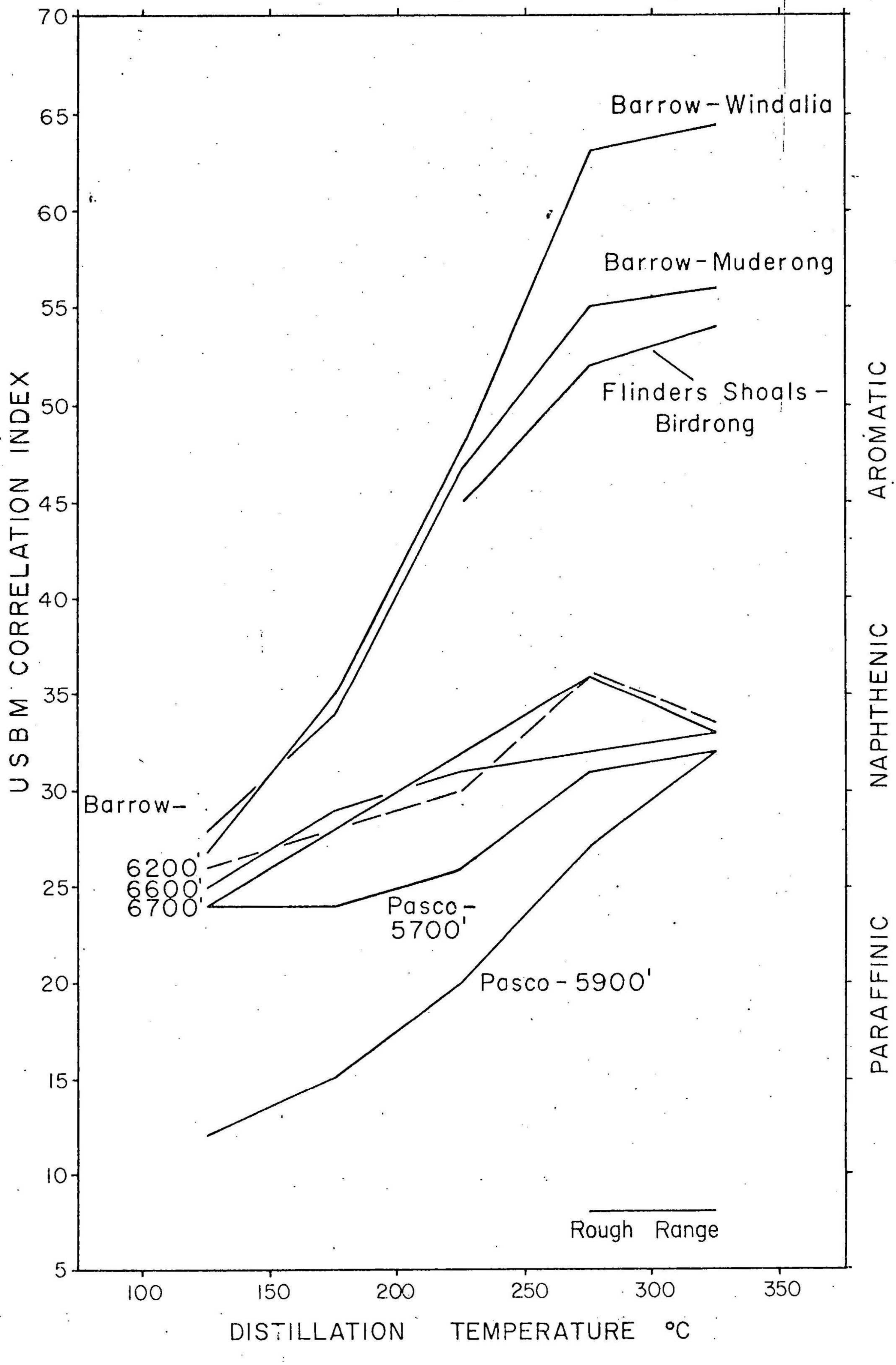
Fig. 4.



X AUS-2-156P

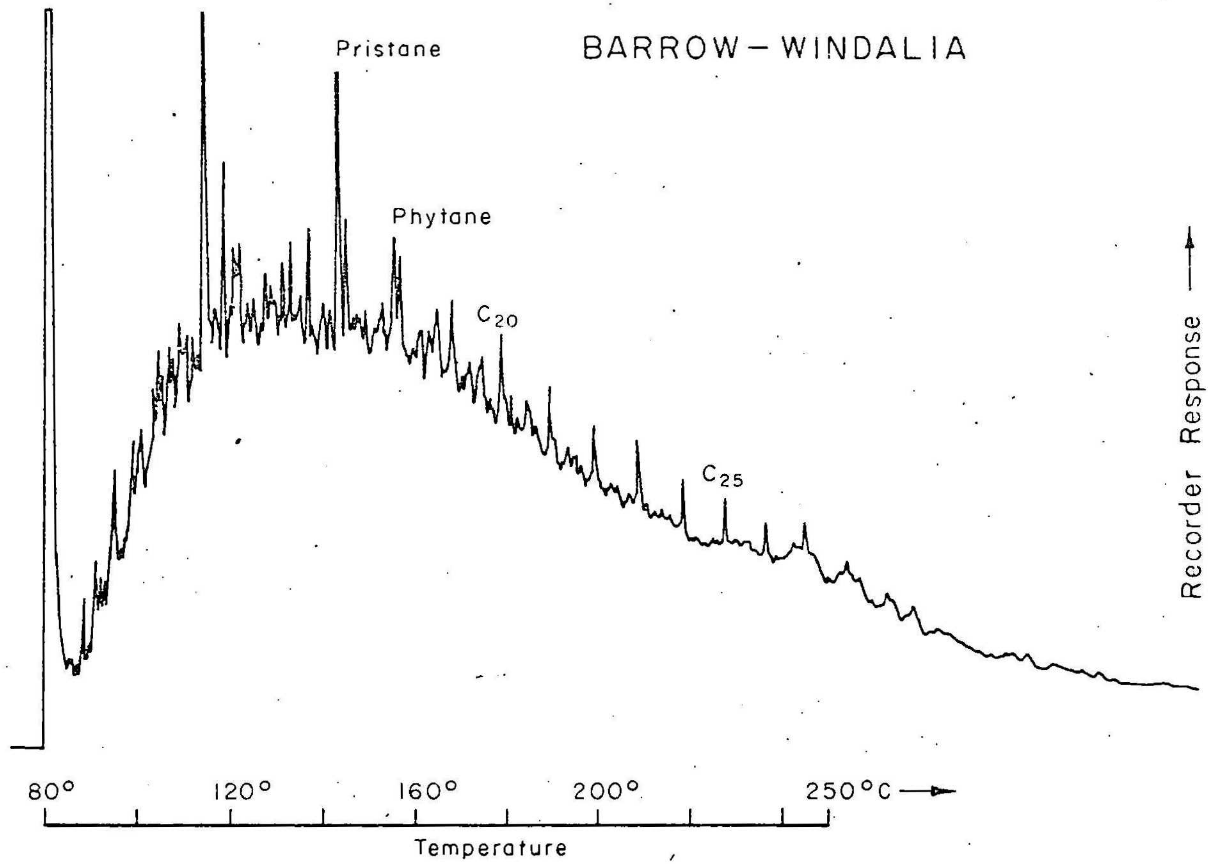
A

B



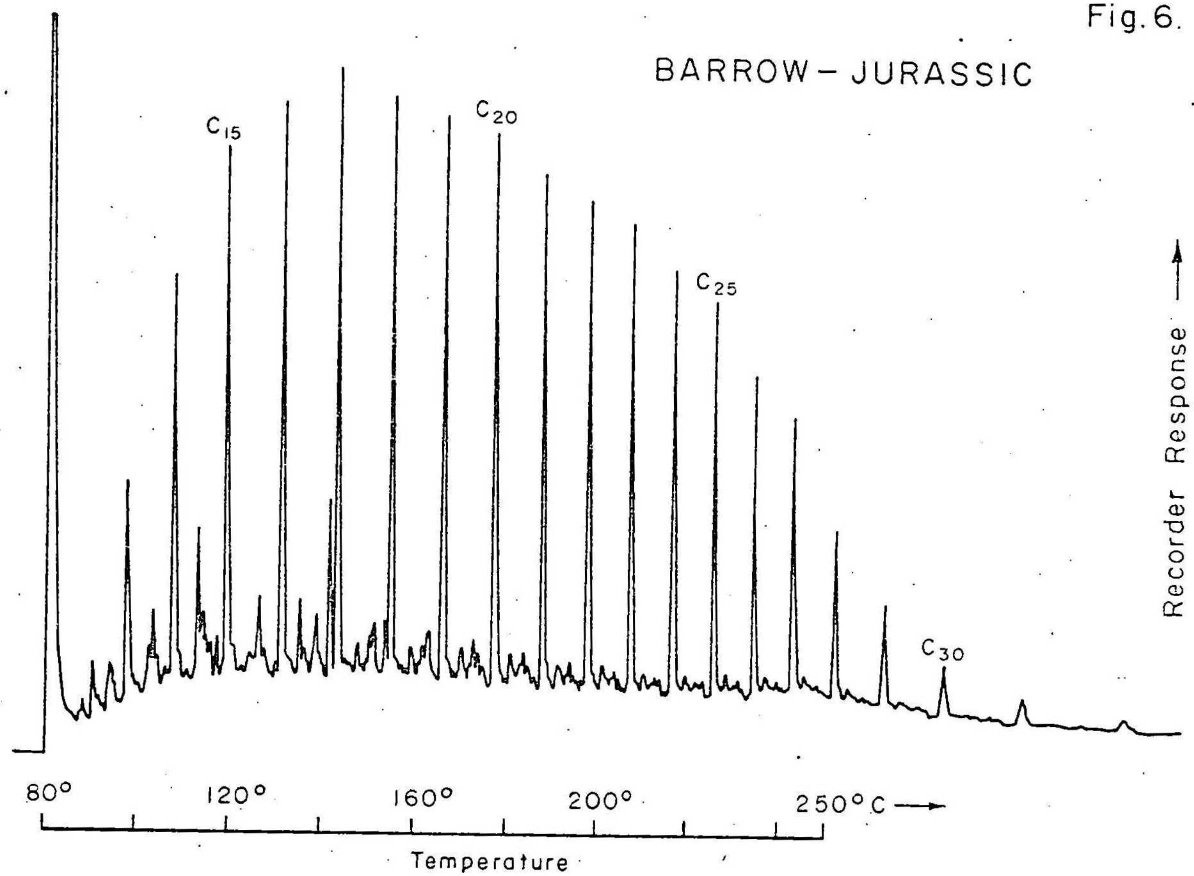
70
65
60
55
50
45
40
35
30
25
20
15
10
5
USBM CORRELATION INDEX
Barrow-Windalia
Barrow-Muderong
Flinders Shoals-
Birdrong
Barrow-
6200'
6600'
6700'
Pasco-
5700'
Pasco-5900'
Rough Range
AROMATIC
NAPHTHENIC
PARAFFINIC
100
150
200
250
300
350
DISTILLATION TEMPERATURE °C

Fig. 6



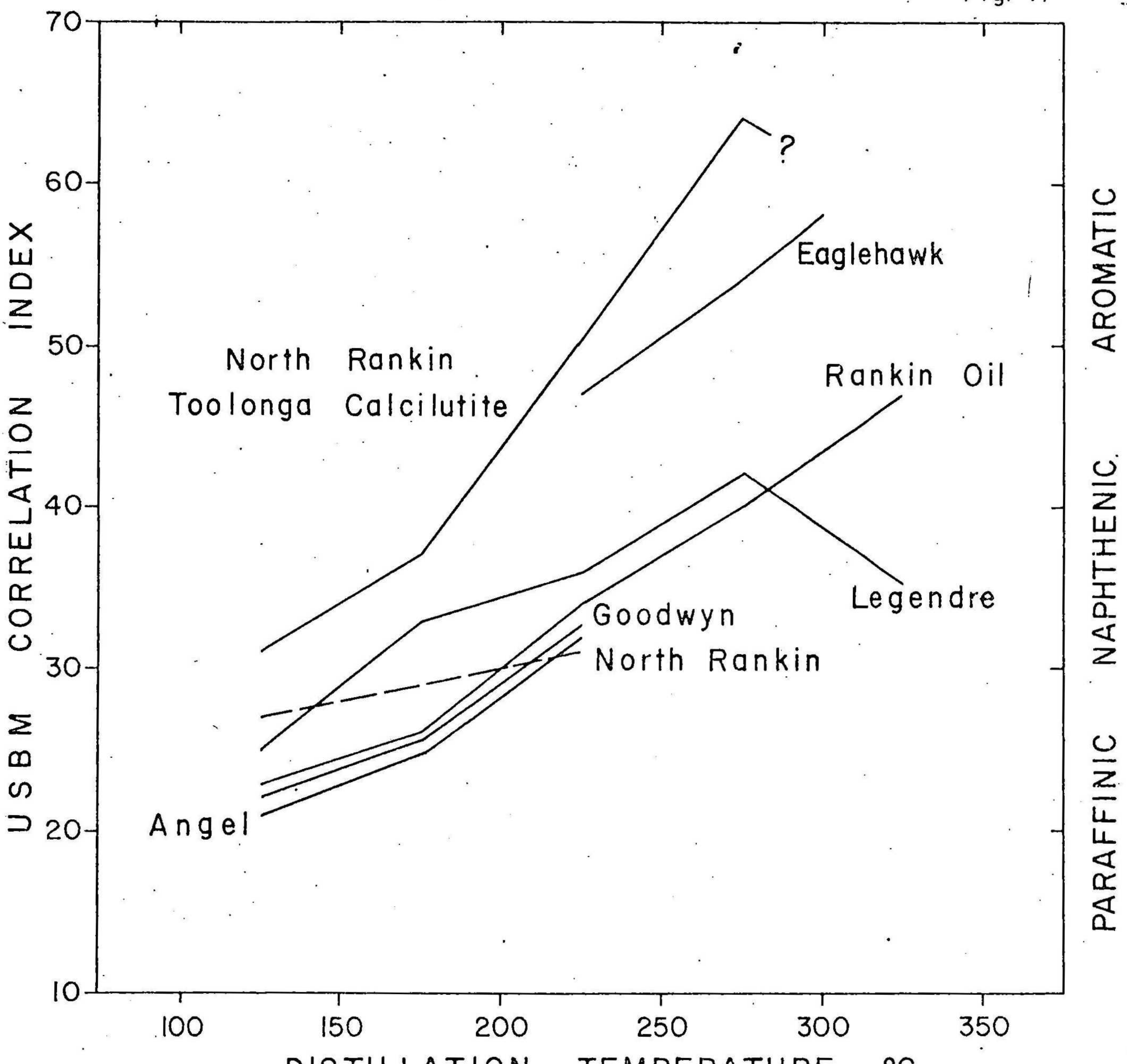
X AUS - 2 - 156 M

Fig. 6.



X AUS - 2 - 156L

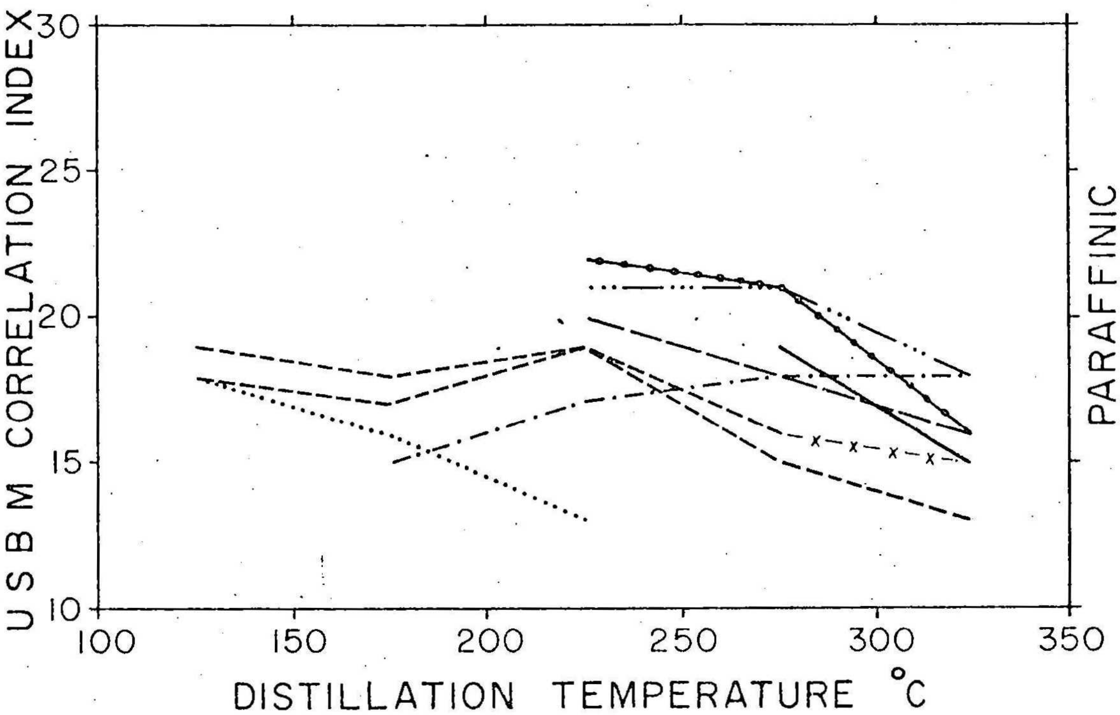
Fig. 7.



70
60
50
40
30
20
10
USBM CORRELATION INDEX
AROMATIC
NAPHTHENIC
PARAFFINIC
?
Eaglehawk
North Rankin
Toolonga Calcilutite
Rankin Oil
Legendre
Goodwyn
North Rankin
Angel
100
150
200
250
300
350
DISTILLATION TEMPERATURE °C

X-M-51

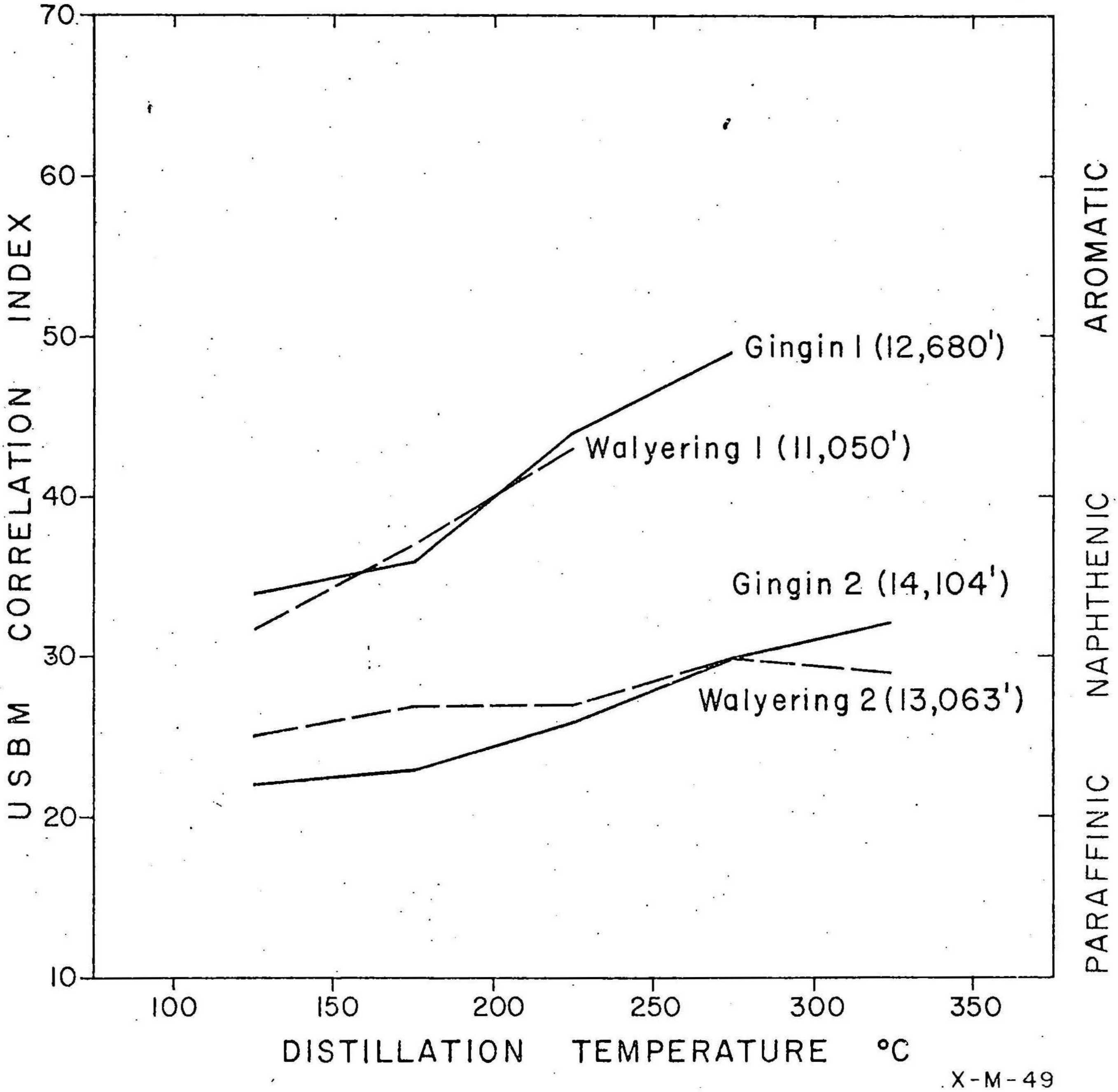
Fig. 8.



	OIL	CONDENSATE
Mondarra	————————	- - - - - - - -
Dongara	— — — — —	....
Yardarino	—x—x—x—x—x	
Erregulla	—··—··—··—	
N Erregulla	••••••••••	
Mt Horner	—·—·—·—·—	

X-M-50

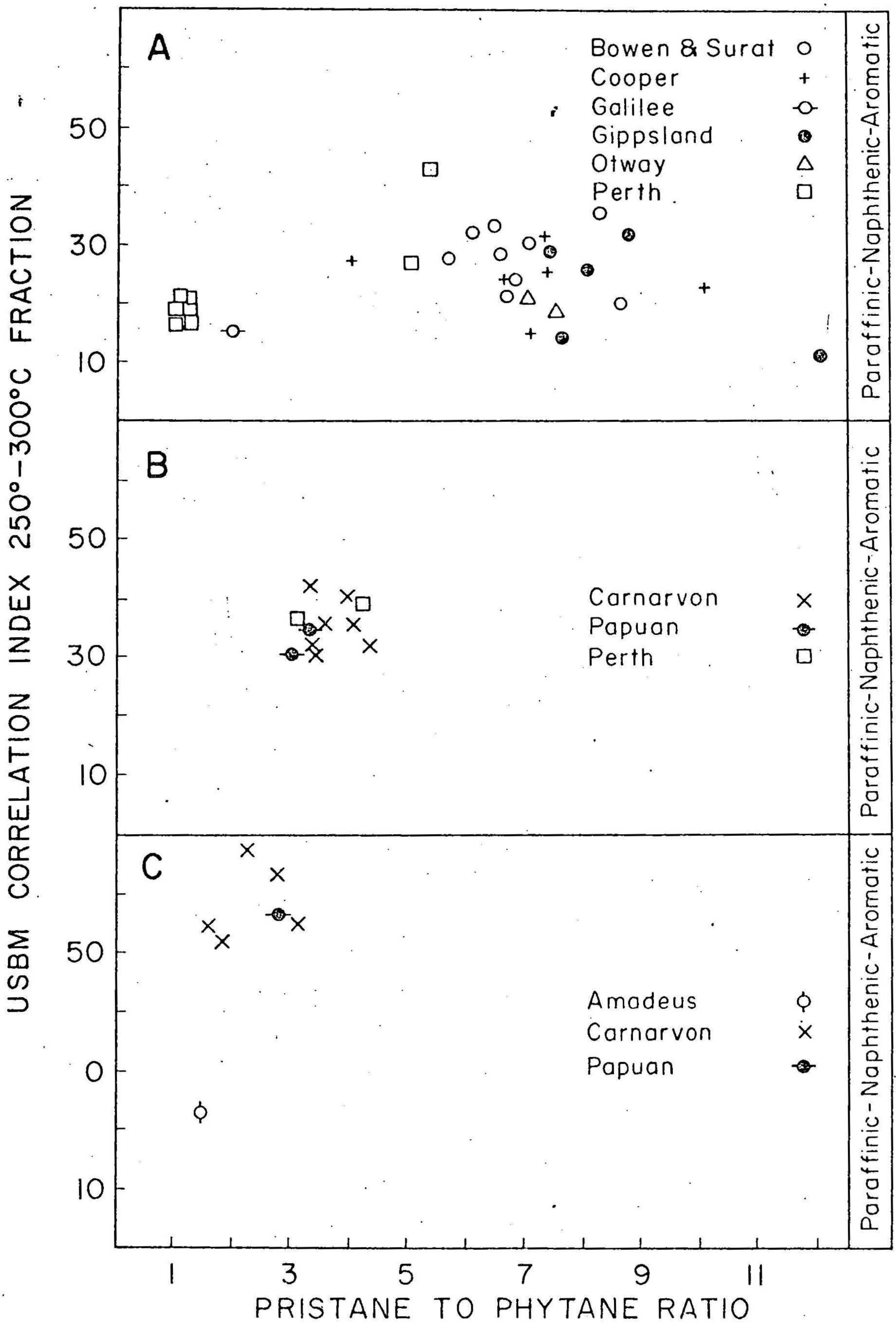
Fig. 9



USBM CORRELATION INDEX
70
60
50
40
30
20
10
100
150
200
250
300
350
DISTILLATION TEMPERATURE °C
AROMATIC
NAPHTHENIC
PARAFFINIC
Gingin I (12,680')
Walyering I (11,050')
Gingin 2 (14,104')
Walyering 2 (13,063')

X-M-49

Fig. 10



A
Bowen & Surat
Cooper
Galilee
Gippsland
Otway
Perth
B
Carnarvon
Papuan
Perth
C
Amadeus
Carnarvon
Papuan
50
30
10
0
1
3
5
7
9
11
PRISTANE TO PHYTANE RATIO
USBM CORRELATION INDEX 250°-300°C FRACTION
Paraffinic-Naphthenic-Aromatic

XM-65A