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## **Genesis and entrapment of oils in multi layered reservoirs of well A-3, Western Offshore Basin**

### **Abstract**

The recent discovery of commercial hydrocarbons in multi layered Tertiary reservoirs in the well A-3 in BH-DCS block; western offshore basin, has elicited an enormous interest in understanding the geochemical characteristics of the oils. These oils are grouped into genetic types using the similarities of various bulk and molecular geochemical parameters. The distribution of the oil types in the basin has been mapped with their probable source kitchens. The compositional features and biomarker fingerprints of the oils reveal the presence of two distinct oil families. Oils from Basal clastics and Oligocene reservoirs constituting Group A have been inferred to have originated from source rocks with predominantly marine algal-bacterial matter along with terrigenous input deposited in oxic conditions. Oils from Miocene reservoirs constitute the other Group (Group B) which has been sourced from terrestrial organic matter deposited in coastal, paralic to deltaic conditions. Oil to source correlation studies indicates that Group B oils are charged from the Panna clastics of E low with minor contribution from Panna sediments of F low, which are the established source kitchens of the area. The occurrence of Tricyclic Terpane biomarkers in older reservoirs suggests the existence of an additional source kitchen apart from the established ones which might be contributing to the accumulations in this area in varying proportions.

### **Introduction**

The deep continental shelf lying west of MH area is emerging as a high prospective zone for hydrocarbon exploration especially from the Oligo-Miocene carbonates. The recent successes in A and B areas have further accelerated the process. The exploratory well A-3 drilled in wedge out area of Mumbai High, flowed oil from the various stratigraphic levels from Basal clastics to Miocene. Geochemical studies on the hydrocarbon fluids and the source rocks were carried out in order to characterize and classify the oils/condensates into genetic oil families, describe the geographic and stratigraphic distributions of the different oil families, identify the generative source pods to establish the petroleum systems in the study area. The inter layer variations in the geochemical characteristics due to differences in source input; depositional setting and effects of maturity were assessed. Oil to oil correlation with oils in the vicinity and oil to source correlation with source sediment extracts from the established source pods in DCS area were carried out to substantiate the source systems operational in this area.

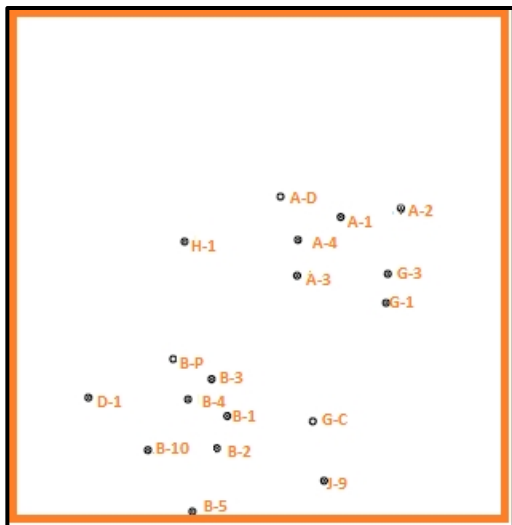


Fig. 1. Location map

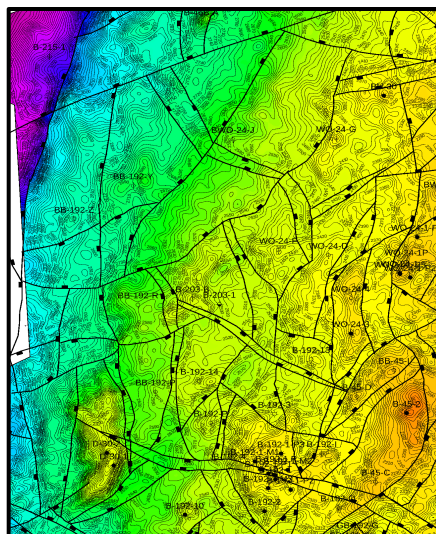


Fig. 2. H5 Depth structure map of the studied area

The area under study is located in the Mumbai High platform adjoining the western Bombay High. The dominant structural trends in this area is the NW-SE, with the major faults are aligned in the ENE-WSW trend, along with strike slip component is also apparent from lateral displacement of some of the structural highs.

The Oligo-Miocene carbonates of this area were deposited in an unstable carbonate platform with cyclic deposition of low and high energy carbonates and several short lived exposures. The vadose and mixed zone diagenesis along with short lived exposures (diastems) have enhanced secondary porosity of these reservoirs. In area A the major hydrocarbon occurrences have been established from Miocene plays along with some levels in Oligocene and Basal clastics.

## Results and discussion

Selected cutting samples from Late Oligocene to Basement interval (2100-2300m) were analysed to evaluate the source characteristics. The well fluids were analysed for the bulk properties, GC fingerprinting, biomarker analysis<sup>1</sup> and stable carbon isotopic studies. The compositional disparities and presence of diagnostic biomarkers suggests the existence of two different oil families. The oils from A-3 can be classified into two groups:

- **Group A oils:** *Oils from Basal clastics, Mukta and Panvel formations (Object I, II and III)*
- **Group B oils** *Oils from LIII and LIV reservoirs of Ratnagiri formation (Object V, VI, VII, VIII and IX)*

### The Geochemical features of these oils are discussed below

#### Group A oils: Oils from object I, II and III

The crude oils reservoired from Basal clastics to Oligocene successions having API gravities within the range (49.8-44.4) are characterized as light oils bordering into condensate regime. The fluids are nonwaxy and paraffinic in nature.

Normal alkane profile of these oils show relatively higher concentration of lower homologues indicate<sup>3</sup> the absence of higher land plant input in source organics or can be due to the effects of migration/fractionation. High value of Pristane/Phytane ratio indicate that these oils are derived from terrestrial organic matter deposited in oxic to sub oxic environment<sup>2</sup> which is corroborated by the cross plot of relative abundance of Pr/nC17 and Ph/nC18<sup>4</sup> (Fig.3)

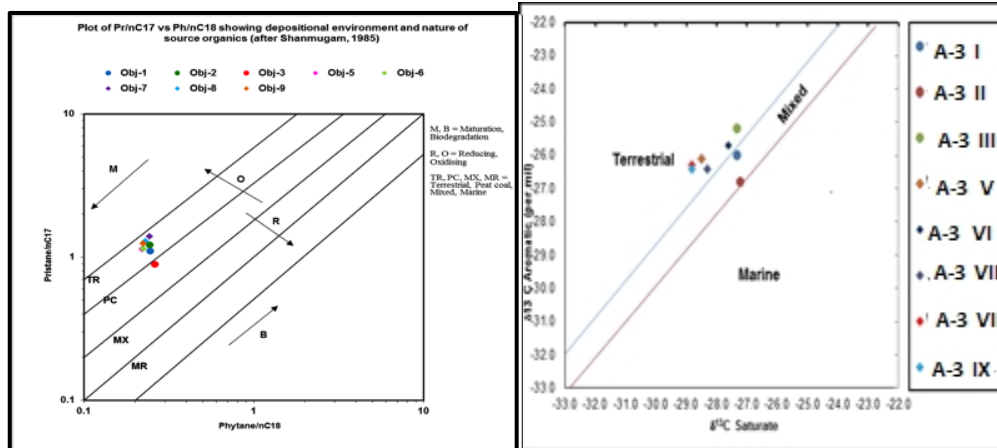


Fig. 4. Sofer plot of  $\delta^{13}\text{C}_{\text{sat}}$  Vs  $\delta^{13}\text{C}_{\text{arom}}$

Biomarker finger prints show the conspicuous presence of Tricyclic terpanes (Fig. 6) along with the ubiquitous pentacyclic Terpanes. Tricyclic terpanes especially the higher homologues is usually found in crude oils from saline lacustrine to marine sources<sup>6, 7</sup>.

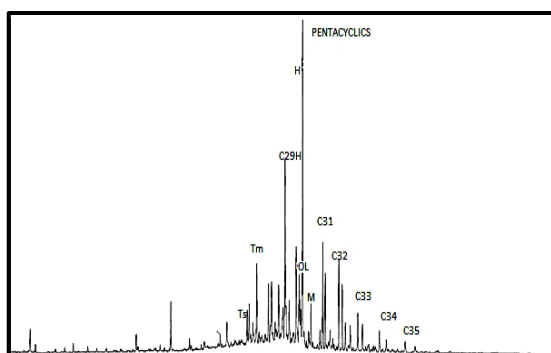


Fig. 5. Mass chromatogram ( $m/z191$ ) of Group B

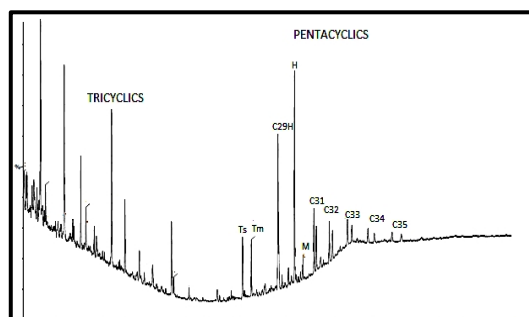


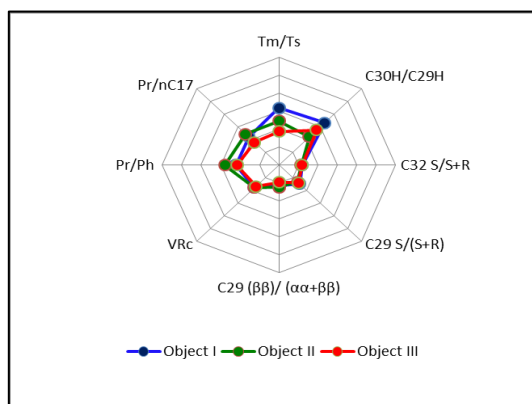
Fig. 6. Mass chromatogram ( $m/z191$ ) of Group A

The biomarkers 28,30- Bisorhopane and Methyl steranes which are rampant in group B oils are absent in group A oils. While Group A oils show similarity in compositional parameters, GC and Biomarker fingerprints, there is a subtle difference among them which is brought out in the kinks in the star diagram (Figures 7 & 8).

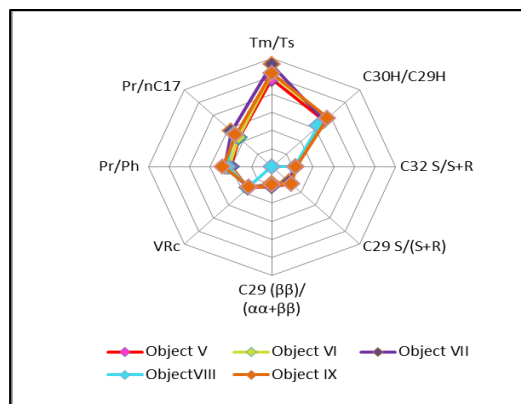
The oil from Basal clastics (object I) shows the presence of Oleanane and Bacadinane which is absent in the Oligocene oils (object II and III).

This shows that though all the three oils share a common source input, object I oil has some remnants of land derived organic matter with higher plant input. The analytical data is subjected to multivariate analysis where different geochemical ratios were plotted as in the star diagram placed in Fig 7 & 8. The diagram brings out the subtle variations in nature of oils.

Stable carbon isotopic distribution of saturate and aromatic fractions of studied oils suggests that while the oils of object II and III are from mixed source organics, the rest of the oils have originated from predominantly terrestrial source.



**Fig. 7. Star diagram representing the correlatability of Group A oils**



**Fig. 8. Star diagram representing the correlatability of Group B oils**

### Group B oils: Oils from object V, VI, VII, VIII and IX

API gravities of the Miocene oils constituting Group B (36.9-35.3) indicate that the oils are light and waxy (Wax content 13.4-17.6 %) in nature. Normal alkane envelope extends up to C35+. Indicating the well preserved nature of the oils. The presence of higher normal alkanes is indicative of terrigenous lipids and waxes. High value of Pristane/Phytane ratio for these oils and cross plot of relative abundance of Pr/nC17 and Ph/nC18 indicates that these oils have originated from terrestrial organic matter deposited in coastal, paralic to deltaic conditions in a relatively oxic environment.

The dominance of C30 Hopanes over C29 Hopanes, good abundance of C31 to C35 hopanes, along with the presence of Oleanane and Biscadenane in the m/z 191 and 217 fragmentograms suggests terrestrial origin of these oils. Tricyclic terpanes are totally absent from these oils, which makes them distinct from Group A oils. There is also the presence of 28,30 Bishnorhopane (BNH) and C-30 Methyl Steranes albeit in minor proportions which are absent in Group A oils. Polar plots of various molecular level parameters (Fig. 8) indicate that the oils reservoired in Miocene are similar and correlatable with each other.

The sofer plot between stable carbon isotopic composition of saturate and aromatic fractions of studied oils suggest that the oils are similar and have originated from a predominantly terrestrial source.

### Maturity of oils

The various Biomarker maturity indicators suggest that the oils are generated at peak oil window maturity (Fig. 9). This is further supported by the calculated Vitrinite Reflectance (%VRc >0.6%) values from MPI from aromatic hydrocarbons for studied oil. Both the oil families are iso mature suggesting that these oils share similar thermal histories.

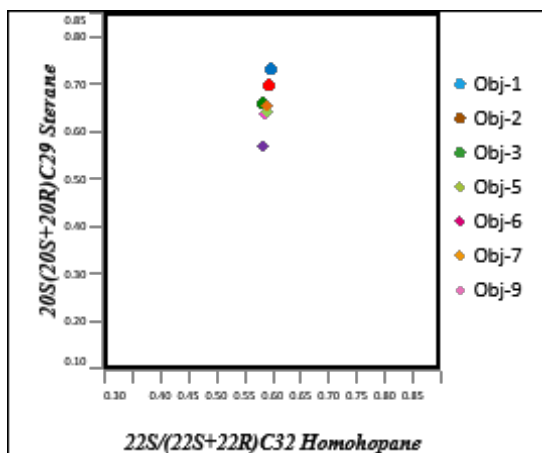


Fig.9. Cross plot between C32 homohopane and C29 sterane ratios

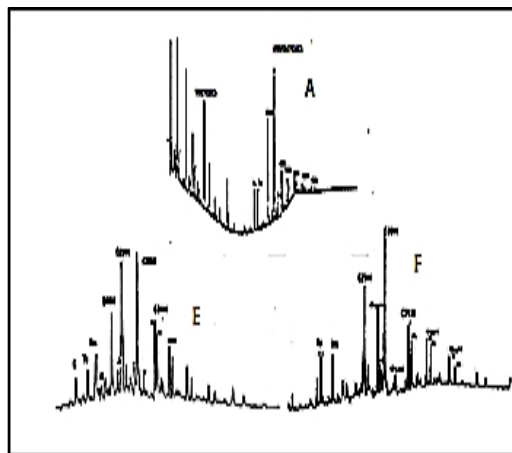


Fig 10. Oil to source correlation envisaged with the sediment extracts from E and F lows

### Oil to oil correlation studies

Commercial oil pools have been found in multi stacked reservoirs in DCS area of Bombay Offshore. Oils are encountered in Oligocene carbonates in E-18, Miocene carbonates in E1 structure, Early Eocene- Paleocene sediments in F structure and Oligocene and Eocene successions in B structure and in Panvel & Bombay formation of A structure etc.

Oils of the present well A-3 have been correlated with the oils of well A-1 and B structures in the vicinity. The oils of the area, range from light oils to condensates (API 50.1-32.7) and characterized by pour point in the range of <12 to 36°C indicating their paraffinic nature. Pristane/Phytane ratio, and the cross plot of relative abundance of Pr/nC17 and Ph/nC18 for the oils of wells suggests that oils have been generated from terrestrial organic matter deposited in near shore environments.

Oleanane, a biomarker indicative of angiosperms of Late Cretaceous and younger ages and Bisdalanes is present in all the oils except oils of objects-II and III of the present well. Bisdalanes (BNH) in m/z 191 fragmentogram is absent in the Group A oils from A-3 and also absent in oils from A and B, area.

Thus, the oils constituting Group A are largely correlatable with oils from A-1 and B wells.

### Oil to Source Correlation studies

The siliciclastic and carbonate rocks with thin beds of coal and carbonaceous shales of Paleocene–Eocene age deposited in the southern lows are the principal source rocks established in this area. Deep seated faults passing through the kitchen to the up dip reservoirs acted as conduits. The source systems<sup>5</sup> constitute two major depressions viz., the lows near E and the F area. Rock Eval studies conducted on cutting samples from Late Oligocene to Basement (depth 2100-2300m) from the present well infers poor source potentials. Since the well flowed oil/gas at various levels, in situ generation of oil/gas is not envisaged. The oils encountered in the studied well are correlated with the sediment extracts from E and F depressions. Source rock extract (EOM) of Paleocene to Lower Eocene sequence of well E indicated close similarity with the Miocene oils as evident from presence of Bisdalanes and Bisdalanes. These oils also have a minor presence of C30 steranes which marks its origin from F low. Thus, Miocene oils (Group B) might have originated from the Paleocene to Early Eocene sediments of both E and F lows.

The biomarker Tricyclic Terpanes which has a significant presence in Group A oils is not encountered in the sediment extracts from the established source pods studied in DCS area. This implies that, there could be a source pod albeit small, apart from the proven ones which has charged the accumulations in the older reservoirs of the well.

## Conclusions

The oils from the studied well can be traced to have developed into two oil families. On the basis of biomarkers it can be inferred that there exist at least two different sources for these oils and both the sources are contributing to the oil accumulations in varying proportions.

## Way Forward

Detailed geochemical analysis using advanced techniques will be carried out to characterise and establish the presence of Tricyclic terpanes in oils of DCS area. This will enable in understanding source kitchens and the Petroleum systems operating in this Region.

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