



# Biomarkers as an effective tool for predicting the source kitchens, Tapti Daman block, Mumbai Offshore, India

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## Abstract

Tapti Daman block is located in north-east of Mumbai High. This block is bound by Deccan trap outcrops in the eastern and north western boundaries, Panna-Bassein block towards south and Diu block in west. The main reservoirs in the block are Mahuva (Early Oligocene) and Daman (Late Oligocene) formations.

The oils were derived from terrestrial organic matter deposited in sub-oxic condition. Therefore, oils of this block have similar triterpane (m/z 191) and sterane (m/z 217) fingerprints. Yet, there are distinct signatures due to the thriving of different living organisms in different redox potential, Bisnorhopane, 4-Methyl C30 Sterane, Biscadinaneetc, differentiating their source organic facies. This has been utilised as a tool for oil to oil correlation and predicting the source kitchens.

The specific biomarker signatures along with the H5-H4 time thickness map of Tapti Daman block predicts the source kitchens as Daman low (F, B, A) filling the reservoirs D, C, E, G, T & H. PurnaGraben filling the reservoirs I and J, Navsari low filling the reservoirs I and north Tapti wells. Diu low in situ generation and filling.

## Introduction

Tapti-Daman block covers an area of about 27,000 sq. km. in the north eastern part of Mumbai offshore basin. It is bounded by Deccan trap outcrops in the east and north, Diu fault in the south and Diu arch in the west. It comprises Saurashtra Homocline, Eastern Homocline and number of ENE-WSW trending lows viz. Daman low, Purna low and Navsari low. Entrapment is generally structural and combination type in clastic reservoirs of Daman (Late Oligocene) and Mahuva (Early Oligocene) formations (Fig.1&2).

The Early Eocene-Paleocene (Panna formation) is the major source rock observed in this area. Out of the 38 wells studied in the area, good thickness of effective source rocks are found in wells ranges from streaks in N-2A, NN-1(20m), L-4 (50m), U-2(95m), NM-2 (160m), M-1 (200m) to about 500m in K-1.

The wells in this block are terminated at Oligocene sediments except in the wells on flanges of the lows, where the Panna Formation had been penetrated. SOBMs mud system was used in the recently drilled wells in the lows. Therefore, no conclusive new detailed source rock study and



Fig.1: Location Map of Mumbai Offshore



Fig.2: Tectonic Map of Mumbai Offshore

study of extracted organic matter from the sediments could be done.

## Objective of The Study

The main objectives of this work are

1. To identify the source kitchen in the absence of source rock and source to oil correlation studies.
2. To decipher the heterogeneous source facies input for the oils from wells of the same structure as revealed by the biomarker data of about 65 oils from this Tapti-Daman block.

The present study was undertaken to decipher this heterogeneity observed and source kitchens with all the available data and maps like the time thickness map of H4-H5 marker (H4, Early Eocene H5, Cretaceous).

## Discussion

Biomarkers are complex organic compounds composed of carbon, hydrogen and other elements such as oxygen, nitrogen and sulfur, which are found in crude oils, bitumens and source rock. These biological markers are from precursor molecules in living organisms and have retained their carbon skeleton during and after incorporation into the sediments. They had survived diagenesis and much of catagenesis and are available in petroleum. Biomarker compounds are typically analyzed using gas chromatography and mass spectrometry.

Hopanes (C<sub>27</sub>-C<sub>35</sub>) are pentacyclotriterpanes that originate from bacteriohopanoids in bacterial (decomposition of terrestrial organic matter by aerobic/anaerobic microbes) membranes and generally dominate as triterpanes in petroleum. Various isomers such as diahopanes, neohopanes, moretananes are also present. Among them C<sub>30</sub> hopane is normally the most abundant in the chromatogram m/z 191.

Steranes originate from sterols which are from eukaryotic organisms. Steranes in the range C<sub>26</sub>-C<sub>30</sub> are detected in petroleum.

### 1. Nature of input source organic matter for the oils

The oils are derived from terrestrial organic matter as

1. Saturate hydrocarbons are >56% in all the studied crude oils.
2. The Shanmugam plot<sup>3</sup>, cross plot of Phytane/nC<sub>18</sub> vs Pristane/nC<sub>17</sub> (Fig.3)
3. Sofer Plot<sup>4</sup>, the cross plot of isotopic values of C<sup>13</sup> saturate vs C<sup>13</sup> aromatic fractions of the crude oils (Fig.4).
4. Oleananetriterpane (a representative of terrestrial organic matter of upper Cretaceous or younger age) has been found in biomarker finger print in all the oils indicating the source rocks are from upper Cretaceous or younger sediments.

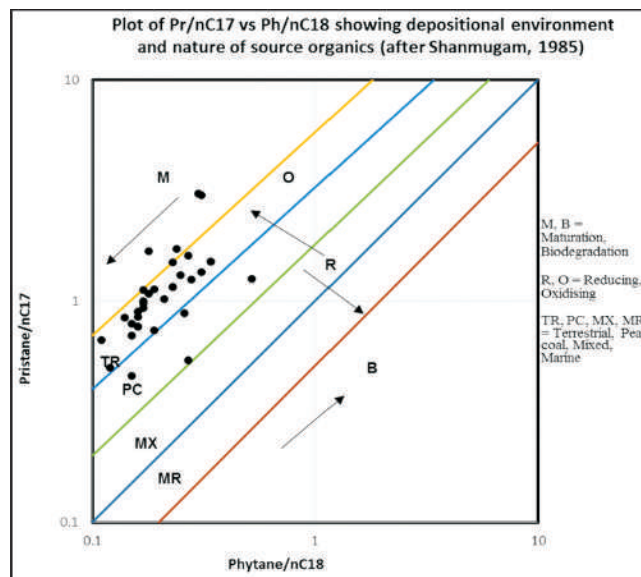


Fig.3: Plot of Phytane/nC<sub>18</sub> vs Pristane/nC<sub>17</sub>

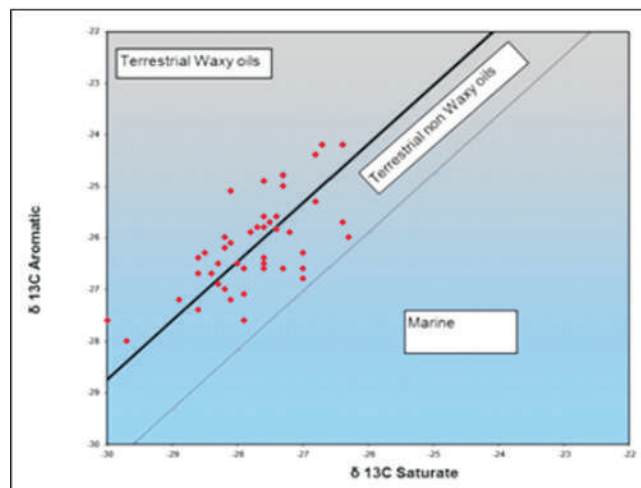


Fig.4: Plot of δ<sup>13</sup>C Sat Vs δ<sup>13</sup>C Aromatic

## 2. Maturation of oils

Figures 3 & 4 indicate there is wide variation in the maturity of the crude oils/condensates of this block.

Mango (1990) found that the isomerization of the n-heptane to mono & branched iso alkanes plus five and six ring cycloalkanes occurs before expulsion of the oil from source rock and does not change after expulsion except for biodegradation. The temperature at which oil was generated expelled was calculated using ratio of C<sub>7</sub> isomers (Mango Parameters<sup>1</sup>) from light hydrocarbon gas chromatographic analysis. The study indicates that most of the oils were generated at late catagenetic stage (Fig.5), which is also corroborated by the plot of iC<sub>4</sub>/nC<sub>4</sub> vs C<sub>2</sub>/C<sub>3</sub>+ from gas compositional analysis data, indicating that most of the gases are wet in nature (Fig.6). This also explains the API of most of crude oil/condensates being >45°.

The biomarker maturity parameters of some of the oils/condensates do not match with the light hydrocarbon

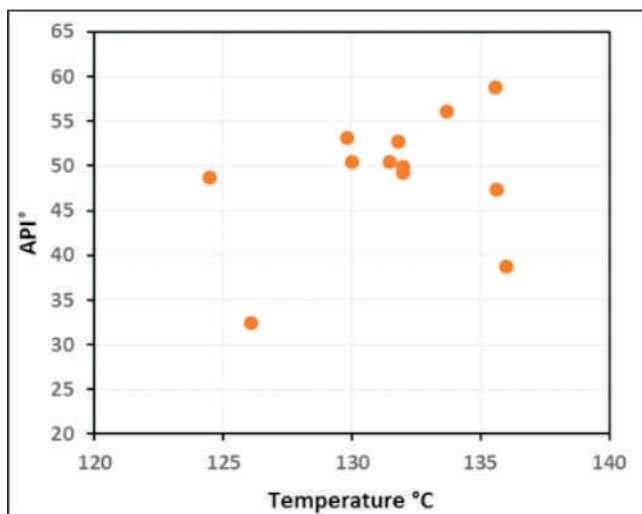


Fig.5: Plot of temperature vs API

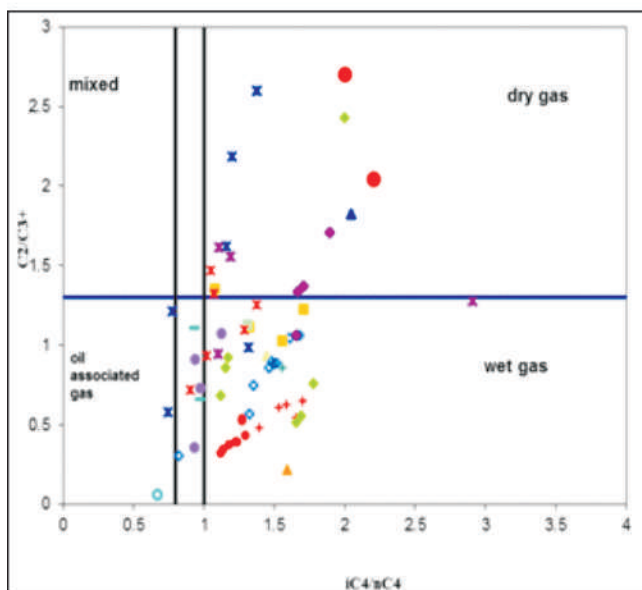


Fig.6: Plot of  $iC_4/nC_4$  Vs  $C_2/C_{3+}$

indicating mixing of light & heavy hydrocarbon components of differing thermal maturity.

### 3 Environment of deposition

Pristane /Phytane ratio of the crude oils ranges from 3 to 12 based on the redox potential at the time of deposition of organic matter.

The hopane & sterane distribution of terrestrial oils are given in Fig.7. The variation in the redox potential (given above) gave rise to the survival of different microorganisms which in turn gave rise to distinct biomarker signatures in the oils of this Tapti Daman block in addition to the normally detected in the terrestrial oils, (Fig.7).

It is assumed that the oils near the source kitchen will have concentration of the distinct biomarker signatures more than the oils away from the source kitchen. The profiles trace the source kitchens of the oils of this block as given in figure 8.

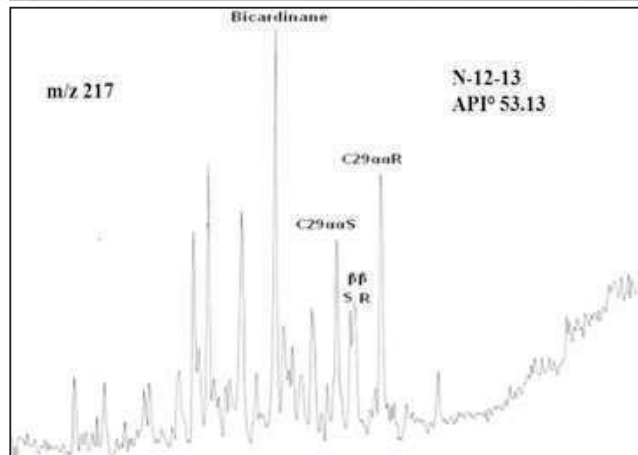
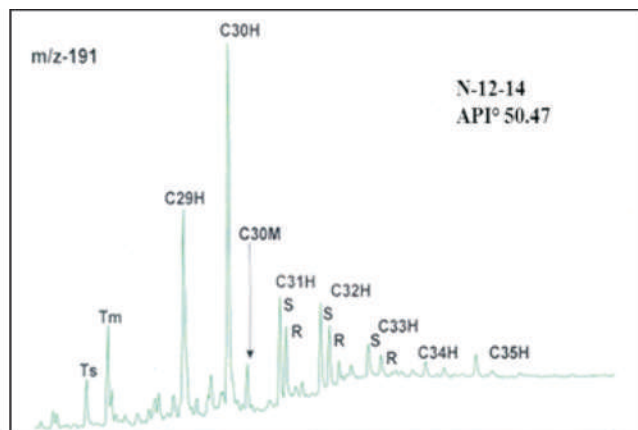


Fig.7: Hopane (m/z 191) & sterane (m/z 217) distribution of any terrestrial oils

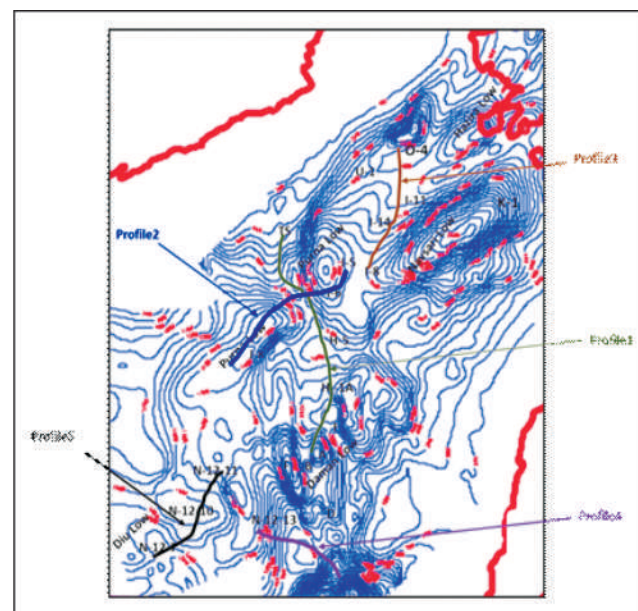
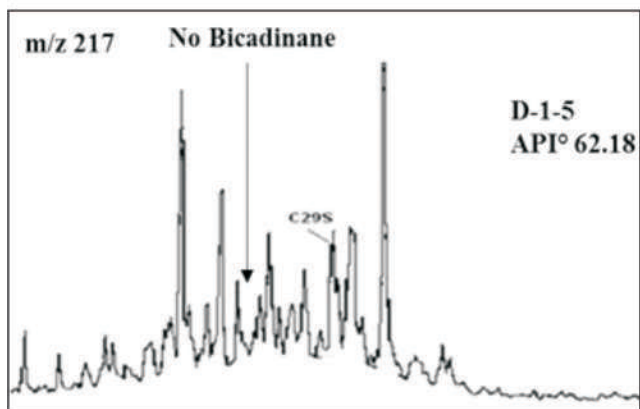
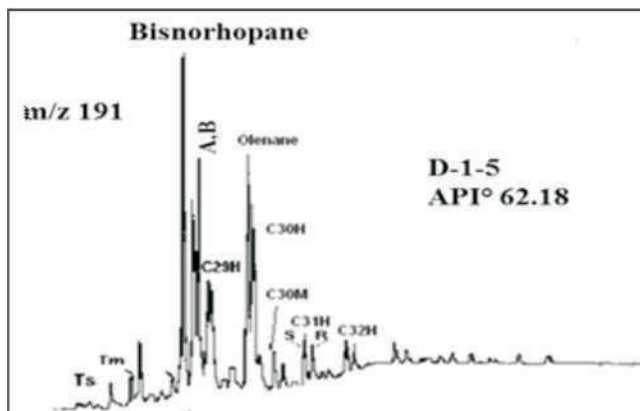
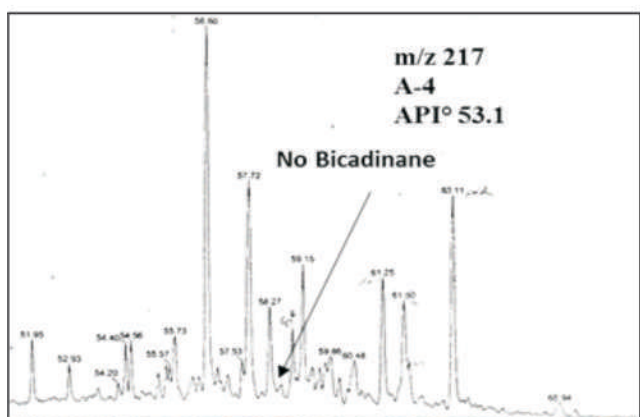
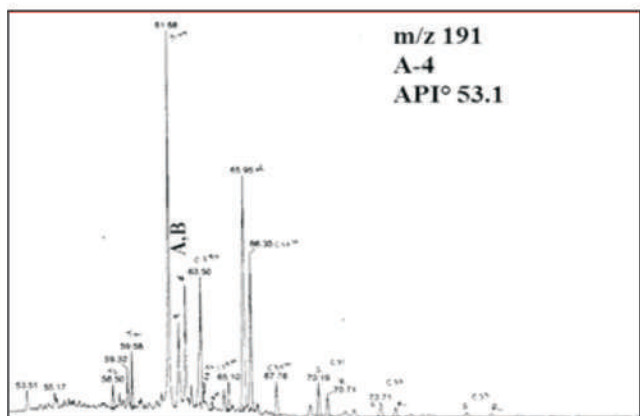


Fig.8: Time thickness map of H4-H5 marker (H4, Early Eocene H5, Cretaceous) showing, profile 1 to profile 5

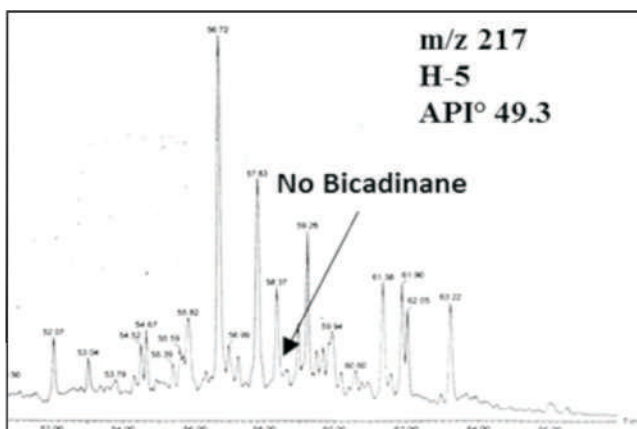
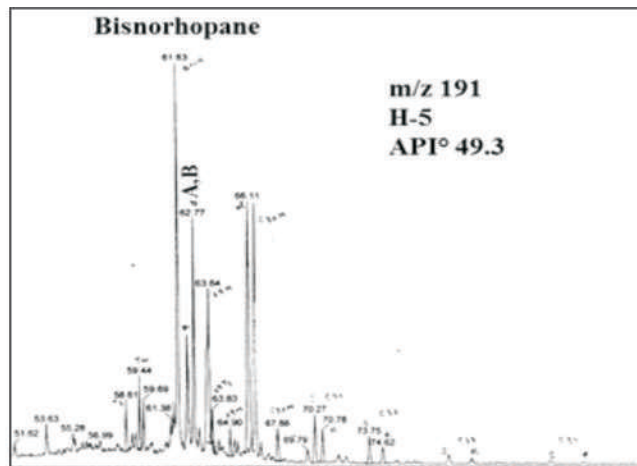
The oils from the wells, D-1-5, A-4, G-1, H-5, H-1A, H-6, T-1 on the profile1 had been generated from the Daman low having the distinct signature of Bisnorhopane(m/z 191), doublet A,B and absence of Bicadinane (m/z 217) as illustrated in Fig.9a,9b,9c.



**Fig.9a:** Hopane (m/z 191) & sterane (m/z 217) distribution of oil from D-1-5 on profile 1



**Fig.9b:** Hopane (m/z 191) & sterane (m/z 217) distribution of oil from A-4 on profile 1



**Fig.9c:** Hopane (m/z 191) & sterane (m/z 217) distribution of oil from H-5 on profile 1

Oils from the wells, J-2, J-14, J-8, I-5, I-6 on the profile 2 had been generated from the Purna low having the distinct signature of Bisnorhopane, doublet A,B & UI (unidentified) in m/z 191 chromatogram and presence of Bicadinane (m/z 217) (Fig.10a & 10b).

On Profile 3 Extracted organic matter from Early Eocene sediments of U-2, oils from O-4, I-14, I-8 have the terrestrial signatures with no other distinct signatures as depicted in Fig.11a & 11b.

The biomarker signature of oils wells from I-14 & I-8 are different from that of I-5 & I6 as the wells I14 & I8 are on flanges of Navsari low, whereas the I-5 & I6 are on flanges of Purna low.

Oils from wells N-12-13, N-12-14, N-170-2 on Profile 4 have only the terrestrial signatures with no distinct signatures as depicted in Fig.7, generated from Central Graben.

Oils from the wells, N-12-7, N-12-9, N-12-10 & N-12-11 on the profile5 had been generated from the Diu low having the distinct signature of C29>C30 hopanes & C35>C34 in m/z 191 chromatogram indicating calcareous source rock and absence of Bicadinane (m/z 217) (Fig.12).

The heterogeneity in biomarker signature of oils wells

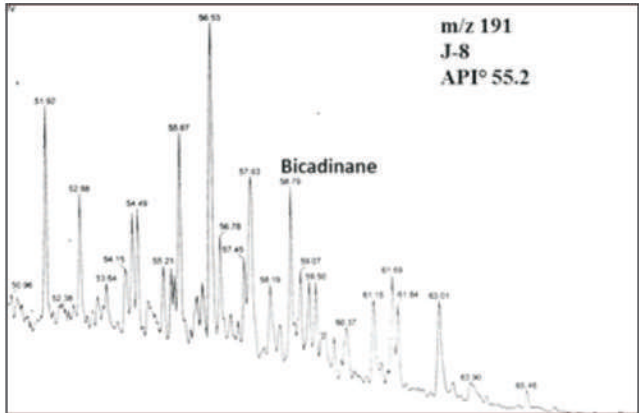
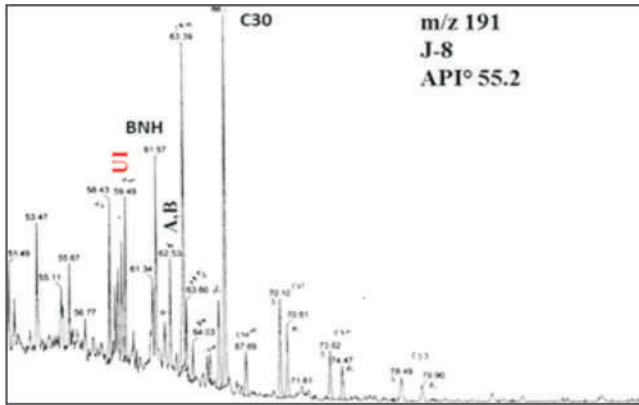


Fig.10a: Hopane (m/z 191) & sterane (m/z 217) distribution of oil from J-8 on profile 2

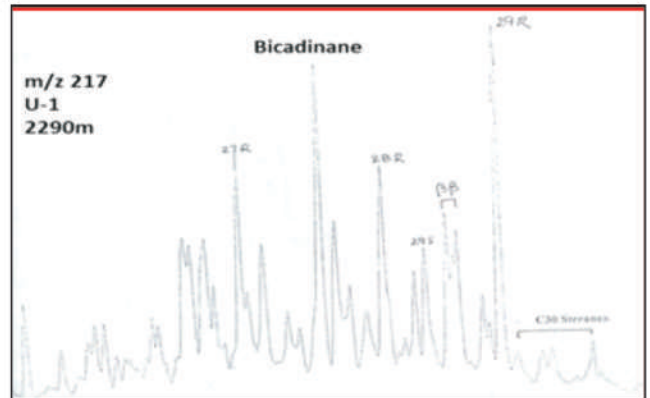
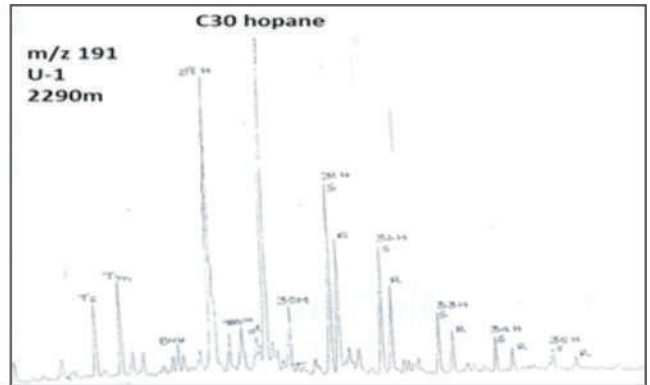


Fig.11a: Hopane (m/z 191) & sterane (m/z 217) distribution of extracted organic matter from sediment sample (2290-2340m) on profile 3

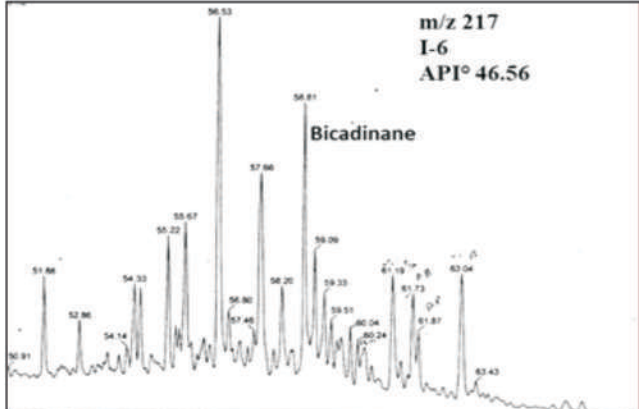
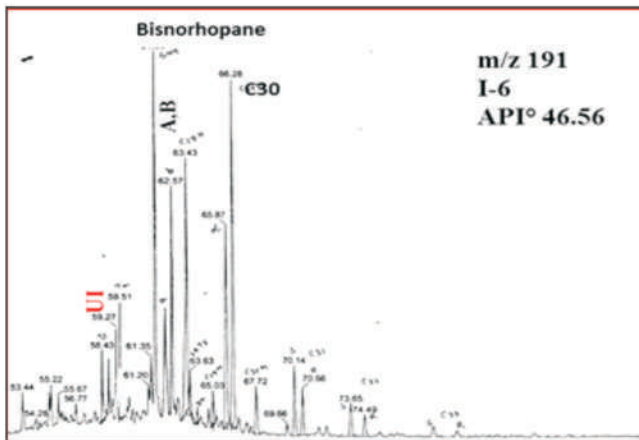
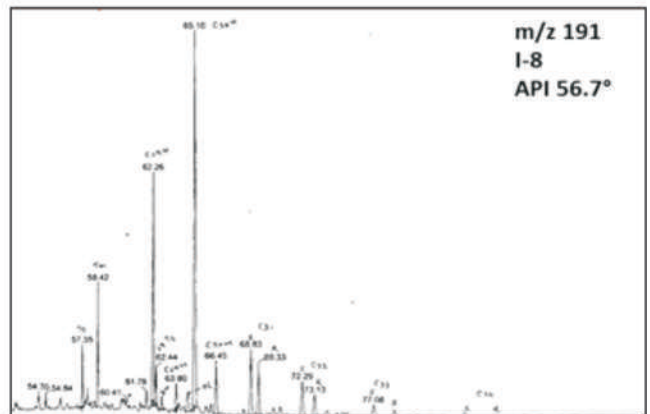
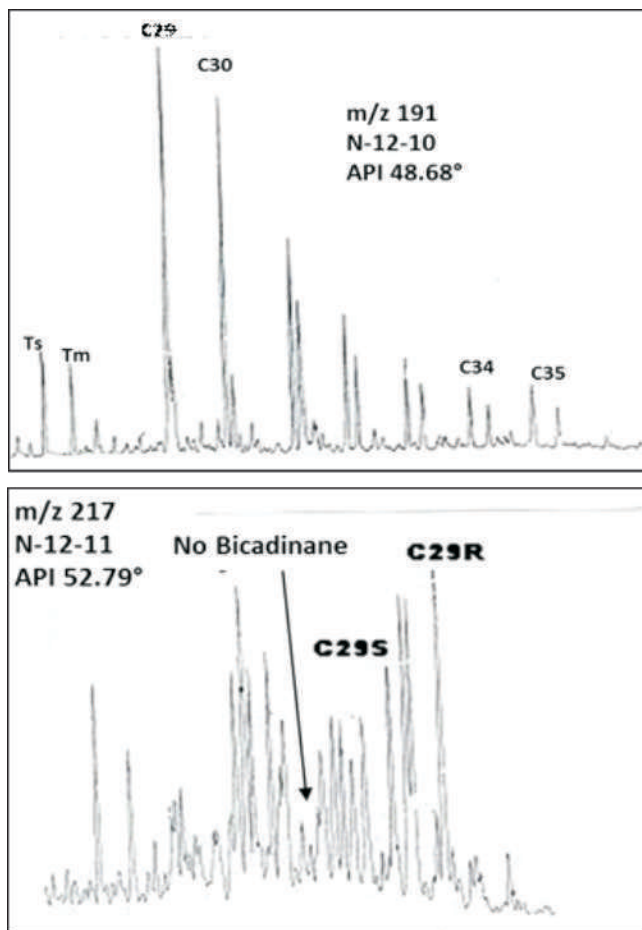


Fig.10b: Hopane (m/z 191) & sterane (m/z 217) distribution of oil from I-6 on profile 2



from N-12-13, N-12-14 and that from N-12-7, N-12-9, N-12-10 & N-12-11 as the wells N-12-13, N-12-14 are on flanges of Central Graben, whereas the N-12-7, N-12-9, N-12-10 & N-12-11 are on flanges of Diu low.

The above profiles indicates that the nearby lows (Diu, Purna, Central Graben, Daman, Navsari) have sourced the reservoirs.



**Fig.12:** Hopane (m/z 191) & sterane (m/z 217) distribution of oil from N-12-11 on profile 5

## Conclusions

This study has led to the following

1. The oils of Tapti-Daman have been generated from nearby lows and have not undergone long distance migration.
2. The heterogeneity in the input source organics as revealed in the biomarker fingerprints of the wells of N-

12 & I structure has been explained from the location, on which flanges of nearest low, with respect to the time thickness map of H5-H4.

3. The specific biomarker signatures along with the H5-H4 time thickness map of Tapti Daman block predicts the source kitchens as Daman low (F, B, A) filling the reservoirs D, C, E, G, T & H. PurnaGraben filling the reservoirs I and J, Navsari low filling the reservoirs I and north Tapti wells. Diu low in situ generation and filling.

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## Abbreviation

C1 - carbon no 1  
 C35 - carbon no 35  
 BNH Bisnorhopane  
 iC4 iso butane

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## Author's Profile



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She joined ONGC in year September 1982. She is a postgraduate in Chemistry from Madras University, PG diploma (Software technology, NCST) and MBA (Operations Research, IGNOU). She has worked in Pertophysics, Phase Behaviour (PVT), Gas & Geochemical Prospecting and Source Rock & Oil Geochemistry. She had undergone training in special core analysis at CoreLab BV, Kuala Lumpur.