# Source Potential and Oil-Source Correlation in Olpad Formation of Ahmedabad-Cambay-Tarapur Blocks of Cambay Basin, India*

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## Abstract

Petroleum prospects of Olpad Formation still remain a challenging to explorationists. To meet this challenge, it is imperative to know the depositional pattern and paleo-structural conditions of the Olpad Formation for identification of reservoir facies. In margin areas, juxtaposition with effective source rocks may account for hydrocarbon accumulation in the Olpad Formation. In the basinal part, however, prospectivity will depend upon generative capacity of source within Olpad Formation itself. Therefore, in the present work source potential of the Olpad Formation has been assessed in the area. In the eastern side, thick source sequences with moderate potential to generate hydrocarbons have developed in drilled sections of Indrora and Gamij fields and these are immature to early mature. In the west, Sanand-C has encountered 280 m excellent mature source rock. In the central part of the basin, Wadu-A has about 230 m, Kalol-D has 160 m and Wadsar-A has 90 m of source rock with fair generation potential and the sequences are at peak maturation state. As the central part has already generated hydrocarbons, original potential might have been much higher than seen at present. In Cambay Tarapur Block, the Olpad Formation in general does not show source characteristics except in Piswada-A and Indernaj-A which have (305 m and 80 m) fair to excellent source unit in catagenetic stage. Thus, in the basinal part adequate source is present for charging reservoirs within the Olpad Formation. Oil in the eastern margin has migrated up dip from low in the west.

## Introduction

Exploratory efforts in post rift sequences of Cambay Basin have been quite successful in establishing in-place reserves. To convert balance prognosticated resources, attention needs to be paid to deeper prospects of the Olpad Formation which comprises thick synrift sediments derived from Deccan Trap. The Nawagam Field in the Ahmedabad Block has been producing from the Olpad Formation since its discovery in 1963. But after that, success has been met only in a few wells in the eastern margin and petroleum prospects of Olpad Formation still remain a challenging to explorationists.

The depositional pattern the Olpad Formation will provide insight to favourable areas for development of quality reservoir facies and likely entrapment of hydrocarbons. These reservoir facies will be prospective for hydrocarbon accumulation either through migration of hydrocarbons generated within the formation or if they are in juxtaposition with effective source rocks. In margin areas, Olpad Formation is shallow and not mature enough to generate hydrocarbons, and juxtaposition with effective source rock may account for hydrocarbon accumulation in it. In the basinal part, however, prospectivity will depend upon generative capacity of source within Olpad Formation itself. Therefore, one needs to assess source potential of the Olpad Formation in the area for exploration in deeper prospects.

## Regional Source Distribution

Source rock identification has been done in Olpad Formation in 65 wells of the Ahmedabad-Cambay-Tarapur blocks of Cambay Basin. Total organic matter content is good (avg. 1.8%) in almost all the wells indicating that the Olpad Formation has received an adequate amount of organic matter. However, source potential varies in different wells. Source sequences have been correlated along three N-S profiles (along the eastern margin, in the central axial part and western part), one NEE-SWW profile in the Ahmedabad block, and one E-W profile in the Cambay-Tarapur block (Figure 1).

### Eastern Margin

In the northern-most studied well Limbodra-A, Olpad Formation is encountered at 971
m and source rock is scanty in this well. However, in Limbodra-B, 90 m of fair to excellent source sequences for mainly gas have been observed between 820-970 m. In the Indrora Field, Olpad is buried deeper and its top is encountered around 1670-1860 m. In the three wells studied, Indrora-A, B and C source thickness of about 200-485 m has been observed and it is just at the threshold of the oil window, whereas the bottom has reached peak generation stage. The kerogen has predominant type III organic matter with some contribution of type II. In Halisa Field, the Olpad is shallow (~990 m) and is devoid of source development. In Dahegam-A, only a

few streaks of source rock occur. Thick source sequences (130-185 m) are present in the Gamij Field (Gamij-B, C and D) with fair generation potential. The section is immature to early mature. Olpad Formation is buried deeper (2227 m) in Manjipura-A and is at the early catagenetic stage. Seventy meters of source rock with good potential has been identified. The Olpad Formation drilled in the eastern margin of Cambay Tarapur Block is thin (23-118 m) except in Uttarasanda-A where it is about 775 m but that also lacks significant development of source rock

**Central Axial Part**

Figure 2 shows variation of source distribution in the central axial part of Ahmedabad Block. The Olpad top is at about in 2500 m in Wadu, Kalol and Wadsar fields. In Nawagam, Olpad top is around 1800 m and again goes down in southern part (Naika and Mahelaj) to about 2100-2300 m. In general, about 200 m thick source development with fair potential is seen from Wadu to Nawagam, but in the Naika-Mahelaj area source development appears to be poor. In Wadu, Wadsar and Kalol, top of the Olpad is at peak generation stage and in Kalol-D which is drilled to 4500 m, the bottom part (3542-4500 m) is in the gas phase. Since this area has already generated hydrocarbons, original potential of the source may be much higher. In the Nawagam area Olpad is in early to peak maturation stage. From geochemical analysis both accumulation zones and source facies have been identified in this area. It is also very well reflected in HI and Tmax values.

**Western Area**

In Sanand Field, Olpad Formation shows excellent source sequences (280 m) in Sanand-C that are within the oil window. But Sanand-D located down dip does not have any significant source development. In Wasnalawa and Wasnakelya data control is not good enough to make any conclusions. In Ambliyala-A about 800 m Olpad has been drilled without any signature of source rock. Kolat-A and Asmali-B also lack source rock in drilled sections. In Piswada-A and Indernaj-A good source development (305 and 80m respectively) is seen that is within oil window. Fig. 3 shows a NEE-SWW profile through Wasnalawa-A, Sanand-C, Wadsar-A, Indrora-A and Halisa-A. There is no source development on the margins and improves in basinal part.

**Cambay Tarapur Block**

East-west profile through Akholjuni-C, Cambay-A, Kathana-B and Siswa-A, and a north-south profile in eastern margin in Cambay Tarapur Block show that, in general, thickness of the Olpad Formation is minimal in these wells and no significant source rock development has been observed. Piswada-A and Indernaj-A on the western side, however, have encountered significant thickness of Olpad Formation which shows characteristics of good source rock in early to peak maturity state.

## Characterization of Source Sequences From Bitumen Studies

Bitumenological data of Cambay Shale and Kalol formations have also been taken along with the Olpad Formation for comparison. Gas chromatograph data shows that both the Cambay Shale and Olpad sediments have dominant terrestrial organic matter deposited in peat coal environment, whereas organic matter in the Kalol Formation has a more oxidizing environment. From source specific parameters like abundance of C30 hopane compared to C29 hopane, distribution of homohopanes, high hopane/sterane ratio, oleanane index and absence of gammacerane, all the sediments have dominant terrestrial input deposited in a suboxic environment.

## Characteristics of Oils

The oils from Olpad Formation have API gravity varying from 20.8 to 43.3$^{o}$ with pour points in the 21-42$^{o}$C range and wax content varies between 6.6-24.9%. NSO content is in the 6.55-13.06% range in Nawagam area, whereas in the Halisa area it is in the 16.53-20.83% range. Paraffinic nature of the oils is seen from component analysis, percentage of saturate is 54.22-78.76% and saturate/aromatic ratio is in the 1.52-4.78 range.

Pristane/Phytane ratio in oils under study varies from 2.35 to 3.9. Contribution of terrestrial source input deposited in suboxic environment is indicated from isoprenoid to n alkane ratios and shapes of chromatograms. Triterpane fingerprints are also indicative of terrigenous and/or microbially reworked organic matter. The sterane distribution of the oils is characterized by presence of C30 steranes (4-methyl-24-ethyl cholestanes) in mass chromatogram at 217 m/z that is indicative of contribution of lacustrine input. Gammacerane is negligible in the oils and homohopane distribution shows a regular decrease from C31 to C35 indicating absence of highly reducing environment during deposition of organic matter. The oils are generated at early to peak maturity from various maturity indicators.

## Oil-Source Correlation

Biomarker data is not available for Nawagam oils, so oil-source correlation has been attempted only for eastern margin oils. Oil is being produced from the Olpad Formation in eastern margin from the Limbodra (2 wells), Halisa (4 wells) and Gamij (2 wells) fields. As discussed above either source facies have not developed in these fields or they are not adequately mature to generate hydrocarbons. In Indrora, Walod area thick source sequences (85-750 m) of moderate generation potential have developed in drilled sections of Olpad and Cambay Shale formations. In Figure 4 source-related parameters of both oils and bitumen have been plotted and correlation between the oils and extracts except Kalol extracts of Indrora-C and Walod-B is demonstrated.

From this it is inferred that Cambay Shale and Olpad source sequences have contributed to the oil accumulations in Olpad in the eastern margin. The structural low in the west area of the studied wells has good thicknesses of Cambay Shale and Olpad formation and is buried deep enough to have adequate maturity matching those of the oils. Thus the studies indicate that this low is the main kitchen and oil has migrated up dip to the eastern margin.

## Conclusions

Source sequences have been identified in Indrora, Gamij, Wadu, Kalol, Wadsar, Nawagam, Sanand, Piswada and Indernaj. They are immature to early mature in Gamij, early-peak in Indrora, Nawagam, Sanand, Indernaj and Piswada, peak- to post-mature in Wadu, Kalol and Wadsar. Oils reservoired in the Olpad Formation in the eastern margin are sourced by Cambay Shale and Olpad formations deposited in the structural low in the west. In the basinal part, adequate source is present for charging reservoirs within the Olpad Formation.

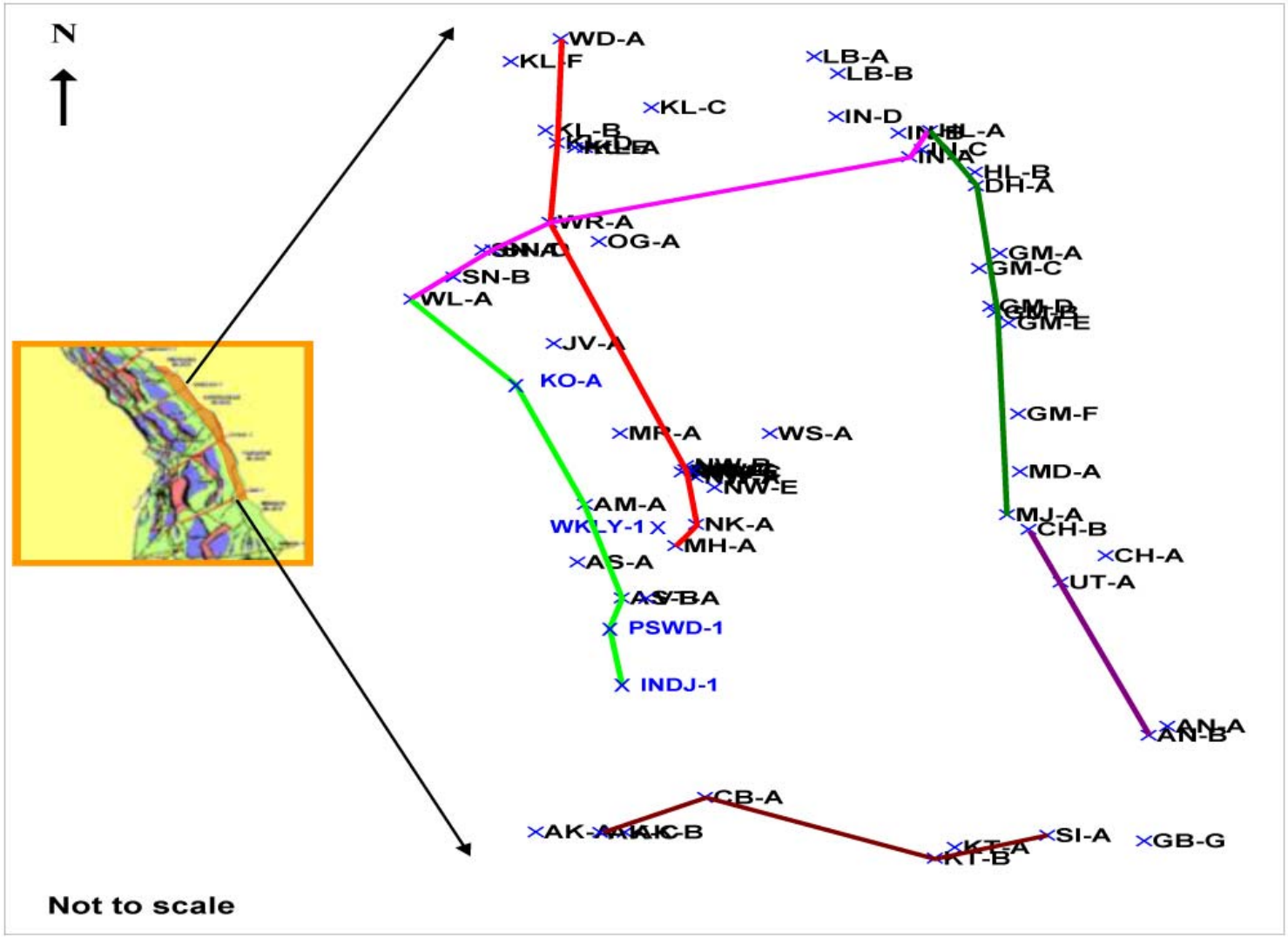



Figure 1. Location of wells studied and profiles for source correlation.

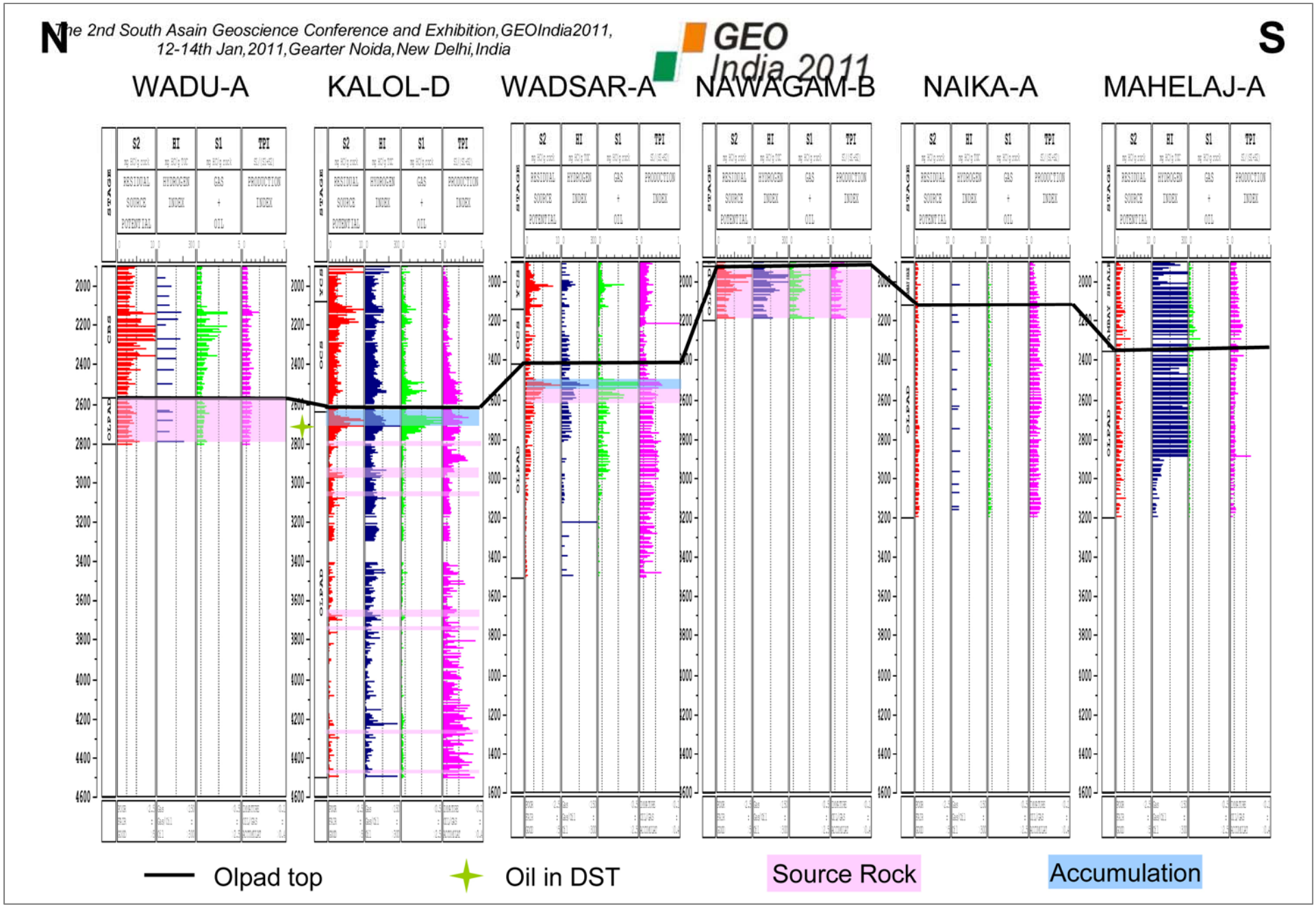



Figure 2. Source correlation in central axial part of Ahmedabad block.

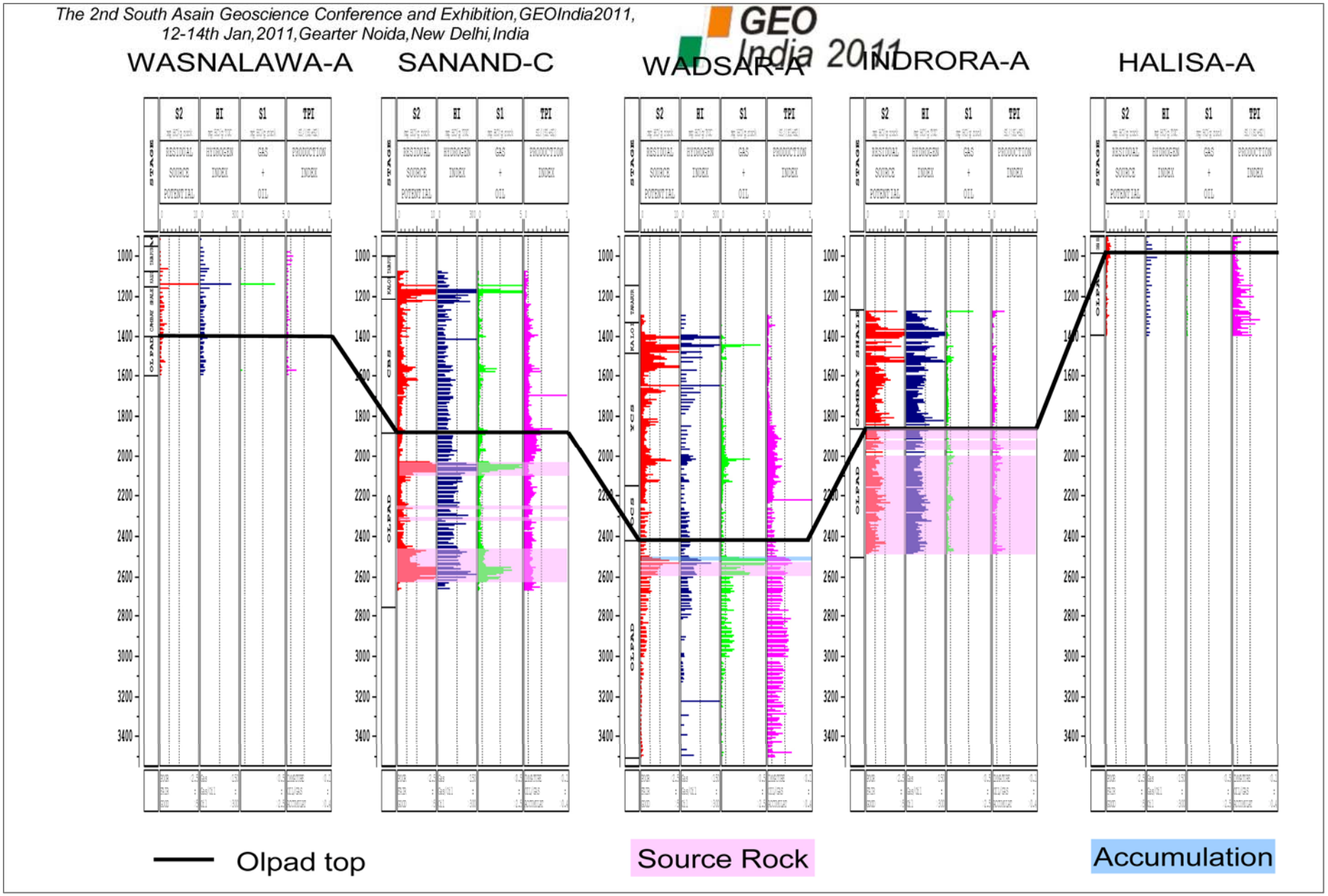
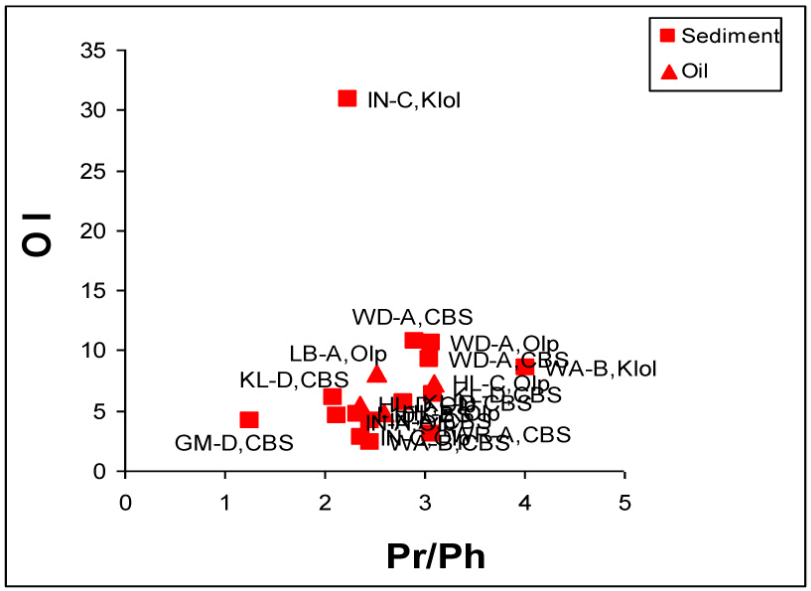
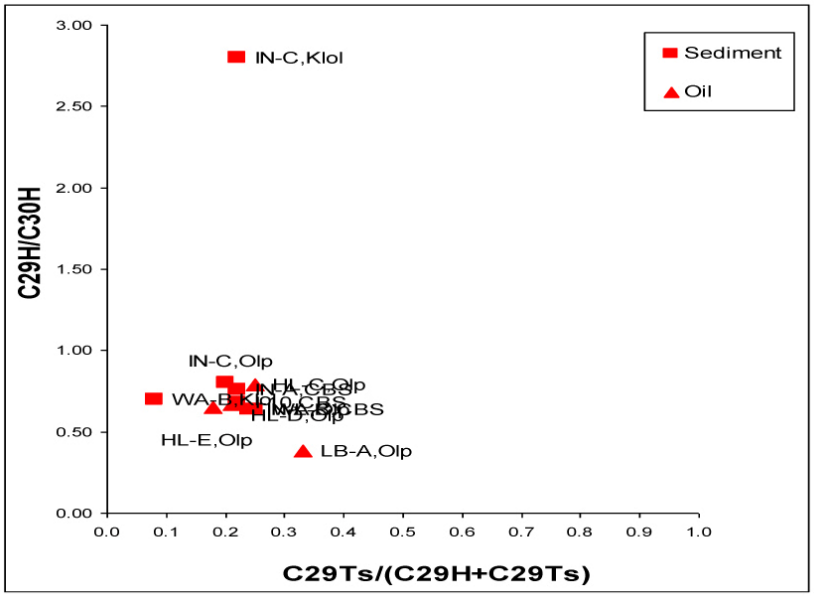



Figure 3. Source correlation along east-west profile of Ahmedabad block.



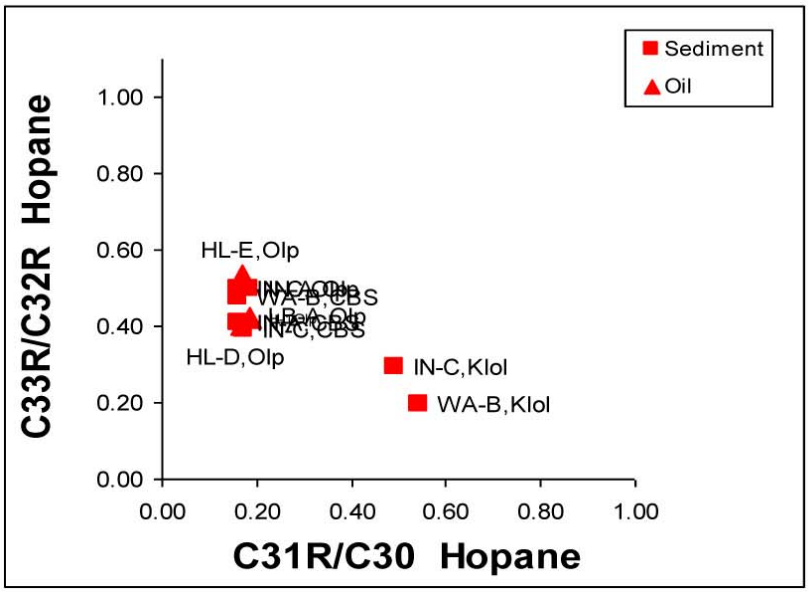




Figure 4. Correlation between all the Olpad oils and extracts, except Kalolextracts of Indrora-C and Walod-B, is demonstrated by source specific parameters: a) Oleanane Index vspristane/phytane; b) C29/C30 hopanes vs C29Ts/(C29H+C29Ts); c) C33R/C32R hopane vs C31R/C30 R hopane.