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Pay zones detection through integration of improved geochemical technique and log data: A case study from North Assam Shelf, Assam & Assam Arakan Basin, India

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Summary

The Upper Paleocene-Lower Eocene clastic reservoirs contribute one of the most important hydrocarbons producing horizons in the North Assam Shelf of Assam & Assam Arakan Basin. These reservoirs are characterised by the presence of normal gravity oil, low to intermediate gravity oil, gas and light oil/condensates. The sand stone reservoirs show complex wire line log signature, which are commonly misleading. Geochemical analysis of sidewall core extracts by thin layer chromatography with flame ionisation detection (TLC-FID) and gas chromatograph (GC) provide valuable, cost effective input for reservoir fluid characterisation. The important parameters needed to identify the nature and composition of the reservoir fluid include (1) the bulk composition of the sidewall core extract (content of saturate, aromatic and nitrogen, sulphur and oxygen (NSO) compounds) (2) amount of extract in mg/g of rock (3) GC finger print and (4) the ratio of pristane (Pr) to nC17 . These parameters integrated with geological and geophysical (wire line logs) evidence, yield more accurate and reliable formation evaluation criteria.

This technique has been applied in the KA-A and LK-A wells of North Assam Shelf and identified the oil-bearing zones. The technique is simple and inexpensive and may find applications as an additional formation evaluation tool in any geological setting. The geochemical parameters of the extract of side wall cores of KA-4 well at the depth interval from 4638- 4641m suggests that the zones are oil bearing which was not identified by the logs. The gas chromatograph fingerprints of saturate fraction of extractable organic matter (EOM) of the sidewall cores from Basal Sandstone Formation of Eocene age in the well LK-A shows oil signature. Good amount of extractable organic matter content and high concentration of saturate hydrocarbons suggests possibility of oil accumulation.

Introduction

In recent years, reservoir geochemistry has developed rapidly, being applied to solve exploration appraisal and production problems. The geochemical technique involves identifying the fluid type (gas/oil/water) using gas chromatography (GC) of residual hydrocarbons extracted from side wall core/ sediments. Results are used to assist formation evaluation in identifying reservoir fluids because open-hole neutron-density data do not always accurately reflect the type of hydrocarbons in the reservoir. Oil fingerprinting of residual hydrocarbons from side wall core extracts can provide an independent means of identifying reservoir fluid type. Finger prints of oil-saturated sands are typical of topped (C15+) whole oils, whereas finger prints of hydrocarbons extracted from the gas-dominated sands show an abbreviated hydrocarbon distribution more typical of gas condensates. Finger prints of extracts from water- productive intervals show a further abbreviated signature, suggesting that high molecular weight hydrocarbons did not migrate in to these intervals (Baskin et al., 1995).

The Iatroscan thin layer chromatography and ionization detection (TLC-FID) technique has been successfully applied to screen petroleum reservoirs and provide data appropriate for selection of sample for high resolution analysis. This technique can often be used to provide data indicators of polar compound enrichments, which may indicate barriers such as asphaltene rich zones (Karlsen and Larter, 1989). Iatroscan TLC-FID data can be used to define oil-water contacts (OWC) not identified by well logs. This technique can provide direct chemical characterization of petroleum in cores, by which one can identify the features in reservoirs that in turn can be helpful during exploration, appraisal and production. Iatroscan-

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TLC-FID offers high precision and accuracy, in addition to rapid analysis.

The concentration of heavy oil at or near the oil-water contact in a reservoir is called tar mat. They comprise oil enriched in asphaltene, which can be generated in situ or accumulated by gravity segregation. For reservoir exploitation the tar mat aerial extent would be beneficial for field development. Tar mats or polar enriched zones (PEZs) often occur close to geological discontinuities and oil water contacts may show concentration of asphaltenes reaching 20-60 wt% of the C15+ fraction of the petroleum (Wilhelms et., 1994). Iatroscan screen analysis has been found to be a very fast and accurate technique for detection of tar mats. The objective of the present study focused on the development of geochemical technique integrate with log data to identify the potential hydrocarbon bearing zones from the study of side wall core samples by Iatroscan-TLC-FID and gas chromatography.

Geological settings

The evolution of Assam foreland based on plate tectonics has been studied extensively and well-documented (Rangarao and Murthy, 1983). Stratigraphic analysis by Deshpande et al. (1993), reveal that in the basin, the PreCambrian granites from the basement which is mostly overlain by an arenaceous sequence called Basal Sand Stone/Tura Formation. This is overlain by Sylhet Limestone Formation that grades upward into splintery shales with few thin alternations of sand stones and sparse marl streaks of the Kopili. Barail group of rocks consisting of sand stones, shales and coal beds, overlies the Kopili Formation. The location map of North Assam Shelf oil fields is shown in Fig. 1. Thirteen side wall core samples from KA-A of Tura Formation of age ranging Paleocene to Early Eocene and six side wall cores from LK-A of Basal Sand Stone Formation of Eocene were studied for identification of hydrocarbon bearing zones. The generalised stratigraphy of Assam & Assam Arakan Basin is shown in Fig. 2.

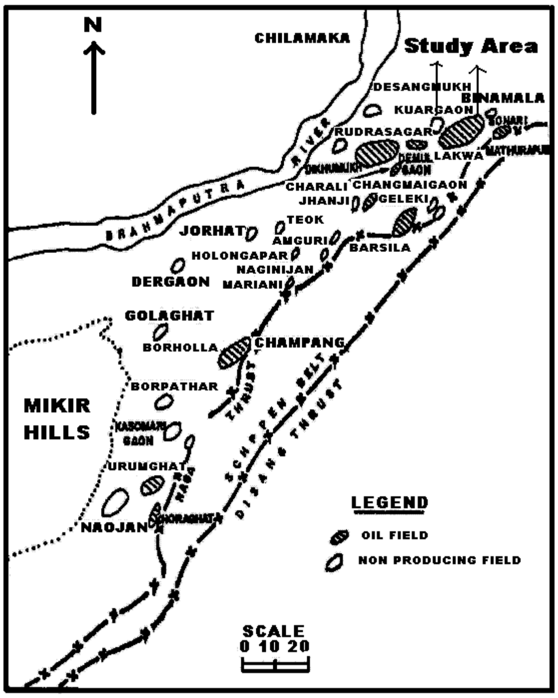

Figure 1: Location map of North Assam Shelf showing the study area.

Methodology

The cleaned side wall core samples are soxhlet extracted using chloroform. Following solvent evaporation, the bitumen were dried and weighed to the constant weight. An Iatroscan TLC-FID Model MK-5 was used to determine the group type composition of the extracts. Elution using n-hexane to separate saturated hydrocarbons, toluene for aromatics and methanol: dichloromethane (95:5 v/v) for NSO compounds followed by drying at 120oC for 2-3minutes each. The amount of saturates, aromatics, NSO and asphaltenes in micrograms was determined by individual response factors for each fraction.

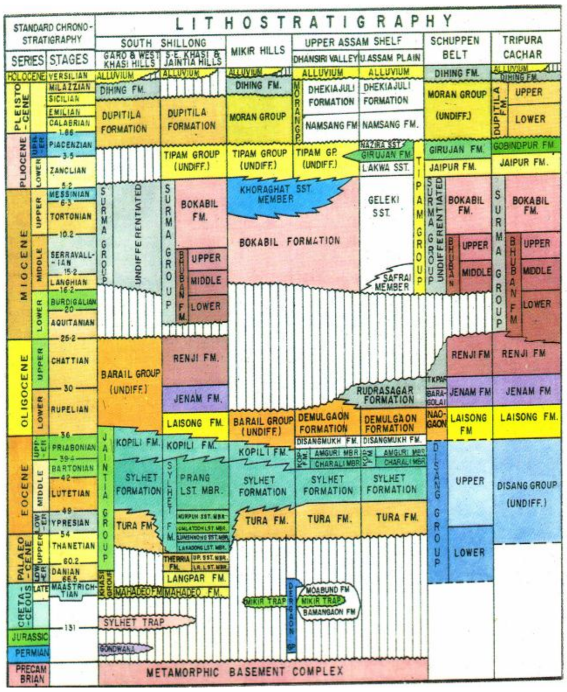

Figure 2: Generalised stratigraphy of A & AA Basin

A weighed amount of the bitumen was dissolved in petroleum-ether (40-60oC) and was placed on the top of a silica-alumina (1: 1) column and saturates were eluted by petroleum-ether. The saturate fraction was analyzed for normal and isoprenoid alkane distribution on Chemito 1000 Gas Chromatograph equipped with OV-101 coated with fused silica capillary column (30m x 0.25mm). Nitrogen was used as a carrier gas. Injector temperature was maintained at 300oC and column was programmed from 80°C - 300oC at 4oC/min with final hold time of 20 min.

Results and discussion

Identification of tar mats

In KA-A the Tura Formation at 4635.5m the geochemical analysis shows that the extractable organic matter is quite high (54.4 mg/g of rock) and the extract contains very low saturates (6.6 %), high NSOs (60.4 %) and low saturates / aromatic ratio (0.20) indicative of the presence of tar mat.

The log interpretation for the formation at this depth also suggests some geological barrier. The fact that this interval is water bearing and can explain the presence of tar mat. The tar mat is formed by water washing is also reinforced by the GC fingerprint which shows the depleted n-alkane peaks which are removed by water washing (Fig. 3a). Early expelled oil filled these low permeability sands and was washed by the water existing in this zone, resulting in the formation of tar mat. This tar mat is acting, as good barrier to vertical fluid movement and this zone has isolated.

Hydrocarbon bearing zones

The GC finger prints of saturate fraction of extractable organic matter from side wall core of KA-A at the depths 4638m, 4639m, 4640m and 4660.5m are quite similar while that of 4641m shows different GC fingerprint suggesting presence of fluid barrier at 4641m. The extractable organic matter for the side wall cores of 4638m, 4639m and 4640m ranges between 3.3 to 6.6 mg/g of rock. Although geochemical parameters (Table-1) of these three side wall cores extractable organic matter are slightly differ from each other and the geochemical evidence points towards the presence of intermediate gravity oil between intervals 4638m to 4640m. At 4640m the extractable organic matter has quite different geochemical parameter but the extractable organic matter percentage is quite good so this zone may also be considered as oil accumulation zone (Fig. 3b).

In LK-A the side wall core samples between 4996m to 5091.5m show high extractable organic matter content ranging from 3.9 to 9.1 mg/g of rock suggesting accumulation of oil at 4996m, 5037.5m, 5081m, 5083.5m, 5088m and 5091.5m. The GC finger prints and geochemical parameters suggest that these accumulations are compositionally different (Table-1). This difference may be attributed to heterogeneity of reservoir rocks. Though log signatures and absence of fluorescence indicate that these sections are water bearing, the GC finger prints and the geochemical evidence point towards presence of normal gravity oil in these zones (Fig. 4a) which are matching with the produced oil at the depth of 4983m on testing (Fig. 4b).

Interpreting oil-water contacts (OWC)

The location of oil-water contacts and its extent depend on the pore size distribution, which affects the capillary pressure. A pressure differential is required for non-wetting phase fluids (hydrocarbons) to displace the wetting phase fluid (water). This is equal to a minimum threshold capillary pressure and is dependent on a pore size (Archer and Wall, 1986). In KA-A at 4693m depth the extractable organic matter (11.9 mg/g of rock), NSO (85.7 %) are high and saturates (9.2 %) are low, which suggests that the sediments are near to the oil water contact (OWC).

Table 1 Geochemical and hydrocarbon group type composition of side wall cores by Iatroscan -TLC-FID

Well No.	Formation	Depth (m)	EOM (mg/g)	Sat %	Aro %	NSO %	Sat/ Aro	Pr/Ph	Pr/nC_{17}	Ph/nC_{18}	$Pr+nC_{17}/Ph+nC_{18}$
KA-A	Tura	4635.5	54.4	6.60	33.0	53.0	0.20	4.91	4.24	0.81	2.72
KA-A	Tura	4638.0	3.3	17.2	4.60	74.1	3.74	0.73	0.93	0.51	0.51
KA-A	Tura	4639.0	6.6	28.6	5.30	60.9	5.40	2.56	1.67	0.43	1.07
KA-A	Tura	4640.0	4.8	20.0	7.50	61.8	2.67	1.25	1.48	0.52	0.72
KA-A	Tura	4641.0	5.3	17.7	12.3	57.0	1.44	0.19	0.55	1.71	0.35
KA-A	Tura	4660.5	6.4	26.2	3.80	68.5	6.89	1.58	1.39	0.50	0.76
KA-A	Tura	4683.2	4.3	41.0	4.10	44.1	10.0	2.21	2.98	0.68	1.19
KA-A	Tura	4683.5	2.2	14.9	2.90	77.6	5.14	1.23	1.56	0.67	0.89
KA-A	Tura	4684.0	5.3	49.4	4.70	42.4	10.5	4.54	5.82	1.15	2.85
KA-A	Tura	4688.0	4.4	17.1	12.9	58.2	1.33	0.83	3.59	1.17	0.57
KA-A	Tura	4689.0	2.4	37.3	15.0	41.8	2.47	2.76	7.33	1.39	1.82
KA-A	Tura	4690.0	3.6	32.3	5.70	56.7	2.15	1.36	5.79	1.31	0.90
KA-A	Tura	4693.0	11.9	9.20	5.10	79.5	1.80	5.29	3.08	0.48	2.27
LK-A	Tura	4996.0	9.1	53.2	10.0	29.2	5.32	2.50	1.66	1.66	1.66
LK-A	Tura	5037.5	3.9	21.2	4.20	71.5	5.05	1.56	5.03	1.52	1.13
LK-A	Tura	5081.0	9.0	21.8	5.70	67.4	3.82	0.50	0.72	0.72	0.79
LK-A	Tura	5083.5	6.8	52.2	11.1	31.5	4.70	1.66	1.97	1.72	1.14
LK-A	Tura	5088.0	5.0	17.1	12.9	58.2	1.33	0.95	2.78	0.75	0.55
LK-A	Tura	5091.5	5.8	37.3	15.0	41.8	2.49	5.12	1.21	1.16	3.02

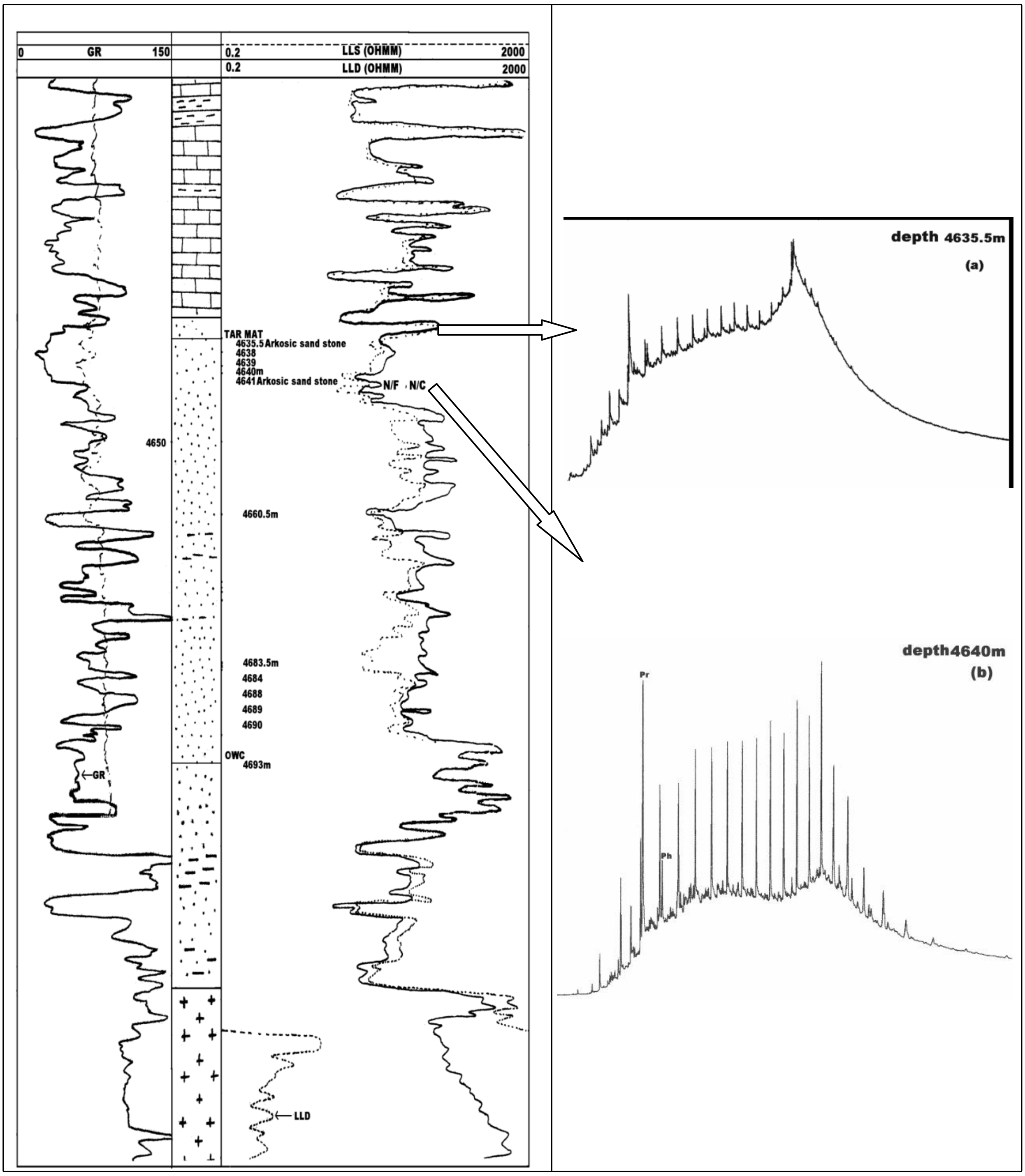

Figure 3: The GC finger prints of extracts of side wall cores from well KA-A show presence of tarmat (water bearing) (a) and presence of normal oil with uniform distribution of n-alkanes (b), whereas the log indicates water bearing in this zone. GR-gamma ray log; LLS- laterolog shallow; LLD- laterolog deep.

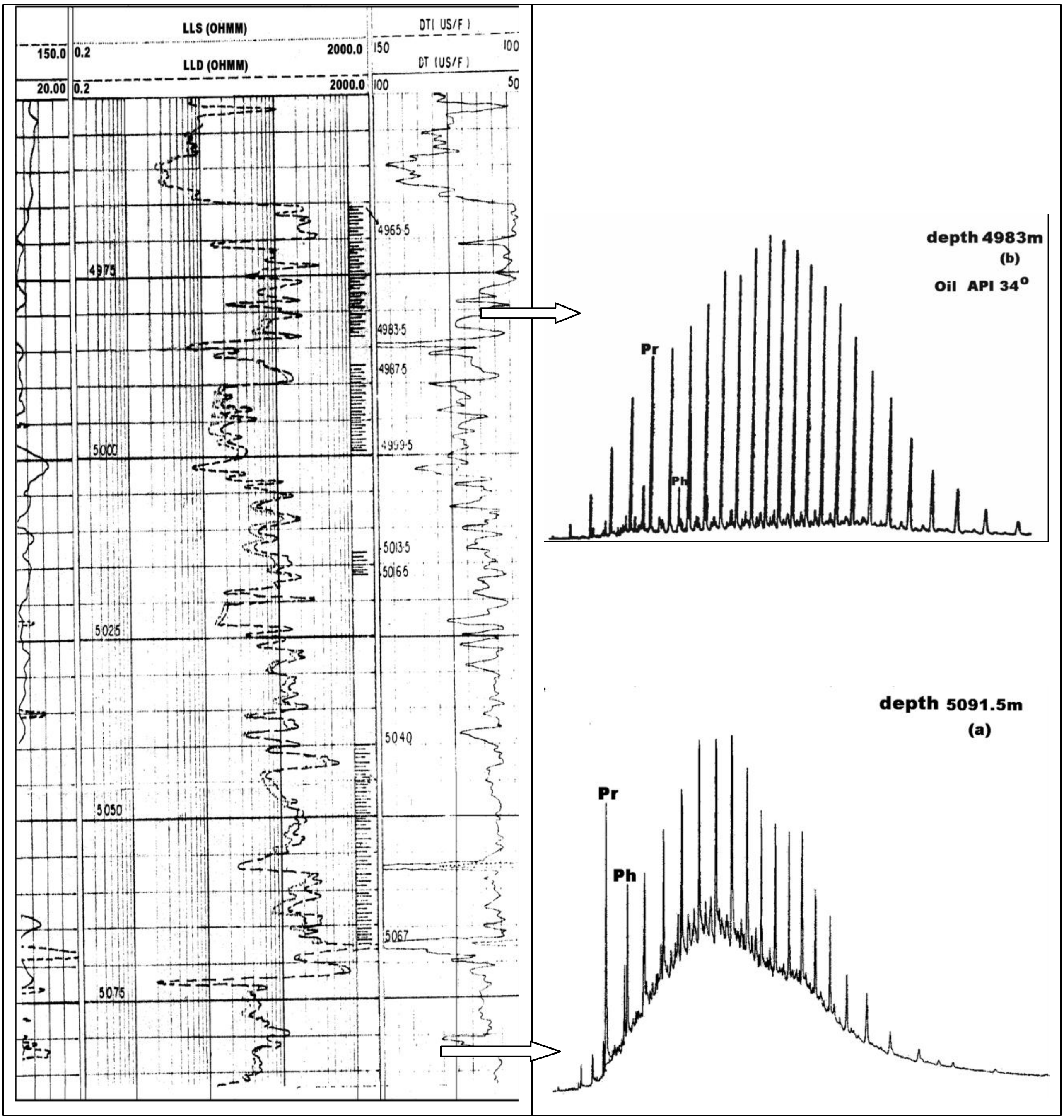

Figure 4: The GC finger prints of extracts of side wall cores from well LK-A show presence of normal oil with uniform distribution of n-alkanes (a), whereas the log indicates water bearing and produced oil of normal API gravity (b). GR-gamma ray log; LLS- laterolog shallow; LLD- laterolog deep.

Conclusions

1. Iatroscan TLC-FID integrated data and gas chromatographic fingerprints with log interpretation used to identify the reservoir fluid and their properties more precisely. This technique involves direct determination of the group type hydrocarbon through analysis of reservoir fluid can find application in solving complex formation evaluation problems in any geological setting.
2. In KA-A well the depth interval from 4638m to 4641m having good amount of extractable organic matter, high saturate content and the gas chromatographic fingerprints indicates presence of intermediate gravity oil.
3. All the side wall cores of the GC fingerprints of saturate fraction of extractable organic matter between the intervals 4996-5091.5m of Basal Sandstone Formation of Eocene age in the well LK-A shows oil signature. Good extractable organic matter content and high concentration of saturated hydrocarbons suggests possibility of oil accumulation in these zones.
4. Geochemical parameter shows the presence of tar mat at the depth 4635.5m in the well KA-A. The log interpretation for the formation also suggests some geological barrier at this depth.
5. At 4693m-core depth the side wall core sample of KA-A showed high extractable organic matter content of 11.9 mg/g of rock, less percentage of saturated hydrocarbons (9.2 %), which suggests that the sediments are near to oil water contact (OWC).

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