Geochemical Investigation of Shallow Sediment Samples near a Gas Show Site and its Exploration Significance in Mandi Area of Himalayan Foot Hills Basin, India*

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Abstract

The increasing demand for petroleum products in India will force exploration activity to expand into frontier areas such as the Himalayan Foothills belt having an area of approximately 30,000 km^2 consisting mostly of Mesoproterozoic-Cenozoic rocks. At this time, twenty-three wells have been drilled in this basin, but no major source rock sequences have been identified. Due the lack of commercial discovery/producing wells, the identified petroleum systems are only speculative. However, hydrocarbon shows in some of the wells and gas seeps in different parts of the basin indicate that hydrocarbon generation and migration have taken place. In the drilled wells, Late Paleocene-Mid Eocene was not penetrated but in the exposed Late Paleocene-Mid Eocene sections, two oil shows in bituminous limestone are known near Mandi and Punch. The associated coal in the Late Paleocene-Mid Eocene outcrops of Jangal-Gali has attained metamorphism that is normally noticed in the peak-mature oil source beds. This may be due to local tectonic factors.

An initial attempt was made to apply an integrated approach for characterizing both gaseous and liquid range hydrocarbons in the shallow sediments in order to derive more firm exploration leads regarding generation and migration of hydrocarbons. Geochemical investigations of surface and subsurface samples in the past have shown that the Siwalik and Dharmasala sediments have very poor potential of hydrocarbon generation. The well JMI-B is the deepest well, drilled to the depth of 6,720 m and terminated within Late Eocene-Oligocene; however, the Late Paleocene-Mid Eocene was not penetrated. Two oil shows in bituminous limestone are known near Mandi and Punch in the exposed Late Paleocene-Mid Eocene sections. Stable carbon isotopic studies of surface gas shows recorded at many places in Himachal Pradesh also reveal thermogenic origin of the gas. These findings indicate that the mature source may lie in the deeper part of the basin and hydrocarbons migrated upwards.

Gas presence was reported during drilling of the borehole for installation of Hand Pump at Mera Masit, Mandi, Himachal Pradesh. In order to collect gas sample, the ONGC team visited the site and found no gas flow. The team collected six sediment samples from the site. Rock Eval pyrolysis studies of sediments indicate that out of six, three samples exhibit very good to excellent organic richness, remaining hydrocarbon generation potential (4.72-97.47mgHC/g rock) and they are in peak maturity stage (Tmax: 458-464° C).

Appreciable presence of free hydrocarbons (up to 4.04Kg/Ton of Rock) in the samples along with GC traces of the saturate hydrocarbon fractions of the bitumen extracts and presence of adsorbed gas of thermogenic origin enable us to draw an inference that the studied sediments are at the threshold of maturity. The equivalent sediments in the deeper part of the basin may act as good effective source rock capable of filling nearby structures and hence worthy as leads for future exploration.

Samples and Methodology

All the sediment samples were pyrolysed on RE-VI by the methods of Espitalie and Lafargue. Total Organic Carbon measurements were performed on a multi EA 2000C carbon analyser after decomposing inorganic carbon with 4N HCl. The EOM of the samples were extracted (Rapid Solvent Extractor), concentrated and deasphalted with petroleum ether (40-60 °C). The precipitated asphaltenes were filtered from the solution and saturated and aromatic hydrocarbons fractions were separated by column (50 cm length and internal diameter 0.75cm) chromatography. These fractions were concentrated under reduced pressure and dried by blowing nitrogen. The saturate fractions were analyzed for normal and isoprenoid alkanes distribution on Varian CP3800 Gas Chromatograph. After removal of n-alkanes by urea adduction, the branched and cyclic hydrocarbons in the saturated hydrocarbon fractions of EOM were analyzed on a Quattro II triple quadrupole mass spectrometer. Selective Ion Recording (SIR) for hopanes (m/z 191) and steranes (m/z 217) carried out in EI+ Ionization mode at 70 e.v in the mass range: m/z 50 to 650. The adsorbed gas analysis for gaseous hydrocarbons was performed on sieved 63µ portion of the sediments by acid desorption method followed by quantitative and qualitative analysis on Chemeto-1000 gas chromatograph equipped with a flame ionization detector.

Results and Discussions

Rock Eval and TOC data of six samples indicate that three samples (Table 1a) have very good to excellent organic richness and remaining hydrocarbon generation potential and they are in peak maturity stage (TOC%: 4.05-43.59, S2:4.72-97.47mgHC/g rock, Tmax: 458-464 °C and VRo: 0.62-0.7%). High S1 indicate the presence of free hydrocarbons (0.28-4.04Kg/Ton of Rock) in the samples (Table 1b).

Adsorbed gas analysis indicate that all the samples contain appreciable quantity of C_2+ gases (10.77-14.85%) indicative of thermogenic origin of gaseous hydrocarbons as evident from the Table1d. As evident from the Table 1d, adsorbed gas data from the study area document gas compositions that are characteristic of gases associated with oil and/or condensate. The cross plot of total gas versus wetness (Figure 1D) clearly indicates that, except for sample M-3, all desorbed gases show dominance of light hydrocarbons of thermogenic origin.

GC and GCMS based biomarker studies (Figure 1 A-C and Table 1c) of bitumen extracts of the samples suggest siliciclastic mixed source organofacies deposited in a well preserved reducing environment with dominant contribution from marine source organic matter (Figure 1E). The GC analysis of saturate hydrocarbon fractions of respective bitumen extracted from sediments shows oil-like GC fingerprints, which also supports the presence of free liquid hydrocarbons. Maturity as indicated by aromatic biomarkers reveals that the organic matter is near peak oil generation stage (VRc 0.7 – 0.75), which also supports the VRo and Tmax data of the studied samples.

Appreciable presence of free hydrocarbons (up to 4.04Kg/Ton of Rock) in the samples along with GC traces of the saturate hydrocarbon fractions of the bitumen extracts enable to draw an inference that deeper parts of the equivalent sediments may act as good and effective source rock capable of filling nearby structures. Biomarker and isotopic studies suggest siliciclastic mixed source organofacies deposited in a well-preserved reducing environment with a dominant contribution from marine source organic matter.

Conclusion

The presence of thermogenic gases, oil-like GC fingerprints and peak maturity (Tmax: 458-464°C & VR° %: 0.63-0.71) suggest the generation of hydrocarbons in these sediments. The sediments are in peak hydrocarbon generation stage and in the deeper part, the equivalent sediments may act as good effective source rock capable of filling near by structures. The results of the study warrant further investigation on extension of the equivalent sediments in nearby areas to get leads about the presence of hydrocarbons accumulations.

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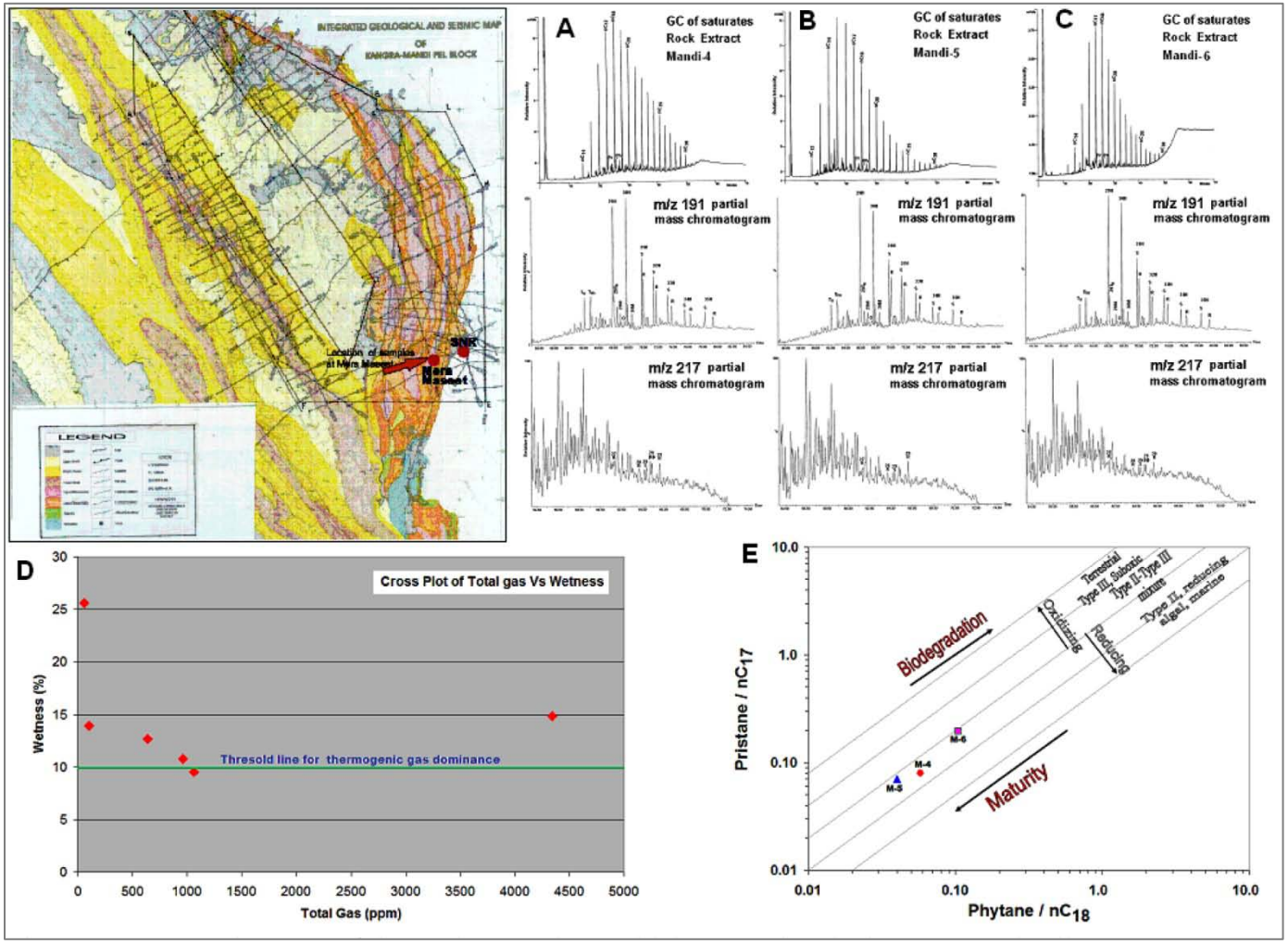

Figure 1. Location map of the study area along with key geochemical parameter details.

Sample No.	Lithology	S1 mg.HC/g rock	S2 mg. HC/ g rock	S3 mg.CO_2/ g rock	PI	HI mg.HC/g TOC	T_{max} ^0C	TOC (%)	Min c	VRo (%)	δ13C Saturate (‰)	δ13C Aromatic (‰)
M-1	Not known	0.01	0.02	0.33	0.33	17	492	0.12	0.25	-	-	-
M-2	Not known	0.01	0.02	0.82	0.33	25	482	0.08	3.59	-	-	-
M-3	Not known	0	0.01	0.12	0.00	33	483	0.03	0.07	-	-	-
M-4	Carbonaceous Shale with coarse grained free quartz	0.28	4.72	0.20	0.06	117	464	4.05	1.10	0.66	-28	-26.9
M-5	Black highly Carbonaceous Shale with lignitic coal	4.04	97.47	0.30	0.04	224	462	43.59	2.17	0.63	-27.8	-26.7
M-6	Dark colour Carbonaceous Shale	2.5	43.13	0.49	0.05	197	458	21.94	0.89	0.70	-27.6	-27.6

Table 1a. Rock Eval Analysis of Samples.

Table-1b Free hydrocarbons present in the sediments

Sample	Free Hydrocarbons (Kg/Ton of Rock)
M-4	0.28
M-5	4.04
M-6	2.5
The presence of high S1 indicates free hydrocarbons (0.28-4.04Kg/Ton of Rock) in the samples.	

Table 1b. Free hydrocarbons present in the sediments.

Table-1c Saturate and Aromatic biomarker data of sediments

Sample	Ts/Ts+Tm	Tm/Ts	C29H/ C30H	C30M/ C30H	Ol/30H	31H 22S/ (22S+22R)	32H 22S/ (22S+22R)	35H/34H
M-4	0.52	0.94	0.94	0.11	0.04	0.59	0.59	0.91
M-5	0.47	1.11	1.14	0.18	0.04	0.58	0.58	0.90
M-6	0.45	1.20	1.07	0.13	0.04	0.59	0.58	0.84

Table 1c. Saturate and Aromatic biomarker data of sediments.

Table-1d Adsorbed Gas Composition of Samples

Sample No.	C1	C2	C3	iC4	nC4	iC5	nC5	Total gas	C2+%
M-1	43	7	2	0.3	4	1	-	58	25.60
M-2	550	42	16	6	10	5	0.8	636	12.70
M-3	961	71	18	4	4	2	0.6	1062	9.50
M-4	3700	382	156	52	30	20	5	4345	14.85
M-5	857	70	21	6	2	3	0.4	961	10.77
M-6	85	8	3	0.7	0.8	1	0.4	99	13.90

#All concentration is in ppm V/wt

Table 1d. Adsorbed gas composition of samples.