

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

Trilok Chand, M.K.Shukla, Sanjeev Kaushal and I.V.S.V.Prasad
Geochemistry Group, KDMIPE, Oil & Natural Gas Corporation Limited, Dehradun-248 195,
Uttarakhand, India
E-mail: chand_trilok@ongc.co.in

The increasing demand for petroleum products in India will enforce exploration activity to expand into frontier areas such as the Himalayan Foothills belt having an area of approximately 30000sq.km mostly consists of Mesoproterozoic-Cenozoic rocks. Twenty three wells have so far 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 drilled wells and gas seeps in different parts of the basin are indications 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.

A maiden attempt have been made to apply integrated approach for characterizing both gaseous and liquid range hydrocarbons in the shallow sediments in order to derive more firm exploration lead regarding generation and migration of hydrocarbons. Geochemical investigations of surface and sub surface 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 6720m and terminated within Late Eocene-Oligocene and Late Paleocene-Mid Eocene was not penetrated. However, 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 Borehole for installation of Hand Pump at Mera Masit, Mandi, Himachal Pradesh, in order to collect gas sample 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 (upto 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 to draw an inference that the studied sediments are at 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 lead for future exploration.

Samples & Methodology

All the sediment samples were pyrolysed on RE-VI by the methods of Espitalie and Lafargue. Total Organic Carbon measurements were performed on multi EA 2000C carbon analyser after decomposing inorganic carbon with 4N HCl. The EOM of the samples were extracted (Rapid Solvent Extractor) and 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 analysed 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 Flame ionization detector.

Results & Discussions

Rock Eval and TOC data of six samples indicate that out of six, 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, T_{max}: 458-464°C and V_{Ro}: 0.62-0.7%). High S₁ indicate the presence of free hydrocarbons (0.28-4.04Kg/Ton of Rock) in the samples.

Adsorbed gas analysis indicate that all the samples contain appreciable quantity of C₂₊ gases (10.77-14.85%) indicative of thermogenic origin of gaseous hydrocarbons as evident from the table-1d. As evident from the table 1d, sorbed 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 (Fig.1D) clearly indicates that except sample M-3 all desorbed gases shows dominance of light hydrocarbons of thermogenic origin.

GC and GCMS based biomarker studies (Fig.1A-C and Table-1c) of bitumen extracts of the samples suggest silici-clastic mixed source organofacies deposited in a well preserved reducing environment with dominant contribution from marine source organic matter. 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 (V_{Rc} 0.7 – 0.75), which also supports the V_{Ro} and T_{max} data of the studied samples.

Appreciable presence of free hydrocarbons (upto 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 part the equivalent sediments may act as good and effective source rock capable of filling nearby structures. Biomarker and isotopic studies suggest silici-clastic mixed source organofacies deposited in a well preserved reducing environment with dominant contribution from marine source organic matter.

Table-1a Rock Eval Analysis of Samples

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} °C	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	97.4 7	0.30	0.04	224	462	43.59	2.17	0.63	-27.8	-26.7
M-6	Dark colour Carbonaceous Shale	2.5	43.1 3	0.49	0.05	197	458	21.94	0.89	0.70	-27.6	-27.6

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-1c Saturate and Aromatic biomarker data of sediments

Sample	Ts/Ts+Tm	Tm/Ts	C29H/ C30H	C30M/ C30H	Ol/30H	31H 22S/ (22S+2 2R)	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-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

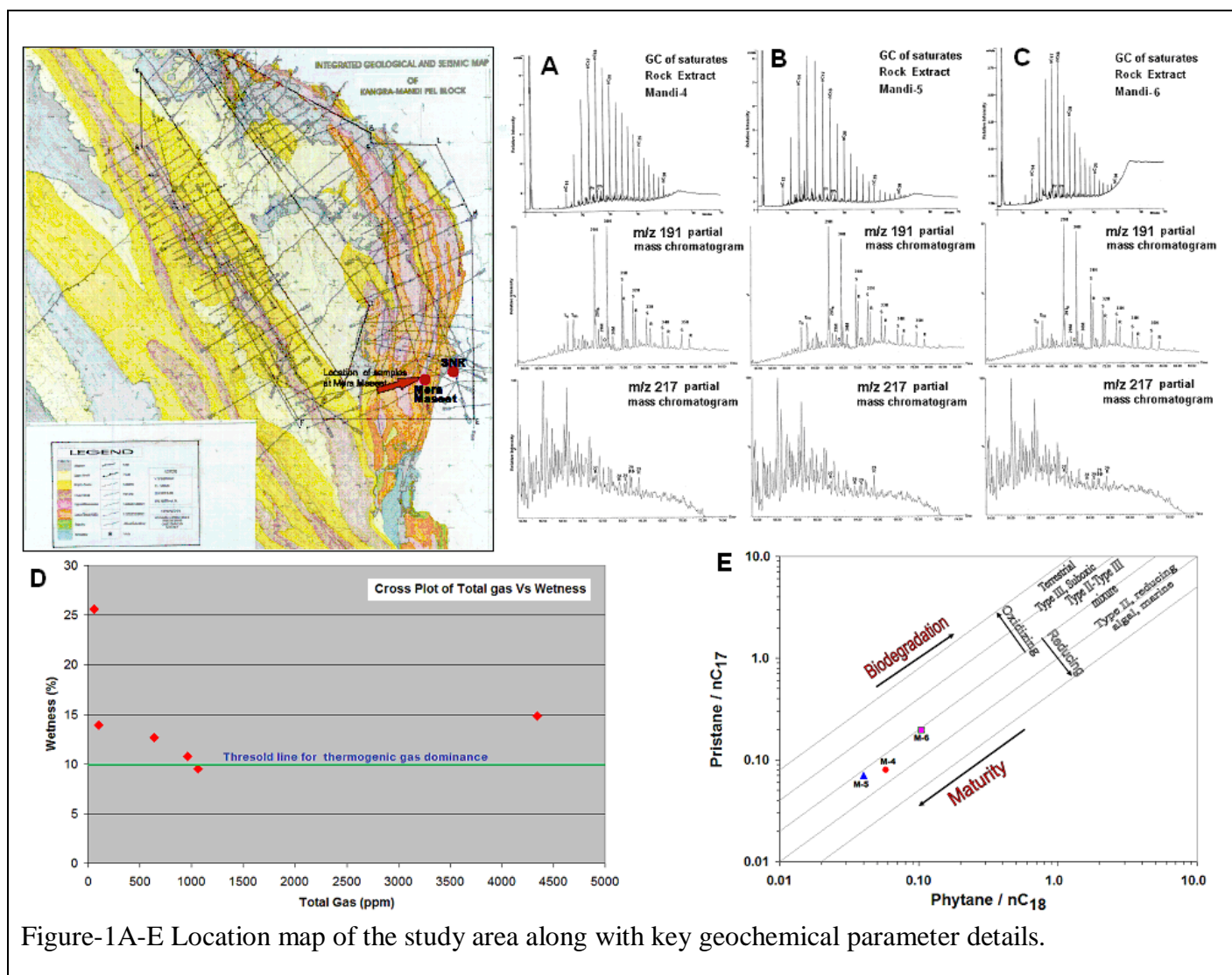


Figure-1A-E Location map of the study area along with key geochemical parameter details.

Conclusion

The presence of thermogenic gases, oil like GC fingerprints and peak maturity (T_{max} : 458-464°C & $VR_o\%$: 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 area to get lead about the presence of hydrocarbons accumulations.

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