ORIGINAL RESEARCH PAPER

Microbiology

DELINEATION OF HYDROCARBON ZONES IN TARAPUR BLOCK OF CAMBAY BASIN

KEY WORDS: geochemical prospecting, light hydrocarbons, adsorbed soil gases, thermogenic

M.A.Rasheed*	Petroleum Research Management, Gujarat Energy Research and Management Institute*Corresponding Author
Braj Mohan	Petroleum Research Management, Gujarat Energy Research and Management Institute
Anuj Gogoi	Petroleum Research Management, Gujarat Energy Research and Management Institute
P.L. Srinivasa Rao	Petroleum Research Management, Gujarat Energy Research and Management Institute
Syed Zaheer Hasan	Petroleum Research Management, Gujarat Energy Research and Management Institute

ABSTRACT

The surface geochemical prospecting techniques were employed to characterize thelight gaseous hydrocarbons seepage zones in Tarapur block of Cambay basin,Gujarat. A set of 664 sub-soil samples were collected and analyzed for the adsorbed soil gas andmicrobiological analysis. To study the origin and nature of these gases, soil sampleswere analyzed for light hydrocarbons(C1 – C5). The adsorbed soil gas analysis data show the presence of moderate to highconcentrations of methane (1 – 743 ppb), ethane (1 – 332 ppb), propane 1 – 194),n-butane (1 – 70.2 ppb), i-butane (3.7 – 70.2 ppb), C2+ (30.9 – 596.3 ppb). Thecross plots between C1-C2, C3-iC3, and cross plot C1/C2 vs C1/(C2+C3) showsgood correlation coefficient r = 0.9 between C1-C2, C3-iC3, and cross plot C1/C2vs C1/(C2+C3). Finally, the data obtained and their interpretation indicate that the light hydrocarbons bear thermogenic origin.

Introduction

The fundamental form for the most geochemical, microbiological and non-seismic geophysical hydrocarbon detection methods is the occurrence of hydrocarbon microseepage that occurs in every petroleum basin (Schumacher, 2012). The microseepage is mainly vertical such that areal extent of the reservoir at depth can be estimated through the extent of surface anomaly (Schumacher, 2012). The microseepage leads to various chemical reactions and oxidation of hydrocarbon through micriobial activity. In organic geochemical exploration, the analysis of recent sediments is carried out for light gaseous hydrocarbons (Sokolov et al. 1970). The soil adsorbs the light gaseous hydrocarbons such that anomaly shows the higher concentration to the vicinity of the source. The geochemical compositional data along with the subsurface geological information which includes structure and isopach maps provides the information about drilling locations with highest success probability (Belt and Rice, 2002).

Cambay basin is known for its multiple generative depressions and multiple source rocks at different maturity levels resulting to different oils in different parts of basin. (Khatri et.al 2015). From the future exploration perspective, the basin is still good with almost assured chances of discovering small fields in multiple plays with exploration strategies like "new oil in old fields" and deliberate search for "yet to find oil" (Biswas 2012). With the depletion of the easily accessible hydrocarbon at the surface in the mature basin, presence of few inaccessible potential reservoir and increasing demand, new method needs to be employed that provides minimum risk as well as cost and maximum grade in short duration. Many source rock units are present in the central part of the Tarapur region due to higher maturity owing to high geothermal gradient (Biswas, 2013).

The current paper represents the result of adsorbed soil gas surveys carried out in Tarapur zone of Cambay basin. The main objective of research is to know the hydrocarbon prospects of the area based on the adsorbed soil gas analysis and to distinguish the anomalous zone of hydrocarbon by integrating it with geological and geochemical studies for exploration purpose.

Geological setting:

Cambay, an intracratonic rift basin is the northern extension of Dharwar rifting along the western margin forming its southern extension offshore as a narrow graben parallel to coast between Bombay high and mainland (Biswas, 1982). The half graben kind of basin geometry formed as a result of propagation of basin in sinusoidal manner having moderate angle along with the bounded listric fault pattern due to oblique extensional/trans-tensional dynamics (Kundu et.al, 1993; Thakreand Padhy, 1993; Padhy and Singh, 1998). Structural traps over block uplifts and block edge folds are responsible for the accumulation of hydrocarbon sequences ranging in age from Paleocene through Miocene and major middle Eocene (Raju and Srinivasan, 1993; Raju et.al, 2005).

The unique sedimentation patterns divide the Cambay Basin into Northern Depositional Basin, Central Depositional Basin and Southern Depositional Basin (Kundu et.al 1993). Tarapur block, between Mahisagar and Sabarmati rivers, is located at the central part of Cambay Basin. Mehsana-Ahmedabad and Jambusar-Broach blocks bound the Tarapur block in north and south directions respectively, along west and east borders basin marginal faults are present. Tarapur block shows the presence of multi-directional depositional system, sediments have been received from all directions in the depocenter (Biswas, 2013). Land derived dispersed organic matter is found in the sediments along with marine derivatives in bulk amount which indicates good source rock development for oil and gas directed capabilities (Shanmukhappa, 2011). Tarapur depression, the central part of the block is the junction between two anticlines- Tarapur syncline to the SW (Cambay Structure) and to the SE (Kathana Structure) with small structures in NW and SE, echelon faults form the important lineaments in the blocks (Dixit, 2010). Tarapur block is the only block of Cambay Basin which is devoid of post rift inversion that occurred during Miocene time in other blocks, in this block the syn-rift faults emerge from top of Deccan Trap and continues through syn-rift sediments as normal faults they got reactivated later on due to differential compaction in post-rift section (Misra et.al 2019).

Tarapur block has thinner syn-rift Olpad formation compared to other blocks deposited during Paleocene time (Misra et.al 2019). The Olpad formation is overlain by the source rock, thick Cambay Shale Formation which represents shallow marine environment, first major transgression of basin of Late Paleocene- Early Eocene times (Misra et.al 2019; Biswas et.al 2013; Bhandari and Chowdhary 1975). During Middle- Late Eocene, the other blocks contained deltas whereas the Tarapur block, devoid of delta formation, contained silt and shale, after Oligocene all the blocks had similar lithologies due to gross depositional environment (Misra, 2019). Babaguru Formation of Lower Miocene mainly consists of sandstone, lesser amount of mudstone, conglomerate and siltstone representing fluvial to shallow marine environment, its lower part represents Miocene Basal Sands owing to sand reworking by tidal processes which gives it better reservoir facies (Singh et.al 2013). The Tarapur block experienced delta progradation during Holocene as to high sediment load from Proto Mahi and Proto Vatrak rivers (Agarwal, 1995).

Stratigraphy of Cambay basin consists of Quaternary and Tertiary (Figure-1) sediments which are mainly sandstone, siltstone, claystone and shale (Biswas 1982, 1987, Merh 1995). The basement for these sediments were the Deccan Traps below which Mesozoic sediments are found to be present (Awasthi et al., 1971; Biswas, 1982, 1987; Kaila et al., 1990; Tewari et al., 1991, 2009; Dixit et al., 2010; Nabhakumar et al., 2012).

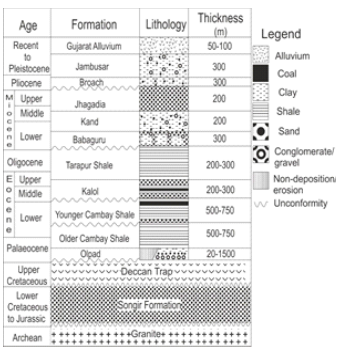

Figure-1 Generalized stratigraphy of Camby Basin (after Raju and Srinivasan, 1993)

Table:1 Statistical summary of adsorbed soil gas data (values in ppm)

	C1	C2	C3	iC4	nC4	iC5	nC5
Minimum	0	0	0	0	0	0	0
Maximum	170.68	81.46	98.58	90.42	94.01	4.36	1.36
Mean	7.85	0.61	0.34	0.21	0.22	0.01	0.00
Standard deviation	17.5085	4.30121	4.75257	4.34566	4.51796	0.20969	0.06539
Mean+ Standard deviation	25.36	4.92	5.10	4.56	4.74	0.22	0.07

Methodology Adopted

Field Work

435 soil samples were collected from 1-2 m depth range by manual hammering in grid pattern. The samples collected were labelled and their coordinates were noted using GPS (Rasheed et.al, 2008). Aluminum foils and poly-metal packs were used to seal the samples for their laboratory analysis.

Laboratory Proceedings

1 gm of wet sieved 63μm fraction sample is treated with orthophosphoric acid in vaccum to desorb light gaseous hydrocarbons from soil core samples. KOH solution is used to remove the CO2 evolved from carbonate minerals which separates the desorbed light gaseous hydrocarbons in a graduated tube fitted with rubber septa through water displacement (Kumar et al., 2002).

Thermally stable and volatile compounds of a mixture were identified and quantified using gas chromatography. A gas extraction system was used to extract light gaseous hydrocarbons (Horvitz, 1981). Electronic detection and identification of the given sample is done as it passes through column of the narrow tube. Stationary phase of the column separates various components in different time period due to their different retention times.

The volume of desorbed gases was noted and Vaian CP-3380 Gas Chromatograph coupled to Porapak Q Column and Flame Ionization Detector was used to inject 500 1 of gas. Calibration of the instrument was carried out using external standards of known concentrations of methane (C1), ethane (C2), propane (C3), i-butane (i-C4) and n-butane (n-C4). The gas concentrations are reported in ppm on dry weight basis. The GC accuracy of measurement of C1 to C4 components is ±1 ppb.

Results

Assessment of adsorbed soil gas data

Measurement of adsorbed soil gas data consists of graphical representation and statistical analysis (Table-1) to distinguish the anomalous sample data from the background samples (Abrams, 2005). The histograms and probability plots of C1 and C2+ are used to obtain the varying populations of samples in data set. Hydrocarbon cross plots and correlation coefficient of the data are used as tools for determining the hydrocarbon sources as well as for grouping of hydrocarbon pairings for inter-correlation (Belt and Rice, 2002; Schumacher, 2003).

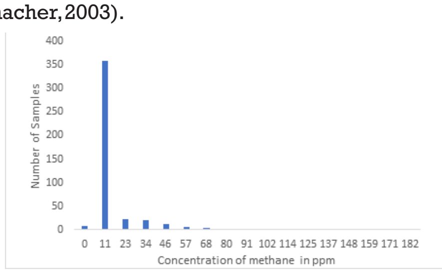

Figure-2Histogram for methane concentration

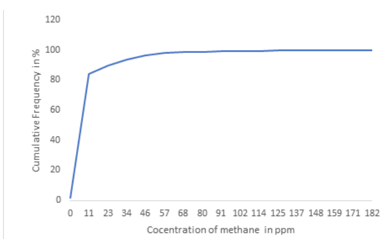

Figure-3 Cumulative frequency for methane

Table-2 Correlation coefficient between various adsorbed gas components

Component	C^1	C^2	C^3	C^{2+}
C_1	1.0	--	--	--
C_2	0.4	1.0	--	--
C_3	0.2	0.9	1.0	--
C_{2+}	0.3	0.9	1.0	1.0

Histograms enable to measure frequency distribution of variables in the dataset. For dataset with nearly normal frequency distribution, mean indicates the background and the samples with one or two standard deviation are anomalous (Abrams 2005; Mani et al. 2011a). Histograms of methane and C2+ shows positively skewed asymmetrical curve. Hydrocarbon cross plots enable to establish genetic relationship among hydrocarbons as well as to know linearity among themselves (Madhavi et al. 2009; Kalpana et al. 2010; Prasanna et al. 2010). The correlation coefficient of hydrocarbon components is given in Table 2 which indicates that there is a good correlation for all alkanes except for C1 which may be due to methane oxidizing bacteria.

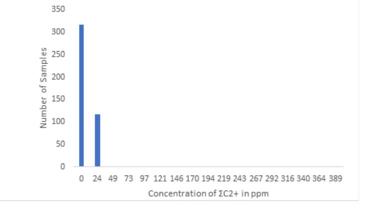

Figure-4 Histogram for $\sum C_{2+}$ concentration

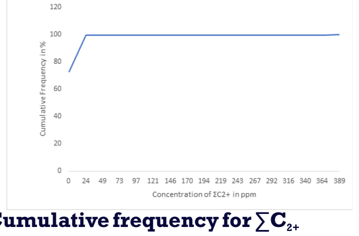

Figure 5: Cumulative frequency for $\sum C_{2+}$

Discussion

Adsorbed soil gas data

Histograms of methane and C2+ given in Figures 2& 4 with one standard deviation and mean plus one standard deviation, respectively (C1: 11 ppm and C2+: 24 ppm), as class interval shows an asymmetrical curve with positive skewness and the values skewed to the right are considered to be anomalous.

Linear transformation of normal distribution is obtained by cumulative frequency scale in probability plot and the straight line indicates normally distributed population whereas the change in slope indicates deviation in dataset from statistical normality (Rice et al., 2002). The probability plots of methane and C2+ of the Figure 3 & 5 show change in linearity at 23 and 49 ppm, respectively, separating the anomalous ones from the background population. The correlation coefficient for C2–C3, C2+ (Table 2) shows good linear correlation (r) and indicates that (i) these hydrocarbons are genetically related, (ii) they may be affected by secondary alteration during their migration from the subsurface or the bacteria may have oxidized the methane hydrocarbon, (iii) they may have been generated thermogenically.

REFERENCES

1. Abrams, M.A., 2005. Significance of hydrocarbon seepage relative to petroleum generation and entrapment. Mar. Petrol. Geol. 22, 457–477
2. Awasthi, D.N., Ramakotaiah, G., Varadarajan, S., Rao, N.D.J. and Behl, G.N., 1971. Study of the Deccan Traps of Cambay Basin by Geophysical methods. Bull. Volcanol., 35: 743-749.
3. Belt Jr., J.Q., Rice, G.K., 2002. Application of statistical quality control measures for near surface geochemical petroleum exploration. Comput. Geosci. 28, 243–260.
4. Biswas, S. K. (2012). Status of petroleum exploration in India. In Proc. Indian Natl. Sci. Acad (Vol. 78, No. 3, pp. 475-494).
5. Biswas, S. K. (1987). Regional tectonic framework, structure and evolution of the western marginal basins of India. Tectonophysics, 135(4), 307-327.
6. Biswas, S. K. (1982). Rift basins in western margin of India and their hydrocarbon prospects with special reference to Kutch basin. AAPG Bulletin, 66(10), 1497-1513.
7. Clark, J. R., Reno, N. V., & Tompkins, R. (2003, May). Mapping of reservoirs and subsurface structures using selective analysis of the surface chemistry of soil particles. In 88th Annual Meeting of AAPG (Extended Abstract), Salt Lake City, May (pp. 11-14).
8. Dixit, M. M., Tewari, H. C., & Rao, C. V. (2010). Two-dimensional velocity model of the crust beneath the South Cambay Basin, India from refraction and wide-angle reflection data. Geophysical Journal International, 181(2), 635-652.
9. Horvitz, L. (1981) Hydrocarbon prospecting after forty years. In: B.M. Gottleib (Ed.), Unconventional Methods in Exploration for Petroleum and Natural Gas II. Southern Methodist University Press, Dallas, TX, pp.83-95.
10. Kalpana G, Madhavi T, Patil D J, Dayal A M and Raju S V 2010 Light gaseous hydrocarbon anomalies in the near-surface soils of Proterozoic Cuddapah Basin: Implications for hydrocarbon prospects; J. Petrol. Sci. Eng. 73 161–170.
11. Kaila K. L., Tewari H. C., Krishna V. G., Dixit M. M., Sarkar D. and Reddy M. S. (1990) Deep seismic sounding studies in the north Cambay and Sanchor basins, India. Geophys. J. Int. 103, 621-637.
12. Khatri, A., Chauhan, P., Rao, P.S., & Rao, P.H. (2015). Hydrocarbon Prospectivity of Indian Sedimentary Basins-A Review. Energy Research, 4(2).
13. Kumar, B., Patil, D.J., Kalpana, G., 2002. National Facility for Studies on Surface Geochemical Prospecting of Hydrocarbons. Proceedings of 9th Annual India Oil and Gas Review Symposium, 9–10 Sept. Mumbai, pp. 274–278.
14. Kundu, J., Wani, M.R. and Thakur, R.K. (1993) Structural styles in South Cambay Rift Basin and its control on post rift deltaic sedimentation: Proc. of the 2nd Seminar on Petroliferous Basins of India, eds. S. K. Biswas et al., Indian Petroleum Pub., Dehradun, Vol. 2, P. 79-96
15. Madhavi, T., Satish Kumar, T., Rasheed, M.A., Kalpana, G., Patil, D.J. and Dayal, A.M. (2009) Light hydrocarbon geochemistry of surface sediment from petroliferous region of the Mehsana block, North Cambay Basin. Jour. Geol. Soc. India, v.74, pp.7- 15.
16. Mani D, Kumar S T, Rasheed M A, Patil D J, Dayal A M, Rao T G and Balaram V 2011a Soil iodine determination in Deccan Syneclise, India: Implications for near-surface geochemical hydrocarbon prospecting; Nat. Res. Res. 20 75–88
17. Mathur, L. R, K. L. N. Rao, and A. N. Chaube, 1968, Tectonic framework of Cambay basin, India: India Oil and Nat. GasComm. Bull., V. 5, p. 7-28.
18. Mayor, S. et al, (2004) Identification of Prefered Reservoir development in Olpad formation for the exploration of deeper prospects Broach block, SPG 2004.
19. Merh, S.S. (1995). Geology of Gujarat. GSI Publications, 2(1).
20. Nabhakumar K, Lakra M N, Kumar D and Niyogi K 2012 Estimation of thickness of Deccan trap in Broach Jambusar block of Cambay basin – an innovative approach; 9th Biennial international conference and exposition on petroleum geophysics, Hyderabad, 114p.
21. Padhy, P. K., & Singh, D. (1998, October). Geologic setting and petroleum system of heavy oil occurrences in sedimentary basins of India. In 7th UNITAR international conference on heavy crudes and tar sands, heavy oil—a major energy source for a 21st century, (2) p (pp. 1580-1589).
22. Prasanna M V, Rasheed M A, Madhavi T, Kalpana G, Patil D J and Dayal A M 2010 Light gaseous hydrocarbon anomalies in the near-surface soils of Sagar District, Vindhyan Basin, India; Curr. Sci. 99 1586–1590.
23. Raju D S N, Peter James, Ravishankar and Kumar Gopendra (2005) An overview of Litho-Bio-Chrono Sequence stratigraphy and sea level changes in Indian sedimentary basins In: APG Special Publication, Allied Printers, Dehradun, pp 210.
24. Raju, A. T. R., & Srinivasan, S. (1993). More Hydrocarbons from well explored Cambay Basin: Petroleum Asia Journal.
25. Rasheed, M. A., Prasanna, M. V., Kumar, T. S., Patil, D. J., &Dayal, A. M. (2008). Geo-microbial prospecting method for hydrocarbon exploration in Vengannapalli Village, Cuddapah Basin, India. Current Science, 361-366.
26. Rice G K, Belt J Q Jr, Berg G E 2002 Soil-gas hydrocarbon pattern changes during a west Texas waterflood; In: Surface exploration case histories: Applications of geochemistry, magnetics, and remote sensing (eds) Schumacher D and LeSchack L A, AAPG Studies in Geology No. 48 and SEG Geophysical References Series No. 11, 157–174.
27. Schumacher, D., &Clavareau, L. (2012). Finding New Pays in Old Plays: New Applications for Surface Geochemistry in Mature Basins.
28. Schumacher, D., 2003. Geochemical Exploration for Oil and Gas-Strategies for Success: An Exploration Short Course sponsored by National Geophysical Research Institute, Hyderabad, India, December 8, 2003, pp. 1–175.
29. Sokolov, V.A., Geodenkyan, A.A., Grigoryev, G., Krems, A.Y., Stroganov, V.A., Zorkin, L.M., Aeiddson, M.I. And Vainsaum, S.J. (1970) The new methods of gas suverys, gas investigations of wells and some practical results. Can. Inst. Min. Metal., v.11, pp.538-543
30. Tedesco, S.A., 1995, Surface Geochemistry in Petroleum Exploration.
31. Tewari, H. C., Rao, G. S. P., & Prasad, B. R. (2009). Uplifted crust in parts of western India. Journal of the Geological Society of India, 73(4), 479-488.
32. Tewari H. C., Dixit M. M., Sarkar D. and Kaila K. L. (1991) A crustal density model across Cambay basin, India and its relationship with the Aravallis. Tectonophysics 194, 123-130.
33. Thakre, A. N., &Padhy, P. K. (1993). Cambay rift basinarchitecture and exploration play system. Abstract Vol." Rifting of Wstern margin of India and its bearing on geological evolution and mineralization.
34. Waples, D. W. (2013). Geochemistry in petroleum exploration. Springer Science & Business Media.