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# Hydrocarbon Exploration in Sediments of Gulf of Kutch Using Geochemical and Stable Isotope Techniques

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## Summary

*Seafloor sediment samples collected from the Gulf of Kutch, located in the northwestern part of India and have been analyzed for hydrocarbon gases resident in samples by using the technique of adsorbed gas analysis, the results reveal that the gas content is in tens to hundreds ppm (vol. in wet sediments). These hydrocarbons are genetically related and might have been generated from a thermogenic source because of the presence of $C_2$ & $C_3$ components. The stable carbon isotope signatures of individual hydrocarbon components indicate the gas generated from thermogenic source. Based on gas chromatography and isotopic analysis the origin for these gases may be thermogenic. The preliminary investigation suggests that area seems to be warm for future hydrocarbon exploration.*

## Introduction:

Technique for surface geochemical exploration for hydrocarbons consists of taking shallow cores from sea floor and analyzing them by geochemical means to detect various types of surface anomalies. The basis of the method is to map the concentration of light gaseous hydrocarbons in sediments. The concentration differences presumably reflect differences in flux of gases from lower depths, which in turn reflect migration from hydrocarbon traps. This seepage of hydrocarbons is usually classified in terms of macro-seepage and micro-seepage. While the macro-seepage is defined as flow of large quantities of petroleum to the surface along confined migration routes such as faults and fractures, the micro-seepage on the other hand is less dramatic as it involves minute amounts of hydrocarbons. It is pertinent to mention here that we did not encounter any evidence of macro-seepage in the samples analyzed in the present study. Some workers (Kennicutt et al., 1988) have put the upper concentration limit for micro-seepage to be 500 ppm of extractable organic matter in sediments. Possible mechanisms for micro-seepage have been proposed by Price (1985).

The purpose of this paper is to present initial results on gases found in shallow marine sediments from the Gulf of Kutch region. The objective was to map the presence and distribution of gas seepage and to identify areas with a high potential for petroleum reservoirs but because of limited number of samples that could be collected during the survey, only the source of light gaseous hydrocarbons will be discussed.

Hydrocarbons reside in sediments in variety of forms including adsorbed gas (liberated on acid treatment), interstitial gas (liberated by means of mechanical disintegration) and headspace gas (free gas). The data pertaining only to sediment core analysis is presented here.

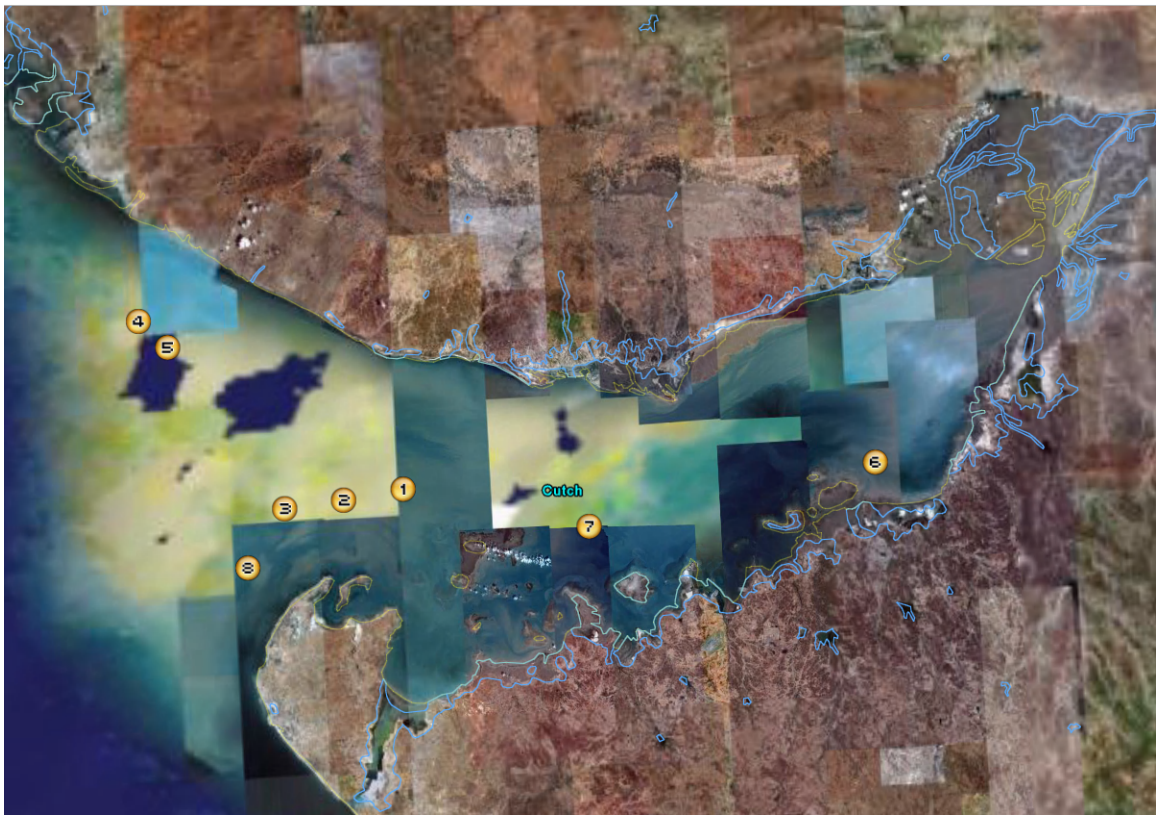


Fig. 1 Sample location map, Gulf of Kutch.

The survey was taken up jointly by National Geophysical Research Institute and Scripps Institution of Oceanography, San Diego for Marine Magnetotelluric (MMT) surveys for delineating Mesozoic sediments buried below the basaltic cover. Hence, the major ship time was taken up by this survey. However because of constraints in time and facilities (only 50 m length of winch cable was available for gravity corer) onboard ORV Boris Petrov, thus only 8 locations could be tried, out of which only 4 locations yielded samples for analysis. Gravity corer with an overall weight of 1500 Kg was used to sample the shallow sediment. The 6 inch bottom most portion of sleeve (12 cm dia.) of gravity core was cut, placed in polythene bag and Shifted to onboard cold storage room maintained at –4°C. In all but one location, 1-meter sediment core was possible.

Sediment gas has many sources including bacterial methanogenesis, thermal cracking of kerogen or coal, or by secondary cracking of oil. Bacterial gas is identified by the presence of methane with low $\delta^{13}C$ values (<-55‰). Overall, gas chemistry is also indicative of its origin because microbial processes produce only methane in significant quantities (>1 mol vol. %), so that higher chain hydrocarbons are attributable to thermogenic generation.

The Gulf of Kutch, covering nearly 7000 $km^2$, is located in the northwestern part of India between $22^0 15'$ to $23^0$ N and $69^0$ to $70^0 15'$ E. The east-west length of Gulf is ~ 180 km, while the width decreases from ~70 km in the west to about 1-2 km in the narrow creeks at Navlakhi in the east. The geomorphological studies of Kutch show that the present topography is very young and that there has been very late uplift. Four plains of erosion have been recognized in the Kutch, viz. Paleocene, Post-Paleocene, Post-Miocene and Early Quaternary. The Jurassics out crop in E-W trending anticlinal ridges cover a large area and their thickness is estimated to be 1950 m. The overlying marine Tertiary formations represent a shelf facies and attain a thickness of 600 m in the southwest. These are bordered to the south by Deccan Traps while on the north lies the saline marsh of the Rann of Kutch

## Methods and Results:

Sediment core samples were subjected to gas chromatographic and compound specific isotopic analysis the results of which are described below

*Adsorbed Gas Analysis*

Light gaseous hydrocarbons were extracted from the four sediment samples collected from Gulf of Kutch using a gas extraction system (Horvitz 1981). Chemical compositions of methane ($C_1$), ethane ($C_2$),

propane ($C_3$), i-butane ($iC_4$), n-butane ($nC_4$) have been measured by Varian Gas Chromatograph using flame ionization detector. The detection limit of GC is reported to be 1 ppb.

Molecular characteristics determined by Gas Chromatographic method on surface sediment gases very with type of gas present in the sediment. The analysis indicates that the concentrations of methane ethane propane and butane are moderate to high, methane being the dominant gas followed by ethane and propane in the analyzed samples only one sample showed the presence of butane. The cross plots between $C_1$-$C_2$; $C_1$-$C_3$ and $C_2$-$C_3$ show excellent correlation Fig 2. ($r \geq 0.9$) indicating that i) these hydrocarbons are genetically related; ii) are not affected by secondary alteration during their migration from subsurface to subsequent adsorption in the sediment and iii) might have been generated from a thermogenic source because of the presence of $C_2$ & $C_3$ components. The relative amounts of methane ethane propane and butane provide a clue about the origin of gases in the analyzed sediments. It may be possible that methane can be derived from either biogenic or thermogenic processes but the wet gases (ethane, propane and butane) are believed to be derived from only thermogenic source.

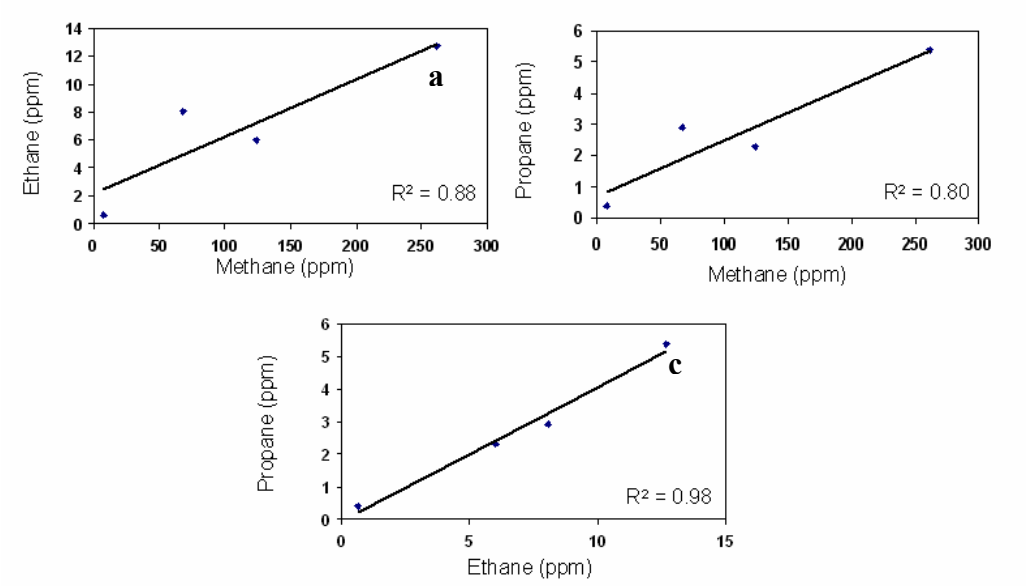


Fig. 2 Cross plots between a) $C_1$ & $C_2$; b) $C_1$ & $C_3$; c) $C_2$ & $C_3$

*GC-IRMS Analysis*

Isotopic composition of gases extracted from the sediments namely methane, ethane and propane were measured using GC-IRMS, which comprises of Agilent 6890 Gas Chromatography coupled to a Finnigan-Delta plus $^{XP}$ Isotope Ratio Mass Spectrometer. All samples were analyzed in the Stable Isotope Lab of National Geophysical Research Institute. $\delta\ ^{13}C$ values are reported in the $\delta$ notation in parts per thousand deviations, relative to PDB standard. Replicate analysis performed on some samples yielded values within $\pm$ 0.5‰.

1 ml of desorbed gas was injected in GC-C-IRMS to determine the isotopic compositions of $C_1$ to $C_4$ components. However only methane ethane and propane peaks could be identified in the analysis. Data points of all samples plot within the zone of thermal gas generation in the Bernard diagram.

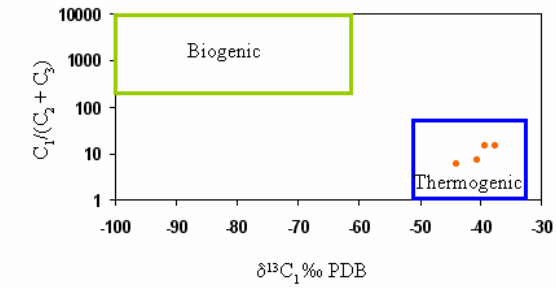


Fig.3 Relation between the logarithm of $C_1/(C_2 + C_3)$ and the isotopic composition of of hydrocarbons in sediments.

## Conclusion

The light gaseous hydrocarbons namely methane, ethane and propane in sediments were derived from the same source, not altered and based on gas chromatography and isotopic analysis the origin of these gases is thermogenic. As this preliminary

investigation suggests that area seems to be, warm and detail geochemical sampling along with geological data are need for any meaningful hydrocarbon exploration.

## Acknowledgement

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