8th Biennial International Conference
& Exposition on Petroleum Geophysics

"HYDERABAD 2010"

P-284

Geochemical Exploration-Near Surface Expression of Hydrocarbon: A Case Study from Frontier Block of Assam-Arakan Basin

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Summary:

The principal objective of a geochemical exploration survey is to establish the presence and distribution of hydrocarbons in the area and, more importantly, to determine the probable hydrocarbon charge to specific exploration leads and prospects.

The conventional geochemical techniques have included direct soil analysis, active soil gas measurement, and microbial techniques for detection of hydrocarbon on surface with some limitations. The limitations include the poor adsorptivity of soils, sampling difficulty due to poor soil permeability, low analytical sensitivity, and limited data sets of C_1-C_5 hydrocarbons (methane-pentane), problems resulting from variable meteorological conditions, and interference from biologically generated methane. To deal with the limitations of early surface geochemical survey, a more advance and well established technique has been deployed which uses the passive sorbent-based collector with time-integrated approach of hydrocarbon detection over an extended period of time. The passive soil vapor sampling device results in direct detection of surface hydrocarbons potentially related to micro seepage from reservoir hydrocarbons.

This study focuses on the characterization of hydrocarbon microseepage using geostatistical analysis of regional hydrocarbon geochemical data yielded from soil samples in one of the frontier block of the Assam Arakan basin. The result of near-surface and subsurface data can be integrated to add confidence to the interpretation and a predictive tool to reduce exploration risk. The scope and perspective of passive geochemical surveys in this frontier block of Assam Arakan Basin of India are presented here.

Introduction:

Geologically the survey area is quiet complex with repeated folding and thrusting coupled with steep sub-surface dip of the strata, that seismic interpretation alone may not be able to reduce the risk of exploration. It is therefore desired that, seismic interpretation needs to be guided by a robust geological model combined with geochemical analysis of the area of interest to mitigate the exploration risk.

The surface geochemical prospecting clearly identified anomalously high surface occurrences of hydrocarbon compounds and such anomalies can be linked to a migration of hydrocarbons into scattered accumulations. Hydrocarbons generated and trapped beneath the surface seep or leak to the surface in varying but detectable quantities. These phenomena occur because processes and mechanisms such as diffusion, effusion, and buoyancy allow hydrocarbons to escape from reservoirs and migrate to the surface where they may be retained in the sediments and soils or diffuse into atmosphere or water columns (Klusman, 1993; Schumacher and Abrams, 1996) (Fig.-1).

The survey area is located within the Assam – Arakan sedimentary basin of eastern India. The basin system includes shelf slope and basinal components, with the shelf slope area covering the Brahmaputra Valley and the basinal component including the Naga Schuppen, Cachar, Tripura, Mizoram, and Manipur fold belts.

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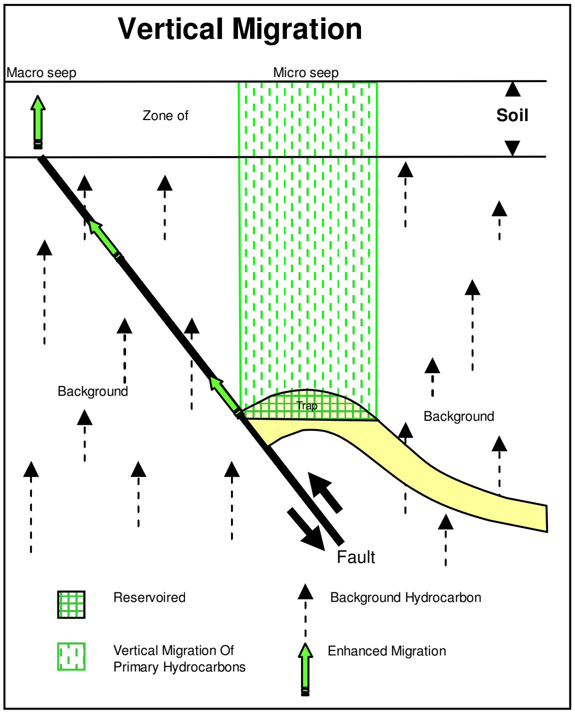


Figure 1 – Concept of surface micro seepage
(Adapted from Potter et al, 1996)

Methodologies:

To deal with the deficiencies of the conventional surface geochemical techniques, the passive sorbent-based collector is deployed to eliminate or minimize the above said limitations. The design and application of the new technique has focused improvements in four areas:

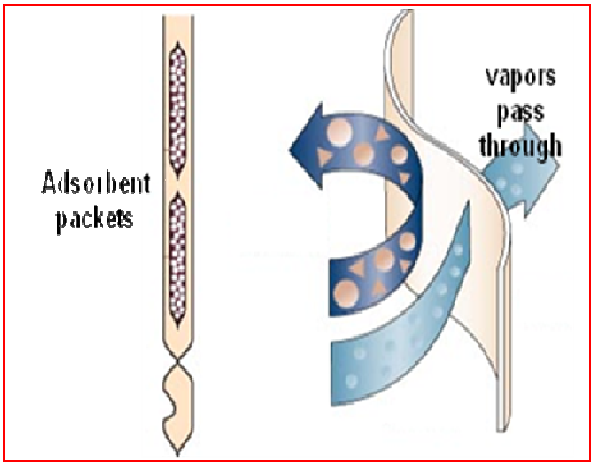
1. The collector was designed to eliminate issues with soil adsorbtivity and non-uniformity, and
2. The deployment method eliminates the effects in variation in both soil conditions and ambient weather conditions, and
3. The analytical method was improved to expand the data set allowing for multivariate analysis and the method significantly boosts sensitivity allowing detection of hydrocarbons and
4. A multivariate analytical technique was applied to utilize the robust data set to improve the imaging of charged hydrocarbon reservoirs.

The collector consisting of sorbent collection units (sorbers) composed of hydrophobic adsorbent specifically to collect C_2-C_{20} hydrocarbons was carefully selected because of their affinity for a broad range of volatile and semi-volatile organic compounds while minimizing uptake of water vapor.

The collector (Fig-2) is easily deployed by inserting it into narrow diameter holes drilled into the ground to about 0.6 meters depth. Field installation and retrieval are easy and low cost and allows economical deployment over difficult terrain, with no disruption to landowners or the environment. The module is left in the ground for a period of about 17 days, during which it passively collects volatile compounds in the soil and vertically migrating from the reservoir. This extended period smoothes out any potential variations due to atmospheric changes, solar heating, rain, or other meteorological events. Additionally, the longer time boosts the hydrocarbon signal on the module by continually collecting vapors while in the ground. The collector is retrieved by hand and returned to the laboratory for analysis and data processing.

Geochemical Survey Design

Prior to initiating a survey, specific survey objectives are established with appropriate sampling scheme and modeling strategy is identified. Information relating to target size and type, any preferred reservoir orientation characteristics, such as channel sand, and the existence of analogous production and specific well characteristics and production history are important factors in developing an appropriate survey design. Sample spacing generally ranges from 300 meters to one kilometer following a regular or variable spacing.



(Courtesy: W. L. Gore & Associates, Inc, USA)
Fig-2: Gore-Sorber Module

Data Processing and Modeling

This newly advanced technique incorporates statistical processing and modeling of the complex geochemical signatures obtained for each sample. Some of the processes include hierarchical cluster analysis and discriminant analysis. After completion of the organic compound signal-to-noise evaluation, and removal of disqualified compounds from the data, field sample data is processed statistically to determine the potential for outlier samples. Field sampler data were transformed from chemical response values to component scores using Principal Component Analysis (PCA) which is used later in data interpretation and mapping. Canonical variants analysis (CVA) was used for evaluating the relationship between sets of variable measurements.

Soil gas data are processed statistically using mathematical transformation and classification algorithms such as Principal Component Analysis (PCA), Hierarchical Cluster Analysis (HCA), and Linear Discriminant Analysis (LDA).

Hierarchical Cluster Analysis (HCA)

The Hierarchical cluster analysis method is used to determine the structure of a set of data when no other geological or geophysical information for the prospect are available. HCA proceeds by grouping samples of like composition according to the values of all input variables. The result is a list of subsets of samples of the data which are alike (forming "clusters" of similar samples). Since the input variables of the data are in the form of hydrocarbon compound intensities, the clusters are subsets of chemically similar samples. The results of HCA is further used to classify the samples of the data (i.e.; whether particular samples show petroleum hydrocarbon influence).

Discriminant Analysis (DA)

Discriminant analysis is a multivariate data classification technique. At least two subsets of input samples must be identified as belonging to separate groups. The DA technique then finds the best separation of the groups in a minimum residual sense, in terms of the input variables for the samples. Since the input variables are of a chemical nature, the separation of the sample groups is expressed as a chemical difference between the groups. The classification of samples of unknown influence is then performed; each unknown sample is compared to the identified groups of samples and a probability of match to each sample group is calculated. Therefore, if a group of samples is identified as petroleum-influenced, and another group of samples is identified as being like geochemical background, DA statistically describes the difference between these two groups. The comparison of unknown samples to these two groups yields for each unknown sample a probability of being like the petroleum influence, as well as a probability of being like the geochemical background influence.

Example:

The survey is carried out in Mizoram which is one of the frontier blocks of OIL's operational area. The field samples (867 samples) were acquired using the GORE module passive soil gas collector along the stations as shown in the Fig.-3. Survey samples were placed at variable intervals ranging from approximately 500 m to 1000 m along trail or road. The samples were placed in the soil to a depth of at least 60 cm for a period of around 17 days. Data pre-processing were carried out in order to remove noise variables and determination of data fitness for use with Canonical Variates Analysis (Fig.-4). Sample data were plotted by two separate procedures to determine if spurious data points exist. Component scatter plots and the Mahalanobis distance plot of samples were examined for evidence of outlier samples (Fig.-5). These techniques involve plotting sample data points according to their inherent data space distance from some reference point. Spurious data values may be defined as significantly distant from the majority of survey data on various plots of chemical data space. Outlier samples are removed from the data to avoid corruption of sample classifications. Mahalanobis distance plot is drawn for the geochemical survey data where survey samples are shown along x-axis and ordinate shows multivariate data space distance from sample to survey data centroid of all measured organic compounds. Distance is a function of mean and standard deviation of the survey data, taking into account the multivariate shape of data in the distance calculation. Sample distances are calculated by first excluding the sample from mean and standard deviation calculations for the survey data. Potential outlier samples are defined at data space distance of between 5 and 10.

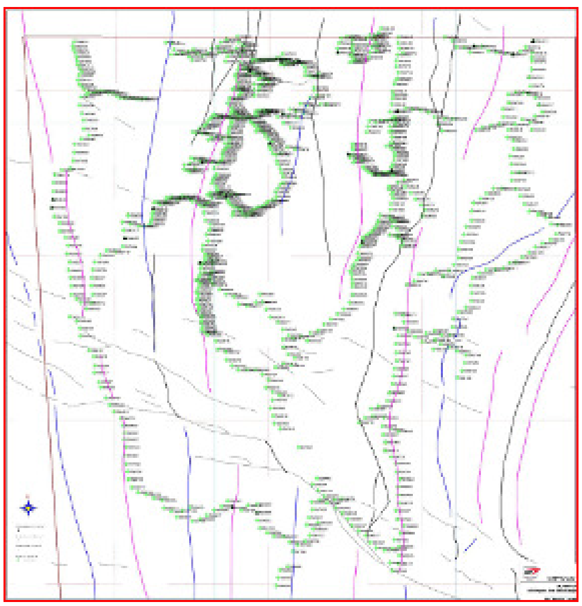


Fig.3: Geochemical samples base map

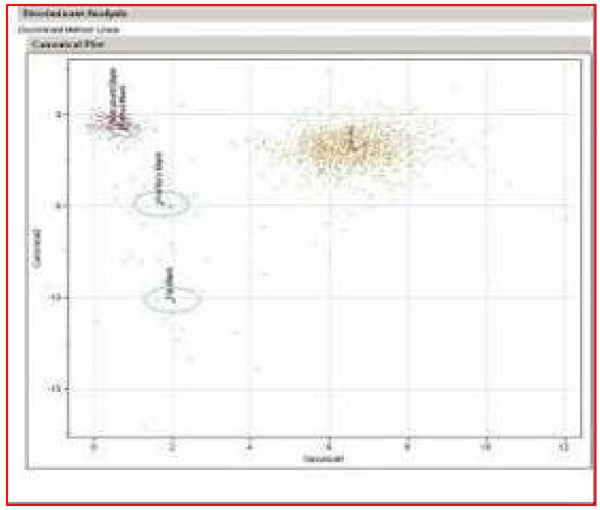


Fig.4: Canonical plot–showing good sample class separation

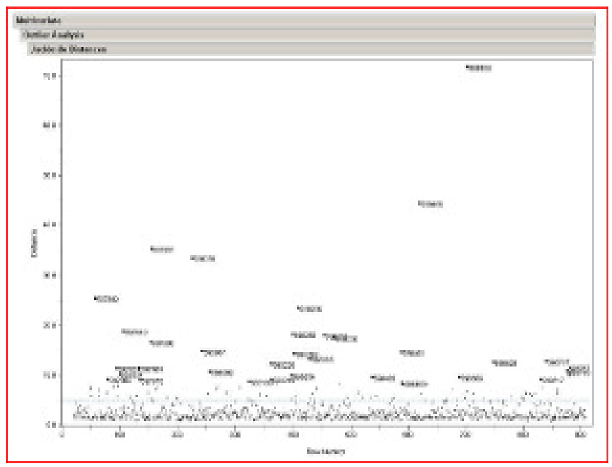


Fig.-5: Mahalanobis distance plot

The chemical data space was transformed to component space using principal component analysis. The transformed data were then input to linear discriminant analysis to determine the geochemical differences between the end-member model sets and simultaneously compared all survey sample analytical results to the signatures of the geochemical models. End-member model sets were determined by the application of Hierarchical Cluster Analysis (HCA).

Since no petroleum production or dry well sites were available for calibration a geochemical model is also prepared for this survey data using the cluster analysis technique The result of the model comparison was a probability value indicating whether a given field sample was of petroleum character (high probability value), or of geochemical background character (low probability value).

The geochemical signature of interpreted geochemical survey data is shown in Fig-6(b) representing the petroleum influence.

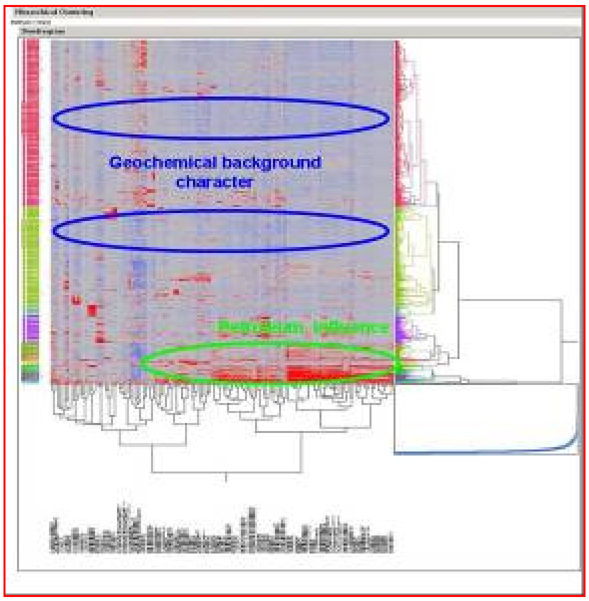


Fig-6: Hierarchical cluster analysis dendrogram

The evaluation of cluster results, indicated by Fig-6 led to the calculation of Geochemical Model (Fig-8) for petroleum influence. This model defines several prominent geochemical anomalies in the northern part of the survey area. The signature plot of this geochemical model is shown in Fig.-7.

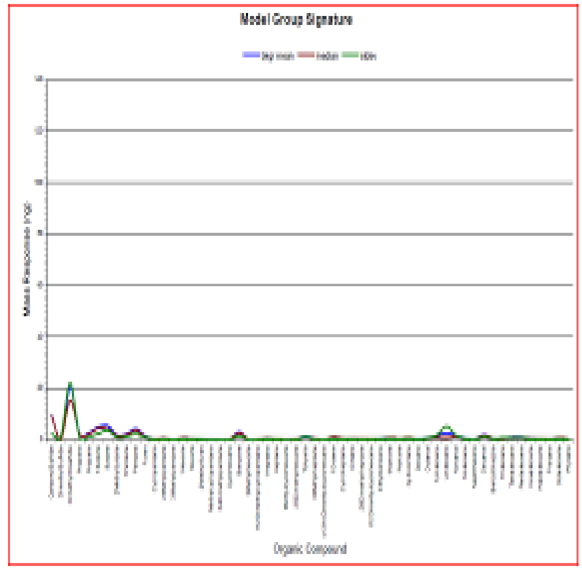


Fig.-6(a) Geochemical signature of sample representing regional background character

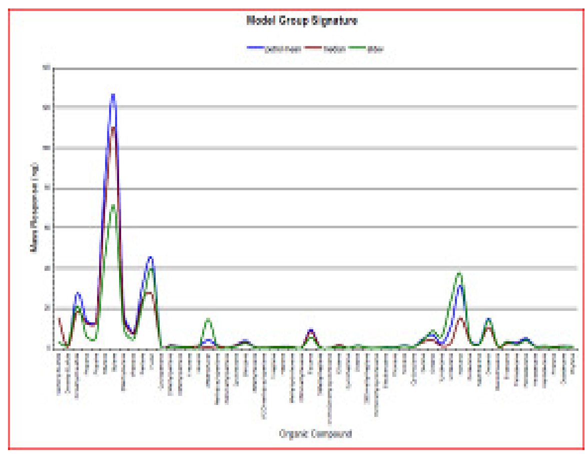


Fig.6(b)- Geochemical signature of sample subset group representing petroleum influence.

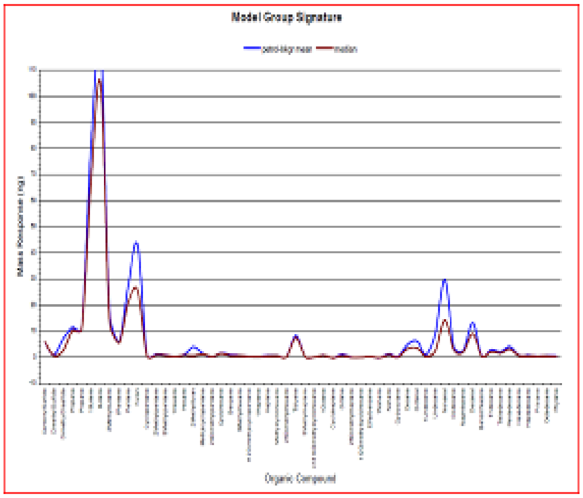


Fig-7: Signature plot of Geochemical Model

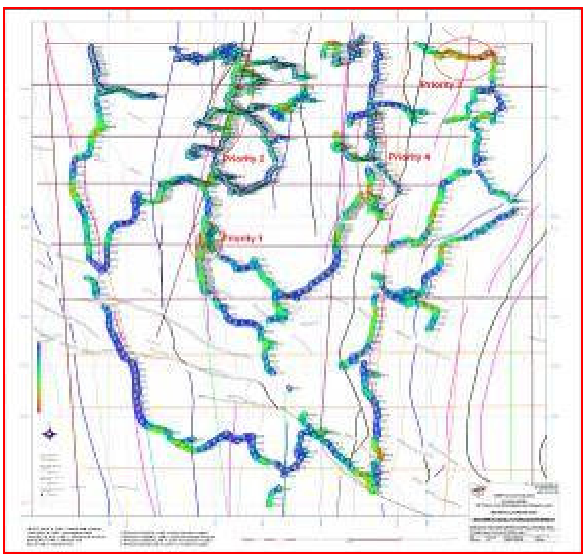


Fig-8: Geochemical Model

Signature plot (Fig.-8) of Geological model is calculated as the difference between the petroleum influence signature and the background influence signature across all compounds. Blue line is mean value, red line is median and green line is standard deviation. Model is an enhanced light alkane model (C3 – C5), with slight heavy alkane compound contribution (C10 – C15). The model character is consistent with gas prone thermogenic hydrocarbon generation.

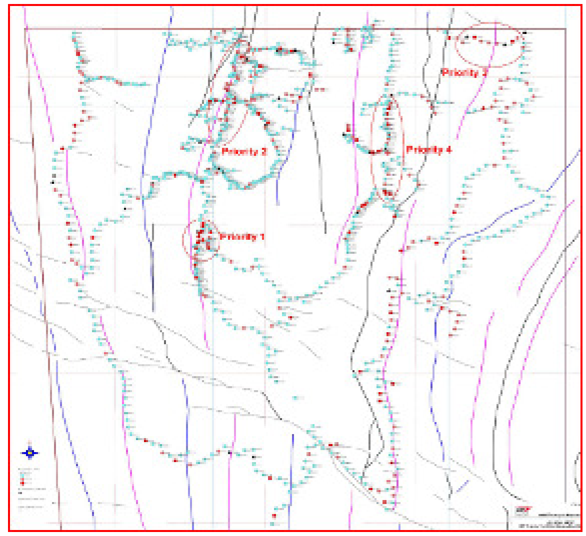


Fig-9: Map of summed light Alkane mass response.

In Fig-9 the sample location symbols are color coded according to the log base 10 value for summed mass. Red color symbols show regions of high light alkane emanation, and blue colors represent low (background) emanation areas. Geochemical anomalies are defined by higher summed values, and generally correspond to or encompass geochemical features defined by Geochemical Model.

Results:

The objective of this survey was to define and delineate hydrocarbon signatures related to petroleum prospectivity in the frontier block as well as to determine the hydrocarbon concentration in that area and thereby reduce the risk of exploration and increase the confidence level for proposing locations for exploratory drilling. After interpretation of the geochemical survey the prospects are identified and are indicated on map by priority number as shown in Fig-9. Leads #1 and 2 are located on the Aizawl (Aibawk) anticline, Lead #3 is on the Keifang anticline, and Lead #4 is on the Seling anticline. The model character is also consistent with gas prone thermogenic hydrocarbon generation.

The result of this geochemical survey will be integrated with other geological or geophysical information to prioritize areas for exploratory drilling in Mizoram block.

Conclusions:

Seepage is a fascinating phenomenon which has played a unique role in frontier exploration and the approach of generating a geochemical model by independent geophysical observations has led to an objective exploration strategy in this frontier area. The multivariate statistical techniques employed to analyze the geochemical data proved very efficient and provided an easy understanding of the spatial distribution of microseepage over the entire basin. Few locations having good hydrocarbon probability (Fig.-9) have also been identified in this frontier block as a result of this amplified geochemical imaging technique. However, the surface geochemical exploration method cannot replace conventional exploration methods, but they can be a powerful complement to them and the combination of surface and subsurface exploration methods do help in mitigating the exploration and development risk.

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Acknowledgements:

This paper appears with the kind permission of management of OIL and W.L. Gore & Associates, USA for allowing this article to be published. The authors are also thankful to Suveera Energy, Mumbai for their immense support.