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# Integration of Geochemical and Seismic attribute Data: Enhancement of hydrocarbon exploration success ratio

*S.K.Thadoju*[1], B. R. Bharali[2], Reba Devi[1] & B. P. Sarma[1], Oil India Ltd.*

***Summary***

*In present day scenario exploration for hydrocarbons needs a paradigm shift in integration approach and it can be achieved by interpretation and integration geochemical data with seismic data is best practice strategies to enhance hydrocarbon exploration success ratio. An analysis of adsorbed soil gases distribution of light hydrocarbons from the southern part of Gouthami- Godavari Delta, KG basin, reveals new insight to the complex origin of gas. Sub-surface soil samples represent the intersection of a major migration conduit from the deep subsurface. The geochemical behavior observed that condensate gas in nature. Fairly active seepage suggests largest magnitude of soil gas anomalies in S & SW and dominated fault related seepage, which is thermogenic in nature. Integrated the geochemical anomalies, seismic volume attributes anomalies and structuration at Early Cretaceous is well correlated and these prospect areas are might be favorable for hydrocarbon exploration in future.*

***Keywords**: Adsorbed soil gas, light hydrocarbons, seismic attributes, KG Basin*

## Introduction

Present day exploration for oil and gas requires a coordinated effort based on the successful integration of geophysics, geology, and geochemistry. Seismic data are unrivaled for imaging trap and reservoir geometry; no direct information about whether a trap is charged with hydrocarbons. However, the geophysical data will maintain its importance, the expanding application of geochemical and, more specifically, hydrocarbon microseepage surveys can help reduce the risks and costs of exploration projects by predicting probable hydrocarbon charge, identifying structural and subtle stratigraphic traps, improving exploration success by helping avoid unnecessary dry holes. The basic assumption of near- surface geochemical exploration is that thermogenic hydrocarbons generated and trapped at depth, leak in varying quantities towards the earth's surface in detectable amounts (Schumacher et al, 1996, Jones et al, 2000; satish, 2009). The near-surface geochemical anomalies are close association with faults and fractures are well known. These fractures act as favored pathways for hydrocarbons flow from the source beds to the reservoir, and from there on towards the surface.

Seismic attributes are the fundamental pieces of information contained within a recorded seismic trace: time, amplitude, frequency, and attenuation (Brown, 2001). It is widely used method to decrease the spatial uncertainty of the parameter prediction. The attributes analysis allows identification of seismic facies and its geometry of a buried volume of rock that would typically be beneath the resolution of traditional seismic amplitude data. The paper describes application of geochemical prospect and integration with seismic attribute to enhance hydrocarbon exploration success ratio and also 1) to establishing hydrocarbon seepage 2) identification of source of gas 3) delineation of anomalous areas for future hydrocarbon exploration.

[1.] *G&R Dept., Oil India ltd, Duliajan,Assam*
[2.] *KG project, KG Basin, Oil India Ltd, Andhra Pradesh*
*G & R Dept., Oil India Ltd, Duliajan, Assam-786602;*
*satishkumar.thadoju@gmail.com*

The study area is situated in southern part of Goutami-Godavari river; Krishna-Godavari Basin (KG Basin) covered 141 sq km (Fig-1). The KG Basin is pericratonic basin and one of petroliferous basin of India. It is located near the mid point of East Coast Peninsular India. It is associated with rifting and drifting tectonics, followed by development of platform type carbonates, and in the final stage is superimposed by a delta system. The study area lies in the Gouthami- Godavari Delta and falling between Chintalapudi and Pithapuram cross trends. Tectonically majority of the area is within the rift/drift tectonics and NE-SW trending basin margin fault area. Generalized stratigraphic succession of the area is shown in Table 1. Stratigraphy in study area is from Early Cretaceous to recent.

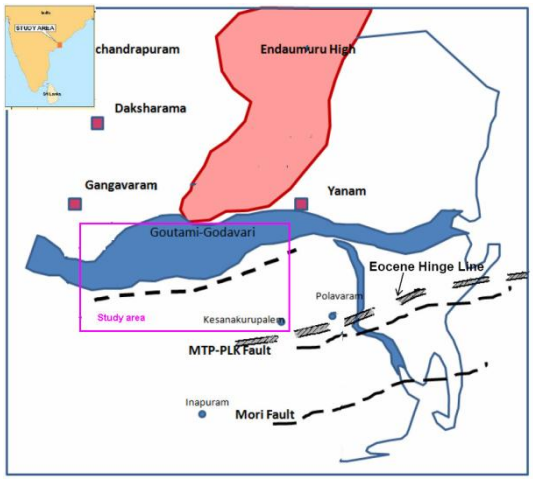


Fig-1: The location map with Major tectonic features of study area, KG Basin

## Materials & Methodolgy

The Soil gas survey (adsorbed soil gas) has been carried out during 3D seismic acquisition and sample collected at seismic shotholes as improves the quality and information content of geochemical data. A total 202 soil samples was collected in grid pattern with interval 2.5km at depth of ~2.5m. The adsorbed soil gas analysis was carried out using GC-FID to analyzed light hydrocarbons (Methane-$C_1$, Ethane-$C_2$, Propane- $C_3$ and Butane-i$C_4$, n$C_4$). The calibration of GC was done by using external standards and quantitative estimation of light gaseous hydrocarbon constituents in each sample was done on the basis of peak area measurement and the correction for moisture content was applied to the data obtained. The accuracy of measurement of $C_1 - C_4$ components is ±1 nano- liter/gram (nL/g). The statistical data of geochemical analysis is given in Table-2.

Table-1: Generalized stratigraphic succession of study area

| AGE | Ma | Formation | Lithology | Expected Fm. Top range (m) | Lithologic Description |
|---|---|---|---|---|---|
| Recent | 0.01 | Rajamundry Sst./ Godaveri Clay | | Not defined | -Brick colored ferruginous s.st.<br>-Clay stone expected |
| Miocene | 23 | Narsapur Clay St. | | | |
| Oligocene | 34 | Matsyapuri Sst. | | 500- 700 | -S.st with Shale/clay interbeds |
| Eocene | 56 | BMP Lst | | 600- 950 | -Mainly Lst |
| | | Pasarlapudi Fm. | | | -Shale with lenticular sand bodies |
| | | Palakollu Shale | | 1000-1650 | -Mostly shale; possible channel sand in the area |
| Paleocene | 65 | Razole Fm. | | | -Present at northern part but some remnant possible in parts of the area |
| Cretaceous | 145 | Raghavapuram Shale/ Chintalapalli Shale | | 1400- 2400 | -Dominantly shale. channel sand bodies expected |
| | | Gollapalli S.st. | | 4700-5900 | -Dominantly syn -rift sandstone with shale interbeds<br>-Absent in the northern part or very thin cover of sediment in parts of the area |
| Archean | 3800 | | | 3700- 8500 | Metamorphic/ quartzitic Basement |

Table-2: Summary of statistical parameter of soil gas constituents.

| | $C_1$ | $C_2$ | $C_3$ | $\varepsilon C_4$ | $\varepsilon C_2$+ |
|---|---|---|---|---|---|
| **Mean*** | 44.79 | 6.76 | 3.09 | 0.21 | 10.07 |
| **Median** | 37.20 | 4.63 | 2.25 | 0.00 | 7.08 |
| **Mode** | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Standard Deviation** | 35.10 | 6.17 | 5.80 | 0.70 | 10.46 |
| **Skewness** | 1.83 | 1.47 | 7.97 | 4.05 | 2.25 |
| **Minimum** | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Maximum** | 232.51 | 36.59 | 67.61 | 5.29 | 71.01 |
| **Anomaly** | 62 | - | - | - | 16 |

* Mean value is considered as background value

The 3-D seismic data of 141 sq km has been acquired and seven (7) regionally correlatable sequences were mapped in the area. Various seismic attributes were generated at possible reservoir surfaces to capture grossly facies patterns of those horizons. These attribute patterns fairly matching with some of the structural features which may be suitable place for target area for exploration.

## Interpretationos & Discussions

***Adsorbed soil gas*** **:** The analysis is indicating, that the concentrations of $C_1$, $C_2$, $C_3$ are moderate to low in concentration and $C_4$ present in less samples with very concentrations. The sample density and variation between median and mean is very less hence mean value is considered as background value. Different ratio plots are prepared to define/differentiation the geochemical signature in the study area. Pearson correlation has examined and show good correlation (r = 0.7) indicating that, these hydrocarbons are genetically related and are not effected by secondary alteration during their migration from subsurface to subsequent adsorption on to the surface soil (Tedesco, 1995)(Table-3). Pixler (1969) defined the compositional signatures displayed by methane to ethane ($C_1/C_2$); methane to propane ratios ($C_1/C_3$) to discriminate oil, condensate and gas signature. The Pixler plot showing that, samples are lying in condensate and oil zones (Fig-2). Approximate empirical range of microseep compositional rations for gas, gas condensate and oil (Jones and Drozd, 1983) are applied and identify that the soil gas has associated with oil and gas condensate. Cross plot between $C_2/(C_3+C_4)$ and $C_1/(C_2+C_3)$ for gas signature of study area showing oil zone and condensate. The magnitudes and compositions of the near-surface soil gases were used to identify locations of anomalous seepage and in some cases to constrain the source or sources of the light hydrocarbons. The Anomaly distribution maps are prepared for $\Sigma C_2+$ by using mean and standard deviation as anomalies. Anomaly distributions maps are showing three (3) promising prospect (A, B &C) areas in S and SW of the study area. The composite anomalies of $\Sigma C_2+$ show excellent correlation for the anomalous concentrations and fault associated seepage.

***Seismic attribute Analysis*****:** Seismic attribute analysis mainly volume attributes maps have been prepared to draw some broad meaningful inferences about the seismic facies distribution wherever possible from 3D data. The volume attributes generated from PSTM seismic volume and attributes viz, heterogeneity seismic amplitude magnitude

Table-3: Pearson correlation between $C_1$-$C_2$-$C_4$ and $\sum C_2+$

| | C1 | C2 | C3 | C4 | C2+ |
|---|---|---|---|---|---|
| C1 | 1.00 | | | | |
| C2 | 0.85 | 1.00 | | | |
| C3 | 0.43 | 0.43 | 1.00 | | |
| C4 | 0.37 | 0.49 | 0.24 | 1.00 | |
| C2+ | 0.77 | 0.86 | 0.83 | 0.49 | 1.00 |

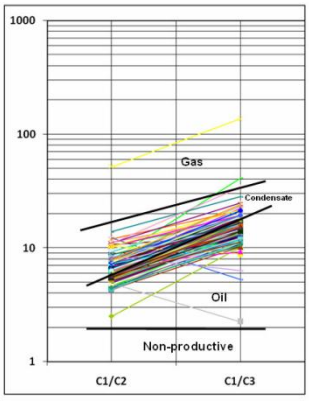


Fig-2: Pixler plot to discriminate oil, condensate and gas zones of study area

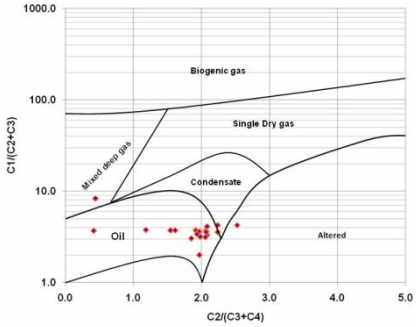


Fig-3: Cross plot between $C_2/(C_3+C_4)$ and $C_1/(C_2+C_3)$ for gas signature of study area

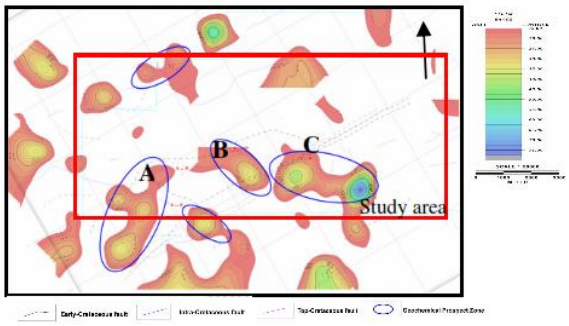


Fig-4: $C_2$+ anomaly distribution map showing major prospect (A, B& C) areas with rank in the study area.

and heterogeneity instantaneous frequency magnitude were generated for Younger horizons and Early Cretaceous for certain offset from mapped horizons looking at the package of high amplitude event seen in seismic section (Fig-5a & 5b). However there are divided of structuration as well as anomalies. The heterogeneity seismic amplitude magnitude attribute and structure is clearly showing positive anomaly in S & SW of the study area (Fig-6,7, 8 and 9). This may be due to better facies development where hydrocarbon accumulation (gas) may be charged.

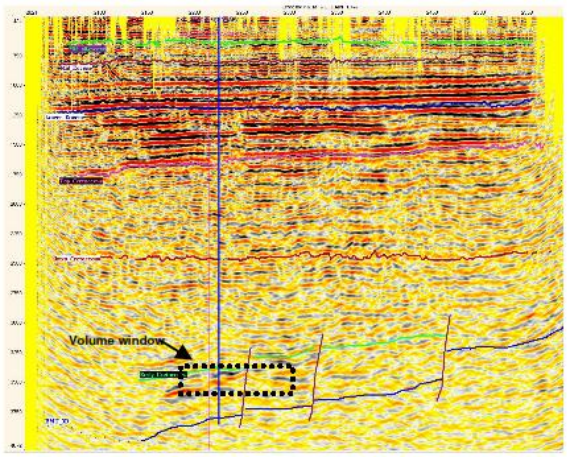


Fig-5a: A seismic section across prospect-A area showing high amplitude reflectors at Early Cretaceous Formation where volume window zone (80 ms) with dotted line.

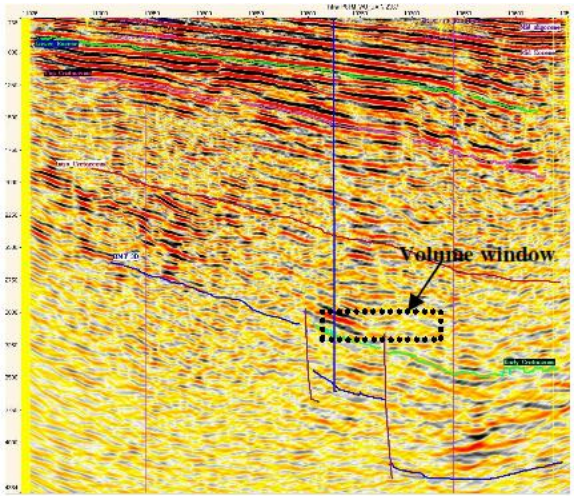


Fig-5b: A seismic section across prospect-C area showing high amplitude reflectors at Top of Early Cretaceous Formation where volume window zone (80 ms) with dotted line.

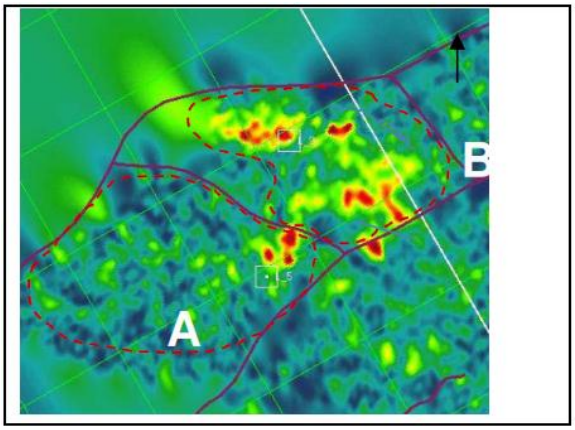


Fig-6: Heterogeneity seismic amplitude magnitude map at 80 ms, Early Cretaceous

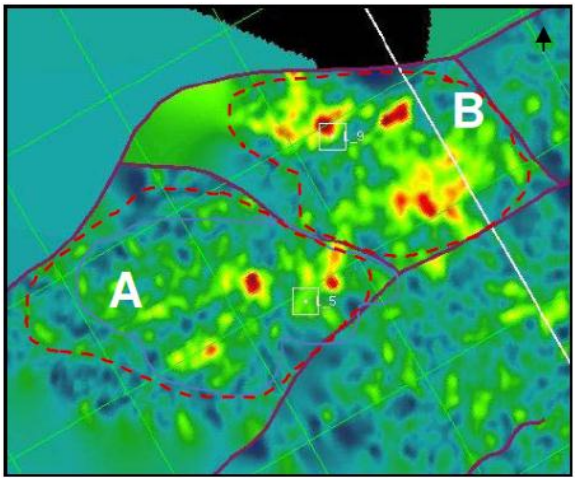


Fig-7: Heterogeneity seismic amplitude magnitude map at 160 ms, Early Cretaceous

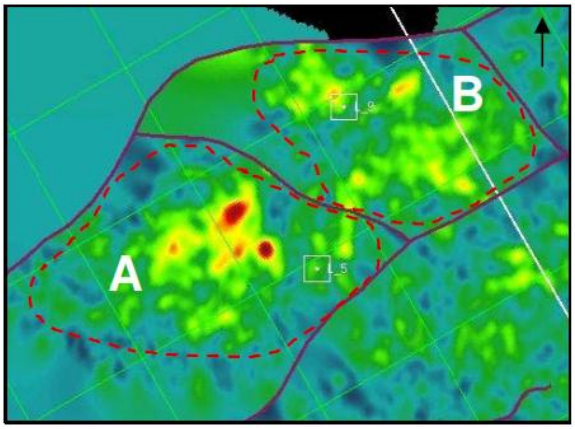


Fig-8: Heterogeneity seismic amplitude magnitude map at 300 ms, Early Cretaceous

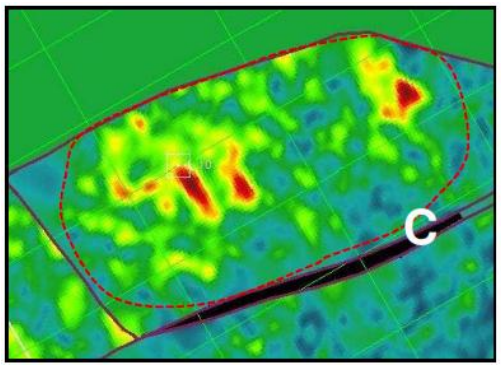


Fig-9: Heterogeneity seismic amplitude magnitude map at 160 ms with offset (-) 212 ms, Early Cretaceous

Integration of geochemical anomalies of $\sum C_2+$ with heterogeneity seismic amplitude magnitude anomalies at 80ms, 160ms & 300ms are showing linear correlation in the study area (Fig-10&11). It can be inferred that geochemical anomalies of the prospect area A, B & C lies primarily in the Early Cretaceous and older formations particularly in the southern part of the block. Possibly hydrocarbons seepage migration is take place from the Early Cretaceous.

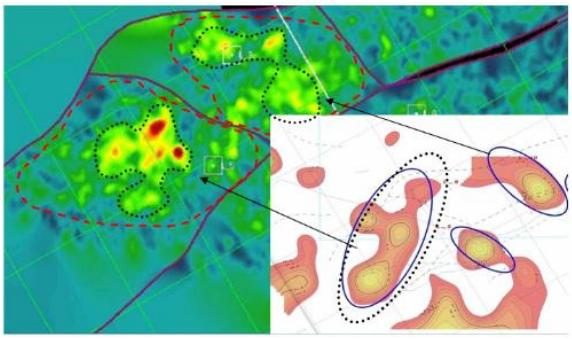

Fig-10: Correlation Seismic attribute and ∑C2+ geochemical anomaly at prospect- A & B

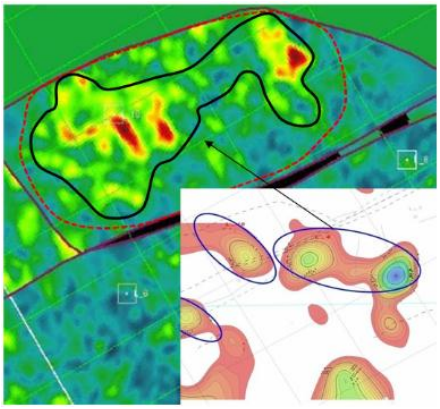

Fig-11: Correlation Seismic attribute and geochemical anomaly at prospect- C

## Conclusion

Based on geochemical studies, adsorbed soil gases of light hydrocarbons are showing linear correlation. It indicates that these gases are cogenetic, have not been influenced by secondary alteration effects during their migration from subsurface to surface and are thermogenic in nature. The different cross plot suggested that hydrocarbon seepages

presented and these characterized to oil and gas condensate zones in the area. An anomaly distribution map $C_2$+ indicates that the S & SW areas are prospective zones for hydrocarbon exploration. Seismic anomalies have been mapped in the area at different levels, however there are divided of structuration as well as anomalies. Inference of geochemical anomalies, seismic attributes anomalies and structurations are good correlated at Early Cretaceous, hence hydrocarbon seepage in this area, might be migrating from the Early Cretaceous.

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