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Hydrocarbon Microbial Blooms: Significant, Yet Underutilized Exploration Method

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Summary

The author conceptualized, developed and applied microbial prospecting method to different geological situations in India during the period 1987-2005. The method proved its worth as an effective supplementary tool in hydrocarbon exploration through drilled results in Saripalle of KG Basin and Disangmukh of Assam Foreland and Deepwater Provinces of KG Basin. The recent well drilled as Saripalem (August, 2013) in KG Basin did reinforced the efficacy of microbial prospecting method as the well produced gas to the tune of 74,600 cubic meter/day on production testing from Raghavapuram Formation. It is to note that microbial method categorized Saripalem area as a high prospective area in the year 1987-88 itself. In the light of these positive and negative proofs, microbial prospecting method deserves due consideration and better utilization to mitigate the exploration risks.

Keywords: *Microbial Prospecting, Hydrocarbon Prediction*

Introduction

Near-surface geochemistry in conjunction with local geology and geophysics provides critical information on working petroleum system, an important factor in the capital-intensive petroleum exploration paradigm. Local geology and geophysics denotes the involvement of mobile strata or immobile strata/compressional tectonics (Pettingill and Weimer, 2002) in the study area. Mobile strata (salt or shale tectonics) and compressional tectonics facilitate active-seepage system (Abrams, 1994). Abrams, 1994, on near surface expressions of hydrocarbon migration concluded that: (a) subsurface hydrocarbon accumulations are dynamic and seals are imperfect; (b) petroliferous basins have some type of near-surface hydrocarbon leakage; (c) surface expression of leakage is not always detectable by conventional means; (d) hydrocarbon seepage can be active or passive and it can be visible (macroseepage) or only chemically detectable ;(e) hydrocarbon seepage can be active or passive and is a function of many factors other than mere presence or absence of active hydrocarbon generation and migration; (f) migration occurs vertically and can also occur over long distance laterally; (g) hydrocarbons can move vertically through thousands of meters of strata without observable faults or fractures in relatively short time(weeks to years); (h) relationship between seepages and subsurface accumulations can be complex needing integration of local geology, geophysics and hydrology; (i) present evidence on migration mechanisms favors effusion as the process of macroseepage and buoyancy of micro-bubbles as the mechanism for micro-seepage.

Near-surface geochemistry has been used for many years with varied success, attesting to the complex relationship between the surface and subsurface. Not all petroleumbearing basins have a detectable surface signal. In addition, not all petroleum accumulations have a vertical, or nearly vertical, geochemical signature with the surface. Understanding controls on hydrocarbon movement from depth to surface, as well as near-surface processes that can alter, mask or confuse the surface geochemical signal, are critical for effective use of seabed seepage data in exploration (Abrams et al, 2004).

The interpretation methodology (Nathaniel et al, 1995) enables characterization of the near surface into different zones of biological habitats and generates ‘microbial bloom’ maps. Such maps would be invaluable as input into the planning and designing of hydrocarbon exploration exercise. Nathaniel et al, 1995 elaborated the procedures and methodologies involved in near surface soil sample

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collection, laboratory analysis, generation of microbial bloom maps and their integration with local geology and geophysics. Therefore, the end results are only discussed here along with global experiences on studies related with petroleum seepages and their success rate.

Krishna-Godavari Onland Basin: Saripalle-MoriNarasapur Area

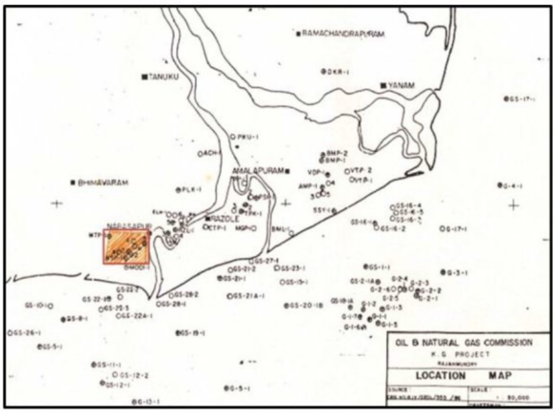

Figure 1: Map indicating study area (brown shade), KG basin

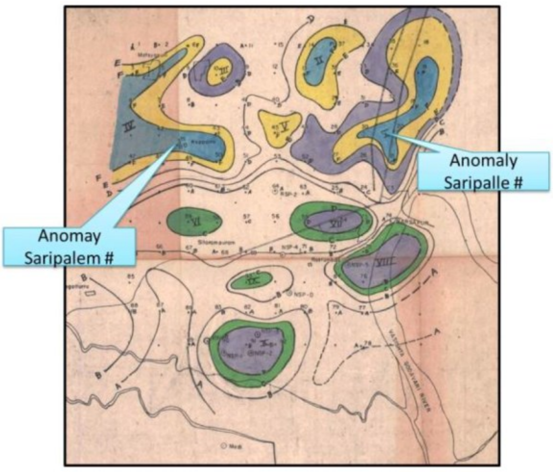

Figure 2: Microbial blooms in the study area(KG basin) Microbial anomalies of Saripalle and Saripalem wells.

Initially, geomicrobial-prospecting method was applied on known and unknown hydrocarbon bearing areas of Krishna-Godavari Basin to standardize the technology. Thereafter, Saripalle-Mori-Narasapur area had been selected for application of this methodology in the year 1988, to test its pre-drill prediction capabilities (fig.1). The technique has brought out excellent microbial “blooms” possibly related to subsurface hydrocarbon accumulations and also areas with poor microbial expressions (fig.2)(Nathaniel et.al, 1995). An excellent microbial bloom was drill tested in the year 1995 as Saripalle, which encountered gas from Paleocene sands with water cut, thereby proving the methodology’s pre-drill prediction capability. Another well viz. Sarepalem-1 drilled recently i.e. 2013 in the same area did encounter gas from Raghavapuram Formation (74,600 cubic meter/day; 6mm bean). It is to note that this well locates on another excellent microbial bloom mapped in the year 1988(fig.2). This is a strong positive correlation between microbial blooms and hydrocarbon charged reservoirs.

Krishna-Godavari Offshore Basin: Deepwater Province

Four areas within a deepwater acreage of KG basin (Fig.3) was entrusted for micro-seep studies through gravity-core program in the year 2004 and accordingly samples were collected from the near-surface of ocean-bottom by employing gravity-core method (red dots). It is to note that the sampling density was poor i.e. could not be collected on a grid pattern as was done in the on land parts of KG and Assam Basins. The cores were investigated for various parameters such as quantum of hydrocarbon utilizing bacterial counts, physical-chemical parameters such as oxidation-reduction potential, conductivity and TOC (Nathaniel et al, 2006&2008). Fig.4 indicated interesting aspects about the subsurface hydrocarbon charge patterns (red contour represents the highest and dark blue the lowest microbial count): (a) block-A, is characterized by microbial bloom (red color contour) only in the southwestern part. However, this high microbial bloom was generated based on only one sample. The bigger dot (green color) is the well position;(b) block-B indicates microbial blooms in SSW and NNE only. Again, these blooms are generated based on single sample in SSW and two isolated samples NNE; (c) block-C has an anomaly in the central part and such concentric values may correspond to subsurface hydrocarbon accumulations. However, the well (green dot) drilled is situated within the high microbial count area (red to yellow color); (d) block-D, showed a concentric microbial bloom in the central part of the basin and the well was drilled on the very bloom. This bloom is again based on single sample. It is to note that the three unproductive wells were drilled subsequent to this microbial analysis. The sampling could not be done on a grid pattern due to economic constraints involved in deepwater regime.

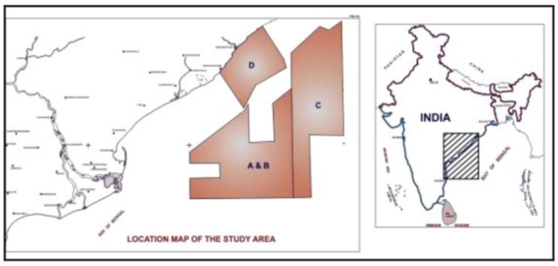

Figure 3: Study Area (brown color) illustrating the blocks A,B,C&D: KG Deepwater Basin, India.

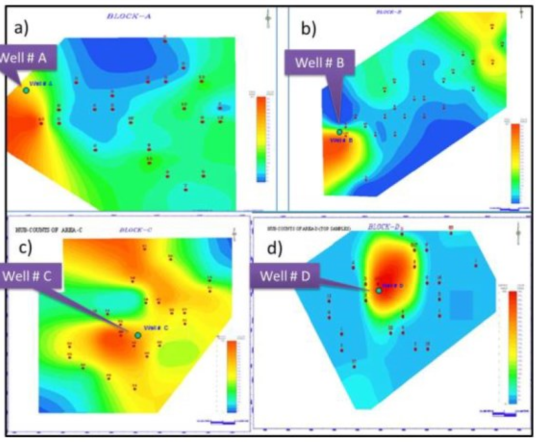

Figure 4: Microbial blooms (red) in KG offshore basin.

As mere expression of anomalies does not guarantee underground hydrocarbon accumulations, they need to be tied with seismo-stratigraphic information to ascertain the causatives in terms of structural or stratigraphic entities.

Assam Foreland Basin: Disangmukh

Disangmukh prospect was the first prospect drilled based on 2D seismic data in the year 1959 by ONGC. Oil-gas shows were reported from multiple levels: (a) 2345.52470.75m ;(b) 2047-2059m;(c) 1840-1870m;(d) 720-740m. However, none of them could yield hydrocarbons in commercial quantities (Nathaniel et al., 1997). Consequently, it remained as an unattractive province for exploration till the later part of 1990s. However, Disangmukh attained exploration interest subsequently and both 2D seismic and microbial surveys were together conducted in the area. Fig.5and 6 illustrate the location of the study area and corresponding microbial bloom map of the area. The ‘microbial blooms’ were tied with the seismic prospects and it is found that the seismic prospect Disangmukh(4-way) situated in the NNE looked promising as it matches with higher microbial count shown in ‘yellow’ color (dark blue-lowest and red-highest microbial count). Consequently, the area was categorized into prospective and less prospective zones (Nathaniel et al, 1997). Subsequent exploratory drill program on Disangmukh (#DSMK) confirmed subsurface hydrocarbon accumulation. The discovery was reported as commercial in nature in Paleocene/Early Eocene Tura reservoir with the best onland test flow rate of 226 cubic meter/day through 6mm bean. It is important to note that the well was drilled the northeastern most microbial anomaly (fig.6) that correspond to seismic prospect Disangmukh and thus once again proved its predictability of subsurface hydrocarbon accumulation.

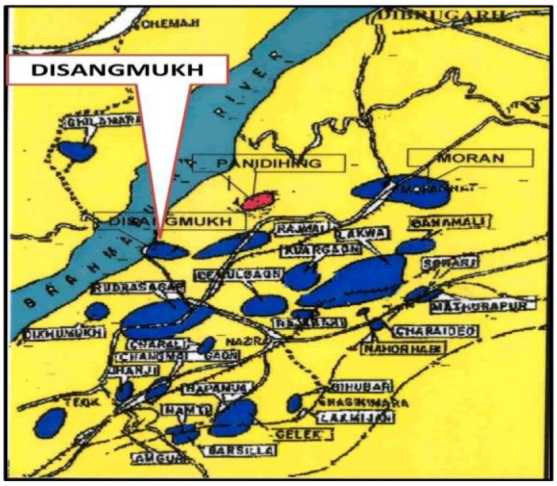

Figure 5: Disangmukh Area, Upper Assam Basin

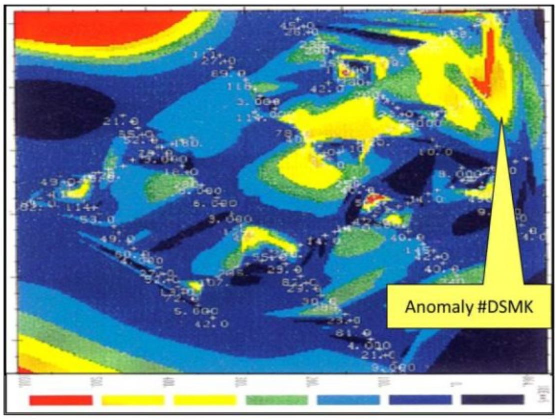

Figure 6: Microbial blooms (Red and yellow). The wells drilled subsequent to this work (yellow area) produced hydrocarbons.

Discussion-Review

Unequivocal petroleum seepage does not usually occur directly above the prospect, but is found at the end of migration pathways often tens or even hundreds of kilometers away (Thrasher et al, 1996). Hence it involves both vertical and lateral aspects that are to be assessed to link the identified seepage to possible prospect. However, Schumacher (2012) opines that the said microseepage is widespread, dynamic and predominantly vertical. He further states that seismic data will continue to be unsurpassed for imaging trap and reservoir geometry, but in many geologic settings seismic yields no information about whether a trap is charged with hydrocarbons. He reviewed about 2700 US and international exploration wells - all drilled after completion of microseepage surveys - documented that 82% of wells on prospects with a microseepage anomaly were completed as oil or gas discoveries; in contrast, only 11% of wells drilled on prospects with no associated seepage anomaly resulted in a discovery. In essence, exploration risk can significantly get reduced and also costs by improving success rates and shortening development time. Macgregor (1993) suggested some guidelines while interpreting such data as seepage patterns are strongly controlled by regional and local tectonics. They are: visible seeps are most common in ovepressured and diapered basins; visible flowing seepage is most commonly related to active compressional faulting and diapirism; seeps are also common on the outcrops of carrier beds on uplifted basin margin; seepage are rare in tectonically inactive basins or in regions where structures are now inactive and are draped by undisturbed overburden.

Consequently, it is necessary to understand where the basin/region fits into the spectrum of seepage styles. In other words, present and past migration in terms of timing of petroleum generation, migration pathways and reservoir leakage etc need to be ascertained for proper interpretation.

The studied areas presented in this paper pertain to different tectonic styles: Narasapur-Saripalle-Sarepalem of KG Onland (rift basin); KG Deepwater (passive margin with Pliocene tectonic activity); Disangmukh of Upper Assam (foreland basin with strike-slip tectonics). It is to note that the positive correlations between microbial blooms and seismic prospects could be well established, wherever the availability of sampling is uniform i.e. on a grid pattern. In other words, good correlations could be established in KG onland and upper Assam. Whileas, deepwater KG lacked sampling on an uniform grid and thus the correlations are awry. For example, the blooms in block-A,B&D are derived from either one or two isolated samples, which could be erroneous due to aliasing in contouring methodology. However, the microbial bloom in block-C did contain reasonable sample density and still the well went dry. This necessitates a relook into integrated interpretation of microbial data with seismic data for assessment of the causatives as pertain to local or regional tectonics as suggested by Macgregor (1993). It is observed that the sampling density of microbial survey elsewhere in the world much higher than the density followed in the land part of KG and Assam Basins. The optimum sample density is 0.5km for exploration and even 0.1km for developmental studies as per the published literature (Sundberg, 1994).

Narasapur-Saripalle-Sarepalem of KG Basin was microbially studied by 1.0km X 1.0km grid and thus the correlations are reasonably productive in predicting the subsurface hydrocarbon accumulations. It is worth to recapitulate the saga of microbial exploration: (1) microbial survey was conducted in the year 1987-88 wherein the area consisted of dry wells (MTP-1& NSP-4), gas wells (NSP1,2, 3,5&6) and to be drilled locations NSP-D and SRP-2; (2) the dry wells and the to be drilled locations fall in the poor zone of microbial counts, which immensely helped in calibrating the microbial blooms; (3) the integrated interpretation of microbial bloom with the Saripalle seismic prospect was accepted for exploration test in the year 1988 and was drilled in the year 1995, which produced gas. Similarly, the Sarepalem prospect was drilled in the month of August 2013 that discovered gas in substantial quantity on production testing. A relook on the map (fig.2) denotes that the well Saripalem exactly correspond to another excellent microbial bloom. Similar is the case with Disangmukh field, wherein sampling density was adequate.

In the light of the above, microbial surveys conducted in regions mentioned above pertain to moderately active regions in terms of tectonics and therefore faults could be the leaking paths for the seepages to occur at the near surface soil that influence the microbial populations related to hydrocarbons.

Further, an understanding of microbial modification and decomposition of hydrocarbons helps interpreting other geochemical results since the migrating gas concentrations will be influenced by the ability of microorganisms to produce or consume them. It is to note that the microbial method is the most economical and less time consuming methodology when compared with conventional exploration tools. The routine and confined-explorationthought-processes on exploration technology needs a revamp by incorporating less expensive and direct tool like microbial prospecting method that reduces risks and uncertainties.

Conclusions

Microbial prospecting method permits a better prospect evaluation and risk assessment when conducted on grid pattern and combined with seismic interpretations. Productivity of exploratory drill campaign gets enhanced, when serious consideration is given to microbial methodology. In other words, the underutilized microbial technology deserves its inclusion into the suit of exploration tools as its applicability is well evident through the case studies discussed in this paper.

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