Geo-Microbial Prospecting for Hydrocarbons: Application and Experiences.

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Summary

Microbial prospecting method was developed by the author during the period 1986-1988 through a series of pilot studies and subsequently applied to various areas of KG and Assam Foreland basins. Results of this method in conjunction with local geology and geophysics identified areas needing exploration focus and de-focus. Subsequent exploratory drill programs validated both positive and negative prediction capabilities of this methodology as in the cases of Saripalle-1 of KG basin and Disangmukh-3 of Assam Foreland basin, discussed in this paper. Consequently, an integrated exploration paradigm based on traditional tools and microbial method may be an answer to finding more difficult yet-to-be-found hydrocarbon entrapments.

Introduction

A wide variety of techniques in identifying hydrocarbon micro-seeps pertaining to sub-surface pools have been developed as a part of improvising exploration efficiency. The rate and volume of hydrocarbon micro seepage to the surface modify the near surface geochemical, geophysical, geological and biological responses (fig.1). Petroleum seepages usually occur directly above or near the prospect and also can occur at the end of migration pathways often tens or even hundreds of kilometers away. This means that both lateral and vertical migration aspects need to be assessed if identified seepage is to be linked to possible prospects (fig.2). Further there is no way to estimate the commerciality of subsurface hydrocarbon accumulations based on the quantum of seeps due to the strong influence of tectonics and the variety of different processes responsible for surface seeps. As a result, only some of them imply an underlying hydrocarbon accumulation. Further, the near surface expression of hydrocarbon seepage is controlled by the interrelationships of sediment fill, tectonics (migration pathway), hydrocarbon generation (source and maturation), regional fluid flow (pressure regime and hydrodynamics) and near surface processes. Geochemical surveys and research studies document that hydrocarbon micro seepage from oil and gas accumulations (1) is common and widespread, (2) is predominantly vertical (with obvious exceptions in some geologic settings), and is dynamic (responds quickly to changes in reservoir conditions). A recent review of more than 850 wildcat well-all drilled after completion of surface geochemical surveys finds that 79% of wells drilled in positive geochemical anomalies resulted in commercial oil or gas discoveries; in contrast, 87% of wells in the absence of an associated geochemical anomaly resulted in dry holes (Schumacher, 2000).

Figure 1: Hydrocarbon Seepage Models and Geochemical Zonation (after Schumacher, 2000)
Some of the geochemical methods measure hydrocarbon fluxes directly and others detect them indirectly. Geo-microbial prospecting technique pertains to the later class and it is reliable than other surface geochemical methods as understanding microbial modification and decomposition of hydrocarbons will help in interpreting the geochemical results since migrating gas concentration will be influenced by the ability of micro-organisms to produce or consume them.

Geomicrobial exploration is based on the assumption that hydrocarbon micro-seeps influence the microbial populations in the near surface soil situated above the buried hydrocarbon deposits. It involves collection of soil samples, their laboratory screening and interpretation in conjunction with local biology and geophysics.

The technique has been applied to different areas in Krishna-Godavari (land and offshore) and Assam Foreland basins of India in various phases (Nathaniel et.al, 1995, 1997, 19997, 2001, 2003 and 2005). The tantalizing exploration results recorded for these areas such as structurally higher positions going dry whereas structurally lower positions giving sustained oil production perplexed the pace of exploration. As it becomes difficult to select the next exploratory drilling location based on existing exploration knowledge, geo-microbial technique was applied to the areas as a supplementary or complimentary tool to augment exploration decision process.

Case Studies:

The technique has brought out excellent geo-microbial “blooms” possibly related to petroleum traps and also microbially poor-expressive areas, thereby suggesting exploration focus and defocus paradigms for the respective areas. Method of sampling, laboratory processes and interpretation techniques were detailed by Nathaniel D.E, 1995 and therefore the end results are only discussed here.

Krishna-Godavari basin: Situated in the east coast of India, it is one of the promising basin for hydrocarbon exploration and exploitation with a wide stratigraphic distribution of oil and gas from almost every interval i.e., Permian to Pliocene geological times wherein distribution of reservoirs and entrapment style are distinct in nature. Thus, the need to develop a supplementary exploration tool was recognized to increase productive drilling for hydrocarbons. Initially, geomicrobial prospecting method was applied on known and unknown hydrocarbon bearing areas of Krishna-Godavari Basin to standardize the technology. Thereafter, Narsapur-Saripalle area had been selected for application of this methodology in the year 1989, to test its pre-drill prediction capabilities.

Fig. 3a illustrates excellent microbial blooms superposed on a time-structure map (Lower Paleocene-seismic horizon above trap) of a virgin prospect corresponding to the said microbial anomaly which permitted to draw the following conclusion. The trends of microbial contour (pink in color) of microbial bloom follow the same structural trend of the prospect Delta-B. Another seismic prospect i.e., Delta-A, situated in low microbial contour value of B, was drilled (blue dot in the inset) subsequent to the findings of microbial prospecting technology in the area (fig.3a) and was declared as a dry well in the absence of hydrocarbons.

Assam Foreland Basin: Disangmukh-1 well drilled in the year 1959 was in fact the first well drilled by
Oil and Natural Gas Corporation Limited, in Upper Assam basin. Although, oil and gas shows had been recorded at all the stratigraphic levels, including alluviums, commercial petroleum occurrence was elusive and thereby the well was declared as dry, which dampened pace of exploration of the area. Necessitated by this predicament, microbial surveys were pressed into for petroleum potential re-assessment of Disangmukh prospect and its surroundings. (for survey details refer Nathaniel et.al, 1997).

The survey was conducted along 2D seismic campaign and subsequent microbial map (fig.4b) described the quantum of microbial proliferations in terms of color contour map red-high & blue-low). It indicated the northern part as characterized by high microbial counts (in comparison to southern part) is more prospective for hydrocarbons. Thus, the area was emphasized for renewal of exploration through a careful elimination of false anomalies occurring through fault planes. The prospect was revisited with improvised 3D seismic image (without the benefit of microbial results) and the second well was drilled as Disangmukh-2 without a commercial find. However, third well Disangmukh-3 drilled in the year 2006 to a depth of 3835m met with a commercial discovery in Paleocene-Early Eocene Tura reservoirs with one of the highest on land test flow rate of 226 m3/day through 6 mm bean (fig 4C). Oil is of very good quality with API gravity of 33 and pour point 300c.

It is important to note that the well Disagmukh-3 drilled the northern most microbial anomaly (fig 4D) and thus once again proved its predictability of subsurface hydrocarbon accumulations. The find is indeed significant from two perspectives: firstly it has added the much needed reserve accretion and production in the North Assam Shelf and secondly, it established commercial viability of Tura play over North Assam shelf in terms of productivity behavior and oil quality and further reinforced the confidence in active Tura-Sylhet play over much larger area.

Conclusions

Microbial prospecting method has proved to be a valuable complimentary exploration tool as demonstrated by the examples viz., Saripalee-1 of KG basin and Disangmukh-3 of Assam Foreland basin. Exploration paradigm based on confined-thought-processes (employing traditional tools) needs a thorough revamp in the light of microbial results in order to explore yet-to-be-found hydrocarbon entrapments successfully.

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Figure 4a: Time-structure map at Barail Top (Oligocene).
4b: Microbial anomaly map along 2D seismic grid.
4c: Log motif of the pay zone of the well Disanghmukh-3. (Green dot on 4b: Disangmukh-3 well)
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