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Grey areas in Indian onland frontiers

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Abstract

Sedimentary basins in Indian onland frontier areas are spread over ten northern Indian states in diverse geo-tectonic set up starting from intracratonic Vindhyan Basin, peripheral foreland set up in Ganga Basin, rift related Gondwanas in isolated linear tracts to converging plate margins in the Himalayas. Decades after decades have passed in building knowledge bank about these basins without appreciable commercial success. Exploration for hydrocarbons in these insufficiently explored basins has been both cost and technology intensive. The current study encompasses a relook in to the geo-scientific data and enumerates various grey areas prevailing in understanding the subsurface geology and hydrocarbon potential in these basins. Attempt has been made to propose the possible ways out to address these issues.

Introduction

With the growing global demand for energy from hydrocarbons, browning of mature fields, fluctuating market price and geopolitical uncertainties affecting oil securities from foreign acreages, eyes naturally turn towards improving the national hydrocarbon resource by giving a thrust in exploration of areas which are less explored, geologically complex with diverse tectono-sedimentary history, high cost and technology intensive involving high risk and uncertain reward, geologically prospective and/or deemed prospective based on global analogy i.e. the Indian onland Frontiers with category III and IV basins. The recent finds, though far from being prolific, in these areas, coupled with application of improved technologies for better performances and progress in improved geo-scientific understanding of the subsurface in these basins have given a boost in pursing vigorous exploration with an objective of identification of new petroleum provinces and their early monetisation.

The very fact that success in exploring hydrocarbons in Indian onland Frontiers has been far from being satisfactory even after more than five decades of endeavour by national oil companies and disappointment in alluring the private/foreign players for committed involvement in these difficult oil areas indicate that the task to unblock the potential of frontier areas culminating in significant oil and gas discoveries is a stupendous one with the hope in the promising phrase that today's producing basins were once frontiers of yester years and current frontier basins need to be converted as producing basins of the future to be pursued with conventional and out-of-box ideas from both industries and academia.

This paper enumerates various aspects of hydrocarbon exploration which have so far escaped apposite understanding in bridging the breaches in the current perceived potential of the areas as well as the challenges posed by these basins in acquisition, processing and interpretation of geo-scientific data.

Onland Frontiers

Some of the important sedimentary basins in frontier areas (Fig.1) discussed in this paper include the enigmatic Himalayan Sector from foothills up to base of Karakoram and beyond, the wide spread Indo-Gangetic Basin including the Punjab plains, the Son Valley Vindhyan segment with presence of gas established in Jardepahar/Kajrahat and Rohtas Limestone in Lower Vindhyan and Kaimur Sandstone in Upper Vindhyan in the subsurface, the Chambal Valley Vindhyans showing a ray of hope especially in Suket Formation and the Gondwanas in Satpura and South Rewa basins. The exploratory exertions encountered in these basins are briefly deliberated.

Himalayan Sector

So far the efforts have been made to explore the potential of Outer Himalayas particularly in Kangra-Mandi sector and less vigorously in Nahan-Solan sector. The results obtained are far from commercial. Determination to venture in to understanding the structural complexities of the areas have been justified by progress made in terms of reprocessing the 2D seismic data with the help of M/s Thrust Belt Imaging, Canada and also by in house facilities in India, use of state of the art 2D Move software for section balancing as well as reinterpretation of geo-scientific data in light of new concepts in understanding the Barsar back thrust and its role in evolution of structural entrapment conditions. However, strategy to implement the concepts based on revisiting the geo-scientfic data and undertaking activities in Lambagraon syncline with thick sedimentary sequence in relatively less disturbed area, need to be formulated.

Gas production during testing in Jwalamukhi area might not have been attractive then. But with the present perception on gas as a major energy source as important as, if not better than oil, it may be prudent to revisit these wells. The current understanding on the depositional pattern of Lower Siwalik sands in Jwalamukhi area and their subsequent tectonic evolution and distribution in different thrust blocks need to be enhanced taking help of the recently reprocessed seismic, surface geology, well data and structural modelling. With gas shows both on surface and in the subsurface, the area may be considered for covering with well-conceived and model based 3D seismic survey with an objective for bringing out more specific subsurface picture which may prove to be promising.

Another area of concern is the Tertiary-PreTertiary boundary in Himalayan Foreland. Subathu Formation, the envisaged source rock of the area, has been penetrated in a well drilled in Nahan-Solan Salient and found to be lithologically marl with representative microfossils. The marl section found below the fossil bearing Subathus is taken to be the Proterozoic Bilaspur Limestone lying unconformably below the Subathus as it has crossed Tertiary-PreTertiary boundary represented by the corresponding prominent seismic reflector in the region.

The Tethyan Himalayas (Fig.2), bounded by South Tibetan Detachment towards SW and Indus-Tsangpo Suture towards NE, with thick sedimentary sequence starting from Proterozoic to Cretaceous has remained an area cryptic in terms of hydrocarbon exploration. Focussed exertions with invigorate dedication are prerequisite for attempting hydrocarbon exploration in the areas like Sarchu plain, Morey plain, Spiti valley and Zanskar valley (Pradhan et. al., 2011). Selected seismic lines may be shot and few parametric wells may be drilled in these less explored areas which will provide significant clues for further exploration in terms of sedimentary thickness, subsurface strati-structural disposition and nature of sediments and their geochemical characters. The Paleozoic-Mesozoic section which represents the major hydrocarbon producing strata elsewhere in the world, may provide various elements of a petroleum system like souce, reservoir, seal, and entrapment. The timing of migration vis a vis that of formation of entrapment conditions need to be worked out. Moreover, with hydrocarbon pools established across the international boundary, the Poonch-Rajourie sector, though geopolitically challenging, also needs to attract attention of hydrocarbon explorers. Similarly, efforts may be made to enrich the knowledge base in areas of Shyok suture zone, Saltaro range and beyond Karakoram which is at present far from adequate for exploration.

Ganga Basin

With its vast stretch, thick sedimentary sequence, intrabasinal highs and lows, the Ganga Basin has been explored with limited well density with no significant success so far. Gas and oil shows in subsurface have failed to get translated in terms of appreciable finds, let aside commerciality. Mostly structural and few stratigraphic prospects have been tested dry. The age of the PreTertiaries has been debated quite often. Whether they belong to NeoProterozoic to Earliest Cambrian or even as young as Devonian, is still a matter for deliberation. The point is yet to be settled as the various agencies working on the issue citing reasonably convincing evidences from their independent study of small shelly fossils, acritarch or other palynological evidences resulting in a non-converging opinion.

Another grey area is the nature of inter linkage between Ganga and Vindhyan Basin (Fig.3). Whether Vindhyans have acted as provenance for the PreTertiaries of Ganga or the PreTertiaries are time equivalent to Vindhyans? An intermediate view proposes that part of the Ganga PreTertiaries have been time equivalent to Vindhyan Proterozoic and partly they have been sourced by Vindhyans Pradhan et. al.,2011). All these factors have a bearing on the GME modelling of the basin.

Based on the limited available geochemical source rock data of Ganga Basin, the present perception is that Siwaliks with adequate TOC have remained immature and the hydrocarbon shows in drilled wells have mainly been contributed by PreTertiaries in general and Ujhani and Karnapur formations in particular. Another prevailing concept that the Siwaliks buried deep across the international boundary in the north are envisaged to be mature which after migration might have been entrapped in shallower southern part of Ganga Basin. However, this concept could not be proved by a well recently drilled in the Gandak depression in Ganga Basin. Wells drilled in the deepest part in Gandak depression have not yielded adequate oil/gas though there were indications of presence of methane rich gas in Lower Siwalik as well as in Karnapur formations.

Based on the drilled well data it has been established that hydrocarbons have been generated and migrated in the basin. Proper entrapment conditions are also available. Nature and extent of regional seal may be an issue for consideration. But another factor which seems to be of importance is the colossal gap in sedimentation in Ganga Basin with the Tertiary Lower Siwaliks sitting unconformably on the PreTertiary Karnapur Formation. Therefore, with GME modelling it may be worked out to decipher whether the timing of migration is earlier or that of structure formation taking in to consideration both scenarios i.e. Karnapur Formation is of Neo Proterozoic or as young as Devonian. This will be an essential input for formulating exploration strategy for the basin.

Vindhyan Basin

Proterozoic sediments around Bundelkhand massif prominently exposed towards south east in a plunging syncline in Son valley and towards south west in Chambal Valley constitute the Vindhyan Basin (Fig.4). From simple interior basin model (Biswas, 1993) to Great Vindhyan Basin model covering the Vindhyan, PreTertiaries of Ganga and the Proterozoic Bilaspur Limestone in Himalayan Foreland (Azmi, R J, 2011) to peripheral foreland basin model (Jokhan Ram et. al., 1996) have been conceived.

However, understanding on few vital issues still remains far from clear and satisfactory. One of them is the Son-Vindhyan connection. The intervening area between Son Valley and Chambal Valley is mostly covered by Deccan Volcanics, though outcrop of Vindhyan sediments are also present within the trap covered area. This indicates that possibly both Son and Chambal valley were connected once. Magneto Telluric data acquired in part has not been able to sort out the problem fully. Effect of Bundelkhand Massif, which is considered to be main provenance of Vindhyan sediments, has its role in the overall regional geological set up.

Recent discovery of gas within Rohtas Limestone Formation in Son Valley Vindhyan Basin coupled with establishment of gas in deeper Charkaria/Jardepahar formation in Lower Vindhyan in Jabera area as well as that in basal part of Kaimur Sandstone in Upper Vindhyan have given a boost to the exploration activities in the area. Presence of gas has been proved and gas has surfaced during well testing in Nohta, Damoh and Jabera area. However, production on commercial scale is yet to be achieved and has remained as a daunting issue because of poor porosity and very poor permeability. The reason thereof for the poor gas flow during testing is mainly attributed to two factors, viz. hard, compact and tight nature of the reservoir as well as sub-hydrostatic formation pressure. Mostly the gas bearing reservoirs have secondary porosity, both open and partially open fractures developed. Fractures completely filled with secondary mineralisation have also been observed to occur thereby reducing the reservoir potential. But presence of fractures not necessarily ensures presence of gas. The reservoir characteristics and nature of fracture development have been regionally controlled by faults nearly parallel to the ENE-WSW Son-Narmada Geofracture and faults orthogonal to it in NW-SE direction. There is a need to augment the current level of perception on the pattern of fracture development and its role in hydrocarbon entrapment. In view of the fact that wherever gas has been found in Upper Vindhyan Kaimur Sandstone, it is always at the basal part of the Kaimur Formation that lies unconformably in contact with the Lower Vindhyan Rohtas Limestone, the role of fractures affecting the Rohtas and extending in to Kaimur and their distribution have to be better understood through focussed study before estimation of inplace gas and early monetisation of the prospect are taken up.

The entrapment of thermogenic wet gas within Rohtas has to be closely looked into. One possibility is that the gas has been generated within shale/limestone in Rohtas and is entrapped locally within Rohtas or migrated in to the fractures developed in the overlying Kaimur sandstone. This opens up the Basin even for shale gas exploration. Another view envisages the possibility of generation of gas from the source in Arangi Shale, though currently over mature, below Kajrahat Limestone and entrapped in Rohtas / Kaimur by long distance migration through major faults. The point still remains unsettled. The existence of both systems is also a strong possibility.

In Chambal valley the sediment input is from the Aravali Mountain in NW and Bundelkhand massif in NE. The available seismic data indicates the deepening of the basin towards southwest where at present Vindhyan sediments are exposed in and around Chitorgarh. The carbonate facies of Bhagwanpura Limestone of Lower Vindhyan Tirohan Group has been encountered as clastic facies in subsurface near the Bundelkhand massif. Well data across Mukundara reverse Fault indicate that more than 2km thick sediments of Upper Vindhyan Group has been eroded in the south west. Moreover, the thickness encountered in drilled wells indicate that the Lower Vindhyan sediments is thickening towards south west thereby indicating the basin deepening towards southwest.

The basinal set up, nature and deposition of sediments, effect of post depositional tectonics including that of Himalayan orogeny on the sediments need to be better understood.

Gondwana Basin

The Gondwanas, especially in the peninsular India, found in long linear tracts, viz. Damodar valley, Mahanadi valley, Pranhita-Godavari, Satpura and South Rewa basins (Fig.5), represented by grabens and half grabens formed as a result of reactivation of ancient shear zones, faults and rift valleys coupled with ground subsidence and downfaulting of the cratonic blocks. Late in the Paleozoic era, the Indian mass was overwhelmed by strong tectonic tension, the Hercynian crustal upheaval. The supercontinent Gondwanaland was beginning to split into smaller cratonic blocks, and the Indian plate started moving northwards (Valdiya,K S, 2010). The Gondwanas attract the attention of petroleum geoscientists since coaly shale and even coal are perceived to be possible source rocks for hydrocarbons. Exploratory wells have been drilled for conventional hydrocarbons in these basins and a lot of geo-scientific data have been generated. Well density in these basins is poor and need to be improved in spite of initial disappointments from drilled wells. Positive indications from analogous basins like Karoo in South Africa, Parana in Brazil, Cooper and Canning etc. in Australia as well as Mandapeta field in KG Basin, India, has triggered enthusiasm for exploring Gondwanas. Exploration for coal bed methane from Gondwanas is being pursued in Damodar and Satpura basins.

However, the difficulty in exploration particularly in central Indian Satpura and South Rewa basins is that these basins are partly covered by basaltic trap and are also affected by a network of doleritic intrusives which have been exposed to surface at places. These affect the seismic data quality. Wide angle survey or any other geophysical method like magneto telluric may be employed to decipher the trap thickness and improve the subtrap imaging. A more definitive picture on the nature, age and disposition of the intrusive network in these basins and their effect on the GME cycle of hydrocarbons need to be brought out while identifying prospective area for exploration. The second aspect that requires attention is to understand the nature, extent and effectiveness of intervening shales as effective seals on regional scale.

The hydrocarbon potential of extra-peninsular Gondwana sediments is another grey area. Much work is needed to be done starting from identification of areas including those in the trans Himalaya region, basic geological mapping and finally to evaluation of GME conditions for envisaging petroleum system.

Conclusion

Focussed, systematic approach in attempts for converting the prognosticated resource into in place volumes of hydrocarbons in challenging frontier areas is the need of the hour to partially diminish the gigantic and widening gap between demand and supply of energy in India. As the frontiers have diverse tectono-sedimentary set up, formulation of suitable exploration strategy for individual frontiers is essential. Enhancing the knowledge base and elevating the level of understanding on different aspects of petroleum system in these basins with innovation in terms of ideas and technology is the prerequisite before any discovery is expected to make a definitive impact on the national energyscape and economy.

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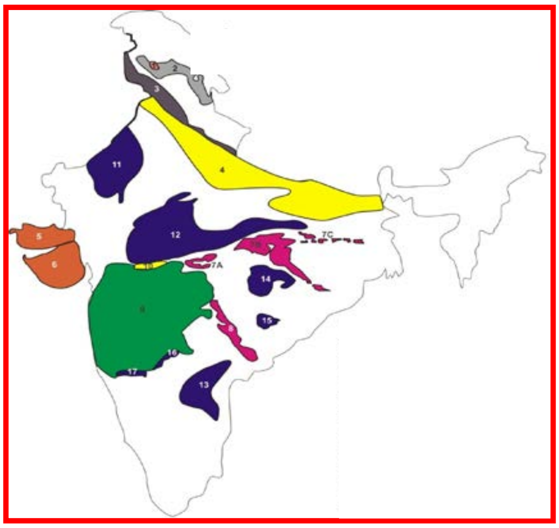

1 Karewa
2 Spiti-Zanskar-Kashmir
3 Himalayan Foreland
4 Ganga Basin
5 Kutch
6 Saurashtra
7 Satpura-S. Rewa-Damodar
8 Pranhita-Godavari
9 Deccan Syneclise
10 Narmada
11 Bikaner Nagaur
12 Vindhyan
13 Cuddapah
14 Chattisgarh & Bastar
15 Bastar
16 Bhima
17 Kaladgi

Fig.1 Frontier Onland Basins

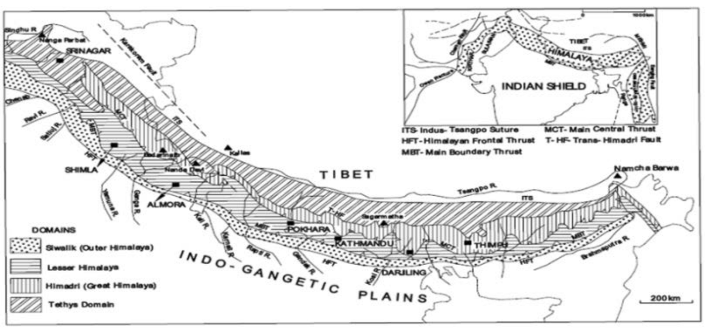

Fig.2 Subprovinces of the Himalaya **(After Valdiya, 2010)**

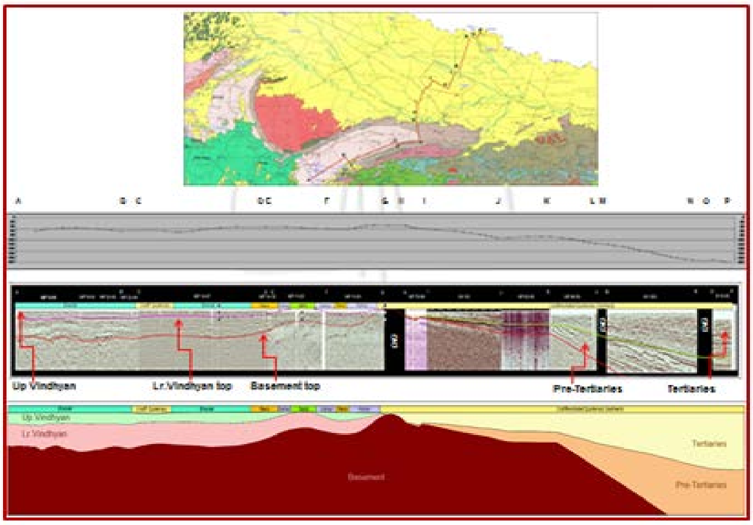

Fig.3: Vindhyan –Ganga Interlinkage

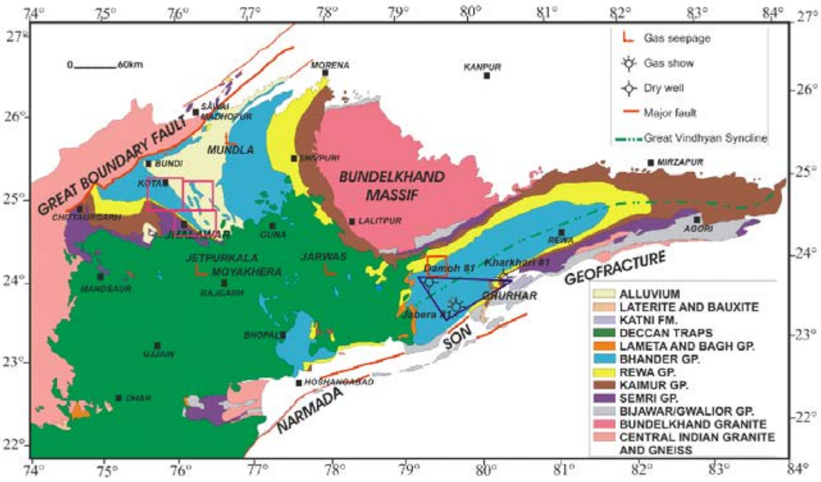

Fig 4: Geological map, Vindhyan Basin

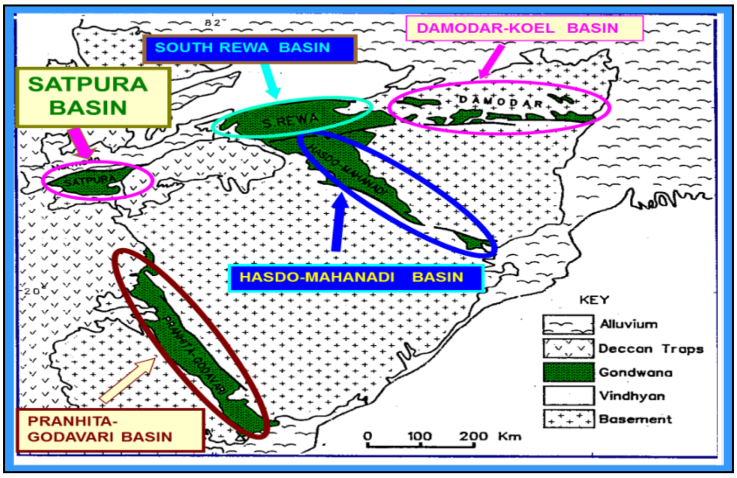

Fig 5: Peninsular Gondwana Basins, India