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Petroliferous Basins and Shale Gas - An Unconventional Hydrocarbon Asset of India

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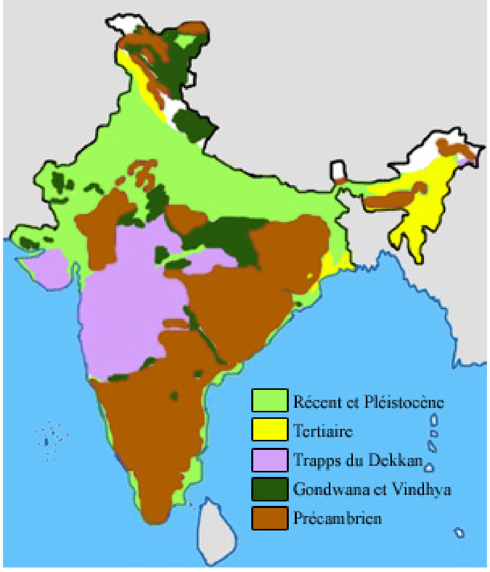
Abstract There are many major assets of hydrocarbon potential that are distributed all over India. The Brahmaputra valley of NE India, the Cambay region of Gujarat coast, the west coast offshore and the east coast offshore regions are the major assets from where the maximum hydrocarbon production is being tapped. The offshore regions have share around two-third and the rest is shared by the onshore regions. The average annual production of crude oil is close to 35MMT and gas is 32BCF which in total is far behind the projected demand which may increase many fold by the end of this decade. This increase in demand leaves no option except to explore vigorously for the unconventional resources namely Coal Bed Methane, Tight reservoirs, Shale Gas, Underground Coal Gasification, Gas Hydrates etc. Except the Coal Bed Methane and the Shale Gas the knowledge and efforts towards other alternate resources are in embryonic stage. The present study highlights the importance of Shale Gas in filling the gap between demand and supply as a model in Cambay Basin.

Keywords Unconventional Hydrocarbon Resource, Coal Bed Methane, Gas Hydrates, Shale Gas, Underground Coal Gasification, Tight Reservoirs

1. Introduction

India has a diversified geological system wherein; it contains rocks covering almost the entire spectrum of the Geological Time Scale (Figure-1). Sedimentary basins of India are evolved through different geological ages, by different processes. The country has vast sedimentary cover both onshore and offshore. With an areal extent of about 3.14 million sq. km, a total of 26 sedimentary basins have been identified and categorized depending upon the degrees of hydrocarbon prospectivity. Based on the exploration carried out so far and status of knowledge in terms of occurrence of hydrocarbons, sedimentary basins of India are divided into four categories (Figure-2), the proven commercial productivity; the identified prospectivity; the prospective; and the potentially prospective basins.

The study is based on the hydrocarbon resources of Indian petroliferous basins and the role of unconventional hydrocarbons as an alternative to the conventional resource in future. To meet the rapidly increasing demand for fossil fuels, especially the hydrocarbon based energy resources and faster depletion of conventional energy resources, the unconventional hydrocarbon resources are the only option left to create a balance between demand and supply and a step ahead towards sustainability. Apart from other discovered and undiscovered resources, the shale gas along with the CBM will play one of the most important roles in the days ahead.



(source: Wikipedia)

Figure 1. Geological map of India[19]

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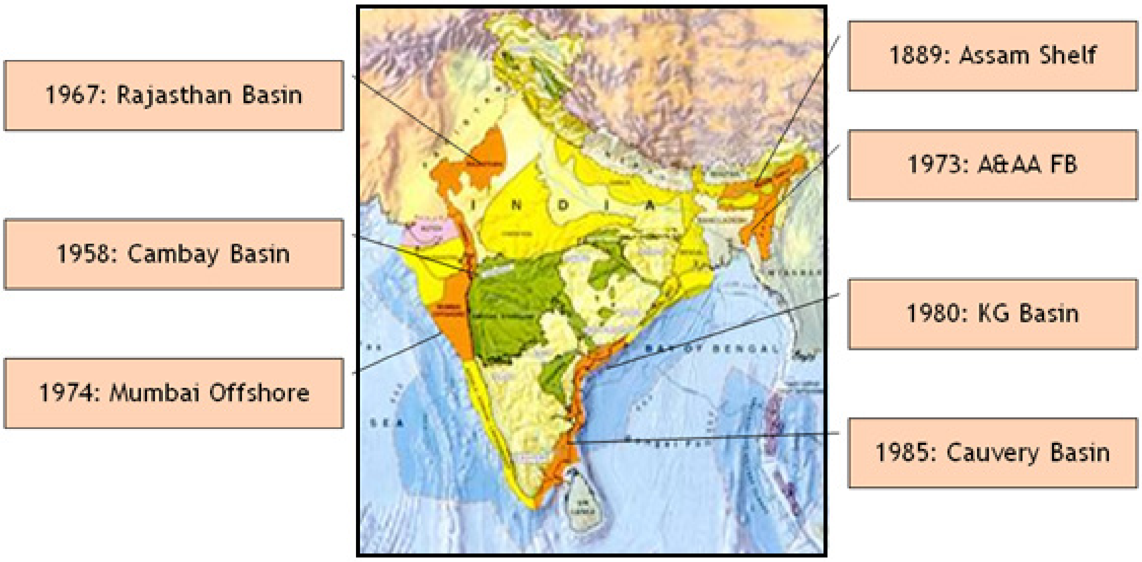
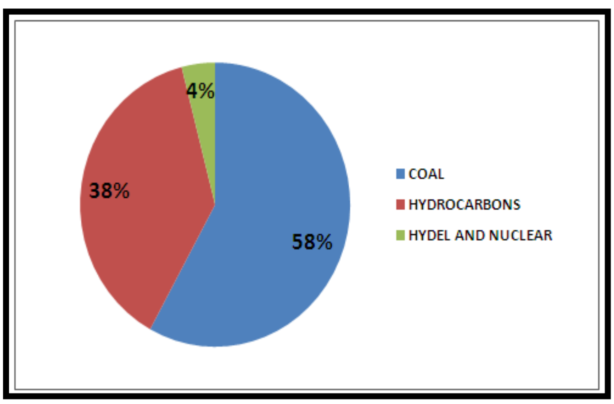


(Source: Directorate General of Hydrocarbons, India)

Figure 2. Petroliferous basins of India[20]

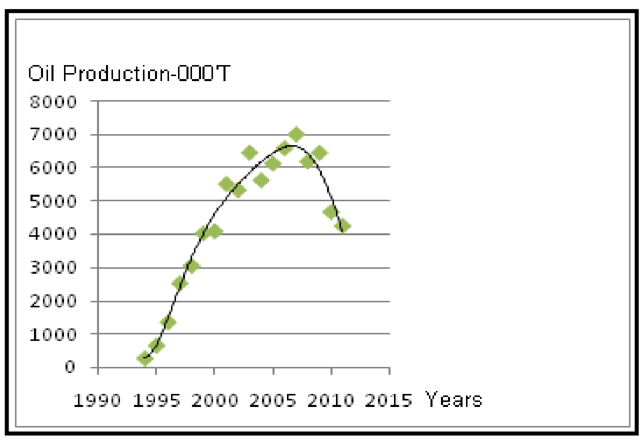
On the present day scenario the energy demand of India is mostly met from coal, hydrocarbons and nuclear and hydroelectric power resources (Figure-3). Being an oil importer for decades, supporting more than 60% of its demands, it becomes inevitable to assess the unconventional sources of energy especially the hydrocarbons. The growing demands of natural gas would also require huge imports as our conventional sources are unlikely to meet such demand[1]. Chandra, 1997). Approximately 18 areas have been identified for shale gas exploration in India. They are associated with active or potentially prospective petroleum basins[2]. Despite being trapped in low permeability horizons, integration of laboratory and field data will help in determining the best targets for sustainable production[3].



(Modified from Chandra, 1997)

Figure 3. Energy scenario of India[1]

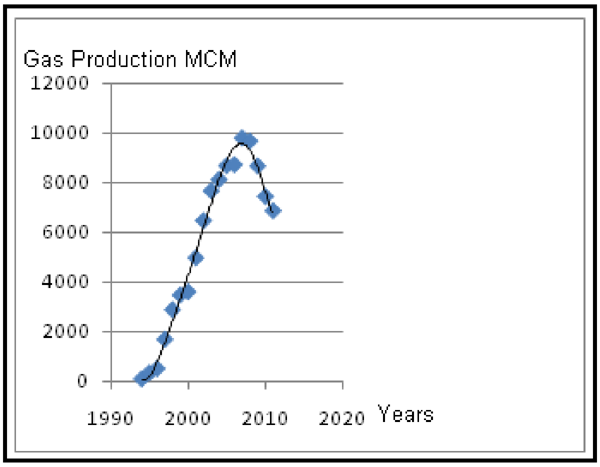
The petroliferous basins both onshore and offshore range in age throughout the Phanerozoic. Most of the commercial hydrocarbon discoveries in India are from Cenozoic succession[4]. However, not all the Phanerozoic basins in India are prospective. Based on the oil exploration activities and successes, it is observed that a small number of basins produce most of the hydrocarbons. The categories of proven petroliferous basins of India with commercial production include Mumbai Offshore, Cambay, Assam-Arakan, Cauvery, Krishna-Godavari and Tripura-Cachar basins. Another category of basins with known occurrence of hydrocarbons, but without commercial production includes Andaman-Nicobar, Bengal, Mahanadi, and Himalayan foothills. Out of the total sedimentary basins 15 have been explored out of which 7 are under production.



(Data Source: Directorate General of Hydrocarbons, India)

Figure 4. Oil Production in India[20]

The current production and development can be seen from the trend (Figure 4 and 5). It gives an idea regarding the future production and go on helping in better management, appraisal and demands more search for prospects of unconventional reserves[5]. The Government of India's Document[5] vividly explains to encourage the use of natural gas as eco-friendly fuel and to tap its unconventional sources and to develop hydrocarbon sector as a globally competitive industry that could be benchmarked against the best in the world through technology upgradation and capacity building in all facets of the industry.



(Data Source: Directorate General of Hydrocarbons, India)

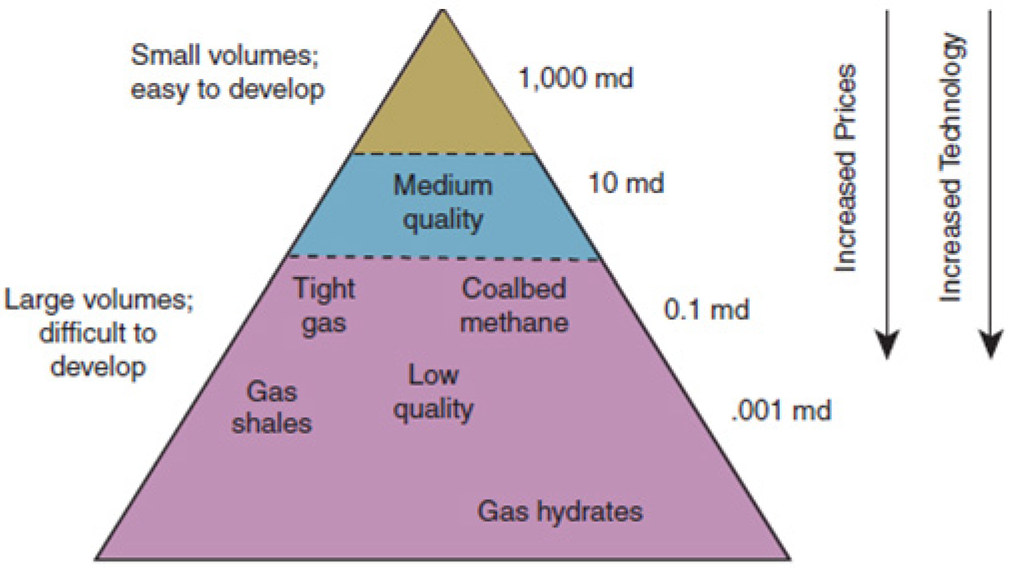
Figure 5. Gas Production in India[20]

2. Unconventional Hydrocarbon Resource

All natural resources are distributed log normally in nature (Figure 6 and 7) describing the sense that as we go deeper into the gas-resource triangle, the reservoirs are lower grade. This usually means the reservoir permeability is decreasing. These low-permeability reservoirs are much larger in size than the high-quality reservoirs[6]. The common theme is that low-quality deposits of natural gas require improved technology and adequate gas prices before they can be developed and produced economically.

Unconventional hydrocarbons are the sources that mainly include tight gas sand; coal bed methane; shale gas; gas hydrate; and underground coal gasification. They require methods for extraction which are not normally necessary in the conventional extraction. They are traditionally known for their low permeability. The faster depletion of conventional resources vis-à-vis rapidly increasing demands from various sectors, India along with other countries have started exploring the alternatives to conventional energy. Only one third of worldwide hydrocarbon reserves are conventional, the remaining sources are unconventional (Figure 8).

Shale gas is a natural gas formed and trapped within the shale formation that typically functions as the reservoir, source rock and the seal. . Its evolutionary history over the globe (figure 9) and its accumulation in India (Figure 10) highlights the huge prospects of further exploration and sustainable production. The shale gas in Cambay basin is dealt in detail as part of the present study.



(After Holditch, 2006)

Figure 6. Resource triangle for natural gas[6]

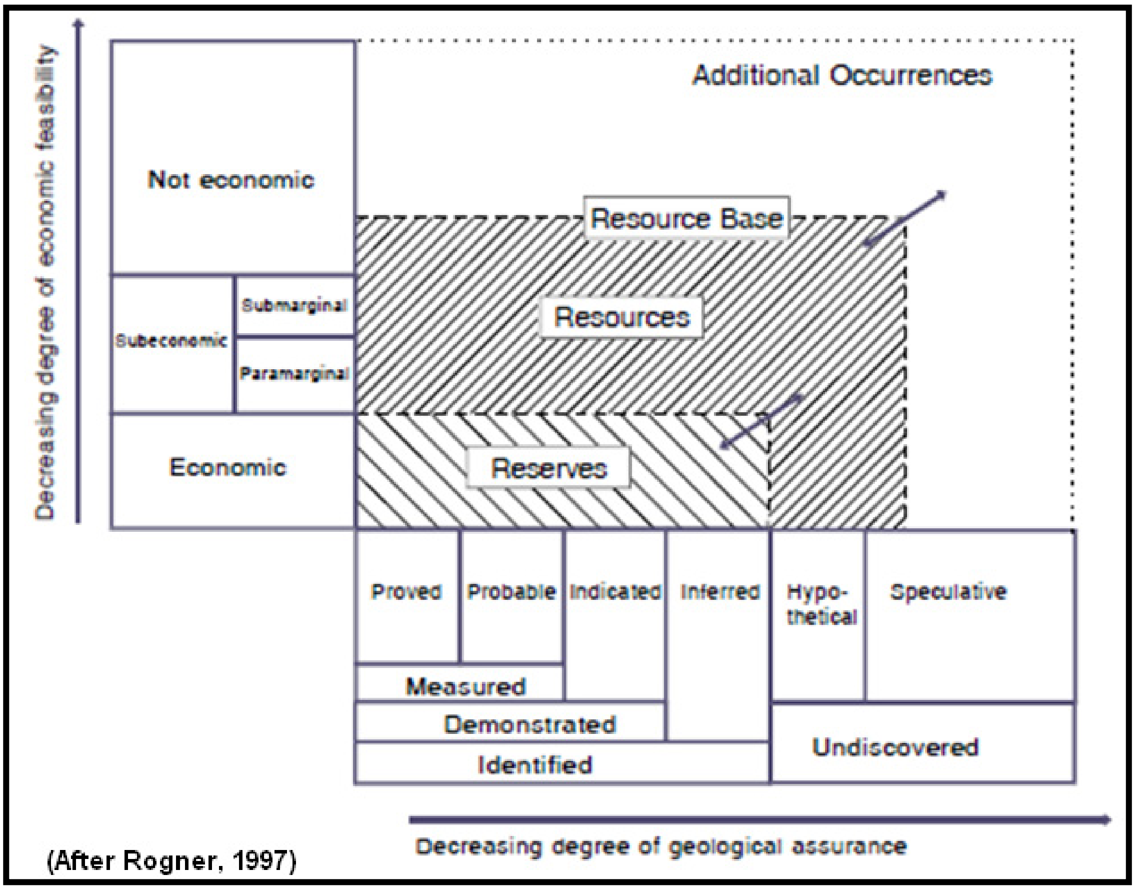
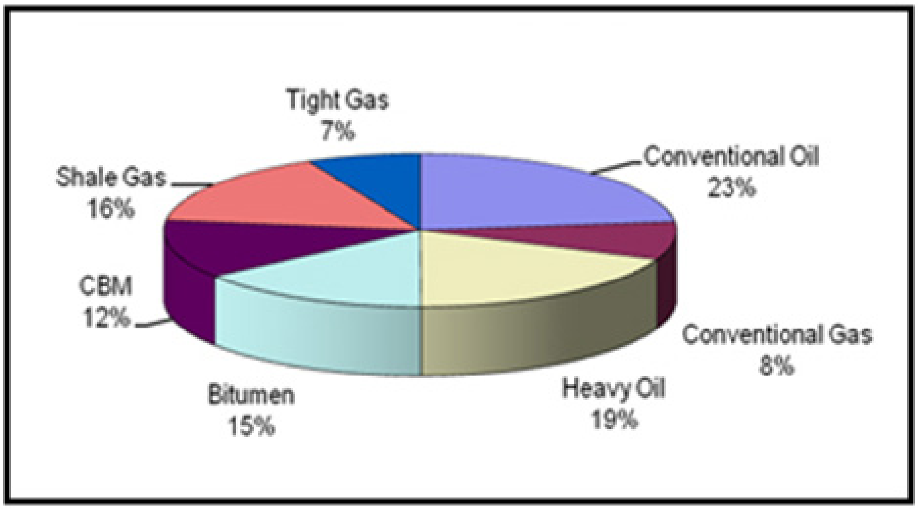
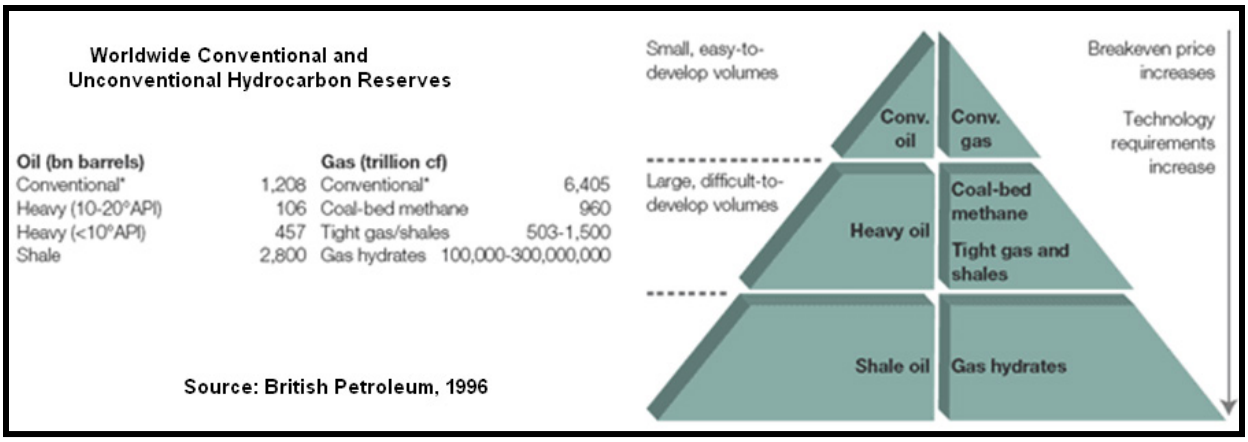


Figure 7. Classification of energy reserves and resource[21]



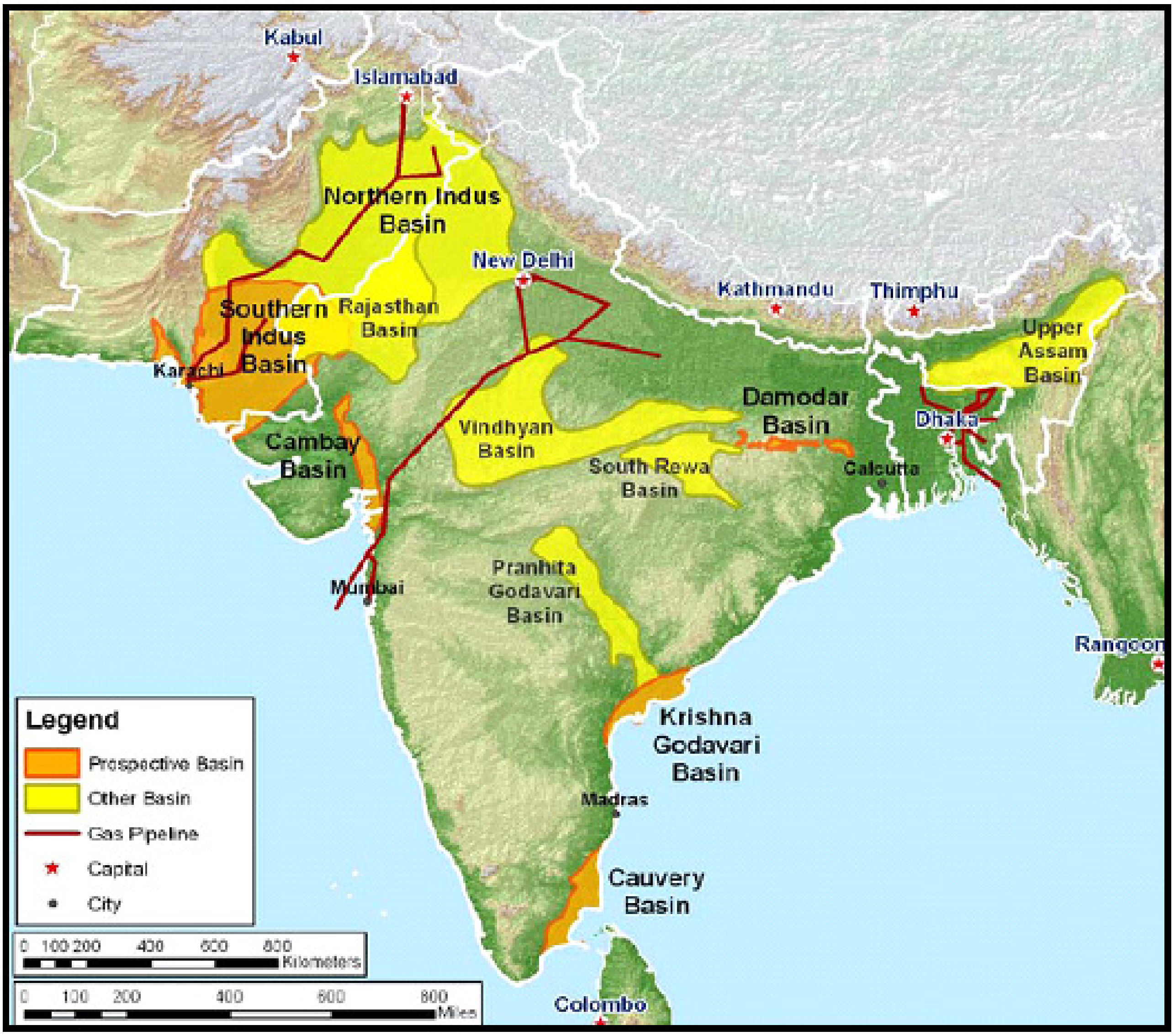
(After British Petroleum, 1996)

Figure 8. Worldwide hydrocarbon reserves[22] (After British Petroleum, 1996)



(After British Petroleum, 1996)

Figure 9. Shale gas as global resource[22]



(Source: IUGF-2011)

Figure 10. Potential shale gas basins of India[23]

3. Shale Gas in Cambay Basin

The Cambay basin a rich petroleum province of India is a narrow, elongated rift graben, extending from Surat in the south to Sanchor in the north (Figure 11). It began evolving following the extensive outpour of Deccan Basalts during late Cretaceous covering large tracts of western and Central India[7, 8 and 9].

The Cambay rift valley is bounded by well demarcated basin margin step faults. Based on the cross trends, the basin has been divided into five tectonic blocks. From north to south, the blocks are: Sanchor, Ahmadabad, Tarapur, Broach and Narmada.

The Early Tertiary sediments ranging in age from Paleocene to Early Eocene represent syn-rift stage of deposition that was controlled by faults and basement highs in an expanding rift system[10]. The Middle Eocene witnessed a regressive phase with oscillating conditions of deposition and development of deltaic sequences in the entire basin[11].

Thick Cambay shale has been the main hydrocarbon source rock in the basin wherein the coal developed within the deltaic sequence of other source rocks[12]. The lithological heterogeneity gave rise to permeability barriers, which facilitated entrapment of hydrocarbons (Figure 12). The associated unconformity also helped in the development of secondary porosity.

The source rock intervals in the Cambay basin, ranges from early Paleocene to Oligocene in age. The proven reservoirs are dominated by sandstones, siltstones, conglomerates, fractured shales and basalts forming less important reservoir. Shales, ranging from Paleocene to Miocene in age dominate the proven seals in the Cambay basin.

The hydrocarbon production trends, (Figure 13 and 14) depict decline during the recent years. In order to overcome the deficient hydrocarbons, exploiting shale gas reserves is the best alternate as they have enormous amount of gas and the larger formations. They can continue to produce at a steady rate for decades[13].

3.1. Methodological Approach

The essential factors for the development of shale gas reservoirs are the gas content and the recovery rate. Both require the detailed laboratory investigation leading to organic richness and degree of maturity where extremely low permeability leaves no option except to create a dense network of fractures to sustain the production. The time has come to infuse newer technologies that are harmonious with environmental norms and significant towards hydrocarbon value chain leading to energy security and prosperity[14].

The approach can be classified as under,

A. Field Work

1. Identification of prospects for testing the methodology

o Collection of data

- Geological, geophysical and geochemical data
- Core and reservoir data
- Testing details and production data
- Review of all available data.

B. Laboratory Work

1. Detailed core analyses with special reference to-

o Storage and transmission

o Mineral composition

o Chemical behaviour of reservoir rock

o Selection of applicable technique

2. Well data interpretation

3. Detailed structure and fault mapping of pay zones using seismic and well data

4. Reservoir characterization using seismic and log data

5. Development of Technology for incremental increase in production in varied geological and reservoir conditions.

6. Testing the technique in a pilot prospect/well

Expected Outcome

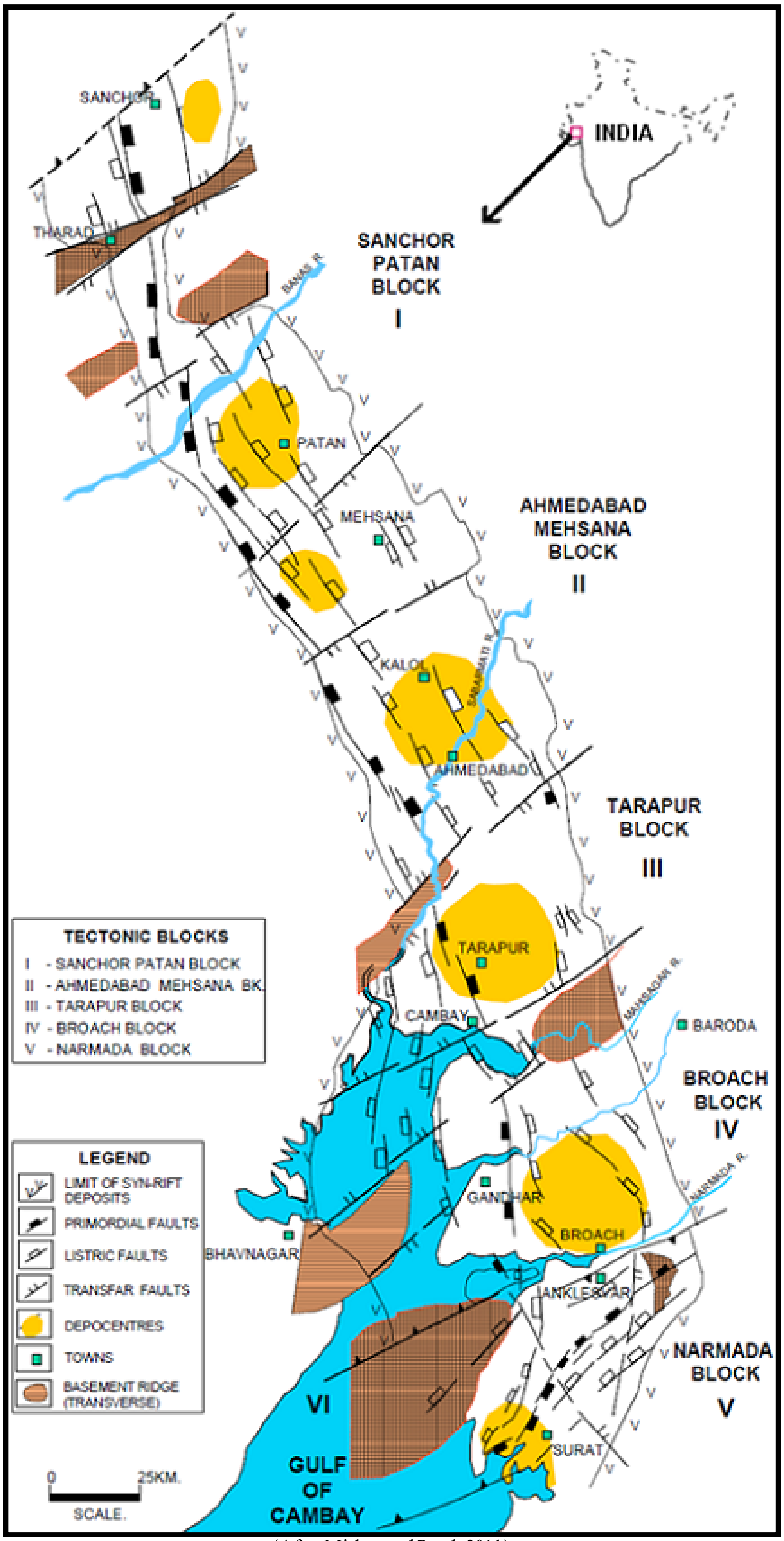
1. The result will provide the technologies to adopt for sustainable recovery
2. The findings decide the effective future predictions
3. The study will be a model for similar field conditions
4. Development, enhancement, adoption and absorption of technology

Some of the gas produced is held in natural fractures, some in pore spaces, and some is adsorbed onto the organic material. The gas in the fractures can be produced immediately. The gas adsorbed onto organic material is released as the formation pressure is drawn down by the well[15]. The total organic carbon content, matrix porosity and water saturation are the key parameters to have an answer for shale gas potential of any basin. However, there are other elements to be considered for the development of successful shale gas plays (Figure 15). The physico-chemical parameters (Table-1) and stratigraphic pattern together show high end prospects of shale gas accumulation in the basin.

The hydraulic fracturing is usually conducted mostly with water based fluids using additives as friction reducer, scale inhibitor and proppants to hold the fractures open[16]. (Kaufman et al 2008). Hence, needs to be addressed along with the environment concern as well[17 and 18].

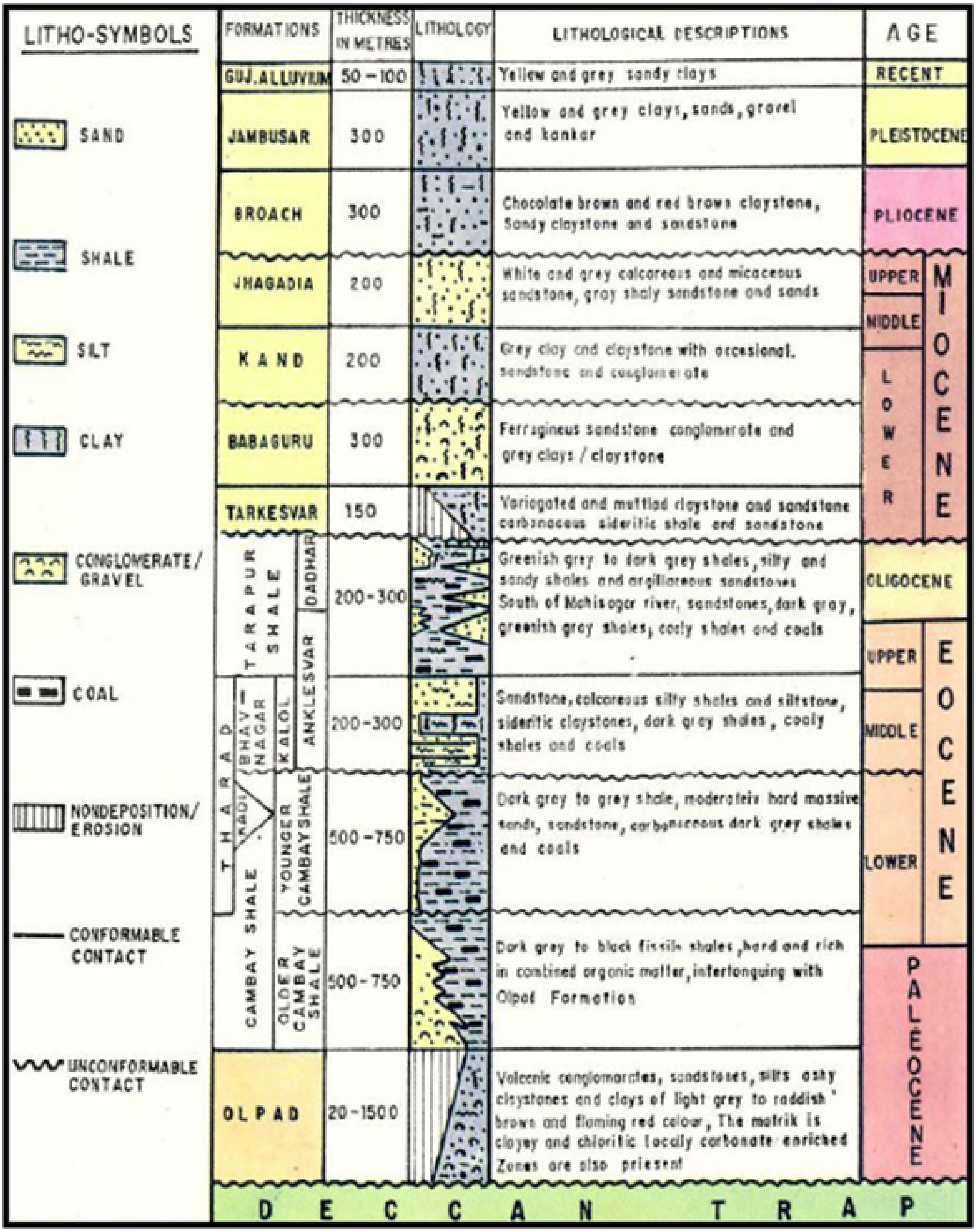
Table 1. Shale characteristics of Cambay Basin (Source: IUGF, 2011)

Formation	Thickness (m)	TOC (%)	VRo (%)	Kerogen Type
Olpad	340-2700	1.5-4.0	0.75	II&III
Older Cambay Shale	500-1900	1.5-4.0	0.75-0.85	II&III
Younger Cambay Shale	520-1500	1.5-4.0	0.75-0.85	II&III
Kalol	200-300	--	0.75	II&III
Tarapur	60-400	--	0.63	--



(After Mishra and Patel, 2011)

Figure 11. Tectonic map of Cambay basin[24]



(Source: IUGF-2011)

Figure 12. Shales in stratigraphy in Cambay basin[23]

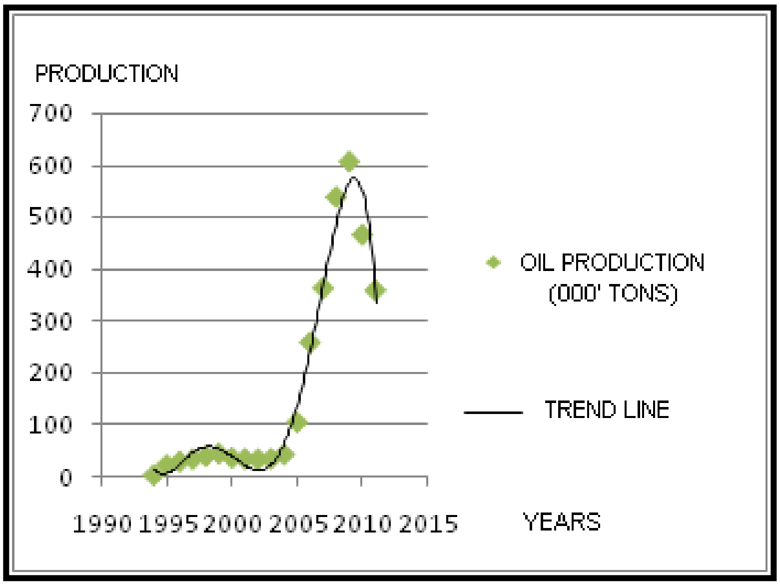
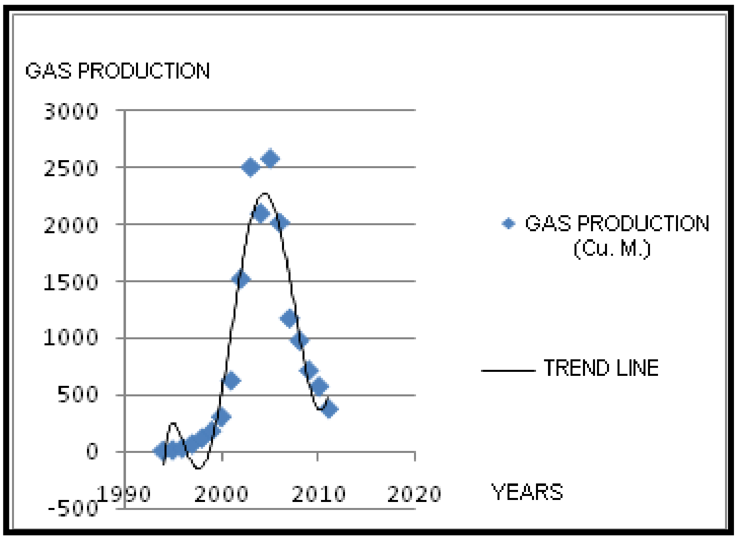
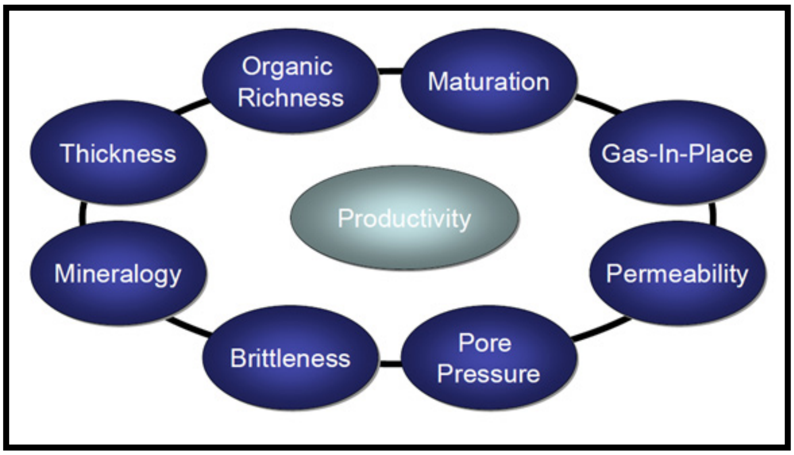


Figure 13. Oil production and trend in Cambay basin[20]



(Data Source: Directorate General of Hydrocarbons, India)

Figure 14. Gas production and trend in Cambay basin[20]



(Source: PGA, 2011)

Figure 15. Elements for the development of successful shale gas play[25]

4. Conclusions

The decline in production trends draws attention to step ahead towards the resources which are unconventional but can be sustained with production for decades. The shale gas now become an important part of energy mix that require thorough laboratory investigation followed by controlled hydraulic fracturing to surge in economically sustained recovery.

The stratigraphic succession of the Cambay basin is largely influenced together by the tectonic set-up and sedimentary patterns. There exists a vast possibility of unconventional resources especially shale gas as evidenced by previous researches that deserve to enlarge the exploratory horizons with time and space.

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REFERENCES

[1] Chandra K., 1997, Alternative hydrocarbon resources in the next millennium, www.spgindia.org / geohorizon pp 1-19.

[2] Thusu B., Levey R. and Bhat G. M. 2011. Shale gas exploration and production research in India by the Energy and Geoscience Institute, university of Utah-a model for Indian universities, Abstracts-international Conference on Unconventional Sources of Fossil Fuels and Carbon Management (ICUSFFCM-2011), pp 21.

[3] Hasan S. Z. and Farooqui M. Y. 2011, A Laboratory Based Study for Shale Gas Reservoir Characterization, Stimulation and Production Evaluation, Abstracts-International Conference on Unconventional Sources of Fossil Fuels and Carbon Management (ICUSFFCM-2011), pp 31.

[4] Bhowmick P. K. and Misra R., 2010 Phanerozoic petroliferous basins of India, In Glimpses of Geoscience Research in India Eds Singhvi, A. K., Bhattacharya, A. and Guha, S.) INSA, New Delhi, pp 218-228

[5] India Hydrocarbon Vision (IHV), 2025. Ministry of Petroleum, Government of India, Source: petroleum.nic.in/vi sion.doc

[6] Holditch, S. A., 2003, The increasing role of unconventional reservoirs in the future of the oil and gas business. SPE President Publications, pp 34-38.

[7] Bhandari, L. L. and Chowdhary, L. R., 1975, Stratigraphic analysis of Kadi and Kalol formations, AAPG Bulletin, V 59, pp 856-871.

[8] Biswas, S. K., Rangaraju, M. K., Thomas J. and Bhattacharya S. K., 1994, Cambay-Hazad(!) petroleum system in the south Cambay basin, India In: Petroleum system-from source to trap Eds Magoon B. L. and Dow W. G., AAPG Memoir, 60, pp 615-624.

[9] Kundu, J. and Wani, M. R., 1992, Structural styles and tectono-stratigraphic framework of Cambay rift basin, western India, Indian Journal of Petroleum Geology, V 1, pp 181-202.

[10] Balakrishnan, T. S., Gupta, T. C. and Bisht, H. S., 1997, Regional tectonic and sedimentation in studies of Cambay basin, Unpublished report-ONGC.

[11] Biswas, S. K., 1977, Mesozoic stratigraphy of Kutch, Gujarat, Quarterly Journal-Geology, Mineral and Metallurgical Society of India V 49 (3-4), pp 1-52.

[12] Banerjee, A., Pahari, S., Jha, M., Sinha, A. K., Jain, A. K., Kumar, N., Thomas, J., Misra, K. N. and Chandra, K., 2002, The effective source rocks in the Cambay basin, India, AAPG Bulletin, V 86, pp 433-456.

[13] Frantz, J. H. and Schlumberger, V. J., 2005, White paper on shale gas by M/s Schlumberger Marketing Committee, pp 1-10.

[14] Associated Chambers of Commerce and Industry of India (ASSOCHAM), 2011, India formulating policy for shale gas exploration: DGH, Press release, May 10, 2011.

[15] Tyagi, A., Abedeen, A. and Dutta, T., 2011, Petrophysical Evaluation of Shale Gas Reservoir: A Case Study from Cambay Basin, India, In Proceedings SPE / DGS Annual Technical Symposium and Exhibition, Tackling upstream challenges: fueling the world safely, reliably and cost-effectively, Publication No. SPE 149039.

[16] Kaufman, P., Penny, G. S. and Paktinat, J., 2008, Critical evaluation of additives-used in shale gas slickwater fractures, Society of Petroleum Engineers, SPE-119900, November -2008.

[17] Porges, R. and Hammer, M., 2001, The compendium of hydrogeology, National Groundwater Association-USA, 303p.

[18] National Resources Defense Council (NRDC), 2007, Drilling down: protecting western communities from the health and environ effects of oil and gas production, An official document-USA, October-2007, 48p.

[19] Wikipedia, India Geological Zones, source: www.en.wikepe dia.org

[20] Directorate General of Hydrocarbons (DGH), India. Source: www.dghindia.org

[21] Rogner, H H, 1997, An assessment of world hydrocarbon resources, Annual Reviews Energy and Environments No. 22, 99, pp 217-262.

[22] British Petroleum, 1996, Statistical review of world energy, Technical report by British Petroleum Company P.Lc, London.

[23] India Unconventional Gas Forum (IUGF), 2011, Unlocking the value of unconventional gas, Technical presentation by Dr. V. K. Rao, Sr. V. P., Reliance Natural Resources.

[24] Misra, M. and Patel, B. K., 2011, Gas shale potential of Cambay formation, Cambay basin, India, Proceedings: The 2nd South Asian Geosience Conference and Exhibition,

GEOIndia-2011, pp 1-5.

[25] Potential Gas Agency (PGA), 2011, Future US and Canadian shale gas resources, Annual Report, Colorado School of Mines, USA.