Current Scenario and Future Prospects of Shale Gas in India*

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Abstract

Unconventional oil resources are increasingly important in the quest for energy security. There is concern that conventional oil resources will be unable to meet growing supply requirements. This concern has triggered a scramble to secure long-term oil supplies. In a high oil price environment, unconventional resources are viewed as important and economically attractive components of future oil supplies.

Shale gas is natural gas produced from shale formations. Gas shales are organic-rich shale formations. In terms of its chemical makeup, shale gas is basically a dry gas composed of methane. Various factors which have contributed to its rapid development are mainly advancement in horizontal drilling, hydraulic fracturing, and, perhaps most importantly, rapid increase in natural gas prices in the last several years as a result of significant supply and demand pressures.

India has high potential of shale reserves. According to sources, a comprehensive shale gas pilot project carried out in Damodar Valley Basin, has made an initial gas-in-place estimate of 300-2,100 trillion cubic feet (tcf) in Indian shale gas basins which is around 300 times higher than Krishna Godavari (D6) Basin, by far the largest gas field in the country. In matured Cambay Basin wherein more than 5000 wells have been drilled and initial oil in -place of the order of 1150 million tonnes have already been established. But for the first time, gas has been struck from Shale Reservoir of Middle Eocene section. The paper presents discovery of gas from shale reservoir thereby viewing Cambay Shales not only as cap and source rock but also as reservoir rock. This has opened new frontier for exploration.

With most of the conventional oil already depleted, industry hopes to increase liquid supplies through the development of unconventional resources. Difficult to manage unconventional reservoirs, though, challenge the ability to transform even huge in-place resources like extra-heavy oil and oil shales to supplies. The paper reviews the evolving plays and technologies that impact the development and future of the shale resources in India.

Introduction

Unconventional sources of energy are one of the hot topics of debate in the international energy sector at the moment. In the present scenario, the rapidly growing energy demand worldwide and the higher depletion rates of existing reserves as compared to their discoveries are a major causes of the gap between supply and demand. This situation of the increasing gap between supply and demand has impelled the world to explore and develop unconventional resources of gas.

Three such unconventional gas resources are tight gas reservoirs, coal bed methane, and shale gas. These resources hold great potential as a source of natural gas and at the moment extensive work is being done for the development of these resources across the world. However, the technological advancements, environmental benefits, long term potentials, and attractive gas prices bring unconventional gas resources more rather than oil into the forefront of our energy future. Nowadays the world is witnessing an increasing demand of gas and thus unconventional gas resources development has the focus of increased attention. In future, a significant percentage of the world's energy demands will be satisfied by the natural gas. Gas consumption will increase and it will be a key factor in the future economic performance and strategic stability of any nation. Furthermore, some experts believe that the consumption of gas will exceed that of oil by about 2025.

Shale Gas: A Promising Unconventional Resource

Shale gas is natural gas produced from shale. Shale is a fine-grained, clastic sedimentary rock composed of mud that is a mix of flakes of clay minerals and tiny fragments (silt-sized particles) of other minerals, especially quartz and calcite. Shale gas is defined as a fine-grained reservoir in which gas is self-sourced, and some of the gas is stored in the sorbed state. Sorbed gas is predominantly stored in the organic fraction – so organics are present. Shale gas is not just "shale". Productive gas shales range from organic-rich to fine-grained rocks.

Shale has low matrix permeability, so gas production in commercial quantities requires fractures to provide permeability. Shale gas has been produced for years from shales with natural fractures; the shale gas boom in recent years has been due to modern technology in hydraulic fracturing to create extensive artificial fractures around well bores. Horizontal drilling is often used with shale gas wells, with lateral lengths up to 10,000 feet (3,000 m) within the shale, to create maximum borehole surface area in contact with the shale.

The gas is produced by inducing fracs preferably by water from multilevel completions. The pressures are generally low but the length of production period compensates by volume. Among various unconventional gas resources; the Coal Bed Methane (CBM), tight gas, and shale gas are being commercially exploited in the US and Canada, Australia, China etc in different proportions (see Figure 1 and Figure 2). India too has kept pace with the CBM industry but the tight gas and shale gas are yet to find a place in the country's energy basket.

Shale Gas in India

India has huge shale deposits across the Gangetic plain, Assam, Gujarat, Rajasthan, and many coastal areas. Gas has long been found in shale across the world, but its extraction has been viewed as uneconomic because of shale's low permeability — gas does not flow easily through this rock. So, exploration for oil and gas has traditionally focused on limestone and sandstone, which have high permeability.

India contains a number of basins with organic-rich shales, mainly the Cambay, Krishna Godavari, Cauvery, and Damodar Valley basins. There are some other potential reserves such as the Upper Assam, Vindhyan, Parinhita- Godavari, and South Rewa, but it was found that either the shales were thermally too immature for gas or the data with which to conduct a resource assessment were not available.

Shale basins in India are geologically highly complex. Many of the basins, such as the Cambay and the Cauvery, have horst and graben structures and are extensively faulted. The prospective area for shale gas in these basins is restricted to a series of isolated basin depressions (sub-basins). While the shales in these basins are thick, considerable uncertainty exists as to whether (and what interval) of the shale is sufficiently mature for gas generation.

Recently, ONGC drilled and completed the India's first shale gas well, in northwest of Calcutta in West Bengal. The well was drilled to a depth of 2,000 meters and reportedly had gas shows at the base of the Permian Barren Measure Shale. Two vertical wells were previously tested in the Cambay Basin and had modest oil and shale gas production in the shallower, 4,300 foot thick intervals of the Cambay "Black Shale". Overall, ARI estimates a total of 290 Tcf of risked shale gas in-place for India. The technically recoverable shale gas resource is estimated at 63
Tcf in India. These estimates could increase with collection of additional reservoir information.

Potential Shale Gas Reserves in India

Cambay Basin, India

The Cambay Basin is an elongated, intra-cratonic rift basin (graben) of Late Cretaceous to Tertiary located in the State of Gujarat in northwestern India. The basin covers an onshore area of about 20,000 m^2. It is bounded on its eastern and western sides by basin-margin faults. It extends south into the offshore Gulf of Cambay, limiting its onshore area, and north into Rajasthan. The Cambay Basin contains five distinct fault blocks, from north to south (see Figure 5):

- Sanchor Patan (Too Shallow for Shale Gas)
- Mehsana-Ahmadabad (Prospective Area)
- Tarapur (One Prospective Area)
- Broach (Prospective Area)
- Narmada (Insufficient Data)

Each of these blocks is characterized by local lows, some of which appear to have sufficient thermal maturity to be prospective for shale gas.

Krishna Godavari Basin, India

The Krishna Godavari Basin extends over a 7,800 m^2 area onshore (plus additional area in the offshore) in eastern India. The basin consists of a series of horsts and grabens. The basin contains a series of organically rich shales, including the deeper Permian Kommugudem Shale, which is gas prone (Type III organics) and appears to be in the gas window in the basin's grabens. The Upper Cretaceous Raghavapuram Shale and the shallower Paleocene and Eocene shales are in the oil window.

Cauvery Basin, India

The Cauvery Basin covers an onshore area of about 9,100 m^2 on the east coast of India, plus an additional area of about 9,000 m^2 in the offshore. The basin comprises numerous horsts and rifted grabens. The basin contains a thick interval of organic rich source rocks in Lower Cretaceous Andimadam and Sattapadi shale formations which overly the Archaean basement. With a combined prospective area of 1005 m^2 and an average resource concentration of 143 Bcf/m^2, around 43 Tcf of risked shale gas in-place is estimated of which 9 Tcf is considered technically recoverable.

Damodar Valley Basin, India

The Damodar Valley Basin is part of a group of basins collectively named the "Gondwanas", owing to their similar dispositional environment and Permian-Carboniferious through Triassic stratigraphic fill. The "Gondwanas", comprising the Satpura, Pranhita-Godavari, Son-Mahanadi and Damodar Basins, were part of a system of rift channels in the northeast of the Gondwana super continent.

Along with the Cambay Basin, the Damodar Valley Basin is a priority basin for shale gas exploration by the Indian government. In late September 2010, Indian National Oil and Gas Company (ONGC) spotted the country's first shale gas well, in the Raniganj sub-basin. The well was completed mid-January 2011, having reportedly encountered gas flows from the Barren Measures Shale at approximately 5,600 feet. Detailed well test or production results are not publicly available.

General Methodology for Exploration

The shale gas exploration workflow **(**as shown in Figure 3**)** typically starts with observation of gas in the cuttings with the mud. Understanding the extent of shale gas pay with the help of pilot wells, seismic interpretation, and log correlation is important. Quantification of shale gas can be done by adsorption and desorption studies on the cores to measure Langmuir volume and gas content with change in pore pressure.

The petrophysical evaluation and reservoir characterization is the backbone of evaluating a shale gas reserve. Various other techniques such as coring methodology, open-hole logging, elemental spectroscopy, and lithology identification are essential for understanding the Total Organic Content (TOC) and estimate the production potential. Geomechanical analysis and the study of stress regime help to design well completion, drilling horizontal wells, and selecting appropriate perforation technique.

The data gathered during the process, right from drilling to completion and fracturing, can be used to predict the performance of the shale gas production for future using numerical reservoir simulator. The use of horizontal and multilateral techniques in shale gas reservoirs is expanding rapidly.

Hydraulic fracturing stimulation is the most extensively accepted tool used for the development of shale gas reservoirs. This is due to the fact that shale reservoirs have a very tight nature with low permeability and to make them flow at an economical rate stimulation by hydraulic fracturing is necessary. The ultimate aim is to increase the productivity index. This method helps to gain vertical connectivity amongst various gas bearing layers and allow easy connectivity.

Challenges and Environmental Issues

The primary differences between modern shale gas development and conventional natural gas development are the extensive uses of horizontal drilling and high-volume hydraulic fracturing. Although shale gas has been produced for more than 100 years in the United States, the wells were often marginally economical. Higher natural gas prices and the recent advances in hydraulic fracturing and horizontal completions have made shale gas wells more profitable. Shale gas tends to cost more than gas from conventional wells, because of the expense of massive hydraulic fracturing required to produce shale gas, and of horizontal drilling. However, this is often offset by the low risk of shale gas wells.

It has been a belief that shale releases fewer greenhouse gas (GHG) emissions than other fossil fuels. However, there is growing evidence that shale gas emits more greenhouse gases than conventional national gas, and may emit as much or more than oil or coal. Methane is a very powerful greenhouse gas, although it stays in the atmosphere for only one tenth as long a period as carbon dioxide. Recent evidence indicates that methane has a global warming potential that is 105-fold greater than carbon dioxide when viewed over a 20-year period and 33-fold greater when viewed over a 100-year period, compared mass-to-mass.

Some basic challenges faced are (see Figure 4):

- Screening exploration targets
- Gas in place
- Matrix permeability
- Determining intervals to frac or drill horizontals
- Predicting production rates
- Predicting decline rates
- Determining drainage areas (spacing units) in thick intervals of shale
- Gas producers have no confidence in their Original Gas in Place calculations

Non-Technical Challenges

Many companies operating in the upstream gas industry in Asia and Middle East are interested in the outstanding success achieved by the USA and Canadian tight and shale gas producers. It seems almost miraculous that companies can obtain economic gas production rates from rocks with permeability measured in nanodarcies - so low in fact that it is impossible to determine it accurately.

The companies in this region have now realized that they may be sitting on top of huge untapped gas reserves that had previously been evaluated as sub-economic. But there exist certain non technical issues or regulations which bound them to produce gas from these areas.

Some of the vital issues are as follows:

1. **Cost of field development operations.**
   Cost of drilling and completing in Asian countries is 2.5 to 5 times higher than similar operations in USA and Canada. This may be due to less infrastructure and government support in terms of subsidies.

2. **Lack of fiscal incentives and infrastructure.**
   Unlike the USA and Canada, most countries have so far not offered significant fiscal incentives.

3. **Inability to experiment with wellbores.**
   Reservoir development in western countries is built around the need to experiment with the wellbore - a process of trial and error. But Asian based companies find this concept difficult to grasp. Here much of the engineering is done retroactively, based on the actual performance of the well bore, rather than up-front before the well is drilled.

4. **Lack of wellbore-specific information.**
   In the USA, most states mandate disclosure of substantial and significant information for each wellbore drilled and this information is in turn available on public-access databases. Thus it is possible for operators to compare completion methods and practices for huge number of wells in similar formations. The lack of widely shared information in Asian countries makes it harder for the efficient independent operators to exploit resources.

5. **Lack of political will.**
   There are considerable political differences among many of the countries in this region - so much so that some of the countries have actually been to war with each other in the recent memory. Apart from this corruption, bureaucracy, political instability, and prohibitive customs regulations all mean that operations are often significantly delayed or cancelled altogether.

6. **Competition from alternative sources**
   Companies need to face a huge market competition from existing products and also due to the monopoly of gas rich countries.

Solutions

India’s gas demand is limited by its access to gas supplies based on domestic production and imports availability. If India can produce more gas, then it can reduce its coal imports which is environmentally more unfriendly.

Unfortunately, the Indian government has not been able to implement the right kind of gas policies even after the recommendations given by several high powered commissions. The basic requirement for proper gas sector development in India is that the government should allow the market to set the prices as recommended by many gas committees. Why has no company in India explored for shale gas despite several rounds of bidding for exploration blocks in the last two decades? The sad answer is that our exploration policy allows companies to produce only conventional oil and gas from their exploration blocks. If they find non -conventional energy — such as coal-bed methane or shale gas — they are forbidden to produce this!

This is because the petroleum ministry regards any non-conventional deposit as an unwarranted windfall for the exploring company, and wants separate bidding for non-conventional energy. For coal bed gas, it has called for bids and awarded exploration contracts in known coal deposits. But gas can also be found in deep coal deposits unknown today. When drilling for oil, Indian companies have already hit thick coal seams deep underground, but not bothered to test these for gas because they would not be allowed to extract it. The same holds for shale gas. When drilling for oil, every company hits shale deposits, but ignores their gas potential since they are not allowed to harness it.

Two changes in exploration policy are urgently needed:

- The government needs to come out with a shale gas policy. It should facilitate seismic surveys that can quickly delineate potential shale gas deposits, and then invite bids for exploration.
- All future exploration contracts for oil should permit exploitation of shale gas as well as conventional gas.

Recent Developments

- In November 2010, India and the United States decided to cooperate in the fields of clean tech and shale gas.

- The Director General of hydrocarbons and the petroleum ministry are working on the changes required in the exploration laws for shale gas to be produced, because current exploration licenses do not include unconventional sources.

- In January 2011, India's biggest energy explorer Oil and Natural Gas Corporation (ONGC) has discovered the country's first shale gas reserve at Durgapur in Burdwan district of West Bengal. The Sarpi deposit is Asia's first, and the only tapped shale gas reserve outside North America.

- The ONGC, which began its exploration of the Damodar Basin last September in India's first such experimental project, hit upon the gas source while drilling its first well.

- It has opened up new hopes for meeting our energy needs and encouraged to venture into many shale sequences in well explored Cambay, KG, Cauvery and Assam-Arakan Basins for exploitation of shale gas in Indian subcontinent.

Conclusions

Though India possesses significant reserves of natural gas, 38 Tcf in 2009, it still relies on imports to satisfy domestic consumption. In 2009, the country consumed 5.1 Bcfd of natural gas, while producing 3.9 Bcfd. Were India to develop the technically recoverable shale gas resources, it may add an additional 63 Tcf of natural gas to its domestic reserve base. India's vast resources of shale gas were untapped due to strict government policies and the lack of interest from the industry. However, with the advent of new technologies and the growing energy needs coupled with appropriate market prices make this time right to explore and exploit this resource on equal priority. Reservoir characterization and detailed planning is necessary for success in shale gas exploration. Drilling of horizontal wells and techniques like hydraulic fracturing will increase recovery and economic viability to produce shale gas.

Selected References

Bustin, R.M., 2005, Comparative analyses of producing gas shales; rethinking methodologies of characterizing gas in place in gas shales: Bulletin West Texas Geological Society, v. 45/2, p. 9-10.

Creties, D.J, and C.M. Boyer, II, 2008, Coalbed and Shale-Gas Reservoirs: SPE 103514, 8 p.

EIA, 2011, World Shale gas Resources: An initial assessment of 14 regions outside the United States, 365 p. Web accessed 12 December 2012. http://www.eia.gov/analysis/studies/worldshalegas/pdf/fullreport.pdf

Misra, R., 2008, Shale Gas Exploration in India: Opportunities and Challenges: AAPG Search and Discovery Abstract (2008). Web accessed 16 November 2012. http://www.searchanddiscovery.com/abstracts/html/2008/geo_india/abstracts/misra.htm

Selected Websites

Airy, A., 2010, India emerges as shale gas hub: Web accessed 12 December 2012. http://www.hindustantimes.com/India-emerges-as-shale-gas-hub/Article1-594853.aspx

Alyar, S.A., 2009, Shale gas: Could it be a new energy source? Web accessed 12 December 2012. http://blogs.timesofindia.indiatimes.com/Swaminomics/entry/shale-gas-could-it-be

India Today, 2010, India eyes US tec to exploit shale gas: Article from October 28, 2010. Web accessed 12 December 2012. http://indiatoday.intoday.in/site/Story/118024/Business/india-eyes-us-tech-to-exploit-shale-gas.html

Shenoy, B.V., 2012, Shale Gas: A game changer that India should turn to: Deccan Herald, 5 p. Web accessed 12 December 2012. http://www.deccanherald.com/content/44366/shale-gas-game-changer-india.html

Region	Tight Gas Sands (Tcf)	Coalbed Methane (Tcf)	Shale Gas (Tcf)
North America	1,371	3,107	3,840
Latin America	1,293	39	2,116
Western Europe	353	157	509
Central and Eastern Europe	78	118	39
Former Soviet Union	901	3,957	627
Middle East and North Africa	823	0	2,547
Sub-Saharan Africa	784	39	274
Centrally Planned Asia and China	353	1,215	3,526
Pacific (OECD)	705	470	2,312
Other Asia Pacific	549	0	313
South Asia	196	39	0
World	**7,406**	**9,051**	**16,103**

Figure 1. Distribution of worldwide Unconventional gas resources by region.

Region	Tight Gas Sands (Tcf)	Coalbed Methane (Tcf)	Shale Gas (Tcf)
USA	350	100	45.2
Asia & Oceania	703.57	238.05	390.8
Middle East	321.05	0.0	52.97
East Siberia and Far East	31.08	45.91	1.059

Figure 2. Technically recoverable Unconventional gas resources by region.

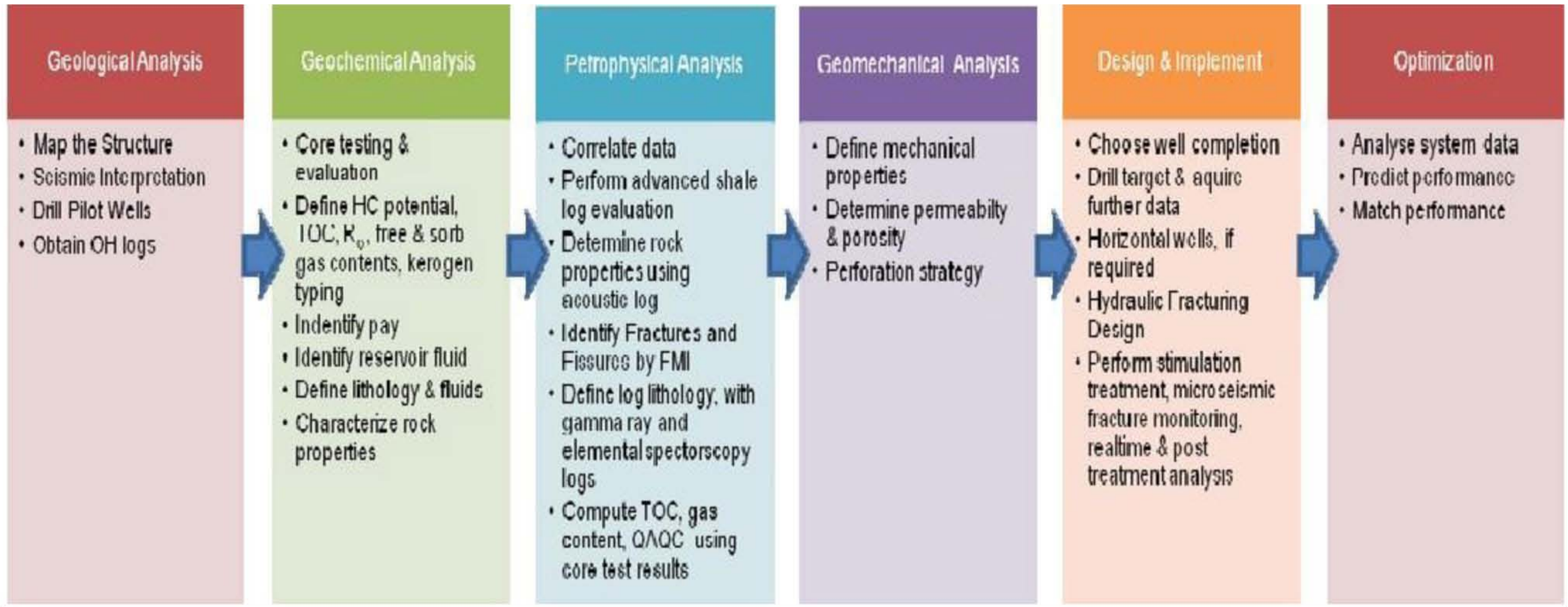

Figure 3. General methodology for shale gas exploration.

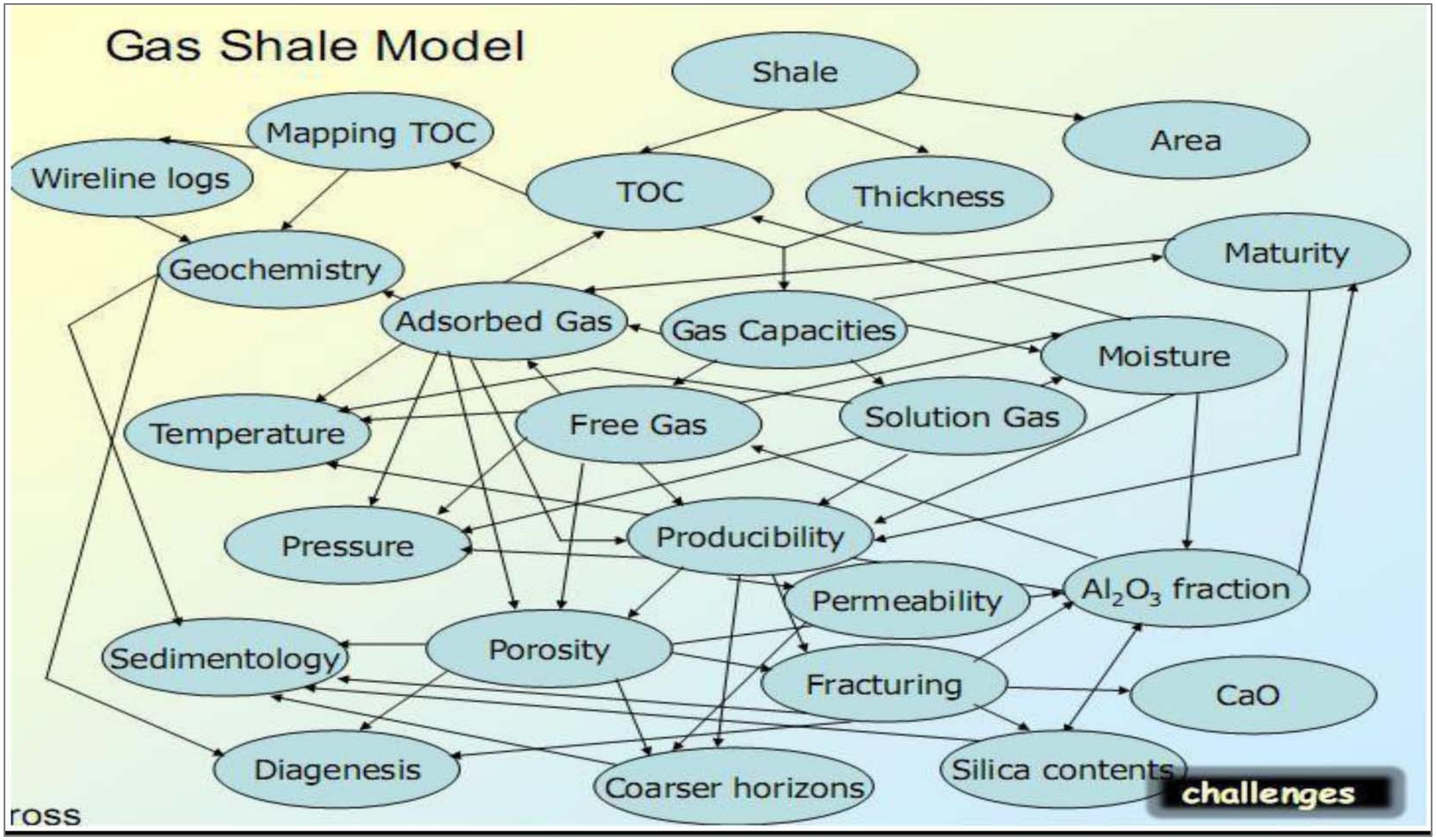

Figure 4. Showing the Factors to be Considered while Planning to Exploit Shale Gas Resources.

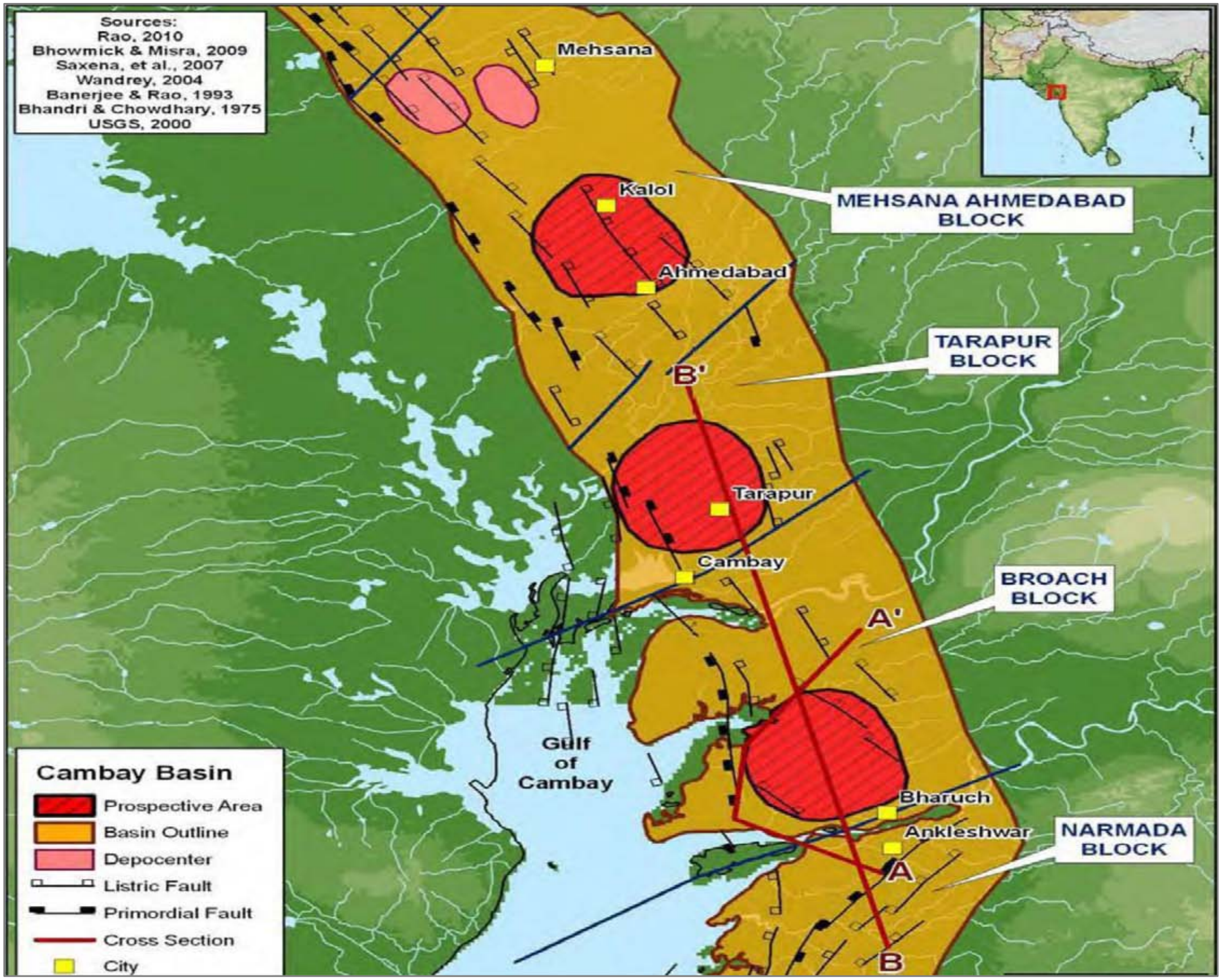

Figure 5. Organic Content of Cambay Basin.