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Review Paper

Geological characteristics, technical status, future prospects and challenges of Shale Gas Exploitation in India

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Abstract

The shale gas revolution has aided the United States to achieve energy independence and has turned around the pattern of world oil and gas supply by motivating the other counties to move towards the exploitation of unconventional reservoirs like shale gas. In unconventional resource like Shale Gas, the flow of natural gas is limited/restricted without the use of artificial cranks because of its very low permeability. India's dependency on oil or gas imports can be substantially reduced by sustainably developing shale gas reserves. Since India is at an earlier stage of shale gas exploitation, there is a huge gap between India and the United States in terms of expertise, resources and technology. This paper analyses the current situation of shale gas exploitation in India and discusses the issues (pad drilling, multi-stage horizontal fracturing, and environmental impacts, etc.) which are constraining its development in India. This paper also discusses the geology of shale gas formation in India, the technical status of its exploitation and the future development prospects associated with its exploitation.

Keywords: Geology, energy, shale gas, hydraulic fracturing, environmental impact.

Introduction

Natural gas could be the fastest growing element of world energy consumption by 2020. The usage of natural gas is increasing day by day contrast to other types of energy. The growth in natural gas usage is because of the properties like good ignition efficiency, reliability, flexibility, availability, versatility, low emission and less cost which makes it applicable in different industrial sectors like chemicals, fertilizers and transportation sector. The continuous exploitation of natural gas makes the depletion of conventional resource and made us to depend on the unconventional resource. The unconventional resources encompass shale gas, coal bed methane (CBM), tight oil and gas hydrate. It is predicted that there is about $456x10^{12}$ cubic meter shale gas in the world which is equal to the sum of coal bed methane and tight sands gas[1]. Shale gas is a growing unconventional gas resource, whose exploitation and exploration has been increased due to its vast availability.

Shale gas is trapped in fine-grained sedimentary rock and is formed by the process of compaction of the sedimentary particles over millions of years. As a result, the organic matter which is under compaction gets transformed to hydrocarbons under pressure and temperature. The main reason for the extraction of shale gas is its methane which is in between 70-90% of composition with small amounts of carbon dioxide, oxygen, nitrogen, hydrogen, sulphur-dioxide, radon and other rare gases. The conventional oil and gas migrate upwards through permeable layers of rock such as sandstone, limestone to become trapped under the impermeable layers, whereas, shale gas which is formed inside an impermeable/low permeability shale rock can't migrate upwards and this makes the extraction process of shale gas difficult as compared from other gas and oil resources, hence it is called as unconventional energy resource[2].

Shale gas gets trapped in the fine grained siliciclastic sedimentary rock which contains clay, quartz, feldspar micas etc. The clay minerals include smectite illite, kaolinite and chlorite. The other minor constituents include organic particles, carbonate, minerals, iron oxide minerals, sulfide minerals and heavy mineral grain .Shale in the shale gas has biogenic, thermogenic or both biogenic and thermogenic conglomeration which makes it as self-generating and self-preserving reservoir, therefore it can act as both source rock and reservoir which is quietly different from conventional reservoirs. The geological conditions of shale gas determines the conditions at which shale gas can be formed which includes- the total organic content (TOC >2%) and the vitrinite reflectance (R_o).For gas generating source rock, R_o will be ranging from 1.1% - 1.3%.The depth of shale gas formation ranges between 1500-4000m with a typical depth of 2500m, while the permeability of shale matrix is very less (equal to Nano Darcy).

The thermogenic gasses are formed in the temperature range between 157-221°C, whereas the biogenic gasses formation will occur at comparatively less temperatures i.e., <50°C. These prevailing conditions should be there to evaluate the shale gas resource[3].

U.S shale gas resources scenario

Shale gas has become a game changer in the U.S. The growth of shale gas inthe US had occurred from various factors like increased gas prices[0,] in the 2000 market that affected US economy and it made the country to search for the alternative gas resource and which let the shale gas boom in the US. Also, the government policy made the US to exploit the shale gas from its own shale gas resources profitably which led to the remarkable growth of shale gas production and has made the US from being importer of LNG, to the country which is self-sufficient to export gas from the terminals that were built for imports[4].

Indian shale gas basins and geological information

According to US Energy Information Administration (EIA), India contains 96 TCF of recoverable shale gas reserves which is equal to 26 years of country energy demand. India, the 4th largest consumer of energy, identified six shale gas basins which has potential to produce shale gas which are classified as Cambay basin (in Gujarat), Assam-Arakan basin (in North East), Gondwana basin (in central India), KG basin onshore (In Andhra Pradesh), Cauvery basin and Indo-Gangetic plains. The EIA-2013 report suggested that India is having a huge gas potential which can meet its growing energy demand and reduce its dependence on expensive energy imports which makes the hampering the economic growth of India[5].

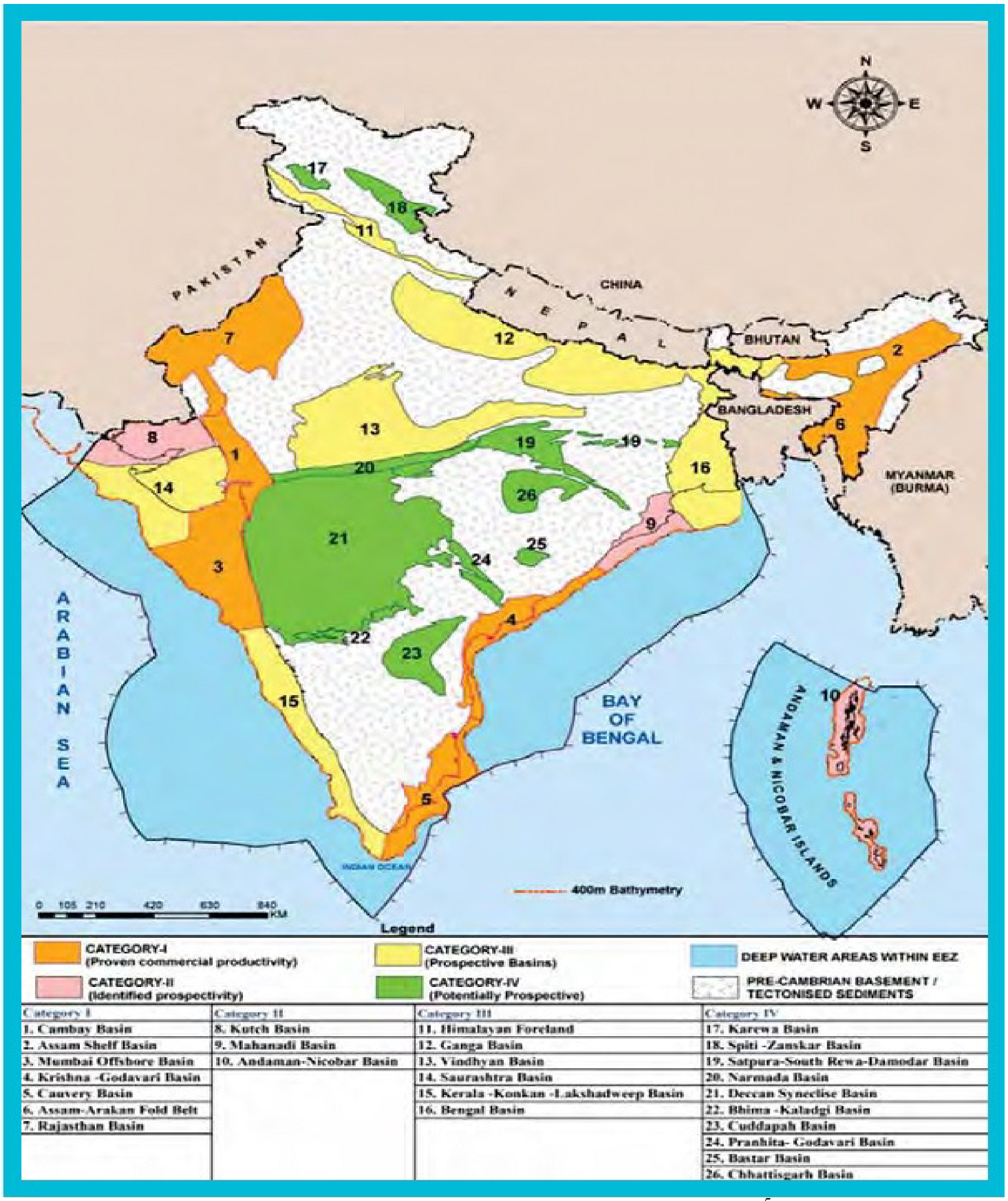

Figure-1: Categories of sedimentary basins in India[5].

Table-1:- Information about the Indian Basins[6].

	Basin/Gross area		Cambay Basin (20,000 mi^2)	Damodar Valley (1,410 mi^2)	Krishna-Godavari (7,800 mi^2)	Cauvery Basin (9,100 mi^2)	Southern Indus Basin (67,100 mi^2)	
Basic Data	Shale formation		Cambay shale	Barren measure	Kommugudem shale	Andimadam formation	Sembar formation	Ranikot formatio n
	Geologic age		Upper cretaceous/ Tertiary	Permian-Triassic	Permian	Cretaceous	Early cretaceous	Paleoce ne
Physical Extent	Perspective area (mi^2)		940	1,080	4,340	1005	4000	4000
	Thickne ss (ft)	Interval	1,600-4,900	0-2,100	3,100-3,500	600-1200	1500-2500	2000-4000
		Organic rich	1,500	1,050	1,000	800	1000	1500
		Net	500	368	300400	400	300	450
	Depth (ft)	Interval	11,500-16,400	3,280-6,560	6,200-13,900	7000-13000	13000-15000	10000-13000
		Average	13,000	4,920	11,500	10000	14000	11500
Reservoir Properties	Reservoir pressure		Moderately over pressured	Moderately over pressured	Normal	Normal	Normal	Normal
	Average TOC (wt. %)		3.0%	4.5%	6.0%	2.0%	2.0%	2.0%
	Thermal Maturity (%RO)		1.10%	1.20%	1.60%	1.15%	1.25%	1.15%
	Clay content		Medium	High	High	High	Low	Low
Resources	GIP concentration (Bcf/mi^2)		231	123	156	143	100	157
	Risked GIP (Tcf)		78	33	136	43	80	126
	Risked recoverable (Tcf)		20	7	27	9	20	31

Shale gas exploitation techniques[7]: Even though shale gas has huge potential but the problems lies in its exploitation. Shale gas is extracted widely using combination of technologies i.e. hydraulic fracturing and horizontal drilling. The shale gas drilling includes drilling a conventional wellbore till shale zone is reached and then drilling horizontally along the shale zone along and then creating multiple fractures along the shale zone in the matrix by pumping fracturing fluid at a pressure greater than parting pressure of shale formation[8]. The horizontal drilling with the high deviation angle makes a large contact area with the reservoir and increases the drainage area for production of the fluids from the subsurface which is not possible with the vertical well having very negligible vertical permeability[9].

Nowadays it is common to use pad drilling which reduces the surface location of the wells and allow us to drill the multiple wells from the single well which is economically efficient in the exploration of shale gas. Stacked wells are also normally used when various shale rock layers are located on regular successive layer which makes the use of one vertical well to extract gas from various wells at varied depth[10]. Multilateral drilling is also used for shale gas exploitation which is same as stacked drilling and it involves drilling of two or more deviated wells from single well bore. The use of these techniques significantly increases the production rates for reduced incremental cost[11].

Challenge's related to the shale gas exploitation in India[12]

In US there is a competition between all exploration, production and integrated oil companies for acreage along with good quality sub-surface data and advanced technologies like multistage fracking. However in India until now only National Oil companies were the big player having limited data and advanced technologies. The available limited data makes the exploration of shale gas difficult for the selection of appropriate well completion methods and complexity in evaluating shale gas[13].

Indian Government policies has not also been feasible for shale gas extraction, which is more effected by high operating cost, production cost, difficulties in getting permit for acquiring exploration and production licenses which makes the Indian oil and gas companies to be in dilemma for investing money for the exploration of shale gas because of complicated circumstances[14]. Also, Indian government is likely to follow the same process for shale gas exploitation like CBM developments which was done a decade ago[15].

The geology of shale gas reservoirs in India is not uniform which makes difficult for the prediction of rock response to simulating jobs like hydraulic fracking and horizontal drilling which disturbs the fracture geometry and these complexities became a critical issue while extracting shale gas. Also, there are challenges associated with shale gas drilling because presence of clay minerals causes swelling of shale formation and higher the clay content higher will be the chances of well bore instability, pipe sticking, formation damage, bit balling[16].The infrastructure needed for extracting shale gas like hydro fracking and deviated horizontal/directional drilling is not yet developed in India and gas storage facilities, laying of pipe lines and other transport facilities is big challenge for Indian shale gas sectors[17]. Also, the environmentalist are concerned with the seismic activity caused by the creating hydraulic fractures and underground fluid disposal which mainly occurs because drilling near faults and not monitoring of micro seismicity before, during, after fracking which damages the well integrity. The shale gas exploration needs a huge amount of water between 9000-29000 m^3 to carry out multistage fracking[18] which affects the depletion of water consumed by the people and other activities like agriculture, industry etc. Also, the fracturing fluid used for hydraulic fracturing consists of chemicals, proppants which makes the reuse and disposal of used water difficult[19].

Conclusion

The shale gas is a natural gas which will create less pollution and less carbon emissions when burnt in air. India is having a huge shale gas potential but the recovery of the resource is becoming difficult because of the lack of experts, technology and infrastructure but there is a need for India to exploit the shale gas for the future requirements and to develop the India's economy. The Indian shale gas can be recovered by developing properly which meets the challenges associated with its recovery, increase in technology, polishing of government policy, appreciating the innovative ideas and techniques, developing the R&D sector, planned drilling and completion program. The availability of land and technology should be developed and government policy should be modified for the exploitation of the shale gas and migration of the people from one place to another place should be done with compensation.

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