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# INSIGHTS OF SHALE GAS EXPLORATION AND DEVELOPMENT IN INDIA: REVIEW

Earth Science

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## ABSTRACT

Encouraging results of shale gas production in different countries viz. USA, China and Australia, India is also inspired to explore shale gas resources, which may not only support meeting the growing energy demand but also assist to reduce the import of hydrocarbons. This paper aims to review the current status of shale gas exploration programs in various sedimentary basins in India for a better understanding of the prospect of shale gas. The significant thickness of organic-rich shale deposits is reported in various Gondwana and Tertiary sedimentary basins including Damodar valley, Krishna-Godavari, Cauvery, Cambay, Assam-Arakan, Ganga and Vindhayan basins. The geochemical properties like TOC and thermal maturity, Organo-inorganic mineral compositions, pore-network system, and depth of shale deposits are favoring the potential prospect of shale gas in India. Several agencies namely EIA, ONGC, USGS, Schlumberger, and CMPDI reported enormous resources of shale gas in its various sedimentary basins.

## KEYWORDS

TOC, Thermal maturity, horizontal drilling, hydro-fracturing.

## 1. INTRODUCTION

Unconventional reservoirs, mainly shale gas reservoirs contributing significantly to attain the growing energy demand worldwide. Technological advancement in drilling and hydro-fracturing technology makes feasible shale reservoirs become potential hydrocarbon reservoirs. Although, shale is well known as a source rock of hydrocarbons, due to the ultra-low permeability the production of gas from these reservoirs is not feasible economically. Gas in shale deposits is dominantly methane ($CH_4$) derived from the organic materials through the biogenic and thermogenic process under suitable conditions, where shale work as both the source rock and reservoir rock [1, 2, 3, 4 5]. Shale is fine-grained clastic sedimentary rock deposited under low energy conditions characterized as very complex in terms of mineralogical compositions due to highly mixing, transportation mechanisms before depositions [6]. The production performance of shale reservoirs in the past two decades makes it a game-changer in the field of the oil and gas industry and is considered as one of the leading sources of alternative energy for clean natural gas globally [7]. According to reports (EIA, 2011) huge production of gas from shale reservoirs, reduced the oil and gas price worldwide [8]. USA and China attained substantial progress in the field of shale gas exploration and production, reported about 1161 and 1115 TCF of shale gas resources respectively [7]. The contribution of natural gas is increased rapidly from 67.8 % to 71.3% due to the enormous production of gas from shale reservoirs [9] in the USA, which made self-sufficient country in natural gas production and reduced the import of natural gas drastically.

Inspiring from the commercial development and production profile of shale gas in countries like USA, China, Australia, Europe and Canada, India is also actively engaged in developing shale gas resources in its different sedimentary basins to strengthen energy security for India under the promotion of the clean energy technologies [3, 4, 5, 10, and 11]. In India, a series of regional research projects are on-going in the various field of shale gas exploration covering characterization of shale concerning the richness of organic materials and thermal maturity for being potential shale gas reservoirs in allied with the gas storage capacity by the academic institutions, national laboratories and national operator companies. At present, very limited numbers of shale gas have been drilled in India to distinguish the production behavior of shale gas from the other country basins. However, based on the preliminary research, the potentiality of shale gas in India is much attractive for further evaluation and commercial development.

## 2. Geological Characteristics for potential shale gas reservoirs

Foremost criteria for shale deposits to become potential reservoirs for hydrocarbon is the richness of organic materials, the thickness of shale horizons, depth of deposition, inorganic mineral assemblages, maturity level, porosity, tectonic disturbances and ultimately the gas content [1,2,3,5, and 12]. Another most important facet is the permeability and efficient hydro-fracturing stimulation of shale deposits, which may be the very crucial factor for the economical recovery of shale gas [4, 3 and13]. Occurrences of the significant amount of organic matters in shale deposits are accountable for the generation and storage of gaseous hydrocarbons under favorable pressure-temperature conditions although inorganic constituent's clay and clay minerals are also crucial for the storage capacity of gas in shale [1, 2, 3, 5 and 14]. Organic content and their thermal maturity level in shale deposits are influenced by the geological process covering sediments-diagenesis, transportation-behavior, depositional-conditions and tectonics involved [5, 12, and 13]. For being, the potential reservoir of shale gas, the content of TOC ranged more than 2% although based on the TOC content several researchers classified the quality of shale reservoir for the potentiality of gas as very poor if less than 0.5%, poor: 0.5 to 1%, fair: 1.0 to 2.0 %, good: 2.0 to 4.0%, very good: 4.0 to 12.0 % and excellent: if >12% [2,3,5,12and13]. The content of organic materials is derived through well-known Rock-Eval pyrolysis analyses in percentage. The gas in shale reservoirs are stored in three forms as free gas in pores associated with the organo-inorganic mineral constituents, as in adsorbed state on the surfaces of clays, non-clays and organic matters, and as a dissolved gas in water [2, 3, 5, 12 and 14]. Adsorbed gas and free gas contributing dominantly to the resources assessment of shale gas whereas, the contribution of dissolved gas is minimal [3,5,14and15]. The gas adsorbate behavior of different clay and non-clay minerals is very crucial and affecting the OGIP requires a detailed geological understanding of depositions. Organo-inorganic minerals compositions and their associated pore network system providing free space and path for the storage and transportations of gas in shale deposits are controlled by various geological process including thermal history, depositional sequences and structural disturbances [12, 15, and 16]. Thus focuses on the geological, geochemical, mineralogical and petrographical nature of shale deposits to distinguish the potential source of hydrocarbon is the indispensable focus to distinguish the potential source of hydrocarbon.

## 3. Potential of shale gas in Indian Basins

The estimated shale gas potentiality of the Indian sedimentary basin was reported by several agencies like the USA Energy Information Administration (EIA), advanced resource international (ARI), Schlumberger, CSIR-CIMFR, ONGC, and CMPDI reported the availability of enormous resource of shale gas-based on preliminary basin information's [9and17]. In the Initial stage of shale gas exploration, a total of 8 numbers of basins Damodar Valley, Pranhita-Godavari, Krishna-Godavari, Cauvery, Cambay, Rajasthan, Vindhyan and Upper Assam basins have been identified as the significant thickness of organic-rich shale deposits with good TOC content (Fig. 1). According to EIA reports, the estimated shale gas resource in India is about 584 Trillion cubic feet (TCF) of which 96 TCF technically recoverable. However, these numbers may be changed with the advancement of exploration techniques [9and17].

In Damodar valley Basin, Raniganj, Jharia, Bokaro, North Karanpura, South Karanpura and Sohagpur 6 sub-basins are characterized as the most prospective basins for the exploration of shale gas. According to CMPDI reports the basin holds about 950 BCM of shale gas resource (Table. 1). Barakar and Barren Measure Formation characterized as organic-rich shale bed with significant thickness at a considerable depth ranging 500m to 1500m with favorable geochemical properties viz. TOC content, maturity, and pore morphology were deliberated as

most prospective horizons for shale gas exploration [3,5,and18].

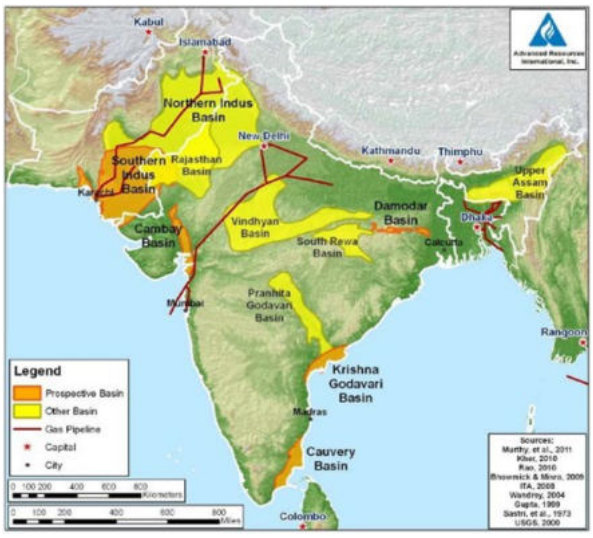


**Fig. 1: Potential Shale gas basins of India [8,9,and18].**

In Damodar valley Basin, oil and natural gas corporations, Ltd. (ONGC) in collaboration with Schlumberger had drilled two pilot wells that produced shale gas from Barren Measures formation of Permian age in the Raniganj sub-basin and has estimated a shale gas potential of 7 TCF [3, 5, and 18]. The main target Barren measure shale gas was encountered from 985 to 1380 meters. A significant amount of gas flowed from Barren measure shale after hydro-fracturing. The shale horizons of Barakar, Barren Measures and Raniganj of Gondwana basins in India are demarcated as most prospective potential sources of shale gas [3, 5, ]. Organic-rich Permian shale deposits extensively distributed in basins namely Jharia¸ Bokaro, North Karanpura, South Karanpura, Raniganj and Sohagpur in India may be a potential reservoir for shale gas exploration [3,5].

**Table 1: Shale gas resource potential of major prospective Basin [17, 18].**

| Major prospectiveBasin | Potential area ($km^2$) | Geological characteristics for potential shale gas reservoir (ARI, USGS) | | | | |
|---|---|---|---|---|---|---|
| | | Avg. depth of shale deposits (m) | Avg. thickness of shale deposits (m) | Avg. TOC (wt. %) | Avg. thermal maturity (Ro %) | Total OGIP (TCF) |
| Damodar valley basin | 2800 | 1500 | 300 | 4.50 | 1.20 | 33 |
| Cambay | 931 | 4000 | 450 | 4.0 | >1.1 | 78 |
| Cauvery | 1551 | 3048 | 250 | 2.0-2.5 | 1.0-1.50 | 43 |
| Krishna-Godavari | 4108 | 3500 | 300 | >2.4 | >1.6 | 136 |

Cambay basin is a well-known petroliferous basin located in the state of Gujarat, India. The Basin is characterized as thick organic-rich shale deposits of Late Palaeocene to Mid Eocene age distributed over the different sub-basins Hazira, Broach, Tankari, Tarapur and Patan controlled by the faults. Geochemical properties viz. TOC content (avg. 4.0 wt%), thermal maturity ($VR_o$ % ~ 1.1), geological parameters like depth and thickness (~450m) of shale occurrences (Table 1) suggests Cambay shale deposits could be prospective for the exploration and production of shale gas. According to EIA, report the prospect of shale gas in the Cambay Basin is 6138 BCM [18,19,and20].

Cauvery Basin characterized as a peri-cratonic basin of Permian to recent age covering an area of about 50,000 square kilometers on the east coast of India. The basin includes thick shale deposits (250) in Andimadam and Sattapadi of lower cretaceous age Formation at considerable depth approx. 3000m [10,11]. The shale in the Cauvery basin is categorized as marine shale with considerable geochemical parameters viz. TOC and thermal maturity range 2.0 to 2.5 and 1.0 to 1.50 respectively interpreted as the enormous prospect of shale gas. According to ARI and USGS report the shale gas resource potential in the Cauvery basin is approximately 43 TCF (Table 1).

Krishna-Godavari Basin is characterized as a peri-cratonic basin covering an area of about 50,000 square kilometers comprises Cretaceous to recent sediments. The principal horizon of shale deposits is Kommugudem and Raghavapuram characterized by thick organic-rich carb-shale with an average thickness of 3500m (Table 1). The geochemical parameters like TOC (>2.40) and thermal maturity (>1.60) indicate the inspiring opportunity of shale gas exploration and development [3, 5 10, and 18]. Additionally, other sedimentary basins viz. Ariyalur-pondicherry, Vindhayan, upper Assam, Rajasthan, and Ganga sub-basin are also may have good prospect of shale gas.

## 4. Polices in shale gas exploration

The Ministry of Petroleum and Natural Gas (MoPNG) is willing to explore unconventional energy resources, particularly shale gas [11, 21] and recently has created a set of policies and directives. The Government is gearing up to move to the Open Acreage Licensing Policy regime as soon as possible to make easier licensing policy for the exploration of hydrocarbons in existing leasehold areas by private companies which is helpful to enhance the domestic production of hydrocarbons [11]. MoPNG offered shale gas exploration blocks to national operator companies mainly ONGC and OIL on a nomination basis to explore prospects of shale gas in different basins. Additionally, a new exploration license policy (NELP) was modified to ease the regulatory framework in getting the hydrocarbon exploration license in new blocks and Launch HELP (hydrocarbon exploration policy) that permits to the exploration of all kinds of hydrocarbon in the allocated blocks to the operator companies. The government of India offered several research and development programs to the academics-industry/laboratories in various fields of shale gas exploration and development in the country. Several, pilot wells are already drilled and tested delivered encouraging results for further prospective evaluation of shale gas in the country.

The government is actively engaged in removing the hurdles posed by a lack of infrastructure, gaps and improving the regulatory framework and public environmental concerns to enhance the domestic productions of hydrocarbons in the country. The MoPNG has provided policy support to businesses by allowing project proponents to exploit conventional and unconventional shale gas resources simultaneously in a block.

## 5. Environmental concerns in shale gas exploration

The development of shale gas exploration and development programs requires special attention to environmental concerns in terms of land and water. Production of shale gas involves hundreds of well drilling and hydro-fracturing, which requires enough land area for drilling and the huge amount of water for fracturing. The flow-back water from drilling and hydro-fracturing operations is mixed with the clay, chemicals and other contaminants affecting the groundwater quality due to seepages [4, 7 8, and 18]. Likewise, environmental concerns related to conventional hydrocarbon exploration are also allied in unconventional hydrocarbon viz. noise pollutions, surface pollutions due to oil and chemical spill at the drilling site. Hydro-fracturing operations in shale gas production may generate some time minor earthquakes characterized as induced seismicity may also be considered in the regulatory framework in shale gas exploration and development. The environmental regulations must be framed to mitigate the hazardous impact on the environment.

## 6. Challenges in shale gas exploration

Shale gas reservoir is the outcome of technological advancement in the field of horizontal well drilling and hydro-fracturing. The major challenge in the field of shale gas exploration is the comprehensive resource assessment of shale gas due to the highly complex nature of shale deposits in various basins under different environmental conditions. The genesis and storage capacity of gas in shale deposits of organo-inorganic mineral compositions required more profound research to elucidate the proper gas holding capacity of different clay and non- minerals. Although, various techniques are introduced by several researchers to determine complete pore network system and gas adsorption behavior with different organo-inorganic mineral compositions to conclude the performance of shale gas reservoirs in different Basins. Scarcity in the technology of efficient shale gas well drilling and hydro-fracturing for the commercial development of shale gas blocks is another major challenge in India. In Shale gas well drilling, accurate trajectory path of wells with a complete understanding of geological framework data, for the efficient hydro-fracturing which requires advanced exploration tool to delineate

accurate data set. Another major challenge in the shale gas field development is the availability of land for drilling. As the drainage area of shale gas well is very less in terms of 40 to 60 acres, so it requires several wells to drain out the gas from shale horizons. The hydro-fracturing process involves the pumping of chemicals and sand with the water at high pressure, which requires a huge amount of water. In India, the huge scarcity of water is another major challenge in the commercial development of shale gas. Lack of necessary infrastructures including pipeline network, road network connecting to a potential area of shale gas basins is creating a hurdle for the development of shale gas exploration and development programs. Thus, in brief, India is facing many challenges in terms of the technological, regulatory framework, environment clearances, skilled manpower and policies in the exploration and development of shale gas.

## 7. Conclusions

The exploration of shale gas resources is very much new in India. At present, shale gas exploration in India is in the early stage of research in terms of distribution of organic-rich shale deposits, kerogen type, thermal maturity, storage and transportation capacity, controls of the organ-inorganic mineral constituent in shale gas genesis and storage capacity. Reinforce fundamental research is very much required to achieve breakthroughs in the field of shale gas exploration in India. The development phase in the shale gas exploration program is very crucial in terms of technological advancement in the field of drilling and hydro-fracturing which requires an integrated approach in the field of geology and engineering. Although, the gap in technological advancement, necessary infrastructure, limitations in funding and socio-political conditions in India slow down the development of shale gas resources.

Based on the preliminary results on shale gas exploration, the prospect of shale gas in India is much attractive. However, a complete understanding of shale gas reservoir study is very much required for allocating commercial development programs in various fields to further explore and produce shale gas. The future of shale gas in India is very much impressive and most feasible unconventional energy.

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## REFERENCES:

[1] Curtis JB. Fractured shale-gas systems. AAPG Bull 2002; 86(11):1921-38.
[2] Jarvie, D.M., Hill, R.J., Ruble, T.E., Pollastro, R.M., 2007. Unconventional shale-gas systems: the Mississippian Barnett shale of north-central Texas as one model for thermogenic shale-gas assessment. AAPG Bull. 91, 475–499.
[3] Varma, A. K., Hazra, B., Samad, S. K., Panda, S., Mendhe, V.A., 2014. Methane sorption dynamics and hydrocarbon generation of shale samples from West Bokaro and Raniganj basins India. Journal of Natural Gas Science and Engineering, 21: 1138-1147.
[4] Mishra S., Mendhe V.A., Kamble A.D., Varma A.K., Singh B.D., Pandey A.K.,2016. Prospects of shale gas exploitation in Lower Gondwana of Raniganj Coalfield (West Bengal), India. The Palaeobotanist 65: 31–46.
[5] Mendhe VA, Kumar S, Kamble AD, Mishra S, Varma AK, Bannerjee M, Mishra VK, Sharma, S, Buragohain J, Tiwari B., 2018b. Organo-mineralogical insights of shale gas reservoir of Ib-River Mand-Raigarh Basin, India. Journal of Natural Gas Science and Engineering 59: 136–155.
[6] Boggs, Jr. S., 2001. Principles of Sedimentology and Stratigraphy, third eds. Prentice-Hall, Upper Saddle River, New Jersey, 88-130.
[7] EIA (U.S. Energy Information Administration) 2016. Annual Energy Outlook 2016 with Projections to 2040.
[8] EIA (Energy Information Administration), 2011. An Initial Assessment of 14 Regions outside the United States.
[9] EIA (U.S. Energy Information Administration), 2017. Annual Energy Outlook 2017: with projections to 2050. U.S. Energy Information Administration, 1-127.
[10] DGH (Directorate General of Hydrocarbons), 2012. Hydrocarbon Exploration and Production Activities, India. Directorate General of Hydrocarbons, Under Ministry of Petroleum & Natural Gas, Govt. of India, 1-162.
[11] DGH (Directorate General of Hydrocarbons), 2018. Policy framework for exploration and exploitation of unconventional hydrocarbons under existing production sharing contracts (PSCs), Coal Bed Methane (CBM) contracts and nomination fields. Directorate General of Hydrocarbons, Under Ministry of Petroleum & Natural Gas, Government of India, p. 1 - 4.
[12] Zhang, J., Nie, H., Xu, B., Jiang, S., Zhang, P., Wang, Z., 2008. Geological condition of shale gas accumulation in Sichuan Basin. Natural Gas Industry, 28(2): 151-156.
[13] Chen, L., Jiang, Z. X., Liu, K. Y., Wang, P. F., 2016. Effect of lithofacies on gas storage capacity of marine and continental shales in the Sichuan Basin, China. Journal of Natural Gas Science and Engineering, 36: 773-785.
[14] Taylor, G. H., Teichmuller, M., Davies, A., Diessel, C. F. K., Littke, R., Robbert, P., 1998. Organic Petrology. Gebrü der Borntraeger, Berlin, Stuttgart, p.1-704.
[15] Cao, T.T., Mo, D., Zhi, G.S., Hou, Y.L., Andrew, S.H., 2018. Characteristics and controlling factors of pore structure of the Permian shale in southern Anhui province, East China. J. Nat. Gas Sci. Eng. 60, 228–245.
[16] Hao, F., Zou, H., Lu, Y., 2013. Mechanisms of shale gas storage: implications for shale gas exploration in China. AAPG Bull. 97, 1325–1346.
[17] Press release, 2017. Press information Bureau, Government of India, Ministry of Petroleum and Natural gas.
[18] Sain K., Rai M., Sen M.K., 2014. A review on shale gas prospect in Indian sedimentary basins. J. Ind. Geophys. Union, V.18, No.2, pp: 183-194.
[19] Banerjee A., Jha M., Thomas N.J., Misra K.N., 2000. The effective source rocks in the north Cambay Basin, India. Marine and Petroleum Geology, 17: 1111–1129.
[20] Kumar, S., Das, S., Bastia, R., Ojha, K., 2018. Mineralogical and morphological characterization of older Cambay shale from North Cambay Basin, India: Implication for shale oil/gas development, Marine and Petroleum Geology, doi: 10. 10 16/ j. marpetgeo. 2018 .07.020.
[21] MoPNG (The Ministry of Petroleum & Natural Gas, India), 2015. Policy for the exploration and exploitation of shale gas in India.