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Shale Gas: An Undepletable Energy Resource

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Abstract – World Energy market is growing day by day in abundance as much as 50 % growth by 2050 as compared to 2010. But the resources are continuously depleting and lowering the energy content. Thus renewable energy resources are not feasible and capable enough to fulfill the increasing demands. Increase in production of nonrenewable energy source, i.e., the fossil fuels may help to fulfill the energy requirement of future generations. Shale gas is one of the optional unconventional sources of energy. Shale gas deposits are scattered all over the planet in low-permeability and low porosity reservoirs. India has overall reserves of shale gas between 600 and 2000 TCF, of which 63 TCF is of recoverable shale gas. Shale exploration techniques are discussed. Light is provided on shale oil and gas global and national data. Challenges faced practically are described.

Key Words: Shale Gas, Sedimentary Rocks, Fracking, Kerogen, Hydraulic Fracturing, Vertical Drilling.

1. INTRODUCTION

Shale rocks are sedimentary rocks that are formed under high pressure compaction of fine grained slit and clay. Shale rocks are characterized on the basis of clay content (chamosite and kaolinite) mixed with quartz. Organic shale is of three types: kerogen-type1, kerogen-type2, kerogen-type3. Sedimentary rocks are found deep inside the ground and get converted to organic rich oil and gas at high temperature and pressure [1]. High amount of oil and gas gets expelled and trapped in ideal places from where easy extraction is possible, this makes conventional oil and gas. Remaining gas is retained inside the rock forming shale gas and oil. This shale gas and oil form has free hydrocarbon that are found in pores, natural fractures, cracks etc. Some portion of gas is also adsorbed by rock surface that makes organic matter of rock. Therefore oil and gas make free movements inside the sedimentary rocks henceforth providing low matrix permeability [2].

Presence of water is also a significant factor that needs to be considered while studying and evaluating a reservoir for the extraction of oil and gas. Shale rocks do not have gas-water contacts. Hence, the flow of gas is not affected by the flow of adjacent water. Also, shale rocks are continuously distributed throughout the area of the basin. This continuous and spread-out accumulation of shale oil and gas primarily depends on three factors viz. extensive reservoir rocks, good source rocks and coexisting reservoir-source intervals [3].

Major reserves and resources are classified as: [4]

1. Remaining oil and gas in place
2. Technically recoverable resources
3. Economically recoverable resources
4. Proved reserves.

2. SHALE OIL and GAS EXTRACTION

Oil and Gas extraction is an extremely difficult process because the unconventional oil and gas are irregularly distributed all over the reservoir. To extract shale oil and gas traditional vertical drilling is not very effective method. Other technologies that can be used are hydraulic fracturing (fracking) and horizontal drilling [3].

A brief process of extraction of shale oil and gas is as follows and is represented in Fig. 1. Due to irregular distribution of unconventional oil and gas in the reservoir traditional vertical drilling is less preferable [4]. Rather for an effective extraction of oil and gas other techniques are more useful. Hydraulic fracturing (fracking) and horizontal drilling methods are considered most impactful. A brief process of extraction of shale oil is as follows and is represented by Figure 1.

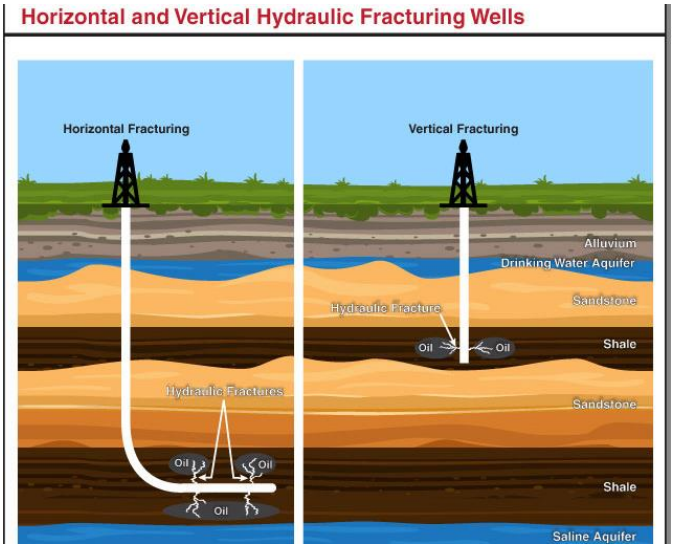

Fig- 1: Horizontal and Vertical Fracturing Wells.

Remarkable company ONGC starts drilling only after identifying the economically recoverable resources. Initialy vertical drilling is employed to break down the solid earth's crust rocks. Vertical drilling is made till the production layer of oil and gas is reached. After reaching this layer, horizontal drilling is employed where horizontal is not a perfect 90° angle with the vertical but an 85° angle with the vertical so that the pressurized oil and gas in the ground is concentrated towards the mouth of the well for efficient extraction. It should be noted that the slope goes to a maximum distance through the production layer. The maximum step out of a well is 14,129 m but the average is as low as 600–900 m [5,6].

2. LITERATURE SURVEY

Horizontal Drilling provides best shale gas extraction. Drilling is done by horizontal wells using horizontal trunk. Horizontal well can be of different shapes such as a fan, a fork or a spine in same production layer [7]. At one go number of wells that can be drilled can vary between minimum 2 to maximum 30 and based on this data about reservoir pressure and characteristics of reservoir can be obtained. This data collected helps in model devising, forecasting the volume of resource, production capacity etc. This data is used for longer term can then be used to devise a model and thus help in forecasting the resource volume, production capacity and development economics which helps in determining the long-term viability of the production of shale oil and gas from the reservoir.

As per availability of Shale in different directions, "Directional Drilling" is used. As shown by Oilfield Market Report, it was first time used in USA and gave a hike to market of about 183% from 2005 to 2015. Later on more efficient version was used in which hydraulic fracturing and directional drilling was used together. This gave more efficiency and market rose by 395%. But this technique has a con that it requires very large capital investment for research and development. There are few more risks involved uncertainty, financial risks, operational risks, low input-output ratio and its sustainability [8]. Hence, it is hard to determine the profitability of the implementation of these techniques.

To improvise as soon as the hole is drilled till production layer, fracking liquid is pumped in the well with high pressure. Fracking liquid can be mixture of water, propping agents and chemicals that would dissolve carbonate reservoir. Fracking liquid pushes oil and gas upwards in the well. The pipe should be of good quality so that it doesn't collapse due to vacuum. Due to this micro-cracks are made in production layer. The fracking liquid is later extracted with the oil and the two are separated and transferred to different reservoirs. Fracking fluid has majorly water rest other chemicals lesser than 1%. Some of the chemicals used are proppants which are sandy materials used to hold open fractures, gelling agents like xantham gum and guar gum which serve the same purpose as proppants, surfactants which are used to reduce surface friction and biocides to kill bacteria [9].

After extraction process the output is macromolecular and organic solvent-insoluble organic matter which is known as kerogen, to decompose it pyrolysis process is done. Pyrolysis is a process of decomposing a substance at high temperature and inert atmosphere. It is an irreversible process. For oil shale it is a bit complicated as series of parallel reactions are carried out since kerogen is a heterogeneous mixture difficult to breakdown. Based on physical properties a method called Terahertz time-domain spectroscopy (THz-TDS) is used [10]. To enhance it further optical method with the same baseline idea but with different sensitivities to gas, oil, water and minerals is also developed [11].

For effective and successful evaluation of shale oil and gas from the reservoir, its basins should be assessed firstly. The depressions at different levels in the basin show the amount of reservoir oil and gas presence [12]. Volume Method is one of evaluation method. In this based on reserves of shale oil and shale gas using gas-bearing properties of shale it is concluded total gas resource is equal to the sum of free gas, adsorbed gas and the dissolved gas. Second evaluation method is analogue method used in areas with a low degree of exploration and limited availability of data. Hence, the result produced from the method is not of high accuracy but still is capable enough to guide decisions of initial exploration and investment [13].

3. RESEARCH

Data is obtained from various research papers, review papers, journal articles, published articles and books that are available on online databases like Scopus and Google Scholar. Numerical or statistical data is referred from the official websites of regulating and governing bodies like Ministry of Petroleum and Natural Gas (MoPNG), Ministry of Power (MoP), Directorate General of Hydrocarbons (DGH), The Energy Research Institute (TERI), Ministry of New and Renewable Energy (MNRE), Central Electricity Authority (CEA), etc. Also, the data from websites of various international agencies like US's Energy Information Administration (EIA), Germany's Schlumberger, British Petroleum (BP), etc. are used as their studies, surveys and data collection.

4. SHALE RESERVES IN INDIA

India is not able to match the requirement of natural gas demands. The difference in demand and supply is around 40% [14]. India imports natural gas from Qatar and LNG from Russia at very high rates. To provide an economical supply of natural gas, India is working out on the plan to bring out natural gas from Turkmenistan by pipeline. The energy demand in India is increasing continuously, and energy production is mainly dependent on natural gases. But we cannot rely only on conventional sources, so we have to move toward some unconventional source to reduce the import of natural gases. India is actively discovering its natural gas deposits.

Shale gas reserves could be found in Gujarat, Jharkhand, West Bengal, Andhra Pradesh, Tamil Nadu, Rajasthan, and other areas. India has 26 sedimentary basins, from which 6 basins have prospects of shale gas (Petroleum & Natural Gas Regulatory Board 2013). There has been limited exploration in India, and according to EIA, we have the majority of shale gas opportunities in Cambay, Krishna-Godavari, Cauvery, and Damodar Valley [15]. Total 50 blocks have been distributed amongst Indian basins. Although India is not a giant player as U.S. or China but still India has shown much advancements. There are no firm estimates of Shale oil and gas in the country. As per NITI report different estimates for India are shown in Table-1 [17].

1.	M/S Schlumberger	300 to 2100 tcf
2.	Energy Information Administration (EIA), USA (4 baisns- Cambay Onland, Damodar, Krishna Godavari Onland & Cauvery Onland),)	584 f
3.	ONGC 6 basins	187.5 tcf
4.	Central Mine Planning and Design Institute (CMPDIL) 6 sub basins	45 tcf
5.	United States Geological Survey (USGS) in 3 basins	6.1 tcf

Table 1: Estimates of shale gas for Indian sedimentary basins

To make advancements further India has implied following techniques for shale gas and oil production from Indian sedimentary basins:

- Wide azimuth surveys
- Long offset 2D seismic surveys for deeper imaging
- Onshore carpet 3D surveys
- D-3C/4D seismic surveys
- Broadband surveys
- Bean PSDM processing
- Node-based wide-angle refraction cum reflection profiling
- Discrete fracture network analysis
- CSEM surveys and microgravity data for delineation
- Permeability structure analysis and fluid replacement studies
- Common reflection angle migration processing [16].

5. SHALE GAS AROUND THE WORLD

The shale gas discovery has no pattern as it is very irregular around the world. Shale rock is although evenly distributed and easy to recover as compared to shale rock. Shale rock recovery is displayed in Graph showing the countries of recoverable shale gas reserves are situated which may vary from 200 m to 7000 m. It can be noticed that shale gas reserves have ample gas while some have none. Main emphasis is laid on countries having ample shale reserves. Accurate shale presence in shale reserves cannot be predicted accurately [17].

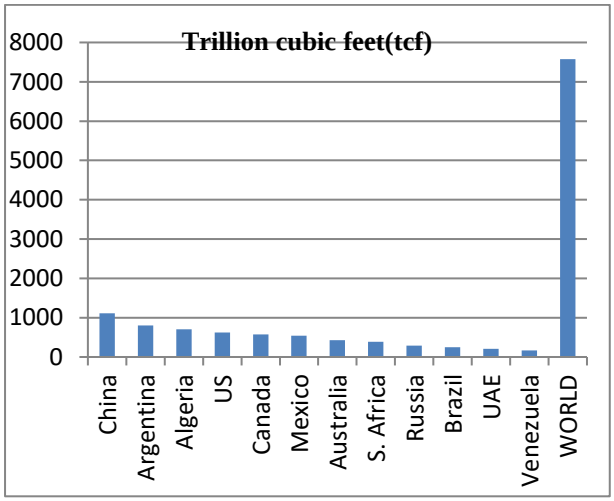

Fig -2: Shale Rock Recovery in Different Countries

Reports presented by the US Department of Energy, the quantity of technically recoverable shale gas vary from 200 to 7000 cms. As shown in Figure 2 are the top 12 countries with the highest amount of recoverable shale gas reserves. It will not be fair if we take a look at only the top countries having recoverable shale gas. Thus, the shale resources are divided in into six areas as Asia and Oceania, North America, Latin America and the Caribbean, Africa, the European Union and Eastern Europe. As noticed in Fig-2, the Asia and Oceania region holds the largest part in the regional distribution of recoverable shale resources, China having largest. The second most region is North America, as US is very successfully exploiting the shale resource as for the credit goes to the American Shale Revolution [18].

6. CHALLENGES FACED AND NATIONAL PREPAREDNESS

Shale gas has vast ability to meet energy requirements in the world as can be seen by facts. Natural gas, is the best fossil fuel, as it releases lesser amount of greenhouse gases when compared to other energy sources. Environmental concerns need to be considered as well before entirely relying on shale gas as an unconventional fuel. Such issues need to be kept in mind as well, they cannot be neglected. By inducing seismicity and contaminating the aquifers the reservoir can be fractured the requirement of large amounts of freshwater for fracking creates a problem as it can affect the local water system [19]. Moreover, many of the shale gas reservoirs are located in remote and arid locations which can again produce a problem of availability of large amounts of water. A large number of chemicals and additives are added to the fracking fluid to create fractures in the shale rock and produce gas from the reservoir. Several new additives need to be studied to enhance the property of the fracking fluid. These new additives should be cheaper, environment friendly, and should be able to enhance gas production. Alternative fracking fluids which can replace water and serve these purposes need to be studied, and more number of experiments need to be carried out [20, 21]. The water that has been used already in fracking fluid gets contaminated and thoughtless disposal of this water can pose much threat to the marine ecosystem. Hence, the purification and sustainable reuse of such wastewater need to be studied in the future studies [22, 7, and 8].

7. CONCLUSION

India is not as big player as China and the U.S. in shale market. The Government should make more policies and investments to lie emphasize on R&D to uncover more of presence of shale oil and gas in Nation. The statistics generated would help more in forecasting and production of shale oil and gas reservoirs. The cost to be incurred and production schedule can be calculated. The outcomes would let government frame the policies and concrete required for development of shale oil and gas resources. India needs to lay more focus on R&D or bring new technologies that are available from other countries. By studying operational costs and other factors could be optimized. New technologies imparted should also be suitable for Indian environment and other operating conditions. Thus, India needs to develop technologies that are suitable for Indian conditions. Not just for the sake of shale gas development, but for overall fluid transmission network. With immediate effect India needs to consider on priority basis its pipeline network which needs to be robust, secured and very effectively spread throughout the Indian landmass. That way, the energy resources that are explored at any place in the country can be effectively supplied to the refineries for further processing on the upstream side as well as the transportation of fuel and its distribution on the downstream side. Also, these pipelines will be operative for longer period of time.

India needs to take into account the water scarcity present in the country which gets severe during the summer season. Hence, it would be great if India can come up with a technology that can replace hydraulic fracking and use much less amount of water, something like how China uses carbon dioxide as fluid to save on water. If India looks forward to work on economical extraction of shale gas, it needs to settle disputing factors which may not be monetized but are a strong

obstruction viz. bureaucracy, political opposition, land disputes and tax credits. Although not all issues, like corruption and local mafia threats, can be eliminated it should be reduced wherever possible.

One of the factors that has become a major issue in US and could have impact in India as well the separation of ownership of carriers and content of the gas. That is, the gas generator will have the responsibility to produce the demanded amount of gas resource while the ownership of the pipeline network should be in the hands of a separate company, not the generator, and will have the responsibility to expand and maintain the pipeline network. That way, the gas generator cannot own the flow of gas in the grid and restrict the supply of gas from competition to earn more shares in an unethical way. The Government of India can sign various MoUs with national and international agencies who will contribute in exploration and exploitation of Indian shale gas resources. Proper incentives should be provided to keep their interests as well as attract more companies and increase the competition. This is will significantly increase the innovation in the shale gas sector in attempts to reduce the capital and operating costs, which in turn will reduce the final shale gas prices.

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