246. The Technical Aspects of Unconventional Reserves

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Abstract

In Unconventional reservoirs both the shale oil and gas are the prospective sources of energy of the world. And these resources can be proved as a game changer in the "international market of energy". Pakistan is mentioned among top 10 countries having largest unconventional reserves i.e. 105 tcf of shale gas and 9 billion barrel of oil.

This paper presents an analytical overview of unconventional reservoirs in the major regions of the world as well as in the Pakistan. Revolutionary research work and pilot projects have been initiated in the developed countries like China, USA and Canada to produce the unconventional reservoirs but unfortunately due to lack of improper management system in Pakistan no such work has been started which can be appreciated. As well as the lack of technological implementation is also the main reason of fall of unconventional reservoirs in this country.

Whereas according to studies the 70% area of the Pakistan has shale rocks. So the govt. must take steps to initiate the research as well as technological projects which will be proved as prosper and will be big achievement in the development of this country.

Keywords: *"Unconventional Reserves" "Lithological Properties" "Fracturing".*

1. Introduction

Conventional hydrocarbons recovery has reached on its peak and soon there is going to be global decline in the conventional reserves. However if we analyze the quantity of oil is not declining, but it is instead changing form-geographically, geologically, chemically and economically. as the new technologies are discovered the world has been looking for the change from conventional hydrocarbons to unconventional sources of energy just like wind renewable sources Along with this the huge shale formations have been explored in the world, acting as a good source of desirability for the hydrocarbons producing states.

The huge positive impact on revenue generation is left by shale reserves which have recently laid a competitive impact upon E&P activities worldwide.

2. Understanding Unconventional Reservoirs

Commonly the unconventional reservoir is defined as the reservoir whose effective permeability is less than 1 md and generally the unstimulated gas flow rates is less than 1.0 mmsfcd. Conventional reservoir is essentially a medium to high permeability reservoir in which the vertical well can be drilled, pay interval can be perforated, and then the well can be produced at commercial flow rates and sufficient volumes of oil and gas can be recovered. In tight gas reservoirs there are lots of uncertainty regarding (i). Connate gas saturation and irreducible water injection. (ii). Overburden correction factor that has a big impact on the low permeability range value. (iii). Net pay of the formation. (iv). Presence or absence of natural fractures. Before going to deep study of Unconventional Reservoirs, it must be understood that what makes the reservoir unconventional are they are fine grained, rich organic, sedimentary rock formation, commonly shales and similar composition rocks. The international Societies illustrate the "unconventional hydrocarbons" as accumulations which have been blocked throughout huge zone and are not exaggerated by water pressure (hydrodynamic influences) also known as "tight formations". However conventional deposits accumulate in porous and permeable formations. The Unconventional formations can be as porous as conventional but the lack of permeability makes them comparatively resistant to the flow of hydrocarbon, due to which they will remain in the formation until and unless fracture occurs naturally of artificially. For different types of unconventional reserves see Fig. 1:

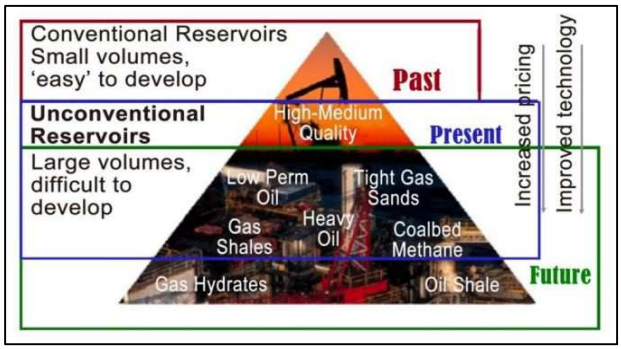

Fig. 1 Different unconventional hydrocarbons

3. What Makes the Reservoir Tight/Unconventional?

Number of reasons can be there for making a reservoir tight. Actually it is the property of permeability which is the ability of the rock to transmit the fluid through its pore spaces, it is a property overseen by the Darcy law in porous media, fluid saturation, capillary pressure, viscosity and effective porosity are the factors controlling the effective permeability of a formation. In addition the factors relating to the fluid nature, parameters of rock are also important. These are organized by post depositional and depositional surroundings subjected to the reservoir. Deposition of very fine sand to silt and clays, which make deprived reservoirs on lithification are more disposed by depositional arrangement like deep basinal site banks in flood plain areas. In the United States Low-permeability sandstone formations are not dominated by muddy and immature sandstones having large volumes of diagenetically responsive detrital clay matrix, but somewhat are usually sandstones which are clean deposited in high-energy depositional sites whose intergranular pores are essentially obstructed by authigenic cements (mainly quartz and calcite) (Dutton et al., 1993).Mostly the Post-depositional diagenetic actions act negatively, decrease the effective porosity due to which rock becomes less permeable. Actually the permeability of the unconventional reserves is less than 0.1 md [1]. See Fig. 2:

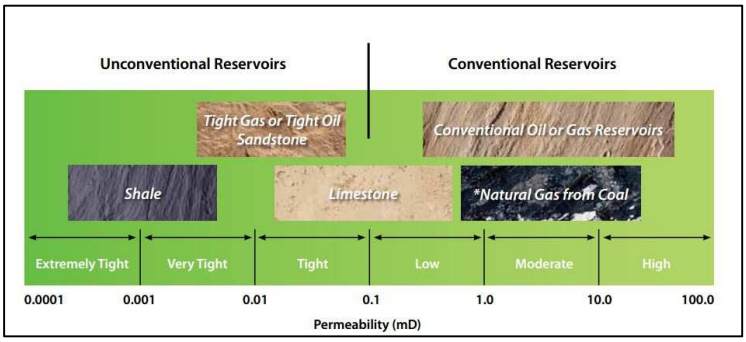

Fig. 2 Difference between Conventional and Unconventional

4. Types of Unconventional

4.1. Oil shale

It can be defined as fined-grained sedimentary rocks which are gorgeous in immature organic material called kerogen.

Properties:

It is found at a not extraordinary depth that requires a thermal maturity to alter kerogen into gas and oil. Oil shale comprises more inert mineral matters than coal like carbonates, silica or even sulphides. 500-400 Kcal/Kg is heating value of oil shale when crushed and burned directly.

4.2. Coal-Bed Methane

Coal Bed Methane is found when natural gas gets stored in deeply buried coal seams.[2]

Properties:

Coal which originates from mines is environmental free. During alteration method biogenic Methane produced. During alteration method coal get shrinks, microporosity increases, strength of coal decreases and fracture occur. Coal generally contains methane but CO_2, N_2, C_2H_5, H_2S and H_2 can also occurs in them. The volume of gas adsorbed at a low depth is commonly higher than the amount of conventional gas present at the same depth: it depends on the uplift history, temperature, type of coal and pressure.

4.3. Tight Gas Sands

The Reservoirs that have permeability less than 0.1 md are known as tight gas sands. The sands are known as tight because there poor sorted and centered nature.[2]

Properties

In tight gas sands Buoyancy forces do not succeeds because of low permeability jail due to which poor sorting causes. The permeability jail results in a gas slippage or turbulence flow. It is expected that there is about 7405 Tcf of tight gas is present in the world.

4.4 Shale Gas

The Gas which is found from shale rocks is known as shale gas. The permeability of Shale varies between the ranges of nano and micro darcy. Where viscous flow is dominant in microdarcy range and diffusion flow is dominant in nanodarcy ranges, extended completion is required. Mostly stimulation job or horizontal drilling are done to produce such reservoirs.[2]

Properties

Net pay thickness is typically 50-600 ft. with porosity of less than 3%, they occurs in overpressure zones. The in-place organics are shrunk by high thermal maturity and having favorable in situ stress for fracturing.

5. Comparison Between Conventional and Unconventional

There is a lot of difference between conventional and unconventional reservoirs in terms of recovery rate, productivity

factor, API and environmental factor as well as the sources required to produce them as shown in **table 1.** Whereas in **table 2** it is shown that what is the difference between conventional and unconventional reserves in terms of their quantity [2].

Table 1

Factors	Conventional Oil	Unconventional Oil
API	22°-45°	7°-8°
Recovery Factor (RF)	34%	5%-10%
Productivity Rate	100 barrels	5-10 barrels
Reservoir Pressure	Existent	Non-existent
Diluents	Not needed	Essential
Flow Rate	Free flowing	Viscous/Semi-solid
Production Costs	$1-$10/barrel	$40-$60/barrel
Classification	Crude	Non-crude

Table 2

Conventional	Unconventional
3 barrels are equal to	1 barrel of heavy oil
4 barrels are equal to	1 barrel of medium oil
5 barrel are equal to	1 barrel of light oil

6. Current Status of Unconventional Reservoirs

Currently very few countries are producing the unconventional reservoirs. In many parts of North America contains Shale in which natural gas deposits trapped in shale formations that would have formed 300-400 million years ago. The gas is not evenly scattered in shale, but focused in vastly rich “sweet spots”. Advancement in 3D seismic imaging has made it possible to detect shale gas and tight oil reserves with ever exactness.

According to Energy Information Administration (EIA) estimates that the US has about 14 trillion m^3 of unproven shale gas resources which are technically recoverable. Yet it is still not confirmed that all of this can be produced or not. The commercially producible US gas reserves plus conventional reserves improved to 9.3 trillion m^3 in 2013-about 13 times annual US consumption, out of which mostly came from shale gas reserves[5]. Commercially worthwhile reserves of oil in US, comprising conventional reserves, improved to 33.4 billion bbl. in 2012 – around five years of US oil consumption – with tight oil accounting for 22% of the total. The Orinoco belt which is actually present in Venezuela can produce up to 570 kb/d of extra heavy oil. Although Canada is the only country which is extracting oil sand at commercial level. The production of oil sand in 2008 was about 1.3 mb/d Currently oil shale is exploited in China, Germany, Israel and Brazil. In 2005 the oil shale production was recorded 5 mb. Worldwide and North America is the only country with the largest production of unconventional gas. In 2006 US produced 161 bcm of tight gas, 51 bcm of coal bed methane and 31 bcm of shale gas reserves. At the end of 2005, the estimated figures of unconventional resources were: 2484 bbl. Of extra heavy oil, 3272 bbl. of oil sand, 2826 bbl. of oil shale, 210 tcm of tight gas, 256 tcm of CBM, 456 tcm of shale gas and between 1000-5000 tcm of natural gas from hydrates. In Western Canada the largest oil sand deposits are located, in USA largest resources of oil shale, whereas the largest reserves of tight gas and shale gas are estimated to present in Asia Pacific and largest CBM resources are located in Former Soviet union. According to Mohr and Evans (2010), the peak production of unconventional reserves would range between 49 mb/d in 2076 and 88 mb/d in 2084. At this moment North America is producing unconventional gas resources and in this region production is estimated to rise till 2030. [6]

Fig. 3 Shale in North America

7. Availability of Unconventional Reserves in Pakistan

The natural gas sector of Pakistan needs to consider the most affordable and efficient paths and to make such policies in order to meet the energy requirements of the country. Previously the strategies of gas sector were busy to explore new opportunities to import natural gas, but the exploration was limited for local resources. Though Pakistan is rich in shale oil and gas, which can be seen as game changer. In fact these resources have great potential to boost the economy along with resulting saving of $15 billion, which were previously utilized for importing products of petroleum.[4]

In North America, US and Canada the shale gas revolution changed the global energy landscape. It is worth stating that now that China also plans to boost production of Shale Gas from 7 bcf in 2013 to 52.95 bcf in 2014. Because of such achievement China has placed its 30 year gas pipeline projects to import Natural Gas on the state of postpone.

More than 827,365 Km^2 sedimentary areas in Pakistan is naturally filled with shale formations as source and has proven hydrocarbon reserves. Substantial amount of gas has been confined in the unconventional reservoirs having tight gas, CBM and shale oil and gas separately from conventional reservoirs. Apart from proven conventional gas reserves, the Pakistan has been blessed with about 200 Tcf resources of shale gas in the shale formations. According to the studies the area of about 70% of Pakistan is covered with shale rock.[3]

According to EIA the shale gas potential of Pakistan is 105 Tcf and shale oil of 9.7 billion barrels. As the demand of energy is increasing day by day and the joint challenge of climate change and energy security, the govt. must take active initiative in order to increase the projects on development of unconventional reservoirs. As the country takes this step, exploring this valuable resource, a clear policy framework will get conclusive. Furthermore the production records are shown in **table 3 and 4.** In table 5 and 6 the availability of shale gas and tight oil resources of most of the regions are shown.

Table 3

Extra Heavy Oil	Resources BBL.	Reserves BBL.	Cumulative Production(BBL)
L America	2448	59	14
Venezuela	2446	59	14
Asia	18	0.8	0.9
Others	19	0.3	1.4
World	2484	60	16.5
Nat. Bitumen			
N. America	2451	174	5
Canada	2397	174	5
Asia	427	42	0.0
Europe	349	29	0.0
Others	6	1.5	0.0
World	3272	246	5
Oil Shale			
N. America	2100	N/A	0.0
United States	2085	N/A	0.0
Africa	159	N/A	0.0
Europe	368	N/A	2.5
Others	198	N/A	2.5
world	2826	N/A	5

Table 4

Region	Tight gas tcm	CBM tcm	Shale Gas tcm
M. East & N. Africa	23	0	72
Sub-Saharan Africa	22	1	8
F. Soviet Union	25	112	18
Asia Pacific	51	49	174
N. America	39	85	109
L. America	37	1	60
Europe	12	8	16
World	210	256	456
Easily Accessible	100	180	380
US Product. (bcm)			
1996	102	31	8
2006	161	51	31

Table 5

Shale Gas		
Country	Trillion m^3	% of total
China	32	15.3%
Argentina	23	11%
Algeria	20	9.7%
U.S	19	9.1%
Canada	16	7.9%
Mexico	15	7.5%
Australia	12	6.0%
South Africa	11	5.3%
Russia	8	3.9%
Brazil	7	3.4%
Rest of the world	43	21.0%
World Total	207	100%

Table 6

Tight Oil		
Country	Billion BBL	% of total
Russia	75	21.7%
U.S	58	16.8%
China	32	9.3%
Argentina	27	7.8%
Libya	26	7.5%
Australia	18	5.2%
Venezuela	13	3.8%
Mexico	13	3.8%
Pakistan	9	2.6%
Canada	9	2.6%
Rest of the World	65	18.8%
World Total	345	100%

7.1 Potential Shale Basins & Formations

Potential shale basins and the problems which are evaluated in different formations are categorized in table 7 and 8.

Table 7.

Lower Indus basin	Upper Indus Basin
Shale formations are wide spread from north to south	Shale formations are laterally restricted
Mostly deep>3000m	Both shallow and deep formations
In some regions very thick >400m	Thickness is variable
Prospective formations include:	**Prospective formations include:**

Lower Goru, shale members, Sembar Formation, Ghazij formation, Mughal kot formation.	Patala formation, Hangu, chichali, Datta formation, Sardhai foramtion

Table 8.

Formations	Challenges
Lower Goru Formation	• Shale member is deep in various regions. • Geological heterogeneity is present
Sembar Formation	• Extremely deep in various regions • Coning issue due to large thickness
Patala formation	• Accessibility problems in some areas.

7.2 Economic Viability

Due to many reasons Pakistan should go for unconventional resources. Few are below:

7.2.1 Huge Unmet Gas Demand

Domestic gas production of Pakistan from conventional resources was 4.2 bcf but there was demand of 8 bcf in winter. This gets more critical in the near future (Jadoon 2011) [8].

7.2.2 Fulfilment of Energy Demand

As the country will produce unconventional resources, so the government can use such resources to meet the energy demands of the Pakistan. [8].

7.2.3 Cheap Transport Fuel

The unconventional Shale gas could be very helpful in solving the issues of public transport. [8]

7.2.4 Poor Economic Conditions

Nowadays the country is facing the economic and energy crisis. Many companies have been transferred from Pakistan to Bangladesh because of crisis which could be accomplished by the help of shale gas power plants. [8]

7.2.5 Technical Availability

The appreciable point is that the Pakistani personal's and technicians who are working in the Middle East countries are supporting the economy. The same thing can be applied in the country. [8]

7.2.6 Capacity to Take Over Such Project

Pakistan should move towards World Bank and Asian Development Bank to get support in order to start projects on Shale oil and gas. Single pilot project costs about $10 million. Just sincere professionals are required to plan the projects and then they will imply it so that Pakistan fulfil its energy demands ASAP.[8]

8. Key challenges in Producing Unconventional Reserves

8.1 Required Technology for TGR Development

- Pre-stimulation is less than 1.0 MMscf/d of wells productivity.[7]
- In order to improve the productivity of wells, following stimulation techniques should be applied.[7]

a. Hydraulic fracturing (some examples in Pakistan).
b. Multi-fractured horizontal wellbore (Not applied in Pakistan).
c. Multi-lateral wells (Not applied in Pakistan).

8.2 Horizontal Drilling

The horizontal well is drilled in order to increase the contact between the wellbore and the reservoir. Wells are drilled to predetermined depth vertically (typically 1000m-3000m) above the tight oil formation. Then the well is started to "kicked off" at an increasing angle until it runs parallel in the reservoir. Once horizontal, at selected length the well is drilled it can be extended up to 3-4 km which is called horizontal leg.[7]

8.3 Hydraulic Fracturing

Unconventional reservoirs need stimulation job like hydraulic fracturing, which is nowadays used by oil and gas industry. In this process the pressure is applied by pumping fluids into the wellbore as shown in figure 4. In simple words the hydraulic fracturing will create permeability in the reservoir artificially. In unconventional reserves the permeability is very low as mentioned above that they have less than 0.1 md so additional permeable channels must be created so the fluid will flow. Whereas in conventional reserves the permeable channels are already formed so there is no need of hydraulic fracturing method.[7]

8.4 Policy Focus

The govt. should make the policies to start the shale production projects at the pilot level and it can take help from the countries like USA, china and Canada for such projects. Because enough work is being done in these countries and these are those countries along with whose Pakistan has good relations.[7]

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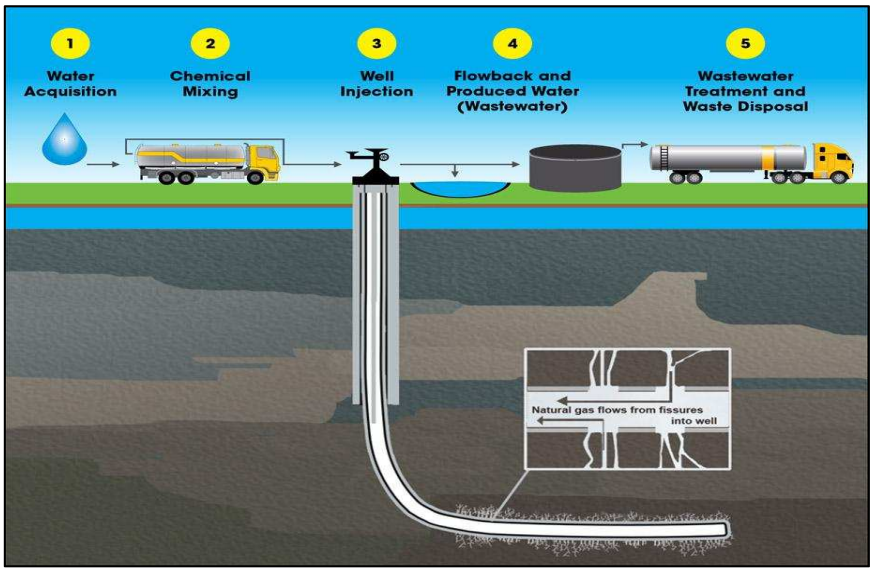

Fig. 4 Hydraulic Fracturing

9. Conclusion:

As we know that the permeability of unconventional reservoirs is less than 0.1 md, so it's very difficult to extract from subsurface to surface due to no flow path. So in order to create channels or flow path hydraulic fracturing method is commonly used. In hydraulic fracturing the proppants allowing with the slurry are pumped down through wellbore that create fractures in formation and proppants are used to holdup these fractures through which unconventional fluid will flow towards surface. 5701 tcf of shale gas is present all over the world which has high potential so after the depletion of conventional reserves these unconventional reserves will be proved sufficient to meet the energy demands of the world.

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