283. Challenges of Unconventional Reservoir: It's Time to Overcome Them

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Abstract

As oil and gas industry passing their decades, number of challenges and problems are encountering continuously which not only creates issues but also make panic in industry. Today the one of major issue in oil and gas industry is extraction of unconventional reservoir.

A large share of world remaining oil is classified as unconventional oil. Unconventional reservoir are those reservoirs in which oil and gas is being trapped in rocks deep underground beneath surfaced having the rock permeability less than 1. These unconventional reserves include tight gas, shale gas, coal bed methane and oil shale. Among all methods hydraulic fracturing is only way to extract unconventional reserves with less ratio of damages. Mostly problems encountering are Heavy Machineries are required for extraction, Extra steps and capital needed to produce, Extra Heavy Refinery Section to be installed, Lots of water needed for hydraulic fracturing, Shale wells has high decline rate and Pakistan has currently worst condition than all over. It is estimated there is 7405 Tcf of tight gas is present in the world. And Pakistan has 227 billion barrel of oil shale reserves. It is predicted by energy resources that at the end of 2030 oil reserves will be depleted and at the end 2050 gas will be depleted. This ratio can be move from actual point of view but later or after this will be happen.

Current technologies are not as much feasible to extract as much oil and gas from unconventional reserves. But what happen in future when there will be no oil and gas and energy shortfall become enter into dark shadows. On that time we have only way to explore and produce unconventional reserves. So why not now, to take some advance steps in relating to exploration of unconventional reserves and ready for extraction before the time when conventional become boost down.

Keywords: *Unconventional Reserves;Hydraulic Fracturing;Shale Economics in Pakistan.*

1. Overview of Unconventional Reservoir

Unconventional reservoir are those reservoirs in which oil and gas is being trapped in rocks deep underground beneath surfaced having the rock permeability less than one [1]. Advancements in current technologies regarding drilling and well site enables to produce these unconventional reservoirs.

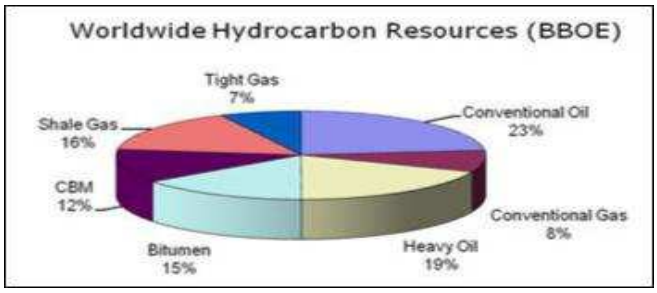


Fig. 1.1 Worldwide Hydrocarbon Resources

1.2 Types of Unconventional Reservoirs

The whole world is totally depends on energy which is lifeline for communications, transportations, and heating and electric power generation. Most of energy is produced through fossil fuel [1].

Following are the main types of unconventional reservoirs

1.2.1 Oil shale

Definition:
Oil shale is fined-grained sedimentary rocks which are rich in immature organic material called kerogen.

Properties:
Oil shale is found at a not great depth that requires a thermal maturity to convert kerogen into oil and gas. Oil shale contains 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.

Commercial Use and Economics:
Shale oil recovery has been improved a lot since current oil prices and depletion of the conventional reserves. Average shale oil production cost is greater than 60 $ /bbl, which is comparatively high [2].

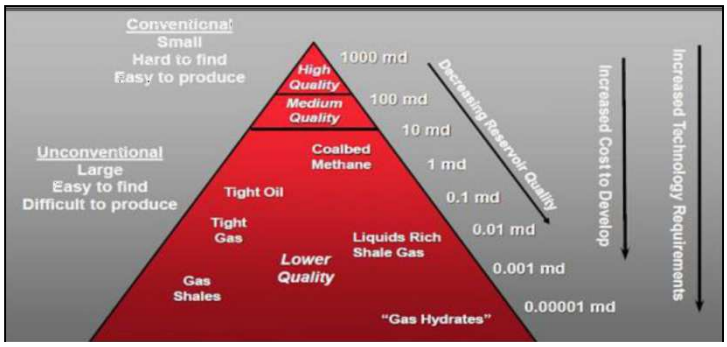


Fig. 1.2. Types of Unconventional Reservoir

1.2.2 Coal-Bed Methane

Definition:
Natural Gas that is stored in deeply buried coal seems is known as Coal Bed Methane.

Properties:
Coal that is originates from mines is environmental free. During transformation method biogenic Methane is produced. In transformation method coal shrinks, micro porosity increases and coal strength decreases and fracture occur. Coal generally contains CH4 but CO2, N2, C2H5, H2S and H2 can also occurs in them. The quantity of adsorbed gas at a shallow depth is usually higher than the quantity of conventional gas located at the same depth: it depends on the burial, temperature, type of coal, pressure and uplift history.

Extraction of Coal Bed Methane:
Coal is basically filled with water during the transformation process coal cleats is depressurized which consequently amount of gas exceeds critical gas saturation and gas flows to the well bore.

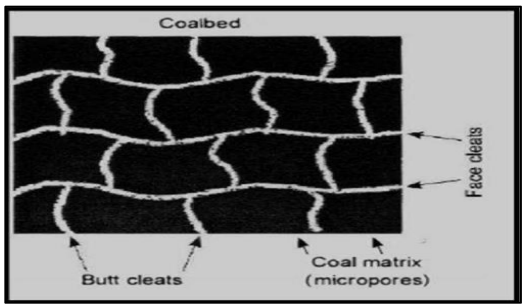


Fig. 1.3 Reservoir Structure of Coal Bed Methane

1.2.3 Tight Gas Sands

Those Reservoirs that have permeability less than 0.1 md is known as tight gas sands. The sands are called tight because these are poor sorted and cemented. Buoyancy forces in tight gas sands do not succeeds due to low permeability jail which cause poor sorting. The permeability jail results in a gas slippage or turbulence flow.

It is estimated there is 7405 Tcf of tight gas is present in the world.

1.2.4 Shale Gas

Gas which is produced from shale rocks is known as shale gas. Shale permeability varies between the ranges of micro and nanodarcy. Where diffusion flow is dominant in nanodarcy ranges and viscous flow is dominant in microdarcy range, long completion is required. These reservoirs are mostly produced through stimulation job or horizontal drilling.

Following are the main properties of shale gas[13].

- -Thick net pay. (Typically 50-600 ft.)
- -Porosity is >3 % (typically 2-8%)
- -High pressure (overpressure zone)
- -TOC is >2 wt. % (typically 1-14%)
- -Higher thermal maturity shrinks the in-place organics and creates more pore space for storing gas.
- -Favourable in situ stress for fracturing.
- -Depth is 1,000-13,000 ft. typically.

1.2.5 Natural Gas Hydrates

Natural gas hydrates are cage-like lattice of ice which is forms only in the presence of liquid water.

It behaves like solution of gases in crystalline solids rather than chemical compounds. Methane hydrate occurs at high pressure and low temperature in the arctic, below permafrost as “boulders” on the sea floor and beneath the ocean floor at water depth greater than 500meter. Hydrate deposits can be several meters thick. If these occur in sedimentary rocks, the value of hydrate saturation and rock permeability for future production is very important.

1.3 Conventional Reservoir versus Un-Conventional Reservoir

The major difference between Conventional Reservoir and Un-Conventional Reservoir is API Gravity whose ranges are from 7-8%. These ranges are compares with 22% or less for conventional heavy oil, 22-33% for medium and 31-45% for light or sweet oil [14].

Table -1 shows Major Difference B/w Conventional and Unconventional Reservoir

Factors	Conventional Oil	Unconventional Oil
API	22%-45%	7%-8%
Recovery Factor (RF)	34%	5%-10%
Productivity rate	100 barrels	5-10 barrels
GHG emissions	64 kg / barrel	75 kg / barrel
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

It means one barrel of conventional heavy oil is equal to 3 barrel of unconventional oil and remaining for other see in following table.

Table 2. Quantitative Relationship Between Conventional and Unconventional

Unconventional Oil	Equality	Conventional Oil
3 Barrel	=	1 Barrel of heavy oil
4 Barrel	=	1 barrel of medium oil
5 Barrel	=	1 barrel of light oil

There are also many others comparisons between unconventional and conventional reservoirs like the recovery factor for conventional oil average of 34% whereas unconventional oil ranges from 5%-10%. There is also dependence on productivity rate which is estimate that conventional oil is 10-20 time more than of unconventional oil which means extraction ratio is 5-10bbl/D of unconventional= 50-100b/d of conventional oil. In case of environmental issue unconventional oil releases 75kg of gas emission which is 15% greater than conventional oil gas emission. In case production when natural pressure of conventional reservoirs is being depleted then artificial lift methods or EOR methods are applied where as in case of unconventional reservoir it requires additional diluents (gas condensate, NGL, or light crude oil) to transport by pipeline [7].

1.4 Extraction Methods of Unconventional Reservoir

Following are main techniques involved in the extraction of unconventional reservoirs [13].

1.4.1 Oil Shale

There are two techniques oil shale extraction

Technique 1:
In this technique Oil shale is produced through chemical process known as pyrolysis. This process happens when it is heated up to 400-500 C so that kerogen is converted to shale and shale gas.

Technique 2:
In this technique Oil shale is produced from sands through surface retorting in which mined oil shale is electrically heated up to 1000 degree F which cause to stable oil that is present in shale and oil become release from shale.

1.4.2 Coal Bed Methane

Coal is basically filled with water during the transformation process coal cleats is depressurized which consequently amount of gas exceeds critical gas saturation and gas flows to the well bore.

1.4.3 Tight Gas Sands and shale Gas Reservoir

Due to its low permeability fluid cannot move from sub surface to surface. That's why artificially permeability to be created. In these types of reservoirs through one of the stimulation job known as Hydraulic Fracturing.

In Hydraulic Fracturing job artificially fracturing is created into shale which is commonly present at 6000 ft. to 8000 ft. these fracture is later than be opened through propants that cause fluid to produce from sub-surface to surface [20].

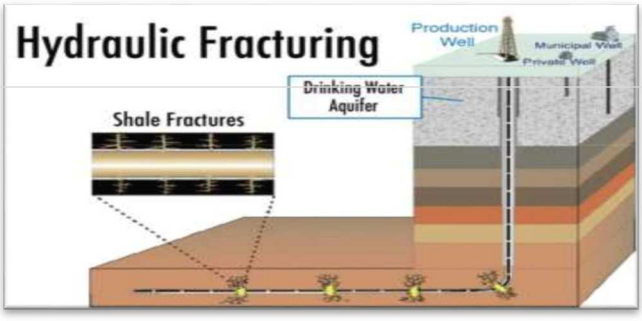


Fig. 1.4 Hydraulic Fracturing

There is another technique of extraction of tight gas sands and shale reservoir without using water. In this technique five wells are drilled in the oil shale each of well one kilometre in length. Heaters are installed between each well that produce heat up to 600 Fahrenheit which cause breakdown of organic compound and convert into vapours which will produce up to surface along pressure gradient. These vapors are cooled down at surface and separate into constituents [12].

This method is very costly than other method but this method is environment friendly. The recovery factor may vary from 10% to 50% of OGIP, due to complicated pore structure, lithology, morphology and the diving mechanism.

1.5 Challenges in Unconventional Reservoir

Following are number of challenges in unconventional reservoir [3].

- Shale wells has high decline rate. Typical rate of first year of production is 60-70 %.
- Due to its decline rate more and more wells are to be drilled to maintain production.
- Heavy Machineries are required for extraction of unconventional reservoir.
- Extra steps and capital needed to produce a useable product.
- Cost of producing unconventional reservoir is much higher than conventional reservoir.
- Average cost of producing shale gas is estimated to be around us dollar of 4-7/ MMBtu which is 5 times higher than conventional reservoir.
- Extra Heavy Refinery Section to be installed to distillates heavy oil.
- Lots of water needed for hydraulic fracturing [20].

- There is a high environmental issue due to continuous emission of inherent gases.
- Potential issues rose with hydraulic fracturing that cause to create earthquakes, water contamination, and soil destruction etc.
- In case of Coal bed Methane there is potential risk of contamination of qualify drinking water present sub-surface.
- There is big issue of handling contamination causes through spills, leaks from pits and siltation of streams from drilling and pad construction activities.
- Among other potential challenges many other mitigates relates to safeguard, existing technologies and best practices.
- There are many other challenges during practices of unconventional reservoir. But now days there are many other technologies are introduced that have potential to overcome these challenges.

1.6 Un-conventional Reservoirs in Pakistan

Pakistan is very rich in shale oil and gas. It is estimated that Pakistan has 227 billion barrel of oil shale reserves out of which 9.1 billion barrel is recoverable by recent technology, furthermore Pakistan has 586 trillion cubic foot of gas out of which 105 trillion cubic of gas is recoverable [10-15].

Pakistan's shale oil and gas resources are mostly located in the lower Indus basin region, predominantly in Ranikot and Sembar, mainly in upper Sindh and lower Punjab while a sizeable reserve is also found in Khyber Pakhtunkhwa. Prospective basins are Southern Indus Basin and Central Indus Basin along with the important Baluchistan basin and Northern Indus Basin. The following map illustrates the shale gas basins and its potential in Pakistan [8] See Fig 1:.

(a) 

(b) 

Fig. 5. Geological Illustration of Shale Reserves (a) Middle Indus Pakistan (No of Reservoir= 7, GIIP (bcf) = 7400) (b) Suleiman FB (Pakistan) (No of Reservoir= 3, GIIP (bcf) = 19000)

(a) 

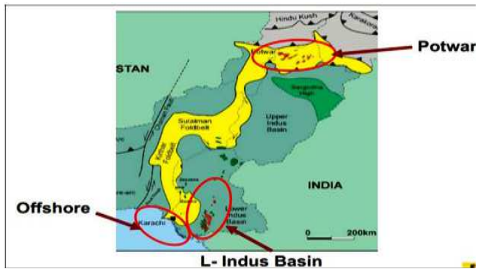
(b) 

Fig. 6. Geological Illustration of Shale Reserves (a) Kirthar Area of Pakistan (No of Reservoir= 2,GIIP (bcf) = 7300) (b) Other regions (Pakistan)

Following Fig. shows the geology of Pakistan

Basic Data	Basin/Gross Area		Lower Indus (169,000 mi²)			
	Shale Formation		Sembar			Ranikot
	Geologic Age		L. Cretaceous			Paleocene
	Depositional Environment		Marine			Marine
Physical Extent	Prospective Area (mi²)		26,700	25,560	31,320	26,780
	Thickness (ft)	Organically Rich	1,000	1,000	1,000	1,000
		Net	250	250	250	200
	Depth (ft)	Interval	4,000 - 6,000	6,000 - 10,000	10,000 - 16,400	6,000 - 13,000
		Average	5,000	8,000	13,000	9,000
Reservoir Properties	Reservoir Pressure		Normal	Normal	Normal	Normal
	Average TOC (wt. %)		2.0%	2.0%	2.0%	2.0%
	Thermal Maturity (% Ro)		0.85%	1.15%	1.50%	0.85%
	Clay Content		Low	Low	Low	Low
Resource	Gas Phase		Assoc. Gas	Wet Gas	Dry Gas	Assoc. Gas
	GIP Concentration (Bcf/mi²)		14.3	57.0	82.7	17.0
	Risked GIP (Tcf)		45.9	174.7	310.8	54.8
	Risked Recoverable (Tcf)		3.7	34.9	62.2	4.4

1.7 Challenges in Extraction of Unconventional Reservoir in Pakistan

- Technical expertise is required for extraction.
- Heavy Machinery is required.
- Enough cost is required about investment of about 1.5 billion dollars initially.
- 500 wells should be drilled for pilot testing.
- To move gently deeper of about 6000-8000 fits is big issue in Pakistan due to critical geology.
- There is no proper environment in Pakistan to do these jobs like hydraulic fracturing and horizontal drilling.

- Thousands feet deep blasting is big issue in Pakistan [21].

1.8 Need of un-conventional Resources in Pakistan

Shale development in Pakistan can resolve issue of energy crisis. The current annual fuel consumption of Pakistan is about 150 million barrel oil and 1.6 trillion cubic feet gas. And Pakistan generates electricity with heavy reliance on gas and oil, i-e around 47% and 30% respectively. Pakistan is currently faces shortage of 1400 million cubic feet of gas per day, which results in currently shortfall of 5000-6000 MW per day [11].

By 2020, Pakistan's domestic gas production is anticipated drop from existing value of 4 billion cfd to 2 billion cfd where as the demand is projected to raise 8 billion cfd by that time, generating a 6 billion cfd shortage. Pakistan is currently facing even worst condition in requirement of oil. Pakistan is investing 12 billion dollars to import 75% of oil. It is estimated that ratio of import will rise to about 122 million metric tons which will result in oil bill of around $40-50 billion [5].

Pakistan has only way to explore as much as unconventional reservoir and get production quickly.

1.9 Unconventional Resources in all over the World

The production of unconventional reservoir is currently amount to 2.05 mbd and is projected to rise to 3.05 mbd by 2020 and 3.75mbd. In 2011, unconventional oil contributed 2% to global oil demand and this is projected to rise to only 3% by 2030.this level of production will not even offset the depletion of conventional oil production estimated at 3.5 to 3.9 mbd [14].

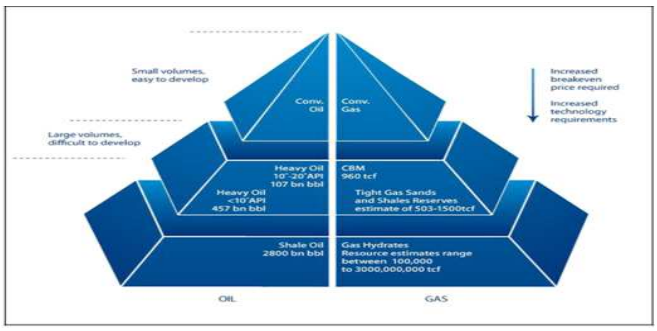


Fig. 7. Unconventional Reserve Estimation

1.10 Prospects of oil and gas in 2030 and 2050

It is predicted by energy resources that at the end of 2030 oil reserves will be depleted and at the end 2050 gas will be depleted. This ratio can be move from actual point of view but later or after this will be happen. On that time these unconventional resources will fulfil requirements of energy crisis [16].

2 Conclusion

The whole world is totally depends on energy which is lifeline for communications, transportations, and heating and electric power generation. Most of energy is produced through fossil fuel. But now conventional resources are going to deplete day by day. Conventional power is shifting toward unconventional resources. It is predicted by energy resources that at the end of 2030 oil reserves will be depleted and at the end 2050 gas will be depleted.

Current technologies are not as much feasible to extract as much oil and gas from unconventional reserves. But what happen in future when there will be no oil and gas and energy shortfall become enter into dark shadows. On that time we have only way to explore and produce unconventional reserves. So why not now, to take some advance steps in relating to exploration of unconventional reserves and ready

for extraction before the time when conventional become boost down.

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