

Shale Gas: History of Development

Sergey S. Zhiltsov and A.V. Semenov

Abstract The history of shale gas production goes back more than two centuries. The production of this hydrocarbon resource was pioneered by the USA that accumulated considerable experience in development of the shale gas plays. The shale gas play development pushed further the development of new technologies that ensured considerable increase of this hydrocarbon resource production, thus, affecting the situation in the global gas market.

Keywords History, Production technology, Shale gas

Contents

1	Introduction	10
2	Shale Gas: Definition	10
3	History of Shale Gas Production	11
4	Technology of Shale Gas Production	13
5	Conclusion	15
	References	16

S.S. Zhiltsov (✉)

Peoples' Friendship University of Russia, 6, Miklukho-Maklaya Street, Moscow 117198, Russia

S.Yu. Witte Moscow University, 12, Building 1, 2nd Kozhukhovsky Proezd, Moscow 115432, Russia

Diplomatic Academy of the Ministry of Foreign Affairs of the Russian Federation, 53/2, Building 1, Ostozhenka Street, Moscow 119021, Russia

e-mail: sszhiltsov@mail.ru

A.V. Semenov

S.Yu. Witte Moscow University, 12, Building 1, 2nd Kozhukhovsky Proezd, Moscow 115432, Russia

e-mail: semen7777@gmail.com

1 Introduction

The first information about the shale hydrocarbon production appeared in the nineteenth century. However, in that time, the cost of shale gas development was very costly, so the commercial production of this gas was not attained. Regardless of this fact, the production technologies were permanently improved. The pioneer here was the USA that for many decades made their best to advance the production technology.

A real breakthrough in the shale gas production was attained with the appearance of the hydraulic fracturing technology that permitted to increase enormously the volumes of shale gas extraction. Combined with application of chemicals and directional drilling, this technology provided for considerable increase of shale gas extraction within a short time.

In the recent decades, many petroleum and gas companies turned their views to the shale gas production. The development of shale plays became a part of the state policy in many world countries. Their efforts to develop shale gas plays were supported by the endeavors to attain energy independence.

2 Shale Gas: Definition

Shale gas is a kind of natural gas trapped within shale formations representing the sedimentary rocks containing a great quantity of organic matter required for petroleum and gas formation and consisting mostly of methane (Fig. 1). Apart from methane, the shale gas also contains ethane, propane, butane, and some non-hydrocarbon compounds.

The natural gas fields are usually confined to sandy soils, while shales are denser soils – clay stones with low porosity composed of smaller and more solid particles.

Fig. 1 An organic-rich fine-grained sedimentary rock called shale (<http://www.thomaswhite.com/wp-content/uploads/2012/08/img-shale-gas-the-fuel-for-future.jpg>)



The shales proper are the type of sedimentary rocks most widespread on the Earth. They are parent rocks of hydrocarbons migrating further into permeable reservoir formations forming traps for petroleum and gas in the underlying sedimentary rocks.

In the conditions of high temperature and high pressure, the new minerals are formed. Here the organic material turns into petroleum and gas. The shales are distinguished by low porosity and low permeability. Here gas spreads evenly through the whole shale play. The quantity of extracted gas depends on the thickness and density of a shale play where organic and mineral material prevails. The play thickness varies from one meter to some hundreds of meters with the depth of occurrence from several hundred meters to several kilometers.

Shale gas is one of the so-called unconventional forms of natural gas. The *unconventional gas* is an industrial term denoting natural gas trapped in clay shales, in coalbeds, and in dense sandstones occurring deeply in the geozones under not high pressure.

3 History of Shale Gas Production

The USA is justly considered the parent land of the “shale revolution.” The first commercial gas well was drilled in the shales in 1821 in America by William Hart who is considered in the USA the “father of natural gas.” The gas producing well was drilled in shale formations in the state of New York.

In the 1920s US engineers Floyd Farris and J.B. Clark suggested the hydraulic fracturing technology that became the platform for further researches and permitted to get down to practical production of shale gas. The USA initiated shale gas field development in the states of Kentucky, Michigan, Ohio, and Indiana. By the end of the last century, they were the main sources of shale gas production. The development of these fields was facilitated by such factors as shallow shale occurrence and their development by vertical wells. The average production was about 5–6 billion cubic meters per year [1].

In the 1950s, the former USSR also developed technologies of shale gas production, but these researches were conducted largely for experimental purposes. The theoretical basis of the technology for shale gas extraction from rocks was developed by Soviet Academician S. A. Khristianovich at the Institute for Oil Research of the USSR Academy of Sciences. This technology implied injection into a well of liquid under pressure that would break geological formations. This method permitted to increase oil recovery from formations.

Unlike the USSR where the shale gas plays were developed on a limited scale, the USA showed great interest to extraction of this hydrocarbon resource. Stanolind Oil and Gas Corporation (presently Amoco Corporation) in 1947 conducted trial hydraulic fracturing in the Klepper play in the state of Kansas. That time the experiment was considered unsuccessful as there was not increase of gas production [2]. However, already in 1949 Company Halliburton used the hydraulic fracturing

technology in the states of Oklahoma and Texas applying water and sand as propping reagents. This technology proved effective, and in the next decade, a great number of fracking operations were conducted in the USA.

The successful application of the hydraulic fracturing technology spurred the researches in this field targeted to increase the efficiency of shale gas extraction in the developed plays. In 1976 the Energy Research Center in Morgantown, USA, launched the “Eastern Project” connected with the shale gas research. The goal of this project was to study the possibilities of gas extraction from shales and other unconventional sources in order to make the country less dependent on oil supplies. The US Department of Energy financed into development of the shale gas production technologies. In 1977 with the ministry’s support, the mass hydraulic fracturing of shale play for gas recovery was conducted in the state of Colorado, USA (Fig. 2).

The first experimental developments of gas extraction from shale plays were initiated in 1980 in the USA by Mitchell Energy and Development headed by George P. Mitchell, one of the US Top 200 richest businessmen. Specializing in petroleum engineering, he started his career in the Oil Drilling Company and later on became its shareholder. Some time passed and George P. Mitchell and his brother bought out the remaining shares and renamed the company into Mitchell Energy & Development.

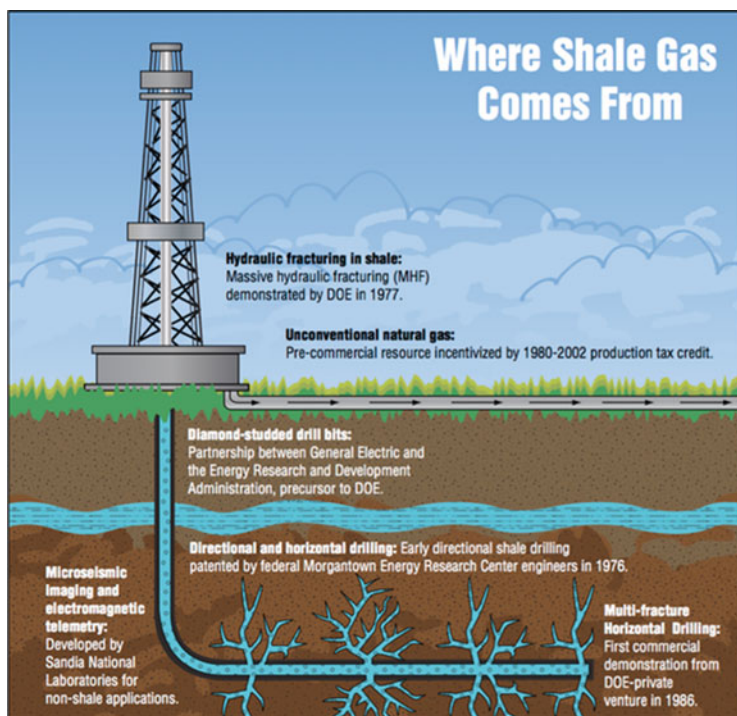


Fig. 2 Where shale gas comes from (http://thebreakthrough.org/blog/Shale_Gas_Infographic-thumb-550x529.png)

In the early 1980s, the company possessed the Barnett play in the Northern Texas that was considered to have poor prospects. Many wells were drilled, but with no success and with several million dollars of investments for 10 years. However, that time the shale gas plays were inaccessible, and development of the respective technologies of shale gas production was stopped after the oil price drop in the 1980s. But the company did not completely abandon its endeavor to develop shale plays. This was facilitated immensely by the fact that beginning from 1980 the companies engaged in development of unconventional energy sources were granted the tax credit in accordance with the US federal law.

The financial crisis triggered the mass application of new technologies. Among the stakeholders were such widely renowned multinational corporations as BP, Royal Dutch Shell, Total, and Statoil. However, the leader of the “shale rush” was Chesapeake Energy of Oklahoma that owned the shares of Barnett, Fayetteville, Bossier, Haynesville, and also Marcellus Shales. Apart from Chesapeake, the leading gas producing companies in the USA specializing in shale gas production are such companies as Apache, Devon Energy, and Noble Energy.

In 1997 Mitchell Energy & Development applied the hydraulic fracking technology with the use of propping reagents which gave positive effect. After this the company was quickly developing bringing dividends to its owners.

The Barnett Shales of Texas where George P. Mitchell tried to attain the commercial scale of shale gas production was the testing ground for the directional drilling technology. It is from this very play that the shale gas epoch started. Tom L. Ward and his company Chesapeake Energy were also working in this direction from 1989.

4 Technology of Shale Gas Production

The shale gas production has its specific features. Shale gas is recovered from hard rocks which drilling involves many difficulties. In addition, the gas reserves in such formations are much smaller than in traditional gas fields.

The shale plays are distinguished, first, by confinement to hard rocks which drilling is difficult; second, small resources, i.e., small quantity of gas per unit of play; and, third, low permeability of shale formations so the gas flows by microfissures to the borehole at a low rate.

In view of high density and strength of the shales, the only technique to recover gas from them is destruction of the formation with hydraulic fracturing (HF) when the hard rocks are broken with water and specific chemical reagents.

The hydraulic fracturing (HF) is the use of fluid and material to create or restore small fractures in a formation in order to stimulate inflow of the target fluid (gas, water, condensate, oil, or their mix) to the borehole. The HF technology includes pumping into a well of specialty fluid and after this adding of the propping agent with the help of powerful pumping plants for fracturing fluid (consisting of chemicals, sand, water, and acids that corrode the walls of fractures in a formation)

under a pressure higher than the pressure for fracturing the oil and gas formation. For hydraulic fracking, the pressure varies from 500 to 1,500 atm. This creates numerous fractures in a formation housing shale gas. The natural sand or other artificial material pumped together with water serve to keep fractures from closing up. After this the water is pumped out and sand fills the expanded fractures and let gas flow freely to a well along which it moves up to the surface. In this way the highly conductive fracture is formed in a hard rock that ensures considerable growth of well yield. The released gas moves up along the wellbore. Regarding the depth of occurrence of a formation, the vertical wells to 2 km deep and more are drilled. Moreover, the companies have already learned how to construct horizontal branches 1.5–2 km long.

As a result of hydraulic fracturing, the walls separating gas “pockets” are broken, and the released gas is pumped out through the vertical wellbore [3]. The directional drilling is also used for shale gas extraction which improves significantly the efficiency of shale gas production.

The determining factors of the reservoir productivity are the type of rocks and threshold systems. Permeability, thickness, pressure of a formation, and viscosity of a formation fluid are the components of the main equation of productivity.

The thickness of formations containing shale gas is averaging from several meters to dozens of meters. Accordingly, the standard vertical drilling provides the insignificant quantity of gas.

For increase of the gas extraction from formation, the directional drilling technique was developed which permits to drill a horizontal well going along a formation and inside it. The technique of 3D maps made on the basis of microseismic data is applied for accurate determination of well coordinates. The wellbore deviation is controlled by an operator locating on the surface. The length of a horizontal well averages several kilometers.

The directional drilling was developed more than 70 years ago and became a breakthrough that allowed for increase of the shale gas production. But initially this technique was not widely applied due to its high cost, and only in 1986, the multiple hydraulic fracturing of formation was successful. In the 1990s, the expenses on directional drilling became less due to the reduced costs of materials and drill pipes, but still the cost of a horizontal well was nearly fourfold higher than that of traditional vertical well.

The drainage area of a well is very small and the quantity of gas extracted by one well is also not large. The caloric power of shale gas is twice lower than of natural gas. In addition, it contains carbon dioxide, nitrogen, and hydrogen sulfur; thus, the shale gas in the USA is used only as fuel for domestic needs in settlements located not far from its production points from where it may be transported via low-pressure gas lines.

To ensure stable shale gas production, it is necessary, first, to drill new and new wells which cost is evaluated in the USA as 2.6–4 billion dollars; second, to have vacant land sites for well construction; and, third, to have a great number of drilling rigs and pumping plants for multiple hydraulic fracturing of formations. Usually one hydraulic fracturing operation requires about 4,000 tons of water and 200 tons

of sand. During a year from 3 to 10, HF may be performed with each well. Accordingly, every year 7.1 million tons of sand and 47.2 million tons of water are needed for hydraulic fracturing. The average daily yield of a well is around 6,000 cubic meters, i.e., about 50% of wells are performing periodically or idling.

With low concentration of shale gas in a play, the drilled wells quickly decline their production – by 30–40% per year. In 3 years of operation, the shale well gives only 14% of its initial production. For this reason, the service life of shale wells varies from several months to 5 years (the wells constructed for natural gas production perform for 50 years). Moreover, the unconventional hydrocarbon resources require specific production techniques that increase significantly the costs of their development.

This explains the fact that only around 2.5 million hydraulic fracturing operations have been made in the world, out of which about 1 million in the USA. Without hydraulic fracturing, the commercial scale of shale hydrocarbons is impossible [4].

In the recent years, the shale gas production technology includes drilling of a vertical well and several horizontal wells with multiple branches at the same depth. The construction of multistep horizontal wells with the horizontal wellbore length to 3 km is currently practiced. A mix of water, sand, and chemicals is pumped into drilled wells. The hydraulic fracturing breaks the walls of gas reservoirs, thus, allowing for extraction of all accessible gas. At directional drilling, the seismic modeling 3D GEO is applied combining geological surveys and mapping with computerized data processing, including visualization.

In the recent years, the cluster drilling technology is applied when several horizontal wellbores are drilled from the vertical well. This improves significantly the efficiency of shale gas production.

5 Conclusion

In the 1990s, some small US companies returned to the idea of gas recovery from shales. This was facilitated by development of new technologies applying directional drilling and performance of certain works in a well for hydraulic fracturing of formations using great volumes of water and surfactants. At the same time, gas consumption in the USA has boosted quickly due to wide construction across the country of efficient and environmentally friendly combined cycle power units, while the gas prices were rather high.

The technology of shale gas production that was developed some decades before was offered: inside a formation, the drill rig was gradually deviated from the vertical until it reached the angle of 90°, and then the rig continued moving parallel to the ground surface (horizontal drilling). This technology was applied for the first time in the 1940s, but it was abandoned in view of high costs.

In the gas-bearing shales, the mix of water, sand, and special chemicals was pumped into such horizontal wells. It was assumed that the hydraulic fracturing

would break the walls of gas pockets and permit accumulation of all gas resources making drilling of numerous low-value vertical wells unnecessary. The developments of the 1990s and application of new materials for drill pipes reduced considerably the costs. But regardless of this fact, the cost of horizontal well construction for shale gas production remained still higher than that of the traditional vertical well – nearly four times, on the average.

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