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Research Article

Joint exploration and development: A self-salvation road to sustainable development of unconventional oil and gas resources

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Abstract

Commercial production of unconventional oil and gas resources will not be easily achieved without large-scale engineering measures, let alone the additional operation cost, increasingly stricter requirement for safety and environment, fluctuating low oil and gas prices, etc., defeating the confidence of those investors. Therefore, unconventional measures are urgently needed to guide the exploration and exploitation of unconventional oil and gas resources. Thus, we put forward the concept of joint exploration and development by integrating research methodologies and operating techniques for a variety of oil and gas resources to simultaneously achieve analysis, construction, gathering and exploitation of multiple hydrocarbon sources. In this way, the annoying interference between the produced mixture of hydrocarbon flow resulting in the reduction of single-well flowrate will be possibly turned into a dynamic mutual force to enhance the well's flowrate. We also point out that the inevitability of joint exploration and development is determined by the occurrence conditions of oil and gas resources, its feasibility relies on the advancement of technologies, and its arduous and long-term nature is attributed to the current energy market and environment. In spite of various problems and difficulties, we believe that joint exploration and development will be a feasible option to achieve both cost reduction and production & benefit enhancement, boost investors' confidence, raise energy comprehensive utilization, and enhance energy supply efficiency. In conclusion, the advantages of joint exploration and development outweigh its disadvantages for both countries and enterprises.

Keywords: Unconventional oil and gas resources; Joint exploration and development; Coalbed methane (CBM); Tight sandstone gas; Shale gas; Tight oil; Economical efficiency; Cost; Benefit

0. Introduction

In the 1970s, some oil and gas resources could not be developed economically due to low technological levels. Under this background, the concept of unconventional oil and gas resources was put forward relative to the resources that could be developed economically. With the advancement of technology, oil and gas resources that were regarded unconventional may become conventional. Due to the continuous depletion of reserves, some conventional oil and gas resources may become unconventional or hard-to-recover. Clearly, it is only a relative concept of unconventional oil and gas resources. In the earliest studies, Berkowitz and Chakrabartty [1] classified oil sand, shale oil and tar oil as unconventional oil resources from the perspective of development technology and economic feasibility. In 1979, Maters [2] constructed a "resource triangle" by using reserves, formation permeability,

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resource development cost and technology and other factors, to figure out the differences between unconventional resources and conventional resources. According to Maters, unconventional oil and gas resources were described as the resources with extensive reserves but low reservoir permeability, high development cost, and high technological requirements, including tight sandstone gas, tight oil, heavy oil, shale gas, coalbed methane (CBM), shale oil and natural gas hydrate, etc. Now, it seems that the above definitions have both intersection and omissions. As a common consensus currently, natural gas like CBM, shale gas, tight sandstone gas, natural gas hydrate and basin-centered gas, and oil like tar oil, shale oil, tight oil, oil sand oil, heavy oil and native bitumen, are collectively called unconventional oil and gas resources. The formations where oil and gas are preserved are called unconventional oil and gas reservoirs. The oil and gas preserved in a single type reservoir is called single resource. In the 1980s, as the production of conventional oil and gas resources could not meet the demand, researchers represented by Kuuskraa [3] proposed exploiting tight sandstone gas, shale gas and CBM to supplement the energy gap. This suggestion has accelerated the development of unconventional oil and gas resources with the first success achieved in North America.

This success resulted in higher oil and gas production and introduction of a series of topics in relation to unconventional oil and gas resources, such as theory, methods, technologies, economics, environmental protection, and safety. Thus, the definition of unconventional oil and gas resources was extended from original economics and technology to wider aspects. Gautier et al. [4] considered from the perspective of geology that unconventional oil resources are characterized by continuous deposition, extensive accumulation and little hydrodynamic effect. After comparing the differences of shale gas, CBM, oil sand and conventional oil and gas resources in resource generation and migration, Ethefington & McDonal [5] put forward that unconventional oil and gas resources belong to oil and gas resources in a large sense, and further advanced the petroleum geology theory. The unconventional petroleum geology studies were mainly conducted to determine "whether reservoir contains oil" and evaluate 6 indicators (i.e. lithology, physical property, brittleness, oil-bearing potential, source rock property, and stress anisotropy) and their matching relations. Later, Society of Petroleum Engineers (SPE), American Association of Petroleum Geologists (AAPG) and World Petroleum Congress (WPC) jointly defined unconventional oil and gas resources as the oil and gas resources existing in extensive area and not susceptible to a hydrodynamic effect, which is also called continuous resources. The resources include CBM, basin-centered gas, shale gas, natural gas hydrate, natural bitumen, oil shale, etc [6]. This definition is recognized by the industry. In view of actual exploration and development, this definition is relatively complete, with more types of resources to be supplemented. With the deeper understanding to unconventional oil and gas resources, this definition may be further improved. It is also acceptable at present that the word "unconventional" is used to describe the oil and gas resources which are low in production and benefits.

Instead of further discussing the definition, this paper analyzes the influence of unconventional oil and gas resources development. Admittedly, scale development of unconventional oil and gas resources will bring stress on environmental protection [7]. Reservoir stimulation is a good example. It is an indisputable fact that massive hydraulic fracturing has resulted in serious pollution, enormous investment and costly exploitation [8]. Nevertheless, the exploitation of unconventional oil and gas resources has changed the pattern of world oil and gas resources [9]. More importantly, it has expanded the thinking mode of oil and gas explorers and developers, making them consider the high investment and low return of unconventional oil and gas resources in a broader mind and driving them to innovate in other aspects.

The joint exploration and development proposed in this paper is an innovative practice that operation cost control is reckoned through restrict exploration and development behavior with an acceptable cost, so as to find the probability to meet benefit targets. When the expected profit cannot be reached in the exploitation of single resources, broadening sources of income and reducing expenditure becomes a common and practical option. Single resource production may not reach the economic level. If multiple oil and gas resources can be exploited via single well or multiple wells simultaneously in the same area, the cumulative production obtained can be a considerable economic production; in this way, sources of income are broadened. Compared with the exploitation of single resource via single well, exploitation of multiple resources with less investment can be realized via one operation of joint exploration and development. Generally, joint exploration and development is characterized by less investment, higher production, higher profit, improved investors' confidence, higher comprehensive utilization efficiency of energy, and upgraded energy supply conditions. Its advantages outweigh its disadvantages for both countries and enterprises. However, whether thinking innovation will drive action innovation needs to be demonstrated in terms of the occurrence conditions of oil and gas resources, technology developing rules and social development reality. In this way, the practitioners can be provided with a clear basis for decision-making.

1. The occurrence conditions of unconventional oil and gas resources decide the necessity of joint exploration and development

Unconventional oil and gas resources coexist in a common area, which provides the material foundation for joint exploration and development. In scale operation during exploitation process, the neighboring or nearby horizons will inevitably be penetrated or transformed. In view of the objective conditions, it is feasible and profitable to use one well to exploit all oil and gas resources or use multiple wells to exploit all resources in the whole area. Therefore, joint exploration and development becomes the intersection of the external reality of oil and gas resources coexisting in one area and the internal driving force of cost reduction and benefit improvement. This joint