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RESEARCH PAPER

Assessment of global unconventional oil and gas resources

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Abstract: This paper evaluates the recoverable unconventional oil and gas resources around the world, reveals main controlling factors and potential regions for the rich accumulation of unconventional oil and gas, and standardizes the classification of seven types of resources (i.e., heavy oil, oil sand, tight oil, oil shale, shale gas, tight gas, and coalbed methane). By virtue of commercial databases for global petroliferous basins, together with single-well data packages in North America and basic data of exploration and development of Chinese companies in unconventional oil and gas resources blocks around the world, contour maps of abundance for global recoverable resources are formed through spatial graphic interpolation of key assessment parameters of seven types of unconventional oil and gas resources on the Geographic Information System (GIS) platform, which systematically evaluate the potential of seven types of unconventional oil and gas resources. The assessment reveals: (1) These seven types of resources around the world are distributed predominantly in 476 formations in 363 petroliferous basins. (2) Total recoverable unconventional oil and gas resources in the world are respectively 442.1 billion tons and 227 trillion cubic meters. (3) Unconventional oil and gas resources can be divided into "source-bound type" and "strata-bound type". The "source-bound type" resources are mainly controlled by 6 groups of high-quality source rock around the world, among which, the tight oil and gas resources are featured by the "integration of reservoir and source", presenting the best prospect for the development and application, and the "strata-bound type" oil sand and heavy oil resources, controlled by the transformation of the late structure, are mainly distributed in the slope belt of the Mesozoic-Cenozoic basins, presenting a good prospect for the resource development and application in the shallow layers. (4) Besides hot spots in North America, tight oil in the West Siberia Basin and the Neuquen Basin as well as heavy oil in the Arab Basin will become potential targets for the development of unconventional oil and gas resources in the future.

Key words: unconventional oil and gas; resources assessment; assessment parameters; assessment methods; recoverable resources; main control factors of enrichment

Introduction

Currently, unconventional oil and gas resources which have been in commercial development and application around the world can be classified into seven types, i.e. heavy oil, oil sand, tight oil, oil shale, shale gas, coalbed methane, and tight gas. In recent years, the production of unconventional oil and gas has increased continuously. In 2015, the annual production of unconventional oil amounted to 3.7×10^8 t, accounting for 9% of the global annual production of oil, and the annual production of unconventional gas was 9 273×10^8 m^3, accounting for 27% of the global annual production of gas[1]. In the same year, the US annual production of tight oil amounted to 2.59×10^8 t, accounting for 45% of its annual production of oil, and the unconventional gas was 4 500×10^8 m^3, accounting for 50% of its annual production of gas[2–3]. Unconventional oil and gas resources have made significant impact on global oil and gas supply and demand structure[2], and are now gradually becoming alternatives of conventional oil and gas resources[4–5].

To evaluate the global unconventional oil and gas resources, 3 issues need to be addressed: (1) geological conditions for the formation of resources and their distribution; (2) selection of assessment parameters and methods; and (3) selection of favorable areas based on the recoverability of resources.

Since 2000, with the exploration and development of unconventional oil and gas, several world famous energy assessment agencies such as the United States Geological Survey (USGS), Energy Information Administration (EIA), and Hart Energy have successively evaluated potential unconventional oil and gas resources around the world[6–13]. However, these assessment agencies only released their assessment results without specific assessment methods and key parameters,

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so the results are not comparative and summarizable, and it is difficult to tell their accuracy. For example, EIA released that the total recoverable shale gas resources in China was 32×10^{12} m^3, many Chinese researchers question its assessment basis and reliability because they didn't provide any proof[2].

Based on the assessment technique of global unconventional oil and gas resources and favorable zone selection of China National Petroleum Corporation (CNPC), the global unconventional oil and gas resources have been evaluated in this study. The assessment involves four steps: (1) based on international universality and operability of geological assessment, reviewing the definitions and screening standards of 7 types of unconventional oil and gas resources; (2) examining the resource distribution in global petroliferous basins in details, including the strata combination of every basin; (3) dividing evaluation objects into two types, i.e. detailed assessment and statistical assessment, according to screening results and data details. The former need to make contour maps according to assessment parameters, while the later only need to make maps of key parameters (for other parameters, only probability distribution values are needed); (4) selecting assessment method, improving currently prevailing volumetric method, realizing spatial interpolation operation of several assessment parameters on the geographic information system (GIS) platform, and calculating the contour map of recoverable resource abundance of the assessment units. The assessment results of resources for one assessment unit change from one figure to one contour map of resource abundance, which makes the selection of favorable zones much easier. For basins with high development degree of tight oil and shale gas, estimated ultimate recovery (EUR) is used to calculate the distribution of recoverable reserve abundance of assessment units. Based on recoverable resource abundance and reserve distribution obtained, potential zones can be ranked based on their abundance values, and accordingly the favorable zones of global unconventional oil and gas resources can be selected.

1. Assessment of unconventional oil and gas resources

1.1. Resource classification

In order to simplify assessment process and make assessment results more practical, this study establishes the definitions and classification criteria for every type of unconventional resource (Table 1) based on applicable Chinese

Table 1. Definitions and classification criteria of unconventional oil and gas resources

Resource type	Definition	Criteria					References
		Viscosity/(mPa·s)	Overburden pressure matrix permeability/10^{-3} μm^2	Oil content/%	Calorific value/(MJ·kg^{-1})	Methane content/%	
Heavy oil	Refers to the crude oil that is difficult to or cannot flow at reservoir temperature.	50–10 000					[4,6,13]
Oil sand	Or called tar sand, specially refers to sandstone or other rocks containing natural asphalt, which is composed of asphalt, sand, water, clay, and other minerals.	>10 000					[4,14,19]
Tight oil	Refers to a kind of oil accumulating in tight sandstone, tight carbonatite, and other reservoirs; tight oil wells generally have no natural production capacity, but can obtain industrial oil production by taking some technical measures under certain economic conditions.		≤0.200				[1,4,9,11,15,20–23]
Oil shale	Refers to combustible shale with high ash content and high organic matter content;shale oil can be obtained through low temperature carbonization.			>3.5	>4.18		[4,19,24]
Shale gas	Refers to natural gas occurring in rich organic shale reservoir in free and absorbed states; shale gas wells generally have no natural production capacity, but can obtain industrial oil production with some technical measures under certain economic conditions.		≤0.001				[1–2,4,9,12,16]
Tight gas	Refers to natural gas accumulating in tight sandstone and other reservoirs; tight gas wells generally have no natural production capacity, but can obtain industrial oil production under certain economic conditions and technical measures.		≤0.100			>85	[4,17,23]
Coalbed methane	Refers to hydrocarbon gas occurring in coal seam, which mainly absorbs on the surface of coal matrix grains, but part of which exists in free state in coal pores or dissolves in coalbed water.						[7–8,18]