Energy xxx (2015) 1–12

Contents lists available at ScienceDirect

Energy

journal homepage: www.elsevier.com/locate/energy

China's unconventional oil: A review of its resources and outlook for long-term production

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ARTICLE INFO

Article history:
Received 9 July 2014
Received in revised form
11 December 2014
Accepted 16 December 2014
Available online xxx

Keywords:
Unconventional oil
Production modeling
Resources
Chinese oil

ABSTRACT

Due to the expected importance of unconventional oil in China's domestic oil supply, this paper first investigates the four types of China's unconventional oil resources comprehensively: heavy and extra-heavy oil, oil sands, broad tight oil and kerogen oil. Our results show that *OIP (Oil-in-Place)* of these four types of resources amount to 19.64 Gt, 5.97 Gt, 25.74 Gt and 47.64 Gt respectively, while *TRRs (technically recoverable resources)* amount to 2.24 Gt, 2.26 Gt, 6.95 Gt and 11.98 Gt respectively. Next, the Geologic Resources Supply-Demand Model is used to quantitatively project the long-term production of unconventional oil under two resource scenarios (TRR scenario and Proved Reserve + Cumulative Production scenario). Our results indicate that total unconventional oil production will peak in 2068 at 0.351 Gt in TRR scenario, whereas peak year and peak production of PR (proved reserves) + CP (Cumulative Production) scenario are 2023 and 0.048 Gt, significantly earlier and lower than those of TRR scenario. The implications of this growth in production of unconventional oil for China are also analyzed. The results show that if the TRR scenario can be achieved, it will increase total supply and improve oil security considerably. However, achieving the production in TRR scenario has many challenges, and even if it is achieved, China will still need to rely on imported oil.

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1. Introduction

China's oil demand is forecast to keep increasing in the next several decades due to its continuous economic growth. In 2012, a total of 483.70 million metric tonnes (Mt) of oil was consumed in China [1], and this figure is estimated to reach 650 ± 50 Mt in 2030 and 750 ± 50 Mt in 2050, by CAE (Chinese Academy of Engineering) [2]. In the forecast of IEA (International Energy Agency), even in the fairly low-growth New Policies Scenario, the figure will rise to approximately 750 Mt by 2030 [3], 20 years earlier than estimated by CAE for the same consumption.

Most scholars expect that China's conventional oil production will peak before 2020, with peak production of approximately 200 Mt; thereafter, production will decline steadily [4,5]. As a result of limited conventional oil supply and soaring oil demand, China's oil security will face unprecedented challenges. Because of these issues, development of unconventional oil has been recognized as an important and realistic option for China to offset the effects of decline in its conventional oil production and to improve its oil security, especially after the U.S. shale-energy revolution [6].

Recently, a number of studies have focused on Chinese unconventional hydrocarbons. Nearly all of these papers limit their analyses to general concepts, types of formations, characteristics, resource potential, and technology of unconventional oil [7–10]. Furthermore, conclusions regarding resource potential vary considerably. For example, the OIP (*Oil-In-Place*) of Chinese oil sands is estimated by Mohr and Evans [11] to be only 273 Mt, while the corresponding estimate by Zou et al. [7] is 6000 Mt. At present, many scholars have missed that these differences in resource estimates exist, since no comparative analysis or explanatory discussion of current literature are available. In addition, there has been no quantitative research focusing on future production of

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http://dx.doi.org/10.1016/j.energy.2014.12.042
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Please cite this article in press as: Wang JL, et al., China's unconventional oil: A review of its resources and outlook for long-term production, Energy (2015), http://dx.doi.org/10.1016/j.energy.2014.12.042

Chinese unconventional oil, although some scholars have made quantitative predictions of world unconventional hydrocarbons' production [11,12].

The primary purposes of this paper are (1) to present a comprehensive and systematic investigation of China's four types of unconventional oil resources, i.e. heavy & extra-heavy oil, oil sands, broad tight oil, and kerogen oil, (2) to use these resource estimates to forecast a range of long-term production amounts, and (3) to analyze the implications of this long-term production growth in unconventional oil resources on future total oil supply (combining both conventional and unconventional oil) and China's oil security.

2. Categories of unconventional oil

Oil can be commonly divided into conventional and unconventional oil. Definition of conventional and unconventional oil differs slightly from one institute to another, and there is no completely consistent definition of these two terms. A general definition of them is based on density, i.e. oil with a density of less than 1.0 g/cm^3 (or its API (American Petroleum Institute) more than 10) belongs to conventional oil, while others belong to unconventional oil [13].

According to this definition, unconventional oil usually includes extra-heavy oil, oil sands and kerogen oil, since their APIs are less than 10 (Fig. 1). The major difference between oil sands and extra-heavy oil is viscosity. Generally, oil sands has a viscosity of greater than 10 000 centipoise (cP), which means it does not flow under reservoir conditions, while extra-heavy oil has a viscosity of less than 10 000 cP and can flow under reservoir conditions [14,15].

Kerogen is mixture of solid organic matter that is a precursor to oil. It is thermally immature and has not been properly transformed into oil by geological processes, thus requiring additional heat treatment to yield useable hydrocarbon liquids. According to the definition of IEA [16], kerogen oil is "*oil produced by industrial heat treatment of shale, which is rich in certain types of kerogen*". The kind of shale used in this process is called oil shale [17–19], and in China, oil from it is usually called "*oil shale oil*" [7,20]. Therefore, the term of "*kerogen oil*" used by international institutes and "oil *shale oil*" used by China is the same, and the term of "*kerogen oil*" is used in this paper (Fig. 1).

Heavy oil is liquid crude oil with an API degree of between 10 and 20 [13]. Therefore, based on the previous definition, heavy oil should be categorized as conventional oil [3]. However, China doesn't differentiate between heavy oil and extra-heavy oil. The term of "*heavy oil*" is usually used by China to represent the total of both heavy oil and extra-heavy oil, implying that resources of extra-heavy oil are also included in statistics of "*heavy oil*" resources. Consequently, it is nearly impossible to find the separate analyses of extra-heavy oil resources in China. Based on this reasoning, this paper uses the term of "*heavy & extra-heavy oil*" to represent the total of heavy oil and extra-heavy oil, and treat it as unconventional oil, although part of these resources belong to conventional resources (Fig. 1).

Light tight oil refers to two different types of reservoirs: oil in shale or claystone rocks, and oil in other rocks [13,16]. Oil in the first type of reservoir is still in the formation where it was generated, i.e. source rock = reservoir. Since these kinds of rocks normally consist of shales, crude oil produced from these formations is also called "*shale oil*" (labeled as ❶ in Fig. 1) [13]. In the second type of reservoir, oil has actually migrated (from its source rock) over a relatively short distance into other, usually low permeability, rock formations, such as sandstone and carbonate rocks, i.e. source rock ≠ reservoir [13,16]. Crude oil from these kinds of formations is called "*tight oil*" (labeled as ❷ in Fig. 1) [17]. It is challenging to differentiate these two types of formations clearly due to the high degree of similarity [13]. Consequently, many studies combine both types under the term "*light tight oil*" [13,16,21].

In China, scholars tend to analyze the oil resources from the two types of formations separately [6,22]. The term "*narrow shale oil*" is used to represent oil in the first type of formations, and the term "*narrow tight oil*" is used to refer to oil from other low permeability formations [17,23]. When "*narrow shale oil*" and "*narrow tight oil*" are referred to together, the term "*broad tight oil*" is used [17,23]. In this paper, the term of "*broad tight oil*" is used.

Broad tight oil is originally divided into conventional oil, since its API degree is much higher than 10, just as IEA classified it prior to 2012 (Fig. 1) [16]. However, after 2012, IEA treat it as unconventional oil, since it is an analog of shale gas, using the similar technologies, i.e. horizontal wells and multi-stage hydraulic fracturing, and shale gas is seen as unconventional gas [24]. Therefore, this paper also treats it as unconventional oil.

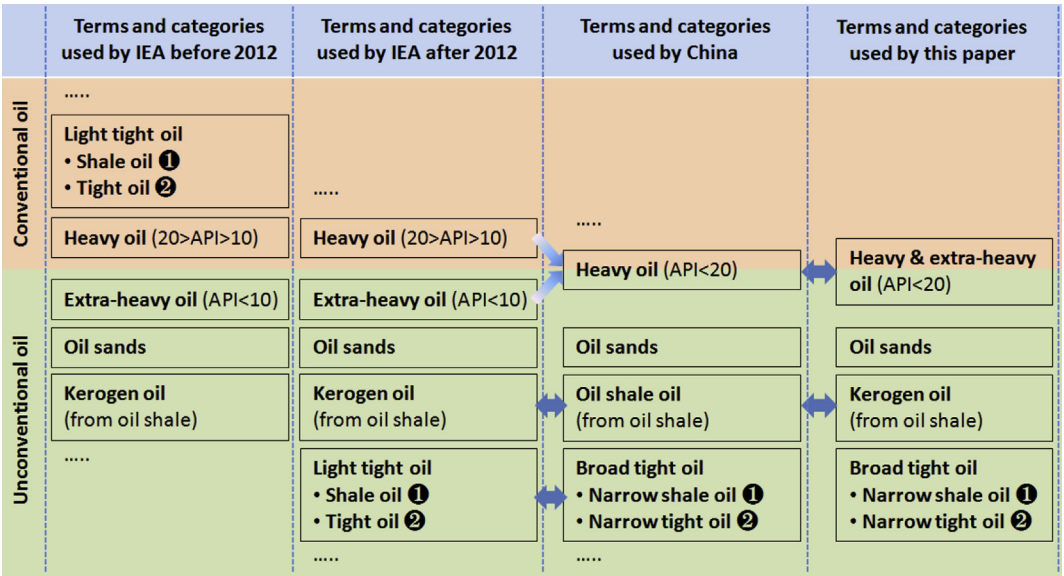

Fig. 1. The terms and categories of unconventional oil resources.

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