

Exploring in China for Oil and Gas in Fractured and Weathered Basement Reservoirs

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Introduction

Oil and natural gas occurs in basement reservoirs in many parts of the world. The reserves of basement fields are as small as one or two million barrels of oil or gas-equivalent to as much as almost 2.0 billion barrels of oil as in Libya's Auguila – Naafora field. Exploration for oil and gas in basement has been remarkably successful in the past one and a half decade with important discoveries in basement in Indonesia, Norway, Chad, and Argentina. Little known and little appreciated is that in the past decade, major to giant-size discoveries, especially gas, have been made in basement reservoirs in China.

In China, the exploration for oil and gas in basement has had a significant impact on China's oil and gas production, especially gas. Due to few publications on the geology and production characteristics of China's oil and gas fields, the success of basement exploration is little known and appreciated. The purpose of this paper is to provide a comprehensive overview of a select number of China's most important basement oil and gas fields.



Figure 1. Global distribution of oil and gas in fractured and weathered basement.

Yaerxia Basement Oil Field

The Yaerxia Field is an onshore oil field discovered in 1959 and is the first basement “buried hill” field ever discovered in China. The oil is produced from Paleozoic phyllites, slates, and meta-sandstones. The basement reservoir is described as hard and compact with porosity of less than 2.5%. However, because joints, faults and fractures are well developed, production from wells has been as high as with initial flow rates of 1,050 barrels of oil per day.

The wells are moderately productive with 12 wells producing less than 70 barrels of oil per day, 3 wells producing at 200 barrels of oil per day and 2 wells producing at 875 barrels of oil per day. The wells are not highly productive since the phyllites and slates do not naturally fracture optimally as do carbonates or granites. Similarly, phyllites and slates do not produce good granite-wash type reservoirs when they are weathered. Weathered crust is better developed at the top of the buried hill. The depth of the weathering is less than 35 m in thickness. Reserves data nor cumulative oil production is not available on Yaerxia. This field is significant since it was the first basement field discovered in China. Although the reserves were small, the “lessons learned” in the exploration and development of this field lead to the discovery of the giant Renqiu basement oil field and other basement fields in the Bohai Bay basin.

Renqiu Basement Oil Field

This field has been described by Chinese researchers as having giant reserves. Giant reserves have been defined as reserves over 0.5 billion barrels of recoverable oil by the American Association of Petroleum Geologists (AAPG) and the Society of Petroleum Engineers (SPE). The Renqiu oil field was discovered in 1975 by the Renqiu-4 well which flowed at 7,283 barrels of oil per day from Precambrian dolomite. By the end of 1976, there were 19 producing oil wells with an average flow rate of 13,789 barrels of oil per day. The highest producing well reached 32,123 barrels of oil per day. The oil column is very thick at 870 m.

According to Chung-Hsiang P’an (AAPG, 1982), this field is a giant field due to (1) The buried hill is optimally positioned in the middle of the Raoyang trough (2) The hill is 1,300 m high with an oil column of 870 m. (3.) Carbonate is the best reservoir rock and its age is old (4.) Before deposition of the lower Tertiary, the region was continually rising and underwent long periods of weathering and erosion. Consequently, the solution cavities and fractures are well-developed and enhances the reservoir quality.

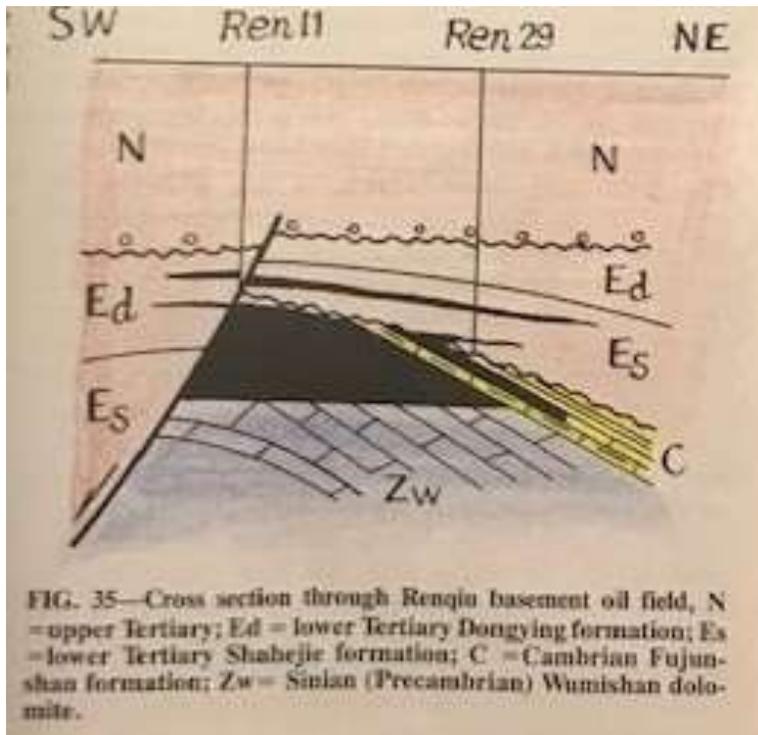


Figure 2. Cross section through the Renqiu basement oil field.
From: Chung-Hsiang P'an (AAPG, 1982)

Dongshenpu Basement Oil Field

This field is located onshore central China and like the Yaerxia oil field is an example of a Chinese “buried hill” basement oil field. The Dongshenpu oil field was discovered in 1983. The reservoir consists of Precambrian granites, granulites, diabases, and hornblende gneisses. The rocks have no primary porosity but porous reservoirs were developed by weathering and natural fracturing. The discovery well tested at 1,570 barrels of oil per day and subsequent development drilling has found the oil column to be 400 m thick. The reserves in this field were estimated at approximately 190 million barrels of oil (XiaoGuan & Zuan, 1991).

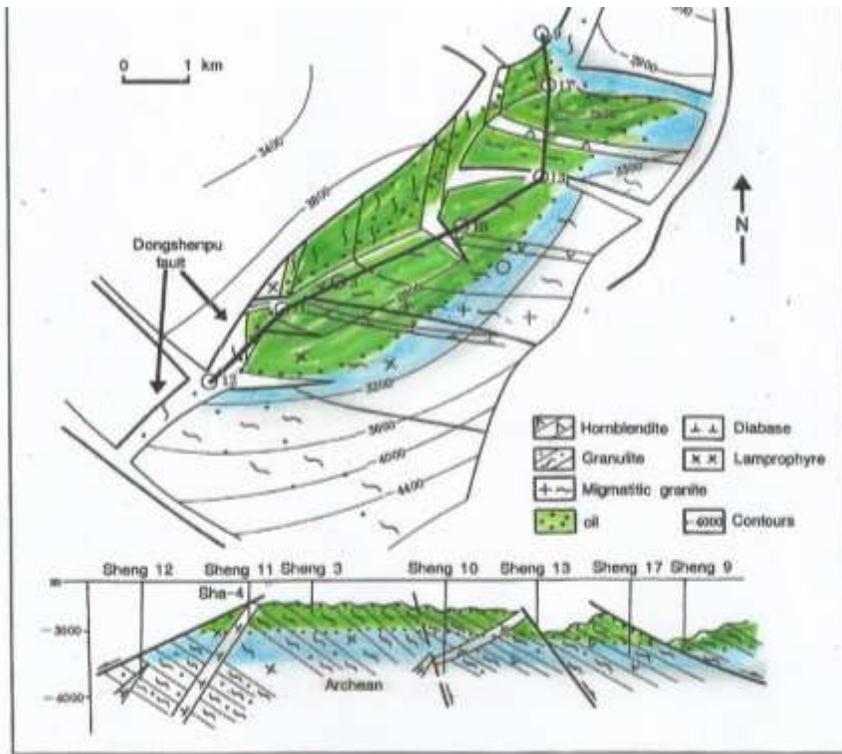


Figure 3. Structural cross-section through the Donshepu oil field. The oil column shown in green is separated from the underlying water zone shown in blue by the oil-water contact at 3,060 – 3,100 m. Modified from XiaoGuang & Zuan, 1991.

Bozhong 19-6 Basement Gas - Condensate Field

The Bozhong 19-6 gas-condensate field was discovered by CNOOC in 2017. This field is defined as a giant field based on the estimated reserves of gas and condensate. This field is located in the Bohai Gulf basin in 24 m of water depth. The discovery well 19-6-1 intersected 100 m of pay in an Archean-age buried hill reservoir and 240 m of pay in the Lower Paleogene Kongdian Formation. A significant paper was published a year ago on this gas field by Linda Wang, HIS Markit in 2021 which provided the following information. Bozhong 19-6 is a deep gas-condensate field with the top of the basement reservoir varying in depth from 2,825 to 5,475 m. The deepest well drilled in this field had a total depth of 5,508 m. The Archean reservoirs consist of metamorphic rocks, granites, amphibolites and migmatites with high-quality reservoirs concentrated within a 120 m interval from the top of the buried hill. The fractured reservoirs are also weathered and core analysis indicates porosity varying from 0.2% to 22.0% with an average porosity of 4.4% and an average permeability of 5 mD.

Appraisal wells 19-6-2 and 19-6-3 had average gas test rates of 6.4 million of cubic feet per day and 1,000 barrels per day of condensate. Wang (2021) estimated that the proven in-place gas

was 4 trillion cubic feet of gas (TCF) and 600 million barrels of condensate. The gas consists 75% of methane, 10% CO₂, and the remainder condensate. I have independently estimated the recoverable reserves in the Bozhong field. The overlying Tertiary gas field is located only at the far western part of the field. Thus 90% of the gas in Bozhong is in basement with only 10% in the Tertiary. Accordingly, the basement portion of the field has in-place gas of 3.6 TCF and 540 million barrels of condensate. Assuming an 80% recovery factor, the recoverable reserves are 2.9 TCF gas and 430 million barrels of condensate. Accordingly, the Bozhong field ranks as one of the largest gas-condensate fields in basement in the world. The Suban basement-reservoir gas field in south Sumatra, Indonesia is believed to be the world's largest basement gas field with gas reserves between 5 to 7 TCF.

The Bozhong field, discovered only five years ago, illustrates that the basement oil and gas play remains under-explored in China. Indeed, the gas potential in the Bozhong Depression is estimated at 67 TCF gas (Wang, L., 2021).

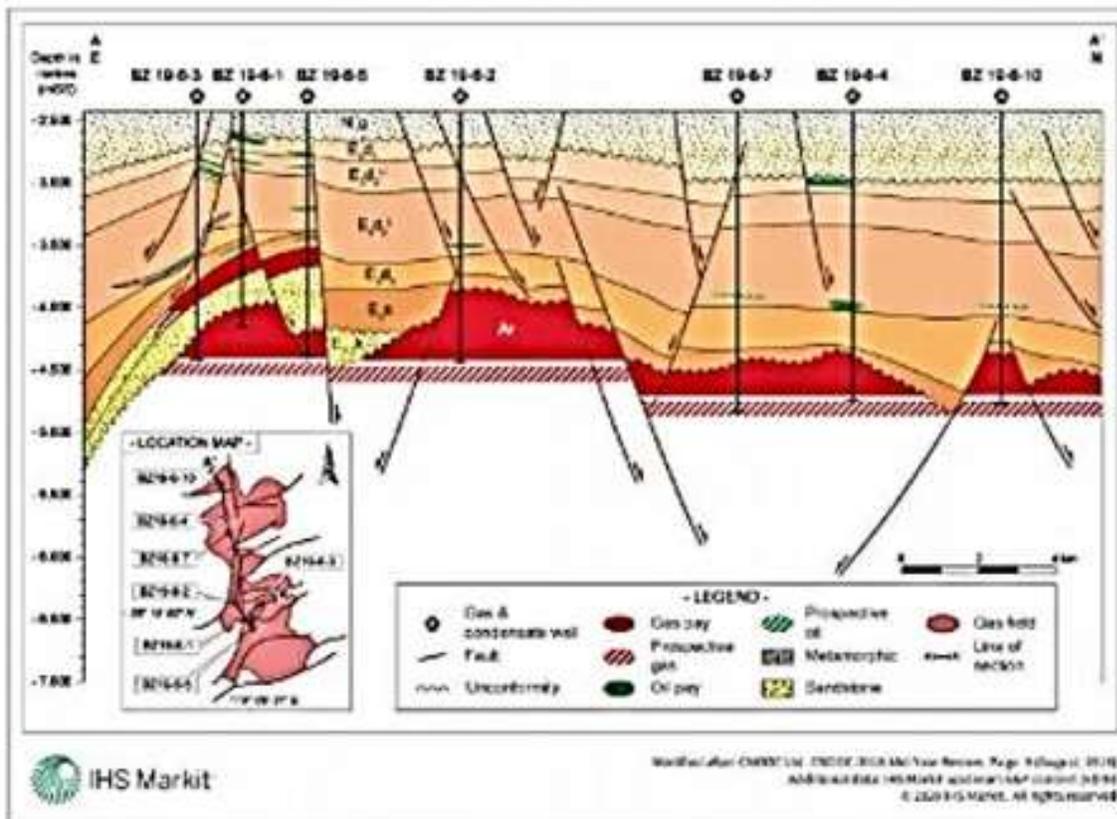


Figure 4. Cross section of the Bozhong 19-6 gas-condensate field in the Bohai Gulf Basin. From Wang, L., IHS Markit, 2021, modified after CNOOC.

China's Oil and Gas Production

As shown below, China is the 6th largest oil producer in the world.

Top Ten Oil Producers

1. USA	11.2 Millions barrels oil per day (MMbopd)
2. Russia	10.3
3. Saudi Arabia	10.0
4. Canada	4.4
5. Iraq	4.4
6. <i>China</i>	4.0
7. Brazil	3.0
8. UAE	2.6
9. Kuwait	2.5
10. Iran	2.4

In terms of energy consumption China is at times called “the hungry dragon”. China is the world’s No. 1 oil importer and the world’s No 2 consumer of oil. China consumes 14.1 MMbop and imports oil at a rate of 10.0 MMbopd. The USA is the world’s largest consumer of oil at a rate of 17.2 MMbopd.

China is also the 3rd largest consumer of natural gas in the world, consuming 370 billion cubic meters (bcm) in 2021. China’s enormous need for oil and gas is due to its population of 1.3 billion people, which is the largest in the world and also due its strong economy.

China in the Energy Transition

In early 2021, China’s President Xi Jinping announced that China will reach peak CO2 emissions by 2030 and will be carbon-zero before 2060. Figure 5 highlights the USA and China’s levels of emissions in the past four decades.

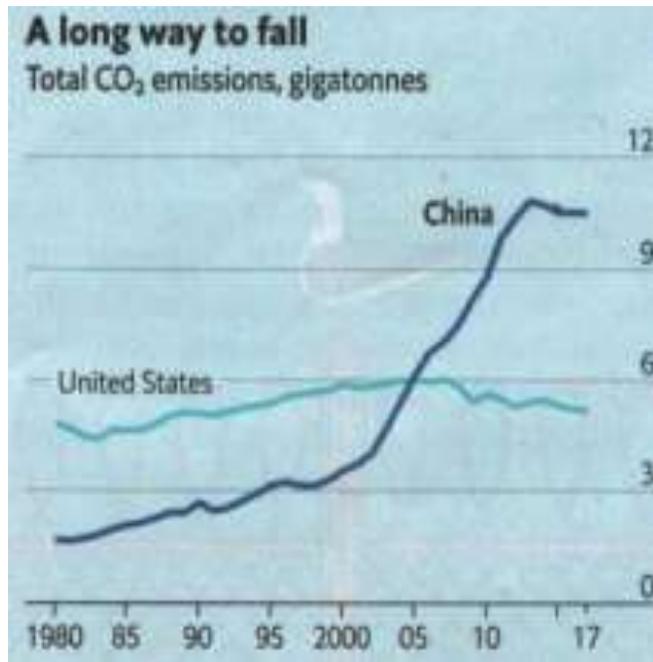


Figure 5. China and USA CO₂ emissions, 1980 – 2019.
Source: USA Energy Information Agency, published in *The Economist*, September 26, 2020.

China's need to meet soaring power demand is resulting in China investing massively in renewables. Wood Mackenzie projects in its latest report *Power Play* (Energy Voice, 17/02/2022), that China's production capacity for solar modules is rising faster than forecast global demand, while its wind turbine component and battery manufacturing capacity will grow by 42% and 150%, respectively, over the next two years. The report states that "This production of renewables capacity is of epic proportions and is enough to meet what China needs to accelerate decarbonization while supporting the ambitions of much of the rest of the world".

In the meantime, China consumes 55% of the world's supply of coal, mainly for the generation of electricity. Coal is burned to provide two-thirds of China's electricity. In order for China to achieve net-zero by 2060, it will need to substantially reduce the burning of coal. Natural gas is the cleanest burning of the fossil fuels thus in the short to medium term, China will need to substitute gas for coal

China's need for gas will need to be met by increased importing of LNG. Indeed, China's soaring need for gas resulted in China's LNG imports in 2021 reaching record high levels. China is also importing gas through the Far Eastern Pipeline from Russia. China has been importing 38 bcm gas per year from Russia's Gazprom. Recently Gazprom has announced that China will increase its imports by 30% to 48 bcm per year (Gas Processing News, 17/02/22).

Summary: Opportunities to Explore for Oil and Gas in China

China is highly dependent on imports of oil and gas from outside of China. For geopolitical reasons, China very much wants to be less dependent on imported oil and gas. Therefore, I expect an accelerated push by China to explore for more domestic oil and gas. China has always welcomed investment in its oil and gas industry by foreign oil companies who bring in capital and leading-edge Western technology. My view is that especially the need for gas will also result in China increasing exploration for gas in deep basement reservoirs. Oil and gas companies who wish to invest in China should seriously consider the opportunity to explore for deep gas in fractured and weathered basement.

References

Anyone wishing to review papers referenced in this presentation can contact the author at tako.koning@gmail.com.