

## Research Article

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## Analysis of the Distribution of Onshore Sedimentary Basins and Hydrocarbon Potential in China

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### Abstract

Based on 20 years of onshore exploration in China, we compiled onshore sedimentary basin maps and oil and gas horizontal distributions for the major basins in China and analyzed the characteristics of basin distribution and hydrocarbon potential, which can be summarized in the following four points. (1) More than 400 basins have developed in China's onshore region. The development of large-scale basins is based on paleo-platforms (plates) or the micro-plate geological background. (2) The Tianshan-Xingmeng orogen and basin cluster along the North China/eastern Yangtze Platform host the majority of China's onshore oil reserves (66.64%). (3) The three major craton basins, Tarim, North China and Yangtze, host 70.19% of the total onshore natural gas reserves. (4) China's onshore oil reserves are concentrated in layers originating from the Cenozoic and Mesozoic, and the natural gas reserves are primarily distributed in layers originating from the Cenozoic, Mesozoic, and Upper Paleozoic.

**Keywords:** Onshore China; Sedimentary basin; Resource extent; Oil and gas; Layer series

### Introduction

There are a large number of basins in China's onshore region. The type, distribution, formation, and development of sedimentary basins have been well studied by numerous scholars since the twentieth century, and numerous oil and gas fields have been detected since 2000 [1,2]. Our understanding of the geological characteristics of these basins has also increased; however, the exploration of unconventional resources (oil shale, oil sand, coalbed gas, shale gas, etc.) requires increased study of sedimentary basins.

China has a large reserve of oil and gas, and because of the rapid development of oil and gas exploration over the past 30 years, China's hydrocarbon potential has been increasingly evaluated [1-4]. The Ministry of Land and Resources proposed a new nation-wide evaluation of the hydrocarbon reserve resources and conducted a series of studies on the geological conditions of oil and gas formation, enrichment regularity, and potential areas to be explored in the future [3]. In the past ten years, the Ministry of Land and Resources strengthened the exploration of unconventional resources. Based on previous results, this paper will systematically study the characteristics of China's onshore sedimentary basins and distribution of oil and gas. The exploration of different fossil energy also has an important impact on the application of related technology.

### Methods and Data

#### Sedimentary basin data

The distribution of basins is based on the following: "Map of exploration results of oil and gas basins in China" [5] "Distribution of Sedimentary Basins and Oil and Gas in China" [6] "Map of Oil and Gas Basins and Fields in China" [7], and "China Atlas of Oil and Gas Basin" [8]. The data from certain basins (Qiangtang, Songpan-Abei, South Yellow Sea, etc.) were selected from results within the national oil and gas strategic area. There are 410 sedimentary basins included in the distribution, and the total area is  $421.8 \times 10^4 \text{ m}^2$  (Figure 1).

Figure 1 the sedimentary basins and their hydrocarbon potential in the onshore region of China. The boundaries of the basins were digitized by the MapGIS software and the selected basin boundaries were compiled together according to their coordinates except the

duplicate. The details are as follows: (a) All the large basins, the middle and small basins of the West, the Northwest and the Northeast of China are selected from "Distribution of Sedimentary Basins and Oil and Gas in China" [6]. (b) The middle and small basins of the Yangtze-Platform and the Southwest of China are selected from "Map of exploration results of oil and gas basins in China" [5]. (c) The middle and small basins of the Southeast of China are selected from "Map of Oil and Gas Basins and Fields in China" [6]. (d) The boundaries of the basins (Qiangtang, Songpan-Abei, South Yellow Sea) are selected from the results of MLRSCOG [3]. (e) The oil and gas fields are selected from the "China Atlas of Oil and Gas Basin" [8] and the new oil and gas fields discovered by Petro China and SINOPEC in the last 10 years.

#### Oil and gas data

Table 1 presents data on the exploited, detected, and show basins that contain major oil and gas reserves within China's onshore region. The data were collected from evaluations of national oil and gas resources [3], petroleum geology annals of China, and exploration results from PetroChina, SINOPEC.

#### Oil and gas resource basic data

Table 2 shows the oil and gas reserves of seven major basins. The data are from evaluations of national oil and gas [9].

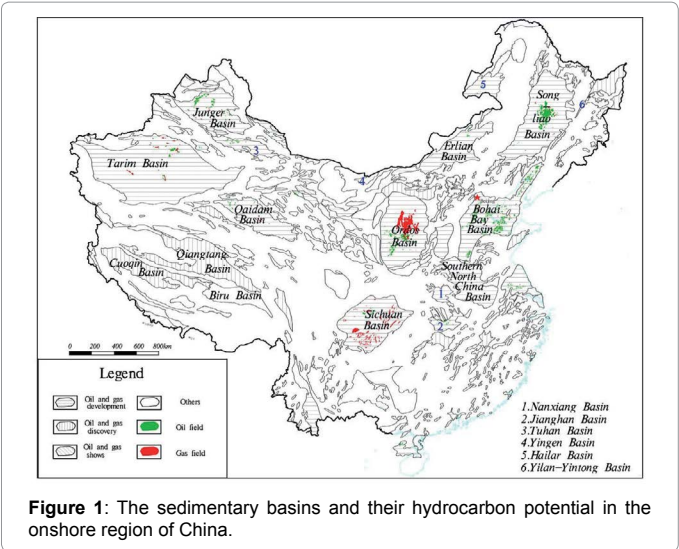
The methods to evaluate the onshore conventional oil and natural gas resources are selected mostly on the basis of the exploration degrees and types of the basins [3]. The data of Tables 3, 4 and 5 are integrated from the results of the national oil and gas resources evaluation [3].

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Exploration Situation	Typical Basin
Exploitation	Songliao, Bohai Bay, Ordos, Junggar, Sichuan, Tarim, Qaidam, Turpan-Hami, Santanghu, Erlian, Hailar, Jiuxi, Jiudong, Jiangnan
Detected	Yitong, Zhangwu, Fuxin, Huahai
Show	Dayangshu, Jiaolai, Wutang, Changdu, Cuoqin, Dongting, Hetao, Kumukuli, Liupanshan, Luoyang-Yichuan, Sanjiang

Table 1: Typical onshore petroleum basins in China.

Basin	Oil (10 <sup>8</sup> t)	Natural Gas (10 <sup>12</sup> m <sup>3</sup> )	Total (10 <sup>8</sup> t Oil Equivalent)
Bohai Bay	224.52	1.088	235.4
Songliao	113.07	1.403	127.1
Ordos	73.53	4.666	120.19
Junggar	53.19	6.514	118.33
Tarim	80.62	8.862	169.24
Qaidam	12.91	16	28.91
Sichuan	11.35	5.374	65.09
Total	569.19	29.507	864.26

Table 2: China's major onshore basin oil and gas resources.

Table 3 presents the extent of oil and gas resource in three petroliferous craton basins. The classification and statistical analysis are based on the petroleum geology conditions of the basins and the results of oil and gas exploration.

Table 4 presents the statistical results based on the distribution layers and areas of China's onshore petroleum resources. The layer series are Cenozoic, Mesozoic, Upper Paleozoic and Lower Paleozoic, and the areas are divided into East China, Central China, West China, South China and Qinghai-Tibet.

Table 5 presents the statistical results based on the distribution layers and areas of China's onshore natural gas resources. The layer series are Cenozoic, Mesozoic, Upper Paleozoic and Lower Paleozoic. Areas are divided as East China, Central China, West China, South China and Qinghai-Tibet.

Result and Discussion

Analysis of the sedimentary basin areas

The 410 basins (Figure 1) can be grouped into four categories according to area. There are 11 basins larger than 10 × 10<sup>4</sup> m<sup>2</sup>: Tarim, Songliao, Ordos,

Basin	Regional Tectonic Settings	Structural Feature	Source Rocks	Oil and Gas Formation	Resources	
					Oil (10 <sup>8</sup> t)	Gas (10 <sup>12</sup> t m <sup>3</sup> )
Tarim	Paleo-plate since the Paleozoic, evolved into a craton basin in the Mesozoic	Active crust motion, strong vertical motion, developed faults	J-T, C-P, E-O	K-E, T-J, C, E-O	80.62	8.862
Ordos	Departed from the North China plate after Indo-China movement, evolved into a craton basin after Yanshan movement	Stable basin, several uplifts	J <sub>1</sub> -T <sub>3</sub> , P <sub>1</sub> , C <sub>3</sub> , E-O	J <sub>1</sub> , T <sub>3</sub> , P <sub>1</sub> , C <sub>3</sub> , O <sub>1</sub>	73.53	4.666
Sichuan	Craton basin formed from the Yangtze paleo-plate after Indo-China movement	Basin under the lateral extrusion after Mesozoic, formed a number of regional tectonic settings.	J <sub>1</sub> , T <sub>3</sub> , P, S, C	J <sub>1</sub> , T <sub>3</sub> , T <sub>1+2</sub> , P, C, Z	11.35	5.374

Table 3: Characteristics of three petroliferous craton basins in China (reorganized according to the resource data of the database of MLRSCOG).

Layer Series	Resources (10 <sup>8</sup> t)	East	Central	West	South	Qinghai-Tibet	Total
Cenozoic	Detected	159.60	2.24	28.86	0.74	5.40	196.84
	Available	40.83	0.61	8.56	0.17	0.81	50.98
Mesozoic	Detected	144.80	81.18	64.84	1.01	64.21	356.04
	Available	54.20	18.89	18.95	/	13.19	105.23
Upper Paleozoic	Detected	2.36	3.07	42.40	1.27	/	49.1
	Available	0.58	0.73	11.61	0.23	/	13.15
Lower Paleozoic	Detected	17.64	/	39.03	/	/	56.67
	Available	4.62	/	8.75	/	/	13.37
Total	Detected	324.41	86.48	175.13	2.02	69.61	657.65
	Available	100.24	20.23	47.87	0.40	14.00	182.74

Table 4: National Petroleum Resources Distribution (reorganized according to the resource data of the database of MLRSCOG).

Bohai Bay, Sichuan, Cuoqin, North Qiangtang, Junggar, Erlian, south of North China, and Qaidam. There are 51 basins with an area of approximately 10 to 1 × 10<sup>4</sup> m<sup>2</sup>, including the following: southern Qiangtang, Gamba Tingri, southern Guizhou - Guangxi, BadanJilin, Nanpanjiang, Turpan-Hami, Hailar, Subei, and Biru. There are 66 basins with an area of approximately 1 to 0.5 × 10<sup>4</sup> m<sup>2</sup> and 46 with an area of approximately 0.5 to 0.2 × 10<sup>4</sup> m<sup>2</sup>. The remaining 236 basins have an area smaller than 0.2 × 10<sup>4</sup> m<sup>2</sup>.

The development of large-scale sedimentary basins in China's onshore region is based on the paleo-platform (plate) or micro-plate geological background [10]. Among the basins larger than 10 × 10<sup>4</sup> m<sup>2</sup>, Tarim, Ordos, Bohai Bay, Sichuan and southern North China basins developed from the Paleozoic craton. Junggar and Qaidam basins had micro-plate background. Songliao and Erlian basins were the Mesozoic depression basins, and developed from the relative stable Late Paleozoic Jiangmeng

Layer Series	Resources (10 <sup>12</sup> m <sup>3</sup> )	East	Central	West	South	Qinghai-Tibet	Total
Cenozoic	Detected	0.62	/	4.77	0.01	/	5.4
	Available	0.36	/	2.92	0.01	/	3.29
Mesozoic	Detected	1.84	3.29	4.39	0.44	1.35	11.31
	Available	0.97	2.01	3.02	0.28	0.82	7.1
Upper Paleozoic	Detected	0.08	5.07	0.97	0.24	0.34	6.7
	Available	0.02	3.42	0.57	0.13	0.21	4.35
Lower Paleozoic	Detected	0.23	1.76	1.46	0.06	/	3.51
	Available	0.12	0.94	0.95	0.03	/	2.04
Total	Detected	2.77	10.11	11.6	0.76	1.69	26.93
	Available	1.47	6.37	7.46	0.44	1.03	16.77

Table 5: National Natural Gas Resources Distribution (reorganized according to the resource data of the database of MLRSCOG).

block.

Analysis of the basin hydrocarbon potential

**Exploited oil and gas basins:** There are 40 exploited oil and gas basins (Table 1 and Figure 1), and the Bohai Bay, Longliao, Ordos, Sichuan, Tarim, Junggar and Qaidam basins are the seven major production bases.

**Detected oil and gas basins:** The detected onshore oil and gas reserves are concentrated in Bohai Bay, Songliao, Ordos, Sichuan, Tarim, Junggar and Qaidam basins (Table 1 and Figure 1).

Commercial hydrocarbon flows have been found in 45 basins in China. The oil reserves are over 10 × 10<sup>8</sup> t for Bohai Bay, Songliao, Ordos, Junggar and Tarim basins. Bohai Bay basin has the largest detected oil reserve at more than 1000 × 10<sup>8</sup> t. There are six basins (Ordos, Sichuan, Tarim, Songliao, Bohai Bay, and Qaidam) that have detected gas resources larger than 1000 × 10<sup>8</sup> m<sup>3</sup>. Among them, the Ordos and Sichuan basin contain more than 1 × 10<sup>12</sup> m<sup>3</sup> gas resources [10].

**Oil and gas basins:** There are 17 basins with detected oil and gas reserves that have not produced oil and gas. The Qiangtang and Cuoqin basins have large areas and a high density of resources, and each has an estimated reserve greater than 1 billion tons. The Changdu, Hetao, Sanjiang and Liupanshan basins each have an estimated reserve larger than 0.3 billion tons (Table 1 and Figure 1).

**Other sedimentary basin:** In addition to the previously mentions basins, 348 basins have no detectable oil and gas reserves (Figure 1).

Distribution of exploited oil and gas

China's petroleum basins can be characterized as oil enrichment rift basins and gas enrichment craton basins [11]. China's middle- and large-sized oil fields are mostly distributed in rift basins, whereas the middle- and large-sized gas fields are distributed in craton basins and foreland basins [1] (Figures 2 and 3).

**Two oil enrichment zones:** The oil reserve in the Tianshan-Xingmeng Mountains, North China and eastern Yangtze-Platform rift basin cluster is approximately 440 × 10<sup>8</sup> t, which is 66.64% of the total onshore oil reserve of China (Figure 2).

(1) The oil enrichment zone of Tianshan-Xingmeng orogeny: A 3000 km long orogenic belt located in a northern rift of the Zhongtian Mountains and Yanbula-Chifeng rift starting from Xingjiang and connecting Gansu, Ningxia, Inner Mongolia, and Heilongjiang. The Tianshan-Xingmen orogen includes the Junggar, Tuhan, Yingen, Erlian, Hailar and Songliao basins from west to east. The west central part contains the Jurassic basin in the northern rift of the Tian and Qilian Mountain. The basins are all located in the Junggar-Inner Mongolia-Songliao suture zone

and along the ancient Asian Variscan fold belt. From west to east are pre-rift volcanic eruption events from the Carboniferous to Jurassic.

The rift basin structure is created by rifting and uplifting and mainly belongs to the Jurassic-Cretaceous period. The oil enrichment layers uplift from the Middle and Lower Jurassic to the Upper Cretaceous, and they form a major oil production belt from west to east. The total oil reserve is approximately 200 × 10<sup>8</sup> t, which represents 30.32% of the total onshore oil resources in China.

(2) The oil enrichment zone of eastern rift basin cluster in the North China and Yangtze-Platform: Belt located between the east fault of the Taihang Mountains and Tancheng-Lujiang fault and within most of the Bohai Bay basin. The northern part contains the Yilan-Yitong basin, and the southern part includes the southern North China, Nanxiang and Jiangnan basins. It is composed of a tertiary oil enrichment rift basin belt [11]. The oil reserve in this area is approximately 240 × 10<sup>8</sup> t, which represents 36.32% of the total onshore reserve.

**Three gas enrichment craton basins:** The Tarim, North China and Yangtze paleo-plates were formed in the Early Paleozoic. They were under the Tethys Ocean, where they formed thick marine carbonate sedimentation. The plate tectonic process in the Mesozoic and Cenozoic created the Tarim, Ordos and Sichuan craton basins, and the hinterland preserved the entire Paleozoic strata. These gas enrichment craton basins contain 70.19% of the total onshore natural gas in China.

Distribution of oil and gas resources and layer series (or Era)

The long-term, multi-cycle and complex characteristics of China's tectonic evolution determined the sedimentation conditions of the multi-stage basins, multi-cycle sediments and multi-type and overlapping characteristics of origin basins that are controlled by different tectonic settings. Therefore, source rocks are widely distributed in China, and oil and gas are buried in layers from the Middle and Upper Proterozoic to the Quaternary (Figure 3).

Based on the results of recent evaluations of national resources, onshore conventional oil resources are estimated at approximately 657.65 × 10<sup>8</sup> t in China and conventional gas resources are estimated at approximately 26.93 × 10<sup>12</sup> m<sup>3</sup>. The distribution layer series are shown

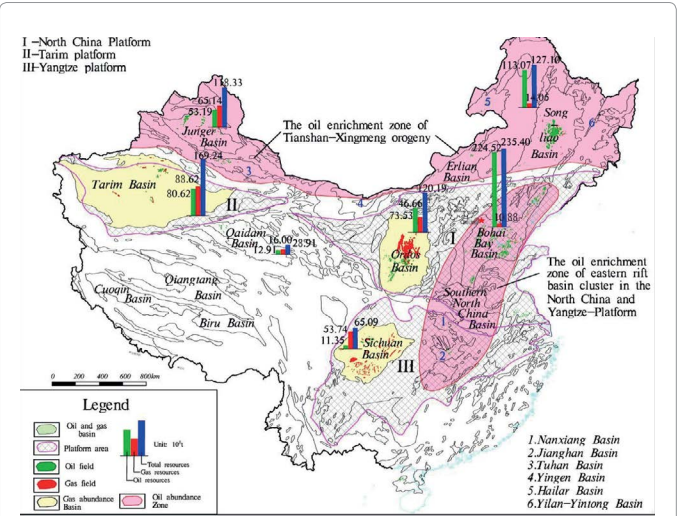


Figure 2: Oil and gas distribution of the main sedimentary basins in the onshore region of China.



below.

(1) The oil resources in the Cenozoic layer is approximately  $196.84 \times 10^8$  t (29.93% of the total reserve), whereas the Mesozoic layer contains  $356.04 \times 10^8$  (54.14% of the total reserve) (Figure 4 and Table 4).

(2) The natural gas resources are distributed in layers from the Cenozoic, Mesozoic and Upper Paleozoic, with reserves of [missing in origin draft] (20.05%),  $5.4 \times 10^{12}$  m<sup>3</sup> (41.99%) and  $3.29 \times 10^{12}$  m<sup>3</sup> (24.88%), respectively (Figure 5 and Table 5).

(3) The distribution of the petroleum resources layer series is strongly uneven, and there are various oil and gas distribution features in different regions. In the eastern region, oil is primarily concentrated in Cenozoic and Mesozoic layers and gas is concentrated in Mesozoic layers. In the central region, oil occurs in Mesozoic layers, whereas gas occurs in Upper Paleozoic and Mesozoic layers. In the western region, oil is observed in all four layer series, with the most abundant in the Mesozoic, and gas occurs in Cenozoic and Mesozoic layers. In the southern region, rich oil deposits are found in the Upper Paleozoic and Cenozoic layers, whereas natural gas is mainly distributed in Mesozoic and Upper Paleozoic layers. The oil and gas in the Qinghai-Tibet region is mostly concentrated in the Mesozoic layers (Tables 4 and 5).

Conclusion

There are more than 400 onshore sedimentary basins in China, with 11 basins larger than  $10 \times 10^4$  m<sup>2</sup> and 236 basins smaller than  $0.2 \times 10^4$  m<sup>2</sup>. The development of large-scale sedimentary basins is based on the paleo-platform (plate) or micro-plate geological background.

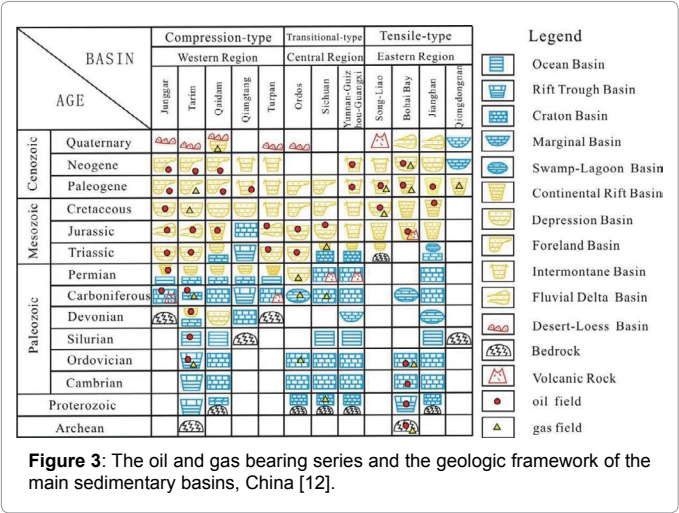
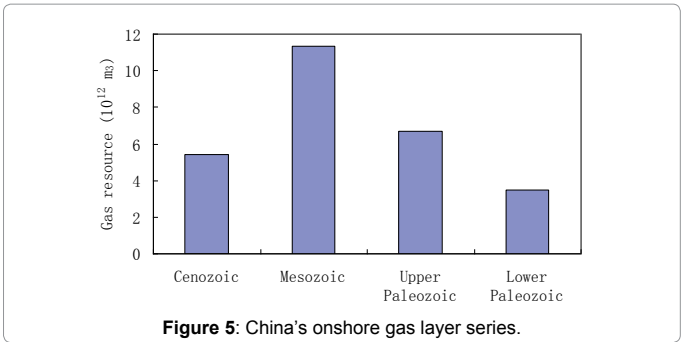


Figure 4: China's onshore oil layer series.



The Tianshan-Xingmeng orogen and basin cluster in the North China/eastern Yangtze Platform are the major distribution areas of China's onshore oil reserves (66.64%).

The three major craton basins, Tarim, North China and Yangtze, host 70.19% of the total onshore natural gas reserve in China.

The onshore oil resources in China are concentrate in Cenozoic and Mesozoic layers, and the natural gas reserves are mainly distributed in Cenozoic, Mesozoic, and Upper Paleozoic layers.

Acknowledgements

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Software

The software used in this study is MpaGis Ver. 6.7. The base map references are the State Bureau of Surveying and Mapping's 1:4,000,000 base maps. The maps are displayed as Albers equal-area conic projections with a central longitude of 110° and standard latitudes of 25° and 47°.

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