The Resources of Oil-rich Coals in China

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Abstract

The resource characteristics of coal-rich, oil-deficient, and low-gas have determined the need to fully exploit the advantages of coal resources in China. China holds a large amount of low-rank coal with high volatile content and high tar yield. Based on the abundant oil-rich and low-rank coal resources, resource evaluation and research on its development and utilization are of great significance to the coal geology. According to the estimated reserves, the low-rank coal reserves are about 63.86 billion tons. Among the low-rank coals, the tar yield is greater than 7%, which is called oil-rich coal. Gas and semi-coke resources, which can greatly increase the application value of this type of coal resources. The oil-rich coal resources are widely distributed in the Carboniferous-Permian, Triassic, Jurassic, Cretaceous, and Neogene in China. They are mainly distributed in the three provinces of Inner Mongolia, Shaanxi, Xinjiang, and also Qinghai and Gansu in space. The Carboniferous-Permian oil-rich coal is mainly distributed in Shaanxi Fugu mining area, and the Triassic oil-rich coal is mainly distributed in the Zichang mining area of Shaanxi Province. It shows that the oil-rich coals are mainly lignite and long-flame coal with low metamorphism but also contains a small amount of gas coal and gas-fat coal. The tar yield and volatile content generally have a positive correlation. It has great significance to further study on the oil-rich coal resources.

0 Introduction

The characteristics of energy in China which indicates that coal would be the main energy source. Coal would bear the responsibility of national energy security and economic sustainable development continuously (Sun, Chen et al. 2017, Wang, Duan et al. 2019). The energy system requires coal to achieve clean and efficient utilization in the new period, and reduce environmental pollution caused by the combustion of bulk coal. With the upgrading of coal deep-processing industry and the development of coal’s clean safe and efficient utilization, the development of coal-to-oil has become one of the hot issues of technology in clean coal of China (Hu, Yan et al. 2019, Wang, Duan et al. 2019). Among them, the development and utilization of coal resources with high tar yield is one of the significant methods for coal-to-oil.

Coal resource with high tar yield is an effective supplement to petroleum-based products, which could be produced high-quality motor fuels and chemicals through qualitative utilization, and it is an influential transition from traditional energy to renewable energy supply systems. Compared to the direct combustion of coal, the coal resource processed by coal with high tar yield has much less pollution to the environment. Most components such as sulfur and nitrogen could be recycled, and the sulfur and nitrogen contents are even lower than the crude petroleum products. Although the research on the development and utilization of coal with high tar yield has been highly valued, the distribution and formation of coal with high tar yield are still unclear. Furthermore, this work evaluates the coal resource with high tar yield, discusses the genetic characteristics of oil-rich coals.

1 The Definition And Background Of Oil-rich Coal
Coal-to-oil refers to the liquid hydrocarbons generated during coal formation process by concentrated and dispersed terrestrial organic matters in coal seams and coal-bearing rock series (Zhong and Chen 2009). Coal refining is the direct or indirect conversion of coal into a liquid fuel suitable for transportation through decarbonization and hydrogenation. Oil extraction in coal refers to the process technology for producing oil products, gas products and various chemical products using coal as raw materials, including direct and indirect liquefaction of coal, gasification of methanol and dimethyl ether and so on (Petersen, Andsbjerg et al. 2000, Wilkins and George 2002, Jayaraman, Gokalp et al. 2015, Roets, Strydom et al. 2015). Coal-to-oil and Coal-to-gas are the processes of liquefying and gasifying coal into liquid or gas fuel (Franklin, Peters et al. 1981, Katheklakis, Shi-Lin et al. 1990, Aboyade, Carrier et al. 2013, Howaniec 2016, Chen and Wang 2017).

According to the tar yield of coal, divides coal into three grades: Coal with a low-temperature tar yield \(\leq 7\%\) is called oily coal; Coal with a low-temperature tar yield \(7\% \leq \leq 12\%\) is called oil-rich coal; Coal with a low-temperature tar yield \(\leq 12\%\) is called high-oil coal. Through the technical and economic comparison of low-rank coal quality utilization and direct utilization (power generation), it shows that higher economic benefits before taxing compare to the low-rank coal direct powder generation. In this paper, the coal resource with tar yield \(\leq 7\%\) is defined as an oil-rich coal resource, which is the main research emphasis.

The research on tar yield of coal has been developed for many years, and it achieved important results on the coal chemical industry. In China, the coal with high volatile content and high oil yield are mainly low-metamorphic coal, which including lignite, long-flame coal, gas coal and gas-fat coal (Sun, Tang et al. 2017). The tar yield is related to the high inertinite (Mo, Huang et al. 2008), and the higher hydrogen content of microscopic components in the coal, the more molecules of the oil-dumping group increasing, so that it shows the oil-dumping properties of the coal. Recent research results show that the average of tar yield reach to 11.75% in the Triassic and arrive at 10.25% in the Jurassic coal of Shaanxi. Generally, the high tar yield resources have great potential for converting to oil and gas.

Wang et al. (2019) suggested that transferring the low-rank coal into gas, liquid and solid material by low-temperature pyrolysis process, which could realize the conversion of coal into scarce oil and gas resources, and replace the anthracite and coke into semi-coke in China. In recent years, the research of coal-to-oil pyrolysis technology mainly focuses on the catalyst, temperature and coupling mechanism. The light tar yield could be improved by coupling of in-situ catalytic cracking and the process of ethane steam reforming on the carbon-based catalyst (Zhao, Li et al. 2016). Meanwhile, the methods for increasing tar yield and its quality were supposed such as strengthen the structure of volatiles and the control of composition, design a novel pyrolysis reactor to regulate the pyrolysis of coal particles and the secondary reaction process of volatiles, coordinately control pyrolysis conditions, control the dust content in oil and gas, etc (Yang, Fu et al. 2015). The tar yield could be increased from 5.84–7.82% by adding the additives and catalysts. Besides, it is suggested that increasing temperature has a great impact on the tar yield in northern Shannxi (Hu, Yan et al. 2019). With the research of coal organic geochemistry, the high-
wax crude oil and condensate were launched successively, and the oil-generating capacity is being focused (Luo 2017).

2 The Distribution Of High Tar Yield Of Coal In China

According to the surveys and statistics of 162 coal-mining areas in China, the high coal tar yield areas are mainly distributing at Inner Mongolia, northern Shannxi, Xinjiang, Shandong, Anhui province and so on (Fig. 1). The tar yield ranges from 0.4–27.5%, and the average tar yield ranges from 7.5–14.0%. The average of coal tar yield at high tar yield areas reaches to 9.5%. A small amount of coal tar yields is more than 12.0% and distribute at Hulieyetu mining are in Inner Mongolia, Santanghu, Balikun and Fukang mining areas in Xinjiang, Fugu mining area in Shannxi, Jining and Juye mining areas in Shandong, Huainan mining area in Anhui province. Part of coal seams belongs to the ultra-high volatile and ultra-high oil content coal at Yaotian and Longgou mining areas in Gansu province. At Qujingliaohu, Jiangchuanzhuangzi and Yongdextiaoshicheng mining areas in Yunnan province, the coal tar yields are all exceeded 12.0% and reached to the standard of high-oil coal.

For the coal-forming era, the coal with high tar yield was distributed in the Carboniferous-Permian, Triassic, Jurassic, Cretaceous and Neogene in China. The coal tar yields were 9.2% for the Carboniferous-Permian, 9.6% for Jurassic, 9.5% for Cretaceous and 8.5% for Neogene (Fig. 2). Depending on the analysis of coals, it is mainly composed of lignite with low metamorphism and long flame coal, also containing a small amount of gas coal and gas fat coal.

The age distribution of coal resources with high tar yield is closely related to the deposition environment and system of each coal accumulation period. Also, many factors such as the evolution of geological history and the composition of higher plants affect the distribution and diversity of coal resources with high tar yield. Generally, the high tar yield coal resources have little change in tar yield during each coal-forming period in China. The highest tar yield is distributed in the Jurassic period, which probably reflects the good oil-producing conditions of the Jurassic, especially the Tuha basin in Xinjiang has oil-generating potential in the coal-forming age (Sun, Tang et al. 2017). Meanwhile, from the paleo-structural and the paleo-geographical analysis, it also has sedimentary facies which favouring the coal-to-oil.

2.1 The distribution of high tar yield coal resource of Carboniferous-Permian

The high tar yield coal resources of Carboniferous-Permian are mainly distributed at Zhungeer mining area in Inner Mongolia, Xingtai mining area in Shanxi, Fugu mining area in Shaanxi, Jining, Juye mining area in Shandong and Huainan mining area in Anhui province (Table 1).

The medium-high tar yield coal resources at the Junggar coalfield in Inner Mongolia are mainly enriched in the 6# coal of the Carboniferous Taiyuan Formation. The coal type is relatively single, mainly long flame coal, with a small amount of non-stick coal and lignite. The tar yield ranges 10.9–14.2%, with an average value of 8.8%; The coal resources with high tar yield in Shaanxi are mainly concentrated in the formation of the Carboniferous Taiyuan Formation, which are mainly gas coal and long flame coal, with a
tar yield of 6.0-11.6%, and the average value is 9.7%; The coal resources with high tar yield in Hebei Province are mainly formed in the Carboniferous-Permian period, which is mainly gas coal, and the tar yield ranges 7.8–13.1% with the average value of 11.5%; The high tar yield coal resources in Shaanxi Province are mainly in Shanxi group and Taiyuan group, which is mainly long flame coal with tar yield ranges 3.4–17.8%, and the average value is 9.6%; The high tar Coal resources in Shandong province are mainly distributed in Jining and Juye mining areas, the tar yield is between 0.5 and 14.5%, with an average value of 11.8%; The high tar yield coal resources in Anhui province are mainly distributed in Huainan mining area, and the tar yield ranges 0.5–16.4 % with the average value of 10.9%.

| Province | Mining Area | Coal-forming Era | Tar Yield(%) | Mean Value |
|----------|-------------|------------------|--------------|------------|
|          |             |                  | Min. | Max. | (No. of Samples) |          |
| Inner Mongolia | Jungar | C₂₄ | 2.4 | 14.2 | 8.6(206) |
| Shanxi    | Hequ       | C₂₄ | 6   | 11.6 | 9.7(12)  |
| Hebei     | Xingtai    | C-P | 7.8 | 13.1 | 11.5(29) |
| Shaanxi   | Fugu       | C-P | 3.4 | 17.8 | 9.6(376) |
| Shandong  | Jining     | P₁ₛ | 0.5 | 17.2 | 12.5(330) |
|           | Juye       | P₁ₛ | 0.1 | 17.7 | 10.8(391) |
| Anhui     | Huainan    | P₁ₛ | 0.5 | 16.4 | 10.8(155) |

2.2 The distribution of high tar yield coal resource of Jurassic

The high tar yield coal resources of early-Middle Jurassic are most widely distributed in China, and the resources of Early-Middle Jurassic are mainly distributed at Hugilite, Jilin Gol mining areas in Inner Mongolia, Shenfu and Yuheng mining areas in Shaanxi, it also existed at Gansu, Qinghai, Xinjiang in the Early-Middle Jurassic coal-bearing formations (Table 2).

The main coal-bearing stratum of Dongshengxinjie mining area in Inner Mongolia is mainly distributed in the Yan’an Formation of Jurassic, which is dominated by non-caking coal, with a tar yield ranges 6.6–15.1% and the average value is 9.8%; The high tar yield coal resources in Gansu Province are mainly distributed in the Yan’an Group, the tar yield ranges 4.2–14.2% with an average value of 8.1%; The high tar yield coal resources at Majiatan Mining Area in Ningxia are also mainly concentrated in the Yan’an Group, and the tar yield ranges 3.9–12% with average value of 7.9%; The high tar yield coal resources in Qinghai province are mainly distributed in Muli and Yuka coal fields, with tar yields ranging 2.7–14.4%.
and the average value is 9.2%; The high tar yield coal resources in Shaanxi province are mainly concentrated in Yan'an Group, the tar yield ranges 1.1–16.5% with an average value of 9.4%; The high tar yield coal resources in Xinjiang are mainly distributed in the Xishanyao Formation and Badaowan Formation, with a tar yield ranges 0.7–12.5% and the average value is 10.2%. The low-rank coal resources are not only rich in reserves, but also have good coal quality. Compared with other low-rank coal-rich areas in China, their low-rank coals generally have high oil content in Xinjiang.

### Table 2
The tar yield of Jurassic in China

| Province   | Mining Area | Coal-forming Era | Tar Yield (%) | Min. | Max. | Mean Value (No. of Samples) |
|------------|-------------|------------------|---------------|------|------|-----------------------------|
| Inner Mongolia | Dongshengxinjie | J₁ - 2         | 6.6 | 15.1 | 9.8(139) |
| Gansu      | Huating     | J₂y             | 5.0 | 16.2 | 7.6(82)  |
|            | Ningzheng   | J₂y             | 4.2 | 13.3 | 8.5(119) |
|            | Shazijing   | J₂y             | 5.8 | 9.2  | 7.5(9)   |
| Ningxia    | Majiatan    | J₂y             | 3.9 | 12   | 7.9(121) |
| Qinghai    | Muli        | J₂              | 2.7 | 12.1 | 8.6(8)   |
|            | Yuka        | J₂              | 3.7 | 14.4 | 9.4(21)  |
| Shaanxi    | Shenfu      | J₂y             | 1.1 | 16.5 | 9.3(636) |
|            | Yuheng      | J₂y             | 7.6 | 13.3 | 10.4(45) |
| Xinjiang   | Aidinghu    | J₁ - 2          | 0.7 | 21.2 | 9.2(338) |
|            | Yining      | J₁ - 2          | 2.2 | 21.4 | 9.0(68)  |
|            | Balikun     | J₁ - 2          | 3.2 | 27.5 | 10.7(168) |
|            | Naomaohu    | J₁b             | 1.5 | 19.1 | 10.1(36) |
|            | Baiyanghe   | J₂x             | 3.4 | 15.9 | 8.4(93)  |
|            | Fukang      | J₂x             | 3.8 | 18.7 | 12.0(65) |
|            | Heishan     | J₂x             | 0.4 | 17.1 | 9.5(180) |
2.3 The distribution of high tar yield coal resource of Cretaceous

Coal resources with high tar yield in the Early Cretaceous are mainly existing at the Baqibe, Hulieyetu, Jilin Gol, Wuyi Ranch mining areas in Inner Mongolia, and are mainly concentrated in the Bayanhua Formation, with long flame coal and lignite as dominate. The tar yield ranges 2.7–26.9% with an average value of 10.1% (Table 3).

| Province       | Mining Area | Coal-forming Era | Tar Yield(%) | Min. | Max. | Mean Value (No. of Samples) |
|----------------|-------------|------------------|--------------|------|------|-------------------------------|
| Inner Mongolia | Baqi        | K₁b₂             | 2.8          | 26.9 | 8.9 | (353)                         |
|                | Bayanhushuo | K₁b₂             | 3.0          | 21.7 | 9.6 | (658)                         |
|                | Hulieyetu   | K₁d              | 2.7          | 18.7 | 11.9| (306)                         |
|                | Jilinguole  | K₁b              | 6.4          | 13.6 | 9.5 | (123)                         |

2.4 The distribution of high tar yield coal resource of Neogene

The high tar yield coal resources of Neogene are mainly distributed in the Zhaotong Basin. The Zhaotong Group is the main coal-bearing stratum with a simple structure. The tar yield ranges 5.8–10.2% with an average value of 8.5% (Table 4).

Besides, Xinjiang Santanghu Mining Area, Naomaohu Mining Area, Inner Mongolia Shengli Coalfield, Shaanxi Yonglong Mining Area, Yunnan Xundian holding the oil-rich coal. Among them, the coal reserves in the Santanghu mining area are large, especially the in the western district of the Santanghu mining area, such as Hanshuiquan and Kumusu, the average of tar yield is over 13%.

| Province  | Mining Area | Coal-forming Era | Tar Yield(%) | Min. | Max. | Mean Value (No. of Samples) |
|-----------|-------------|------------------|--------------|------|------|-------------------------------|
| Yunnan    | Kuazhu      | N₁               | 5.8          | 9.5  |      | 8.3(9)                         |
|           | Zhaotong    | N₁               | 5.9          | 10.2 |      | 8.7(17)                         |
3 Case Studies Of Coal Resources With High Tar Yield Coals

The coal resources of high tar yield coal have its certain characteristics under the influence of factors such as coal formation, coal formation environment, coal formation plants and so on so that it has strong hydrocarbon generation ability. The tar yield at in the Xiandianxianfeng mine are in Yunnan is as high as 27.85%, the volatile is 75.85%, and the vitrinite reflectance is 2.51%. It is an advanced raw material for high-yield coal resource utilization. The Taiyuan and Longtan Formations of Carboniferous-Permian are rich in oil-generating coal at eastern and southwestern in China, however, the oil-rich coals discovered are distributed in the northwestern region of China. Here are discussions on the origin of high tar yield coal resources of three cases below (Fig. 3):

3.1 Case 1: Naomaohu mining area in Xinjiang

This mining area is located at Yiwu of Xinjiang. The mainly coal-bearing stratum is the Xishanyao Formation of middle Jurassic. The macro coal type is bright coal, with grey-black-dark black color, which has a strip and lens structure. Microscopic coal rock is classified to vitrinite. The vitrinite component is mainly the matrix vitrinite and detrital vitrinite in the unstructured vitrinite, and the inertinite is mainly the fusinite and semifusinite. Generally, the inertinite content is around 6.0-13.2%, the vitrinite content is less than 85%, and the extinite content ranges 5.8–5.89% (Table 5).

| Number of Coal Seam | Maceral Composition | Reflectance |
|---------------------|---------------------|-------------|
|                     | Vitrinite | Inertinite | Exinite |
| B<sub>2</sub>        | 29.8–95.9 | 0.6–37.4 | 0.4–9.8 | 0.267–0.471 |
|                     | 80.8(12) | 13.2(12) | 5.9(12) | 0.365(8) |
| B<sub>1</sub>        | 83.1     | 6.0       | 5.8     | 0.332 |

* Min.-Max Value/Mean Value (Number of Samples)

From bottom to top, the vitrinite composition gradually increases and the inertinite gradually decreases. The low mineral content indicates that the coal-forming environment is stable for a long period. The tar yield of each minable coal seam is between 2.9 to 16.7%, and the average ranges 8.03–12.54%, both of which are greater than 7% and classified as rich-high oil coal (Table 6).
Table 6
The test of low temperature carbonization of Naomaohu mining area in Xinjiang

| Number of Coal Seam | Coal Species     | Tar Yield (%) | Mean Value of Tar Yield (%) | Classification          |
|---------------------|------------------|---------------|----------------------------|--------------------------|
| B₂                  | Long flame coal  | 7.1–16.7      | 12.5(16)                   | Oil-rich and High-oil Coal |
| B₁                  | Long flame coal  | 2.9–10.4      | 8.0(4)                     | Oil-rich Coal            |

3.2 Case 2: Chicheng coalfield in Gansu

The Yan'an Formation is the mainly coal-bearing stratum in the middle Jurassic. In the coal-bearing stratum of this coalfield, the joints of vitrinite are developed. The calcite veins, pyrite grains and thin films can be seen in the fractures. The macro coal composition is light coal, followed by vitrain and durain. Occasionally a thin layer of fusain has appeared, and the band structure is obvious.

Table 7
The maceral composition of Chicheng coal field in Gansu

| Number of Coal Seam | Maceral Composition | Reflectance |
|---------------------|---------------------|-------------|
|                     | Vitrinite           | Inertinite  | Exinite | Reflectance |
| 2–2                 | 24.5                | 60.4        | 4.2     | 0.663       |
| 3 – 1               | 28.2–46.9           | 45.6–68.5   | 0.6–2.4 | 0.510–0.540 |
|                     | 37.6                | 57.1        | 1.5     | 0.530       |
| 3 – 2               | 20.4–87.9           | 10.8–68.8   | 1.9–5.4 | 0.507–0.656 |
|                     | 54.8                | 39.1        | 3.75    | 0.612       |
| 5 – 1               | 29.2–87.7           | 10.6–57.4   | 1.5–2.8 | 0.500–0.660 |
|                     | 59.8                | 34.1        | 1.15    | 0.60        |
| 5 – 2               | 22.9–76.0           | 23.0–62.2   | 0.40–3.2| 0.586–1.280 |
|                     | 53.3                | 43.7        | 1.6     | 0.757       |

* Min.-Max Value/Mean Value (Number of Samples)

The average of 2–2#, 3 – 1# coal contents of vitrinite range 24.5%-37.6%, the inertinite content is between 57.1% and 60.4% on average, and the exinite content is between 1.50% and 4.20%. The other vitrinite coals with an average of 53.3%-59.8%, the inertinite content with an average of 34.1%-43.7%, and the
The average value of vitrinite ranges 34.5%-40.0%, the inertinite content is between 50.1% and 62.5% on average, and the exinite content is between 1.3% and 2.1% (Table 9). The tar yield of each minable coal seam is between 5.0 to 16.2%, and the average ranges 6.8–10.6%, which classified as rich-high oil coal (Table 8).

### Table 8
The test of low temperature carbonization of Chicheng coal field in Gansu

| Number of Coal Seam | Coal Species       | Tar Yield (%) | Mean Value of Tar Yield (%) | Classification |
|---------------------|--------------------|---------------|-----------------------------|----------------|
| 2–2                 | Non-caking coal    | 8.6           | 8.6                         | Oil-rich Coal  |
| 3–2                 | Non-caking coal    | 5.0–16.2      | 10.6(2)                     | Oil-rich Coal  |
| 5–1                 | Non-caking coal    | 5.6–8.5       | 6.8(3)                      | Oily coal      |
| 5–2                 | Non-caking coal    | 7.1–7.5       | 7.3(3)                      | Oil-rich Coal  |

### 3.3 Case 3: Hagu mining area in Shaanxi

The Hagu mining area is located on the west side of the Hedong fault fold belt on the eastern edge of the Ordos Basin in North China. The coal seams are mainly durain and bright coal. The long strip or lens of fusain distributed along with the layer about 1–3 mm thick, which can be seen in the carbonized plant leaves and stem slices of different degrees of crushing. The macro coal type is mainly semidurain coal, followed by semi-bright coal.

### Table 9
The test of low temperature carbonization of Hagu mining area in Shaanxi

| Number of Coal Seam | Maceral Composition | Reflectance |
|---------------------|---------------------|-------------|
|                     | Vitrinite           | Inertinite  | Exinite |
| 51                  | 12.9–49.8           | 48.6–81.4   | 0.2–3.2 | 0.481–0.498 |
|                     | 34.5                | 62.5        | 1.3     | 0.488      |
| 52                  | 39.4                | 50.1        | 1.6     | 0.528      |
| 52                  | 26.5–56.8           | 40.0–70.2   | 0.2–3.8 | 0.492–0.601 |
|                     | 40.0                | 55.2        | 2.1     | 0.550      |

* Min.-Max Value/Mean Value (Number of Samples)
seam is between 6.9 to 12.1%, and the average ranges 8.6–9.5%, which classified as rich-high oil coal (Table 10).

| Number of Coal Seam | Coal Species | Tar Yield (%) | Mean Value of Tar Yield (%) | Classification |
|---------------------|--------------|---------------|-----------------------------|----------------|
| 5¹                  | Non-caking coal | 9.1–10.3      | 9.53(3)                     | Oil-rich Coal |
| 5²                  | Non-caking coal | 6.9–9.8       | 8.6(11)                     | Oil-rich Coal |
| 5²                  | Non-caking coal | 1.5–12.1      | 8.0(22)                     | Oil-rich Coal |

### 4 Discussion On The Origin Of High Tar Yield Coal Resources

For those 3 case studies, the coal-bearing seams are all in middle Jurassic formations. The Naomaohu mining area (Case 1) is located in the Jurassic coal-bearing Junggar basin in Xinjiang. It is a large inland depression basin. The coal seam was formed on the basis of the lake delta plain during the early recession period. In the coal forming period, the main plants are the pern types, and the coal-forming primitive plants are the humic coals. For the Case 2, when the Yan'an Formation deposited, the deposition rate was quite slow, resulting in the lack of fast-deposited molasse on the edge of the basin. Due to the abundance of terrestrial detrital materials and the balance of sedimentary compensation, in addition to the climate and humidity, the lake delta has a lot of soil minerals and rich in plant nutrients, which the material basis of coal accumulation formed. As for Case 3, the sedimentary environment types of the coal-bearing strata in the Hagu mining area in Shaanxi can be divided into two categories: lake delta system and river sedimentary system, and the former is dominant one. There are various sedimentary assemblages and facies constitute units. The lake delta system is distributed in the middle of the coal-bearing formation, and the river system is distributed in the lower and top of the coal-bearing formation. In summary, the Jurassic lake delta sedimentary environment provides a good material basis for the formation of oil-rich coal.

By comparing the relationship between the exinite and volatile content of three mining areas with the tar yield, it is showing that the content of the exinite in the Case 1 is significantly higher than that of the other two mining areas, and the content of the exinite and the tar yield have a certain positive correlation (Fig. 4). However, the tar yield in Case 3 is negatively correlated with the content of the exinite and tar yield. Whether there is an inevitable connection between exinite and tar yield still to be confirmed by further studies. By comparing the volatile contents of those three cases, it shows that Case 1 is significantly higher than the other two (Fig. 5).

### 5 Conclusions
(1) The coal resources with high tar yield are mainly spatially distributed in the three provinces of Xinjiang, Inner Mongolia and Shaanxi in China, and also there are small amounts distributed in Qinghai and Gansu. Temporally distributed in the Carboniferous-Permian, Triassic, Jurassic, Cretaceous and Neogene periods.

(2) Coal resources with high tar yield are mainly composed of lignite and long flame coal with low metamorphism, and it contains a small amount of gas coal and gas fat coal. Tar yield is generally positively correlated with volatile contents.

(3) The Jurassic coal in northwestern has strong oil and hydrocarbon generation potential in China. It has great significance to further study on the chemical characteristics and metamorphic degree characteristics.

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**Figures**
Figure 1

The distribution of coal resource with high tar yield in China. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.
Figure 2

The distribution of coal-forming era with tar yield in China
Figure 3

The locations of three cases. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.
Figure 4

The relationship between tar yield and exinite of three cases
Figure 5

The relationship between tar yield and volatile of three cases