# [PS]The Geochemical Characteristics of Coal Measure Strata and Coal-Derived Hydrocarbon in Huhehu Sag, Hailaer Basin, China*

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## Abstract

The Hailar Basin is a Mesozoic inland rift type basin in northeast China which contains a series of fault basins of more than 20 sags (Figure 1a). The Hailar Basin is a petroliferous basin, and also one of the basins with low coal rank in China. Not only some of the periphery sags, such as Yimin, Dongming, Huhehu, Chagannuoer sags, developed coal seams widely, but also the central structural zone of the basin, such as Wuerxiong and Beier sags have a few thin coal seams and coal streaks. At present, the discovered oil fields are mainly in the central depression belt of Hailar Basin.

Hydrocarbon shows widely appear favorably in the periphery coal-bearing sags, and every coal-bearing sag shows a little industrial oil flow by oil testing, but the key exploration breakthrough has not been achieved for a long time. The hydrocarbon generation potential of coal measure strata will be the key problem of petroleum exploration. In this paper Huhehu sag is used as the example (Figure 1b, c), and the geochemical index of coal seams and dark mudstone in the Nantun Formation source rock containing organic carbon, chloroform asphalt "A", pyrolysis chromatography, gas chromatography, carbon isotope, organic elements, and maceral are studied based on testing data; the hydrocarbon generation potential of coal measure strata in Huhehu sag is synthetically researched combined with the sedimentary environment.

## Analysis of Sedimentary Environment and Characteristics of Coal Measure Strata in Huhehu Sag

Member 1 of Nantun Formation is composed mainly of thick bedded, massive, grey conglomerate, glutenite and thin bedded gritstone, silty-fine sandstone and grey mudstone, and was controlled by the fan delta sedimentary environment during the rapid faulted depression period.

Member 2 of the Nantun Formation is composed mainly of thin bedded dark mudstone, thin coal bed and bedded siltstone, indicating the sedimentary environment evolved rapidly, which chiefly includes fan delta front, pro-fan delta, marsh and laucustrine environments. It is

considered that lacustrine facies mainly developed in the south and north subsag in Huhehu depression. That created advantageous conditions to form hydrocarbon source rock.

## Geochemical Characteristics of Coal Measure Strata

Organic carbon

The organic carbon content in the coal measure is mal-distributed. The organic carbon content generally ranges from 26.8~72%, and the average content is 54.6%. While the organic carbon content of dark mudstone generally is 0.23~16.67%, and the average is 2.56%.

Chloroform bitumen “A”

The content of Chloroform extracts distinctly varied in the coal measure strata. The content in the coal is 0.0042~1.83%, and the average value is 0.75%. The content in dark mudstone is 0.0008~1.22%, and the average value is 0.058%.

Oil generation capacity

The content of Chloroform bitumen “A” is 0.1~25.6 mg/g in the coal beds in Huhehu depression, and the average value is 16 mg/g. The content of Chloroform bitumen “A” is 0.4~352.2 mg/g in the dark mudstone, and the average value is 22 mg/g. According to the oil generation capacity and sedimentary environment, it is considered that the dark mudstone has its oil generation capacity distributed in the south subsag and the north subsag.

Pyrolysis chromatographic characteristics

The S1 of coal bed is 1.6~30.9 mg/g, and the average value is 10.9mg/g. The S2 content is relatively higher, and that is generally 50.8~293.5mg/g, and the average value is 130.79mg/g. The hydrocarbon generation potential (PG) obviously varied. Those values are generally 4~324.4mg/g, and the average is 123.5mg/g. The hydrogen index (IH) is 113~460 mg/g, and the average is 207.2 mg/g. While the hydrocarbon index (HCI) is relatively lower, which ranges from 4.3~48.4 mg/g (48.4 mg/g only from one sample), and the average is 13.8 mg/g. Most of the sample values are lower than 15 mg/g. The oil production index (OPI) is 1~11.7%, and the average is 6.9 mg/g.

The Tmax value of dark mudstone is 420~508°C in the coal beds, and the average is 447°C. The Tmax values from most samples are higher than 435°C. This indicates the kerogen has developed into the mature period. Those S1 are in 0.03~2.1 mg/g, and the average is 0.38 mg/g; the S2 are in the range 0.29~15.9 mg/g, and the average is 4.09 mg/g. The PG greatly varied, which generally is in the range 0.29~18.1 mg/g, and the average is 4.4 mg/g. The IH values are 28.2~261 mg/g, and the average is 128.2mg/g. While the HCI is relatively lower and HCI range from 0.2~40.7 mg/g, the average is 11.8 mg/g. The OPI generally ranges between 1~35%, and the average is 9 mg/g. The analysis indicates the dark mudstone which has the oil generation capacity is mainly distributed in the south subsag and in the north one.

Analysis on Ro of coal measure strata

The Ro and the depth demonstrate a linear relationship of the coal measure strata in the Nantun Formation. The Ro 0.5 corresponds to 1550 m, which is the critical point for the immature source rocks. The Ro 0.7 corresponds to 1950 m, which is the critical point for the mature source rocks. The samples whose Ro value (0.5-0.7) is relatively more while the samples whose Ro value ($\geq$0.7) are relatively less, only counting for ca. 30% in all samples. The mature source rocks are distributed mainly in the south subsag, in the north one, and in the central one, which respectively occupy 150 $km^2$, 71 $km^2$ and 34 $km^2$. It is clear that the south subsag and the north subsag are relatively larger and their prospect potential is relatively promising.

Group composition features of coal measure strata

The coal saturated hydrocarbon content is in 7.3~23.26%, and the average is 15%. The content in the mudstone varied greatly, ranging from 1.11~62% and the average is 29%. The content in the oil-bearing sand is 66~76%, and the average is 71%. The content in the crude oil is more than 80%.

The coal aromatic content is 14.45~27.9%, and the average is 22%. The content in the mudstone is 6.95~36.7%, the average is 25.6%. The content in the oil-bearing sand is 13~16.4%, and the average is 14.5%. The content in the crude oil is 9.2%. The ratio between saturated hydrocarbon and aromatic hydrocarbon in the coal ranges between 0.37~1.15, and the great majority are lower than 0.7. The ratio in the dark mudstone ranges between 0.037~3.23, and the average is 1.24. The ratio in the oil-bearing sand and the crude oil is 4~8.8. The ratio value between saturated hydrocarbon and aromatic hydrocarbon in the general hydrocarbon source rock is more than in the coal measure strata.

The non-hydrocarbon content in the coal is 6.8~31.7%, and the average is 18.9%. The amount of dark content is 15.2~38.4%, and the average is 25%. The content in the oil-bearing sand is 7.6~10.6%, and the average is 9.1%. The content in the crude oil is 7.6%. The above three contents are basically consistent.

The asphaltene content in the coal is 18.7~48.7%, and the average is 40%. The content in the dark mudstone is 1.48~41.4%, and the average is 17%. The content in the oil-bearing sand is 3.9~7.0%, and the average is 4.5%. The content in the crude oil is 2.34%. That content is obviously more than the others.

The asphaltene and non-hydrocarbon contents are more than the saturated hydrocarbon and the aromatic contents in the coal and the mudstone of the coal measure strata. The crude oil and the normal generating rock are characterized by higher saturated hydrocarbon content. The group composition feature of the coal measure strata is prone to non-hydrocarbon and asphaltene. While the saturated hydrocarbon content of the dark mudstone is relatively higher, and non-coal hydrocarbon is prone to the saturated hydrocarbon. Thus the dark mudstone has greater hydrocarbon potential, which is located in the south sub-sag and the north one.

Gas chromatographic characteristics of coal measure strata

The carbon number range of the coal bed was nC15-nC36, and the main peaks carbon range is nC22-nC25. The C21-/C22+ ratio is 0.35~0.641, and the average value is 0.51. The OEP value is 0.984~1.28, and the average is 1.19.The pristane/phytane ratio is 3.7~10.5, and the average value is 5.5.

The carbon number range of the dark mudstone is nC14-nC36, and the main peaks carbon range is nC18-nC32. The statistical main peaks of most samples are nC19 and nC21. The C21-/C22+ ratio is 0.314~1.725. The statistical data show the ratio of the samples whose ratio are more than 1 and the samples whose ratio are less than 1 respectively occupy 50% of the total. The OEP value is 0.431~1.23, and the average is 1.03. The pristane/phytane ratio is 1.49~4.2, and the average is 2.4. The carbon number range of the crude oil is nC14-nC35, and the main carbon peaks are nC20 and nC21. The C21-/C22+ ratio is 1.132. The OEP value is 1.06, and the pristane/phytane ratio is 3.4.

The organic carbon of the coal bed came mainly from continental high plants which have high carbon number; that has no oil-generation potential. The organic carbon of the mudstone (occupy ca. 40%) which has high carbon number and lower carbon number was from lacustrine creatures and continental high plants; that has a little oil-generation potential. The most organic carbon which has lower carbon number of the dark mudstone (occupy ca. 60%) was mainly from lacustrine lower plankton and aquatic plants; that has great oil-generation potential and is chiefly distributed in the south subsag and the north subsag.

Elemental composition characteristics of organic matter in coal measure strata

The carbon content in the coal bed is relatively high in the Huhehu depression. The content is generally 60.43~83.57%, and the average is 70.4%. The hydrogen content is relatively low, ranging between 3.92~20.13%, and the average is 13.3%. The H/C ratio is 0.23~0.94%, and the average is 0.74%.

The carbon content of the dark mudstone in the coal measure strata vary greatly. The content is 33.2~80.7%, and the average is 66.3%. The hydrogen content is 3.07~7.67%, and the average is 4.7%. The oxygen content is 3.07-17.5%, and the average is 11.3%. The H/C ratio is 0.66~1.3%, and the average is 0.87%; most values are less than 1.

The above data indicate the coal beds cannot generate oil, and the mudstone which has high carbon content has a little oil-generation potential because that is influenced by the coal bed, and the H/C index can reach the standard of source rock in the part of the dark mudstone. Such mudstone is mainly distributed in the south subsag and the north subsag, and these oil generation indexes are pretty good.

Carbon isotopic composition characteristics of coal measure strata

The δ13C value ranges from -23.17~-26.5‰ in the He 2 well and the He 3 well in the Huhehu depression, and the average is -24.5‰. The δ13C value of the chloroform bitumen “A” and the group composition ranges from -27.05~-23.94‰ in the 23 oil-soaked sandstone samples in the He 2 well, and the average is -25.63‰. The δ13C value of the chloroform bitumen “A” and the group composition ranges from -

28.49~-25.02‰ in the 10 crude oil samples in the He 2 well in Nantong Fm., and the average is -26.22‰. The δ13C value ranges from -34.34~-23.63‰ in the 57 dark mudstone samples in the He 1 well, the He 2 well, and the He 3 well, and the average value is -26.4‰.

## Conclusions

The coal seam of the Huhehu sag is non-normal source rock without hydrocarbon generation potential; some dark mudstones of coal measure strata in Huhehu sag have high organic carbon content influenced by the coal seam, and have certain hydrocarbon generation capability but low potential and belong to non-major source rocks; the geochemical index of the other dark mudstones fall within normal source rock range and are the major source rocks distributed in the southern and northern sub-depression of the Huhehu depression. This type of mudstone could possibly produce much oil flow. The southern and northern sub-depression are thus favorable plays for oil exploration.

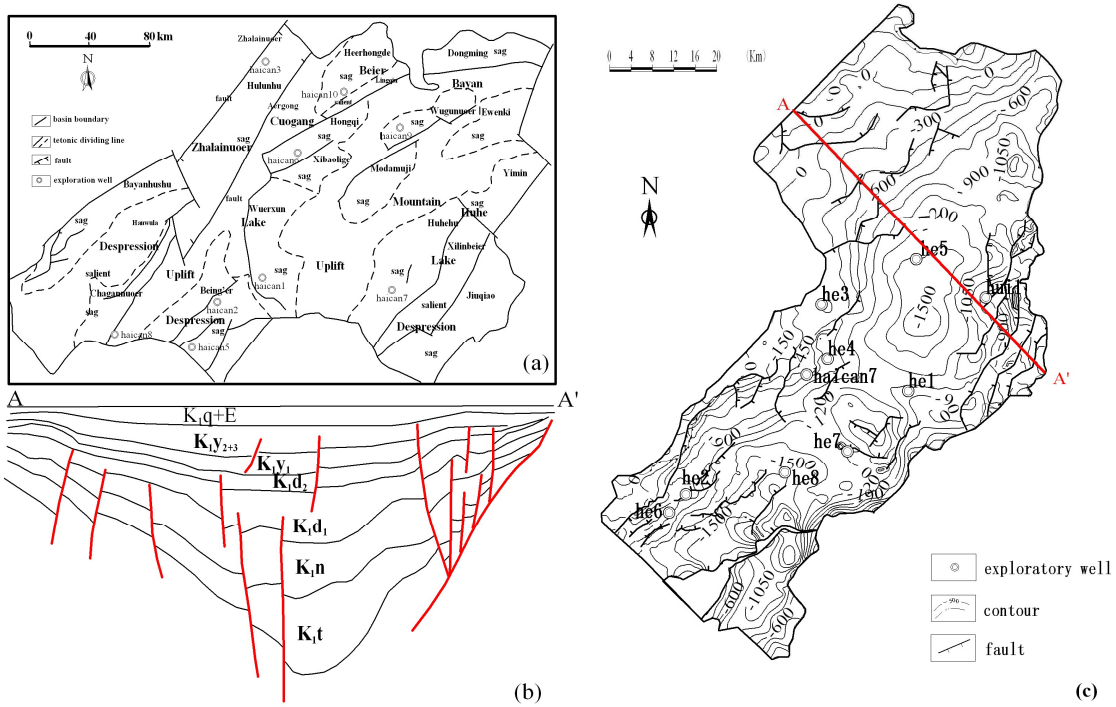


Figure 1. (a) Structural framework map of Hailaer Basin; (b) Cross section in Huhehu sag (location in c); (c) Structure map of top Nantun Formation in Huhehu sag. $K_1t$ - Tongbomiao Formation, $K_1t$ - Nantun Formation, $K_1D$ - Damoguihe Formation, $K_1t$ - Yimin Formation, $K_1q$+E - Qingyuangang Formation + Tertiary.