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Evaluation of Permian Hydrocarbon Source Rocks in Cheng 6 Wells of Dongdao Haizi Depression

Taowen Huang

School of Earth Sciences and Engineering, Xi'an Shiyou University, Xi'an, China
Email: 1419635394@qq.com

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Abstract

The Dongdao Haizi Depression is one of the important oil and hydrocarbon producing depressions in the Junggar basin and the Permian formations are the main hydrocarbon source rocks and the main hydrocarbon producing formations in the Dongdao Haizi Depression. In this paper, through the determination of the TOC and the S1 + S2 of the hydrocarbon source rocks of the lower Urho formation of the Permian, we judge that this hydrocarbon source rock belongs to the better oil-generating category, and through the determination of the microscopic composition of the casein, we find that the organic matter of this source rock is mainly of type II_1, and a few of them are of type II_2; all of them have reached the mature-high mature stage. The organic matter of the hydrocarbon source rocks was found to be mainly of type II_1, with a small part of type II_2; the hydrocarbon source rocks of the lower Urho formation have all reached the mature-highly mature stage.

Subject Areas

Petrochemistry

Keywords

Dongdao Haizi Depression, Permian, Hydrocarbon Source Rock Evaluation

1. Introduction

Junggar Basin is a large oil and gas basin in the west of China, which is very rich in oil and gas resources, but the rate of oil and gas prospecting is very low. The recent resource assessment shows that the conventional natural gas and oil resources are 20,925 × 108 m^3 and 85.87 × 108 t respectively, but the rate of prospecting is only 3.96% and 20.74% [1], which shows that Junggar Basin has a lot of potential for oil and gas exploration. At present, the main exploration part is concentrated in the north-western margin, and the abdomen is less explored, but with the exploration in recent years, the abdomen of Junggar basin has become an important oil and gas resources producing area in the whole basin. Along with the increasing energy consumption, it is urgent to find new oil and gas resources. The Junggar Basin has developed several sets of hydrocarbon source rocks, and the Permian is one of the main hydrocarbon source rocks, which is dominated by oil production. Most of the Permian hydrocarbon source rocks in the eastern part of Junggar Basin are buried below 4500 m, which belongs to the deep exploration field [2]. With the improvement of oil and gas exploration in the shallow and middle layers of the basin and the advancement of methodology and technology, the expansion of oil and gas exploration to the deep and ultra-deep layers is an important way and an inevitable trend to achieve new breakthroughs in China's oil and gas resources and to improve the degree of resource security. Therefore, this paper evaluates the hydrocarbon source rock of the Permian deep layer in the Cheng 6 well to verify the necessity of ultra-deep exploration in the Cheng 6 well.

2. Regional Overview

The Junggar Basin is located on the southeastern edge of the Kazakhstan Plate and is an important part of the Central Asian orogenic belt. The Junggar Basin is surrounded by various mountain ranges, as shown in **Figure 1**, the north-western margin rests on the Zaire and Harat mountain ranges, the northeastern margin is enclosed by the Tsingelidi and Krameri mountain ranges, and the south-western and southern margins are the Ilyinhebirgan and Bogda mountain ranges. According to the internal tectonic features of the basin and the characteristics of late modification the Junggar Basin is divided into 6 primary tectonic units and 44 secondary tectonic units, the primary tectonic units are the western uplift, the Ulungu depression, the eastern uplift, the Tien Shan pre-mountain fault zone, the Luliang uplift, and the central depression [3] [4].

The Dongdao Haizi depression is located in the northeastern part of the Junggar Basin, between the Dongdao Haizi North Fracture and the Dishuiquan Fracture Zone. It is about 100 km long in the east-west direction and 70 km wide in the north-south direction, with an area of about 7000 km^2. It is bounded by the Wucaiwan Depression to the east, the Moso Bay and the Mo Bei Bulge to the west; the Baijiahai Fracture and the Baijiahai Bulge to the south; and the Dixi South Bulge and the Dixi South Bulge of the Dishuiquan South Fracture to the north [5] [6]. The Middle Permian Dongdao Haizi Depression is connected to the water bodies of the Fukang Depression and the Wucaiwan Depression, at which time a lacustrine depositional system of the Permian Pindiquan Formation was developed, **Figure 2** shows the lithology of the Lower Urho Formation the Pindiquan Formation (P2p): the lithology mainly consists of grey sandy conglomerates, muddy siltstones, powdered and fine sandstones, brownish-grey small conglomerates, and conglomerate-bearing mudstone, which is interspersed with dark grey, grey-black, and greyish-brown mudstone as well as powdered sandy mudstone, and greyish-white muddy greywacke is interspersed at the top. The Baijiahai Bulge and Dinan Bulge on the two sides are continuously dominated by tectonic uplift, and not only the strata have not received deposition, but also the high parts are still subjected to weathering and erosion. In the late Permian, the Dongdao Haizi depression was in the depositional stage of the fill-and-fill type, and the topographic height difference was basically made up. At this time, the activity of the Dripping Spring Fracture was weakened substantially, and the stratum of the upper Permian Wutonggou formation crossed the Dripping Spring Fracture and gradually overtopped to the northwest of the Dripping South Bulge. This layer is basically a south-dipping monoclinic belt with a single structure.

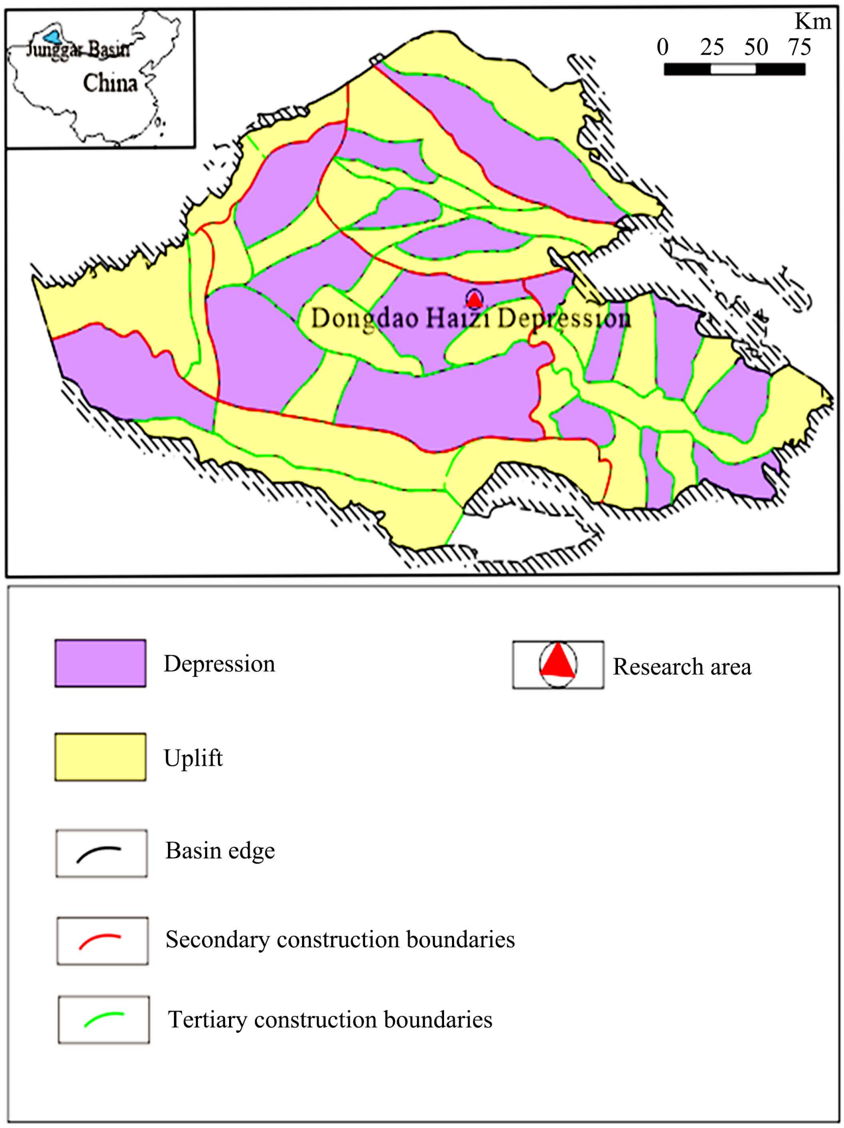

Figure 1. Division of tectonic units in Junggar basin.

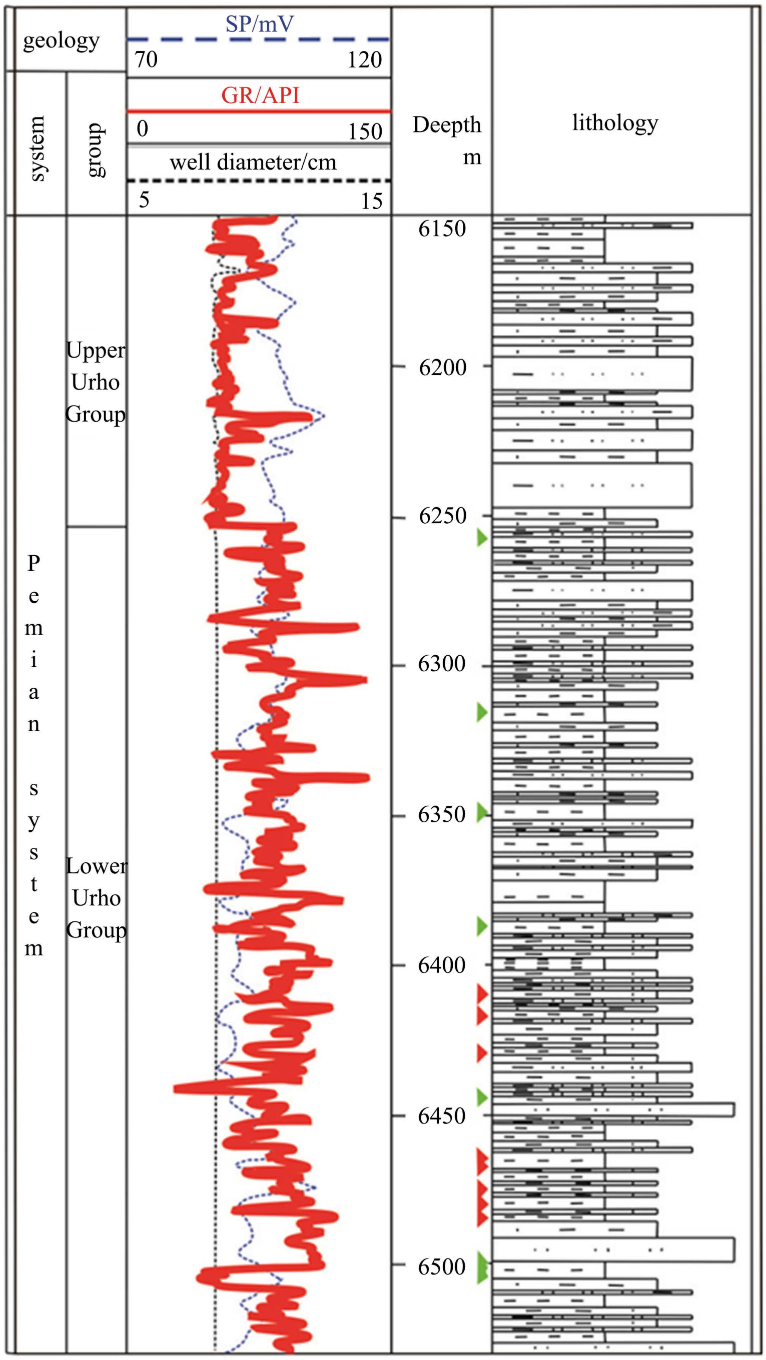

Figure 2. Stratigraphic lithology map.

3. Evaluation of Hydrocarbon Source Rocks

3.1. Sample Photos

This is a photograph of a core sample taken from the Cheng 6 well at 6495.5 m, one of the materials used in this experiment, which belongs to the mudstone. (Figure 3) We chose a total of 24 samples and conducted many experiments, such as organic carbon analysis, pyrolysis analysis, microcomponent analysis, and so on.

Figure 3. Sample photos.

3.2. Organic Matter Abundance

According to previous research, the Middle Permian Pingdiquan Formation is distributed in all depressions in the Jundong area, except for a few uplift areas. Previous data show that this formation has high organic matter abundance and good type, and it is the main hydrocarbon source rock of many oilfields in the Jundong area. A large number of samples show that the average value of TOC content of this hydrocarbon source rock is 2.82%, mainly greater than 1.0%; the average value of chloroform asphalt "A" is 1.73%; the average value of HC content is 0.926‰; the average value of pyrolysis hydrocarbon potential (S1 + S2) is 13.73 mg/g. In addition, previous researchers have studied. In addition, in 20 samples of the Pingdiquan formation, the organic matter abundance is even higher than the previous statistics. The average TOC content is as high as 5.54%, and there are quite a number of samples above 5.0%; the average value of S1 + S2 is as high as 32.32 mg/g, and most of the samples are above 10.05 mg/g. From this, it can be seen that the Middle Permian hydrocarbon source rock is an excellent hydrocarbon source rock, which can generate a large amount of hydrocarbons [7].

In this experiment, 24 hydrocarbon source rock samples from the Urho Formation under the Cheng 6 well were selected for TOC content testing, as shown in Figure 4, 3 samples with TOC values below 0.5% belong to the poor hydrocarbon source rock, 3 samples with TOC contents in the range of 0.5% to 1% belong to the category of medium hydrocarbon source rock; the other 11 samples with TOC values in the range of 1% - 2% belong to the category of good hydrocarbon source rock; and 7 samples with TOC values above 2% belong to the category of good hydrocarbon source rock. The other 11 samples have TOC values in the range of 1% to 2%, which belongs to the category of good hydrocarbon source rocks; and 7 samples have TOC values above 2.5%, which belongs to the category of good hydrocarbon source rocks. The average TOC value of all samples is 1.58%, and according to the histogram of TOC content of each sample, the hydrocarbon source rocks of the Lower Urho Formation belong to the good category.

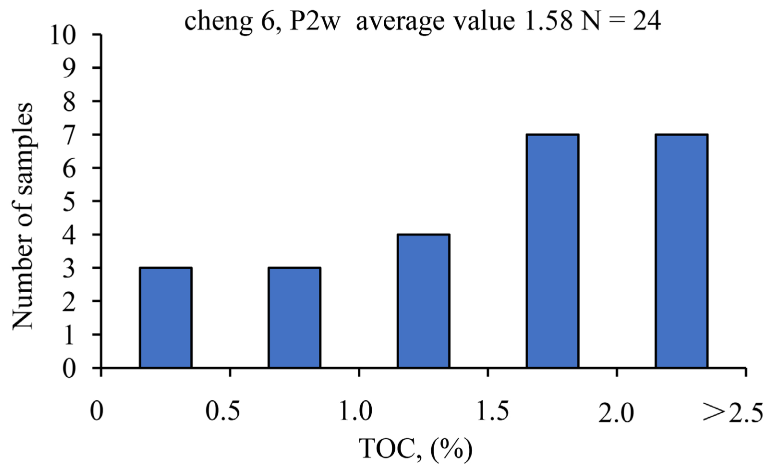

Figure 4. TOC values of hydrocarbon source rocks of the lower Urho formation.

In terms of S1 + S2 (as shown in **Figure 5**), 11 out of 24 samples have S1 + S2 values below 2 mg/g, which belongs to the category of poor hydrocarbon source rock; the highest S1 + S2 value of the remaining 13 samples reaches 4.62 mg/g, and the other samples are basically in the range of 2 mg/g - 4.3 mg/g, which belongs to the category of medium hydrocarbon source rock, and the mean value of the S1 + S2 of the samples in the present case is 2.51 mg/g, which belongs to the category of medium. The average value of S1 + S2 of this sample is 2.51 mg/g, which belongs to the medium category and is slightly different from the identification result of TOC value obtained in the previous experiments.

3.3. Organic Matter Type

Six mudstone samples from the Lower Urho Formation of the Permian were selected for the study of microcomponents in this experiment, as shown in **Figure 6**, all the samples are basically dominated by the corrosive mudstone group + chitin group, and one of the samples has a higher content of inertin group. Combined with **Table 1**, the type of casein in the Lower Urho Formation of Cheng 6 wells basically belongs to the Type II_1, and a small amount of them belongs to the Type II_2, and the depositional environment may belong to the deep-basin lake or the The depositional environment may belong to deep basin lake or deltaic complex deposition.

In addition, from the H/C and O/C of the hydrocarbon source rock samples of the Urho Formation under well Cheng 6 (**Figure 7**), most of the samples have H/C in the range of 1.2 - 1.5 and O/C in the range of 0.1 - 0.2, which, combined with **Table 1**, belongs to the II1 type of tyrosine, and there are also some tyrosine samples that have H/C in the range of 0.7 - 1.2 and O/C in the range of 0.2 - 0.3, which, combined with **Table 1**, belongs to the II1 type of tyrosine. The H/C and O/C of some other casein samples were in the range of 0.7 - 1.2 and 0.2 - 0.3 respectively, which belonged to type II_2 as shown in **Table 1**, and were in agreement with the results of the casein microscopic composition.

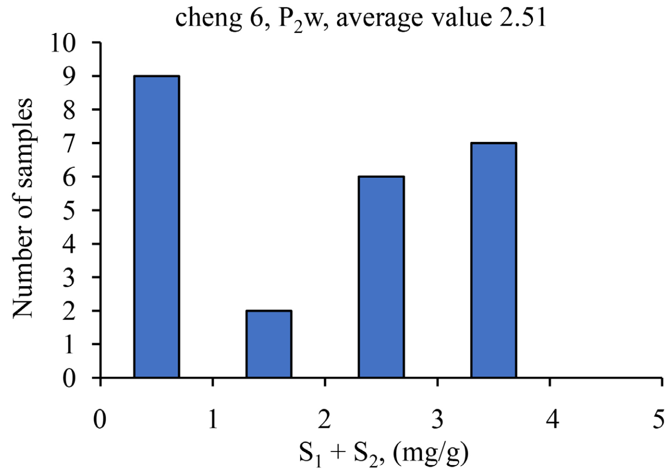

Figure 5. S1 + S2 values of hydrocarbon source rocks of the lower Urho formation.

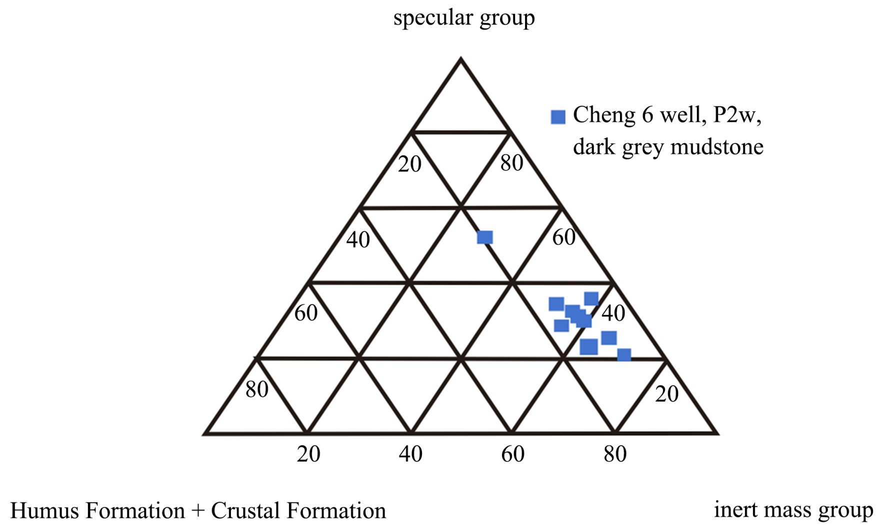

Figure 6. Microcomposition of casein root samples from the Urho formation in the Cheng 6 well.

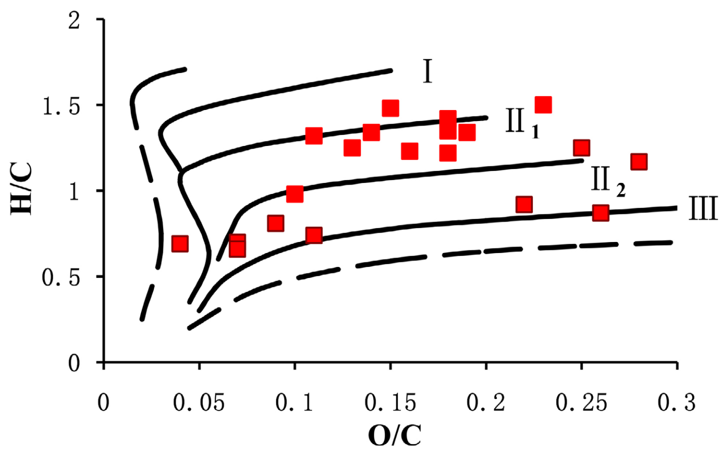

Figure 7. O/C and H/C atomic ratios of hydrocarbon source rocks of Urho formation under Cheng 6 wells.

Table 1. Classification criteria of organic matter types in China's terrestrial phase.

Type	TI values for microscopic fractions of cheese root	Elemental composition of cheese root		Cheese root & ^{13}C‰	Thermal cleavage (*i.e.* sth splits when heated) HI (mg/g)
		H/C	O/C		
I	>80	>1.5	<0.1	<−28	>400
II_1	0 - 40	1.2 - 1.5	0.1 - 0.2	−26 - −28	180 - 400
II_2	40 - 80	0.8 - 1.2	0.2 - 0.3	−25 - −26	60 - 180
III	<0	<0.8	>0.3	>−25	<60

3.4. Maturity of Organic Matter

Maturity is the main parameter to measure the degree of organic matter to oil and gas conversion, in principle, as long as in the maturation evolution process reflects regular changes, reflecting such changes in the parameter that is the maturity index. Therefore, elemental composition, functional group composition, reflecting the evolution of hydrocarbon matrix casein, reflectivity of specular plasma and soluble organic matter content changes can be indicators of maturity. (Table 2) In this paper, the hydrocarbon source rock of Cheng 6 well near 6490 - 6500 m is selected as the experimental material. (Table 3)

The highest pyrolysis peak temperature (T_{max}) was preferred after the indexes, and the vertical stratification evaluation mainly used the highest pyrolysis peak temperature of the rock, T_{max}, as the index. Referring to the previous criteria for the division of the stage of thermal evolution of organic matter, according to the analysis results of the hydrocarbon source rock samples and the relevant analytical test data of the previous authors, the scatter plot of the maximum pyrolysis temperature (T_{max}) of the hydrocarbon source rocks was made (Figure 8) to study the maturity stage and hydrocarbon production characteristics of the hydrocarbon source rocks. From the data, almost all of the hydrocarbon source rock samples have Ro above 1% - 1.2%, and the average value is above 1.3%. Combined with Table 2, it can be seen that the hydrocarbon source rocks of the Lower Urho Formation have reached the maturity-high maturity stage, which is also known as the condensate and moisture zone, and mainly produces condensate gas and light hydrocarbons.

The above figure shows the measured T_{max} and Ro values of the samples selected from Cheng 6 wells around 6200 m to 6500 m, the Ro value of the Urho Formation under Cheng 6 wells ranges from 1.2% to 1.6%, with an average value of 1.45%, and the corresponding T_{max} value ranges from 400˚C to 440˚C, and the corresponding correlation between them is relatively poor, and comparing with Table 2, we can find that the T_{max} value is on the low side, and it is not able to reach the value of what we have envisaged 480˚C or so.

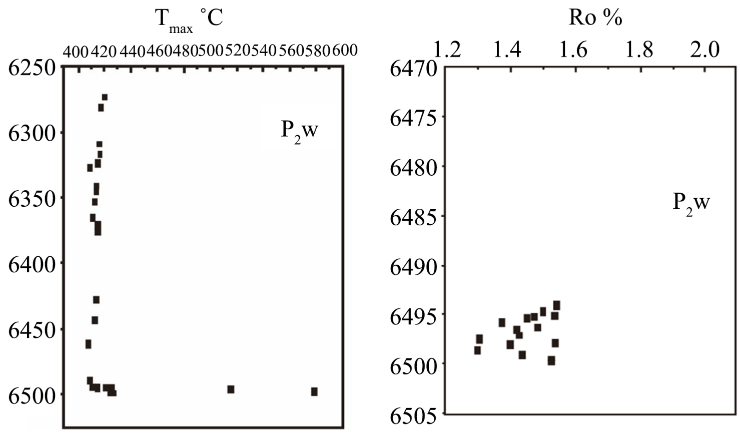

Figure 8. Measured T_{max} and Ro values of hydrocarbon source rock of Urho formation under Cheng 6 well.

Table 2. Reflectance of specular bodies and delineation of organic matter evolution.

Evolutionary stage	Immature	Low maturity	Maturity	High maturity	Over-mature
Ro/%	<0.5	0.5 - 0.7	0.7 - 1.3	1.3 - 2.0	>2.0
T_{max}/˚C	<435	435 - 445	445 - 480	485 - 510	>510

Table 3. Measured values of Ro at various depths for hydrocarbon source rock samples of the Urho formation under Cheng 6 well.

Pound sign	Sample description	Depth (m)	Ro %			Organic matter type
			Min	Max	average	
Cheng 6 well	Dark grey mudstone	6494.2	1.221	1.836	1.544	Main II_1, less II_2
Cheng 6 well	Dark grey mudstone	6494.8	1.225	1.779	1.502	
Cheng 6 well	Dark grey granular limestone	6495.1	1.495	1.754	1.540	
Cheng 6 well	Dark grey mudstone	6495.25	1.234	1.745	1.476	
Cheng 6 well	Dark grey granular limestone	6495.4	1.354	1.558	1.456	
Cheng 6 well	Dark grey calcareous mudstone	6495.7	1.165	1.585	1.375	
Cheng 6 well	Dark grey granular limestone	6495.75	1.287	1.683	1.485	
Cheng 6 well	Dark grey calcareous mudstone	6495.95	1.298	1.550	1.424	
Cheng 6 well	Dark grey granular limestone	6496.4	1.216	1.619	1.426	
Cheng 6 well	Dark grey calcareous mudstone	6496.6	1.145	1.465	1.305	
Cheng 6 well	Dark grey granular limestone	6497.1	1.372	1.717	1.538	
Cheng 6 well	Dark grey calcareous mudstone interbedded with mudstone	6497.6	1.224	1.653	1.401	
Cheng 6 well	Dark grey mudstone	6498.1	1.028	1.680	1.302	
Cheng 6 well	Dark grey mudstone	6498.7	1.233	1.693	1.438	
Cheng 6 well	Dark grey granular limestone	6499.1	1.287	1.765	1.526	
Cheng 6 well	Dark grey conglomerate-bearing sandstone	6499.8	1.253	1.717	1.508	

There are many reasons for the low T_{max} value, firstly, it may be the intrusion of soluble organic matter, the increase of soluble organic matter will cause the S1 peak to increase, and the soluble heavy components into the S2 peak will lead to the decrease of T_{max}. The amount of soluble organic matter into the S2 peak is proportional to the magnitude of T_{max} reduction, the greater the difference between the S2 values before and after chloroform extraction of the rock, the more soluble hydrocarbons into the S2 peak, the greater the difference between the T_{max} values before and after the extraction of the rock. Another reason is related to the microcomposition of casein [8]. In conclusion, after the H/C and O/C measurements as well as the study of microcomposition, it was determined that the sample belongs to type II1 casein, which has more chitin group components, and the more resinous body in it may lead to low T_{max} peaks, therefore, the low T_{max} value in this experiment may be due to the more resinous body components.

4. Conclusion

The average TOC value of the hydrocarbon source rock of Urho formation (P2w) under Cheng 6 well is 1.58%, and the average value of S1 + S2 is 2.51 mg/g, which belongs to the category of medium to good oil-producing rock, and the type of organic matter is dominated by II_1 and supplemented by II_2, and the Ro is in the range of 1.3 - 1.6, which belongs to the high-mature hydrocarbon source rock. This indicates that the hydrocarbon source rock of Urho formation (P2w) under the Cheng 6 well has good potential for oil and hydrocarbon production. The hydrocarbon source rock has great potential for oil and hydrocarbon production, so it is very necessary to explore and develop the ultra-deep layer of the Cheng 6 well.

Conflicts of Interest

The author declares no conflicts of interest.

References

[1] He, D.F., Chen, X.F., Zhang, Y.J., *et al.* (2004) Hydrocarbon Enrichment Law in Junggar Basin. *Petroleum Journal*, **25**, 1-10.

[2] He, D.F., Zhang, L., Wu, S.T., Li, T. and Zhen, Y. (2018) Stages of Tectonic Evolution and Their Characteristics in the Junggar Basin. *Oil and Gas Geology*, **39**, 845-861.

[3] He, D.F., Wu, S.T., Zhao, L., Zheng, M.L., Li, T. and Lu, Y. (2018) Tectonic-Sedimentary Background of the Permian-Triassic of the Circum-Mahu Depression and Its Evolution. *Xinjiang Petroleum Geology*, **39**, 35-47.

[4] Zhao, B. (1993) Tectonic Features and Tectonic Delineation of the Junggar Basin. *Xinjiang Petroleum Geology*, **14**, 209-213.

[5] Zhao, B. (1992) Basal Nature of Junggar Basin. *Xinjiang Petroleum Geology*, **13**, 95-99.

[6] Qiao, J.Q. (2017) Study on the Oil and Gas Formation Conditions of the Permian

System in the Eastern Part of the Dongdao Haizi Depression, Junggar Basin. Master's Thesis, China University of Petroleum, Beijing.

[7] Wu, L.Y., Zhou, G.X., Wang, L.M., *et al.* (1983) Influence of Minerals on Pyrolysis Hydrocarbon Volume and T_{max}. *Petroleum Exploration and Development*, **10**, 75-78.

[8] Qiu, N.S., Yang, H.B., and Wang, X.L. (2002) Characteristics of Tectonic-Thermal Evolution of Junggar Basin. *Geological Science*, **37**, 423-429.