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# Characteristics and Main Controlling Factors of Source Rock in Cambrian Yuertus Formation in Aksu Area, Tarim Basin

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**Abstract:** *According to previous research, Cambrian Yuertus source rocks is considered to be an important source rocks in the Tarim Basin, which was affected by upwelling and deposited on the ramp platform facies. But the latest analysis of field reconnaissance and experimental results showed that Yuertus source rocks should be divided into two sections. Chert and mudstone are the main component of the lower section source rocks, Chert formation is influenced by the bottom of the hydrothermal which have been confirmed by trace element analysis, we believed that the source rocks formed in the restricted platform facies, and affected by the bottom hydrothermal; organic carbon content is relatively high, and average more than 5% in this section; kerogen carbon isotope ratios are mainly distributed in the -37‰ ~ -34‰.The main lithology of the upper source rock section was the shale interbedded with limestone, the sedimentary environment of the upper source rocks section is the slope basin facies, and controlled by the upwelling; total organic carbon content is relatively low, with an average of about 1% in this section; and kerogen carbon isotope ratios are mainly distributed in the -36‰~-33‰, relative to the lower source rocks is more enriched $^{13}C$. Thus, the two sets of source rocks sedimentary environment and formation mechanism is completely different, we believe that the deposition process of Yuertus is complicated, so we should give full consideration about the main factors of the development of two sets of source rocks when predicting the distribution of Yuertus Formation source rocks.*

***Keywords:*** *Tarim Basin; Yuertus Formation; source rocks; controlling factors*

## 1. Introduction

The issue of main marine hydrocarbon source rock of oil and gas in Tarim Basin remain controversial since the oil and gas breakthrough of Ordovician Formation in the 1980s [1-3]. Currently, most of scholars believe that marine oil and gas in Tarim Basin are mainly derived from the Cambrian-Ordovician source rocks [4-5]. In recent years, with the breakthrough in Cambrian system from deep wells of ZS1 and ZS5, marking the first success of commercial hydrocarbon flow in dolomite formation under salt in Tarim Basin, it confirms the Cambrian dolomite formation under salt have petroleum geological conditions of large-scale accumulation, which has opened a new field for deep exploration in Tarim Basin [6]. Meanwhile, crude oil from Cambrian system in the deep well ZS1 and ZS5 further confirmed that the important contribution of Cambrian hydrocarbon source rock to oil resources in Tarim Basin.

The upper Cambrian series comprises of a large set of light-colored and gray dolomite, which is not the hydrocarbon source rocks; the middle Cambrian series developed typical regional cap rock of gypsum-salt, only the upper Awatage Formation developed hydrocarbon source rocks locally; however, the lower Cambrian hydrocarbon source rocks distribute widespread and stably, which is a set of effective hydrocarbon source rock in Tarim Basin. Based on sedimentary environment, the Cambrian hydrocarbon source rocks could be preliminarily divided into evaporate platform facies and margin slope facies. The source rock deposited in the restricted platform facies mainly developed in the lower Cambrian Xiaoerblak Formation and Wusonger Formation, in which mainly developed dark-colored micrite, limy dolomite and shale. Data from existing exploration wells show that H4, F1, and K2 wells in Bachu area all drilled the set of hydrocarbon source rocks, which lithology is mainly dark-colored shale and gypseous micrite with total organic carbon content (TOC) up to 2.68%, the average TOC>0.5%, and the effective thickness of the interval >50m, indicating a certain hydrocarbon-generating potential.

The Cambrian hydrocarbon source rocks, Yuertus Formation widely developed in Aksu area, Xinjiang Province, with high abundance of organic matter (TOC was 4%~16%), thickness of 10 to 20m and the lithology is mainly for the black phosphorus siliceous shale and mudstone, indicative of typical hydrocarbon source rocks in slope-basin facies. Recently it is thought to be the marine high-quality hydrocarbon source rocks with the highest TOC [7], and considered as one of the main hydrocarbon source rocks in Tarim Basin [8]. However, only XH1 well in the basin area drilled Yuertus Formation which was over 20m, the other 20 wells that drilled through Cambrian

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formation lack of Yuertus Formation or source rocks. For example, H4 and F1 wells in Bachu area drilled Yuertus Formation, however, with lithology of brown siliceous mudstone and shale respectively, and the organic carbon content mainly less than 0.5%, which does not have the production ability of oil and gas; in addition, Manxi platform that possibly developed source rocks of Yuertus Formation could be difficult to predicting the distribution of Yuertus Formation only with seismic data due to the high burial depth. Thus, the Formation mechanism and the main controlling factors of the hydrocarbon source rocks remain unclear, and the distribution prediction of hydrocarbon source rock need further research.

This paper mainly focuses on field outcrop in Aksu area. Combining field reconnaissance, sampling and laboratory analysis. This paper first divided Yuertus source rocks into the upper and lower sets to analyses the main controlling factors and formation mechanism of hydrocarbon source rocks based on lithologic combination, sedimentary environment and geo-chemical characteristics and so on, in order to provide good suggestions for the prediction of hydrocarbon source rock distribution and the exploration of oil and gas in Tarim basin.

## 2. Geological setting

Aksu area in Xinjiang province, located in the north-western margin of Tarim Basin, north to Tianshan fold belt and Kuqa piedmont depression, and south to the Southern and Northern depression area (Fig.1). Intense tectonic movements of southern Tianshan fold belt, strongly affect the tectonic evolution of the study area. Previous researches show that Aksu area has experienced four tectonic stages since Proterozoic, namely the Pre-sinian geosyncline stage, the Paleozoic platform stage, Mesozoic uplift - denudation stage and Cenozoic inland basin stage, which can be divided into five tectonic cycles, namely, Jinning cycle, Caledonian cycle, Variscan cycle, Yanshan-Indosinian cycle and Himalaya cycle [9].

Keping orogeny and early Caledonian orogeny basically determine the sedimentary environment in early Cambrian period. The top of upper Sinian Qigeblak Formation suffered from varying degrees of erosion resulting in bumpy geomorphology. And the overlying lower Cambrian Yuertus Formation developed phosphorus concrete or block mass at the bottom, which inset over the weathered surface at the top of Qigebulake Formation, showing unconformity contact. And the degree of denudation of upper Qigebulake Formation increases from west to east, reflecting the geomorphology of the last stage of late Sinian, which is high in east and low in west [10].

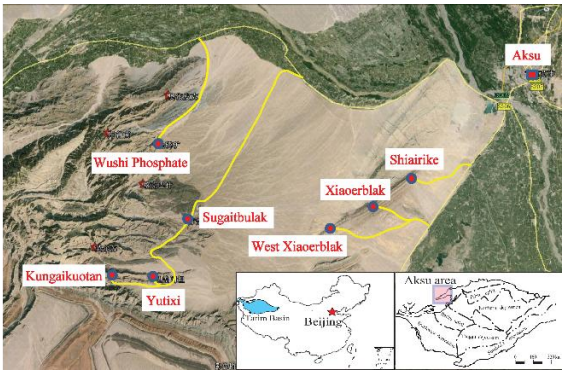


***Figure1.*** *Outcrops location of the Yuertus Formation in the Tarim Basin*

## 3. Discovery of Yuertus source rocks

Previous studies reported Yuertus Formation source rocks appear in Mountain Kuluketage and Xiaoerbulake outcrop in Aksu area. The results shows that Cambrian Yuertus Formation developed high-quality hydrocarbon source rocks with high organic matter abundance, which organic carbon content of black shale could be as high as 4 to 16%, stably distributing in the Aksu area and the thickness of mainly 10~15 m, and thought to be deposited in the middle to lower gentle slope environment, in which the enrichment of organic matter is controlled by rising ocean currents [7].

Drilling data show that in the Bachu uplift and margin of Manjiaer depression wells drilled Yuertus Formation, such as H4, F1 and K2 wells in the Bachu uplift area, and TD1, TD2, WL1 and KN1 well in the margin of Manjiaer depression area, However, only XH1 well drilled Yuertus Formation of more than 20 meters high quality source rocks [11]. The gray-black carbonaceous shale of Yuertus Formation in XH 1 well has organic carbon content of 1%~9.43%, average more than 5%; the lower hydrocarbon source rocks that concomitant with phosphorus layer, characterizing by decline upward; equivalent vitrinite reflectance ranges from 1.38% to 1.5%, i.e. reaching high mature stage of thermal evolution; characteristics of organic matter biomarker compound show that the set of hydrocarbon source rocks has a close relationship with Ordovician crude oil in northern Tarim Basin [11].

## 4. Characteristics of Cambrian Yuertus source rock

### 4.1 Lithology and abundance of organic matter

Outcrops in the study area show that lithological combination of upper and lower intervals of Yuertus source rock differ greatly. The bottom of lower Yuertus Formation developed brown-gray and gray-black laminated phosphorous siliceous rocks, then interbeded with black shale upward, with abundant barite concrete inside, and thickness of about 2m. Upward developed varved black shale, containing interlayers of gray-black siliceous rock, the top of the

lower Yuertus Formation deposited black shale mainly of about 3m thick, and organic carbon content up to 16%, the average of more than 5%. Between the two sets of source intervals is a gray middle bedded silty dolomite of about 0.5~1m thick and strong heterogeneity, whose thickness varies obviously (Fig.2).

Upward developed another interval of dark grey-black shale of about 1~2 m thick, compared with the lower interval, clay content is relatively low, limy content increases; the overlying of black shale interbedded thin-layer micrite contains a small amount of lenses of limestone, upward thickness of black shale decreases and thickness and numbers limestone layers increase, of about 4m thick. Basically, the upper interval of Yuertus source rock has relatively lower organic carbon content than the lower interval, average of about 1% TOC (Fig.2).

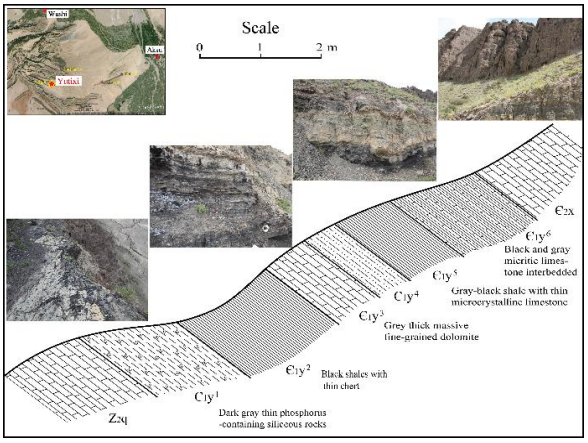


***Figure2.*** *The lithology schematic and photograph of Kungaikuotan outcrop*

### 3.2 Carbon isotope of kerogens

According to the results of experimental analysis of outcrop samples in the study area, two intervals of Yuertus source rocks of Kungaikuotan Profile in Aksu area that separated by dolomite of about 1m thick all show the cycle that carbon isotope increase upward. The carbon isotope value of the lower interval increases from -36.6‰ to -34.6‰, with the increase of 2‰; while that of the upper interval increases from -35.7‰ to -33.2‰, with the increase of 2.5‰ (Fig.3).

Meanwhile, carbon isotope of the lower interval in Shiairike Profile mainly ranges -38 ‰~-34 ‰, similar with the lower interval of source rock in Kungaikuotan Profile as well as similar lithology association of dark-colored siliceous rocks combining the overlaying black shale. Therefore, Shiairike Profile only developed the lower interval of high-quality source rock in Kungaikuotan Profile, in other words, Shiairike Profile merely developed the upper interval of source rock, upon which directly deposited one set of thick fine-grained crystalline dolomite (Fig.4).

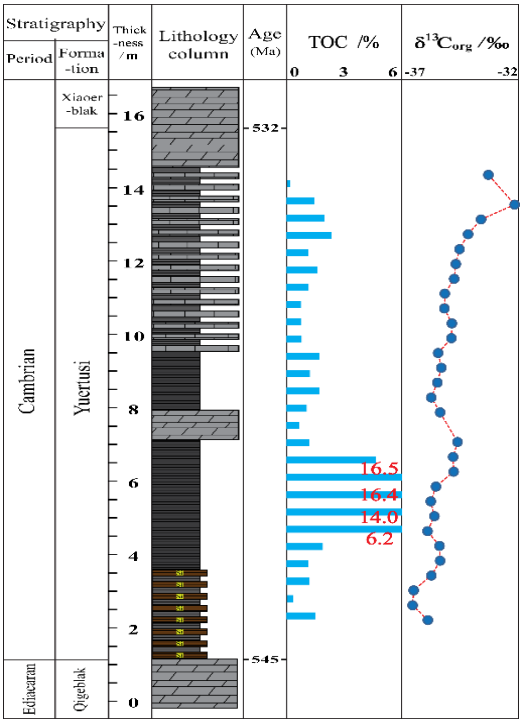


***Figure3.*** *The vertical distribution characteristics of organic carbon isotope of Kungaikuotan Profile*

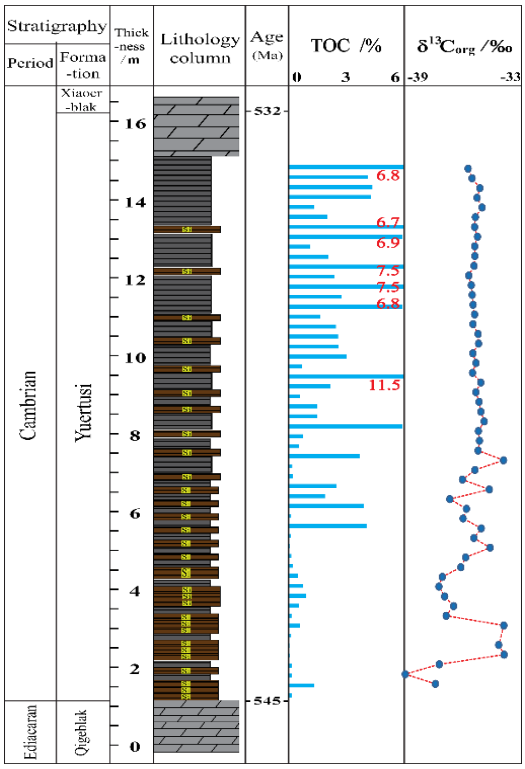


***Figure4.*** *The vertical distribution characteristics of organic carbon isotope of Shiairike Profile*

### 3. Sedimentary environment of the source rocks in Yuertus Formation

Combined with the previous research, we believe that seafloor hydrothermal activities and upwelling in the area significantly affected the development of hydrocarbon source rocks. This viewpoint figure out

that the seafloor hydrothermal activities offers a wide range of nutritional components to the microorganism. Some scholar also found out that the Iron group elements, trace elements and the TOC value present obvious positive correlation which can prove his viewpoint. This viewpoint figures out that the upwelling which developed mainly in the open ocean carried the underlying hydrothermal activity nutrients to the surface [12]. That caused surface creature such as diatoms and radiolarian multiply and developed. According to the special sedimentary environment, the layer developed biogenic siliceous rocks.

Sedimentary model is the main part of the research on the sedimentary environment and distribution characteristics of the hydrocarbon source rocks. There are plenty of researches on the sedimentary facies palaeogeography and development model in Yuertus Formation Tarim Basin [13,14].

Based on the analysis of measured data and lateral comparison, this paper amended the development model of the hydrocarbon source rocks in Yuertus Formation, and proposed that the sedimentary environment is middle-under shelf of the gentle slope. The development of the hydrocarbon source rocks was controlled by multi-factor, including the upwelling, the hydrothermal activity, the sea-level eustacy and the organic matter preservation conditions (Fig.5).

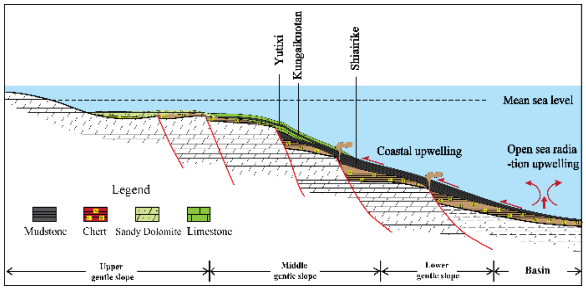


***Figure5.*** *Sedimentary schematic diagram of the Yuertus Formation in the Tarim Basin*

## 4. Conclusions

Depending on the kerogen carbon isotope values, organic matter abundance and lithology differences, combined with the bottom of the lower source rocks containing hydrothermal cherts on the lithological composition and source rocks with interbedded limestone, the source rocks of Yuertus formation can be divided into upper and lower sets of source rocks. Combined with previous research results initially speculated that lower hydrocarbon source rocks are restricted platform facies, the basin fault depression inherited product by hydrothermal influence, organic carbon content average more than 5%, which is an important set of high-quality source rocks in Tarim Basin; An upper section of the shale source rocks organic carbon content is relatively low, with an average of about 1%, mainly characterized by a combination of lithology and limestone interbedded shale, sedimentary environment ramp basin facies, upwelling an important factor in the Formation of source rock.

Overall, the two sets of source rocks sedimentary environment and formation mechanism is completely different, with the long deposition time of Yuertus Formation, we believe that the deposition process of Yuertus is complicated, so we should give full consideration about the main factors of the development of two sets of source rocks when predicting the spatial distribution of Yuertus Formation source rocks.

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