Stratigraphic characteristics and geological significance of Qingshankou Formation in Songliao Basin

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Abstract: The Qingshan Formation is the first large-scale lake invasion in the geologic evolution history of the Songliao Basin, the central depression area of the basin is widely distributed with black mudstone and shale, and the coarse clastic rocks in the western slope area and the northern dumping area are obviously increased, while the large sets of green-gray and purplish-red mudstone appear in the eastern uplift area and the southeast uplift area. By chronological analysis of the zircon minerals in the lacustrine sedimentary layers of the lake facies of the Qingshan formation, the U-Pb isotope harmonic ages were 91.35Ma, 91.06±0.69 Ma, it is confirmed that the bottom of Qingshankou Formation is proven to belong to the lower part of Turonian period; the 40Ar/39Ar isotope plateau age and the age of equal time line obtained from two or three section of Qingshankou Formation in Jin 6 well are 88.0±0.3 Ma, confirming that the top boundary of Qingshankou Formation has been extended to Coniacian period. At the same time, the appearance of Borealipollis, Plicapollis and Complexiopollis, which has important geologic age significance, indicates that the bottom boundary of Qingshankou has already entered to the late.

1. Introduction
Songliao Basin is a large Mesozoic-Cenozoic oil and gas basin with the Cretaceous as the main body on the foundation of the paleozoic in eastern China[1], the basin is filled with a thickness of 11 km, with a double structure of "lower break and upper depression", and the lower fault-period is filled mainly of volcanic rock and volcanic debris, developing Huoshiling formation, Shahezi formation, Yingcheng formation, Denglouku formation and the 1st-2nd members of Quantou formation; the upper depression period is a normal sedimentary sequence, developing the 3rd-4th members of Quantou formation, Qingshankou formation, Yaojia formation, Nenjiang formation, Sifangtai formation and Mingshui formation. The sedimentation period of the late Cretaceous Qingshankou formation is the development period of the lake basin, the maximum area of the lake basin can reach 87,000 square kilometers or more, and a set of thick layer black mudstone, shale-based lake-phase sedimentation combination is widely developed, which is the main contributor to the oil and gas generation in the late Songliao Basin. The volcanic rock in this article is produced in the mezzanine layer in the mudstone in the middle of Qingshankou formation. The existing data of thousands of drilling wells show that the volcanic rocks in the Qingshankou formation in the basin are mostly exploration non-purpose segments, and the drilling wells reveal that there are few wells in volcanic rock and volcanic debris rock, and the yield of volcanic ash acquisition is small and lacks systematic research. Based on the research results in recent years[2-10], this paper conducts an anthology study on the sedimentary mezzanine of volcanic ash in order to provide geological data for the age attribution of
the stratosphere in the middle and shallow layers of the basin, mainly sedimentary debris rock, and then provide scientific basis for the exploration and development of the basin.

2. The characteristics and distribution regularity of strata development

During the deposition period of Qingshankou formation, the first large-scale lake invasion occurred in Songliao Basin, and a set of sedimentary construction characterized by large lake-delta system was deposited, with dark mudstone and shale-based debris sedimentation combination, and volcanic rock and bentuem soil were found in some areas. The area with the largest sediment thickness in a section of the Qingshankou formation is mainly located in the central depression area, with black, gray-black mudstone, shale oil-clamped shale, and thin layered diamond iron ore strips. The bottom develops 10-30m black shale and sepia oil shale, which divides the basin formations into a comparative first-level marker layer. The western slope area of the basin and the northern dumping area became gray-black, gray-green mudstone and sandstone mutual layer gradually, which is a kind of sedimentary environment from the deep lake and semi-deep lake phase of the strong reduction to the weak reduction and weak oxidation. The sedimentary thickness of the 2nd, 3rd members of Qingshankou formation changes greatly, the middle of the basin is thick, the edges are thin, and the thickness can be more than 500m. The rock is gray-black, gray-green mudstone sandwich layer gray calcium and calcium powder sandstone, local sandwich biological ash rock. The rock phase changes greatly, the middle of the basin is all gray-black mudstone, in the southern, northern, western and northern of the Daqing Changxuan sandstone development, the southeastern bulge area of the basin are red mud rock mesoformized fossil layer and powder sandstone thin layer, the central part of the basin is seen in andesite and andesite basalt distribution. The line between Qingshankou formation and Quantou formation is continuous deposition and integrated contact. Apart from the exact Qingshankou formation, which has not yet been seen in Kailu depression area, it is widely distributed in other areas of the basin, but in the north-eastern Suiling area and the western slope area of Tailai-Baicheng, the bottom of the Qingshankou formation is incomplete, and its upper part is directly over the former Cretaceous.

3. Bio-fossil combination characteristics

The fossils, especially the micro-chemical stone, which form the main body of the Songhuajiang River biota, are abundant in the late Cretaceous formation of Songliao Basin. Qingshankou formation of biological diversity characteristics are distinct, a wide variety of fossils, species rich, including ostracoda, conchostracan, gastropoda, fish, charophyceae and plants, such as more than ten categories. The bottom of the Qingshankou formation is characterized by the initial appearance of Triangulicypris torsuosus and its rapid and substantial prosperity, followed by the emergence of key mesothroids such as Cypridea dekhoinensis, C. adumbrate, C. vicina, C. Panda, Limnocypridea copiosa, L. bucerusa, L. inflata et al. important mesothermal fossils[11]. From the view of the mesoform evolutionary genealogy of Quantou-Qingshankou formation, there is a certain inheritance, which is inseparable, which shows the development and prosperity of Cyprideidae. The conchostracan fossils are mainly found in the upper Qingshankou formation, the main molecules are Nemestheria lineata, N. qingshankouensis, N. robusta, N. jiutaiensis, N. fuscata, Jilinestheria nonganensis, J. Qianguoqiensis, J. insculpta, Orthestheria bayanensis, et al[12]. The study concluded that the Mao 206 well of 1st member of Qingshankou formation has Dinogymniopsis - Granodiscus - Filisphaeridium combination; the 2nd, 3rd members of Qingshankou formation has Kiokansium-Dinogymniopsis-Botryococcus combination. Rarely occurring greek spores, follicle powders, microcystic powders, it is speculated that its era should be the late Cretaceous.

Based on the iconic paleontical fossils, the comparison between the Cretaceous in Songliao Basin and the European sea-phase formations has been studied and summarized by previous generations. In the pollen of the plant, the appearance and prosperity of positive pollen is also of great significance of the times, which generally appeared in the Cenomanian period, and developed rapidly and flourished during and after the Turonian period. A small number of positive powders were found in the four
sections (842.07-846.17m) of the Chao 73-87 well spring head group, suggesting that the era of the four sections of the spring was the Late Cretaceous Cenomanian period. In addition, the Qingshankou formation also appeared such as Borealipollis, Plicapollis, Complexiopollis and other quilt plant pollen, Complexiopollis is a mouth and wall layer are more complex orthodontic powder, showing that the Qingshankou formation has late Cretaceous Turonian period after the quilt plant pollen color, which on the other hand implies that the bottom of the Qingshankou formation has entered the late Cretaceous Turonian period.

4. Chronostratigraphy characteristics

The volcanic rock and volcanic debris rock in Songliao Basin are mainly developed in the Lower Cretaceous Huoshiling formation Yingcheng formation, and the main development of the Upper Cretaceous is a set of river phase and lake debris rock, and volcanic rock and volcanic debris rock are occasionally seen in local areas. These volcanic rock and volcanic debris rock measured age data have been the main basis for defining the attribution of the Songliao Basin stratosque era.

The lower 2nd-3rd members of Qingshankou formation in the Jin 6 well develop a set of 191.0 m thick basalt-andesite and andesite basalt with volcanic breccia stratum. Wangjun et al. [14] carried out dating of volcanic rock samples at the 1972.8m of the Jin 6 Well, obtained a mixed sample of 40Ar/39Ar isotope age and isochrone age are 88.0±0.3Ma, and the opposite isochrone age age is 86.1±0.2Ma. Compared to the reference criteria given by the International Commission on stratigraphy (2020), this age data is from the Coniacian period, indicating that the 2nd members of Qingshankou formation has been extended to at least the Coniacian period.

This study carried out systematic volcanic rock age testing in Qingshankou formation, and obtained important strata age data. Among them, the Mao 206 well Qingshankou formation Lake dark mud rock found 3 layers of gray-white volcanic ash thin mezzanine, respectively, appeared at the bottom of the 1st member of Qingshankou formation (1780.0m, 2.93m from the bottom), the top of the 1st member of Qingshankou formation (1705.8m, from the top 3.48m) and the bottom of the 2nd member of Qingshankou formation (1673.0m, 28.52m from the bottom). After testing by the ion probe laboratory of the Institute of Geology and Geophysics of the Chinese Academy of Sciences, three layers of volcanic ash U-Pb isotope harmony and age values were obtained, respectively, 91.35±0.48Ma, 90.05±0.56Ma and 90.40.44Ma, indicating that the bottom boundary of the Qingshankou formation belongs to the Turonian period.

In addition, dating study of volcanic ash from the 1st member of Qingshankou formation in the Chao 73-87 well. From table 1 can be seen, the 15-point zircon 206Pb/238U age obtained by using the zircon Shrimp method is more concentrated, with a weighted average age of 91.06±0.69Ma According to the Cretaceous Strata Division Scheme proposed by the International Strata Commission (2020), the age of the bottom line of the Cenomanian period was 100.5Ma, the age of the bottom boundary of the Turonian period was 93.9Ma, and the age of the bottom boundary of the Coniacian period was 89.8±0.3Ma. Indicates that the bottom boundary of the Aoyamakou group has been extended to the Turonian period.
5. Conclusions

5.1. Attribution of the geological age of the Qingshankou Formation

(1) A small number of orthotype pollen were found in the 4th members of Quantou formation of the Chao73-87 well, suggesting that the era of the 4th members of Quantou formation belonged to the late Cretaceous Cenomanian period; the discovery of orthotype pollen such as Borealipolis, Plicapollis and Complexiopollis in the Qingshankou formation of the Mao 206 well, which suggests that the bottom of the Qingshankou formation has been extended to the Turonian period;

(2) From the sedimentary debris rocks in the Qingshankou formation, obtaining the geological age is 89Ma and 92.8Ma, respectively, according to the reference criteria given by the International Strata Commission (2020), is already in the late Cretaceous Turonian period, and the upper limit has been extended to the Coniacian period. The zircon U-pb isotope harmonic age of the bottom of the Qingshankou formation in the Mao 206 well is 91.35Ma, volcanic ash zircon U-Pb isotope harmony and age is 91.06±0.69Ma of the bottom of the Chao 73-87 well, confirmed that the bottom boundary of Qingshankou formation is roughly equivalent to the lower of late Cretaceous Turonian period; The rock zircon U-Pb isotope harmony and age of the 2nd-3rd members of Qingshankou formation in the Mao 206 well is 90.4Ma, the 40Ar/39Ar isotope age of the 2nd member of Qingshankou formation in the Jin 6 well is 88.0Ma, confirmed that the top boundary of Qingshankou formation has been extended to at least the Coniacian period.

5.2. Qingshankou formation biological prosperity and greenhouse climate

The concentration of oil and gas resources in the middle of the Cretaceous period was an indirect manifestation of biological prosperity at that time. Qingshankou produces ostracoda, conchostracan and other types of palaeontological fossils, its species richness and heterogeneity is the largest in the Cretaceous period, ostracodas often have layered output, indicating the prosperous period of Cretaceous lake life. The Taikang region in the western part of the basin develops bio-fragmentary ash and bio-greystone, indicating the existence of a relatively stable and suitable environment for reef-building organisms. The study of microphytophytes also showed that phytoflora in ancient lakes at that time was also quite prosperous, which constituted the main source of oil in the basins of land-phase lakes. Huang Qinghua and other academics believe that the Cretaceous Cenomanian-Turonian period has extreme greenhouse climate, palynological also revealed that the deposition period of Qingshankou formation is a kind of hot and humid climate, therefore, the cretaceous Qingshankou formation sedimentary period biological prosperity and greenhouse climate has a close cause relationship.
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