Sequence stratigraphic division of the Shisanlitai Formation of Neoproterozoic in Southern Liaoning, China

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Abstract. Sequence stratigraphy is the most important prediction theory in the field of petroleum exploration, and is hailed as a theoretical revolution in geology. At present, countries around the world have begun to pay attention to the study of marine carbonate rocks. The Shisanlitai Formation in Dalian, Liaoning is an important Neoproterozoic stratum in China, with a large number of carbonate rocks. Through comprehensive analysis of the field measured profiles, the sequence stratigraphy of the Shisanlitai Formation was studied. A total of 4 sequence boundary were identified, and 3 sequence, 7 para-sequence sets and 20 para-sequences were divided. It is considered that the Shisanlitai Formation is a platform marginal sedimentary facies. The regional geotectonic and astronomical cyclic methods are used to discuss the environmental evolution of the Ganjingzi Formation. Platform marginal beach → platform marginal slope → platform marginal reef evolution process, and summarized that there were 4 short exposures from the end of the Majiatun period to the Shisanlitai Formation period in the Dalian area affected by the low-amplitude tectonic ups and downs in the late Yangtze cycle 4 sequence boundary and 3 sequences are formed. Through comprehensive and systematic analysis of the sequence stratigraphy and sedimentary evolution of the Shisanlitai Formation, it provides a basis for exploring the oil and gas resources in southeastern Liaoning.

1. Introduction

Marine carbonates are currently a very important exploration area, and the Neoproterozoic is an important marine carbonate formation. Large gas fields have been discovered in the Sinian system in the Sichuan Basin, China, which proves that China’s Neoproterozoic- The Cambrian system has broad prospects for finding oil and gas. Sequence stratigraphy is a theoretical change in the field of geology, and it is also the most important theoretical method in the field of oil and gas exploration.

The Dalian area is located in the southern part of the eastern Liaoning Peninsula and the southernmost point of Liaoning Province. The Neoproterozoic and Paleozoic strata developed in the study area. The Shisanlitai Formation is a set of carbonate-clastic rocks in the Neoproterozoic Sinian, distributed in Dalian, Lushun, Jinzhou, Wafangdian and other places. Previous research work focused more on the
entire Neoproterozoic or a wider range of research objects, or the research focused on paleontology, rock strata division, and event stratigraphy, with few research results on sequence stratigraphy. Zhang Guoren and others made preliminary research work on the Sinian-Early Cambrian stratigraphic framework in the Jinzhou area of Dalian [1]. Meng Xianghua et al. Made a brief discussion on the sequence stratigraphy of the Neoproterozoic strata in the Chinese and Korean plates [2]. Wang Dehai did a systematic study of Neoproterozoic strata in Xuhuai area, Jiliao [3], and Wu Zijie did research on the sequence stratigraphy of Neoproterozoic Ganjingzi Formation [4].

Due to the different research purposes in different periods and the limitations of working accuracy, working methods and data, there are still many disputes on the level, number and internal composition of the Neoproterozoic sequence stratigraphy in Dalian, and the predecessors have not The para-sequence patterns within the sequence and the structural characteristics of the para-sequence group are studied. Therefore, the Sinian system in the Dalian area still needs to be further studied and discussed, especially using sequence stratigraphy theory to discuss the formation of the Sinian system and the depositional environment. In this paper, we use the latest field data and sequence stratigraphy to understand the sequence stratigraphy of the Shisanlitai Formation in recent years in order to explore the Neoproterozoic oil and gas resources in southeastern Liaoning.

2. Geological overview

The study area belongs to the Qaidam-North China Plate (Ⅲ) -North China Land Block (Ⅲ5) -Liaodong Neoproterozoic-Paleozoic Depression (Ⅲ57) -Dalian Neoproterozoic-Paleozoic Depression (Ⅲ57-6)) (Figure 1) [5]. The intrusive rocks in this area are concentrated in the east of Jinzhou, Pulandian, Songshu, Wanjialing, and north of Xingshutun, Chengzitan, and Zhuanghe. Magmatic intrusion has the characteristics of multiple cycles and multiple stages. The rock types are mainly diorite granite and granodiorite, supplemented by diorite, with a small distribution of basic-ultrabasic rocks. The intrusive age is: new Archean, Paleoproterozoic, Mesoproterozoic, Paleozoic, Triassic, Jurassic and Cretaceous, of which the Triassic and Jurassic magmatic intrusion activities are the strongest, and the formed complex bodies are widely distributed and large in area, A large-scale compound rock foundation output.

Figure 1. Location map of earth structure in the study area
The Shisanlitai Formation is a typical platform marginal reef sedimentary structure, which is in integrated contact with the Xiyingyingchengzi Formation. It can be divided into three parts: the lower part is dark gray medium-thick layer micrite limestone, oolitic argillaceous limestone, laminated limestone; central gray, purple micrite limestone, laminated limestone, gray purple, yellow-green shale; The upper part is dominated by purple and yellow-green shale, with interbedded limestone. In this group of rocks, horizontal bedding and lenticular bedding are mainly seen, and the stratified structure is developed. Interference wave marks are seen locally, which is a shallow sea barrier type platform edge reef deposition environment.

3. Sequence division and characteristics
According to the field survey data, comprehensive analysis of lithology, stratigraphic structure, sedimentary structure, rock color and other characteristics, the Shisanlitai Formation is divided into three three-level sequence, which are ZS9-ZS11, of which ZS9 contains 2 quasi-layers Sequence group and 8 para-sequences. ZS10 includes 2 para-sequence sets and 9 para-sequences. ZS11 contains 3 para-sequence sets and 13 para-sequence sets.

3.1. ZS9 sequence
When entering the ZS9 sequence and starting to deposit, the sedimentary environment gradually shifted to the sea and entered the platform marginal beach deposit. Due to the deepening of the seawater, its deposition thickness is relatively thin. The sequence characteristics are shown in Figure 2. The sequence consists of the transgressive system domain (TST) and the high-level system domain (HST). The TST is located in the lower part of the sequence and consists of a para-sequence group, which contains 4 para-sequences. The para-sequence is composed of shale-lime and upward lime circulation. The para-sequence group shows the structural characteristics opposite to that of the para-sequence, and it generally becomes thinner upward. HST is also composed of four para-sequences. The para-sequence is composed of shale and oolitic limestone, with upward oolitic limestone increasing to the top of the sequence as thick oolitic limestone. The bottom of the sequence is an SB2 interface, and the sequence is type II sequence.

3.2. ZS10 sequence
The ZS10 sequence is mainly platform marginal reef deposits, and its corresponding rock stratigraphic unit is the central part of Shisanli. The sequence characteristics are shown in Figure 2. The sequence consists of the transgressive system domain (TST) and the high-level system domain (HST). TST is located in the lower part of the sequence and consists of a para-sequence group, which contains 4 para-sequences. The para-sequence is composed of shale-algae limestone and the cycle of increasing limestone. The para-sequence group shows the structural characteristics opposite to that of the para-sequence, and it generally becomes thinner upward. HST is also composed of five para-sequences. The para-sequence is composed of shale and algal limestone, and the upward algal limestone increases to the top of the sequence as thick algal limestone. The bottom of the sequence is an SB2 interface, and the sequence is type II sequence.

3.3. ZS11 sequence
The ZS11 sequence is located in the upper part of the Shisanlitai Formation, which is deposited on the platform margin beach- platform margin slope- platform margin reef. The sequence characteristics are shown in Figure 2. The sequence consists of the transgressive system domain (TST) and the high-level system domain (HST). TST is located in the lower part of the sequence and is composed of 2 para-sequence sets (PSS1-PSS2), of which PSS1 contains 4 para-sequences and PSS2 contains 5 para-sequences. The para-sequences of both are composed of shale and middle-layer algal limestone, and the cycle of increasing algal limestone is increased, while the para-sequence group is reflected by the backward accumulation type of thinning upward. HST is also composed of four para-sequences. The para-sequence is composed of shale and algal limestone, and the upward algal limestone increases to...
the top of the sequence is a thick layer of algal limestone. The bottom of the sequence is an SB2 interface, and the sequence is type II sequence.

Figure 2. Sequence stratigraphic division structure diagram

4. Sedimentary environment evolution
The Sinian in the Dalian area belongs to the late stage of development and evolution of the Yangtze cycle. At the beginning of the Sinian, the Dalian Basin south of the Wafangdian-Zhuanghe line continued to subsidence, accepting the Sinian carbonate-clastic rock deposition. The Shisanlitai Formation is one of the products of the Dalian Basin settlement. The Sinian Thirteen-Litai Formation in
the Dalian area has experienced the evolution process of platform marginal beach → platform marginal reef → platform marginal beach → platform marginal slope → platform marginal reef. The evolution of the sequence sedimentary environment of the Shisanlitai Formation is mainly influenced by two major factors, the late tectonic movement of the Yangtze cycle and the periodic astronomical cycle. Although the late Yangtze cycle did not have a large tectonic uplift and subsidence, it frequently occurred at low amplitudes. Occasionally occurs when the structure goes up and down. These low-amplitude movements caused four short-term exposures in the late Majiatun-Shenglitai Formation period in Dalian, forming four sequence boundaries, and three tertiary sequences were defined by the interface. The low-level cycles inside the sequence are more affected by periodic astronomical cycles, forming para-sequence, layer-to-layer high-frequency cycles.

5. Conclusion

Using the para-sequence as the basic research unit to conduct sequence stratigraphic studies on the Shisanlitai Formation in Dalian, Liaoning Province, a total of 4 sequence boundaries were identified, and 4 third-order sequences (ZS9~ZS11) were divided. 7 para-sequence sets and 20 para-sequence sets summarize the deposition patterns of the para-sequence sets and the overlapping patterns of the para-sequence sets.

Through comprehensive research, it is believed that the Ganjingzi Formation was formed in the sedimentary environment of the platform margin. Using regional geotectonic and astronomical cyclic methods to discuss the environmental evolution of the Ganjingzi Formation, it is believed that the Sinian Shilili Formation in the Dalian area experienced platform marginal beach → Platform marginal reef → Platform marginal beach → Platform margin slope → Platform marginal reef evolution process. It also concluded that 4 short-term exposures occurred in the late Majiatun period-Shisanlitai Formation period in Dalian area, which were affected by the low-amplitude tectonic ups and downs in the late Yangtze cycle, forming 4 sequence boundaries and 3 third-order sequences.

Acknowledgments

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