Sedimentary Characteristics of Microspar Structure Carbonate in Proterozoic

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Abstract. Microspar Structure carbonate is a special carbonates that developed in Proterozoic. It is filled with uniform, equiaxial and polygonal microsparry calcite (or dolomite) crystals, 5-15μm individual in size, display sharpen lateral boundaries with hosting rocks. According to its origin, microspar structure can be divided into two categories: in-situ and allochthonous. In-situ Microspar Structure almost developed in micrite, calcisiltite, marl, mudstone. Allochthonous Microspar Structure in calcisiltite or calcirudite. Microspar structure based on its petrology features, occurrence identically constrained within middle-shallow gentle ramp and peritidal, particularly the bottom of shallowing- upward cycle in middle-shallow ramp, and storm-base in the ramp is the distal sea-floor limit of microspar formation. Microspar Structure carbonate, with global intention and restrictive quantum distribution range, are favor of aggrandizing accuracy of correlation in Proterozoic.

Keywords: Proterozoic, Microspar Structure, Carbonates, Depositional environment.

1 Introduction

Microspar Structure Carbonate refers to carbonate rock with microcrystal structure or Molar-tooth Structure (MT for short), which is filled with calcite (or dolomite) and is intestinal, banded, spherical or folded. The composition and sedimentary characteristics of MT are different from normal carbonate rocks or cements(Table 1). MT only developed in Precambrian, especially in Proterozoic, and have been found in more than 50 outcrop sections in 20 countries[1-4]. The genesis and formation environment of MT is a hot topic in the world geoscience, but it is difficult to study because it only appears in Precambrian and there is no similar sediment in modern sedimentary environment. Based on the study of petrology and sedimentology, this study discusses the sedimentology and stratigraphic significance of MT in Xuhuai area, Jilin Province, China, combined with Proterozoic microlithite carbonate rocks such as Australian and Norwegian.It is found that the development of MT is limited[2-4]. Although MT - like

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arc strata in rocks first appeared in the late Archean, MT rarely existed in most early Proterozoic strata. Nor did it appear in Phanerozoic strata.

2 Data and Methods

The research is based on detailed field outcrop measurement and description. Fifteen outcrop sections are analyzed to describe the sedimentary environment and explain the diagenetic sequence. The samples are mainly taken from the Neoproterozoic strata. The diagenesis characteristics of 60 thin sections were studied by microscope XPL-20. Fifteen samples were observed by LSM-900.

Table 1. Difference between MT, limestone and cement

Rock type	MT	Micrite or mud limestone	Bright crystal cementation
Composition	Calcite	Calcite, Mud Quality, Etc	Calcite
Structure	Equiaxial, polyhedrdral (or polygon) aggregate, <10 μ m	Generations cryptic crystal or granular aggregate, about 4 μ m; no generation	Various crystals, > 10 μ m; with generations
Mode of occurrence	It mainly occurs in impure micrite or mud limestone	Independent rock formation	Filling the pores between the particles fineness
Pure	Pure, no impurities	Not pure, between the particles of the mud filling	Pure, no impurities
Formation	More complex, various causes, this paper tends to low mg / ca medium conditions, supersaturated caco3 water, in the biological action quickly crystallization formation.	More complex, multi-origin theory: marine erosion cause, chemical or biochemical precipitation and formation.	Usually, under the sedimentary conditions with strong hydrodynamic force, the fine-grained plaster particles between grains are washed out and chemically precipitated in the gap between grains during diagenesis.
Time	Proterozoic Dominated	Any Time	Any Time

3 Result and Discussion

3.1 Macroscopic sedimentary characteristics of MT

According to the way MT appears in the stratum, it can be divided into two categories, namely, primary MT and exotic MT (Fig.1). The primary MT is not transformed and transported after deposition, and the off-site MT refers to the primary MT transformed by waves, tides or storms and formed by transportation and re-deposition.

Primary MT can be divided into four sub-categories: ① Thin strips or bent folded intestines, which are mainly found in silty limestone and micrite limestone. It is several centimeters to tens of centimeters long and 0.2-0.6 cm wide, distributed obliquely or vertically, passing through the thin striation, or being pulled by the striation but not passing through the striation. This type is the most common and widely distributed; ②Filamentous structures are mainly distributed in fine-grained limestone, such as marl and micrite limestone, which are 1- 8 cm long and 0.1-0.3 cm wide and vertical or nearly vertical to the bedding plane; ③Reticular or interlaced, and the MT produced in several directions crosses each other; Common in silty limestone and dolomite limestone; ④"Shrimp-like" is mainly found in Mesoproterozoic Gaoyuzhuang Formation in Jixian County, Tianjin, with a large individual.

MT in different places can be divided into four categories according to its genesis and morphological characteristics: ①pea-shaped or short columnar. This form of MT is generally associated with storm bamboo-leaf limestone or hilly cross bedding, especially the coarse-grained part of storm grain sequence layer. Usually, MT can occur in many kinds of micro-cycle sequences, the most common one is the micro-cycle sequence related to storm action. The characteristics of this kind of micro-cycle sequence are as follows: the bottom of the cycle is storm gravel limestone composed of MT debris from different places, which can be rich in integrated layers and has good lateral stability; Upward, it becomes an in-situ MT coexisting with storm conglomerates, with a large vertical plane, and the top is micrite limestone or marl with less or smaller MT structure; ② Internal clastic, rich in integrated layers. Generally, it is fine gravel, which is arranged along or near the bedding, and is often located at the bottom of the micro-cycle sequence; ③The "pebble-like" MT in different places is mainly an MT aggregate, which is located in a spherical gravel with a diameter of 10-30cm, and the MT can be clastic or a strip with vertical internal striations. ④Spherical "oolitic", with an annular cladding of surrounding rock, similar to oolitic grains, with MT as the core, but larger than oolitic grains, with a diameter of 0.5-2.5cm.

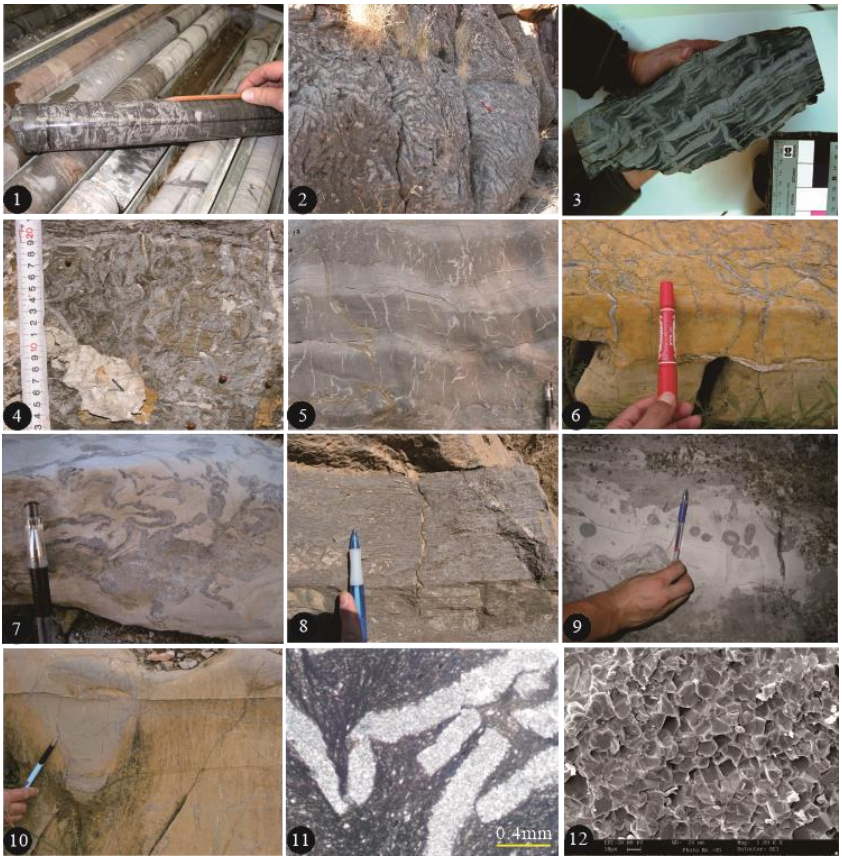

Fig. 1. Macro and micro characteristics of MT

1, 2- Bitter Spring Formation of Amadeus Basin, Australia; 3- Batsfjord Formation of Finnmark area, Norway; 4-Wanlong Formation of Qinggouzi, Jilin province; 5-Jiudingshan Formation of Liangtang, Jiangsu Province; 6-Jiayuan Formation of Xuzhou, Jiangsu province; 7-Gaoyuzhuang Formation of Jixian, Tianjin; 8-Gaoyuzhuang Formation of Pingquan, Hebei province; 9-Gaoyuzhuang Formation of Banbishan, Jixian, Tianjin;10-Zhaowei Formation of Xuzhou, Jiangsu province; 11-Wanlong Formation of Laoling, Jilin province; 12-Xingmincun Formation of Jinshitan, Dalian, Liaoning province

3.2 Structural characteristics and composition of MT

Microscopically, the boundary between MT and "surrounding rock" is clear. The microcrystals are composed of clean, bright, uniform calcite (or dolomite) with a size of 5-15μm, and a small amount of microcrystals are recrystallized. Under scanning electron microscope, the isomorphic and homogeneous structure of microcrystals is clearer.

The rock containing MT consists of two parts: microcrystal calcite (or dolomite) and matrix. Petrological statistics show that terrigenous debris is generally less than 50% in the composition of rock matrix, and the main components are argillaceous, terrigenous silt and a small amount of pyrite, sometimes containing a small amount of powder crystal or sand debris. Mud content is less than 35%, terrigenous silt content is generally less than 25%, and pyrite content is less than 2% (Table 2). This shows that the massive input of detrital materials is not conducive to the formation of MT. In rocks where MT develops, the content of terrigenous components is usually less than 25%. When the terrigenous materials exceed 50%, MT no longer develops in large quantities.

Table 2. The material component of MT deposit strata

	Strata	Siltstone	Mustone	MT	Powder crystal	Sample
Jiangsu-Anhui	Jiayuan Formation, Zhaoxu	5-37/26	2-10/4	7-20/16	40-50/46	9
	Zhaoyu Formation, Zhaoxu	0-21/4	3-8/6	15-30/23	55-70/62	14
	Niyuan Formation, Zhaoxu	0-1/0.5	1-20/9	10-60/26	65-88/73	16
	Jiudingshan, Liangtang	0-2/1	5-18/12	20-40/35	50-70/63	13
	Zhangqu Formation, Lingbi	0-0/0	2-30/4	10-85/27	5-90/57	24
	Weiji Formation, Lushan	0-0/0	3-10/5	45-95/70	2-45/21	17
	Wangshan, Heiwowo	0-1/1	2-13/4	8-55/26	15-65/32	22
Jilin-Liaoning	Xingmincun, Jinshitan	0-2/1	0-30/10	3-80/17	0-94/80	23
	Wanlong, Qinggouzi	0-20/2	0-35/2-3	1-77/37	35-99/76	16
	Wanlong,Laoling	0-94/5	0-35/8	1-70/37	0-90/50	16
	Bandung, Erdaojiang	0-70/8	0-20/5	10-93/60	0-45/15	25
	Yingchengzi, Qipanmo	0-0.1/0	0-30/5	0.5-70/25	0-98/55	25
	Guanling, Southern Dalian	0-2/0.73	2-15/6	1-85/33	0-98/79	36
Shandong	Shiwangzhuang Formation	0-15/2	2-13/8	4-20/9	0-85/75	7
Tianjin	Gaoyuzhuang, Jixian	0-0/0	10-70/25	5-65/15	20-60/45	20
	Gaoyuzhuang, Banbishan	0-0/0	10-50/35	1-25/12	15-40/35	12
Hebei	Gaoyuzhuang, Pingquan	0-5/2	5-35/20	5-90/45	35-55/40	16

Note: a-b/c.a represents the minimum value, b represents the maximum value, and c represents the average value; Because the content of pyrite and organic matter is very small, this statistic is not the focus.

There are both in-situ and off-site Microspar Structure Carbonates. In-situ MT is generally distributed in impure fine-grained rocks such as micrite, silty micrite limestone or marl, silty mudstone, etc., and the main material composition is microcrystal calcite, with the content ranging from 0.5 to 100% (Table 1). Most of them are single minerals, and they are composed of uniform, equiaxed or polygonal calcite microcrystal aggregates with clear boundaries on the plane. The particle size is about 10μm, and some of them contain siliceous detritus and pyrite cubes, which are in abrupt or dissolved contact with the matrix.

3.3 Sedimentary environment of MT

Although some people think that carbonate rocks containing MT are intermittently exposed and deposited in shallow water environment, most scholars think that MT was formed in shallow water and subtidal environment[3-4]. For example, Smith pointed out that MT developed in a deeper and quieter environment than polycyclic stromatolites. James thinks that MT is a sign of the subtidal facies in shallow water[5]; When Rossetti studied MT in Mauritania, he also thought that they were distributed in the subtidal shallow carbonate environment. Sediments are always submerged, and the obvious condition around them is low energy. On the basis of predecessors' work, the author has done a lot of field observation and indoor sedimentology research on Neoproterozoic MT-bearing structural strata in Xuhuai, Hebei, Tianjin and other places, and analyzed the sedimentary environment of main sections. The research results confirm Meng Xianghua's and Ge Ming view that MT was formed and developed in the stable gentle slope sedimentary environment on the edge of craton platform[4, 6].

MT was formed and developed in the subtidal environment and some intertidal environments of craton shallow continental shelf. Therefore, carbonate rocks containing MT have many common characteristics in rock composition, but because they are in different sedimentary facies zones under the same similar sedimentary background, the sedimentary thickness, matrix composition, MT content and morphology of such rocks are different. Because MT is homologous to the surrounding sediments, the formation environment of MT can be studied through the petrological properties of the matrix, sedimentary structure and MT strip morphology.

3.4 Geological significance of MT deposition

By comparing microcrystalline carbonate rocks in different regions and different periods, we can understand the earth environment and biological activities in Proterozoic. The main evidence comes from geochemical environmental analysis, elemental dating and paleoenvironmental analysis.

Most of the discovered MT appeared in the specific historical period of 850-720Ma. Its extensive development in the Middle-Neoproterozoic, especially in the Neoproterozoic, is related to the evolution from the inanimate world to the living world in the historical development of the earth[3-4]. The historical stage of the formation and development of MT is just between the Archean lifeless marine world-a transitional historical period from the sedimentary period of inorganic carbonate aragonite and aragonite volcanic ash to the biological explosion period of carbonate deposition of Phanerozoic crusted skeletons. According to the study of Meng Xianghua, the $^{87}Sr/^{86}Sr$ isotopic ratios of the Neoproterozoic MT in the China-Korea plate, such as the carbonate rocks in Wanlong Formation, Yingchengzi Formation and Xingmincun Formation, are determined, and the locations of the time variation curves are all greater than 750Ma. This shows that the disappearance of microcrystal carbonate rocks on the earth may be 700Ma ago. It has the characteristics of specific time-limit distribution range, which is of great significance for solving Precambrian

stratigraphic correlation and is conducive to improving the accuracy of Proterozoic stratigraphic correlation[3-6].

In recent years, based on the study of microstructure and geochemical characteristics of MT, it has been proved that it has the characteristics of early diagenesis and retains the information of original sedimentation[7-9], which may be the chemical precipitation involving microorganisms. Therefore, it has become a consensus that the formation of MT is closely related to specific paleo-marine chemical conditions. The genetic model of MT established in the early stage can perfectly explain the material source, formation process and controlling factors of MT microcrystal calcite.

There are few fossils in Precambrian strata, and the rock strata are complex and changeable. In addition, the lithostratigraphic unit itself is diachronic, so it is difficult to accurately define the sedimentary environment only from the lithofacies. However, MT is widely distributed and have complex and diverse shapes, and have a wide development environment in the shallow sea shelf of Precambrian platform, from shallow water to shallow sea shelf(Fig. 2). Therefore, it can be used as a marker of subtidal shallow water slope facies, which is beneficial to the analysis of the sedimentary environment and sedimentary facies of Precambrian[10]. Because of the time-limited distribution of MT, it can provide basic geological basis for the correlation of Proterozoic strata lacking biological fossils.

4 Conclusion

(1)MT is mainly in the form of thin strips or bent folds, intestines, filaments, beans or short columns, which can be divided into in-situ MT deposits and off-site MT deposits, all of which are composed of polygonal calcite (or dolomite) grains with uniform size of 5-15μm.

(2) The macro-micro-cycle characteristics and petrological characteristics of MT indicates that it was mainly formed and developed in the shallow tidal environment or tidal flat environment of the stable craton, especially at the bottom of the upward shallow cycle in the upper part of the middle-shallow gentle slope, and it was often destroyed by waves, tides or storms, forming hilly staggered layers and storm rocks composed of broken MT debris.

(3) The transitional or symbiotic spatial relationship between MT and stromatolite may indicate that microlite may be a similar organic matter or algae-derived substance. Therefore, microbial activity may be the main cause of MT production.

(4) MT has a specific time-limited distribution range (mostly concentrated in 850-720Ma), which is of great significance for solving Precambrian stratigraphic correlation and improving the accuracy of Proterozoic stratigraphic correlation.

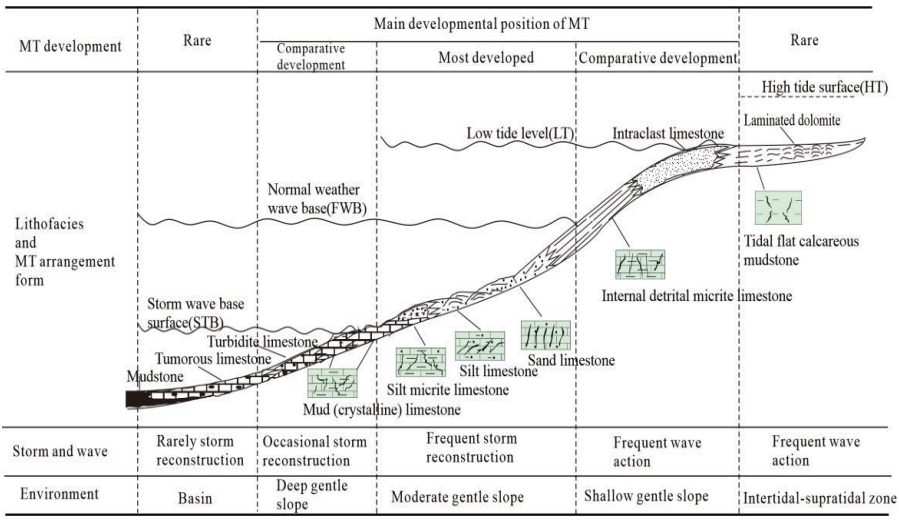

Fig. 2. Sedimentary background and development characteristics of Proterozoic MT[10]

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