Environment, Resource and Ecology Journal (2023)
Clausius Scientific Press, Canada

DOI: 10.23977/erej.2023.070205
ISSN 2616-3756 Vol. 7 Num. 2

Research of Cherts in Longjiayuan Formation of Mesoproterozoic

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Keywords: Western Henan; Mesoproterozoic; Chert; Silicon Source; Silicalite Origin

Abstract: The Longjiayuan Formation of the Mesoproterozoic Guandaokou Group in the southern margin of North China Craton is widely developed layered, banded and massive cherts, which are good materials for studying the deep time climate and marine environment in the early Mesoproterozoic. By means of field profile measurement, petrological analysis and geochemical analysis, the cherts in Longjiayuan Formation were studied. The results show that the cherts are evenly distributed in the section, and can be divided into layered-bended cherts, deformed layered cherts, nodule-crumby cherts and chrysanthemum cherts. Siliceous components have two sources of hydrothermal and Ocean dissolved silicon (DSi). Cherts are formed by biochemical deposition accompanied by low temperature metasomatism, and experienced three stages: sedimentary stage, early diagenesis stage and diagenesis stage. During the deposition stage, the siliceous components in seawater are mainly deposited in the form of siliceous gel; in the early diagenesis stage, unconsolidated siliceous sediments accumulate in low-lying areas under the action of gravity, and form some storm-derived cherts under the action of external forces such as storms. During the diagenetic stage, siliceous sediments are gradually consolidated by diagenetic compaction. Layered cherts are formed at gentle terrains and agglomerated cherts are formed at low-lying areas. This study provides evidence for further restoration of ancient oceans and paleogeographic information during this period.

1. Introduction

Cherts is a kind of sedimentary rock composed of authigenic siliceous minerals such as cryptocrystalline quartz, flint and chalcedony, and the content of authigenic siliceous minerals is not less than 70 %[1-3]. The formation of cherts requires sufficient siliceous sources and specific geochemical conditions[4-7]. Its single component and stable structure make it have a strong ability to resist the later transformation, which is less affected by the later diagenesis, and can better preserve the geological information during its formation. Cherts mostly appear in the key geological periods of major changes, and mostly represent important geological evolution stages[8-9]. Mesoproterozoic formed a stable period of nearly one billion years due to low and stable atmospheric oxygen content and nearly stagnant biological evolution[10-11]. It is known as ' Boring billion ' (1.8~0.8 Ga)[12-16]. A large number of Mesoproterozoic siliceous banded carbonate rocks are preserved in the Xiong 'er Basin on the southern margin of the North China Craton, which can

provide some evidence for further revealing the Earth's supergene environment and paleogeographic evolution during this period.

In this study, we combined the synergistic indication significance of petrological methods and geochemical methods to classify the Mesoproterozoic Guandaokou group in western Henan. We also used geochemical indicators to determine the siliceous source of chert in Longjiayuan formation, discussed the siliceous enrichment-deposition system in the study area, and used siliceous deposition events to provide an important basis for the evolution of Mesoproterozoic marine environment in the study area.

2. Geologic Setting

The Longjiayuan Formation of the Guandaokou Group is mainly distributed in the Lushi, Lingbao, Luanchuan areas of Henan Province and the Luonan area of Shaanxi Province. It is a set of thick siliceous dolomite and stromatolite dolomite shallow sea carbonate deposits[14]. The bottom is a combination of quartz sandstone and sandy dolomite; the lower part is gray-gray white laminated dolomite and thick layered dolomite; the middle part is siliceous dolomite, siliceous band dolomite, gravel dolomite and stromatolite dolomite; the upper part is a combination of light gray algal reef dolomite and thick dolomite. The lithology and thickness are relatively stable in the Shimen-Duguan syncline, and the sedimentary environment is the tidal flat facies of shallow sea carbonate platform[6]. The bottom age of Longjiayuan Formation is about 1.59-1.54 Ga[7]. This study mainly focuses on the survey and field geological profile measurement of the siliceous enrichment layer the Longjiayuan Formation.

3. Profile Characteristics

The measured section is located in Lingbao City, Henan Province. The section in the group is exposed completely, which is in unconformity contact with the underlying alpine river group and in conformity contact with the overlying Xunjiansi group. The siliceous bands and stromatolites appear alternately on the section, which can be divided into three sections according to the lithological changes. Among them, the development of chert of Longjiayuan Formation is the best in the whole group, and its lithology shows the transition from micritic dolomite to powder dolomite from bottom to top. The total thickness of the section is 200 m. It is mainly a set of siliceous dolomite, and locally develops neritic carbonate deposits dominated by stromatolites. A large number of synsedimentary structures were found in chert during field measurement.

4. Petrological Characteristics

Through field profile and indoor analysis, it is found that the morphology of chert the Longjiayuan Formation mainly includes lamina-banded, deformed lamellar, chrysanthemum-like and nodule-mass.

Laminated-banded chert is evenly distributed on the profile, which is the main type of chert Longjiayuan Formation. The thickness of siliceous layer≤ 0.5 mm is lamellar, and> 0.5 mm is banded. The lamellar chert extends not far horizontally on the profile and is in transitional contact with the dolomite surrounding rock; the banded chert is macroscopically characterized by light and dark stripes with a thickness of 10-40 mm, which has a clear boundary with the microcrystalline dolomite surrounding rock.

The deformed layered chert is developed in a small amount at the lower part of the profile, which is characterized by a large area of banded siliceous layer with co-depositional deformation.

The nodules-masses are common in the middle and lower part of the profile, mostly lenticular-

ellipsoidal, with obvious contact with the surrounding rock, and the interior is mostly concentric circles alternating white and sooty.

The chrysanthemum-like chert occasionally appears above and below the profile, showing radially arranged tabular siliceous gravels with a thickness of 0.3-1.6 mm.

5. Discussion

5.1 Silicon Source

The ratio of Fe/Ti and Al/ (Al+Fe+Mn) can well judge the sedimentary water medium conditions of chert[10], which is an important index to distinguish the source of siliceous. The Al-Fe-Mn triangle diagram and Fe/Ti-Al/ (Al+Fe) diagram of chert show that most samples fall into the hydrothermal sedimentary area, indicating that the siliceous components in the study area have both hydrothermal and non-hydrothermal sources. This is consistent with the results that the Middle Proterozoic chert in the northern margin of North China has two siliceous sources of silicon-rich hydrothermal and terrestrial material weathering[14]. The Fe_2O_3/TiO_2-$Al_2O_3/(Al_2O_3+Fe_2O_3)$ diagram shows that the samples are mostly invested near the mid-ocean ridge area, indicating that the source of the siliceous components has a certain correlation with the deep ocean hydrothermal fluid. The REE curve of Chert is a slightly right-leaning 'flat type ', indicating that siliceous sediments have the characteristics of both hydrothermal and normal seawater deposition[10-12]. No obvious trace of terrigenous clastic particles was found in the samples of the first member of the Longjiayuan Formation under the microscope, indicating that the non-hydrothermal siliceous components were not directly derived from terrigenous recharge.

In summary, the siliceous source of most samples of chert the Longjiayuan Formation is composed of silicon-rich hydrothermal solution and ocean DSi. The contribution of dissolved silicon is at a low level when the hydrothermal activity is relatively intense, and it is dominant when the hydrothermal activity is weak.

5.2 Formation Process of Cherts

The whole formation process of chert can be divided into sedimentary period, early diagenesis period and diagenesis period.

A large amount of dissolved silicon from deep hydrothermal fluid carrying and early continental weathering in the seawater formed siliceous colloids ($xSiO_2 \cdot yH_2O$)[15] under special marine chemical conditions, which deposited siliceous colloids under gravity and formed transitional alternating deposition of siliceous sediments and dolomitic sediments. Due to the shallow water depth of the shallow sea carbonate platform, the seabed sediments are more susceptible to the disturbance of the sea storm, and the siliceous sediments are broken to form chrysanthemum-like chert[16]. In the deep water area, the storm disturbance is weak, and chert appears plastic bending deformation in shape and becomes a deformed layered chert. The discovery of chert indicates that the storm events occurred frequently during the deposition of the first member of the Longjiayuan Formation, which is consistent with the conclusion that the North China Craton was located near the equator with frequent storms at~1.5 Ga[2].

In the early diagenesis stage, siliceous sediments have not been fully consolidated, and they will still deform due to external forces such as storms and earthquakes. In the diagenesis stage, siliceous sediments begin to suffer from compaction, and siliceous sediments deposited in different terrains will undergo different diagenetic compaction processes. Due to the accumulation of more siliceous sediments in low-lying areas, this part of siliceous sediments will receive more stress extrusion and form a series of lenticular cherts during diagenesis and compaction. The siliceous sediments in the

gentle position are evenly stressed, and the formed cherts are mostly stable layers[7].

6. Conclusion

(1) The chert of Longjiayuan Formation is well developed and can be divided into four types: lamellar-banded chert, deformed lamellar chert, nodule-mass chert and chrysanthemum chert, among which lamellar-banded chert is the most important type.

(2) The chert of Longjiayuan Formation contains two sources: silicon-rich hydrothermal solution and oceanic DSi.

(3) The chert of Longjiayuan Formation is the product of sedimentation-diagenesis. The dissolved silicon in seawater slowly aggregates in the form of siliceous colloids to form layered siliceous sediments, which develop into laminar-banded and nodule-mass chert according to different sedimentary substrates. The layered and banded siliceous sediments form chrysanthemum-like and deformed layered chert under the influence of external forces such as storms.

Acknowledgements

The authors gratefully acknowledge the financial support from HPU.

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