Macro-micro features of microbial carbonates affected by volcanism in lower Cretaceous Shipu Group in Zhejiang Province, East China

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Abstract. Based on macroscopic observations of outcrop, microscopic examination of thin sections, Field Emission Scanning Electron Microscopy (FESEM) imaging analysis and Energy Dispersive X-ray Spectrometry (EDS) analysis, nine units of microbial carbonates has been recognized in Lower Cretaceous Shipu Group and their thicknesses increase gradually upwards as the volcanism strength decreasing. Unit 7 is the thickest association of microbial carbonates-volcanics. These microbial carbonates consist of stromatolites, spherulites and laminated micorbialites with common recrystallization and local dolomization and analciritization. Thanks to intensive silicification, microorganisms have been preserved in crystal lattice so well that the original microstructure even the chamber of microorganism can be observed clearly through Field Emission Scanning Electron Microscopy (FESEM) imaging analysis. Macrostructure of microbialites are massive, domal or laminated and micro structure of them are fanshaped, wavy, crenulate or spherical.

1. Introduction

Although many papers about microbialites found through the geological record have been reported[1-6], microbial carbonates developing intermittent period of volcanic eruption remains elusive. This paper aims to describe the macro-micro structures of microbial carbonates influenced by volcanic activities which is a kind of unique and relatively complicated lithofacies. With the advent and application of new high-resolution microscopic, investigations of microbialites could yield additional information regarding original texture and subsequent diagenesis. The Shipu microbial carbonates outcrop section, which is commonly termed the Shipu limestone, is located at Shipu town, Xiangshan county in eastern Zhejiang Province on the coast of southeast China along the coastal lowlands of the western Pacific Ocean[7](Figure 1). The well-preserved carbonate microbialites has not been investigated extensively until now. This microbial carbonates-volcanics provides an excellent example to investigate the macro-micro structures of microbial carbonates influenced by volcanic activities.

2. Geological setting and Stratigraphy

The study area is located in Shipu Town, Xiangshan county, Zhejiang Province (Figure 1). The base of
the section has faulted contacts with the volcanic breccia and ignimbrite of the Lower Cretaceous Moshishan Group, and the top is covered by Quaternary sediments.

As shown in Figure 2, the total thickness of the Shipu section is 150m. The lower part of the section (0~30m) consists mainly of volcanic agglomerate, volcanic breccia and tuffaceous sandstone. And in the middle part of the section(31~105m) contains mainly silicified tuffaceous sandstones, silicified tuffaceous siltstones, rhyolite, lava, silicified tuffites and microbial carbonates which have been silicified partly. In contract, the upper part(106~150m) is composed mainly of silicified tuffites, microbial carbonates and silicified tuffaceous siltstones, these microbial carbonates also have been silicified partly. There are nine units of microbial carbonates in the section and their thickness increase gradually upwards because the volcanism strength decreased gradually(Figure 2).

3. Macro structures
Former scholars thought that Shipu section belonged to transitional sedimentary environment which
was a tidal flat or restricted bay. After each stage of volcano eruption, there were some toxic substances such as cuprum element which made most macro-organisms can not to survive. However, unconsolidated volcano ashes and water contained abundant nitrogen, phosphorus, kalium and so on. These elements can provide ample nutrition for development of microorganisms. The biggest microbial reef is 1.8m wide and 1.2m tall. Reef-building organism are mainly algae and Serpulidae and they exist meanwhile or separately. Clustered serpulidae mostly are coated by algae. These microbial reefs developed joining with adjacent one or individually. The microbialite facies are mainly stromatolites, laminated microbialites and spherulites. Based on macroscopic observations of outcrop, there are mainly three kinds of macro structures of microbialites in the Shupu section: (A) massive; (B) domal; (C) laminated (Figure 3).

4. Micro structures

Based on microscopic examination of thin sections and according to Bahniuk(2015)\(^5\), four types of micro-structure of microbialites in Shupu section have been recognized: (A) fanshaped; (B) wavy; (C) crenulate; (D) spherical(Figure 4).

Because of the intensive silicification, the original texture of microorganism has been preserved very well. Some freshly broken and polished chips(by Wide Beam Argon Ion Polishing Instrument) of laminated structure in stromatolites were prepared for Field Emission Scanning Electron Microscopy(FESEM) imaging analysis. These samples were all coated with platinum for surface texture analysis and Energy Dispersive X-ray Spectrometry(EDS) analysis. These analyses were conducted in the Key Laboratory of Carbonate Reservoirs, CNPC, China.

Figure 3. Outcrop photos showing different macro structures of microbial carbonates in Shupu section 
(a) Massive. (b) Massive. (c) Domal. (d) laminated.
Figure 4. Photomicrographs showing four main kinds of micro-texture of microbial carbonates. (a)-(b) Fanshaped. (c)-(d) Wavy. (e)-(f) Crenulate. (g)-(h) Spherical. 10X, plane-polarized light and cross-polarized light. These spherulites show cross extinction in cross-polarized photograph(pointed by white arrow).The black square is pyrite.

As shown in Figure 5, a stromatolite sample was chosen to search for the microorganism which may hid in the darker lamina(red square, Figure 5a). Under plane-polarized light, photomicrograph shows stromatolite presents well preserved morphology(Figure 5b). Many microorganism remains can be seen in FESEM photomicrographs which display darker colour(Figures 5c–e), and some looks like spherical(Figure 5D); some seem like a cellular network(Figure 5e). In calcite crystal lattice, some microorganism are preserved so well that the chamber can be seen clearly(Figure 5e). Energy Dispersive X-ray Spectrometry(EDS) analysis shows the carbon element content is high up to 67.6wt%(Figure 5f).
Figure 5. (a) A hand specimen showing stromatolite lamina with different colours and darker lamina may contain algae and other microorganisms (the lower left corner is a fingernail). (b) Photomicrograph of stromatolite showing crenulate textures, 1.25X, plane-polarized light. (c) Field Emission Scanning Electron Microscopy (FESEM) image showing microbial remains (darker). Sample was not polished. (d) FESEM image showing spherical microorganisms. Sample was not polished. (e) FESEM image showing some preserved well microorganism with clear chamber in calcite crystal lattice. Sample was polished. (f) Energy Dispersive X-ray Spectrometry (EDS) analysis showing the carbon element content of microbial remains is high up to 67.6wt%. The detecting point is shown in (E) with a red rhombus.

5. Conclusion

(1) Nine units of microbial carbonates has been recognized in Shipu section and their thickness increase gradually upwards as the volcanism strength decreasing. These microbial carbonates consist mainly of stromatolites, laminated microbialites and spherulites.

(2) Based on macro-scopic observations of outcrop, there are mainly three kinds of macro structures of microbialites in the Shipu section: (A) massive; (B) domal; (C) laminated.

(3) Four types of micro-structure of microbialites in Shipu section have been recognized: (A) fanshaped; (B) wavy; (C) crenulate; (D) spherical (Figure 4).

(4) Owing to intensive silicification, microorganisms have been preserved in crystal lattice so well
that the original microstructure even the chamber of microorganism can be observed clearly through Field Emission Scanning Electron Microscopy (FESEM) imaging analysis.

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