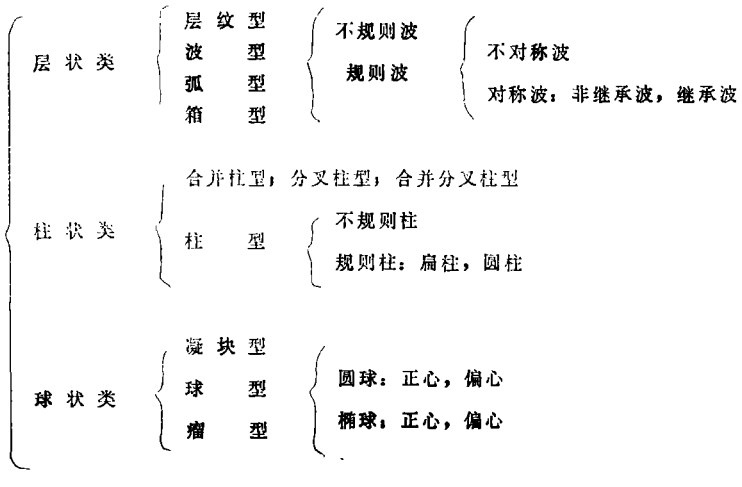
金属硫化物的沉淀。

矿床矿物包裹体研究发现本区存在温度为170—220℃、盐度达16.5%的热卤水，它对铜质的溶滤、重溶与运移，对沉积成岩铜矿层的生成起了重要的作用。

表1 藻叠层石的分类



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ENVIRONMENT SIGNIFICANCE OF ALGAL STROMATOLITES AND THEIR RELATION WITH COPPER ORE FROM LUOXUE FORMATION OF KUNYANG GROUP IN DONGCHUAN, YUNNAN*

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Copper deposits of Dongchuan occur in the algal reef dolomites of the Luoxue Formation of Kunyang Group in the Kangdian Axis. This time, four stratalithofacies sections (Mazhudong, Tangdan, Laobeichong, Luoxue, Youzhafang and Mianshan, Yinmin) have been measured, lithofacies in gallery (Luoxue and Yinmin) have been mapped, morphology and distributive character of the algal stroma-

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tolites, showing lithofacies-paleogeographic environment and relation with copper mineralization, have been studied in Dongchuan District.

Ⅰ. Morphologic Character and Classification of Algal Stromatolites

There are two methods, morphology and paleontology, for the classification and name of the algal stromatolites. We used the former[1—3], [6—9].

The algal stromatolites have been classified three classes by their three-dimensional shapes into lamellar, cylinder and sphere, and each has been sub-classified into some forms according to the details of variety in the stromatolithic shapes. (Fig.1):

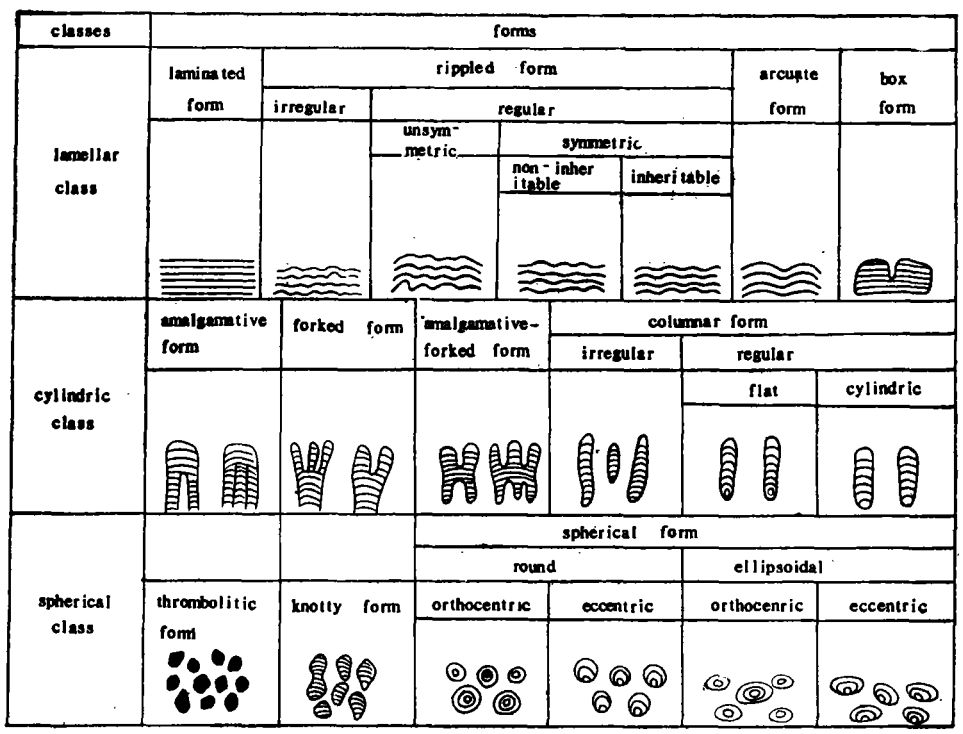

Fig.1 Classification of algal stromatolites

1. Lamellar stromatolites

This class occurs in lamellar in large area and the spreading direction of principal laminae of lamellar stromatolites generally parallels with the rock formation. It has been sub-classified into four forms by shapes of the principal laminae:

(1) Laminated form

The principal lamina is straight or broken-line, forming lamellar, i.e. stripped cryptalgalaminate (Photo 2).

(2) Rippled form

The principal lamina is rippled. It has a wavelength of 1—10cm and a wave-height of 0.5—5cm. It may be divided into two subforms: irregular and regular

wave. The latter may be subdivided into unsymmetric and symmetric wave. The symmetric wave may be done into inheritable (Photo 1) and non-inheritable wave.

(3) Arcuate form

The principal lamina is arcuate. It has an arcuated-length of 50—150cm and an arcuated-height of 5—30cm with mostly inheritable superimposition.

(4) Box form

The principal lamina is vertical superimposed of box form which has a length of 25—50cm and a height of 5—12cm.

2. Cylindric stromatolites

This class is cylinder in three-dimensional shapes. It is made of hemispherical principal-laminae in longitudinal superimposed. Such cylinders in dense heaps have mostly been reef. This class can be subclassified into four forms according to its fork, regularity and size.

(1) Amalgamative form

2-4 small cylinders (diameter of 5—20cm and 30—60cm in height) were upwards amalgamated into a bigger cylinder.

(2) Forked form

A big cylinder was upwards forked into some amall cylinders.

(3) Amalgamative-forked form

The cylinder was amlgamative at the middle, but forked at the both ends.

(4) Columnar form

The column is neither amalgamative nor forked, Each of the columns arranges in verticality to the rock formation(Photo I-2, 4). The form may be divided into irregular column (which is expansive and contractive) and regular one (which is not expansive and contractive). The latter varies in size of column: the big ones are 40—70cm in height, 20—40cm in diameter and principal laminae from 2 to 7cm in arc -height; the middle ones 40—100cm, 5—20cm and 3—5cm (Photo 2); the small ones 40—80cm, 1—5cm and 1—3cm; the smallest ones 0.1—0.5cm, 0.1—0.3cm and less than 0.1cm.

The cross section of the column has flat-cylindric shape in which the principal lamina approximates to ellipse besides cycloid.

3. Spherical class

(1) Thrombolitic form

It is a form of irregular lump whose principal lamina is not clear or is absent. It is 1—5cm in diameter and is difficult to distingush it from the thrombolite.

(2) Knotty form

The form is knotty or gyroidal, its principal lamina is superimposed in semi-involution. It is 2—7cm in diameter.

(3) Spherical form

This form is round or ellipsoidal, its principal lamina in spherical crust is enveloped and superimposed round a center from inside to outside. The center is

usually made of rock fragments or grains (Photo 3). Such form can be subclassified into two subforms: the orthocentric and the eccentric.

Ⅱ. Environmental Significance of Algal Stromatolites

Some research workers hold that the morphologic variety of the algal stromatolites closely relates to the hydrodynamic conditions, i. e. stromatolithic shapes have a significance of environments showing sedimentary facies. According to the foreign studies on the stromatolites in morphology in recently sedimental environments[5—7] and the domestic studies in Sinian Period of Yanshan[1], the results of the cryptoalga studies in Triassic period of the northwestern part of Sichuan, China[3]; the synthetic recount on "Classification and Environmental Significance of Cryptoalgal Carbonates" (Zeng Yunfu, 1981)[1], and combining the sedimental character with Luoxue Formation in Dongchuan, Yunnan, we analysed the environment forming algal stromatolites as follows:

1. Lamellar class

(1) Laminated form

This form referred to striped cryptalgalaminate. The carbonate sediments of recent blue-cryptalgalaminate generally develop in the upper part of the close intertidal-zone and spread out in the micrite flat composed of carbonates from the supratidal zone[3], but some of them can also develop in the lower part of the intertidal zone or subtidal zone, where the base is smooth and the water is calm. This form especially indicates the zone where the activity of wave and tide is weak. Some of them develop in pink dolomite in this region and with gypsum crystals[2], which shows that there is a supersaline water area and has an exposed sign.

(2) Rippled form

According to the studies on recent and ancient stromatolites, it is held that the rippled form develops in the mud flat composed of carbonates in the upper part of intertidal zone, especially in the bay in which the sea water was partly trapped by barrier and the wave activity was weak[3], [9]. The unsymmetric rippled form shows the water flowed gently[8].

(3) Arcuate and box forms

Arcuate and box forms in recent times mostly develop in very shallow-water to intermittently exposed environments, They associate with middle column stromatolites. It shows that the algal laminae were washed and parted in various degrees by the tide.

2. Cylindric class

(1) Amalgamative, forked and amalgamative-forked forms

These forms generally develop in the moist environments of hollow of the lower part of intertidal zone or in the intermittently exposed algal flat[1]. They develop in the blue- grey dolomites, with algal fragments and breccias, and interca-

1) 曾允孚，1981，隐藻类碳酸盐岩的分类及环境意义

late with columnar stromatolites. It shows that it is a turbulent environment of the wave current at the lower part of intertidal zone.

(2) Columnar form

This form generally develops in the turbulent environment of the wave current, such as that in the cape beach of Shark Bay, Western Australia. In this region, the dolomites bearing columnar stromatolites present blue-grey, with bamboo -leaf-shaped brrccias and algal fragments. It indicates the turbulent character at the subtidal. The small and flat columns of stromatolites represent deep water environment at the subtidal. There is a directional relationship between the axis of flat column and the flow of wave. The arc-height of the principal laminae of column is in direct proportion to the intensity of wave action.

3. Spherical class

This class develops, in general, in the part of intertidal zone to subtidal environment where the current is strongly turbulent[3].

(1) Thrombolitic form

This stromatolite is similar to thrombolite. It is of wide distribution, but mostly develops in the lower part of intertidal zone or subtidal environment, where the wave current is gentle or turbulent. In this region, it occurs in the carbonaceous dolomite, which shows the gentle environment at the subtidal.

(2) Knotty form

This form develops in the subtidal environment in which the wave current is frequently turbulent.

(3) Spherical form

This form develops in the lower part of intertidal zone to subtidal environment where the wave current is strongly turbulent. The current presented by the round subform is more turbulent than by the ellipsoidal. The eccentric round shows a frequent turbulence of the current, while the orthocentric shows a continuous one.

Ⅱ. The Algal Stromatolites and Sedimentary Facies from Luoxue Formation

The stromatolites completely develop in the section of Youzhafang, Yinmin. The Luoxue formation has been classified into seven beds. The lithologic character, stromatolithic distribution and sedimentary facies are recounted, from the lower to the upper stratum, as follows (see Fig. 2):

Bed 1

This bed is 24.5m in thickness. It is greyishyellow, yellowish-white thin to middle-thick-bedded argillo-arenaceous micrite dolomite occasionally intercalated with dolomitic shale, without stromatolites, and with cross-stratifications. Such bed belongs to the upper part of intertidal zone.

Bed 2

This bed is 13.1m in thickness. Yellowish, yellowish pink thick-bedded dolomite develops rippled stromatolites, the lower part is irregular, the middle symme

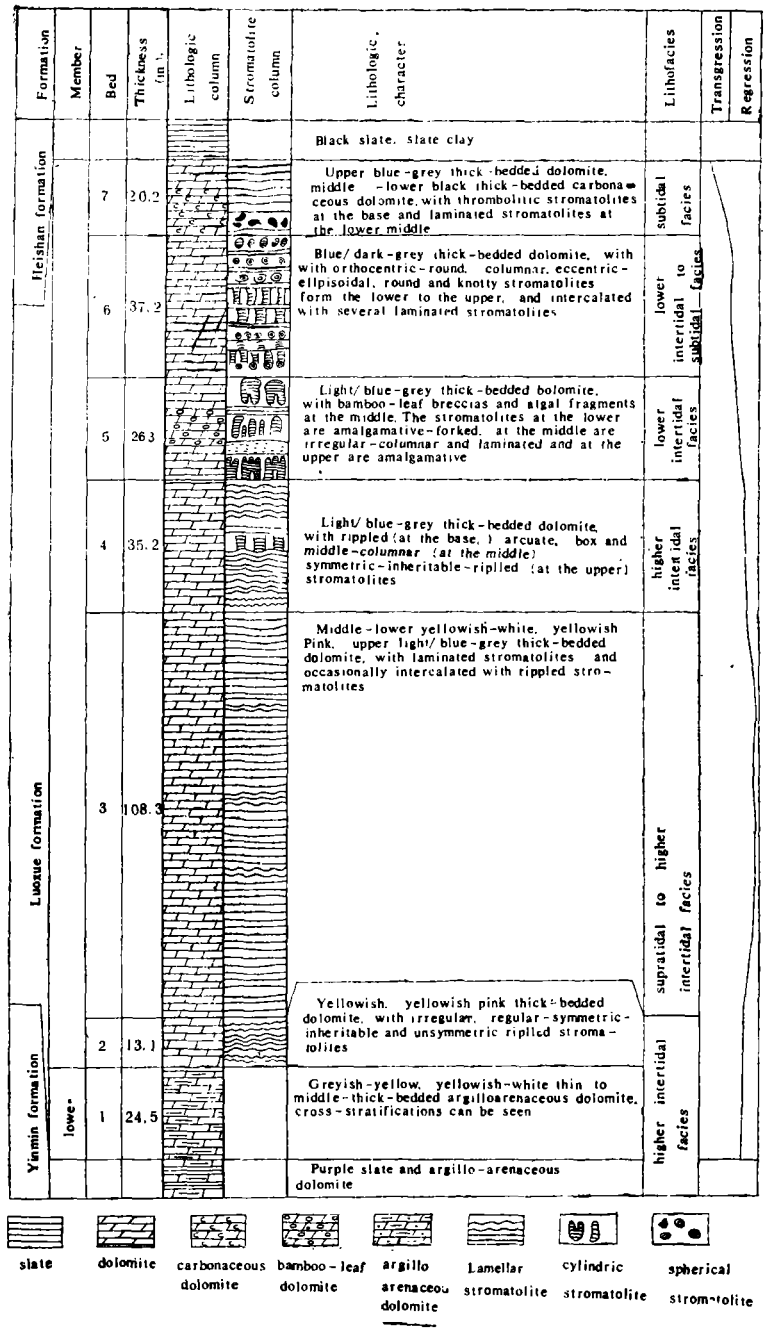

Fig.2 The columnar section of facies, Luoxue formation, in Yinmin

tric-inheritable (its wavelength becomes bigger upward) and the top unsymmetric. It belongs to the close bay where the wave current is weak.

Bed 3

This bed is 108.3m in thickness. Middle-lower yellowish-white, yellowish pink, upper light/blue-grey thick-bedded dolomite develops horizontal beddings, with si-

liceous stripes and laminated, occasionally intercalated with rippled stromatolites. It belongs to the upper part of intertidal zone to the micrite flat of carbonates at the supratidal zone where the wave current flows gently.

Bed 4

This bed is 35.2m in thickness. Light/blue-grey thick-bedded dolomite develops horizontal beddings, lower with irregular- rippled and symmetric-inheritable-rippled stromatolites, the middle with arcuate, box and middle columar, and the up per with symmetric-inheritable-rippled and laminated. In general, it belongs to the micrite flat of carbonates at the upper part of intertidal zone where the wave current is not strong, but the stromatolithic forms at the middle indicate the tidal lash to a different extent.

Bed 5

This bed is 26.3m in thickness. Light-grey/grey thick-bedded dolomite with bamboo-leaf-shaped breccias and algal fragments at the middle, develops the columnar stromatolites; the lower part is amalgamative-forked, the middle irregular and the upper amalgamative, and all have intercalated with laminated stromatolites. This region belongs to wide basement of the lower part of intertidal zone where the turbulent and gentle wave was replaced each other.

Bed 6

This bed is 37.2m in thickness. Blue/dark-grey thick-bedded dolomite develops horizontal beddings and stromatolites. The stromatolithic forms; the lower part is orthocentric-round, middle/small-columnar; the middle is small/middle columnar and eccentric ellipsoidal, and both occasionally have intercalated with laminated; the upper is spherical and knotty. The bed belongs to the lower part of intertidal zone to the subtidal zone where the gentle wave occasionally replaced the strongly turbulent.

Bed 7

It has a thickness of 20.2m. The middle and lower part is black carbonaceous dolomite, the upper blue-grey thick-bedded dolomite developed horizontal beddings, with thrombolitic stromatolites at the base and laminated stromatolites at the upper and middle. This bed belongs to subtidal zone where the wave current is relatively gentle.

In summary, the stromatolites of Luoxue Formation in Yinmin Region are mainly lamellar in the lower part of the formation, cylindrical in the middle, spherical in the upper and occasionally intercalated with lamellar,and lamellar in the top. The fact shows that this sedimentalogical environment is a tidal-flat of transgression series from higher intertidal zone to subtidal facies (see Fig. 2).

The distributed stability of the stromatolites in the same horizon is variant. It is related to the variety of the sedimentary place and the micro-paleogeograph which the stromatolites occur in. Along the coastline, there is the same association of the stromatolites in the same facies, but some stromatolites in the association appear and some do not because of locally micro-paleogeographic variety and then diffe-

rently hydrodynamic condition; Perpendicular to coastline, the succession of stromatolithic association from the supratidal, intertidal to subtidal zone is consistent with their evolution in the stratum. The former is shown clearly in the stratigraphic correlation section of Yinmin, Luoxue and Tangdan Regions; The latter may be seen clearly in the section of Yinmin comparing with Dayanjiu[2].

In the Tangdan region, the Luoxue formation has a thickness about 439m. Mainly blue-grey dolomite, in which the developed character of algal stromatolites is similar to that of Yinmin, but the micro-columnar stromatolites only appear at the lower stratum.

In the Luoxue region, the Luoxue formation has a thickness of 415m. Mainly the yellowish pink dolomite; with lamellar class and middle-columnar stromatolites at the lower, big/amalgamative-columnar and spherical at the middle, and small/flat-columnar at the upper. It could be seen that the stromatolites in here comparing with the Yinmin and Tangdan regions have slight difference, which shows distributed unstability of some stromatolites in the same horizon. Tangdan and Luoxue Regions are also the tidal-flat environment of transgression series.

In a general, The developed and distributed character of algal stromatolites of Luoxue Formation in Dongchuan Mine is numerous classes, The lamellar (at the lower), cylindric (at the middle), spherical and small-columnar (at the upper), and laminated in all the stratum. The stromatolites only develop in dolomites, but do not in sedimentary rocks in which argillo-arenaceous content is rich.

Ⅳ. Relationship between Algal Stromatolites and Copper Ore

In the world many stratiform copper deposits are frequently associated with the algal reef[8]. And so is the Dongchuan copper deposit in China. This deposit includes the bedded orebodies and the vein orebodies. Its orebearing horizons include the transition bed, the algal dolomite at the base, the argillic dolomite at the middle-lower and the argillo-arenaceous dolomite at the top of Luoxue Formation. The relationship between algal dolomite and bedded copper ore is shown as follows:

1. Both occur in dolomite of same horizon;

2. It seems to be a positive relationship between copper mineralization and development of algal stromatolites;

3. The copper mineralization related to the rippled stromatolites mainly (Photo 5), but the copper minerals occur in the cylindric or spherical stromatolites also (Photo 6);

4. The copper sulfide minerals distributed along the principal laminae of stromatolites in tiny spots or broken-line, resulting "horse-tail" structure (Photos 5, 6). Under the microscops they impregnated in the interstitial spaces of quartz from bright laminae (quartz laminae) of the principal laminae of stromatolites (Photo 7), and few of them in the interstitial spaces of dolomites from dark laminae (Photo 8). It shows that the bedded deposits are related mainly to diagenesis.

The reef dykes and dams composed by algal strematolites confined or partly confined the high-energy sea water to form local water basins—a bay or lagoon, formed a stagnant, low-energy reducing environment in which developed anaerobic bacteria, beneficial to the primary sedimentation of the cupreous materials from the terrigenous. Such a geological setting for the deposition of copper during the diagenesis was formed, and enriched copper in place.

The silicon cemented or replaced by algae or the mud filled in the pore of stromatolites may absorb copper; the bacteria and organism contained in algae and the organic carbon in the sediments may provide sulfur. The bacterial reduction of sulfates may cause the deposition of metallic sulfides.

The author has studied the fluid inclusions in mineral from Luoxue copper deposits[1], and has found that there is wholly pure liquid-inclusions whose quantity is small and grain is tiny in the wall rock of stratiform orebodies. Such inclusions show the sedmentary-genesis. In the stratiform orebodies, the inclusions are also pure liquid mainly, but with liquid partly. In them, the ratio between gas and liquid is 2—25%. Whose T=170—220℃ and salinity=16.5 wt%. These results show that the hot brine had permeated through bedded ore during sedimentary-diagenesis. Such salt-rich brine played an important part in the lixiviation, resolution and migration of copper, namely, in the genesis of copper beds formed by sedimentary -diagenesis.

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