

Shell micro-structure of the Late Miocene freshwater unionid *Parreysia binaiensis* (Mollusca : Bivalvia) from Nepal

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Abstract

A Late Miocene freshwater bivalvian shell of *Parreysia binaiensis* Takayasu, Gurung & Matsuoka, 1995, is examined to assess its state of preservation as well as to determine its shell structure and mineral composition. The characters of shell micro-structure are valuable for their systematics, phylogeny and environmental analysis. It is found that the shell is well preserved with most of the shell layers intact. The X-ray diffraction analysis shows that the mineral species of the shell is wholly aragonite. Shell structure type is typical of a common freshwater bivalve of the family Unionidae, i. e. with nacreous and aragonite prismatic layers.

Key words: Freshwater, Late Miocene, Molluscs, Micro-structure, Nepal

Introduction

State of preservation of an internal shell micro-structure in fossil specimens depends upon many factors, such as the original shell, depositional environment, diagenetic processes, age and so on. Generally, shell fossils of earlier age are less well preserved than the later ones. Such kind of study may provide insight into the diagenetic processes active after burial (Turekian and Armstrong, 1961; Omori *et al.*, 1974; Kamiya, 1975; Clark II, 1993). Similarly, it is expected that these studies will provide some evidences about its growth environment (Lutz and Rhoads, 1980) and aid in taxonomical study (Kobayashi, 1964, 1971; Taylor *et al.*, 1969; Kobayashi, 1988; Togo and Suzuki, 1988). In the present paper the micro-structure of the fossil bivalve mollusc from the Late Miocene bed of the Churia Group of Nepal is examined by using optical and scanning electron microscopes. From these results, especially, fossil preservation and phylogenetic problems are discussed in this report.

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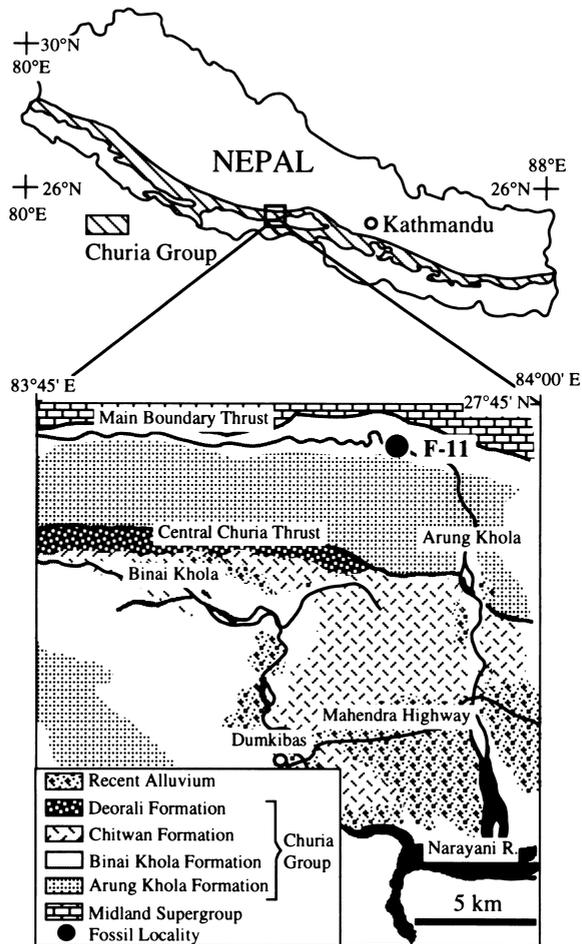


Fig. 1. Index map and generalized geology (modified after Tokuoka *et al.*, 1986) of the Arung Khola, west-central Nepal with the fossil locality, F-11.

Material and Method

1. Material

The examined specimen is obtained from fossil locality F-11, in the lower part of the Binai Khola Formation of Churia Group (Tokuoka *et al.*, 1986) distributed in the Arung Khola area, west-central Nepal (Fig.1). The lower part of this formation is mainly composed of thick-bedded medium to coarse grained sandstones and thin-bedded siltstones. The fossiliferous bed is composed of bluish gray to dark gray siltstones. The Group is dated paleomagnetically and the lower part of this formation ranges from about 9 Ma to 8 Ma in age (Fig.2).

The bivalve shell examined belongs to the Indian subcontinent Genus *Parreysia* Conrad, and has been identified as a fossil species *Parreysia binaiensis* Takayasu, Gurung & Matsuoka, 1995

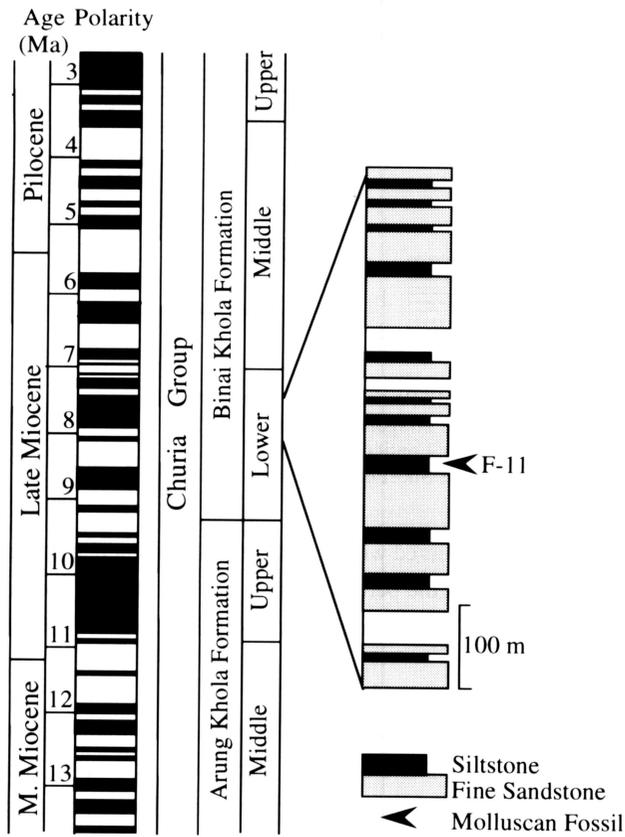


Fig. 2. Columnar section with magnetostratigraphy (after Cande and Kent, 1992) of the Churia Group and the fossil locality F-11.

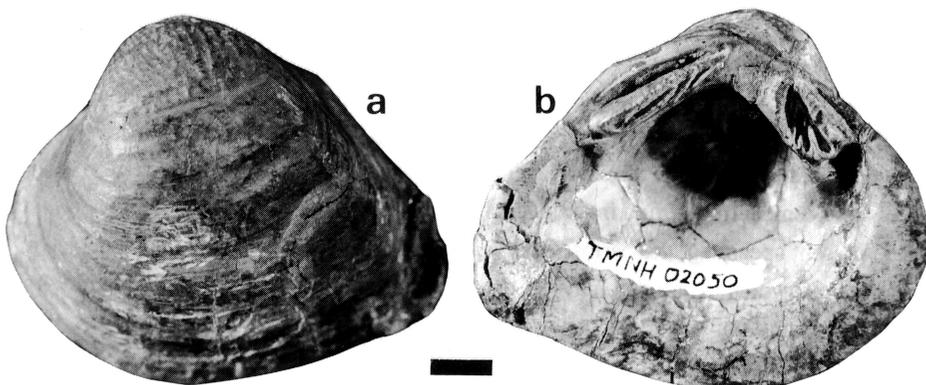


Fig. 3. *Parreysia binaiensis* Takayasu, Gurung & Matsuoka, 1995, collected from F-11. a: outer view of a shell. b: inner view of a shell. Scale bar: 5 mm

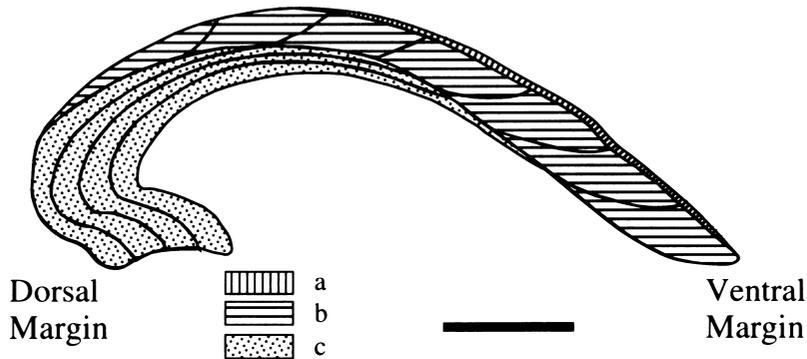


Fig. 4. Radial section of the shell.
 a: Aragonite prismatic layer.
 b: Lenticular nacreous layer.
 c: Sheet nacreous layer. Scale bar: 5mm.

(Fig.3). The specimen is well preserved with very little replacement and deformation. The external surface markings are distinct, but the periostracum is not found to be preserved. The size of the specimen is 33 mm in length, 26 mm in height and about 3 to 2 mm in thickness.

2. Method

The shell to be examined was buried in epoxy resin, cut and polished in three different directions for observations under optical and scanning electron microscopes. Fractured, and polished and etched planes of the shell were prepared for scanning electron microscopy. The polished planes were etched by 0.5 mol EDTA solution (pH 7.4) for 5 to 10 minutes. Mineral composition of the shell was determined by X-ray diffractometer.

Observation

1. General feature

The shell is composed of outer periostracum and inner calcareous layers. The fossil shell is composed of thick calcareous shell layer, about 3 to 2 mm in thickness, thicker around the umbonal area. In the Unionidae group, the calcareous shell layer (Fig.4) is divided into three layers, namely outer, middle and inner calcareous shell layers (Kobayashi, 1964, 1971; Taylor *et al.*, 1969). The boundary between the middle and inner layers is not well defined.

In the present specimen, the periostracum is not observed, however, the outer surface of the shell is partly brownish in color. It may be due to surface coating with a sheet of altered organic film and or deposition of iron materials by solution containing iron.

The outer calcareous shell layer is very thin, about $50\mu\text{m}$ to $130\mu\text{m}$ in thickness, thins out towards the apical part and is dissolved at the most apical part. The middle and inner calcareous shell layers are comparatively thick and whitish translucent with weak pearly lusture. The thickness of the middle layer increases toward a ventral margin. The thickness of the inner layer is also not equal throughout, but tends to thin out from umbonal to ventral part.

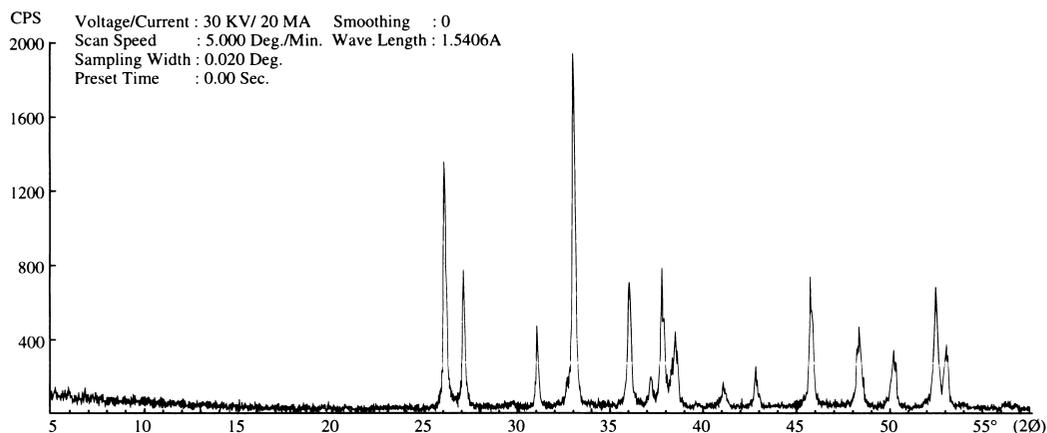


Fig. 5. X-ray diffractometer spectrum of powdered specimen of *Parreysia*. (Radiation of Cu α , Ni-filter)

2. Mineral composition

The mineral species of the powdered sample of a whole shell is identified by the use of X-ray diffractometer. The result indicates that the mineral composition is wholly aragonite (Fig.5). The composition indicates that the original shell composition of aragonite has not changed. Commonly, aragonite changes to more stable calcite in the fossil. The present specimen shows that it has undergone very little diagenetic alternation.

3. Morphological shell type

The original shell micro-texture is retained well in the fossil specimen. The outer calcareous shell layer is composed of aragonite prismatic structure (Fig.6a). The middle and inner calcareous shell layers are composed of nacreous structure. They can be distinguished by the manner of arrangement of the building blocks, which are made up of small, roughly polygonal tablets. The middle layer is composed of piling up of tablets into columns, called lenticular (or pillar) nacreous structure (Fig.6b). In the inner layer the tablets are arranged in a brick-laying manner, forming sheet nacreous structure (Fig.6c).

3.1. Aragonite prismatic structure

The outer layer is composed of aragonite prismatic structure (Taylor *et al.*, 1969; Kobayashi, 1971; Nakahara, 1979) which is made up of subpolygonal prisms arranged nearly perpendicular to the shell surface (Fig.6a). Figures 7a and 7b show the optical microscope photograph of a radial section of this layer. Figure 8 is the scanning electron microscope photographs of a radial section of this layer. This structure consists of tight prisms with their axes arranged parallel to each other (Fig.7b). The axes are a little oblique to the outer shell surface. The inside of each prism is made up of an aggregation of crystallites arranged in cone shape (Fig.8b). Each crystallite is made up of

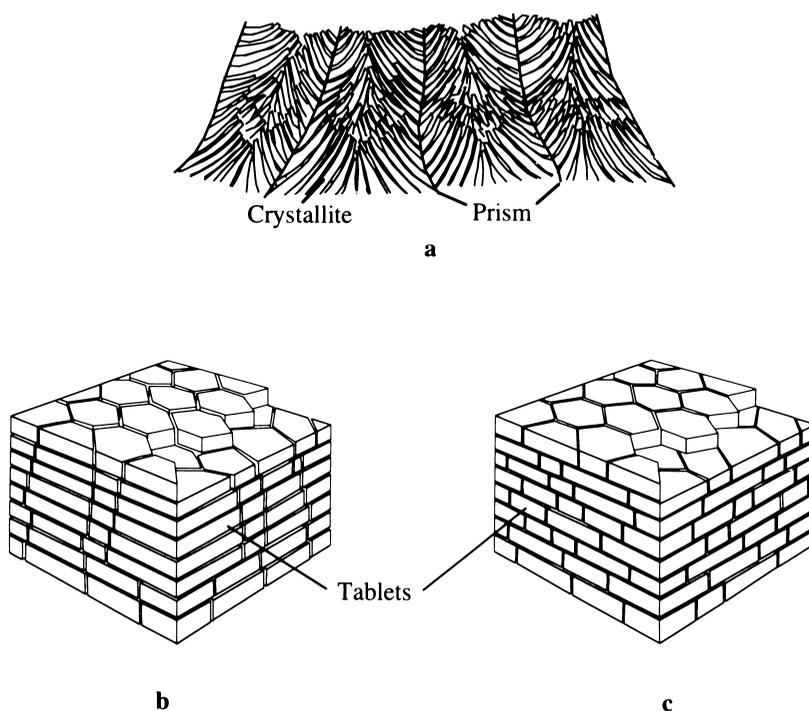


Fig. 6. Three morphological shell structures.
 a: Aragonite prismatic structure.
 b: Lenticular nacreous structure.
 c: Sheet nacreous structure.

aragonite crystal and its shape is elongate rectangular rod. In a living shell these prisms are surrounded by organic sheaths. But, the organic remains are not clearly seen in the fossil specimen. The boundary with the middle layer is sharp and distinct (Fig. 7a, 8a). Under higher magnification (Fig. 8c), crystallites forming a prism continue to the tablet forming a lenticular nacreous layer.

3.2. Lenticular (or pillar) nacreous structure

The middle layer is composed of vertically piled tablets forming prisms which are arranged side by side, called lenticular nacreous structure (Wise, 1969; Fig. 6b). Figure 8a is the scanning electron microscope photograph of a radial section under low magnification. Under higher magnification of scanning electron microscope (Fig. 9), it is observed that each tablet is roughly polygonal in shape, about 8 to 12 μm in diameter and about 1 μm in thickness. Many tablets are placed one above the other forming pillars.

Generally, there is a special pellucid layer which is formed at the area where adductor muscles are attached with the shell. It is not observable in this specimen. Moreover, in general there are membranous organic matrixes around tablets (Nakahara, 1979), but they also are not observable.

3.3. Sheet nacreous structure

The inner calcareous shell layer consists of aggregation of roughly polygonal tablets. In radial section the horizontally arranged tablets give a brick-wall appearance (Fig. 6c). Figure 7c shows

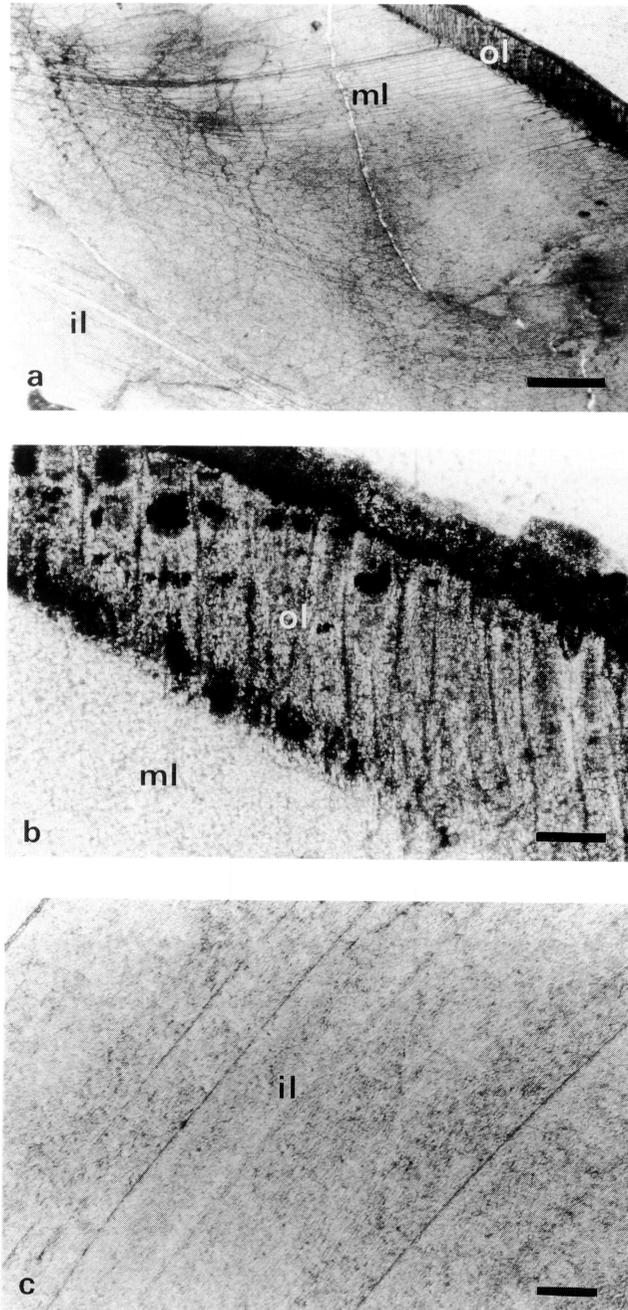


Fig. 7. Optical microscopic photographs of the radial section.
a: Outer layer (ol), middle layer (ml) and inner layer (il). Scale bar: 250 μ m.
b: Outer layer (ol) composed of aragonite prismatic structure.
ml: middle layer. Scale bar: 50 μ m.
c: Inner layer composed of sheet nacreous layer. Scale bar: 100 μ m.

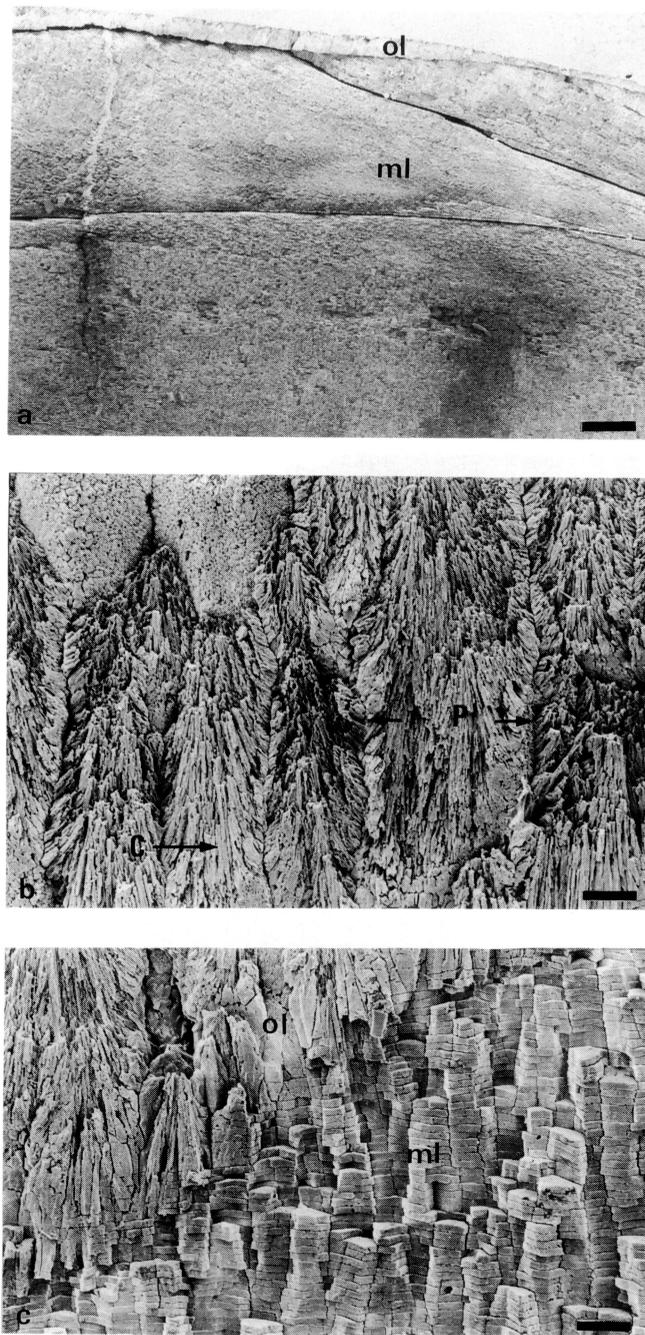


Fig. 8. Scanning electron microscopic photographs of the radial section.
 a: Under low magnification. ol: outer layer, ml: middle layer. Scale bar: $100\mu\text{m}$.
 b: Aragonite prismatic layer under higher magnification. P: prism, C: crystallite. Scale bar: $10\mu\text{m}$.
 c: The boundary area between the outer (upper-left side) and middle (lower-right side) layers. Scale bar: $10\mu\text{m}$.

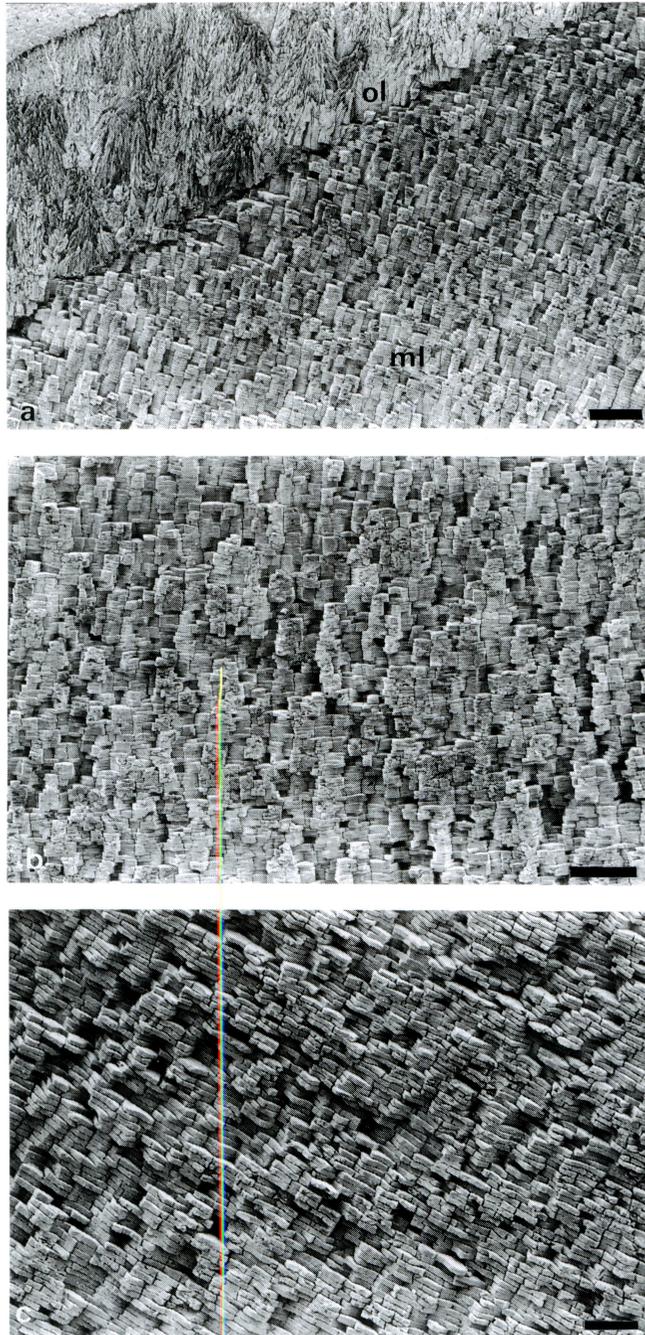


Fig. 9. Scanning electron microscopic photographs of the radial section.
a: Outer aragonite prismatic layer(ol) and middle lenticular nacreous layer (ml). Scale bar: $25\mu\text{m}$.
b: Middle lenticular or pillar nacreous layer. Tablets are accumulated in vertical direction. The direction of shell growth is downward. Scale bar: $25\mu\text{m}$.
c: Ditto. The vertical accumulation of tablets is a little irregular. Scale bar: $10\mu\text{m}$

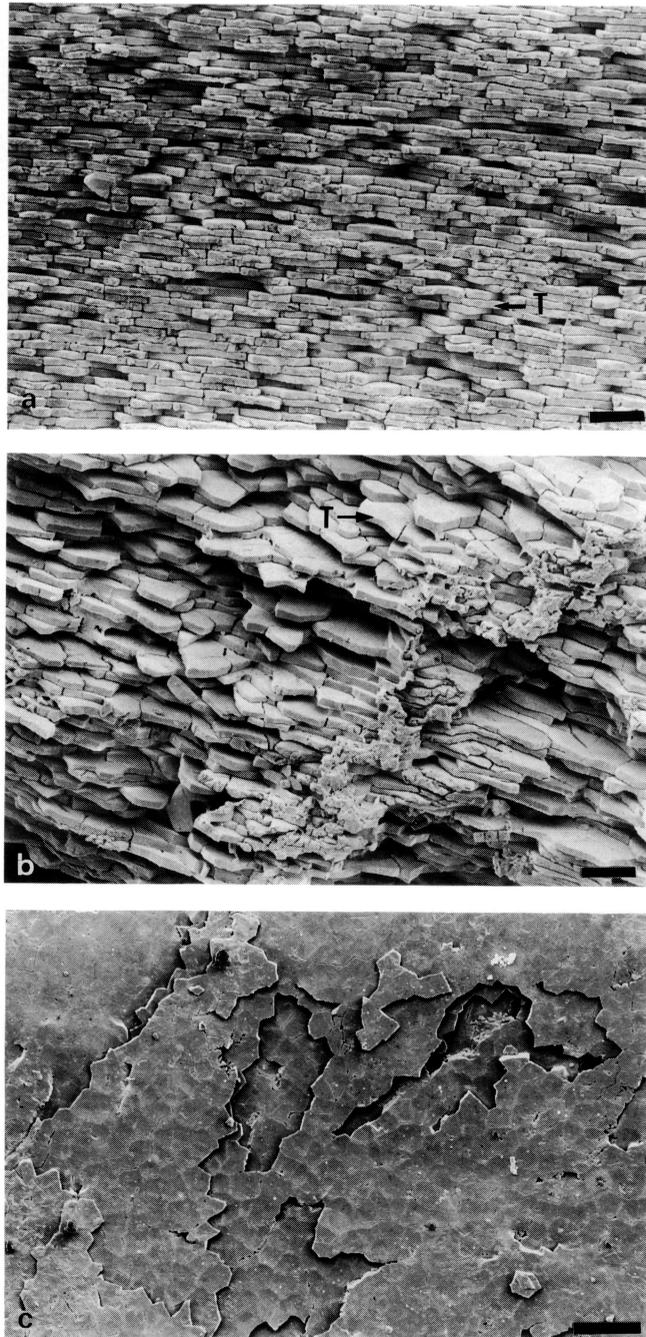


Fig.10. Scanning electron microscopic photographs of sheet nacreous layer.
a: Radial section of sheet nacreous layer. T: tablet. Scale bar: $10\mu\text{m}$.
b: Under high magnification, each tablet is polygonal. T: tablet. Scale bar: $10\mu\text{m}$.
c: Horizontal view of sheet nacreous layer. Several sheets of tablets are horizontally aggregated. Scale bar: $25\mu\text{m}$.

the optical microscope photograph of a radial section of this layer. Under higher magnification of scanning electron microscope (Fig. 10), it is observed to be composed of accumulation of horizontally arranged tablets in sheet-like manner. Each tablet is roughly polygonal in shape (Fig. 10c), about 6 to 10 μm in diameter and about 1 μm in thickness. In general these are also surrounded by membranous organic matrixes (Nakahara, 1979), which are not preserved.

4. Growth structure

Growth lines are not observed in the outer layer. In the middle and inner layers the growth lines are observed clearly in the thin section. According to the direction of growth lines the middle and inner layers can be separated. In the middle layer these lines are finer and the direction of growth is parallel to the ventral margin of a shell. The lines in the inner layer are coarser comparatively and the direction of growth lines are nearly parallel to the inner shell surface.

Discussion

1. Preservation of shell micro-structure

The shell micro-structure of the older aged fossils with original aragonitic composition is rarely preserved due to metastability of aragonite under common burial condition. The original aragonite is very often replaced by calcite in the fossil specimens from Mesozoic and Palaeozoic ages in Japan and the original micro-structure is mostly destroyed. Although Japanese specimens of Late Miocene usually have an original structure retained well (Kobayashi, 1976), Early Miocene ones are mostly with altered structure. The present Late Miocene specimen has its original biomineral composition as well as shell micro-structure well preserved. On the other hand, organic matrixes in the examined shell is not clearly observable, but their remains could be detected.

2. Morphological shell-type structure

Due to the well preservation state, the original micro-structure in the present fossil specimen is found retained. The fossil shell micro-structure is very similar to the recent unionids. It is composed of outer aragonite prismatic, middle lenticular nacreous and inner sheet nacreous layers. In most unionids the outer layer consists of aragonite prismatic structure (Taylor *et al.*, 1969). But, in the present specimen it shows some similarity to composite prismatic structure in the arrangement of crystallites.

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