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Upper Cretaceous Chelonian Egg from Hokkaido, Japan

By

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Abstract An Upper Cretaceous egg fossil from the Upper Yezo Group was examined by the scanning electron microscope, the energy dispersive spectrometer, and by X-ray powder diffractometer studies which proved that it is composed of calcite with an amorphous silica. The shell layer of this fossil egg is composed of a zone of spicular crystallite aggregates (shell units) radiating from an organic core which is characteristic for modern and fossil chelonian eggshell. Thus, this paper is the first detailed description of a confirmed fossil chelonian egg from Asia.

Introduction

As to the eggs and eggshell fragments of dinosaurs, there are many and various studies (*e.g.* ERBEN *et al.*, 1979; HORNER, 1982; HORNER & WEISHAMPEL, 1988; HIRSCH & QUINN, 1990). Studies on fossil chelonian eggs and shell fragments date back over 100 years, but rather little is known about the details, as pointed out by HIRSCH (1983). Since VAN STRAELEN (1928) summarized the early studies of chelonian eggs, a few papers have been published (*e.g.* HIRSCH, 1983; HIRSCH & LOPEZ-JURADO, 1987; KOHRING, 1990). Most of the described specimens, however, are eggshell fragments and are incompletely preserved.

The late Cretaceous egg from Japan in this report is almost complete in preservation (See OBATA *et al.*, 1972, pl. 5, fig. 2). The purpose of this study is to describe and illustrate the structure of the egg.

Stratigraphic Notes

The upper Cretaceous egg in question was collected in the summer of 1970, by Mr. Ryota NAKAMURA. The locality is at a point of Kechikauen-obirashibe River, 1 km north-northeast from the junction with the Akanozawa River, Obira-mura, Rumoi-gun, Hokkaido (Fig. 1). The egg fossil, 28.5 mm in diameter, was found in a calcareous nodule together with *Baculties* cf. *yokoyamai* TOKUNAGA et SHIMIZU. The nodule occurred in fine sandy mudstone of Uc-d bed (TSUSHIMA *et al.*, 1957), the main part of the Upper Yezo Group. The Uc-d bed yields such marin molluscans as *Gaudryceras denseplicatum* (JIMBO), *Damesites damesi* (JIMBO), and *Inoceramus uwajimensis* YEHARA, and is assigned to Coniacian in age.

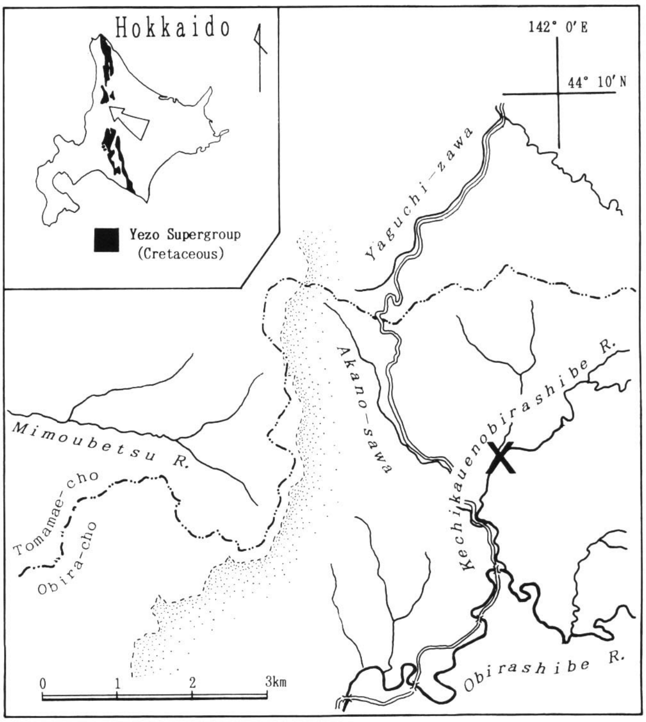

Fig. 1. Locality map of the upper Cretaceous egg from Obira-mura, Rumoi-gun, Hokkaido, Japan. Read Sankebetsu for Mimoubetsu.

Preparation

The specimen studied has been preserved at the National Science Museum with the registered number, NSM-PV15018.

A part of the eggshell was stripped from the specimen for the SEM observation of internal structure. The cross section of the eggshell fossil was polished and the polished surface was etched with 3% hydrochloric acid for several minutes. Subsequently, the etched specimen was washed with pure water several times. The eggshell microstructure was observed with a scanning electron microscope (Hitachi Co., H450 type) of the Chiba Prefectural Institute of Public Health. Another piece of the eggshell was also sliced off for observation under back-scattered image (BEI) and for chemical analyses with an energy dispersive spectrometer (EDS) (Link Systems) attached to the SEM of the National Science Museum, Tokyo. The observed material was also subjected to X-ray diffractometer study for mineral identification, employing the surface of slice without pulverization.

Observation and Discussion

Gross Morphology: The spherical egg fossil is 28.5 mm in diameter. In the cross section of the specimen we can distinguish three structural zones with the naked eye. The outermost zone and the surface of the specimen is dark brown in color, consisting of probably granular or netted structure. The middle zone of the observed cross section is grayish white and about 500 μm in thickness. The inner part of the specimen is almost filled with calcite, leaving small openings (voids) in places.

SEM Observation: With the aid of SEM and BEI (Back-scattered Image) we can distinguish the following layers within the outer zones (Fig. 2A-F). The first or the outer layer (Fig. 2A), about 80 μm thick, is composed mostly of calcite (MgO 0.41 wt%, FeO 0.85 wt%, MnO 0.56 wt%) with a subordinate amount of pyrite. The

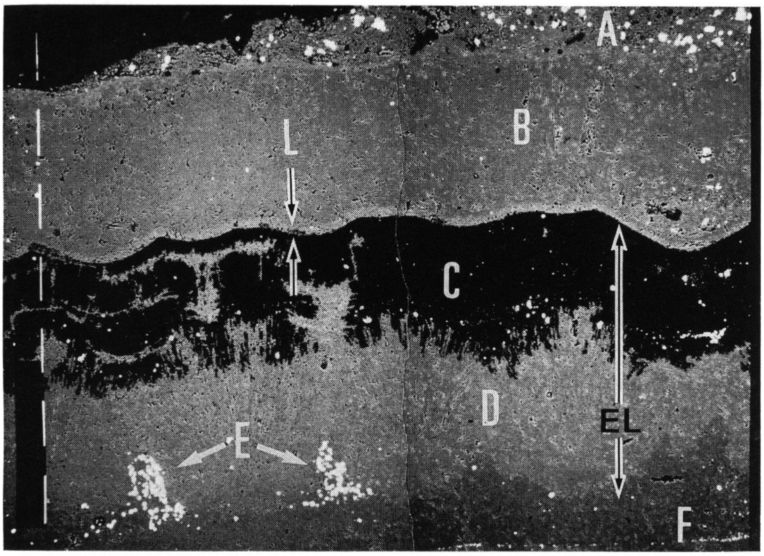

Fig. 2. A photograph of BEI (Back-scattered Image) observation: Bar shows 100 μm.

A: Outer layer, about 80 μm in thickness, composed mostly of calcite with a subordinate amount of pyrite.

B: Second layer, totally of calcite, about 250 μm in thickness.

C: Upper half of eggshell layer. Original calcium carbonate of eggshell structure mostly replaced by opal.

D: Lower half of eggshell layer which is calcium carbonate characterized by enrichment of FeO. Note radiating spicular crystallites.

E: Interstices between two shell units, often filled with pyrite-carbonate aggregate. E also demonstrates a shell unit.

F: Layer of, about 80–100 μm in thickness, Mg-rich calcium carbonate. It once may have been the membrane.

L: Lamellae, EL: Egg-shell layer.

second layer, about 250 μm thick, is totally composed of calcite (MgO 1.39 wt%, FeO 0.00 wt%, MnO 0.09 wt%) (Fig. 2B). In both layers no features of eggshell structure were observed. The structure of the layers is very irregular with numerous fractures and openings, probably causing the granular, netted structure observed on the outer surface of the specimen (Figs. 3, 4). Based on these facts, it is assumed that both layers are secondary diagenetic deposits.

The next to continuous, lamellar-like layers, 40 μm in thickness, probably represent the uppermost part, that is the outer surface of the original eggshell layer (Figs. 3, 4). The two layers show in most part a radiating structure of needle-like crystals (Fig. 5). Both lamellae run, with an intervening gap of about 50 μm thick, in a gentle wavy curve; they also show concentric growth lines near the eggshell surface as KOHRING (1990) described in eggshell from the Jurassic of Portugal.

The layer below the lamellae, represents the main body of the eggshell layer (Fig. 2C, D). The lower half of this layer (Fig. 2D) is formed of aggregates of spicular crystallites radiating from an organic core on the inside of the eggshell (Fig. 6) and is composed of calcium carbonate with traces of MgO 0.24 wt%, FeO 1.86 wt%, MnO 0.49 wt%. Analysis by EDS and BEI shows that the upper half of this shell layer (Fig. 2C) is replaced in most places by opal. The crystallites of the shell units interdigit with those of the adjacent shell units (Fig. 7). The crystallites are about 2 μm in diameter (Fig. 8). A few concentric growth lines can be recognized in the shell

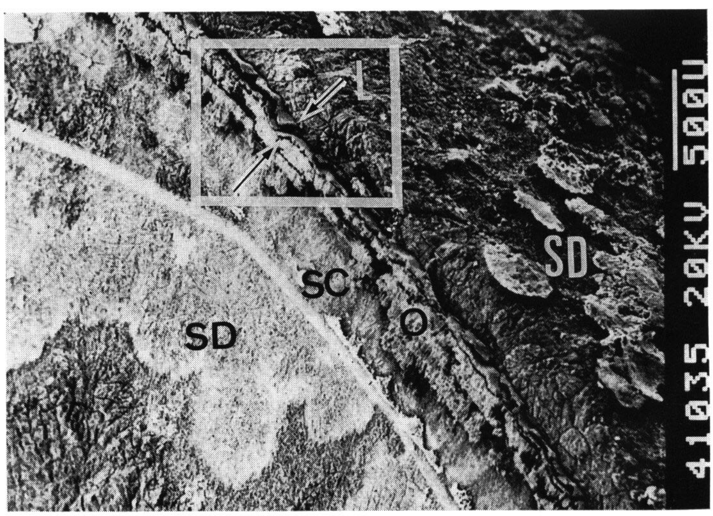

Fig. 3. Scanning electron microscope image of the cross section of polished eggshell: Most of the right upper half from the diagonal on the photograph shows secondary deposits (SD) on the shell surface. Under the secondary deposits the characteristic feature of eggshell structure can be observed: Lamellar outer layer (L); spicular crystallites (SC) composed of calcium carbonate; area of calcium carbonate replaced by opal (O). Bar shows 500 μm. The enclosed part with white lines is enlarged in Fig. 4.

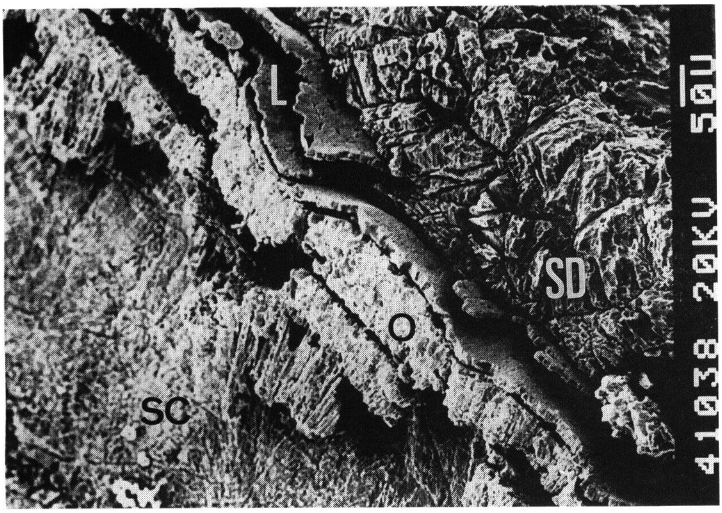

Fig. 4. Cross section of the outer secondary deposits and the upper part of original eggshell: Outer secondary deposits associated with numerous carcks. The original eggshell surface consists of two continuous lamellae shows gentle wavy curve. Bar shows 50 μm. Lamellar outer layer (L); spicular crystallites (SC) composed of calcium carbonate; area of calcium carbonate replaced by opal (O).

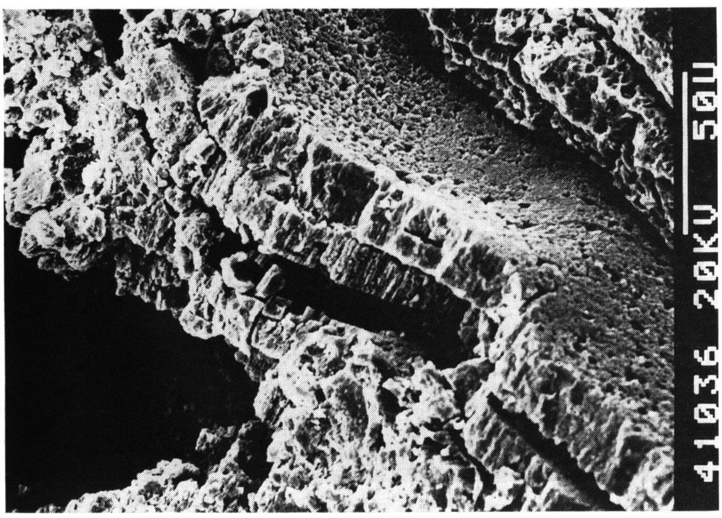

Fig. 5. Enlarged photograph of two continuous lamellae of the original eggshell surface: Both lamellae consist of the radiating spherulitic structure. Bar shows 50 μm.

units (Fig. 4). The shell units are about 500 μm high and 250 μm wide (Fig. 6). Pore openings could not be observed between the shell units. It is noteworthy that the interstices between the shell units are often filled with pyrite-carbonate aggregate

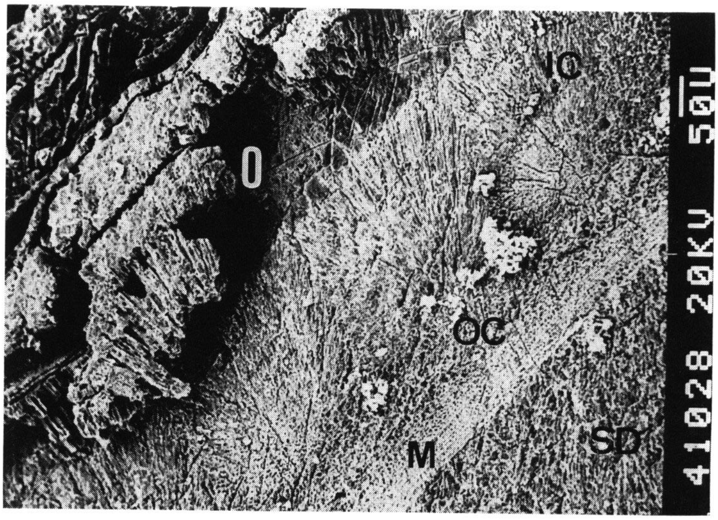

Fig. 6. Characteristic chelonian eggshell layer: the spicular crystallites radiate from the organic core (OC) upward, thus forming spherulitic shell units. Note interdigitating crystallite (IC) of adjacent shell units; area replaced by opal (O); replaced shell membrane layer (M); secondary deposits (SD).

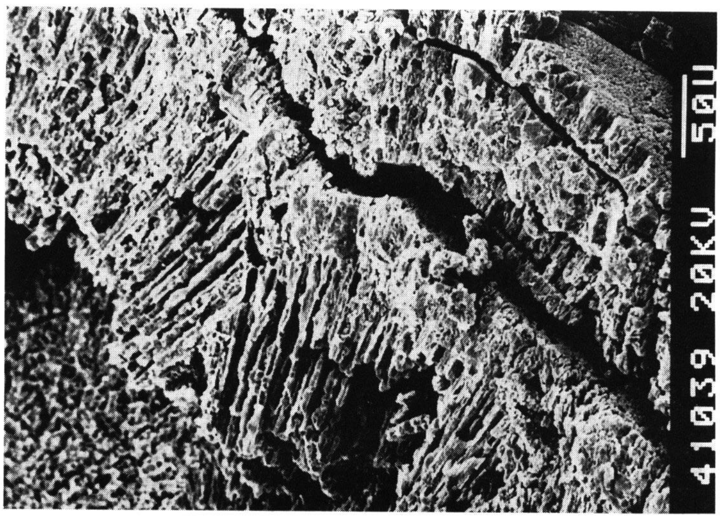

Fig. 7. Interdigitating crystallites of two adjacent shell units of the eggshell. Bar shows 50 μm.

(Fig. 2E).

Just below the shell layer, where the eggshell membrane should be, is a layer, 80 to 100 μm thick, of Mg-rich calcium carbonate (MgO 1.52 wt%, FeO 0.58 wt%, MnO 0.63 wt%) (Fig. 2F). Although no fibers could be observed, the thickness and

Fig. 8. Enlarged image of the radiating spicular crystallites. Each spicular crystallite is about 2 μm in diameter. Bar shows 5 μm.

the way this layer peels away from the crystalline shell layer strongly suggests that it once may have been the eggshell membrane. However, it is rather difficult to prove whether this layer represents the original shell membrane replaced by inorganic matter or not.

The X-ray powder pattern obtained on the surface of sliced material corresponds to that of calcite (JCPDS Card No. 5–0586), although very slight shifts to higher angle side are recognized to reflect the minor substitutions of Fe, Mn and Mg for Ca.

Conclusive Remarks

The described egg from the Upper Cretaceous of Hokkaido, with its shell layer of radiating spicular aggregates can be assigned to the structural morphotype for modern and fossil chelonian eggshell as described by HIRSCH (1983), HIRSCH and LOPEZ-JURADO (1987), HIRSCH and PACKARD (1987), and KOHRING (1990). The interdigitating crystallites of the adjacent shell units indicate that this egg belongs to the group of rigid-shelled chelonian eggs (HIRSCH, 1983).

Since all modern sea chelonians have soft shelled eggs, and this egg in all probability does not belong to a sea chelonian, it should be noted that the described egg was found in a calcareous nodule together with *Baculites* cf. *yokoyamai*. This occurrence of a rigid-shelled chelonian egg with marine invertebrates may suggest an allochtonous origin of the former and may not be an unusual case of the ancestor of a rigid-egg shelled chelonian being present in the marine circumstances.

Recent chelonian eggs are composed of aragonite (HIRSCH, 1983). In fossil chelonian eggs the metastable aragonite of the eggshell may change into calcite and the needle-like aragonitic structure may be preserved, somewhat altered or completely changed (HIRSCH, 1983, 1987; BRUNI and WENK, 1985). Our study has supported the above conclusions.

Acknowledgments

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