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SECRETED CALCITIC MATRIX IN FOSSIL AGGLUTINATED FORAMINIFERA?

by

H.J. HANSEN and E. ABD-ELSHAFY

With 3 plates

ZUSAMMENFASSUNG

Typische Arten der Gattungen *Pfenderina, Meyendorffina* und *Pseudomarsonella* (alle Oberjura), sowie der Gattungen *Orbitolina, Orbignyna* und *Ataxophragmium* (Kreide) wurden mit polierten und angeätzten Schnitten im Raster-Elektronenmikroskop untersucht.

Aufgrund der Struikturnachweise wird angenommen, daß nur die Gattungen *Orbignyna* und *Ataxophragmium* eine Wandstruktur haben, die auf eine ursprünglich sekretiv gebildete Karbonatmatrix hinweist. Die anderen Gattungen sind aus kleineren und größeren Karbonatpartikeln, zusammen mit Fossilbruchstücken agglutiniert.

ABSTRACT

Representative species of the genera *Pfenderina, Kurnubia, Meyendorffina* and *Pseudomarssonella* (all Late Jurassic) *Orbitolina, Orbignyna* and *Ataxophragmium* (Cretaceous) have been studied in polished and etched sections in SEM.

It is suggested from structural evidence that only the genera *Orbignyna* and *Ataxophragmium* contain a structure which can be interpreted as representing a former secreted carbonate matrix.

The other genera are agglutinated with a carbonate shell built of larger and smaller carbonate particles along with fragments of fossils.

INTRODUCTION

At the occasion of the First Workshop on Arenaceous Foraminifera, Amsterdam, 1981, Toksvad and Hansen (1983) presented a study of primary calcitic matrix in Recent agglutinated foraminifera. These authors concluded from structural evidence that a primary secreted calcitic matrix in addition to agglutinated particles does exist in Recent agglutinated genera (see also Murray 1973).

In the fossil forms, the question of presence of a primary secreted matrix is much more doubtful, as documented by numerous studies indicating either a microgranular or a finely agglutinated shell in many fossil genera.

With the work of Green *et al.* (1980), it was convincingly documented by high voltage electron microscopy of ion-thinned specimens that a microgranular form had preserved organic material within the single blocks of calcite in the wall, which precludes the possibility of recrystallization, by which process such organic material would normally be expelled. Therefore the existence of the microgranular wall structure now rests on a firm basis (see also Hansen 1979).

Hansen, H.J., Department of Geology, University of Copenhagen, Øster Voldgade 10, DK-1350 Copenhagen, DENMARK.
Abd-Elshafy, E., Department of Geology, University of Zagazig, EGYPT.

Jørgensen (1977) suggested that primary secreted calcitic matrix might exist in some Late Maastrichtian agglutinated forms. However, the author expressed doubts as to the origin of such structures since at that time no sufficiently documented Recent examples were known with which an analogue could be made, and since diagenetic phenomena in the Danish White Chalk are common.

The present study deals with selected forms from different time periods, forms which have been regarded by some authors as having either a microgranular or an agglutinated wall structure (but with reservations).

Representative species of the following genera have been studied: *Pfenderina, Kurnubia, Meyendorffina, Orbitolina, Ataxophragmium* and *Orbignyna.*

METHODS

Specimens were embedded, sectioned, polished and etched according to standard techniques such as those described in Hansen and Lykke-Andersen (1976). The sectioned specimens were coated with pure gold and examined in a Cambridge Mark IIa or 180 scanning electron microscope housed in the Geological Central Institute of the University of Copenhagen. The latter microscope is further equipped with a Link EDX system.

OBSERVATIONS

Pfenderina, Kurnubia and *Meyendorffina*
Plate 1, figures 1-6; plate 2, figure 1.

Our material of *Pfenderina,* namely specimens of the species *Pfenderina trochoidea* Smout and Sugden, 1962 and of the genus *Kurnubia* represented by the species *Kurnubia jurassica* (Henson, 1948) originate from the Callovian Kurnubia jurassica Zone in the Betty well no. 1 drilled in the Qattara Depression in the Western Desert in Egypt.

In 1962, Smout and Sugden in their diagnosis of the foraminiferal family Pfenderinidae described the wall material as microgranular without detectable agglutinated material. Later, Redmond (1964) quoted this and added in his descriptions of new genera and species of this family, many interesting observations regarding chamber morphology, but added nothing new concerning the wall structure itself. Since well preserved material was at hand, we undertook an electron microscopical study of the wall structures.

The representatives of the three genera are essentially identical from a structural point of view. The chamber cavities are filled with sparry calcite. From these filled-in cavities and from the shell surface, one could expect recrystallization fronts. Such phenomena are not found and, coupled with the rather varying grain sizes of the units constituting the walls along with fragments of fossil coccoliths incorporated into the shells, strongly indicate that the original wall was agglutinated and that very minor diagenetic alterations have taken place.

Only in one specimen of *Meyendorffina* did we observe an obviously recrystallized area with interlocking and mosaic grains. This convinced us that the structure generally observed in our specimens as very little affected diagenetically.

The structures are different from that of true microgranular forms such as fusulinids (Hansen 1979). In the latter forms the grain size of the single crystallites varies very little and has a cube-like appearance when seen under the electron microscope.

In spite of the rather deep etching applied, the varying grain sizes along with recognizable incorporated fossil fragments and coccoliths lead us to the conclusion that the genera in question are agglutinated calcareous forms. We have not observed any non-carbonate materials in the walls.

Pseudomarssonella
Plate 2, figures 2-3.

Our material of this genus consists of specimens of the species *Pseudomarssonella inflata* Redmond, 1965 from the Callovian *Kurnubia jurassica* Zone in the Betty well no. 1, Qattara Depression, Western Desert in Egypt.

Although the specimens had suffered a slight surface abrasion, they did not show obvious signs of diagenesis.

Like in *Pfenderina, Kurnubia* and *Meyendorffina* the chamber cavities are filled by sparry calcite. The walls are built of a wide size range of particles, of which some of the larger ones appear to be incorporated fragments of fossils. Among these, coccolith-shaped bodies were recognized.

Like in the other forms from the deposits described above, we interpret the structures observed as being very little affected by diagenesis. We did not find any non-carbonate grains in the walls. Accordingly, we believe that *Pseudomarssonella* is an agglutinated foraminifer which uses carbonate particles for wall construction and see no indication that secreted calcitic matrix is or has been present.

Orbitolina
Plate 2, figures 4-6.

Some characters of the *Orbitolina* group suggest that these forms might be candidates for possessing a primary secreted calcitic matrix. The large flat, sometimes concavo-convex shells with their subepidermal cellules or microcompartments are in some respects, such as placement and size, reminiscent of the alveolae of fusulinacean walls. This would suggest that the shells of the living animals were equipped with symbiotic algae. In larger foraminifera, it is well established that many forms are dependent upon algal symbiosis and have been demonstrated to have morphological adaptations towards this goal. Some of the forms have been demonstrated to show changes in the stable isotope composition of the shell carbonate material in accordance with the light gradient in the sea (Buchardt and Hansen 1977), indicating that calcification is enhanced through the relationship between the photosynthetic activity of the algae and uptake of released metabolic products by the animal. For this reason, the *orbitolina* is an obvious candidate in the search for aprimary calcitic matrix among fossil foraminifera.

We studied specimens of *Orbitolina texana* (Roemer, 1849) from the Cretaceous Glen Rose Limestone in Texas.

The outer wall of subepidermal cellules is in many cases less than 5µm thick. This is in the order of size of the thin outer walls of many symbiont-bearing porcellaneous forms. Such thin walls in the porcellaneous forms were shown to be permeable for diffusion of labelled CO_2 in connection with activity of algal symbionts (Hansen and Dalberg 1979) and would constitute an obvious analogue to *Orbitolina*.

In a few cases, however, the material forming the outer walls of the cellules was observed to contain coccoliths.

The cellules are lined on their interior surface by drusy calcite which may fill almost the entire cavity. Some areas close to the surface of the shells showed early crystallization leading to grain enlargement and an almost interlocking mosaic. However, even in such areas the grains are of rather different sizes, indicating that many of them would have retained their original size and shape.

In other areas, recognizable fragments with their original structure preserved occurred. That coccoliths are preserved is not surprising, since some of them are known to be strongly dissolution resistant. In contrast, the preservation of molluscan cross-lamellar structure along with smaller particles indicates that diagenesis in such areas has not advanced very far.

It therefore seems likely, due to the varying grain sizes and agglutinated fossil fragments, that *Orbitolina* was originally an agglutinated form. It is constructed of much larger building elements than would be expected if it had a secreted calcitic matrix as seen in Recent forms (Toksvad and Hansen 1983).

Specimens of the type species of *Orbitolina*, namely *Orbitolina lenticulata* (Lamarck, 1816) from Le Mans were rather deeply recrystallized and are not illustrated here. The specimens did, however, show agglutinated rounded particles of glauconite on the ventral region of the shell.

Orbignyna and *Ataxophragmium*
Plate 3, figures 1-4.

In the White Chalk of Late Maastrichtian age in the Danish Basin, is a clay-rich layer about 25 cm thick which can be followed across Denmark. It was originally described by Troelsen (1955) as the Kjølby Gaard Marl and was named after one of the outcrops in northwestern Denmark. It is positioned 6-15 m below the Cretaceous-Tertiary boundary and thus represents an upper Late Maastrichtian deposit. Preservation of calcareous fossils in this horizon is exceptionally good in comparison with that of the white chalk.

From the Kjølby Gaard Marl, different species of agglutinated foraminifera were sampled. Among the different genera, representatives of *Orbignyna* and *Ataxophragmium* showed remarkable structures. The preservation is good, without drusy calcite in the empty chambers.

The surface of *Orbignyna* is equipped with quartz grains neatly lining the exposed and earlier unexposed faces. Jørgensen (1977) commented upon this phenomenon in detail and related it to the strong selectivity of this form as he was able to demonstrate that the main part of the quartz grains of the relevant size fraction was picked up by agglutinated foraminifera. Other forms from the same layer use sponge spicules for surface covering and incorporation into the shell.

In sections examined in the SEM, one observed a curious structure where the wall is built of a mixture of fossil fragments (of which many apparently are planktonic foraminiferal shells judging from their shape and structure) and almost structureless enveloping material. The latter in many cases envelops the fossil fragments and makes them appear to "float" in structureless material.

The structureless enveloping material is more massive than the fossil fragments and is therefore left in a slightly higher level in the polished and etched sections. The enveloping material is, however, affected by etching and therefore is built of carbonate which was substantiated by EDX analysis. Jørgensen (*op. cit.*) demonstrated the presence of prominent organic enveloping material by applying very deep etching. Such material does, however, appear different from the enveloping carbonate material shown here, not withstanding that it is present in addition to the carbonate material.

By analogy with the Recent forms with a secreted carbonate matrix demonstrated by Toksvad and Hansen (1983), we suggest that what is seen as the enveloping massive-looking matrix is a secreted calcareous wall material produced by the once living animal.

The reasoning behind this suggestion is as follows:
(1) Agglutinated forms of other genera from the same samples, also having empty chambers with no diagenetic growth of drusy calcite, do not show this structure. If it was a purely diagenetic phenomenon, it would be expected in other agglutinated forms, unless there was a prominent difference in "structural permeability" which we are unable to see with the technique applied.
(2) The gross configuration of "floating" agglutinated particles in the matrix is strongly reminiscent of the structure in living forms with secreted calcitic matrix.
(3) There is little doubt that the massive-looking matrix is recrystallized. In no area of the sections did we observe any fine structure reminiscent of that of the matrix in the living forms. We therefore have to speculate in terms of resistance against recrystallization. There, the very small units found by Toksvad and Hansen (*op. cit.*) in the living forms would render a secreted matrix more likely to suffer recrystallization than the fossil fragments with their surrounding organic membranes.

CONCLUSIONS AND DISCUSSION

From a study of fossil representatives of different genera *i.e. Pfenderina, Kurnubia, Meyendorffina* and *Pseudomarssonella* (all Late Jurassic), *Orbitolina, Orbignyna* and *Ataxophragmium* (Cretaceous), it can be concluded that with the exception of the two last named genera, the others do not possess a secreted calcareous matrix in additon to their agglutinated particles.

In most cases, the argument against recrystallization, and thereby to a large extent for the preservation of original structures rests upon the observation that the size range of the particles of the walls, as seen in polished and etched sections, is very wide, including also very small particles, which most likely would have disappeared through diagenetic grain growth.

Only in cases of *Orbignyna* and *Ataxophragmium* do the authors feel convinced that the enveloping matrix was originally secreted by the animal. This is based on the massive appearance, "floating" fossil fragments incorporated into the shell, the lack of such structures in other agglutinated forms occurring together with the forms in question, and the very small size of crystallites in Recent cement-secreting agglutinated forms, making such a structure easily recrystallized.

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PLATE 1

Figures 1-3 *Pfenderina trochoidea* Smout and Sugden
Details of polished and etched sections showing large variation in grain size of particles of the wall. Note in figure 1 (in the lower right hand corner of the micrograph) sparry infilling calcite in a chamber lumen. Various unidentified fragments of fossils occur among the grains.
Scalebars: figures 1-2: 20µm, figure 3: 10µm.

Figures 4-5 *Kurnubia* (Henson)
Details of polished and etched sections showing wide range of grain diameters. Chamber interiors with sparry calcite.
Scalebars: figure 4: 20µm, figure 5: 10µm.

Figure 6 *Meyendorffina* sp.
Detail of polished and etched section demonstrating wall structure identical to that of *Kurnubia.*
Scalebar: 4µm.

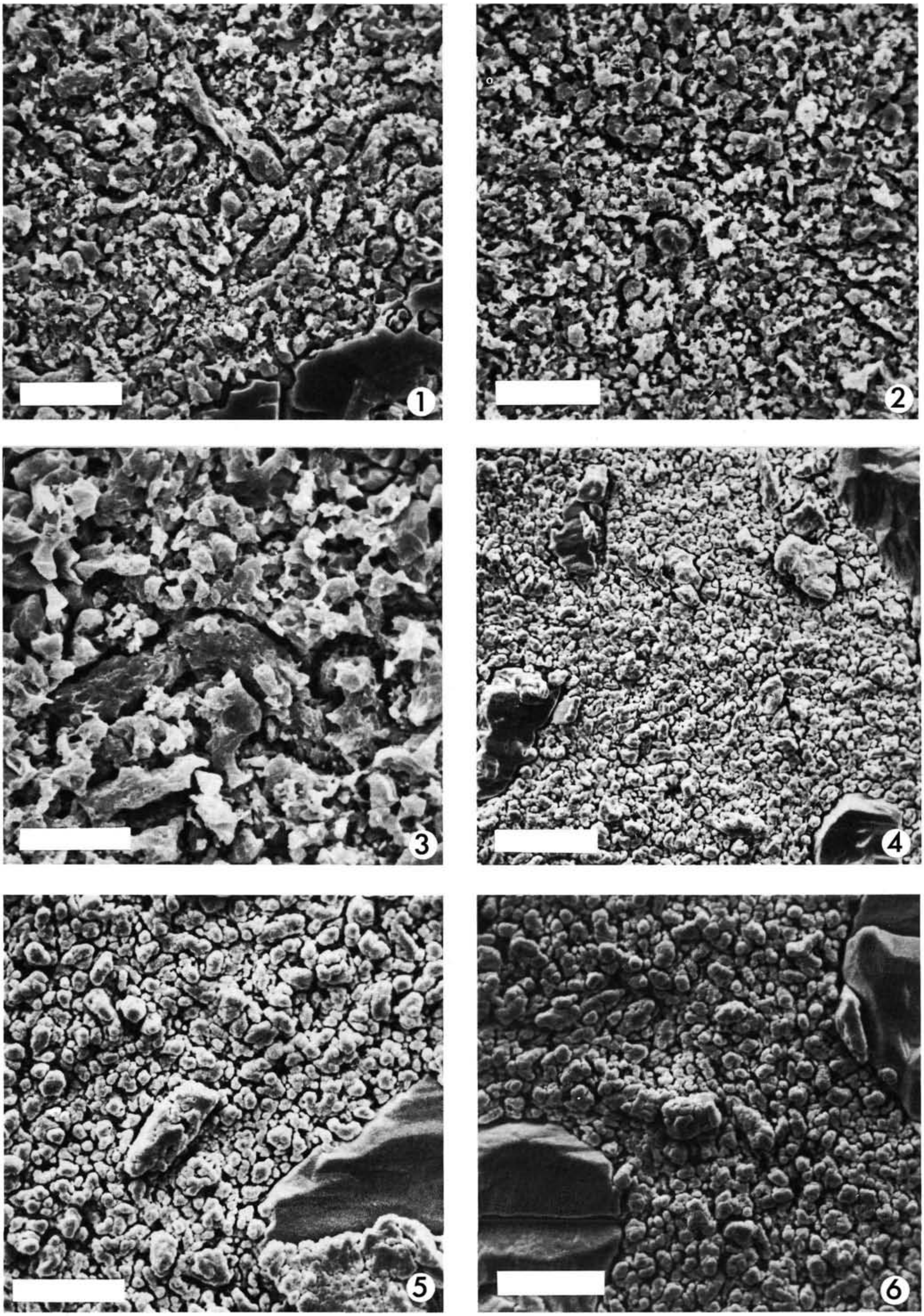
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PLATE 2

Figure 1	*Meyendorffina* sp. Detail of polished and etched section from an area close to the shell surface where recrystallization is evident. An interlocking grain mosaic is developed. Scalebar: 10µm.
Figure 2-3	*Pseudomarssonella inflata* Redmond Detail of polished and etched sections showing wide range of grain sizes along with agglutinated fragments of fossils. Scalebars: figure 2: 10µm, figure 3: 4µm.
Figure 4-6	*Orbitolina texana* (Roemer) Figure 4: Detail of vertical, polished and etched section showing dorsal surface with thin outer wall of subepidermic cellule. Chamber cavity partly filled by drusy calcite. The chamber wall is partly recrystallized leading to an interlocking mosaic structure. Scalebar: 10µm. Figure 5: Detail of slightly recrystallized area with wide size range of particles among which are coccoliths. Scalebar: 10µm. Figure 6: Partly recrystallized walls showing remnants of fragments of fossils with cross-lamellar structure. Scalebar: 10µm.

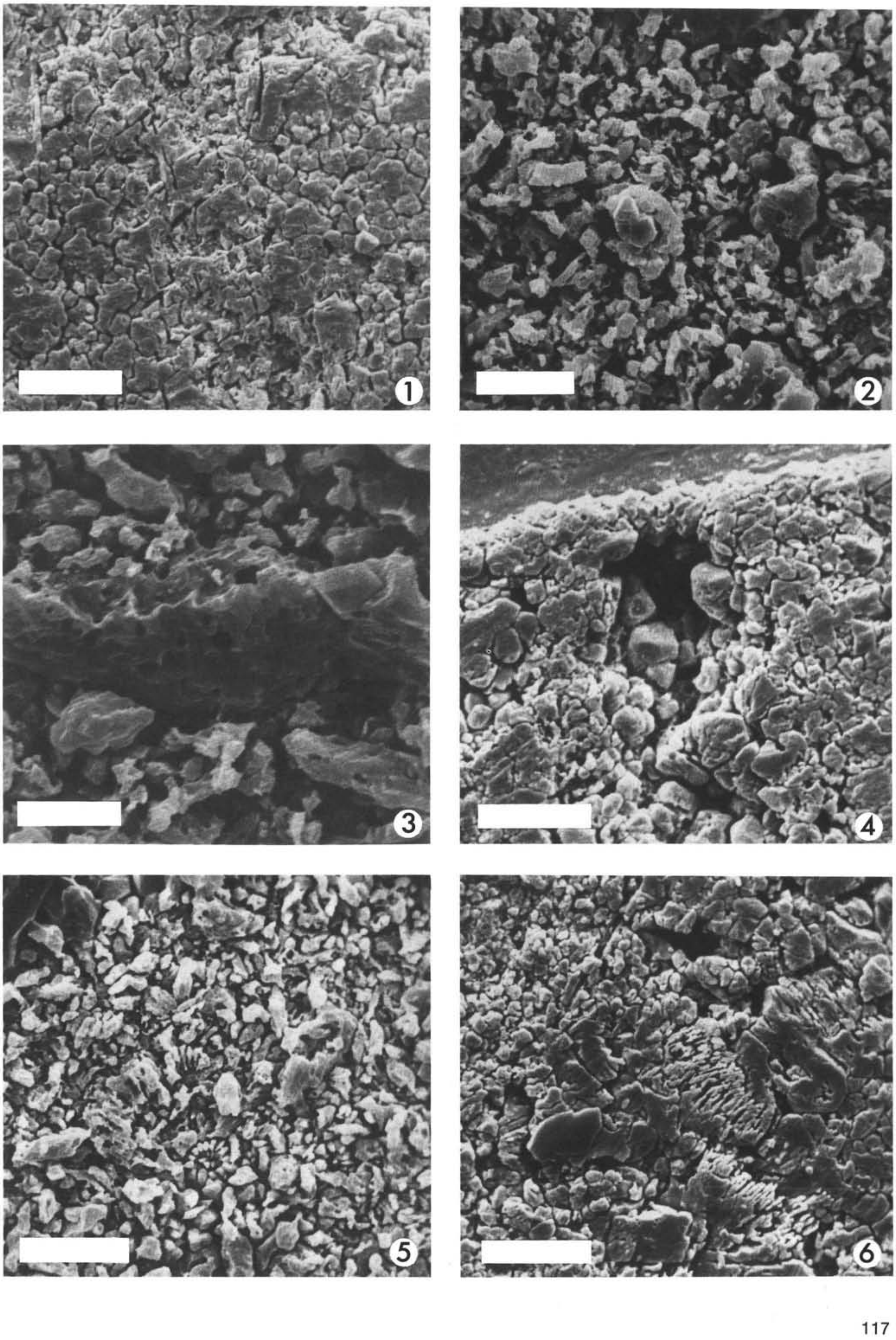
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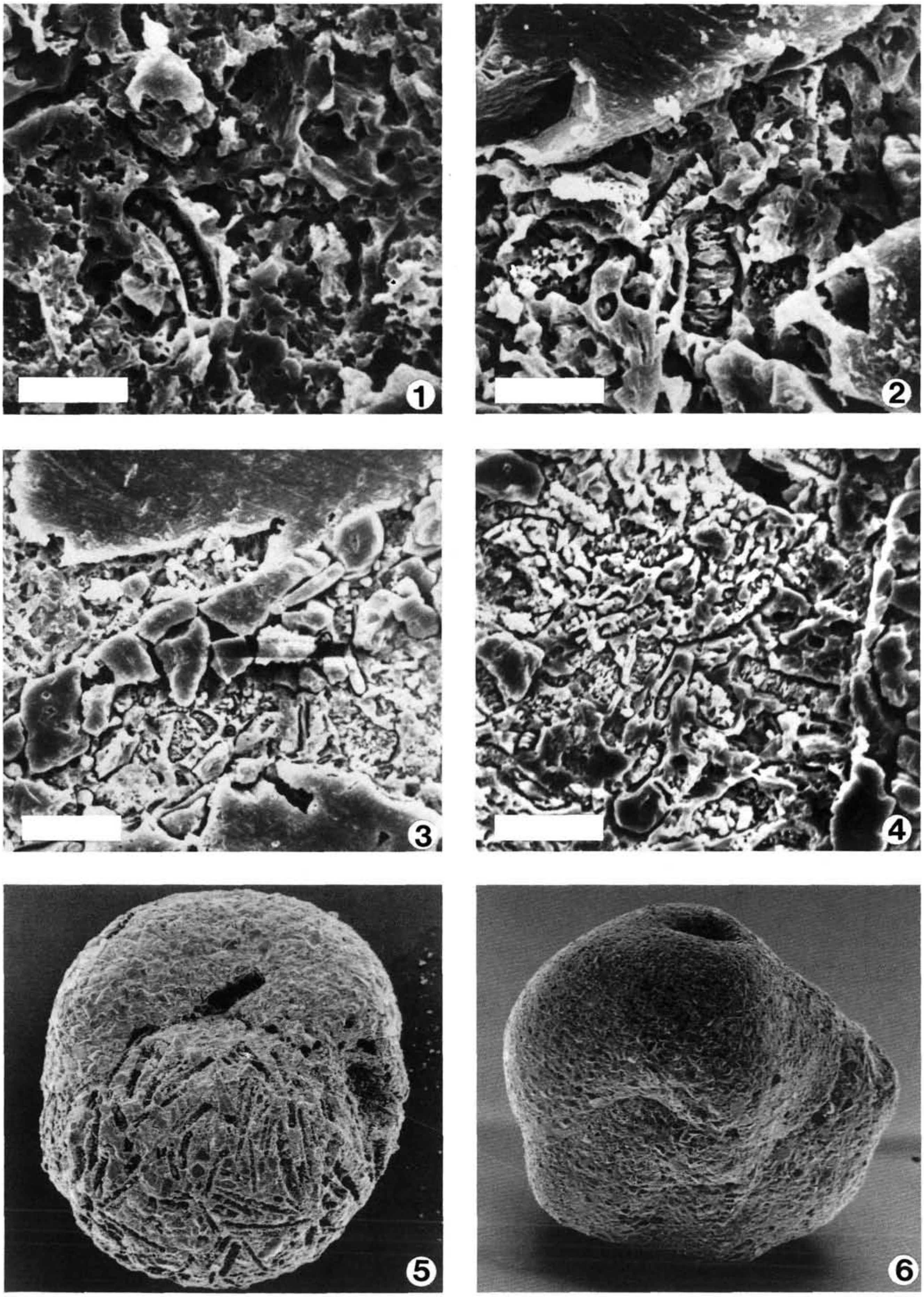
PLATE 3

Figures 1-2 *Ataxophragmium* sp.
Detail of polished and etched sections showing "floating" fragments of fossils embedded in an almost structureless calcitic matrix which is interpreted as the recrystallized remains of an originally secreted calcitic matrix.
Scalebar: 10µm.

Figures 3-4 *Orbignyna* sp.
Detail of polished and etched sections showing accumulations of quartz grains along earlier surfaces. The interior of the walls show "floating" fragments of fossils in an almost structureless matrix. The latter is interpreted as the recrystallized remains of an originally secreted calcareous matrix.
Scalebar: 20µm.

Figure 5 *Ataxophragmium* sp. Upper Maastrichtian, Jylland, Denmark.
Specimen diameter: 600µm.

Figure 6 *Orbignyna* sp. Upper Maastrichtian, Jylland, Denmark.
Specimen diameter: 800µm.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