STUDIES ON THE LATEST PRECAMBRIAN AND EOCAMBRIAN ROCKS IN NORWAY

No. 6.

FOSSILS FROM PEBBLES IN THE BISKOPÅSEN FORMATION IN SOUTHERN NORWAY

By *Nils Spjeldnæs*, Geologisk Institut, Aarhus Universitet, Denmark.

Abstract.

Fossils are reported from pebbles in the lowest part of the Biskopåsen Conglomerate in the Late Precambrian Lillehammer Subgroup at the northern end of lake Mjøsa in Southern Norway. The most common and widespread fossils are *Papillomembrana compta* Spjeldnæs (1963), calcareous structures (pisolites and others), and cross sections of "Sporomorphs." The present material is not sufficient for biostratigraphical correlations. The geological development of the basin at this time is supposed to be due to epirogenic movements rather than to tectonics. The lithology of the pebbles in the conglomerate is highly variable, and some of them have passed through complicated and severe diagenetic changes.

Introduction.

In 1959 the author found some structures in limestone pebbles in the Biskopåsen Conglomerate (Esmarkian), which were interpreted as organic. Further work revealed a number of organic structures in different types of rock. The most striking one, *Papillomembrana compta* has been described separately (Spjeldnæs 1963).

All the material described here come from the lower part of the Biskopåsen Conglomerate at the base of Biskopåsen (about 125 kms. N. of Oslo). The localities are cuts in the main road, and the railway along the Eastern share of Mjøsa, at the border between the Biskopåsen Conglomerate and the Brøttum Formation. The general geology of the area has been described by Holtedahl (1953, 1960) and by Skjeseth (1963). A detailed study of the region is now made by cand. mag. L. Kirkhusmo. The stratigraphic terminology used in this paper is taken from Henningsmoen 1957.

The present find appear to be the first undoubted records of fossils from the lower part of the Lillehammer Subgroup. Worm burrows of the *Skolitos-*, *Monocraterion-* and *Diplocraterion*-types have been recorded from the upper part of the Eocambrian Vangsås Formation in Furnes by Skjeseth (1963), and similar structures have also been recorded from Ringsaker by Spjeldnæs (written communication, Fossilnytt 1962—3). Rothpletz (1910) recorded a number of supposed microfossils from the Biri Limestone, which he regarded to be of Ordovician age. Timofeef (1963) has also recorded some carbonaceous microfossils from the various horizons of the Sparagmite Group.

None of the fossils were seen in the field, they were all found in thin sections of pebbles from the conglomerate.

The author is indebted to professor O. Holtedahl for inspiring discussions and encouragement in the earlier stages of this study. The author has also benefited from discussions on the sedimentology and stratigraphy of the Biskopåsen Conglomerate with cand. real. K. O. Bjørlykke and cand. mag. L. Kirkhusmo, who has also supplied important informations. Dr. S. Manum has kindly undertaken to study the material, and other samples palynologically, and his results are reported in another paper in this volume. NAVF (The Norwegian Research Council for Science and Humanities) has supported the studies with a grant, for which the author would like to express his gratitude.

The material containing organic remains, or structures supposed to be of organic origin, is deposited in Paleontologisk Museum, Oslo.

Geological Setting.

The Biskopåsen Conglomerate, in which the fossils are found, is part of the Sparagmite Group. In Southern Norway, the older (Esmarkian) part of the Sparagmite Group, (the Lillehammer Subgroup) is found in the central part of the Sparagmite basin, whereas the younger, Eocambrian part, the Rena Subgroup has a wider geographical distribution (cf. Spjeldnæs 1964, pp. 27—31, textfig. 2).

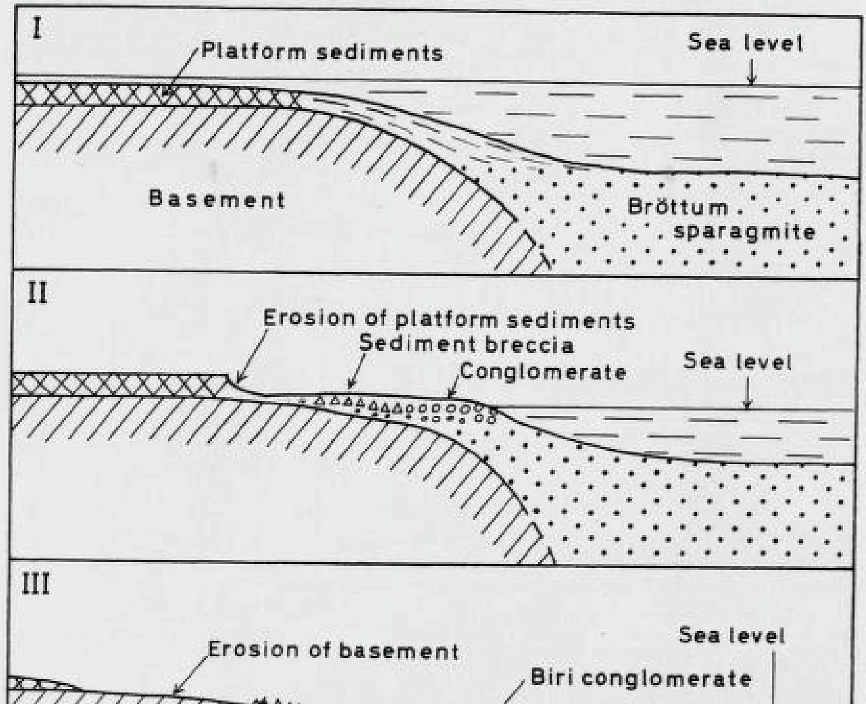
The Biskopåsen Conglomerate is interpreted as a fluviatile-deltaic formation, because of its structures, such as imbrication of pebbles, and lag-bedding. This is supported by the shape of the pebbles (high sphaericity, but not always well rounded), and geologic distribution.

It has been demonstrated by Skjeseth (1963, p. 28—29) and Bjørlykke (1966, pp. 11—12) that the Biskopåsen Conglomerate forms a

Textfig. 1. The typical Biskopåsen Conglomerate, from just S. of the fossil-locality. The pebble frame-work is clearly visible, filled with finer, graywacke or arkose material.

series of fan-like deltas along the southern margin of the basin with transport directions from the South and South-East. In the West and North, the conditions are somewhat more complicated (Englund 1966), but here also the Biri Conglomerate is interpreted as a shallow water deposit.

Traditionally (cf. Skjeseth 1963, p. 29) the formation of the Biskopåsen Conglomerate was explained by a sharpening of the relief and resulting erosion, due to sinking of the basin along faultlines. Since a sinking of a marine basin (the Brøttum Formation is supposed to be


I
Platform sediments
Sea level
Basement
Bröttum
sparagmite
II
Erosion of platform sediments
Sediment breccia
Conglomerate
Sea level
III
Erosion of basement
Sea level
Biri conglomerate
IV
Sea level
Biri shale & limestone

marine) would lead to a transgression, and the Biskopåsen Conglomerate must be regarded as regressive, the author has suggested that the Biskopåsen Conglomerate was formed when previously deposited sediments were exposed to erosion during an epirogenic lowering of the sea-level. This is illustrated diagrammatically in textfig. 2.

This hypothesis also explains the presence of large quantities of pebbles of different sediments and other supracrustal rocks in the basal parts of the Biskopåsen Conglomerate. This is best seen in the fossil-locality, where the basal beds almost resemble a sedimentary breccia, with angular fragments of easily rounded rocks, mostly limestones (Textfig. 3). The largest fragments may be up to 2 metres in diameter (Textfig. 4), and the sediment is not well sorted, except for the lack of the finest fractions. The breccia-like conglomerate consists of a peculiar mixture of tolerably well rounded and often highly sphaerical pebbles of hard rocks, such as quartzite, pegmatite quarts and granites, and angular pebbles of highly variable size, mostly consisting of rather soft sediments, most of them calcareous, or with carbonate cement.

This indicates two different sources of the pebbles, one distant, giving hard, presumably older, crystalline rocks, and a very close one, giving sediments which presumably are not very much older than the formation of the conglomerate itself, even if no exact information of their relative age can be found. The source of the "soft" pebbles must have been a very close one. Considering the rapid rounding of limestone pebbles in a fluviatile environment (cf. Pettijohn 1957, pp. 526—27 pls. 37—38) the transport distance can hardly have been more than a few hundreds of metres. This, and the thorough mixing of the diffe-

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Textfig. 2. Diagram, showing the author's hypothesis of the formation of the Biskopåsen Conglomerate (Biri Conglomerate on fig. III). *I.* indicates the time of formation of the Brøttum Formation, with flysch-like sedimentation in the basin, and shallow-water sediments on the submerged platform. *II.* Indicate the beginning of the regression, resulting in erosion of the shallow-water sediments at the platform, and formation of short transported sedimentary breccias at the base of the Biskopåsen Conglomerate. *III.* Further erosion leads to formation of more long-transport fluviatile-deltaic conglomerates in the upper part of the Biskopåsen formation. *IV.* A new transgression results in the deposition of the Biri Formation, with limestones on the platform and marginal parts of the basin, and shales in the central part of it.

Some of the Biri Formation sediments so also occur below the Biskopåsen Conglomerate in some localities, indicating that such sediments were deposited in the initial stages of the regression, and have in some cases been preserved below the conglomerate in the marginal part of the basin.

Textfig. 3. Sedimentary breccia at the base of the Biskopåsen Conglomerate in the fossil-locality. Note the difference between the angular limestone pebbles (i. a. just above the hammer head) and the more rounded, white quartz pebbles. The small black pebbles are either dark limestone or phosphorite, some of which are fossiliferous.

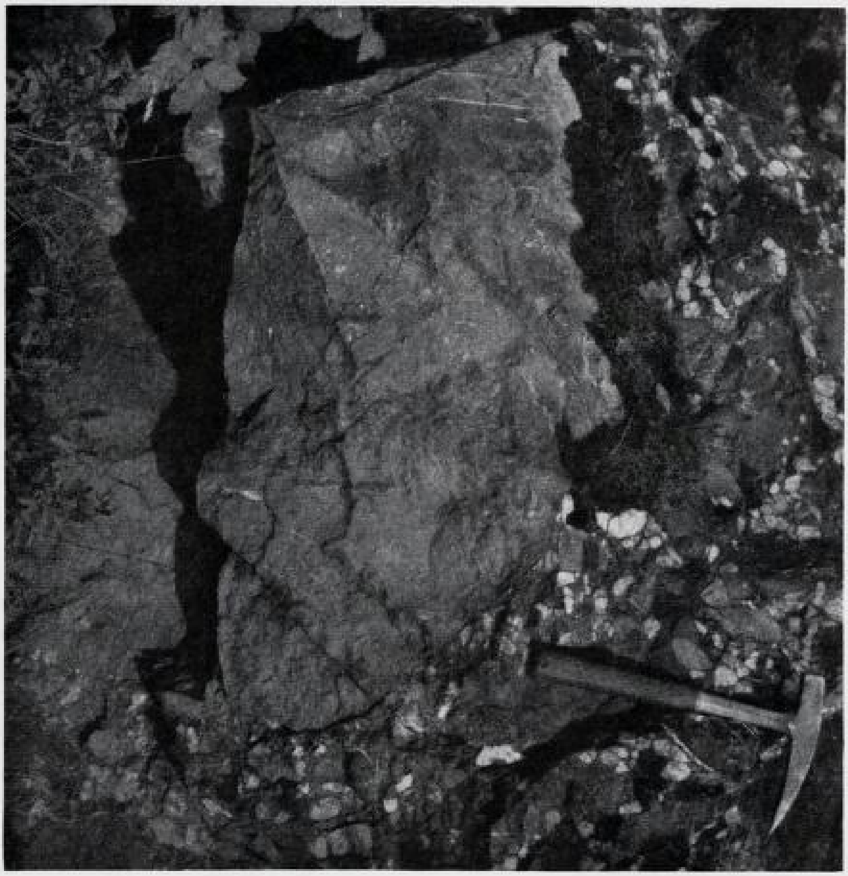
rent types of pebbles suggest an accumulation shortly below a coastal or river cliff. In the upper parts of the conglomerate, the pebble content is more uniform (Textfig. 1), as the "hard" types dominate, and the few "soft" sediments are found as well rounded pebbles. This indicate that the original cliff receded rapidly, probably in a southerly direction.

The sediments found as pebbles may be the lateral equivalent of the Brøttum Formation on the shelf outside the basin (Textfig. 2). Below the Biskopåsen Conglomerate, and the Brøttum Sparagmite there are sometimes found limestones and shales, which have been named the Brøttum Shale and Limestone (cf. Skjeseth 1963, p. 28). According to oral information from cand. real. L. Kirkhusmo, this unit is just a lower part of the Biri Shale and Limestone, and the Biskopåsen Conglomerate must therefore be regarded as a tounge in the Biri Formation.

The latter may indicate that the sediments and therefore also the fossils are derived from the lower part of the Biri Shale and limestone. This will explain the fact that the supposed erosional cliff must have been considerably North of the presumed southern border of the basin, especially if the later tectonic movements are taken into consideration.

The variety of rocks found as pebbles is, however, much wider than that found in the Biri Shale and limestone, and it can not be excluded that other sources are involved also. One of the common rock types among the "soft" ones in the fossil-locality, is a fairly fresh, medium-grained diabase, often developed as a vesicular rocks (cf. Bjørlykke 1905, p. 29). Most of the pebbles, which are up to ½ metre in diameter are fresh, but some of them show a concentric weathering crust, indicating some distance and time of transport. This kind of diabase is not known from the Precambrian area South of the Sparagmite Basin —but being an ordinary diabase type, it may have been confused with the Permian diabase dykes occurring in the Precambrian East of the Oslo Graben (cf. Hjelle 1959). Palaeomagnetic dating of the dykes may show if any of these are of Late Precambrian age. It is difficult to decide if the diabase pebbles come from dykes, sills or thick lava flows, but the absence of very fine-grained types with lava structures points to dykes or sills. The vesicular rocks may indicate lavas, but such rocks are not uncommon in diabase dykes. Anyhow, the presence of a large number of diabase pebbles of uniform petrology may indicate a pene-contemporaneous volcanism.

In the fossil-locality itself, which consists of three parallel sections in the main road, the railway and the shore of lake Mjøsa, there is only a short distance between the base of the Biskopåsen Conglomerate, developed as a sedimentary breccia, and the Brøttum Formation. No intervening limestone or shale is exposed here. In the upper (southern) part of the section, a considerable part of the Biskopåsen Conglomerate, is well known, and especially its tectonics has been described by a number of authors (i.a. Münster 1900, pp. 9–12, Bjørlykke 1905, pp. 28–30, Holtedahl 1944, p. 29).



Textfig. 4. A large boulder of limestone in the sedimentary breccia at the fossil-locality.

The exact position of the breccia-like conglomerate with fossiliferous pebbles is quite clear, being the lowermost conglomeratic bed above the typical Brøttum Sparagmite. There are, however, arkose/grayvacke beds between the conglomerate horizons higher up, and they are almost indistinguishable from the typical Brøttum Formation lithology. This is also the case higher up in the Biskopåsen Conglomerate, but here the arkose/grayvacke is restricted to thin beds between the conglomerate horizons, and as fill in the pebble-framework in the well sorted, coarse conglomerates.

Bjørlykke (1966, p. 10—12) reports that the border between the

Textfig. 5. Thin section of the sedimentary breccia, showing a phosphatic pebble consisting of an assemblage of different, phosphatecemented rocks, and also a quartz pebble (upper left). Both pebbles are strongly sutured. From the fossil-locality. 5 x

Brøttum Formation and the Biskopåsen Conglomerate is difficult to define, because conglomerate horizons appear with increasing frequency in the upper part of the former formation, and Holtedahl (1944, p. 29) specifically refers to some beds about 20 m. *above* the fossiliferous ones at Biskopåsen as "conglomerate beds in the Brøttum Sparagmite."

Following these authors, the beds discussed here should therefore probably belong in the upper part of the Brøttum Formation. Since the border between these formations is hard to define sharply, and the bed in question—in the opinion of the present autor—belongs to the Biskopåsen Conglomerate both lithologically and by geological genesis, it is referred to the latter formation, at least until a more refined stratigraphical terminology of the border beds has been made.

Structures in carbonate pebbles.

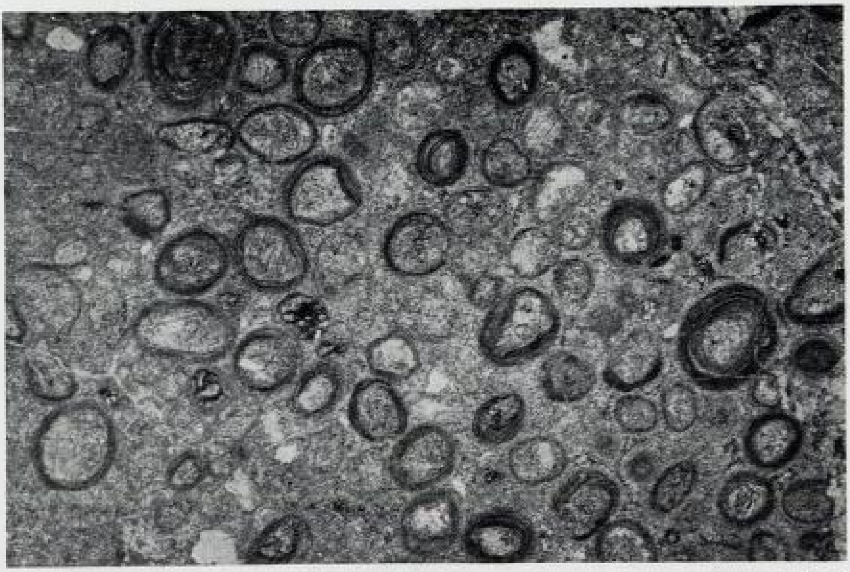
Most of the "soft" pebbles are carbonate rocks, or carbonate cemented ones. The most common type is medium gray, with a yellowish to brown weathering colour. It represents one general type, because all

Textfig. 6. Thin section of limestone pebble showing oolites or pisolites completely recrystallized to monocrystalls unless where dark substances still show "ghosts" of the original structure. Note quartz and microcline crystalls of variable size as the core in some of them. From the fossil-locality. 5 x

gradations between the end members are found. It ranges from rather pure carbonate rocks, often oolitic, to carbonate cemented arkoses. The content of terrigenous clastics is highly variable in amount and grain-size, but constant in mineralogy, consisting of quartz and feldspar (normally microcline). The grains—even the larger ones—are often conspicuously angular, and the feldspar content varies from 20 to over 50 %. Clay minerals are generally absent, or difficult to observe. Some of these rocks look like the ordinary Brøttum Sparagmite, where the fine-grained argillaceous matrix has been replaced by carbonate.

The carbonate pebbles have been exposed to severe diagenetic changes, falling into three categories, bulk solution, internal solution, and dolomitization.

The bulk solution shows up as indented pebble surfaces, and as stylolites. The former are certainly due to pressure after deposition of the conglomerate, and these structures are found not only in the carbonate pebbles, but also in the phosphorites and even in the quartz pebbles (textfig. 5). When the pebbles from the Biskopåsen Conglomerate



Textfig. 7. Thin section of limestone pebble showing oolites or pisolites most of which do not have a mineral grain as the core. Some appear tolerably well preserved, but others have almost disappeared. From the fossil-locality. 5 x

weather out free, they often show distinct solution marks where the adjoining pebbles have been pressed into oneanother. This is especially the case with the carbonate pebbles, even if they do not appear to have been drastically deformed in shape during this process.

The stylolithes are quite common, as black lines in the limestones. Some of them might be predepositional (in relation to the conglomerate), as they do not show any orientation, neither to bedding nor to directions of tectonic pressure. In some of the pebbles, the stylolithes are exceptionally irregular, and grade into thin shale flakes.

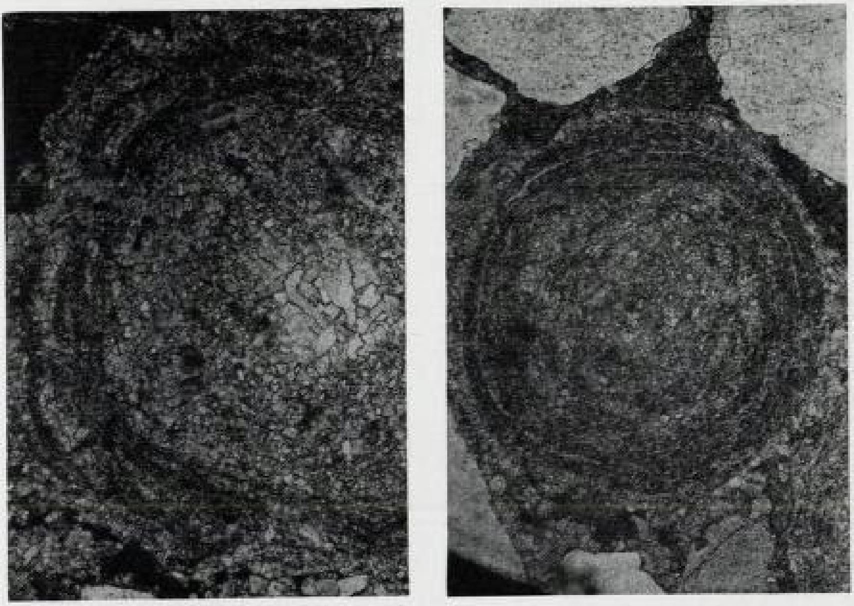
The internal solution is seen as corrosion of quartz grains, and to a lesser degree in feldspars (cf. textfig. 3, 6, 10). In a number of rocks the quartz grains are reduced to mere skeletons, and it is possible that some of the pure carbonate rocks have been formed by carbonatization of an original greyvacke. In some cases a decrease in volume has accompanied this metasomatism, as a reconstruction of the original shape of the quartz grains indicate that they would fill more than the present volume of the rock.

Such a carbonatization of an arkose or graywacke material can be

Textfig. 8. Thin section through a dolomitized pebble, with more quartz in the matrix than most of the others, and completely recrystallized oolites or pisolites. In the centre of some of them new calcedon-like quartz has formed (i.a. lower right). From the fossil-locality. 5 x

expected in a well aerated, warm shallow water sea, and may have occurred just after deposition, or considerably later. Judging from the frequent observations of highly corroded quartz in many of the carbonate cemented rocks of the Sparagmite Group, the author is inclined to regard many of them as the result of carbonatization of normal arkoses and greywackes. The observations made on the present material indicate that this process may lead to almost pure carbonate rocks. As usual in this type of metasomatism, the clay minerals, and other fine grained material disappear first, then the quartz, and last the large feldspars.

A number of the pebbles are more or less dolomitized. This was suspected because of their brownish weathering colour, and it was confirmed by X-ray diffraction studies. (The method used for a semi-quantitative study is the same as that used by Jørgensen & Spjeldnæs 1964.) They range from almost pure limestones with only traces of dolomite to almost pure dolomites. Of the 9 samples studied, 5 are in the interval between 40 and 60 % dolomite. The carbonatization is very strong also in the dolomite rocks, but not significantly stronger than



Textfig. 9. Thin sections of two tolerably well preserved structures, which are interpreted as algal pisolites. From the fossil-locality. 40 x

in the more calcittic ones. This may indicate that even if both dolomitization and carbonatization were dependant on the same environmental factors (temperature, pH and Eh), they were not directly interconnected.

Some of the purer carbonate rocks are oolitic or pisolitic. In most cases the oolites are rather irregular in shape, and in many cases they consist only of a thin crust over a clastic mineral grain, which may be highly decomposed. This grain may either be quartz, feldspar or a carbonate. The layers in the oolites are in some cases accentuated by phosphate, iron-oxides or organic matter. Such oolites remain intact, at least superficially, when a slight recrystallization destroys the normal ones (cf. textfigs. 6–7). By further recrystallization, the whole oolite is transformed into a sphaerical carbonate monocrystal, often with the original clastic mineral as a core (textfig. 6).

In the present material it is difficult to distinguish between real oolites and algal pisolites, because the finer structure have generally been lost by recrystallization. No specimens with the typical radial orientation of oolites are found, but it is assumed that some of the almost sphaerical bodies with regular and continuous concentric lines are genuine oolites. Typical algal pisolites are met with in some cases (textfigs. 9—10) but mostly they are too much recrystallized to be properly identified. This is especially true with the ones having a large core (textfig. 6).

A number of stages in diagenetic changes can be seen. At first, the central part of the oolite or pisolite recrystallize, and the original concentric structure disappears where it is not accentuated by dark substances.

Then the whole body is changed into one single crystal of carbonate (mostly calcite). Because of the cleavage surfaces of the calcite, the oolite rocks at this stage have a striking resemblance to a crinoidal limestones. In other cases the whole sphaere is transformed into a diffuse mass of fine-grained dolomite (textfig. 8). At a last phase in this line of diagenetic change, fine-grained quartz appear in this central part of the sphaeres.

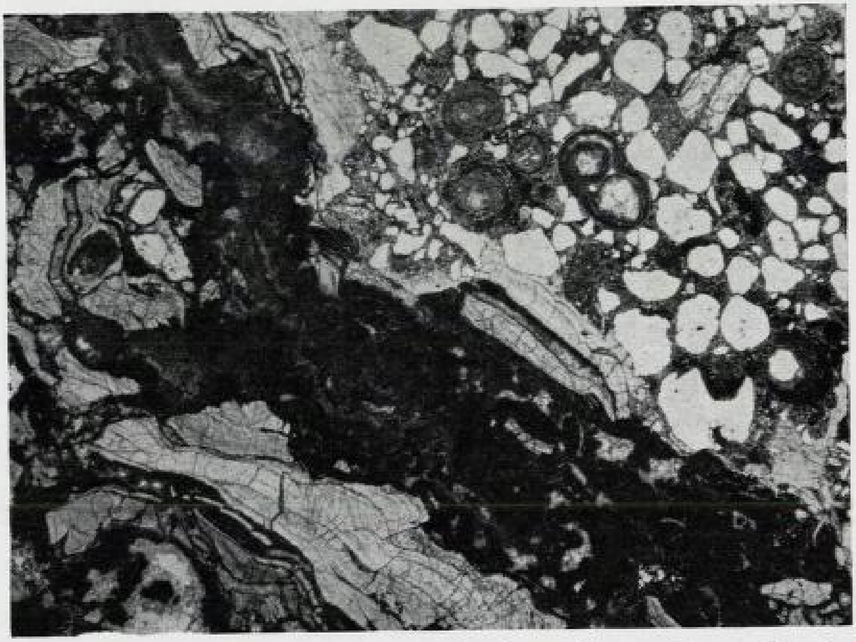
There can hardly be any doubt that the more typical pisolites are formed by organisms (possibly blue-green algae), but it is impossible to define these organisms closer, and also to tell whether the other sphaerical bodies are due to organic activity or are purely inorganically formed oolites. The pisolites are of the general type met with in beds of all ages, ranging from the Precambrian to the Recent, and they lack features which can be utilized stratigraphically.

Other structures of doubtful origin are frequently found in the carbonate pebbles, and some of them may recall cross-sections of fossils. Having in mind all the peculiar pseudo-fossils which may arise during diagenetic changes of carbonate rocks, the author is inclined to regard all these structures as inorganic, or at least too doubtful to warrant a description.

In addition to the ordinary carbonate pebbles referred to above, there are some other ones. Most of them are transitional to the phosphorite pebbles described below. There are also some dark, recrystallized limestones with no fossils or typical structures.

In one of the largest carbonate boulders, there is a complex cavity, filled with stalagmitic calcite (recrystallized), phosphorite and calcedony, in that order (textfig. 10). The preserved part of the cavity is of decimetre size, and the structures in the limestone is otherwise very well preserved, as illustrated by the pisolites in textfig. 9.

Another, unexpected type is an antraconittic limestone of exactly the



Textfig. 10. Thin section of a lime-cemented sandstone with strongly corroded grains of quartz and feldspars, and numerous pisolites. A cavity was formed in the rock, and was later (before erosion of the rock) filled with stalactitic calcite, phosphorite and calcedony. The part of the cavity preserved in the boulder is about 35 cm. long and 15 cm. high. From one of the largest boulders in the fossil-locality. 5 x

same type as found in the Middle and Upper Cambrian of the Oslo Region. Only one boulder, about 30 cm in diameter was found, consisting of several cm. long, columnar crystals of almost black calcite, which smell strongly when hit with a hammer. Even the smell is similar to that of the Cambrian rocks. The antraconites are supposed to have originated in a rather specialized environment (cf. Henningsmoen 1957, p. 61—62), and the presence of this rock-type in the Biskopås Conglomerate indicates that the source area was one with a variety of different sediments.

Structure in phosphorite pebbles.

The phosphorite pebbles are much fewer and smaller than the carbonate ones. The largest is about 10 cm. in diam., and most of them are 1½—3 cm. In contrast to the carbonate pebbles many of them are also well rounded, and it is possible that they have passed through more than one sedimentary cycle.

In composition they range from limestones or sandstones with minor quantities of phosphate cement to almost pure phosphorites, where fossils are more common than identifiable quartz grains, and where X-ray diffraction analysis show only apatite (probably F-apatite) besides very minute traces of quartz and clay-minerals. In many cases the intermediate types show a polymictic assemblage of different rocks, mostly phosphorite cemented, and of different shape and size (text-fig. 5). Even the pure phosphorites often show micro-brecciation and a complex history of recementation (pl. 3 figs. 2–3). Some of the phosphorite pebbles must, judging from their black powder and coal-like appearance have a considerable carbon content.

Organic remains are found only in the rather pure phosphorites, and only in a small fraction of these. Either the pebble is devoid of fossils, or they occur in profusion. The fact that many of the fossils are not well preserved, and that all transitions are found between tolerably well preserved fossils, and those which are almost completely destroyed, may indicate that the fossils were originally much more wide-spread, but were destroyed by diagenetic changes in the sediment.

The organic remains fall into two groups, *Papillomembrana compta*, and "sporomorphs." The latter noncommittal term is used in accordance with Roblot (1963, p. 1559, 1964, pp. 107–108) for small (5–60 μ) single or complex, sphaerical structures with carbonaceous walls.

It is used here in a slightly extended sense, including also larger structures incorporating small ones, even if they have a mineralized shell. Another term which might also have been used, is acritarchs, in the sense of Downie, Evitt & Sarjeant (1963), but as the studies of the present material has not progressed far enough to allow commitments as to biological affinities, they are referred to as sporomorphs and related structures—in short sporomorphs. This does not indicate that the author believes that all of them necessarily are of vegetable origin, even if most of them may be so.

Papillomembrana was described by the author (Spjeldnæs 1963), and there is nothing to add to the description of the well preserved specimen, although the figures of the type specimens are given (pl. 1, figs. 1–3, pl. 2, fig. 1) here because of the bad reproduction in the original paper. Neither is there any new information on the possible biologic relationship of the organism nor any records of it, or similar ones, from other localities.

The holotype is still the only tolerably uncompressed specimen known, all the others are more or less flattened. It is difficult to give an exact number of the specimens found, because there are many badly preserved specimens, and a complete series exist from compressed, but readily identifiable specimens, to "ruins" which can only be suspected to belong to *Papillomembrana* because of their resemblance to the better preserved specimens in size, colour and gross shape. In one thin-section more than 30 such "ruins" are found, but only 3–4 specimens can definitively be referred to *Papillomembrana*.

Several different types of sporomorphs occur, most of them in the same pebbles as *Papillomembrana*.

Type I. 600–700 μ in longest diameter, slightly compressed from one side. The walls are thin, black and irregular, presumably consisting of an organic membrane (pl. 3, figs. 1–2). The irregularities of the walls may be partly original, but has evidently been much modified by diagenetic processes. In some cases the wall has disappeared completely, and in others it is only preserved in small fragments. The interior is filled with clear, isotropic phosphorite, without the structures found in the darker phosphorite outside the sphaere. In most cases there are also small, black granules distributed in the interior, and in one or two cases (pl. 3, figs. 1–2) they are partly aggregated into a large number of small sphaeres, 8–15 μ in diameter, consisting of one layer of granules, which are up to 2–2½ μ in diameter. The larger granules are "cellular," but the smaller and more common ones appear just as black dots.

The number of specimens belonging to this type is difficult to establish, as there are all transitions from the well defined ones to lumps of light phosphorite with the same general size and shape, but entirely without a wall. About 6–8 well defined ones, and approximately 20 diffuse ones have been observed.

Type II. Sphaerical, uncompressed, 250–450 μ in diameter with a wall resembling that of type I in structure, but with a much more irregular outline, mostly as bulges of the wall and thread- or filament-like protuberances of considerable dimensions. These structures may have been modified through diagenesis, but are too common and regular to be all accidental (pl. 3, fig. 3, pl. 4, fig. 1, pl. 5, fig. 1, 5). There might also be apertures in the walls, but it is difficult to discriminate between original apertures and dissolved parts of the walls in this type of material. Like the first type, they are filled with clear phosphorite, often with some granules, but without the filamentous structure common to most of the phosphorite outside the sporomorphs. In one of the specimens of this type, (pl. 5, figs. 1, 6) there is a rather dense mass of rod-like bodies about 5–7 μ in length and 1–1½ μ in width. The interpretation of these structures must be left open at present, even if they resemble features described as fossil bacteria and fungi, as their organic nature is not entirely beyond doubt.

About 10 well preserved specimens, and more than 40 diffuse ones have been observed.

Type III. Almost perfect sphaeres (in a few cases aggregates of sphaeres), without visible ornamentation or outgrowths of the wall (pl. 2, figs. 2–3). Most of them are 70–90 μ in diameter. Smaller cross-sections show thick and diffuse walls, indicating that they are peripheral rather than equatorial sections. There are also a large number of smaller, more or less circular sections, but they are hard to study, because their diameter is too close to the thickness of the thin-sections used (approximately 20 μ). It is therefore impossible to give exact information on the real size-distribution of this type, the figures above refers to the larger, and well preserved specimens, and do only give a definite upper limit for their size.

Like the two other types, the interior is filled with light, isotropic phosphorite, and there are no structures observed inside this type. The walls appear to be thicker, but that might be due to the fact that more specimens are well preserved, and the difficulty in measuring the wall thickness in the other types. In a few specimens the clear phosphorite is also found in a thin band outside the wall. This may indicate either that the clear phosphorite was formed by late diagenetic processes, or that these specimens had an outer wall which has been dissolved. It is difficult to give an exact number for the specimens of this type, but it is the most common one in the present material. More than 80 undoubted specimens have been observed, and a large number of diffuse or small ones do also occur.

Type IV is found only in a few specimen, and all characteristic features are found only in one of them (pl. 3, fig. 2, pl. 5, fig. 4). It is about 125 μ in longest diameter, slightly assymetrically dorsoventrally compressed (bunlike). The wall appears to be granulose, and laterally thickened. The irregularities in the wall may be due to diagenesis, as the material is not large enough to prove its constancy. In the central part there is a sphaerical body, granular and quite similar in appearance to the phosphorite outside the sporomorphs, but without the characteristic filamentous structure. Between the sphaerical body and the wall, there is a thin layer of clear phosphorite, which also continues outside the wall, with a diffuse outer border.

Type V. Only three specimens have been found, and the description is based on the best preserved one (pl. 3, fig. 3, pl. 5, fig. 3). It consists of a cluster, 160—190 μ long of irregular sphaeres with granular walls. The sphaeres are from 30 to 80 μ in diameter. The wall substance is light brown, and entirely different from those in the other types. The thickness of the walls are also highly variable, and there seems to be openings between the sphaeres.

In addition to these rather common, or well defined types, there are some others which are either less well defined, or occur only in one specimen.

Type VI. Only one fragmentary specimen has been observed (pl. 5, fig. 6). It consists of a sphaerical shell, consisting of quartz, about 500 μ in outer diameter, and 60—65 μ in thickness. The fragment, which consists of about 170° of the shell, consists of three single crystals of quartz, but this may be due to later recrystallisation. There is no sculpture to be observed neither on the outside nor on the inside of the shell. The interior is filled with an irregularly globular mass of granulose material. This may be interpreted as diffuse sphaeres, approx. 30 μ in diameter, with granulose walls, but they have suffered too much from diagenetic changes to be properly described.

Type VII. Only one specimen has been observed (pl. 4, figs. 2—3), consisting of an highly irregular membrane or wall surrounding a roughly sphaerical mass consisting of small, granular sphaeres. The shape of the outer wall may easily be due to external and diagenetic changes. The granular sphaeres vary in diameter from 5 μ to 20 μ, and are of brownish colour, different from the ordinary walls. There are also several other irregular membranes resembling the present one in size and structure, but without the granular sphaeres inside.

Type VIII. Three specimens are found, and the description is based on the best preserved one (pl. 5, fig. 2). It is an irregular, angular body, possibly a fragment of a larger one, 350 μ in length, and darker in colour than the surrounding phosphorite. It shows a system of thin, distinct lines or tubes parallel to the margins, and branching at the widest end.

In addition to these, well defined types there are in the phosphorites a number of stylolite-like membranes, often of considerable size. Some of them are similar enough to stylolites in other rocks to be interpreted as inorganic structures, but other are very irregular, curved, and appear to carry long protuberances. Some of these membranes may therefore be of organic nature, even if it is impossible to define them properly on the present material. Some of them are shown in figures illustrating other structures, particularly pl. 1, fig. 1, and pl. 3, figs. 2—3.

There are also some micro-structures in some of the specimens (pl. 5, fig. 5) as referred to above. The whole phosphorite also shows a characteristic, filamentous structure, which under high magnifications appear as tufts of very fine filaments. Such structures are known also from other, younger phosphorites, and may be biological in origin. They recall fungal threads, but since the thin sections used for this study are too thick to observe the details of the filamentous structures, they are only mentioned here. The appearance of the structure in the thin sections without immersion optics is seen in pl. 5, fig. 5 and pl. 2, fig. 3, and some of the details observed in higher magnification, and with the use of immersion optics can be seen in pl. 1, fig. 2 (inside the holotype of *Papillomembrana compta*).

Concluding Remarks.

The fossils found in the pebbles in the Biskopåsen Conglomerate are remarkable in several ways.

They are more numerous, and varied than most Precambrian assemblages described up to now. This may partly be explained by the comparatively young age supposed for these beds, but it is perfectly understandable that some authors (i.a. Rothpletz 1910) have suggested an Ordovician age for the Biri Formation, with similar lithology as the pebbles described here. The observation of some types of fossils where small bodies occur within larger ones in the Biskopåsen pebbles recall similar observations from Ordovician beds (Kozlowski 1963, Henry 1964). The structure and dimensions are, however, different, and the fossils described here are at present not of any stratigraphic value, as similar material from other, contemporaneous beds have not been studied with the same methods.

As mentioned above, no fossil resembling *Papillomembrana* has yet been described from other localities, and the other structures are either too generalised, or also unknown in other localities. A structure (Fossil I) described by Ewers (1933, figs. 2–3) from the Visingsø Formation in Sweden resembles type VI described here in having a quartz shell, but differs in details of structure, and in size. The other structures described by the same author do not recall any of the forms from the Biskopåsen pebbles, even if the material is the same (phosphorite pebbles), and the supposed age (young Precambrian) is roughly the same.

When the present fossils are compared with the assemblage described from essentially the same material by Manum (1967) the differences are immediately apparent. In Manum's material, the organized structures are very few, whereas organic debris is very common. The sizes are also different, as the most important structures described here are much larger than those in the palynological material. This is partly due to the fact that the smaller specimens are difficult to observe in the thin sections, and are easily overlooked. The lack of large specimens in the dissolved material is explained by the fact that the walls of most specimens, as visible in thin sections, are incomplete, and often almost completely destroyed. There are only some very few specimens, which survive both the diagenetic changes and the extraction process. On the other hand, these are much better preserved than the average ones observed in the thin sections.

It is evident that also the larger specimens (including *Papillomembrana)* occurred in the material which has been studied palynologically, since most of the pebble which yielded the type specimen of *Papillomembrana compta* was used for these studies, and the two thin sections made from the same pebble both showed numerous large specimens.

It is also interesting to note that (except for *Papillomembrana)* none of the specimens seem to have been compressed. This, and the filling of most of the specimens with light coloured phosphorite, contrasting strongly against the darker groundmass, indicate that the phosphorite was formed at an early stage of diagenesis.

The smaller bodies found inside type I can with great certainty (because of their size, and wall structure) be referred to Manum's type A, and it is likely that a number of the smaller specimens of type III can be referred to his types E and F. A conclusion about the preservation and distribution of the fossils in the pebbles is that the palynological technique gives a well preserved, but highly selective assemblage whereas the thin section studies gives a much richer, but less well preserved one.

As regards the age of the pebbles, there is lots of coherent geological and lithostratigraphical evidence pointing to young Precambrian age, possibly rather close to the Cambrian/Precambrian border, but there are some uncertainties to this, aside from the young aspect of the assemblage, and the obvious fact that the pebbles are older than the conglomerate in which they are found.

Absolute age determinations of beds in Northern Kola (Polevaya & Kazakov, 1961, p. 110), which have been correlated with the Sparagmite Group in Finnmark gives ages both on clay minerals and glauconite which are just above 1000 m. y. The Porsanger and Lillehammer subgroups are correlated because of their striking lithological similarity, especially in the upper part, but it should be noted that the crystalline basement below them are of different age, being much older in Finnmark than in southern Norway. In fact, if the Lillehammer subgroup could be proved to be about 1000 m. y. old, it would be older than the supposed age of the crystalline basement (8–900 m. y.)! The geochronology of the basement is also somewhat in doubt, as it is possible that the basement of the Lillehammer Group belongs to the older Precambrian, on the Eastern side of the "mylonite" zone, which divides the Precambrian both of Sweden and Norway (cf. Hjelle 1963, fig. 1).

Even if the evidence for a young Precambrian (Vendian or Riphean III) age of the Lillehammer Subgroup seem good, the uncertainties mentioned here make more studies necessary. Both the isotope ages of the immediate basement, and biostratigraphic studies, especially correlations with the Russian platform will be valuable.

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Explanation to plates.

All figures on the plates are from thin sections of phosphorite pebbles from the basal part of the Biskopåsen Conglomerate, at the fossil locality.

The thin sections belong to Paleontologisk Museum, Oslo.

The photographs shown in pl. 1, figs. 2 and 3, and pl. 2, fig. 1 were taken by Dr. S. Manum, the rest by the author.

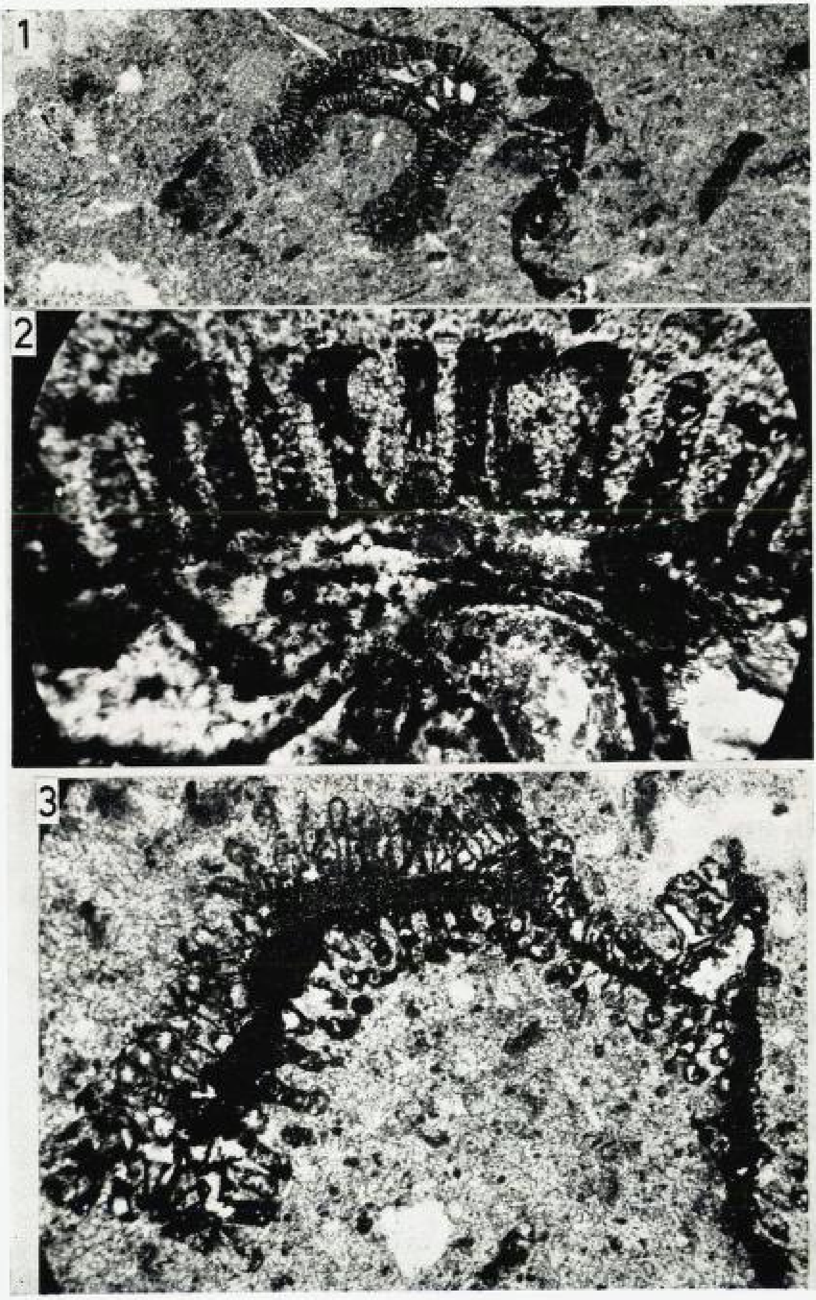
PLATE 1

Papillomembrana compta Spj.

fig. 1. Holotype (PMO 73173) and the surrounding rock, including a stylolite-like black membrane. 60 x.

fig. 2. Detail of holotype, showing structure of protuberances and enigmatic internal features. On the internal walls, there are tufts of very thin threads (fungal or algal?). 740 x.

fig. 3. A compressed specimen, showing the hollow protuberances.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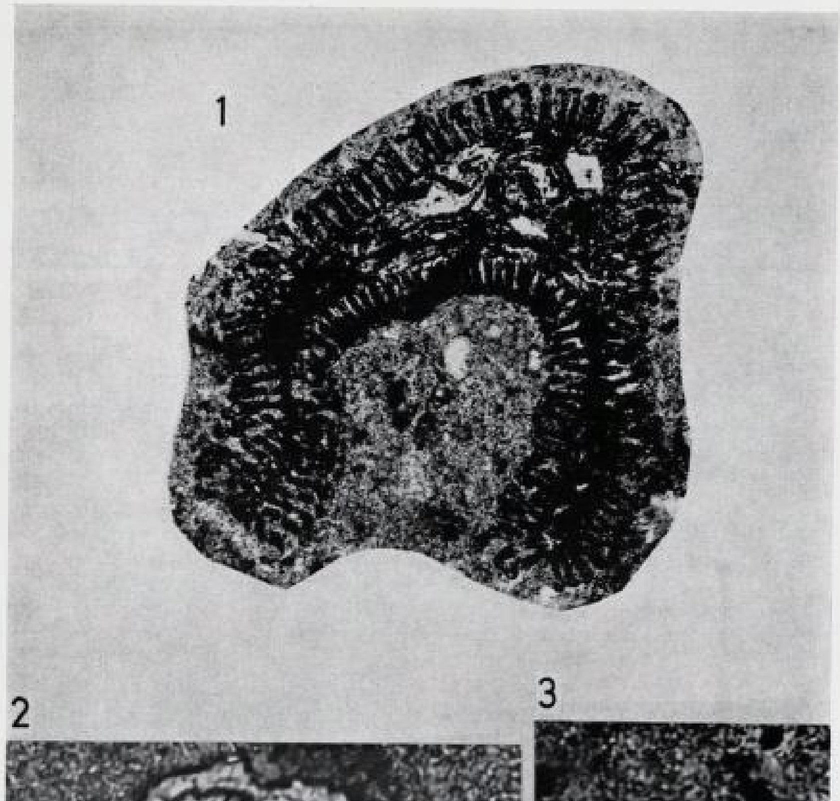
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PLATE 2

fig. 1. *Papillomembrana compta* Spj. The holotype. 135 x.

fig. 2. Sporomorph, type III. The structures seen in the walls may be due to partial destruction of the walls, or be original. 675 x.

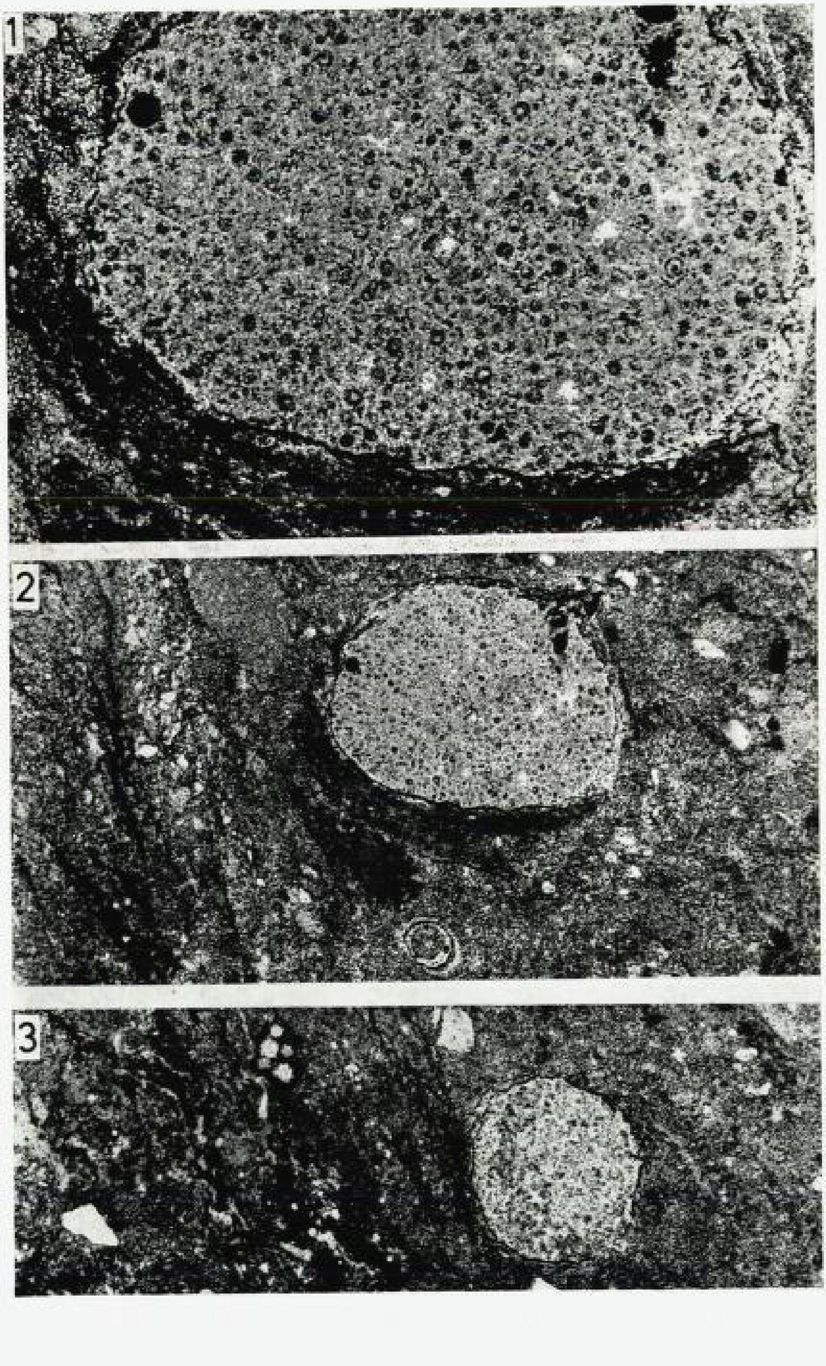
fig. 3. Sporomorph, possibly belonging to type III, consisting of an aggregate of three sphaeres. This is the only specimens of this kind observed. 675 x.

PLATE 3

fig. 1. Sporomorph of type I, with small sphaeres inside, resembling Manum's type A. 150 x.

fig. 2. Sporomorph of type I, the same specimen as above, but also showing one of type IV (cf. pl. 5, fig. 4) 60 x.

fig. 3. Sporomorphs of type II (cf. pl. 4, fig. 1) and type V (pl. 5, fig. 3) 60 x.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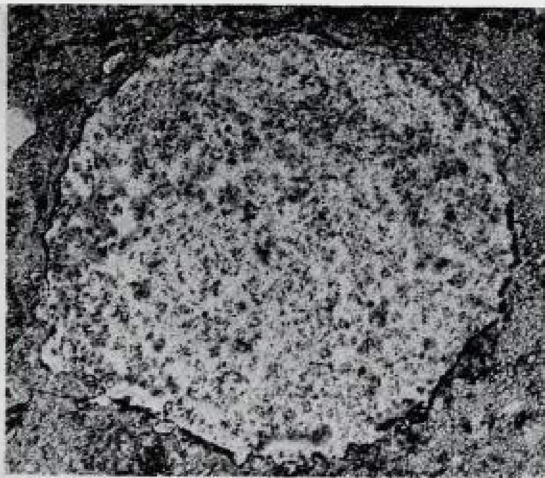

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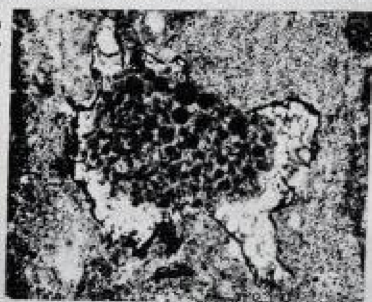

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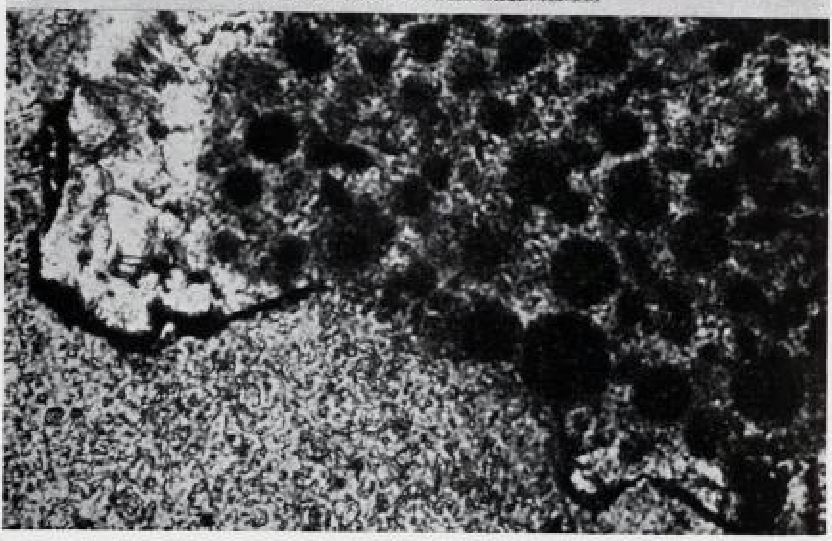


PLATE 4

fig. 1. Sporomorph of type II, showing protuberances of the wall, and badly defined internal structures. 150 x.

fig. 2. Sporomorph of type VII, showing thin, irregular outer membrane, and cluster of sphaerical bodies inside. 150 x.

fig. 3. The same specimen as in fig. 2, but enlarged to show the sphaerical bodies, and structure in the phosphorite. 675 x.

PLATE 5

fig. 1. Sporomorph of type II, with rod-like bodies inside. cf. also fig. 5. 150 x.

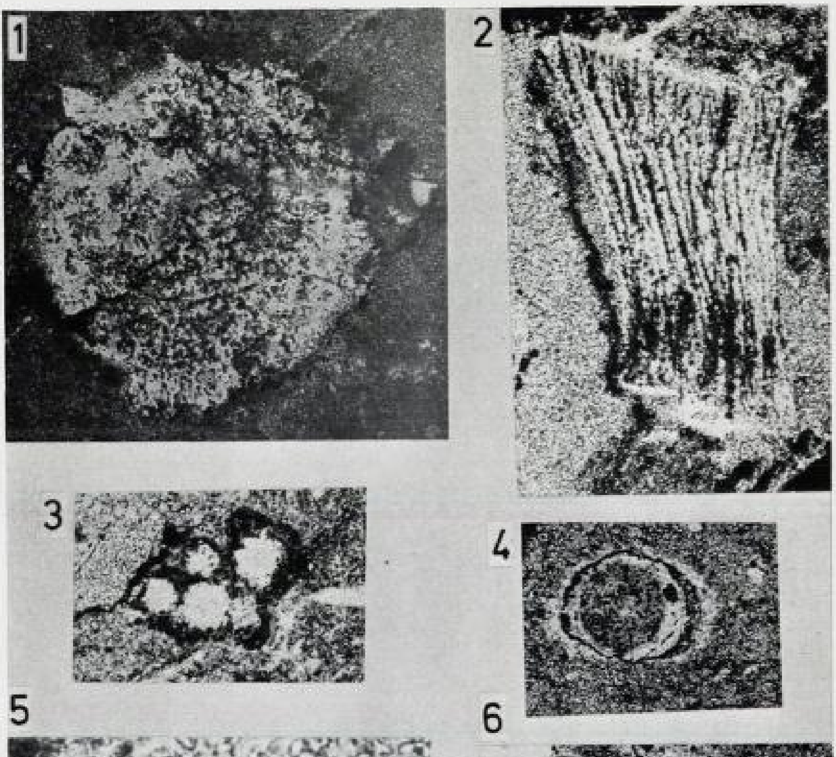
fig. 2. Problematic fossil, type VIII, showing internal structure. 150 x.

fig. 3. Sporomorph of type V, showing thick, somewhat diffuse walls, and possible connections between the agglomerated bodies. 150 x.

fig. 4. Sporomorph of type IV, showing thickened, granulose walls, and clear phosphate also outside the structure itself. 150 x.

fig. 5. Detail of wall of the sporomorph shown in fig. 1. The wall structure is almost completely lost, and the different filamentous structures inside and outside the wall is easily seen. 675 x.

fig. 6. Sporomorph of type VI, showing quartz shell, and globular bodies inside it. It should be noted that the quartz in the shell is the bulk of the quartz found in the whole thin section. 150 x.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