

# GIANT ACANTHOMORPH ACRITARCHS FROM THE UPPER PROTEROZOIC IN SOUTHERN NORWAY

by G. VIDAL

**ABSTRACT.** Large microfossils from a single phosphatic pebble in the late Riphean–early Vendian ( $> 612 \pm 18 - 665 \pm 10$  Ma) Biskopås Conglomerate in the Hedmark Group in southern Norway were described by Spjeldnæs (1963) under the name *Papillomembrana compta* and interpreted as a possible dasycladacean alga. The microfossils are evidently organic-walled and here regarded as giant acanthomorph acritarchs. The diagnosis of *Papillomembrana compta* is emended. Possibly related Proterozoic taxa are discussed. A new acanthomorph acritarch, *Ericiasphaera spjeldnaesii* gen. et sp. nov., found with *P. compta* within the same petrographic thin-section is described. Contrary to former conceptions, recent data seem to indicate that large complex acritarchs were common in late Proterozoic times.

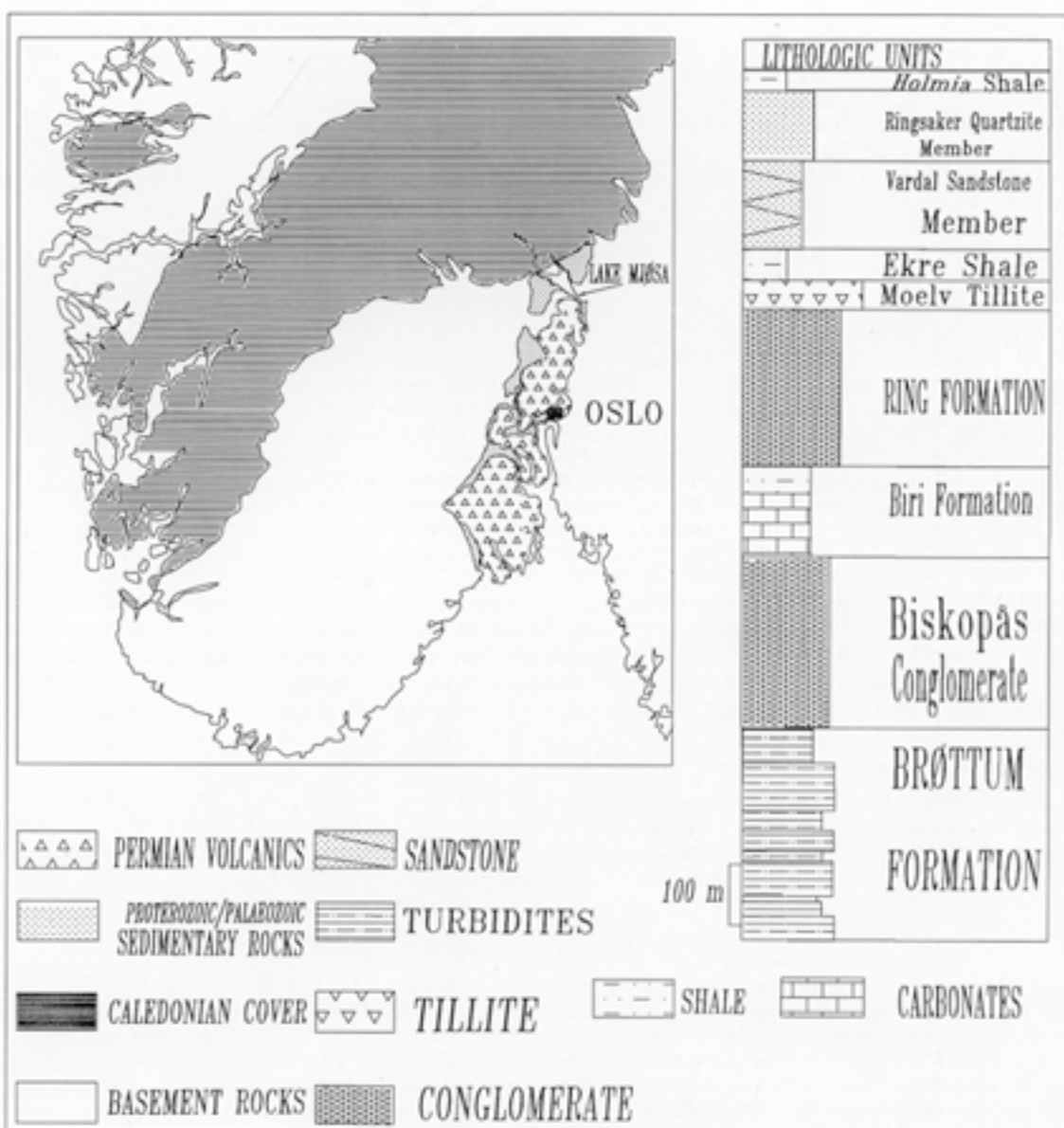
RECENT studies of Precambrian fossils reveal a formerly unsuspected degree of complexity in the late Proterozoic biota (Knoll and Calder 1983; Vidal and Knoll 1983; Knoll 1985; Butterfield *et al.* 1988; Zhang, 1989; Zang and Walter 1989). At the same time, the emerging picture sheds additional light on the importance of microfossils of planktonic primary producers for the understanding of the metazoan radiation at, or near the Proterozoic–Cambrian boundary (Germs *et al.* 1986; Moczyłowska and Vidal 1986; Knoll and Swett 1987). In this light a proper understanding of the taxonomic affinity of Proterozoic fossils seems of prime importance as it aids the acquisition of a more precise picture of the complexity of existing food webs (Knoll and Calder 1983).

In this paper, as a result of an ongoing study of the micropalaeontology of Proterozoic–Cambrian sections in southern Norway (Vidal and Nystuen, unpublished data), previously reported microfossils from the Upper Proterozoic Hedmark Group (Spjeldnæs 1963, 1967) are reinterpreted as acritarchs and a new acritarch taxon is described.

## GEOLOGICAL SETTING AND AGE

The Hedmark Basin is located within the southern limit of the Scandinavian Caledonides. The basin contains the Upper Proterozoic Hedmark Group (text-fig. 1), a sequence that has been comprehensively studied, particularly with respect to its general lithostratigraphy, structural geology, sedimentology and depositional history (Bjørlykke *et al.* 1967; Nystuen 1981; Kumpulainen and Nystuen 1985; Nystuen 1987). The Hedmark Group (Bjørlykke *et al.* 1967) is a wedge of predominantly detrital rocks with subordinate carbonate and igneous rocks which until recently were widely referred to as 'sparagmites'. The group has a variable thickness of 1500–4000 m (Bjørlykke *et al.* 1976) and consists of eight formal rock units in part overlain by epicontinental Cambrian–Silurian deposits which attain a thickness of approximately 1000 m. Both the Hedmark Group and the overlying Cambrian–Silurian strata underwent folding and thrusting during the Caledonian Orogeny. The Hedmark Group is considered to have been deposited in connection with fault-bounded basins (Kumpulainen and Nystuen 1985; Nystuen 1987); either within intra-cratonic rift-valleys (Bjørlykke *et al.* 1976; Bjørlykke 1978) or an aulacogen (Roberts and Gale 1978; Kumpulainen and Nystuen 1985; Nystuen 1987). The deposition history and facies associations were related to a model of development of the Hedmark Basin which involves succeeding episodes of crustal stretching, deep crustal fracture and ensuing block faulting and a final phase of thermal cooling and slow subsidence (Kumpulainen and Nystuen 1985; Nystuen 1987).

The Biskopås Conglomerate (Bjørlykke *et al.* 1967) is a clastic wedge within the Biri Formation (Bjørlykke *et al.* 1976). It occurs in several distinctive fan-shaped bodies in the southern and western part of the Sparagmite Basin (Bjørlykke *et al.* 1976), and the conglomerates interfinger basinward into the Brøttum turbidite sandstones or shales of the Biri Formation (Nystuen 1982). Its thickness varies between 200 and 15 m.



TEXT-FIG. 1. Sketch map showing location of Sparagmite Basins in southern Norway. Composite section of the Hedmark Group in the Lake Mjøsa region (after Nystuen 1987). The fossiliferous sample with *Papillomembrana* derives from the basal sedimentary breccia in the Biskopås Conglomerate (Spjeldnæs 1963).

The formation consists of well-rounded pebbles and cobbles and occasional boulders in a coarse-grained, slightly clayey arkose matrix (Bjørlykke *et al.* 1976) interbedded with massive sandstone layers.

The conglomerate contains carbonate and phosphate clasts in its lower part which are believed to have been eroded from the early transgressive part of carbonate deposits in the Biri Formation which accumulated in shelf area adjacent to the basin (Bjørlykke 1966; Spjeldnæs 1967). Absence of sedimentary structures appears to indicate deposition in a submarine environment. The conglomerate beds contain clasts, matrix-supported textures and massive and inversely graded bedding. Accordingly, the conglomerates were interpreted as

subaqueous fans laid down in front deltas by gravity sediment flow processes (R. Otter, pers. comm. in Nystuen 1982). Bjørlykke *et al.* (1976) favoured deposition in connection with floods as coarse sheet flows being deposited directly into the basin, or as a fluvial delta becoming reworked into a submarine environment. They also considered it unlikely that the depositional depth could have been greater than 200–300 m. Bjørlykke *et al.* (1976) pointed out that the conglomerate resembles Quaternary glaciofluvial conglomerates, and that pebbles are often faceted and similar to Quaternary glaciofluvial pebbles. However, they clarified that there is no evidence of ice-contact and that sorting is generally better than in glacial outwash deposits. Roundness and pebble contents suggest long transport (Bjørlykke *et al.* 1976).

The Biri Formation containing the fossiliferous Biskopås Conglomerate is 50–100 m thick and comprises a variety of lithofacies, including subtidal micritic limestone, intertidal to supratidal carbonates and shales with some dolomite displaying mud cracks and intraformational conglomerates, carbonate platform margin oolitic limestones, platform-slope calcareous shales and sandstones and intra-basin dark shale (Bjørlykke *et al.* 1976). Rocks of the lower member of the Biri Formation are locally missing, probably as a result of erosion preceding the deposition of the Biskopås Conglomerate. Both the upper and lower junctions of the formation are evidently diachronous. Where the Ring Formation is missing, rocks of the Biri Formation are overlain by the Moelv Tillite, while in areas where the Biskopås Conglomerate is absent the Biri Formation is in contact with the Brøttum Formation (Bjørlykke *et al.* 1976). Normal salinity and open marine deposition conditions were suggested by Bjørlykke *et al.* (1976).

Phosphate pebbles in the Biskopås Conglomerate yielded scattered microfossils (Manum 1967) and specimens of the problematic fossil *Papillomembrana compta* (Spjeldnæs 1963, 1967) and *Ericiasphaera spjeldnaesii* sp. nov., and a number of quartz replaced, circular structures in the fossiliferous thin-section may represent sections of microfossils as indicated by Spjeldnæs (1967). In fact, some resemble transverse sections of siliceous casts of vase-shaped microfossils (perhaps similar to *Melanocyrrillum* Bloeser, in Bloeser 1985) as recorded in siliceous phosphates from the late Riphean Visingsö Group in Sweden (Knoll and Vidal 1980).

Acritarchs and cyanobacterial microfossils (Vidal and Siedlecka 1983; Vidal and Nystuen unpublished data) occur in detrital rocks of several units of the Hedmark Group and in the overlying Lower Cambrian units (Downie 1982; Moczyłowska and Vidal 1986).

Age data from rocks of the Hedmark Group are restricted to one single, Rb/Sr whole rock age (Welin unpublished; Rankama 1973) of  $612 \pm 18$  Ma on the Ekre Shale. An indirect estimation of the age of the Hedmark Group is offered by Rb/Sr whole rock dates of the Ottfjället dolerite dike swarm (Claesson 1976, 1977; Claesson and Roddick 1983) which yielded ages of  $720 \pm 260$  and  $665 \pm 10$  Ma. Acritarchs from the Biskopås Conglomerate and the Biri Formation indicate a late Riphean to early Vendian (*sensu* Vidal and Siedlecka 1983) age for units underlying the Moelv Tillite.

## DISCUSSION

Microfossils of organic-walled microorganisms are generally abundant in Proterozoic rocks. Their proper taxonomic affiliation is poorly understood and they are therefore treated among the acritarchs (Downie *et al.* 1963; Evitt 1963; Downie 1973), although morphologically simple forms are occasionally considered among the cryptarchs (Diver and Peat 1979). The probable algal affinity of Proterozoic and early Palaeozoic acritarchs is generally accepted, as it is the idea that they may represent the abandoned organic envelopes of encysted and/or motile stages of prasinophycean green algae, dinoflagellates, or similar groups now extinct (Dale 1977; Tappan 1980).

The diagnostic features of acritarchs are the general shape of the vesicle, its surface ornamentation and (if present) the shape and ornamentation of processes and excystment mechanism (Tappan 1980). Being restricted to these few taxonomically diagnostic attributes, descriptions are often imprecise and accompanied by poor illustrations. These are features which have probably contributed to the erroneous generic attribution of some Proterozoic acritarchs to early Palaeozoic genera. Irrespective of this, the taxonomy of acritarchs is meaningful only at the species level, because acritarch genera are simple groupings of form-species sharing superficially similar morphological features which do not necessarily imply close biological affinity.

Wide-ranging dimensional variability is a feature observed among modern eukaryotic plant protists. This same feature appears to apply to Phanerozoic acritarchs, which generally display a broad size range (5–500  $\mu\text{m}$ ; Tappan 1980). Despite this, the significance of large acritarchs in the total picture of the late Proterozoic biota has been strongly overemphasized in the past. Certain

Proterozoic acritarchs have been compared to the phycoma stages of prasinophycean green algae (Knoll and Calder 1983; Vidal and Knoll 1983), which may be the living counterparts of several acritarch form-genera such as *Leiosphaeridia*, *Tasmanites* and *Cymatiosphaera*. Prasinophycean phycomata are initially about 10  $\mu\text{m}$  in diameter, but the mature cyst may be as much as 100–175  $\mu\text{m}$  in diameter (Tappan 1980). This attribute may be particularly significant to the interpretation of the taxonomic affinity of certain Proterozoic acritarchs which display polymodal, often megascopic or nearly megascopic dimensions (Vidal 1974, 1976; Vidal and Ford 1985).

Until quite recently the generally accepted view was that Precambrian acritarchs are mainly spheroidal, morphologically simple forms lacking diagnostic features (Downie 1973). Timofeev *et al.* (1976) and Vidal (1976) first reported Proterozoic acanthomorphs ornamented with simple, conical and complex membrane-bounded processes, and polygonomorphic acritarchs, a degree of morphological complexity once thought to be restricted to Phanerozoic fossils (Brasier 1977). However, recent data (Vidal 1981; Knoll and Calder 1983; Knoll 1984; Awramik *et al.* 1985; Pjatiletov and Rudavskaya 1985; Vidal and Ford 1985; Yin 1985; Butterfield *et al.* 1988; Knoll and Ohta 1988; Zang 1988; Zang and Walter 1989) seem to demonstrate that complex acritarchs were relatively common in the late Proterozoic. It now appears that *Papillomembrana compta* Spjeldnæs (1963) (and an additional acanthomorph acritarch; see below) from the late Proterozoic Biskopås Conglomerate in the southern Norway Sparagmite Basins (Spjeldnæs 1963) may in fact be the earliest report of giant Proterozoic acanthomorph acritarchs (Zhang 1989).

Most occurrences of late Proterozoic acanthomorph acritarchs are in probably early diagenetic cherts within subtidal shallow shelf carbonates (Knoll and Calder 1983; Knoll 1984; Awramik *et al.* 1985; Yin 1985, 1987; Knoll and Ohta 1988), and subtidal shallow marine shales and carbonates (Timofeev *et al.* 1976; Vidal 1976, 1981; Vidal and Ford 1985; Pjatiletov and Rudavskaya 1985; Butterfield *et al.* 1988). Zang and Walter (1989) suggested that a rather diverse acritarch assemblage from the late Proterozoic Pertatataka Formation accumulated in distal turbidites and explained the apparent rarity of late Proterozoic 'giant' acanthomorphs as perhaps depending on insufficient sampling of deep-marine settings. Lack of convincing sedimentological evidence to support hypothetical turbidite deposition in the Pertatataka shales leaves the occurrence of Proterozoic 'giant' acanthomorphs open to alternative explanations (Knoll and Butterfield 1989).

Late Proterozoic (Riphean and Vendian) turbidites have been extensively studied, with results differing much from those reported by Zang (1988) and by Zang and Walter (1989). Thus, laminated hemipelagic mud deposits are usually rich in detrital organic matter (Palacios-Medrano 1986) and yielded chiefly planktonic microfossils interpreted as chroococcalean cyanobacteria (Mansuy and Vidal 1983; Vidal and Siedlecka 1983; Palacios-Medrano 1986). The scarcity or absence of identifiable non-cyanobacterial acritarchs in turbidite sequences does not imply total absence of eukaryotic plankton in the overlying water column. In fact, cysts may simply have not been produced or alternatively, if produced, had low fossilization potential or accumulated in insignificant numbers (Vidal and Siedlecka 1983). As for any other microfossil group, the concentration of acritarchs in submarine fan deposits would be expected to be small compared with that of adjacent shallow shelves. Thus, while early Cambrian-age platform siliciclastic and carbonate rocks yield rich acritarch assemblages, time-equivalent turbidites in southeastern Poland yield extremely rare acritarchs (Pozaryski *et al.* 1981).

Little is known about the preservation potential of motile stages of microscopic algae or of reproductive structures of thallophytes (e.g. cysts, aplanospores or zygotes), although some inferences are perhaps possible from dinoflagellate data (Evitt 1985). However, routine microscopic examination of thin-sections of numerous rock samples failed to reveal the existence of such hypothetical stages. In fact, it is possible that, like the geologically more recent dinoflagellates, Proterozoic acritarchs may have alternately produced preservable and non-preserved cysts (Evitt 1985).

In the above context environmental information concerning the *Papillomembrana*-bearing Biskopås Conglomerate is of some interest. Available models favour deposition either as subaqueous fans laid down in front deltas (R. Otter, pers. comm. in Nysteuun 1982), coarse sheet

flows being deposited directly into the basin, or a fluvial delta becoming reworked into a submarine environment Bjørlykke *et al.* (1976). In any event it appears that numerous features apparently indicate deposition in a submarine environment. Carbonate and phosphate clasts in the lower part of the formation are believed to have been eroded from early transgressive shallow shelf carbonate deposits in the Biri Formation (Bjørlykke 1966; Spjeldnæs 1967). Complex acritarchs occur sporadically in the Biskopås Conglomerate and in the Biri Formation (Vidal and Nystuen, unpublished data). On the other hand, as in many previous reported occurrences (see above), greywackes and hemipelagic mudstones from the turbidite-dominated Brøttum Formation yield a monotonous assemblage consisting of benthic (possibly reworked) and planktonic cyanobacterial microfossils.

#### SYSTEMATIC PALAEOLOGY

The symbol v\* means that the type specimen of the species has been examined. All specimens come from a single petrographic thin-section of a phosphorite pebble from the basal part of the Biskopås Conglomerate (for details see Spjeldnæs 1963, 1967) with specimen number PMO 73173. The number refers to the collections of the Palaeontological Museum, Oslo. England Finder coordinates are herein provided for figured microfossil specimens (thin-section label orientated to left side of the microscope stage).

#### Group ACRITARCHA Evitt, 1963 Genus ERICIASPHAERA gen. nov.

*Type species. Ericiasphaera spjeldnaesii* gen. et sp. nov.

*Diagnosis.* As for the type and only species of the genus, *Ericiasphaera spjeldnaesii*.

*Derivation.* From the Latin *ericus*, meaning hedgehog, referring to the spiny appearance, and *sphaera* meaning 'sphere', a spiny, hedgehog-like sphere.

#### *Ericiasphaera spjeldnaesii* sp. nov.

Plate 1, fig. 1

v\* 1985 *Comasphaeridium?* sp. Yin, p. 239, pl. 2, figs. 1 and 2; text-fig. 12.

v\* 1985 *Baltisphaeridium* sp. Yin, p. 239, pl. 4, figs. 5–8.

v\* 1987 *Baltisphaeridium maximum* sp. nov., Yin, p. 439, pl. 14, figs. 14 and 15.

*Diagnosis.* Large, spherical or spheroidal vesicle which bears numerous evenly scattered, simple, conical processes. Processes are solid and lack communication with the vesicle cavity. Processes are closely arranged, with conical-shaped bases which taper into cilia-shaped distal portions. Diameter of the vesicle cavity is about 280  $\mu\text{m}$ . Diameter of the periphery including the processes is about 300  $\mu\text{m}$ . Space between conical shaped bases is 2–4  $\mu\text{m}$ . Length of processes is 6–10  $\mu\text{m}$ .

*Holotype.* Specimen PMO 73173, England Finder coordinate H/35. Pl. 1, fig. 1.

*Derivation.* Named in honour of Professor Nils Spjeldnæs.

*Type locality.* Lower part of Biskopås Conglomerate (Spjeldnæs 1963, p. 65) at locality Hjellund. Topographic Map Sheet Gjøvik, UTM coordinates 585400/676900.

*Description.* The holotype and only specimen in the present material is strongly deformed, thus providing an irregular section of the vesicle. The digitalized periphery was converted into a circular projection, which indicates that the minimum diameter of the vesicle cavity could have been at least 277  $\mu\text{m}$ . The restored circular

periphery of the distal end of processes indicates a diameter of about 292  $\mu\text{m}$ . The space between the conical-shaped bases is 2–4  $\mu\text{m}$ . Digitalized measurements of the processes indicate lengths of 6–10  $\mu\text{m}$  ( $\bar{x}$  = 7.6  $\mu\text{m}$ ,  $\sigma$  = 1.68  $\mu\text{m}$ , nine measurable processes). A reconstruction of *E. spjeldnaesii* is shown in text-fig. 2.

*Discussion.* *B. maximum* Yin (1987) and other microfossils from the late Proterozoic, Doushantuo Formation in western Hubei, China (Yin 1985, 1987) were examined during 1983 and colour micrographs were produced. The microfossils are rare, and occur in black early diagenetic chert within dolomitic limestones of the Doushantuo Formation (Yin 1985). The diagnosis given by Yin (1987) indicates with some uncertainty a diameter of 215–345  $\mu\text{m}$  for the apparently only section of the single-walled vesicle. Digitalized images of colour micrographs suggest a minimum diameter comparable to that calculated for *E. spjeldnaesii*. The major difference is in the closely spaced conical-shaped processes of *B. maximum*, but this feature appears to vary considerably on parts of the section of the apparently only available specimen. From the examination of the holotype it is evident that the processes are simple and solid, having conical bases. No connection could be observed between the vesicle cavity and the thin processes. This excludes the specimen from the most diagnostic feature of the Lower Palaeozoic acritarch genus *Baltisphaeridium*. Furthermore, *B. maximum* displays dimensions and a vesicle diameter/process length relationship different from Palaeozoic forms. The estimated minimum diameter for the preserved section of this specimen is c. 300  $\mu\text{m}$  (length = 197–232.5  $\mu\text{m}$ , width = 99–112.5  $\mu\text{m}$ ; Yin 1985). It thus appears likely that *B. maximum* is most likely conspecific with *E. spjeldnaesii*.

Some doubts remain on the taxonomic attribution of the specimen described by Yin (1985) as *Comasphaeridium* sp. This has to do with the more widely spaced and longer processes. However, this kind of discrepancy might be within the acceptable limits of the same acritarch taxon. In any event the specimen has overall dimensions and vesicle diameter/process length relationship not seen among species of *Comasphaeridium* Staplin *et al.* (1965). Yin (1985) also expressed strong uncertainty as for the taxonomic attribution.

The late Proterozoic, Upper Riphean *Nucellohystrichosphaera megalea* Timofeev, in Timofeev *et al.* (1976) and *Trachyhystrichosphaera aimika* German, in Timofeev *et al.* (1976) (undoubtedly conspecific with the former) bear a superficial resemblance to *E. spjeldnaesii*. The type material of *N. megalea* and *T. aimika*, and another similar species, *T. vidalii* Knoll (1984) has been examined. *T. vidalii* has membrane-bounded tubular processes and is very different from any of the forms under discussion. *N. megalea* and *T. aimika* possess cylindrical processes and differ substantially from the taxa discussed in this paper. However, it deserves mentioning that the diagnoses of both taxa are extremely generalized and that they take into account non-diagnostic features such as compactional folds, colour and presence of condensed intra-vesicular organic matter.

#### Genus PAPILOMEMBRANA Spjeldnæs emend.

*Type species.* *Papillomembrana compta* Spjeldnæs emend.

*Diagnosis* (emended). As for *Papillomembrana compta*. Type and only known species of the genus.

#### EXPLANATION OF PLATE I

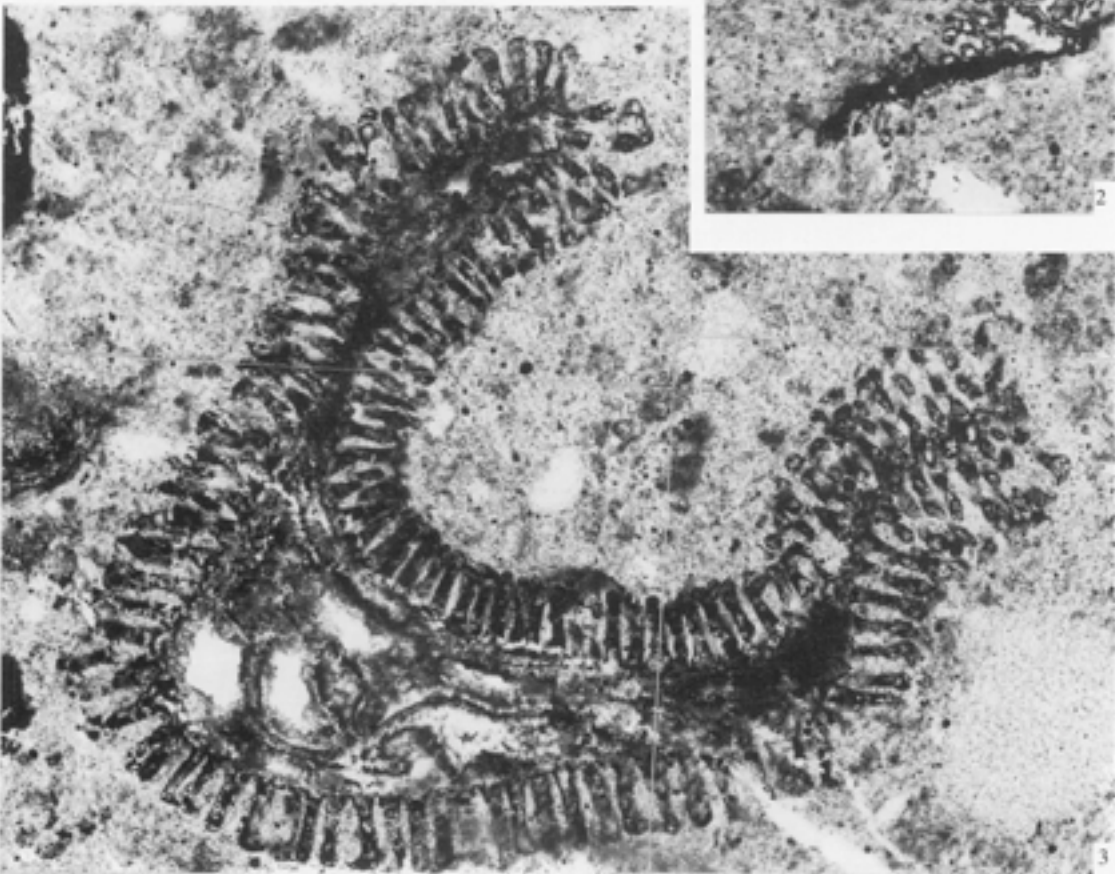
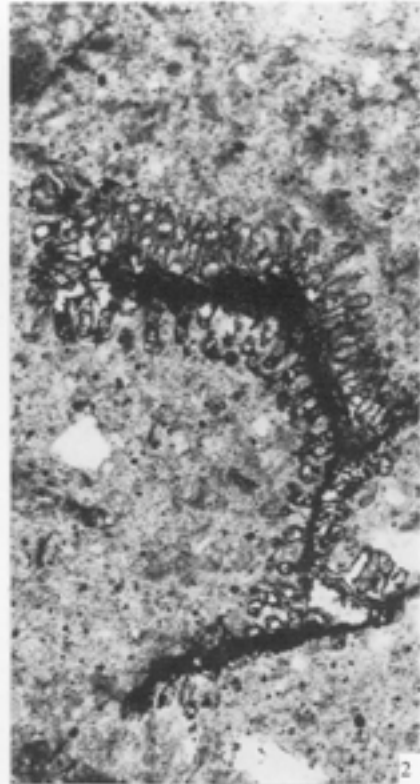
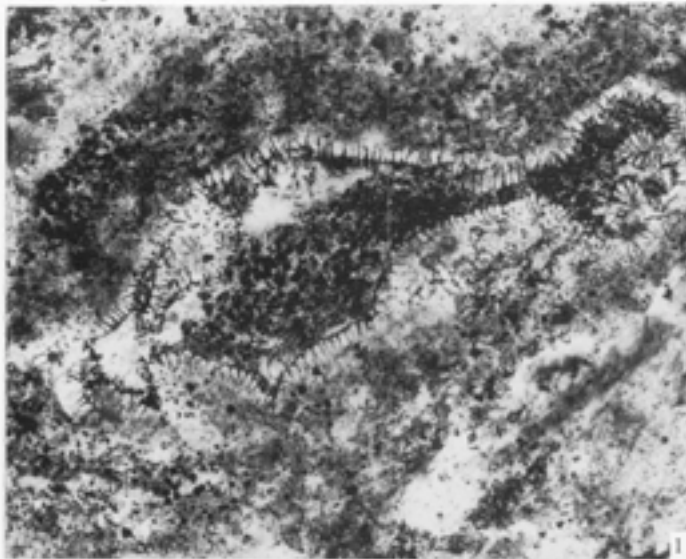
Specimen number refers to the collections of the Palaeontological Museum, Oslo. England Finder coordinates are given for each microfossil specimen (label orientated on left side of microscope stage).

Fig. 1. *Ericiasphaera spjeldnaesii* gen. et sp. nov. (holotype). Specimen PMO 73173, England Finder coordinates H/35. Transmitted light micrograph,  $\times 240$ .

Fig. 2. *Papillomembrana compta* emend. Vidal. Specimen PMO 73173, England Finder coordinates V/33. Transmitted light micrograph,  $\times 190$ .

Fig. 3. *Papillomembrana compta* emend. Vidal (holotype). Specimen PMO 73173. England Finder coordinates R/31. Transmitted light micrograph, oil immersion,  $\times 240$ .





VIDAL, *Ericiasphaera*, *Papillomembrana*

*Papillomembrana compta* Spjeldnæs emend.

Plate 1, figs. 2 and 3; Plate 2, figs. 1–3

v\* 1963 *Papillomembrana compta* gen. et sp. nov. Spjeldnæs, p. 63, figs. 1–3.v\* 1967 *Papillomembrana compta* Spjeldnæs; Spjeldnæs pp. 78, 79, pl. 1, figs. 1–3; pl. 2, fig. 1.

*Diagnosis* (emended). Large, spherical or spheroidal vesicles which bear numerous ( $> 131$  on the holotype) evenly spaced, tightly arranged processes. The processes are hollow, cylindrical, with angular proximal contacts and bulbous or bifurcated distal ends. Connection between vesicle and process cavity is not evident. Diameter of the inner cavity is c.  $518 \mu\text{m}$ , while the diameter of the total periphery including processes is c.  $768 \mu\text{m}$ . Length of processes is  $30\text{--}42 \mu\text{m}$  ( $\bar{x} = 36.5 \mu\text{m}$ ,  $\sigma = 3.1 \mu\text{m}$ ,  $n = 30$ ), with bases  $9\text{--}13 \mu\text{m}$  in width ( $\bar{x} = 11.6 \mu\text{m}$ ,  $\sigma = 1.6 \mu\text{m}$ ,  $n = 9$ ), while the width of the top of the processes is  $7\text{--}15 \mu\text{m}$  ( $\bar{x} = 9.6 \mu\text{m}$ ,  $\sigma = 1.8 \mu\text{m}$ ,  $n = 20$ ). Wall thickness not measurable.

*Holotype*. PMO 73173, England Finder coordinates R/31. Pl. 1. fig. 3.

*Type locality*. Lower part of Biskopås Conglomerate (Spjeldnæs 1963, p. 65) at locality Hjellund. Coordinates on the Topographic Map Sheet Gjøvik, UTM coordinates 585400/676900.

*Description*. The holotype of *P. compta* is deformed, a feature which results in an irregular section of the vesicle. The compressed vesicle has vertically standing processes, a feature which can be observed at the right corner of the micrograph on Pl. 1, fig. 3 (holotype). This indicates that the whole surface of the vesicle was probably covered with cylindrical, bulbous processes (text-fig. 3). Digitalized added images produced from optical sections of the rather thick petrographic thin-section appear to support this conclusion. The digitalized peripheries of the three best-preserved specimens (Pl. 1, figs. 2 and 3, Pl. 2, figs. 1 and 2) were converted into circular projections which indicate the minimum diameters of the sectioned specimens. In the case of the holotype (Pl. 1, fig. 3), the measured inner diameter is  $517.8 \mu\text{m}$ , while the diameter of the outer periphery including the processes is  $767.7 \mu\text{m}$ . The inner diameter of the specimen in Pl. 2, fig. 2 is  $331.5 \mu\text{m}$ . The outer diameter is c.  $381 \mu\text{m}$ . These dimensions are probably not more than rough estimates since the specimen is completely compressed and the inner cavity is not evident. The same appears true of the specimen in Pl. 1, fig. 2. The holotype (Pl. 1, fig. 3) displays irregular convolute organic strands, most likely irregularly folded, condensed cellular remains. However, it cannot be excluded that they may constitute a deformed inner layer of the vesicle wall.

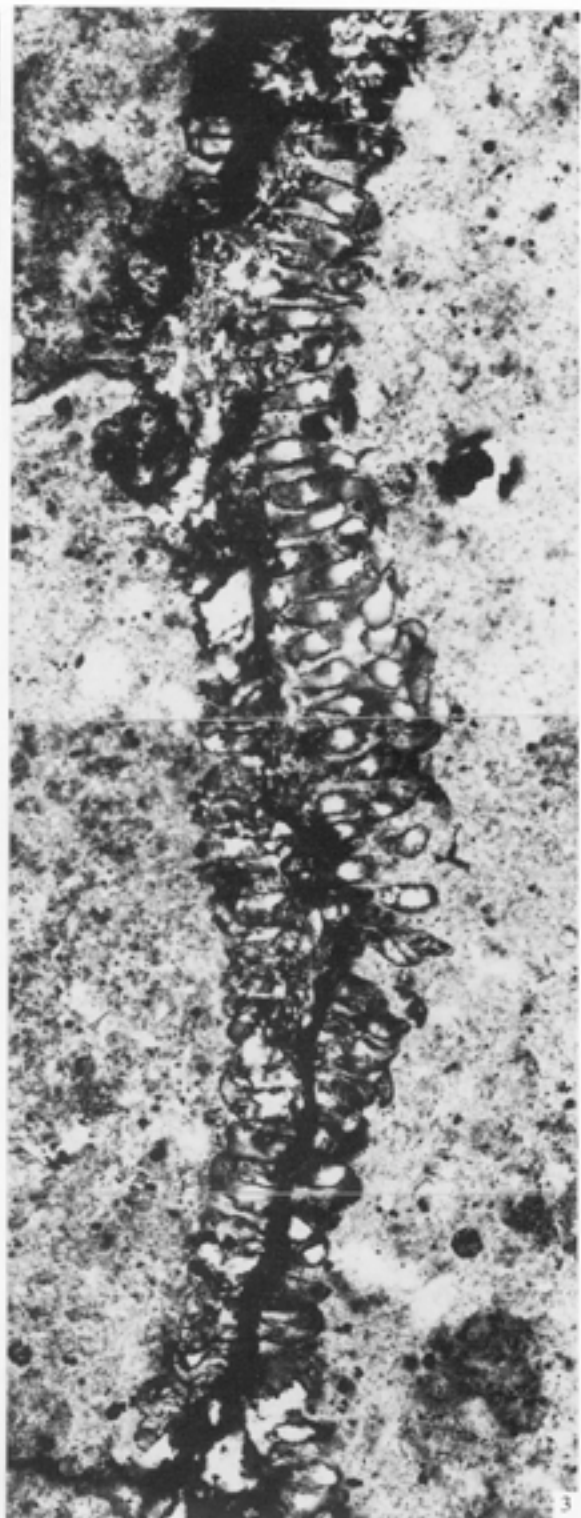
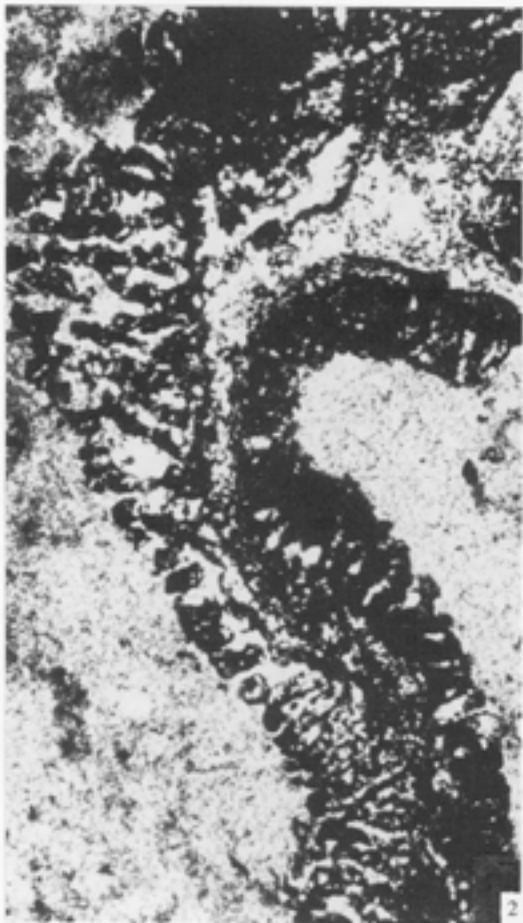
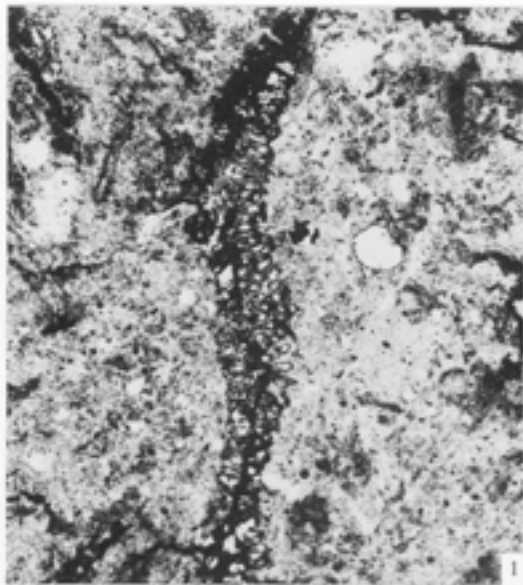
*Discussion*. Spjeldnæs (1963, p. 63) pointed out some superficial resemblance to dasycladacean green algae. He also indicated that the fossil is not carbonate encrusted, a feature which, although common, is not general among dasycladaceans. The general features of the dasycladacean thallus, which has an undivided erect axis bearing whorls of simple or bifurcated lateral branches, are in any event missing in *Papillomembrana*. The taxonomic affiliation of the fossil remains unknown and is here treated among the acritarchs. Nevertheless, this does not exclude the possibility that the fossil(s) could be reproductive structures of thallophytes (e.g. cysts, aplanospores or zygotes). There is compelling evidence indicating that metaphytic green and red algae were extant in late Proterozoic times (Hofmann 1985; Butterfield *et al.* 1988; Zhang 1989; Vidal 1989). It is evident

## EXPLANATION OF PLATE 2

Specimen number refers to the collections of the Palaeontological Museum, Oslo. England Finder coordinates are given for each specimen (label orientated on left side of microscope stage).

Figs. 1–3. *Papillomembrana compta* emend. Vidal. 1, low magnification view showing surrounding phosphate matrix, specimen PMO 73173, England Finder Coordinate V/29,  $\times 67$ . 2, poorly preserved specimen, specimen PMO 73173, England Finder coordinates K/41,  $\times 200$ . 3, detail view of specimen in 1, note the hollow processes, England Finder coordinate as for specimen in fig. 1. Transmitted light micrograph,  $\times 200$ .





VIDAL, *Papillomembrana*

that *P. compta* resembles a number of comparatively large pre-Phanerozoic acritarchs, and another 'acritarch-like' form (*E. spjeldnæsii*) was found in the same sample.

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