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Stratigraphic significance of acritarchs in Cambro-Ordovician boundary strata, Hassi-Rmel area, Algerian Sahara

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ABSTRACT – *Palynological investigation of 37 samples cored from boreholes Nl-2 and Uc-101 in Cambrian-Ordovician boundary beds of northwestern Algeria (Hassi-Rmel area) enables the definition of three, stratigraphically successive acritarch assemblages: HM/A, HM/B, and HM/C, tentatively referred here to the uppermost Cambrian, basal lower Tremadoc, and lower Tremadoc, respectively. The first assemblage has been found in the lower and middle parts of the arenaceous «Grès de Bordj Nili» unit and includes, inter alia, Cristallinium randomense, Dasydiacrodium obsonum, Ladogella rotundiformis, Timofeevia phosphoritica, Trunculumarium sp., and Veryhachium dumontii. Assemblage HM/B (upper third of the same stratigraphic unit) is characterized by: Acanthodiadrodium complanatum, A. sp. cf. A. angustum, Dasydiacrodium tumidum, Polygonium pungens, Stelliferidium cortinulum, and S. furcatum, together with an increase in abundance and differentiation of Diacromorphitae and Herkomorphitae. The third assemblage, HM/C, is marked by the introduction of: Cymatiogalea cristata, C. membranispina, C. gorkae, Polygonium gracile, Stelliferidium stelligerum, S. simplex, and, in the upper part, Vulcanisphaera britannica and Acanthodiadrodium ubui. Chronostratigraphic attributions are based on comparison with previously established acritarch zones correlative with macrofossil zones. Occurrence of graptolites of the Rhabdinopora flabelliformis s.l. group in the «Argiles d'El Gassi» confirms an early Tremadoc age for that unit. The discordance in the composition of acritarch suites between assemblages HM/A and HM/B is tentatively proposed here as a palynologically easily detectable horizon approximating regionally to the Cambrian-Ordovician boundary. In the systematic section, 51 acritarch species are described and illustrated, including the following new species: Acanthodiadrodium baculatum, A. capillatum, Baltisphaeridium verutum, Cymatiogalea parva, and Stelliferidium velatum.*

RIASSUNTO – [Significato stratigrafico degli acritarchi nei livelli di transizione Cambro-Ordoviciani della regione di Hassi-Rmel, Sahara Algerino] – *Lo studio palinologico (acritarchi) di 37 campioni prelevati per mezzo dei sondaggi Nl-2 e Uc-101 da livelli di transizione Cambro-Ordoviciani dell'Algeria Nord-Occidentale (regione di Hassi-Rmel), permette la definizione di tre diverse associazioni ad acritarchi: HM/A, HM/B e HM/C, attribuite rispettivamente al Cambriano terminale, al Tremadoc basale, ed al Tremadoc inferiore. La prima associazione è stata riconosciuta nei due terzi inferiori del membro (unità informale) «Grès de Bordj Nili», e comprende, tra l'altro: Cristallinium randomense, Dasydiacrodium obsonum, Ladogella rotundiformis, Timofeevia phosphoritica, Trunculumarium sp., e Veryhachium dumontii. L'associazione HM/B (terzo superiore della medesima unità stratigrafica) è caratterizzata da: Acanthodiadrodium complanatum, A. sp. cf. A. angustum, Dasydiacrodium tumidum, Polygonium dentatum, Stelliferidium cortinulum, e S. furcatum. In questa associazione si nota tipicamente un aumento nelle abbondanze e una spiccata differenziazione dei gruppi Diacromorphitae e Herkomorphitae. La terza associazione, HM/C (Argiles d'El Gassi), si distingue per la comparsa di: Cymatiogalea cristata, C. membranispina, C. gorkae, Polygonium gracile, Stelliferidium stelligerum, S. simplex, e, nella parte superiore, di Vulcanisphaera britannica e Acanthodiadrodium ubui. Le attribuzioni cronostatigrafiche sono state basate su confronti con associazioni ad acritarchi correlate con biozonazioni a macrofossili precedentemente stabilite per l'intervallo Cambriano Superiore-Tremadoc inferiore. La presenza di graptoliti del gruppo Rhabdinopora flabelliformis nelle «Argiles d'El Gassi» permette una sicura attribuzione al Tremadoc inferiore per questa unità. La discontinuità nella composizione delle microflore ad acritarchi tra le associazioni HM/A e HM/B viene qui proposta, a titolo d'ipotesi, come un livello palinologico facilmente individuabile, approssimabile al limite Cambriano-Ordoviciano nell'area studiata. Nella parte sistematica vengono descritte ed illustrate 51 specie di acritarchi, tra cui le seguenti cinque nuove specie: Acanthodiadrodium baculatum, A. capillatum, Baltisphaeridium verutum, Cymatiogalea parva, e Stelliferidium velatum.*

INTRODUCTION

The Cambrian-Ordovician boundary has been recognized worldwide by means of several diagnostic fossil groups: graptolites in Europe, trilobites in North America, and conodonts in Asia and Australia. As a result, there has been some inconsistency in regional stratigraphic recognitions of the systemic boundary. Miller (1988) demonstrated that the supposed boundary levels are dispersed through a stratigraphic interval which ranges, in conodont-zonal terms, from the base of the *Cor-*

dylodus proavus Zone to about the base of the *C. lindstromi* Zone. Given this disparity, it is clearly impossible to refer unequivocally to the Cambrian-Ordovician boundary.

Comprehensive studies pertaining to this problem have been carried out since 1974 by the International Working Group on the Cambrian-Ordovician Boundary (IWGCOB). In 1985, the Working Group decided unanimously to select the boundary at a specific horizon, within a specific section («golden spike» principle), just below the first influx of planktic (nematophorous) graptolites.

Because of their abundance, diversity, and low provinciality, conodonts have been chosen as the main biostratigraphic tool for the definition and correlation of the C/O boundary (Miller, 1988; Norford, 1991). The specific boundary horizon will be defined so as to coincide with a suitable conodont zonal boundary, readily correlative with other biozonations.

The following three alternative horizons are being considered (Miller, 1988, 1992; Norford, 1991):

- base of the *Cordylodus proavus* Zone;
- base of the *Cordylodus intermedius* Zone; and
- base of the *Cordylodus lindstromi* Zone.

The sudden, first appearance of planktic graptolites (*Rhabdinopora flabelliformis* s.l.), traditionally used in Europe to define the base of the Ordovician (base of the Tremadoc series in North Wales), has been documented as occurring within the lower part of the *Cordylodus lindstromi* Zone, with the exception of Estonia, where the same event seems to occur earlier, within the *Cordylodus proavus* Zone (Kaljo *et al.*, 1988; Norford, 1991). Each of the above-named conodont zones could potentially be used to define the C/O boundary, but it is beyond the aims of this paper to discuss which is the most useful and appropriate one.

It is worth mentioning here that the biostratigraphic perspective is complicated by the existence of at least three global eustatic events (Erdtmann, 1988; Miller, 1992), ranging in age from latest Cambrian to early Tremadoc. The last of these events can be related, according to Erdtmann (1988), to the first influx of the planktic graptolites. Owing to these eustatic circumstances, C/O boundary sequences are often characterized by hiatuses, condensations, and reworked fossil contents. Among the various sections reviewed by the IWGCOB, the Xiaoyangqiao sections at Dayangcha, Jilin province, China (Chen *et al.*, 1988) and the Green Point and Broom Point sections in Newfoundland are regarded as the prime candidates to constitute the global boundary stratotype.

The application of acritarchs to C/O boundary recognition has been reviewed by Martin (1993), who proposed that acritarch data should only be used in conjunction with reliable independent age control. Inadequate documentation of the occurrence and range of acritarch species currently limits their efficacy in relative dating.

Until now, only a few acritarch zonations correlative with macrofossil or conodont zones have been published for the C/O boundary interval. In general, palynodata are fairly abundant but tend to be chiefly of local value and insufficiently precise to facilitate accurate correlations.

The most suitable acritarch zonations of the C/O boundary interval have been published by Yin Lei-ming (1986; *in* Chen *et al.*, 1988), covering the Xiaoyangqiao section at Dayangcha, Jilin province, China; and by Volkova (1990) for Estonia and the Moscow Syncline. Martin (*in* Martin & Dean, 1981, 1988) published a detailed acritarch zonation of the Upper Cambrian at Random Island, Newfoundland, eastern Canada. The Green Point section in western Newfoundland, proposed as global boundary stratotype, cannot here be taken into consideration because it lacks acritarchs (Barnes, 1988).

At Xiaoyangqiao, the horizon chosen to represent the base of the Ordovician is the FAD (First Appearance Datum) of the following conodont taxa: *Hirsutodontus simplex* – *Cordylodus drucei* – *Albiconus postcostatus*, at 5.23 m below the first influx of nematophorous graptolites (Chen *et al.*, 1988). But, at this level, no major change in the acritarch assemblage is discernible, and the first appearance of Ordovician index acritarchs (species of *Aryballomorpha* Martin & Yin Lei-ming, 1988 and *Athabascaella* Martin & Yin Lei-ming, 1988) is too far above the systemic boundary for defining the latter accurately (Martin & Yin Lei-ming, 1988). According to Martin (1993, p. 514), northeast China's acritarch assemblages are impoverished and not chronologically definitive, as they are characterized by such long-ranging taxa as *Acanthodiacrodium achrasii* Martin, 1973 and *Cymatiogalea* spp. (Deunff) Deunff *et al.*, 1974, and by morphologically simple and non-diagnostic taxa such as *Multiplicisphaeridium abnormisum* Yin Lei-ming, 1986.

At Random Island, eastern Newfoundland, the C/O boundary has not been detected owing to the presence of faults and discontinuities in the sections studied (Martin & Dean, 1981, 1988). Nonetheless, a very useful Upper Cambrian acritarch zonation, reaching the third highest of the four subzones of the *Acerocare* trilobite Zone, has been established (Martin *in* Martin & Dean, 1981, 1988). Here the presence of the lower Tremadoc has not been proved, and beds containing the trilobite *Parabolina argentina* and the acritarch *Acanthodiacrodium angustum* (Downie) Combaz, 1967 may belong to either the Upper Cambrian or the lower Tremadoc.

Volkova (1990) based an acritarch zonation on outcrop and borehole sections in Estonia and the Moscow Syncline. From her own observations and review of the available literature, she proposed that *Acanthodiacrodium angustum* marked the base of the Ordovician, in that region considered to coincide with the base of the *Cordylodus proavus* conodont Zone.

However, biostratigraphic data across the C/O

boundary beds in Estonian sections cannot be considered satisfactory, and correlations between conodont-based and acritarch-based zonations are somewhat unclear. In particular, Volkova's (1990) affirmation that *A. angustum* appears at the very base of the *C. proavus* conodont Zone is questionable on the basis of her own data (see discussion below). Uncertainty as to the initial occurrence of *A. angustum* has also been highlighted by Martin (1993, p. 516) and Vecoli *et al.* (1995, pp. 520-521).

Critical examination of the biostratigraphic data provided by Volkova (1989, 1990) furnishes no direct evidence that *A. angustum* appears at the very base of the *C. proavus* conodont Zone. Volkova's Vk5 assemblage has been recognized in the Maardu and Suurjõgi Members of the Kallavere Formation in two sections (Suhkrumägi and Vihula) and in the borehole Maardu 9, all located near Tallin, north Estonia. In each of these sections, the base of the formation is transgressive above a major hiatus which can reach the Lower Cambrian (Vihula; Volkova, 1989). At Suhkrumägi, *A. angustum* is introduced at the base of the Maardu member, referred to the *C. proavus* Zone, but the underlying *C. andresi* Zone is apparently lacking. In a detailed study of the Tõnismägi section (in the same region and close to Suhkrumägi), Kaljo *et al.* (1988) concluded that, in this area, the base of the Maardu Member is correlative with the upper part of the *C. proavus* Zone. At Vihula, where the Maardu Member is evidently more completely represented (comprising also the *C. andresi* Zone), *A. angustum* first occurs in the highest of four sampled levels (sample 17/7; Volkova, 1990). In the Maardu 9 borehole, the same species makes its appearance very high in the section (sample 131,4; Volkova, 1989, 1990), within the *C. proavus* Zone. Similarly, at Mäekalda (Mens *et al.*, 1989), the Maardu Member has an erosional base and the lowermost *C. proavus* Zone is absent; here, *A. angustum* appears in sample 86-14, together with ill-preserved specimens of *C. proavus*, and the immediately overlying sample (Ma-86-x; Mens *et al.*, 1989, p. 108) contains *C. intermedius*.

Recent biostratigraphic studies of Upper Cambrian and lower Tremadoc strata of Estonia (Mens *et al.*, 1993; Paalits, 1992, 1993), while substantiating Volkova's (1990) acritarch zonation, do not further clarify correlation with the different biozonations (conodonts, graptolites, and lingulate brachiopods) around the C/O boundary of that region. Thus the exact stratigraphic location of the systemic boundary remains unresolved.

In North Africa, Tremadoc acritarch palynofloras have been described by Deunff (1961, 1964), Combaz (1967), Jardiné *et al.* (1974), and

Elaouad-Debbaj (1988). Deunff & Massa (1975) reported a Middle Cambrian assemblage in Libya. No palynological assemblages of undoubted pre-Tremadocian age have been described in that region. However, Martin (1993) suggested that the age of the acritarch assemblage B0 of Jardiné *et al.* (1974), found in the «Grès d'El Gassi» formation, could possibly range into the uppermost Cambrian. Her suggestion took account of the presence of problematic fragmentary lingulids and the diachronism of the formation (age varying locally from Late Cambrian to early Tremadoc; Martin, 1993, p. 517, with references). Combaz (1967) presented the results of a palynological investigation of 2.2 m of black shales and shaly siltstones belonging to the upper part of the «Grès d'El Gassi» formation. The palynological assemblage (containing diacrodian and herkomorphic acritarchs, «spores», and chitinozoans) was ascribed to the lower Tremadoc, although no corroborative evidence was available. The lower part of the formation (between 3478 m and 3450 m) proved unfossiliferous, but the author dated it as early Tremadoc mainly on sedimentological grounds (Combaz, 1967, p. 20, fig. 3).

This paper details the results of a palynological investigation of uppermost Cambrian to lower Tremadoc beds of Algerian Sahara (Hassi-Rmel area), with emphasis on the biostratigraphic significance of the acritarch assemblages and their potentiality for detecting the C/O boundary in the studied sequence, and possibly elsewhere.

MATERIAL AND METHODS

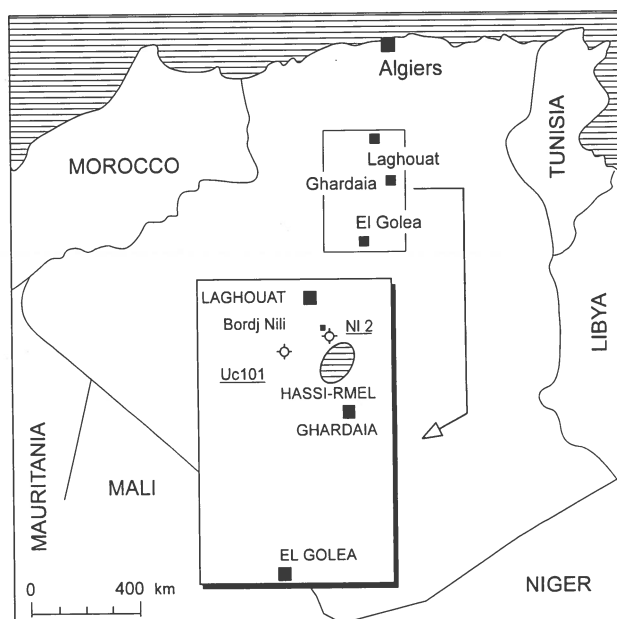
The material studied consists of 37 core samples from the two boreholes, N12 (Bordj Nili; 32 samples) and Uc101 (Oued Mehaiguene; 5 samples), in the central Sahara of Algeria. The samples are indicated herein with the borehole name abbreviation, followed by the sampling depth (in m): see Text-fig. 4 and Appendix 1. All the samples studied were cored from the finest grained beds of the various formations, so that their lithology varies from very fine grained sandstone to siltstone and shale. Thirty to 50 g of each sample were processed with the standard palynological method used at the Palynological Laboratory of the Dipartimento di Scienze della Terra, Università di Pisa (see Tongiorgi *in* Bagnoli *et al.*, 1988, pp. 168-170). The stratigraphically lowest 15 samples from borehole N12 and the lowest 3 samples from borehole Uc101 (all from the «Grès de Miribel» unit) yielded only rare leiosphaerids and/or sparse fragments of indeterminate acritarchs. All the other samples proved palyniferous, containing an

abundance of mostly well-preserved, pale yellow to light brown specimens, commonly flattened. Slightly corroded specimens were found in the upper part of the «Grès de Miribel» unit; the best-preserved specimens were retrieved from the «Argiles d'El Gassi» unit. Both palynological strew slides and SEM preparations (permanently mounted in polyester resin) have been studied.

GEOLOGICAL OUTLINE

The Algerian Sahara covers part of the vast sedimentary zone which crosses northern Africa between parallels 24 and 36° N lat., from the Atlantic to the Red Sea. It is bounded on the north by the mountains of the South Atlas Range, on the south by the outcrops of the Saharan Shield (Yetti Eglab and Ahaggar Massifs), on the west by Morocco, and on the east by south Tunisia and western Libya. Lower Palaeozoic successions occur over the greater part of the Sahara Platform, outcropping in the Ougarta, Gourara, and Touat Ranges, and around the border of the Precambrian Yetti-Eglab basin and Ahaggar. Subsurface explorations of the northern Sahara conducted by oil companies mainly during the 1950s and 1960s have revealed the existence of a number of uplifts («resistant ridges» of Balducci & Pommier, 1970) with a general southerly trend to the south but swinging westward or eastward to the north (Legrand, 1985), separating the Sahara into several basins, each fairly complex. Borehole data have shown that the Lower Palaeozoic is represented mainly beneath the Mesozoic cover in the principal Saharan basins. The northeastern Algerian Sahara, containing the Hassi-Rmel gas field and the Hassi Messaoud oil field, is characterized by a vast platform which acquired its character very early and retained it virtually throughout the entire Palaeozoic. In the Hassi-Rmel area (Text-fig. 1), boreholes NI2 and Uc101 are closely associated with the M'Zab Dorsal, a subsurface positive feature that was probably initiated during the final phase of Caledonian orogeny (Magloire, 1970, pp. 489-491, figs. 1, 4).

In this area, the Cambrian is represented by thick (350-650 m), mainly arenaceous formations, often lacking macrofossils. Precise dating of the stratal sequences has been very tentative (Legrand, 1985); their age has been roughly deduced from their stratigraphic position between Precambrian and Ordovician successions. These lithological units are (in ascending order): «Grès de Merhimine» (200-500 m thick), comprising an arkosic lower member and a feldspathic-quartzitic upper member; and the conformably overlying «Grès de Miribel» (ca. 150 m



Text-fig. 1 - Geographic setting and location of wells NI2 and Uc101, close to the Hassi-Rmel gas field.

thick), consisting of quartzitic sandstones with interbedded black silty clays. Sequentially above are the glauconitic sandstones of the «Grès de Bordj Nili». The lower Ordovician is undoubtedly represented in the overlying argillaceous «Argiles d'El Gassi» unit, which yielded a rich fauna of graptolites of the *Rhabdinopora flabelliformis* s.l. group (Legrand, 1974, 1985).

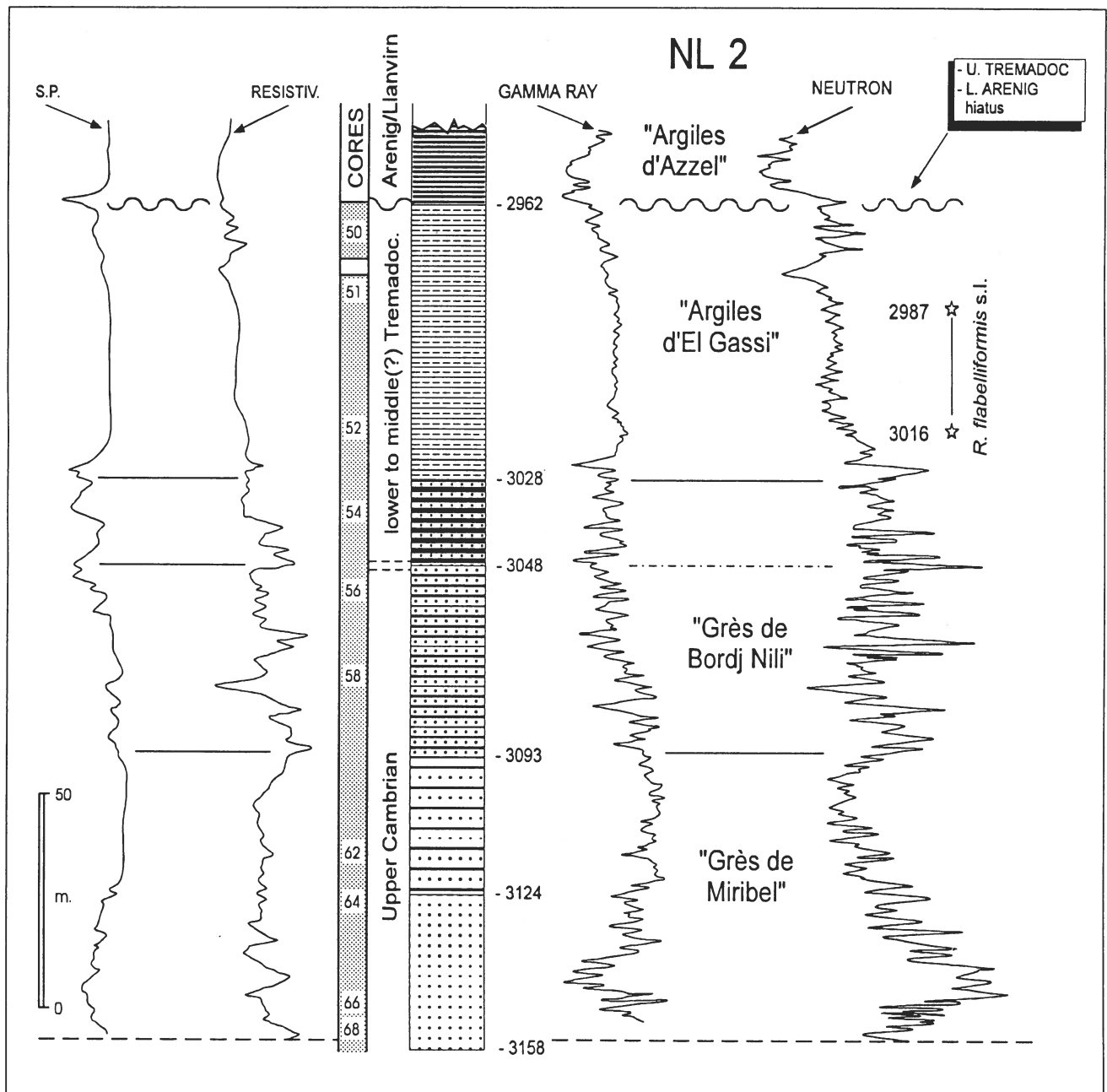
LITHOSTRATIGRAPHY

The NI2 and Uc101 boreholes intersect the following conformable lithostratigraphic units (ascending order; Text-figs. 2, 3):

«Grès de Miribel» unit (>65 m thick), predominantly quartzitic (with «tigillites» = *Skolithos*) in the lower half, with interbedded black or green micaceous, pyritic shales toward the top.

«Grès de Bordj Nili» unit (ca. 65 m), characterized by regular alternations of white quartzites and black shales rich in pyrite nodules, followed by fine-grained arenaceous beds with interbedded conglomeratic horizons within the middle part. Green shales and interbedded fine-grained chloritic sandstones follow in the upper part of the unit between 3028 and 3048 m. This horizon is emphasized on the gamma-ray log (Text-fig. 2). The presence of inarticulate brachiopods and crinoids indicates a marine depositional environment.

«Argiles d'El Gassi» unit (66 m), forming a



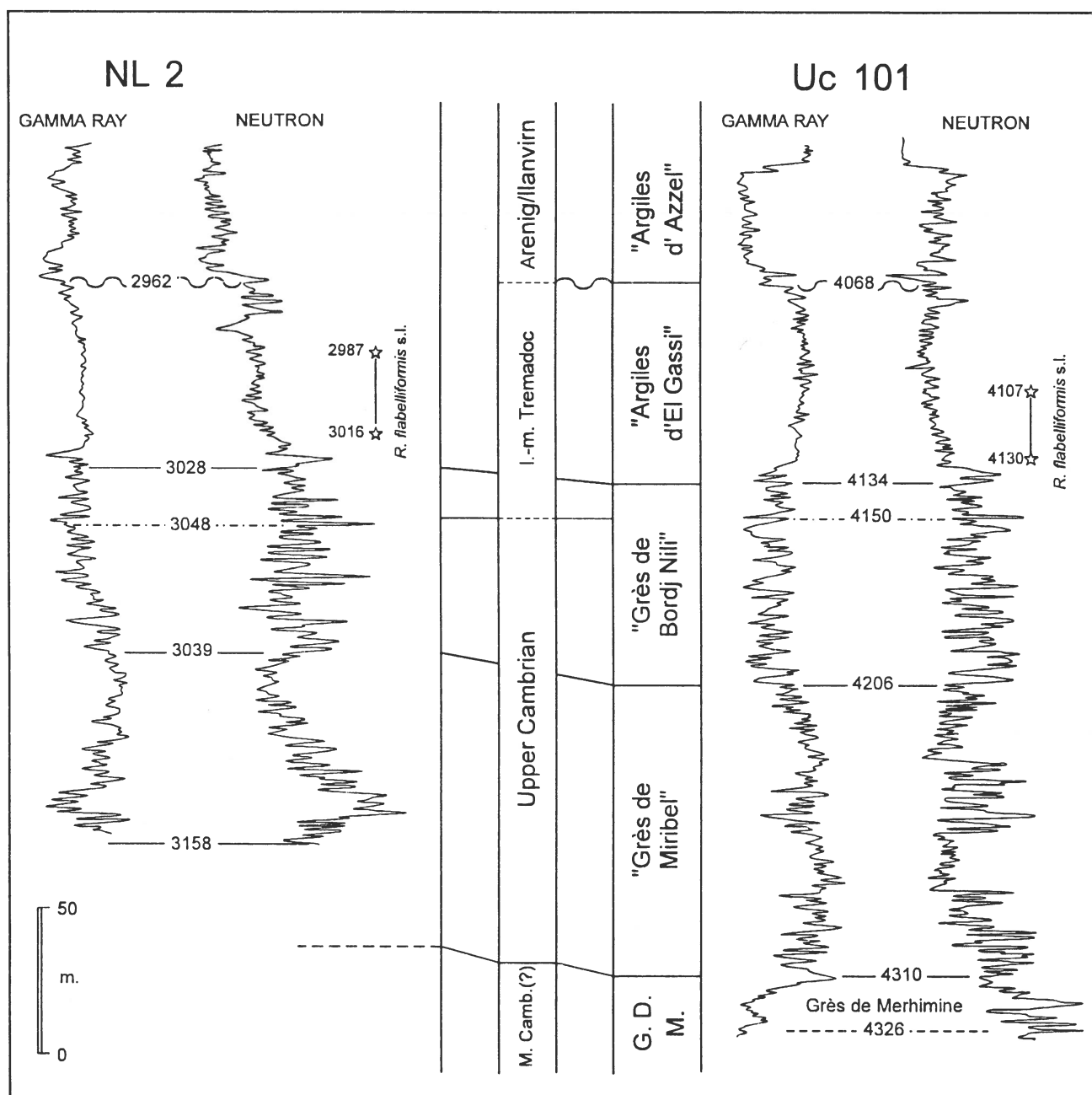
Text-fig. 2 - Spontaneous potential, resistivity, gamma ray, and neutron logs of the Cambrian-Ordovician part of the NL2 borehole. Regional stratigraphic units are easily recognizable.

distinct cycle which begins with coarse sandstones, followed by grey-green siltstones and shales containing graptolites of the *Rhabdinopora flabelliformis* s.l. group.

A distinct erosional surface at the top of the last-named unit marks the beginning of a sandy-shaly transgressive cycle («Argiles d'Azzel») of late Arenig-Llanvirn age (Oulebsir, 1992), truncating the Tremadoc sequence (Vecoli *et al.*, 1995).

PREVIOUS STUDIES

The lithostratigraphic nomenclature of Lower Palaeozoic formations of Algeria is somewhat confused. Litho- and chronostratigraphic attributions of the Cambrian and Ordovician rocks were reviewed by Legrand (1985). Biostratigraphic study of the Lower to Middle Cambrian successions has been traditionally hindered by their characteristically un-



Text-fig. 3 - Comparison of gamma ray and neutron logs from Uc101 and NL2 boreholes and correlations.

fossiliferous sandstones. In the Hassi-Rmel area, the «Grès de Miribel» informal unit, which yielded an abundant brachiopod fauna characterized by *Lingulepsis acuminata* (Conrad), has been attributed, at least in its upper part, to the Upper Cambrian (Legrand, 1985). This formation is equivalent to the «Grès d'El Gassi» in the Hassi Messaoud area (Combaz, 1967). But, as Legrand (1985, p. 18 and tab. 2) suggested, the «Grès de Miribel» unit is probably diachronous across the Cambrian- Ordovician bound-

dary over a vast area, and its variation in thickness is poorly understood owing to scarce subsurface data.

The overlying glauconitic sandstones of the «Grès de Bordj Nili» unit, with *Lingulobolus* (?) *septentrionalis* (Legrand) have been attributed hypothetically to the lowermost Tremadoc (Legrand, 1974; 1985, p. 18). The early Tremadoc age attribution for the «Argiles d'El Gassi» relies on the presence of graptolites of the *Rhabdinopora flabelliformis* s.l. group (Legrand & Nabos, 1962;

Blain, 1963; Legrand, 1974, 1985). According to Legrand (1985, p. 18, tab. 2), and Combaz (1967, fig. 2, p. 23), those two stratigraphic units show little lateral continuity, with general east-west reduction in thickness, and probable diachroneity.

In 1974 Legrand published a biostratigraphic study of the C/O boundary sequences of the Hassi-Rmel area, as penetrated by N12 and Uc101 boreholes. From the presence of graptolites (assemblage v1 of Legrand, 1974, with *Rhabdinopora flabelliformis* s.l.), he ascertained an early Tremadoc age for the «Argiles d'El Gassi». Legrand (1974) described a brachiopod assemblage (v3, with *Lingulepsis acuminata*) from the «Grès de Miribel» unit, for which he proposed a possible late Cambrian age. The position of the C/O boundary remained undefined because of the lack of diagnostic fossils in the 65 m-thick «Grès de Bordj Nili» unit.

As mentioned before, published palynological studies of Cambrian and/or Ordovician successions of Algerian Sahara are not numerous. Combaz (1967, fig. 5) presented a synthesis of the Ordovician stratigraphy of Algerian Sahara, including a palynological biozonation subdividing the Ordovician in 5 biozones («A-E»), mainly based on unpublished data from oil companies. The first of those biozones («A») is characterized by the presence of terrestrial spores and is considered of earliest Tremadoc age. Martin (1993, p. 517) advanced some reservations about this age attribution since Combaz «attributed to the lower Tremadoc the oldest acritarchs from the "Grès d'El Gassi" on the basis of a comparison with those from the *Obolus* Beds of the East European Platform». Kaljo *et al.* (1986, 1988) demonstrated that the so-called «*Obolus* Sandstones» of the East Baltic area are at least partly attributable to the Upper Cambrian. This, according to Martin (1993) could affect the age attribution of Combaz's (1967) palynological zone «A». Middle Cambrian acritarchs from the Ghadamis Basin (western Libya-southern Tunisia) were first described by Deunff & Massa (1975). Extending that study, Albani *et al.* (1991) identified two acritarch associations which they assigned to the Middle and Late Cambrian, respectively. The important work of Jardiné *et al.* (1974) was the first attempt at establishing a practical palynozonation of the Palaeozoic of the Algerian Sahara; but, as mentioned previously, some problems exist regarding the age attribution of the first biozone (B0), considered equivalent to Combaz's (1967) biozone «A». Oulebsir (1992) proposed a detailed chitinozoan zonation of the Middle-Upper Ordovician of Algerian Sahara, based upon a study of various boreholes including N12 (see also Oulebsir & Paris, 1993). No detailed

acritarch zonations of the C/O boundary interval have hitherto been proposed for the North African region.

THE ACRITARCH CONTENT OF N12 AND Uc101

The lowest 15 samples of N12 are barren or, at best, contain indeterminate acritarchs. Sample N12-3088.55 yielded a profusion of acritarchs, albeit poorly preserved. In that sample only a few species could be identified; and, for some species, only a questionable identification was possible. Samples N12-3082.80 to N12-3060.70 are characterized by better preserved specimens, though they are sometimes slightly corroded. At higher stratigraphic levels (beginning with sample N12-3054.75), the state of preservation shows considerable improvement, so that very appreciable percentages of the acritarchs proved identifiable. Among the five samples cored from borehole Uc101, only the two highest samples (Argiles d'El Gassi) yielded abundant and well-preserved palynofloras. Sample Uc101-4298.00 (Grès de Miribel) contains badly preserved specimens, mainly sphaeromorphs, and the two lowest samples are barren.

A complete inventory of the identified species is as follows:

- Acanthodiacrodium achrasii* Martin, 1973
- Acanthodiacrodium baculatum* n. sp.
- Acanthodiacrodium capillatum* n. sp.
- Acanthodiacrodium complanatum* (Deunff) Umnova, 1975
- Acanthodiacrodium comptulum* Rasul, 1979
- Acanthodiacrodium rotundatum* Górka, 1967
- Acanthodiacrodium ubui* Martin, 1969
- Acanthodiacrodium* sp. cf. *A. angustum* (Downie) Combaz, 1967
- Acanthodiacrodium* sp. cf. *A. divisum* (Deunff) Downie & Sarjeant, 1965
- Arbusculidium destombesii* Deunff, 1968
- Baltisphaeridium crinitum* Martin, 1978
- Baltisphaeridium verutum* n. sp.
- Baltisphaeridium* sp. cf. *B. microspinosum* (Eisenack) Downie, 1959
- Cristallinium ovillense* (Cramer & Diez) Fensome *et al.*, 1990
- Cristallinium randomense* (Martin) Fensome *et al.*, 1990
- Cymatiogalea cristata* (Downie) Rauscher, 1974
- Cymatiogalea cuvillieri* (Deunff) Deunff, 1964
- Cymatiogalea gorkae* Rauscher, 1974
- Cymatiogalea membranispina* Deunff, 1961
- Cymatiogalea multarea* (Deunff) Eisenack *et al.*, 1973
- Cymatiogalea parva* n. sp.
- Cymatiogalea velifera* (Downie) Martin, 1969

Cymatiogalea virgulta Martin, 1988
Dasydiacrodium obsonum Martin, 1988
Dasydiacrodium tumidum (Deunff) Tongiorgi, 1988
Elenia armillata (Vanderflit) Volkova, 1984
Eupoikilofusa squama (Deunff) Elaouad-Debbaj, 1988
Ladogella rommelaerei (Martin) Di Milia *et al.*, 1989
Ladogella rotundiformis Golub & Volkova, 1985
Lophodiacrodium valdaicum (Timofeev) Downie & Sarjeant, 1965
Multiplicisphaeridium cervinacornuum Welsch, 1986
Multiplicisphaeridium sp. 1
Ooidium sp. cf. *O. rossicum* Timofeev, 1957
Polygonium dentatum (Timofeev ex Konzalová-Mazancová) Albani, 1989
Polygonium gracile Vavrdová, 1966
Saharidia fragilis (Downie) Combaz, 1967
Stellechinatum uncinatum (Downie) Molyneux, 1987
Stelliferidium cortinulum (Deunff) emend. Deunff *et al.*, 1974
Stelliferidium distinctum (Rasul) Elaouad-Debbaj, 1988
Stelliferidium furcatum (Deunff) emend. Deunff *et al.*, 1974
Stelliferidium gautieri (Martin) Pittau, 1985
Stelliferidium simplex (Deunff) emend. Deunff *et al.*, 1974
Stelliferidium stelligerum (Górka) emend. Deunff *et al.*, 1974
Stelliferidium velatum n. sp.
Timofeevia phosphoritica Vanguetaine, 1978
Timofeevia sp. aff. *T. microretis* Martin, 1981
Trunculumarium sp. 1
Veryhachium dumontii Vanguetaine, 1973
Vulcanisphaera africana Deunff, 1961
Vulcanisphaera britannica Rasul, 1976
Vulcanisphaera capillata Jardiné *et al.*, 1974

ACRITARCH ASSEMBLAGES

Vertical distribution of acritarch species in the boreholes studied enables recognition and definition of three, distinct, stratigraphically successive assemblages (Tab. 1; Text-fig. 4; HM=Hassi-Rmel).

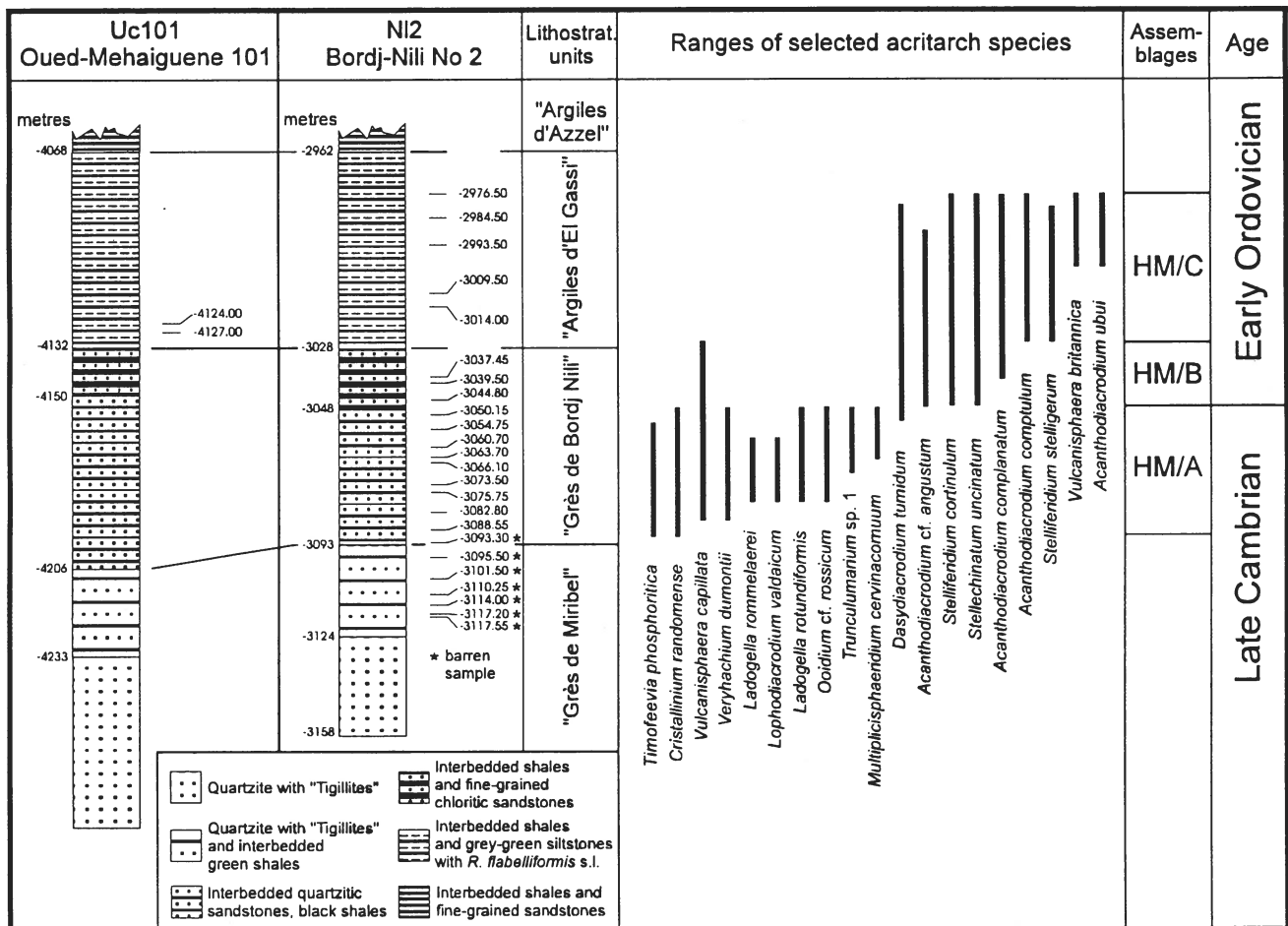
1. HM/A assemblage: samples N12-3088.55 to N12-3050.15; lower and middle parts of the «Grès de Bordj Nili» unit.

This assemblage is characterized by the following taxa: *Cristallinium randomense*, *Cymatiogalea virgulta*, *Ladogella rommelaerei*, *L. rotundiformis*, *Multiplicisphaeridium cervinacornuum*, *Trunculumarium* sp. 1, and *Veryhachium dumontii*. *Timofeevia phosphoritica* is present stratigraphically up to and including sample N12-3060.70. Samples N12-3075.75 to N12-3063.70

Species	Samples	3088.55	3082.80	3075.75	3073.50	3066.10	3063.70	3060.70	3054.75	3050.15	3044.80	3039.50	3037.45	3014.00	3009.50	2993.50	2984.50	2976.50
C. RANDOMENSE		R	R	R	X	X		R		R								
T. PHOSPHORITICA		?	X	U	R	X	R	R	?									
V. CAPILLATA			X	R	R	R	U	C	U	C	C	C	A					
A. ACHRASII			U	C	C	U	C	C	C	A								
C. OVILLENSE			U	R	R	X	U	R	U	U		R	R	X				
V. DUMONTII			X	X	X	R	R	R	R	U								
L. ROMMELAEREI				C	C	R	R	R	R	U								
B. CRINITUM				C	U	U	R											
L. VALDAICUM				C	U	R	X	X										
C. CUVILLIERI				C	U	U	C	C	U	U	U	U	C	C	C	C	C	C
L. ROTUNDIFORMIS				X		X	R	R	U	U								
O. cf. ROSSICUM				X	X	?	X	X										
V. AFRICANA				X	X	R	U	U	U	U	U	A	A	A	A	C	C	C
STELLIFERIDIUM SPP.				U	U	U												
E. ARMILLATA				X	X	X			R				R		R			
S. GAUTIERI						R	U	U	U	R	R	R						
D. OBSONUM						?	?	X										
S. FRAGILIS						C	C	C	C	C	C	C	C					
T. SP. 1						X	R	R	C	A								
C. VELIFERA						U	U	U	C	C	U	C	C	C	C			
S. DISTINCTUM						R	R	R	C	A	R	R	R					
M. CERVINACORNUI							R	U	U									
E. SQUAMA							U	U	U	U	R	U	U	U	U			
C. VIRGULTA								X	R									
T. aff. MICRORETIS								X					X					
D. TUMIDUM										R	R	U	U	C	U	U	U	
A. cf. ANGUSTUM											X	X	X			X		
A. BACULATUM											C	C	U	U				
S. CORTINULUM											C	C	C	C	C	C	U	U
P. DENTATUM											R	C	A	C	C	U	U	U
S. FURCATUM											U	U	C	C	A	U	R	R
S. UNCINATUM											U	C	C	C	C	A	C	C
S. VELATUM											R	C	A	R		R	X	
A. CAPILLATUM											R	C	C	R	X			
C. PARVA												R	U					
A. DESTOMBESII													X					
A. COMPLANATUM												R	C	A	A	A	A	A
A. COMPTULUM													U	U	C	C	C	
B. VERUTUM													A	R				
S. SIMPLEX													U	C	C	C	C	
S. STELLIGERUM													R	U		X		
C. MEMBRANISPIA													X	X	R			
C. CRISTATA														C	C	A	C	C
C. GORKAE														R	R	R	R	R
C. MULTAREA														R	U	R	R	
A. ROTUNDATUM														U	C	C	U	
A. cf. DIVISUM														U	U	U		
P. GRACILE														C	C	U	C	U
M. SP. 1															X			
B. cf. MICROSPINOSUM																X		
V. BRITANNICA																X	U	C
A. UBUI																R	C	A
Assemblages		HM/A					HM/B					HM/C						

Table 1 - Occurrences and abundance of acritarch species in assemblages from borehole N12 ? = questionably present, X = very rare, R = rare, U = uncommon, C = common, A = abundant.

contain *Lophodiacrodium valdaicum*, and a few, ill-preserved specimens of *Ooidium* sp. cf. *O. rossicum* were found in samples N12-3075.75 to N12-3060.70. The latter sample also contains *Dasydiacrodium obsonum* whose presence in samples N12-3075.75 to N12-3063.70 is only dubious, owing to its similarity to *Acanthodiacrodium achrasii* (see discussion in the systematic part). Also present are species of lesser stratigraphic significance, such as *Acanthodiacrodium achrasii*, *Cymatiogalea velifera*, *Cymatiogalea cuvillieri*, *Elenia armillata*, *Vulcanisphaera africana*, *V. capillata*, *Saharidia fragilis*, and *Stelliferidium* spp. Samples N12-3054.75 and N12-3050.15 are characterized by abundant *Stelliferidium distinctum*; it is



Text-fig. 4 - Uc101 and NI2 boreholes: lithological logs with location of the studied samples, lithostratigraphy, and biostratigraphy.

possible that some of the specimens included here in *Stelliferidium* spp. belong to *S. distinctum*, but their poor preservational state impedes more precise attribution. HM/A assemblage also contains a limited number of diacrodians, principally *Acanthodiadrodium achrasii*.

2. HM/B assemblage: samples NI2-3044.80 to NI2-3037.45; upper part of the «Grès de Bordj Nili» unit.

Characteristic attributes of the HM/B assemblage include the introduction of the following taxa: *Acanthodiadrodium* sp. cf. *A. angustum*, *A. baculatum*, *A. capillatum*, *A. complanatum*, *Arbusculidium destombesii*, *Polygonium dentatum*, *Stellerchinatum uncinatum*, *Stelliferidium cortinulum*, *S. furcatum*, and *S. velatum*. The following species, characteristic of the preceding (HM/A) assemblage, are absent: *Cristallinium randomense*, *Ladogella rommelaerei*, *L. rotundiformis*, *Multiplicisphaeridium cervinacornuum*, *Trunculumarium* sp. 1, *Veryhachium*

dumontii, and *Timofeevia phosphoritica*. Ooid forms are also notably absent.

Vulcanisphaera capillata, *V. africana*, *Saharidia fragilis*, *Eupoikilofusa squama*, *Cymatiogalea velifera*, and *C. cuvillieri* persist from the HM/A assemblage.

3. HM/C assemblage: samples NI2-3014.00 to NI2-2976.50; Uc101-4127.00 and Uc101-4124.00; «Argiles d'El Gassi» unit.

This assemblage is marked by the introduction of the following taxa: *Cymatiogalea cristata*, *C. gorkae*, *C. membranispina*, *C. multarea*, *Polygonium gracile*, *Stelliferidium simplex*, and *S. stelligerum*. *Acanthodiadrodium ubui* and *Vulcanisphaera britannica* are especially noteworthy components of samples NI2-2993.50 to NI2-2976.50. Many of the taxa from the lower assemblage persist, with the exception of *Saharidia fragilis*, while samples from NI2-3009.50 upwards are devoid of *Elenia armillata*. Quantitatively, diacrodians and herkomorphitids dominate this assemblage.

EVALUATION OF THE ACRITARCH ASSEMBLAGES

The acritarch suites discussed here show clear affinities with assemblages from western Europe (Belgium, England, and Wales), eastern Newfoundland (Canada), and the Eastern European Platform (Text-fig. 5). Certain similarities are evident with acritarch palynofloras of Baltica; however, no significant taxa are shared with North China.

Regarding stratigraphic correlation with other areas, pertinent references are mainly Volkova (1990) for the C/O boundary interval of Estonia; Martin (*in* Martin & Dean, 1988), for her detailed Upper Cambrian acritarch biozonation of eastern Newfoundland, and Jardiné *et al.* (1974) for Ordovician palynostratigraphy of Algerian Sahara.

ASSEMBLAGE HM/A

This, stratigraphically lowest assemblage (HM/A: samples N12-3088.55 to N12- 3050.15)

shares a significant number of species (9 out of 14) with the upper part (A5b) of Microflora A5 («*Arbusculidium*» = *Ladogella rommelaerei-Vulcanisphaera africana*) of Martin (*in* Martin & Dean, 1988): viz., *Acanthodiacrodium achrasii*, *Cristallinium ovillense*, *C. randomense*, *Dasydiacrodium obsonum*, *Ladogella rommelaerei*, *Saharidia fragilis*, *Timofeevia phosphoritica*, *Veryhachium dumontii*, and *Vulcanisphaera africana*. The absence of *Trunculumarium revinium* (Vanguetaine) Loeblich and Tappan, 1976, and the presence of *Saharidia fragilis* are consistent with the proposed correlation. Microflora A5b is correlated with the upper part of the *Peltura* and with *Acerocare* p.p. trilobite Zones. Among the taxa listed above, *Cristallinium randomense*, *Dasydiacrodium obsonum*, *Timofeevia phosphoritica*, and *Veryhachium dumontii* are unknown from indubitably post-Late Cambrian rocks.

Ladogella rotundiformis, *Lophodiacrodium valdaicum*, and *Ooidium rossicum* are also considered

LITHO-STRAT. UNITS	BIOSTRATIGRAPHY		BIOSTRATIGRAPHIC CORRELATIONS (ACRITARCHS)			AGE
	Acritarch assemblages (this study)	Graptolites, brachiopods (Blain, 1963; Legrand, 1974)	Sahara (Jardiné et al., 1974)	Newfoundland (Martin & Dean, 1981; 1988)	Russia (Volkova, 1990)	
"Argiles d'El Gassi"	HM/C	<i>Bryograptus</i> sp.	B2 Zone and B1 Zone			Early Ordovician
		<i>Rhabdinopora flabelliformis</i>				
		<i>R. flab. aff. anglica</i> <i>R. flabelliformis. aff. flabelliformis</i> <i>R. flab. socialis</i>				
"Grès de Bordj Nili"	HM/B	?	B0 Zone	Microflora A6	Assemblage Vk5	Late Cambrian
	HM/A	barren of megafossils ?		?		
				Microflora A5b	Assemblage Vk4b	

Text-fig. 5 - Proposed correlations between acritarch zonation and graptolite occurrences in Cambro-Ordovician stratal sequence of Hassi-Rmel with acritarch zonations from Sahara (Jardiné *et al.*, 1974), eastern Newfoundland (Martin *in* Martin & Dean, 1981, 1988), and Russia (Volkova, 1990).

here as very important biostratigraphic indices. These species have been recorded from Upper Cambrian deposits of the European Platform by Volkova (1990). The upper stratigraphic limit of *L. rotundiformis* lies within the *Cordylodus intermedius* conodont Zone (Volkova & Mens, 1988), while, in the same region, the stratigraphic ranges of *O. rossicum* and *L. valdaicum* are restricted to the upper part of the *Peltura* trilobite Zone (Vk4b acritarch zone of Volkova, 1990). Owing to the relative scarcity of specimens and to disadvantageous preservation, the presence of *O. rossicum* in borehole N12 cannot be confirmed; it is possible that conspecificity exists between the latter species and the (rather poorly preserved) forms included here in *Ooidium* sp. cf. *O. rossicum*. Welsch (1986) described *O. rossicum* from samples collected in the lower part of the Berlogaissa Formation (Finnmark, Norway), accepting an early Tremadoc age for this deposit. However, the highest palyniferous horizon (1b-1c14) containing the latter species lies in a stratigraphic interval lacking macrofossils, well below the incoming of graptolites belonging to the *Rhabdinopora flabelliformis* s.l. group (Welsch, 1986, figs. 6, 8). Furthermore, the same interval has been correlated by Welsch (1986, fig. 6; pp. 22, 89) with the *Obolus* sandstones of the East European Platform, now considered Late Cambrian (Kaljo *et al.*, 1986).

The upper part of assemblage HM/A shows some similarity also to the lower part (lacking *Acanthodiacrodium angustum*) of Volkova's (1990) Vk5 zone. Species shared with that zone are the following: *Cymatiogalea cuvillieri*, *C. velifera*, *Elenia armillata*, *Ladogella rotundiformis*, *Multiplicisphaeridium cervinacornuum*, *Saharidia fragilis*, and *Timofeevia phosphoritica*. According to Volkova (1990), the C/O boundary in the East European Platform lies within her zone Vk5, and is marked by the initial occurrence of *A. angustum*. The latter species is absent in the HM/A assemblage.

Minor similarities exist between the upper part of HM/A assemblage and B0 palynological zone of Jardiné *et al.* (1974); namely the absence of ooid forms, presence of *Vulcanisphaera africana* and *Saharidia fragilis* (neither stratigraphically important), and prevalence of diacrodian over herkomorphitic forms.

From the foregoing discussion, the following correlations are proposed here for the HM/A assemblage. The lower part of the assemblage (samples N12-3088.55 to N12-3063.70), with *Lophodiacrodium valdaicum* and *Ooidium* sp. cf. *O. rossicum*, is possibly correlative with the Vk4b zone of Volkova (1990), of Late Cambrian age (*Peltura* trilobite Zone). The younger part of the assemblage (sample

N12-3060.70 upwards) is correlative with the upper part (A5b) of Martin's (1988) Microflora A5 (Late Cambrian: *Peltura* and *Acerocare* p.p. trilobite Zones); and also with the lower part of Volkova's (1990) Vk5 palynological zone (latest Cambrian: *Acerocare* trilobite Zone).

ASSEMBLAGE HM/B

This assemblage shows clear affinities with Microflora A6 (*Arbusculidium destombesii*-*Vulcanisphaera capillata* assemblage) of Martin (*in* Martin & Dean, 1981) in eastern Newfoundland. Many of the taxa originally indicated by Martin (1981) as characteristic of Microflora A6, such as *Cymatiogalea cuvillieri*, *C. velifera*, *Eupoikilofusa squama*, and *Vulcanisphaera capillata* (all present in the HM/B assemblage) occur also in Upper Cambrian deposits (Martin *in* Martin & Dean, 1988), and therefore have longer vertical ranges than initially proposed. In fact, the first occurrences of two other species, *Acanthodiacrodium angustum* and *Arbusculidium destombesii*, seem to be more significant biostratigraphically. In Martin's Microflora A6, the lower Tremadoc is undoubtedly represented even if some of the associated macrofossils may range lower, into the *Acerocare* trilobite Zone. Resemblances exist with palynological B0 zone (Jardiné *et al.* 1974), although the latter's characteristic species [*Acanthodiacrodium simplex* Combaz, 1967, *Arbusculidium ornatum* (Combaz) Jardiné *et al.*, 1974, *A. ramusculosum* (Combaz) Jardiné *et al.* 1974, and *Dasydiacrodium glabrum* Combaz, 1967] have not been recorded in borehole N1-2. Moreover, the abrupt palynofloral change marked by massive appearance of Herkomorphitae, observed by Jardiné *et al.* (1974) between their B0 and B1/B2 palynological zones, is quite consistent with the discontinuity between HM/B and HM/C acritarch suites recorded here. At the base of Assemblage HM/B, many acritarch taxa of no clear stratigraphic significance (especially belonging to Diacromorphitae and Herkomorphitae) are introduced, but species of indubitable Cambrian age are absent. Until now, *Acanthodiacrodium angustum* has been regarded as a uniquely Ordovician species, appearing at a stratigraphic level very close to the Tremadoc base (Volkova, 1990). The latter species is missing in the section studied, but a form morphologically very close to it (recorded herein as *A. sp. cf. A. angustum*) makes its first appearance in sample N12-3044.80.

ASSEMBLAGE HM/C

The presence of some diagnostic Tremadoc taxa in this assemblage – such as *Acanthodiacrodium ubui*,

Cymatiogalea cristata, *Polygonium gracile*, *Stelliferidium simplex*, *S. stelligerum*, and *Vulcanisphaera britannica* – confirms the previous early Tremadoc attribution of the «Argiles d'El Gassi» unit (Legrand, 1974) based on the presence of graptolites of the *Rhabdinopora flabelliformis* s.l. group. The assemblage clearly shows very close alliance with the early Tremadoc B1 and B2 palynological zones (Jardiné *et al.*, 1974) of the Algerian Sahara.

Vulcanisphaera britannica, which appears in sample NL2-2993.50, indicates an immediately post-basal Tremadoc age (Rasul, 1976).

DISCUSSION AND CONCLUSIONS

Palynological data across the Cambrian-Ordovician boundary are very scarce, and both the stratigraphic ranges and the taxonomy of many typical forms are still to be satisfactorily resolved. This applies particularly to members of the Diacromorphitae and Herkomorphitae subgroups. For these reasons, as well as continuing uncertainty as to exact placement of the C/O boundary, the use of acritarchs in pinpointing the base of the Ordovician is only at a preliminary stage, though it does hold considerable promise.

Uppermost Cambrian acritarch assemblages have not previously been described from the Algerian Sahara region. However, some components of Assemblage HM/A – viz., *Cristallinium randomense*, *Dasydiacrodium obsonum*, *Ladogella rotundiformis*, *Timofeevia phosphoritica*, and *Veryhachium dumontii* – have been recorded from upper to uppermost Cambrian stratal sequences of eastern Newfoundland (Martin *in* Martin & Dean, 1981, 1988), Belgium and northern France (Ribecai & Vanguetaine, 1993), and the East European Platform (Volkova, 1990). *C. randomense* and *L. rotundiformis* are typically present also in the Upper Cambrian (*Peltura scarabeoides* trilobite Subzone) of Baltica (Di Milia *et al.*, 1989).

On the other hand, many taxa previously regarded as indicative of an early Tremadoc age (including mostly species of *Cymatiogalea* and *Stelliferidium*) have been proved to range downward into the Upper Cambrian (Martin, 1993, pp. 514-515). The sole taxon regarded as undoubtedly early Tremadoc is *Acanthodiacrodium angustum* (Volkova, 1990). As noted before, the lower stratigraphic limit of that species is still debatable. Nevertheless, its inception is considered by several authors (Volkova, 1990; Martin, 1982, 1993; Paalits, 1995) to constitute an important palynostratigraphic «event» signifying proximity to, if not coincidence with, the (albeit still precisely undefined) C/O boundary.

In borehole NL2, the abrupt change in the acritarch assemblages occurring between the samples NL2-3050.15 and NL2-3044.80 is signified and emphasized by the disappearance of many Upper Cambrian taxa and by the introduction of new forms including one close to *Acanthodiacrodium angustum*. There is concomitant increase in diacromorphs and herkomorphitids. This abrupt change in the composition of acritarch suites is tentatively proposed here as a palynologically easily detectable horizon which could possibly approximate to the C/O boundary in the area studied. A lithological change occurs in borehole NL2 within the 5.35 m-thick stratigraphic interval between the upper limit of assemblage HM/A and the lower limit of assemblage HM/B. The actual boundary between assemblages HM/A and HM/B (proposed here as a palynologically defined C/O boundary) lies in the same stratigraphic interval, but there are no particular reasons to think that the palynological and the lithological changes coincide. However, the Tremadoc cycle is considered to be widely transgressive in Libya (Massa, 1988), western Sahara, and Morocco (Destombes *et al.*, 1985). In the area studied, the Upper Cambrian is of shallow marine derivation and a minor hiatus at the base of the upper third of the «Grès de Bordi Nili» cannot definitely be excluded. Accordingly, the abrupt discordance in the acritarch assemblages (i.e. HM/A vs. HM/B) might possibly reflect a stratigraphic break.

The presence of coarse-grained sediments would suggest a minor hiatus at the base of the «Argiles d'El Gassi». The upper Tremadoc is missing in NL2, as the upper Arenig-lower Llanvirn (Legrand, 1985, Oulebsir, 1992) «Argiles d'Azzel» disconformably cuts the underlying lower Tremadoc sediments.

SYSTEMATIC PALAEOONTOLOGY

Synonymy listings include basionym followed, where applicable, by synonyms and citation of prior emendations, together with any published records of the particular taxon that are regarded as erroneous. Descriptions of new species are based on a minimum of 20 well-preserved specimens occurring in more than one sample. Morphological terminology is in accordance with the glossary of Williams *et al.* (1978). The term «eilyma» is adopted for vesicle wall, as defined by Sarjeant & Stancliffe (1994, p. 10). Abundance values are expressed semi-quantitatively, as follows: very rare (X) = 1-2 identified specimens; rare (R) = 3-5 identified specimens; uncommon (U) = 6-20 identified specimens; common (C) = 21-50

identified specimens; abundant (A) = >50 identified specimens.

Detailed descriptions are provided only of taxa that have particular stratigraphic value and/or taxonomic significance. Particular emphasis is drawn to the stratigraphic distribution of the species recorded below. Lower and upper stratigraphic limits verified by means of independent age control (macrofossils or conodonts) are given where available. A complete inventory of the geographic and stratigraphic occurrences appear under «previous records». Questionable attributions have not normally been taken into account.

Generic and specific taxa are treated in accordance with the provisions of the current International Code of Botanical Nomenclature (ICBN; Greuter *et al.*, 1988; see also Fensome *et al.*, 1990, pp. 5-18).

REPOSITORY

All specimens illustrated herein (Pls. 1-9) are deposited in the type collections of the Museo di Storia Naturale e del Territorio, Certosa di Calci, Pisa. Catalogue numbers (prefixed CPT) of that institution and stratigraphic data pertaining to each specimen, are incorporated in Appendices 1 and 2.

Group ACRITARCHA Evitt, 1963

Genus ACANTHODIACRODIUM Timofeev, 1958
emend. Deflandre & Deflandre-Rigaud, 1962

Type species – *Acanthodiacrodium dentiferum*
Timofeev, 1958; by monotypy.

Discussion – The confused taxonomy of diacrodians has been reviewed by Deflandre & Deflandre-Rigaud (1962), Loeblich & Tappan (1978), and Tongiorgi (*in* Bagnoli *et al.*, 1988). The interpretation of the genus *Acanthodiacrodium* Timofeev, 1958 by Tongiorgi (*in* Bagnoli *et al.*, 1988, pp. 179-181) is followed herein, in particular rejection of both *Priscotheca* Deunff, 1961 and *Actinotodissus* Loeblich & Tappan, 1978 in favour of *Acanthodiacrodium* as senior synonym.

ACANTHODIACRODIUM ACHRASII Martin, 1973
Pl. 1, fig. 1

- 1973 *Acanthodiacrodium achrasi* MARTIN, pp. 30-31; pl. 5, fig. 11; pl. 6, figs. 8, 11, 19; pl. 8, figs. 1, 2, 4.
p.p. 1985 *Acanthodiacrodium uniforme* auct. non Burmann - Yin Lei-ming *in* CHEN *et al.*, pl. 28, fig. 1, non pl. 28, fig. 24.

1986 *Actinotodissus achrasi* (Martin) Yin Lei-ming *in* CHEN, p. 332; pl. 84, figs. 1, 3, 5, 7-11, 13, 15, 16; pl. 92, figs. 1, 2, 4, 6; pl. 93, figs. 1, 2, 6-7; pl. 94, fig. 5; pl. 96, fig. 4; pl. 97, fig. 8; text-fig. 122.

Dimensions – Vesicle length 21 (25) 28 μ m, vesicle width 16 (20) 23 μ m; length of processes 6-8 μ m, basal diameter of processes 3-4 μ m, number of processes 6-8 at each pole (based on 18 specimens).

Remarks – Martin (*in* Martin & Dean, 1988, p. 35) recorded specimens characterized by vesicle and processes wall «covered with reduced spines, each of which has a granulose base and hair-like tip». No such spines have been observed in specimens from borehole N12 (perhaps owing to the preservational state), but a well-developed granulation on both vesicle and processes is always present. Vesicle sculpture is considered here diagnostic for specific attribution to *Acanthodiacrodium achrasi* Martin, 1973.

Occurrence and abundance – Sample N12-3082.80: uncommon. Samples N12 3075.75 and N12-3073.50: common. Sample N12-3066.10: uncommon. Samples N12-3063.70 to N12-3054.75: common. Sample N12-3050.15: abundant.

Previous records – Upper Cambrian: Dayangcha, Jilin Province, China (Yin Lei-ming, *in* Chen *et al.*, 1985; *in* Chen, 1986; *in* Chen *et al.*, 1988); Öland, Sweden (Di Milia *et al.*, 1989). Upper Cambrian-lower Tremadoc: Random Island, eastern Newfoundland, Canada (Martin *in* Dean & Martin, 1978; *in* Martin & Dean, 1981, 1988). Lower Tremadoc: central Sardinia (Di Milia & Tongiorgi, 1993). Tremadoc: Belgium (Martin, 1973; Cocchio, 1982); Petite Kabylie, Algeria (Baudelot *et al.*, 1981).

Stratigraphic range verified by independent age control – Lowest record: Upper Cambrian (*Parabolina spinulosa* trilobite Zone), Random Island, eastern Newfoundland, Canada (Martin *in* Martin & Dean, 1981, 1988). Highest record: lowermost Tremadoc (*Parabolina argentina* trilobite Zone), Random Island, eastern Newfoundland, Canada (Martin *in* Martin & Dean, 1981, 1988).

ACANTHODIACRODIUM BACULATUM n. sp.
Pl. 1, fig. 2

Diagnosis – Vesicle elliptical in outline. Eilyma apparently single-layered, ca. 0.5 μ m thick, scabrate under light microscope; bearing fine irregular sculpture consisting of grana (predominantly) and coni;

elements both discrete and basally fused, 0.5 μm in basal diameter and height (SEM observations). Numerous, small, stout, closely spaced processes located in each polar region. Processes of generally conical or spinose form, solid, sculptured on both trunk and distal end with very small, cylindrical, rodlike projections (bacula), *ca.* 0.5-0.7 μm long, terminating bluntly. Distal end of processes simple to manate. Proximal process contacts angular. Equatorial zone narrow, devoid of processes. Excystment by simple longitudinal or latitudinal splitting of eilyma.

Dimensions – Vesicle length 30 (36) 40 μm , vesicle width 24 (28) 33 μm ; length of processes 2-5 μm , basal diameter of processes *ca.* 0.5 μm , number of processes 50-80 at each pole, process spacing regular, *ca.* 3-4 μm apart (based on 32 specimens).

Holotype – Slide CPT203036-03; pl. 1, fig. 2. Elliptical vesicle 31 μm long, 28 μm wide; eilyma with discrete and basally coalescent, mainly granulate sculptural elements; *ca.* 70 processes located at and about each pole; processes small, elongate, distally tapering, *ca.* 2-4 μm long, 1.5 μm broad basally, strongly sculptured with bacula *ca.* 0.5 μm long; no excystment structure.

Type locality – Algerian Sahara, Bordj Nili, «Grès de Bordj Nili» unit, N12 borehole, core 54, sample N12-3037.45, lowermost Tremadoc.

Name derivation – Lat. *baculum*, rod, with reference to process sculpture.

Remarks and comparison – The large number of small, cone- or spine-like, sculptured processes is the major distinguishing feature of *Acanthodiacrodium baculatum* n. sp. Variability of *A. baculatum* includes process length and vesicle size; generally speaking, small specimens have shorter process length: vesicle length ratio. *A. angustum* (Deunff) Combaz, 1967 from the Tremadoc of Sahara and *A. papillare* Timofeev, 1959 from the Upper Cambrian of the Baltic region

both have a large number of small unsculptured processes. *A. digermulense* Welsch, 1986 from the lower Tremadoc of Norway is close to *A. baculatum*, but differs in having more numerous and robust, longer processes and a narrower equatorial zone.

Occurrence and abundance – Samples N12-3044.80 and N12-3039.50: common. Samples N12-3037.45 and N12-3014.00: uncommon.

ACANTHODIACRODIUM CAPILLATUM n. sp.

Pl. 1, fig. 5; Pl. 2, figs. 4, 5

Description – Vesicle elliptical to oval in outline. Eilyma relatively thick (>1 μm), scabrate to minutely granulate under light microscope, equatorial zone *ca.* 1/3 of vesicle length, faintly striated longitudinally. Under SEM, eilyma sculpture consisting of sparse grana (*ca.* 0.5 μm in diameter) and very fine, discontinuous, longitudinally arranged rugulae. Processes homomorphic, elongate, slender, simple, distally tapering, solid in the sculptured distal ends (1/3 of process length), hollow proximally, freely communicating with vesicle interior, closely spaced (<5 μm apart). Processes sculptured with echinae (*ca.* 0.5 μm in length). Proximal process contacts angular to slightly curved. Excystment by longitudinal splitting of eilyma.

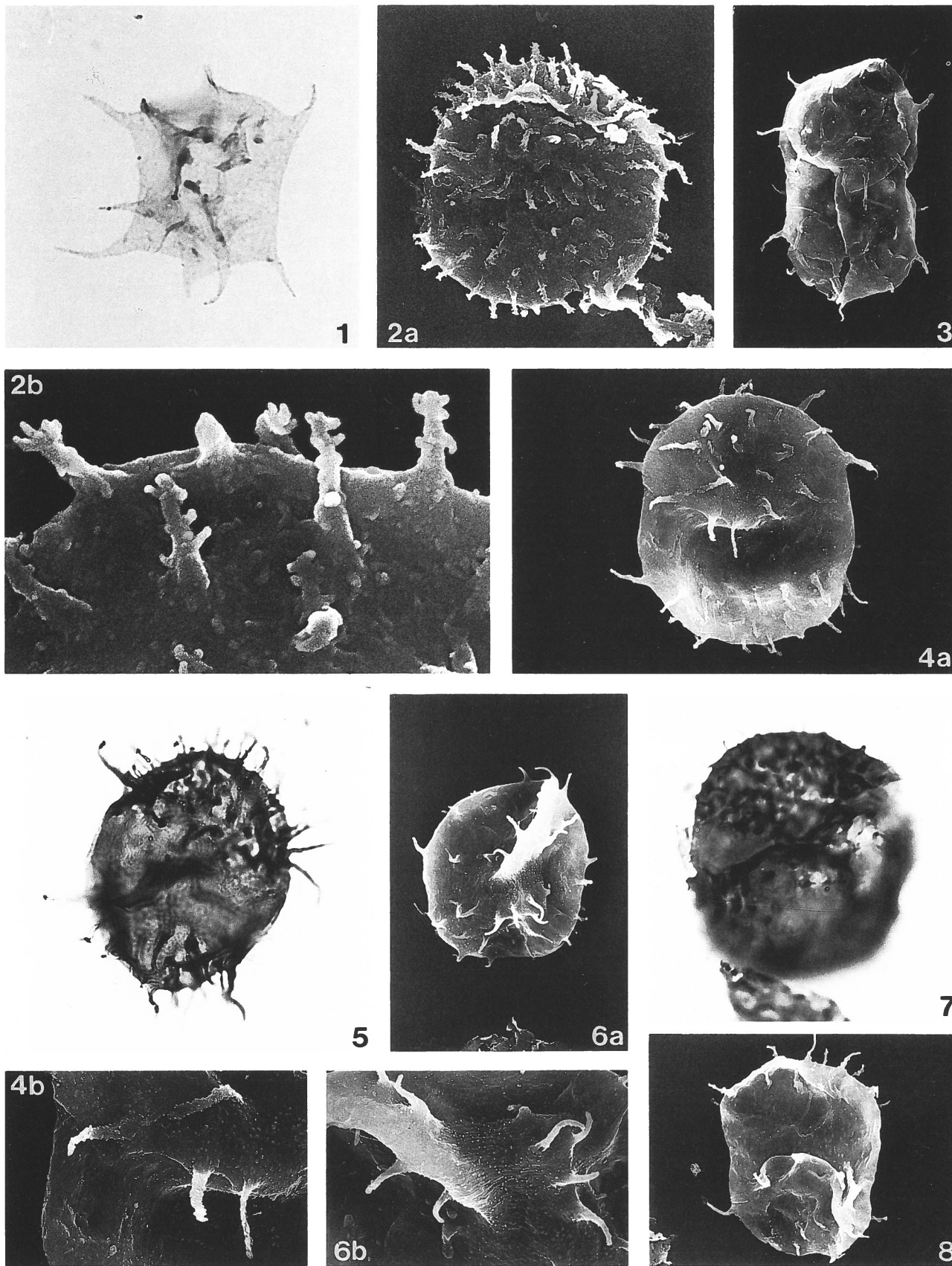
Dimensions – Vesicle length 33 (38) 43 μm , vesicle width 25 (33) 37 μm ; length of processes 7-14 μm , basal diameter of processes *ca.* 2 μm , number of processes *ca.* 40 at each pole (based on 36 specimens).

Holotype – Slide CPT203034-01; pl. 1, fig. 5. Elliptical vesicle 43 μm long, 37 μm wide; *ca.* 40 slender, echinate processes located in each polar region. Equatorial zone with fine longitudinal striae.

Type locality – Algerian Sahara, Bordj Nili, «Grès de Bordj Nili» unit, N12 borehole, core 55, sample N12-3039.50, lowermost Tremadoc.

EXPLANATION OF PLATE 1

- Fig. 1 – *Acanthodiacrodium achrasii* Martin, 1973; x 1500.
 Fig. 2 – *Acanthodiacrodium baculatum* n. sp. 2a) holotype, x 1500; 2b) holotype, detail of processes and eilyma sculpture, x 5000.
 Figs. 3, 8 – *Acanthodiacrodium rotundatum* Górka, 1967; x 1000.
 Figs. 4, 6 – *Acanthodiacrodium comptulum* Rasul, 1979. 4a) x 1500; 4b) detail of processes and eilyma sculpture, x 3000. 6a) x 1000; 6b) detail of processes and sculpture of equatorial region, x 3000.
 Fig. 5 – *Acanthodiacrodium capillatum* n. sp., holotype; x 1250.
 Fig. 7 – *Acanthodiacrodium* sp. cf. *A. angustum* (Downie) Combaz, 1967; x 1500.
 For locality, stratigraphic, and curatorial details see Appendices 1, 2.



Name derivation – Lat. *capillatum*, hairy.

Comparison and remarks – *Acanthodiacrodium capillatum* n. sp. is morphologically close to *A. ubui* Martin, 1969 from the Tremadoc of Belgium and *A. formosum* Górka, 1967 from the upper Tremadoc of Poland. The latter species is distinguished from *A. capillatum* in having fewer, more rigid, and shorter processes. *A. ubui* has fewer processes with broad bases, and its equatorial zone features well-developed longitudinal wrinkles. In *A. capillatum*, processes located at or near pole are slender and short, while those bordering the equatorial zone are longer and more robust.

Occurrence and abundance – Sample Nl2-3044.80: rare. Samples Nl2-3039.50 and Nl2-3037.45: common. Sample Nl2-3014.00: rare. Sample Nl2-3009.50: very rare. Samples Uc101-4127.00 and Uc101-4124.00: rare.

ACANTHODIACRODIUM COMPLANATUM (Deunff)
Umnova, 1975
Pl. 2, figs. 1, 3, 6

1961 *Priscotheca complanata* DEUNFF, p. 43; pl. 3, fig. 7.

1975 *Acanthodiacrodium complanatum* (Deunff) UMNova, p. 84; pl. 12, fig. 15.

Dimensions – Vesicle length 28 (34) 46 μm , vesicle width 19 (25) 35 μm ; length of processes 6-15 μm , basal diameter of processes ca. 3 μm , number of processes 6-15 at each pole (based on 41 specimens).

Remarks and comparison – The original description by Deunff (1961, p. 43) is based only on the holotype and thus does not allow for sufficient intraspecific variability. Specimens described and figured as *Acanthodiacrodium complanatum* (Deunff) Umnova, 1975 by Martin (1977) from the Tremadoc of Belgium are very close to those recorded from borehole Nl2. Faint longitudinal striae, detectable only by means of SEM observations, modify the vesicle wall; the hollow processes have broad bases, with acuminate distal ends and communicate with the vesicle interior.

Occurrence and abundance – Sample Nl2-3037.45: rare. Sample Nl2-3014.00: common. Samples Nl2-3009.50 to Nl2-2976.50: abundant. Samples Uc101-4127.00 and Uc101-4124.00: common.

Previous records – Uppermost Cambrian-lower Tremadoc: eastern Newfoundland, Canada (Martin in Martin & Dean, 1981). Lower Tremadoc: Belgium (Martin, 1977); central Sardinia (Di Milia & Tongiorgi, 1993). Tremadoc: Finnmark, Norway (Welsch, 1986); Anti-Atlas, Morocco (Elaouad-Debbaj, 1988); Sahara (Deunff, 1961); Petite Kabylie, Algeria (Baudelot *et al.*, 1981); Russia (Umnova, 1975); Shropshire, England (Rasul & Downie, 1974). Tremadoc-Arenig: France (Cocchio, 1982). Upper Tremadoc-lower Arenig: northern Iran (Ghavidel-Syooki, 1995). Upper Arenig-Llanvirn: Bohemia (Vavrdová, 1965, 1972, 1977).

Stratigraphic range verified by independent age control – Lowest record: Upper Cambrian (*Peltura* trilobite Zone), Random Island, eastern Newfoundland, Canada (Martin in Martin & Dean, 1981). Highest record: lower Llanvirn (*Didymograptus lonchotheca* graptolite Zone), Bohemia (Vavrdová, 1977).

ACANTHODIACRODIUM COMPTULUM Rasul, 1979
Pl. 1, figs. 4, 6

1979 *Acanthodiacrodium comptulum* RASUL, p. 65; pl. 2, fig. 8.

Dimensions – Vesicle length 38 (45) 52 μm , vesicle width 30 (34) 42 μm ; length of processes 3-7 μm , basal diameter of processes ca. 1-1.5 μm , number of processes 22-30 at each pole, spacing ca. 5 μm apart (based on 21 specimens).

Remarks and comparison – Algerian specimens of *Acanthodiacrodium comptulum* Rasul, 1979 closely resemble those from the type area (Shropshire, England) both in morphology and dimensions. Eilyma sculpture consists of discrete tubercles, 0.4-0.5 μm in diameter, mainly developed on polar caps and process surfaces. Equatorial region is also

EXPLANATION OF PLATE 2

Figs. 1, 3, 6 – *Acanthodiacrodium complanatum* (Deunff) Umnova, 1975. 1) x 1000. 3) x 1000. 6) x 1500.

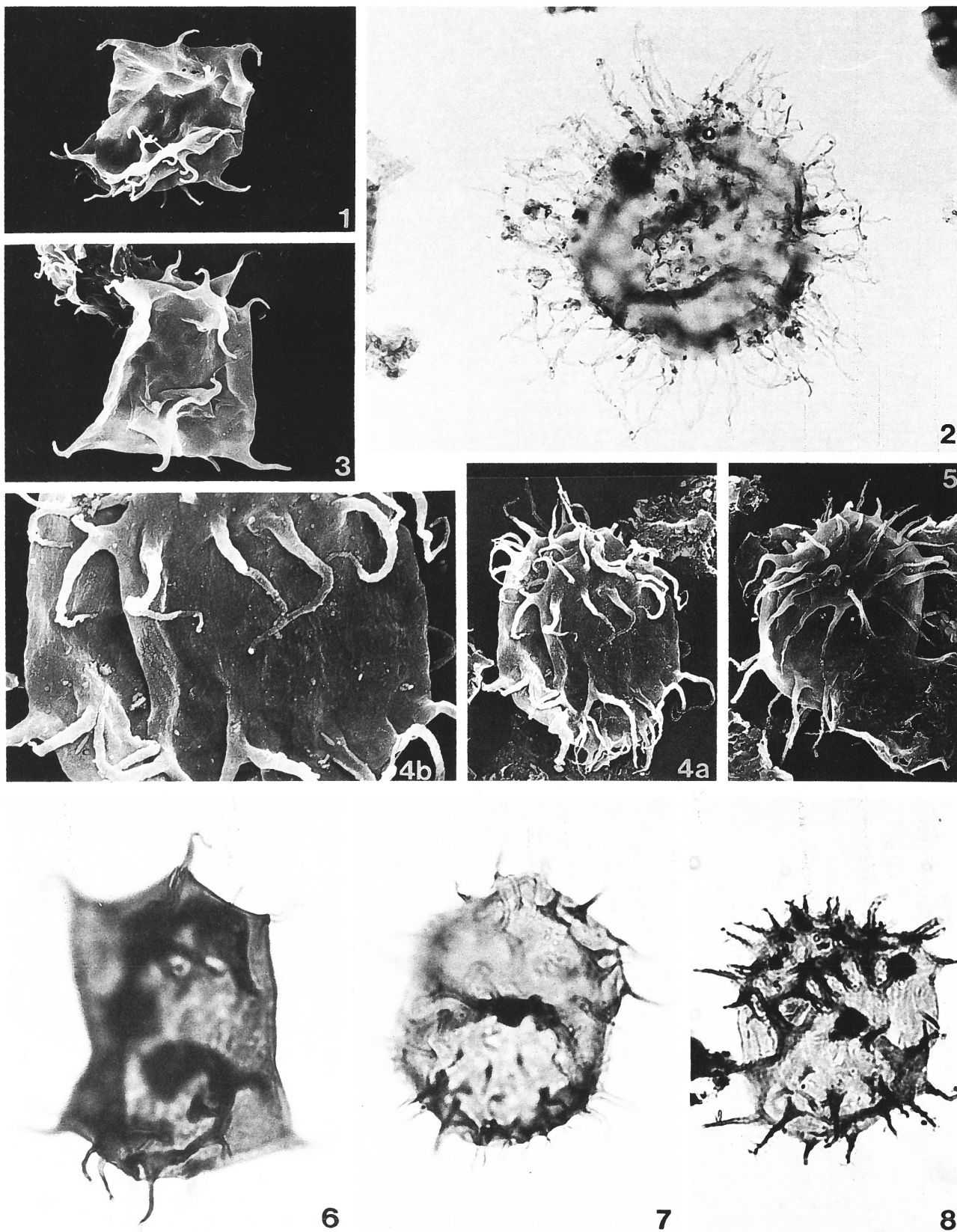
Fig. 2 – *Baltisphaeridium crinitum* Martin, 1978; x 1500.

Figs. 4, 5 – *Acanthodiacrodium capillatum* n. sp. 4a) x 1000; 4b) detail of processes and equatorial region, x 2000. 5) x 1000.

Fig. 7 – *Acanthodiacrodium* sp. cf. *A. divisum* (Deunff) Downie & Sarjeant, 1965; x 1500.

Fig. 8 – *Acanthodiacrodium ubui* Martin, 1969; x 1250.

For locality, stratigraphic, and curatorial details see Appendices 1, 2.



sculptured with discontinuous rugulae arranged longitudinally and appearing as faint longitudinal striae under optical microscope. A specimen figured by Paalits (1995), from Cambrian-Ordovician boundary strata of north Estonia, apparently has smaller processes, larger vesicle, and more conspicuous eilyma sculpture compared with specimens from the type area. No morphological or dimensional information is provided by Paalits (1995); this specific attribution of specimens from north Estonia is here considered questionable.

Occurrence and abundance – Samples N12-3014.00 and N12-3009: uncommon. Samples N12-2993.50 to N12-2976.50: rare. Samples Uc101-4127.00 and Uc101-4124.00: uncommon.

Previous records – Uppermost Cambrian(?)–lowermost Tremadoc: north Estonia (Volkova & Mens, 1988; Mens *et al.*, 1989; no figured specimens). Lower through middle Tremadoc: Morocco (Elaouad-Debbaj, 1988). Middle through upper Tremadoc: Shropshire (Rasul, 1979).

Stratigraphic range verified by independent age control – No precise biostratigraphic data available.

ACANTHODIACRODIUM ROTUNDATUM Górka, 1967
Pl. 1, figs. 3, 8

1967 *Acanthodiacrodium rotundatum* GÓRKA, pp. 4-5; pl. 2, figs. 6-7.

Dimensions – Vesicle length 48 (52) 60 μm , vesicle width 34 (36) 38 μm ; length of processes 6-12 μm , basal diameter of processes 1-1.5 μm , number of processes *ca.* 12 at each pole (based on 23 specimens).

Remarks and comparison – Sculptural elements consist of grana and tubercles, these latter present mainly on process walls. Granulation of eilyma occurs on specimens from the type material (upper Tremadoc of Poland: Górka, 1967, 1969), but process sculpture was not mentioned in the original diagnosis. This difference is regarded here as possibly reflecting intraspecific variability, as all other morphological features accord well with the original description and illustrations (see also Górka 1969, text-fig. 29; pl. 23, figs. 4, 5).

Occurrence and abundance – Sample N12-3014.00: uncommon. Samples N12-3009.50 and N12-2993.50: common. Sample N12-2976: uncommon. Sample Uc101-4127.00: uncommon. Sample Uc101-4124.00: rare.

Previous records – Tremadoc: Shropshire, England (Rasul & Downie, 1974; cited as «*A. rotundum*»); upper Tremadoc, Poland (Górka, 1967, 1969).

Stratigraphic range verified by independent age control – No precise biostratigraphic data available.

ACANTHODIACRODIUM UBUI Martin, 1969
Pl. 2, fig. 8

1969 *Acanthodiacrodium ubui* MARTIN, pp. 127-128; pl. 1, fig. 51; text-fig. 81.

Dimensions – Vesicle length 29 (38) 45 μm , vesicle width 26 (31) 35 μm ; length of processes 6-12 μm , basal diameter of processes 1.5-2 μm , length of spinae on process walls 0.5-2 μm , number of processes 18-20 at each pole (based on 33 specimens).

Remarks – Eilyma is variable in thickness (from <0.5 μm to *ca.* 1 μm) and sculptured equatorially with distinct longitudinal striae. Depending on eilyma thickness, specimens appear light to dark brown under optical microscope. Processes always bear relatively long, closely spaced spinae, generally longer toward distal ends of processes.

Occurrence and abundance – Sample N12-2993.50: rare. Sample N12-2984.50: common. Sample N12-2976.50: abundant.

Previous records – *Acanthodiacrodium ubui* Martin, 1969 has been typically recorded in lower through upper Tremadoc sediments of Europe (Martin, 1969, 1977; Rauscher, 1971; Vanguetaine, 1978; Rasul & Downie, 1974; Rasul, 1979; Welsch, 1986; Tongiorgi *in* Bagnoli *et al.*, 1988), north Africa (Baudelot *et al.*, 1981; Elaouad-Debbaj, 1988). For detailed records of occurrences see also Welsch (1986) and Tongiorgi (*in* Bagnoli *et al.*, 1988). An uppermost Cambrian occurrence reported by Martin (*in* Martin & Dean, 1981) in eastern Newfoundland, Canada, is questionable; the specimens she attributed to *A. ubui* are probably only designable as *A. cf. ubui* (Martin *in* Martin & Dean, 1988). According to Martin (*in* Martin & Dean, 1988, p. 35) the specimens represent a new species that was not introduced because only poorly preserved and insufficient specimens were available.

Stratigraphic occurrence verified by independent age control – Upper Tremadoc (*Paltodus deltifer* conodont Zone), Öland, Sweden (Tongiorgi *in* Bagnoli *et al.*, 1988).

ACANTHODIACRODIUM sp. cf. *A. ANGUSTUM*
(Downie) Combaz, 1967
Pl. 1, fig. 7

- cf. 1958 *Diornatosphaera angusta* DOWNIE, pp. 345-346; pl. 17, figs. 7-8; text-fig. 3e.
cf. 1967 *Acanthodiacrodium angustum* (Downie) COMBAZ, p. 15; pl. 4, figs. 67-72.
? 1995 *Acanthodiacrodium angustum* (Downie) Combaz - PAALITS, pl. 1, fig. 1.

Description – Vesicle elliptical-oval in outline. Eilyma psilate to shagrinata, 1-1.5 μm thick. Numerous, short, simple, spine-like, apparently solid processes located at each pole. Central portion of vesicle (equatorial zone) devoid of processes. Excystment by longitudinal splitting.

Dimensions – Vesicle length 29 (34) 45 μm , vesicle width 21 (27) 37 μm ; length of processes 3-5 μm , basal diameter of processes <0.5 μm , number of processes 50-60 at each pole, processes ca. 2 μm apart (based on 18 specimens).

Remarks and comparison – The equatorial zone is sometimes constricted, but this character is considered here to be secondary, owing to sample processing and/or poor preservation. The present specimens differ from typical *Acanthodiacrodium angustum* (Downie) Combaz, 1967 from the Tremadoc of Sahara in having essentially psilate vesicle wall and a smaller number of processes. General shape of vesicle and dimensional ranges are, however, very close to the latter species. The Estonian specimen figured by Paalits (1995, pl. 1, fig. 1) and attributed to *A. angustum* apparently lacks longitudinal striae in the equatorial zone. Number of processes is variable and was unspecified in the original diagnosis and in subsequent descriptions. Owing to imperfect preservation and to the small number of specimens recorded, an open nomenclature at specific level is preferred here.

Occurrence and abundance – Samples N12-3044.80 to N12-3037.45 and sample N12-2993.50: very rare.

ACANTHODIACRODIUM sp. cf. *A. DIVISUM* (Deunff)
Downie & Sarjeant, 1965
Pl. 2, fig. 7; Pl. 3, fig. 2

- cf. 1961 *Diornatosphaera divisa* DEUNFF, p. 44; pl. 3, fig. 12.
cf. 1965 *Acanthodiacrodium divisum* (Deunff) DOWNIE & SARJEANT, p. 78.
cf.p.p. 1988 *Acanthodiacrodium divisa* (sic) (Deunff) ELAOUAD-DEBBAJ, p. 94; pl. 3, fig. 12, non fig. 14.

Description – Vesicle elliptical in outline. Eilyma thin (<0.5 μm), normally sculptured with sparse grana, sometimes scabrate. Processes located at each vesicle pole, hollow, with broad bases, tapering uniformly to simple, acuminate tips, communicating with vesicle interior. Proximal process contacts curved to slightly angular. Process walls granulate. No longitudinal striae observed on equatorial zone (or elsewhere). Excystment by longitudinal splitting.

Dimensions – Vesicle length 31 (35) 38 μm , vesicle width 18 (21) 24 μm ; length of processes 3-6.5 μm , basal diameter of processes ca. 1.5 μm , number of processes ca. 30 at each pole, process spacing regular, ca. 5 μm apart (based on 18 specimens).

Remarks and comparison – Variation in proximal process contacts, noted above, is considered here to depend on state of preservation. In specimens with a slightly collapsed vesicle, processes bases are widened and the curved contact with vesicle is enhanced. Generally, processes located at the vesicle poles have smaller dimensions. Deunff's (1961, pl. 3, fig. 12) figured specimen of *Acanthodiacrodium divisum* (Deunff) Downie & Sarjeant, 1965 from the Tremadoc of Sahara is very close to the forms described here. However, the original diagnosis of *A. divisum* (Deunff, 1961, p. 44) is sketchy and was probably based only on the holotype. Thus, it does not facilitate precise specific attribution of the present specimens. The latter possess slightly longer processes and smaller vesicle. Their size range could well fall within reasonable intraspecific variability of *A. divisum*.

Occurrence and abundance – Samples N12-3014.00 to N12-2993.50: uncommon.

Genus ARBUSCULIDIUM Deunff, 1968 emend.
Welsch, 1986

Type species – *Arbusculidium destombesii* Deunff, 1968; by original designation.

ARBUSCULIDIUM DESTOMBESII Deunff, 1968
Pl. 3, fig. 1

- 1968 *Arbusculidium destombesii* DEUNFF, pp. 101-102; text-figs. 1-3, 5-9, 11-14.

Dimensions – Vesicle length 34 μm , vesicle width 29 μm ; number of apical (simple) processes 15, number of antapical processes 15, length of apical pro-

cesses 12-14 μm , length of antapical processes 10 μm (based on 4 specimens).

Remarks – Only one well-preserved specimen has been found. Dimensions and morphology are in accord with the original circumscription of *Arbusculidium destombesii* Deunff, 1968.

Occurrence and abundance – Sample NL2-3037.45: very rare.

Previous records – Uppermost Cambrian: East European Platform (Volkova, 1990, 1993). Lower Tremadoc: eastern Newfoundland, Canada (Martin in Dean & Martin, 1978; in Martin & Dean, 1981); Finnmark, Norway (Welsch, 1986); Anti-Atlas, Morocco (Deunff, 1968; Elaouad-Debbaj, 1988); Ghadames Basin, Libya (Deunff & Massa, 1975); Brabant Massif, Belgium (Martin, 1977); Shropshire, England (Rasul & Downie, 1974).

Stratigraphic range verified by independent age control – Lowest record: Upper Cambrian (*Cordylodus andresi* conodont Zone), East European Platform (Volkova, 1990). Highest record: lowermost Tremadoc (*Parabolina argentina* trilobite Zone), Random Island, eastern Newfoundland, Canada (Martin in Martin & Dean, 1981).

Genus BALTISPHAERIDIUM Eisenack, 1958 emend.
Eiserhardt, 1989

Type species – *Baltisphaeridium longispinosum* (Eisenack) Eisenack, 1959; by subsequent designation of Eisenack (1959, p. 194).

- 1958 *Baltisphaeridium* (nom. nud.) EISENACK, pp. 398-399. [type-species combination, hence designation invalid: ICBN, Arts 33.2, 37]
- 1959 *Baltisphaeridium* EISENACK, pp. 194-196.
- 1963 *Baltisphaeridium* (Eisenack) emend. DOWNIE & SARJEANT, p. 89.
- 1965 *Baltisphaeridium* (Eisenack) emend. STAPLIN, JANSONIUS & POCKOCK, pp. 188-189.
- 1969 *Baltisphaeridium* (Eisenack) emend. EISENACK, p. 249.
- 1970 *Actipilion* LOEBLICH, pp. 710-711.
- 1984 *Baltisphaerosum* TURNER, pp. 101-102.
- 1989 *Baltisphaeridium* (Eisenack) emend. EISERHARDT, pp. 88-89.

Discussion – The genus *Baltisphaeridium* is applied here according to the emendation of Eiserhardt (1989); i.e., to incorporate spherical (with some tendency to polyhedral) vesicles from which arise homomorphic, typically long and slender, spine-like, hollow processes having simple terminations and lacking communication with the vesicle cavity

characteristically due to basal «plugging» of the processes. Eilyma is uni- or, possibly, multi-layered, and all basic types of excystment mode are represented: viz., partial rupture, median splitting of vesicle into two halves, and (very rarely) pylomes. Reasons for the difficulty of further subdivision on the basis of excystment criteria were given by Eiserhardt (1989, pp. 85-87, 90). As pointed out by the latter author (1989, p. 84), no pylome (or other excystment structure) can be detected in the published photomicrographs of either the holotype or the neotype of the type species *B. longispinosum*. Eisenack himself (1951, p. 188) wrote: «With the same certainty it may be stated that *H. longispinosum* never has a pylome. My statement is based on the observation of thousands of specimens». However, in his emendation of the genus, Eisenack (1969, p. 249) proposed that *Baltisphaeridium* should be characterized by an excystment structure in form of a circular pylome, even if this latter has been only rarely observed. It is probable that this apparent discrepancy originates from Eisenack's idea that a pylome is a normal, generalized excystment mode, without diagnostic relevance, that can be expected to occur even in species where such a structure has never been observed (Eisenack, 1962, pp. 71-74; M. Tongiorgi, personal communication, 31 August 1995). The presence of «rare pylomes» mentioned in Eisenack's emendation (1969) of *Baltisphaeridium* could be interpreted as a hypothetical, descriptive remark; on the contrary, the lack of a pylome in the type species seems to be reasonably well documented (Eisenack, 1951, p. 188; M. Tongiorgi, personal communication, 31 August, 1995). Given this situation, and without a revision of Eisenack's original type specimen, Eiserhardt's (1989) interpretation appears as the most formally correct, even if the presence of different excystment structures within the same genus may be considered unacceptable, indeed incongruous, from a biological viewpoint. Accordingly, both *Actipilion* Loeblich, 1970 and *Baltisphaerosum*, Turner 1984 are to be considered junior synonyms of *Baltisphaeridium* Eisenack, 1958 emend. Eiserhardt, 1989.

BALTISPHAERIDIUM CRINITUM Martin, 1978
Pl. 2, fig. 2

- 1978 *Baltisphaeridium crinitum* Martin in DEAN & MARTIN, p. 7; pl. 3, fig. 5.

Dimensions – Vesicle diameter 35 (44) 50 μm ; length of processes 14 (16) 18 μm , basal diameter of processes ca. 1.5-2 μm , estimated total number of processes ca. 100 (based on 20 specimens).

Remarks – Specimens recorded herein closely conform with Martin's (*in* Dean & Martin, 1978) diagnosis. Processes are sculptured with thin spinae about 1-1.5 μm long; eilyma is slightly granulate.

Occurrence and abundance – Sample N12-3075.75: common. Samples N12-3073.50 and N12-3066.10: uncommon. Sample N12-3063.70: rare.

Previous records – Uppermost Cambrian(?)–lower Tremadoc: Finnmark, Norway (Welsch, 1986); eastern Newfoundland, Canada (Martin *in* Dean & Martin, 1978; *in* Martin & Dean, 1981).

Stratigraphic range verified by independent age control – Lowest record: ?uppermost Cambrian (*Acerocare* trilobite Zone)–lowermost Tremadoc (*Parabolina argentina* trilobite Zone), eastern Newfoundland, Canada (Martin *in* Martin & Dean, 1981). Highest record: lower Tremadoc, Digermul peninsula, Finnmark, Norway (Welsch, 1986).

BALTISPHAERIDIUM VERUTUM n. sp.
Pl. 3, figs. 3, 4

? 1983 *Baltisphaeridium granosum* Kjellström - MARTIN, p. 22; pl. 6, figs. 1, 2.

1988 *Baltisphaerosum granosum* (auct. non Kjellström) ELAOUAD-DEBBAJ, pp. 98-99; pl. 5, figs. 5, 6, 7?, 8, 12-14; pl. 6, figs. 7-9.

Diagnosis – Vesicle originally spherical; outline circular to subcircular, clearly set off from processes. Eilyma 0.8-1 μm thick, single-layered, densely granulate; grana uniformly close-spaced, variable in size. Processes evenly distributed, thin-walled, homomorphic, hollow, slender, tapering gradually to simple acuminate apex, not communicating with vesicle interior. Length of processes generally about 1/2 or slightly more of vesicle diameter. Process walls densely granulate to echinate. Proximal process contacts angular. Excystment structure a simple slit in eilyma.

Dimensions – Vesicle diameter 40 (46) 61 μm ; length of processes 20 (24) 35 μm , basal diameter of processes ca. 3-4 μm , estimated total number of processes 40-45 (based on 20 specimens).

Holotype – Slide CPT203044-02; pl. 3, fig. 3. Vesicle with circular outline, 57 μm in diameter; discrete, granulate sculptural elements on both eilyma and process walls; ca. 45 evenly distributed processes, 28 μm long, 3.5 μm broad basally, regularly spaced (about 10 μm apart); no excystment structure.

Type locality – Algerian Sahara, Bordj Nili, «Argiles d'El Gassi» unit, N12 borehole, core 53, sample N12-3014.00, lower Tremadoc.

Name derivation – Lat. *verutus*, armed with a dart.

Remarks and comparison – Arcuate folding of eilyma is sometimes present. Processes are usually more strongly sculptured than eilyma, particularly at their distal ends. *Baltisphaeridium granosum* Kjellström, 1971a differs from *B. verutum* n. sp. in having a larger vesicle and a considerably lower ratio of vesicle diameter: process length. Dimensional ranges of the two species do not overlap. Specimens from the Tremadoc of Morocco, described and figured by Elaouad-Debbaj (1988), are morphologically and dimensionally closer to *B. verutum* than to *B. granosum*. Two specimens recorded by Martin (1983) from the upper Arenig-Llanvirn of Quebec, Canada, are of similar size to *B. verutum*, but their morphological detail is unclear owing to poor preservation.

Occurrence and abundance – Sample N12-3014.00: abundant. Sample N12-3009.50: rare. Samples Uc101-4127.00 and Uc101-4124.00: common.

BALTISPHAERIDIUM sp. cf. *B. MICROSPINOSUM*
(Eisenack) Downie, 1959
Pl. 3, fig. 7

1988 *Baltisphaeridium* sp. cf. *B. microspinosum* (Eisenack) Downie - Tongiorgi *in* BAGNOLI *et al.*, pl. 33, fig. 5.

Description – Vesicle originally spherical; outline circular to subcircular. Eilyma sparsely granulate, ca. 1 μm thick. Processes short, conical, simple, apparently hollow, not communicating with the vesicle interior, uniformly close-spaced on vesicle surface. Proximal process contacts angular. Excystment by simple splitting of eilyma.

Dimensions – Vesicle diameter ca. 45 μm ; length of processes 5-6 μm , basal diameter of processes <1 μm , estimated total number of processes ca. 200 (based on 3 specimens).

Remarks and comparison – The observed specimens are almost identical with that recorded by Tongiorgi (*in* Bagnoli *et al.*, 1988, pl. 33, fig. 5) from the Tremadoc of Öland, Sweden. Morphological features are close to those of *Baltisphaeridium microspinosum* (Eisenack) Downie, 1959 which,

however, bears much shorter processes (1.5 μm long).

Occurrence and abundance – Sample NL2-3009.50: very rare.

Previous records – Tremadoc: Öland, Sweden (*Paltodus deltifer* conodont Zone, Tongiorgi in Bagnoli *et al.*, 1988).

Genus CRISTALLINIUM Vanguetaine, 1978
ex Fensome *et al.*, 1990

Type species – *Cristallinium ovillense* (Cramer & Diez) Fensome *et al.*, 1990; by subsequent designation of Fensome *et al.* (1990, p. 160).

CRISTALLINIUM OVILLENSE (Cramer & Diez)
Fensome *et al.*, 1990
Pl. 3, fig. 5

- 1968 *Dictyotidium cambriense* SLÁVIKOVÁ, p. 201; pl. 2, figs. 1, 3. [publication invalid, ICBN, Art. 37].
1972 *Cymatiosphaera ovillensis* CRAMER & DIEZ, p. 44; pl. 2, figs. 4, 7, 10.
1990 *Cristallinium ovillense* (Cramer & Diez) FENSOME *et al.*, p. 161.

For other synonymy see Bagnoli *et al.* (1988, p. 188).

Dimensions – Vesicle diameter 20 (32) 37 μm ; number of polygonal fields 5-15, diameter of polygonal fields 8-15 μm ; height of septa *ca.* 1.5 μm , width of septa *ca.* 1 μm (based on 15 specimens).

Remarks – Septa delimiting polygonal areas always bear small denticles *ca.* 0.5 μm high. Numbers and dimensions of polygonal fields vary appreciably; vesicle wall is granulate to shagrinose. Excystment structure consists of a rupture of the vesicle wall along the sides of polygonal fields. According to Martin (*in* Martin & Dean, 1988, p. 36), the sculptural variation mainly relates to the state of

preservation. That conjecture was discounted by Albani *et al.* (1991) who observed considerable variation in sculpture seemingly independent of the preservational state. Material from borehole NL2, abundant but poorly preserved, is uninformative in this regard; the variability is chiefly related to number and dimensions of polygonal fields rather than to vesicle sculpture.

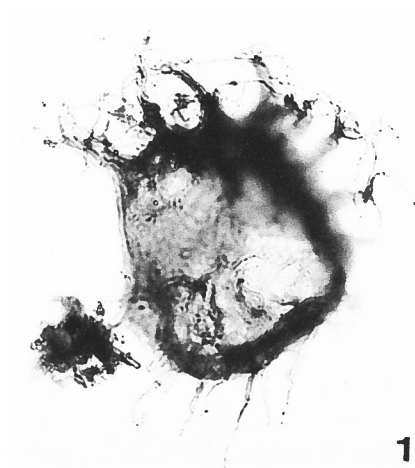
Occurrence and abundance – Sample NL2-3082.80: uncommon. Samples NL2-3075.75 and NL2-3073.50: rare. Sample NL2-3066.10: very rare. Sample NL2-3063.70: uncommon. Sample NL2-3060.70: rare. Samples NL2-3054.75 and NL2-3050.15: uncommon. Samples NL2-3039 and NL2-3037.45: rare. Sample NL2-3014.00: very rare.

Previous records – *Cristallinium ovillense* (Cramer & Diez) Fensome *et al.*, 1990 is a widely distributed species having been recorded in Lower Cambrian through Tremadoc deposits in various parts of the world. Only some occurrences (the most recent and/or related to the C/O boundary interval) are reported herein; for other records see Tongiorgi (*in* Bagnoli *et al.*, 1988) and Martin (*in* Martin & Dean, 1981, 1988). Upper Cambrian: East European Platform (Mens *et al.*, 1989, 1993; Volkova, 1990); Libya (Albani *et al.*, 1991); eastern Newfoundland, Canada (Martin *in* Martin & Dean, 1988); Dayangcha, Jilin Province, China (Yin Lei-ming *in* Chen, 1986, *in* Chen *et al.*, 1988); Stavelot Massif, Belgium (Ribecai & Vanguetaine, 1993). Lower Tremadoc: eastern Newfoundland, Canada (Martin *in* Martin & Dean, 1981, 1988); Dayangcha, Jilin Province, China (Yin Lei-ming *in* Chen *et al.*, 1988).

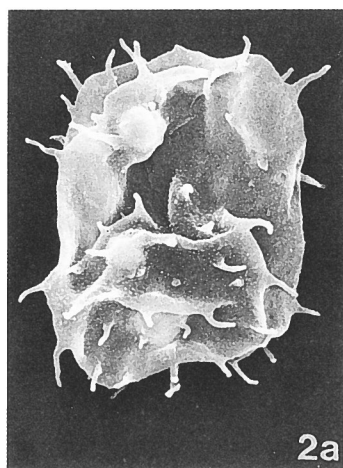
Stratigraphic range verified by independent age control – Lowest record: Middle Cambrian (*Ptychagnostus atavus* – *Tomagnostus fissus* trilobite Zone), eastern Newfoundland, Canada (Martin *in* Martin & Dean, 1981). Highest record: ?lowermost Tremadoc (*Cordylodus lindstromi* conodont Zone), Dayangcha, Jilin Province, China (Yin Lei-ming *in* Chen, 1986).

EXPLANATION OF PLATE 3

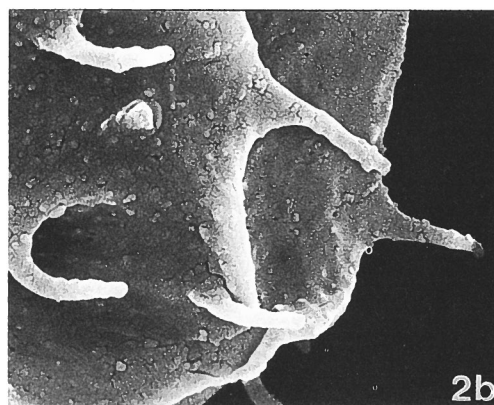
- Fig. 1 - *Arbusculidium destombesii* Deunff, 1968; x 1000.
Fig. 2 - *Acanthodiacrodium* sp. cf. *A. divisum* (Deunff) Downie & Sarjeant, 1965. 2a) x 1500; 2b) x 5000.
Figs. 3, 4 - *Baltisphaeridium verutum* n. sp. 3) holotype, x 1500. 4a) x 500; 4b) detail of processes, x 3000.
Fig. 5 - *Cristallinium ovillense* (Cramer & Diez) Fensome *et al.*, 1990; x 1000.
Fig. 6 - *Cristallinium randomense* (Martin) Fensome *et al.*, 1990; x 1000.
Fig. 7 - *Baltisphaeridium* sp. cf. *B. microspinosum* (Eisenack) Downie, 1959; x 750.
For locality, stratigraphic, and curatorial details see Appendices 1, 2.



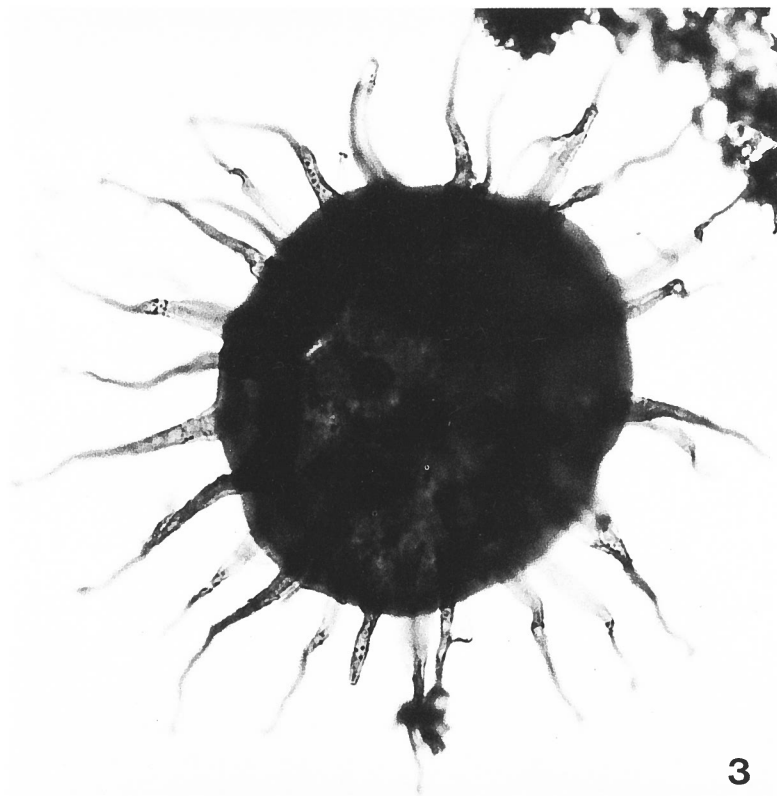
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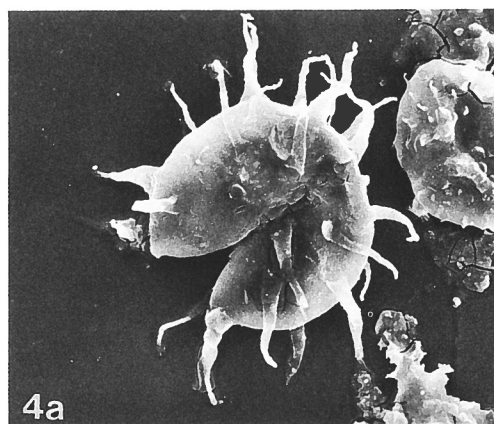
2a



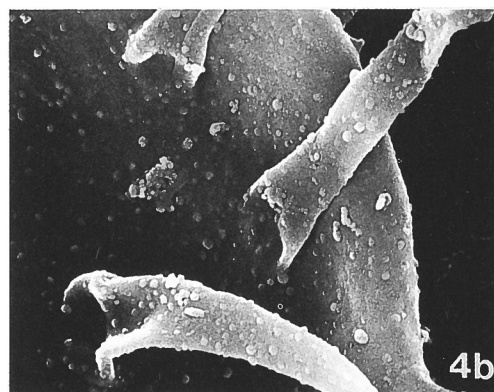
2b



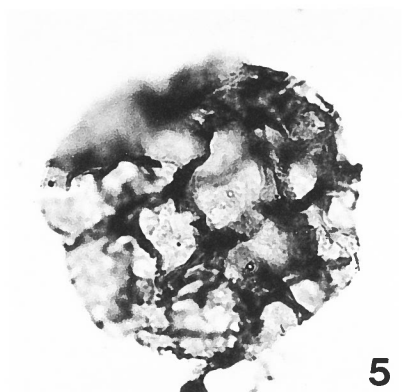
3



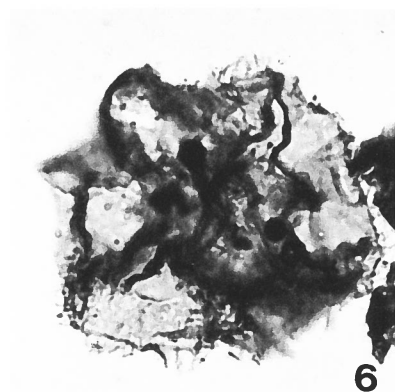
4a



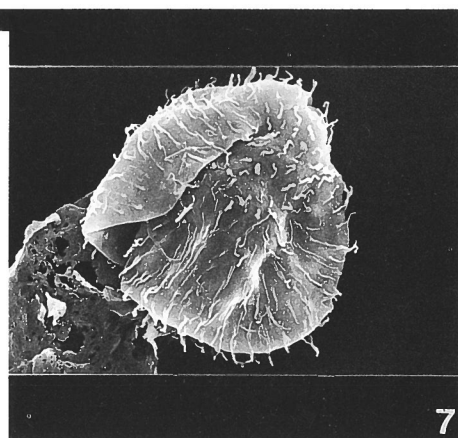
4b



5



6



7

CRISTALLINIUM RANDOMENSE (Martin)

Fensome *et al.*, 1990

Pl. 3, fig. 6

- 1981 *Cristallinium randomense* Martin in MARTIN & DEAN, p. 18; pl. 3, figs. 2, 10, 12, 17, 20, 24, 26; pl. 6, figs. 4, 6.
 1988 *Cristallinium randomense* (Martin) Martin in MARTIN & DEAN, pp. 36-37; pl. 13, figs. 1-17.
 1990 *Cristallinium randomense* (Martin) FENSOME *et al.*, p. 161.

Dimensions – Vesicle diameter 27 (34) 38 µm; number of polygonal fields 6-8, diameter of polygonal fields *ca.* 10 µm; length of processes *ca.* 3-5 µm; height of septa *ca.* 1 µm, length of septa 8-10 µm, width of septa *ca.* 1 µm (based on 8 specimens).

Comparison – *Cristallinium randomense* (Martin) Fensome *et al.*, 1990 is easily distinguishable from *C. ovillense* by its longer processes located on the upper part of the septa. Moreover, polygonal fields are normally fewer and larger in *C. randomense*. Eilyma is thin (<0.5 µm thick) and commonly shagrinose to granulate.

Occurrence and abundance – Samples NL2-3088.55 to NL2-3075.75: rare. Samples NL2-3073.50 and NL2-3066.10: very rare. Samples NL2-3060.70 and 3050.15: rare.

Previous records – Upper Cambrian: Stavelot Massif, Belgium (Ribecai & Vanguetaine, 1993); Öland, Sweden (Di Milia *et al.*, 1989; Tongiorgi & Ribecai, 1990); north Estonia (Mens *et al.*, 1989; Paalits, 1995); eastern Newfoundland, Canada (Martin in Martin & Dean, 1981, 1988). Uppermost Cambrian - ?lower Tremadoc: eastern Newfoundland, Canada (Martin in Martin & Dean, 1981, 1988).

Stratigraphic range verified by independent age control – Lowest record: Upper Cambrian (strata without macrofossils between the *Olenus* trilobite Zone and the *Parabolina spinulosa* Zone), eastern Newfoundland, Canada (Martin in Martin & Dean, 1981, 1988). Highest record: uppermost Cambrian (*Peltura* trilobite Zone) - ?lower Tremadoc (strata assigned to *Acerocare* p.p. - *Parabolina argentina* trilobite Zones), eastern Newfoundland, Canada (Martin in Martin & Dean, 1981, 1988).

Genus CYMATIOGALEA Deunff, 1961 emend. Deunff, Górka & Rauscher, 1974

Type species – *Cymatiogalea margaritata* Deunff, 1961; by original designation.

CYMATIOGALEA CRISTATA (Downie) Rauscher, 1974

Pl. 4, fig. 6

- 1958 *Hystericosphaeridium cristatum* DOWNIE, pp. 338-339; pl. 16, fig. 4; text-fig. 4f.
 1967 *Cymatiogalea polygonophora* GÓRKA, p. 3; pl. 1, figs. 5, 6.
 1969 *Priscogalea cristata* (Downie) MARTIN, p. 85; pl. 1, figs. 43, 44, 46.
 1974b *Cymatiogalea cristata* (Downie) RAUSCHER, p. 65; pl. 1, fig. 21.
 non 1990 *Cymatiogalea cristata* (Downie) Rasul - VOLKOVA, pl. 9, fig. 9.

Dimensions – Vesicle diameter 25 (29) 35 µm; number of polygonal fields 10-12; number of processes at each side of polygonal fields 4-6, length of processes 4.5-7 µm, basal diameter of processes *ca.* 1 µm (based on 23 specimens).

Remarks and comparison - Granulation of eilyma, short distally furcated processes, polygonal polar opening, and absence of membranes are distinctive characters of *Cymatiogalea cristata* (Downie) Rauscher, 1974. Dimensions of polygonal fields vary on a single specimen. The specimen figured by Volkova (1990, pl. 9, fig. 9) from the uppermost Cambrian of East European Platform has simple processes and an apparently psilate eilyma; thus its specific attribution is regarded here as incorrect.

Occurrence and abundance – Samples NL2-3014.00 and NL2-3009.50: common. Sample NL2-2993.50: abundant. Samples NL2-2984.50 and NL2-2976.50: common. Samples Uc101-4127.00 and Uc101-4124.00: common.

Previous records – Lowermost Tremadoc: north Estonia (Mens *et al.*, 1989; Paalits, 1995). Tremadoc: northern Iran (Ghavidel-Syooki, 1995); Anti-Atlas, Morocco (Elaouad-Debbaj, 1988); Shropshire, England (Downie, 1958; Deunff *et al.*, 1974; Rasul, 1974, 1979; Rasul & Downie, 1974); Brabant Massif, Belgium (Martin, 1969, 1977); Montagne Noire, France (Martin, 1973; Rauscher, 1974b; Fournier-Vinas, 1978); Finnmark, Norway (Welsch, 1986); Poland (Górka, 1967); Mouthoumet Massif, France (Baudelot & Bessière, 1977); Celtiberia, Spain (Wolf, 1980). Uppermost Tremadoc- lower Arenig: South Wales (Molyneux & Dorning, 1989). Tremadoc- Arenig: Algeria (Baudelot & Gery, 1979); southeast Ireland (Gardiner & Vanguetaine, 1971). Caradoc: Shropshire, England (Turner, 1982, reworked specimens).

Stratigraphic range verified by independent age control – Lowest record: lower Tremadoc (*Rhab-*

dinopora flabelliformis s. l. graptolite Zone), Anti-Atlas, Morocco (Elaouad-Debbaj, 1988). Highest record: upper Tremadoc (*Clonograptus tenellus* graptolite Zone), Finnmark, Norway (Welsch, 1986).

CYMATIOGALEA CUVILLIERI (Deunff) Deunff, 1964
Pl. 4, fig. 8

- 1961 *Priscogalea cuvillieri* DEUNFF, p. 41; pl. 1, fig. 2.
1964 *Cymatiogalea cuvillieri* (Deunff) DEUNFF, p. 124; pl. 1, figs. 2, 3.
1973 *Priscogalea cuvillieri fucata* MARTIN, pp. 19-20; pl. 1, fig. 7; pl. 3, figs. 2, 3, 7; pl. 4, figs. 1, 18; pl. 5, figs. 1-3, 16, 29; pl. 9, figs. 3-5; text-figs. 9-12.

Dimensions – Vesicle diameter 25 (28) 35 µm; number of polygonal fields *ca.* 10; number of processes at each side of polygonal fields 4-5, length of processes <0.5-2 µm, basal diameter of processes *ca.* 0.5 µm (based on 53 specimens).

Remarks – Diameter of polar opening is between 80 and 90% of vesicle diameter. Eilyma is psilate. Specimens with very short processes (*ca.* 0.5 µm) and those with longer processes (up to 2 µm) constitute end members of a series of intermediate forms in which process length varies continuously. Process shape is another variable character; smaller processes being often of conical form, sometimes basally fused, and longer processes being subcylindrical and discrete. Accepting this variability, *Priscogalea cuvillieri fucata* Martin, 1973 is considered here inseparable from *C. cuvillieri* (Deunff) Deunff, 1964.

Occurrence and abundance – Sample N12-3075.75: common. Samples N12-3073.50 and N12-3066.10: uncommon. Samples N12-3063.70 and N12-3060.70: common. Samples N12-3054.75 to N12-3039.50: uncommon. Samples N12-3037.45 to N12-2976.50: common. Samples Uc101-4127.00 and Uc101-4124.00: common.

Previous records – *Cymatiogalea cuvillieri* has been recorded worldwide in Upper Cambrian through lower Ordovician (Arenig) sediments. Previous records were listed by Tongiorgi (*in* Bagnoli *et al.*, 1988, p. 190).

Stratigraphic range verified by independent age control – Lowest record: Upper Cambrian (*Parabolina spinulosa* trilobite Zone), Moscow Syncline, Russia (Volkova, 1990). Highest record: upper Tremadoc (*Paltodus deltifer* conodont Zone), Öland, Sweden (Tongiorgi *in* Bagnoli *et al.*, 1988).

CYMATIOGALEA GORKAE Rauscher, 1974
Pl. 5, figs. 3, 6

- 1974b *Cymatiogalea gorkae* RAUSCHER, pp. 66-67; pl. 1, fig. 30; text-fig. 23.
? 1989 *Cymatiogalea gorkae* Rauscher – DI MILIA, RIBECAL & TONGIORGI, pp. 12-13; pl. 4, figs. 12-15; pl. 5, figs. 1-2.
? 1990 *Cymatiogalea gorkae* Rauscher – TONGIORGI & RIBECAL, text-fig. 3c.

Dimensions – Vesicle diameter 24 (28) 30 µm; number of polygonal fields 5-7; number of processes at each side of each polygonal field usually 2-3, length of processes *ca.* 6 µm, basal diameter of processes *ca.* 1 µm, length of pinnae 2-3.5 µm (based on 12 specimens).

Remarks and comparison – Swedish Upper Cambrian specimens attributed to *Cymatiogalea gorkae* Rauscher, 1974 by Di Milia *et al.* (1989, pp. 12-13; pl. 4, figs. 12-15; pl. 5, figs. 1, 2) show little variability, much less than the Algerian specimens identified herein with that species. Unfortunately, the original diagnosis and illustrations provided by Rauscher (1974b) are inadequate to establish intraspecific variation and consequently positive identification with *C. gorkae* may be problematical. Similar problems exist in relation to certain other insufficiently defined species of the genus. For the present, the study specimens seem attributable to *C. gorkae*, but doubt exists as to the specific attribution of the Upper Cambrian Öland specimens recorded by Di Milia *et al.* (1989) and Tongiorgi & Ribecai (1990).

Occurrence and abundance – Samples N12-3014.00 to N12-2976.50: rare. Samples Uc101-4127.00 and Uc101-4124.00: rare.

Previous records – Upper Cambrian: Öland, Sweden (possible records: Di Milia *et al.*, 1989; Tongiorgi & Ribecai, 1990); north Estonia (Volkova, 1993). Tremadoc- Arenig: Montagne Noire, France (Rauscher, 1974b).

Stratigraphic range verified by independent age control – Lowest possible record: Upper Cambrian (*Peltura scarabeoides* trilobite Zone) Öland, Sweden (Di Milia *et al.*, 1989). Highest record: lower Tremadoc (*Rhabdinopora flabelliformis* s. l. graptolite Zone), present study.

CYMATIOGALEA MEMBRANISPINA Deunff, 1961
Pl. 5, fig. 4

- 1961 *Cymatiogalea membranispina* DEUNFF, p. 42; pl. 1, fig. 6.
non 1974 *Cymatiogalea membranispina* RASUL, pl. 4; fig. 3.

Dimensions – Vesicle diameter *ca.* 30 μm ; number of polygonal fields 8-10; number of processes at each side of polygonal fields 5-6, length of processes *ca.* 10 μm , basal diameter of processes *ca.* 1 μm (based on 4 specimens).

Remarks – Morphological features of specimens recorded herein conform with Deunff's (1961) original diagnosis. They are slightly smaller than the holotype described by Deunff (1961), but are within the dimensional range provided subsequently by that author (1964, p. 121; pl. 1, fig. 18). Processes have simple to trifurcate distal ends, and are transparent, apparently hollow, and uncommunicative with vesicle interior. Membranes are transparent, unsculptured. Rasul's (1974, pl. 4, fig. 3) specimen has simple and considerably shorter processes than shown by the holotype and is not attributable to the species.

Occurrence and abundance – Samples NL2-3014.00 and NL2-3009.50: very rare. Sample NL2-2993.50: very rare.

Previous records – Tremadoc: Shropshire, England (Rasul & Downie, 1974); Algerian Sahara (Deunff, 1961, 1964; Deunff *et al.*, 1974); northern Iran (Ghavidel-Syooki, 1995); Mouthoumet Massif, France (Cocchio, 1982); Grande Kabylie, Algeria (Baudelot & Gery, 1979).

Stratigraphic range verified by independent age control – No precise biostratigraphic data available.

CYMATIOGALEA MULTAREA (Deunff) Eisenack,
Cramer & Diez, 1973
Pl. 4, fig. 2

1961 *Priscogalea multarea* DEUNFF, p. 41; pl. 1, fig. 5.

1967 *Cymatiogalea multarea* (Deunff) COMBAZ, pl. 3, figs. 78, 79. [combination invalid: ICBN, Art. 33.2]

1973 *Cymatiogalea multarea* (Deunff) EISENACK, CRAMER & DIEZ, p. 229.

non 1974 *Cymatiogalea multarea* (Deunff) RASUL, pp. 54-56; pl. 4, fig. 7; pl. 7, fig. 6; text-fig. 4.

Dimensions – Vesicle diameter 24 (27) 30 μm ; number of polygonal fields 12-14; number of processes at each side of polygonal fields 3-4, process length 7-9 μm , basal diameter of processes *ca.* 1 μm (based on 13 specimens).

Comparison and remarks – *Cymatiogalea multarea* (Deunff) Eisenack *et al.*, 1973 differs from *C. cristata* (Downie) Rauscher, 1974 in having psilate to scabrate eilyma and a rounded polar opening (which is always polygonal in *C. cristata*). Distal ends of processes are simple to furcate (with two pinnae which may be subdivided into very short pinulae). Membranes are invariably absent. The holotype of *C. multarea* (Deunff, 1961, pl. 1, fig. 5) and the specimen figured by Deunff *et al.* (1974, pl. 6, fig. 4) clearly include at least some distally furcant processes. Specimens attributed to *C. multarea* by Rasul (1974) have exclusively simple processes and a significantly higher vesicle diameter: process length ratio than shown by the holotype; consequently, they are regarded as misidentified specifically.

Occurrence and abundance – Sample NL2-3014.00: rare. Sample NL2-3009.50: uncommon. Samples NL2-2993.50 and NL2-2984.50: rare.

Previous records – Tremadoc: Algerian Sahara (Deunff, 1961, 1964; Combaz, 1967; Deunff *et al.*, 1974; Jardiné *et al.*, 1974); Shropshire, England (Rasul & Downie, 1974); Montagne Noire, France (Martin, 1973).

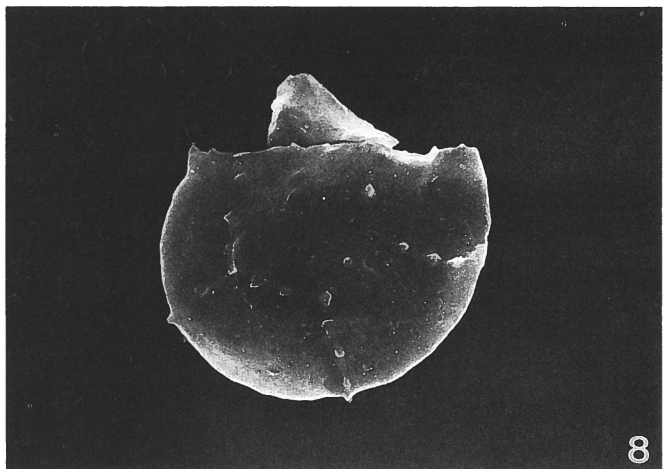
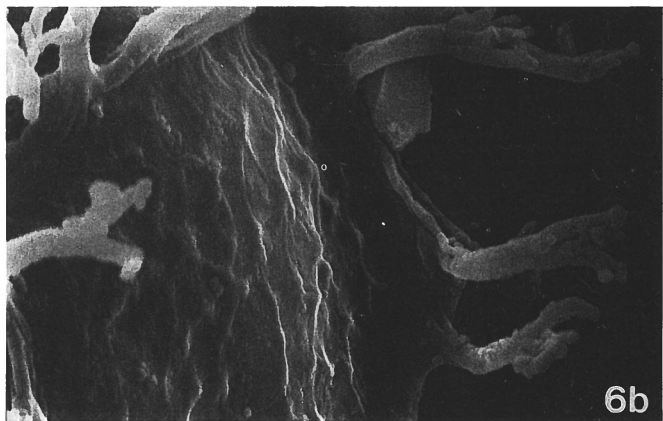
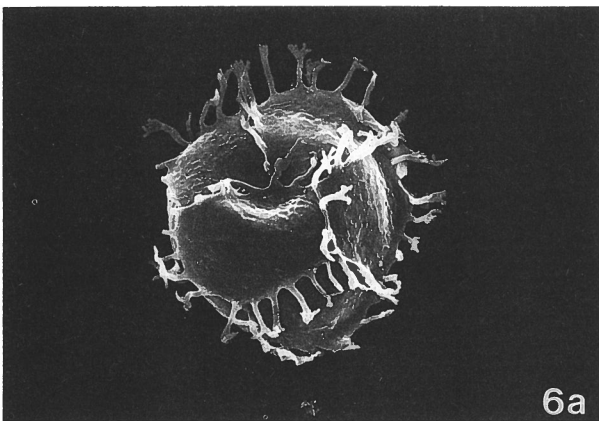
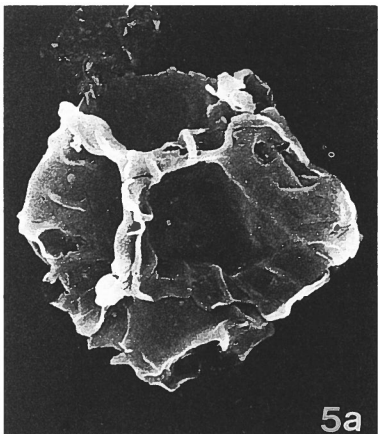
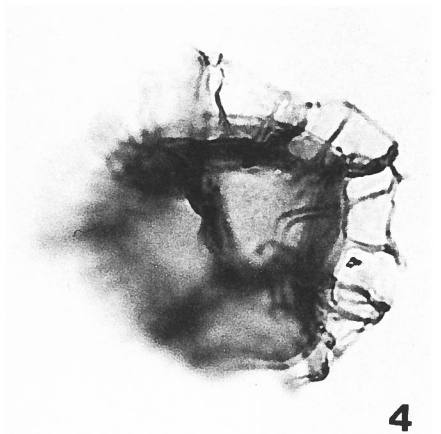
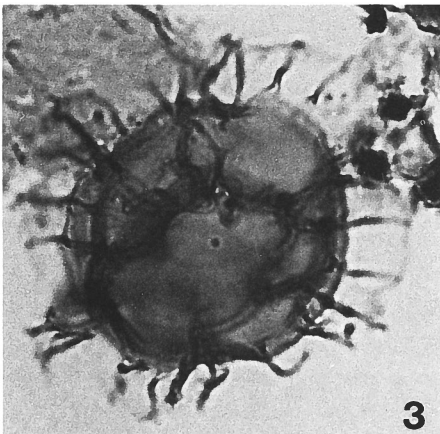
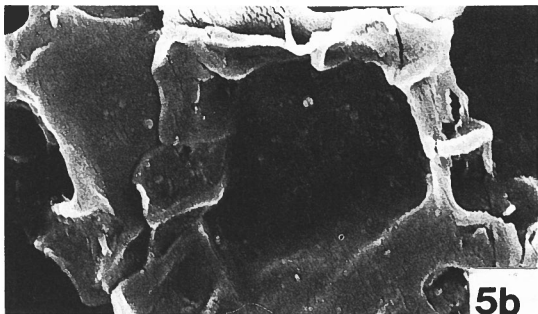
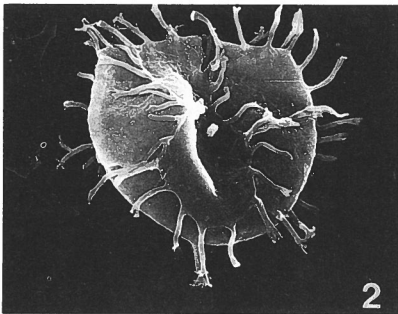
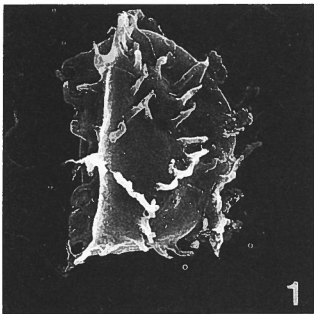
Stratigraphic range verified by independent age control – No precise biostratigraphic data available.

CYMATIOGALEA PARVA n. sp.
Pl. 4, figs. 1, 7; Pl. 5, fig. 2

Diagnosis – Vesicle near-hemispherical. Eilyma *ca.* 0.8 μm thick, shagrate to scabrate or sparsely granulate. Processes homomorphic, cylindrical, psilate, hollow, not communicating with vesicle interior, mostly simple, sometimes bifurcate, rarely

EXPLANATION OF PLATE 4

- Figs. 1, 7 – *Cymatiogalea parva* n. sp. 1) x 1000. 7) holotype, x 1500.
Fig. 2 – *Cymatiogalea multarea* (Deunff) Eisenack *et al.*, 1973; x 1000.
Figs. 3, 4, 5 – *Cymatiogalea velifera* (Downie) Martin, 1969. 3) x 1500. 4) x 1500. 5a) x 1500; 5b) x 3000.
Fig. 6 – *Cymatiogalea cristata* (Downie) Rauscher, 1974b. 6a) x 1000; 6b) x 5000.
Fig. 8 – *Cymatiogalea cuvillieri* (Deunff) Deunff, 1964; x 1500.
For locality, stratigraphic, and curatorial details see Appendices 1, 2.



trifurcate with very short pinnae. Processes aligned along the sides of polygonal (pentagonal to hexagonal) fields, bearing thin, transparent membranes (which may be partly degraded). Dimensions of polygonal fields variable within a single specimen. Large, rounded polar opening rimmed with short processes. Operculum circular, with a thin, denticulate border, width *ca.* 1/4 of operculum diameter.

Dimensions – Vesicle diameter 26 (28) 32 μm ; number of polygonal fields 10-12; number of processes at each side of polygonal fields 3-4, length of processes 4-6 μm , basal diameter of processes *ca.* 1 μm (based on 16 specimens).

Holotype – Slide CPT203036-01; pl. 4, fig. 7. Vesicle diameter 30 μm , length of processes 5 μm , basal diameter of processes 1 μm , number of processes 45, spacing regular (*ca.* 4 μm apart), diameter of polar opening 27 μm , number of polygonal fields 10, membranes unsculptured, very thin, partially degraded, eilyma shagrinated.

Type locality – Algerian Sahara, Bordj Nili, «Grès de Bordj Nili» unit, N12 borehole, core 54, sample N12-3037.45, lowermost Tremadoc.

Name derivation – Lat. *parvus*, small.

Remarks and comparison – Short, mostly simple processes, presence of delicate membranes, and very fine sculpture of eilyma are distinguishing features of *Cymatiogalea parva* n. sp. *C. velifera* (Downie) Martin, 1969 and *C. membranispina* Deunff, 1961 both have mainly furcate and longer processes. *C. multiclaustra* (Deunff) Deunff, 1964 from the Tremadoc of Algerian Sahara differs from *C. parva* in having considerably longer processes and, apparently, larger and fewer polygonal fields. A specimen from the Tremadoc of South Wales attributed by Rasul (1974) to *C. membranispina* is morphologically very close to *C. parva* and could possibly represent the latter.

Occurrence and abundance – Sample N12-3039.50: rare. Sample N12-3037.45: uncommon.

CYMATIOGALEA VELIFERA (Downie) Martin, 1969
Pl. 4, figs. 3, 4, 5

1958 *Hystriochosphaeridium veliferum* DOWNIE, p. 340; pl. 17, fig. 2; text-fig. 4c.

1969 *Cymatiogalea velifera* (Downie) MARTIN, p. 133; pl. 1, figs. 8, 9.

Dimensions – Vesicle diameter 24 (27) 30 μm ; number of polygonal fields 8-10; number of processes at each side of polygonal fields 3-4, length of processes 5-7 μm , basal diameter of processes *ca.* 1 μm (based on 21 specimens).

Remarks – Membranes are supported by short, slender, psilate processes usually bifurcated at distal extremities. Specimens from borehole N12 have psilate membranes; eilyma is usually psilate to scabrate, rarely sculptured with sparse grana. Accepted intraspecific variability for *Cymatiogalea velifera* is wide, including specimens with spinose (Martin, 1969, p. 340), strongly granulate (Volkova, 1990, pl. 9, figs. 7, 8; Turner, 1982), or microreticulate (Downie, 1958, p. 340) eilyma.

Occurrence and abundance – Samples N12-3066.10 to N12-3060.70: uncommon. Samples N12-3054.75 and N12-3050.15: common. Sample N12-3044.80: uncommon. Sample N12-3039.50 to N12-3009.50: common. Samples Uc101-4127.00 and Uc101-4124.00: common.

Previous records – Upper Cambrian-lowermost Tremadoc: East European Platform (Volkova, 1990). Tremadoc: Brabant Massif, Belgium (Martin, 1969, 1977); Shropshire, England (Downie, 1958; Rasul, 1974; Rasul & Downie, 1974). Tremadoc-lower Arenig: Lake District, England (Molyneux & Rushton, 1988). Caradoc: Shropshire, England (Turner, 1982; reworked specimens).

Stratigraphic range verified by independent age control – Lowest record: Upper Cambrian (*Olenus* trilobite Zone), East European Platform (Volkova, 1990). Highest record: lower Arenig (*Tetraraptus approximatus* graptolite Zone), Lake District, England (Molyneux & Rushton, 1988).

CYMATIOGALEA VIRGULTA Martin, 1988
Pl. 5, fig. 1

1988 *Cymatiogalea virgulta* Martin in MARTIN & DEAN, p. 38; pl. 14, figs. 10, 13, 14, 17.

Dimensions – Vesicle diameter 23 (30) 32 μm ; number of polygonal fields 10-12; number of processes at each side of polygonal fields 3-5, length of processes 3-7 μm , basal diameter of processes 0.5-1 μm (based on 10 specimens).

Remarks and comparison – The Algerian specimens are very similar to those recorded by Martin (in Martin & Dean, 1988) from the Upper Cam-

brian of eastern Newfoundland, but show variability in eilyma sculpture (psilate to scabrate) and have slightly larger vesicle diameter. SEM observations of sculptural elements (small, closely spaced linear markings *ca.* 2 μm long) suggest that these may be of secondary origin, induced by slight vesicle collapse. All the other morphological features conform with the original diagnosis of *Cymatiogalea virgulta* Martin, 1988. Veils between processes are rarely preserved, and have not been observed under SEM.

Occurrence and abundance – Sample NL2-3060.70: very rare. Sample NL2-3054.75: rare.

Previous records – Upper Cambrian: eastern Newfoundland, Canada (Martin *in* Martin & Dean, 1988); Estonia (Mens *et al.*, 1993; Paalits, 1995); Stavelot and Rocroi Massifs, Belgium and northern France (Ribecai & Vanguestaine, 1993).

Stratigraphic range verified by independent age control – Lowest record: Upper Cambrian (*Parabolina spinulosa* trilobite Zone), eastern Newfoundland, Canada (Martin *in* Martin & Dean, 1988). Highest record: Upper Cambrian (*Peltura* trilobite Zone), eastern Newfoundland, Canada (Martin *in* Martin & Dean, 1988).

Genus DASYDIACRODIUM Timofeev *ex* Deflandre & Deflandre-Rigaud, 1962 emend. Deflandre & Deflandre-Rigaud, 1962

Type species – *Dasydiacrodium eichwaldii* Timofeev, 1959; by subsequent designation of Deflandre & Deflandre-Rigaud (1962, p. 194).

DASYDIACRODIUM OBSONUM Martin, 1988
Pl. 5, fig. 7

1988 *Dasydiacrodium obsonum* Martin *in* MARTIN & DEAN, pp. 38-39; pl. 10, figs. 6, 7, 10, 11, 13-15.

Dimensions – Vesicle length 29 μm , vesicle width 24 μm ; length of processes 9-10 μm , basal diameter of processes *ca.* 2 μm , number of processes 4 at one pole, 8 at the other (based on one specimen only).

Remarks – The single well-preserved specimen recorded from borehole NL2 conforms with the original diagnosis of *Dasydiacrodium obsonum* Martin, 1988 (*in* Martin & Dean, 1988). As noted by Martin the species is very close to *A. achrasi* Martin, 1973 and distinction between the two is arbitrary.

Forms in which the difference between the number of processes located at opposite poles exceeds three were attributed by Martin (*in* Martin & Dean, 1988) to *D. obsonum*. Several specimens recorded herein show such a difference in process numbers around three; these specimens are tentatively attributed to *D. obsonum*. Both eilyma and processes are distinctly granulate. No specimens were observed under SEM.

Occurrence and abundance – Samples NL2-3066.10 and NL2-3063.70: questionably present. Sample NL2-3060.70: very rare. Sample NL2-3050.15: questionably present.

Previous records – Upper Cambrian: eastern Newfoundland, Canada (Martin *in* Martin & Dean, 1988); Stavelot and Rocroi Massifs, Belgium and northern France (Ribecai & Vanguestaine, 1993); north Estonia (Paalits, 1992).

Stratigraphic range verified by independent age control – Lowest record: Upper Cambrian (*Parabolina spinulosa* trilobite Zone), eastern Newfoundland, Canada (Martin *in* Martin & Dean, 1988). Highest record: uppermost Cambrian (*Acerocare p.p.* trilobite Zone), eastern Newfoundland, Canada (Martin *in* Martin & Dean, 1988).

DASYDIACRODIUM TUMIDUM (Deunff) Tongiorgi,
1988
Pl. 5, fig. 8

1961 *Priscotheca tumida* DEUNFF, p. 43; pl. 3, fig. 6.

1988 *Dasydiacrodium tumidum* (Deunff) Tongiorgi *in* BAGNOLI *et al.*, pp. 193-194; pl. 33, figs. 7-9; pl. 35, figs. 6, 7.

Dimensions – Vesicle length 47 (53) 62 μm , vesicle width 30 (33) 37 μm ; length of processes 4-6 μm , basal diameter of processes 1.5-2 μm , number of processes 2-4 at one pole, 4-10 at the other (based on 18 specimens).

Remarks and comparison – Vesicle poles usually bear slightly disparate numbers of small processes, sometimes of differing sizes. The few Algerian specimens recorded here tend to confirm Tongiorgi's interpretation (*in* Bagnoli *et al.*, 1988) of the species as an heteropolar diacrodian and its consequential transfer to the genus *Dasydiacrodium*. Algerian specimens are slightly smaller than those from the type area (Algerian Sahara: Deunff, 1961) and show greater variability in the total number of processes. SEM observations of the eilyma reveal a fine, dense granulate sculpture, not visible under the light microscope.

Occurrence and abundance – Samples NL2-3050.15 and NL2-3044.80: rare. Samples NL2-3039.50 and NL2-3037.45: uncommon. Sample NL2-3014.00: common. Samples NL2-3009.50 to NL2-2984.50: uncommon. Samples Uc101-4127.00 and Uc101-4124.00: common.

Previous records – Uppermost Cambrian-basal Tremadoc: north Estonia (Volkova & Mens, 1988). Lower Tremadoc: central Sardinia (Di Milia & Tongiorgi, 1993). Tremadoc: Algerian Sahara (Deunff, 1961; Combaz, 1967); northern Iran (Ghavidel-Syooki, 1995); Shropshire, England (Rasul & Downie, 1974). Lower Tremadoc-Llanvirn: Algerian Sahara (Jardiné *et al.*, 1974). Upper Tremadoc: Öland, Sweden (Tongiorgi in Bagnoli *et al.*, 1988); north Estonia (Volkova, 1993).

Stratigraphic range verified by independent age control – Lowest record: Cambrian- Ordovician boundary strata (*Cordylodus proavus*?) conodont Zone), north Estonia (Volkova & Mens, 1988). Highest record: upper Tremadoc (*Paltodus deltiifer* conodont Zone), Öland, Sweden (Tongiorgi in Bagnoli *et al.*, 1988).

Genus ELENIA Volkova, 1984

Type species – *Elenia armillata* (Vanderflit) Volkova, 1984; by original designation.

ELENIA ARMILLATA (Vanderflit) Volkova, 1984 Pl. 5, fig. 5

- 1971 *Latoporata armillata* Vanderflit in UMNova & VANDERFLIT, p. 62; pl. 2, figs. 29, 30.
1984 *Elenia armillata* (Vanderflit) VOLKOVA, p. 8; pl. 1, figs. 1-12; text-fig. 1.

Dimensions – Vesicle diameter 22 (29) 34 µm; diameter of polar opening 15-20 µm; maximum

separation between internal and external layers ca. 10 µm (based on 21 specimens)

Remarks – Specimens of this study are compatible with the type material (Upper Cambrian of East European Platform: Volkova, 1984) and with specimens recorded from the Upper Cambrian of Öland, Sweden (Di Milia *et al.*, 1989; Tongiorgi & Ribecai, 1990). Numerous folds, radiating from the border of the polar opening toward the aboral pole, wrinkle the outer, very thin, psilate layer. The rounded polar opening is rimmed by a collar-like structure.

Occurrence and abundance – Samples NL2-3073.50 to NL2-3063.10: very rare. Sample NL2-3050.15: rare. Sample NL2-3037.45: rare. Sample NL2-3009.50: very rare. Samples Uc101-4127.00 and Uc101-4124.00: rare.

Previous records – Uppermost Cambrian: East European Platform (Volkova, 1984, 1990, 1993); Öland, Sweden (Di Milia *et al.*, 1989; Tongiorgi & Ribecai, 1990). Tremadoc: Estonia and Moscow Syncline, Russia (Umnova & Vanderflit, 1971; Umnova, 1975).

Stratigraphic range verified by independent age control – Lowest record: Upper Cambrian (*Proconodontus* conodont Zone), Estonia (Volkova, 1990). Highest record: uppermost Cambrian(?)–lowermost Tremadoc (*Cordylodus proavus* trilobite Zone), Estonia (Volkova, 1990).

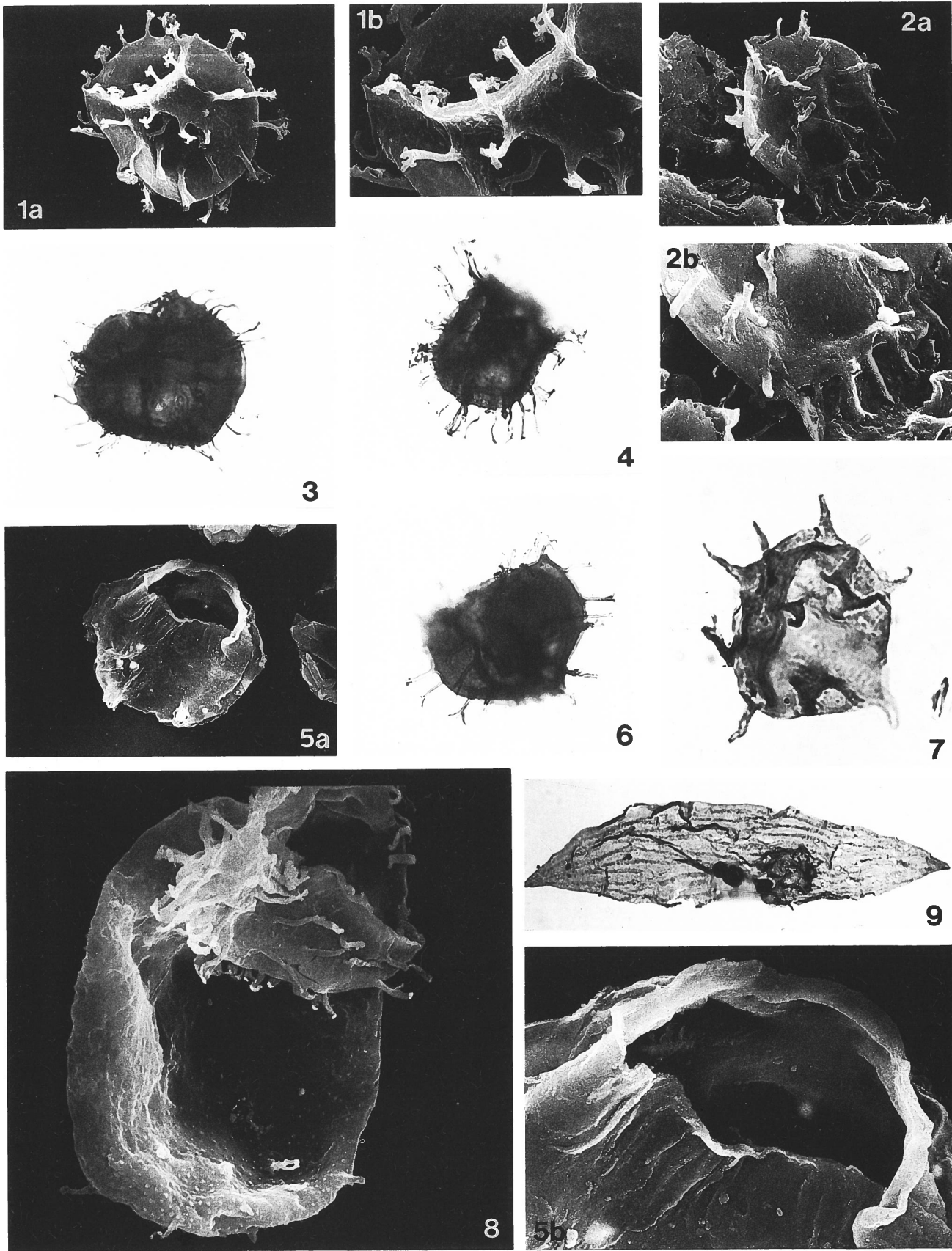
Genus EUPOIKILOFUSA Cramer, 1971

Type species – *Eupoikilofusa striatifera typica* Cramer & Diez, 1972; by original designation.

Discussion – Usage of the four genera *Leiofusa*, *Dactylofusa*, *Eupoikilofusa*, and *Poikilofusa* has been very inconsistent (see discussions in Combaz *et al.*, 1967; Cramer, 1971). According to Dörning (1994), all these genera are validly published and of practical value. Generic distinction is based on the nature and

EXPLANATION OF PLATE 5

- Fig. 1 - *Cymatiogalea virgulta* Martin, 1988. 1a) x 1000; 1b) detail of processes and eilyma, x 2000.
Fig. 2 - *Cymatiogalea parva* n. sp. 2a) x 1000; 2b) detail of processes and eilyma, x 2000.
Fig. 3, 6 - *Cymatiogalea gorkae* Rauscher, 1974b. 3) x 1000. 6) x 1000.
Fig. 4 - *Cymatiogalea membranispina* Deunff, 1961; x 1000.
Fig. 5 - *Elenia armillata* (Vanderflit) Volkova, 1984. 5a) x 1000; 5b) detail of polar opening, x 3000.
Fig. 7 - *Dasydiacrodium obsonum* Martin, 1988; x 1000.
Fig. 8 - *Dasydiacrodium tumidum* (Deunff) Tongiorgi, 1988; x 1500.
Fig. 9 - *Eupoikilofusa squama* (Deunff) Elaouad-Debbaj, 1988; x 1000.
For locality, stratigraphic, and curatorial details see Appendices 1, 2.



disposition of sculptural elements on the eilyma. In *Eupoikilofusa*, small simple elements (grana, echinae, rugulae) are arranged in longitudinal rows that converge near the ends of the vesicle.

EUPOIKILOFUSA SQUAMA (Deunff) Elaouad-Debbaj,
1988
Pl. 5, Fig. 9

- 1961 *Leiofusa squama* DEUNFF p. 40; pl. 2, fig. 8.
1967 *Dactylofusa squama* (Deunff) COMBAZ, LANGE & PANSART, p. 295. [combination invalid: ICBN, art 33.2]
1973 *Poikilofusa* aff. *squama* (Deunff) MARTIN, p. 30.
1974b *Dactylofusa squama* (Deunff) RAUSCHER, p. 63; pl. 1, figs. 14, 15.
1988 *Eupoikilofusa squama* (Deunff) ELAOUAD-DEBBAJ, pp. 100-101; pl. 1, figs. 9, 10, 15.

Dimensions – Vesicle length 85 (95) 110 μm , vesicle width 10 (12) 18 μm ; longitudinal striae ca. 1.5 μm apart (based on 33 specimens).

Remarks – *Eupoikilofusa squama* (Deunff) Elaouad-Debbaj, 1988 is characterized by distinct longitudinal striae that converge polewards. Each stria consist of a longitudinal series of minute (<0.5 μm in diameter) granulose elements.

Occurrence and abundance – Samples N12-3063.70 to N12-3050.15: uncommon. Sample N12-3044.80: rare. Samples N12-3039.50 to N12-3009.50: uncommon. Samples Uc101-4127.00 and Uc101-4124.00: rare.

Previous records – Lower Tremadoc: Random Island, eastern Newfoundland, Canada (Martin in Martin & Dean, 1981); Algerian Sahara (Jardiné *et al.*, 1974); Anti-Atlas, Morocco (Elaouad-Debbaj, 1988); Montagne Noire, France (Rauscher, 1974b). Tremadoc: Brabant Massif, Belgium (Martin, 1977); Algerian Sahara (Deunff, 1961; Combaz, 1967); Shropshire, England (Rasul & Downie, 1974; Rasul, 1979). Lower Ordovician: Bohemia (Vavrdová, 1978).

Stratigraphic occurrence verified by independent age control – Lower Tremadoc (*Parabolina argentina* trilobite Zone), eastern Newfoundland, Canada (Martin in Martin & Dean, 1981).

Genus LADOGELLA Golub & Volkova, 1985 emend.
Di Milia, Ribecai & Tongiorgi, 1989

Type species – *Ladogella rotundiformis* Golub & Volkova, 1985; by original designation.

LADOGELLA ROMMELAEREI (Martin) Di Milia,
Ribecai & Tongiorgi, 1989
Pl. 7, fig. 1

- 1981 *Arbusculidium rommelaerei* Martin in MARTIN & DEAN, p. 16; pl. 3, figs. 6, 8, 21, 23; pl. 5, fig. 1.
1989 *Ladogella rommelaerei* (Martin) DI MILIA, RIBECAI & TONGIORGI, pp. 16-17; pl. 7, figs. 3, 7.

Dimensions – Vesicle length 23 (28) 32 μm , vesicle width 16 (24) 26 μm ; length of apical processes 4-8 μm , length of first-order antapical processes 3-8 μm , basal diameter of first-order processes 3-7 μm (based on 15 specimens).

Remarks – The present specimens of *Ladogella rommelaerei* (Martin) Di Milia *et al.*, 1989 show no significant intraspecific variability. The presence of two distinct types of antapical processes (first- and second-order, see Di Milia *et al.*, 1989) is clearly observable in all the specimens recorded from borehole N12.

Occurrence and abundance – Samples N12--3075.75 and N12-3073.50: common. Sample N12-3066.10 to N12-3054.75: rare. Sample N12-3050.15: uncommon.

Previous records – Upper Cambrian: Random Island, eastern Newfoundland, Canada (Martin in Martin & Dean, 1981, 1988; Martin, 1982); Öland, Sweden (Di Milia *et al.*, 1989; Tongiorgi & Ribecai, 1990); Rocroi Massif, France (Ribecai & Vanguetstaine, 1993); north Estonia (Volkova, 1993). Upper Cambrian-lower Tremadoc: Montcornet-en-Ardenne, France (Meilleux & Vanguetstaine, 1983). Lower Tremadoc: Random Island, eastern Newfoundland, Canada (Martin in Martin & Dean, 1981, 1988; Martin 1982).

Stratigraphic range verified by independent age control – Lowest record: Upper Cambrian (*Peltura scarabeoides* trilobite Zone), Öland, Sweden (Di Milia *et al.*, 1989). Highest record: lowermost Tremadoc (*Parabolina argentina* trilobite Zone), Random Island, eastern Newfoundland, Canada (Martin in Martin & Dean, 1981, 1988).

LADOGELLA ROTUNDIFORMIS Golub & Volkova in
Volkova & Golub, 1985
Pl. 6, fig. 5

- 1984 *Barakella?* sp. 1 VOLKOVA & GOLUB, p. 96; pl. 1, figs. 9, 11, 13.

1985 *Ladogella rotundiformis* Golub & Volkova in VOLKOVA & GOLUB, p. 95; pl. 8, figs. 1-5.

Dimensions – Vesicle length 28 (36) 43 μm , vesicle width 17 (25) 33 μm ; length of apical processes 5-18 μm , length of first-order antapical processes 13-5 μm , basal diameter of first-order processes *ca.* 3 μm (based on 21 specimens).

Remarks and comparison – Recorded specimens are consonant with those of the type material (Upper Cambrian of East European Platform: Volkova & Golub, 1985) and do not show significant variation. This contrasts with the observations of Di Milia *et al.* (1989) on specimens from the Upper Cambrian of Öland, Sweden. They divided their populations of *Ladogella rotundiformis* Golub & Volkova, 1985 into two separate categories: forma A, characterized by numerous, relatively long first-order processes, together with second-order processes dispersed on the greater part of the antapical cap; and forma B, with smaller first-order process together with second-order processes that form a small structure in the vicinity of the antapical pole. A phylogenetic trend was also proposed, with forma B representing the more evolved stage of the intraspecific differentiation. Specimens of *L. rotundiformis* recorded here typically feature a small, polar-centred tuft of second-order processes and are thus attributable to forma B of Di Milia *et al.* (1989).

Occurrence and abundance – Sample NL2-3075.75 and NL2-3066.10: very rare. Samples NL2-3063.70 and NL2-3060.70: rare. Samples NL2-3054.75 and NL2-3050.15: uncommon.

Previous records – Upper Cambrian: East European Platform (Volkova & Golub, 1984, 1985; Mens *et al.*, 1993; Volkova, 1993); Öland, Sweden (Di Milia *et al.*, 1989; Tongiorgi & Ribecai, 1990); Rocroi Massif, France (Ribecai & Vanguetaine, 1993). Uppermost Cambrian-lowermost Tremadoc(?): East European Platform (Volkova & Mens, 1988; Volkova, 1990).

Stratigraphic range verified by independent age control – Lowest record: Upper Cambrian (*Peltura scarabeoides* trilobite Zone), Öland, Sweden (Di Milia *et al.*, 1989). Highest record: Cambrian-Ordovician boundary interval (*Cordylodus proavus*(?) conodont Zone), Estonia (Volkova & Mens, 1988).

Genus LOPHODIACRODIUM Timofeev, 1958 emend. Deflandre & Deflandre-Rigaud, 1962

Type species – *Lophodiacrodium obtusum* Timofeev, 1958; by original designation.

LOPHODIACRODIUM VALDAICUM (Timofeev) Downie & Sarjeant, 1965
Pl. 6, fig. 3

1959 *Lophorytidodiacrodium valdaicum* TIMOFEEV, p. 63; pl. 5, fig. 17; pl. 23, fig. 21.

? 1959 *Lophorytidodiacrodium tosaense* TIMOFEEV, p. 62; pl. 5, fig. 10.

? 1959 *Lophorytidodiacrodium tuberculatum* TIMOFEEV, p. 62; pl. 5, fig. 11.

? 1959 *Lophorytidodiacrodium primarium* TIMOFEEV, p. 62; pl. 5, fig. 13.

? 1959 *Lophorytidodiacrodium turulosum* TIMOFEEV, p. 67; pl. 5, fig. 32.

1965 *Lophodiacrodium valdaicum* (Timofeev) DOWNIE & SARJEANT, p. 128.

Description – Vesicle elliptical in outline. Polar caps sculptured with numerous, closely spaced, rounded verrucae. Equatorial zone narrow, with faint longitudinal striae. No excystment structure observed.

Dimensions – Vesicle length 22 (29) 33 μm , vesicle width (equatorial zone) 21 (24) 26 μm ; height and basal diameter of polar verrucae 4-6 μm , number of verrucae at each pole *ca.* 50 (based on 15 specimens).

Comparison and remarks – The study specimens are closely comparable with those described by Volkova (1990) from the Upper Cambrian of Estonia, except for the presence of faint longitudinal striae (SEM observations only) in the equatorial zone.

Occurrence and abundance – Sample NL2-3075.75: common. Sample NL2-3073.50: uncommon. Sample NL2-3066.10: rare. Samples NL2-3063.70 and 3060.70: very rare.

Previous records – Upper Cambrian: Baltic region (Timofeev, 1959); East European Platform (Volkova, 1990).

Stratigraphic occurrence verified by independent age control – Upper Cambrian (*Peltura* trilobite Zone), Bughino Formation, Moscow Syncline, Russia (Volkova, 1990).

Genus *MULTIPLICISPHAERIDIUM* Staplin, 1961
emend. Turner, 1984

Type species – *Multiplicisphaeridium ramispinosum*
Staplin, 1961; by original designation.

MULTIPLICISPHAERIDIUM CERVINACORNUM Welsch,
1986
Pl. 6, fig. 4

1986 *Multiplicisphaeridium cervinacornua* WELSCH, pp.
61-62; pl. 6, figs. 7-10; text-fig. 21.
p.p. 1990 *Vogtlandia notabilis* VOLKOVA, pp. 89-90; pl. 23, fig.
1-3, non fig. 6.

Description – Vesicle originally spherical, but strongly deflected by processes to assume a polygonal outline. Eilyma *ca.* 0.8-1 μ m thick, psilate or sculptured with discrete, irregularly distributed grana *ca.* 0.5 μ m in height and basal diameter. Processes $\pm$ homomorphic, hollow, uniformly developed on vesicle surface, broad-based, gradually tapering toward branching distal extremities, whence two pinnae project, each bearing pinnulae up to fourth order (usually up to third order). Process interiors freely communicating with vesicle interior; curved proximal contacts with vesicle. Sculpture of processes same as that of eilyma. No excystment structure observed.

Dimensions – Vesicle diameter 18 (25) 35 μ m; process basal width 5-10 μ m, length of process trunks *ca.* 5 μ m, length of pinnae 3-5 μ m, total length of processes 8-13 μ m, number of processes 12-18 (based on 25 specimens).

Remarks and comparison – Sculpture of eilyma is evidently influenced by state of preservation: indifferently preserved specimens are distinctly granulate, in contrast to well-preserved specimens which are normally psilate. Specimens from the type area (Digermöl Peninsula, Finnmark, Norway: Welsch, 1986), and seemingly also from the East European Platform (Volkova, 1990), have psilate vesicle walls. Proximal part of processes, originally

with concave profile, is frequently modified to assume a convex profile. Two of the three specimens figured by Volkova (1990, pl. 23, figs. 1, 3, but not fig. 6, which probably represents another species) are virtually identical with *Multiplicisphaeridium cervinacornuum* Welsch, 1986, although Volkova identified all three as *Vogtlandia notabilis* sp. nov. The distal process branches do not interconnect to form a «dense tree-like crown» (as specified in the diagnosis of *Vogtlandia* Burmann, 1970, p. 292) but remain clearly separated. Therefore, the species under discussion belongs to *Multiplicisphaeridium* Staplin, 1961 emend. Turner, 1984 rather than to *Vogtlandia*.

Occurrence and abundance – Sample NL2-3063.70: rare. Sample NL2-3060.70 to NL2-3050.15: uncommon.

Previous records – Uppermost Cambrian: East European Platform (Volkova, 1990, 1993); north Estonia (Mens *et al.*, 1993), Finnmark, Norway (Welsch, 1986).

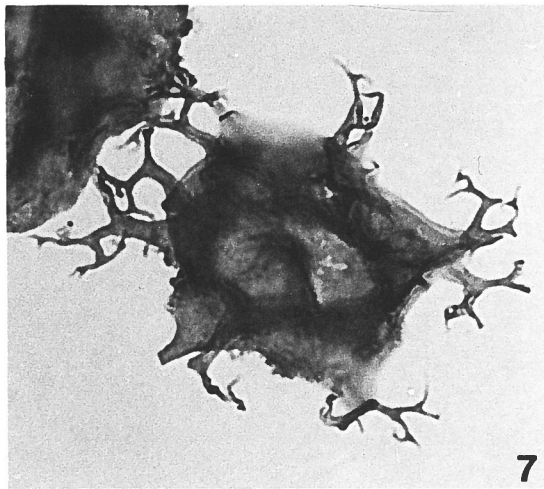
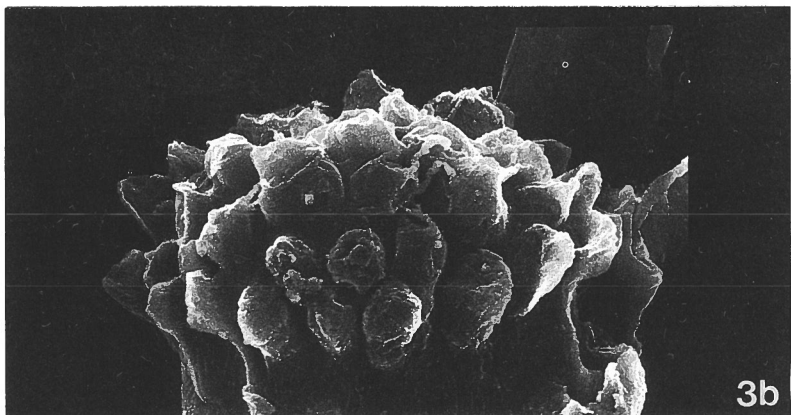
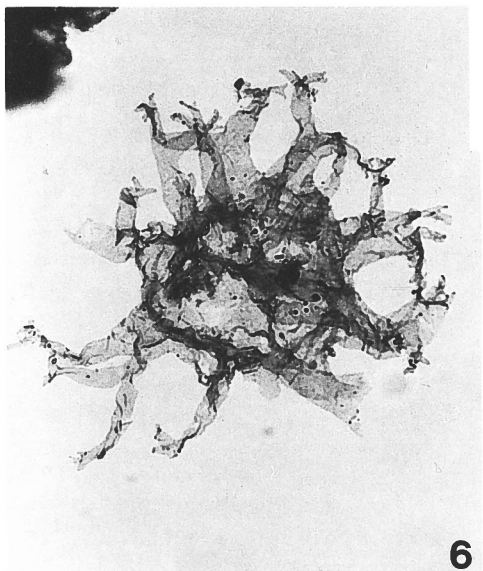
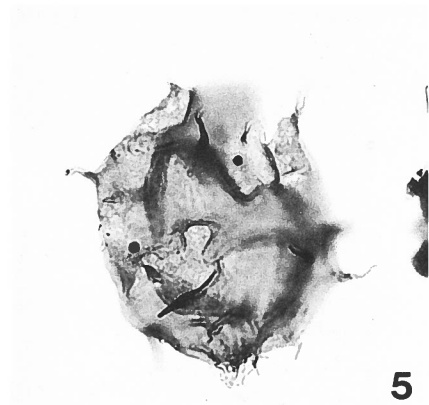
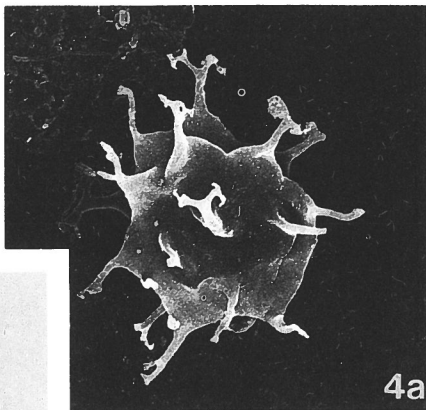
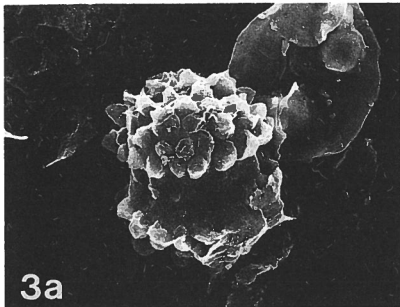
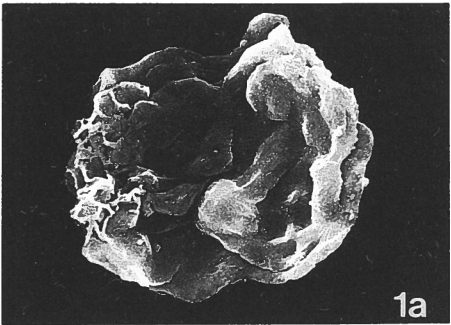
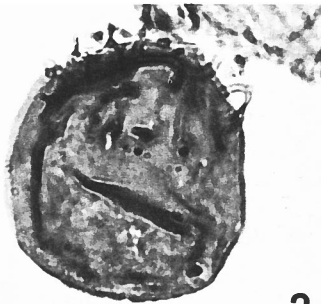
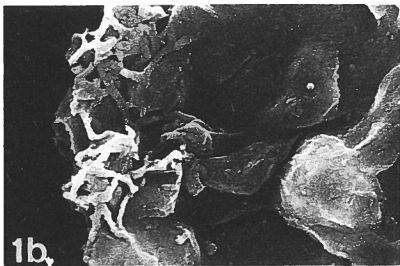
Stratigraphic range verified by independent age control – Lowest record: Upper Cambrian (*Peltura scarabeoides* trilobite Zone), East European Platform (Volkova, 1990; Mens *et al.*, 1993). Highest record: uppermost Cambrian (*Acerocare* trilobite Zone), East European Platform (Volkova, 1990; Mens *et al.*, 1993). In its type area this species has its highest occurrence in strata lacking macrofossils, slightly below the introduction of graptolites of *Rhabdinopora flabelliformis* group (Welsch, 1986, figs. 6, 8).

MULTIPLICISPHAERIDIUM sp. 1
Pl. 6, fig. 6

Description – Vesicle originally spherical, circular to subpolygonal in outline, modified by processes. Eilyma thin (<0.5 μ m), transparent, shagrinated, frequently folded. Curved proximal process contacts with vesicle. Processes $\pm$ homomorphic, hollow,

EXPLANATION OF PLATE 6

- Figs. 1, 2 – *Ooidium* sp. cf. *O. rossicum* Timofeev, 1957. 1a) x 2000; 1b) detail of anastomosing trabeculae on polar cap, x 3000. 2) x 1250.
Fig. 3 – *Lophodiactrodium valdaicum* (Timofeev) Downie & Sarjeant, 1965. 3a) x 1000; 3b) detail of polar verrucae, x 3000.
Figs. 4, 7 – *Multiplicisphaeridium cervinacornuum* Welsch, 1986. 4a) x 1000; 4b) detail of processes and eilyma, x 3000. 7) x 1500.
Fig. 5 – *Ladogella rotundiformis* Golub & Volkova, 1985; x 1000.
Fig. 6 – *Multiplicisphaeridium* sp. 1; x 1000.
For locality, stratigraphic, and curatorial details see Appendices 1, 2.



freely communicating with vesicle interior. Process trunk cylindrical, broad, distally branched with 2 long pinnae usually about the same length as process trunk, less commonly as much as 1.5 times process trunk. Pinnae branching into usually 3 pinnulae each bearing two second-order pinnulae. Excystment structure not evident.

Dimensions – Vesicle diameter 25 (28) 30 μm ; length of process trunk 6–8 μm (variable on a single specimen), basal width of processes 3–5 μm (variable on a single specimen), length of pinnae 6–10 μm , length of first-order pinnulae *ca.* 3 μm , length of second-order pinnulae 1–1.5 μm ; number of processes 12–18 (based on 8 specimens).

Remarks – Eilyma is characteristically very thin, faintly sculptured, and not clearly differentiated in thickness from process walls. Normally, the first-order branches are the same length as the process trunk, rarely longer, but are highly variable even on a given specimen.

Occurrence and abundance – Sample NL2-3014.00: very rare.

Genus *Ooidium* Timofeev, 1957 emend. Norris & Sarjeant, 1965

Type species – *Ooidium rossicum* Timofeev, 1957; by subsequent designation of Norris & Sarjeant (1965, p. 45).

Ooidium sp. cf. *O. rossicum* Timofeev, 1957
Pl. 6, figs. 1, 2

cf. 1957 *Ooidium rossicum* TIMOFEEV, p. 281; text-figs. 1–5.
cf. 1986 *Ooidium rossicum* Timofeev - WELSCH, p. 89; pl. 6, figs. 11–14.

Description – Vesicle elliptical to ovoidal in outline. Eilyma apparently single-layered, thin ($<0.5 \mu\text{m}$ thick). Eilyma sculpture consisting of grana confined to one polar region, and faint longitudinal striae developed on equatorial region. Small, slender, psilate rods or trabeculae (*sensu* Loeblich & Tappan, 1976, p. 305) sometimes anastomosing, sometimes isolated, apparently not communicating with vesicle interior, located on the polar region opposite to that with granulate sculpture. No excystment structure observed.

Dimensions – Vesicle length *ca.* 25 μm , vesicle width *ca.* 20 μm ; height of trabeculae *ca.* 2–3 μm (based on 4 specimens).

Remarks and comparison – Specimens recorded are ill-preserved, often with collapsed vesicle, broken trabeculae, and obscure eilyma sculpture. One specimen observed per SEM exhibits all the diagnostic features of *Ooidium rossicum* Timofeev, 1957, but its vesicle is both collapsed and deformed (the latter by pyrite crystals). Owing to the scarcity of specimens encountered and their indifferent preservational quality, positive attribution to Timofeev's species is withheld. Specimens of *O. rossicum* figured by Welsch (1986) from the uppermost Cambrian of Norway show close similarity to those encountered during the present study.

Occurrence and abundance – Samples NL2-3075.75 and NL2-3073.50: very rare. Sample NL2-3066.10: questionably present. Samples NL2-3066.10 and NL2-3060.70: very rare.

Previous records (*O. rossicum*) – Upper to uppermost Cambrian: Leningrad region (Loeblich, 1970; Timofeev, 1957); Finnmark, Norway (Welsch, 1986); East European Platform (Volkova, 1990, 1993); Estonia (Mens *et al.*, 1993).

Genus *Polygonium* Vavrdová, 1966

1966 *Polygonium* VAVRDOVÁ, pp. 412–413.
p.p. 1969 *Goniosphaeridium* EISENACK, p. 256.
p.p. 1989 *Polygonium* Vavrdová emend. LE HÉRISSE, p. 181.

Type species – *Polygonium gracile* Vavrdová, 1966; by original designation.

Discussion – The feasibility of restricting vesicle size ranges in order to distinguish *Polygonium* Vavrdová, 1966 from *Micrhystridium* Deflandre, 1937 was pointed out by Le Hérisse (1989, p. 181). Accordingly, he emended *Polygonium* to include forms featuring subspherical to polyhedral vesicles more than 20 μm in diameter with simple, hollow, spine-like, homomorphic processes and free communication between process and vesicle interiors. Only minor consideration was given by Le Hérisse to sculpture of eilyma and process walls, which, conforming to his 1989 emendation, may be psilate, granulate, or echinate. Consequently, *Stellechinatum* Turner, 1984 (together with *Goniosphaeridium* Eisenack, 1969) was considered by Le Hérisse to be a junior synonym of *Polygonium*. Observation of the very numerous «polygonomorph» acritarchs encountered during the present study suggests, however, that the two genera should be retained separately on the grounds of form, distribution, and dimensions of sculptural elements on the eilyma and

process walls. In the material studied, two distinct categories are distinguishable: (a) forms with psilate to finely granulate-echinate process walls (sculptural elements $<0.5\ \mu\text{m}$ high), assignable to *Polygonium*; and (b) forms with more coarsely sculptured processes, in which the length of the sculptural elements (echinae) varies from 0.5 to $5\ \mu\text{m}$, here retained in *Stellechinatum*. On the other hand, no significant differences exist between the diagnoses of *Goniosphaeridium* Eisenack, 1969 and *Polygonium* which are thus considered synonymous (as per Le Hérissé, 1989).

POLYGONIUM DENTATUM (Timofeev ex
Konzalová-Mazancová) Albani, 1989
Pl. 7, fig. 5

- 1959 *Archaeohystrichosphaeridium dentatum* TIMOFEEV, p. 41; pl. 3, fig. 44. [type-species combination, hence designation, invalid: ICBN, Arts. 33.2, 37]
- 1959 *Archaeohystrichosphaeridium pungens* TIMOFEEV, p. 39; pl. 3, fig. 33. [type-species combination, hence designation, invalid: ICBN, Arts. 33.2, 37]
- 1969 *Baltisphaeridium dentatum* (Timofeev) KONZALOVÁ-MAZANCOVÁ, p. 87; pl. 15, fig. 6.
- 1969 *Baltisphaeridium pungens* (Timofeev) MARTIN, p. 60; pl. 1, figs. 16, 23, 24, 34, text-fig. 14.
- 1974b *Goniosphaeridium dentatum* (Timofeev) RAUSCHER, p. 61; pl. 1, fig. 6.
- 1974b *Goniosphaeridium pungens* (Timofeev) RAUSCHER, p. 62; pl. 1, figs. 7, 8.
- ? 1984 *Goniosphaeridium gracile* (Vavrdová) - TONGIORGI, ALBANI & DI MILIA, pl. 1, fig. 3.
- ? 1984 *Goniosphaeridium* cf. *G. pungens* (Timofeev) - TONGIORGI, ALBANI & DI MILIA, p. 671; pl. 1, figs. 4, 5.
- 1986 *Goniosphaeridium dentatum* (Timofeev) WELSCH, pp. 45-46; pl. 9, figs. 8-12.
- 1989 *Polygonium dentatum* (Timofeev) ALBANI, pp. 24-25; pl. 3, figs. 7, 8.
- 1989 *Polygonium pungens* (Timofeev) ALBANI, pp. 25-26; pl. 3, fig. 10.

Description – Vesicle originally subspherical to polyhedral; subpolygonal in outline. Eilyma psilate or shagrinate, *ca.* $1\ \mu\text{m}$ thick. Processes $\pm$ homomorphic, evenly distributed on vesicle surface, hollow, broad-based, and commonly tapering to acuminate distal end; process and vesicle interiors freely communicating. Very rarely, 1 or 2 processes on a single specimen may be terminally bifurcant. Process walls psilate to finely granulate or echinate; sculptural elements $<0.5\ \mu\text{m}$ high. Sculptural elements typically increasing in size toward distal ends of processes. Excystment opening not observed.

Dimensions – Vesicle diameter 23 (25) $28\ \mu\text{m}$; length of processes 9-16 μm , basal diameter of processes 4-5 μm , number of processes 20-35; vesicle

diameter: process length ratio *ca.* 2.5 (based on 44 specimens).

Remarks and comparison – Welsch (1986, p. 45) considered *Goniosphaeridium pungens* (Timofeev) Rauscher, 1973 (sic) synonymous with *G. dentatum* (Timofeev) Rauscher, 1973 (sic), because he viewed the supposed difference in process sculpture (psilate in *G. dentatum*, minutely granulate in *G. pungens*) as inadequate for species differentiation. Albani (1989, pp. 24-25) preferred to retain the two species separately. Welsch's (1986) proposal of synonymized *dentatum* and *pungens* is accepted herein, because of continuous morpho-gradation between forms with psilate processes and those with minutely granulate to echinate processes. The specific names *dentatum* and *pungens* were not validly published in Timofeev (1959) because in that work the generic name *Archaeohystrichosphaeridium* was not validly published (ICBN Arts. 33.2, 37). The name *dentatum* was validated by Konzalová-Mazancová (February 1969, p. 87), who assigned the species to the genus *Baltisphaeridium*, and has priority over *pungens*, validated by Martin (April 1969, p. 60) as *Baltisphaeridium pungens*. The specimens illustrated by Tongiorgi *et al.* (1984, pl. 1, fig. 3, «*G. gracile*»; and pl. 1, figs. 4, 5, «*G. cf. pungens*») from the Tremadoc of central Sardinia are morphologically close to *P. dentatum*, but their poor preservational state impedes precise specific attribution.

Occurrence and abundance – Sample N12-3044.80: rare. Sample N12-3037.45: common. Sample N12-3037.45: abundant. Samples N12-3014.00 and N12-3009.50: common. Samples N12-2993.50 to N12-2976.50: uncommon. Samples Uc101-4127.00 and Uc101-4124.00: common.

Previous records – Upper Cambrian-upper Llanvirn: Great Britain (Downie, 1984). Lower Ordovician: Rabat area, Morocco (Rahmani, 1983). Lower Tremadoc: central Sardinia (Di Milia & Tongiorgi, 1993). Tremadoc: Libya (Deunff & Massa, 1975); northern Iran (Ghavidel-Syooki, 1995); Baltic region (Timofeev, 1959). Uppermost Tremadoc-uppermost Llanvirn: Isle of Man, England (Molyneux, 1979). Tremadoc-Arenig boundary: Sierra Morena, Spain (Mette, 1989). Lower Arenig: Montagne Noire, France (Rauscher, 1971, 1974b); South China (Li Jun, 1987, 1990). Arenig: Montagne Noire, France (Rauscher, 1974b); South China (Gao Lianda, 1991); Bakony Mountains, Hungary (Albani *et al.*, 1985b); central Sardinia (Tongiorgi *et al.*, 1984; Albani *et al.*, 1985a; Albani, 1989); Hubei Province, China (Tongiorgi *et al.*,

1995). Arenig-Llanvirn: Sierra Morena, Spain (Mette, 1989). Llanvirn-Llandeilo: Libya (Deunff & Massa, 1975). Upper Ordovician: Bulgaria (Kalvacheva, 1978). Lower Devonian (reworked specimens): southern England (Richardson & Rasul, 1978).

Stratigraphic range verified by independent age control – Lowest record: ?uppermost Cambrian (levels without macrofossils, ca. 100 m. below first appearance of graptolite *Rhabdinopora flabelliformis parabola*), Berlogaissa Formation, Digermul Peninsula, Finnmark, Norway (Welsch, 1986). Highest record: Llanvirn-Llandeilo, Bir Ben Tartar Formation, Libya, dated by first appearance of the graptolites *Neseuretus* sp. and *Didymograptus* (Deunff & Massa, 1975).

POLYGONIUM GRACILE Vavrdová, 1966
Pl. 7, fig. 2

- 1966 *Polygonium gracilis* VAVRDOVÁ, pp. 413-414; pl. 1, fig. 3; pl. 3, fig. 1; text-fig. 3b.
1971 *Polygonium gracile* Vavrdová - RAUSCHER, p. 292; pl. 1, fig. 5.
1984 *Goniosphaeridium gracile* (Vavrdová) - TONGIORGI, ALBANI & DI MILIA, pl. 1, fig. 2.
1989 *Goniosphaeridium gracilis* (Vavrdová) METTE, pl. 2, fig. 18.

Dimensions – Vesicle diameter 17 (23) 28 µm; length of processes 8 (13) 23 µm, basal diameter of processes 2-3 µm, number of processes 8-17; vesicle diameter: process length ratio ca. 1 (based on 22 specimens).

Remarks – This apparently simple form is nonetheless very distinctive in the Algerian acritarch assemblages. *Polygonium gracile* Vavrdová, 1966 is readily distinguishable from *P. dentatum* in having a smaller number of processes and a different vesicle diameter: process length ratio; furthermore, eilyma and process walls are always psilate. Size ranges of *P. gracile* do not overlap with those of *P. dentatum*.

Occurrence and abundance – Samples Nl2-3014.00 and Nl2-3009.50: common. Sample Nl2-2993.50: uncommon. Sample Nl2-2984.50: common. Sample Nl2-2976.50: uncommon. Samples Uc101-4127.00 and Uc101-4124.00: common.

Previous records – Upper Cambrian-upper Llanvirn: England (Downie, 1984). Lower Tremadoc: central Sardinia (Di Milia & Tongiorgi, 1993). Tremadoc: Libya (Deunff & Massa, 1975); Shropshire, England (Rasul & Downie, 1974). Uppermost Tremadoc-Llanvirn: Isle of Man, United Kingdom (Molyneux, 1979). Tremadoc-Arenig boundary: Sierra Morena, Spain (Mette, 1989). Lower Arenig: Montagne Noire, France (Rauscher, 1971, 1974b); Guizhou and Hunan Provinces, South China (Li Jun, 1987, 1990). Arenig: Central Bohemia (Vavrdová, 1966, 1972); Montagne Noire, France (Rauscher, 1974b); Yunnan Province, South China (Gao Lianda, 1991); Bakony Mountains, Hungary (Albani *et al.*, 1985b); central Sardinia (Tongiorgi *et al.*, 1984; Albani *et al.*, 1985a; Albani, 1989). Upper Arenig-upper Llanvirn: Central Bohemia (Vavrdová, 1977). Llanvirn-Llandeilo: Libya (Deunff & Massa, 1975). Upper Ordovician: Bulgaria (Kalvacheva, 1978). Lower Devonian: southern England (Richardson & Rasul, 1978; reworked specimens).

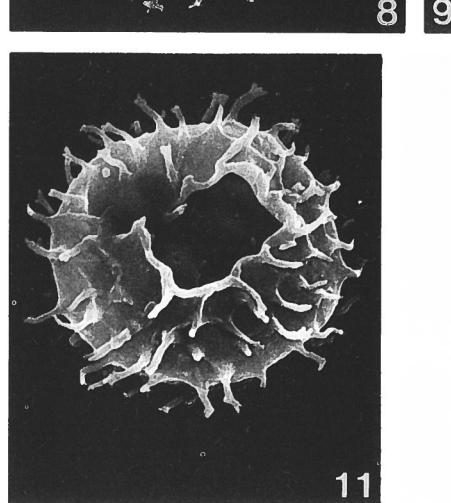
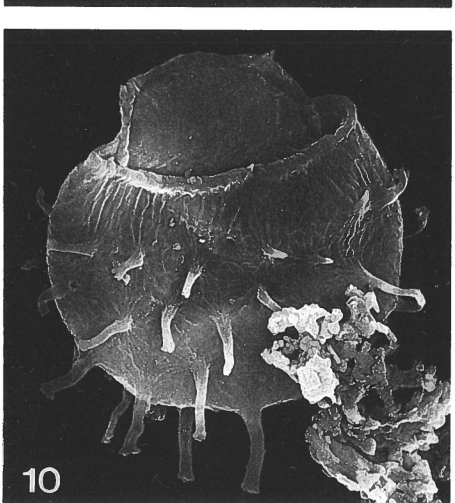
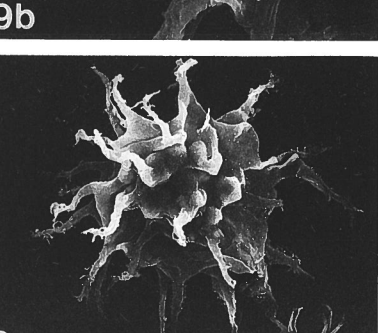
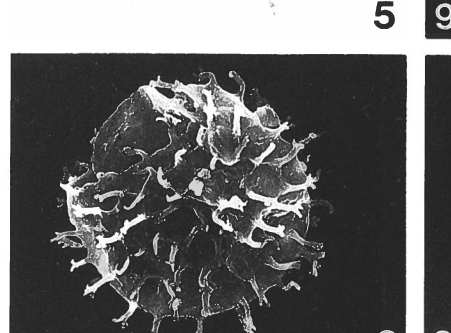
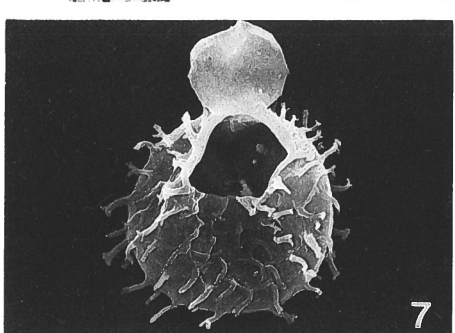
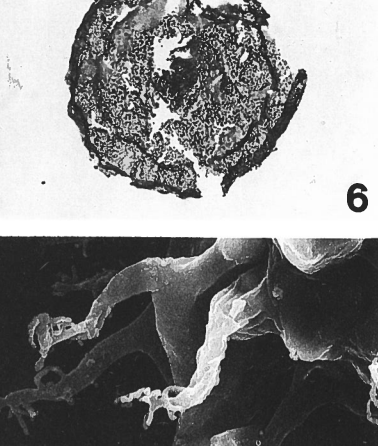
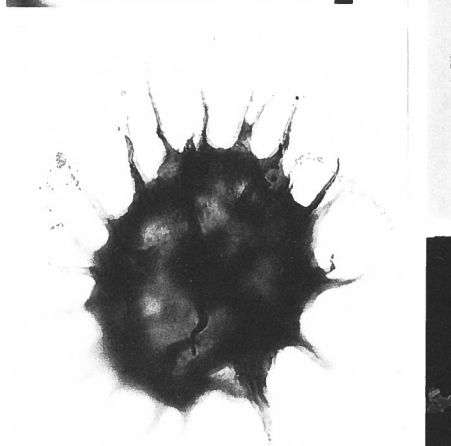
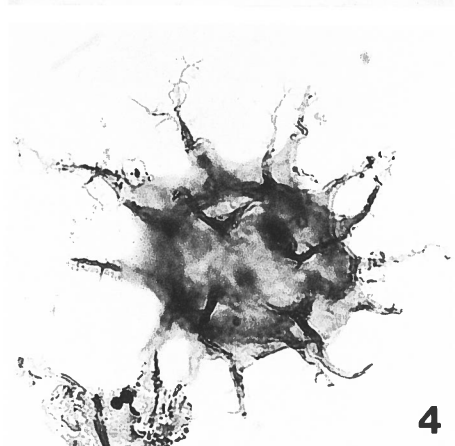
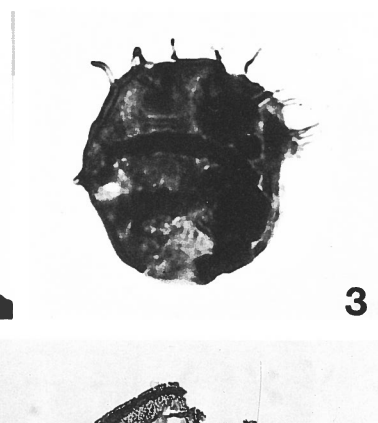
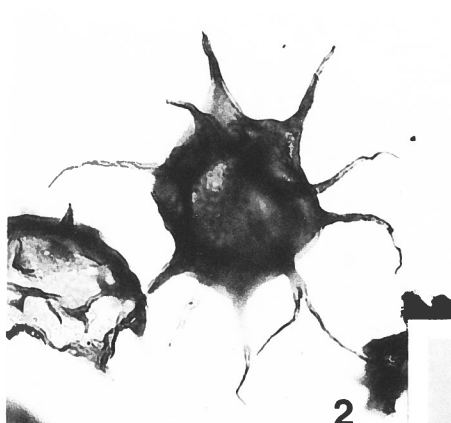
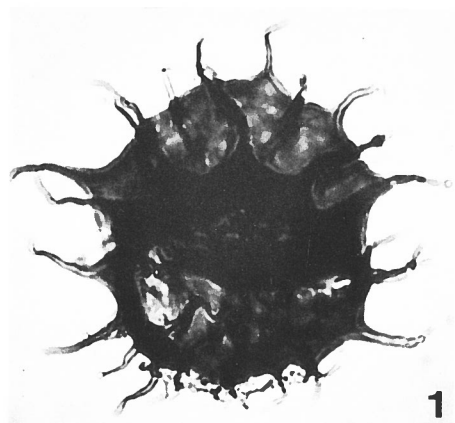
Stratigraphic range verified by independent age control – Lowest record: Upper Cambrian (*Parabolina spinulosa* trilobite Zone), England (Downie, 1984). Highest record: Llandeilo (dating based on the occurrence of *Neseuretus* sp. and *Didymograptus* of graptolite zone «6»), Libya (Deunff & Massa, 1975).

Genus SAHARIDIA Combaz, 1967

Type species – *Saharidia downiei* Combaz, 1967; by original designation.

EXPLANATION OF PLATE 7

- Fig. 1 - *Ladogella rommelaerei* (Martin) Di Milia *et al.*, 1989; x 1250.
Fig. 2 - *Polygonium gracile* Vavrdová, 1966; x 1000.
Fig. 3 - *Trunculumarium* sp. 1; x 1250.
Figs. 4, 9 - *Stellechinatum uncinatum* (Downie) Molyneux, 1987. 4) x 1000. 9a) x 750; 9b) detail of processes, x 2000.
Fig. 5 - *Polygonium dentatum* (Timofeev ex Konzalová-Mazancová) Albani, 1989; x 1000.
Fig. 6 - *Saharidia fragilis* (Downie) Combaz, 1967; x 750.
Figs. 7, 8, 11 - *Stelliferidium furcatum* (Deunff) emend. Deunff *et al.*, 1974. 7) x 1000. 8) x 1000. 11) x 1250.
Fig. 10 - *Stelliferidium cortinulum* (Deunff) emend. Deunff *et al.*, 1974; x 1500.
Fig. 12 - *Stelliferidium simplex* (Deunff) emend. Deunff *et al.*, 1974; x 1000.
For locality, stratigraphic, and curatorial details see Appendices 1, 2.



SAHARIDIA FRAGILIS (Downie) Combaz, 1967
Pl. 7, fig. 6

- 1958 *Leiosphaeridia fragilis* DOWNIE, p. 344; pl. 17, fig. 6.
1967 *Saharidia fragilis* (Downie) COMBAZ, p. 13; pl. 2, figs. 37, 38.

Dimensions – Vesicle diameter 58 (62) 77 µm; pylome diameter 13-17 µm (based on 32 specimens).

Remarks – Apart from vesicle size, the simple morphology of this species does not show significant variation. The eilyma is always distinctly granulate.

Occurrence and abundance – Samples N12-3066.10 to N12-3037.45: common.

Previous records – Uppermost Cambrian: Random Island, eastern Newfoundland, Canada (Martin in Martin & Dean, 1981; Martin 1982); East European Platform (Volkova, 1990). Lower Tremadoc: Algerian Sahara (Jardiné *et al.*, 1974; Combaz, 1967). Tremadoc: Montagne Noire, France (Martin, 1973); Shropshire, England (Rasul & Downie, 1974; Downie, 1958, 1984). Caradoc: Shropshire, England (Turner, 1982; reworked specimens).

Stratigraphic range verified by independent age control – Lowest record: Upper Cambrian (*Peltura* trilobite Zone), Random Island, eastern Newfoundland, Canada (Martin in Martin & Dean, 1988). Highest record: lower Tremadoc (*Cordylodus proavus* conodont Zone), East European Platform (Volkova, 1990).

Genus STELLECHINATUM Turner, 1984

- 1984 *Stellechinatum* TURNER, p. 137.

Type species – *Stellechinatum celestum* (Martin) Turner, 1984; by original designation.

Discussion – Morphological resemblances between *Stellechinatum* Turner, 1984 and *Polygonium* have been emphasized by Le Hérisse (1989, p. 181). Nevertheless, the characteristic echinate sculpture of the processes of *Stellechinatum* is regarded here as a distinctive character at generic level. In order to clearly differentiate the two genera, it is desirable to adopt a restriction on dimensional ranges of sculptural elements (see discussion under *Polygonium*, above).

STELLECHINATUM UNCINATUM (Downie) Molyneux, 1987
Pl. 7, figs. 4, 9

- 1958 *Hystriosphæridium longispinosum* var. *uncinatum* DOWNIE, p. 337; text-fig. 2a.
1966 *Baltisphaeridium uncinatum* (Downie) MARTIN, pp. 425-426; text-fig. 1.
non 1971b *Goniosphaeridium uncinatum* (Martin) (sic) KJELLSTRÖM, p. 27; text-fig. 18.
? 1973 *Goniosphaeridium uncinatum* (Downie) Kjellström - MARTIN, pp. 9-10; pl. 7, fig. 15.
non 1978 *Goniosphaeridium uncinatum* (Downie) Kjellström - Martin, in DEAN & MARTIN, pl. 1, figs. 4, 5.
1987 *Stellechinatum uncinatum* (Downie) MOLYNEUX, pp. 342-344; text-figs. 93, 94.
non 1988 *Stellechinatum uncinatum* (Downie) Martin in MARTIN & DEAN, p. 40; pl. 17, figs. 12-15.

Description – Vesicle subpolyhedral, outline polygonal. Eilyma shagrinose to finely granulate, ca. 1 µm thick. Processes ± homomorphic, evenly distributed on vesicle surface, hollow, broad-based, tapering to acuminate distal end. Processes and vesicle interiors freely communicating. Process walls sculptured with echinae 1-5 µm long, usually becoming coarser towards distal ends of processes, which are rarely bifurcant. Excystment opening consisting of a simple slit in eilyma.

Dimensions – Vesicle diameter 21 (26) 32 µm; length of processes 13 (16) 18 µm, basal diameter of processes 4-5 µm, number of processes 25-35 (based on 50 specimens).

Comparison – Kjellström's (1971b, fig. 18) specimen, from the Swedish middle Ordovician and attributed by him to this species, has a rounded vesicle outline and a relatively large number of less distinctly sculptured processes compared to the holotype (Downie, 1958, text-fig. 2a) and is thus excluded from *Stellechinatum uncinatum* (Downie) Molyneux, 1987. Exclusion applies likewise to specimens recorded by Martin (in Dean & Martin, 1978; in Martin & Dean, 1988) from Upper Cambrian-lower Ordovician strata of eastern Canada. In the former case, Martin's (1978) specimen features a strongly sculptured vesicle and virtually unsculptured processes; in the latter (1988) record, both eilyma and process surfaces bear «spinose ornamentation». Thus these specimens are regarded as unassignable to *S. uncinatum*. Certain other specimens, from the lower Ordovician of France (Martin, 1973), apparently possess psilate or very faintly sculptured eilyma and process walls; hence their identification with *S. uncinatum* is doubtful.

Occurrence and abundance – Sample N12-3044.80: uncommon. Samples N12-3039.50 to N12-2993.50: common. Sample N12-2984: abundant. Sample N12-2976.50: common. Samples Uc101-4127.00 and Uc101-4124.00: common.

Previous records – *Stellechinatum uncinatum* (Downie) Molyneux, 1987 has been recorded worldwide in uppermost Cambrian through Silurian sediments. Type material is from the Tremadoc of Shropshire, England (Downie, 1958). Volkova (1990) recorded specimens of *S. uncinatum* from the uppermost Cambrian of the East European Platform; other Upper Cambrian occurrences are questionable (see above). Paalits (1995) reported the first occurrence of a form attributed to *Stellechinatum* aff. *uncinatum* at Tõnismagi, north Estonia, from just below the base of the *C. lindstromi* conodont Zone (lowermost Tremadoc). In Algerian Sahara, *S. uncinatum* seems to first occur in lowermost Tremadoc strata [Jardiné *et al.*, 1974, p. 103, text-fig. 3; as *Goniosphaeridium* cf. *uncinatum* (Downie) Kjellström]. Tremadoc occurrences have been recorded in North Africa by Deunff & Massa (1975; Libya) and Elaouad-Debbaj (1988; Morocco). For detailed listings of other occurrences, see Welsch (1986, pp. 50–51) and Elaouad-Debbaj (1988, p. 102).

Stratigraphic range verified by independent age control – Lowest record: Upper Cambrian (*Parabolina spinulosa* trilobite Zone), eastern Newfoundland, Canada (Martin *in* Martin & Dean, 1988). Highest record: middle Caradoc, Bothnian Sea (dating based on ostracods, Tynni, 1975).

Genus STELLIFERIDIUM Deunff, Górká & Rauscher, 1974

Type species – *Stelliferidium striatulum* (Vavrdová) Deunff, Górká & Rauscher, 1974; by original designation.

Discussion – In a recent paper, Servais & Eisehardt (1995) revised the taxonomic concept of the «galeate» acritarch plexus, including the genera *Stelliferidium*, *Cymatiogalea*, *Priscogalea*, and *Caldariola*. They proposed restriction of *Stelliferidium* to species showing the following features: «striae radiating from the base of the processes ... not connected, but limited by polygonal meshes, forming fields in which the processes are centred» (Servais & Eisehardt, 1995, pp. 196–198). According to the latter authors most of the species currently attributed to *Stelliferidium* do not

correspond to this description (deduced from the illustration of the holotype), in that they show «star-shaped striae at the base of the processes». Moreover, «these striae are connected together forming polygonal (triangular) fields (the processes are at the corners of polygonal fields)»: Servais & Eisehardt, (1995, p. 196). In the present author's opinion this sculptural distinction should not be considered of generic significance. In fact it seems quite subjective to decide if a given process is located at the centre or at the corner of a polygonal field when the striae are interconnected (a rare situation indeed: see Rauscher, 1974b, text-fig. 24). The number, length, and thickness of the star-shaped striae radiating from process bases are all variable characters which realistically should be considered of no more than specific (i.e., intrageneric) value.

Accordingly, the interpretation of *Stelliferidium* by Deunff, Górká & Rauscher (1974) is accepted herein.

STELLIFERIDIUM CORTINULUM (Deunff) emend.

Deunff, Górká & Rauscher, 1974

Pl. 7, fig. 10; pl. 8, fig. 7

1961 *Priscogalea cortinula* DEUNFF, p. 41; pl. 1, figs. 8, 10.

1964 *Baltisphaeridium cortinula* (Deunff) DEUNFF, p. 120; pl. 1, fig. 10.

1973 *Priscogalea cortinula* (Deunff) MARTIN, pp. 15–16; pl. 1, figs. 2–4, 12, 13; pl. 4, figs. 13, 15; text-fig. 5.

1974 *Stelliferidium cortinulum* (Deunff) emend. DEUNFF, GÓRKA & RAUSCHER, p. 14; pl. 3, figs. 3, 4, 6; pl. 4, fig. 5; pl. 6, figs. 1, 13; pl. 7, figs. 9, 12.

non 1988 *Stelliferidium cortinulum* (Deunff) emend. Deunff, Górká & Rauscher - Tongiorgi *in* BAGNOLI, STOUGE & TONGIORGI, pl. 35, fig. 8.

non 1990 *Stelliferidium cortinulum* (Deunff) emend. Deunff, Górká & Rauscher - TONGIORGI & RIBECAL, pl. 1, fig. 5.

? 1992 *Stelliferidium cortinulum* (Deunff) emend. Deunff, Górká & Rauscher - PAALITS, pl. 6, fig. 6.

Dimensions – Vesicle diameter 24 (28) 35 µm; length of antapical processes 6–8 µm, basal diameter of processes 1.5–2 µm, number of processes 25–35 (based on 42 specimens).

Remarks and comparison – Process length gradually decreases toward the polar opening, which is devoid of processes. This characteristic, though not mentioned in either the original diagnosis (Deunff, 1961) or in the emended one (Deunff *et al.*, 1974), is clearly observable in the holotype. Intraspecific variability concerns mainly vesicle and process dimensions. Specimens attributed to *Stelliferidium cortinulum* (Deunff) emend. Deunff *et al.*, 1974 by Tongiorgi (*in* Bagnoli *et al.*, 1988) and by

Tongiorgi & Ribecai (1990) from the Upper Cambrian-Tremadoc of Öland, Sweden, have a polar opening rimmed with short processes. Moreover, the number of processes in the form figured by Tongiorgi & Ribecai (1990, pl. 1, fig. 5) is significantly greater (50-60) than that normally recorded for *S. cortinulum* (ca. 30). Accordingly, these Öland specimens are here excluded from Deunff's species. The Estonian Upper Cambrian specimen figured by Paalits (1992) has very robust processes, mainly developed on the aboral portion of the vesicle, and its attribution to *S. cortinulum* is regarded here as questionable.

Occurrence and abundance – Samples NL2-3044.80 to NL2-2993.50: common. Samples NL2-2984.50 and 2976.50: uncommon. Samples Uc101-4127.00 and Uc101-4124.00: common.

Previous records – Uppermost Cambrian: Estonia (Mens *et al.*, 1989, 1993; no figured specimens). Uppermost Cambrian-basal Tremadoc: Random Island, eastern Newfoundland, Canada (Martin *in* Martin & Dean, 1981; Martin, 1982; no figured specimens); Belgium (Vanguetstaine, 1973; no figured specimens). Uppermost Cambrian-Arenig: southwest Sardinia (Pittau, 1985). Lower Tremadoc: Mouthoumet Massif, France (Baudelot & Bessière, 1977); Brabant Massif, Belgium (Martin, 1977); Shropshire, England (Rasul & Downie, 1974); central Sardinia (Di Milia & Tongiorgi, 1993). Tremadoc: Algeria (Baudelot *et al.*, 1981); Montagne Noire, France (Martin, 1973); Libya (Deunff & Massa, 1975); Algerian Sahara (Deunff, 1961, 1964; Combaz, 1967; Jardiné *et al.*, 1974; Deunff *et al.*, 1974); Shropshire, England (Rasul, 1979). Upper Tremadoc-Arenig: Mouthoumet Massif, France (Cocchio, 1982). Caradoc: Shropshire, England (Turner, 1982; reworked specimens).

Stratigraphic range verified by independent age control – Lowest record: Upper Cambrian (*Peltura* trilobite Zone), Random Island, eastern Newfound-

land, Canada (Martin *in* Martin & Dean, 1981; no figured specimens). Highest record: Tremadoc (*Clonograptus tenellus* graptolite Zone), Shropshire, England (Rasul, 1979).

STELLIFERIDIUM DISTINCTUM (Rasul)

Elaouad-Debbaj, 1988

Pl. 8, fig. 8

1974 *Priscogalea distincta* RASUL, p. 50; pl. 4, fig. 1; pl. 7, fig. 3.
1988 *Stelliferidium distincta* (Rasul) ELAOUAD-DEBBAJ, p. 106; pl. 1, figs. 6, 7, 8.

Dimensions – Vesicle diameter 27 (31) 34 μ m; length of process trunks 4-5 μ m, length of pinnae 1.5-3.5 μ m, basal width of processes ca. 1.5 μ m, number of processes 50-70 (based on 44 specimens).

Comparison – *Stelliferidium distinctum* (Rasul) Elaouad-Debbaj, 1988 differs from *S. furcatum* (Deunff) emend. Deunff *et al.*, 1974 in having longer and more robust processes. *S. gautieri* (Martin) Pittau, 1985 has less numerous processes with digitate distal termini.

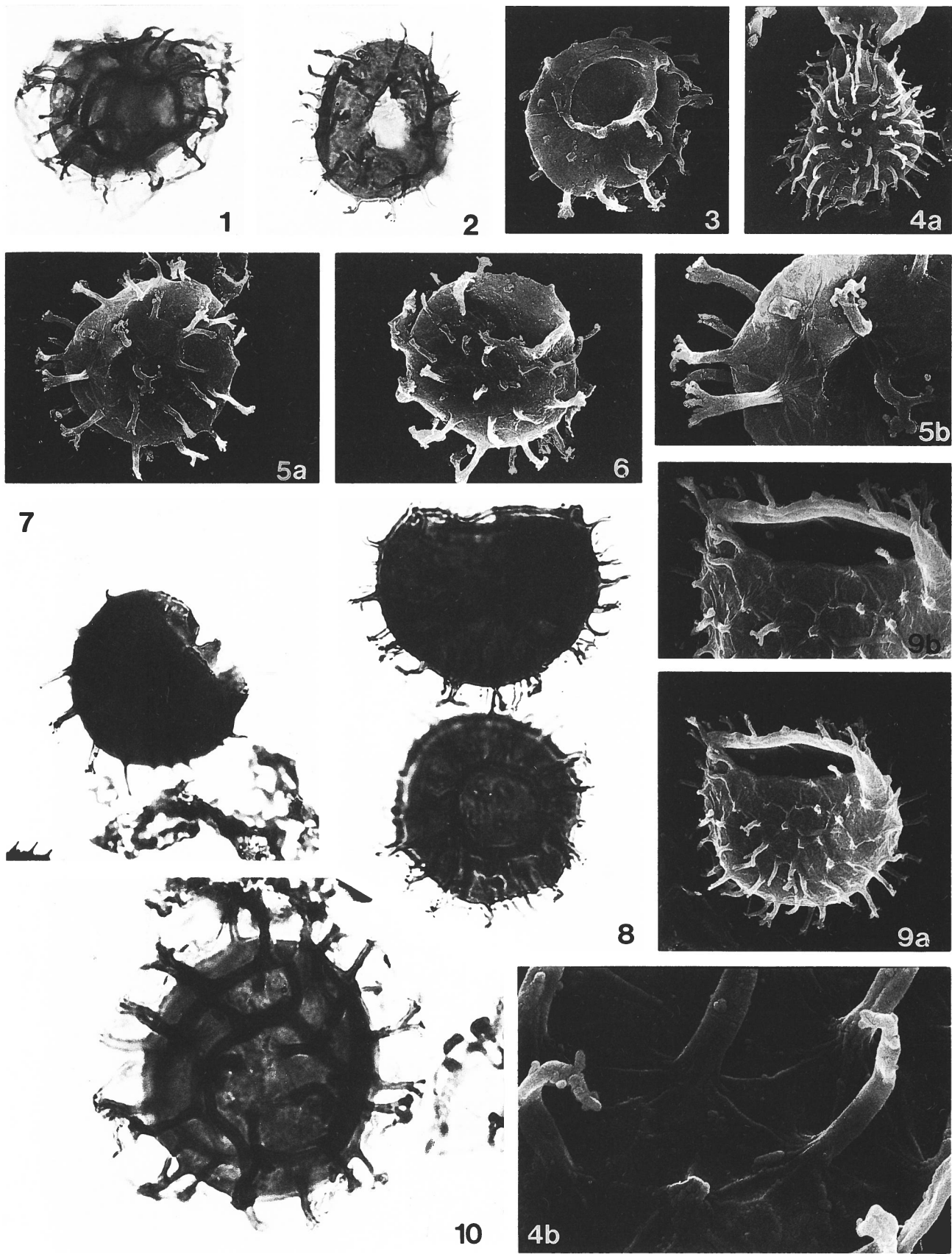
Occurrence and abundance – Samples NL2-3066.10 to NL2-3060.10: rare. Sample NL2-3054.75: common. Sample NL2-3050.15: very common. Samples NL2-3044.80 to NL2-3039.50: rare. Samples NL2-3044.80 to NL2-3037.45: rare.

Previous records – Lower Tremadoc: Morocco (Elaouad-Debbaj, 1988). Tremadoc: Shropshire, England (Rasul, 1974; Rasul & Downie, 1974). Lower Tremadoc?-Arenig: southwest Sardinia (Pittau, 1985).

Stratigraphic occurrence verified by independent age control – Lower Tremadoc (*Rhabdinopora flabelliformis* s. l. graptolite Zone), Anti-Atlas, Morocco (Elaouad-Debbaj, 1988).

EXPLANATION OF PLATE 8

- Figs. 1, 3, 6, 10 – *Stelliferidium velatum* n. sp. 1) x 1000. 3) x 1000. 6) x 1000. 10) holotype, x 1500.
Figs. 2, 5 – *Stelliferidium gautieri* (Martin) Pittau, 1985. 2) x 1000. 5a) x 1000; 5b) detail of processes and eilyma, x 2000.
Figs. 4, 9 – *Stelliferidium stelligerum* (Deunff) emend. Deunff *et al.*, 1974. 4a) x 1000; 4b) detail of process bases and eilyma sculpture, x 5000. 9a) x 1500; 9b) detail of polar opening, x 2000.
Fig. 7 – *Stelliferidium cortinulum* (Deunff) emend. Deunff *et al.*, 1974; x 1000.
Fig. 8 – *Stelliferidium distinctum* (Rasul) Elaouad-Debbaj, 1988; two specimens, x 1000.
For locality, stratigraphic, and curatorial details see Appendices 1, 2.



STELLIFERIDIUM FURCATUM (Deunff) emend. Deunff,
Górka & Rauscher, 1974
Pl. 7, figs. 7, 8, 11

- 1961 *Priscogalea furcata* DEUNFF, p. 41; pl. 1, fig. 11.
1964 *Baltisphaeridium furcatum* (Deunff) DEUNFF, p. 121; pl. 1, fig. 4.
1974 *Stelliferidium furcatum* (Deunff) emend. DEUNFF, GÓRKA & RAUSCHER, p. 14; pl. 7, fig. 14.

Dimensions – Vesicle diameter 25 (28) 32 μm ; length of antapical processes ca. 4 μm , length of processes around the polar opening 1.5–2 μm , length of pinnae ca. 1 μm , basal diameter of processes ca. 1 μm , number of processes 60–70 (based on 55 specimens).

Remarks – The original diagnosis of *Stelliferidium furcatum* is incomplete, apparently based only on the holotype. The emended diagnosis by Deunff *et al.* (1974) does not add significant information on morphological or size variability. The numerous short processes, commonly bi- or trifurcated distally into very short pinnae, are considered here to be definitive for this species.

Occurrence and abundance – Samples N12-3044.80 and N12-3039.50: uncommon. Sample N12-3037.45 and N12-3014.00: common. Sample 3009.50: abundant. Sample N12-2993.50: uncommon. Samples N12-2984.50 and N12-2976.50: rare. Samples Uc101-4127.00 and Uc101-4124.00: common.

Previous records – Lower Tremadoc: central Sardinia (Di Milia & Tongiorgi, 1993). Tremadoc: North Africa (Deunff, 1961, 1964; Deunff *et al.*, 1974); Öland, Sweden (Tongiorgi in Bagnoli *et al.*, 1988).

Stratigraphic occurrence verified by independent age control – Upper Tremadoc (*Paltodus deltifer* conodont Zone), Öland, Sweden (Tongiorgi in Bagnoli *et al.*, 1988).

STELLIFERIDIUM GAUTIERI (Martin) Pittau, 1985
Pl. 8, figs. 2, 5

- 1973 *Priscogalea gautieri* MARTIN, pp. 21–22; pl. 3, fig. 13; pl. 5, fig. 21; pl. 6, fig. 3; pl. 7, figs. 9, 10; pl. 10, figs. 1–6; pl. 11, figs. 1–6.
1985 *Stelliferidium gautieri* (Martin) PITTAU, p. 195; pl. 7, fig. 14.
1988 *Stelliferidium* sp. cf. *S. gautieri* (Martin) Pittau - ELAOUAD-DEBBAJ, p. 106; pl. 2, figs. 7, 8.

Dimensions – Vesicle diameter 24 (29) 34 μm ; length of antapical processes 7–9 μm , length of

processes around the polar opening 3–4 μm , basal diameter of processes 1.5–2 μm , number of processes 30–40 (based on 35 specimens).

Remarks and comparison – *Stelliferidium gautieri* differs from *S. cortinulum* in having the polar opening rimmed with very short processes and, commonly, in having longer distal processes. Moroccan specimens figured by Elaouad-Debbaj (1988, pl. 2, figs. 7, 8) do not differ in any diagnostic character from the type species.

Occurrence and abundance – Sample N12-3066.10: rare. Samples N12-3063.70 to 3050.15: uncommon. Samples N12-3044.80 to N12-3037.45: rare.

Previous records – Uppermost Cambrian-lower Tremadoc: Random Island, eastern Newfoundland, Canada (Martin in Martin & Dean, 1981). Lower Tremadoc: Anti-Atlas, Morocco (Elaouad-Debbaj, 1988); Montagne Noire, France (Martin, 1973). Tremadoc-Arenig: southwest Sardinia (Pittau, 1985).

Stratigraphic range verified by independent age control – Lowest record: Upper Cambrian (*Acerocare* trilobite Zone), Random Island, eastern Newfoundland, Canada (Martin in Martin & Dean, 1981). Highest record: lower Tremadoc (beds containing graptolites of the *Rhabdinopora* group), Anti-Atlas, Morocco (Elaouad-Debbaj, 1988).

STELLIFERIDIUM SIMPLEX (Deunff) emend. Deunff,
Górka & Rauscher, 1974
Pl. 7, fig. 12

- 1961 *Priscogalea simplex* DEUNFF, p. 41; pl. 1, fig. 9.
1964 *Baltisphaeridium simplex* (Deunff) DEUNFF, p. 121; pl. 1, figs. 14, 15.
1974 *Stelliferidium simplex* (Deunff) emend. DEUNFF, GÓRKA & RAUSCHER, p. 15; pl. 5, figs. 5, 6; pl. 6, figs. 3, 17.

Dimensions – Vesicle diameter 27 (31) 38 μm ; length of antapical processes 4–9 μm , length of processes around the polar opening 2–4 μm , basal diameter of processes ca. 1 μm , number of processes 70–80 (based on 30 specimens).

Remarks – Diagnostic features of *Stelliferidium simplex* (Deunff) Deunff *et al.*, 1974 are numerous, closely spaced, slender and mostly simple processes. Eilyma sculpture consists of faint striae radiating from process bases, with psilate to shagrinete eilyma between the striae.

Occurrence and abundance – Sample N12-3014.00: common. Sample N12-3009.50: abundant. Samples

Nl2-2993.50 to Nl2-2976.50: common. Samples Uc101-4127.00 and Uc101-4124.00: common.

Previous records – Uppermost Cambrian(?)–lower Tremadoc: Stavelot Massif, Belgium (Vanguetaine, 1967, 1974). Lower Tremadoc: Shropshire, England (Rasul, 1974, 1979; Downie, 1984); north Estonia (Volkova & Mens, 1988); central Sardinia (Di Milia & Tongiorgi, 1993). Tremadoc: Algerian Sahara (Deunff, 1961, 1964); Montagne Noire, France (Martin, 1973); Mouthoumet Massif, France (Baudelot & Bessière, 1977; Cocchio, 1982); Sierra Morena, Spain (Wolf, 1980). Upper Tremadoc: Öland, Sweden (Tongiorgi in Bagnoli *et al.*, 1988). Tremadoc–Arenig: southwest Sardinia (Pittau, 1985).

Stratigraphic occurrence verified by independent age control – Upper Tremadoc (*Paltodus deltifer* conodont Zone), Öland, Sweden (Tongiorgi in Bagnoli *et al.*, 1988).

STELLIFERIDIUM STELLIGERUM (Górka) emend.
Deunff, Górka & Rauscher, 1974
Pl. 8, figs. 4, 9

- 1965 *Peteinosphaeridium?* sp. STAPLIN, JANSONIUS & POCKOCK, p. 195; pl. 18, figs. 19, 20.
1967 *Cymatigalea stelligera* GÓRKA, pp. 2-3; pl. 1, figs. 1-4.
1974a *Priscogalea stelligera* (Górka) VANGUESTAINE, p. 70; pl. 2, fig. 9.
1974 *Stelliferidium stelligerum* (Górka) emend. DEUNFF, GÓRKA & RAUSCHER, pp. 15-16; pl. 1, figs. 1-5; pl. 2, figs. 1-6; pl. 3, figs. 1, 2, 5, 7; pl. 5, figs. 3, 4; pl. 7, fig. 13.

Dimensions – Vesicle diameter 25 (28) 33 μm ; length of antapical processes 5-8 μm , length of processes around the polar opening 2-3 μm , basal diameter of processes *ca.* 1 μm , number of processes 50-60 (based on 15 specimens).

Remarks – The conspicuous striae (generally 5-6), radiating from the base of each process, reach the adjacent process base, so that the vesicle surface is effectively subdivided into polygonal (triangular to hexagonal) fields. Morphological variability of *Stelliferidium stelligerum* (Deunff) emend. Deunff *et al.*, 1974 includes the length of the processes and their distal ends, which may be either simple or subdivided into short pinnae and then very short pinnulae up to second order.

Occurrence and abundance – Sample Nl2-3014.00: rare. Sample Nl2-3009.50: uncommon. Sample Nl2-2984.50: very rare. Samples Uc101-4127.00 and Uc101-4124.00: rare.

Previous records – Lower Tremadoc: central Sardinia (Di Milia & Tongiorgi, 1993). Tremadoc: Montagne Noire, France (Martin, 1973; Rauscher, 1971, 1974a); Mouthoumet Massif, France (Baudelot & Bessière, 1977; Cocchio, 1982); Spain (Wolf, 1980; Mette, 1989). Upper Tremadoc: Öland, Sweden (Tongiorgi in Bagnoli *et al.*, 1988); Poland (Górka, 1967, 1969). Tremadoc–Arenig boundary: Spain (Wolf, 1980). Arenig: Montagne Noire, France (Rauscher, 1974b); central Sardinia (Albani *et al.*, 1985a). Upper Arenig: Morocco (Elaouad-Debbaj, 1984). Caradoc: England (Turner, 1982; reworked specimens).

Stratigraphic occurrence verified by independent age control – Upper Tremadoc (*Paltodus deltifer* conodont Zone), Öland, Sweden (Tongiorgi in Bagnoli *et al.*, 1988).

STELLIFERIDIUM VELATUM n. sp.
Pl. 8, figs. 1, 3, 6, 10

Diagnosis – Vesicle originally spherical, outline subcircular but modified by excystment opening. Eilyma thick (*ca.* 1 μm), apparently single-layered, sculptured with faint striae radiating from process bases. Numerous (*ca.* 30-40) processes uniformly distributed on vesicle surface. Process trunk cylindrical, hollow, not communicating with vesicle cavity. Distal portion of processes commonly forked with 2 robust pinnae bearing very short pinnulae of first and second orders. Wall of processes psilate. All processes linked, throughout their entire length, by radial, transparent, psilate-shagrinat membranes. Maximum length of processes *ca.* 1/4 of vesicle diameter. Processes normally long and broad in antapical portion of vesicle, shorter and slender around excystment opening. In unexcysted specimens, margin of polar opening, rimmed with short processes, is slightly elevated, to form a $\pm$ prominent ring. Operculum subcircular to subpolygonal, rimmed by a thin, transparent ring, and bearing a few, small processes.

Dimensions – Vesicle diameter 26 (28) 30 μm ; length of antapical processes *ca.* 7 μm , length of processes around the polar opening 3-4 μm , basal diameter of antapical processes *ca.* 1.5 μm , number of processes 30-40 (based on 52 specimens).

Holotype – Slide CPT203036-01; pl. 8, fig. 10. Vesicle diameter 28 μm , length of antapical processes 7 μm , number of processes 30, spacing regular (about 4 μm apart), diameter of polar opening 14 μm , inter-process membranes shagrinat.

Type locality – Algerian Sahara, Bordj Nili, «Grès de Bordj Nili» unit, N12 borehole, core 54, sample N12-3037.45; lowermost Tremadoc.

Name derivation – Lat. *velatum*, veiled.

Remarks and comparison – The presence of transparent membranes together with the striae radiating on the eilyma from process bases are diagnostic features of *Stelliferidium velatum* n. sp. The membrane may be partly or totally lost (as a result of sample processing and/or preservational degradation). Where the membranes are completely gone, recognition of this species can be difficult, and such specimens (showing all the other diagnostic characters) are tentatively attributed here to *S. velatum*. *S. philippotii* (Henry) Deunff *et al.*, 1974, from the Llanvirn-Llandeilo of Brittany, France, is sufficiently close to *S. velatum* to merit comparison with it. Both species have multifurcate processes linked by transparent membranes, but *S. philippotii* differs from *S. velatum* in having more numerous, shorter processes and larger vesicle diameter.

Occurrence and abundance – Sample N12-3044.80: rare. Sample N12-3039.50: common. Sample N12-3037.45: abundant. Samples N12-3014.00 and N12-2993.50: rare. Sample N12-2984.50: very rare.

STELLIFERIDIUM spp. indet.

Remarks – Badly preserved specimens of *Stelliferidium*, unidentifiable at specific level, occur in the lower part of borehole N12 (samples N12-3075.75 to N12-3063.70) and in sample Uc101-4298.75. Incompleteness in morphology, often owing to erosion of distal terminations of processes, impedes a positive specific identification, while the characteristic striae radiating from process bases are always preserved on the vesicle surface.

Genus TIMOFEEVIA Vanguetaine, 1978

Type species – *Timofeevia lancarae* (Cramer & Diez) Vanguetaine, 1978; by original designation.

TIMOFEEVIA PHOSPHORITICA Vanguetaine, 1978
Pl. 9, figs. 1, 2

1978 *Timofeevia phosphoritica* VANGUESTAINE, p. 272-274; pl. 3, figs. 1-8, 10-12; text-fig. 11.

Dimensions – Vesicle diameter 24 (28) 31 μm ; length of processes 4-8 μm , basal diameter of

processes 1.5-2 μm , number of processes 20 (24) 33; diameter of polygonal fields 8-10 μm , number of polygonal fields ca. 15 (based on 16 specimens).

Remarks and comparison – Specimens recorded here are generally flattened and slightly corroded. Only rarely are processes fully preserved: in general, their distal ends are partly or entirely missing. Nevertheless, morphological features and dimensional ranges correspond well with Vanguetaine's (1978) original diagnosis of *Timofeevia phosphoritica*. Length and branching of processes are variable characters for this species but, generally speaking, well-preserved specimens of this study have short processes (average length 5 μm) and very short pinnae. Eilyma is psilate to scabrate. Öland (Sweden) specimens described by Tongiorgi (*in Bagnoli et al.*, 1988, pp. 206-207) have polygonal (hexagonal or pentagonal) fields arranged in a definite geometrical pattern of hexagonal symmetry. The present specimens apparently do not exhibit such a regular pattern of polygonal fields, but their scarcity and inimical state of preservation inhibit closer comparisons.

Occurrence and abundance – Sample N12-3088.55: questionably present. Sample N12-3082.80: very rare. Sample N12-3075.75: uncommon. Sample N12-3073.50: rare. Sample N12-3066.10: very rare. Samples N12-3063.70 and N12-3060.70: rare. Sample N12-3054.75: questionably present.

Previous records – *Timofeevia phosphoritica* Vanguetaine, 1978 occurs commonly in Middle through Upper Cambrian deposits, virtually worldwide. Tremadoc and later occurrences have been interpreted as reworked. More recent reports are cited below; for details of other occurrences see Welsch (1986), Tongiorgi (*in Bagnoli et al.*, 1988), and Martin (*in Martin & Dean*, 1988).

Upper Cambrian: East European Platform (Volkova, 1990); north Estonia (Paalits, 1992, 1995; Mens *et al.*, 1989, 1993; Volkova & Mens, 1988); Öland, Sweden (Di Milia *et al.*, 1989); Stavelot and Rocroi Massifs, Belgium and northern France (Ribecai & Vanguetaine, 1993).

Stratigraphic range verified by independent age control – Lowest record: Middle Cambrian (*Paradoxides paradoxissimus* trilobite Superzone), eastern Newfoundland, Canada (Martin *in* Martin & Dean, 1981, 1988). Highest record: Upper Cambrian (*Peltura* and, perhaps, *Acerocare* p.p. trilobite Zone), eastern Newfoundland, Canada (Martin *in* Martin & Dean, 1981, 1988) and Finnmark, Norway (Welsch, 1986).

TIMOFEEVIA sp. aff. *T. MICRORETIS* Martin, 1981
Pl. 9, fig. 5

aff. 1981 *Timofeevia microretis* Martin in MARTIN & DEAN, p. 21; pl. 2, figs. 4, 10, 13, 16, 17.

Description – Vesicle circular or subpolygonal in outline. Eilyma thin (<0.5 µm thick), transparent, single-layered, psilate to shagrinata. Processes homomorphic, cylindrical, hollow, freely communicating with vesicle interior; distally branched, forming 2 large pinnae, each divided distally as thin, thread-like pinnulae up to second order; pinnulae sometimes anastomosing. Processes arranged at edges of subpolygonal fields. Process walls undifferentiated with respect to eilyma. No excystment opening observed.

Dimensions – Vesicle diameter ca. 30 µm; length of process trunks 6-15 µm, length of pinnae 2-6 µm, length of filamentous pinnulae 3-7 µm, number of processes ca. 30; diameter of polygonal fields 7-9 µm (based on 5 specimens).

Remarks and comparison – The present specimens resemble *Timofeevia microretis* Martin, 1988 in possessing subpolygonal fields (albeit not always easily discernible) and in the nature of distal process branching. *T. microretis* has at least twice as many processes and anastomosing filamentous threads forming «a loose network around the whole vesicle» (Martin in Martin & Dean, 1988, p. 21). Distal branches of processes in specimens reported here sometimes anastomose, but usually remain separated. Attribution to *Timofeevia* is based on the presence of subpolygonal fields.

Occurrence and abundance – Samples N12-3060.70 and N12-3037.45: very rare.

Genus TRUNCULUMARIUM Loeblich & Tappan, 1976

Type species – *Trunculumarium revinium* (Vanguestaine) Loeblich & Tappan, 1976; by original monotypic designation.

TRUNCULUMARIUM sp. 1
Pl. 7, fig. 3

1992 *Trunculumarium* aff. *revinium* PAALITS, pl. 2, figs. 1, 2; pl. 3, figs. 1, 2.

Description – Vesicle elliptical to oval in outline. Eilyma apparently single-layered, ca. 0.5 µm thick,

faintly granulate. Processes, located on one polar region, apparently hollow, spine-like, short, mostly simple, rarely bifurcating. Distal ends of processes blunt or acuminate. Process walls psilate. No excystment structure observed.

Dimensions – Vesicle length 26 (31) 35 µm, vesicle width 22 (27) 30 µm; length of processes 3-6 µm, basal width of processes ca. 0.5 µm, number of processes 18-26 (based on 17 specimens).

Remarks and comparison – Dimensions of processes vary significantly among specimens recorded herein; ratio of vesicle length: process length ranges from ca. 1/6 to 1/15. This species differs from the Upper Cambrian type species *Trunculumarium revinium* (Vanguestaine) Loeblich and Tappan, 1976 in having shorter, psilate processes. Upper Cambrian Estonian specimens designated informally as *Trunculumarium* aff. *revinium* by Paalits (1992) are seemingly identical with the study specimens.

Occurrence and abundance – Sample N12-3066.10: very rare. Samples N12-3063.70 and N12-3060.70: rare. Sample N12-3054.75: common. Sample N12-3050.15: abundant.

Genus VERYHACHIUM Deunff, 1954 emend. Sarjeant & Stancliffe, 1994

Type species – *Veryhachium trisulcum* (Deunff) Deunff, 1959; by subsequent designation of Downie (1959, p. 62).

VERYHACHIUM DUMONTII Vanguestaine, 1973
Pl. 9, figs. 3, 4

1973 *Veryhachium dumontii* VANGUESTAINE, p. 28; pl. 1, figs. 1, 2, 8.

Dimensions – Vesicle length 24 (27) 30 µm, maximum width of vesicle 15 (20) 25 µm; length of processes 10-15 µm (based on 11 specimens).

Remarks – Only poorly preserved specimens were encountered. Owing to the thinness of eilyma most specimens are broken or irregularly distorted. The better preserved specimens show the characteristic isosceles-triangular shape and densely granulate eilyma. No secondary processes (cf. Martin in Martin & Dean, 1988, p. 42) were observed in the Algerian specimens.

Occurrence and abundance – Samples N12-3082.80 to N12-3073.50: very rare. Samples N12-3066.10 to N12-3054.75: rare. Sample N12-3050.15: uncommon.

Previous records – Upper Cambrian: eastern Newfoundland, Canada (Martin *in* Martin & Dean, 1981, 1988; Martin, 1982); Stavelot and Rocroi Massifs, Belgium and northern France (Vanguetaine, 1973; Ribecai & Vanguetaine, 1993); East European Platform (Volkova, 1990); Montcornet-en-Ardenne, France (Meille & Vanguetaine, 1983). Uppermost Cambrian: Estonia (Mens *et al.*, 1989, 1993; Paalits, 1992, 1995; Volkova, 1993). Lower Tremadoc: central Sardinia (Di Milia & Tongiorgi, 1993; reworked specimens).

Stratigraphic range verified by independent age control – Lowest record: Upper Cambrian (*Parabolina spinulosa* trilobite Zone), Random Island, eastern Newfoundland, Canada (Martin *in* Martin & Dean, 1981, 1988). Highest record: ?lowermost Tremadoc (a single specimen found in a sample containing the trilobite *Parabolina* cf. *P. argentina*), eastern Newfoundland, Canada (Martin *in* Martin & Dean, 1988).

Genus VULCANISPHAERA Deunff, 1961 emend.
Rasul, 1976

Type species – *Vulcanisphaera africana* Deunff, 1961; by original designation.

VULCANISPHAERA AFRICANA Deunff, 1961
Pl. 9, figs. 9, 10

- 1958 *Hystriosphæridium* sp. DOWNIE, p. 340; pl. 16, fig. 10.
1961 *Vulcanisphaera africana* DEUNFF, p. 42; pl. 2, fig. 1.
1967 *Vulcanisphaera africanum* Deunff - COMBAZ, pl. 2, fig. 42.
1974a *Vulcanisphaera* RAUSCHER, pl. 1, figs. 1, 2.
1976 *Vulcanisphaera cirrita* RASUL, pp. 480-481; pl. 1, fig. 3; text-fig. 1:2.

Dimensions – Vesicle diameter 29 (38) 49 µm; length of primary shafts 3-5 µm, number of primary shafts 45-50, length of processes 6-17 µm (based on 52 specimens).

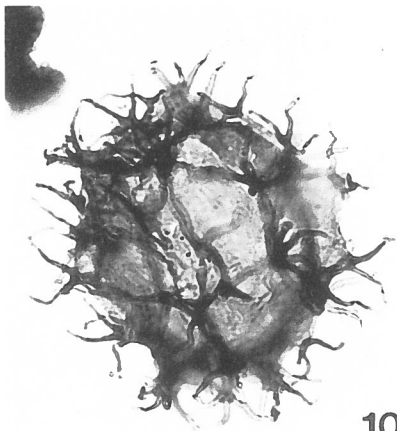
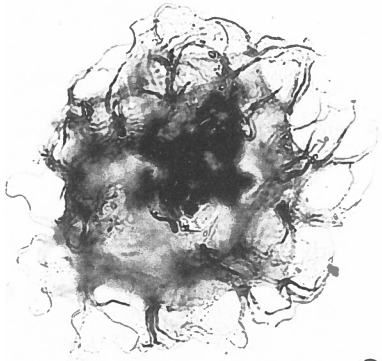
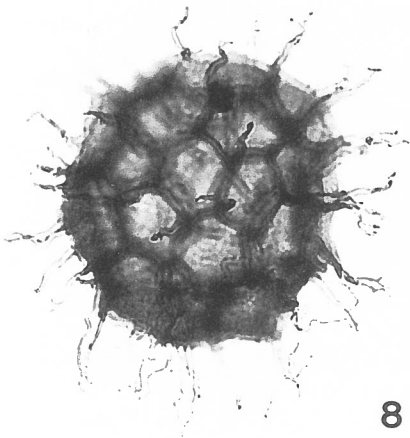
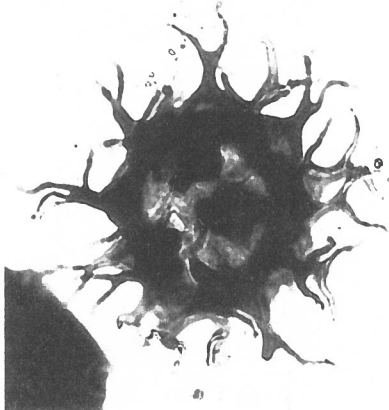
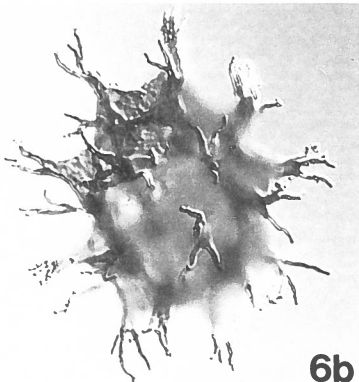
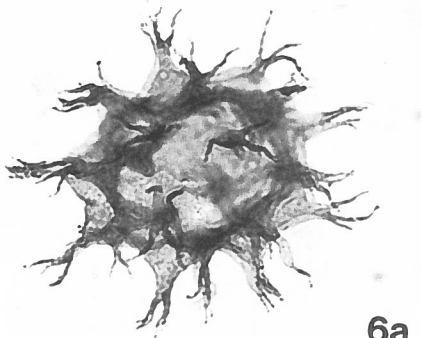
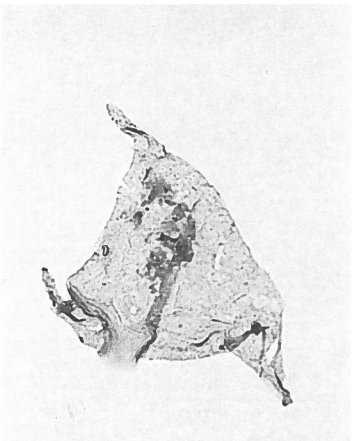
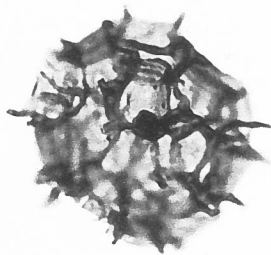
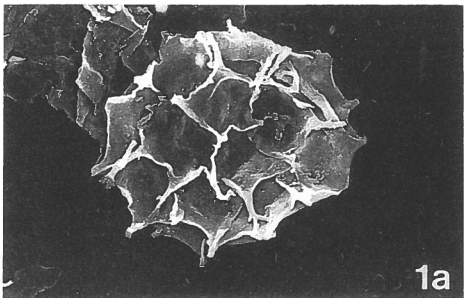
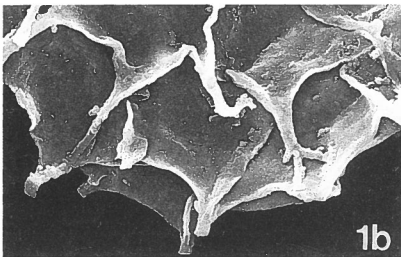
Remarks – The number, dimensions, and density of anastomosing process threads vary considerably. This variation shows no break in continuity between forms having rigid processes with short distal ramifications to those featuring longer and more flexible processes with numerous, thin, elongate, anastomosing ramifications. The variability of *Vulcanisphaera africana* was not originally diagnosed (Deunff, 1961), but was subsequently pointed out by Rauscher (1974b), Martin (*in* Martin & Dean, 1981), and Welsch (1986). Accepting this variability, *V. cirrita* Rasul, 1976, which putatively differs from *V. africana* only in having longer and thinner distal process ramifications, is considered here a junior synonym of *V. africana*.

Occurrence and abundance – Samples N12-3075.75 and N12-3073.50: very rare. Sample N12-3066.10: rare. Samples N12-3063.70 to 3044.80: uncommon. Samples N12-3039.50 to N12-3009.50: abundant. Samples N12-2993.50 to N12-2976.50: common. Samples Uc101-4127.00 and Uc101-4124.00: common.

Previous records – Upper Cambrian: Öland, Sweden (Di Milia *et al.*, 1989; Tongiorgi & Ribecai, 1990); Stavelot and Rocroi Massifs, Belgium and northern France (Ribecai & Vanguetaine, 1993). Upper Cambrian-lower Tremadoc: Random Island, eastern Newfoundland, Canada (Martin *in* Martin & Dean, 1981, 1988). Lower Tremadoc: Mouthoumet Massif, France (Baudelot & Bessière, 1977). Tremadoc: Kielce, Poland (Górka, 1967); Shropshire, England (Downie 1958; Rasul & Downie, 1974; Rasul, 1976); Lake District, England (Molyneux & Rushton, 1985); Algerian Sahara (Deunff, 1961; Combaz, 1967; Jardiné *et al.*, 1974); Anti-Atlas, Morocco (Elaouad-Debbaj, 1988); northern Iran (Ghavidel-

EXPLANATION OF PLATE 9

- Figs. 1, 2 - *Timofeevia phosphoritica* Vanguetaine, 1978. 1a) x 1000; 1b) detail of polygonal fields and processes, x 2000. 2) x 1000.
Figs. 3, 4 - *Veryhachium dumontii* Vanguetaine, 1973. 3) x 1250. 4) x 1000.
Fig. 5 - *Timofeevia* sp. aff. *T. microretis* Martin, 1981; x 1000.
Figs. 6, 7 - *Vulcanisphaera britannica* forma 2 of Rasul, 1976. 6a) x 1250; 6b) same specimen as fig. 6a, interference contrast, x 1250.
Fig. 8 - *Vulcanisphaera capillata* Jardiné *et al.*, 1974; x 1000.
Figs. 9, 10 - *Vulcanisphaera africana* Deunff, 1961. 9) x 1000. 10) x 1000.
For locality, stratigraphic, and curatorial details see Appendices 1, 2.



Syooki, 1995); Brabant Massif, Belgium (Martin, 1969, 1977); Montagne Noire, Hérault, France (Rauscher, 1971, 1974a, 1974b; Martin, 1973; Fournier-Vinas, 1978); Mouthoumet Massif, France (Baudelot & Bessière, 1977). Upper Tremadoc-Arenig: Lake District, England (Molyneux & Rushton, 1988); southwest Sardinia (Pittau, 1985); Bell Island, eastern Newfoundland, Canada (Martin in Dean & Martin, 1978, Martin, 1982). Caradoc: Shropshire, England (Turner, 1982; reworked specimens).

Stratigraphic range verified by independent age control – Lowest record: Upper Cambrian (*Parabolina spinulosa* trilobite Zone), Random Island, eastern Newfoundland, Canada (Martin in Martin & Dean, 1988). Highest record: basal Arenig (*Tetragraptus approximatus* graptolite Zone), Lake District, England (Molyneux & Rushton, 1988; Molyneux & Dorning, 1989).

VULCANISPHAERA BRITANNICA Rasul, 1976
Pl. 9, figs. 6, 7

1976 *Vulcanisphaera britannica* RASUL, pp. 482-484; pl. 1, figs. 2, 7-9, 11, 13-16, text-figs. 1:4, 5.

Dimensions – Vesicle diameter 22 (29) 35 μm ; length of primary shafts 3-5 μm , number of primary shafts ca. 25, length of processes 6-8 μm (based on 34 specimens).

Remarks – Dimensional ranges and morphological features are in accord with the description of *Vulcanisphaera britannica* forma 2 of Rasul (1976).

Occurrence and abundance – Sample N12-2993.30: very rare. Sample N12-2984.50: uncommon. Sample N12-2976.50: abundant.

Previous records – Tremadoc: Shropshire, England (Rasul, 1976, 1979); lowermost Arenig: South Wales (Molyneux & Dorning, 1989). Arenig: south west Wales (Molyneux, 1987; reworked specimens).

Stratigraphic range verified by independent age control – Lowest record: lower Tremadoc («*Dictonema flabelliforme* Beds»), Shineton Shales, Shropshire, England (Rasul, 1976). Highest record: upper Tremadoc, Shineton Shales («Arenaceous Beds»), Shropshire, England (Rasul, 1976).

VULCANISPHAERA CAPILLATA Jardiné, Combaz,
Magloire, Peniguel & Vachey, 1974
Pl. 9, fig. 8

1974 *Vulcanisphaera capillata* JARDINÉ, COMBAZ, MAGLOIRE, PENIGUEL & VACHEY, p.119; pl. 2, fig. 8.

Dimensions – Vesicle diameter 35 (41) 45 μm ; length of primary shafts ca. 3 μm , number of primary shafts 50-60, length of processes 6-15 μm (based on 35 specimens).

Remarks – As noted by Martin (in Martin & Dean, 1981), the bases of the processes delimit the angles of polygonal fields. This character is clearly visible in all the specimens here attributed to *Vulcanisphaera capillata* Jardiné et al., 1974. The filamentous threads which arise along the whole length of the processes are sometimes lost, inducing possible misidentification with species of *Timofeevia*.

Occurrence and abundance – Sample N12-3082.80: very rare. Samples N12-3075.75 to N12-3066.10: rare. Sample N12-3063.70: uncommon. Sample N12-3060.70: common. Sample N12-3054.75: uncommon. Samples N12-3050.15 to N12-3039.50: common. Sample N12-3037.45: abundant.

Previous records – Uppermost Cambrian: Estonia (Volkova, 1990). Tremadoc: eastern Newfoundland, Canada (Martin in Martin & Dean, 1981; Martin 1982); Algerian Sahara (Jardiné et al., 1974). Tremadoc-Arenig boundary: Lake District, England (Molyneux & Rushton, 1988).

Stratigraphic range verified by independent age control – Lowest record: uppermost Cambrian (*Cordylodus andresi* conodont Zone), Estonia (Volkova, 1990). Highest record: basal Arenig (*Tetragraptus approximatus* graptolite Zone), Lake District, England (Molyneux & Rushton, 1988).

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APPENDIX 1

LIST OF SAMPLES

All samples are from the finest grained cored lithologies of each formation: shales from the Argiles d'El Gassi; shales and siltstones from the Grès de Bordj Nili; and siltstones and very fine grained sandstones from the Grès de Miribel.

Borehole	Sampling depth (m)	Core number	Lithostrat. unit	Palynologically productive (P) or barren (B)
N12	2976.50	51	Argiles d'El Gassi	P
"	2984.50	"	Argiles d'El Gassi	P
"	2993.30	"	Argiles d'El Gassi	P
"	3009.50	52	Argiles d'El Gassi	P
"	3014.00	53	Argiles d'El Gassi	P
"	3037.45	54	Grès de Bordj Nili	P
"	3039.50	55	Grès de Bordj Nili	P
"	3044.80	"	Grès de Bordj Nili	P
"	3050.15	56	Grès de Bordj Nili	P
"	3054.75	"	Grès de Bordj Nili	P
"	3060.70	"	Grès de Bordj Nili	P
"	3063.70	"	Grès de Bordj Nili	P
"	3066.10	"	Grès de Bordj Nili	P
"	3073.50	58	Grès de Bordj Nili	P
"	3075.75	"	Grès de Bordj Nili	P
"	3082.80	59	Grès de Bordj Nili	P
"	3088.55	"	Grès de Bordj Nili	P
"	3093.30	"	Grès de Miribel	B
"	3094.75	"	Grès de Miribel	B
"	3095.50	60	Grès de Miribel	B
"	3101.50	"	Grès de Miribel	B
"	3102.25	"	Grès de Miribel	B
"	3102.75	61	Grès de Miribel	B
"	3104.50	"	Grès de Miribel	B
"	3106.50	"	Grès de Miribel	B
"	3107.00	"	Grès de Miribel	B
"	3110.25	62	Grès de Miribel	B
"	3114.00	"	Grès de Miribel	B
"	3114.70	"	Grès de Miribel	B
"	3115.50	"	Grès de Miribel	B
"	3117.20	63	Grès de Miribel	B
"	3117.55	"	Grès de Miribel	B
Uc 101	4124.00	40	Argiles d'El Gassi	P
"	4127.00	"	Argiles d'El Gassi	P
"	4298.75	53	Grès de Miribel	B
"	4300.70	"	Grès de Miribel	B
"	4302.10	"	Grès de Miribel	B

APPENDIX 2

REGISTER OF ILLUSTRATED SPECIMENS

Ho - holotype; Pa - paratype; Hy - hypotype.

Species and type	Plate: figure	Sample number	England finder	Catalogue number
<i>Acanthodiacrodium achrasii</i>				
Hy	1: 1	N12-3066.10	T 51/3	CPT203024-01
<i>Acanthodiacrodium baculatum</i> n. sp.				
Ho	1: 2a, b	N12-3037.45	Q50/4	CPT203036-03
<i>Acanthodiacrodium capillatum</i> n. sp.				
Ho	1: 5	N12-3039.50	N33	CPT203034-01
Pa	2: 4a, b	N12-3039.50	U33	CPT203034-05
Pa	2: 5	N12-3039.50	R38/2	CPT203034-05
<i>Acanthodiacrodium complanatum</i>				
Hy	2: 1	N12-3009.50	N38/3	CPT203047-03
Hy	2: 3	N12-3009.50	S41/1	CPT203047-03
Hy	2: 6	N12-3009.50	D27	CPT203047-01
<i>Acanthodiacrodium comptulum</i>				
Hy	1: 4a, b	N12-3014.00	R39/3	CPT203044-03
Hy	1: 6a, b	N12-3014.00	N36/1	CPT203044-04
<i>Acanthodiacrodium rotundatum</i>				
Hy	1: 3	N12-3009.50	N40	CPT203047-03
Hy	1: 8	N12-3009.50	N37	CPT203047-04
<i>Acanthodiacrodium ubui</i>				
Hy	2: 8	N12-2976.50	K30	CPT203059-01
<i>Acanthodiacrodium</i> sp. cf. <i>A. angustum</i>				
	1: 7	N12-3039.50	X36	CPT203034-01
<i>Acanthodiacrodium</i> sp. cf. <i>A. divisum</i>				
	2: 7	N12-3014.00	P50-P50/1	CPT203044-01
	3: 2	N12-3014.00	L36/2	CPT203044-03
<i>Arbusculidium destombesii</i>				
Hy	3: 1	N12-3037.45	X35/2	CPT203036-01
<i>Baltisphaeridium crinitum</i>				
Hy	2: 2	N12-3073.50	J47/2	CPT203022-01
<i>Baltisphaeridium verutum</i> n. sp.				
Ho	3: 3	N12-3014.00	L46/4	CPT203044-02
Pa	3: 4a, b	N12-3014.00	M39/3	CPT203044-04
<i>Baltisphaeridium</i> sp. cf. <i>B. microspinosum</i>				
	3: 7	N12-3009.50	N43/3	CPT203047-03
<i>Cristallinium ovillense</i>				
Hy	3: 5	N12-3039.50	E46	CPT203034-01
<i>Cristallinium randomense</i>				
Hy	3: 6	N12-3060.70	P32	CPT203029-01
<i>Cymatiogalea cristata</i>				
Hy	4: 6a, b	N12-3014.00	H51/3	CPT203044-03
<i>Cymatiogalea cuvillieri</i>				
Hy	4: 8	N12-3014.00	R42	CPT203044-03
<i>Cymatiogalea gorkae</i>				
Hy	5: 3	N12-3014.00	V24/1	CPT203044-01
Hy	5: 6	N12-3009.50	V28/1	CPT203047-01
<i>Cymatiogalea membranispina</i>				
Hy	5: 4	N12-3014.00	D49/4	CPT203044-01

(continue)

Cymatiogalea multareae

Hy	4: 2	NI2-3014.00	K39/1	CPT203044-03
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Cymatiogalea parva n. sp.

Pa	4: 1	NI2-3037.45	D48/1	CPT203036-04
Ho	4: 7	NI2-3037.45	K53/1	CPT203036-01
Pa	5: 2a, b	NI2-3037.45	G41	CPT203036-04

Cymatiogalea velifera

Hy	4: 3	NI2-3054.75	U45/1	CPT203031-01
Hy	4: 4	NI2-3039.50	L28	CPT203034-01
Hy	4: 5a, b	NI2-3054.75	N37	CPT203031-06

Cymatiogalea virgulta

Hy	5: 1a, b	NI2-3054.75	O38/3	CPT203031-06
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Dasydiacrodium obsonum

Hy	5: 7	NI2-3060.70	L41	CPT203029-02
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Dasydiacrodium tumidum

Hy	5: 8	NI2-3009.50	N43	CPT203047-03
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Elenia armillata

Hy	5: 5a, b	NI2-3073.50	V38/3	CPT203022-03
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Eupoikilofusa squama

Hy	5: 9	NI2-3050.15	R50/3	CPT203032-01
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Ladogella rommelaerei

Hy	7: 1	NI2-3050.15	D22/3	CPT203032-01
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Ladogella rotundiformis

Hy	6: 5	NI2-3054.75	V30/3	CPT203031-01
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Lophodiactrodium valdaicum

Hy	6: 3a, b	NI2-3066.10	Q36/2	CPT203024-04
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Multiplicisphaeridium cervinacornuum

Hy	6: 4a, b	NI2-3054.75	J47	CPT203031-01
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Multiplicisphaeridium sp. 1

	6: 6	NI2-3014.00	W34/3	CPT203044-01
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Ooidium sp. cf. *O. rossicum*

	6: 1a, b	NI2-3066.10	M40/4	CPT203024-04
	6: 2	NI2-3060.70	R43	CPT203029-02

Polygonium dentatum

Hy	7: 5	NI2-3009.50	X25	CPT203047-01
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Polygonium gracile

Hy	7: 2	NI2-3009.50	O32/2	CPT203047-01
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Saharidia fragilis

Hy	7: 6	NI2-3037.45	Y53	CPT203036-01
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Stellechinatum uncinatum

Hy	7: 4	NI2-3039.50	S29/3	CPT203034-01
Hy	7: 9a, b	NI2-3009.50	Q42	CPT203047-03

Stelliferidium cortinulum

Hy	7: 10	NI2-3014.00	O40/3	CPT203044-03
Hy	8: 7	NI2-3009.50	O30	CPT203047-01

Stelliferidium distinctum

Hy	8: 8	NI2-3050.15	F59/3	CPT203032-02
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Stelliferidium furcatum

Hy	7: 7	NI2-3009.50	M39/2	CPT203047-03
Hy	7: 8	NI2-3009.50	M40/3	CPT203047-03
Hy	7: 11	NI2-3009.50	R40/1	CPT203047-04

Stelliferidium gautieri

Hy	8: 2	NI2-3039.50	D28/4	CPT203034-01
Hy	8: 5a, b	NI2-3039.50	P36	CPT203034-06

Stelliferidium simplex

Hy	7: 12	NI2-3009.50	P45-P45/4	CPT203047-01
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Stelliferidium stelligerum

Hy	8: 4a, b	NI2-3009.50	M40/3	CPT203047-04
Hy	8: 9a, b	NI2-3009.50	Q43	CPT203047-03

Stelliferidium velatum n. sp.

Pa	8: 1	NI2-3039.50	D53/4	CPT203034-01
Pa	8: 3	NI2-3037.45	N44/3	CPT203036-03
Pa	8: 6	NI2-3037.45	O48	CPT203036-03
Ho	8: 10	NI2-3037.45	P59/2	CPT203036-01

Timofeevia phosphoritica

Hy	9: 1a, b	NI2-3073.50	N57/1	CPT203022-04
Hy	9: 2	NI2-3073.50	S53/2	CPT203022-01

Timofeevia sp. aff. *T. microretis*

	9: 5	NI2-3037.45	P49	CPT203036-01
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Trunculumarium sp. 1

	7: 3	NI2-3050.15	G40/4	CPT203032-01
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Veryhachium dumontii

Hy	9: 3	NI2-3050.15	K36	CPT203032-01
Hy	9: 4	NI2-3073.50	T49/2	CPT203022-01

Vulcanisphaera africana

Hy	9: 9	NI2-3014.00	Y29	CPT203044-01
Hy	9: 10	NI2-3009.50	D52/2	CPT203047-01

Vulcanisphaera britannica

Hy	9: 6a, b	NI2-2976.50	C54/3	CPT203059-01
Hy	9: 7	NI2-2976.50	D52/3	CPT203059-01

Vulcanisphaera capillata

Hy	9: 8	NI2-3037.45	F41/2	CPT203036-01
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