THE GRAPTOLITE FAUNA OF THE DICTYONEMA SHALES OF THE OSLO REGION

BY

O. M. B. BULMAN

(Sedgwick Museum, Cambridge, England)

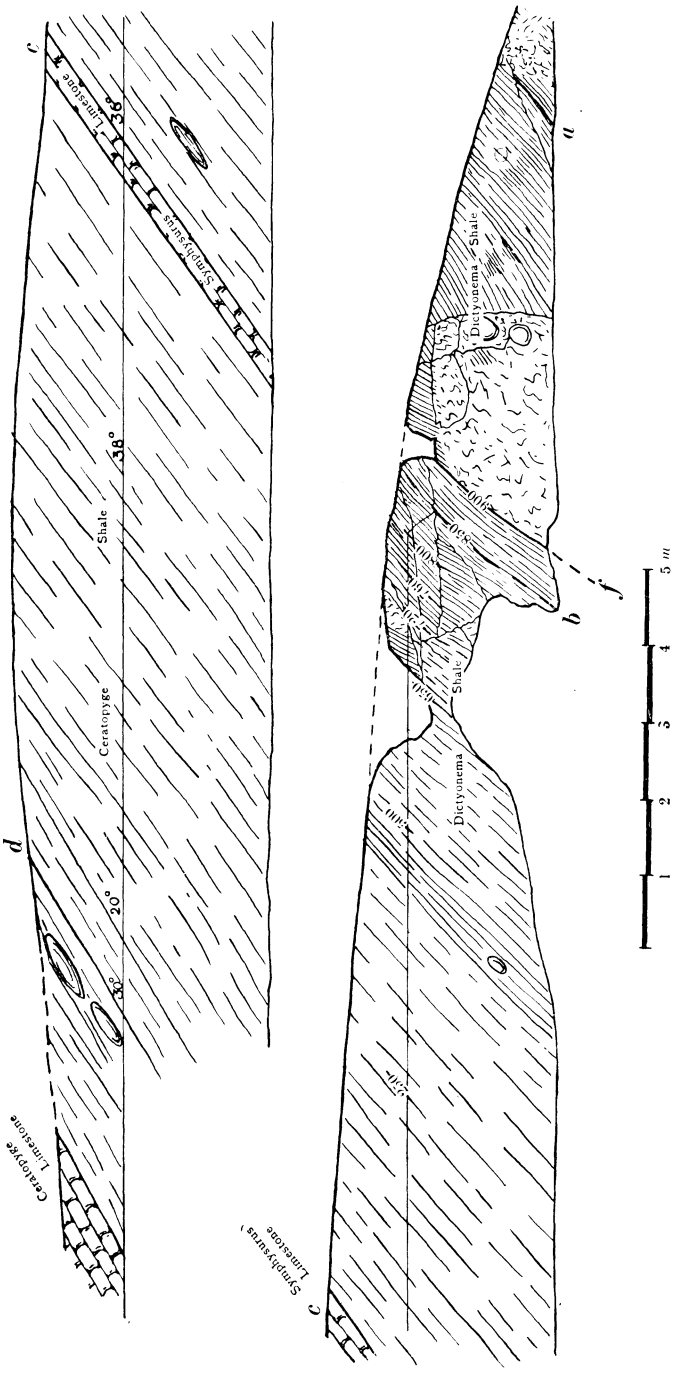
CONTENTS

A b s t r a c t. This is the first attempt at a complete revision of the graptolite fauna of the Dictyonema Shales (2e) of the Oslo district. Two localities have been selected, Tøyen and Hammersborg; the former provides a practically complete succession, and the latter has furnished a remarkably rich *Anisograptus* fauna in its upper portion. The presence of anisograptids as a characteristic component of the fauna, and the absence (or extreme rarity) of *Clonograptus*, seems to link the Norwegian succession with the Dictyonema Shales of eastern North America. Variation in *Dictyonema flabelliforme* and the stratigraphical value of its varieties are discussed; and the systematic section comprises descriptions of eighteen forms (*Dictyonema* and Anisograptidae) including three new species and three new varieties.

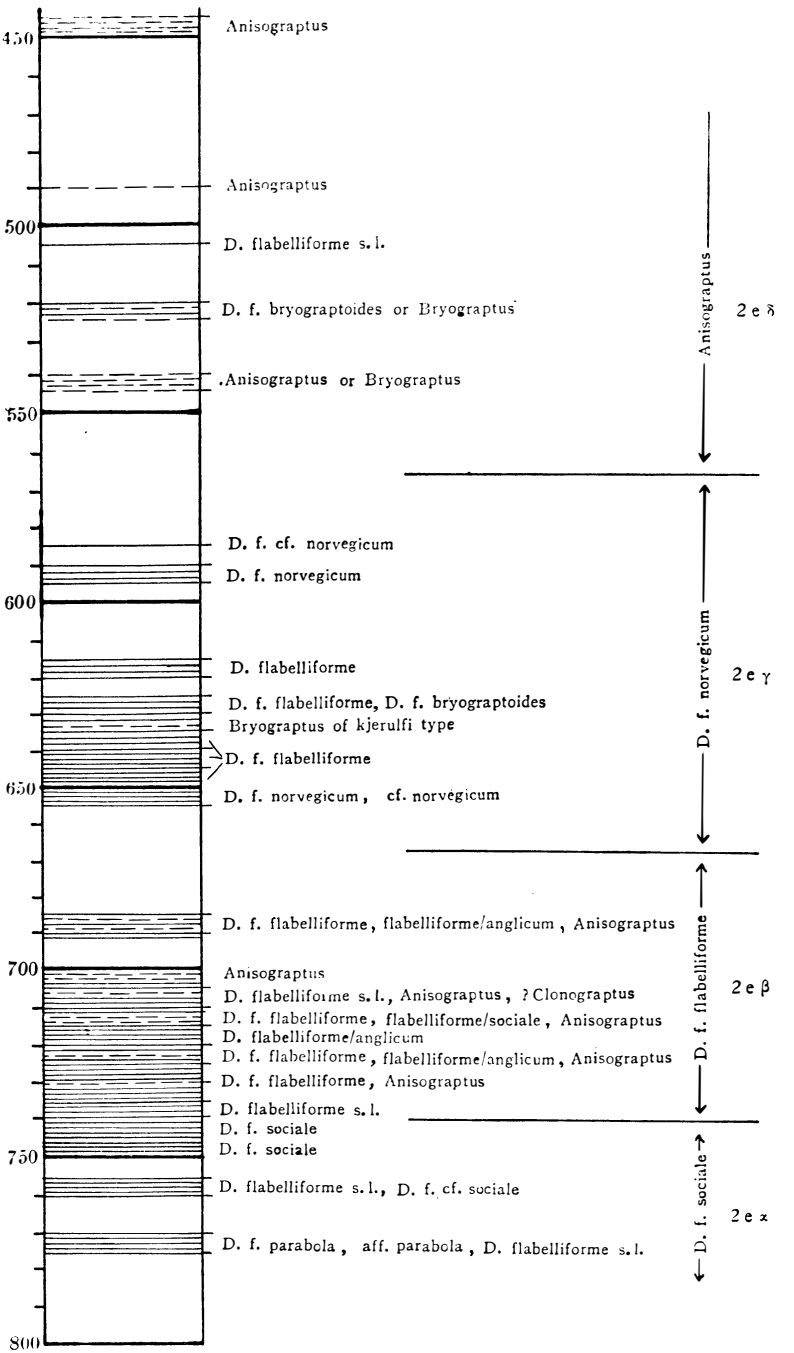
Introduction.

The Dictyonema Shales (2e) of the Oslo Region provide the best and most complete section of graptolitic Tremadoc rocks yet described, and detailed collections have been made from carefully measured sections at four localities. Minor tectonic disturbance undoubtedly occurs in these soft shales, but the effects where they can be checked are never great, and there is no evidence of any serious interference. In consequence, the stratigraphical succession is as certain as that of Scania (the generally accepted European standard) where the sequence has recently been confirmed by the evidence of a borehole (HEDE 1951); it is more extensive than has been described elsewhere in northwest Europe; and the shales are richly fossiliferous.

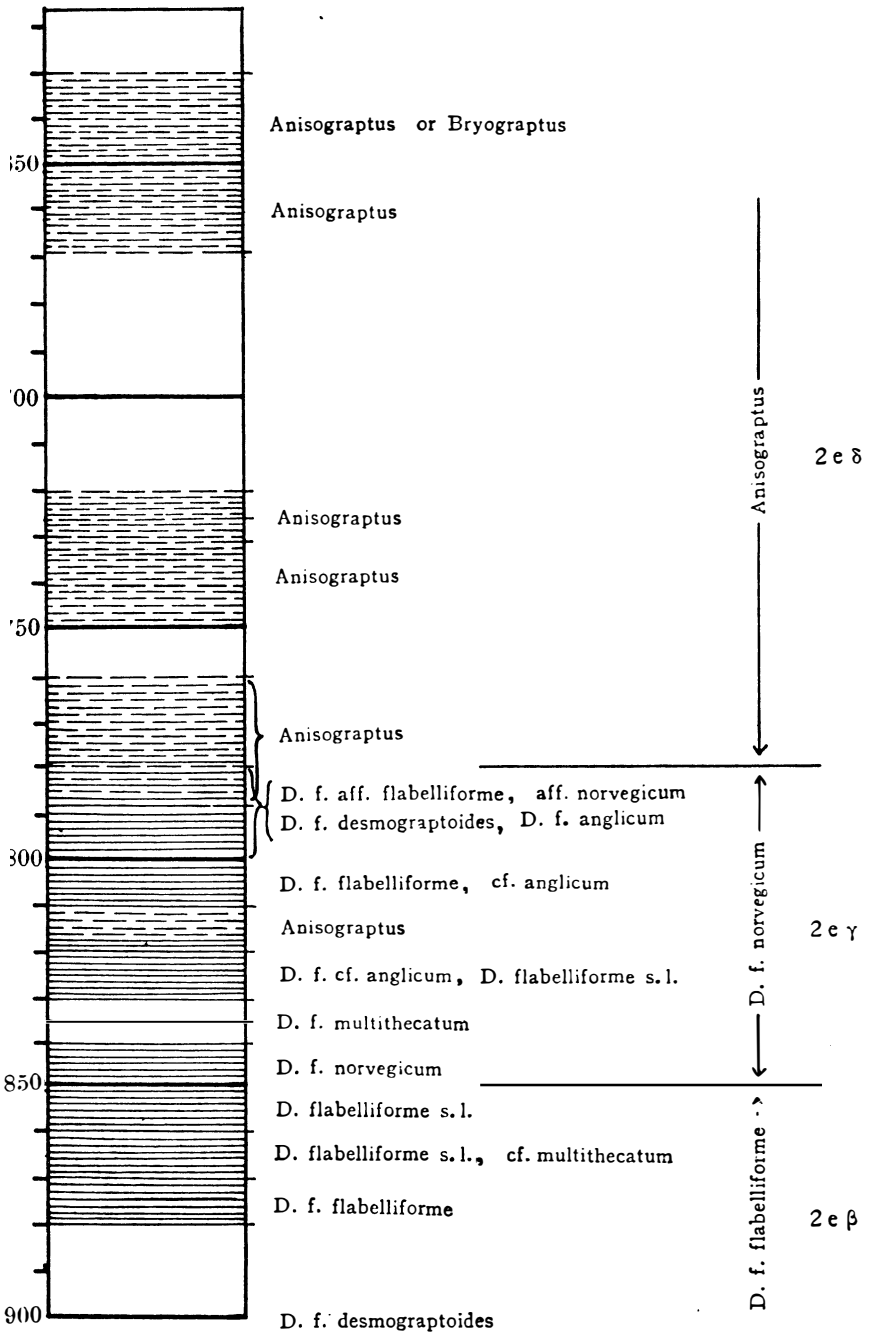
The four sections from which collections have been obtained are: — Vækkerø, Bygdøy Sjøbad, Tøyen and Hammersborg. It has only been possible to work over two of these in detail: Tøyen (collected by L. STØRMER in 1940) which is probably the most complete, and is that from which KJERULF originally described his variety *norvegicum;* and Hammersborg (collected by O. REKDAL in 1922) which is now no longer accessible and is that which has yielded the richest anisograptid fauna. The profile at Hammersborg is shown



Text-fig. 1. Profile of the section from the Dictyonema Shales to the Ceratopyge Limestone at Hammersborg, after an unpublished drawing by O. REKDAL, to the scale of 1:100. Measurements are recorded from the base of the Symphysurus Limestone. Below the fault *f* at 900, the sections is repeated and the fauna has not been described. a, b, c, d, datum lines used by REKDAL.



Text-fig. 2. Section through the Dictyonema Shale at Tøyen, scale 4.9 cm to 1 metre. The Symphysurus Limestone is not exposed, and figures on the left represent distances + x below the Symphysurus Limestone. This is the most complete and least disturbed section. Horizons characterized by anisograptids are indicated by broken lines; *Dictyonema* by continuous lines.



Text-fig. 3. Section through the Dictyonema Shale at Hammersborg, scale 6.0 cm to 1 metre. Figures on the left give distances below the Symphysurus Limestone. This section corresponds to the upper part of the Tøyen section and is remarkable for the profusion of anisograptids. *Anisograptus* alone occurs rather sparingly throughout the uppermost 1.5 m of the section (as shown by broken lines) but is abundant at the main *Anisograptus* horizon, 760—790. *Dictyonema* horizons indicated by continuous lines.

in text-fig. 1 (copied from a drawing prepared by REKDAL), while faunal details of the two sections are summarised in text-figs. 2 and 3.

STØRMER (1940, p. 162) has published a short account of the Dictyonema Shales in which he established as a standard for the Oslo Region the succession: —

2eδ	*Dictyonema*	*flabelliforme*	*anglica* Bulman
2eγ	—	—	*norvegica* (Kjerulf)
2eβ	—	—	forma *typica* Brøgger
2eα	—	—	*sociale* (Salter)

at Vækkerø and Bygdøy Sjøbad. Neither at Tøyen nor Hammersborg, as shown in the following pages, is *D. flabelliforme anglicum* well represented; but (especially at Hammersborg) the *norvegicum* horizon is followed by beds containing *Anisograptus*. It may well be that the *anglica* subzone is equivalent to the base, if not to the whole, of the *Anisograptus* horizon; and since both these successions occur within the Oslo district, I would suggest that STØRMER's scheme be slightly modified: —

2eδ	Subzone of	*Dictyonema*	*flabelliforme*	*anglicum* or	*Anisograptus*
2eγ	—	»	—	—	*norvegicum*
2eβ	—	»	—	—	*flabelliforme*
2eα	—	»	—	—	*sociale*

The approximate limits of these subdivisions are shown in the Hammersborg and Tøyen profiles, text-figs. 2 and 3.

I am grateful to Professor STØRMER for placing all this material at my disposal, and for his generous invitation to visit Oslo at the end of 1951 to study further collections preserved in the Palaeontological Museum there. He and his staff have done everything possible to facilitate my work; I am indebted to Prof. L. STØRMER, cand. real. G. HENNINGSMOEN and cand. real. N. SPJELDNÆS for discussion and advice, and to Miss L. MONSEN, Miss B. MAURITZ and cand. real. N. SPJELDNÆS for numerous photographs. Other photographs have been taken by Mr. A. BARLOW and myself at the Sedgwick Museum, Cambridge. For the preparation of clear and accurate illustrations of meshstructure in the variants of *Dictyonema flabelliforme*, it has been found best to trace in Indian ink upon x4 photographic enlarge-

ments on matt paper, which were subsequently bleached and have been reduced (in making the blocks) to magnification x2. To illustrate the general appearance of the rhabdosome, however, photographs still seem most satisfactory.

Variation in Dictyonema flabelliforme.

The variability of *Dictyonema flabelliforme* is so great that hardly any two specimens ever seem exactly comparable and in any large collection of these organisms the range of variation and diverse combination of characters is bewildering. Most workers must have felt hesitation in distinguishing varieties at all, and doubt as to the validity of such varieties as they attempted to define. This situation was recognized long ago by BRØGGER, who while separating var. *conferta* (=*sociale*) and *norvegicum* from his *forma typica*, nevertheless wrote (1882, p. 35): »Die verschiedenen Varietäten aus einander zu halten, scheint aber bei der grossen Mannichfaltigkeit des Variirens kaum möglich». In addition to the above, however, other varieties have since been recognized, notably by HAHN in 1912; and in working on the extensive material from Tøyen and Hammersborg, I have reluctantly added to the number in the following pages. But it is clearly desirable to keep the number of these rather arbitrary varieties as small as possible, especially when there is no definite evidence of positive stratigraphical value, and to make considerable use of the qualifications «cf.» and «aff.», or even to employ the designation «*D. flabelliforme* sensu lato». A general review of the position may perhaps be of interest.

Thecal characters have been employed but little in the subdivision of the species, chiefly because of the comparative rarity with which they can be observed, and partly because the thecae do appear in general to be more constant than other features of the rhabdosome. Admittedly there is some variation in number per unit length, but on the whole this seems to be more a geographical feature affecting all varieties of one district or area than a distinction between different varieties. Thecal form varies scarcely at all, but one variety described below (*multithecatum*) has long slender apertural spines in addition to unusually numerous autothecae.

The features most readily observable and therefore most naturally used in the subdivision of the species are (1) mesh characters (determined by regularity, width, direction and closeness of branches and dissepiments) and (2) rhabdosome shape. Neither of these is altogether satisfactory in application, for the appearance of the mesh depends a great deal upon the preservation of delicate dissepiments (and these are liable to destruction and still more to concealment by matrix), and rhabdosome shape requires for its use the preservation of the entire rhabdosome. These conditions are not fulfilled with sufficient regularity to make the use of quantitative methods a very practicable proposition, although the characters themselves would seem ideally suited to such methods.

These two apparently unrelated variables (mesh characters and rhabdosome shape) are in fact linked by a third, namely, frequency of branching, which determines the actual number of stipes in a rhabdosome. A change in shape from narrow- to wide-angled cone must be accompanied by a compensatory increase in the frequency of branching if the mesh character is to remain comparable. If not accompanied by such an increase, it must result in wider spacing of the branches (as seems actually to have occurred in *flabelliforme* and *anglicum* as compared with *sociale*). On the other hand, a marked decrease in the power of branching without change in rhabdosome shape would also result in a more open mesh (as in the aberrant rhabdosome labelled «aff. *flabelliforme*» in pl. 4, fig. 1); and carried further could result in a still narrower rhabdosome even if the branches became further apart (as seems to have occurred in *bryograptoides*). There does seem to be a general tendency towards reduction in the number of branches and the development of greater regularity, resulting in the formation of more-or-less regular *zones* of branching, but this never becomes so regular that the zones can be accurately measured and strictly applied as a varietal character. The use of the same feature, expressed as branch density at successive distances from the sicula, is tempting; but even this has never proved practicable because, like rhabdosome shape, it requires the preservation of complete colonies. We are therefore in practice thrown back upon a *qualitative* study of mesh characters and an estimate (where possible) of rhabdosome shape.

In the above paragraph, I have assumed a transition from *sociale* through *flabelliforme* to *anglicum* and *bryograptoides* for which the stratigraphical evidence is discussed later and is contained in the details of the Tøyen section (text-fig. 2). Granting this, it is of interest to note that change in rhabdosome shape from narrow- to wide-angled cone, and reduction in the frequency of branching are both expressions of the same two trends (change in direction of growth, and stipe reduction) that operate later in the early Graptoloidea.

The characters of the dissepiments themselves are of course independent either of rhabdosome shape or of branching. KOZLOWSKI has stated (1942, p. 42) that dissepiments are mainly composed of cortical substance, and it is to be inferred that they were therefore secreted by that hypothetical outer covering of soft tissue which is believed to have enveloped the graptolite branch. It is consequently probable that they, more than any other feature of the rhabdosome, might reflect variation in external conditions (i.e., they would exhibit what are currently termed phenotypic modifications). It is observable that their density appears to some extent directly related to the density of the branches themselves, suggesting that their development may perhaps be influenced by the proximity of neighbouring branches; and it is quite probable that their function is as much (if not more) to hold branches apart as to hold them together. Thus the high density of dissepiments in *sociale* may be linked with the closeness of stipes in that variety. But the extreme width of dissepiments in, for example, *norvegicum* may perhaps be related to variation in some environmental factor. Were this the case, the stratigraphical value of such a variety would be impaired since it might arise at different times in different regions — i. e,, it could be both local and recurrent. In this connection, the occurrence of a form closely resembling the true *norvegicum* at the low Tøyen horizon referred to on p. 25 is perhaps significant.

Stratigraphical value of the varieties of Dictyonema flabelliforme.

The Scandinavian succession was in the first instance established by BRØGGER (1882) working in the Oslo region, when he recorded

norvegicum from «a higher level» (p. 36) than his *forma typica* (=*flabelliforme*), and *conferta* (=*sociale*) from «the lower part of the Dictyonema Shales» (pp. 35, 36). WESTERGÅRD (1909) established the zonal succession: —

c. *D. flabelliforme norvegicum* & *Bryograptus kjerulfi*
b. *Clonograptus tenellus* & *Adelograptus hunnebergensis*
a. *Dictyonema flabelliforme flabelliforme*

but he recorded *sociale* from both the upper and lower part of subzone *a* at Pålstorp and Storberg respectively (p. 60).

STUBBLEFIELD & BULMAN (1927) recognized a comparable but incomplete succession in Shropshire, and BULMAN (1927) while describing a new variety, *anglicum*, from the upper part of the *flabelliforme* subzone and beds transitional to *Clonograptus*, considered *sociale* to be restricted to the lower part. The stratigraphical relations of *anglicum* to *norvegicum* remained undecided, but the succession of varieties was generally believed to be: —

norvegicum
Clonograptus
anglicum
flabelliforme
sociale

Apart from WESTERGÅRD's Pålstorp reference, the only serious exception to this placing of *sociale* is reported from the Dyle Valley in Belgium (LECOMPTE 1948), where a form which appeared to the present writer to be *sociale* occurs in association with trilobites which indicate at least the *Clonograptus tenellus* subzone. HEDE, (1951) in his recent account of the Fågelsång boring, has described a well-defined *sociale* horizon underlying that of *flabelliforme* s. str., though he notes (p. 20) that the variety persists into the basal beds of the overlying (*flabelliforme*) zone where the index fossil itself is rare — i. e., there is a sort of transition series. This would seem to be sufficient to establish the general succession in Scania, but it is very desirable that the Belgian record and that of WESTERGÅRD should be clari-

fied before the occurrence of *sociale* can in itself be confidently accepted as a reliable index of low zonal horizon.

In the Oslo successions, particularly that of Tøyen, the actual ranges of all these varieties show considerable overlap although the horizons of their maximum development agree reasonably well with previous observations. The main exception concerns *anglicum*, which appears to be approximately contemporaneous with *norvegicum*; it even occurs above *norvegicum* at Hammersborg (where the latter is not particularly abundant), while *norvegicum* occurs at two levels above *flabelliforme/anglica* transients at Tøyen. The best of the Oslo *anglicum* material comes from Vækkerø (not described here) where again it overlies *norvegicum*. Comparison with ranges in other countries is somewhat complicated by the extreme rarity, if not complete absence, of *Clonograptus* and *Adelograptus* from the Norwegian succession. It is noteworthy that *flabelliforme flabelliforme* (or a form only doubtfully distinguishable from this) persists to a level even higher than *norvegicum*, and evidently *anglicum* also persists longer here. This point may later be settled by detailed examination of the Vækkerø section.

To summarise, it appears that none of the many varietal forms of *flabelliforme* is universally restricted to a narrow horizon, and furthermore, there will be found throughout the succession many examples which can only be identified as *D. flabelliforme* s. l., or referred with some qualification to described varieties. At the same time, in an assemblage large enough to be representative, it is probable that dominance of *sociale*, *flabelliforme* and even *norvegicum* justifies recognition of these subzones. In most areas, *anglicum* characterises the higher part of the *flabelliforme* subzone; but is has not been recognized in Sweden as yet, while in Norway it persists and may characterise a horizon above *norvegicum*. The *Adelograptus* and *Clonograptus* subzone, where this occurs, interrupts the *Dictyonema* sequence above the *flabelliforme* subzone. It may be added that var. *bryograptoides* seems appropriately characteristic of a high level (*norvegicum* subzone), but there is not sufficient evidence to suggest that the remaining varieties have any particular stratigraphical significance, unless the limited occurrence of the rare *parabola* proves to be characteristic.

Comparison with the graptolitic Tremadoc of other areas.

Three distinctive features emerge from this examination of the Norwegian Dictyonema Shale succession, viz.: the presence of *Anisograptus*, here described for the first time from Europe; the extreme rarity, if not absence, of *Clonograptus;* and the persistence of *Dictyonema* itself almost uninterruptedly through these shales.

The presence of anisograptids in the Dictyonema Shales of Oslo raises again the question of the age of the Matane Shales of Quebec, from whence they were first described. These shales were provisionally assigned to a horizon in the lower part of the Upper Tremadoc or the upper part of the Dictyonema Shales (BULMAN 1950) on various grounds; partly features of the *Dictyonema* species and partly the presence of *Triograptus*, till then only known from the Upper Tremadoc, 3aβ, in Norway (MONSEN 1925), where it was likewise associated with early *Didymograptus*. But as then stated (1950, p. 66): «Clearly a fauna of the general aspect of the Matane anisograptid fauna can occur much lower than the Ceratopyge Shales, 3aβ; apparently in the *norvegica* zone of the Dictyonema Shale, 2e». The Tøyen and Hammersborg sections have not only furnished abundant anisograptids in the Dictyonema Shale (associated with *Triograptus* and even ?*Didymograptus*), but the additional variation in *Dictyonema flabelliforme* illustrated by the spined *multithecatum* suggests that the Canadian species could after all be approximately contemporaneous. Nevertheless, it is pertinent to add that neither *D. flabelliforme* itself nor any of its well-recognised varieties occurs in Quebec. If, therefore, the Matane fauna is of Lower Tremadoc (Dictyonema Shale) age, it must be a curiously restricted development. Moreover, though anisograptids occur in the lower parts, the main *Anisograptus* horizon in the Oslo area occurs in and just above the highest *Dictyonema*-bearing shales, and anisograptids persist there after the disappearance of *Dictyonema*.

However, even if the Matane Shales are of later age than the Dictyonema Shales of Norway, the abundance of anisograptids in both regions suggest that possibly we have here evidence of a graptolitic sub-province. The Dictyonema beds of other parts of eastern North America — Cape Breton, New Brunswick, Newfoundland and even New York — are not really well-enough known to establish

their relationship to such a province, but it may be noted that anisograptids occur in several of them, and that *C. tenellus* and its variety *callavei*, and *Adelograptus*, have not been recorded from any of them. The Norwegian succession undoubtedly seems to have more affinity with this region than with other parts of northwest Europe.

The persistence of *Dictyonema* almost uninterruptedly through the Norwegian succession also deserves a little further comment. Details recently given by HEDE (1951, pp. 14, 20—28) show that in Scania (Fågelsång) there is a break of over 4 metres without *Dictyonema* between the *flabelliforme* and *norvegicum* levels. The lower *Dictyonema* horizon is remarkably thin (*sociale* and *flabelliforme* together make only 0.60 m) compared with the zone of *Adelograptus hunnebergensis* (and *C. tenellus*) which totals 2.95 m; and even though *flabelliforme* persists into the lowermost 35 cm of this, there is still a gap of 2.60 m of this zone, followed by 1.6 m of Brachiopod Beds (4.2 m altogether) before the reappearance of *Dictyonema* in the form of var. *norvegicum*.

In Britain, there is a similar disappearance of *Dictyonema* soon after the entry of *Clonograptus* and *Adelograptus;* but with the probable exception of cf. *norvegicum* from the Coventry boring (the strati-

NORWAY Oslo	SWEDEN Scania	BRITAIN Shropshire
Symphysurus limestone and shales (3 *a* α) Main *Anisogr.* horizon	Ceratopyge shales and limestones	Brachiopod Beds
norvegicum & *anglicum*	*norvegicum* Brachiopod Beds	
flabelliforme with some *Anisogr.* and ? *Clonogr.*	*Adelogr.* and *Clonograptus*	*Clonograptus* and *Adelograptus* Transition Beds with *anglicum*
sociale *parabola*	*flabelliforme* *sociale*	*flabelliforme* *sociale*

graphical relations of which are a little doubtful), the species does not re-enter the area, and the true *norvegicum* is not represented. Sweden, on the other hand, appears to lack the development of *anglicum* which characterises the upper part of the *flabelliforme* zone in Britain, and beds transitional to *Clonograptus*, and appears in the upper part of the Oslo succession.

In Belgium, *sociale*, *flabelliforme* and *anglicum* (with transients) have all been reported (e. g., LECOMPTE 1949), but their stratigraphical relations are not very clearly established as yet. Neither *Clonograptus* and *Adelograptus* nor *Anisograptus* has so far been recorded; *Dictyonema* appears to be almost continuous.

Systematic descriptions.

1. *Dictyonema flabelliforme flabelliforme* (EICHWALD).

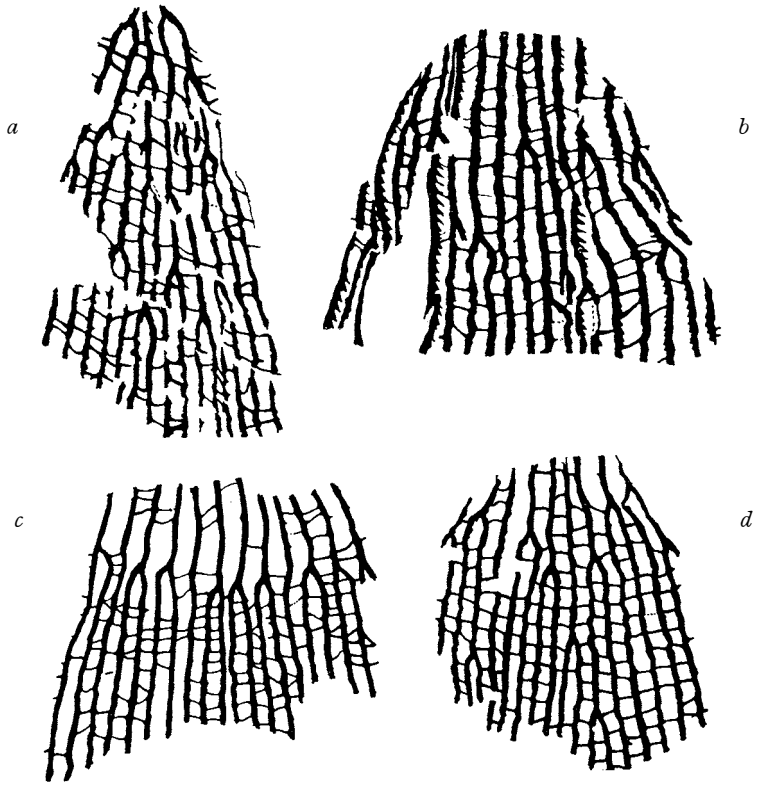
Pl. 2, figs. 1—5; text-fig. 4 a-d.

Gorgonia flabelliformis EICHWALD, 1840, p. 207.
Rhabdinopora flabelliformis EICHWALD, 1855, p. 435.
Dictyonema Graptolithinum KJERULF, 1865, p. 1, figs. 4, 5.
Dictyonema flabelliforme TULLBERG, 1882, p. 20, pl. III, figs. 1, 2, ?4, (*non* 3).
Dictyograptus flabelliformis forma typica BRØGGER, 1882, p. 31, pl. XII, figs. 17, 18.
?*Dictyonema flabelliforme* var. *Acadicum* MATTHEW, 1891, p. 36.
Dictyonema flabelliforme RUEDEMANN, 1904 (*pars*), p. 599.
Dictyograptus flabelliformis MOBERG & SEGERBERG, 1906, p. 59, pl. I, fig. 6.
Dictyograptus flabelliformis forma typica WESTERGÅRD, 1909, p. 57, pl. III, figs. 1—6.
?*Dictyonema flabelliforme* var. *acadica* HAHN, 1912, p. 137, pl. XX.
Dictyograptus flabelliformis POULSEN, 1922, p. 6, fig. 2.
Dictyonema flabelliforme forma typica BULMAN, 1927, p. 24, pl. II, figs. 3, 4.
Dictyonema flabelliforme typica LECOMPTE, 1949, pp. 4 *et seq.*

Diagnosis: Rhabdosome with length/breadth ratio from 1.2:1 to 1.6:1; mesh characteristically regular, composed of slender straight stipes (7—9 in 10 mm) united by slender straight dissepiments (about 7—9 in 10 mm) not appreciably enlarged at their bases, forming more-or-less rectangular meshes; thecae 12—16 in 10 mm.

Description: Probably the most distinctive feature of this form is a certain «open» character of the mesh, which is composed of slender

straight stipes, generally a trifle less than 0.5 mm wide, separated by interspaces nearly twice as great, and united by extremely fine and rather infrequent dissepiments. Typically, as noticed apparently by EICHWALD, the mesh is regular and rectangular; but there is considerable range of variation in the number and direction of dissepiments. In some examples these are comparatively close-set (8—10 in 10 mm), regularly spaced and at right angles to the branches, producing a remarkably regular squarish mesh. In other examples, they may be more widely spaced (6—8 in 10 mm), not (so far as can be deter-



Text-fig. 4. *Dictyonema flabelliforme flabelliforme* (EICHWALD). *a*, specimen P. M. O. 62869a from Hammersborg 450 below fault at 900; *b*, KJERULF's original *Dictyonema Graptolithinum* from Tøyen (cf. pl. 2, fig. 1); *c*, specimen from Baltischport, Esthonia (probably topotype material); *d*, from the Shineton Shales, Cherme's Dingle, near the Wrekin, Shropshire. All figs. x 2.

mined) as the result of injury or damage, and are oblique to the stipes, producing triangular or trapezoidal meshes: in places, two dissepiments may spring from the same point on one branch and diverge strongly. Very regular, square meshes (text-fig. 4d) characterise material from the Shineton Shales (Shropshire); the more irregular and sometimes oblique meshes are represented in topotype material (text-fig. 4c), from Baltischport (Esthonia), the type of KJERULF's *D. Graptolithinum* (text-fig. 4b) from Vækkerø, and are perhaps commoner in the Oslo region generally. It does not seem possible to separate these forms, and appreciable variation may occur in the same rhabdosome.

Rhabdosomes frequently attain a considerable size; thus at Tøyen 730—735 there are specimens 12 cm broad which would probably have had a length of 16 cm or more, and specimens 10—12 cm long occur at several localities and horizons (e.g. pl. 2, fig. 5). From 6 to 8 cm is, however, certainly a more usual length.

Both in rhabdosome shape (length/breadth ratio) and mesh structure (density of branches and dissepiments) there occur forms which serve to connect *flabelliforme* s. str. with *sociale*, *norvegicum* and *anglicum* and can best be identified as transients. There remain also many specimens which, for various reasons, can only be identified as *D. flabelliforme* aff. *flabelliforme*, or even as *D. flabelliforme* sensu lato.

Inwardly-directed thecae are sometimes visible along marginal branches of the rhabdosome in this variety. Indications on the Oslo specimens seem to average 12—13 in 10 mm, which is indeed the number cited by BRØGGER. It is of interest to note in this connection that the Swedish material agrees with the English material in having a higher thecal number, averaging 15—16 in 10 mm (WESTERGÅRD, 1909, p. 58; BULMAN, 1927, p. 25)[1]. MATTHEW, in his var. *acadia*, which is probably synonymous with *flabelliforme*, records 16—17 (1891, p. 37). They generally appear to be sharply denticulate, but unspined, and in compressed specimens are inclined at about 40° to the dorsal wall of the stipe.

STØRMER (1933, 1935) has described and figured some remark-

[1] TULLBERG (1882, p. 20), however, allows the very wide range of 10—15; this is possibly in part owing to the inclusion of other varieties.

able basal modifications in young rhabdosomes mainly referable to *D. flabelliforme flabelliforme*. The interpretation of these is not absolutely certain, but they are distinct from the root-like fibres and «basal organs» that have been described in *D. flabelliforme* by many authors; for the best of them (1933, text-fig. 1 and pl. 1) is a bladder-like object which involves the basal branches of the rhabdosome and is not merely an enlargement of a thickened nema, and it has morever a firm outline and a smoothly rounded shape. STØRMER interprets it as a floating organ (or pneumatocyst), in which case it might perhaps be better compared with the float of some biserial graptolites than with the central web-structure of certain dichograptids. At this stage we can only state that such an interpretation is quite plausible, but it must be added that there appear to be other specimens (mainly extra-Norwegian) possibly transitional between this and structures that can only be regarded as irregular «root» modifications.

Horizons: Tøyen 625—630, 640—645, 685—692, 710—715, 720—725, 730—735, ?755.

Hammersborg ?780—800, 790—800, 800—810, 870—880 (also at various levels below fault at 900, such as $a = 1350$).

From the evidence of these new collections, it appears that *D. flabelliforme flabelliforme* may persist to a higher level than was previously realised, occurring with and even above *norvegicum*. Some of this higher material seems indistinguishable from that found at lower horizons, but some specimens (e. g., pl. 4, fig. 2) show an unusually rapid initial bifurcation and consequently a rounded proximal end. If this could be definitely established as characteristic, it might be worth separating such forms as a distinct variety; only one or two are known, however, and these are provisionally identified as aff. *flabelliforme*.

2. *Dictyonema flabelliforme anglicum* BULMAN.

Pl. 4, figs. 3 & 5; text-fig. 5*a*.

Dictyonema flabelliforme var. *anglica* BULMAN, 1927, p. 28, pl. 2, figs. 5—8.
?*Dictyonema flabelliforme* var. *anglica* RUEDEMANN, 1930, p. 308, figs. 1, 2.
?*Dictyonema flabelliforme* var. *anglica* RUEDEMANN, 1947, p. 160, pl. 2, figs. 3—5, pl. 4, fig. 25.
Dictyonema flabelliforme var. *anglica* LECOMPTE, 1949, pp. 4 *et seq.*

Diagnosis: Rhabdosome characterised by its broadly conical form (length/breadth ratio 1.2:1 to 1:1) and open mesh; stipes 6—8 in 10 mm, 0.3—0.4 mm wide and separated by interspaces which may be three or even nearly four times as great; dissepiments 6—10 in 10 mm; thecae 14—16 in 10 mm, acutely denticulate or with short spines.

Remarks: Specimens definitely referable to this form are not common, but occur in the upper part of the Hammersborg section (pl. 4, fig. 3) and at Vækkerø (pl. 4, fig. 5). They are characterised by their slender, widely separated branches and open mesh, combined with the broadly conical rhabdosome form. Examples identifiable as *flabelliforme/anglicum* transients, or as cf. *anglicum* (pl. 4, fig. 4) occur more commonly both in the Tøyen and Hammersborg sections (Tøyen 720—725, 688—692, and Hammersborg 820—830, 800—810).

Imperfectly preserved specimens are liable to be confused with *bryograptoides* and *multithecatum;* the former should be distinguishable by their very infrequent bifurcation and acute rhabdosome form, and their exceptionally sparse dissepiments; the latter are mainly distinguishable by their sparse dissepiments and thecal characters.

Horizon: Hammersborg 780—800; also Vækkerø.

3. *Dictyonema flabelliforme bryograptoides* var. nov.

Pl. 4, figs. 6, 7; text-fig. 5 *b, c.*

Diagnosis: Rhabdosome small, with length/breadth ratio 1.4:1 or 1.5:1, branching at infrequent intervals (approximately 3½, 9 and 15 mm); branches straight, slender (less than 0.5 mm), separated by interspaces two to three times as great, 6—8 in 10 mm; dissepiments so infrequent that their number has little significance; thecae ?12—13 in 10 mm, acutely denticulate but not spined; stolothecae and bithecae observed.

Description: The rhabdosome does not seem to exceed 2½ cm in length, nor to have more than 18—20 terminal branches (9—10 visible when compressed); and has a high length/breadth ratio. The stipes are slender, widely separated, and connected by a few dissepiments in the middle and distal portions.

The variety is distinguished from young *anglicum* by its narrow

cone and far more infrequent dissepiments; it more closely resembles the form referred to cf. *multithecatum*, but its even less frequent branching and much lower thecal number should serve to discriminate

Text-fig. 5. *a*, *Dictyonema flabelliforme anglicum* BULMAN, Vækkerø, P.M.O. 114 (cf. pl. 4, fig. 5).
b, *c*, *Dictyonema flabelliforme bryograptoides* nov., Tøyen 625, P.M.O. 61977; *b*, holotype (cf. pl. 4, fig. 6). All figs. x 2.

between them. It is, in fact, a morphological intermediate between *D. flabelliforme* and a *Bryograptus;* and it is possible that the specimen figured by WESTERGÅRD (1909, pl. 5, fig. 7) as *Bryograptus kjerulfi* is referable to this variety. It occurs high in the succession, associated with *norvegicum*, which is about the horizon where bryograptids first make their appearance.

Holotype: P.M.O. 61977 (the rhabdosome shown on the right in fig. 6, pl. 4, and in text-fig. 5b).

Horizon: Tøyen 625, 625—630, ? 520—525.

4. *Dictyonema flabelliforme desmograptoides* HAHN.

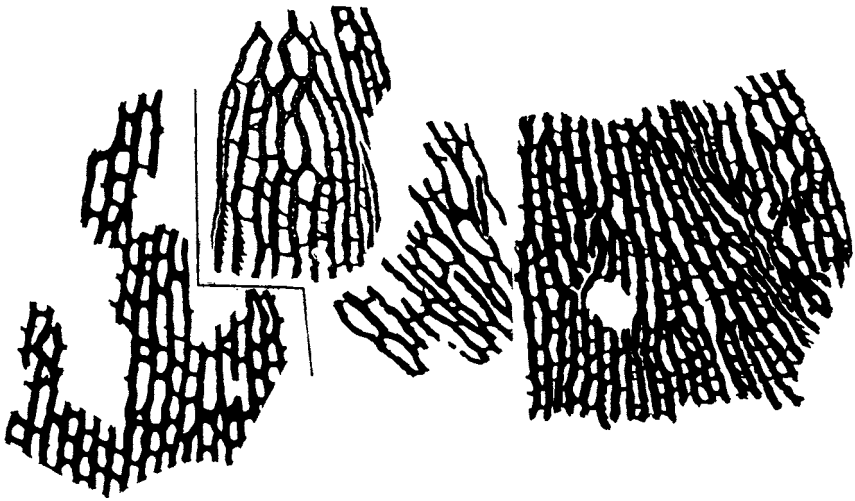
Pl. 5, figs. 1—4; text-fig. 6 a-c.

Dictyonema flabelliforme var. *desmograptoidea* HAHN, 1912, p. 139, pl. XX.

Diagnosis: Rhabdosome form uncertain; stipes 8—12 in 10 mm, somewhat undulating and occasionally appearing to anastomose; dissepiments irregular, often widely spaced to produce elongate meshes, sometimes close-set (10—11 in 10 mm), not infrequently

thickened, and generally expanded at their bases; thecae ?15—16 in 10 mm.

Remarks: HAHN's original description is very brief, and the variety rests upon a number of rather vague characters not at all



a *b* *c*

Text-fig. 6. *Dictyonema flabelliforme desmograpoides* HAHN. *a*, Hammersborg 780—800, P.M.O. 62683 (cf. pl. 5, fig. 1); *b*, unknown locality (?Eiker), P.M.O. 236 (cf. pl. 5, fig. 4); *c*, Eiker, P.M.O. 65672 (cf. pl. 5, fig. 2). All figs. x 2.

easy to define; it has not been recognized hitherto outside New Brunswick, but there seems little doubt that Professor STØRMER's MS identification of the variety among the Oslo material is correct.

The form of the complete rhabdosome is uncertain, most of the material being torn and broken; but there is some indication that it flared out distally from an initially narrow cone like the hypothetical *acadia/conferta* transient figured by HAHN on his plate XX (1912). There is one such specimen among the Navy Island material in the Sedgwick Museum, and several in the Oslo material, one of which (from an unknown locality, possibly Eiker) is shown in fig. 3, pl. 5.

Most characteristic specimens show a slight sinuosity of the branches, and elongate rectangular or ovoid meshes formed by

thickened dissepiments greatly expanded at their bases and by very rare anastomosis. The stipes are 8—10 in in 10 mm, separated by interspaces slightly greater than the stipe witdth. There is, however, an element of irregularity both in spacing of dissepiments and in the branching itself; stipes often end blindly and are replaced by the division of adjacent stipes, as shown in text-fig. 6c. Here the stipes tend to be more numerous, and are often separated by interspaces actually less than the stipe width, while dissepiments are finer and more numerous.

HAHN reports that sometimes an old stage of *acadica* (? = *flabelliforme* s.str.) shows the characters of *desmograptoides*, but I am inclined to think that he is mistaking a general irregularity, with premature termination of various branches (which may occur exceptionally in most varieties), for the true *desmograptoides* structure. Certainly *desmograptoides* shows such terminal irregularities rather freqently, but in the Oslo material at least, the true *desmograptoides* characters as described in the preceding paragraph are generally most pronounced in the proximal rather than the distal end of the rhabdosome.

Where the dissepiments are more numerous and the elongate mesh is not so well developed, the variety may show considerable resemblance to *flabelliforme* cf. *norvegicum*.

Horizon: Not known for certain at Tøyen; Hammersborg 780—800 (rare) and just below fault at 900; also Eiker, and an unknown locality (old collections).

5. *Dictyonema flabelliforme multithecatum* var. nov.

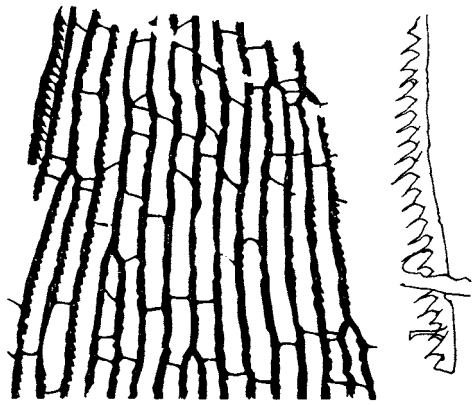
Pl. 5, fig. 5; text-fig. 7a, b.

Diagnosis: Rhabdosome shape and proportions uncertain; mesh very open, with straight slender stipes separated by interspaces 2 to 2½ times the stipe width, 6—7 in 10 mm, connected by sparse dissepiments 2—5? in 10 mm; autothecae 18—20 in 10 mm, provided with straight apertural spines ½ mm or more in length.

Description: The form of the entire rhabdosome is not known, but it appears to have been much as in *flabelliforme* s.str.; some immature specimens (e. g., pl. 5, fig. 6) referred to this variety with reserve suggest a length/breadth ratio of about 1.4:1.

The stipes are straight and parallel, slender (not more than

0.5 mm wide) and separated by interspaces from two- to two-and-a-half times as wide. Branching in the mature part of the colony is infrequent and irregular; at the proximal end, it seems to be somewhat between *flabelliforme* s.str. and *bryograptoides*. Dissepiments



a *b*

Text-fig. 7. *Dictyonema flabelliforme multithecatum* nov. *a*, Hammersborg 835, P.M.O. 62415, x 2. *b*, thecae showing apertural spines, Hammersborg 835, P.M.O. 62412 (holotype, counterpart of P.M.O. 62415), x 4. (cf. pl. 5, fig. 5).

are very sparsely developed and in some places absent altogether over a length of a centimetre or more between adjacent pairs of stipes; in other places, two may occur in the space of one mm. So far as can be determined, their absence is primary and not due to damage or to poor preservation. Nevertheless the stipes remain parallel and the colony shows little tendency to disruption such as commonly affects rhabdosomes of the Canadian *D. lapworthi*, where dissepiments are also sparsely developed.

Apart from this looseness of the mesh, the most distinctive feature of this rare variety are the close-set thecae (numbering 18—20 in 10 mm) and their stiff slender apertural spines. The former is all the more notable because as previously remarked most of the Norwegian varieties seem to differ from their Swedish and English counterparts in having rather fewer than the normal number of thecae.

The spined character of the thecae raises the question whether the autothecae of other varieties of *D. flabelliforme* were similarly spined, their denticulate appearance being due to defective preservation. Re-examination of the best available material from various localities leads me to believe that, while the thecae of other varieties may have been very acutely denticulate, they did not carry the acicular spines that characterise *multithecatum*.

Holotype: P.M.O. 62412; P.M.O. 62415 (represented in text-fig. 7a) is the counterpart.

Horizon: Hammersborg 835 (loose); immature forms referred to cf. *multithecatum* occur at Hammersborg 860—870.

Remarks: A comparable if not identical variety apparently occurs at Baltischport, Esthonia. Most of the Baltischport material is referable to *flabelliforme flabelliforme*, but one specimen (A22651) in the Sedgwick Museum collections shows numerous thecae (18—20 in 10mm) with conspicuous apertural spines, rather shorter (0.25 mm) than those of Hammerborg, and sparse and erratic dissepiments.

6. *Dictyonema flabelliforme norvegicum* (KJERULF).

Pl. 3, figs. 1—3, ?5; text-fig. 8a-d, ?e

Dictyonema norvegicum KJERULF, 1865, p. 1, figs. 1 *a*, *b*, *non* figs. 2, 3.
Dictyograptus flabelliformis mut. *norvegica* BRØGGER, 1882, p. 36 (no figs.).
Dictyograptus norvegicus MOBERG & SEGERBERG, 1906, p. 60, pl. 1, fig. 7.
Dictyograptus flabelliformis var. *norvegica* WESTERGÅRD, 1909, p. 60, pl. III, figs. 8, 9.
?*Dictyonema flabelliforme* var. *norvegica* HAHN, 1912, p. 139, pl. XX.

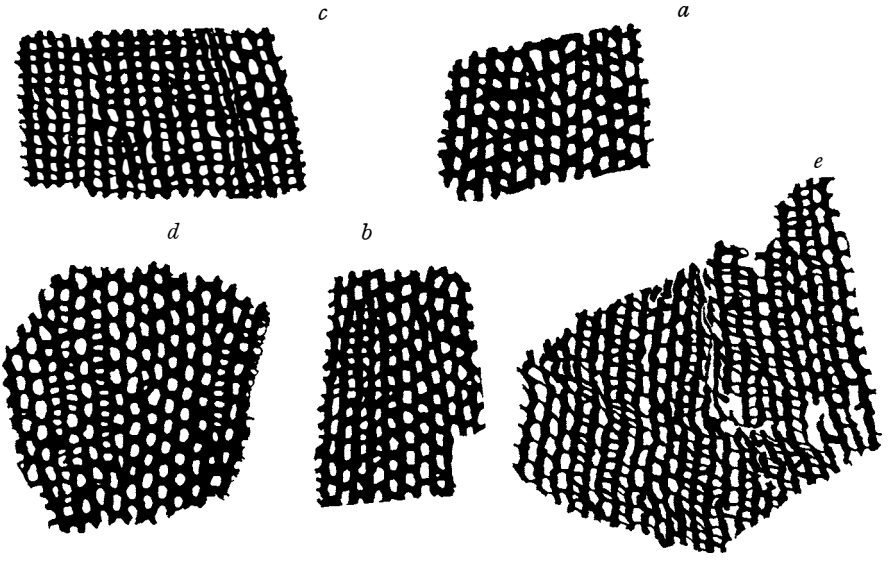
Diagnosis: Stipes connected by thick dissepiments, comparable in thickness to the branches themselves, expanded at their bases to produce rounded meshes.

Description: The shape of the rhabdosome and the proximal end are practically unknown, and the variety is almost invariably represented by irregular fragments, often of considerable size[1]. There is some indication (e. g., pl. 3, fig. 2) that the length/breadth ratio was around 1:1.

The mesh structure of the typical variety is unmistakable. Stipes

[1] WESTERGÅRD (1909, p. 60) refers to one piece 11.5 cm long and 13 cm broad, but fragments of 4 or 5 cm are more usual.

number 9—10 (rarely 10—11) in 10 mm, are 0.5—0.6 mm wide, and are separated by interspaces of about the same dimension. They are connected by broad dissepiments nearly as wide as, and rarely



Text-fig. 8. *Dictyonema flabelliforme norvegicum* (KJERULF). *a*, *b*, typical coarse mesh with broad dissepiments, Tøyen 590—595; P.M.O. 62000 (cf. pl. 3, fig. 1); *c*, close mesh with fine dissepiments, with patches of coarse mesh on right, Tøyen 650; P. M.O. 61936 (cf. pl. 3, fig. 3); *d*, contrasting areas of coarse and fine mesh, Bygdøy Sjøbad S. 605 (old collections); *e*, specimen from low level (Tøyen 750) with comparable coarse and fine mesh, P.M.O. 61913 (cf. pl. 3, fig. 4). All figs. x 2.

a little wider than, the branches themselves; and these are expanded at their bases to produce oval or rounded meshes. Dissepiments number about 8 in 10 mm. Plate 3, fig. 1 is typical; so too are text-figs. 8*a* and *b*, and MOBERG & SEGERBERG's fig. 7 or WESTERGÅRD's fig. 8. There is, however, considerable variation in mesh structure and one common variant, almost as characteristic as the above, results from much finer and more numerous dissepiments, up to 12—14 in 10 mm. These are inseparable, for the two commonly occur together in the same rhabdosome, and the second type may affect the dissepiments between two or three stipes only, adjacent

parts of the rhabdosome being composed of the coarse round-meshed type described above (e. g., pl. 3, fig. 1 and text-figs. 8*c* and *d*).

Thecae were unknown to previous authors, but a marginal branch on one rhabdosome (P.M.O. 61998, Tøyen 590—595) in this collection affords definite evidence of thecae numbering 12 in 10 mm; they are acutely denticulate, the denticles possibly drawn out into short spines, but preservation is not sufficiently good to determine this with certainty.

Type data: KJERULF's original material (1865) came from Tøyen, but has not been identified in the Paleontological Museum Collection.

Horizons: Tøyen 590—595, 650. Hammersborg 840—850.

Remarks: In addition, there are many forms which I refer to this variety with some reserve. Mostly (e. g., pl. 3, fig. 5) these recall the material described as cf. *norvegicum* from the Shineton Shales of the Coventry boring (BULMAN, 1928, p. 29 and 1927, pl. ii, figs. 9, 10). The dissepiments are irregular in spacing, being in places as few as 6, or as many as 10—11, in 10 mm; they are rarely as thick as the stipes, nor are they so conspicuously expanded at their bases as in the typical variety. Such forms seem clearly related to *norvegicum*, perhaps as transients between that variety and *flabelliforme* s.str; they occur both above (Hammersborg 780—800) and below (Tøyen 650—655) the true *norvegicum*. I regard *norvegicum* as a somewhat unstable variety, and would restrict the name to those examples which agree with the material from Tøyen 590—595 and 650 described above; for the remainder, the names cf. *norvegicum* and aff. *norvegicum* may be used.

Finally, there is the interesting specimen shown in pl. 3, fig. 4 and text-fig. 8*e*. At a first glance, this would be accepted as a normal *norvegicum*, though the dissepiments are perhaps somewhat more numerous than even in the fine meshed type. It comes, however, from a low level in the Tøyen section (750) where it is associated with *flabelliforme* s. l. and *sociale*, and it seems to represent a development of *norvegicum* characters in some *sociale* stock (see p. 9).

7. *Dictyonema flabelliforme parabola* var. nov.

Pl. 1, figs. 3—5; text-fig. 9.

Diagnosis: Rhabdosome with rounded «shoulders» and more or

less parabolic outline, developed from probably four initial branches; length/breadth ratio varying with age, but approximately 1.2 : 1 to 1.4 : 1 in mature rhabdosomes; stipes 8—10 in 10 mm, separated by interspaces about twice as wide ; dissepiments extremely irregular in spacing and direction, usually slender, somewhat expanded at their bases; thecae ? 13—14 in 10 mm.

Description: One of the most distinctive features of this variety is the rounded proximal end and very rapid initial branching, which is reminiscent of *D. cristatum* of Canada. It is probable that the rhabdosome originates in four primary branches; these divide rapidly at first, but form no significant zones of branching.

Text-fig. 9. *Dictyonema flabelliforme parabola* nov. Counterpart of holotype (pl. 1, fig. 3), Tøyen 770—775, P. M. O. 61773, x 2.

The mesh has typically a rather «loose» and highly irregular appearance; the stipes themselves lack the sub-parallel regularity characteristic of most *D. flabelliforme* varieties, and are instead often slightly flexuous. They not infrequently end blindly and are replaced by the division of an adjacent stipe. They are slender, 0.5 mm wide, separated by interspaces often twice as broad as the stipes and are united by very irregularly developed dissepiments. A few of these have been observed which are actually longitudinal in direction, connecting adjacent dissepiments and they are very variable both in spacing and direction; those shown in pl. 1, fig. 3 (and text-fig. 9) are considered typical, but forms with closer dissepiments (e. g., pl. 1, fig. 4) are also referred to this species. Young rhabdosomes with few dissepiments are rather easily distorted and may assume various shapes.

Young rhabdosomes may present some resemblance to *anglicum*, largely because of the broad rhabdosome form and widely-spaced branches, but the rounded proximal end and irregular dissepiments usually afford adequate distinction. They differ from the Canadian *D. cristatum* by their size and altogether coarser mesh. The rounded proximal end should distinguish them from *D. rusticum*, and although

they have something of the mesh characters of that species the dissepiments are more irregular and do not show the peculiar «knotted» appearance of *D. rusticum* (BULMAN, 1950).

Holotype: P.M.O. 61772 (pl. 1, fig. 3); P.M.O. 61773 (text-fig. 9) is the counterpart.

Horizon: The type has been selected from Tøyen 770—775, the lowest *Dictyonema*-bearing horizon of the Tøyen section. It occurs here associated with *D. flabelliforme* s. l. and with poorly preserved and mostly juvenile forms which I have referred to *D. flabelliforme* cf. *parabola*. The species also occurs at Nersnes (collected by G. HENNINGSMOEN) 50 cm below *Jujuyaspis;* very fragmentary specimens from 40—50 cm above *Boeckia hirsuta* at Nersnes (which probably represents the same horizon) may similarly be referable to this variety. In view of its early occurrence, it is of some interest to note that it has so little in common with *D. flabelliforme sociale*, other than its initial rapidity of branching.

8. *Dictyonema flabelliforme sociale* (SALTER).

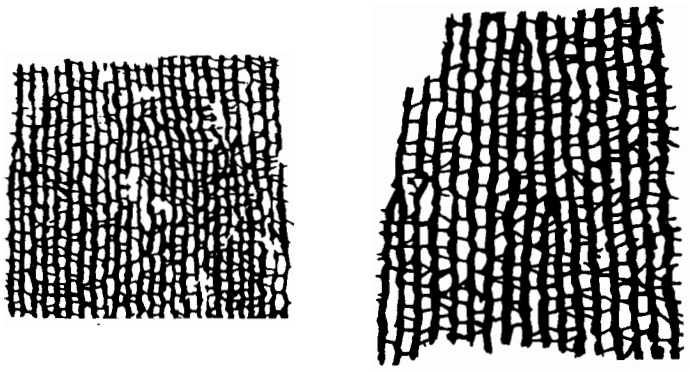
Pl. 1, figs. 1, 2; text-fig. 10a

Dictyonema sociale SALTER, 1866, p. 331, pl. iv, figs. 1, 1a-c.
Dictyonema sociale SALTER, 1881, p. 535, pl. iv, figs. 1, 1a-c.
Dictyograptus flabelliformis var. *conferta* LINNARSSON MS, BRØGGER, 1882, pp. 35 & 36 (no figs.).
?*Dictyonema flabelliforme* var. *confertum* MATTHEW, 1891, p. 36.
Dictyograptus flabelliformis var. *conferta* WESTERGÅRD, 1909, p. 59, pl. 3, fig. 7.
?*Dictyonema flabelliforme* var. *conferta* HAHN, 1912, p. 138, pl. XX.
Dictyonema flabelliforme var. *sociale* BULMAN, 1927, p. 26, pl. ii, figs. 1, 2.
Dictyonema flabelliforme var. *sociale* LECOMPTE, 1949, pp. 4 *et seq.*

Diagnosis: The rhabdosome is characterised by its elongate form (length/breadth ratio 1.6 : 1 to 2 : 1 or even slightly more) and fine close mesh — stipes 11—13, dissepiments 13—16, in 10 mm; dissepiments often irregular in direction, but are always very fine in comparison with stipe width.

Remarks: The branching is initially somewhat rapid, though it is difficult to recognise definite zones of branching; but it becomes very infrequent in the more mature portion of the rhabdosome. The stipes are virtually straight, but sometimes present finely irregular, almost zig-zag edges owing to the expansion of dissepi-

mental bases; they are appreciably wider than the interspaces by which they are separated. The dissepiments are mostly straight and at right angles to the stipes, but do show some irregularity both in spacing and direction; they seem to average about 16 in 10 mm in



a *b*

Text-fig. 10 *Dictyonema flabelliforme sociale* (Salter) *a*, typical close and fine mesh, Tøyen 745—750, P.M.O. 61816 (cf. pl. 1, fig. 1); *b*, *sociale/flabelliforme* transient, Tøyen 710—715, P.M.O. 61872. Both x 2.

the Tøyen material. There are no definite indications of thecae, which in British forms number 14—15 in 10 mm; WESTERGÅRD (1909, p. 60) cites 16.

The Tøyen specimens are noteworthy for their size, many rhabdosomes attaining the unusual length (for this variety) of more than 10 cm.

There is no evidence in the Tøyen section of a gradual transition from *sociale* to *flabelliforme* s.str., and the main *sociale* horizon (745—750) is succeeded abruptly by the large well-developed *flabelliforme* of 730—735. Moreover, *sociale/flabelliforme* transients are rare; one of these is illustrated in text-fig. 10*b* from Tøyen 710—715, and they are of course relatively common elsewhere (e. g., Shropshire, Belgium).

Lectotype: The syntypes figured by SALTER in 1866 have now been identified in the collections of the Geological Survey & Museum, and are as follows: fig. 1, 37500; fig. 1a, 10428 (upper part) and

10425 (lower part); fig. 1b, probably 37506; fig. 1c has not yet been traced. G.S.M. 37500 is selected as the lectotype.

Horizon: Tøyen 475—750, ? 755—760.

The variety is not represented at Hammersborg, but occurs at Bygdøy Sjøbad and Eiker, and also (as recorded by BRØGGER) at Vækkerø.

9. *Anisograptus norvegicus* sp. nov.

Pl. 7, figs, 1—5; text-figs. 11a, b.

Diagnosis: Rhabdosome triradiate, horizontal, branching to 4th order to produce 14—16 terminal branches in a mature rhabdosome about 4 cm in diameter stipes 0.3—0.4 mm wide (dorsal view), 0.7—0.9 mm in lateral view measured across the autothecal aperture, composed of autothecae (10—11 in 10 mm), stolothecae and bithecae.

Description: This is a rather variable form in respect of branching. First-order branches range from 1¼ to 3¾ mm in length (generally 1½ to 2½ or 3 mm); they are usually unequal in any given rhabdosome, either one long and two short, or two long and one short (cf. *Anisograptus matanensis*), rarely subequal (all short). Second-order branches average 3½—5 mm, with one recorded instance of 9 mm. Third-order branches are sometimes undivided (up to 2 cm or more in length) or give rise to fourth-order branches at 4½, 5 or even 9—10 mm. Fourth-order branches are all undivided, up to 2 cm in length, with the possible exception of a fifth-order division shown in text-fig. 11*a*.

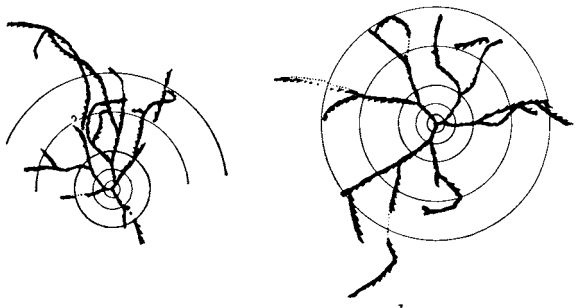
The stipes are slender, 0.3—0.4 mm in dorsal view, 0.7—0.9 mm in lateral view; autothecae number 10—11 or 11 in 10 mm, conspicuous and acutely denticulate in lateral view. Stolothecae and bithecae are present, but not well enough preserved for description.

Holotype: P.M.O. 62224A (pl. 7, fig. 1).

Horizons: Hammersborg 760—790, 740—750, 730—745, ? 720—730. Tøyen ?450.

This is the commonest of the Oslo anisograptids, and mainly characterises a horizon just above the last of the Dictyonemas, though occurring sparingly in the uppermost *Dictyonema* beds. Specimens from the uppermost levels (730—754, pl. 7, fig. 5) differ somewhat from those below in being rather smaller and more delicate, and some examples show evidence of stipe reduction.

Remarks: The species differs from *matanensis* (from which it is possibly only varietally distinct) in its larger size and greater branching capacity and rather fewer thecae; also it does not exhibit that almost



a *b*

Text-fig. 11. *Anisograptus norvegicus* sp. nov. *a*, Hammersborg 760—790, P.M.O. 62224B (cf. pl. 7, fig. 3); *b*, holotype, same locality and horizon, P.M.O. 62224A (cf. pl. 7, fig. 1). Both x 2. Concentric circles drawn at radii 1, 2½, 5, 10, and 15 mm.

diagnostic feature of *matanensis*, namely, that one of the three primary branches is always much shorter than the other two. The terminal branches are longer and more flexuous than in typical *matanensis*.

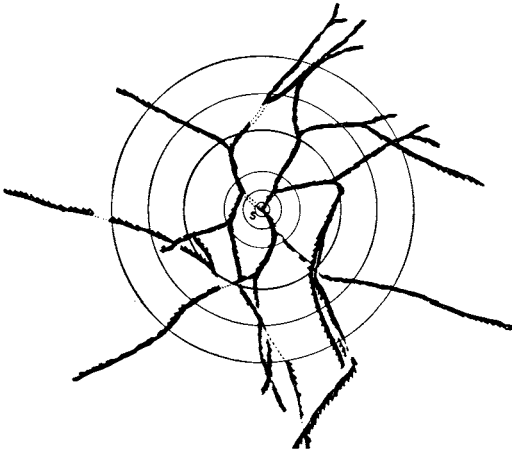
10. *Anisograptus grandis* sp. nov.

Pl. 6, figs. 1—4; text-fig. 12.

Diagnosis: Rhabdosome triradiate, horizontal, branching to 3rd, 4th or rarely 5th order at increasing and comparatively infrequent intervals to produce about 20—25 terminal branches in a full-grown rhabdosome some 6—7 cm in diameter; stipes 0.5—0.6 mm wide in dorsal view, 0.8—1.0 mm in profile measured across the autothecal aperture, composed of autothecae (13 in 10 mm), probably stolothecae and bithecae.

Description: The species is not common, but is distinctive in its large size and infrequent branching. First-order branches are subequal, 3—4 mm in length; second-order branches 5—9 mm (mostly 7—8 mm); some third-order branches are 3—3½ cm long and undivided, others divide at 8—12 mm; of the resulting fourth-order branches, most are 3—3½ cm long and undivided, but a few divide

at about 1 cm to produce short fifth-order branches. The branches diverge at a considerable angle (usually about 70°) and though not infrequently displaced, they give an impression of rigidity more like *matanensis* than *flexuosus*.



Text-fig. 12. *Anisograptus grandis* sp. nov. Counterpart of the holotype (pl. 6, fig. 1), Hammersborg 760—790, P.M.O. 62222 x 2. Concentric circles drawn at radii 1, 2½, 5, 10, 15 and 20 mm.

Autothecae number 12—13 (usually 13)in 10 mm; they are denticulate, but seem rather less acutely so than either *matanensis* or *flexuosus*. Stolothecae and bithecae are almost certainly present, but not well preserved.

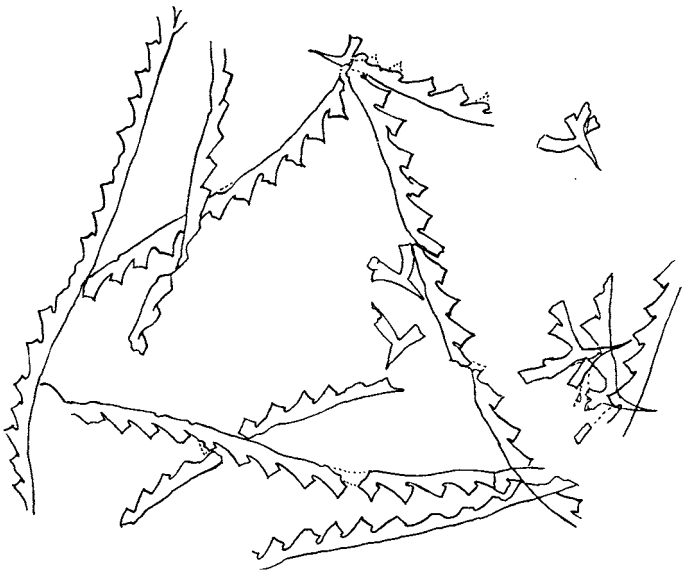
Holotype: P.M.O. 62222 (pl. 6, fig. 1); P.M.O. 62221, text-fig 12, is the counterpart.

Horizon: Hammersborg 760—790. Tøyen ?450.

Remarks: The species is distinguished from *matanensis* by its greater size and greater capacity for branching, and by its three sub-equal first-order branches. From *flexuosus* it is distinguished by its more «open» proximal end (the three first-order branches are here about 3 mm in length) and the greater length of all orders of branches. Circles are drawn in text-fig. 12 at the same intervals as those used in describing the Canadian forms (BULMAN, 1950) to facilitate comparison.

11. *Anisograptus isolatus* sp. nov.
Pl. 8, fig. 3, ?2; text-fig. 13.

Diagnosis: Form of the complete rhabdosome unknown, apparently triradiate and infrequently branching; stipes flexuous, 0.9—1.0 mm wide in profile measured across the autothecal aperture;



Text-fig. 13. *Anisograptus isolatus* sp. nov. Holotype, Tøyen 700—705, P.M.O. 61876, x 4. (cf. pl. 8, fig. 3).

autothecae 9—10 in 10 mm, with isolate apertural region, bluntly denticulate; stolothecae and bithecae unknown.

Description: The species is known only in a fragmentary condition, though sometimes (e.g., pl. 8, fig. 3) matted fragments almost cover an entire bedding plane. It is impossible to make out the complete rhabdosome form, or even to be positive that it is an *Anisograptus*, but more than one example gives the impression that three branches diverge from the sicula, one of which divides almost immediately. Subsequent branching is very infrequent, and branch fragments can be traced from 10 to 20 mm or more without any trace of division; rare dichotomy is, however, probable.

The distinctive feature is the character of the autothecae, which

are tubular and distinctly isolate distally. They number 9 or 9—10 in 10 mm; the ventral wall is gently concave and the apertural margin is also slightly concave, so that though the thecal tubes are truncated almost at right angles by the apertural margin, the aperture is slightly denticulate in profile view. The state of preservation of all available material does not permit any observations concerning the presence or absence of bithecae and stolothecae.

Holotype: P.M.O. 61876 (Pl. 8, fig. 3).

Horizons: Tøyen 700—705, 705—710. Hammersborg 780—800, ?740—750.

Remarks: The flexuous branches and infrequent bifurcation give a superficial resemblace to *Anisogr. retroflexus* (BRØGGER) and *Adelogr. hunnebergensis* (MOBERG). but the character of the autothecae is quite distinctive. It should, however, be noted that in poorly preserved material, or when the stipes are not preserved in true profile, this may be difficult to determine.

12. *Anisograptus ruedemanni* BULMAN.

Pl. 6, fig. 5.

Anisograptus ruedemanni BULMAN, 1941, pp. 111, 112, figs. 4a-e.

Remarks: The species was originally described from the *norvegicum* zone of the Dictyonema Shales at Vækkerø; the specimen shown here (pl. 6, fig. 5) comes from a horizon (810—810) just above *norvegicum* at Hammersborg. The three declined primary branches are considerably longer (6½-7 mm) than was recorded for *ruedemanni*, but details of the range in variation of this feature were not included in my 1941 description; re-examination of all the Vækkerø material preserved at Cambridge shows that primary branches may occasionally attain a length of 7 mm. The other dimensions and general habit of the Hammersborg specimen agree well with *A. ruedemanni*.

Holotype: Sedgwick Museum A 10066*a*. Vækkerø.

Horizon: Hammersborg 810—820.

13. *Anisograptus* spp.

Unidentifiable anisograptid remains occur at many horizons both at Tøyen and Hammersborg, often so abundantly as to cover an entire bedding-plane with a tangled mat of broken fragments; that

shown in fig. 1, pl. 8, is fairly typical. It is possible that many of these are identical with or near to *A. norvegicus*, but the fragments are too small to admit identification, there is some evidence that a somewhat smaller species is also present.

Horizons: Tøyen 725, 710—715, 705—710, 688—692, 490—450. Hammersborg 810—820, 790—800, 780—800, 650—670.

14. *Bryograptus kjerulfi* LAPWORTH.

Graptolithus tenuis KJERULF, 1865, pp. 1 & 3, fig. 6a, A & B (*non* c)
Bryograptus kjerulfi LAPWORTH, 1880, p. 164, pl. 5, figs. 22a, b.
Bryograptus kjerulfi BRØGGER, 1882, p. 37, pl. XII, figs. 20, 20a.
Bryograptus kjerulfi MOBERG & SEGERBERG, 1906, p. 61, pl. 1, fig. 14.
Bryograptus kjerulfi WESTERGÅRD, 1909, p. 66, pl. V, figs. 8, ?7, 9.

Remarks: Fragments probably referable to *B. kjerulfi* occur in the upper part of the Tøyen section; but they are far from common, and what appear at first sight to be bryograptids often prove on closer inspection to be immature and fragmentary *Dictyonema*. The species was originally described by KJERULF and BRØGGER from the Vækkerø section, where it may be relatively abundant, but to judge from the Tøyen and Hammersborg sections it is by no means a characteristic zonal index.

Horizons: Tøyen 630—635, 625, ?520—525.

15. *Bryograptus* cf. *ramosus* BRØGGER.

Pl. 4, fig. 9.

Remarks: The specimens here referred with reserve to *Bryograptus ramosus* are fragmentary, but they come from a comparable horizon (about 6 m above the Symphysurus Limestone — actually somewhat higher than the topotypes) and agree well in all determinable features. As remarked elsewhere (BULMAN, 1941, p. 106) it seems probable that there were three primary branches and that the species is correctly referred to *Bryograptus*.

Horizon: Hammersborg d + 20 (see text-fig. 1).

16. ?*Clonograptus tenellus* var. or *Anisograptus* sp.

Pl. 7, figs. 6, 7.

Remarks: The difficulty of distinguishing generically between

Anisograptus and *Clonograptus* rhabdosomes in the absence of a well-defined sicula is very real, and has been commented upon elsewhere several times; with only incomplete rhabdosomes, the difficulty is still greater. There is, however, something about the appearance of the fragments shown on pl. 7, figs. 6 & 7 (which occur on one of the bedding-planes covered with a mat of broken anisograptids) which causes me to suspect that these may be fragments of a *Clonograptus*. The branching is rather too regular for a typical anisograptid; there is a sense of greater rigidity, perhaps because all branches are preserved in dorsal view and there is no visible trace of thecae; and there is a slight but distinctive curvature to the branches, which at bifurcation are slightly more U-shaped than the acute V-shape of typical anisograptids. These points amount to little more than an impression, and the material occurs at a horizon (Tøyen 705—710) slightly lower than *Clonograptus* might be expected to characterise (say around 670—680). If the fragments belong to a *Clonograptus*, they are perhaps nearer to var. *callavei* than any other described variety, but they probably represent a distinct form; if they are anisograptid, they are certainly distinct from anything described above, but the material is really too fragmentary for diagnosis.

Horizon: Tøyen 705—710.

17. *Triograptus* sp.

Pl. 6, fig. 6.

Remarks: The genus is represented by several specimens, but none is sufficiently well-preserved for specific description. All apparently belong to the same species, and in the best of them (shown on pl. 6, fig. 6) the stipes are about 1 cm in length (the longest is 11 mm) and straight; they are 0.35 mm wide at origin,. and 0.7 mm measured across thecal apertures in the mature portion of the stipe. The thecae number 14—15 in 10 mm distally and are gently inclined. As none of the stipes is quite in true profile, the maximum width is certainly slightly greater than that quoted above, and the true inclination probably near 30—35°. The presence of bithecae is not certain, but there are indications of stolothecae.

Judging from its straight branches, this species seems nearer

T. canadensis than *T. osloensis* of 3aβ, but the thecae are more numerous than in either of those.

Horizons: Hammersborg 770—780, 760—790.

18. ?*Didymograptus* sp.

Pl. 5, figs. 7—9.

Remarks: Numerous examples of what may be a *Didymograptus* occur in the main *Anisograptus* horizon of Hammersborg. It is possible that they are simply young stages of an *Anisograptus* (probably *A. grandis*), but none show any trace of a third primary stipe and a reference to *Didymograptus* is possible. The sicula is slender, 2.2 mm long and 0.5 mm wide at the aperture. From this arise apparently two branches, which in no specimens exceed a few millimetres in length. They are initially declined, but rapidly become horizontal; they are 0.4 mm wide at origin, and attain an almost uniform width of 0.9 mm measured across the thecal apertures. Thecae occur at the rate of 12—13 in 10 mm and there is no trace of bithecae or stolothecae.

The specimens differ from others described from the Tremadocian by the initially declined rhabdosome, and should the generic reference be well founded, they certainly represent a new species.

Horizon: Hammersborg 760—790.

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Manuscript received March 28. 1953.

PLATES 1 – 8

All figures x 1½; untouched photographs except where otherwise stated,
P.M.O. = Paleontological Museum, Oslo.

PLATE 1.

Dictyonema flabelliforme sociale (SALTER).

Fig. 1. Typical large rhabdosome; Tøyen 745—750; P.M.O. 61816.
Fig. 2. Smaller and narrower rhabdosome from the same locality and horizon. P.M.O. 61814.

Dictyonema flabelliforme parabola var. nov.

Fig. 3. Holotype; Tøyen 770—775; P.M.O. 61772. (counterpart of specimen shown in text-fig. 9).
Fig. 4. 50 cm below *Jujuyaspis* at Nersnes; P.M.O. 66407.
Fig. 5. Same locality and horizon; unnumbered specimen with P.M.O. 66403.
Figs. 6, 7. *Dictyonema flabelliforme* cf. *parabola*. Immature rhabdosomes with root-like threads from the apex of the sicula. Both on the counterpart of P.M.O. 61776, Tøyen 770—775.

Figs. 5, 6, 7 slightly retouched.

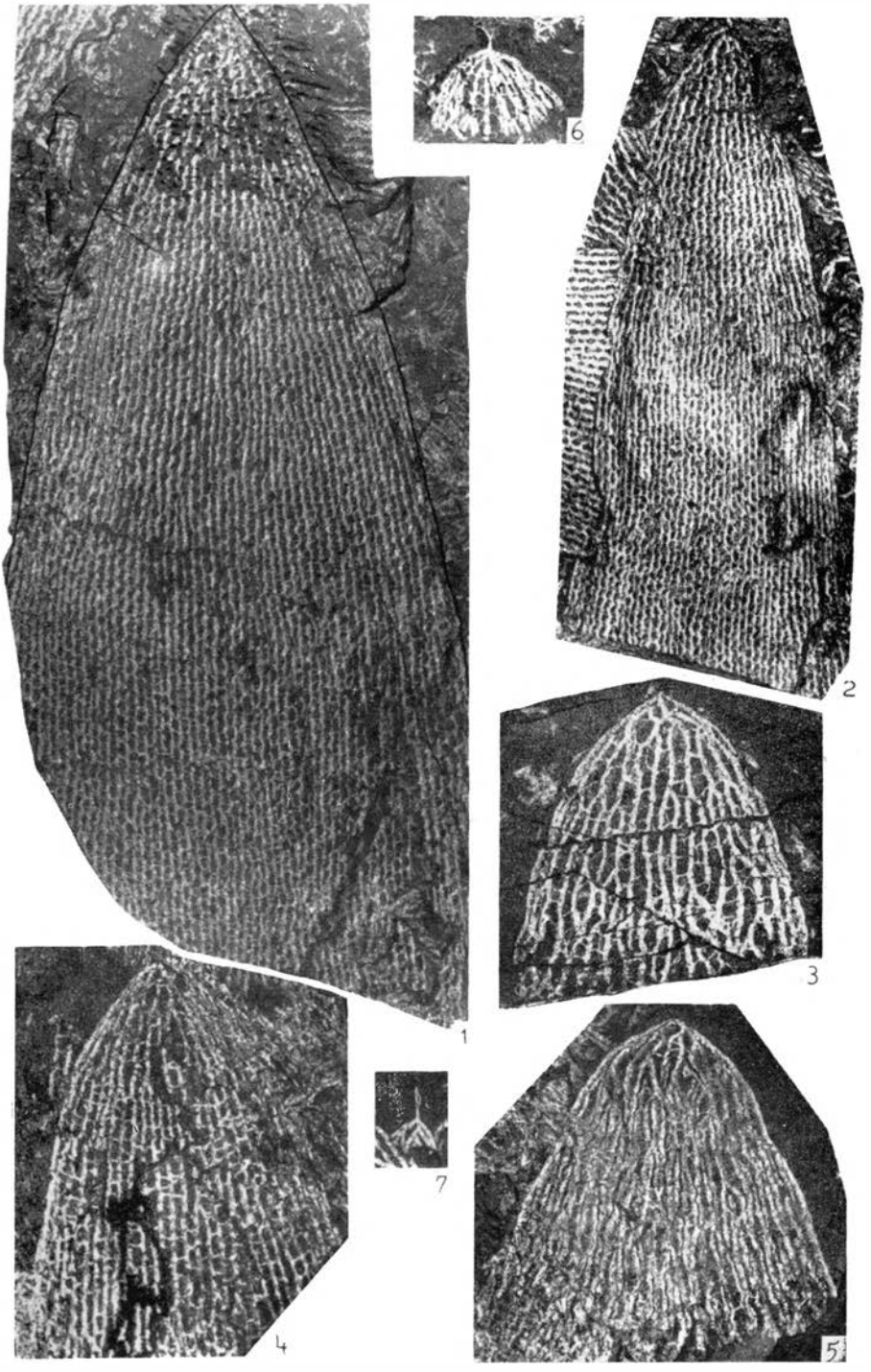
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PLATE 2.

Dictyonema flabelliforme flabelliforme (EICHWALD).

Fig. 1. The original of KJERULF's *Dictyonema Graptolithinum* (1865, fig. 4a) from Vækkerø.

Fig. 2. Another part of the same specimen giving an indication of the size of the rhabdosome.

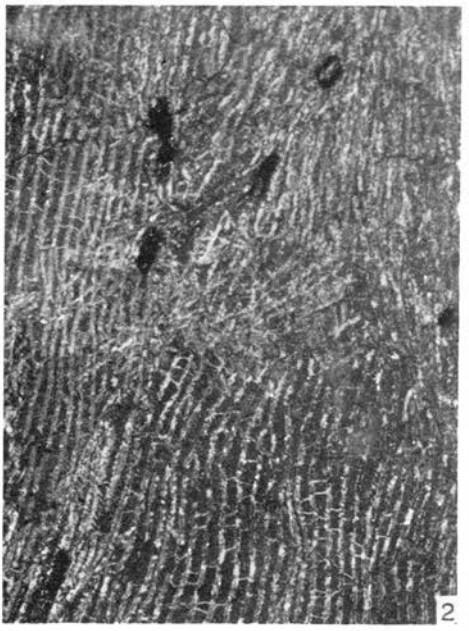
Fig. 3. Almost complete rhabsome showing typical shape and mesh characters; Tøyen 710—715; P.M.O 61866.

Fig. 4. Somewhat similar rhabdosome from Hammersborg 790—800; P.M.O. 62441.

Fig. 5. A portion of one of the large rhabdosomes from Tøyen 625—630; P.M.O. 61980b. The photograph includes about one-half of the distal end

Figs. 1—4 very slightly retouched.

PLATE 2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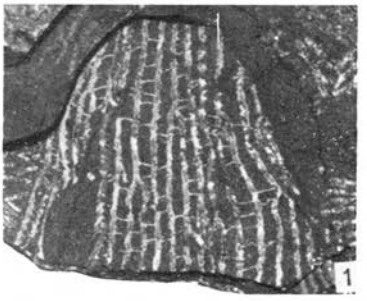
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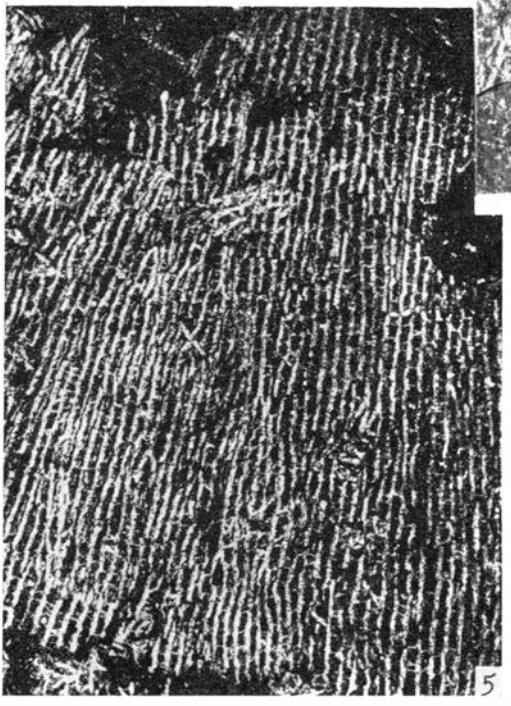
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PLATE 3.

Dictyonema flabelliforme norvegicum (KJERULF).

Fig. 1. Portions of two rhabdosomes showing, especially top left, the characteristic mesh characters. Tøyen 590—595; P.M.O. 62000.

Fig. 2. Almost complete rhabdosome giving indication of low length/breadth ratio. Hammersborg 840—850; P.M.O. 62450.

Fig. 3. Distal portion of specimen showing fine, close dissepiments on same rhabdosome as more widely-spaced, thick ones. Tøyen 650; P.M.O. 61936.

Fig. 4. Specimen from low level (Tøyen 750) associated with *D. flabelliforme* s. l. and *sociale*, but showing the characters of true *norvegicum* (cf. fig. 3). P.M.O. 61913.

Fig. 5. *D. flabelliforme* cf. *norvegicum*. Typical of specimens so named in this paper. Tøyen 650—655; P.M.O. 61932.

Fig. 2 slightly retouched.

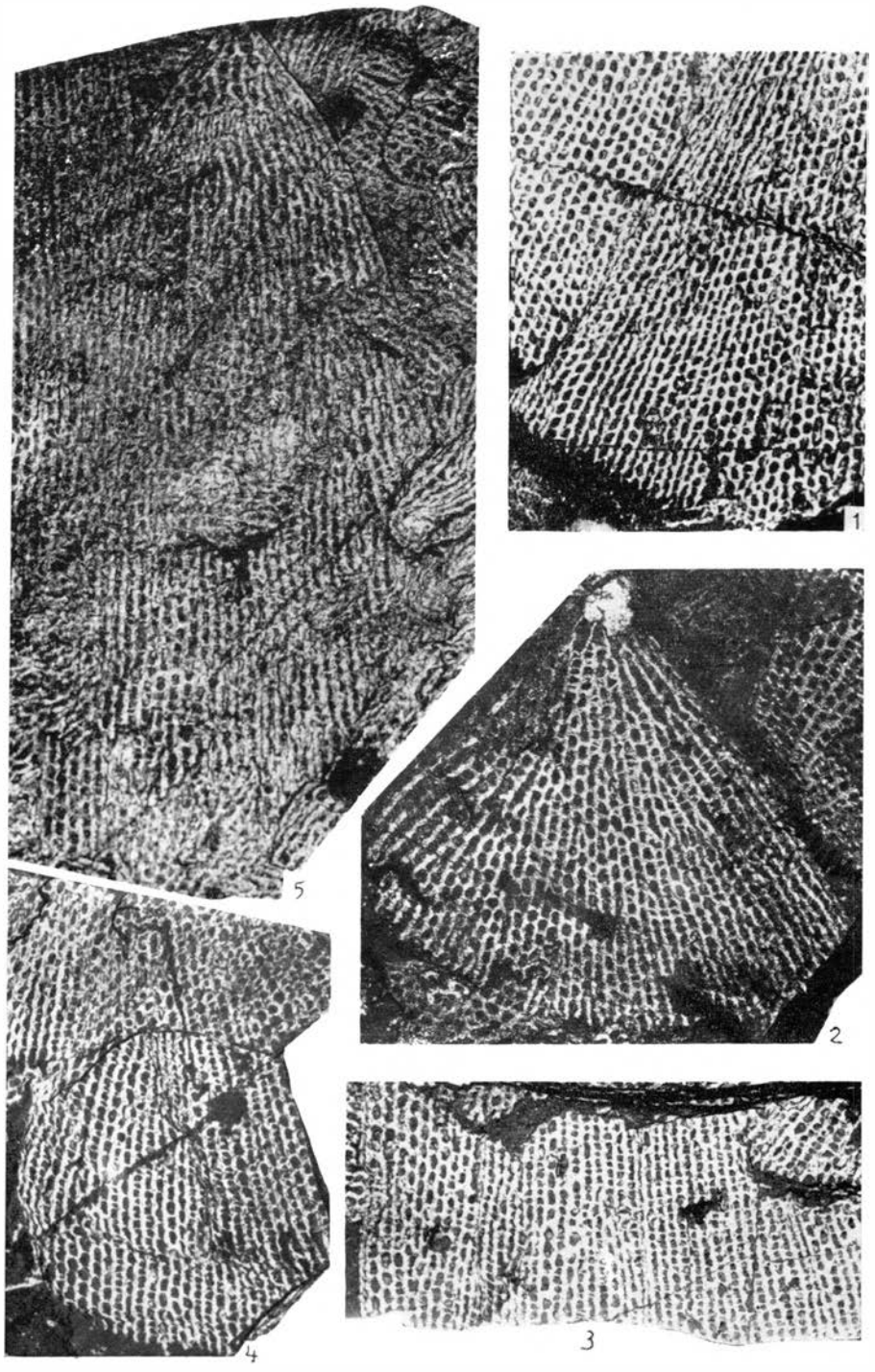
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PLATE 4.

Dictyonema flabelliforme aff. *flabelliforme* (EICHWALD).

Fig. 1. Specimen combining the rhabdosome shape of *sociale* with the mesh characters of *flabelliforme* s. str. (see p. 8); the two sides of the rhabdosome are pressed together and cannot be clearly distinguished. Slemmestad; P.M.O. 143.

Fig. 2. Specimen from high level, above *norvegicum*, showing rapid initial bifurcation. Hammersborg 780—800, P.M.O. 62648.

Dictyonema flabelliforme anglicum BULMAN..

Fig. 3. Typical mesh characters and low length/breadth ratio. Hammersborg 780—800; P.M.O. 62669.

Fig. 4. *D. flabelliforme* cf. *anglicum*. Hammersborg 820—830; P.M.O. 62395.

Fig. 5. Typical well-preserved rhabdosome of *D. flabelliforme anglicum*; the two sides of the rhabdosome are both visible and for clarity, that at the back has been partially blocked-out. Vækkerø, P.M.O. 114.

Dictyonema flabelliforme bryograptoides var. nov.

Fig. 6. The more complete rhabdosome on the right is the holotype. Tøyen 625; P.M.O. 61977.

Fig. 7. Tøyen 625—630; P.M.O. 61969.

Fig. 8. *D. flabelliforme* cf. *bryograptoides*. Probably immature rhabdosome with somewhat lower length/breadth ratio. Hammersborg 820—830; P.M. P.M.O. 62402.

Bryograptus cf. *ramosus* BRØGGER.

Fig. 9. Fragmentary rhabdosomes from the Ceratopyge Shale, Hammersborg d+20; P.M.O. 62184.

Figs. 1, 5, somewhat retouched.

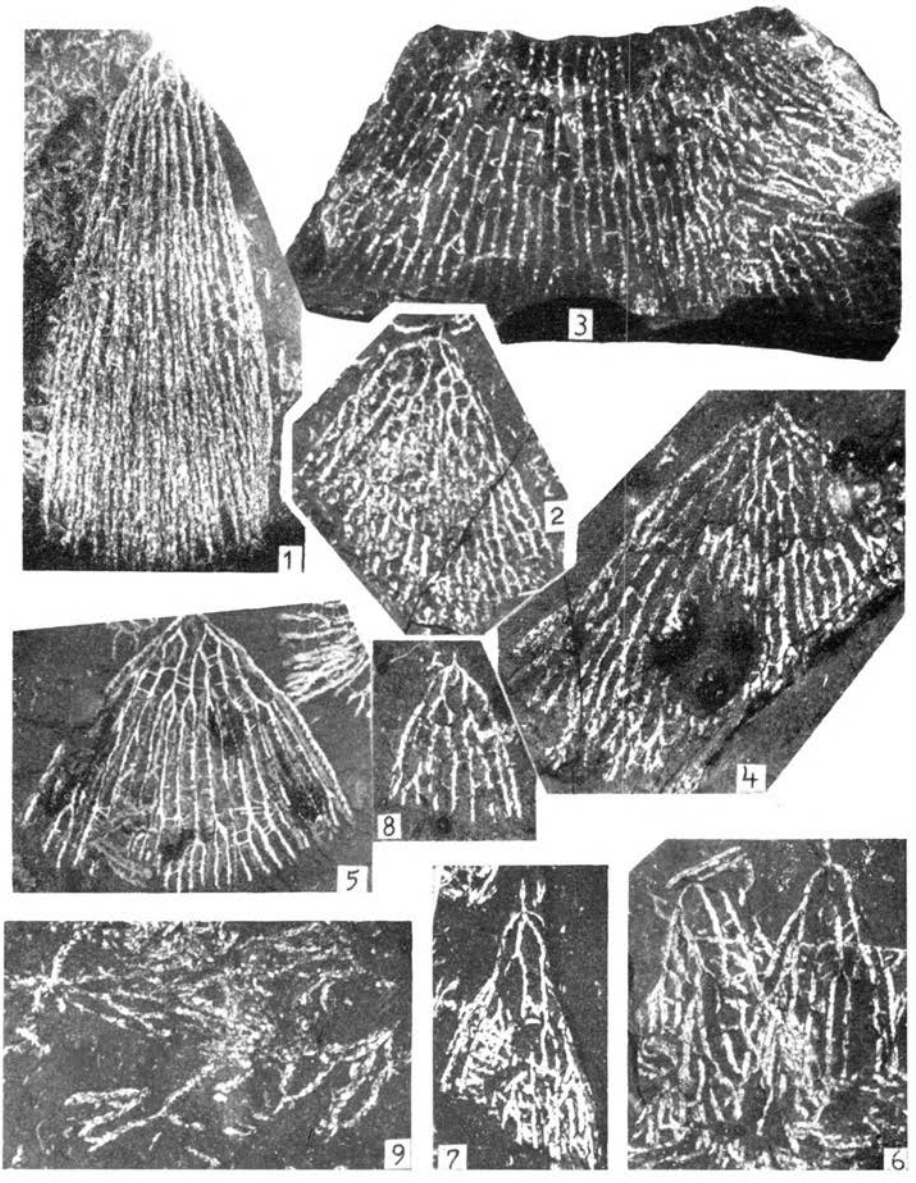
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PLATE 5.

Dictyonema flabelliforme desmograptoides HAHN.

Fig. 1. Fragmentary rhabdosomes showing irregular, rather coarse mesh characters. Hammersborg 780—800; P.M.O. 62683.

Fig. 2. More nearly complete rhabdosome; Eiker; P.M.O. 65672.

Fig. 3. Specimen showing form of proximal end of rhabdosome. Unknown locality, possibly Eiker; P.M.O. 236.

Fig. 4. Other fragments on same piece of shale as fig. 3, showing typically irregular proximal mesh.

Dictyonema flabelliforme multithecatum var. nov.

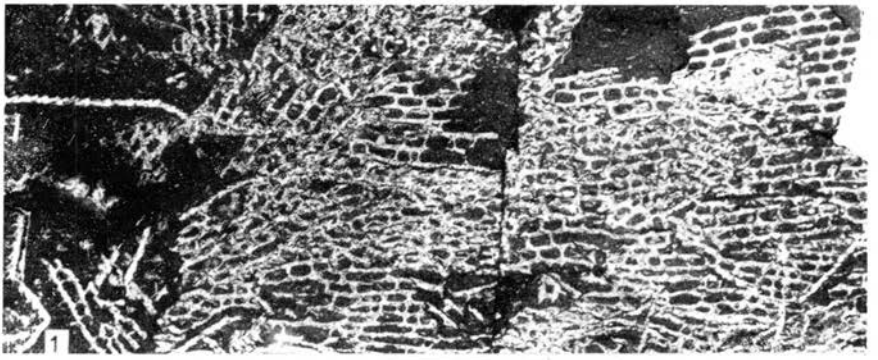
Fig. 5. Portion of holotype showing sparse dissepiments and long apertural spines. Hammersborg 835; P.M.O. 62412.

Fig. 6. *D. flabelliforme* cf. *multithecatum*. Proximal end, apertural spines not visible. Hammersborg 860—870; P.M.O. 62897.

?*Didymograptus* sp.

Figs. 7—9. Three examples from the main *Anisograptus* horizon, Hammersborg 760—790; P.M.O. 62222.

Figs. 5—9 slightly retouched.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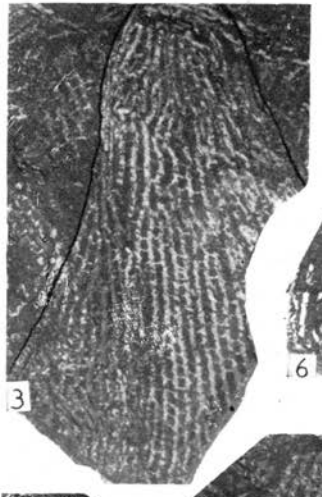
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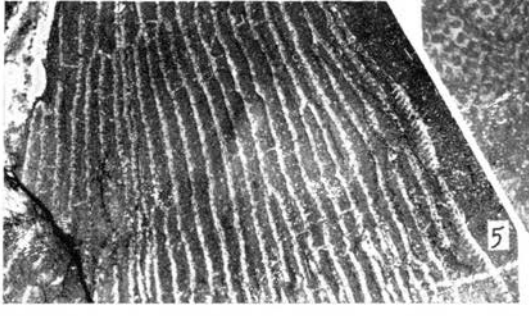
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PLATE 6.

Anisograptus grandis sp. nov.

Fig. 1. Holotype, and counterpart of specimen shown in text-fig. 12. Hammersborg 760—790; P.M.O. 62221 .

Fig. 2. Two less well-preserved and probably immature rhabdosomes. Hammersborg 760—790; P.M.●. 62255.

Fig. 3. Two early growth stages. Hammersborg 780—790; P.M.●. 62479.

Fig. 4. Another similar example. Hammersborg 780—790; P.M.●. 62971.

Anisograptus ruedemanni BULMAN.

Fig. 5. Hammersborg 810—820: P.M.O. 62430.

Triograptus sp.

Fig. 6. Typical rhabdosome from the main *Anisograptus* horizon, Hammersborg 760—790; P.M.O. 62222.

Fig. 6 slightly retouched.

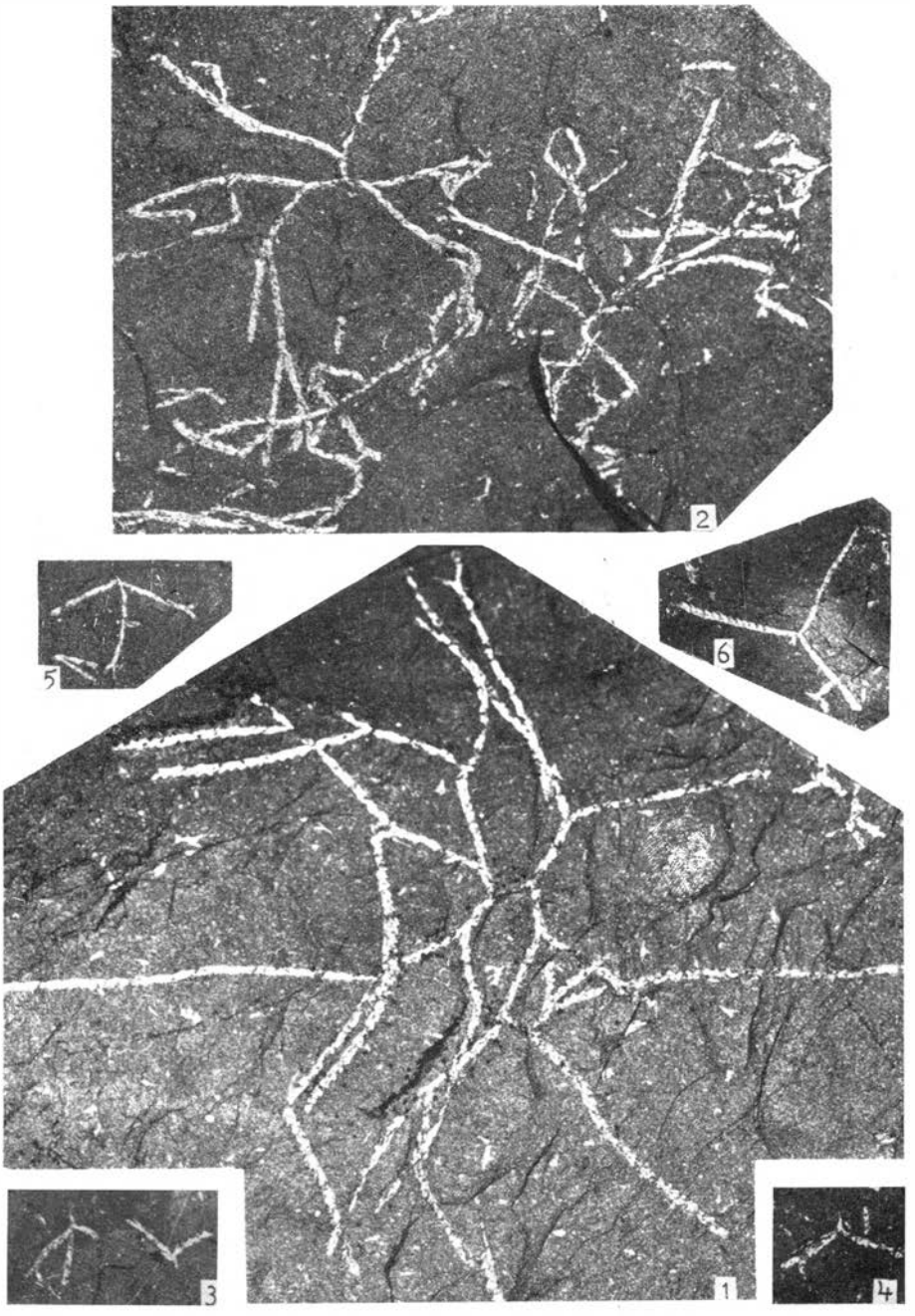
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PLATE 7.

Anisograptus norvegicus sp. nov.

Fig. 1. Holotype, Hammersborg 760—790; P.M.O. 62224A.

Fig. 2. Typical but less well-preserved rhabdosomes. Hammersborg 760—790; P.M.O. 62253.

Fig. 3. Another characteristic rhabdosome. Hammersborg 760—790; P.M.O. 62224B.

Fig. 4. Examples from a slightly higher level. Hammersborg 740—750; P.M.O. 62230.

Fig. 5. Specimens from the uppermost level, Hammersborg 730—745; P.M.O. 62151.

?Clonograptus tenellus var. or *Anisograptus* sp.

Figs. 6, 7. Various examples from a bedding-plane covered with a tangled mat of broken anisograptids. Tøyen 705—710; P.M.O. 61875.

Figs. 1, 3, 6 and 7 retouched.

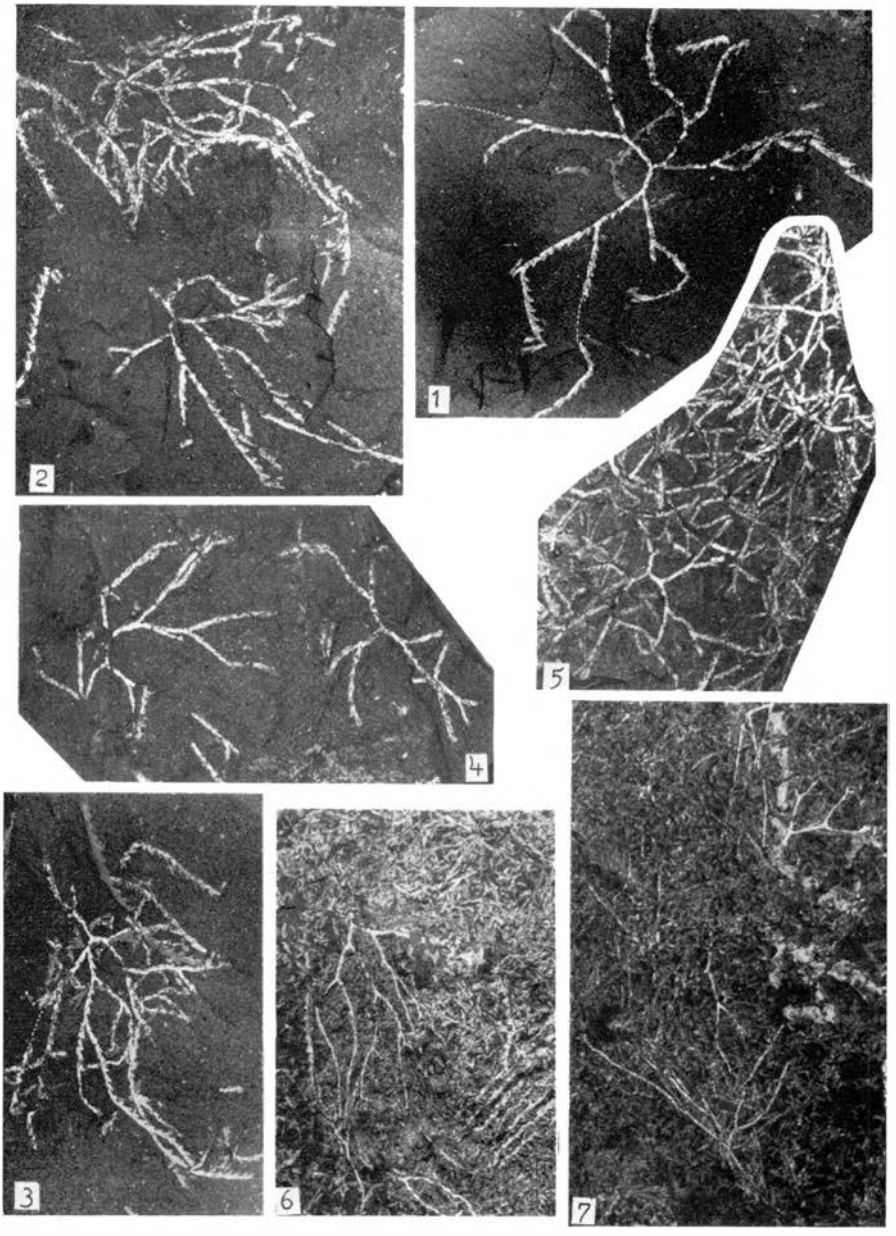
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PLATE 8.

Anisograptus sp.

Fig. 1. Indeterminate anisograptid remains showing characteristic mode of occurrence on various bedding-planes both in the Tøyen and Hammersborg sections. Tøyen 688—692; P.M.O. 61895.

Anisograptus isolatus sp. nov.

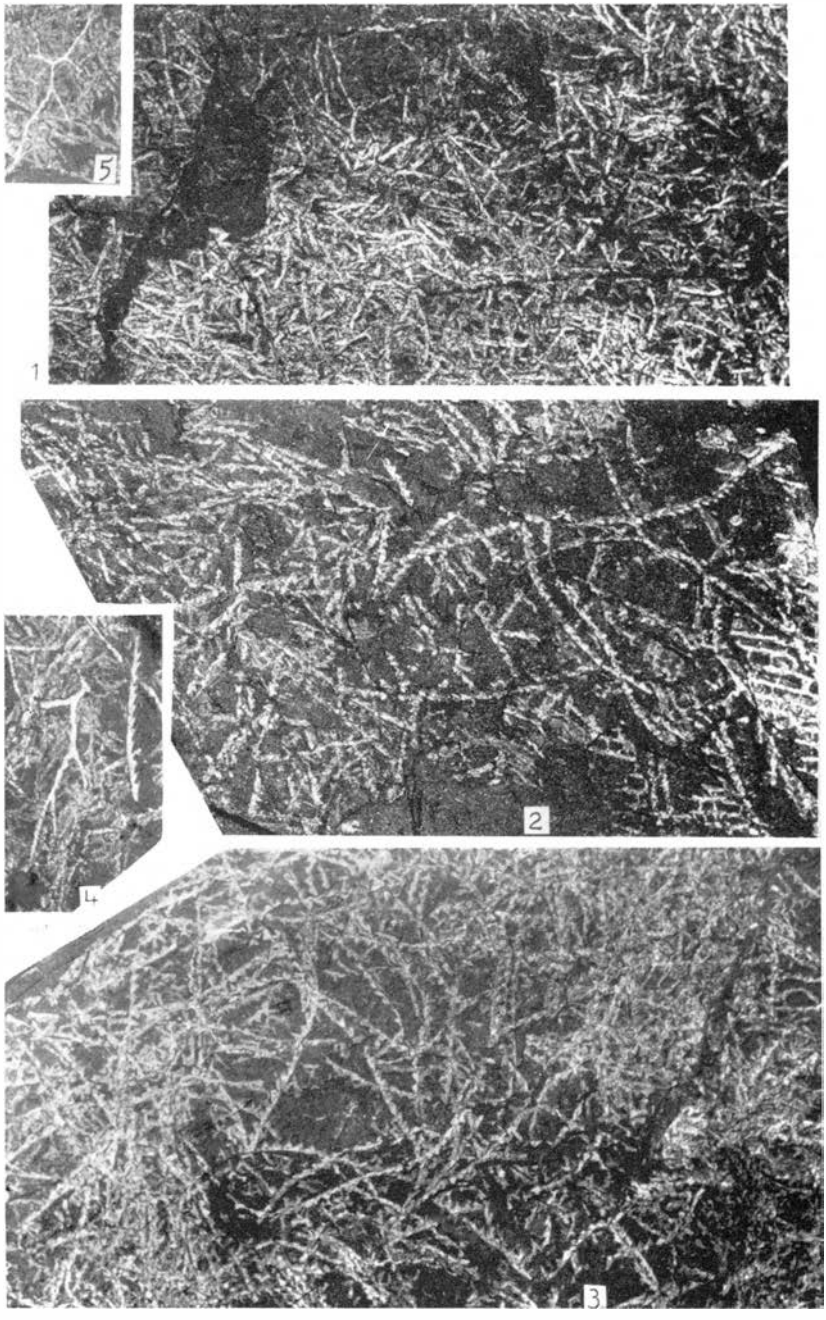
Fig. 2. Specimens probably referable to this species, associated with *D. flabelliforme desmograptoides*. Hammersborg 780—800; P.M.O. 62646.

Fig. 3. Holotype. Tøyen 700—705; P.M.O. 61876.

Anisograptus sp.

Figs. 4, 5. Two indeterminate anisograptid rhabdosomes from a horizon 5 m above the highest *Dictyonema*. Tøyen 450; P.M.O. 62034.

Figs. 4 & 5 retouched.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