Uppermost Viruan and Lower Harjuan (Ordovician) Stratigraphy of Västergötland, and Lower Harjuan Graptolite Faunas of Central Sweden

By

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ABSTRACT.—The stratigraphy of the uppermost Viru (Middle Ordovician) and lower parts of the Harju (Upper Ordovician) Series of Västergötland, Central Sweden, is based on the sequence in six borings and four exposures. Two new litho-stratigraphic units are distinguished, *viz.* the Mossen and Bestorp Formations, Viruan and Harjuan, respectively. At the type locality the lower part of the Mossen Formation is developed as a graptolitiferous shale (Z. of *Dicranograptus clingani*), whereas the upper part consists of calcareous mudstone with an ostracode fauna indicative of *Macrourus* beds. The Bestorp Formation, developed as a dark calcilutite displays a considerable variation in thickness and has a limited distribution. If present it constitutes the basal part of the Harju Series.—In all sections examined there is a pronounced hiatus at the boundary between the two series. The main part of the hiatus seems to fall within the Harju Series, since typical Slandrom Limestone is recorded nowhere and the Bestorp Limestone as well as the lower part of the Fjäcka Shale are missing or badly developed in most localities. In the Harjuan sequence the zones of *Pleurograptus linearis* and *Dicellograptus complanatus* are recognized.

The systematic part of this paper treats isolated graptolites from the Harjuan Fjäcka and Jonstorp Formations of Västergötland, and in addition isolated specimens from the Fjäcka Formation of Dalarna and Östergötland. Most isolated specimens are flattened with a well preserved periderm which often could be successfully bleached. *Pseudoclimacograptus clevensis* n.sp. is described from the Fjäcka Shale of Västergötland, and from contemporaneous beds in Dalarna and Östergötland *inter alia Diplograptus pristis* (HISINGER) and *Climacograptus styloideus* ELLES & WOOD are treated.

Contents

Introduction

This study was originally started in order to try the application of isolating methods on graptolites preserved in shale and mudstone of the Harju Series of Västergötland. As the method proved to be useful on specimens preserved under certain conditions the investigation was extended to comprise also the graptolite fauna of the Harju Series of Östergötland and the Siljan district, Dalarna.

The stratigraphy of the beds adjacent to the boundary between the Viru and Harju Series was incompletely known in the Billingen-Falbygden district. This is due to the lack of good natural exposures in this part of the sequence. There the rocks on either side of the serial boundary in question consist mostly of graptolitiferous shales and mudstones. The study of the graptolite fauna was therefore extended also to cover the stratigraphy of the uppermost Viru and Lower Harju Series of Västergötland. For the latter purpose cores of six borings were available. The entire sequence of one of these borings (Kullatorp on Kinnekulle; WÆRN *et al.* 1948) and the Viruan portion of another boring (Stora Åsbotorp on northern Billingen; JAANUSSON 1963a) has previously been described, whereas sections of the other borings have not been published. A section of the Harju Series of the Stora Åsbotorp boring is given here, and of

other borings, for the sake of completeness and with the exception of the Häggum core, the whole Ordovician sequence of the core is described. In addition, the boundary region in question was exposed by excavation at Mossen, Kinnekulle, and at Jonstorp, Mösseberg, and the section of the Skultorp boring was complemented upwards to the base of the *Dalmanitina* beds by a section measured at the Skultorp exposure. Only the graptolitiferous parts of the sections have been subjected to a close examination. The lower boundary of the sequence treated here in detail is drawn at the base of the Mossen Formation (*Dicranograptus clingani* Shale), and the upper boundary at the base of the main reddish-brown portion of the Jonstorp Mudstone.

The stratigraphic terminology of the Harju and Viru Series used in the present paper is that proposed by JAANUSSON (1963a, 1963b).

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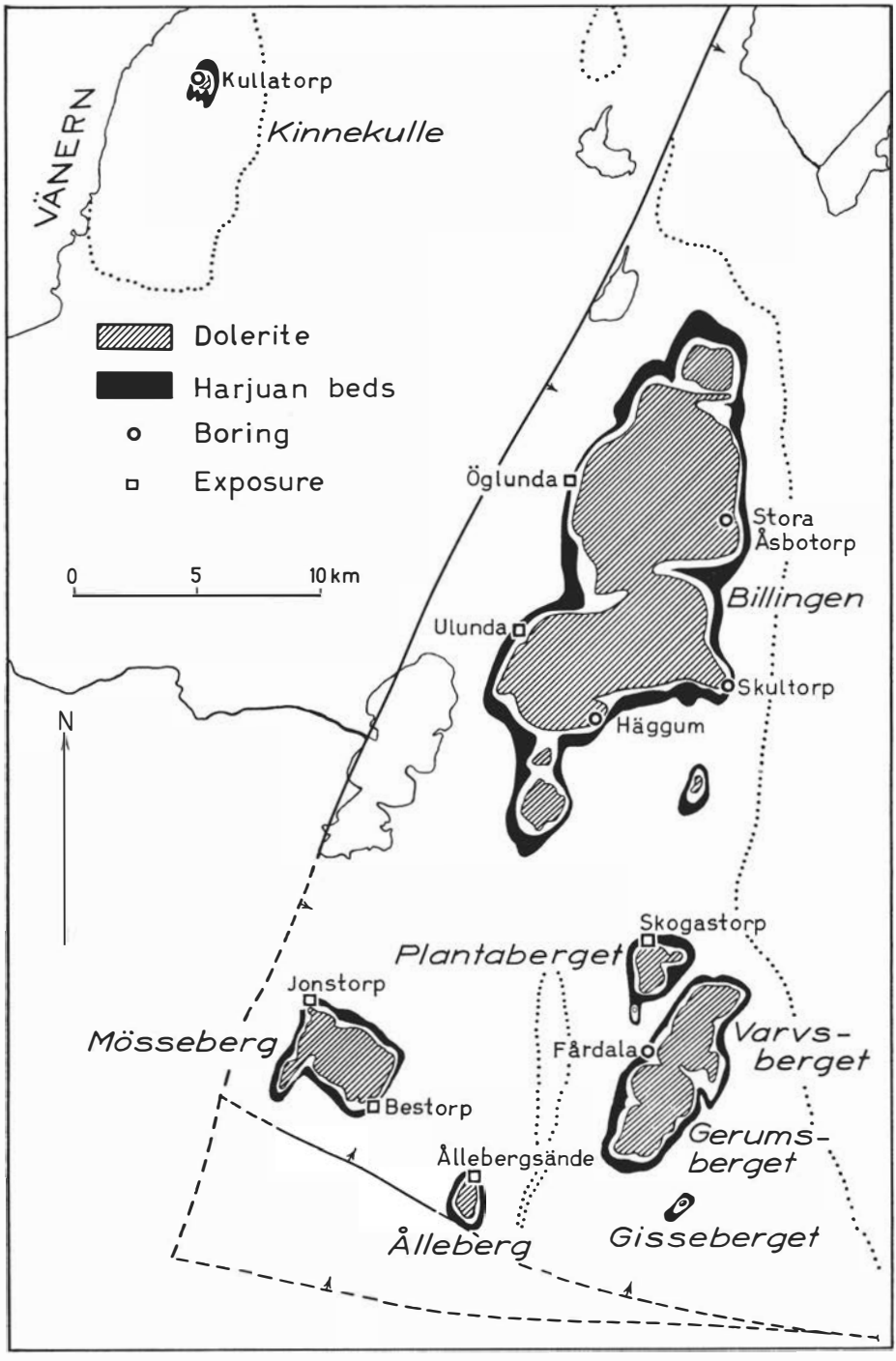
Core material has kindly been placed at the writer's disposal also by Dr. C. MÅRTENSSON, Atomenergi AB, Stockholm and Civiling. I. ÖHBERG, Rockwool AB, Skövde.

Material and Methods

MATERIAL.—The stratigraphic description of the Harju Series of Västergötland is based on six borings (Kullatorp, Stora Åsbotorp, Skultorp, Häggum, Bestorp, Fårdala I) and four exposures (Mossen, Skultorp, Bestorp, Jonstorp). The location of the borings and the exposures is given in Text-fig. 1.

The graptolites examined originate from (1) the cores, (2) collections in Swedish museums, and (3) from material collected by the present writer during parts of the summers of 1961 and 1962. The collections were obtained from the following museums: Palaeozoological Department, State Museum of Natural History, Stockholm (abbreviated RM), Museum of the Geological Survey of Sweden, Stockholm (SGU), and Museum of the Palaeontological Institute, University of Uppsala (UM).

For purpose of comparison the present writer had access to material from Scania and Bornholm collected and described by HADDING (1915), and now



Text-fig. 1. Map showing the locations of the borings and exposures through the Harju Series of Västergötland. After H. MUNTHE.

belonging to the Palaeontological Institute, University of Lund. From the same institute graptolite material of the Lindegård boring (GLIMBERG 1961) was borrowed. Topotypes of the species described from the Harjuan sequence of Bornholm by POULSEN (1936) were borrowed from the Institute of Palaeontology, University of Copenhagen. In the summer of 1961 the present writer has had the opportunity of examining type specimens in the Sedgwick Museum, University of Cambridge, and the Museum of the Geological Department, University of Birmingham. In the same summer topotypes were collected of several species described from Dobbs Linn, Moffat district, by LAPWORTH (1880) and ELLES & WOOD (1903, 1904, 1906, 1907).

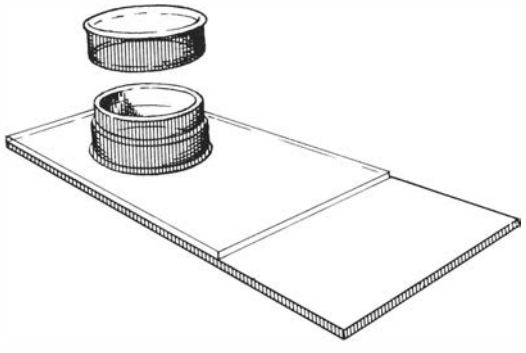
METHODS.—All graptolites examined from Västergötland, Östergötland, and Dalarna are preserved in shales or mudstones. Specimens with the periderm preserved have been isolated by hydrofluoric acid according to the method previously described (SKOGLUND 1961). Most specimens are flattened, but some have been preserved with a slight relief or, in rare cases, in full relief. The latter state of preservation occurs in specimens from the Fjäcka and Jonstorp Formations of Västergötland. Specimens filled with pyrite are mostly in full relief, but cannot be isolated by chemical methods without destroying the periderm. The graptolitiferous shale of the Mossen Formation as well as parts of the Fjäcka Formation are developed as black or dark grey shales in which the periderm of the graptolites is preserved as a thin film. Specimens in that state of preservation can not be isolated.

The graptolites from the Fjäcka Formation of Östergötland and Dalarna which occur in black shale are mostly strongly carbonized, and specimens preserved in full relief are very rare. Species with a thick periderm, e.g. *Diplograptus pristis* and *Climacograptus styloideus*, are in spite of strong carbonization very resistant to mechanical treatment.

Growth stages occur in most of the graptolitiferous beds treated in this paper. The interpretation of the development of the proximal end if based on flattened specimens only is, however, difficult, especially in diplograptids, without having access to a large number of successive growth stages.

Some growth stages and rhabdosomes with a thin periderm have been bleached with concentrated nitric acid and potassium chlorate. Specimens of the two species mentioned above were not transparent without bleaching for 24 hours. Then they were in general too fragile for handling.

Isolated specimens which were not bleached are mounted dry. The bleached ones are all mounted in glycerine in plastic cells (Text-fig. 2). The cell consists of a small plastic box cemented to a glass slide. As the bottom of the plastic box is not transparent, it is removed before the box is stuck to the glass slide. After fixing the box a thin layer of a cement of cellulose acetate is put upon the surface of the glass slide within the box to prevent any leakage of glycerine. The box is closed by a tight-fitting lid which is easily removed, when the mounted specimen is to be studied. The glass slide is glued to a piece of



Text-fig. 2. Plastic box cemented to a glass slide which is glued on cardboard.

cardboard, three centimetres longer than the slide in order to provide a space for a label. The cardboard is provided with a hole of the same diameter as the plastic box, permitting study and photographing of the specimens in transmitted light.

Unbleached specimens were whitened with ammonium chloride before photographing. Text-figures are drawn from enlarged photographic prints.

The measurements made on specimens of *Orthograptus gracilis* were performed with a Wentworth-Hunt integrating stage with an accuracy of the reading of 0.005 mm. All other measurements are made with an ocular micrometer in a stereomicroscope.

Historical Survey

An historical account on the stratigraphy of the Harju Series is given by JAANUSSON (1963 b). The historical survey given here mainly deals with previous investigations of the graptolite faunas in these beds.

The occurrence of graptolites in the shales and mudstones of the Harju Series of Sweden has long been known. As early as 1837 HISINGER described *Diplograptus pristis* from the Fjäcka Shale of Dalarna. Later, Harjuan graptolites of Dalarna were treated by TÖRNQUIST (1881, 1891), who described the following species: *Dicellograptus anceps* NICHOLSON (=*morrisi* HOPKINSON), *Diplograptus pristis* (HISINGER), *Diplograptus* (=*Orthograptus*) *truncatus* LAPWORTH, and *Lasiograptus margaritatus* LAPWORTH. A further species of the genus *Dicellograptus* was recorded, but with the scanty material at hand TÖRNQUIST did not give any specific name or description (1891, p. 23). In previous papers the species *Dicellograptus morrisi* had been recorded by TÖRNQUIST as *Didymograpsus ludensis* S.S. (1867, p. 15), *Didymograpsus* sp. (1874, p. 17) and *Dicranograptus Moffatensis*? CARRUTHERS (1876, p. 56). The graptolite fauna of the Fjäcka Shale of Dalarna was treated again in 1935, when TÖRNQUIST's misidentification of *Dicellograptus morrisi* was corrected (BULMAN in THORSLUND 1935, p. 48). The following species were recorded: *Dicellograptus morrisi* HOPKINSON, *Climacograptus minimus* (CARRUTHERS) [=*angustus* (PERNER)], *Climacograptus styloideus*

LAPWORTH (=ELLES & WOOD), *Diplograptus* (*Mesograptus*) *pristis* HISINGER [=*Diplograptus pristis* (HISINGER)]. The assemblage was considered to indicate the zone of *Pleurograptus linearis*.

From the Fjäcka Shale of Östergötland TÖRNQUIST (1876) mentioned *Dicellograptus Moffatensis*? CARRUTHERS (=*morrisi* HOPKINSON) and *Diplograptus pristis* (HISINGER). The former species was later recorded as *Dicellograptus anceps* (LINNARSSON & TULLBERG 1882; TÖRNQUIST 1913).

Graptolites from the Harjuan sequence of Västergötland were first recorded by LINNARSSON (1866, 1869) who listed *Didymograpsus* (=*Dicellograptus*) and *Diplograpsus* (=*Orthograptus*) from the Billingen-Falbygden district. In a paper on the fossiliferous sequence of Dalarna TÖRNQUIST (1867) also mentioned graptolites from the Harjuan of Västergötland, viz. *Diplograptus pristis* HISINGER (=*Orthograptus* spp.) and *Didymograptus ludensis* S.S. (=?*Dicellograptus complanatus* LAPWORTH). The species were recorded without any information about the locality. Probably influenced by TÖRNQUIST's statement on the occurrence of *Dicellograptus anceps* in the Fjäcka Shale of Dalarna, some authors recorded the species also from the Harju Series of Västergötland. TULLBERG (1883, p. 252) gave no further information about the occurrence of the species, but MUNTHE (1906, p. 31) mentioned it from Mösseberg. In addition to TÖRNQUIST's records *Diplograptus pristis* (=*Orthograptus* spp.) was listed from Kinnekulle by HOLM (1901) and from the Billingen-Falbygden district by MUNTHE (1906). MOBERG (1910) also reported the species from Västergötland without referring to any particular locality. Later TÖRNQUIST (1913) stated that *Diplograptus pristis* could not with certainty be proved to occur outside Dalarna and Östergötland. The first report on *Dicellograptus complanatus* LAPWORTH was given by TÖRNQUIST (1913) from Mösseberg. After 1913 no Harjuan graptolites were treated from Västergötland until HENNINGSMOEN's (1948) description of the Harjuan sequence of the Kullatorp boring was published. The following species were treated by him: *Dicellograptus johnstrupi* HADDING, *Diplograptus* (*Orthograptus*) cf. *truncatus* (=*Orthograptus* cf. *truncatus*) LAPWORTH, *Diplograptus* (*Orthograptus*) *truncatus pauperatus* (=*Orthograptus pauperatus*) ELLES & WOOD, *Diplograptus* (*Orthograptus*) *quadrimucronatus* (=*Orthograptus quadrimucronatus*) (HALL), *Climacograptus styloideus* LAPWORTH (=ELLES & WOOD), *Climacograptus* cf. *minimus* (CARRUTHERS) (=*Pseudoclimacograptus clevensis* n. sp.) and *Leptograptus flaccidus macer* ELLES & WOOD (=*Leptograptus* sp.). Only one of these specimens was figured (*Dicellograptus johnstrupi*; HENNINGSMOEN 1948, p. 402, Fig. 2). The assemblage was regarded as indicative of the zone of *Pleurograptus linearis* (*op. cit.* p. 425).

The presence of the zone of *Pleurograptus linearis* has thus been proved in the Siljan district, Dalarna, and on Kinnekulle, Västergötland, where in the Kullatorp core (THORSLUND 1948) also the Viruan zone of *Dicranograptus clingani* was recognized (cf. p. 25). In the Billingen-Falbygden district the two zones have been recognized for the first time by the present writer. Nor has the

zone of *Dicellograptus complanatus* previously been known from Kinnekulle and Billingen. As regards Östergötland the graptolitiferous shale of the lower Harjuan sequence could be correlated with the Fjäcka Shale of Dalarna as stated by TÖRNQUIST (1876).

In the Black Tretaspis Shale (=Fjäcka Shale) of Jämtland THORSLUND (1940) found a graptolite fauna which was indicative of the zone of *Pleurograptus linearis*. Some species recorded by him are common to the contemporaneous beds in Dalarna e.g. *Dicellograptus morrisi* HOPKINSON and *Climacograptus styloideus* ELLES & WOOD. The stratigraphic classification of the lower Harjuan sequence of Scania has mainly been based on the graptolite fauna. The two zones of *Pleurograptus linearis* and *Dicellograptus complanatus* have been properly defined since 1906 (OLIN). In addition to these zones GLIMBERG (1961) also recognized the zone of *Dicellograptus anceps*.

Description of Two New Litho-Stratigraphic Units

MOSSEN FORMATION.—The formation is in some localities bipartite with the lower part developed as a dark-grey or black graptolitiferous shale and the upper part as a grey occasionally calcareous mudstone. The lower boundary is drawn at the top of the Skagen Limestone. The upper boundary, which coincides with the boundary between the Viru and Harju Series is the base of the Bestorp Limestone or that of the Fjäcka Shale. The type locality is the exposure at Mossen on the eastern slope of Kinnekulle.

The formation was first distinguished as a separate stratigraphic unit by THORSLUND (1948). It was previously termed the zone of *Dicranograptus clingani* (THORSLUND 1948) or the *Dicranograptus clingani* Shale (THORSLUND & JAANUSSON 1960, p. 19). However, in some localities a considerable part of the formation consists of a calcareous mudstone with a rich shelly fauna and without graptolites. The use of a term of the graptolitic sequence for a unit including also the latter beds does not seem to be appropriate, and a more neutral formational name is, therefore, preferred here.

As here defined the Mossen Formation can at present be distinguished in Västergötland only. Its graptolitic shale facies can be regarded as a tongue from the *Dicellograptus* Shale of Scania and on Bornholm. The formation has a peculiar patchy distribution in Västergötland being known only from Kinnekulle, the easternmost part of southern Billingen, western Mösseberg, and Varvsberget. The thick succession of black shale facies recorded from western Billingen by BYSTRÖM (1957, Fig. 1) makes it probable, that this unit is developed there also. The following thickness of the formation is known from different exposures and borings:

Mossen 1.57 m
Kullatorp boring 1.05 m
Skultorp boring 0.25 m
Jonstorp 0.35 m
Fårdala boring I 0.41 m

Fossils recorded from the shale:

Dicranograptus clingani CARRUTHERS
Dicellograptus sp. indet.
Climacograptus diplacanthus BULMAN
Pseudoclimacograptus sp.
Diplograptus sp.
Corynoides cf. *calicularis* NICHOLSON
Lonchodomas minutus THORSLUND
Parapyxion obesum (THORSLUND)
Onniella sp.
Chonetoidea sp.

Fossils recorded from the calcareous mudstone:

Tretaspis ceriodes (ANGELIN)
Piretella cf. *oepiki* THORSLUND
Steusloffia n.sp.
Uhakiella n.sp.
Euprimites n.sp.
Sigmobolbina n.sp.
Parapyxion obesum (THORSLUND)

THORSLUND (1948, p. 345) has recorded also the following graptolites from the shale: *Climacograptus brevis* ELLES & WOOD, *Diplograptus multidens* var. *compactus* LAPWORTH, *Amplexograptus pulchellus* (HADDING), *Amplexograptus vasae* TULLBERG, and *Corynoides curtus* LAPWORTH. Specimens of these species identified by him from the Kullatorp core could not be localized.

BESTORP LIMESTONE.—Dense, thick-bedded, dark-grey calcilutite with intercalations of black shale. The lower boundary, which coincides with the boundary between the Harju and Viru Series, is drawn at the top of the Skagen Limestone or that of the Mossen Formation. The upper boundary is the base of the Fjäcka Shale. The type locality is Bestorp on the eastern slope of Mösseberg, where the upper part of the formation is exposed, and where the whole formation has been pierced by a boring.

The beds constituting the Bestorp Formation were previously included in the Slandrom Limestone (THORSLUND 1940, p. 124; 1948, p. 357). The reasons for distinguishing it as a separate formation are given on p. 28.

The formation is developed only in the Billingen-Falbygden district, Västergötland. It is known from eastern Billingen except for its southernmost part, from Mösseberg, and Varvsberget. Its thickness shows great fluctuations:

Bestorp boring 4.55 m
Jonstorp 0.20 to 0.35 m
Fårdala boring I 0.33 m
Skultorp boring 0.21 m
Stora Åsbotorp boring 1.80 m

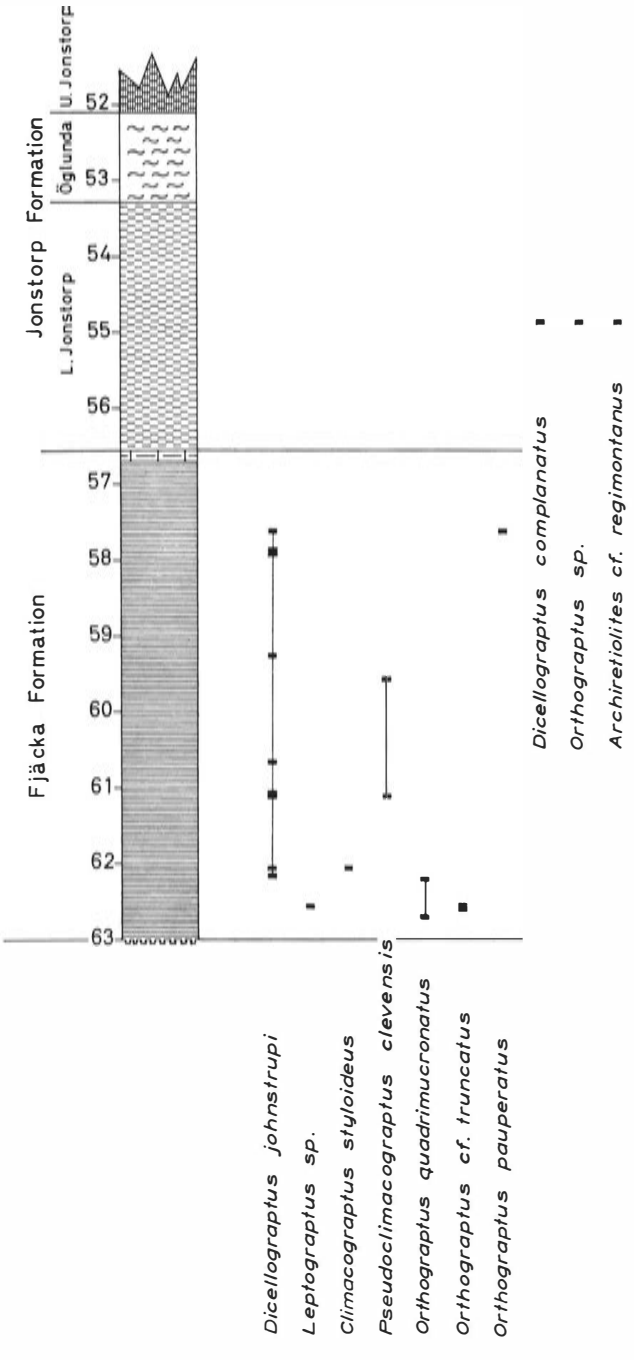
The formation is very poor in fossils. The following forms only have been found:

Leptograptus sp.
Dicellograptus sp. indet.
Remopleurides sp.
»*Acidaspis*» cf. *dalecarlicus* TÖRNQUIST

Review of Borings and Exposures in Västergötland

Kullatorp Boring, Western Slope of Kinnekulle

The Kullatorp boring was carried out by the Palaeontological Institute of Uppsala University in 1944, and the sequence of the core was described by WÆRN *et al.* (1948). In the description of the Harju Series HENNINGSMOEN



Text-fig. 3. Kullatorp core. Range of graptolite species within the Fjäcka and Jonstorp Formations. Legend, see Text-fig. 4.

recorded a graptolite fauna indicative of the zone of *Pleurograptus linearis* from the Black *Tretaspis* Shale (=Fjäcka Shale). In the superimposed mudstone he observed indeterminable fragments of graptolites. The present writer dissolved a sample from the layers in question and obtained the following species between the levels of 54.85 and 54.98 m: *Dicellograptus complanatus* LAPWORTH, *Orthograptus* sp., and *Archiretiolites* cf. *regimontanus* EISENACK. Consequently also the zone of *Dicellograptus complanatus* has been recognized in the core.

The columnar section of the core figured in this paper is based on HENNINGSMOEN's description. The present presentation of the lithology is somewhat simplified, as each litho-stratigraphic unit is given a uniform sign. The boundaries of the units are drawn according to HENNINGSMOEN (1948, p. 380). The data concerning the vertical range of the graptolites from the Fjäcka Shale as given in Text-fig. 3 are based upon the original description and upon the graptolite material of the core kept in the Museum of the Palaeontological Institute, Uppsala.

Mossen Section, Eastern Slope of Kinnekulle

A diagrammatic section comprising the uppermost Viruan sequence and evidently also the basal beds of the Harju Series of the exposure at Mossen was given by THORSLUND (1948, p. 351). The uppermost part of the section (c. 2 m) was marked as shale. Nothing was mentioned about the stratigraphic position of the shaly division and no fossils were recorded. Later unpublished finds of *Dicranograptus clingani* from the shale proved the presence of the zone of *Dicranograptus clingani* in the Mossen Section. The vertical range of the zone was, however, unknown. In order to determine this range and the location of the boundary between the Viru and Harju Series the present writer exposed the uppermost part of the section by excavation. The excavated section showed that the shaly division mentioned above is not uniform. It consists, in ascending order, of black shale, calcareous mudstone, and black shale. Based on the ostracode fauna, the serial boundary is drawn on the top of the calcareous mudstone, where a rusty layer of weathered pyrite occurs. The black shale above the mudstone evidently belongs to the basal part of the Fjäcka Shale. In the Kullatorp core the base of the Fjäcka Shale is developed as a »dark and somewhat loose marlstone» (HENNINGSMOEN 1948, p. 376).

The ostracodes recorded below have been identified by Dr. JAANUSSON.

Description of the Excavated Section

Harju Series 0.30 m. +
  Fjäcka Formation 0.30 m. +
    0.30 m. + Black shale.

Viru Series 1.97 m. +
  Mossen Formation 1.57 m.

0.42 m. Grey calcareous mudstone, in the middle part developed as a coquina which is formed mainly of ostracodes. Two rusty layers (c. 1 cm in thickness) of weathered pyrite, one on top of the division, the other 0.19 m below the top.

Piretella cf. *oepiki* THORSLUND
Euprimites n. sp.
Uhakiella n.sp.
Steusloffia n.sp.
Sigmobolbina n.sp.
Parapyxion obesum (THORSLUND)

1.15 m. Dark-grey, in part slightly speckled shale.

Dicranograptus clingani CARRUTHERS
"*Diplograptus*" sp. (0.30–0.35 m above the base)
Onniella sp. (1.05 m above the base)
Chonetoidea sp. (0.30–0.35 m above the base)

Skagen Formation 0.40 m. +

0.40 m. + Greenish-grey mudstone.

Stora Åsbotorp Boring, Eastern Slope of Northern Billingen

The section described below is the upward continuation of the sequence described by JAANUSSON (1963a) who has also given details about the boring. The *Dalmanitina* beds and the Llandoverian sequence of the core are still undescribed. The Harjuan portion of the core below the *Dalmanitina* beds was searched for macrofossils by Dr. G. HENNINGSMOEN who also prepared a preliminary unpublished description of the core. The somewhat more detailed section given below was measured by Dr. V. JAANUSSON and the present writer. A detailed investigation of this part of the core has not been carried out yet. Diameter of the core is 7 cm.

Description of the Core

Harju Series 23.17 m. +

Ulunda Formation 10.21 m.

15.13–16.61 m. Light- to dark-grey, mostly speckled mudstone.
Tretaspis latilimbata (LINNARSSON) (15.80 m)

16.61–22.96 m. Dark-grey, rarely speckled mudstone and shale.

22.96–23.92 m. Dark-grey, mostly speckled mudstone.

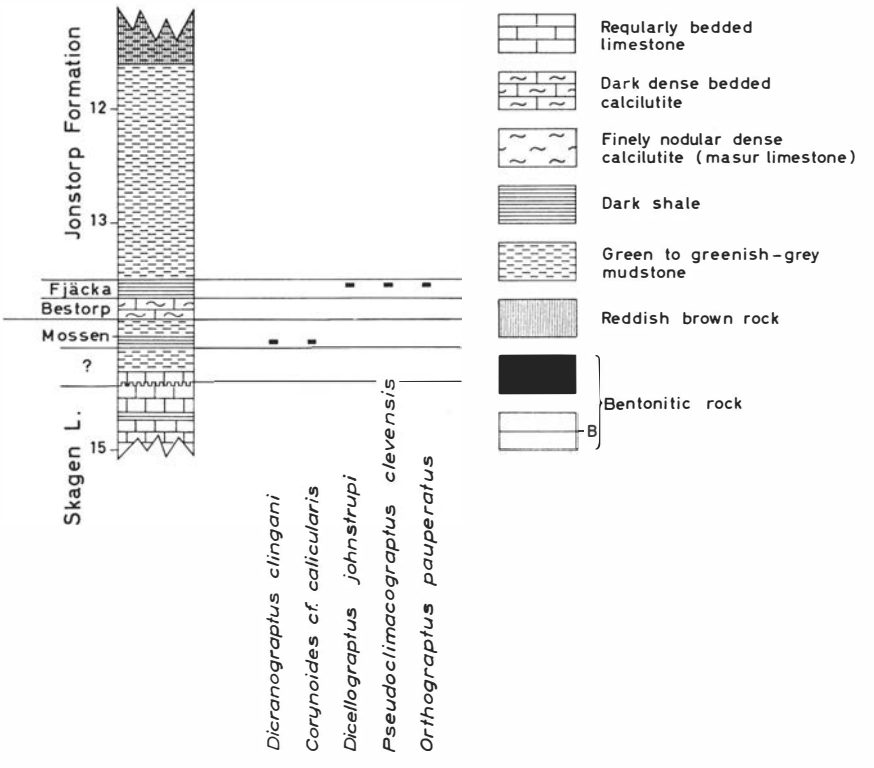
23.92–25.34 m. Dark-grey mudstone and shale. A bed of reddish-brown mudstone between 25.13 m–25.15 m.

Jonstorp Formation 10.96 m.

25.34–34.77 m. Reddish-brown mudstone with intercalations of green mudstone between the levels of 26.13–26.16, 26.23–26.25, and 26.70–26.86 m.

34.77–36.30 m. Greenish-grey to green mudstone with some thin lenses of fine-grained limestone.

Tretaspis granulata (WAHLENBERG) (34.90 m)
Kinnekullea thorslundi HENNINGSMOEN (35.50 m)



Text-fig. 4. Skultorp core. Range of graptolite species within the Mossen and Fjäcka Formations.

Fjäcka Formation 0.20 m.

36.30–36.50 m. Black mudstone. The core in the lowermost part is poorly preserved, and details of the contact with underlying beds are difficult to reconstruct.

Kinnekullea waerni HENNINGSMOEN

Bestorp Limestone 1.80 m.

36.50–38.30 m. Dark-grey, dense, thick-bedded calcilutite. The uppermost and lowermost parts of the core poorly preserved and details obscure. The lower boundary of the formation is drawn at the level of a layer of pyrite.

The Exposure and Boring of Skultorp, Southern Billingen

The uppermost Harju and the lowermost Llandovery Series are exposed in a quarry on the eastern slope of southern Billingen, 700 m W. of the church of Skultorp. In 1955 a drillhole was placed at the bottom of the quarry. The boring was carried out by Silit Ltd., and the core was later taken over by Rockwool Ltd., Skövde. The diameter of the core is 5 cm. The boring penetrated the sequence from the lowermost Ulunda Formation down to the lower part of the

Dalby Limestone. The section of the exposure given below is a direct upward continuation of that of the core, and extends up to the base of the *Dalmanitina* beds.

Description of the Exposed Section

Ulunda Formation 10.12 m. +

0.12 m. Grey, speckled mudstone.
2.44 m. Dark-grey to black shale and mudstone.
0.24 m. Dark-grey, speckled shale.
1.94 m. Dark-grey mudstone to shale.
0.69 m. Dark, dense, finely nodular calcilutite (*masur* limestone) with the argillaceous component developed as dark mudstone. Upward the limestone is limited by a surface of discontinuity.
0.10 m. Light-grey, sandy mudstone.
2.54 m. Dark-grey mudstone to shale, in part speckled.
0.72 m. Dark-grey, speckled shale with intercalations of light-grey mudstone.
1.33 m. Dark-grey shale.

Description of the Core

Harju Series 13.85 m. +

Ulunda Formation 2.36 m. +

0.0–2.36 m. Grey to dark-grey, mostly speckled mudstone, slightly reddish between 1.20 and 1.40 m.

Jonstorp Formation 11.16 m.

2.36–c. 11.60 m. Reddish-brown mudstone, greyish-green to dark-grey between 2.69–2.88 and 3.30–3.52 m. Beds or lenses of argillaceous limestone between 11.48–11.51 and 11.03–11.12 m. Towards the base of the division the reddish-brown colour begins to fade and the greyish-green colour gradually to predominate. It is difficult to draw a distinct boundary between the divisions with predominantly reddish-brown and greyish-green colour, respectively.

c. 11.60–13.52 m. Greenish-grey to greyish-green mudstone with lenses of limestone between 11.82–11.85 and 12.65–12.72 m.

Tretaspis granulata (WAHLENBERG) (11.85 m)
Kinnekullea thorslundi HENNINGSMOEN (12.36 m)

Fjäcka Formation 0.12 m.

13.52–13.64 m. Dark-grey shale.

Conchoprimitia nigra (HENNINGSMOEN)
Dicellograptus johnstrupi HADDING
Pseudoclimacograptus clevensis n.sp.
Orthograptus pauperatus ELLES & WOOD

Bestorp Limestone 0.21 m.

13.64–13.86 m. Dark, dense, argillaceous calcilutite.

Viru Series 10.90 m. +

Mossen Formation 0.25 m.

13.86–14.01 m. Grey mudstone.

14.01–14.11 m. Dark-brown, speckled mudstone with some thin layers of dark-brown shale.

Dicranograptus clingani CARRUTHERS *Corynoides* cf. *calicularis* NICHOLSON

Formation uncertain 0.31 m.

14.11–14.32 m. Grey mudstone.

14.32–14.42 m. Grey, thick-bedded, dense calcilutite.

14.42 m. Discontinuity surface, uneven, containing deep borings produced by organisms. The bed, c. 1 cm thick, above the surface consists of dense limestone with small, scattered chamositic oöids. The same rock fills the borings and, through these, penetrates up to 3 cm deep into the underlying bed.

Skagen Limestone 2.28 m.

14.42–15.77 m. Grey, fine-grained limestone occassionally with up to 10 cm thick intercalations of dark-brown mudstone.

15.77–15.86 m. Bentonitic clay.

15.86–16.31 m. Grey, fine-grained limestone with some thin intercalations of mudstone.

16.31–16.41 m. Bentonitic clay.

16.41–16.70 m. Grey, fine-grained limestone. One very thin irregular seam of bentonitic matter at 16.62 m.

Dalby Limestone 8.06 m. +

16.70–17.50 m. Bentonitic clay.

17.50–24.76 m. + Grey, coarse-grained, thick-bedded limestone, in the upper part (down to c. 20.15 m) with conspicuous, up to 5 cm thick intercalations of dark-grey mudstone; in the lower part the limestone is somewhat nodular, with thin and inconspicuous argillaceous partings, and with chamositic grains at some levels.

Häggum Boring, Southern Billingen

The boring of Häggum was carried out by Atomenergi Ltd. in 1958. The boring penetrated the sequence from the Post-Silurian dolerite down to the uppermost part of the Lower Cambrian Series. The diameter of the core is 5 cm.

Description of the Core

Harju Series 30.50 m.

Ulunda Formation 14.68 m.

49.20–50.06 m. Dark mudstone, mostly speckled with grey spots.

50.06–51.08 m. Black mudstone to shale.

51.08–51.59 m. Light brownish-grey, strongly argillaceous limestone to calcareous siltstone with intercalations of beds of brownish-grey mudstone to siltstone.

51.59–52.12 m. Light-grey to brownish-grey mudstone, mostly speckled.

52.12–54.10 m. Black mudstone to shale.
54.10–54.31 m. Finely nodular, dense calcilutite (*masur* limestone) with the argillaceous component consisting of dark mudstone.
54.31 m. Disconformity, possibly a discontinuity surface.
54.31–54.39 m. Light brownish-grey, finely nodular, argillaceous limestone.
54.39–54.51 m. Light-grey argillaceous limestone.
54.51–63.58 m. Black to dark-grey mudstone to shale, in part speckled.
63.58–63.88 m. Grey mudstone. At the level of 63.70 m a layer (possibly up to 2 cm thick, but incompletely preserved) of bentonitic clay.

Jonstorp Formation 15.68 m.

Upper Jonstorp Member 10.52 m.

63.88–74.40 m. Brownish-red mudstone with intercalations of green mudstone between the levels of 74.11–74.27, 73.60–73.93, and 70.87–71.09 m. A layer of dense calcilutite between 73.20–73.23 m.

Öglunda Limestone 2.12 m.

74.40–75.30 m. Grey, coarse-grained limestone (calcarenite), in the uppermost 10 cm variegated greyish-green and reddish-brown.
75.30–76.52 m. Dark-grey dense calcilutite.
Leptograptus sp. indet. (76.34 m)

Lower Jonstorp Member 3.04 m.

76.52–78.63 m. Dark greenish-grey mudstone with a bed or lens of fine-grained limestone between 77.10–77.13 m.
78.63–79.27 m. Reddish-brown mudstone with intercalations of greenish-grey mudstone.
79.27–79.31 m. Light brownish-red, dense calcilutite.
79.31–79.56 m. Greenish-grey mudstone with a thin intercalation of brownish-red, dense calcilutite.

Fjäcka Formation 0.14 m.

79.56–79.60 m. Dark-grey, somewhat speckled mudstone.
79.60–79.70 m. Dark-grey, calcareous shale, rich in shell fragments and with large nodules of pyrite.

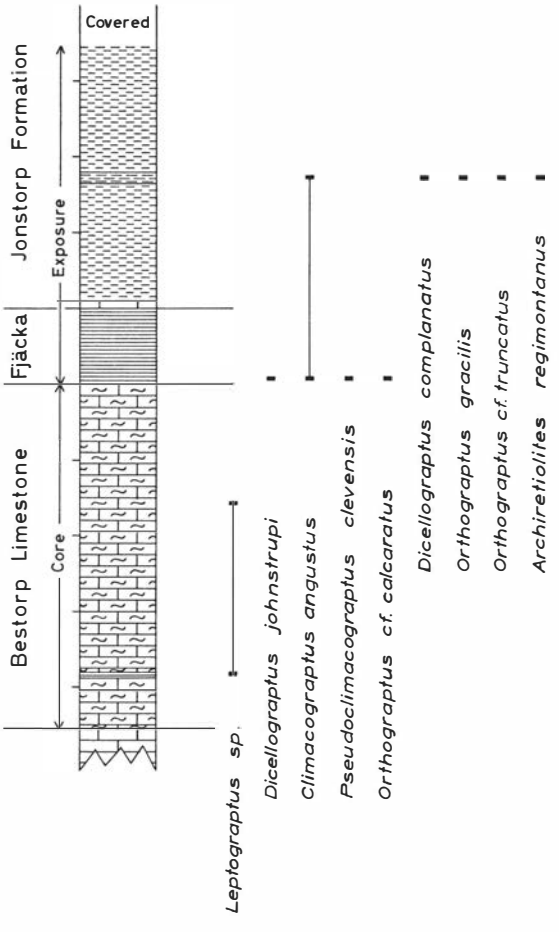
Viru Series 4.50 m. +

Skagen Limestone 1.80 m.

79.70–81.12 m. Thick-bedded, fine-grained, grey limestone.
81.12–81.20 m. Bentonitic clay.
81.20–81.50 m. Fine-grained, grey limestone.

Dalby Formation 2.70 m. +

81.50–82.80 m. Bentonitic clay.
82.80–83.04 m. Fine-grained, grey limestone.
83.04–83.08 m. Bentonitic clay.
83.08–84.17 m. Fine-grained, grey limestone.
84.17–84.20 m. Bentonitic clay.



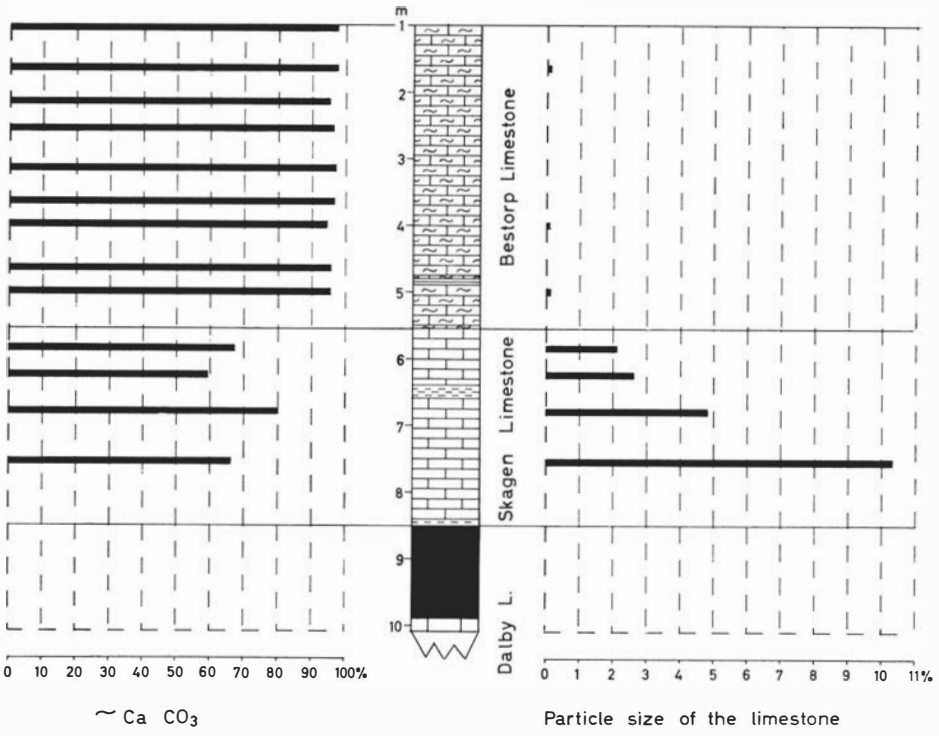
Text-fig. 5. Bestorp core. Range of graptolite species within the Bestorp, Fjäcka, and Jonstorp Formations. Legend and scale see Text-fig. 4.

The Exposure and Boring of Bestorp, Mösseberg

At Bestorp on the eastern slope of Mösseberg the main part of the Harjuan sequence is exposed. The uppermost part of the series (*Dalmanitina* beds) was described by TROEDSSON (1921). Recently a section of the underlying exposed sequence was published (THORSLUND & JAANUSSON 1960), and the section of the Lower Harjuan given below is mainly based on this description. The section of the boring is a direct downward continuation of the section of the exposure.

The boring of Bestorp was carried out by the Geological Survey of Sweden in 1945. It penetrated the Harjuan Bestorp Formation and the Viruan beds down to the lower part of the Dalby Limestone. A diagrammatic section of the core was given by THORSLUND (1958). Otherwise the core has not been described. The diameter of the core is 7 cm.

The core was measured by Dr. V. JAANUSSON and the present writer.



Text-fig. 6. Skagen and Bestorp Limestones of the Bestorp core. Contents of $CaCO_3$, and particle size of the limestone according to the method of JAANUSSON (1952). At the levels of 1.00, 2.10, 2.50, 3.10, 3.60, and 4.60 m the percentage of fossil fragments > 0.10 mm is 0.00, 0,03, 0.00, 0.00, 0.00, and 0.06 respectively.

Description of the Exposed Section

Harju Series 4.44 m. +

Jonstorp Formation 3.43 m. +

1.70 m. + Grey to green mudstone.
0.15 m. Dark, speckled mudstone.

Dicellograptus complanatus LAPWORTH
Climacograptus angustus (PERNER)
Orthograptus gracilis (ROEMER)
Orthograptus cf. *truncatus* LAPWORTH
Archiretiolites cf. *regimontanus* EISENACK

0.75 m. Grey to green mudstone, in part speckled.
0.60 m. Brownish-red mudstone.
0.15 m. Grey to green mudstone, in part speckled.
0.08 m. Dark-grey calcilutite.

Fjäcka Formation 1.01 m.

1.01 m. Dark-grey to black mudstone. In weathered condition the lowermost layers of the formation display a rusty-brown colour. The graptolites occur at (or close to) the base of the formation.

Dicellograptus johnstrupi HADDING
Climacograptus angustus (PERNER)
Pseudoclimacograptus clevensis n. sp.
Orthograptus cf. *calcaratus* LAPWORTH

Description of the Core

0.0–1.00 m. Quaternary deposits.

Harju Series 4.55 m. +

Bestorp Limestone 4.55 m.

1.00–5.55 m. Dense, thick-bedded, dark-grey calcilutite with an intercalation of black shale between 4.85–4.87 m. Details of the lower boundary obscure, since at that level the core has been crossed during the boring process.

Leptograptus sp. (4.85–4.87 m) *Remopleurides* sp. (4.20 m)

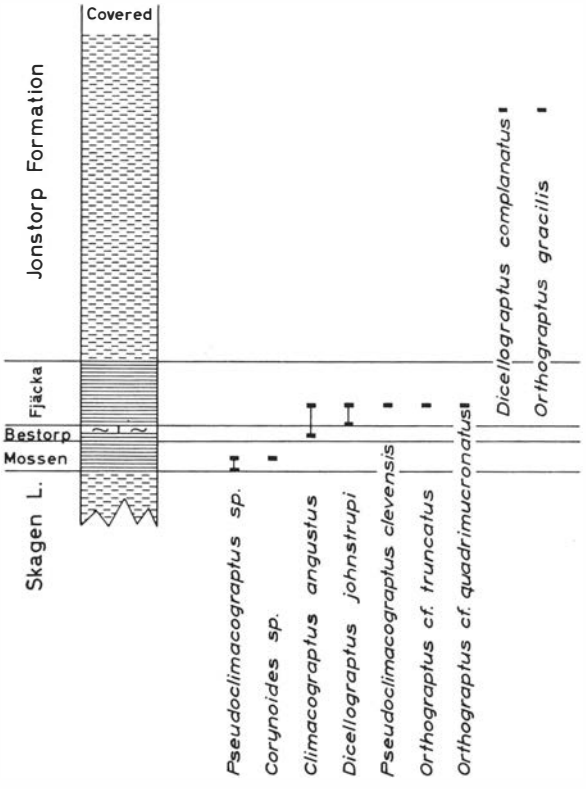
Viru Series 14.45 m. +

Skagen Limestone 2.95 m.

5.55–6.88 m. Fine-grained, thick-bedded, grey calcilutite.
6.88–7.13 m. Dark-grey mudstone.
7.13–8.50 m. Fine-grained, thick-bedded, grey calcilutite. A very thin layer of bentonitic clay at the level of 8.20 m.

Dalby Formation 11.50 m. +

8.50–9.90 m. Bentonite.
9.90–10.16 m. Fine-grained, thick-bedded, grey limestone.
10.16–10.22 m. Bentonite.
10.22–11.02 m. Medium-grained, thick-bedded, grey limestone with intercalations, up to 10 cm thick, of grey to dark-grey mudstone.
11.02–11.77 m. Alternating beds or lenses of fine-grained grey limestone and dark-grey mudstone.
11.77–12.90 m. Grey to black mudstone, in part speckled, with occasional thin intercalations of fine-grained, grey limestone.
12.90–13.03 m. One bed of grey, fine-grained calcilutite.
13.03–13.85 m. Grey to dark-grey, in part speckled mudstone. Core poorly preserved.
13.85–13.94 m. One bed of grey, fine-grained calcilutite.
13.94–14.17 m. Dark-grey mudstone.
14.17–14.36 m. Two beds of fine-grained, grey limestone separated by an intercalation of mudstone, c. 4 cm thick. Core poorly preserved.
14.36–14.77 m. Grey to dark-grey mudstone.
14.77–14.85 m. One bed of fine-grained, grey limestone.
14.85–16.52 m. Dark-grey mudstone. Core poorly preserved.
16.52–16.64 m. One bed of fine-grained, grey limestone.
16.64–c. 16.95 m. Grey to dark-grey mudstone. Core incomplete and poorly preserved.
c. 16.95–c. 17.06 m. One bed of fine-grained, grey limestone.
c. 17.06–18.58 m. Grey to dark-grey mudstone with some thin intercalations of limestone to calcareous mudstone. Upper part of the core incomplete and poorly preserved.
18.58–18.63 m. Bentonite.
18.63–18.89 m. Grey to dark-grey, mostly calcareous, oolitic mudstone with chamosite oöids. In the middle an intercalation of fine-grained grey limestone the exact location of which is difficult to determine on account of poor preservation of the core in that part.



Text-fig. 7. Jonstorp exposure. Range of graptolite species within the Mossen, Fjäcka, and Jonstorp Formations. Legend and scale see Text-fig. 4.

18.89–20.00 m. + Thick-bedded to somewhat nodular, coarse-grained limestone (calcarenite).

Jonstorp Exposure, Mösseberg

At Jonstorp on the western slope of Mösseberg parts of the Skagen and Jonstorp formations are exposed. In 1932 E. JARVIK excavated a section which comprised the uppermost Viru Series and the lower part of the Harjuan sequence. The section was never published, but the manuscript describing it is now deposited in the Palaeontological Institute, Uppsala University. Owing to a thick cover of Quaternary deposits some important parts of the sequence were, however, not accessible to JARVIK. For this reason the present writer made another excavation of the locality in order to study the development of the sequence immediately below and above the boundary between the Viru and Harju Series.

Description of the Excavated Section

Harju Series 5.35 m. +

Jonstorp Formation 4.30 m. +

4.30 m. + Green mudstone with occasional concretions of greenish, dense limestone.

In the lowermost 0.20 m of the division the colour is downwards gradually changing to grey in downward direction.

Dicellograptus complanatus LAPWORTH *Orthograptus gracilis* (ROEMER)

Fjäcka Formation 0.85 m.

0.85 m. Dark-grey to black mudstone.

Dicellograptus johnstrupi HADDING *Orthograptus* cf. *truncatus* LAPWORTH
Climacograptus angustus (PERNER) *Orthograptus* cf. *quadrimucronatus* HALL.
Pseudoclimacograptus clevensis n.sp.

Bestorp Formation 0.20 m.

0.10 m. Dark, dense calcilutite, occasionally with crystals of pyrite.
0.10 m. Dark-grey mudstone

Climacograptus angustus (PERNER)

Viru Series 0.85 m. +

Mossen Formation 0.35 m.

0.35 m. Dark-grey shale to mudstone.

Pseudoclimacograptus sp. *Corynoides* sp.

Skagen Formation 0.50 m. +

0.50 m. + Greenish grey mudstone.

Fårdala I Boring

The Fårdala I boring was performed by the Geological Survey of Sweden in 1945. It is situated on the southern slope of Varvsberget close to the Fårdala farm. The core has not previously been described. The Viruan sequence of the core from the top of the Skagen Limestone downwards was examined for fossils by Dr. B. WÆRN for the Geological Survey of Sweden. The present whereabouts of this portion of the core is unknown, and only slabs with fossils picked out by Dr. WÆRN were available. The below macroscopical description of this part of the section is compiled by Dr. V. JAANUSSON, and is based on the information in WÆRN's diary deposited in the Geological Survey and on the available material of fossils. Parts of the Harjuan portion of the core were searched for fossils by Dr. G. HENNINGSMOEN, and some additional parts were examined in detail by the present writer. However, only few determinable fossils have been found so far. The Harjuan portion of the section was measured by Dr. V. JAANUSSON and the present writer.

Description of the Section

Quaternary deposits 19.50 m.

Harju Series 19.49 m. +

Ulunda Formation 2.70 m. +

19.50–19.70 m. Speckled mudstone.
19.70–19.94 m. Dark-grey to black mudstone and shale.

19.94–20.04 m. Dark-grey to light-grey, speckled mudstone.
20.04–20.21 m. Dark-grey mudstone with brownish tint.
20.21–20.52 m. Dark-grey to brownish-grey, speckled mudstone with light-grey spots.
20.52–22.20 m. Dark-grey mudstone.

Jonstorp Formation 15.85 m.

22.20–22.50 m. Dense limestone, in the upper part reddish-brown, in the lower part greyish-green.
22.50–35.20 m. Reddish-brown mudstone with intercalations of green mudstone between the levels of 23.83–24.15 (greyish-green), 24.60–?25.38 (in part reddish-brown speckled), 25.42–25.48, 26.14–26.47, 26.68–26.97, 27.16–27.21, 27.26–27.67, 28.77–28.86, 30.85–30.88, and 34.73–34.76 m.
35.20–35.66 m. Grey to greenish-grey, mostly speckled mudstone.
35.66–35.89 m. Two beds of dense, grey limestone with a faint brownish tint intercalated (between 35.79 and 35.83 m) by a bed of grey mudstone.
35.89–35.45 m. Grey to greenish-grey, mostly speckled mudstone with beds or lenses of dense limestone between the levels of 35.97–36.01 (fine-grained, with brownish tint), 36.37–36.40, 36.55–36.60 (light brownish-red), and 37.28–37.32m.
37.45–37.80 m. Dark-brown to black mudstone, in the lowermost 4 cm with a somewhat lighter colour.
37.80–37.85 m. One bed of dense, grey limestone.
37.85–c. 38.40 m. Grey to greenish-grey mudstone, occasionally dark and speckled.
Climacograptus sp. indet. (38.20 m.)

? Fjäcka Formation c. 0.26 m.

c. 38.40–38.66 m. Dark-grey, mostly speckled mudstone. The upper boundary is poorly defined.

Bestorp Limestone 0.33 m.

38.66–38.99 m. Dense, finely nodular, dark-grey limestone.
Dicellograptus sp. indet. (38.96 m.)

Viru Series 11.34 m. +

Mossen Formation c. 0.41 m. (+?)

38.99–c. 39.40 m. Dark-brown to dark-grey mudstone and shale, in part speckled.
Climacograptus diplacanthus BULMAN (39.12 m) *Pseudoclimacograptus* sp.
Dicellograptus sp. indet. (39.12 m) *Corynoides* sp. indet.

The core portion between 39.40 and 39.69 m has been moved from its original position and could not be identified with certainty. According to a diagrammatic section of the core made by Dr. B. WÆRN this portion consisted of mudstone or shale down to c. 39.45 m, of limestone between c. 39.45 and 39.57 m, and mudstone or shale between c. 39.57 and 39.69 m.

Skagen Limestone 2.42 m.

39.68–41.84 m. Grey, mostly fine-grained, in part argillaceous limestone with intercalations of grey calcareous mudstone between 40.12–40.26, 40.48–40.55, and 40.65–40.70 m. The upper boundary possibly represents a discontinuity surface with deep, irregular pits and borings filled with a brownish calcareous mud-

stone. The surface is strongly polished and partly destroyed during the boring process, and details are obscure.

Steusloffia costata (LINNARSSON) (40.20; 40.24 m) *Climacograptus* sp. (40.67 m)

41.84–41.87 m. Bentonite.

41.87–42.10 m. Grey, fine-grained limestone with thin intercalations of greyish-green mudstone.

Dalby Formation 8.23 m. +

42.10–42.70 m. Bentonite.

42.70–42.94 m. Grey limestone.

42.94–43.12 m. Bentonite.

43.12–44.05 m. Grey limestone with up to 3 cm thick intercalations of dark-grey calcareous mudstone. Flakes of mica between 43.18 and 43.21 m and at 43.95 m. The limestone contains occasional grains of chamosite at some levels, and abundant chamosite ooids between 44.27 and 44.29 m.

Chasmops sp. indet. *Onniella* sp. indet.

44.05–44.12 m. Bentonite.

44.12–44.19 m. Grey to dark-grey limestone.

44.19–44.60 m. Bentonite, dark and impure.

44.60–44.75 m. Grey limestone, dark-grey in the upper 4 cm.

44.75–44.87 m. Bentonite, impure.

44.87–44.96 m. Dark-grey limestone, calcarenitic between 44.92–44.95 m.

44.96–45.13 m. Bentonite, impure.

45.13–45.25 m. Dark-grey, argillaceous limestone, calcarenitic in the upper part.

Parapyxion sp.

45.25–45.48 m. Bentonite, in part impure.

45.48–45.53 m. Dark-grey limestone, in the upper part calcarenitic.

45.53–45.67 m. Bentonite.

45.67–45.89 m. Grey to dark-grey limestone, in part calcarenitic, with chamosite ooids between 45.69–45.71 m.

Euprimites locknensis (THORSLUND) *Parapyxion* sp.
Actinochilina suecica (THORSLUND)

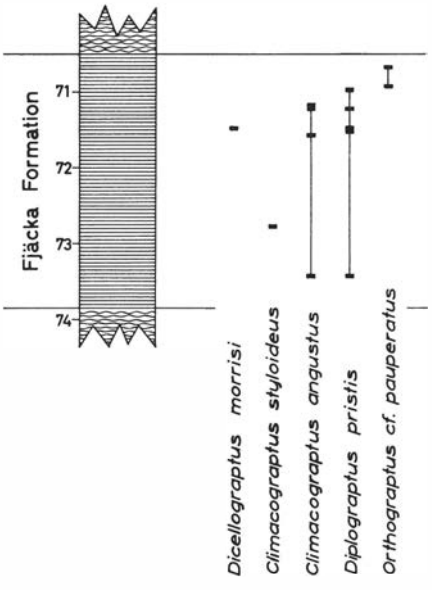
45.89–45.93 m. Bentonitic mudstone with a layer of pure bentonite (c. 1 cm thick) at the top.

45.93–48.56 m. Alternating beds of grey, argillaceous, mostly calcarenitic limestone and dark-grey calcareous mudstone. The limestone predominates, especially in the lower part. Abundant chamosite ooids between 46.87–47.10 and 48.25–48.46 m. A thin layer of bentonite (some mm thick) at 46.81 m. Flakes of mica at 47.03 and 47.06 m. The lower boundary is transitional.

Asaphus (*Neoasaphus*) cf. *ludibundus* TÖRNQUIST *Hemisphaerocoryphe*? sp.
Raymondaspis? sp. *Parapyxion* sp.
Onniella sp. indet.

48.56–49.07 m. Fairly dark-grey, oolitic calcarenite with thin partitions of dark-grey mudstone.

Asaphus (*Neoasaphus*) sp. indet. *Climacograptus rotundatus* JAANUSSON &
Pseudoclimacograptus cf. *scharenbergi* SKOGLUND
(LAPWORTH)



Text-fig. 8. Smedsby Gård core. Range of graptolite species within the Fjäcka Formation. The shale is underlain by bedded limestone and overlain by finely nodular limestone.

49.07–49.10 m. Reddish-brown oolitic calcarenite.

49.10–50.33 m. + Grey, mostly calcarenitic limestone with thin argillaceous partitions. Abundant chamosite grains between 49.63–50.10 and 50.23–50.28 m. The limestone is faintly reddish-brown between 49.16–49.21 and 50.23–50.28 m.

Euprimites locknensis (THORSLUND) (49.64, 50.25 m)
Conchoprimitia leperditioides THORSLUND (50.10 m)

Review of Some Localities in Östergötland

The study of the graptolites of the Fjäcka Shale of Östergötland is based mainly upon collections from the museums mentioned above (p. 3). In addition, the graptolite succession of the Fjäcka Shale in the Smedsby Gård boring has been examined.

The collections studied come from three localities all situated in huge erratic masses, viz. Hamra (TÖRNQUIST 1876), Nässja, and Ullnäs, 3, 16, and 20 km SW, of Motala respectively. No information being available the specimens can not be referred to exact levels within the division.

The Smedsby Gård boring is situated 4.3 km NNW, of Motala (for information about the boring, see JAANUSSON 1962, 1963 b). Only the graptolites are recorded here, as the other components of the fauna are preferably treated in connection with a description of the whole Harju Series in the core. The sequence between 70.52 and 73.85 m belongs to the Fjäcka Shale and is developed as black shale, in part slightly speckled. The following species are recorded:

Dicellograptus morrisi HOPKINSON (71.50 m)
Climacograptus styloideus ELLES & WOOD (72.80 m)

Climacograptus angustus (PERNER) (71.20; 71.25; 71.55 m)
Diplograptus pristis (HISINGER) (71.00; 71.25; 71.45; 71.50 m)
Orthograptus sp. indet. (70.70, 70,95 m)

Remarks on the Lithology and Stratigraphy of the Uppermost Viruan and Lower Harjuan Sequence of Västergötland

UPPERMOST VIRUAN SEQUENCE. — The supra-bentonitic part of the Viruan sequence is formed by the Skagen Limestone and the Mossen Formation. The former division is present in all examined cores and exposures. The overlying Mossen Formation, on the other hand, has a more limited distribution and is missing over extensive areas. There the Skagen Limestone forms the top of the Viru Series.

The greatest thickness of the Skagen Limestone is recorded on Kinnekulle and on northern Billingen, where it attains 3.30 and 3.29 m, respectively. The smallest thickness is known from southern Billingen (Skultorp 2.28 m; Häggum 1.80 m). The upper part of the formation displays a considerable lithologic variation. On Kinnekulle these beds consist to a large extent of calcareous mudstone, and on southern Billingen the whole formation is developed as fine-grained grey limestone. The local variations in the lithologic development are especially conspicuous on Mösseberg. At Jonstorp, on the western slope of Mösseberg, the topmost part of the Skagen limestone is developed as a greenish-grey, calcareous mudstone. At Bestorp, which is situated 5.5 km east of Jonstorp on the eastern slope of Mösseberg, the mudstone forms only thin intercalations in a sequence which consists of thick-bedded calcilutite. The graptolite fauna of the Skagen Limestone is treated in another paper (JAANUSSON & SKOGLUND 1963). For further information about the formation, see JAANUSSON (1963 a).

The most complete development of the Mossen Formation is met with on Kinnekulle. There the formation consists of dark graptolitiferous shales in the lower part, and grey calcareous mudstone in the upper part. Outside Kinnekulle the upper division can with certainty be distinguished at Skultorp only. The graptolites found in the lower part indicate the presence of the zone of *Dicranograptus clingani* (THORSLUND 1948). The index species of this zone is recorded here also from southern Billingen (Skultorp). The shales at Jonstorp and in the Fårdala boring that are referred here to the Mossen Formation have not yielded graptolite species which are known with certainty to be confined to the zone of *Dicranograptus clingani*. Neither do they, however, contradict the stratigraphic assignment of these beds by lithologic criteria. *Climacograptus diplacanthus* BULMAN was originally described from a boulder of calcilutite of the Östersjö Limestone type that was supposed to belong to the lowermost Harjuan Rakvere Stage of the Estonian sequence. The find of this species in the Mossen Formation of Varvsberget is the first record of *C. diplacanthus* in Sweden and in bedrock.

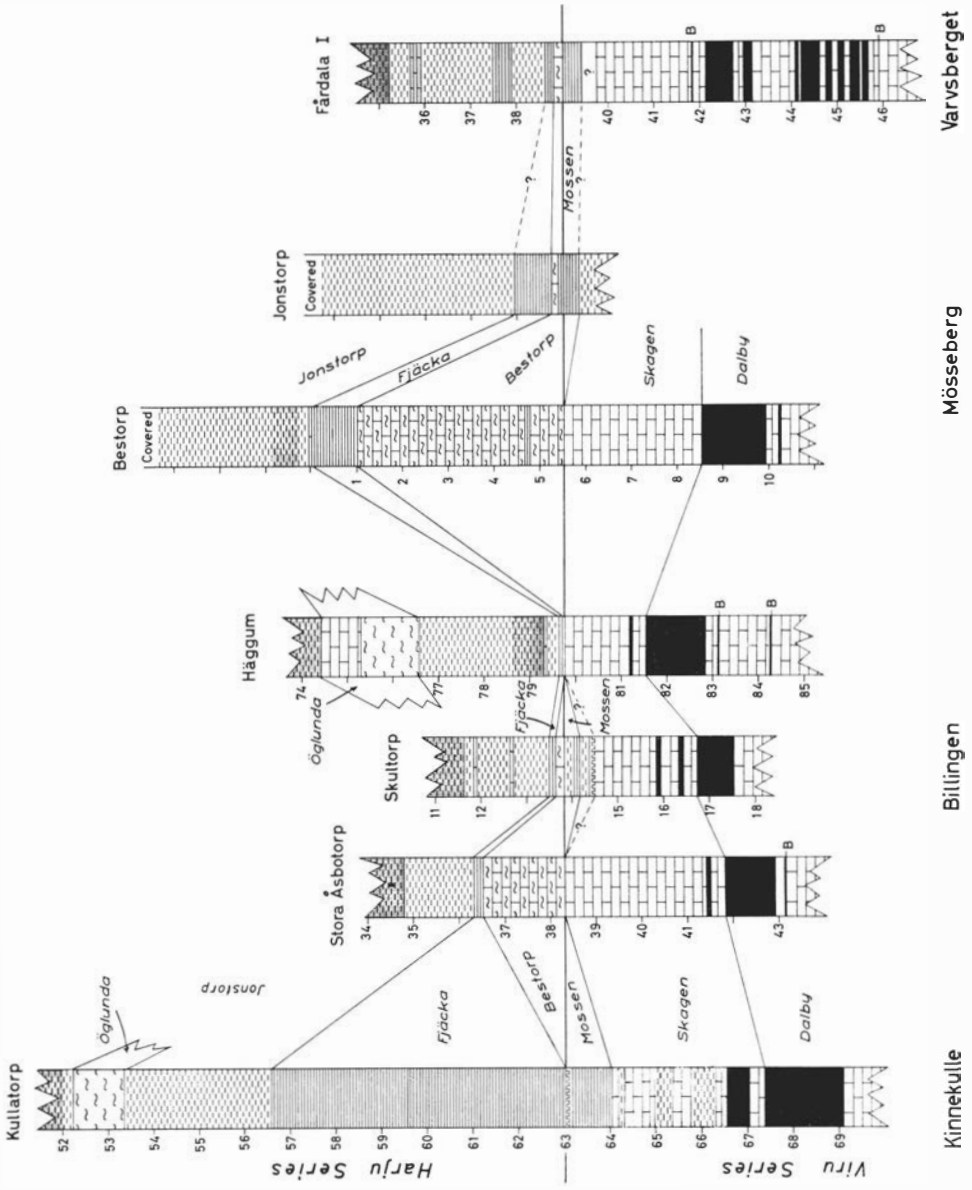
The ostracode fauna found in the upper division of the Mossen Formation is of particular interest. According to an oral communication by Dr. V. JAANUSSON the species recorded here as *Euprimites* n.sp. and *Sigmobolbina* n.sp. occur also in the topmost Viruan (4b δ) of the Oslo-Asker district, Norway. This corroborates the correlation between the zone of *Dicranograptus clingani* and the *Macrourus* (or *Extensa*) beds which had previously been suggested by THORSLUND (1940, 1948). In 1948 this author based his correlation on the occurrence of *Tretaspis ceriodes* in calcareous layers forming the top of the Viruan sequence of the Kullatorp core.

LOWER HARJUAN SEQUENCE.—The base of the series is formed either by the Bestorp Limestone or the Fjäcka Shale. Unfortunately the level of the boundary between the Viru and Harju Series falls into a badly preserved portion of the cores. This makes an examination of details of this contact difficult, and the evidence is often somewhat inconclusive.

In the Kullatorp boring, Kinnekulle, the boundary between the Viru and Harju Series is drawn at the level of a surface of discontinuity (THORSLUND 1948). No such surface has been observed at a comparable level in the Mossen section, where the dark shale of the Fjäcka Formation overlies a calcareous mudstone of the Mossen Formation. There a rusty-brown layer at the top of the Mossen beds may represent a lithological indication of a break.

In the Billingen-Falbygden district no discontinuity surface has been recognized in any of the examined sections at the boundary between these series. In fact, in some sections there is no lithologic evidence of a break at that level though, according to stratigraphic indications, the hiatus at that boundary ought to be considerable throughout Västergötland as has been suggested by THORSLUND (1940, 1948, and in THORSLUND & JAANUSSON 1960) and by JAANUSSON (1963 b). There the absence of a discontinuity surface may depend upon the development of the rock below the boundary as shale or mudstone. At Jonstorp the boundary is situated within a shale sequence, and at Skultorp the Bestorp Limestone overlies an argillaceous rock of the Mossen Formation. These pelitic rocks below the level of the break could not be corroded to the same extent as a limestone, and, possibly, had not been consolidated prior to the deposition of the overlying beds. In the sections, where the Bestorp Limestone overlies the Skagen Limestone (Stora Åsbotorp and Bestorp borings), the core is poorly preserved in the region of the boundary between these series, and there the presence of a discontinuity surface could be neither proved nor disproved. In the Häggum core, where the Fjäcka Formation directly overlies the Skagen Limestone, no discontinuity surface could be observed on the top of the limestone, but the large content of pyrite in the overlying bed may represent a lithologic indication of a break.

The Bestorp Limestone shows striking changes of thickness over short distances that are unique for a limestone unit in the Cambro-Silurian sequence of Västergötland. The thickness varies from 4.55 m (Bestorp) to 0.10 m (Jonstorp),



Text-fig. 9. Diagrammatic sections of the uppermost Viruan and the lower part of the Harjuan sequence of Västergötland.

the distance between these localities being not more than 5.5 km. At Jonstorp the limestone was exposed in two localities 30 m from each other and the thickness varied from 0.10 to 0.30 m. In the Stora Åsbotorp boring, Billingen, the thickness of the limestone is 1.8 m, and 6.5 km southwards (Skultorp boring)

0.21 m only. It is difficult to find any regular pattern in the variation in thickness of this formation.

A microlithological examination of the Bestorp Limestone in the Bestorp core (Text-fig. 6), according to the method described by JAANUSSON (1952), shows the rock to be a calcilutite with an extraordinarily low content of shell fragments and a high content of calcium carbonate. In the type locality the limestone sequence of the formation contains only thin intercalations of shale, whereas at Jonstorp the lowermost part of the formation is developed as dark shale. The considerable variation in thickness and the evidently scattered distribution of the formation probably reflect the influence of local conditions upon the formation of the limestone. The occurrence of crystals of pyrite and the dark colour of the limestone may indicate a deposition in somewhat stagnant conditions, in a hydrochemical environment resembling that which prevailed during the deposition of at least the lower part of the Fjäcka Shale.

The fossils which have been found within the Bestorp Formation are few, and their known correlation value is limited. In the shale forming the base of the Bestorp Formation at Jonstorp *Climacograptus angustus* has been found. This species had hitherto not been recorded from beds earlier than the Harju Series. Previously the limestone at Bestorp has been compared with the Slandrom Limestone which forms the base of the Harju Series in the Siljan district and in Jämtland (THORSLUND 1940, p. 124). Recently it has been tentatively included in the Middle Ordovician (Viru Series) (JAANUSSON in THORSLUND & JAANUSSON 1960). The correlation with the Slandrom Limestone was based upon the similarity in the stratigraphic position, both units being overlain by the Fjäcka Shale. The Bestorp Limestone is, however, doubtless of Harjuan age, and the present writer is inclined to correlate the formation with the lower part of the Fjäcka Shale in the type locality. This interpretation is based upon stratigraphic and some faunistic evidence. However, it ought to be added that the obvious difference in lithology between the Slandrom and Bestorp Limestones, the former being developed as argillaceous limestone with intercalations of finely nodular calcilutite (*masur* limestone), very likely does not by itself exclude a correlation between these formations.

The greatest thickness of the Fjäcka Shale is recorded on Kinnekulle (Kullatorp boring 6.43 m). The thickness decreases considerably in eastern direction, and on eastern Billingen it is not known to exceed 0.20 m. The smallest thickness of the formation has been measured in the Häggum boring (0.12 m), where the Fjäcka Shale directly overlies the Skagen Limestone and the hiatus thus comprises also the Mossen Formation.

The lithological development of the Fjäcka Shale is not quite uniform in Västergötland. In the lower part of the formation on Kinnekulle the rock is predominantly a black, finely laminated shale. In the Billingen–Falbygden district the rock of the Fjäcka Formation agrees with that of the upper part of the formation on Kinnekulle. It consists of dark-grey, often speckled mudstone,

in which the finely laminated structure is poorly developed. This indicates that in that district the thin sequence of the formation corresponds only to the upper part of the formation as developed on Kinnekulle.

From the Fjäcka Shale of Kinnekulle HENNINGSMOEN (1948) has described a fairly rich graptolite fauna indicative of the zone of *Pleurograptus linearis*. On Billingen only the Skultorp boring has yielded sufficient material of graptolites for determining the presence of the same graptolite fauna The known graptolite fauna of this zone of Västergötland has only two species in common with the contemporaneous beds of Östergötland and the Siljan district, viz. *Climacograptus styloideus* and *Climacograptus angustus*. The graptolite fauna of Scania and Bornholm shows closer affinities to that of Västergötland, six species being common to both (cf. Table 1).

The lower part of the Jonstorp Formation, defined as the Lower Jonstorp Member in localities where the Öglunda Limestone is developed, (cf. JAANUSSON 1963b) consists of greenish-grey mudstone with thin intercalations of limestone. The sequence includes also layers of brownish-red mudstone (Häggum, Bestorp) making the name hitherto used, "Green *Tretaspis* Mudstone", unsuitable for the division. At Kullatorp and Häggum the thickness of the Lower Jonstorp Member is 3.25 and 3.04 m, respectively, indicating that the upper boundary of the Member is approximately synchronous. In localities

Table 1. Distribution of some Harjuan graptolites treated in this paper.

	Dalarna and Östergötland (Ög)	Västergötland		Scania and Bornholm	
	Zone of *P. linearis*	Zone of *P. linearis*	Zone of *D. complanatus*	Zone of *P. linearis*	Zone of *D. complanatus*
Dicellograptus morrisi HOPKINSON	+				
Dicellograptus johnstrupi HADDING		+		+	
Dicellograptus complanatus LAPWORTH			+		+
Pseudoclimacograptus clevensis n. sp.		+			
Climacograptus styloideus ELLES & WOOD	+	+		+	
Climacograptus angustus (PERNER)	+	+	+		+
Climacograptus brevis cf. var. *mutabilis* STRACHAN	+ (Ög)				
Diplograptus pristis HISINGER	+				
Orthograptus pauperatus ELLES & WOOD	+	+		+	
Orthograptus gracilis (ROEMER)			+		+
Orthograptus quadrimucronatus HALL		+		+	

without the Öglunda Limestone the boundary between the parts of the Jonstorp Formation with predominantly green and red colour is obviously metachronous, since the variations in thickness of the green mudstone are considerable, from 1.53 m on northern Billingen (Stora Åsbotorp) to 7.50 m at Jonstorp (according to unpublished data by E. JARVIK).

Although the lower part of the Jonstorp Formation contains mainly a shelly fauna, some thin layers are graptolitiferous. At Bestorp graptolites occur, but are, in fact, fairly common only in an intercalation of a dark-grey speckled mudstone. The recorded graptolite assemblage indicates the zone of *Dicellograptus complanatus*. In addition to Bestorp this assemblage has been found at Kullatorp, Öglunda, and Jonstorp. In all these localities the occurrence of the graptolites is restricted to one thin layer within the mudstone. At Bestorp and Kullatorp the mudstone between the top of the Fjäcka Shale and the graptolitiferous horizon in the Jonstorp Formation has almost the same thickness (1.60 and c. 1.65 m, respectively). The corresponding sequence at Jonstorp measures to 3.30 m. This deviation is probably due to local variation, as the green mudstone at this locality has a considerable thickness (see above). At Öglunda the lower part of the Jonstorp Formation is not exposed. The exact level of the boundary between the zone of *D. complanatus* and the underlying zone of *Pleurograptus linearis* is difficult of determination the beds with the index fossils being separated by beds without graptolites. However, it is probable that the boundary between these graptolite zones approximately corresponds to that between the Fjäcka Shale and Jonstorp Formation. This boundary is reflected also in the vertical range of some trilobite species, e.g. of *Tretaspis granulata* which does not seem to have been observed below the base of the Jonstorp Formation.

The mode of occurrence of the graptolites of the zone of *Dicellograptus complanatus* in Västergötland is similar to that of the graptolites of the same zone in the well-known locality at Dobbs Linn, Moffat district. Also there these graptolites are met with only in a thin layer within a mudstone which in that district is otherwise barren. The graptolite fauna of the zone was characterized as a dwarfed fauna and considered to be without greater stratigraphic significance (ELLES & WOOD 1925, 1937). In the Harjuan sequence of Västergötland, Scania, and Bornholm the assemblage of the zone is, however, well defined, even if it does not contain so many well-defined species as the underlying zone of *Pleurograptus linearis*. In Dalarna and Östergötland the corresponding beds have a lithological development which excludes the occurrence of graptolites.

The Öglunda Limestone is developed on Kinnekulle and in the Häggum boring. In the former area the division has a uniform lithologic development, consisting throughout of the *masur* limestone type. In the Häggum core only the lower part of the division can be described as a masur limestone, whereas the upper part is formed by a grey calcarenite partly rich in ostracodes. The Öglunda Limestone has previously been recorded from two localities (Öglunda, Ulunda) on the western slope of Billingen (WESTERGÅRD 1928, pp. 49–50). The

thickness of the part developed as a masur limestone in the Häggum boring is equal to that of the entire division in the Kullatorp core (1.22 and 1.20 m, respectively), whereas the thickness recorded from Öglunda (WESTERGÅRD, *op. cit.* p. 49) amounts to more than twice that value (3.0 m). Hitherto *Leptograptus* sp. indet. (p. 16) is the only fossil recorded from the *masur* limestone. The ostracode fauna, observed in the upper part of the division, has not yet been studied. For information about the distribution of the Öglunda Limestone, see JAANUSSON (1963b).

Systematic description

The description given below of Harjuan graptolites of Västergötland, Östergötland, and Dalarna is restricted to specimens preserved in relief and those flattened ones which have yielded to isolating treatment. Therefore on account of bad preservation some species, mainly from the Mossen and Fjäcka Formations which are recorded above in the descriptions of the cores and the exposures, have not been described.

The specific identification of strongly carbonized and flattened specimens is generally very precarious since few morphological characters of taxonomic value are accessible. Many previous descriptions of species treated below have, however, been based upon specimens in a fairly bad state of preservation and since the material described is often not satisfactority pictured, these descriptions give very little information. Therefore the lists of synonymy given below comprise only the original descriptions and those based upon material that has been accessible to the present writer for comparison. The statements of the geographical distribution and the vertical range of the described species are restricted here to the occurrence in the Harjuan sequence of Scandinavia.

The generic classification used is that proposed by BULMAN (1955), except that the genus *Pseudoclimacograptus* is recognized here. In the description of the thecal form the terms geniculum, supragenicular wall, and infragenicular wall are used according to JAANUSSON (1960).

Family *Dicranograptidae* LAPWORTH, 1873

Genus *Dicellograptus* HOPKINSON, 1871

Dicellograptus morrisi HOPKINSON, 1871

Pl. I, figs. 1–2.

1867 *Didymograpsus ludensis* S.S. — TÖRNQUIST, p. 15.
1871 *Dicellograptus Morrisi* n.sp. — HOPKINSON, p. 24; Pl. I, figs. 2 a–h.
1876 *Dicellograptus Moffatensis?* CARRUTHERS — TÖRNQUIST, p. 66.
1879 *Dicellograptus anceps* NICHOLSON — TÖRNQUIST, p. 448.
1891 *Dicellograptus anceps* HOPKINSON — TÖRNQUIST, p. 21; Pl. II, figs. 16–19.
1904 *Dicellograptus Morrisi* HOPKINSON — ELLES & WOOD, p. 155; Pl. XXI, figs. 6 a–d.
1935 *Dicellograptus morrisi* HOPKINSON — BULMAN in THORSLUND, p. 48.
1940 *Dicellograptus morrisi* HOPKINSON — THORSLUND, pp. 84, 87.

DESCRIPTION.—All available specimens are flattened or preserved in slight relief. The largest stipe is 50 mm long. The proximal parts of the stipes diverge at an axillary angle of about 40°; at the level of the tenth pair of thecae divergence becomes accentuated. In all available specimens the sicula is broken off 0.5 mm above its aperture. At the level of the first pair of thecae the stipes are 0.5 mm wide; the maximum width of 0.9 mm is reached at the level of the sixth pair of thecae. The proximal thecae are provided with stout mesial spines which become gradually shorter distally; the spines have not been seen beyond the eleventh pair of thecae. The semicircular apertural excavations occupy 1/2 of the width of the stipe in the proximal, and 1/3 in the distal thecae. The oblique state of compression of most specimens renders interpretation of the shape of the thecae difficult. The apertures of the proximal thecae can, however, be seen to be introverted and introtorted, producing a conspicuously convex curvature of the supragenicular wall. In distal direction this convexity seems to decrease. The supragenicular wall of the proximal thecae is 0.8 mm long, and that of the distal ones 1.2 mm. Proximally, ten thecae, from th 2^1–th 12^1, occupy a length of 10 mm, while in the distal part of the stipe the same length contains eight thecae (th 13^1–th 20^1) only. The dorsal wall of the stipes is somewhat undulating, but it can not be stated, whether this is due to compression or the presence of prothecal folds.

DISCUSSION.—Obliquely compressed specimens of *D. morrisi* may assume a shape resembling that of *D. anceps*, and this circumstance evidently led TÖRNQUIST to indentify the specimens from Dalarna as *D. anceps*. When, however the specimens are compressed perpendicular to the lateral side of the rhabdosome, *D. morrisi* is distinguished from *D. anceps* by a much wider axil and more convex supragenicular wall of the distal thecae.

OCCURRENCE.—*Fjäcka Shale.* Dalarna: Amtjärn, Vikarbyn, Draggån, Gulleråsen, Enån. Östergötland: Exposure at Hamra and the Smedsby Gård boring (at the level of 71.50 m). Jämtland: Näs (Storgårdsbäcken), Häggenås, Rasten.

Dicellograptus johnstrupi HADDING, 1915

Pl. I, figs. 4–9.

1915 *Dicellograptus johnstrupi* n.sp.—HADDING, p. 24; Pl. III, figs. 12–18.
1948 *Dicellograptus johnstrupi* HADDING—HENNINGSMOEN, pp. 401–402; Text-fig. 2.

DESCRIPTION.—*Dicellograptus johnstrupi* was described recently by HENNINGSMOEN (1948) from the Fjäcka Shale of the Kullatorp core. The description given here is therefore restricted mainly to such features as could be observed in artificially isolated specimens. The available material consists of some isolated proximal ends and distal fragments. The obtained specimens are mostly flattened, but include also those preserved in relief. The proximal end is mostly well preserved, whereas the distal parts of the stipes are often obliquely compressed.

The proximal part of the sicula is always broken off, and thus the total length

of the sicula can not be determined. The preserved part of the sicula of the specimen figured on Pl. I, fig. 5 is 1.5 mm long. On the reverse side of the rhabdosome the apertural part of the sicula is concealed, whereas it is visible on the obverse side for its entire length. The proximal thecae are provided with conspicuous prothecal folds; in the distal thecae these folds are less accentuated. The apertures of the proximal thecae are introverted and introtorted, and the lateral sides of the apertures are formed by a pair of rounded lappets. The semicircular excavations occupy c. 1/3 of the width of the stipe in the proximal thecae. The distal thecae open in almost semicircular excavations, but the apertural part of the supragenicular wall is less introtorted than in the proximal ones. The interthecal septum of the distal thecae is inclined in proximal and dorsal direction.

The initial stages of the proximal development have not been seen, since no early growth stages are available. Externally the budding of th 2^1 and 2^2 is visible, and their development seems to agree with that of the corresponding thecae in *D. complanatus*.

Discussion.—All observed characters of the proximal end of *D. johnstrupi* agree with those of *D. complanatus*. The morphological differences between the two species thus seem to be localized to the distal thecae which in *D. johnstrupi* have a more convex supragenicular wall and include a greater angle with the stipe than in *D. complanatus*. Further differences are the semicircular excavations and the lack of a genicular selvage in *D. johnstrupi*. Judging from the number of features common to *D. johnstrupi* and *D. complanatus* the two species are closely related. *D. johnstrupi* is interpreted here as the immediate ancestor of *D. complanatus*. The latter species has probably been developed from the former species by the introduction of a new thecal type in the distal part.

Occurrence:—*Fjäcka Shale*. Västergötland: Kullatorp (at the levels of 57.65, 57.85, 60.70, 61.10, and 62.20 m) and Skultorp borings (at the level of 13.60 m) and the exposures at Bestorp and Jonstorp. *Dicellograptus Shale* (Zone of *Pleurograptus linearis*). Bornholm: Vasagaard and Risebaeck.

Dicellograptus complanatus Lapworth, 1880

Pl. I, fig. 3; Text-figs. 10 A–E.

1880 *Dicellograptus complanatus* n.sp.—Lapworth, p. 160; Pl. V, figs. 17 a–e.
1882 *Dicellograptus complanatus* Lapworth—Tullberg, p. 18.
1883 *Dicellograptus complanatus* Lapworth—Tullberg, p. 4.
1897 *Dicellograptus complanatus* Lapworth—Roemer & Frech, p. 618, Text-fig. 183.
1904 *Dicellograptus complanatus* Lapworth—Elles & Wood, p. 139; Pl. XX, figs. 1a–d; Text-figs. 84a–e.
1906 *Dicellograptus complanatus* Lapworth—Olin, p. 25.
1910 *Dicellograptus complanatus* Lapworth—Moberg, pp. 116–117.
1913 *Dicellograptus complanatus* Lapworth—Törnquist, p. 426.
1936 *Dicellograptus anceps* var. *bornholmiensis* n.var. — Poulsen, pp. 57–58, Text-figs. 2a–c.
1961 *Dicellograptus complanatus* Lapworth—Glimberg, p. 84.

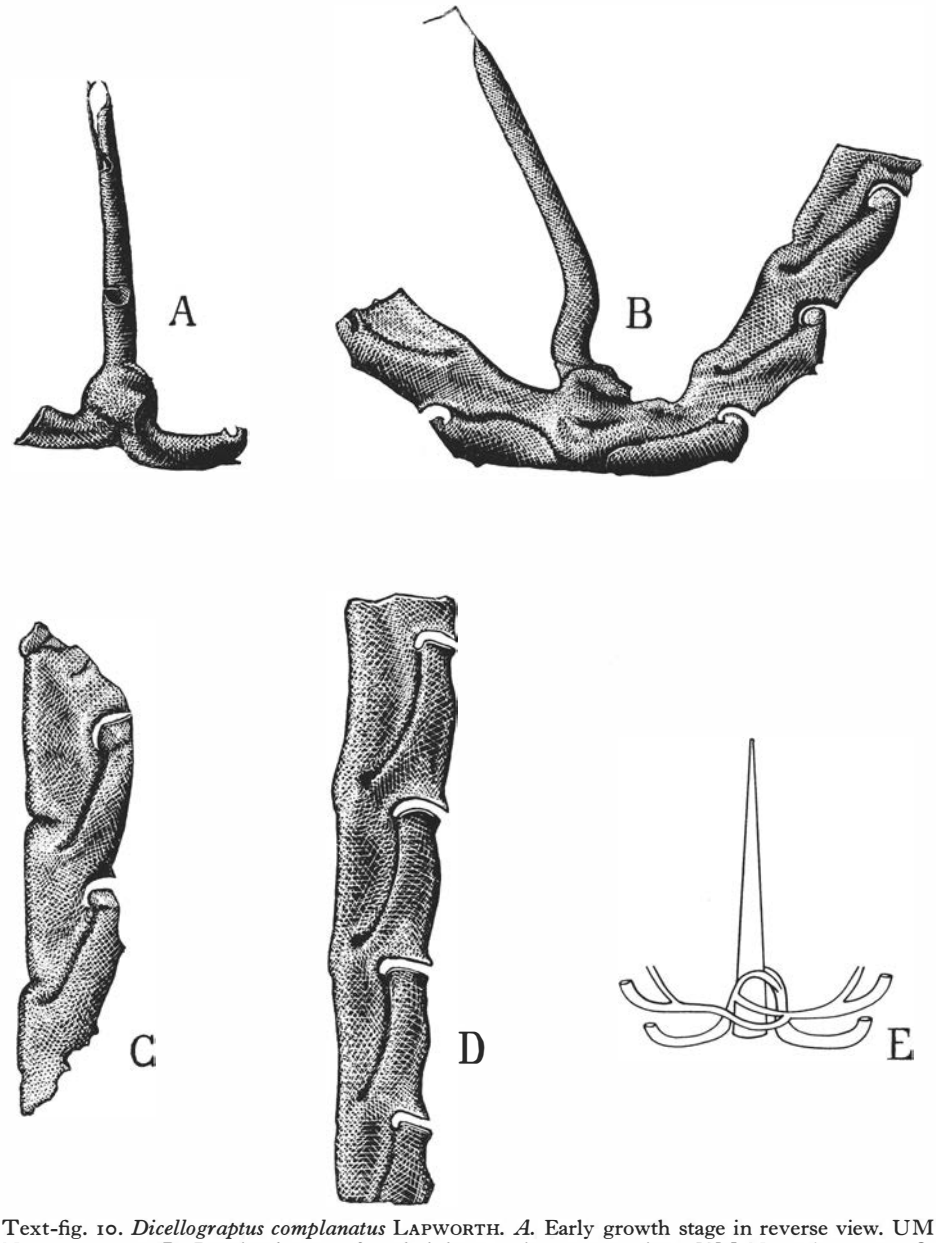
DESCRIPTION.—The description is based mainly upon material from the Bestorp exposure, where most specimens are preserved in relief. The periderm is, however, often provided with fissures and consequently very fragile. For this reason it is impossible to isolate portions of the rhabdosome larger than fragments provided with 4–5 thecae.

The two almost straight stipes diverge at angles between 240 and 270°. The ventral wall of the proximal part of the rhabdosome, directed perpendicularly to the axis of the sicula, is 1.5 mm long. The largest available stipe is 75 mm long; the thecae number 9 to 10 in 10 mm. The stipes are proximally (at the level of the geniculum of th 3^1 and 3^2) 0.5 mm wide increasing gradually to 0.8 mm in distal direction. The sicula is slender and 2.5 mm long; it is provided with nema, virgella, and two apertural spines. On the reverse side of the rhabdosome the apertural portion of the sicula is hidden, whereas on the obverse side it is visible for its entire length. In one specimen (Pl. I, fig. 3; Text-fig. 10 B) the sicula is slightly curved. The shape of the proximal thecae differs conspicuously from that of the distal ones. The transition from the proximal to the distal type is gradual, but already th 6^1 and 6^2 evidently have all the features characteristic of the distal thecae.

Proximal thecae. The proximal thecae have introverted and introtorted apertures that almost fill the semicircular excavations, the latter occupy 1/2 to 1/3 of the width of the stipe. The lateral sides of the apertures are formed by a pair of rounded lappets. In addition the two first pairs of thecae are provided with mesial spines, situated 0.25 mm below the apertures. The proximal part of the supragenicular wall is straight and inclined in dorsal and proximal direction, whereas the distal part forms the ventral wall of the introtorted aperture. The dorsal wall is undulating on account of conspicuous prothecal folds. The course of the interthecal septa is very conspicuous externally. The distal portion of the septa is inclined at an angle of 30° to the axis of the stipe, whereas the thickened initial part of the septum is directed almost perpendicularly to the dorsal wall.

Distal thecae. The supragenicular wall is 0.8 mm long, slightly convex, and almost parallel to the dorsal wall of the stipes; the prothecal fold is less pronounced than in the proximal thecae. The excavations are narrow and occupy c. 1/2 of the width of the stipe. They are perpendicular to the axis of the stipe or slightly inclined in proximal and dorsal direction. The inner part of the excavation is slightly curved in proximal direction. The geniculum is accentuated by a selvage. The course of the interthecal septa are externally visible, and their distal portion is almost parallel to the direction of the stipe.

Development. Some early growth stages are available, but do not show all details of the proximal development. Th 1^1 buds 0.5 mm above the aperture of the sicula then continues down to the sicular aperture, where it turns at a right angle outwards for 0.5 mm, before it develops a spine, and curves the apertural portion slightly upwards. Th 1^2 is evidently initiated on the outer side of the



Text-fig. 10. *Dicellograptus complanatus* LAPWORTH. *A.* Early growth stage in reverse view. UM No. 770. ×20. *B.* Proximal part of a rhabdosome in reverse view. UM No. 767. ×24. *C.* Proximal thecae (th 2^1 and th 3^1) in lateral view. UM No. 771. ×24. *D.* Distal thecae in lateral view. UM No. 772. ×24. *E.* Thecal diagram of the proximal development.

proximal part of th 1^1, grows slightly upwards across the sicula, and continues downwards along the sicula to the level of the aperture, where it turns outwards at right angles to the sicula. Th 1^2 gives off th 2^1 just at the begin of its downward curvature. Th 2^1 grows across the sicula and along the dorsal side of th

1^1; after having crossed the sicula, it gives rise to th 2^2. The proximal part of th 2^2 is comparatively long, since it has to cross the sicula and th 2^1. The two stipes are then developed from th 2^1 and th 2^2, respectively.

DISCUSSION.—The specimens described above have been compared with topotypes of *D. complatatus*. There are, however, only a few characters of taxonomic value that can be compared, since the topotype material is strongly compressed. Angle of divergence, number of thecae in 10 mm, and thecal characters seem to agree with the Swedish specimens which can be considered conspecific. The length of the sicula was recorded by ELLES & WOOD (1904) to be 1.5 mm. Among the examined topotypes one sicula with the prosicular part broken off, is 1.7 mm long, so that the total length of the sicula certainly exceeded 2 mm in the Scotish specimens. Topotypes of *Dicellograptus anceps* var. *bornholmiensis* POULSEN (1936) have also been studied. The specimens are well preserved and are without doubt conspecific with the Swedish material identified as *D. complanatus*.

The details of the proximal end were previously known in two species of the genus *Dicellograptus*, viz. *D. geniculatus* BULMAN (1932) and *D. divaricatus* var. *salopiensis* ELLES & WOOD (STRACHAN 1959). *Dicellograptus complanatus* is provided with three crossing canals, all of them comparatively long, producing a less compact appearance of the proximal end than in *D. divaricatus* var. *salopiensis*. In the latter species and in *D. complanatus* the upward growth of th 1^2 is conspicuous. Judging from the figure given by BULMAN (1932, p. 20, Text-fig. 6) the initial part of th 1^2 has the same development also in *D. geniculatus*.

Prothecal folds similar to those described above have been found also in *Dicellograptus johnstrupi* HADDING, and previously the folds have been recorded in *Dicellograptus vagus* HADDING (1913). The prothecal folds are found also in earlier graptoloids, where they often have an elaborated development, and the presence of prothecal folds was regarded by MU (1957) as a diagnostic character of the family *Sinograptidae*.

OCCURRENCE IN SCANDINAVIA.—*Jonstorp Formation.* Västergötland: Exposures at Bestorp and Jonstorp, Kullatorp core (54.90 m). *Jerrestad Formation.* Scania: Röstånga, Lindegård core. Bornholm: Laesaa (POULSEN 1936 as *D. anceps* var. *bornholmiensis*).

Dicellograptus sp.

P. I, fig. 10.

The available material consists of one proximal end preserved in full relief. The proximal part of the sicula is broken off, and only the thecae 1^1, 1^2, and 2^2 are complete. The proximal parts of the stipes evidently diverge at an axillary angle of 90°. The sicula is provided with a stout virgella, and the preserved thecae carry stout mesial spines which are situated 0.2 mm below the aperture. The specimen has introverted and introtorted apertures which open in semi-

circular excavations occupying 1/3 of the width of the stipe. The distance between the base of the mesial spines of th 1^1 and th 1^2 amounts to 1.5 mm. The stipes are 0.4 mm wide at the level of the base of the mesial spines of th 1^1 and th 1^2, and the supragenicular wall of th 2^2 is 0.75 mm long.

The angle of divergence between the stipes of the specimen described differs conspicuously from that of *D. morrisi*. The material is, however, too scanty to permit a specific identification. Possibly the form described above is that mentioned by TÖRNQUIST (1891, p. 23) from the Fjäcka Shale of Dalarna. He did however, not, give any description of the specimens which could not be localized by the present writer.

OCCURRENCE.—*Fjäcka Shale.* Dalarna: Enån.

Family *Diplograptidae* LAPWORTH, 1873

Genus *Pseudoclimacograptus* PŘIBYL, 1947

Pseudoclimacograptus clevensis n. sp.

Pl. II, figs. 5–8.

1948 *Climacograptus* cf. *minimus* CARRUTHERS—HENNINGSMOEN, p. 404.

HOLOTYPE.—UM No. Vg 757 (Pl. II, fig. 6)

TYPE STRATUM AND LOCALITY.—Fjäcka Shale, Jonstorp, Västergötland.

DERIVATION OF THE NAME.—After Vilske-Kleva, the parish in which the type locality is situated.

DIAGNOSIS.—A species of *Pseudoclimacograptus* with 5 thecae in 5 mm proximally. Width 1.0 mm proximally (th 2^1–2^2), increasing to 1.2 mm at the level of th 4^1–4^2. Apertural excavations occupying about 1/3 of the ventral margin of the stipe, and 1/3 of the width of the rhabdosome. Apertural margin perpendicular to the axis of the rhabdosome. Proximally, to the level of th 3^1, the parietal lists are connected with the median septum by a transverse list. Proximal thecae without spines.

DESCRIPTION.—The available material consists of proximal parts of rhabdosomes most of which are broken distally. Some specimens are in full relief. The largest, well preserved specimen is only 3.5 mm long (Pl. II, fig. 8). In the Kullatorp material the length of a badly preserved specimen is 9 mm. Only some few strictly laterally compressed specimens permit measuring of the width of the rhabdosome. Assuming that the length of the thecae is uniform throughout the rhabdosome, the number of thecae in 10 mm would amount to 14 in 10 mm. The supragenicular wall is slightly convex and 0.5 mm high (*long.*) in all measured thecae (except th 1^1 and 1^2). The apertural excavations are surrounded by a narrow list. The median septum follows a conspicuous angular course. On the reverse side it originates at the level of the geniculum of th 2^2, and on the obverse side at the level of the geniculum of th 3^1.

Some isolated siculae with the proximal part of the initial bud have been found. The sicula is 1.0 mm long, and its apertural width amounts to 0.3 mm in flattened specimens. The only spine protruding from the sicular aperture is the virgella which is stout and 0.2 mm long. Th 1^1 originates 0.4 mm above the aperture of the sicula, grows first downwards to a level 0.2 mm below the sicular aperture, and then upwards for 0.6 mm. On the obverse side of the rhabdosome 0.4 mm of the sicula is visible.

DISCUSSION.—Specimens referred here to *Pseudoclimacograptus clevensis* n.sp. were previously identified by HENNINGSMOEN (1948) as *Climacograptus* cf. *minimus* (CARRUTHERS). According to him the "basal" thecae should be provided with short spines. However, no spines have been observed in the specimens labelled as *Climacograptus* cf. *minimus* in the examined material from the Kullatorp core. In the present writer's opinion the specimens from Kullatorp are not conspecific with *C. minimus*. According to the description given by ELLES & WOOD (1906), this species has neither a zig-zag median septum nor a convex supragenicular wall, neither have these features been observed in examined specimens from Dobbs Linn, Moffat district.

All previously described species of the genus *Pseudoclimacograptus* occur in older strata than those with *P. clevensis*. According to JAANUSSON (1960, p. 327) the youngest species known at that time came from the zone of *Diplograptus multidens*. *Pseudoclimacograptus clevensis* belongs to the assemblage of the zone of *Pleurograptus linearis*, and thus is the youngest species of the genus hitherto known so far.

OCCURRENCE.—*Fjäcka Shale*. Västergötland: exposures at Jonstorp and Bestorp, Skultorp boring (at the level of 13.60 m), and Kullatorp boring (at the levels of 59.60 and 61.10 m).

Genus *Climacograptus* HALL, 1865

Climacograptus styloideus ELLES & WOOD, 1906

Pl. II, figs. 1–4; Pl. III, fig. 3.

1878 *Climacograptus styloideus*—LAPWORTH, p. 330 [*nomen nudum*].
1906 *Climacograptus styloideus* LAPWORTH MS—ELLES & WOOD, p. 205; Pl. XXVII, figs. 9a–e; Text-figs. 138a–c.
1915 *Climacograptus styloideus* LAPWORTH—HADDING, p. 21; Pl. II, figs. 20–27.
1935 *Climacograptus styloideus* LAPWORTH—THORSLUND, p. 48.
1940 *Climacograptus styloideus* LAPWORTH—THORSLUND, p. 22.
1948 *Climacograptus styloideus* LAPWORTH—HENNINGSMOEN, p. 404.

DESCRIPTION.—The available material consists of numerous distal fragments of rhabdosomes and some specimens with the proximal end preserved. No growth stages have been observed. All specimens are flattened.

The largest specimen with preserved proximal end is 12 mm long, and the largest distal fragment measures 22 mm. The width of the rhabdosome increases from 1.0 mm at the level of th 2^1–2^2 to 1.5 mm at the level of th 5^1–5^2, there-

after the rhabdosome gradually becomes parallel-sided. The maximum width of a specimen with the proximal end preserved is 1.9 mm at the level of th 13^1–13^2. A distal fragment preserved in scalariform view is 3.0 mm wide. Virgella 0.5–0.8 mm long. The sicula, 1.5 mm long, is usually completely embedded in the rhabdosome; in some specimens, however, the apertural portion of the sicula is extended like a tube along the virgella (Pl. II, fig. 1). Supragenicular wall straight, parallel to the axis of the rhabdosome, and 0.45–0.80 mm high (*long.*); the variation in height is especially conspicuous in the specimen figured on Pl. II, fig. 2. The apertural excavations are surrounded by a conspicuous peridermal list; their height (*long.*) is 0.15 mm proximally and 0.30 mm distally, their width 0.30–0.40 mm. In opaque, strictly laterally compressed specimens the virgula is outlined as a low ridge upon the surface of the rhabdosome. In some specimens in the Kullatorp material the virgula extends up to 10 mm beyond the distal end of the rhabdosome. In transparent specimens some internal features are discernible. At the level of each theca the virgula is seen to be provided with transverse rods (Pl. III, fig. 3). Also in opaque specimens the rods are sometimes visible, i.e. when they have perforated the periderm (Pl. I, figs. 1, 3). The rods are most conspicuous in the proximal part of the rhabdosome, whereas distally they are narrower. In addition a median septum with an undulating course is visible in transparent specimens (Pl. III fig. 3); however, in the material at hand it is difficult to observe the details of the relation between the median septum and the virgula with the attached rods. Possibly the rods support the median septum, and thus connect the virgula with the lateral walls of the rhabdosome. The periderm of the median septum is evidently very thin as it cannot be distinguished in transparent specimens. In opaque specimens the presence of a median septum can not be proved, as no median furrow is developed. The largest rhabdosome has 10 thecae in 10 mm. Other values observed in the material are 7 thecae in 5 mm (th 3^1–9^1) and 6 thecae in 5 mm (th 2^2–7^2).

DISCUSSION.—*Climacograptus styloideus* has generally been credited to LAPWORTH (1878). The species was, however, not properly established until 1906 by ELLES & WOOD (1906, p. 205) who ought to be regarded as the nomenclatorial authors of this taxon.

All comparisons between the specimens described here and those previously treated must be based upon external dimensions of the rhabdosome. Most data recorded by ELLES & WOOD agree with those given here. One deviating dimension is the length of the rhabdosome. In no case, however, the complete length of the rhabdosome has been observed, all specimens described above being broken distally. The inclination of the apertural excavations is not so pronounced in the specimens from Dalarna and Östergötland as in those from Scotland.

The specimens described by HADDING (1915) and HENNINGSMOEN (1948) are all strongly compressed. To judge from their external dimensions they are conspecific with the specimens described above. Recently KELLER (1956)

described specimens from Kazakhstan as *C. styloideus*. The material is evidently badly preserved and the figures given by KELLER (*op. cit.* Fig. 29; Pl. IV, fig. 4) do not display any characters which permit a specific identification. His reference is, therefore, omitted from the list of synonymy.

Previously a median septum had not been observed in this species. This is, however, explainable, as the septum can not be traced in opaque specimens. The course of the septum is undulating rather than angular. The latter is the case in the genus *Pseudoclimacograptus* in which genus the septum is always externally indicated by a distinct furrow.

An abnormal growth of the apertural part of the sicula, like that observed here, is recorded by BULMAN (1947, p. 69; Text-figs. 36–37) in *Climacograptus scharenbergi*.

OCCURRENCE IN SCANDINAVIA.—*Fjäcka Formation.* Dalarna: Amtjärn, Gulleråsen. Östergötland: Exposures in large erratic boulders at Ullnäs and Hamra, and Smedsby Gård boring (at the level of 72.8 m). Västergötland: Kullatorp boring (at the level of 62.10 m), and Varvsberget. Jämtland: Namn. *Dicellograptus Shale.* Scania: Jerrestad. Bornholm: Vasagaard, Risebaeck.

Climacograptus angustus (PERNER 1895)

Pl. III, figs. 1–2, 4–6; Pl. IV, fig. 7; Pl. V, fig. 6.

1895 *Diplograptus* (*Glyptograptus*) *euglyphus* var. *angustus* n.var.—PERNER, p. 27; Pl. 8, figs. 14a–b.
1895 *Diplograptus* (*Glyptograptus*) *lobatus* n.sp.—PERNER, p. 28; Pl. 7, fig. 15; Pl. 8, fig. 5.
1906 *Climacograptus scalaris* var. *miserabilis* var. nov.—ELLES & WOOD, p. 186; Pl. XXVI, figs. 3a–h; Text-figs. 120a–c.
1915 *Climacograptus brevis* ELLES & WOOD—HADDING, pp. 21–22; Pl. II, figs. 16–18.
1923 *Climacograptus scalaris* var. *miserabilis* ELLES & WOOD—KING, p. 492.
1923 *Climacograptus scalaris* var. *miserabilis* ELLES & WOOD—PUGH, p. 518.
1936 *Climacograptus scalaris* var. *normalis* LAPWORTH—POULSEN, p. 58.
1949 *Climacograptus angustus* (PERNER)—PŘIBYL, pp. 7–10; Pl. II, figs. 2–9.
1961 *Climacograptus angustus* (PERNER)—GLIMBERG, p. 84.

DESCRIPTION.—The available material consists of numerous rhabdosomes. Rhabdosome narrow and parallel-sided. The largest available rhabdosome is 10.9 mm long, and carries 11 thecae in 10 mm (th 2^2–12^2). Width 0.7–0.8 mm proximally (th 2^1–2^2) increasing to a maximum of 0.9–1.0 mm. In obliquely compressed specimens the maximum width amounts to 1.2 mm. Height (*long.*) of the slightly convex supragenicular wall 0.5 mm throughout the rhabdosome. Apertural excavations alternating 0.3 mm high (*long.*) and 0.2–0.3 mm wide; they occupy 1/4 of the width and 1/3 of the length of the rhabdosome. The apertural margin is almost straight, perpendicular to the axis of the rhabdosome, whereas the infragenicular wall is slightly concave. The excavations are marked by a slight thickening of the periderm which is discernible in transparent spe-

cimens. In opaque specimens, preserved in a slight relief, the course of the straight median septum can be traced from a longitudinal furrow on the lateral side of the rhabdosome. In transparent specimens the septum is conspicuous, originating proximally at the level of the aperture of th 1^2 (Pl. III, fig. 5). In growth stages the septum, attached to the virgula, extends distally (Pl. III, fig. 1) beyond the thecae. In opaque flattened specimens the course of the comparatively thick virgula is visible (Pl. IV, fig. 7). In specimens with the distal end preserved the virgula always extends distally beyond the rhabdosome.

The sicula is 1.5 mm long, reaching to the level of the apertural excavation of th 2^1. The prosicula is 0.3 mm long and 0.1 mm wide at the aperture. Width of metasicular aperture 0.3–0.4 mm. The sicula is provided with a virgella, 0.5 mm long. On the obverse side of the rhabdosome 0.4 mm of the sicula is visible. The initial bud originates 0.4 mm above the aperture of the sicula (Pl. III fig. 6) and grows downwards to a level 0.2 mm below the sicular aperture. The distal part of th 1^1 curves upwards and is 0.7 mm long. Some few arly growth stages are available, but do not show all details of the proximal development. In the specimen figured on Pl. III, fig. 4 th 2^1 and 2^2 are visible between the apertural parts of th 1^1 and 1^2. Th 2^1 and 2^2 are separated by a septum which is attached to the sicula. This septum is possibly the proximal part of the median septum.

Discussion.—The dimensions of the rhabdosome given above agree with those recorded by Perner (1895). The presence of a median septum is, however, mentioned neither by him nor by Přibyl (1949). In the specimens figured by Přibyl (1949, Pl. II, figs. 2–9) a longitudinal line runs centrally on the lateral side of the rhabdosome. This line may indicate the course of the virgula or that of the median septum. If the specimens are preserved in a slight relief the line probably indicates the median septum, since in this state of preservation the virgula is seldom externally discernible.

As mentioned by Přibyl (*op. cit.*) *C. angustus* differs from *C. brevis* by a narrow rhabdosome and a smaller number of thecae in 10 mm. The specimens figured by Hadding (1915, Pl. II, figs. 16–18) as *C. brevis* are here referred to *C. angustus*. They are badly preserved, but the external dimensions that could be measured agree with those of *C. angustus*.

Recently Packham (1962, p. 500) mentioned the difficulties connected with the generic determination of species with a thecal shape like that of *Climacograptus angustus* (*C. scalaris miserabilis* of Packham). In flattened and obliquely compressed specimens, the outline of the rhabdosome is similar to that of *Glyptograptus* (Pl. IV, fig. 7). If at the same time the specimens are so strongly carbonized that the thecal excavations have become obscure, the similarity to *Glyptograptus* is further pronounced.

Occurrence in Scandinavia.—*Fjäcka Formation.*—Dalarna: Amtjärn, Gulleråsen. Östergötland: Exposure at Ullnäs, and Smedsby Gård boring (at the levels of 71.20, 71.25, and 71.55 m). Västergötland: Bestorp, Jonstorp. *Jonstorp*

Formation.—Västergötland: Bestorp. *Jerrestad Formation.*—Scania: Lindegård boring (GLIMBERG 1961). Bornholm: Laesaa (POULSEN 1936 as *C. scalaris* var. *normalis*).

Climacograptus brevis cf. *mutabilis* STRACHAN, 1959

Pl. V, figs. 3–4.

cf. 1940 *Climacograptus* aff. *kuckersianus* HOLM MS., WIMAN—BULMAN, in THORSLUND, p. 114.

cf. 1959 *Climacograptus brevis* var. *mutabilis* nov.—STRACHAN, pp. 54–60; Pl. I, figs. 6–10; Pl. II, figs. 2–4; Text-figs. 4–8, 9 (A).

DESCRIPTION.—The available material consists of three isolated flattened specimens that have been bleached. The largest rhabdosome is 5.5 mm long. At the level of th 2^1–th 2^2 the rhabdosome is 1.2 mm wide, and that width is maintained throughout the rhabdosome. The sicula is 1.3–1.5 mm long; when the sicula has its greatest length, it reaches the aperture of th 3^1 (Pl. V, fig. 3). The aperture of the sicula is 0.3 mm wide; it is provided with a virgella, 0.5 to 0.8 mm long. The free ventral wall of th 1^1 and th 1^2 are slightly inclined in relation to the axis of the rhabdosome. The supragenicular wall of the thecae is formed by 7 to 8 fuselli; it is straight and 0.3 to 0.4 mm high (*long.*). Apertural excavations 0.4 mm high and 0.3 mm wide (*tr.*); the apertural margin is straight and perpendicular to the axis of the rhabdosome. The infragenicular wall is slightly concave. The thecal excavations alternate. The virgula is stout and extends beyond the distal thecae; a median septum is initiated at the level of the aperture of th 1^2. The thecae are closely set and number proximally 7 in 5 mm.

DISCUSSION.—The dimensions of the described specimens agree with those recorded by STRACHAN (1959) in *C. brevis* var. *mutabilis* from the *Ludibundus* beds. Comparisons with regard to the proximal development can, however, not be made between the Viruan specimens and those described above, since among the latter no early growth stages are available. In the specimens described by STRACHAN the proximal development displays some very distinctive characters.

The width of the rhabdosome and the closely set thecae of *C. brevis* cf. *mutabilis* agree with the nominal subspecies (ELLES & WOOD 1906, p. 192), whereas the length of the sicula differs (c. 1 mm in *brevis*, 1.3 to 1.5 mm in cf. *mutabilis*). The shortness of the sicula of *C. brevis* is very conspicuous in the specimens from Laggan Burn figured by BULMAN (1947, Pl. IX).

C. brevis cf. *mutabilis* is associated with *C. angustus*. It differs, however, conspicuously from the latter in the width of the rhabdosome and the number of thecae in 10 mm.

OCCURRENCE.—*Fjäcka Shale.* Östergötland: Exposure in erratic boulder at Ullnäs.

Genus *Diplograptus* M'Coy, 1850

Diplograptus pristis (Hisinger, 1837)

Pl. IV, figs. 1–5.

1837 *Prionotus pristis* n.sp.—Hisinger, p. 114; Pl. XXXV, fig. 5.
1881 *Diplograptus pristis* Hisinger—Törnquist, pp. 443–445; Pl. II, figs. 8a–g.
1882 *Diplograptus ? pristis* Hisinger—Tullberg, pp. 10–11; Pl. I, figs. 2–10; [non figs. 1 and 11].
1891 *Diplograptus pristis* Hisinger—Törnquist, pp. 26–27, Pl. I, figs. 18–22.
1907 *Diplograptus* (*Orthograptus*) *pristis* (Hisinger)—Elles & Wood, p. 245; Figs. 165a–c.
1935 *Diplograptus* (*Mesograptus*) *pristis* (Hisinger) — Bulman in Thorslund, p. 48.
1940 *Diplograptus pristis* (Hisinger)—Thorslund, p. 23.
1949 *Diplograptus pristis* (Hisinger)—Přibyl, Pl. IV, figs. 6, 7; Pl. V, fig. 1.

Diagnosis.—Rhabdosome with 12 thecae in 10 mm proximally and 9 to 10 distally; width 1.6 mm proximally increasing gradually to 2.3 mm at the level of the fifth pair of thecae, and to 2.8 mm at the level of the eleventh pair. The thecae are proximally sigmoidal with a poorly defined geniculum and approach the glyptograptid type; in distal direction the free ventral wall becomes gradually straight, and the thecae assume the orthograptid type. The apertural excavations occupy proximally 1/5 to 1/6 of the width of the rhabdosome. The apertural margin is proximally perpendicular to the axis of the rhabdosome and has no lappets. Th 1^1 and 1^2 with short stout apertural spines.

Description.—The available material consists of numerous rhabdosomes and distal fragments. Most specimens are flattened and in general obliquely compressed. Strictly laterally compressed specimens are rare. No early growth stages have been found.

The largest available rhabdosome is 33 mm long. Width of the rhabdosome at the level of th 2^1–2^2 1.6 mm, increasing to 2.3 mm at the level of th 5^1–5^2. The maximum width of a distal fragment is 2.8 mm. The largest width in the available material is 4.0 mm determined in a specimen compressed in scalariform view. The shape of the thecae varies conspicuously according to the degree and direction of compression. In a specimen preserved in semirelief (Pl. IV, fig. 5) the shape of the free ventral wall of the proximal thecae is well seen. In this specimen the free ventral wall has a sigmoidal curvature; the genicular bend is poorly defined, and no distinct geniculum is formed. The genicular portion of the free ventral wall is never seen to be strengthened by a peridermal list. The distal part of the free ventral wall is inclined in dorsal and proximal direction, and in this specimen the shape of the proximal thecae is comparable to what has been termed the glyptograptid type. Upon strong compression in strictly lateral direction the periderm of the subapertural portion of the thecae is ventrally cracked, and on this account the bend and the thecal excavations are conspicuous. In this state of preservation the shape of the thecae resembles that of the

climacograptid type (Pl. IV, fig. 2). Distally the bend of the free ventral wall of the thecae is gradually lost, and the thecae assume the orthograptid type.

In flattened specimens (Pl. IV, fig. 2) the outline of the sicula as well as that of the virgula is discernible through the periderm. The length of the sicula is 1.6 to 1.9 mm. The sicula is provided with a stout virgella, 0.2 to 0.4 mm long. On the obverse side of the rhabdosome 0.4 mm of the sicula is visible. The apertural spines of th 1^1 and 1^2 are situated close to the thecal apertures and, with regard to their small length, extremely thick at the base. Th 1^1 and 1^2 form a comparatively large angle with the axis of the rhabdosome. This feature produces the rounded shape of the proximal end. The apertural margins are supported by a thickening of the periderm. This thickening is most conspicuous in the proximal thecae, where it continues to the free ventral wall of the succeding theca (Pl. IV, fig. 4). In the distal thecae the thickening is restricted to the apertural margin. The cortical layer of the periderm is thick, and the examined specimens are so strongly carbonized that no fuselli can be distinguished in bleached specimens. The only internal structures that are visible are the interthecal septa and the virgula. The overlap amounts to 1/2.

Discussion.—As mentioned above, *Diplograptus pristis* has previously been recorded from all districts on the mainland of Sweden, where the Harjuan sequence is developed. Tullberg (1882) considered specimens from the Fjäcka Shale of Dalarna and Östergötland and also from the Jonstorp Formation of Västergötland as conspecific with *D. pristis*. In this species he also included specimens from the division Dd5 of Bohemia. The specimen figured by Tullberg (1882) as Pl. I, fig. 1 has long, slender apertural spines not observed hitherto in *D. pristis*. The shape of the thecae also differs from that of *D. pristis*. The figured specimen has not been located, but to judge from the figure this form is not conspecific with *D. pristis*. Also the specimen on Pl. I, fig. 11, which obviously comes from the Jonstorp Formation, displays deviating features in the shape of the thecae and evidently belongs to the genus *Orthograptus*. Törnquist's (1913) statement that *D. pristis* does not occur outside Dalarna and Östergötland is confirmed by the present examination as regards southern and central Sweden. Specimens recorded as *Diplograptus pristis* from the Harjuan sequence of Jämtland (Thorslund 1940) are here included in the list of synonymy. They are, however, generally badly preserved making the specific identification somewhat uncertain. The Bohemian specimens mentioned by Tullberg (1882) were recently treated by Přibyl (1949) as *Diplograptus vulgatus* Perner. Přibyl also figured the holotype of *D. pristis* (op. cit. Pl. V, fig. 1). The figure may, however, give an incorrect impression of the shape of the thecae, since they, according to the present writer's examination of the specimen, are partly concealed by matrix.

Törnquist (1881, p. 444; Pl. 17, fig. 8 f) interpreted two slits in the periderm of the ventral wall of th 1^1 and 1^2 as probable thecal excavations. The slits are, however, fissures caused by the compression of the rhabdosome. The same

phenomenon is observed among the examined material in specimens of both *D. pristis* and *Climacograptus styloideus*.

Among previous records of the occurrence of *D. pristis* in North America RUEDEMANN (1947, p. 400) stated that the species "is a European one and is not recognized in America". The specimens recorded as *D. pristis* from Australia (cf. KEBLE & BENSON 1939, p. 82) are omitted here from the list of synonymy, since no detailed information about their characters is available in the literature.

OCCURRENCE.—*Fjäcka Shale.* Dalarna: Draggån, Enån, Amtjärn, and Gulleråsen. Östergötland: Exposures in large erratic boulders at Hamra, Nässja, and Ullnäs; Smedsby gård boring (at the levels of 71.00, 71. 25, 71.45, and 71.50 m. Jämtland: Namn.

Genus *Orthograptus* LAPWORTH, 1873

Orthograptus pauperatus ELLES & WOOD, 1907

Pl. I, fig. 11.

1907 *Diplograptus* (*Orthograptus*) *truncatus pauperatus* var. nov.—ELLES & WOOD, p. 237; Pl. XXIX, figs. 5a–d.

1915 *Diplograptus truncatus* LAPW. var. *pauperatus* LAPW. mscr.—HADDING, p. 15; Pl. II, figs. 8–11.

1948 *Diplograptus* (*Orthograptus*) *truncatus pauperatus* ELLES & WOOD—HENNINGSMOEN, p.403.

DESCRIPTION.—*Orthograptus pauperatus* was recently described by HENNINGSMOEN (1948) from the Fjäcka Shale of the Kullatorp core. For this reason the present description will only give some additional remarks on the morphology. In addition to the material from the Kullatorp core the present writer has had access also to specimens from the Skultorp core. In the Fjäcka Shale of these cores some rhabdosomes are filled with pyrite and preserved in a slight relief. However, the periderm is cracked, and the specimens could not be isolated.

Th 1^1 and th 1^2 are provided with spines close to the apertures. According to HENNINGSMOEN (1948, p. 403) the spine of th 1^2 is situated "where direct upward growth commences". The spine referred to by him is, however, one of the two apertural spines of the sicula. In the specimen figured on Pl. I, fig. 11 the median septum begins on the reverse side at a level somewhat above the aperture of th 3^2. As stated by HENNINGSMOEN, in the specimens from Kullatorp the septum begins at a higher level (fifth pair of thecae). In well preserved specimens the metathecae are developed as tubes with almost equal width throughout the length. HENNINGSMOEN's statement that the thecae widen abruptly immediately below the apertural margin was evidently based upon the conditions in obliquely compressed specimens.

OCCURRENCE.—*Fjäcka Shale.* Västergötland: Kullatorp boring (at the level of 57.60 m) and Skultorp boring (at the level of 13.60 m). Dalarna: Amtjärn.

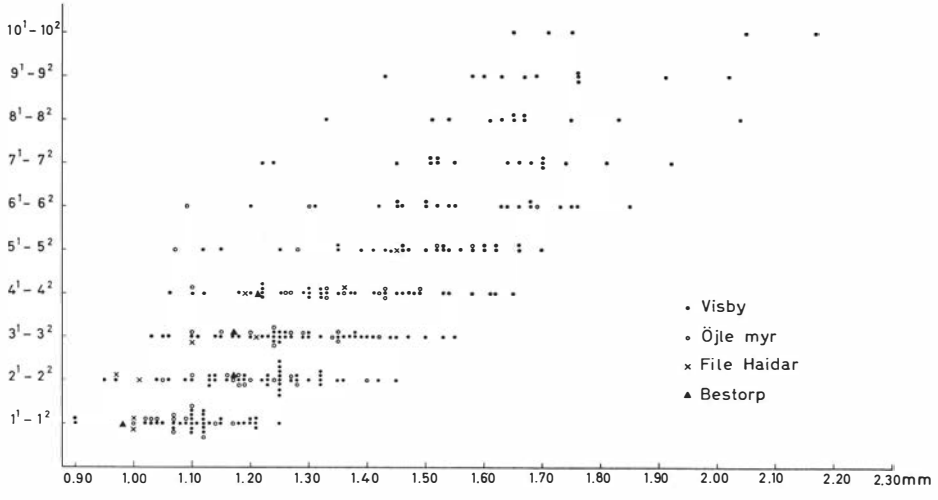
Dicellograptus Shale (Zone of *Pleurograptus linearis*). Scania: Jerrestad. Bornholm: Vasagaard.

Orthograptus gracilis (Roemer, 1861)

Pl. IV, fig. 6; Pl. V, figs. 5, 7; Text-fig. 11.

1861 *Retiolites gracilis* n.sp.—Roemer, p. 31; Pl. V, fig. 1.
1885 *Diplograptus gracilis* Roemer—Roemer, p. 313.
1893 *Diplograptus* sp.—Wiman, pp. 97–104; Pl. VI, figs. 1–12.
1894 *Diplograptus* sp.—Wiman, pp. 267–274; Pl. II, figs. 1–12.
1897 *Diplograptus gracilis* Roemer—Roemer & Frech, p. 629.
1926 *Diplograptus gracilis* Roemer—Kraft, p. 221, *et seq.*; Pls. V–XVI, Pl. XVII, figs. 3–4.
1932 *Orthograptus gracilis* (Roemer)—Bulman, pp. 21–29; Pl. V, figs. 7–24; Pl. VI, figs. 1–36; Pl. VII, figs. 1–22; Text-figs. 11–15.
1936 *Diplograptus* (*Orthograptus*) *gracilis* (Roemer)—Poulsen, pp. 57, 59.
1938 *Orthograptus gracilis* (Roemer)—Thorslund, p. 31.
1951 *Diplograptus gracilis* Roemer—Eisenack, fig. 8.
1959 *Diplograptus gracilis* Roemer—Eisenack, pp. 253–255; Pl. 23, figs. 1 (neotype), 2, and 3.
1961 *Orthograptus gracilis* (Roemer)—Glimberg, p. 84.

Discussion.—Some of the isolated specimens from the Jonstorp Formation of Västergötland are preserved in full relief (Pl. IV, fig. 6). The rest of the material is flattened but fairly well preserved, so that the proximal development could partly be followed in early growth stages. The recognition of the specific characters in flattened diplograptids is often difficult. It could therefore not be stated with certainty that the flattened specimens at hand were conspecific with *O. gracilis* until the material preserved in relief had been found. The spe-



Text-fig. 11. Scatter diagram showing the range of the width of *Orthograptus gracilis* (Roemer) at different levels of the rhabdosome.

Table 2. Means and variations of the width at two levels of the rhabdosome of *Orthograptus gracilis* from the Visby sample. All measurements in millimetres.

	N	M	S.D.	V
th 2^1–2^2	39	1.22±0.01	0.11±0.01	9.02±1.02
th 6^1–6^2	20	1.56±0.04	0.16±0.03	10.25±1.62

cimens from Västergötland contribute, however, nothing to the knowledge of the morphology as described by KRAFT (1926) and BULMAN (1932), and therefore no description of the species is given here.

The specimens described by HADDING (1915) as *Diplograptus peosta* HALL from the *Dicellograptus* Shale (Zone of *Pleurograptus linearis*) of Scania and Bornholm resemble very much *O. gracilis*. The specimens are flattened, but the visible characters (width, shape of thecae, and the number and arrangement of the spines) seem to agree with those of *O. gracilis*. However, better material is needed for a safe identification.

The width of the rhabdosome is often used as a specific character. In order to show its range the width of some specimens of *O. gracilis* has been plotted in the diagram in Text-fig. 11. The measured material consists of 39 specimens isolated by HOLM from erratic boulders from Visby (RM), 12 specimens isolated by the present writer from erratic boulders collected by WIMAN on Öjle Myr, Gotland, 2 specimens from the File Haidar boring isolated by THORSLUND (1938), and the above-mentioned, figured specimen from Bestorp, Västergötland. The measurements have been made at the level of each pair of thecae, and the width denotes the distance between the lips of the apertures of the juxtaposed thecae measured perpendicular to the axis of the rhabdosome. To judge from the material studied the range of the width increases somewhat in distal direction, but as the distal end of most specimens is broken off the available data about the width of the distal part of the rhabdosome are comparatively few.

OCCURRENCE.—*Orthograptus gracilis* was up to 1936 known only from erratic boulders of the Harjuan Östersjö Limestone. In that year the species was recorded from the *Tretaspis* beds (Jerrestad Formation) of Bornholm (POULSEN 1936), where it is associated with *Dicellograptus complanatus* LAPWORTH and *Climacograptus angustus* (PERNER). The two last-mentioned species were, however, recorded as *Dicellograptus anceps* var. *bornholmiensis* n. var. and *Climacograptus scalaris normalis* LAPWORTH. On this account POULSEN included the graptolitiferous bed in the zone of *Dicellograptus anceps*. Recently *O. gracilis* was recorded from the Jerrestad Formation of the Lindegård boring, Scania (GLIMBERG 1961). According to GLIMBERG the species also occurs in the portion of the core compared by him with the zone of *Pleurograptus linearis*. These specimens (at the level of 50.00 m) are, however, badly preserved and

scarcely permit a certain specific determination. In the present writer's opinion there exists furthermore no certain faunal evidence for the presence of that zone in the core. In Scania and Bornholm *O. gracilis* thus certainly occurs in the Jerrestad Formation and possibly also in the *Dicellograptus* Shale (zone of *Pleurograptus linearis*). In Västergötland the species has been found so far only in the Jonstorp Formation of the exposure at Bestorp and Jonstorp, and on Gotland the species is found in Östersjö Limestone in the File Haidar boring (THORSLUND 1938).

Family *Retiolitidae* LAPWORTH, 1873

Subfamily *Archiretiolitinae* BULMAN, 1955

Genus *Archiretiolites* EISENACK, 1935

Archiretiolites cf. *regimontanus* EISENACK, 1935

Pl. V, figs. 1–2; Text-figs. 12 A–C.

cf. 1935 *Archiretiolites regimontanus* n.sp.—EISENACK, pp. 74–84; Pl. 4, figs. 1–14; Pl. 5; Pl. 6; Pl. 7, fig. 3; Text-fig. 1.

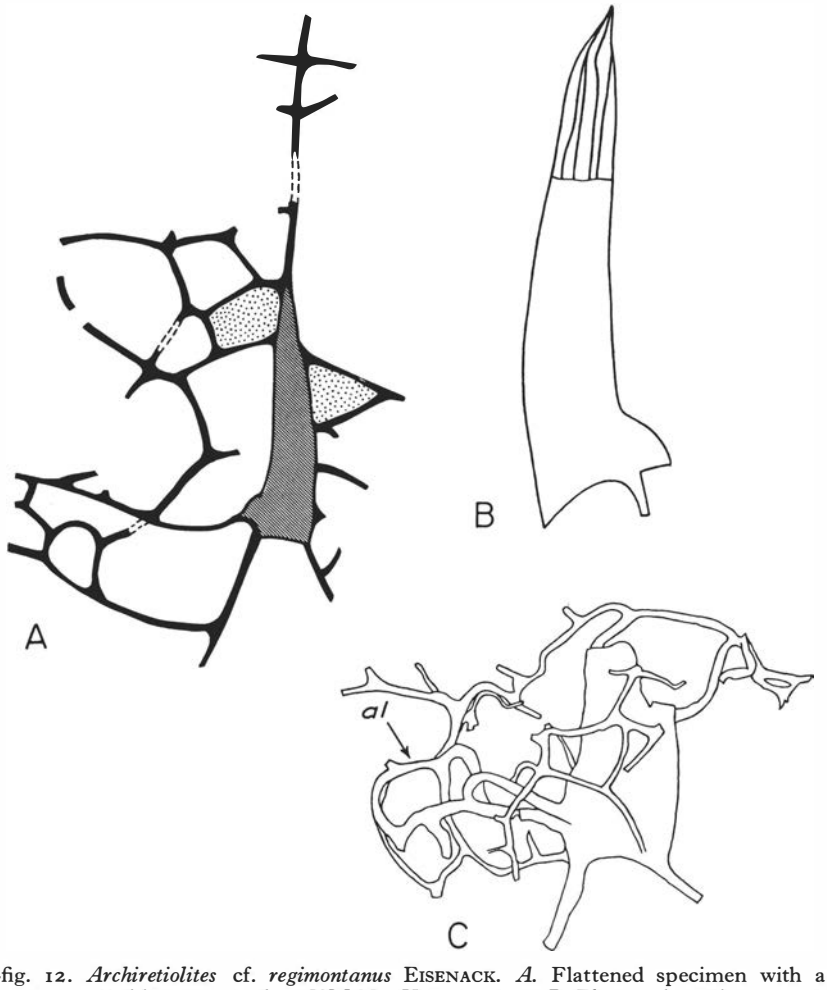
DESCRIPTION.—The available material consists of fragments of rhabdosomes and of numerous siculae. All specimens are flattened.

Sicula and initial bud are provided with a continuous periderm. The remainder of the rhabdosome is developed as clathria and reticula. In one specimen an attenuated periderm is developed in some meshes (Text-fig. 12, A).

Distally the sicula is slightly curved in ventral direction. It is provided with a stout virgella and a dorsally situated apertural spine both of which are an integral part of the clathria. The length of the sicula is 1.1 to 1.3 mm and the width at the aperture 0.3 mm. The prosicula, which is discernible in transparent specimens, is 0.35 to 0.40 mm long and 0.15 mm wide at the aperture. In the apex of the prosicula three or four longitudinal rods are developed. Towards the aperture the rods are split up and become thinner (Text-fig. 12, B). In all isolated siculae the nema is broken off just above the apex of the prosicula.

The initial bud emerges 0.25 mm above the aperture of the sicula and grows downwards for about 0.20 mm. From the apertural margin of the bud two lists are directed perpendicular to the axis of the sicula, and form a ring. The apertural list of th 1^1 can be distinguished (*al.* Text-fig. 12, C) and the ring above mentioned probably surrounds the proximal portion of th 1^2. The sicula evidently has a central position in the proximal part of the rhabdosome as both the virgella and the apertural spine are included in the clathria. The virgula is provided with crossbars which are attached at equal intervals.

DISCUSSION.—The described specimens resemble *Archiretiolites regimontanus* EISENACK (1935) in the development of a continuous periderm in the sicula and the initial bud. The shape of the sicula and the number of apertural spines also agree with those in *A. regimontanus*. EISENACK reported fragments of periderm attached to some lists (1935, Pl. 5, figs. 3, 9) in the proximal part of the



Text-fig. 12. *Archiretiolites* cf. *regimontanus* EISENACK. *A.* Flattened specimen with a thin periderm preserved in some meshes. UM No. Vg 773. × 30. *B.* Flattened specimen, somewhat transparent in the prosicula. × 50. *C.* Proximal fragment of a rhabdosome. See also Pl. V, fig. 2. × 55.

rhabdosome, so that a thin continuous periderm was probably developed in some specimens. In most specimens figured by EISENACK the proximal part of the rhabdosome is developed on the ventral side of the sicula. In one specimen (*op. cit.*, Pl. 6, fig. 3), however, the rhabdosome is developed also on the dorsal side of the sicula. The last-mentioned development is that which is found in the material described above. The two different modes of development may be due to intraspecific variation.

Ordovician graptolites with a reduced periderm have recently been described from isolated material by WHITTINGTON (1954, 1955). Also in *Phormograptus sooneri* WHITTINGTON the continuous periderm is restricted to the sicula and the initial bud. There are, however, significant differences between *Phormo-*

graptus and *Archiretiolites*, especially in the development of the proximal end.

Also the genus *Plegmatograptus* is characterized by a reduced periderm, but details of the proximal end are unknown. Comparisons are therefore hardly possible between the Harjuan species *Plegmatograptus nebula* ELLES & WOOD and the specimens described above. According to ELLES & WOOD (1908, p. 390) *P. nebula* is provided with lacinia, a feature that not has been found in the specimens described as *Archiretiolites* cf. *regimontanus*.

OCCURRENCE.—*Jonstorp Formation.* Västergötland: Exposures at Bestorp and Öglunda (division "e" in the section given by WESTERGÅRD, 1928, p. 49), and the Kullatorp boring (at the level of 54.90 m). *A. regimontanus* was described from boulders of the Östersjö Limestone type in which the species was associated with *Orthograptus gracilis* (ROEMER) (EISENACK, 1935).

Institute of Palaeontology, University of Uppsala, December 15th, 1962.

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Explanation of Plates

The photographs are by Mr. N. HJORTH. All figures are unretouched. The unbleached specimens were coated with ammonium chloride before photographing.

Plate I

Dicellograptus morrisi HOPKINSON

1. Proximal part of a stipe in reverse view; the thecae are more or less obliquely compressed. Fjäcka Shale, Dalarna. RM No. Cn. 978. × 15.
2. Proximal fragment of a stipe which is somewhat obliquely compressed. Fjäcka Shale, Amtjärn, Dalarna. UM No. D 1123. × 20.

Dicellograptus complanatus LAPWORTH

3. Reverse view of the proximal part of a rhabdosome preserved in full relief. Jonstorp Formation, Bestorp, Västergötland. See also text-fig. 10B. UM No. Vg 767. × 20.

Dicellograptus johnstrupi HADDING

All specimens are from the Fjäcka Shale, Jonstorp, Västergötland.

4. Proximal part of a flattened rhabdosome in reverse view. UM No. Vg. 768. × 15.
5. Reverse view of a proximal fragment preserved in slight relief. UM No. Vg 769. × 20.
6. Proximal fragment of a stipe in reverse view. UM No. Vg 751. × 20.
7. Proximal fragment of a stipe in reverse view. UM No. Vg 752. × 20.
8. A somewhat flattened fragment of a stipe. UM No. Vg 753. × 20.
9. Proximal fragment of a stipe (th 4^2 and th 5^2) preserved in full relief. UM No. Vg 754. × 20.

Dicellograptus sp.

10. Obverse view of the proximal part of a rhabdosome preserved in full relief. Fjäcka Shale, Enån, Dalarna. RM No. Cn 977a. × 20.

Orthograptus pauperatus ELLES & WOOD

11. Rhabdosome in reverse view, distal part of the rhabdosome broken off. Fjäcka Shale. Skultorp boring (at the level of 13.60 m), Västergötland. UM No. Vg 755. × 10.

Plate II

Climacograptus styloideus ELLES & WOOD

All specimens are from the Fjäcka Shale, Amtjärn, Siljan district.

1. Rhabdosome in reverse view, with the apertural part of the sicula extended along the proximal part of the virgella. Periderm ruptured by transverse rods of the median septum. UM No. D 1124. × 8.
2. Obliquely compressed rhabdosome showing great variability in the length of the supragenicular wall of the thecae. UM No. D 1125. × 15.
3. Rhabdosome with infra- and supragenicular walls ruptured by transverse rods of the median septum. UM No. D 1126. × 20.
4. Rhabdosome, proximally in lateral view, distally obliquely compressed. UM No. D 1127. × 15.

Pseudoclimacograptus clevensis n. sp.

All specimens are from the Fjäcka Shale, Jonstorp, Västergötland.

5. Proximal fragment of a rhabdosome, obliquely compressed. UM No. Vg 756. × 20.
6. Lateral view of a rhabdosome in full relief. Geniculum of th 2^1 damaged. Holotype. UM No. Vg 757. × 15.
7. Early growth stage in obverse view. UM No. Vg 758. × 20.
8. Obliquely compressed rhabdosome. Damaged proximally. UM No. Vg 759. × 15.

Plate III

All specimens are bleached.

Climacograptus angustus (PERNER)

The specimens figured as 1, 2, 4, and 5 are from the Fjäcka Shale of Ullnäs, Östergötland and that figured as fig. 6 from the Jonstorp Formation of Bestorp, Västergötland.

1. Rhabdosome in lateral view, somewhat obliquely compressed. UM No. Ög 82. × 25.
2. Fragment of a proximal portion, compressed in lateral view. UM No. Ög 83. × 30.
4. Early growth stage. The proximal end of the specimen and the apex of the sicula are damaged. UM No. Ög. 84. × 40.
5. Fragment of a proximal portion. The specimen, except the virgula, is broken distally. UM No. Ög. 85. × 30.
6. Apertural portion of a sicula with the initial bud. The virgella and the apex of the sicula are broken off. UM No. Vg 760. × 50.

Climacograptus styloideus ELLES & WOOD

3. Fragment of a rhabdosome, which is obliquely compressed, showing virgula, transverse rods, and outline of the median septum. Fjäcka Shale. Amtjärn, Dalarna. UM No. D 1128. ×20.

Plate IV

Diplograptus pristis (HISINGER)

All specimens are from the Fjäcka Shale, Amtjärn, Dalarna. The distal portion of all rhabdosomes is broken off.

1. Distal fragment of rhabdosome in lateral view. UM No. D 1129. ×7.5.
2. Proximal portion of rhabdosome in lateral view. UM No. D 1130. ×15.
3. Proximal portion of rhabdosome, obliquely compressed. UM No. D 1131. ×10.
4. Rhabdosome in scalariform view, damaged distally. UM No. D 1132. ×7.5.
5. Proximal portion of rhabdosome preserved in slight relief. UM No. D 1133. ×10.

Orthograptus gracilis (ROEMER)

6. Proximal portion of rhabdosome in relief and slightly compressed perpendicularly to the ventral side. Virgella and apertural spines are broken off. Jonstorp Formation. Bestorp, Västergötland, UM No. Vg 761. ×15.

Climacograptus angustus (PERNER)

7. Rhabdosome in lateral view, slightly obliquely compressed and distally broken off. Fjäcka Shale, Ullnäs, Östergötland. UM No. Ög 86. ×13.

Plate V

The specimens figured as figs. 3–7 have been bleached.

Archiretiolites cf. *regimontanus* EISENACK

The specimens have been isolated from the Jonstorp Formation of the Kullatorp core (at the level of 54.90 m), Västergötland.

1. Proximal fragment of a rhabdosome in obverse view. UM No. Vg 762. ×40.
2. Proximal fragment of a rhabdosome in obverse view UM No. Vg 763. ×40.

Climacograptus brevis cf. *mutabilis* STRACHAN

The specimens have been isolated from the Fjäcka Shale of Ullnäs, Östergötland.

3. Rhabdosome in reverse view, somewhat obliquely compressed. UM No. Ög 87. ×15.
4. Rhabdosome in obverse view; the distal part of the rhabdosome is broken off. UM No. Ög 88. ×15.

Orthograptus gracilis (ROEMER)

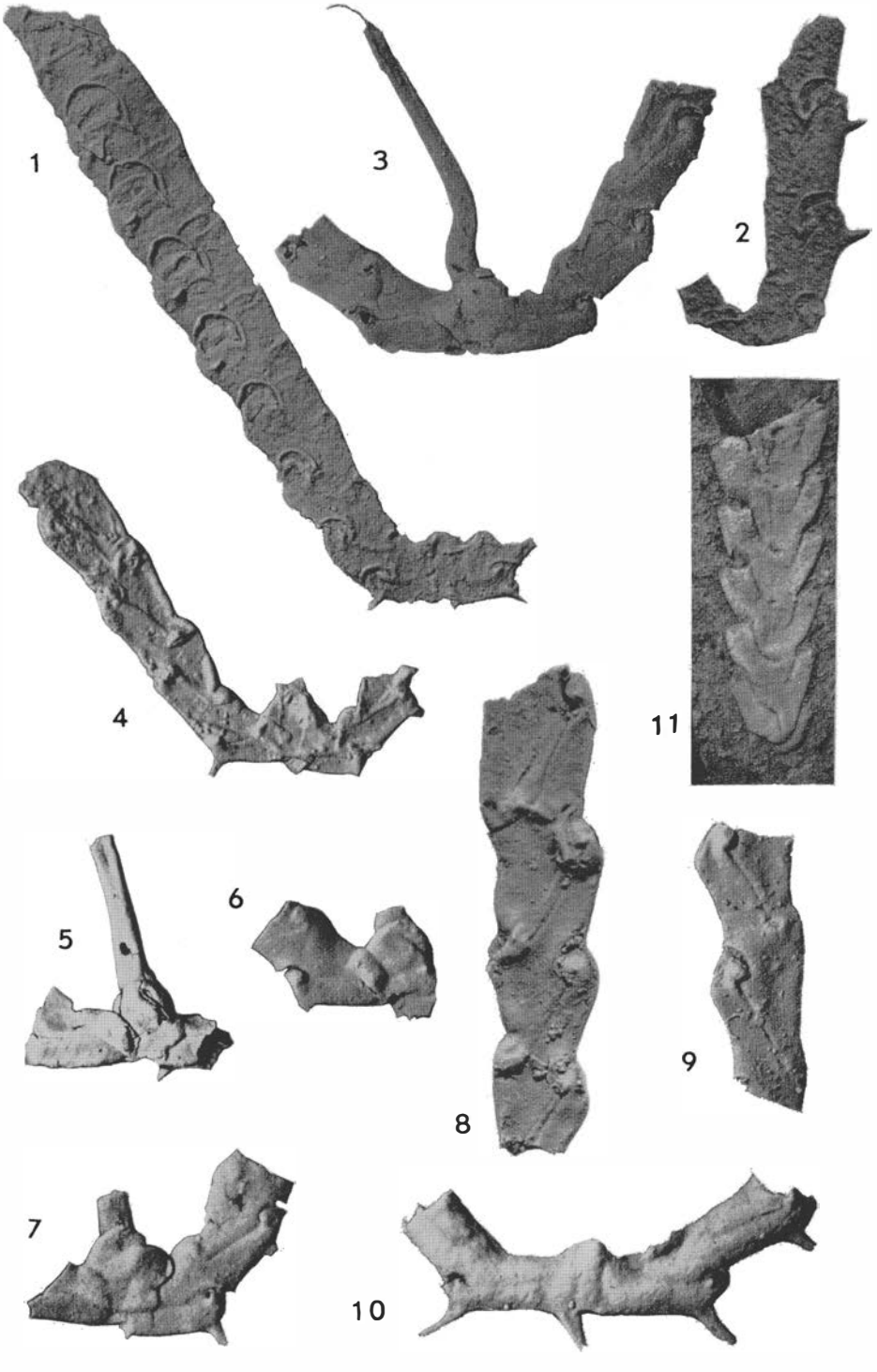
The specimens have been isolated from the Jonstorp Formation of Bestorp, Västergötland.

5. Apertural part of a sicula with the initial portion of th 1^1. UM No. Vg 764. ×40.
7. Early growth stage. Virgella, apertural spines, the spine of the 1^1, and the proximal part of the sicula are broken off. UM No. Vg 765. ×40.

Climacograptus angustus (PERNER)

6. Flattened sicula in dorsal view. Jonstorp Formation, Bestorp, Västergötland. UM No. Vg 766. ×40.

Tryckt den 3 december 1963.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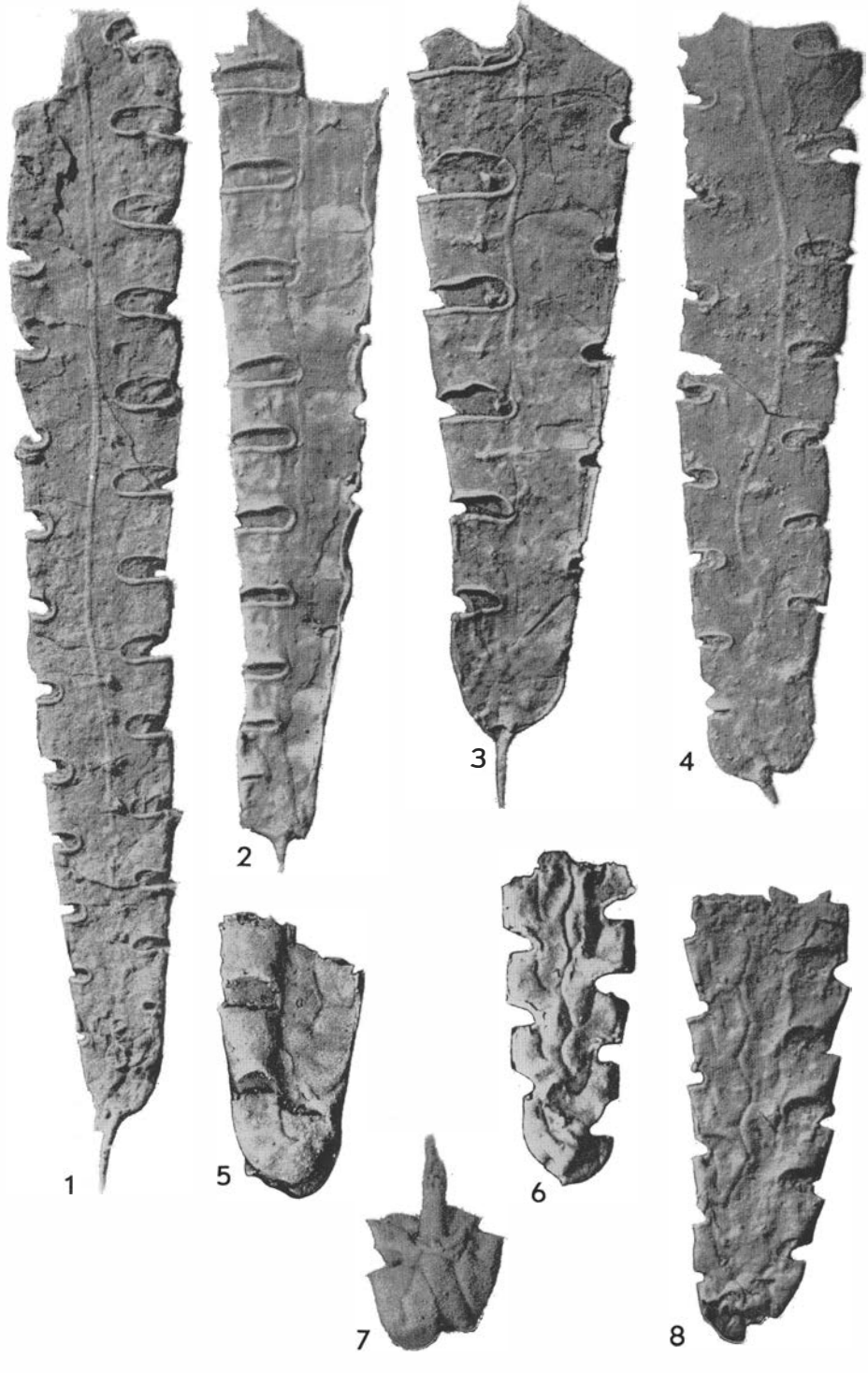
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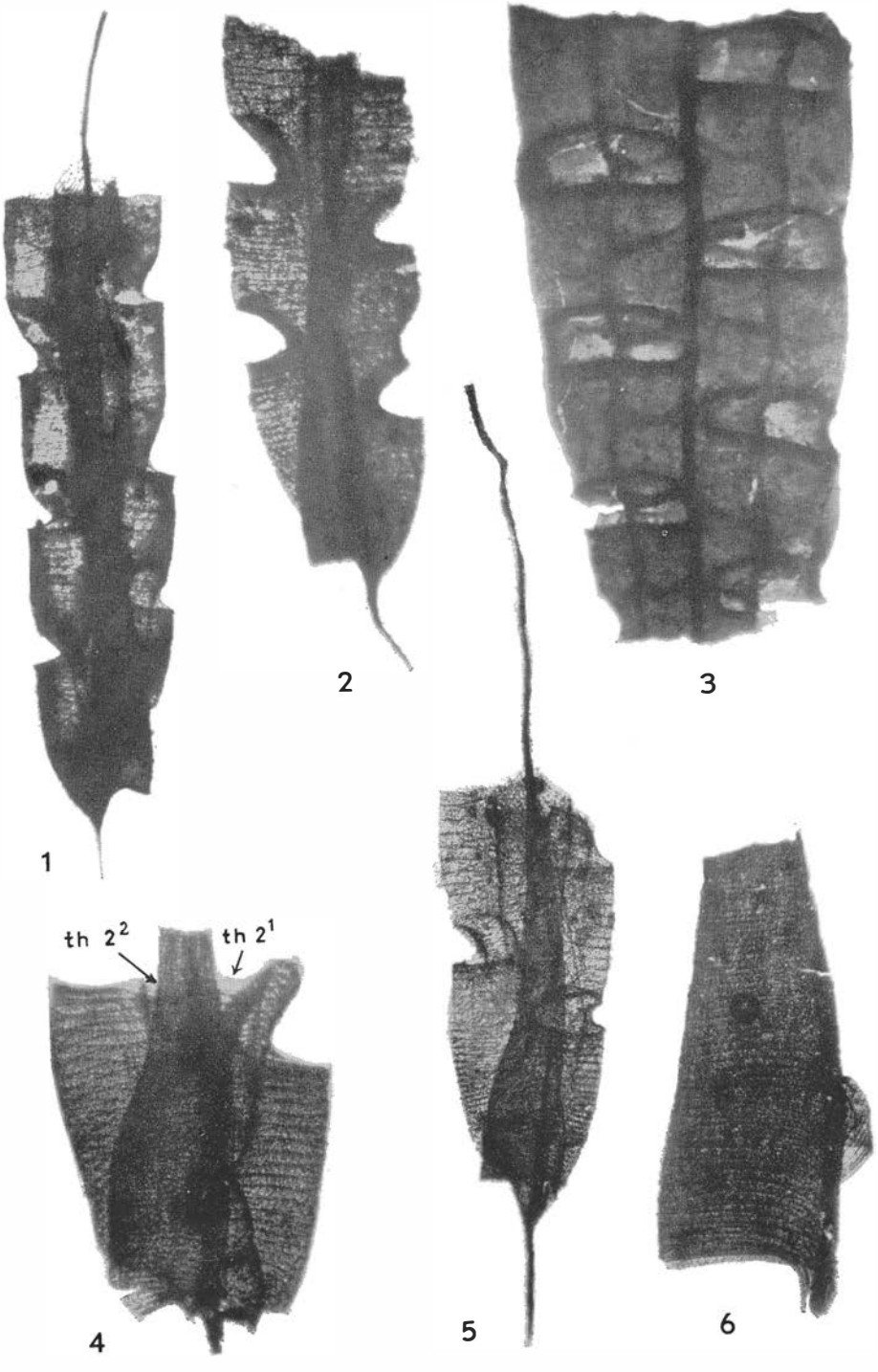
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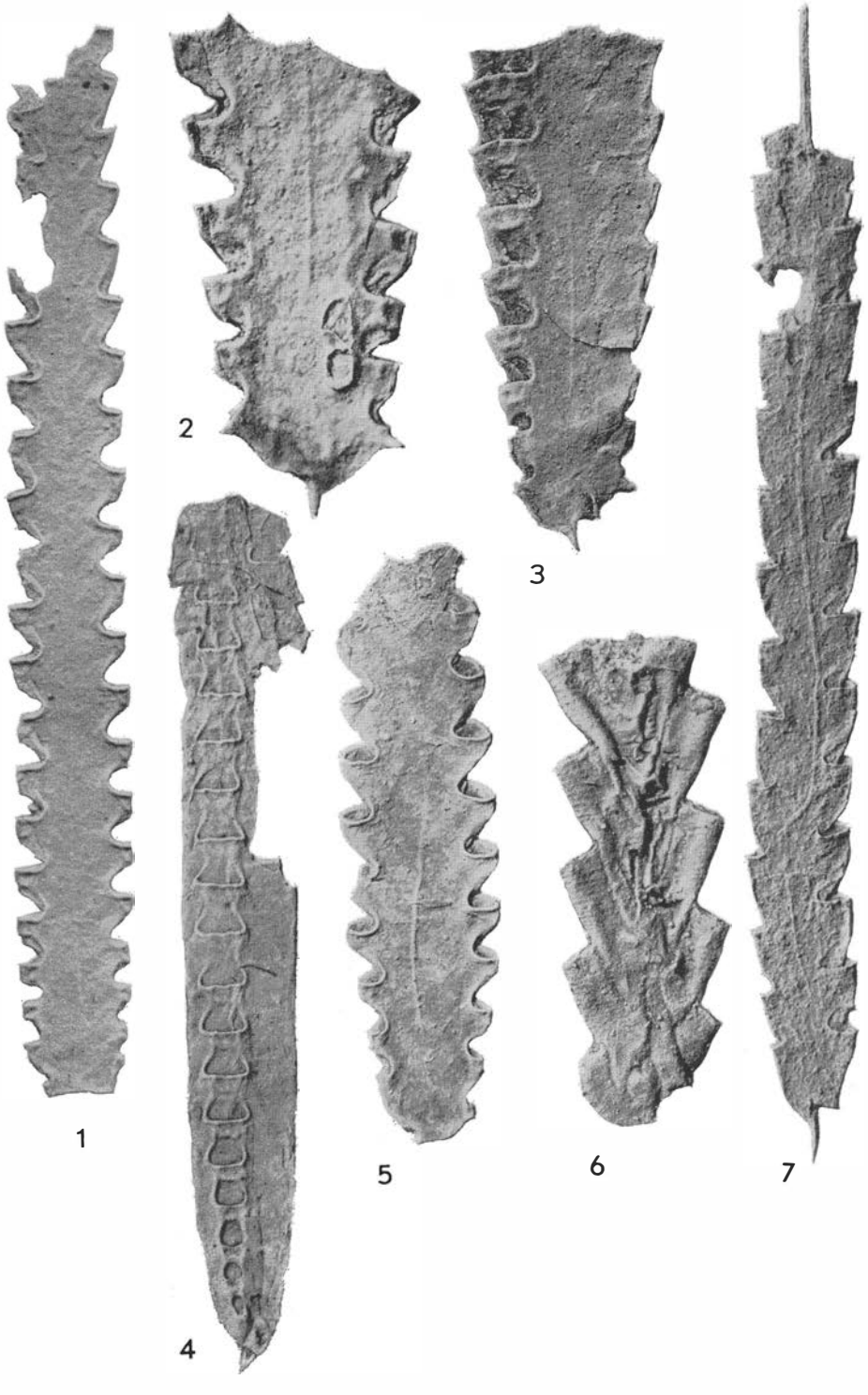
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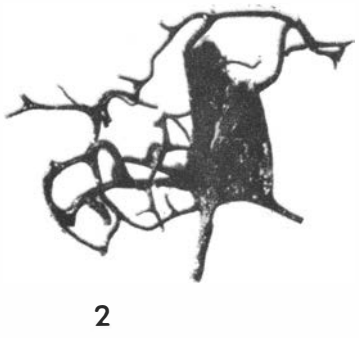
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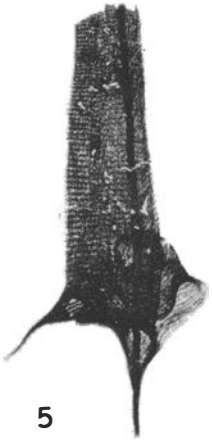
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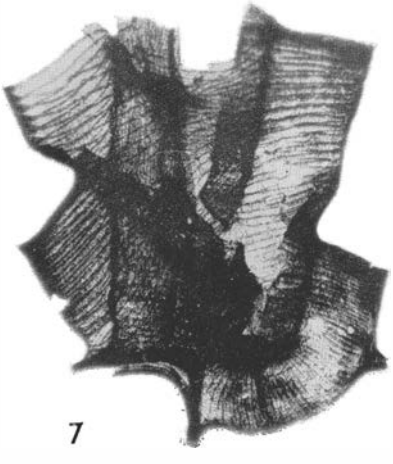
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