SVERIGES GEOLOGISKA UNDERSÖKNING

SERIE C NR 733 AVHANDLINGAR OCH UPPSATSER ÅRSBOK 71 NR 8

RAGNAR NILSSON

A BORING THROUGH MIDDLE AND UPPER ORDOVICIAN STRATA AT KOÄNGEN IN WESTERN SCANIA, SOUTHERN SWEDEN

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ABSTRACT

A drilling core from Koängen in the Fågelsång district, western Scania, southern Sweden represents a section through the uppermost portion of the *Climacograptus haddingi* Subzone of the *Glyptograptus teretiusculus* Zone, the *Nemagraptus gracilis, Diplograptus multidens,* and *Dicranograptus clingani* Zones, and the lowermost part of the Jerrestad Formation (the *Eodindymene pulchra* Zone). It is demonstrated that the *gracilis* Zone of the core is overlain by shales, the lower part of which contains a peculiar mixed graptolite fauna with 15 species or varieties ranging upwards from the *gracilis* Zone and 19 species which appear for the first time, forming a transition between the typical faunas of the *gracilis* and *multidens* Zones, respectively. The stratigraphic interval containing this fauna is assigned to the *multidens* Zone. It is also shown that the interval next above the *gracilis* Zone cannot be equivalent to the *Dicranograptus clingani* Zone in south-eastern Scania, and that the "Zone of *Amplexograptus vasae*" should not be recognized any longer in the Fågelsång district. The *multidens* Zone is overlain conformably by the *clingani* Zone without gap in the succession. The topmost part of the *clingani* Zone and the basalmost part of the overlying Jerrestad Formation are made up of pyritic black shale and this interval apparently includes a stratigraphic break, the *Pleurograptus linearis* Zone being missing. The boundary between the Viru and Harju Series is fixed to the level 17.55 m in this shale interval where the index graptolite *Dicellograptus complanatus* appears. The term Jerrestad Formation is applied to the Harjuan succession of grey, somewhat greenish, mudstone above the *clingani* Zone in the core. It contains a mixed fauna of graptolites and shelly fossils.

No less than 161 bentonite beds are present in the core.

INTRODUCTION

Our knowledge about the Middle and Upper Ordovician in western Scania has been very incomplete in many respects and new observations and data, especially from boring cores, have made it plain that the commonly used biostratigraphic subdivisions of this part of the succession introduced by Moberg (1896), Törnquist (1913), and Hadding (1913, 1915) are in many cases in need of revision.

The general absence of long continuous natural sections, as well as the fact that a thick soil cover does not make excavations feasible, necessitated core drillings in order to obtain a complete section through the Middle and Upper Ordovician in western Scania. In 1953, the Swedish Natural Science Research Council awarded the late Professor Gustaf Troedsson a grant for core drilling through a stratigraphically critical part of the Ordovician succession in the geologically classical Sularp–Fågelsång area. This core, which is herein referred to as the Koängen Core, provides us for the first time with a complete section through a large part of the Upper Ordovician and the upper Middle Ordovician in western Scania. Fig. 1.

The drilling was carried out by Svenska Diamantbergborrningsaktiebolaget at a site about 200 m south-east of the Koängen Farm, about 4.7 km east of Lund. The owner of the farm, Mr. Eric Andersson, kindly granted permission for the drilling to be carried out at this site. The drilling started on February 24 and was completed on March 19, 1954.

The uppermost 4.35 m of the sequence penetrated included soil and glacial deposits and was not cored. Immediately below this depth, Ordovician bedrock was encountered and continuous coring was carried out to a total depth of 70.3 m below ground surface through a sequence of mudstones with scattered beds and nodules of limestone as well as numerous bentonite beds. Core recovery was very good in general throughout the sequence. The diameter of the core is 70 mm. The core comprises strata of a large part of the Viru Series, including the uppermost part of the *Climacograptus haddingi* Subzone, the *Nemagraptus gracilis* Zone, the *Diplograptus multidens* Zone, and the *Dicranograptus clingani* Zone. The Harju Series is represented by the lower part of the Jerrestad Mudstone.

The core, which belongs to the Department of Geology at Lund University, has been the subject of a detailed palaeontological and stratigraphic study. Special attention has been paid to the abundant graptolites and their vertical ranges. In view of the careful examination, to which even the smallest pieces of the core have been subjected, few fossils are likely to have escaped the attention. A count of most fossils found has been made in an attempt to get at least a rough estimate of the frequency of some of the different groups of animals and their mutual relations. The number of specimens of each species encountered is given in brackets close to the name of the species in the lists below. The articulate

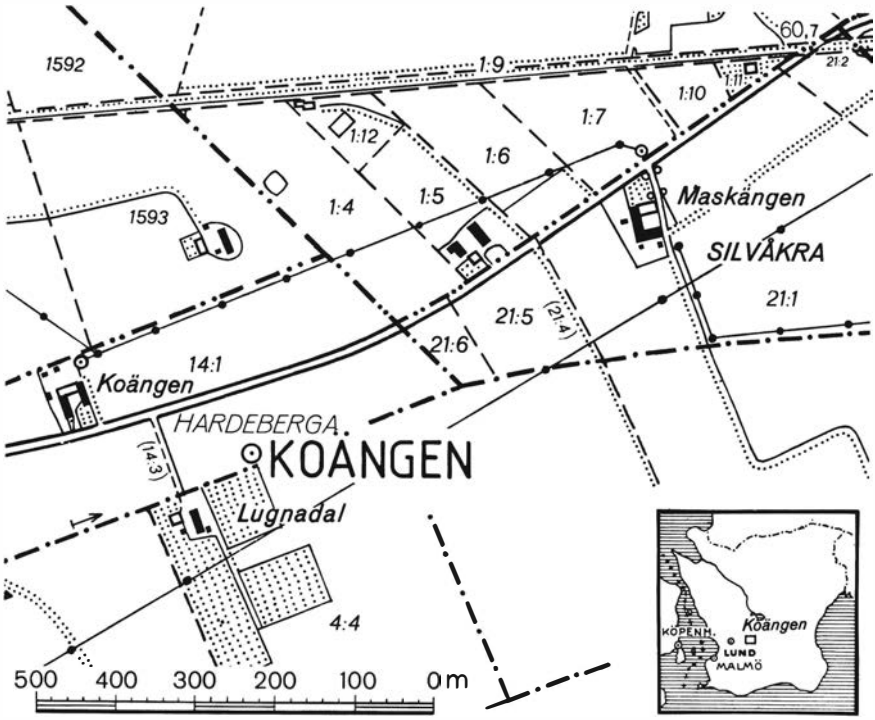

Fig. 1. Map of a part of the Koängen region (with outline map of Scania) showing the site of the boring (circle with central dot).

brachiopods in the Jerrestad Mudstone of the core have been described recently by P. M. Sheehan (1973). The correlation of bentonite beds in the Koängen succession with those in corresponding strata in Bornholm, Västergötland, and Norway has been dealt with by Bergström and Nilsson (1974). The present author (Nilsson 1960) has previously published a preliminary report on the lowermost part of the Koängen core. All fossils listed below, as well as representative rock samples, are kept in the collection of the Palaeontological Institute of the Department of Geology at Lund University.

The Cambro-Silurian beds of the Sularp–Fågelsång area have been subjected to some faulting and evidence of this is present also in portions of the Koängen core. Hence steep-dipping cracks, ranging in size from a fraction of 1 mm to some 5 mm and filled with calcite and/or pyrite, are relatively common throughout the cored sequence. The walls of these cracks are in most cases smooth and only rarely have undulating surfaces been observed. Well developed slickensides, in most cases dipping only slightly, are not very uncommon. The dip of the cored strata varies from 10° to 15°. There is no indication, however, that tectonic activity has cut out any notable part of the cored sequence and there is little doubt that the core is fully representative of this sequence in the Sularp–Fågelsång area. For vertical ranges of fossils, see Tables 1, 2, and 3.

DESCRIPTION OF THE SEQUENCE

VIRU SERIES

The *Glyptograptus teretiusculus* Zone
The *Climacograptus haddingi* Subzone. (70.30—67.495 m.)

Dark grey, almost black, fine-grained, sometimes slightly calcareous mudstone with brown streak. Black, finely crystalline lenses of limestone, 5 mm thick, have been observed between 69.28 and 69.26 and between 69.61 and 69.60 and a thin, laterally impersistent, bed of limestone occurs between 69.56 and 69.55 m. Pyrite is common throughout the whole interval and occurs either as single micro-crystals or as commonly small accumulations of such crystals, sometimes together with micro-crystals of calcite. Pyrite has also been observed as up to three cm long, burrow or tub-like, straight or winding, structures with a diameter between 1 and 4 mm. These structures penetrate the rock vertically or obliquely. More rarely, pyrite occurs as fillings in the cavities formed by brachiopods and graptolites. Biotite flakes, with greatest size of 1 mm, are sparse, as a rule just a few flakes on single bedding planes. Exceptionally, 10—15 biotite flakes have been observed at 70.24, 70.18 and 67.83 m. Non-fossiliferous pieces of phosphorite with inclusions of pyrite and crack fillings of calcite have been found between 67.71 and 67.70 and between 69.21 and 69.195 m. At 68.28, 68.14, 67.85, 67.83 and 67.82 m there are bedding planes with accumulations of microfossils such as small shell fragments of brachiopods, single ostracodes, scolecodonts, conodonts, chitinozoans and machaerids. Conodonts are remarkably numerous on two surfaces between 67.85 and 67.81 m, every accumulations including 4, 8 and 9 and 6, 9, 10 and 12 specimens, respectively. Four beds of bentonite occur between 67.730 and 67.510 m.

The lithological and palaeontological characteristics of the subzone correspond on the whole with the equivalent beds at Fågelsång (formerly called the "Zone of *Climacograptus putillus*"), which have been closely studied and described by Hede (1951, p. 60, 64), and relatively few new data can be added.

The beds are rich in fossils and the following taxa were recognized: *Desmograptus?* cf. *D? tullbergi* HADDING (1), *Azygograptus mobergi* HADDING (7), *Janograptus laxatus* TULLBERG (15), *Nemagraptus subtilis* HADDING (7), *Dicellograptus intortus* LAPWORTH (5), *D. vagus* HADDING (7), *Glossograptus* cf. *G. armatus* (NICHOLSON) (3), *G. scanicus* HADDING (2), *Cryptograptus tricornis* (CARRUTHERS) (3), *C. schaeferi* LAPWORTH (20), *Diplograptus propinquus* HADDING (2), *Amplexograptus perexcavatus* (LAPWORTH) (2), *Climacograptus caudatus* HADDING (non LAPWORTH) (13), *C. haddingi* GLIMBERG (115), *Glyptograptus teretiusculus* (HISINGER) (75), *Pseudoclimacograptus scharenbergi* (LAPWORTH) (98), *Gymnograptus linnarssoni* (MOBERG) (3), *Lingula dicellograp-*

torum HADDING (247), *"Obolus" deltoideus* HADDING (7), *"O". ornatus* HADDING (225), *"O." sularpensis* HADDING (35), *Leptobolus fimbriatus* HADDING (81), *Hisingerella nana* (HADDING) (329), ostracodes (112), phyllocarids (10), scolecodont (1), sponge spicules (7), Machaeridia (174), *Conochitina* cf. *C. minnesotensis* (STAUFFER) (12), *Cyathochitina campanulaeformis* (EISENACK) (25), *C. stentor* (EISENACK) (65), *Desmochitina* sp. (3), and *Tanuchitina?* sp. (23). As can be gathered from this list, the fauna consists of a number of small fossils such as ostracodes, fragments of phyllocarids and sponges, conodonts, Machaeridia, and chitinozoans. The graptolites constitute about 21.8 % of the fauna in the part of the *haddingi* Subzone present. The zone fossil, *Climacograptus haddingi,* is the most common graptolite and confined to the zone together with *Azygograptus mobergi, Janograptus laxatus, Nemagraptus subtilis, Dicellograptus intortus, D. vagus, Glossograptus scanicus,* and *Diplograptus propinquus.* Among the long-ranging species, *Glossograptus* cf. *G. armatus, Cryptograptus tricornis, Amplexograptus perexcavatus, Climacograptus caudatus, Glyptograptus teretiusculus,* and *Pseudoclimacograptus scharenbergi* range up into the *Nemagraptus gracilis* Zone and in some cases into even higher units.

The inarticulate brachiopods are significant, constituting about 53.3 % of the entire fauna. Among the brachiopods, *Hisingerella nana* and *Lingula dicellograptorum* predominate with a frequency of 34.4 % and 25.9 %, as estimated on the same number of brachiopod specimens. *"Obolus" ornatus* is represented by 23.5 % of the brachiopods. *H. nana* and *L. dicellograptorum* occur also in higher beds while *"O." deltoideus, "O". ornatus, "O". sularpensis* and *Leptobolus fimbriatus* do not range further up.

Machaeridia, most of them probably referable to *Plumulites,* occur scattered throughout the zone, except the beds between 69.445 and 69.07 m and between 68.56 and 68.46 m. Smooth ostracode valves are met with, particularly at the top of the zone. Only one scolecodont has been found. Tubular fillings of pyrite with a diameter of between 1 and 4 mm penetrate the beds vertically or more or less obliquely between 70.07 and 70.03, 69.98 and 69.96 m, and between 69.74 and 69.72 m. Perhaps these structures represent fillings of burrows made by worms. Pyritized sponge spicules are rare, only 7 fragments having been found. Chitinozoans are few and flattened and mostly too poorly preserved to be identifiable.

The *Nemagraptus gracilis* Zone. (67.495–60.76 m.)

67.495–67.35 m. The core interval referred to the *haddingi* Subzone is overlain of a bank of phosphorite. The rock is dark grey, slightly brownish, fine-grained, hard, and very rich in pyrite in the form of micro-crystals, which are frequently concentrated in irregular, smaller or larger, concretions or continuous layers. In the upper part of the interval, the amount of pyrite increases and the mineral

Fig. 2. The highly pyritized bed of phosphorite between 67.495—67.35 m that represents the basalmost portion of the *gracilis* Zone. Diameter of core 7 cm.

dominates completely in the upper half of the bank. Micro-crystals of calcite or small druses of such crystals occur in large quantities scattered in the phosphorite, and also associated pyrite and calcite are common. The phosphorite is penetrated by numerous thin cracks filled with pyrite or calcite, or both. Single rare flakes of biotite have been observed. Fossils are sparse and most are microfossils, although small fragments of brachiopod valves as well as traces of indeterminable, pyritized graptolites have been seen. The microfauna includes *Cyathochitina stentor* (EISENACK) and other not identifiable chitinozoans. A few stratigraphically important conodonts have been met with, e. g. *Acontiodus* sp., *Prioniodus variabilis* BERGSTRÖM, and *Pygodus anserinus* LAMONT & LINDSTRÖM. Also single indeterminable ostracodes occur.

67.35—60.76 m. Above the bank of phosphorite just mentioned follow dark-grey to black, very fine-grained, adjacent to limestone beds more or less calcareous, shale and mudstone with grey streak and average hardness. Pyrite occurs relatively sparsely, mainly as scattered micro-crystals, which in some cases are

accumulated to irregular aggregates with a diameter of about 1 cm. More rarely, the pyrite occurs as thin laminae. Biotite, as small thin flakes with a largest size of 1 mm, are relatively common, especially near and in the bentonite beds. Dark grey or black, hard, as a rule finely crystalline, limestone with sometimes very numerous micro-crystals of pyrite occurs at 63.98 (a mm-thick layer), between 63.84 and 63.83 m, 63.701 and 63.694 m, 61.25 and 61.24 m, 61.153 and 61.150 m, and between 61.05 and 61.01 m. Further, there are thin laminae of calcite. Fossils are rare in the limestone. Slickensides and cracks, filled with calcite or pyrite, or both, are common. Fifteen beds of bentonite have been observed.

Also this zone is characterized by a very varied mixed graptolitic and shelly fauna in which chitinozoans and graptolites dominate (36.2 % and 30.6 % of the total number of specimens, respectively). The ostracodes constitute 18.6 % and the brachiopods 13 % of the fauna. The following fossils were found: *Corynoides calicularis* NICOLSON (1), *C. curtus,* LAPWORTH (20), *C.* cf. *C. curtus pristinus* RUEDEMANN (11), *C. incurvus* HADDING (15), *C.* sp. indet. (90), *Nemagraptus gracilis* HALL (6), *N. gracilis remotus* ELLES & WOOD (3), *Nemagraptus* sp. indet. (14), *Leptograptus* cf. *L. flaccidus* HALL (6), *L. flaccidus macer* ELLES & WOOD (17), *L.* aff. *L. grandis* LAPWORTH (5), *L. validus* cf. *L. validus incisus* ELLES & WOOD (1), *L.* sp. indet. (7), *Dicranograptus rectus* HOPKINSON (1), *Dicellograptus divaricatus salopiensis* ELLES & WOOD (87), *D. sextans exilis* ELLES & WOOD (3), *D.* sp. indet. (5), *Glossograptus* cf. *G. armatus* (NICHOLSON) (4), *Diplograptus? molestus* THORSLUND (237), *D. notabilis* HADDING (1), *D. toernquisti* HADDING (2), *Amplexograptus perexcavatus* (LAPWORTH) (27), *A.* sp. indet. (17), *Climacograptus antiquus* LAPWORTH (848), *C. bicornis* (J. HALL) (8), *C. bicornis tridentatus* LAPWORTH (2), *C. brevis* ELLES & WOOD (62), *C.* sp. indet. (91), *Glyptograptus euglyphus* LAPWORTH (8), *G. teretiusculus* (HISINGER) (96), *Orthograptus calcaratus vulgatus* ELLES & WOOD? (1), *O.* sp. indet. (2), *Pseudoclimacograptus scharenbergi* (LAPWORTH) (191), *Lasiograptus spinatus* HADDING (1), *L. costatus* LAPWORTH (2), *Hallograptus mucronatus* (J. HALL) (38), *Reteograptus geinitzianus* (HALL) (13), *Lingula dicellograptorum pulla* HADDING (3), "obolids" (147), *Leptobolus celsus* (HADDING) (10), *L. elatus* (HADDING) (166), *L.? kiaeri* (HADDING) (183), *Paterula bohemica* BARRANDE (3), *Hisingerella nitens* (HISINGER) (223), *Discina compressa* HADDING (1), *Onniella* sp., (2), *Sericoidea* sp. (32), *S.* cf. *S. restricta* HADDING (1), brachiopods indet. (50), ostracodes (1179), scolecodonts (2), orthoconic cephalopods (11), sponge spicules, conodonts (55), Machaeridia (97), *Conochitina minnesotensis* (STAUFFER) (39), *C.* cf. *C. minnesotensis* (STAUFFER) (26), *Cyathochitina campanulaeformis* (EISENACK) (509), *C. kuckersiana* (EISENACK) (2), *C.* cf. *C. kuckersiana* (EISENACK) (5), *C. stentor* (EISENACK) (9), *Eremochitina dalbyensis* LAUFELD (1), and indeterminable chitinozoans (1740).

The *Nemagraptus-Dicellograptus* Subfauna of Bulman (1970), which generally

characterizes the *gracilis* Zone, is little pronounced at this locality; leptograptids, dicranograptids and dicellograptids constitute only 7.9 % of the entire graptolite fauna, which in turn corresponds to 30.6 % of the entire fauna of the zone.

Representatives of Corynoididae make their first entrance at 67.19 with *Corynoides curtus,* at 65.18 m with *C. incurvus* and at 61.60 m with *C. calicularis* and *C.* cf. *C. curtus pristinus.* All these forms occur also in the *Diplograptus multidens* Zone. *C. curtus* and *C. incurvus* are frequent throughout the *N. gracilis* Zone. Other graptolites of this family occur sparsely between 61.60 and 60.91 m. *Nemagraptus gracilis,* which is one of the most common fossils in e.g. the Glenkiln beds of S. Scotland, as well as *N. gracilis remotus,* are fairly rare in the present zone. *N. gracilis* and *N. gracilis remotus* have been found between 67.30 and 65.39 m, and between 66.45 and 64.51 m, respectively and both these forms range up into the *multidens* Zone. A number of indeterminable nemagraptid fragments are met with between 65.79 and 63.01 m.

Dicellograptus divaricatus salopiensis is the most common of the dicellograptids. It occurs between 66.92 and 60.77 m, and covers some of the bedding planes. *D. sextans exilis* is found sparsely between 67.27 and 61.39 m. Only one specimen of *Dicranograptus rectus,* a rare fossil, has been found between 63.06 and 63.04 m. Between 63.77 and 63.60 m *Leptograptus* cf. *L. flaccidus* and *L. flaccidus macer* appear for the first time. The last-mentioned graptolite has been known previously only from the *Pleurograptus linearis* Zone in south-eastern Scania and corresponding beds in Great Britain. Some robust leptograptid stipes from the beds between 63.01 and 62.98 m may be from a species allied to *L. grandis.* A few specimens of *Glossograptus* cf. *G. armatus* were found between 67.18 and 65.23 m; this form persists from the *haddingi* Subzone, but does not range higher in the Koängen sequence. Diplograptids are abundant, twelve species having been determined. *Diplograptus? molestus* is very common, constituting 12.2 % of the graptolites, throughout the zone and continues into higher zones. At 67.35 m *D. notabilis* and *D. toernquisti* are found on the same bedding plane, and these species are confined to the zone.

Climacograptus antiquus, appearing for the first time in this interval, is abundant throughout the zone, and constitutes 43.6 % of the graptolites. 25 bedding planes are entirely covered with specimens of this species, mostly with haphazard distribution; only 2 parallel groupings have been seen. A few specimens of *C. bicornis* have been found in the upper part of the zone and the species ranges up into the *multidens* Zone. *C. tricornis tridentatus,* not earlier known from Sweden, occurs between 63.05 and 63.04 m and between 62.99 and 62.98 m, and is confined to the zone. *Glyptograptus teretiusculus* occurs throughout the zone but is not very common. The species persists from the *haddingi* Subzone and ranges up into the *multidens* Zone. *G. euglyphus* is found for the first time very sparsely between 61.705 and 60.86 m and is also met with in the zone next above.

Between 63.80 and 63.71 m, one specimen of *Orthograptus* cf. *O. calcaratus*

vulgatus and two indeterminable orthograptids were found, making the only significant generic change in the interval of the *Nemagraptus-Dicellograptus* Subfauna. *Pseudoclimacograptus scharenbergi* is rather common, constituting 9.8 % of the graptolites, some bedding surfaces being covered with specimens of this species. It persists from the zone next below and ranges up into higher zones. Among the lasiograptids *Hallograptus mucronatus* is fairly common from 67.27 m upward and disappears at 66.36 m. *Lasiograptus costatus* and *L. spinatus* were found in few specimens at 63.10 and 61.44 m, respectively. *L. spinatus* and *H. mucronatus* make their first appearance in this zone and are confined to it. *L. costatus* continues up into the *multidens* Zone.

Reteograptus geinitzianus appears for the first time in the upper part of the zone between 62.36 and 61.24 m, where it is represented by a few specimens, and ranges up into the zone next above.

Shelly fossils comprise 69.8 % of the fauna. Apart from microfossils it is dominated by brachiopods and ostracodes.

The brachiopod fauna includes 13 forms. *Lingula dicellograptorum pulla, Leptobolus celsus, L. elatus, L.? kiaeri, Paterula bohemica, Hisingerella nitens, Discina compressa, Onniella* sp., and *Sericoidea* cf. *S. restricta,* together with a number of specifically indeterminate specimens of *Sericoidea* sp., first appear in this zone. All of these species, except *D. compressa,* which is confined to the zone, range up into higher beds. *L. dicellograptorum pulla* is rare, only 3 specimens having been found between 63.49 and 63.48 m. Obolids are relatively common and they are, along with *L. elatus, L. kiaeri,* and particularly *H. nitens,* the dominating brachiopods throughout the zone. Among the other brachiopods, *P. bohemica* makes its first appearance at 66.99 m, *D. compressa* at 66.13 m, *Onniella* sp. at 64.11 m, and the sericoids at 65.34 m; all these forms are rather sparsely met with.

Ostracodes are common throughout the zone constituting 18.6 % of the fauna. Their carapaces are as a rule dissolved or so poorly preserved that they cannot be determined with certainty.

Fragments of orthoconic cephalopods were found in the upper half of the zone between 63.03 and 60.14 m.

Single conodonts occur sparsely throughout the zone.

Pyritized sponge spicules have been observed between 65.79 and 62.87 m; they are most frequent between 65.50 and 65.29 m.

A hundred specimens of *Machaeridia* spp. are sporadically distributed between 66.26 and 61.74 m.

Chitinozoans are omnipresent in great numbers. Mostly they are compressed and not identifiable. Among the specifically determined chitinozoans, *Cyathochitina campanulaeformis* is common, whereas *C. kuckersiana, C. stentor, Conochitina minnesotensis,* and *Eremochitina dalbyensis* are met with rather sparsely and mostly at specific levels at long intervals.

The *Diplograptus multidens* Zone. (60.76–30.30 m)

60.76–45.62 m. Black, sometimes darkish grey, predominantly hard, more or less biotite-bearing mudstone. Between 59.32 and 45.94 m there are 54 silicified beds with subconchoidal fracture surfaces – Sularp shale s. s. In most cases, the rock is slightly calcareous. In the lower part of the interval, the $CaCO_3$ content increases and single thin, impersistent beds of calcite appear. Between 60.383 and 58.051 m there are 22 regular, in most cases dark grey, sometimes black, beds of limestone of a thickness between 0.1 and 3 cm. Pyrite is present in, as a rule, very small crystals and grains, which are scattered or in swarms, more rarely in aggregates and small sphaerolites. About 10 thin laminae of finely crystalline pyrite have been observed. Eight occurrences of very small, transparent, yellow – in a couple of cases greenish – mineral crystals (zincblende?) and aggregates of such have been noted. In this interval there are 115 beds of bentonite, 70 of which with a thickness of less than 1 cm; the other have a thickness of between 1 and 94 cm.

45.62–34.50 m. Dark grey, sometimes almost black, predominantly hard, as a rule slightly calcareous mudstone. Single small lenses of limestone occur in the uppermost part of the interval. Also, a couple of thin calcite laminae have been observed. Regular, thin (about 1 cm thick) beds of limestone occur between 44.78 and 44.77 m, 44.51 and 44.50 m, and between 41.71 and 41.70 m. Pyrite occurs relatively sparsely, as a rule as scattered micro-crystals, more rarely as small concretions. In a couple of cases, pyrite is present as sphaerolites, and sometimes as paper-thin, impersistent laminae. It is also present as filling in "worm burrows". Scattered flakes of biotite, of a diameter less than 1 mm, occur throughout the interval, and such flakes in some cases accumulated locally.

The core interval between 60.76–34.50 m is richly fossiliferous and the following fossils were observed: *Dendrograptus* sp. (3), *Koremagraptus* sp. (1), *Corynoides calicularis* NICHOLSON (21), *C. curtus* LAPWORTH (105), *C.* cf. *C. curtus pristinus* RUEDEMANN (4), *C. incurvus* HADDING (52), *C. tricornis* RUEDEMANN (5), *Nemagraptus gracilis* (HALL) (3), *N. gracilis* cf. *N. gracilis remotus* ELLES & WOOD (4), *Dicranograptus* aff. *D. tardiusculus* ELLES & WOOD (1), *D. ziczac* LAPWORTH (19), *Dicellograptus* cf. *D. angulatus* ELLES & WOOD (1), *D. divaricatus salopiensis* ELLES & WOOD (39), *D.* aff. *D. minimus* HADDING (2), *D.* cf. *D. nicholsoni minor* BULMAN (1), *D.* cf. *D. patulosus* LAPWORTH (3), *D. pumilus* LAPWORTH (21), *D. sextans exilis* ELLES & WOOD (1), *Glossograptus* cf. *G. hincksii* (HOPKINSON) (2), *G.* spec. indet. (6), *Nanograptus phylloides* (ELLES & WOOD) (1), *Cryptograptus tricornis* (CARRUTHERS) (1), *Diplograptus compactus* ELLES & WOOD (78), *D.* cf. *D. leptotheca* BULMAN (1), *D.? molestus* THORSLUND (247), *D. multidens* ELLES & WOOD (60), *Amplexograptus* cf. *A. arctus* ELLES & WOOD (8), *A. perexcavatus* (LAPWORTH) (83), *Climacograptus angustus* (PERNER) (3), *C. antiquus* LAPWORTH (53), *C. antiquus lineatus* ELLES & WOOD

(15), *C. bicornis* ELLES & WOOD (20), *C. brevis* ELLES & WOOD (44), *C. brevis* aff. *C. brevis mutabilis* STRACHAN (2), *C.* cf. *C. caudatus* HADDING *(non* LAPWORTH) (1), *C.* cf. *C. minutus* CARRUTHERS (3), *C. peltifer* LAPWORTH (1), *C.* aff. *C. spiniferus* RUEDEMANN (1), *C. supernus* ELLES & WOOD (2), *C.* cf. *C. wilsoni* LAPWORTH (1), *Glyptograptus teretiusculus* (HISINGER) (7), *G. teretiusculus* cf. *G. teretiusculus siccatus* ELLES & WOOD (1), *G. euglyphus* (LAPWORTH) (7), *Orthograptus* cf. *O. apiculatus* (ELLES & WOOD) (2), *O. calcaratus acutus* ELLES & WOOD (1), *O. calcaratus basilicus* ELLES & WOOD (1), *O. calcaratus* (LAPWORTH) (76), *O. calcaratus vulgatus* ELLES & WOOD (65), *O.* cf. *O. pageanus micracanthus* ELLES & WOOD (1), *O. truncatus* cf. *O. truncatus intermedius* ELLES & WOOD (4), *O. truncatus pauperatus* ELLES & WOOD (2), *Pseudoclimacograptus scharenbergi* (LAPWORTH) (104), *P.* n. sp. (19), *P.* sp. indet. (35), *Lasiograptus costatus* LAPWORTH (28), *L. harknessi* (NICHOLSON) (41), *Hallograptus mucronatus* (HALL)? (1), retiolitid graptolite (1), *Thamnograptus* cf. *T. capillaris* HALL (4), "pelmatozoan" stem parts (4), *Lingula* cf. *L. dicellograptorum pulla* HADDING (1), *L. magna* HADDING (7), *"Obolus"* sp. indet. (186), *Leptobolus celsus* (HADDING) (5), *L. elatus* (HADDING) (2), L.*? kiaeri* (HADDING) (75), *Paterula* cf. *P. bohemica* BARRANDE (23), *P. portlocki* (GEINITZ) (46), *P.* sp. indet. (119), *H. nitens* (HISINGER) (135), *Micromitra* sp. (29), *Onniella bancrofti* LINDSTRÖM (439), *O.* sp. indet. (3417), *Sericoidea restricta* (HADDING) (218), *S.* sp. indet. (324), strophomenid brachiopod (1), hyolithids (11), bryozoan (1), *Asaphus glabratus* ANGELIN (1), *Platycalymene* sp. (3), *Chilobolbina* sp. (1), eurychilinid sp. (25), *Sigmobolbina* sp. (19), *Conchoprimitia* sp. (1), *"Primitia"* sp. (6), *Parapyxion* sp. (1), phyllocarid fragments (2), *Caryocaris* sp. (1), *Anatifopsis* sp. (1), scolecodonts (98), *"Spirorbis"* sp. (1), "worm burrows", *"Euomphalus" bullaeformis* HADDING (3), bivalves (40), orthocone cephalopods (21), tentaculite (1), *Pyritonema* sp. (3), sponge spicules in pyrite and in opaline silica (16), radiolarians, *Acontiodus* sp. (1), *Distacodus* sp. (41), *Drepanodus* sp. (63), *Oistodus* sp. (1), *Chirognathus* sp. (1), *Prioniodus* sp. (1); indeterminate compound conodonts (42), indeterminate platform conodonts (8), Machaeridia sp. (4), *Conochitina* sp. (1786), *Cyathochitina campanulaeformis* (Eisenack) (206), other indeterminate chitinozoans (127000) tracks, and trails.

34.50–34.475 m. Dark grey, hard, fine-grained limestone with numerous flakes of biotite in the uppermost part of the interval. One layer is rich in pyrite. Fossils include ostracodes and a large number of indeterminable shell fragments of millimetre size.

34.475–34.46 m. Greyish white bentonite with abundant biotite flakes.

34.46–34.30 m. Dark grey to black, hard, fine-grained, not calcareous mudstone with single small limestone lenses. Biotite flakes are rare but increase in number from 34.40 m upward. At the same time, the mudstone becomes slightly calcareous, softer, and may exhibit rough bedding-planes. Bioturbate structures occur from 34.38 m and are especially well developed from 34.43 m. A bentonite

bed, slightly less than 1 mm thick, with numerous micro-crystals of pyrite occurs between 34.38 and 34.34 m. Fossils are sparse, but include indeterminate brachiopods, hyolithids, ostracodes, a few trilobite fragments, and *Conochitina* sp.

34.30–34.28 m. Dark grey to black, hard, fine-grained limestone with occasional flakes of biotite and a pyrite concretion, 1 cm in diameter. Fossils: *Onniella bancrofti* LINDSTRÖM (3), ostracodes (4), small indeterminable trilobite fragments.

34.28–34.26 m. Whitish grey bentonite with numerous biotite flakes.

34.26–34.155 m. Dark grey, soft, not calcareous mudstone with numerous biotite flakes between 34.21 and 34.155 m. Fossils: *Climacograptus* sp. indet., *Lasiograptus* cf. *L. harknessi* (NICHOLSON) (1), *Leptobolus celsus* (HADDING) (1), *Onniella bancrofti* LINDSTRÖM (3), *Sericoidea restricta* (HADDING) (1), hyolithids (1), indeterminable brachiopods (3), ostracodes (14), indeterminable trilobite fragments (5), *Conochitina* sp. (66), sponge spicule (1).

34.155–34.13 m. Whitish grey bentonite with, in certain layers, numerous flakes of biotite. A concentration of pyrite of 2.5 × 2.5 cm size.

34.13–34.12 m. Black, soft, calcareous mudstone with numerous flakes of biotite. Fossils: *Onniella bancrofti* LINDSTRÖM (1), indeterminable trilobite fragments (2), *Conochitina* sp. (1).

34.12–34.00 m. Grey to darkish grey, hard, fine-grained limestone with relatively common flakes of biotite. Pyrite sparse as small concentrations. Between 34.03 and 34.00 m there are some 25 small grains of a light-green mineral (zinc-blende?). Fossils: indeterminable *Climacograptus*-fragments (6), *Onniella bancrofti* LINDSTRÖM (19), *Sericoidea restricta* (HADDING) (3), ostracodes (8), *Lonchodomas rostratus* (SARS) (1 glabella), *L.* sp. (1 cephalon), indeterminable trilobite fragments (12).

34.00–33.82 m. Zone of crushed rock. Core loss. At 33.82 m an about 5 cm thick bed of whitish grey, partly somewhat greenish, bentonite with numerous small flakes of biotite and single grains of pyrite.

33.82–33.79 m. Zone of crushed rock. Dark-grey, soft, calcareous mudstone with numerous flakes of biotite and some concretions, of 1 mm size, of pyrite crystals. The rock easly disintergrates in water. Possibly, this is a bentonite-bearing sediment. Fossils: *Onniella bancrofti* LINDSTRÖM (4), *Sericoidea restricta* (HADDING) (1), ostracodes (2), *Lonchodomas rostratus* (SARS) (1 pygidium), *Sphaerocoryphe* sp.? (1 glabella), indeterminable trilobite fragments (2), scolecodont (1), *Conochitina* sp. (1).

33.79–33.32 m. Dark-gray, very hard, finely crystalline limestone. Pyrite rare as small concentrations or as fillings in burrows. Flakes of biotite occur from 33.79 m but decrease in number upwards. Fossils: *Leptobolus* cf. *L. celsus* (HADDING) (1), *Onniella bancrofti* LINDSTRÖM (26), ostracodes (2), *Lonchodomas rostratus* (SARS) (2 cephala). Microfossils have not been observed.

33.32–33.25 m. Black, hard, strongly calcareous mudstone with relatively

numerous flakes of biotite. Fossils: indeterminable fragments of *Climacograptus* sp. (10), indeterminable diplograptid (1), *Sericoidea restricta* (HADDING) (2), indeterminable trilobite fragments (3).

33.25–32.85 m. Black, fine-grained, hard (silicified?), between 33.20 and 33.15 m soft, mudstone. It is hard to split and has an uneven fracture surface. Pyrite is present sparsely as very small concretions and as burrow fillings. Between 33.19 and 33.18 there is a bentonite bed, which is one mm thick. Fossils: dendroid graptolite (1), fragment of *Dicellograptus* sp. (1), indeterminable fragments of climacograptids and diplograptids (4), *Orthograptus* sp. of *truncatus*-type (1), *Lasiograptus* sp. (1), *Onniella bancrofti* LINDSTRÖM (77), *Sericoidea restricta* (HADDING) (333), *Sowerbyella* sp. (1), ostracodes (88), *Lonchodomas rostratus* (SARS) (1 cephalon), indeterminable trilobite fragments (22), bivalves (2), gastropod (1), *Conochitina* sp. (80), shell fragments of arthropod.

32.85–32.83 m. Black, hard, not easily split calcareous shale without pyrite and biotite. Fossils: *Paterula portlocki* (GEINITZ) (1), *Hisingerella nitens* (HISINGER) (1), *Onniella bancrofti* LINDSTRÖM (21), *Sowerbyella* sp. (1), ostracodes (60), indeterminable trilobite fragments (10, *"Spirorbis"* sp. (1), Machaeridia sp. (1), *Conochitina* sp. (4), incertae sedis (4).

32.83–32.82 m. Bentonite, yellowish white, towards subjacent beds grey to greyish white, with very numerous flakes of biotite. One indeterminate trilobite fragment.

32.82–31.82 m. Dark grey, from 32.30 m greyish black, hard, calcareous mudstone. Between 31.88 and 31.87 m, 31.92 and 31.90 m, and between 32.20 and 32.15 m there are small lenses and other concentrations of crystalline limestone. At 31.89 m there is a thin bed of crystalline limestone with numerous trilobite fragments and between 32.45 and 32.43 m a bed of dark grey, very hard limestone with some ostracodes, *Onniella bancrofti* LINDSTRÖM, and indeterminable trilobite fragments. Pyrite is scarce as fillings in burrows and trails. A single pyrite concentration, of a size of $4 \times 3 \times 3$ cm, has been observed between 32.64 and 32.61 m. Biotite occurs very sparsely. Fossils: *Dendrograptus* sp. indet. (1), *Corynoides incurvus* HADDING (1), *Climacograptus brevis* ELLES & WOOD (1), *C.* spp. (17), *Diplograptus* cf. *D. leptotheca* BULMAN (1), indeterminable diplograptids (14), *Orthograptus* aff. *O. calcaratus basilicus* ELLES & WOOD (1), *Paterula* cf. *P. portlocki* (GEINITZ) (1), *Hisingerella* cf. *H. nitens* (HISINGER) (1), *Onniella bancrofti* LINDSTRÖM (160), *Sericoidea restricta* (HADDING) (342), hyolithids (5), ostracodes (179), *Remopleurides* sp.? (2), illaenid (1 hypostome), *Ampyx* sp. (2 cephala, 1 pygidium), *Lonchodomas rostratus* (Sars) (16), *Calymene?* sp. (1 pygidium), *Lichidae* gen. et sp. indet. (4), *"Euomphalus" bullaeformis* HADDING (1), indeterminable gastropods (12) and bivalves (10), *Conochitina* sp. (94), *C.* cf. *C. minnesotensis* (STAUFFER) (3), *Cyathochitina campanulaeformis* (EISENACK) (2).

31.82–31.74 m. Between 31.77 and 31.74 m grey, dense, relatively hard

limestone with numerous indeterminable trilobite fragments. At 31.77 m this limestone changes into a darker, dense, very hard limestone with conchoidal fracture and white streak. Pyrite occurs rarely as thin laminae or as accumulations of scattered micro-crystals and as fillings of burrows. The interval is poor in fossils Fossils: *Onniella bancrofti* LINDSTRÖM (1), ostracode (1), *Panderia?* sp. (2), *Lonchodomas* sp. (1). Vertically oriented small fragments of brachiopods and trilobites are relatively common.

Fig. 3. Core section between 31.69—31.56 m showing speckled shale. *Diplograptus multidens* Zone. Diameter of core 7 cm.

31.74—31.56 m. Dark grey, slightly calcareous mudstone with, on some bedding-planes, thin laminae of calcite. Pyrite rarely present as fillings of burrows. Biotite rare. Between 31.70 and 31.59 m there are bioturbate structures and rough bedding-planes. Fossils: *Corynoides curtus* LAPWORTH (2), *Climacograptus antiquus* LAPWORTH (2), *C. brevis* ELLES & WOOD, (2), indeterminable diplograptid (1 fragment), *Pseudoclimacograptus* cf. *P. scharenbergi* (LAPWORTH) (3), *Paterula* cf. *P. portlocki* (GEINITZ) (2), *Onniella bancrofti* LINDSTRÖM (3), *Sericoidea restricta* (HADDING) (7), telson of *Ceratiocaris?* sp., ostracodes (89), *Panderia* sp. (1), *Proetus?* sp. (1), Raphiophoridae gen. et sp. indet. (1 cephalon), *Ampyx* sp. (1 cephalon), *Lonchodomas rostratus* (SARS) (6 cephala, 5 pygidia),

Sphaerocoryphe? sp. (1 glabella), Calymeninae gen. et sp. indet. (1 pygidium), gastropod fragment, *Conochitina* sp. (1), *Cyathochitina campanulaeformis* (EISENACK) (1).

31.56–30.30 m. Dark grey to greyish black, mostly soft, as a rule not calcareous mudstone. Yet, a small lens of limestone has been observed between 30.55 and 30.50. It has a diameter of 3 cm and a thickness of 1 cm. There is also a bed of dark, hard, finely crystalline limestone with numerous micro-crystals of pyrite but without fossils between 30.93 and 30.91 m. There is a bed of bentonite, 1 mm thick, between 30.41 and 30.40 m. Fossils: *Corynoides curtus* LAPWORTH (2), *C. incurvus* HADDING (1), *Climacograptus antiquus* LAPWORTH (3), *C.* cf. *C. brevis* ELLES & WOOD (1), *C. minimus* (CARRUTHERS)? (1), *Diplograptus? molestus* THORSLUND (3), *O.* cf. *O. truncatus pauperatus* ELLES & WOOD (2), *Pseudoclimacograptus scharenbergi* (LAPWORTH) (11), *Lingula dicellograptorum* HADDING (5), *L. dicellograptorum pulla* HADDING (1), *L. magna* HADDING (3), *Paterula* cf. *P. portlocki* (GEINITZ) (15), *Hisingerella nitens* (HISINGER) (1), *Orbiculoidea* sp. (3), *Onniella bancrofti* LINDSTRÖM (16), *Sericoidea restricta* (HADDING) (79), hyolithids (6), ostracodes (639), *Remopleurides sexlineatus* (ANGELIN) (1 cranidium), *R.* sp. (1 cephalon), *Lonchodomas rostratus* (SARS) (1 glabella, 2 pygidia), *Platylichas laxatus* (M'COY) (2), Lichidae gen. et sp. indet. (2), bivalves (21), gastropod fragments (7), *Conochitina* spp. (99), *Cyathochitina campanulaeformis* (EISENACK) (2).

I have observed no sedimentological break between the subjacent *gracilis* Zone and the present zone. Apart from the numerous bentonite beds, the rocks in the *multidens* Zone consist of dark grey to black slightly calcareous mudstone, which is intercalated with a number of limestone beds. In the upper part of the interval, between 59.32 and 45.94 m, there are 54 silicified beds of mudstone (Sularp shale); this figure may be compared to the number of bentonite beds, 86, present in the same interval. However, it should be noted that silicified mudstone occurs also in other intervals, e.g., in the *gracilis* Zone, where it is not associated with bentonite beds. The opinion that the rocks below a bentonite bed always are silicified is not supported by the conditions in the core, in which many mudstones right below bentonite beds do not show any silicification. However, the presence of silicified mudstone layers without association with bentonite beds may be explained as caused by the fact that the original bentonite bed was washed away after having provided the silica to the underlying mudstone bed.

The top portion of the *multidens* Zone between 34.50 and 30.30 m, which seems to form an uninterrupted sequence with the underlying beds, is made up of dark grey, mostly calcareous mudstone. The calcium carbonate is occasionally concentrated in nodules. Calcareous beds are as frequent in this interval as in the lower part of the core; 8 beds have been observed, in most cases 2 or 3 cm thick. Two beds, however, have a thickness of 12 and 47 cm, respectively.

It is evident that a certain change in conditions of the environment of deposition of the mudstone took place in the present interval in view of the increased carbonate content of the rock. The conditions in this sedimentary environment were more favorable for a shelly fauna than those prevailing before, especially in the case of trilobites, which became more common than earlier in Viruan time in the Fågelsång district. Yet, none of these trilobites is suitable as a zonal index.

Like the faunas of the subjacent zones, also the *multidens* Zone fauna represents a mixture of graptolites and shelly fossils with a marked predominance of the ostracodes and brachiopods, especially the genus *Onniella.*

A thin bentonite bed overlying the *gracilis* Zone marks a distinct faunal boundary with several new graptolite species appearing in the mudstone immediately overlying the bentonite bed. *Orthograptus calcaratus* and *O. calcaratus vulgatus,* which occurs in even larger numbers than the former, appear here and characterize the fauna between 60.76 and 36.66 m. Along with these forms, the zonal assemblage includes several forms persisting from the *gracilis* Zone such as *Corynoides* cf. *C. curtus pristinus, Dicellograptus divaricatus salopiensis, Diplograptus? molestus, Climacograptus antiquus, Pseudoclimacograptus scharenbergi,* and *Lasiograptus costatus,* which in many cases cover the bedding planes.

Among the 58 graptolite forms met with in this zone, some indetermined dendrograptids have been found between 47.99 and 47.95 m, 47.48 and 47.46 m, and between 43.92 and 43.91 m. One specimen of *Koremagraptus* sp. has been observed at 43.95 m. The *Corynoides* species all range up from the *gracilis* Zone, except *C. tricornis,* previously not known from Sweden, which is confined to the present zone between 59.49 and 58.90 m. *C. curtus* and *C. incurvus* range through the *multidens* Zone and into the *Dicranograptus clingani* Zone.

A few specimens of *Nemagraptus gracilis* have been observed between 59.67 and 59.46 m and *N. gracilis remotus* between 59.71 and 59.60 m. They do not occur at higher horizons. The dicranograptids are represented by *Dicranograptus ziczac* with 19 specimens between 54.50 and 46.98 m.

The dicellograptids are more common, especially *Dicellograptus divaricatus salopiensis,* which is relatively frequent between 60.29 and 58.32 m. *D.* cf. *D. angulatus* has been observed at 47.70 m, *D.* cf. *D. nicholsoni minor* at 57.60 m, and *D.* cf. *D. patulosus* between 59.25 and 47.74 m. *D. pumilus* has a sporadic occurrence between 60.00 and 47.74 m and a few specimens of *D. sextans exilis* were found between 53.74 and 47.81 m. All these species, except *D. divaricatus salopiensis* and *D. sextans exilis,* which persist from the zone next below, are restricted to the lower portion of the *multidens* Zone.

Young specimens of a species of *Glossograptus,* which most nearly resembles *G. hincksii,* occur sparsely between 58.90 and 47.44 m.

Nanograptus phylloides is represented by a single specimen at 53.85 m. It was previously not known from Sweden.

Cryptograptus tricornis occurs in one specimen at 59.09 m.

Among the diplograptids, *Diplograptus? molestus* is as abundant as in the *gracilis* Zone and ranges beyond the present zone. Also *D. compactus* and *D. multidens* are rather common. *D. compactus* occurs in the lower part of the interval but ranges into the *clingani* Zone, while *D. multidens* is restricted to the interval between 60.00 and 36.71 m. Some specimens of *Amplexograptus* cf. *A. arctus* are found sparsely between 60.18 and 48.41 m and *A. perexcavatus,* which persists from the underlying zone, ranges to about the middle part of the present zone and then disappears.

The climacograptids constitute the numerically dominant graptolites. *Climacograptus antiquus* is rather commonly met with in the lower half of the *multidens* Zone where bedding planes sometimes are covered with specimens of this species. Some specimens of *C. antiquus lineatus* are found sporadically together with *C. antiquus,* a species that ranges up into the *clingani* Zone. *C. bicornis* appears at 60.29 m and is found sparsely up to the 47.25 m level. *C. brevis* is relatively common throughout the zone and its range extends into the *clingani* Zone next above. Some climacograptids appearing for the first time in the *multidens* Zone and confined to it are *Climacograptus* aff. *C. brevis mutabilis, C.* cf. *C. caudatus* HADDING (non LAPWORTH), *C. peltifer, C. supernus,* and *C.* cf. *C. wilsoni.* All these species appear in the lower and lowest beds of the zone, and are represented by single, or in exceptional cases two or three specimens. Further, there is a number of specimens of climacograptids, which are indeterminable owing to their imperfect state of preservation or, because of the silicified nature of the mudstone, the impossibility to prepare the specimens.

Glyptograptus teretiusculus and *G. teretiusculus* cf. *G. teretiusculus siccatus* are sporadically present in the lowermost part of the zone; the first-named species persists from the *gracilis* Zone and is present in beds between 60.76 and 60.24 m. The other form was found at 58.33 m. *G. euglyphus* also ranges up from the underlying zone and it disappears at 46.32 m.

Of particular importance is the entrance of numerous orthograptids, which is the distinctive feature of this interval. *Orthograptus calcaratus acutus, O.* cf. *O. apiculatus* and *O. truncatus intermedius* are present in few specimens and are restricted to the lowermost part of the zone while *O. calcaratus* and *O. calcaratus vulgatus* are common in the lower part of the zone as well as sparsely present in its upper part and both these forms which range up into the *clingani* Zone either separately or both together with other graptolites such as *Corynoides* cf. *C. curtus pristinus, Dicellograptus divaricatus salopiensis, Climacograptus antiquus, Diplograptus? molestus, Glyptograptus euglyphus,* and *Lasiograptus costatus* often cover the bedding planes. *O. calcaratus basilicus* is met with at 36.31 and 32.11 m, some specimens of *O. truncatus intermedius* between 59.23 and 51.52 m, and two specimens of *O. truncatus* at 54.85 and 43.54 m.

Pseudoclimacograptus scharenbergi, which persists from the *haddingi* Subzone

and ranges into the *clingani* Zone, is common throughout the zone. A short-ranging form of *Pseudoclimacograptus,* probably representing a new species, occurs between 59.75 and 58.60 m.

The remaining graptolite forms obtained from the present zone are *Lasiograptus costatus,* which also is found in the upper part of the *gracilis* Zone, and *L. harknessi,* which is most frequent in the lower half of the zone. Otherwise, both species are less common. Further, *Reteograptus geinitzianus* has been found at the very base of the zone together with another, indeterminable, retiolitid graptolite and representatives of *Thamnograptus,* one of which perhaps belonging to *T. capillaris,* occur in few specimens between 59.59 and 48.69 m.

Brachiopods are numerous throughout the zone and even abundant at some levels. The inarticulate brachiopods are dominant, representing 53 % of all the forms present of the phylum. The lingulids appear at about 57.99 m and range up to the top of the zone. *Lingula dicellograptorum pulla,* which persists from the *gracilis* Zone and ranges up into the *clingani* Zone, and *L. magna,* which is restricted to the *multidens* Zone, have rare occurrences between 46.83 and 31.15 m. Rather numerous specimens of indeterminate "obolids" predominate among the inarticulate brachiopods and are found throughout the zone together with a few specimens of *Leptobolus celsus* between 60.56 and 59.60 m. The latter species persists from the underlying zone and ranges up into the zone next above. A few specimens of *Leptobolus elatus* occur between 60.67 and 58.68 m and *L? kiaeri* is fairly common in the lowermost part of the interval between 60.76 and 59.21 m. Both species disappear in the present zone. *Paterula* cf. *P. bohemica* is sparse between 53.23 and 38.65 m and *P. portlocki* is somewhat more common between 53.11 and 34.50 m. In addition, there is a number of unidentified species, possibly belonging to the genus *Paterula,* occurring throughout the zone. *Hisingerella nitens,* which persists from the *gracilis* Zone, is rather common in the lowermost metre of the *multidens* Zone and is rare in the upper part of the zone but ranges up into the overlying zone. *Orbiculoidea* is represented by three specimens between 31.40 and 30.55 m and *Micromitra* by 29 specimens between 39.15 and 38.65 m. The last-named species is confined to the zone. *Onniella* sp. is rare in the upper part of the *gracilis* Zone but is abundant, especially as represented by *O. bancrofti,* between 53.53 and 45.62 m, where it constitutes about 40 % of the brachiopods in the zone. *Sericoidea restricta,* which also occurs in the preceeding zone and ranges up into the *clingani* Zone, is common throughout the interval. Some indeterminate species of Dalmanellidae and Acrotretidae are found sporadically in the lower half of the zone and a single specimen of *Strophomena?* sp. was observed at 54.95 m.

Two bryozoans have been met with between 45.68 and 45.65 m. In the middle part of the zone trilobites are, as a whole, sparse with two species but they are more frequent in the uppermost beds of the zone between 34.50 and 30.30 m where ten species have been counted. One pygidium of *Asaphus glabratus* was

found between 42.81 and 42.71 m and three specimens belonging to *Platycalymene* occur between 47.99 and 46.47 m. In the upper part of the zone, indeterminable trilobite fragments are very frequent. Among the trilobites occurring in this interval, *Lonchodomas rostratus* dominates and is represented by cephala, glabellae as well as pygidia. Some cephala of *Ampyx* were found between 33.25 and 31.73 m and two glabellae, possibly belonging to *Sphaerocoryphe,* were found between 33.82 and 31.59 m. *Platylichas laxatus* appears between 31.26 and 30.30 m and other specimens of *Lichidae* were met with between 32.82 and 30.70 m.

Ostracodes are abundant, about 9400 having been counted, but unfortunately, most are preserved as moulds. Among the determinated ostracodes, about twenty specimens of an eurychilinid and *Sigmobolbina* were found between 48.46 and 46.15 m and 35.62 and 35.00 m, respectively. A single specimen of *Chilobolbina* occurred at 39.20 m. Single or few specimens of *Conchoprimitia* and *Parapyxion* were met with at different levels.

A specimen of *Caryocaris* sp. occurred at 43.11 and a telson of *Ceratiocaris?* sp. was observed at 31.59 m.

One specimen of *Anatifopsis* was found between 42.57 and 42.45 m.

Scolecodonts were found sporadically throughout the zone and a small tube of *"Spirorbis"* occurred at 45.40 m. "Worm burrows", mostly straight and filled with pyrite, in some cases penetrate the rock perpendicularly or obliquely to the bedding. In one case, a burrow with the walls covered with *Onniella* fragments was observed between 47.46 and 47.44 m.

Fragmentary orthoconic cephalopods occur sparsely at various levels between 60.37 and 43.38 m.

A few specimens of *"Euomphalus" bullaeformis* were found between 45.54 and 32.07 m and several indeterminable gastropod fragments throughout the zone.

About seventy indeterminate bivalves were met with at different levels between 48.14 and 30.30 m. Two specimens exhibiting blue colour, perhaps the original colour, have been seen.

Detached sponge spicules preserved in pyrite are not uncommon through the entire zone. Some specimens belonging to the genus *Pyritonema* occur between 57.60 and 55.82 m. A number of spicules changed to opaline silica are met with between 40.31 and 35.35 m, occasionally also between 51.95 and 51.93 m.

A few radiolarians were found in the upper part of the zone between 52.46 and 49.62 m.

A single specimen of *"Tentaculites"* sp. has been found at 35.90 m and hyolithids occur sparsely between 47.48 and 30.35 m.

Conodonts occur sporadically from the bottom of the zone up to 35 m but are not found in the uppermost metres. All conodont elements are embedded in mudstone and have to be studied on the surface of pieces of mudstone, which makes identification difficult. M. Lindström has found specimens of the following

genera in the zone: *Distacodus, Acontiodus, Drepanodus, Oistodus, Chirognathus* and *Prioniodus*. In addition, there is a number of other, unidentified, platform as well as compound conodonts. On the whole 850 conodonts have been counted. Machaerids were found in very few specimens between 46.47 and 36.28 m and "pelmatozoan" stem parts are relatively common between 56.30 and 38.47 m.

Chitinozoans are predominant and omnipresent, the beds between 60.76 and 34.50 m having yielded at least 130,000 specimens. In the succeeding layers between 34.50 and 30.30 m they are less frequent, and even rather sparse. About 345 specimens have been counted. Unfortunately, the chitinozoans are, as a rule, flattened and difficult to determine. The genus *Cyathochitina,* represented by e.g. *C. campanulaeformis,* occurs sparsely and *Conochitina minnesotensis* is rare in the zone a whole, while the genus *Conochitina* otherwise seems to be represented very commonly.

The *Dicranograptus clingani* Zone. (30.30–17.55 m.)

Black, fine-grained, mostly fairly hard shale or mudstone which at 20.53 m changes into very hard, noncalcareous mudstone with a conchoidal fracture (silicified mudstone?). Parts of softer mudstone occur sparsely at some levels. Biotite flakes have been observed throughout the entire interval; they are especially numerous between 18.62 and 18.61 m and between 18.46 and 18.20 m. Pyrite is common, sometimes abundant; in most cases it occurs as thin laminae on the bedding surfaces or as scattered crystals. In exceptional cases it is present as small concretions or filling in "worm burrows" and vertical tube-like structures. Calcite is sparse, usually occurring as fillings in fissures and as thin laminae, sometimes together with pyrite. The fissure fillings consist either of calcite or of pyrite, or of both minerals. The core sequence between 18.20 and 18.05 m is crushed and nothing can be said regarding the precise position of a 2 cm thick layer of black, hard, unfossiliferous limestone with plenty of flakes of biotite and with pyrite present as separate small concretions. Seventeen thin beds of bentonite occur in the mudstone between 30.30 and 17.50 m. It should be noted that the beds underlying the bentonite beds often consist of soft mudstone which is not silicified. Bioturbate structures have been noted between 30.25 and 29.90 m, 29.80 and 29.71 m, 29.55 and 29.50 m and between 29.30 and 29.22 m.

The *clingani* Zone is rather rich in fossils. Apart from the chitinozoans which constitute about 35 % of the fauna, the brachiopods dominate with 2800 specimens or 30 %, followed by graptolites with 1639 specimens or 17 % of the fauna. Fossils: *Dendrograptus* sp. (4), dendograptid fragments (28), *Desmograptus* sp. (17), *Corynoides curtus* LAPWORTH (42), *C. incurvus* HADDING (127), *C.* spp. indet. (34), *Leptograptus* sp. (1), *Dicranograptus clingani* CARRUTHERS (58), *Dicellograptus* sp. (1), *Glossograptus* sp. (1), *Diplograptus compactus* ELLES & WOOD (10), *Diplograptus? molestus* THORSLUND (723), *Diplograptus* spp.

indet. (11), *Amplexograptus* cf. *A. fallax* BULMAN (77), *Diplograptus (Amplexograptus) lacer* HADDING (3), *A. pulchellus* (HADDING) (3), *A. vasae* TULLBERG (16), *Climacograptus antiquus* LAPWORTH (19), *C.* aff. *C. antiquus lineatus* ELLES & WOOD (1), *C. bicornis* (HALL) (8), *C. brevis* ELLES & WOOD (59), *C.* spp. indet. (114), indeterminate diplograptids (27), *Orthograptus calcaratus* (LAPWORTH) (9), *O. calcaratus basilicus* ELLES & WOOD (19), *O. calcaratus robustus* (HADDING) (13), *O. calcaratus* aff. *O. calcaratus tenuicornis* ELLES & WOOD (1), *O. calcaratus vulgatus* ELLES & WOOD? (1), *O.* of *truncatus* type (4), *O.* sp. indet. (14), *Pseudoclimacograptus scharenbergi* (LAPWORTH) (109), *P.* cf. *P. scharenbergi* (LAPWORTH) (38), *Lasiograptus costatus* LAPWORTH (24), *L. harknessi* (NICHOLSON) (8), *L.* cf. *L. harknessi* (NICHOLSON) (4), *Neurograptus margaritatus* (LAPWORTH)? (1), *Lingula dicellograptorum* HADDING (17), *L. dicellograptorum pulla* HADDING (5), *L.* sp. indet. (4), *Leptobolus celsus* (HADDING) (577), *"Obolus" rugosus* HADDING (28), *"O".* sp. (12), *Paterula portlocki* (GEINITZ) (839), *Acrothele* sp.? (3), *Hisingerella nitens* (HISINGER) (32), *H. nana* (HADDING) (2), *Orbiculoidea* sp (47), *Schizambon* sp. (1), *Sowerbyella?* sp. (2), *Onniella bancrofti* LINDSTRÖM (120), *Sericoidea restricta* (HADDING) (1069), *S.* sp. indet. (15), *Remopleurides* sp. (1), Lichidae gen. et spec. indet. (1), *Lonchodomas rostratus* (SARS) (1), indeterminable trilobite fragments (7), *Cerniella* sp. (3), *Parapyxion* sp. (2), indeterminable ostracodes (1829), phyllocarid fragments? (7), *Anatifopsis elongatus* HADDING (26), *A. vomer* HADDING (1), A. sp. (48), scolecodonts (38), orthocone cephalopods (2), *"Euomphalus"?* sp. (1), indeterminable gastropods (29), *Nucula? elliptica* HADDING (6), *N.? reticulata* HADDING (2), *Nucula?* sp. indet. (17), *Modiolopsis? plana* HADDING (2), indeterminate bivalves, hyolithids (27), conodonts (2), *Plumulites* sp. (2), *Lepidocoleus* sp. (19), *Conochitina minnesotensis* (STAUFFER) (1), *Cyathochitina campanulaeformis* (EISENACK), Chitinozoa gen. et spec. indet. (982).

Dendrograptids are not common in the Swedish Ordovician but a fair number of specimens were found in the present zone between 33.18 and 22.84 m. *Dendrograptus* spp. are dominating but specimens belonging to *Desmograptus* are not uncommon. Among the corynoids, *Corynoides incurvus* constitutes more than 60 % of the representatives of genus and this species ranges from the *gracilis* Zone, together with *C. curtus* and indeterminable *Corynoides* specimens, up to the 27.36 m level. A *Leptograptus* fragment was found at 17.95 m. *Dicranograptus clingani* – the zone fossil – is fairly common from the bottom of the zone up to 26.68 m, occurs more sparsely higher up to 18.06 m, and is abundant at the top of the zone, especially between 18.06 and 17.80 m. One specimen of *Glossograptus* sp. was found between 18.05 and 17.70 m. and ten specimens of *Diplograptus compactus* were met with in the uppermost part of the zone. *Diplograptus? molestus,* which is the dominant graptolite in the zone constituting about 44 % of the graptolite fauna and which is common also in the *gracilis*- and *multidens* Zones, occurs frequently throughout most of the interval and dissappears

in this zone. *A. vasae* is restricted to the beds between 20.42 and 18.46 m. In some instances, it occurs together with numerous specimens of a small, flattened graptolite which has been referred to as *A.* cf. *A. fallax* BULMAN. A few specimens of *A. pulchellus* were found between 21.60 and 21.59 m and *A. lacer* between 27.10 and 26.66 m. Both are restricted to the *clingani* Zone. Among the climacograptids, *Climacograptus brevis* dominates, persisting from the *gracilis* Zone and ranging up to near the top of the *clingani* Zone. *C. antiquus* was sporadically met with between 27.93 and 18.06 m. There is one specimen of *C. antiquus* cf. *C. antiquus lineatus* at 27.23 m. *C. bicornis,* present also in the *gracilis* Zone, occurs in few specimens between 26.57 and 25.67 m and does not range further up. A number of indeterminate climacograptids are found throughout the zone. The orthograptids, which are fairly common in the *multidens* Zone are in the present zone of secondary significance. *Orthograptus calcaratus* is uncommon. *O. calcaratus basilicus* and *O. calcaratus robustus* occur sporadically between 26.82 and 17.95 and between 26.82 and 17.60 m, respectively. Single specimens of *O. calcaratus* aff. *O. calcaratus tenuicornis* and *O. calcaratus vulgatus?* have been found at 26.83 and 18.06 m, respectively. Four specimens of orthograptids of the *truncatus* type have been met with between 23.05 and 22.98 and between 17.60 and 17.55 m. *Orthograptus calcaratus* and *O. calcaratus basilicus* make their entrance in the *multidens* Zone and do not occur above the present zone. *O. calcaratus robustus* and *O. calcaratus* aff. *O. calcaratus tenuicornis* belong exclusively to the *clingani* Zone. Only orthograptids of *truncatus* type range up into the Jerrestad Formation. As is the case in lower portions of the core, *Pseudoclimacograptus scharenbergi,* as well as *P.* cf. *P. scharenbergi,* are rather common, especially between 27.98 and 20.33 m. They disappear in the zone. *Lasiograptus costatus,* which appears in the *gracilis* Zone, is sporadically met with up to the level of 27.81 m and a few specimens of *L. harknessi* have been seen between 23.25 and 20.33 m. A doubtful specimen of *Neurograptus margaritatus?* has been found at 21.51 m.

The brachiopod fauna is rich, constituting 30 % of the entire fauna, and it includes forms persisting from the *multidens* Zone and ranging higher than the present zone. Such species include *Paterula portlocki, Hisingerella nitens,* and *Orbiculoidea* sp. *P. portlocki* is very common throughout the zone. *H. nitens* is most common in the upper part of the zone between 18.20 and 17.55 m but only sparse in the rest of the interval. *Orbiculoidea* sp. is restricted to the beds between 29.30 and 28.22 m. *Lingula dicellograptorum pulla* persists from the zone next below and is only sparse between 29.99 and 27.75 m, whereas *Leptobolus celsus* is frequent through the entire zone. *"Obolus" rugosus* is rather sparse. *Acrothele?* sp. is found between 22.65 and 22.53 m and single specimens of *Hisingerella nana* and *Schizambon* sp. were found at 20.06 and at 29.35 m, respectively. Two specimens of *Sowerbyella* were for the first time recognized in the present zone at 26.54 and 29.35 m. *Onniella bancrofti,* which is dominating

in the zone next below, is relatively sparse between 30.30 and 24.34 m. *Sericoidea restricta,* which persists from the *multidens* Zone and disappears in the present zone, is omnipresent throughout the interval, constituting about 39 % of the entire brachiopod fauna. In the lowermost part of the zone, between 30.30 and 27.19 m, the fauna includes some trilobites such as *Remopleurides* sp., *Lonchodomas rostratus,* and a specimen of the family Lichidae, as well as a few indeterminable trilobite fragments. Mostly small, smooth-shelled ostracodes are very common in this portion of the sequence. Up to now, only the genera *Parapyxion* and *Cerniella* have been determined.

The phyllocarids are represented by *Anatifopsis elongata* and *A. vomer.* These are found for the first time in the core in this zone and are met with sporadically throughout the interval together with some fragments which probably represent phyllocarids.

A small number of isolated, simple scolecodonts are sparse from the bottom to the top of the zone.

Two fragments of orthoconic cephalopods were observed at 27.15 and 17.80 m.

Indeterminable gastropod fragments were sparsely found between 30.25 and 24.03 m.

Bivalves are not uncommon but, unfortunately, they have not yet been worked up. *Nucula? elliptica, N.? reticulata, N.?* sp. indet., and *Modiolopsis? plana* occur between 23.75 and 21.25 m and are restricted to the zone.

Detached sponge spicules, changed to pyrite, are very sparsely found throughout the zone.

Also hyolithids occur sparsely, mainly in uppermost three metres of the zone.

Conodonts are rare; only two indeterminate specimens were found between 29.60 and 29.55 and 29.25 and 29.20, respectively.

Among the machaerids, two specimens of *Plumulites* sp. were noted between 23.05 and 22.65 m and 19 specimens of *Lepidocoleus* sp. between 27.88 and 25.56 m.

Chitinozoans are very numerous and as is the case in the *gracilis* and *multidens* Zones, they dominate the fauna also throughout the present zone in terms of the number of individuals, although at a considerable lower degree than in the *multidens* Zone. The abundance of chitinozoans appears to be in some way related to the frequency of graptolites, and these groups may have some similar ecological requirements. The chitinozoans in the core are mainly met with in the mudstone, rarely, if at all, in calcareous beds. They are mostly flattened and difficult to examine. *Conochitina* appears to be the dominating genus. Three specimens of *C. minnesotensis* and seven of *Rhabdochitina* sp. (cf. *Tanuchitina* Jansonius) have been found between 31.90 and 27.71 m. *Cyathochitina campanulaeformis* and other specimens of that genus are also common.

HARJU SERIES

The Jerrestad Formation (The *Eodindymene pulchra* Zone). (17.55–4.35 m.)

17.55–17.40 m. Black, not calcareous, soft, fine-grained, fissile shale, rich in pyrite. The pyrite is present as thin laminae on the bedding surfaces or, exceptionally, as numerous small grains or micro-crystals. The rock, which is penetrated by numerous slickensides, may be referred to as a graptolite shale. Fossils: *Corynoides* sp. (4), *Dicellograptus complanatus* LAPWORTH (6), *Diplograptidae* gen. et spec. indet. (5), *Climacograptus* cf. *C. brevis* ELLES & WOOD (1), *C. scalaris miserabilis* ELLES & WOOD (2), orthograptids of *truncatus*-type (3), *Pseudoclimacograptus?* sp. (1), ostracodes (2), obolids (10), *Paterula* cf. *P. portlocki* (GEINITZ) (9), *Hisingerella nitens* (HISINGER) (dorsal valves are abundant in certain layers), *Sericoidea* cf. *S. restricta* (Hadding) (1), *Conochitina campanulaeformis* (EISENACK) (4), sponge spicules.

17.40–17.20 m. Black, fine-grained, hard mudstone. Rare small crystals of pyrite are present together with rare thin calcite laminae. There are numerous flakes of biotite between 17.40 and 17.38 m. The fauna is completely dominated by numerous inarticulate brachiopods. Fossils: obolid (1), *Paterula* cf. *P. portlocki* (GEINITZ) (40), *Hisingerella nitens* (HISINGER) (1), *Discina?* sp. (4), *Philhedra* sp. (4), hyolithid fragments, *Jonesina? modesta* HENNINGSMOEN? (1), ostracodes indet. (10), *Plumulites* sp. (1), *Conochitina* spp. (8), *Cyathochitina* sp. cf. *C. campanulaeformis* (EISENACK) (4).

17.20–17.15 m. Grey, somewhat greenish, not calcareous, relatively hard, mudstone with abundant small pyrite crystals in one layer. Fossils: *Lingula* sp. (1), *Foliomena folium* (BARRANDE) (3), *Christiania nilssoni* SHEEHAN (1), *Jonesina? modesta* HENNINGSMOEN (2), *Kinnekullea thorslundi* HENNINGSMOEN (1), *Aechmina* n. sp. (3), fragments of trinucleids, planispiral gastropod (1), scolecodonts (2).

17.15–16.65 m. Dark grey, almost black, relatively soft mudstone with small scattered crystals of pyrite. A couple of thin laminae of calcite have been observed. Between 16.94 and 16.86 m there are bioturbate structures, "speckled mudstone", and such structures also characterize an intercalation of greyish green mudstone between 17.08 and 16.97 m. (Table 2). Fossils: Diplograptidae gen. et spec. indet., *Lingula* sp. (1), obolids (5), *Paterula* cf. *P. portlocki* (GEINITZ) (6), *Sowerbyella* sp. (17), *Sericoidea* sp. (3), *Foliomena folium* (BARRANDE) (5), *Christiania nilssoni* SHEEHAN (2), opercula of *Quadrotheca* sp. (15), *Sigmobolbina variolaris* (BONNEMA)? (1), *Lomatobolbina* sp. A (2), *Oecematobolbina* sp. (1), *Grammolomatella vestrogothica* (HENNINGSMOEN) (2), *Primitiella tenera* LINNARSSON (6), *Jonesina? modesta* HENNINGSMOEN (2), *Kinnekullea waerni* HENNINGSMOEN (6), *K.* cf. *K. hesslandi* HENNINGSMOEN (1), *K. thorslundi* HENNINGSMOEN (3), *K.'hofsteni* HENNINGSMOEN (2), *Aechmina* n. sp. (3), *Nankino-*

lithus granulatus (WAHLENBERG) (1), *Raphiophorus?* sp. (1), *Lonchodomas portlocki* (BARRANDE) (1), fragments of phyllocarids, scolecodonts (2), planispiral gastropod (1), sponge spicules, *Plumulites* sp. (7), *Conochitina* spp. (7).

16.65–16.40 m. Grey to dark grey, slightly calcareous, relatively hard mudstone with rare small grains of pyrite. Rough surfaces and bioturbate structures occur. Fossils: *Foliomena folium* (BARRANDE) (6), *Oecematobolbina* sp. (1), *Nankinolithus granulatus* (WAHLENBERG) (2), sponge spicules.

16.40–11.20 m. Dark grey, frequently almost black, as a rule sligthly calcareous, between 13.16 and 11.80 m and between 16.40 and 14.57 m hard mudstone. Pyrite rarely present as small crystals, which may in exceptional cases form small concretions, or as thin, laterally impersistent laminae. There is a hard, dense, poorly fossiliferous limestone between 14.08 and 14.04 m. Between 15.72 and 15.69 m, there are numerous crystals of calcite and pyrite, and between 16.00 and 15.92 m there are thin small beds or lenses of dark, grey, finely crystalline, very hard limestone. Occasional rare flakes of biotite have been noted between 13.75 and 13.30 m. Bioturbate structures occur between 16.40 and 16.35 m, 15.08 and 15.07 m, and between 14.62 and 14.61 m. Fossils: *Dicellograptus* sp. (1), *Orthograptus truncatus* (LAPWORTH) (20), *O. truncatus abbreviatus* ELLES & WOOD (2), "pelmatozoan" stem parts (1), *Lingula* sp. (4), obolids (13), *Paterula* cf. *P. portlocki* (GEINITZ) (30), *Hisingerella nitens* (HISINGER) (8), *Orbiculoidea* sp. (6), *Schizambon* cf. *S. scotia* (DAVIDSON) (1), *Glyptorthis* sp. (6), Dolerorthid genus et spec. indet., *Dedzetina* sp. (1), *Leptestiina paerantli* HAVLÍČEK (6), *Sowerbyella* sp. (33), *Sericoidea* sp. (3), *Foliomena folium* (BARRANDE) (61), *Christiania nilssoni* SHEEHAN (1), hyolithids (1), *Macronotella* sp? (1), *Euprimites* sp. A, cf. *E. minor* (THORSLUND) (2), *Sigmobolbina* sp. (7), *S.* cf. *S. sigmoidea* JAANUSSON (1), *Sigmoidea* sp. (8), *Lomatobolbina* sp. B (4), *Oecematobolbina* sp. (4), *Uhakiella linnarssoni* HENNINGSMOEN (3), *Jonesina? modesta* HENNINGSMOEN (1), *Kinnekullea thorslundi* HENNINGSMOEN (61), *K. hofsteni* HENNINGSMOEN (40), *Aechmina* n. sp. (9), *Trinodus tardus* (BARRANDE) (27), *Amphitryon radians* (BARRANDE) (3), *Remopleurides* sp. (3), *Opsimasaphus jaanussoni* KIELAN? (2), *Cyclopyge rediviva* (BARRANDE) (9), *Microparia speciosa* HAWLE & CORDA (8), *Stygina* sp. (1), illaenids (6), *Panderia megalophthalma* LINNARSSON (7), *Zbirovia longifrons* (OLIN) (3), *Zbirovia* sp., *Phillipsinella parabola* (BARRANDE) (19), *Nankinolithus granulatus* (WAHLENBERG) (9), Hangchungolithinae n. gen. (2), *Tretaspis* sp. (12), *"Holometopus"* cf. *"H." aciculatus* ANGELIN (1), *Dionide subrotundata* KIELAN (1), *Raphiophorus globifrons* (OLIN) (1), *R. gratus* (BARRANDE) (1), *R.* cf. *R. setirostris* ANGELIN (4), *Lonchodomas portlocki* (BARRANDE) (24), *"Cheirurus"* cf. *"C." toernquisti* WARBURG (1), *Dindymene ornata* LINNARSSON (2), *Liocnemis recurvus* (LINNARSSON) (10), *L.* cf. *L. concinnus* KIELAN (1), Odontopleuridae sp. (1), *Ceratiocaris* sp. (1), other phyllocarids (17), *Plumulites* sp. (8), indeterminable gastropod (1), *Conochitina* spp. (10).

11.20–11.05 m. Core loss.

11.05–11.01 m. Grey, somewhat greenish, slightly calcareous mudstone with bioturbate structures. One, about 9 mm thick, bed of bentonite. Fossils: *Foliomena folium* (BARRANDE) (6), *Christiania nilssoni* SHEEHAN (1), *Kinnekullea thorslundi* HENNINGSMOEN (4), *K. hofsteni* HENNINGSMOEN (1), *Liocnemis* sp. (1), indeterminable trinucleid fragments.

11.01–10.91 m. Dark, grey to black, not calcareous, relatively hard mudstone. Bioturbate structures between 10.97 and 10.94 m. Fossils: *Dicellograptus complanatus* LAPWORTH (5), *Lingula* sp. (1), *Paterula* sp. (8), *Foliomena folium* (BARRANDE) (1), hyolithid (1), *Primitiella tenera* (LINNARSSON) (3), *Kinnekullea thorslundi* HENNINGSMOEN (2), *K. hofsteni* HENNINGSMOEN (4), Hangchungolithinae n. gen., *Raphiophorus* sp. (1), *Anatifopsis* sp. (1), "worm trails", scolecodonts (4), *Plumulites* sp. (8), conodont (1), *Conochitina* spp. (22).

10.91–10.87 m. Grey, somewhat greenish, not calcareous, hard mudstone. Fossils: *Paterula* sp. (1), *Foliomena folium* (BARRANDE) (10), *Christiania nilssoni* SHEEHAN (1), *Oecematobolbina* sp. (1), *Kinnekullea thorslundi* HENNINGSMOEN (2), *K. hofsteni* HENNINGSMOEN (1), *Aechmina* n. sp. (1), *Trinodus tardus* (BARRANDE) (1), indeterminate fragments of trinucleids, scolecodont (1), *Plumulites* sp. (1), *Conochitina* spp. (6).

10.87–10.57 m. Dark grey to black, in some cases somewhat calcareous, relatively soft mudstone. Fossils: *Dicellograptus complanatus* LAPWORTH (7), *Climacograptus* spp. (3), *Orthograptus truncatus* (LAPWORTH) (2), *O.* cf. *O. truncatus socialis* (LAPWORTH) (1), *Lingula* sp. (2), obolids (2), *Paterula* cf. *P. portlocki* (GEINITZ) (1), *Paterula* sp. (6), *Hisingerella?* sp. (1), *Glyptorthis* sp. (1), *Anoptambonites* sp. (1), *Leptestiina prantli* HAVLÍČEK *(6), Foliomena folium* (BARRANDE) (11), *Christiania nilssoni* SHEEHAN (10), hyolithids (2), *Sigmobolbina* sp. (2), *Kinnekullea waerni* HENNINGSMOEN (1), *K. thorslundi* HENNINGSMOEN (27), *K. hofsteni* HENNINGSMOEN (7), *Aechmina* n. sp. (1), other indeterminate, as a rule smooth, ostracodes, yet mostly casts and moulds (348), *Trinodus tardus* (BARRANDE) (4), *Nankinolithus* cf. *N. granulatus* (WAHLENBERG) (1), Hangchungolithinae n. gen. (2), *Raphiophorus* cf. *R. setirostris* ANGELIN (1), *Liocnemis* sp. (1), phyllocarid fragment (1), bivalves (4), *Plumulites* sp. (20), chitinozoans, mostly *Conochitina* spp. (318).

10.57–10.50 m. Black, fine-grained, not calcareous, soft mudstone with numerous slickensides. Fossils: *Dicellograptus complanatus* LAPWORTH (1), *Climacograptus* sp. (1), *Orthograptus truncatus socialis* (LAPWORTH) (1), *Paterula* sp. (1), *Foliomena folium* (BARRANDE) (4), *Kinnekullea thorslundi* HENNINGSMOEN (5), *K. hofsteni* HENNINGSMOEN (1), other indeterminate ostracods (31), *Trinodus tardus* (BARRANDE) (1), *Raphiophorus?* sp. (1), indeterminable fragments of agnostids and trinucleids, *"Euomphalus"* sp. (1), *Plumulites* sp. (6), chitinozoans, mostly *Conochitina* spp. (131).

10.50–10.40 m. Grey to dark grey, in some cases somewhat greenish, not

calcareous mudstone with a couple of slickensides and rough surfaces between 10.50 and 10.45 m. Fossils: *Foliomena folium* (BARRANDE) (2), agnostid (1), *Trinodus tardus* (BARRANDE) (1), Hangchungolithinae n. gen., *Dionide euglypta* ANGELIN (1), *Dindymene* sp. (1), indeterminable trilobite fragments. *Kinnekullea hofsteni* HENNINGSMOEN (2), *K. thorslundi* HENNINGSMOEN (6), *Aechmina* n. sp. (1), *Primitiella tenera* (LINNARSSON) (1), *Conchoprimitia?* sp. (1).

10.40–10.35 m. Zone of crushed rock with numerous slickensides.

10.35–10.25 m. Black, fine-grained, not calcareous soft shale. Fossils: *Dicellograptus complanatus* LAPWORTH (6), *Climacograptus* cf. *C. scalaris miserabilis* ELLES & WOOD (5), *Orthograptus truncatus socialis* (LAPWORTH) (15), fragment of retiolitids, *Lingula* sp. (1), obolid (1), *Paterula* cf. *P. portlocki* (GEINITZ) (2), *Hisingerella nitens* (HISINGER) (1), *Glyptorthis* sp., *Heterorthina?* sp., *Anoptambonites* sp., *Leptestiina prantli* HAVLÍČEK, *Eoplectodonta (Kozlowskites) ragnari* SHEEHAN, *Foliomena folium* (BARRANDE) (5), *Christiania nilssoni* SHEEHAN (2), *Cyclospira? scanica* SHEEHAN, *Trinodus tardus* (BARRANDE) (3), *Amphitryon radians* (BARRANDE) (1), *Phillipsinella parabola* (BARRANDE) (2), *Nankinolithus granulatus* (WAHLENBERG), *Kinnekullea hofsteni* HENNINGSMOEN (1), *K. thorslundi* HENNINGSMOEN (5), *Aechmina* n. sp. (1), indeterminate ostracodes (139), phyllocarid fragments? (5), *Plumulites* sp. (2), chitinozoans, mostly *Conochitina* spp. (708).

10.25–10.07 m. Black, between 10.25 and 10.165 m dark grey, fine-grained, not calcareous mudstone with bioturbate structures. Fossils: *Dicellograptus complanatus* LAPWORTH (10), *Climacograptus* aff. *C. angustus* (PERNER) (2), *C. scalaris miserabilis* ELLES & WOOD (2), *C.* cf. *C. scalaris miserabilis* ELLES & WOOD (3), *Orthograptus gracilis* (ROEMER) (4), *O. truncatus socialis* (LAPWORTH) (7), retiolitid fragments, *Lingula* sp. (1), *Paterula* cf. *P. portlocki* (GEINITZ) (2), *Glyptorthis* sp., *Heterorthina?* sp., *Dedzetina* sp., *Anoptambonites* sp., *Leptestiina prantli* HAVLÍČEK, *Eoplectodonta (Kozlowskites) ragnari* SHEEHAN, *Foliomena folium* (BARRANDE), *Christiania nilssoni* SHEEHAN, *Cyclospira? scanica* SHEEHAN, *Trinodus tardus* (BARRANDE) (2), *Amphitryon radians* (BARRANDE) (2), *Phillipsinella parabola* (BARRANDE) (1), *Tretaspis seticornis* (Hisinger)? (2), and fragments of other trinucleid trilobites, *Dionide euglypta* ANGELIN (1), raphiophorid (1), *Lonchodomas portlocki* (BARRANDE) (1), *Eodindymene pulchra* (OLIN) (1), *Liocnemis recurvus* (LINNARSSON) (1), *Kinnekullea hofsteni* HENNINGSMOEN (4), *K. thorslundi* HENNINGSMOEN (5), *Aechmina* n. sp. (3), *Sigmobolbina* aff. *S. variolaris* (BONNEMA) (1), indeterminated ostracodes (168), scolecodonts (5), gastropods (2), chitinozoans (452).

10.07–10.04 m. Core loss.

10.04–4.35 m. Grey to dark grey, sometimes somewhat greenish, occasionally almost black, as a rule not or only slightly calcareous, predominantly relatively soft mudstone. Small crystals or concretions of pyrite are rare. Single thin laminae of calcite have been observed between 8.77 and 8.72 m and between 5.37 and

5.15 m. Biotubate structures are present between 9.02 and 8.99 m, 5.93 and 5.65 m and between 4.90 and 4.53 m. Tube-shaped structures, between 5 and 10 mm in diameter and filled with greyish white calcareous sediment, are present at 5.86 m. At 5.20 m there is a bed of grey bentonite with abundant biotite flakes and scattered minute pyrite crystals. Slickensides have been observed between 5.37 and 5.12 m. Fossils: Indeterminable fragments of leptograptids, *Dicellograptus complanatus* LAPWORTH (58), *D. pumilus* LAPWORTH (9), *Climacograptus scalaris miserabilis* ELLES & WOOD (38), *Orthograptus truncatus* (LAPWORTH) (26), *O. truncatus abbreviatus* ELLES & WOOD (30), *O. truncatus socialis* (LAPWORTH) (14), *O. gracilis* (ROEMER) (3), "pelmatozoan" stem parts (4), *Lingula* sp. (4), obolids (7), *Paterula* cf. *P. portlocki* (GEINITZ) (5), *Schizambon* sp. (1), Dolerorthidae gen. et spec. indet., *Glyptorthis* sp., *Heterorthina?* sp., *Dedzetina* sp., *Onniella?* sp., *Anoptambonites* sp., *Leptestiina prantli* HAVLÍČEK, *Eoplectodonta (Kozlowskites) ragnari* SHEEHAN, *Sericoidea* sp., *Aegiromeninae* gen. et spec. indet. (1), *Foliomena folium* (BARRANDE) (182), *Christiania nilssoni* SHEEHAN, *Cyclospira? scanica* SEEHAN, *Trinodus tardus* (BARRANDE) (14), indeterminable agnostids (2), *Remopleurides* cf. *R. latus* (OLIN) (1), *R.* sp. indet. (3), *Amphitryon radians* (BARRANDE) (2), *Robergia microphthalma* (LINNARSSON) (1), *Opsimasaphus jaanussoni* KIELAN? (3), *O. latus* (ANGELIN) (1), *Cyclopyge rediviva* (BARRANDE) (7), *Microparia speciosa* HAWLE & CORDA (2), *Illaenus* spp. (7), *Panderia megalophthalma* LINNARSSON (4), *Zbirovia longifrons* (OLIN) (4), *Phillipsinella parabola* (BARRANDE) (13), *Nankinolithus granulatus* (WAHLENBERG) (29), Hangchungolithinae n. gen. (8), *Dionide euglypta* ANGELIN (2), *Raphiophorus acus* TROEDSSON (3), *R.* cf. *R. tenellus* (BARRANDE) (2), *R.* cf. *R. setirostris* ANGELIN (12), *Ampyx* sp. indet. (1), *Lonchodomas portlocki* (BARRANDE) (11), *"Cheirurus"* sp. indet. (1), *Eodindymene pulchra* (OLIN), (1), *Dindymene ornata* LINNARSSON (1), *Liocnemis* cf. *L. concinnus* KIELAN (1), *L. recurvus* (LINNARSSON) (1), *Calymene* sp. (1), Sigmopsidae? sp. (2), *Sigmobolbina* sp. (7), *Lomatobolbina* sp. (1), *Oecematobolbina* sp. (2), *Jonesina? modesta* HENNINGSMOEN (2), *Grammolomatella vestrogothica* (HENNINGSMOEN) (3), *"Primitia"* sp. (1), *Laccoprimitia binodosa* HENNINGSMOEN? (1), *Balticella* sp. (1), *Kinnekullea waerni* HENNINGSMOEN (2), *K. thorslundi* HENNINGSMOEN (30), *K. hofsteni* HENNINGSMOEN (80), *Aechmina* n. sp. (12), throughout the zone there occur a great number of small, smooth, nonsulcate ostracods, which have not been identified so far, phyllocarid fragments, scolecodonts (12), "worm trails", orthoconic cephalopod fragments (4), bivalves (49), sponge spicules, *Plumulites* sp. (86), chitinozoans (806), all of *Conochitina* type.

As a whole, the zone of *Eodidymene pulchra* is characterized by rather strong lithological variability. The dominating rock type is a generally dark grey to greenish black, sometimes black, fine-grained, generally noncalcareous mudstone of varying hardness. Between 17.55 and 17.40 m there is also a bed of black, soft, fissile, pyritic shale, which can be regarded as a typical "graptolitic shale",

that is devoid of benthic organisms but contains graptolites and other planktic and pseudoplanktic forms, mostly small, inarticulate brachiopods. Small lenses of limestone and one limestone bed have been noted and thin calcareous films occur in several places. Pyrite occurs sparsely as very minute crystals, either thinly scattered or aggregated. Small flakes of biotite were found in great abundance in the bentonite between 5.21 and 5.12 m and are also frequent in the mudstone between 17.44 and 17.38 m, but biotite is otherwise uncommon. The beds of different colour are intergradational, only the change between the dark shale and the light coloured mudstone being pronounced. The black, hard, dense limestone between 14.08 and 14.04 m is also strikingly different from the overlying and underlying beds. Speckled mudstone is present in ten beds and is characterized by relatively numerous lumps, which are sharply outlined against the surrounding rock. The lumps are irregular, usually elongate bodies; their length and width vary between 10–20 and 2–5 mm, respectively. In the light mudstone the lumps are grey to dark grey, in the dark mudstone light grey. In both cases the structure does not diverge from that of the surrounding rock. No rythmic alternation has been recognized between either the dark to dark grey or dark mudstone on one hand and speckled mudstone on the other, or between the differently coloured beds. It is probable that the speckled mudstone originally was a sediment with alternating lighter and darker layers, which has been re-worked by bottom-living organisms and in that way has received its characteristic appearance.

The beds of the zone are richly fossiliferous and represent a mixed graptolitic and shelly facies. Brachiopods, trilobites, and ostracodes are predominant. Also graptolites are common, but the number of graptolite genera is considerably lower than in older shales in the core. A few specimens of *Corynoides* sp. are confined to the interval between 17.55 and 17.40 m. *Dicellograptus complanatus* occurs for the first time in this interval. This species then disappears and is not met with until the interval between 10.97 and 8.73 m where it is common. A few specimens of *D.* cf. *D. pumilus* are present between 6.67 and 4.90 m. A couple of specimens of *Climacograptus scalaris miserabilis* have been found between 17.55 and 17.40 m. After an intermission, this graptolite is not uncommon between 10.35 and 4.35 m. There is a number of indeterminable fragments of climacograptids between 10.57 and 4.90 m. Among the orthograptids, *Orthograptus truncatus* persists from older strata and is fairly common between 10.08 and 5.65 m. Three specimens of *truncatus*-type were found between 17.50 and 17.40 m. Some thirty specimens of *O. truncatus abbreviatus* first appear in this zone between 8.77 and 8.73 m and the species is also present between 14.04 and 14.02 m. *O. truncatus socialis* is rather common at various levels between 10.57 and 8.73 m, and a few specimens of *O. gracilis* occur between 10.16 and 9.02 m. The latter three species make their first appearance in this zone. Some retiolitid fragments were observed between 10.35 and 10.12 m. It is notable that graptolites

are met with in only few specimens in shale of typical "graptolitic shale" character between 17.55 and 17.40 m and then graptolites are lacking until they occur again in great abundance above the 11 m level. The cause for this temporary disappearance is difficult to envision because the lithology does not exhibit any notable change.

Some small "pelmatozoan" stem parts occur between 11.89 and 5.65 m.

The brachiopod fauna comprises a number of inarticulate brachiopods, among which lingulids are sparse between 17.24 and 17.15 m and between 14.57 and 5.75 m, and obolids occur more or less frequently throughout the zone. *Paterula* is rather common, especially a minute form, *P.* cf. *P. portlocki* (GEINITZ) (95 specimens), and is present in the entire interval. *Hisingerella nitens,* persisting from underlying zones, is rather sparse but is met with between 17.55 and 6.80 m. A couple of specimens of *Discina* sp. were found between 8.10 and 5.62 m and some specimens of *Orbiculoidea* sp. at various levels between 12.54 and 8.22 m. One speciman of *Schizambon* cf. *S. scoticus* occurs between 14.55 and 14.50 m.

Articulate brachiopods, which have been described by Sheehan (1973), are more common than inarticulates in the zone. This is particularly the case with *Foliomena folium* (250 specimens) and *Cyclospira? scania* (190 specimens), both species occurring throughout the zone. Other forms, which are more sparsely represented, include Dolerorthidae genus & spec. indet. (1 specimen between 11.88 and 11.84 m), *Glypthorthis* sp. (7 specimens between 12.56 and 8.50 m), *Dedzetina* sp. (11 specimens between 12.59 and 4.90 m), *Heterorthina?* sp. (4 specimens between 11.39 and 9.26 m), *Anoptambonites* sp. (3 specimens between 10.75 and 5.46 m), *Leptestina prantlii* (23 specimens between 12.72 and 6.94 m), *Eoplectodonta (Kozlowskites) ragnari* (21 specimens between 12.72 and 7.00 m), Aegiromeninae genus & spec. indet. (1 specimen at 6.68 m), *Sericoidea* sp. (1 specimen between 7.20 and 7.10 m), and *Christiania nilssoni* (36 specimens between 15.18 and 8.55 m). Thus the fauna includes 12 articulate taxa, including 3 recently described species *(Eoplectodonta (Kozlowskites) ragnari, Christiania nilssoni, Cyclospira? scanica),* which appear for the first time in this zone. None of the species, except *Sericoidea* sp., is known elsewhere in Scandinavia (Sheehan 1973).

The trilobites include 28 genera and 33 species, which are mostly represented by cephala and pygidia. Complete specimens are rare, apart from some specimens of larval stages. The trinucleids are the commonest forms, occurring throughout the zone between 17.15 and 4.90 m. According to J. K. Ingham (J. Bergström, personal communication), nearly all of them belong to the genus *Nankinolithus.* An early meraspid and fragments of 12 adult trilobite specimens, found between 13.08 and 6.95 m, represent Hangchungolithinae nov. gen. *Nankinolithus granulatus* (WAHLENBERG) occur between 16.65 and 6.96 m and is especially common in the upper half of the interval. *Tretaspis seticornis?* is present at scattered levels between 14.18 and 7.12 m. *Trinodus tardus* is relatively com-

mon between 15.18 and 5.41 m and some indeterminate agnostids were met with between 15.29 and 8.22 m. *Remopleurides* sp. is rare but occurs between 15.18 and 15.08 m, and between 11.31 and 4.90 m. *R.* cf. *R. latus* was found at 8.01 m and *Amphitryon radians* between 13.20 and 10.19 m and at 7.10 and 6.69 m. Several small indeterminate asaphids appear between 9.86 and 4.85 m. *Cyclopyge rediviva* is not uncommon in the zone and was encountered between 15.10 and 4.53 m. A number of *Microparia speciosa* occur at various levels between 15.43 and 8.30 m. One fragmentary specimen of *Stygina* was found at 11.84 m. Poorly preserved fragments of illaenids were met with between 13.45 and 11.31 m and between 9.66 and 8.22 m and *Panderia megalophthalma* between 16.25 and 15.19 m, 11.39 and 11.31 m and between 9.80 and 9.45 m. *Zbirovia longifrons* was found between 14.09 and 11.31 m, and between 9.86 and 7.97 m. *Phillipsinella parabola* is fairly common throughout the zone between 15.63 and 7.56 m. A few specimens of *Dionide euglypta* appear between 13.82 and 10.19 m and at 7.62 m and one specimen of *D. subrotundata* at 11.51 m. The raphiophorids are sparse, except *Raphiophorus setirostris?,* which was found in about twenty specimens between 12.23 and 5.38 m. Two specimens of *R.* cf. *R. tenellus* were found between 9.33 and 5.32 m and *R. acus* (two specimens) between 8.84 and 6.49 m. One specimen of *R. globifrons* occurred between 11.75 and 11.71 m and *R. gratus* was present between 13.66 and 13.11 m. The trilobite fauna includes also a number of indeterminate raphiophorids throughout the zone between 15.80 and 8.79 m. A fairly common species is *Lonchodomas portlocki* which occurs between 14.18 and 11.25 m and between 9.86 and 5.65 m. *"Cheirurus"* cf. *C. toernquisti,* as well as an indeterminate *"C."* sp., are present between 11.96 and 11.93 m and between 9.55 and 9.50 m, respectively. *Eodindymene pulchra* is rare and was met with at 10.17 and 9.86 m. *Dindymene ornata* was found between 11.47 and 11.31 m and between 8.00 and 7.97 m and some pygidia of the species were found between 11.31 and 8.50 m. One hypostome, possibly belonging to *Calymene,* was met with at 8.40 m and one pygidium of the same genus at 9.59 m. *Liocnemis recurvus* is not uncommon between 16.25 and 8.91 m. One glabella of *L.* cf. *L. concinnus* was observed between 12.81 and 12.77 m. Finally, there is a fragment of Odontopleuridae between 12.54 and 12.49 m.

The ostracodes occur abundantly and comprise at least 15 genera. *Kinnekullea thorslundi* and *K. hofsteni* are the dominant forms, both occuring throughout the zone between 17.20 and 4.35 m. The former species is most common between 14.02 and 10.87 m, and the latter between 11.96 and 11.20 m, and between 7.50 and 7.48 m. Both species are more sparse in other intervals. *K. waerni* was found in few specimens between 17.08 and 4.53 m and *K.* cf. *K. hesslandi* is one specimen between 17.15 and 17.12 m. A new species of *Aechmina* is fairly common throughout the zone, especially between 13.82 and 4.53 m. *Euprimites* sp. A and some indeterminate specimens of the same genus were found rarely in some beds between 13.98 and 7.48 m and also *Primitiella tenera* is sparse between 17.15

and 16.65 m, and between 10.97 and 10.40 m. *Laccoprimitia binodosa?* occurs rarely between 8.05 and 7.70 m. Three specimens of *Uhakiella linnarssoni* were met with between 13.16 and 11.93 m. One doubtful *Sigmoopsis?* sp. was found between 16.80 and 16.65 m and *Lomatobolbina* sp. A and *L.* cf. *L. mammilata* in few specimens between 16.96 and 5.37 m. *Oecematobolbina* sp. was sparsely found between 16.80 and 16.40 m, and between 11.96 and 7.02 m. *Sigmobolbina* aff. *S. sigmoidea* was found between 13.16 and 12.90 m and some specimens of *S.* sp. and an indeterminate species of *Sigmobolbina* were found sparsely between 16.80 and 7.12 m. A single specimen of *Baltonotella* sp. occurs at 17.12 m, one specimen of *Conchoprimitia?* sp. between 10.50 and 10.40 m, and specimen of *"Primitia"* sp. between 5.08 and 4.90 m. *Balticella* sp. occurs between 7.10 and 7.00 m and a few specimens of *Jonesina? modesta* were found between 17.20 and 16.65 m, and between 12.90 and 9.26 m. Finally, *Grammolomatella vestrogothica* was found between 17.15 and 16.65 m, and between 10.04 and 8.05 m. Moreover, there is a great number of unidentified smooth ostracodes.

A telson, probably referable to *Ceratiocaris,* and a few indeterminable phyllocarid fragments were found between 17.40 and 16.86 m, and between 11.52 and 5.75 m. One specimen of *Anatifopsis* cf. *A. elongatus* was collected at 6.53 m.

A couple of scolecodonts occur between 16.86 and 16.65 m but such fossils are more common between 11.01 and 4.53 m.

Fragments of orthoconic cephalopods were found rarely between 9.96 and 4.35 m. One specimen of an indeterminate gastropod occurs between 11.47 and 9.93 m. An euomphalid gastropod was found at 10.55 m.

Bivalves are not uncommon between 13.98 and 6.48 m, 45 of them provisionally being distinguished as Bivalvia sp. a.

Sponge spicules were found sporadically between 17.45 and 16.55 m, and between 7.70 and 5.55 m.

Hyolithids are sparse, occurring between 17.40 and 17.38 m, and between 11.39 and 4.90 m. Some small, square opercula, belonging to the genus *Quadrotheca,* were met with between 17.12 and 16.82 m.

Conodonts are rare but a few specimens were found between 17.20 and 17.15 m, and between 11.01 and 10.73 m.

Chitinozoans are fairly common throughout the interval, even if they are considerably fewer than in the graptolitic mudstone of the zone. About 2000 have been counted, most of them being of *Conochitina* type. Only four specimens of *Cyathochitina campanulaeformis* occur between 17.55 and 17.40 m.

"Worm trails" were found mainly in the upper two-thirds of the interval. Between 8.22 and 8.15 m, parallel to the bedding, a cylindrical, pyritized concretion has been seen with a length of 45 and with a diameter of 3 mm and exhibiting traces of transverse ridges. Between 11.01 and 10.91 m there are some similar, pyritized "cylinders", 35×2 mm, with delicate, transverse ridges, sometimes divided by a median furrow.

STRATIGRAPHICAL AND FAUNISTIC REMARKS

VIRU SERIES

The *G. teretiusculus-N. gracilis* zonal boundary

The biostratigraphic position of the phosphoritic band between the *Climacograptus haddingi* Subzone and the *Nemagraptus gracilis* Zone has been uncertain to some degree. Hadding (1913, p. 14–17) and Nilsson (1960, p. 220) were inclined to refer the band to the *C. haddingi* Subzone while Hede (1951, p. 66) considered it probable that the band belongs to the *N. gracilis* Zone. The band itself has not yielded any determinable graptolites, and accordingly, this interval can not be classified in terms of standard graptolite zones on the basis of these fossils. However, the occurrence of the conodonts *Pygodus anserinus* and *Prioniodus variabilis* is significant for determination of the stratigraphic position of this interval. Both these species are present in strata closely associated elsewhere with *Nemagraptus gracilis*-bearing shales and according to Bergström (1971 a; 1971b, p. 180) there is substantial evidence that the upper subzone of the *Pygodus anserinus* Zone is coeval with a lower portion of the *Nemagraptus gracilis* Zone. Bergström (op. cit.) has given expression to the opinion that in central Scania, a lower portion of the *gracilis* Zone is lacking or is represented by the phosphorite band above strata of the *haddingi* Subzone. Hence, the phosphorite band is likely to mark the beginning of the sedimentation of the *gracilis* Zone.

The *Nemagraptus gracilis* Zone

The graptolite fauna of the *N. gracilis* Zone in the Koängen core includes a number of species which are also characteristic of the so-called "Athens assemblage" in eastern North America. Graptolite faunas of the Athens Shale in the Appalachians have been reported from Alabama northward to northern Virginia and similar assemblages are present in the Normanskill Shale of eastern New York. Shales of "Athens type" are also known from eastern Quebec, New Brunswick, and Newfoundland. It seems clear that all these areas were connected with northwestern Europe by a North Atlantic sea in Middle Ordovician time. The trans-Atlantic similarity in the case of the graptolites has a counterpart in the equivalent conodont faunas; for a recent summary of these similarities, and trans-Atlantic correlations of Middle and Upper Ordovician rocks based on conodonts, see Bergström (1971a; 1971b).

The *Diplograptus multidens* Zone

Moberg (1896, p. 15–16) stated that the interval above the *Nemagraptus gracilis* Zone in western Scania was equivalent to the *Dicranograptus clingani* Zone in

south-eastern Scania, in spite of the fact that it was characterized by *Climacograptus rugosus* Tullberg (= *Diplograptus? molestus* THORSLUND) rather than by *D. clingani.* He designated this interval as the Zone of *Climacograptus rugosus* but referred to the beds in a later publication (1907, p. 80) as the "Zone of *Dicranograptus clingani* Carr. or *Climacograptus rugosus* Tullb." Olin (1906, p. 79) found specimens of *D. clingani* together with *C. rugosus,* and Törnquist (1915, p. 421) considered the Zone of *C. rugosus* to be indentical with the Zone of *D. clingani.* In 1915 Hadding stated that the Middle Dicellograptus Shale could be divided into the following zones (in descending order):

Zone of *Climacograptus styloideus*
Zone of *Dicranograptus clingani*
Zone of *Amplexograptus vasae*
Zone of *Climacograptus rugosus*

Since *C. rugosus* (= *Diplograptus? molestus* THORSLUND) is one of the predominant graptolites of the zone of *Nemagraptus gracilis* in the Fågelsång district (Hede 1951, p. 67), its use as an index fossil for a post-*N. gracilis* Zone is inappropriate. In the same district, *Amplexograptus vasae* is confined to a band in the upper part of the *clingani* Zone, and the *Climacograptus styloideus* Zone (now called the *Pleurograptus linearis* Zone) has not been recognized with certainty (Glimberg 1961).

The major part of the core is fairly uniform lithologically, and the sedimentation seems to have proceeded continuously from at least the time of deposition of the shale of the *Nemagraptus gracilis* Zone. The only lithologically conspicuous stratigraphic break in the core is marked by the phosphoritic band between the *haddingi* Subzone and the *gracilis* Zone, provided that the thin layer of bentonite immediately overlying the *gracilis* Zone should not be regarded as an indication of a break. As has been pointed out already, this layer constitutes a well-defined faunal boundary with new graptolite species appearing in the mudstone immediately above the bentonite bed. It has been shown (Nilsson 1960) that in a relatively thin interval immediately above the *Nemagraptus gracilis* Zone there is a co-occurrence of graptolites characteristic of older and younger strata, respectively, and that this interval constitutes transition beds between the *gracilis* and *multidens* Zones. The core observations seem to confirm the opinion that the interval just above the *gracilis* Zone in the Fågelsång District can not be equivalent to the Zone of *Dicranograptus clingani* in south-eastern Scania. As noted above, the range of *Climacograptus rugosus* (= *Diplograptus? molestus)* makes this species unsuitable as a zonal index for an interval above the *gracilis* Zone. However, the graptolite fauna in this interval in the Fågelsång District shows most considerable similarity to that of the *Diplograptus multidens* Zone of the British Isles and it seems highly justified to use this zonal designation for post-*gracilis,* pre-*clingani* Zone strata also in this area.

Lithologically the layers of the *Diplograptus multidens* Zone are similar to the beds of the underlying *gracilis* Zone and no disconformity seems to exist between these zones. However, in the *multidens* Zone there is a greater number of bentonite beds as well as numerous silicified layers. Such layers were referred to as the Sularp Shale by Lindström, who has given a historical account and an exhaustive report of the stratigraphy and palaeontology of that shale (Lindström 1953). Lindström was of the opinion that the shale occupies a very definite stratigraphic position but without to constitute a zone of its own and considered that the shale ought to be placed biostratigraphically immediately above the *gracilis* Zone. In the present core the silicified mudstone for the main part occurs in the upper half of the *multidens* Zone, between 59.32 and 45.94 m, but it is also present at lower levels, e.g. in the *gracilis* Zone (Hede 1951, pp. 66–67), and probably also in the *clingani* Zone where there is a very hard mudstone with a conchoidal fracture. Taking into consideration these facts it is not probable that the Sularp Shale occupies a definite stratigraphic position. On the contrary, this type of rock could evidently be formed anywhere in the sequence provided that similar physical conditions were available as those during the time of deposition of the strata of the *multidens* Zone. It seems clear that the high silica content in the Sularp Shale is derived from volcanic ash, and that this type of shale or mudstone was formed especially beneath bentonite beds. Palaeontologically the characteristic feature of the silicified mudstone is the frequent occurrence of inarticulate brachiopods as well as of representatives of the genus *Onniella,* mostly *O. bancrofti,* which is omnipresent and constitutes about 42 % of the brachiopod fauna. The forms mentioned along with the other faunal elements all occur also in the remaining parts of the *multidens* Zone.

Thus, out of lithological and palaeontological point of view there is no strong reason to introduce a special stratigraphic designation for the silicified mudstone of the *multidens* Zone.

The lithology in the uppermost portion of the *multidens* Zone, between 34.50 and 30.30 m, consists of dark, calcareous mudstone with a number of, in general, dark-grey, hard, fine-crystalline, beds of limestone, one of which with a thickness of 47 cm. The change in lithology is reflected in a change in the type of fauna, in that – as has already been pointed out – the shelly elements in the fauna dominate (about 85 % of the entire fauna). The fauna of this interval is virtually identical with that found in the underlying parts of the *multidens* Zone. The only difference is the relatively greater number of trilobites (10 genera and about 60 specimens). The fauna consists of graptolites (about 5 %), brachiopods (40 %), ostracodes (39 %), trilobites, bivalves and gastropods (all 2 %), and chitinozoans (12 % of the entire fauna).

Among the brachiopods *Onniella* sp., probably *O. bancrofti,* represents about 12 % and *Sericoidea restricta* as much as 24 % of the brachiopod fauna.

The trilobite fauna is dominated by *Lonchodomas rostratus,* which constitutes

43 % of the trilobites. It occurs throughout the interval as is also the case with the remaining trilobite forms, which, however, are represented by only a single or very few specimens.

Unfortunately, the chitinozoans are still undescribed but it can be concluded that *Conochitina* types are predominating, and some of them are *C. minnesotensis*. *Cyathochitina campanulaeformis* specimens are very uncommon.

The graptolite, brachiopod and chitinozoan species have previously been reported from the underlying layers of the *multidens* Zone and the trilobites are not diagnostic of a limited biostratigraphic interval.

Thus, the general aspect of the fauna indicates that of the *Diplograptus multidens* Zone and in agreement with the conditions of Bornholm described below, the topmost layers of the zone seem to be equivalent to the Skagen Limestone at Kinnekulle in Västergötland.

From rocks probably belonging to the top of the *multidens* Zone of Bornholm, Dr. Sven Laufeld has isolated among others, *Desmochitina juglandiformis* LAUFELD, *D. lata* SCHALLREUTER and *Spinachitina multiradiata* (EISENACK). This chitinozoan assemblage is characteristic of the Skagen Limestone (LAUFELD 1967, Fig. 6) i.e. strata immediately above the "Big Bentonite Bed" in Sweden. The graptolite zone equivalent of the Skagen Limestone (including the uppermost part of the *multidens* Zone described above) has been uncertain up to now but the chitinozoan and graptolite data from Bornholm indicate that at least a part of this unit is coeval with the *Diplograptus multidens* Zone. The chitinozoans prove that the beds right above the "Big Bentonite Bed" at Vasagård, Bornholm, are of the same age as strata above the "Big Bentonite Bed" in sections in south – central Sweden and Scania, and evidently are no older than the uppermost portion of the *Diplograptus multidens* Zone (Bergström and Nilsson 1974, p. 31).

The *Dicranograptus clingani* Zone

Lithologically and palaeontologically the beds of this zone differ markedly from the underlying topmost part of the *multidens* Zone. They are, as a whole, black, noncalcareous, mostly fairly hard mudstones intercalated with softer shales. The brachiopods and graptolites dominate the fauna. There is no indication of a stratigraphic break between this zone and the preceding one.

Among the graptolites, *Amplexograptus vasae* and *A.* cf. *A. fallax* are of particular interest. *A. vasae* occurs in some specimens in a band between 20.42 and 18.46 m together with a relatively large number of specimens of *A.* cf. *A. fallax*. In fact, the last-mentioned species constitutes 80 % of the amplexograptids in this interval and is, as is also the case with *A. vasae,* restricted to it. Bulman (1962, p. 464–465) has pointed out the great resemblance between

A. fallax and Tullberg's *A. vasae* and thought that they may eventually be found to be identical. The present flattened material does not permit a definitely conclusion in this respect and for the present time, Bulman's identification is followed.

Previously, *A. vasae* (= *Climacograptus vasae* TULLBERG, 1882) has been considered (Hadding 1915) a zone fossil for a zone of its own. Yet, according to what is now known about the vertical range of this graptolite species there is no reason at all to maintain a separate zone of *A. vasae.*

It ought to be mentioned that the uppermost part of the zone, between 17.60 and 17.55 m consists of black, fine-grained, soft, fissile, noncalcareous shale. Pyrite is frequently present as very thin flakes or coating on the bedding surfaces, in one case as an outwedging layer of a crystalline concretion. The graptolites are sparse and represent the same species as in the *clingani* Zone. The brachiopods dominate.

According to Hadding (1912, p. 601; 1913, pp. 22–28) the *Ogygiocaris* Shale on the island of Andersön in Jämtland includes the *Climacograptus putillus* (= *C. haddingi)* Subzone and the *Nemagraptus gracilis* Zone as well as the *Dicranograptus clingani* Zone. He stated that *N. gracilis subtilis* occurred together with *D. clingani* in the shale overlying the continuous limestone band at loc. No. 3 on the island. Professor S. M. Bergström has collected a number of rock samples from that shale containing i.a. Leptograptidae gen. & spec. indet., *Nemagraptus gracilis* (J. HALL), and *Dicranograptus brevicaulus* ELLES & WOOD. *D. brevicaulus* is fairly abundant in the higher part of the Glenkiln Shales of Scotland and is also reported from the equivalent strata in Shropshire. It is also described from North America (Decker 1953; Berry 1960), Australia (Harris and Thomas 1938) and Argentina (Turner 1960). All these sequences yielding this species broadly correspond to the *gracilis* Zone in Sweden. *D. brevicaulus* is very similar to *D. clingani* and it seems probable that *D. clingani* of Hadding (1913) rather represents *D. brevicaulus* and that the *"clingani* Zone" of Andersön in fact belong to the *Nemagraptus gracilis* Zone.

HARJU SERIES

The Jerrestad Formation

The designation the Jerrestad Formation was proposed by Jaanusson (1963) to include all sedimentary deposits between the *Pleurograptus linearis* Zone and the base of the *Dalmanitina* beds in Scania. These deposits had previously been referred to as the *Trinucleus* (= *Tretaspis)* Beds (Olin 1906). For strata corresponding to the *Pleurograptus linearis* Zone Jaanusson (op. cit.) introduced the term Vasagaard Stage which is defined as corresponding to the interval between the *Dicranograptus clingani* Zone and the Jerrestad Formation.

In south-eastern Scania the Jerrestad Formation and the Vasagaard Stage embrace in descending order:

3. The *Staurocephalus clavifrons* Zone.
2. *The Niobe lata (= Opsimasaphus* aff. *O. latus)* Zone.
1. The *Pleurograptus linearis* Zone.

In western Scania the sequence has been studied by Glimberg (1961) in a boring in Lindegård and by the author in a boring at Koängen, both in the Fågelsång District.

Glimberg divided the *Tretaspis* Series in the following subdivisions in descending order:

3. Lindegård Mudstone.
2. Zone of *Dicellograptus anceps*.
1. Zone of *Tretaspis granulata* (= *Nankinolithus granulatus* (WAHLENBERG)).
   B. Subzone with *Dicellograptus complanatus*.
   A. Subzone with *Pleurograptus linearis*.

The Harjuan of Västergötland (Kinnekulle), central Sweden, which so far is the best known sequence of this age in Sweden, is subdivided into the following units in descending order (Jaanusson 1963, p. 122):

5. Nittsjö Formation (= Grey or Top Sandstone of Henningsmoen (1948)).
4. Upper Jonstorp Mudstone (= Red *Tretaspis* Mudstone of Henningsmoen (1948)).
3. Öglunda Limestone (– *Tretaspis* Limestone or Masur Limestone of Henningsmoen (1948)).
2. Lower Jonstorp Mudstone (= Green *Tretaspis* Shale of Henningsmoen (1948)).
1. Fjäcka Shale (= Black *Tretaspis* Shale of Henningsmoen (1948)).

The Harju Series has been found also in Dalarna (Thorslund 1935), Jämtland (Thorslund 1940, 1943), Östergötland (Jaanusson 1963), as well as on Bornholm (C. Poulsen 1936, V. Poulsen 1966) the Ordovician of which corresponds fairly well with that of Scania.

The lowermost part of the Jerrestad Formation at Koängen is lithologically a continuation of the underlying black, soft, noncalcareous, pyritic shale, a lithology present not only in the *clingani* Zone (17.60–17.55 m), but also in basal beds of the Jerrestad Formation (between 17.55 and 17.40 m). The fauna consists partly of graptolites, among which *Dicranograptus clingani* is present for the last time between 17.60 and 17.55 m and *Dicellograptus complanatus* appears at 17.55 m. Other elements in the fauna include brachiopods, especially *Hisingerella nitens*. In certain beds between 17.55 and 17.40 m, dorsal valves of *H. nitens*

are present closely packed in large numbers and also obolids as well as specimens of *Paterula portlocki* are not uncommon. The lithic character of the rock, including the large content of pyrite in the interval mentioned, together with the peculiar accumulation of brachiopods may indicate a lithological break. A conspicuous break marks the base of the Harju Series in several areas of central Sweden. Jaanusson (1963) has given an exhaustive discussion of the break at the boundary between the Viru and Harju Series not only in Sweden but also in corresponding sequences in the eastern Baltic, Poland, the Oslo region, and the British Isles. It is possible that another break might be in the overlying bed, between 17.40 and 17.20 m, which consists of a black, hard mudstone without graptolites but with numerous inarticulate brachiopods, particularly *Paterula* cf. *P. portlocki.* In any case, the difference between the black shale and mudstone and the overlying, lithologically strongly variable, layers with bioturbate structures, is conspicuous. The boundary between the Viru and Harju Series has been drawn at the level 17.55 m where *D. complanatus* makes its appearance. Thus, there is no evidence of the presence of the *Pleurograptus linearis* Zone and a stratigraphic gap corresponding to at least that zone is apparently present at the boundary between the Viru and Harju Series, that is, at the level 17.55 m in the core.

The fauna above 17.20 m is dominated by brachiopods, trilobites and ostracodes but graptolites are also common throughout the zone.

The graptolite fauna is dominated by *Dicellograptus complanatus* together with *Climacograptus scalaris miserabilis* and *Orthograptus truncatus socialis.* The species occur in the black shale but are fairly common also in the relatively light-coloured, mostly shelly layers. According to Toghill (1970, p. 6) this graptolite association occurs also in the lower part of the *complanatus* Zone of the highest Hartfell Shales at Main Cliff, Dobb's Linn, South Scotland.

The inarticulate brachiopods have not yet been subjected to any detailed studies while the articulate brachiopods were closely investigated by Sheehan (1973). The articulate brachiopod fauna includes 12 taxa; 3 are recently described species *(Eoplectodonta (Kozlowskites) ragnari, Christiania nilssoni, Cyclospira? scanica)* and are currently known only in the collections from the boring. Eight of the 12 genera identified in the zone also occur in the Králuv Dvůr Formation in Bohemia (Ashgill beds equivalent to the *Eodindymene pulchra* Zone, and the *Staurocephalus clavifrons* Zone in Poland). None of the species are known from elsewhere in Scandinavia. *Glyptorthis* and *Christiania* have not been recorded in the Králuv Dvůr Formation and the indeterminate doleorthid has no counterpart in that formation. *Dedzetina, Foliomena* and *Eoplectodonta (Kozlowskites)* as well as the two identified species *Leptestiina prantli* and *Foliomena folium,* have been reported elsewhere only from the Králuv Dvůr Formation. *Anoptambonites, Leptestiina,* and *Sericoidea* are confined to the Caradoc–Ashgill interval, and this is the only age assignment which can be confidently ascertained from the brachiopod data alone (Sheehan 1973, pp. 59–60).

The trilobite fauna of beds equivalent to the Jerrestad Formation has been described by Hisinger (1837), Angelin (1854), Linnarsson (1869), Törnquist (1884), and Olin (1906). Further, Størmer (1930) has treated the trinucleids and Kielan (1959) has described Polish and some Scandinavian forms. A modern, exhaustive investigation of the Jerrestad trilobites of Scania is not yet available. A revision of the Trinucleidae in the present Zone is badly needed, especially in view of the current interpretation of the morphology, classification, and distribution of that family recently presented by Hughes, Ingham and Addison (1975) and also in view of the great usefulness of the trinucleids as zonal indices.

The trilobites identified in this paper are sufficient for a biostratigraphic classification of the beds and for a comparison with equivalent layers in other parts of Sweden as well as in some foreign countries. Most species are unfortunately represented by more or less fragmentary specimens. The trilobite fauna is fairly rich, the most common species being *Trinodus tardus, Lonchodomas portlocki,* and *Nankinolithus granulatus* which are closely followed in terms of abundance by *Phillipsinella parabola, Cyclopyge rediviva,* and *Liocnemis recurvus.* There is also a great number of mostly indetermined trinucleids, mainly of the genus *Nankinolithus.* A meraspid and a number of fragments have been identified as belonging to the subfamily Hanchungolithinae (according to J. K. Ingham and personal communication of J. Bergström). The distribution of this subfamily was previously known as lower Arenig of Wales, The Welsh Borderland, south-eastern Ireland, and southern France; Llanvirn of central China; lower Llandeilo? of Argentina; and undifferentiated middle Ordovician of Iran. Its occurrence in the earliest Harju Series strata in Scania represents the youngest currently known hanchungolithine trinucleid (Hughes, Ingham and Addison 1975 and personal communication of J. Bergström).

Of the trilobites, 13.9 % of the species *(Panderia megalophtalma,* trinucleids, *Nankinolithus granulatus, Hanchungolithus* sp., *Liocnemis recurvus)* appear for the first time between 17.15 and 16.65 m. The great "burst" of trilobites (61.1 %), which includes *Trinodus tardus,* agnostid, *Remopleurides* sp., *Amphitryon radians, Opsimasaphus* sp.?, *O. jaanussoni?, Cyclopyge rediviva, Microparia speciosa, Stygina* sp., illaenids, *Zbirovia longifrons, Phillipsinella parabola, Tretaspis seticornis?, Holometopus* cf. *H. aciculatus, Dionide euglypta, D. subrotundata, Raphiophorus globifrons, R. gratus, R.* cf. *R. setirostris?, Lonchodomas portlocki, "Cheirurus"* cf. *C. toernquisti, Liocnemis* cf. *L. concinnus,* and *Odontopleurides* sp., appears at the 15.10 m level and this assemblage ranges through the sequence up to the level at 10.17 m. At this level, the trilobite relative frequency decreases to 25 % *(Remopleurides* cf. *R. latus, Robergia microphthalma, Opsimasaphus latus, Raphiophorus acus, R.* cf. *R. tenellus, "Ampyx"* sp., *"Cheirurus"* sp., *Eodindymene pulchra, Dindymene ornata, Calymene* sp.? of all the trilobite species in the formation. As a whole, the trilobite fauna corresponds to the fauna of equivalent strata in Västergötland described by Linnarsson (1869) and

Henningsmoen (1948), and in Poland (Kielan 1959). However, *Staurocephalus clavifrons* has not been found and *Eodindymene pulchra* is represented by only two specimens between 10.17 and 9.86 m. The latter species does not seem to have been reported from other equivalent sequences in Sweden north of Scania.

The succession in the part of the Jerrestad Formation studied does not show any palaeontological or lithological differences justifying a further subdivision. According to Jaanusson (1963, p. 114) this interval may be referred to as the *Eodindymene pulchra* Zone even if the designation the *Dicellograptus complanatus* Zone is equally justified in view of the presence of this graptolite and its associates.

Another stratigraphically important part of the fauna is the ostracodes. They are common in *Eodindymene pulchra* Zone and many belong to the same species which have been described by Henningsmoen (1948) from the Harju Series of Västergötland. There are also specimens of *Oecematobolbina* in the same strata (Jaanusson 1957) as well as some species related to forms up to now only known from the Lasnamägian, Uhakuan, and Kukrusean beds of central Sweden (Jaanusson 1957, etc.): *Sigmobolbina* aff. *S. sigmoidea* (Folkeslunda and Furudal Limestones); *Lomatobolbina* cf. *L. mammillata* (lowermost Dalby Limestone); *Euprimites* cf. *E. minor, Lomatobolbina* sp. A, *Sigmobolbina* sp., *Balticella* sp., and *Baltonotella* sp. (all of them from lowermost Dalby Limestone, Tvären area, Södermanland). There are also some longranging genera such as *Conchoprimitia* and *"Primitia"*.

The stratigraphic distribution of not only the graptolites but also the brachiopods, trilobites, and ostracodes indicates that the Jerrestad Formation at Koängen comprises the *Eodindymene pulchra* Zone only. The presence of the *Pleurograptus linearis* Zone has not been established and there are no observations indicating the occurrence of the *Staurocephalus clavifrons* Zone and the *Dicellograptus anceps* Zone.

The Jerrestad Formation is equivalent to parts of the Jonstorp Mudstone of Sweden north of Scania, as well as to beds in the Holy Cross Mountains of Poland and the Králuv Dvůr of Bohemia (Kielan 1959, p. 14–15). There are also faunal affinities with the Ashgill faunas of Great Britain and Canada. According to Kielan (op. cit., pp. 26, 44) the region of Holy Cross Mountains seems to be in certain respects intermediate faunally between Bohemia and Scandinavia in the case of the Upper Ordovician and a free migration probably existed at least between Bohemia, Poland, Scania, and Västergötland. A comparison between the different developments of the Harju Series of Balto-Scandia has been made by Jaanusson (1956, 1963) and by Skoglund (1963).

The thickness of the various units of the Lindegård boring (Glimberg 1961) and the Koängen boring, which are about 2200 m apart, shows rather great differences. The thickness of the various units recognized is given below.

Lindegård Core (Glimberg 1961)		Koängen Core (this paper)	
Lindegård mudstone	27.00 m	Not available in core	
Dicellogr anceps Zone ..	11.33 m	Not available in core	
Tretaspis granulatus and *Dicellogr. complanatus* Zone	6.32 m	= *Eodindymene pulchra* Zone	13.20 m
Pleurogr. linearis Zone ..	3.20 m		
Dicranogr. clingani Zone ..	2.95 m	= *Dicranogr. clingani* Zone	12.75 m
Amplexogr. vasae Zone ..	1.45 m		
Diplogr. molestus Zone .. (topmost part)	2.25 m	= *Diplogr. multidens* Zone	30.46 m
not cored		*Nemagraptus gracilis* Zone	6.735 m
not cored		*Glyptogr. teretiusculus* Zone	
not cored		*Climacogr. haddingi* Subzone	2.805 m

It should also be noted that there are two bentonite beds in the Koängen sequence between 11.05 and 11.01 m and at the 5.20 m level, which are possibly equivalent to the bentonite beds at Lindegård at the levels 49.30 and 48.30 m, respectively (Glimberg 1961, p. 81). In the Kullatorp core, Västergötland, Henningsmoen (1948) noticed two bentonite beds at 42.0 and 38.60 m, respectively, i.e. in the Red Tretaspis Mudstone (= Upper Jonstorp Mudstone). These beds probably can not be correlated with the beds mentioned. No other bentonite layers are currently recorded from the Harjuan of Västergötland.

CONCLUSIONS

Studies of the Koängen core establish for the first time the presence of a succession through the *Climacograptus haddingi Subzone,* the *Nemagraptus gracilis, Diplograptus multidens,* and *Dicranograptus clingani* Zones, as well as a portion of the Jerrestad Formation *(Eodindymene pulchra* Zone) in the Fågelsång District. The phosphoritic band between the *haddingi* Subzone and the *gracilis* Zone is included in the latter zone and is taken to indicate a conspicuous stratigraphic break. Another break may be associated with the thin, black shale between the *clingani* Zone and the Jerrestad Formation and graptolites show that this is the level of the boundary between the Viru and Harju Series. There is no evidence of the presence of the *Pleurograptus linearis* Zone in the cored sequence.

Apart from the break mentioned, the sedimentation was continuous up to the top of the *clingani* Zone. Black or greyish shale and mudstone, sometimes calca-

reous or silicified, dominate the sequence with intercalations of sparse thin layers or nodules of dark-grey, fine-grained limestone. The fauna of this part of the sequence is composed of graptolites along with inarticulate brachiopods, ostracodes, conodonts, chitinozoans, and other fossils, which are common associates with graptolites in a normal graptolite shale. Especially in the silicified parts of the *multidens* Zone *Onniella bancrofti* is omnipresent.

Above the thin, black shale which constitutes the bottom part of the Jerrestad Formation, the formation includes a dark-gray to greenish black, generally non-calcareous mudstone, which is intercalated with beds of speckled mudstone. The fauna of this interval represents a mixed graptolitic and shelly biofacies and is both varied and rich in individuals. Brachiopods, trilobites and ostracodes are predominant, but also some graptolite species are common throughout the zone, particularly *Dicellograptus complanatus*. A fairly great number of the articulate brachiopod species present occur also in the Králuv Dvůr Formation in Bohemia, which is equivalent to the *Eodindymene pulchra* and *Staurocephalus clavifrons* Zones in Poland. The trilobites and ostracodes in that formation are also indicative of the *Eodindymene pulchra* Zone and show similarity to the fauna in the Jerrestad Formation and equivalent strata in Sweden as well to that of the corresponding zones of Poland.

Studies of the Koängen core have disclosed the presence of no less than 161 bentonite beds, most of these – 115 beds – being in the *multidens* Zone. There are 17 bentonite beds in the *clingani* Zone and two in the *Eodindymene pulchra* Zone. The correlation of the Viruan bentonite beds has been discussed by Bergström and Nilsson (1974).

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GFF = Geologiska Föreningens Förhandlingar
SGU = Sveriges geologiska undersökning

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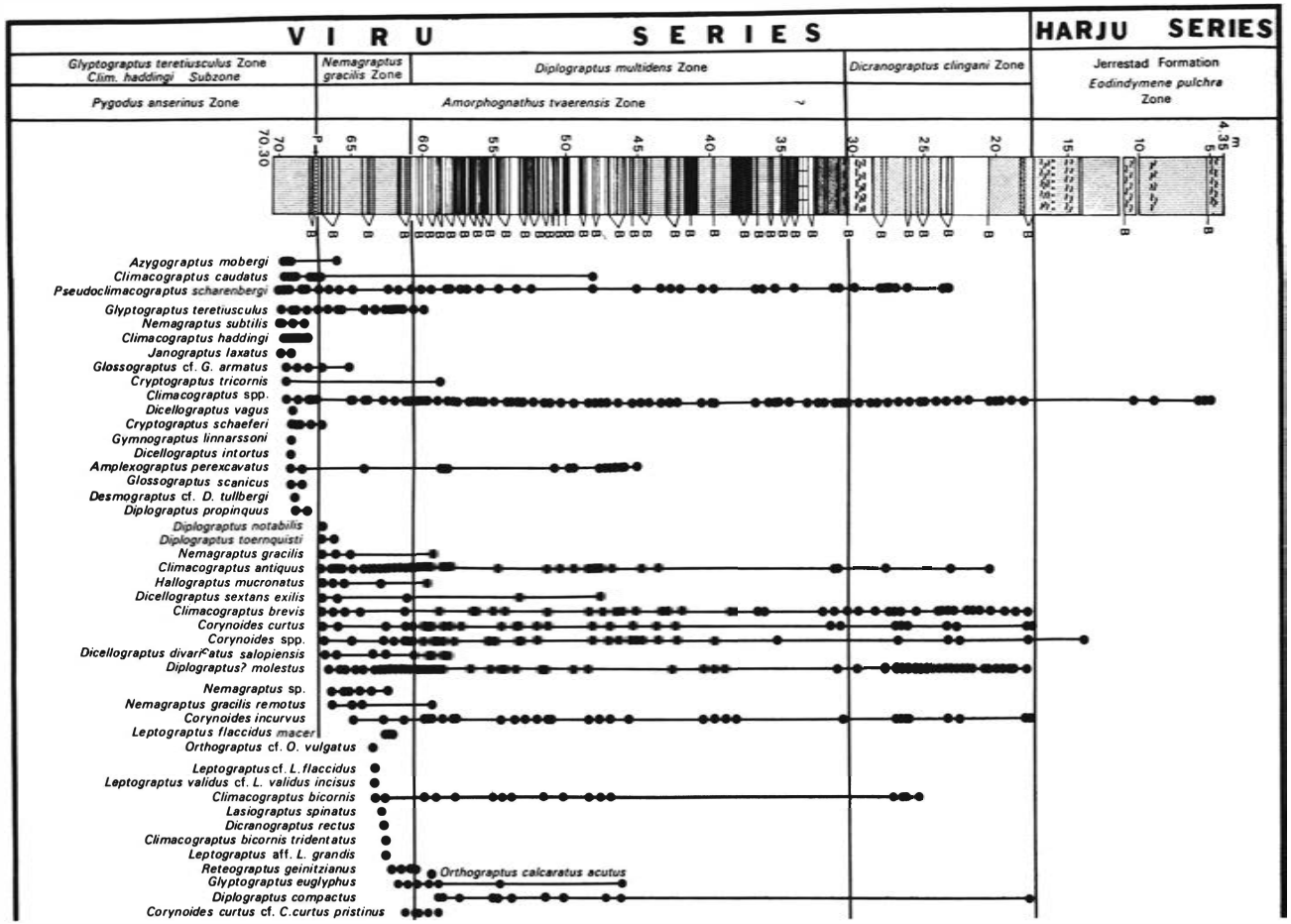
TABLE 1. Vertical ranges of graptolites in the Koängen core and biostratigraphic subdivisions. Each dot represents occurrence of a particular form at a particular level in the core.



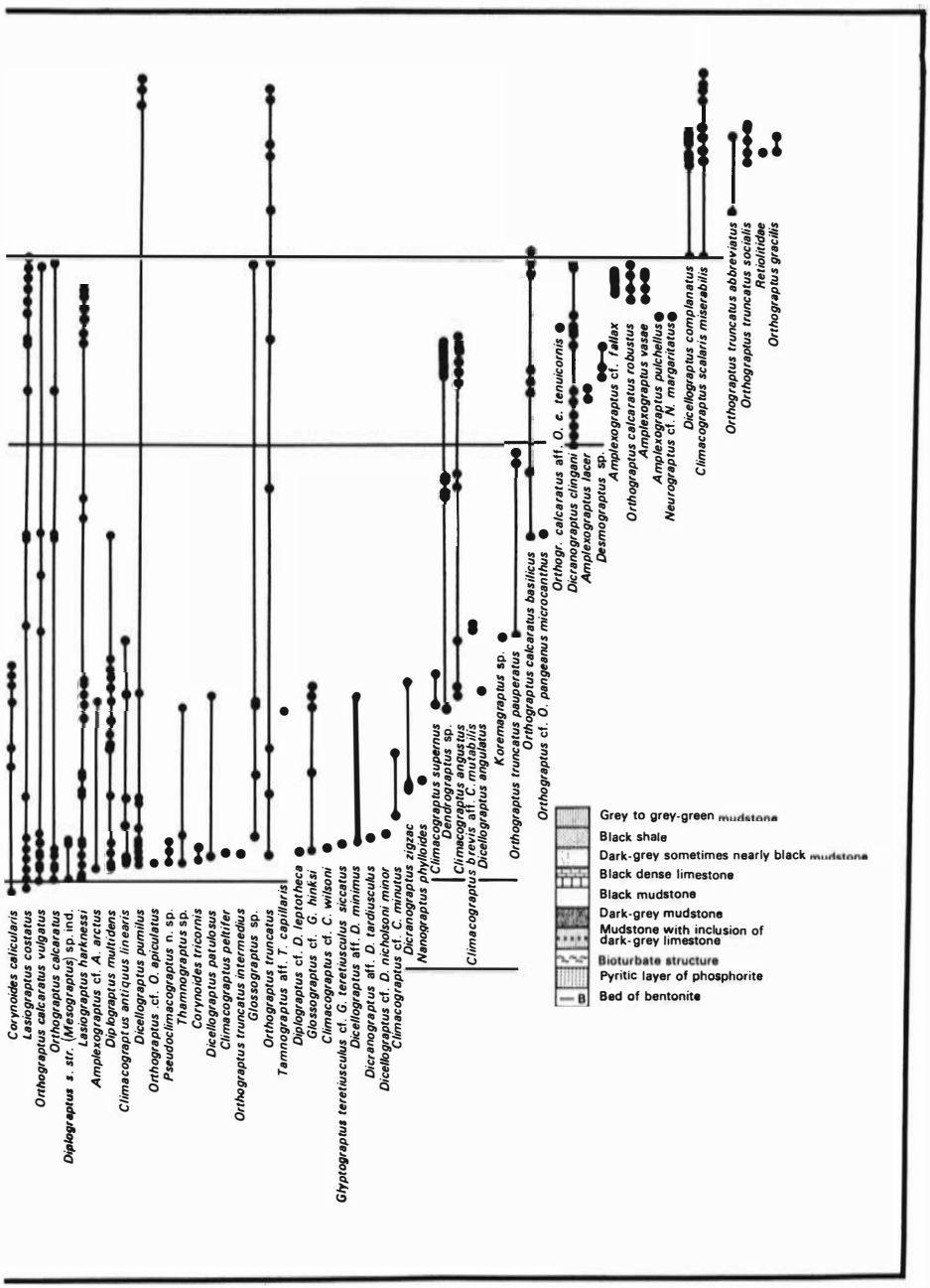

Corynoides calicularis
Lasiograptus costatus
Orthograptus vulgaris
Orthograptus calcaratus calcaratus
Diplograptus s. str. (Mesograptus) sp. ind.
Lasiograptus harknessi
Amplexograptus cf. A. arctus
Diplograptus multidens
Climacograptus antiquus lineatis
Dicellograptus pumilus
Orthograptus cf. O. apiculatus
Pseudoclimacograptus n. sp.
Thamnograptus sp.
Corynoides tricornis
Dicellograptus patulosus
Climacograptus pellifer
Orthograptus truncatus intermedius
Glossograptus sp.
Orthograptus truncatus
Tamnograptus aff. T. capillaris
Diplograptus cf. D. leptotheca
Glossograptus cf. G. hinksi
Climacograptus cf. C. wilsoni
Glyptograptus teretiusculus cf. G. teretiusculus siccatus
Dicellograptus aff. D. minimus
Dicranograptus aff. D. tardiusculus
Dicellograptus cf. D. nicholsoni minor
Climacograptus cf. C. minutus
Dicranograptus zigzac
Nanograptus phylloides
Climacograptus supernus
Dendrograptus sp.
Climacograptus angustus
Climacograptus cf. C. angustus
Dicellograptus angulatus
Koremagraptus sp.
Orthograptus truncatus pauperatus
Orthograptus calcaratus basilicus
Orthogr. calcaratus aff. O. c. tenuicornis
Orthograptus cf. O. pangaeus microcanthus
Dicranograptus clingani
Amplexograptus lacer
Desmograptus sp.
Amplexograptus cf. fallax
Orthograptus calcaratus robustus
Amplexograptus vasae
Amplexograptus pulchellus
Neurograptus cf. N. margaritatus
Dicellograptus complanatus
Climacograptus scalaris miserabilis
Orthograptus truncatus abbreviatus
Orthograptus truncatus socialis
Retiolitidae
Orthograptus gracilis
Grey to grey-green mudstone
Black shale
Dark-grey sometimes nearly black mudstone
Black dense limestone
Black mudstone
Dark-grey mudstone
Mudstone with inclusion of dark-grey limestone
Bioturbate structure
Pyritic layer of phosphorite
Bed of bentonite
B

TABLE 2. Vertical ranges of trilobites and ostracodes in the Jerrestad Formation of the Koängen core. Designations as in TABLE 1.

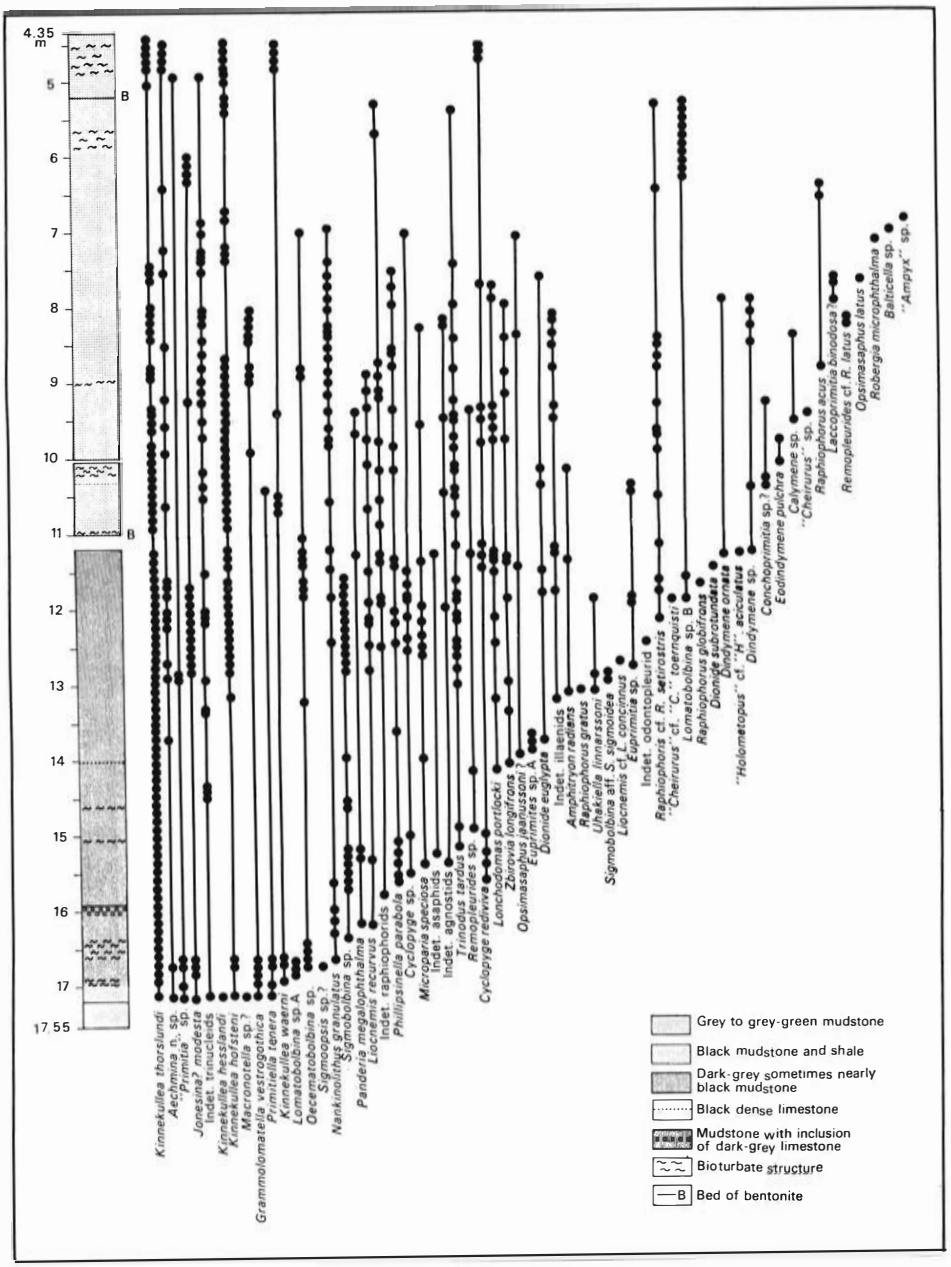


TABLE 3. Zonal distribution of fossils in the Koängen core. 1, *Climacograptus haddingi* Subzone of the *Glyptograptus teretiusculus* Zone; 2, *Nemagraptus gracilis* Zone; 3, *Diplograptus multidens* Zone; 4, *Dicranograptus clingani* Zone; 5, Jerrestad Formation (*Eodindymene pulchra* Zone).

	1	2	3	4	5
GRAPTOLITHINA					
Amplexograptus cf. *A. arctus* ELLES & WOOD	–	–	×	–	–
A. cf. *A. fallax* BULMAN	–	–	–	×	–
A. lacer HADDING	–	–	–	×	–
A. perexcavatus (LAPWORTH)	×	×	×	–	–
A. pulchellus (HADDING)	–	–	–	×	–
A. vasae (TULLBERG)	–	–	–	×	–
Azygograptus mobergi HADDING	×	–	–	–	–
Climacograptus angustus (PERNER)	–	–	×	×	–
C. antiquus LAPWORTH	–	×	×	×	–
C. antiquus lineatus ELLES & WOOD	–	–	×	×	–
C. bicornis (HALL)	–	×	×	×	–
C. bicornis tridentatus LAPWORTH	–	×	–	–	–
C. brevis ELLES & WOOD	–	×	×	×	cf.
C. aff. *C. brevis mutabilis* STRACHAN	–	–	×	–	–
C. cf. *C. caudatus* HADDING (*non* LAPWORTH)	×	–	×	–	–
C. haddingi GLIMBERG	×	–	–	–	–
C. minimus (CARRUTHERS)?	–	–	×	–	–
C. cf. *C. minutus* CARRUTHERS	–	–	×	–	–
C. peltifer LAPWORTH	–	–	×	–	–
C. scalaris miserabilis ELLES & WOOD	–	–	–	–	×
C. aff. *C. spiniferus* RUEDEMANN	–	–	×	–	–
C. supernus ELLES & WOOD	–	–	×	–	–
C. cf. *C. wilsoni*	–	–	×	–	–
C. spp. indet	×	×	×	×	×
Corynoides calicularis NICHOLSON	–	×	×	–	–
C. curtus LAPWORTH	–	×	×	×	–
C. cf. *C. curtus pristinus* RUEDEMANN	–	×	×	–	–
C. incurvus HADDING	–	×	×	×	–
C. tricornis RUEDEMANN	–	–	×	–	–
C. sp.	×	×	×	×	×
Cryptograptus schaeferi LAPWORTH	×	–	–	–	–
C. tricornis (CARRUTHERS)	×	–	×	–	–
Desmograptus? cf. *D. tullbergi* HADDING	×	–	–	–	–
Desmograptus sp.	–	–	–	×	–
Dendrograptus sp.	–	–	×	×	–
Dicellograptus cf. *D. angulatus* ELLES & WOOD	–	–	×	–	–
D. complanatus LAPWORTH	–	–	–	–	×
D. divaricatus salopiensis ELLES & WOOD	–	×	×	–	–
D. intortus LAPWORTH	×	–	–	–	–
D. aff. *D. minimus* HADDING	–	–	×	–	–
D. cf. *D. nicholsoni minor* BULMAN	–	–	×	–	–
D. cf. *D. patulosus* LAPWORTH	–	–	×	–	–
D. pumilus LAPWORTH	–	–	×	–	×
D. sextans exilis ELLES & WOOD	–	×	×	–	–
D. vagus HADDING	×	–	–	–	–
Dicranograptus clingani CARRUTHERS	–	–	–	×	–
D. rectus HOPKINSON	–	×	–	–	–
D. aff. *D. tardiusculus* ELLES & WOOD	–	–	×	–	–
D. ziczac LAPWORTH	–	–	×	–	–
Diplograptus compactus ELLES & WOOD	–	–	×	×	–
D. cf. *D. leptotheca* BULMAN	–	–	×	–	–
D.? molestus THORSLUND	–	×	×	×	–
D. multidens ELLES & WOOD	–	–	×	–	–

	1	2	3	4	5
D. notabilis HADDING	–	×	–	–	–
D. propinquus HADDING	×	–	–	–	–
D. toernquisti HADDING	–	×	–	–	–
Glossograptus cf. *G. armatus* (NICHOLSON)	×	×	–	–	–
G. cf. *G. hinksii* (HOPKINSON)	–	–	×	–	–
G. scanicus HADDING	×	–	–	–	–
G. sp.	–	–	×	×	–
Glyptograptus euglyphus (LAPWORTH)	–	×	×	–	–
G. teretiusculus (HISINGER)	×	×	×	–	–
G. cf. *G. teretiusculus siccatus* ELLES & WOOD	–	–	×	–	–
Gymnograptus linnarssoni (MOBERG)	×	–	–	–	–
Hallograptus mucronatus (HALL)	–	×	–	–	–
Janograptus laxatus TULLBERG	×	–	–	–	–
Koremagraptus sp.	–	–	×	–	–
Lasiograptus costatus LAPWORTH	–	×	×	×	–
L. harknessi (NICHOLSON)	–	–	×	×	–
L. spinatus HADDING	–	×	–	–	–
Leptograptus cf. *L. flaccidus* (HALL)	–	×	–	–	–
L. flaccidus macer ELLES & WOOD	–	×	–	–	–
L. aff. *L. grandis* LAPWORTH	–	×	–	–	–
L. validus cf. *L. validus incisus* ELLES & WOOD	–	×	–	–	–
L. sp.	–	×	–	×	–
Nanograptus phylloides (ELLES & WOOD)	–	–	×	–	–
Nemagraptus gracilis (HALL)	–	×	×	–	–
N. gracilis remotus ELLES & WOOD	–	×	×	–	–
N. subtilis HADDING	×	–	–	–	–
Neurograptus margaritatus LAPWORTH?	–	–	–	×	–
Orthograptus cf. *O. apiculatus* (ELLES & WOOD)	–	–	×	–	–
O. calcaratus (LAPWORTH)	–	–	×	×	–
O. calcaratus acutus ELLES & WOOD	–	–	×	–	–
O. calcaratus basilicus ELLES & WOOD	–	–	×	×	–
O. calcaratus robustus (HADDING)	–	–	–	×	–
O. calcaratus aff. *O. calcaratus tenuicornis* ELLES & WOOD	–	–	–	×	–
O. calcaratus vulgatus ELLES & WOOD	–	cf.	×	?	–
O. gracilis (ROEMER)	–	–	–	–	×
O. sp. cf. *O. pageanus micracanthus* ELLES & WOOD	–	–	×	–	–
O. truncatus (LAPWORTH)	–	–	×	×	×
O. truncatus abbreviatus ELLES & WOOD	–	–	–	–	×
O. truncatus intermedius ELLES & WOOD	–	–	×	–	–
O. truncatus pauperatus ELLES & WOOD	–	–	×	–	–
O. truncatus socialis (LAPWORTH)	–	–	–	–	×
Pseudoclimacograptus scharenbergi (LAPWORTH)	×	×	×	×	–
P. n. sp.	–	–	×	–	–
Reteograptus geinitzianus (HALL)	–	×	×	–	–
Retiolitid graptolite	–	–	×	–	×
Thamnograptus aff. *T. capillaris* HALL	–	–	×	–	–
T. sp.	–	–	×	–	–
BRACHIOPODA – INARTICULATA					
Acrothele? sp.	–	–	–	×	–
Acrotretidae gen. et sp. indet.	–	–	×	–	–
Discina compressa HADDING	–	×	–	–	–
D. sp.	–	–	–	–	×
Hisingerella nana (HADDING)	×	–	–	×	–
H. nitens (HADDING)	–	×	×	×	×
Leptobolus celsus (HADDING)	–	×	×	×	–
L. elatus (HADDING)	–	×	×	–	–
L. fimbriatus (HADDING)	×	–	–	–	–

	1	2	3	4	5
L.? kiaeri (HADDING)	–	×	×	–	–
Lingula dicellograptorum HADDING	×	–	×	×	–
L. dicellograptorum pulla HADDING	–	×	×	×	–
L. magna HADDING	–	–	×	–	–
L. sp.	–	–	–	–	×
Micromitra sp.	–	–	×	–	–
"Obolus" deltoideus HADDING	×	–	–	–	–
"O." ornatus HADDING	×	–	–	–	–
"O." rugosus HADDING	–	–	–	×	–
"O." sularpensis HADDING	×	–	–	–	–
"O." spp.	–	×	×	×	×
Orbiculoidea sp.	–	–	×	×	×
Paterula bohemica BARRANDE	–	×	×	–	–
P. portlocki (GEINITZ)	–	–	×	×	×
P. cf. *P. portlocki* (GEINITZ)	–	–	×	×	×
P. sp. indet.	–	–	×	–	×
Philhedra sp.	–	–	–	–	×
Schizambon cf. *S. scotia* (DAVIDSON)	–	–	–	–	×
S. sp.	–	–	–	×	×
BRACHIOPODA – ARTICULATA					
Aegiromeninae gen. et sp. indet.	–	–	–	–	×
Anoptambonites sp.	–	–	–	–	×
Christiania nilssoni SHEEHAN	–	–	–	–	×
Cyclospira? scanica SHEEHAN	–	–	–	–	×
Dalmanellidae gen. et sp. indet.	–	–	×	–	–
Dedzetina sp.	–	–	–	–	×
Dolerorthidae gen. et sp. indet.	–	–	–	–	×
Eoplectodonta (Kozlowskites) ragnari SHEEHAN	–	–	–	–	×
Foliomena folium (BARRANDE)	–	–	–	–	×
Glyptorthis sp.	–	–	–	–	×
Heterorthina? sp.	–	–	–	–	×
Leptestiina prantli HAVLÍČEK	–	–	–	–	×
Onniella bancrofti LINDSTRÖM	–	–	×	×	–
O. sp.	–	×	×	–	?
Sericoidea restricta (HADDING)	–	cf.	×	×	cf.
S. sp.	–	×	×	×	×
Sowerbyella sp.	–	–	–	×	×
Strophomena sp.	–	–	×	–	–
TRILOBITA					
Agnostids indet.	–	–	–	–	×
Amphitryon radians (BARRANDE)	–	–	–	–	×
"Ampyx" sp.	–	–	×	–	×
Asaphus glabratus ANGELIN	–	–	×	–	–
Calymene sp.	–	–	×	–	×
"Cheirurus" cf. "C." *toernquisti* WARBURG	–	–	–	–	×
"C." sp.	–	–	–	–	×
Cyclopyge rediviva (BARRANDE)	–	–	–	–	×
Dindymene ornata LINNARSSON	–	–	–	–	×
Dionide euglypta ANGELIN	–	–	–	–	×
D. subrotundata KIELAN	–	–	–	–	×
Eodindymene pulchra (OLIN)	–	–	–	–	×
Hangchungolithinae n. gen.	–	–	–	–	×
Holometopus cf. *H. aciculatus* ANGELIN	–	–	–	–	×
Illaenids indet.	–	–	×	–	×
Lichidae gen.et sp. indet.	–	–	×	×	–

	1	2	3	4	5
Liocnemis cf. *L. concinnus* KIELAN	–	–	–	–	×
L. recurvus (LINNARSSON)	–	–	–	–	×
Lonchodomas portlocki (BARRANDE)	–	–	–	–	×
L. rostratus (SARS)	–	–	×	×	–
Microparia speciosa HAWLE & CORDA	–	–	–	–	×
Nankinolithus granulatus (WAHLENBERG)	–	–	–	–	×
N. sp.	–	–	–	–	×
Odontopleuridae gen. et sp. indet.	–	–	–	–	×
Opsimasaphus jaanussoni KIELAN?	–	–	–	–	×
O. latus (ANGELIN)	–	–	–	–	×
Panderia megalophthalma LINNARSSON	–	–	–	–	×
P. sp.	–	–	×	–	–
Phillipsinella parabola (BARRANDE)	–	–	–	–	×
Platycalymene sp.	–	–	×	–	–
Platylichas laxatus (M'COY)	–	–	×	–	–
Proetus? sp.	–	–	×	–	–
Raphiophorus acus TROEDSSON	–	–	–	–	×
R. globifrons (OLIN)	–	–	–	–	×
R. gratus (BARRANDE)	–	–	–	–	×
R. cf. *R. setirostris* ANGELIN?	–	–	–	–	×
R. cf. *R. tenellus* (BARRANDE)	–	–	–	–	×
R. sp. indet.	–	–	×	–	×
Remopleurides cf. *R. latus* (OLIN)	–	–	–	–	×
R. sexlineatus ANGELIN	–	–	×	–	–
R. sp.	–	–	×	×	×
Robergia microphthalma (LINNARSSON)	–	–	–	–	×
Sphaerocoryphe? sp.	–	–	×	–	–
Stygina sp.	–	–	–	–	×
Tretaspis seticornis (HISINGER)?	–	–	–	–	×
Trinodus tardus (BARRANDE)	–	–	–	–	×
Zbirovia longifrons (OLIN)	–	–	–	–	×
OSTRACODA					
Aechmina n. sp.	–	–	–	–	×
Balticella sp.	–	–	–	–	×
Baltonotella sp?	–	–	–	–	×
Cerniella sp.	–	–	–	×	–
Chilobolbina sp.	–	–	×	–	–
Conchoprimitia sp.	–	–	×	–	×
Euprimites sp. A	–	–	–	–	×
Eurychilinid sp.	–	–	×	–	–
Grammolomatella vestrogothica HENNINGSMOEN	–	–	–	–	×
Jonesina? modesta HENNINGSMOEN	–	–	–	–	×
Kinnekullea cf. *K. hesslandi* HENNINGSMOEN	–	–	–	–	×
K. hofsteni HENNINGSMOEN	–	–	–	–	×
K. thorslundi HENNINGSMOEN	–	–	–	–	×
K. waerni HENNINGSMOEN	–	–	–	–	×
Laccoprimitia binodosa HENNINGSMOEN?	–	–	–	–	×
Lomatobolbina sp. A	–	–	–	–	×
L. sp. B	–	–	–	–	×
Oecematobolbina sp.	–	–	–	–	×
Parapyxion sp.	–	–	×	×	–
"Primitia" sp.	–	–	×	–	×
Primitiella tenera (LINNARSSON)	–	–	–	–	×
Sigmobolbina sp.	–	–	×	–	×
Sigmoopsis? sp.	–	–	–	–	×
Uhakiella linnarssoni HENNINGSMOEN	–	–	–	–	×
Ostracoda indet.	×	×	×	×	×

	1	2	3	4	5
PHYLLOCARIDA					
Anatifopsis elongatus HADDING	–	–	–	×	cf.
A. vomer HADDING	–	–	–	×	–
A. sp.	–	–	×	×	×
Caryocaris sp.	–	–	×	–	–
Ceratiocaris? sp.	–	–	×	–	×
Phyllocarida indet.	×	–	×	×	×
POLYCHAETA					
"Spirobis" sp.	–	–	×	–	–
Scolecodonts	×	×	×	×	×
GASTROPODA					
"Euomphalus" bullaeformis HADDING	–	–	×	–	–
"E." sp.	–	–	–	×	×
Gastropoda indet.	–	–	×	×	×
BIVALVIA					
Bivalvia sp. a	–	–	–	–	×
Modiolopsis? plana HADDING	–	–	–	×	–
Nucula elliptica HADDING	–	–	–	×	–
N.? reticulata HADDING	–	–	–	×	–
Bivalvia indet.	–	–	×	×	×
CEPHALOPODA					
Orthocone cephalopods	–	×	×	×	×
HYOLITHA					
Quadrotheca sp. (operculae)	–	–	–	–	×
Hyolitha gen. et sp. indet.	–	–	×	×	×
CRICOCONARIDA					
"Tentaculites" sp.	–	–	×	–	–
PORIFERA					
Pyritonema sp.	–	–	×	–	–
Sponge spicules in pyrite	×	×	×	×	×
Sponge spicules in opaline silica	–	–	×	–	–
RADIOLARIA					
Radiolaria gen.et sp. indet.	–	–	×	–	–
ECHINODERMATA					
"Pelmatozoan" stem parts	–	–	×	–	×
BRYOZOA					
Bryozoa gen. et sp. indet.	–	–	×	–	–

	1	2	3	4	5
CONODONTA					
Acontiodus sp.	–	×	×	–	–
Chirognathus sp.	–	–	×	–	–
Distacodus sp.	–	–	×	–	–
Drepanodus sp.	–	–	×	–	–
Oistodus sp.	–	–	×	–	–
Prioniodus variabilis BERGSTRÖM	–	×	–	–	–
P. sp.	–	–	×	–	–
Pygodus anserinus LAMONT & LINDSTRÖM	–	×	–	–	–
Compound conodonts indet.	–	–	×	–	–
Platform conodonts indet.	–	–	×	–	–
Conodonts indet.	×	×	–	×	×
MACHAERIDIA					
Lepidocoleus sp.	–	–	–	×	–
Machaeridia gen. et sp. indet.	×	×	×	–	–
Plumulites sp.	×	–	–	×	×
CHITINOZOA					
Chitinozoa indet.	×	×	×	×	×
Conochitina minnesotensis (STAUFFER)	×	×	×	×	–
C. cf. *C. minnesotensis* (STAUFFER)	×	×	×	×	–
C. sp.	×	×	×	×	×
Cyathochitina campanulaeformis (EISENACK)	×	×	×	×	×
C. kuckersiana (EISENACK)	–	×	–	–	–
C. stentor (EISENACK)	×	×	–	–	–
Desmochitina sp.	×	–	–	–	–
Eremochitina dalbyensis LAUFELD	–	×	–	–	–
Tanuchitina? sp.	×	–	×	–	–

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