9. Palaeontology and Stratigraphy of the Cambrian and Lowermost Ordovician of the Bödahamn Core

By

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Preface

In the summer of 1948 the Palaeontological Institute of Uppsala University, with the aid of a grant from the "Naturvetenskapliga Forskningsrådet", had a boring executed at Bödahamn, Böda parish, in northernmost Öland, the large island on the south-eastern coast of Sweden. The boring began in Ordovician strata, pierced the Cambrian and ended in the Archaean at a depth of 167.5 m below the local surface.

The palaeontology and stratigraphy of the Cambrian and basal Ordovician have been entrusted to me. I wish to thank the Palaeontological Institute and "Naturvetenskapliga Forskningsrådet" for working facilities and financial support of drawings. Furthermore, I want to thank Dr. E WARBURG, Uppsala, and Dr. A. H. WESTERGÅRD, formerly keeper of the Geol. Survey, Stockholm, who have read my manuscript and given much

good advice. Dr. I. HESSLAND, who is treating the same parts of the core from a lithological point of view, has kindly placed his sedimentological results at my disposal. At the same time he took advantage of my palaeontological evidences.

A. Description of the Sequence

I. Lower Cambrian

In the Lower Cambrian part of the core, between the levels 162.16 and 84.11, remains of true fossils are very scarce, while, on the other hand, trails and burrows are all the more common.

The following fossils have been found:

Discinella holsti MOBERG 1892

3 specimens found at 121.95, 121.55 and 120.1 m, resp. None of the specimens is well preserved.

Torellella laevigata (LINNARSSON 1871)

This species is fairly common in the core section 101.73—91.50. The number of specimens observed exceeds 50. Usually they are fragmentary. The species seems to be restricted to a facies of rather pure quartz sand. The tests are shining with a faint but discernible striation. The colour varies between brown and verdigris green.

Volborthella tenuis FR. SCHMIDT 1888

More than 20 specimens at level 89.65, and 2 specimens at 90.4.

V. conica SCHINDEWOLF 1934

Pl. X, fig. 1 a, b.

One single specimen at 115.0. The specimen is, as is always the case with *Volborthella*, preserved as a cast. It is slightly flattened. Length 3.75 mm, breadth at the broader end 1.75 and 1.10 mm, resp., and at the smaller end 0.65 and 0.50 mm, resp. In the broader view the sides form an angle of 18°. If the elliptical transverse section, which is due to slight compression, is made into a circular section with a breadth of 1.4 and 0.56 mm, resp., the angle of convergence will be 15°.

Brachiopods

Fragments of indeterminate brachiopods with phosphatic shells are met with at 92.25—92.00.

Arenaceous foraminifer

At levels 111.0 and 105.0. For description *vide* p. 230.

Problematicum No. 1

Pl. X, fig. 2 a—c.

At 86.4 there was found an elongated fossil whose systematical position could not be determined. It extends across the core and is cut off at both ends. The fossil seems to have been rounded in cross section but has now a rather flat and, moreover, crushed appearance. The breadth in its present state is from 6 to 9 mm.

Apart from remains of the animals themselves, the existence of life on the bottoms is proved by numerous traces of creeping or burrowing animals. Those traces are seen from quite near the base of the sedimentary rocks and upwards, continuing with but a few gaps throughout the whole stratal sequence.

The trails, which have been observed on numerous levels, are more fully treated by HESSLAND in connection with the sedimentation details. Only exceptionally can it be proved what kind of animals has caused the various kinds of trails. Their value from a stratigraphical point of view is thus very small. The only conclusion to be drawn from them is that the ecological conditions on these levels were favourable for a living bottom fauna.

Part of the burrows indicate the presence of mudeaters, which have forced their way in the uppermost layers of the bottom. Very often they then disturbed or obliterated the original stratification. Many of the winding trails (WESTERGÅRD 1929, fig. 2) in the so-called "kråksten"[1] are most probably caused by such animals.

Stratigraphically most interesting are those burrows which are caused by animals living concealed in the bottom in straight tubes, single or double, the latter with a U-shaped canal between the two tubes. *Monocraterion* and *Diplocraterion* are often found in the Baltic Lower Cambrian. *Skolithos linearis* HALL also occurs, but a number of authors do not consider it to be caused by the activity of animals. (See further WESTERGÅRD 1931.)

Monocraterion has not been observed in the core.

Diplocraterion parallellum has been met with at level 123.45 but nowhere else in spite of a careful scrutiny of the levels where it might be expected.

Skolithos linearis occurs at two different levels, 161.5—about 150.0 and 134.50—124.0. It is only seen in light pure sandstone and has not been

[1] "Kråksten" ("crow stone") is the local name in the Kalmarsund area for a greyish green, argillaceous sandstone with much disturbed bedding. It is unsuitable for millstones and thus considered quite useless.

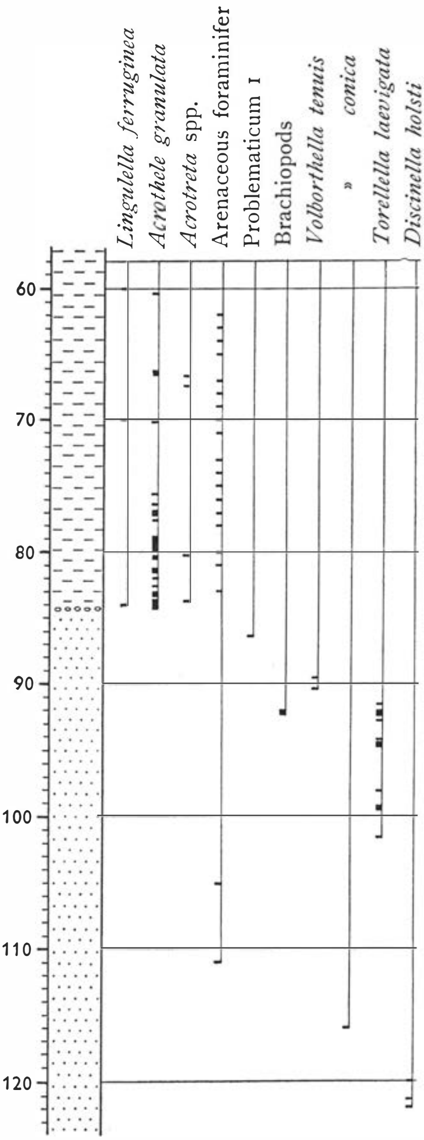


Fig. 1. Distribution of fossils found in the core from the Lower Cambrian and lowermost Middle Cambrian. Explanations: Dotted = sandstone *s. l.*; sparse and broken lines = greyish green shale; close lines = alum shale; rings = conglomerate; "brickwork" = limestone. Fossiliferous levels less than 10 cm apart are united.

found in the more argillaceous sandstone which in the shape of thin strata occurs in the pure one. *Skolithos* is not even found everywhere in the non argillaceous sandstone, but except for the uppermost part of the whole occurrence the gaps are small. The rock in which *Skolithos* occurs is fairly uniform as to particle size and colour, and the stratification is thus not very conspicuous. It follows that the *Skolithos* tubes that break through the stratification do not contrast very much with the surrounding rock. The type of red-striped Skolithos sandstone found in large quantities in the Kalmarsund area, has not been met with in the core. The tubes are usually thin (not over 2 mm thick) and seldom closely packed. They are therefore easily overlooked at some levels.

With regard to its fossil content, both real fossils and burrows, and some lithological features which seem to have such a regional extension as to be of profit in determining the stratigraphy, the Lower Cambrian of the core may be subdivided into the following units from below.

1. 162.16—161.5. Coarse basal sandstone. Barren.
2. 161.5—151.35. Light sandstone with *Skolithos linearis.*
3. 151.35—134.50. Principally argillaceous sandstone with winding trails, "kråksten".
4. 134.50—128.5. Light sandstone with *Skolithos linearis.*
5. 128.5—122.5. Light sandstone alternating with argillaceous sandstone (on several levels of "kråksten"-type).
6. 122.50—109.7. Greyish green sandstone with *Discinella holsti* in the lower parts, and *Volborthella conica* (115.0).
7. 109.7—84.11. Various types of sandstone with some few fossils: *Torellella laevigata* (101.73—91.50), *V. tenuis* (90.4—89.6), brachiopods (92.25—92.00) and problematicum (86.4).

The level 122.50 is of special interest, being the lower boundary of the strata yielding *Discinella holsti*, the oldest real fossil in the core and also in the Baltic area. Furthermore, this is the lowest level for macroscopically visible glauconite in the core, which fact is more fully discussed by HESSLAND (1952), who has treated the lithology of the core. True Lower Cambrian can thus be proved only down to this level.

But while this level indicates a slight change in lithological conditions there is probably no great hiatus.

Thus also the strata down to level 162.16, with the greatest likelihood, might be included in the Lower Cambrian.

II. Middle Cambrian

The Middle Cambrian, which embraces the strata between level 84.11 and level 40.90, together 43.21 m, consists of shale with thin seams of sandstone and some few limestone bands. It is much more fossiliferous than the Lower Cambrian. Trails and burrows appear at several levels but generally seem to be restricted to rather sandy shales and sandstones.

The fauna comprises trilobites, brachiopods, a couple of hyolithids and a foraminifer. The section 84.11—59.75 has yielded exclusively brachiopods and foraminifera, while overlying strata contain a rich fauna of principally trilobites but subordinated also the other animal groups.

With the possible exception of the uppermost layer the sequence belongs to the oelandicus stage.

The following species have been encountered:

Paradoxides oelandicus group

Very numerous between 59.7 and 42.05. Thus there have been listed from 150 levels 65 cranidia, 12 hypostomata, several free cheeks and pleurae.

Because of the difficulty to keep apart the different species when essential parts are missing (the pygidium in the *P. oelandicus* group s. str. and the cranidium in *P. insularis* and *P. sjögreni*) several species are listed together here. Below are listed the instances when a specific determination has been possible.

Paradoxides oelandicus SJÖGREN 1872

One incomplete pygidium at 42.82 probably belongs to this species.

Paradoxides sjögreni LINNARSSON 1877

2 cranidia and 5 pygidia between 58.10 and 52.07.

Paradoxides insularis WESTERGÅRD 1936

2 cranidia at 59.40 and 59.1, resp.

?Paradoxides paradoxissimus (WAHLENBERG 1821)

A thoracic pleura at 41.8 possibly belongs to this group, being abruptly bent and not gently curved like *P. oelandicus*.

Ellipsocephalus polytomus LINNARSSON 1877

Extremely numerous between the levels 59.70 and 42.05. There have been found 13 complete or almost complete specimens, about 500 cranidia, many pleurae, free cheeks, and pygidia (10 isolated pygidia noted). Of the complete or almost complete specimens 8 were flat-lying and 5 flat-lying or slightly enrolled with the cranidium bent under the thorax. This disjointed position of the head is in all probability due to compression of the muddy sediments after the fossils had been embedded. Finally, there was a completely enrolled specimen with the pygidium and the last thoracic segments concealed under the cephalon. It shows *enroulement double* (Barrande) with the ninth thoracic segment closely applied to the doublure of the cephalon (cf. WESTERGÅRD 1936, p. 57).

The species has been observed throughout the above space at 258 levels. A few not fullgrown specimens have been seen between 46.77 (48.67) and 42.68. At 48.13 there was a complete specimen, 10.5 mm long with 13 thoracic segments, obviously not quite fullgrown.

Ellipsocephalus cf. ***polytomus*** LINNARSSON 1877

Pl. I, fig. 3.

A complete flat-lying specimen, body 30 mm long, cephalon 13 mm, and thus to all appearances fullgrown, with 12 thoracic segments. The usual number for *E. polytomus* is 14 and that constitutes the principal specific difference from *E. hoffi* v. SCHLOTHEIM which species has 12 thoracic segments.

Nevertheless I hesitate to refer this specimen to the latter species because the shape of the cranidium is more like that of *E. polytomus* than of *E. hoffi*.

After having compared 18 specimens of *E. hoffi* in Pal. Inst. Mus. with several specimens of *E. polytomus*, I came to the result that the cranidia seem to differ *inter alia* in the following respects. The glabella in *E. hoffi* is rectangular, its anterior part triangular with a broad basis and the corners blunt but discernible. BARRANDE's figure (1852, Pl. X, fig. 26) shows this clearly.

In *E. polytomus* the glabella is more rounded, its outline varying between slightly rectangular to oval. The occipital furrow, as already pointed out by LINNARSSON, may only exceptionally be traced in *E. hoffi* but is fairly distinct in *E. polytomus*, especially in casts of the inner side. My specimen agrees in these details with *E. polytomus*.

Level 56.91.

Condylopyge regia (SJÖGREN 1872)

1 complete specimen, 7 cranidia, and 10 pygidia between 59.40 and 56.28.

Peronopsis fallax (LINNARSSON 1869)

12 cranidia and 6 pygidia between 48.57 and 42.05 and a badly preserved cranidium at 56.82.

Ptychagnostus (Triplagnostus) praecurrens (WESTERGÅRD 1936)

1 pygidium at 56.49.

Hyolithes (s. l.) sp.

3 fragments 59.10—58.8.

Acrothele (Redlichella) granulata (LINNARSSON 1876)

Several (> 60) dorsal and ventral valves and many fragments have been found. The species occurs between 84.11 and 42.44, though with some gaps. It is seen on many levels up to 75.80; from there to 60.55 only three specimens were encountered: Then scattered up to 48.13, with several specimens at 51.96—51.84. Above 48.13 only the topmost occurrence at 42.44. Generally the specimens are in a fragmentary state and connected with occurrences of glauconite.

Acrotreta spp.

On a few levels between 83.8 and 48.57 with a number of valves on each level. In some instances a closer determination has been possible. Thus *A. socialis* v. SEEBACH has been observed at 83.8 and 56.24.

Lingulella ferruginea SALTER 1867

6 specimens between 83.8 and 51.63.

Arenaceous foraminifer

Pl. I, fig. 4 a—f.

The fossil is a small yellowish brown disc more or less regularly rounded. Diameter 0.4—0.9 mm. The thickness does not exceed 0.1 mm. The rim is often somewhat elevated while the central part varies between flat and slightly concave, in small specimens also somewhat convex. The outer side of the test is slightly uneven. The inner side shows labyrinthic swellings of the surface. The test consists partly of silica (hard and insoluble in HCl), partly of chitin (boiling in HF partly dissolved the fossil leaving a brown, limp, coherent residue). Low protuberances which might correspond to apertures have been traced in some specimens.

The taxonomic position of this foraminifer is a question both interesting and difficult. From these very old rocks only few types are available for comparison and the greater part of the foraminifers of the Lower Palaeozoic indicate early stages of development which though superficially alike may later lead to quite different types. It has thus been thought advisable not to propose a name for the fossil at this stage of the investigation but to submit it to a specialist. It might however be permitted to suggest a close affinity to *Thurammina* and *Thuramminoides* (PLUMMER 1945, p. 218, Pl. 15, figs. 4—10).

For help and advice the author offers his thanks to Dr. F. BROTZEN, Stockholm.

Occurrence: The specimens were found in disintegrated shale during the petrographical investigation of the core. They occur in most samples between 83 and 42 metres in the Middle Cambrian and moreover at 111 and 105 metres in the Lower Cambrian. The specimens are not very numerous· About a dozen is the highest number found in any one sample.

The great number of fossils preserved in the core induced me to ascertain whether there could be traced any rules governing their orientation. Most suitable for such an investigation seemed to be the cranidium of *Ellipsocephalus polytomus*. The generally very good preservation of the core allowed the orientation of 372 heads to be determined. The cranidium has a rather simple concavo-convex shape. How a shell of such a shape will orientate itself when sinking or subjected to currents is rather easy to deduce. RUD. RICHTER in 1942 gives a survey of the modes of orientation of arched shells and the rules governing them (Die Einkippungsregel).

Owing to currents along the bottom concavo-convex shells are most often orientated convex side up thus giving less resistance to the currents. Several modifications and special conditions complicate the general rule. RICHTER enumerates a number of common and special cases which result in more or less irregular position or regular position either way.

The trilobites in the present case were in all probability living on the bottom or close to it and when they died or cast their shells they were already at the place or very near it where they got embedded in the sediment. There is thus scarcely any application for the observation that a shell sinking in calm water will arrive at bottom convex side down.

Further I do not think one can always reckon with empty shells. Certainly antennae, feet, and also the rest of the body were much oftener attached to the heads when they became embedded, than is apparent now.

In agreement with what RICHTER writes (*op. cit.*, pp. 185, 194) I draw the conclusion, that an irregular position of the heads with no strong dominance either way indicates calm waters without strong currents, whereas strata with the convex side up indicates more agitated waters and perhaps redeposition.

The following facts were achieved:

In the core portion 45.10—55.70 were counted 291 loose cranidia, 133 of which had their outer convex side orientated upwards and 158 had the same side orientated downwards. In core portion 55.70—59.65 were counted 68 cranidia, 42 up and 26 down. Of the 14 complete specimens there were 5 with the cranidium bent under the outstretched or only slightly enrolled thorax and pygidium. In the upper core portion there were 2 up (viz. cranidium) and 2 down, in the lower core portion 1 down. Further there were 8 flat-lying complete specimens. Of these 4 were down in the upper core portion, 1 up and 3 down in the lower core portion.

The above figures of the orientation scarcely indicate any definite trends. The cranidia lie turned up nearly as often as down. There is a difference, however, between the upper and the lower core portions, the cranidia orientated downwards being in majority in the former, those orientated upwards in the latter. In view of what is said above and considered together with the following facts, we may perhaps be justified in drawing some conclusions. The lower core portion is on the whole a little more sandy; it contains glauconite at several levels and also quite a few brachiopods. All this indicates that the bottom was more current-swept in the beginning, with some redeposition at certain levels. The water thus moved part of the empty trilobite shells till they lay with the convex side up so

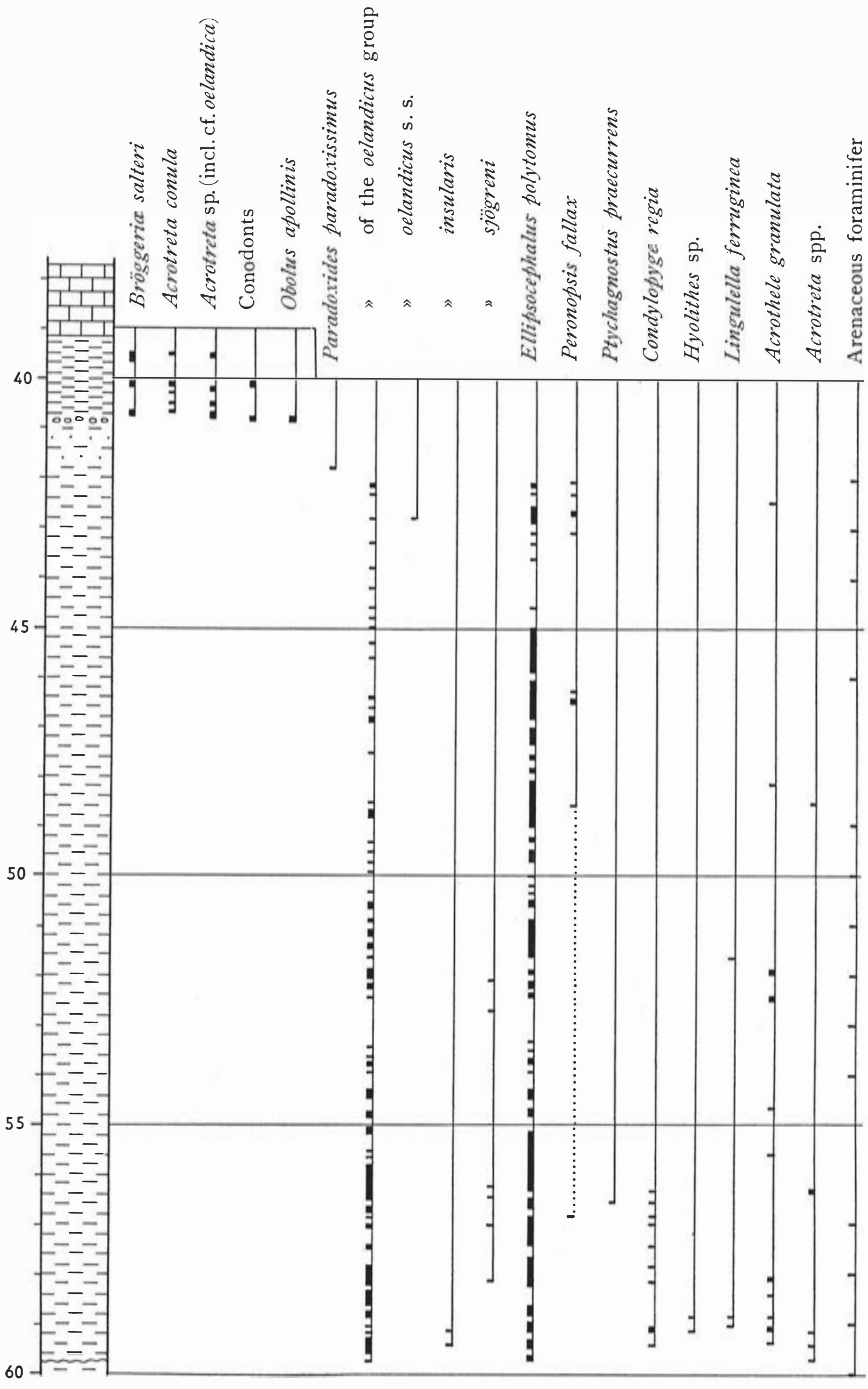


Fig. 2. Distribution of fossils found in the core from the Middle Cambrian (excl. lowermost 24 metres; see fig. 1) and basal Ordovician. For explanations see fig. 1.

that they presented less resistance to the currents along the bottom. Later on the currents grew too faint to move the main part of the empty shells. It is a striking fact that out of 8 complete flat specimens 7 were orientated down. The instances, however, are too few to permit of any conclusions.

The Middle Cambrian may be subdivided into the following three parts from below: 1) Exclusively brachiopod-bearing shale with conglomerate at base. 84.11—59.75. 2) Trilobite-bearing shale with representatives of the zones of *Paradoxides insularis* and *P. pinus,* respectively. There is a limestone with indications of redeposition at base. 59.75—ca. 42. 3) Alternating shale and sandstone, which form transitional strata to the paradoxissimus stage. Only traces of fossils. There is a thin conglomeratic level in limestone with *Acrothele granulata* at the base of this part. Ca. 42—40.90.

Since the lower sandy brachiopod-bearing shales lack a distinguishing fauna they are here provisionally included in the zone of *P. insularis*. (Cf. WESTERGÅRD 1936, p. 22.) They contain *Acrothele* (*Redlichella*) *granulata*, *Acrotreta socialis*, *Acrotreta* sp., *Lingulella ferruginea*, and an arenaceous foraminifer.

The trilobite-bearing part of the zone of *Paradoxides insularis* has yielded *Paradoxides* of *oelandicus* type, *P. sjögreni*, *P. insularis*, *Ellipsocephalus polytomus*, *Condylopyge regia, Ptychagnostus praecurrens*, *Peronopsis fallax*?, *Lingulella ferruginea, Acrothele* (*Redlichella*) *granulata*, *Acrotreta* sp., *Hyolithes* sp., and the arenaceous foraminifer. The upper limit of the zone cannot be fixed more definitely than somewhere between levels 56.28 and 48.57. If all occurrences of *P. sjögreni* should be included in this zone, the limit would be placed above level 52.10, but the species has been found, though rarely, in the zone next in order. Some lithological data induce me provisionally to place the boundary between the insularis and the pinus zones below the limestone 52.50—52.38. Below that level the strata are more sandy than above, and especially near this level sandy beds occur. Glauconite occurs in the limestone and also at some few levels near above (51.92, 51.84, 51.20). Sandy beds are scattered up to 50.8 but above that there is practically only shale. The zone is thus at least 31.5 m thick, possibly somewhat more, of what the trilobite-bearing part makes 7 m.

The zone of *Paradoxides pinus* has not yielded safely determinable parts of the index fossil but the zone is shown by the occurrence of *Peronopsis fallax*. Apart from that, it contains *Paradoxides* spp. of *oelandicus* type, *P. oelandicus* s. s., *Ellipsocephalus polytomus*, *Lingulella ferruginea, Acrothele* (*Redlichella*) *granulata*, *Acrotreta* sp., and the arenaceous foraminifer. The zone extends at least to 42.05. The sequence of soft shale is at 42.49 broken off by calcareous sandstone, columnar limestone, and a thin conglomerate. Above that the shale alternates with thin but numerous sandstone layers. At the top lies a sandstone stratum 18 cm thick.

In the topmost strata no determinable fossils have been found, but at 41.8 a pleura possibly belonging to *P. paradoxissimus* was found. That fossil and the lithology induce me to regard these strata as transitional layers to the paradoxissimus sandstone. In the thin conglomerate at 42.45 *Acrothele granulata* occurs together with some trilobite fragments. Its situation below strata with true oelandicus fauna prohibits its parallellisation with the *Acrothele granulata* conglomerate encountered elsewhere at the lower boundary of the paradoxissimus stage on Öland.

The thickness of the zone is thus about 10 m.

III. Basal Ordovician

Upon the topmost sandstone of the Middle Cambrian rests a conglomerate at levels 40.90—40.88. It contains pebbles of *inter alia* light yellow sandstone, dense, grey limestone and black, finely crystalline, impure stinkstone. No fossils have been seen in the pebbles.

The matrix consists of black shale with lumps and crystals of pyrite and rounded quartz grains. Some fragments of an *Obolus* have been found in it. HOLM, who in 1882 visited Horns Udde, Northern Öland, and made collections *inter alia* in the Obolus conglomerate (1882, p. 72), later on sent his material to MICKWITZ, who (1896, p. 30) determined it as *Obolus apollinis* EICHW. There is every reason to believe that the fragments in the core belong to this species too.

There have also been found several more or less fragmentary conodonts. They agree very well with those figured by WIMAN (1903 a, Pl. III, figs. 42, 43) and those given by WESTERGÅRD (1909, p. 77, Pl. V, figs. 28, 29). They also occur in the overlying shale in the core. WIMAN (1902, p. 66) tells that he found this form in Northern Öland in the alum shale above the real Dictyonema shale.

Above the conglomerate black alum shale follows without any sharp boundary up to level 39.15. In its upper half the shale is at some levels filled with black bituminous crystals and at the top it goes over first into brown and grey shale and then into a glauconitic shale.

The following fossils have been observed:

Bröggeria salteri (HOLL 1864)

Pl. I, fig. 5.

Fairly common on several levels from close to the conglomerate at least up to 39.52 but probably even higher. Most specimens show only the outside of the shell, but at 40.18 there was found a dorsal valve, which shows some internal structures. These closely agree with a specimen figured by MOBERG & SEGERBERG (1906; Pl. I, fig. 27). On this specimen and on another one there could also be observed the fine radiating striae developed under the outermost layer of the shell, as mentioned by the above authors (1906, p. 64).

Acrotreta conula WALCOTT 1912

Pl. I, fig. 6, 7.

Discina? sp. WIMAN 1903 a, p. 66.
Obolella cfr. *sagittalis* WIMAN partim 1903 a, p. 66.
Acrotreta sp. WIMAN partim 1903 a, p. 67, Pl. III, figs. 44—46.
Acrotreta conula WALCOTT 1912, p. 681, Pl. LXXV, figs. 2, 2 a—b.

Very numerous in the lower part of the black shale, occurring between 40.82 and 40.18.

As type locality and horizon WALCOTT states: 310 a "Upper Cambrian: Shales of *Olenus truncatus* zone, Oeland Island, Sweden", which contains (*op. cit.*, p. 241) *Acrotreta conula*, *Orusia lenticularis* and *Olenus truncatus*.

This list causes great doubt as to the purity of the collection and thus as to the stratigraphic horizon for *A. conula*. *Orusia lenticularis* and *Olenus truncatus* have hitherto never been found together in Sweden, except of course accidentally in secondary positions in conglomerates. *Olenus truncatus* is restricted to a low horizon of the zone with *Olenus*, and, as far as I know, *Orusia lenticularis* is found only in the next higher zone, zone with *Parabolina spinulosa* and *Orusia lenticularis*. The picture of the piece of shale (WALCOTT 1912, Pl. LXXV, fig. 2) only shows *A. conula* and none of the other fossils mentioned. On the other hand, the figure shows in its upper left and lower right some shells very much like *Bröggeria salteri*. My supposition is that collection 310 a is composed of pieces from different horizons and that the piece(s) containing *A. conula* belongs to the Ceratopyge shale, with which it shows great similarity.

Looking through WIMAN's material of Ceratopyge shale from the North Baltic area I found that his *Discina*? sp. are in reality ventral shells of *A. conula* and that at least part of his *Obolella* cf. *sagittalis* are dorsal shells of the above species. The "Obolella" shells are plentiful, often very small and only occasionally so well preserved as to show any characteristic features. It is very possible that they represent several species. Of *Acrotreta* sp. WIMAN 1903 a, the figured specimen and a couple of the other specimens from the Trödje boulder belong to *A. conula*.

The species is thus found in Öland and the North Baltic area and so far only found in the Ceratopyge shale.

Acrotreta cf. *oelandica* WESTERGÅRD 1909

Apart from *A. conula* there are some ventral shells of an *Acrotreta* with the apex rather close to the posterior margin. They have a well developed false area. The apex itself is not preserved. Because of their fragmentary state of preservation I hesitate to identify them definitely with *Acrotreta oelandica* WESTERGÅRD 1909 (p. 76, Pl. V, fig. 24 a, b) which they greatly resemble. In the core they occur *i.a.* at 40.82 and 40.18. WESTERGÅRD has found *A. oelandica* on both Southern and Northern Öland in the Ceratopyge shale, and I myself have observed this species in material from various localities on Northern Öland, *inter alia* Horns Udde. Part of the brachiopods in the Trödje boulder, North Baltic Area (WIMAN 1903 a, p. 67, *not* the figured specimen!) are to all appearances identical with *A. oelandica.*

Conodonts

Some conodonts have been observed at levels 40.18 and 40.07. They are of the same type as those found in the Obolus conglomerate (see above p. 234).

Problematicum No. 2

Small, black, irregularly formed, very thin, chitinous flakes with small nodules scattered on the surface. The flakes do not exceed 3 mm in any direction. They are usually found together with fragmentary brachiopods and Problematicum No. 3. They occur very sparsely throughout the black shale. The same thing is described and figured by WIMAN (1903 a, p. 65, Pl. III, fig. 31), who interpreted it as fragments of trilobite shells. He compares the ornamentation of the flakes with that of *Apatocephalus serratus* or *Hysterolenus törnquisti*. But on no fragments studied have I ever been able to find any sutures or borders or anything indicating from which part of a trilobite they may come. I am therefore not ready to agree with that systematical identification.

Problematicum No. 3

Small, black chitinous balls up to 0.12 mm in diameter, rather numerous on certain surfaces throughout the black shale, especially together with brachiopod fragments but also alone.

The absence of trilobites and graptolites makes the dating of the black shale a little difficult, but it can be done indirectly by comparison with other localities. On Southern Öland the presence of *Ceratopyge forficula* (SARS) and *Shumardia pusilla* (SARS) in the shale above the Dictyonema shale indicates that this shale is equivalent to the Ceratopyge shale (3 a β) in the Oslo area. Together with them are found both *Bröggeria salteri* and *Acrotreta oelandica*. In Northern Öland *Dictyonema flabelliforme norvegicum* (KJERULF) has been found at some localities in the basal stratum of the shale immediately above the Obolus conglomerate. Well up in the Ceratopyge stage, in clayey shale interbedded with glauconitic shale, *Clo-*

nograptus (*Staurograptus?*) *heres* WESTERGÅRD has been found at Köpings Klint E of Borgholm (MOBERG & SEGERBERG 1906, p. 61, HADDING 1932, p. 31, 33). At Horns Udde TULLBERG (1882) found a *Dictyonema*, probably the above subspecies (WESTERGÅRD 1947, p. 10), immediately upon the conglomerate. HADDING (1927, p. 85) has seen *Clonograptus* there and so have I. In the northern part of Horns Udde I found in 1943, between the Obolus conglomerate and a glauconitic shale, a 12 cm thick alum shale with some fragments of *Clonograptus* sp. and also *Bröggeria salteri*, *Acrotreta oelandica*, and *A. conula*. The *Clonograptus* sp. could not be further determined and it can thus not be decided whether it is really *C. tenellus* or some younger species.

The age of the alum shale of the core can thus be safely stated as Ceratopyge shale rather close above the subzone of *Dictyonema flabelliforme norvegicum*.

B. Comparison with Adjoining Areas and Palaeogeography

I. Lower Cambrian

For a comparison of the Lower Cambrian in Northern and in Middle Öland only some few borings are available. The boring at Mossberga 12 km south of Borgholm (WESTERGÅRD 1936) pierced only 1.7 m of Lower Cambrian deposits, below which followed Pre-Cambrian quartzite. The boring at Borgholm (WESTERGÅRD 1929) penetrated 58.75 m of the Lower Cambrian but did not reach the subsurface. A percussion drill boring at Solliden not far from the latter has proved the Lower Cambrian to total 78 m. At Mörbylånga only the topmost strata have been examined (HOLST 1893).

The sequence of strata shows great similarities with the Bödahamn core as regards the development of Skolithos sandstone and "kråksten". A level of stratigraphical importance is the conglomerate at 72.6 m in the Borgholm core and at 122.60 m in the Bödahamn core. Connected with it is *Discinella holsti,* the oldest known Swedish real fossil. Most of the specimens were found in and above the conglomerate, but one single specimen was found below it at level 77.6 m.

As the Borgholm core does not reach the substratum of the Cambrian, we do not know the thickness of the strata below the 72.6 m level, but if we suppose that the Lower Cambrian has the same thickness here as at Solliden (78 m), the lower part of the Lower Cambrian is about 46 m thick at or near Borgholm and 40 m at Bödahamn. Above the *Discinella* level there are no means of correlation until the boundary between the

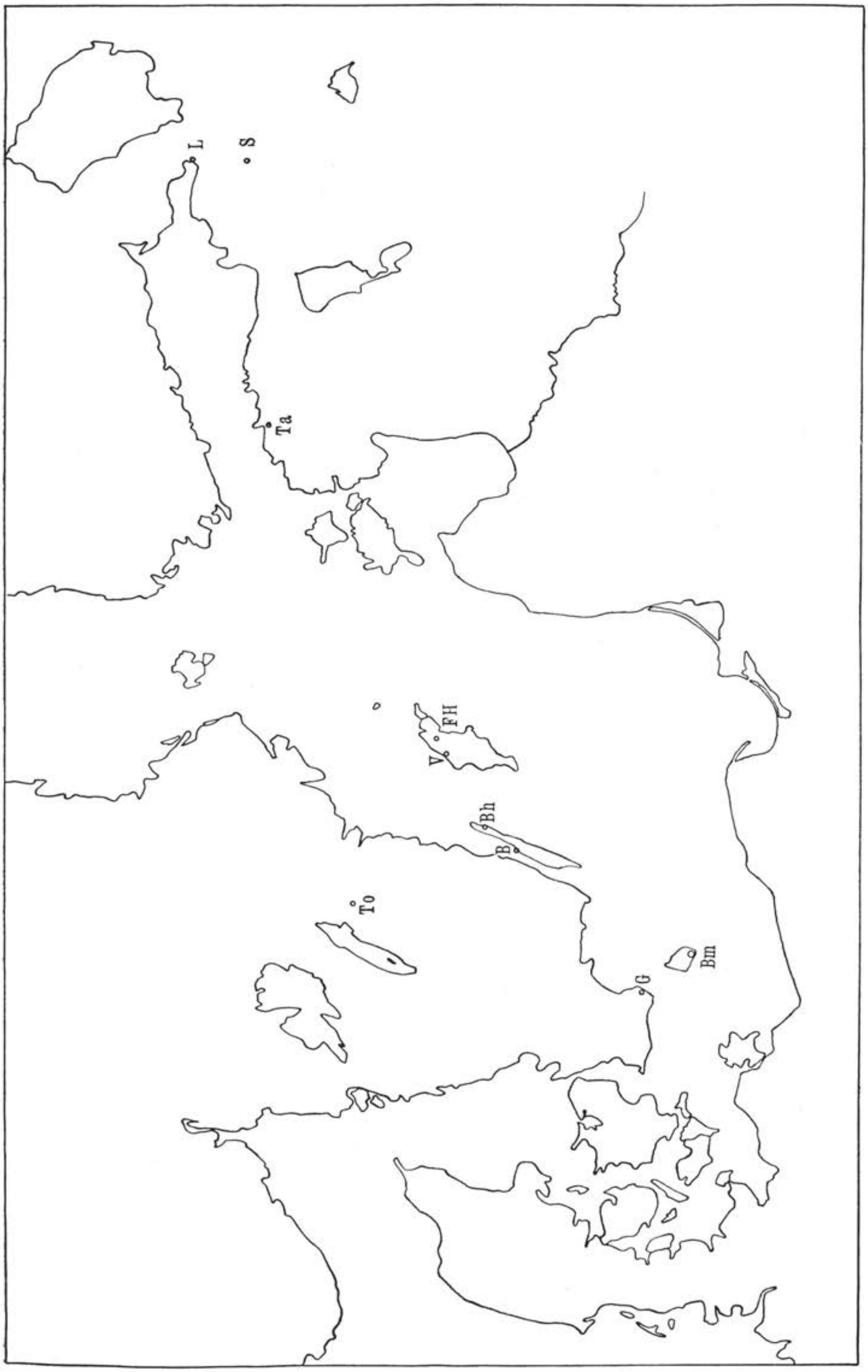


Fig. 3 a.

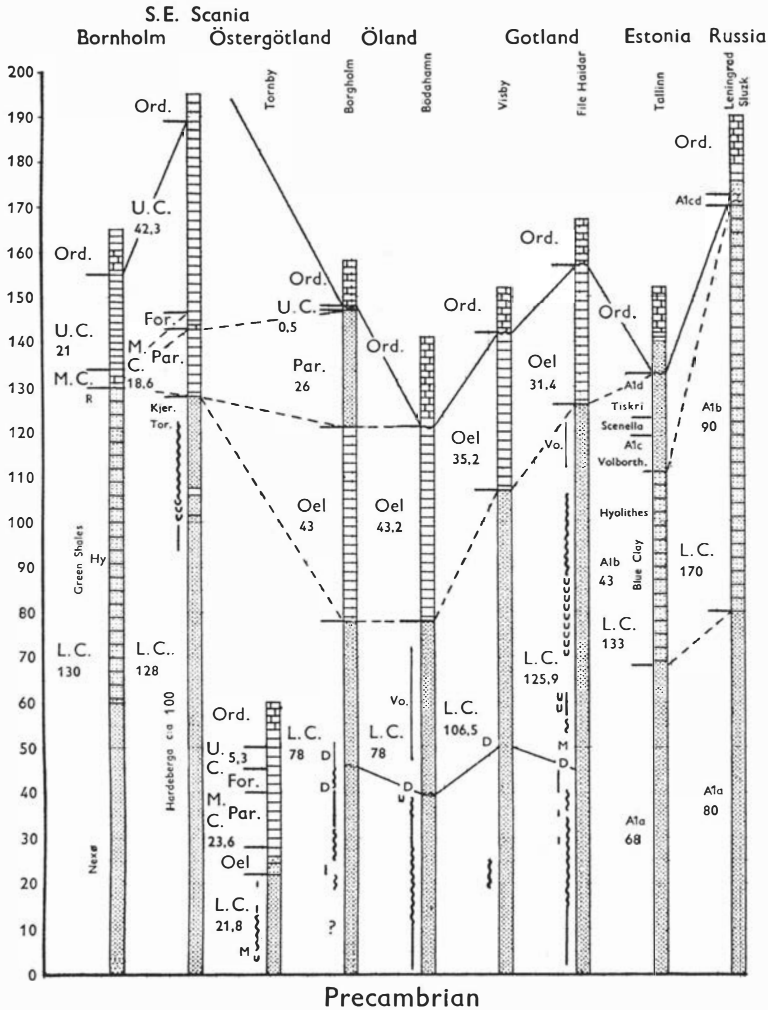


Fig. 3 b.

Fig. 3 a, b. A NE—SW profile through the Cambrian in the southern part of Fennoscandia.

Explanations:

3 a. The map: B = Borgholm (WESTERGÅRD 1929, 1946); Bh = Bödahamn; Bm = Bornholm (MILTHERS 1930); FH = File Haidar (THORSLUND and WESTERGÅRD 1938); G = Gislövshammar (HADDING 1929, WESTERGÅRD 1946); L S = Leningrad (RÜGER 1934), Sluzk on river Tyzwa (NEKRASSOFF 1938); Ta = Tallinn (Reval) (RÜGER 1934, ÖPIK 1934); To = Tornby (WESTERGÅRD 1940); V = Visby (HEDSTRÖM 1923).

3 b. The profiles: L. C. = Lower Cambrian; M. C. = Middle Cambrian; U. C. = Upper Cambrian; Oel(andicus stage); Par(adoxissimus stage); For(chhammeri stage); Ord. = Ordovician; R = Rispebjerg sandstone; Kjer. = Kjerulfi zone; Tor. = Torelli zone.

D = *Discinella*
Hy = *Hyolithes*
M = *Mickwitzia*
Vo = *Volborthella*

| *Skolithos*
Kråksten
Diplocraterion

Sandstone
Shale
Limestone
Discontinuity

Lower and the Middle Cambrian. The thickness of the Lower Cambrian is, apart from Mossberga, remarkably uniform in Middle and Northern Öland, *viz.* 78 and 76 m.

The Lower Cambrian of Gotland shows great affinities to that of Northern Öland. In the cores from Visby (HEDSTRÖM 1923) and File Haidar (THORSLUND and WESTERGÅRD 1938) the sequence under *Discinella* has a thickness similar to that in Öland, 50 and 46 m, respectively. The upper parts increase towards the NE (Visby 65 m, File Haidar 78 m). The development of strata with *Skolithos linearis* and "kråksten" strata is fairly similar in the Bödahamn and the File Haidar cores, namely from below Skolithos sandstone, "kråksten", and Skolithos sandstone again with some scattered occurrences of "kråksten". This indicates no definite synchronism, however, only a similar development at approximately the same time. The higher parts of the Lower Cambrian present few opportunities for a faunistical connection. The occurrence of *Volborthella tenuis* at level 90.4—89.6 (and *V. conica* at 115.0) m in the Bödahamn core is possibly contemporaneous with the occurrence of this fossil at 388.45—377.5 in the File Haidar core.

The North Baltic area, on the Åland Islands and in the southern part of the Bothnian Gulf, presents many interesting palaeogeographical traits. A close comparison with adjoining areas is rendered difficult, as the stratigraphic sequence has to be reconstructed by studying practically only loose boulders (WIMAN 1903 a). Remnants of solid rock are only found at Holmudden 10 km NE of Gävle (WESTERGÅRD 1939, pp. 36 ff., 43 ff.) on older sandstones and in fissure fillings in Precambrian granites and gneisses (*inter alia*, METZGER 1927). The oldest fossil found is *Discinella holsti* in a loose boulder on Åland. It must be kept in mind, however, as already pointed out by WIMAN (1903 a, p. 55), that there is a possibility that the single *Discinella*-bearing boulder was not carried to its resting place by ice or waves but by man, *e.g.* as ballast. Several finds of *Mickwitzia monilifera* show that the *Holmia torelli* zone is represented in that area. Probably also higher zones are represented and there are certain finds that indicate that the sequence possibly continues into the Middle Cambrian.

The areas E of the Baltic Sea, Estonia and Ingermanland, present only few means for stratigraphic correlations with Öland. The lower and greater part of the sequence, the Blue clay *etc.*, is mostly situated below sea level or covered with thick Quaternary deposits. *Discinella holsti* has not yet been encountered in this area but to judge from the conditions under Gotland and Öland the strata where *Discinella holsti* might be expected are probably situated at a very low level in the "Blue clay".

The higher parts, the *Volborthella*, the *Scenella*, and the Tiskri (*Corophioides / Diplocraterion*) zones, are more accessible and better known (RÜGER 1923, 1934, ÖPIK 1933). Locally one or more of these zones may wedge out.

As already mentioned by WESTERGÅRD (THORSLUND and W. 1937, p. 21 f.) the occurrences of *Volborthella* in the File Haidar (and the Bödahamn) core indicate the Estonian *Volborthella* zone. Of the *Scenella* and the Tiskri zones there are no indications either in Gotland or in Öland.

In Latvia Lower Cambrian in contact with Middle Ordovician was pierced in a boring at Dünaburg (KRAUS 1937).

The boring at Johannisburg in East Prussia (letter of K. ANDRÉE $^{17}/_{9}$ 1951), where Zechstein-strata of the Tatarian stage (cf. borings at Memel) were found resting with a coarse quartz conglomerate upon a gabbro-norite at 1365 m, may indicate a rather restricted island in the very expansive Lower Cambrian sea.

The Lower Cambrian fauna in the Swiety Krzyz Mountains, Poland, (CZARNOCKI 1927) shows close affinities to that of Scandinavia.

The scarcity of fossils preserved makes a close comparison with Bornholm and Scania difficult. One has to rely principally on lithological data. HANSEN (1937, p. 170 ff.) and WESTERGÅRD (1929, p. 12 ff.) have discussed these areas in great detail. POULSEN, while investigating part of the exulans limestone on Bornholm (1942), has arrived at some views divergent from those of HANSEN. The results of the Bödahamn boring do not add anything of importance.

The *Holmia torelli* zone is made to include strata with *Volborthella tenuis*, *Mickwitzia monilifera*, and also *Platysolenites*. (Cf. WESTERGÅRD and HANSEN *op.* and *loc. cit.*) Some of the upper parts of the Bödahamn core certainly belong to this zone.

HANSEN assigns some glauconitic sediments in the Kalmarsund area to the *Holmia kjerulfi* zone, but there are no fossil finds to support this assumption. Probably this zone and certainly the *Strenuella linnarssoni* zone fall within the hiatus proved below the Middle Cambrian basal conglomerate on Öland.

The Lower Cambrian sea reached in all probability Central Sweden later than the Kalmarsund area. The oldest real fossil is here *Mickwitzia monilifera,* which is found both in Östergötland, Närke, Västergötland, and Dalsland (GAVELIN 1909, WESTERGÅRD 1940). The question whether the Lower Cambrian sea had reached part of Central Sweden already during the *Discinella holsti* time must be left open. *D. holsti* has not yet been found there and the explanation is either that the sea had not reached the area at that time or that the ecological conditions were not favourable for *Discinella* at the localities and levels where it might be expected (WESTERGÅRD 1940, p. 23 ff.).

In Dalsland *Mickwitzia monilifera* is found in sandstone from fissures in the Pre-Cambrian rock floor and thus marks the date for the Lower Cambrian transgression (GAVELIN 1909). In Central Sweden also a younger member of the Lower Cambrian series is found, *viz.* the Lingulide sandstone. It is by various authors assigned to the *Holmia kjerulfi* zone.

Summary of development during the Lower Cambrian

The Lower Cambrian sea in all probability transgressed upon the Fenno-Scandian platform from SE. In pre-*Discinella* time Öland and Gotland and certainly also Estonia and Bornholm-Scania were inundated. In *Discinella* time the North Baltic area was added. The sediments of these areas seem to increase strongly in thickness from west to east (see fig. 3 b the columns for Öland—Gotland—Estonia—Ingermanland). During the time for the deposition of the *Holmia torelli* zone the Lower Cambrian sediments were most widely spread. Apart from the areas already mentioned the zone is found in Central Sweden *viz*. Östergötland, Närke, Västergötland and Dalsland.

The next higher zone, the zone of *Holmia kjerulfi*, shows a diminishing sea. In Öland and Gotland it is not proved and in Bornholm only scanty traces are found according to POULSEN. In Estonia-Ingermanland the zone is present but may locally wedge out. Central Sweden was inundated and so was Scania. A land seems to begin to appear in SE while the sea moves north and west.

The zone of *Strenuella linnarssoni* is indicated in Scania only and during the end of the Lower Cambrian the whole Fenno-Scandian platform was lifted above sea level.

During the whole of the Lower Cambrian the sea covering that platform was separated from the sea which occupied the area where the Caledonian geosyncline began to form (STRAND 1929).

In other directions connections seem to have existed, *inter alia* with Poland.

II. Middle Cambrian

In Öland there is a distinct hiatus dividing the Lower Cambrian and the oelandicus stage of the Middle Cambrian. At some places, *e.g.* in the Bödahamn core, a conglomerate is present. The basal part of the oelandicus stage contains only a poor brachiopod fauna. At Mossberga, Borgholm and Bödahamn this part of the sequence measures 17, 26 and 24 m respectively. According to WESTERGÅRD (1936, p. 20) these basal strata thin out to the south and are probably missing at Mörbylånga. Above that follow shales with a more varied fauna where trilobite remains are most common. The two zones with *Paradoxides insularis* and *P. pinus*, resp., are to all appearances developed over the whole island. The stage reaches its greatest thickness in Northern and Central Öland.

WESTERGÅRD (1946, p. 11) states the thickness of the stage in Central Öland to be 43 m, a former estimation of 57 m (1936), which was based on an unpublished percussion drill boring S of Borgholm, being admittedly too high. The trilobite-bearing part of the insularis zone at Mossberga measures 18 m and at Borgholm, where an upper part may be missing, 11 m. The pinus zone attains at least 6 m at Mossberga. If we compare the development in Central Öland with that in Northern Öland (trilobite bearing insularis about 7 m and pinus zone about 10 m), we find that the oelandicus shale as a whole has a uniform thickness but that the components vary to some extent. The trilobite-bearing part of the insularis zone does not seem to be so well developed in the north. The fauna in Northern Öland is still rich in individuals but contains fewer species, compared with Central Öland. The delimitation of the zones is thus rendered difficult. The *Acrothele granulata* conglomerate developed on the boundary between the oelandicus and paradoxissimus stages in Central and Southern Öland is missing in the Bödahamn core.

The paradoxissimus stage, which in the neighbourhood of Borgholm attains about 24 m, wedges out towards the north. Still present at Horns Udde on the west coast, it has not been found with certainty in the Bödahamn core on the east. At the northern point WESTERGÅRD (1946, p. 14) has found some few boulders of paradoxissimus sandstone though without fossils, but at a greater distance to the north it seems to have disappeared and the oelandicus stage lies in contact with the Ordovician basal conglomerate (ANDERSSON 1896).

<table>
<tr><th colspan="2"></th><th>Mossberga Öl.</th><th>Bödahamn Öl.</th><th>Visby Gtl.</th><th>Tornby Ög.</th></tr>
<tr><td rowspan="2">Trilobite-bearing</td><td>Pinus zone</td><td>6</td><td>10 (7)</td><td rowspan="2">3.5[1]</td><td>2.5</td></tr>
<tr><td rowspan="2">Insularis zone</td><td>18</td><td>7 (10)</td><td></td></tr>
<tr><td>Brachiopod-bearing</td><td>17</td><td>24</td><td>31.5</td><td>4[1]</td></tr>
<tr><td colspan="2">Total thickness of oelandicus stage</td><td>41</td><td>41</td><td>35</td><td>6.5</td></tr>
</table>

Fig. 4. Thickness of the oelandicus stage in Öland, Gotland and Östergötland.

In Gotland the higher parts of the Middle Cambrian are missing. Only the oelandicus stage is found. The fauna is exceedingly poor both in individuals and species. No species restricted to the one zone or the other has been found. The rock is essentially a sandy shale in the Visby core, and a sandstone in the File Haidar core. In the Visby core (HEDSTRÖM 1923, *cf.* also WESTERGÅRD 1929, p. 17 ff. and WESTERGÅRD in THORSLUND and W. 1938, p. 20, 21) the lower part, ca. 31 m, between levels 276.5 and ca. 245.0, is exclusively brachiopod-bearing while the upper

[1] Zone uncertain.

part, ca. 3.5 m, between levels 245.0 and 241.6, has yielded also trilobites, *Paradoxides* sp. of the *oelandicus* group and *Ellipsocephalus polytomus* (cf. WESTERGÅRD 1939, pp. 42, 45). This change in the character of the fauna resembles very much the conditions in Öland (Bödahamn level 59.75, Borgholm ca. 28, and Mossberga 14.5) and Östergötland (Tornby level 33). The fossils do not give any clues to the exact age of the faunal change. There are two ways of interpreting it.

Either the faunal change at level ca. 245 m in the Visby core is approximately synchronous with the indicated level in the Öland cores but not with the one in Östergötland, which is admittedly younger and points to some important change in the hydrography of the oelandicus sea. For this speaks the fact that these core profiles lie relatively close to each other and on the whole agree more with each other than with the thinned-out sequence in Östergötland.

Or the faunal change indicates a change of facies which gradually proceeds from Central Öland to the north. For this might speak that the brachiopod-bearing part of the insularis zone is increasing in thickness towards the NE, while the trilobite-bearing one decreases (compare table fig. 4). On the other hand the northeastern sequences are also more sandy.

The present author is (in agreement with WESTERGÅRD 1929, p. 18) most inclined to accept the former interpretation.

In the File Haidar core the only 4 specimens of *Ellipsocephalus polytomus* are scattered through the core and provide no means for a closer correlation.

If we continue to Estonia we find that the whole Middle Cambrian is absent.

In conformity with the development on Öland the lower strata of the oelandicus stage in Östergötland (WESTERGÅRD 1940, 1944) are very sandy and have yielded only brachiopods (*Acrothele granulata*, *Acrotreta* and *Lingulella* etc.). The upper strata generally consist of grey shale and, locally, some alum shale. Their fauna, which includes also trilobites, points to the zone of *Paradoxides pinus*. The stage is 6 m thick.

The oelandicus stage of Närke agrees well with that of Östergötland. The thickness varies between 15 and 7 m.

In Västergötland the oelandicus stage is absent or at least very feebly developed, and the same seems to be the case in Scania and Bornholm. Both in Västergötland and in Scania some strata without fossils of sufficiently stratigraphic value might be remnants of a sedimentation during the oelandicus age. But if so the extension of the oelandicus sea over these areas was probably not of very long duration.

It is not quite clear whether the oelandicus stage or the Middle Cambrian is at all represented in the North Baltic area (cf. WESTERGÅRD 1946, p. 17).

Summary of development during the earlier parts of the Middle Cambrian

The oelandicus stage is best and most completely developed in Öland. To the east it extends below Gotland but does not reach Estonia. To the north the sea possibly reached the North Baltic area but indications of sedimentation during the Middle Cambrian are very few and uncertain here. To the north-west Östergötland and Närke were inundated but apparently not till the time of the *P. pinus* zone or possibly late in the time of the *P. insularis* zone. The basal brachiopod-bearing strata of Östergötland are rather like the similarly developed basal strata of Öland. Probably they were deposited under similar lithologic conditions, those of Östergötland being somewhat later. Neither Dalarna, Västergötland, Scania nor Bornholm were reached.

Direct connections with the area of the Caledonian geosyncline probably did not exist during this age. The apparent lack of strata of the oelandicus stage in Västergötland and in the southern part of the Oslo area indicates a threshold at that time. The connections probably traversed Northern or Middle Germany. The thick cover of younger deposits does not permit a confirmation in northernmost Germany. In Poland a *P. oelandicus*-bearing fauna is reported from the Swiety Krzyz Mountains (SAMSONOWICZ 1920). As during the Lower Cambrian close connections appear to have existed with the Baltic area. The Middle Cambrian of Nieder-Lausitz encountered in borings at Dobrilugk (PICARD and GOTHAN 1931), on the other hand, is a northern extension of the Bohemian sea and was probably separated from the Baltic-Polonian sea by a landbarrier (cf. HANSEN 1945, pp. 51—62 where the palaeogeography of Northern Europe during the Middle and Upper Cambrian is discussed).

At the end of the oelandicus age the sea generally moved to the west and southwest. In the paradoxissimus age the main part of the present Baltic sea was land and Central and Southern Sweden was sea. It seems as if a slight tilting to the west of the Baltic shield had taken place. The fluctuations of the sea-level on the shore E and NE of Öland are remarkably well shown along the west coast of Öland (HADDING 1932, p. 12). The same thinning out of the sequence may be traced in a west to east direction in Östergötland (WESTERGÅRD 1940, pp. 27, 28). Bödahamn was reached by at least one oscillation and to judge from the conditions at Horns Udde this happened in the *Agnostus pisiformis* phase. There were probably more oscillations which reached Northern Öland and even farther, but on account of the very even surface but little sediment was brought in circulation, and thus only a thin conglomerate at the base of the Ordovician bears witness of the fluctuations of the sea during Middle and Upper Cambrian.

III. Basal Ordovician

At the beginning of the Ordovician the sea again generally encroached upon the Baltic area. Both in Southern Öland and in Scania the stratal sequence is fairly complete. [See also the account of the Fågelsång boring by HEDE 1951. The limited number of fossils common for this core and that of Bödahamn (*Bröggeria salteri*, *Acrotreta* spp. and scolecodonts) does only allow a tentative correlation between the Ceratopyge shale of Bödahamn and the Ceratopyge shale and the *Ceratiocaris*? *scanica* beds of Fågelsång.] According to WESTERGÅRD (1947, p. 6) the Ordovician alum shales on Öland, Dictyonema shale and Ceratopyge shale, decrease in a north-westerly to westerly direction. The older zones disappear successively. In Northern Öland only the youngest subzone of the Dictyonema shale has been definitely established, and it only occupies a small basal part of the shale. The greater part of the shale consists of Ceratopyge shale (up to 1.4 m). With these observations as a base WESTERGÅRD holds the view that the transgression of the oldest Ordovician sea went in a north-westerly or westerly direction towards a mainland not far west of Öland (1947, p. 10). Strength is added to this by the fact that the Bödahamn core on the east coast pierced 1.7 m of Ceratopyge shale. No trace, however, was to be found of the Dictyonema shale.

In Northern Öland, from Borgholm to the north, the Ordovician is initiated by the Obolus conglomerate. It is interpreted as a shore facies of Dictyonema age. In northernmost Öland the Obolus conglomerate cannot be readily distinguished from the various conglomerates of Middle and Upper Cambrian age. At Horns Udde both *Paradoxides paradoxissimus*, *Lejopyge laevigata* and *Agnostus pisiformis* are found in this conglomerate. In the limited rock volume consisting of conglomerate in the Bödahamn core no fossils occur, but sandstone and stinkstone show conditions similar to those at Horns Udde.

Basal Ordovician is not present under Gotland, but if we proceed to Estonia we find *Obolus*- and *Dictyonema*-bearing strata well developed (RÜGER 1935). In Östergötland *Obolus* has not been found, but WIMAN (1903 b) interpreted a sandstone at the base of the Dictyonema shale as an equivalent to *Obolus*-bearing strata in other areas. True Obolus conglomerate is found in Dalarna and the North Baltic area. At least in the latter area it is definitely contemporaneous with the conglomerate on Northern Öland, both underlying the Ceratopyge shale.

At the end of the Cambrian the greater part of the Baltic shield north of southernmost Öland and east of Kinnekulle, Västergötland, was lifted above the sea. Some parts of it, Gotland and North and East Baltic areas, had been so for a long time. At the beginning of the Ordovician the sea invaded Southern Öland, Östergötland, Southern Falbygden in Västergötland, and the East Baltic area, where the zone of *Dictyonema flabelliforme,* or at least its lower part, is developed. Later on, the whole of Öland and the North Baltic area were reached. Gotland and the areas SE of it were still land and remained so for a considerable time (THORSLUND and WESTERGÅRD 1937, KRAUS 1937). The Dictyonema shale of Östergötland wedges out to the east. Närke shows no sedimentation contemporaneous with the Dictyonema shale and in both areas the Ceratopyge limestone is feebly developed or absent. Thus the sea connecting the two areas in which Ceratopyge shale is preserved, *viz.* Northern Öland and the North Baltic area, was probably not very wide or deep nor on the whole stable, but geological data from the northern part of the Baltic sea are still very scanty. A deep boring at *e.g.* Gotska Sandön would help much in elucidating the palaeogeography of the Cambrian and Ordovician and especially of the strata near the boundary of these systems.

Zusammenfassung

Der Verfasser beschreibt Paläontologie und Stratigraphie des Kambriums und untersten Ordoviziums in einer Bohrung bei Bödahamn, nördliches Öland, Schweden. Das Urgebirge wurde in einer Tiefe von 162.15 m erreicht. Darüber folgt Unterkambrium; zuerst nur mit Grabspuren, bei 122.5 mit *Discinella holsti* und bei 115.0—89.6 mit *Volborthella tenuis* und *V. conica.* Das Profil zeigt gute Vergleichspunkte mit der Bohrung bei Borgholm (WESTERGÅRD 1929) auf Öland und Bohrungen bei Visby (HEDSTRÖM 1923) und File Haidar (THORSLUND und WESTERGÅRD 1938) auf Gotland. Das Unterkambrium ist von dem Mittelkambrium durch ein Konglomerat bei 84.11 getrennt. Das Mittelkambrium ist zuerst ausschliesslich Brachiopoden und Foraminiferen führend, bei 59.75 kommen auch andere Fossilien, hauptsächlich Trilobiten, hinzu. Es ist die Ölandicus-Stufe mit ihren beiden Zonen mit *Paradoxides insularis* bzw. *P. pinus.* Die Fauna enthält weniger Arten als auf Mittelöland (WESTERGÅRD 1936), ist aber sehr individuenreich. Die höchsten Schichten scheinen einen Übergang zur Paradoxissimus-Stufe zu bilden. Eine sandschalige Foraminifere wird beschrieben.

Das basale Ordovizium beginnt bei 40.90—40.88 mit dem Obolus-Konglomerat. Darüber folgt Ceratopyge-Schiefer bis 39.15. Es wird gezeigt, dass *Acrotreta conula* WALCOTT auf dieses Niveau beschränkt ist.

References

G. F. F. = Geologiska föreningens i Stockholm förhandlingar, Stockholm.
K. V. A. = Kungl. vetenskapsakademien, Stockholm.
L. U. Å. = Lunds universitets årsskrift. Ny följd. Avd. 2, Lund.
S. G. U. = Sveriges geologiska undersökning, Stockholm.

ANDERSSON, J. G., 1896. Über cambrische und silurische phosphoritführende Gesteine aus Schweden. — Bull. Geol. inst. Upsala, Vol. II, Part 2. 1895.

BARRANDE, J., 1852. Système Silurien du Centre de la Bohême. Vol. I. Prague.

CZARNOCKI, J., 1927. Le cambrien et la faune cambrienne de la partie moyenne du Massif de Swiety Krzyz (Ste Croix). — C. R. XIV Congrès géol. internat. 1926. Madrid.

GAVELIN, A., 1909. Om underkambriska sandstensgångar vid västra stranden af Vänern. — S. G. U., Ser. C, N:o 217.

HADDING, A., 1927. The pre-Quaternary sedimentary rocks of Sweden. II. — L. U. Å., Bd 23, N:o 5.

——, 1932. Same. IV. — L. U. Å., Bd 28, N:o 2.

HANSEN, K., 1937. Sammenlignende Studier over Kambriet i Skåne og paa Bornholm. I. Nedre Kambrium. — Medd. fra Dansk geol. Forening, Bd 9, H. 2. København.

——, 1945. The Middle and Upper Cambrian sedimentary rocks of Bornholm. — Danmarks geol. Unders. II. Række. N:o 72. København.

HEDE, J. E., 1951. Boring through Middle Ordovician—Upper Cambrian strata in the Fågelsång district, Scania (Sweden). 1. Succession encountered in the boring. — L. U. Å., Bd 46, N:o 7.

HEDSTRÖM, H., 1923. Remarks on some fossils from the diamond boring at the Visby cement factory. — S. G. U., Ser. C, N:o 314.

HOLM, G., 1882. Om de vigtigaste resultaten från en sommaren 1882 utförd geologisk-palaeontologisk resa på Öland. — Övers. K. V. A. Förh. 1882, N:o 7.

HOLST, N. O., 1893. Bidrag till kännedomen om lagerföljden inom den kambriska sandstenen. — S. G. U., Ser. C, N:o 130.

HOWELL, B. F., 1943. Burrows of *Skolithos* and *Planolites* in the Cambrian Hardyston Sandstone at Reading, Pennsylvania. — Publ. Wagner free institute of science, Vol. 3. Philadelphia.

KRAUS, E., 1937. Kambrium und Silur in der Tiefbohrung von Dünaburg (Daugavpils). — Jahrb. Preuss. geol. Landesanst. 1937, Bd 58. Berlin.

METZGER, A., 1927. Zur Kenntnis des nordbaltischen Kambro-Silurs auf Åland und im südwestlichen Küstengebiet Finnlands. — Fennia, Bd 47, N:o 12. Helsingfors.

MICKWITZ, A., 1896. Über die Brachiopodengattung *Obolus* EICHWALD. — Mém. Acad. imp. d. sciences de St. Pétersbourg, Ser. 8, Vol. 4, N:o 2. St.-Pétersbourg.

MILTHERS, V., 1930. Bornholms Geologi. — Danmarks geol. Unders. V. Række, N:o 1. København.

MOBERG, J. C., 1892. Om en nyupptäckt fauna i block af kambrisk sandsten insamlade af Dr. N. O. Holst. — G. F. F., Bd 14, H. 2.

MOBERG, J. C. och SEGERBERG, C. O., 1906. Bidrag till kännedomen om Ceratopygeregionen med särskild hänsyn till dess utveckling i Fogelsångstrakten. — L. U. Å., Bd 2, N:o 7.

NEKRASSOFF, B. A., 1938. Eophyton, Ischora ("Fucoiden") und Obolensandsteine des Leningrader Gebietes. [In Russian language; abstract in German.] — Bulletin de la société des naturalistes de Moscou. N. S. T. XLVI. Section geol. T. XVI (2). Moskva-Leningrad.

ÖPIK, A., 1933. Über *Scolithus* aus Estland. — Acta et Comm. Univ. Tartuensis (Dorpatensis), A XXIV. 3. Tartu 1933.

PICARD, E. und GOTHAN, W., 1931. Die wissenschaftlichen Ergebnisse der staatlichen Tiefbohrungen bei Dobrilugk N.-L., 1927 bis 1931. — Jahrb. Halleschen Verbundes etc. Bd X. N. F. Halle a. Saale.

PLUMMER, H. J., 1945. Smaller foraminifera in the Marble Falls, Smithwick, and lower Strawn strata around the Llano uplift in Texas. — The university of Texas publication 4401.

POULSEN, CHR., 1942. Nogle hidtil ukente Fossiler fra Bornholms Exsulanskalk. — Medd. fra Dansk geol. Forening, Bd 10, H. 2. København.

RICHTER, R., 1942. Die Einkippungsregel. — Senckenbergiana, Bd 25. Frankfurt a. M.

RÜGER, L., 1923. Paläogeographische Untersuchungen im baltischen Cambrium unter Berücksichtigung Schwedens. Ein Beitrag zur Paläogeographie des Baltischen Schildes und Fennoskandias. — Centralblatt f. Min. etc., Jahrg. 1923. Stuttgart.

——, 1934. Die baltischen Länder (Estland, Lettland und Litauen). — Handb. d. reg. Geol., Bd IV, H. 4. Heidelberg.

SAMSONOWICZ, J., 1920. Sur la stratigraphie du Cambrien et de l'Ordovicien dans la partie orientale des montagnes de Swiety Krzyz (Sainte Croix), Pologne centrale. (Résumé in French.) — Bull. Serv. géol. Pologne Vol. I, Livr. 1. Varsovie.

SCHINDEWOLF, O. H., 1934. Bau und systematische Stellung der Gattung *Volborthella* SCHM. — Palaeont. Zeitschr., Bd 16, H. 3/4. Berlin.

STRAND, T., 1929. The Cambrian beds of the Mjösen district in Norway. — Norsk geol. tidsskr., Bd 10. Oslo.

THORSLUND, P. and WESTERGÅRD, A. H., 1938. Deep boring through the Cambro-Silurian at File Haidar, Gotland. — S. G. U., Ser. C, N:o 415.

TULLBERG, S. A., 1882. Geologiska resor på Öland. — S. G. U., Ser. C, N:o 53.

WALCOTT, C. D., 1912. Cambrian brachiopoda. — Monographs of the United States geol. survey, Vol. LI. Washington.

WESTERGÅRD, A. H., 1909. Studier öfver Dictyograptusskiffern och dess gränslager med särskild hänsyn till i Skåne förekommande bildningar. — L. U. Å., Bd 5, N:o 3.

——, 1929. A deep boring through Middle and Lower Cambrian strata at Borgholm, Isle of Öland. — S. G. U., Ser. C, N:o 355.

——, 1931. *Diplocraterion, Monocraterion,* and *Scolithus* from the Lower Cambrian of Sweden. — S. G. U., Ser. C, N:o 372.

——, 1936. *Paradoxides oelandicus* beds of Öland with the account of a diamond boring through the Cambrian at Mossberga. — S. G. U., Ser. C, N:o 394.

——, 1939. Den kambro-ordoviciska lagerserien. In Beskrivning till kartbladet Gävle by R. SANDEGREN, B. ASKLUND and A. H. WESTERGÅRD. — S. G. U., Ser. Aa, N:o 178.

——, 1940. Nya djupborrningar genom äldsta ordovicium och kambrium i Östergötland och Närke. Summary: New deep borings through the Lowest Ordovician and Cambrian of Östergötland and Närke (Sweden). — S. G. U., Ser. C, N:o 437.

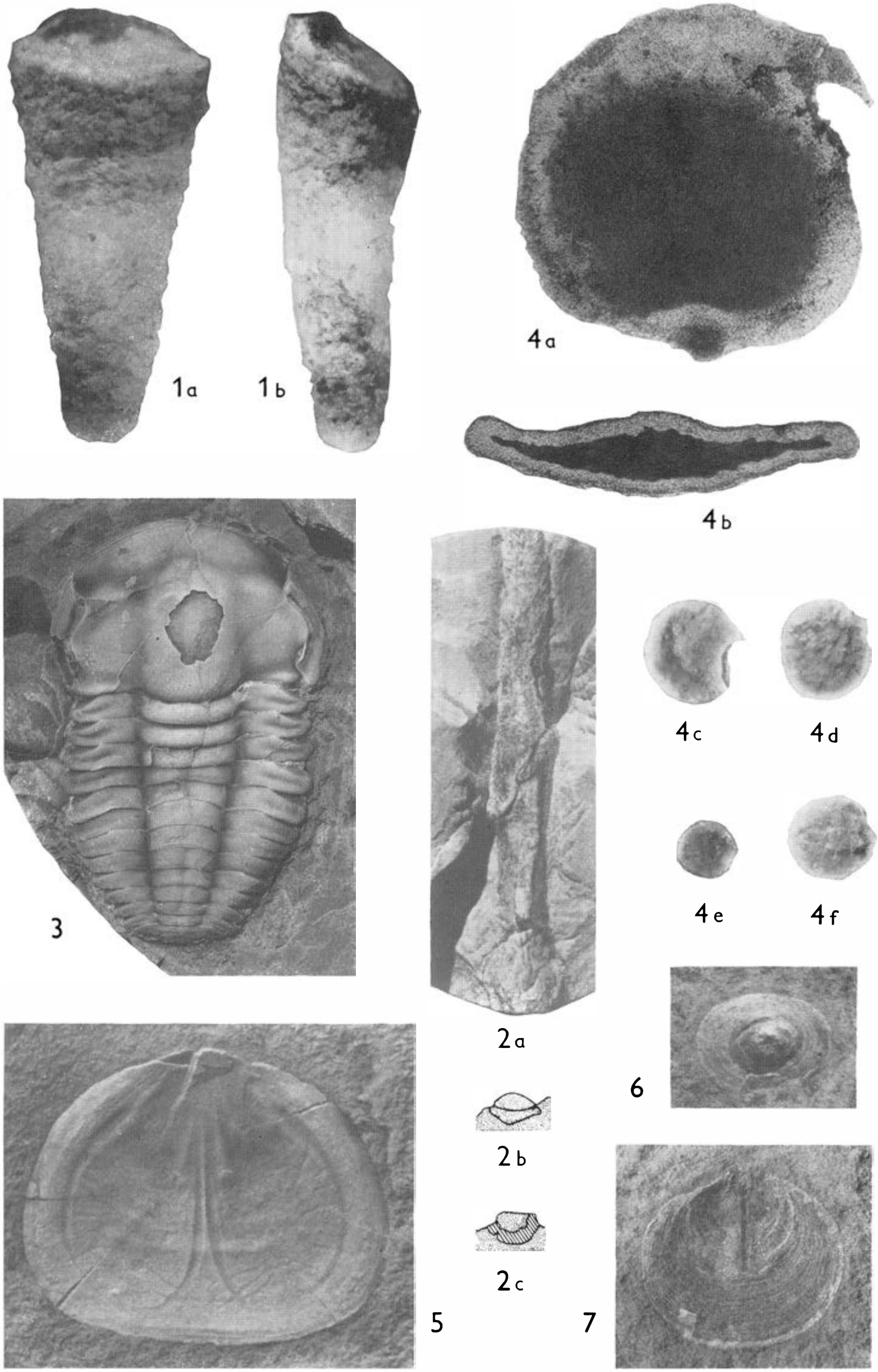
WESTERGÅRD, A. H., 1944. Borrningar genom alunskifferlagret på Öland och i Östergötland 1943. Summary: Borings through the alum shales of Öland and Östergötland made in 1943. — S. G. U., Ser. C, N:o 463.
—, 1946. Agnostidea of the Middle Cambrian of Sweden. — S. G. U., Ser. C, N:o 477.
—, 1947. Nya data rörande alunskifferlagret på Öland. English summary. — S. G. U., Ser. C, N:o 483.
WIMAN, C., 1903 a. Studien über das nordbaltische Silurgebiet. I. — Bull. Geol. inst. Upsala, Vol. VI, Part 1. 1902. Uppsala.
—, 1903 b. Ett nytt fynd av Obolussandsten i Östergötland. — G. F. F., Bd 25, H. 6.

PLATE I

Explanation of plate

All specimens except fig. 5 are from the core and they all belong to the Museum of the Palaeontological Institute of Uppsala. Figs. 3, 5, 6 and 7 whitened. (N. Hjort phot., E. Ståhl and A. Nilsson del. et ret.)

1 a. *Volborthella conica* SCHINDEWOLF. Somewhat compressed specimen. Level 115.0 m (Lower Cambrian). 10 ×.
1 b. Same specimen. From the side. 10 ×.
2 a. Problematicum. Level 86.4 m (Lower Cambrian). Nat. size.
2 b. Same specimen. Drawing of upper end (cf. fig. 2 a). Fossil hatched, rock dotted.
2 c. Same specimen. Drawing of lower end (cf. fig. 2 a).
3. *Ellipsocephalus* cf. *polytomus* LINNARSSON. Complete specimen except left loose cheek. Level 56.91 m (Oelandicus shale). 2 ×.
4 a. Arenaceous foraminifer. Approximately horizontal section, upper margin thinning out. Siliceous test spotted, filling of sediment dark. Level 61.0 m (Oelandicus shale). 110 ×.
4 b. Ditto. Vertical section. Level 61.0 m. 110 ×.
4 c—f. Ditto. 4 c showing in its upper left a low protuberance, possibly aperture. Level 75.0 m (Oelandicus shale). 20 ×.
5. *Bröggeria salteri* (HOLL). Dorsal valve. Djupvikshamn, Föra parish, Öland (Ceratopyge shale). 10 ×.
6. *Acrotreta conula* WALCOTT. Ventral valve. Level 40.18 m (Ceratopyge shale). 10 ×.
7. *Acrotreta conula* WALCOTT. Dorsal valve. Level 40.18 m. 10 ×.


1a
1b
4a
4b
3
4c
4d
4e
4f
2a
6
2b
2c
5
7