13. Deep boring through Ordovician and Silurian Strata at Kinnekulle, Vestergötland.

By

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with a preface by G. Säve-Söderbergh (†).

1. Preface.

The Cambrian, Ordovician, and Silurian sequence of strata in the small mountain of Kinnekulle in Vestergötland probably forms the most widely known of all Swedish geological profiles. It has attracted the interest of naturalists ever since the time of LINNÆUS (»Wästgötaresa» 1747) and was made the classical type profile of the Scandinavian Cambro-Silurian through the work of ANGELIN (1854).[1] Its main features are taught to every school-boy in Sweden and have been reproduced by text-books here and abroad. The mountain was made the object of a fine monograph by G. HOLM in 1901.[2]

All the time, however, it has been known to geologists that in certain respects Kinnekulle is not a most favourable object for geological studies. The sequence of strata is unusually complete and almost undisturbed tectonically. But the dense vegetation and the scarcity of exposures in

[1] ANGELIN, N. P., Palaeontologia Scandinavica. — Holmiae 1854 (2 Ed. 1878).

[2] HOLM, G. and MUNTHE, H., Kinnekulle. — S. G. U., Ser. C, N:r 172. Stockholm 1901.

great parts of the sequence, especially in those which consist of soft and easily weathering rocks, make it very difficult to piece together complete profiles of any considerable length.

The gaps in our real knowledge of the classical profile of Kinnekulle became clearly visible when the description and map sheet Aa 182 Lidköping (including Kinnekulle) was published by the Swedish Geological Survey in 1943. The description by A. H. WESTERGÅRD gives an excellent summary of what was known till then and clearly points out the lacunae. Thanks to the economic importance of the Upper and Middle Cambrian alum shales, the Survey had been allowed to carry out a deep boring (at Norra Skagen) extending from the base of the Chasmops Series (Middle Ordovician) down through the »Orthoceras limestone», the Tremadocian strata, the Upper and Middle Cambrian, to the top of the Lower Cambrian Sandstone. Consequently fairly complete data became available concerning all these lower parts of the sequence. But the higher parts were still quite fragmentarily known.

It now appeared both a duty to Swedish geology and a promising task for our Institute to try securing a fuller knowledge of the remaining upper part of the classical profile and thus make this not only widely known but also, as far as possible, well known. Clearly this could best be done by a deep boring, supplemented by more extensive collecting of fossils in existing exposures. Circumstances were at the moment especially favourable for such an undertaking: specialists were available, or already working at the stratigraphical divisions concerned: Mr B. WÆRN, fil. lic., working since several years on Lower Silurian strata (especially in Dalarna), Dr. P. THORSLUND, formerly at our Institute, now Keeper of the Museum of the Geological Survey, having done extensive work on the Chasmops Series in Jämtland and Dalarna etc., and Mr G. HENNINGSMOEN, Oslo, temporarily working in Uppsala and just starting out on a study of the Tretaspis Series. Accordingly it was entrusted to Mr WÆRN to carry out a planning of the work and estimation of costs; and on the basis of this an application was made for the necessary economic support from the so called Reserve Fund of the University of Uppsala. Thanks very largely to the active interest of the Rector of the University, Professor N. VON HOFSTEN, the sum of 7,000 Sw. crowns was granted to the Palaeontological Institute. The boring was carried out in the summer of 1944 by personnel and tools of the Swedish Diamond Rock Drill Company, under the scientific supervision of Mr WÆRN, partly assisted by Dr. THORSLUND and Mr HENNINGSMOEN. Permission to carry out the boring on the grounds of Råbäck manor was kindly granted by Baron W. KLINGSPOR; and the staff of his office gave much help in arranging transports etc.

The technical details of the boring are given below, in the Introduction, by Mr WÆRN. The resulting core was divided among the three specialists; the Chasmops Series being sent to Dr. THORSLUND in Stockholm, the

Tretaspis Series being worked out by Mr HENNINGSMOEN, partly in Uppsala, partly in Oslo, and the Silurian by Mr B. WÆRN in Uppsala. Each of them here describes his part of the core and is alone responsible for the data given and opinions expressed.

As far as possible, one half of the core was kept for further reference. This, and all the originals of figured fossils and rocks belong to the Palaeontological Institute, Uppsala.

Apart from its importance as a classical (and still useful) type profile, the sequence of Kinnekulle is of great interest in several other respects, stratigraphically as well as palaeogeographically. It is a well known general feature of the Swedish Ordovician and Silurian, that it often shows a difference between a shaly (mudstone) graptolite-bearing facies in the south (Scania) and west (Caledonians) and a shelly limestone facies, found more to the east and shown in extreme form still farther east, in Estonia. Evidently, before any palaeogeographical conclusions can be made about any one special period it is necessary to know precisely which shelly beds correspond to the graptolite zone or zones in question. The detailed correlation of the shelly sequence with the graptolite-bearing one, therefore, is one of the major problems in Swedish stratigraphy.

Although the sequence of Kinnekulle is the type occurrence of several of our special Swedish limestone or trilobite-bearing shale divisions, whose correlation with the international graptolite zone succession has offered many difficulties, its geographical position far to the west, and the occurrence of certain divisions in typical graptolite-bearing facies make it in reality rather a transitional one between the two great facies types. It is therefore natural that a close investigation at Kinnekulle will be of great interest to this problem of correlation; and the boring has revealed the presence of important horizons with graptolites, earlier overlooked *i.a.* because they tend to occur in the more shaly, easily weathering and therefore mostly earthcovered parts of the profile, which now can be more completely studied in the core. The ensuing descriptions will show the results gained by the boring in this and other respects.

In conclusion my pleasant duty is to thank, on behalf of the Palaeontological Institute and the participating specialists, all those who, as mentioned above, made the boring possible and helped in the work: first and foremost the Rector of the University, Professor N. VON HOFSTEN, and other University authorities; Baron W. KLINGSPOR and his staff; and the authorities at the Geological Survey, who put their experience of deep boring at our disposal.

The Institute, and the collaborators of Mr WÆRN are much indebted to him for his self-sacrificing work in carrying out with untiring energy the detailed planning and daily supervision of the whole boring.

Palaeontological Institute, March 1948.

G. Säve-Söderbergh.

2. Introduction.

By

Bertil Wærn.

The site of the drill hole was a small piece of plain ground on the western slope of Kinnekulle, 25 m NE of the Kullatorp spring, Medelplana parish, province of Vestergötland, close to one of the roads which near the top of the mountain embrace its eastern, northern and western sides. By placing the boring in exposed rock it was possible to obtain core almost from the surface.

It would have been advantageous to place the boring at or immediately above the level where the sedimentary sequence is interrupted by intrusive diabase, but for practical reasons this was impossible. There remained but the alternative either to place the boring at an accessible water-supply on the diabase plane or at the one nearest below the diabase. In view of the uncertainty of finding a sufficiently large water-reservoir on the diabase surface and the comparatively high costs entailed by piercing 24 m of diabase, and, furthermore, as the sequence nearest below the diabase is fairly well exposed, it was decided to start the drilling at a lower level, and to establish the profile through the highest sedimentary beds by digging and by exploiting the road cuttings. I was engaged for some time on this work in the summer of 1942.

Thus the drilling began at the place mentioned above, 257.12 m above sea level, 6.24 m above the level of the Kullatorp spring, the highest spring level at Kinnekulle, at least of a size worth mentioning. Its capacity during the drilling was estimated at about 600 litres per hour.

By placing the boring somewhat higher than the spring level it was possible to start the drilling in the Retiolites beds, whereby the stratigraphically and petrographically interesting beds forming the boundary between the Retiolites and Rastrites beds were included in the core.

The boring was limited to a depth of 88.66 as already at this level it was possible to correlate, with sufficient certainty, the lowest beds with certain higher beds in the core of Norra Skagen 1941 (WESTERGÅRD 1943, p. 51). In that boring the sharp lithological change, earlier thought to denote the boundary between »Chasmops Shale» and »Orthoceras Limestone» (*cf.* THORSLUND, below, p. 359, whose level 6.6 m corresponds to WESTERGÅRD's level 9.4 m) was crossed at 174.0 m above sea level (9.4 m level in the N. Skagen core). In the Kullatorp boring approximately the same level was crossed at 172.1 m (85.00 m level in the Kullatorp core).

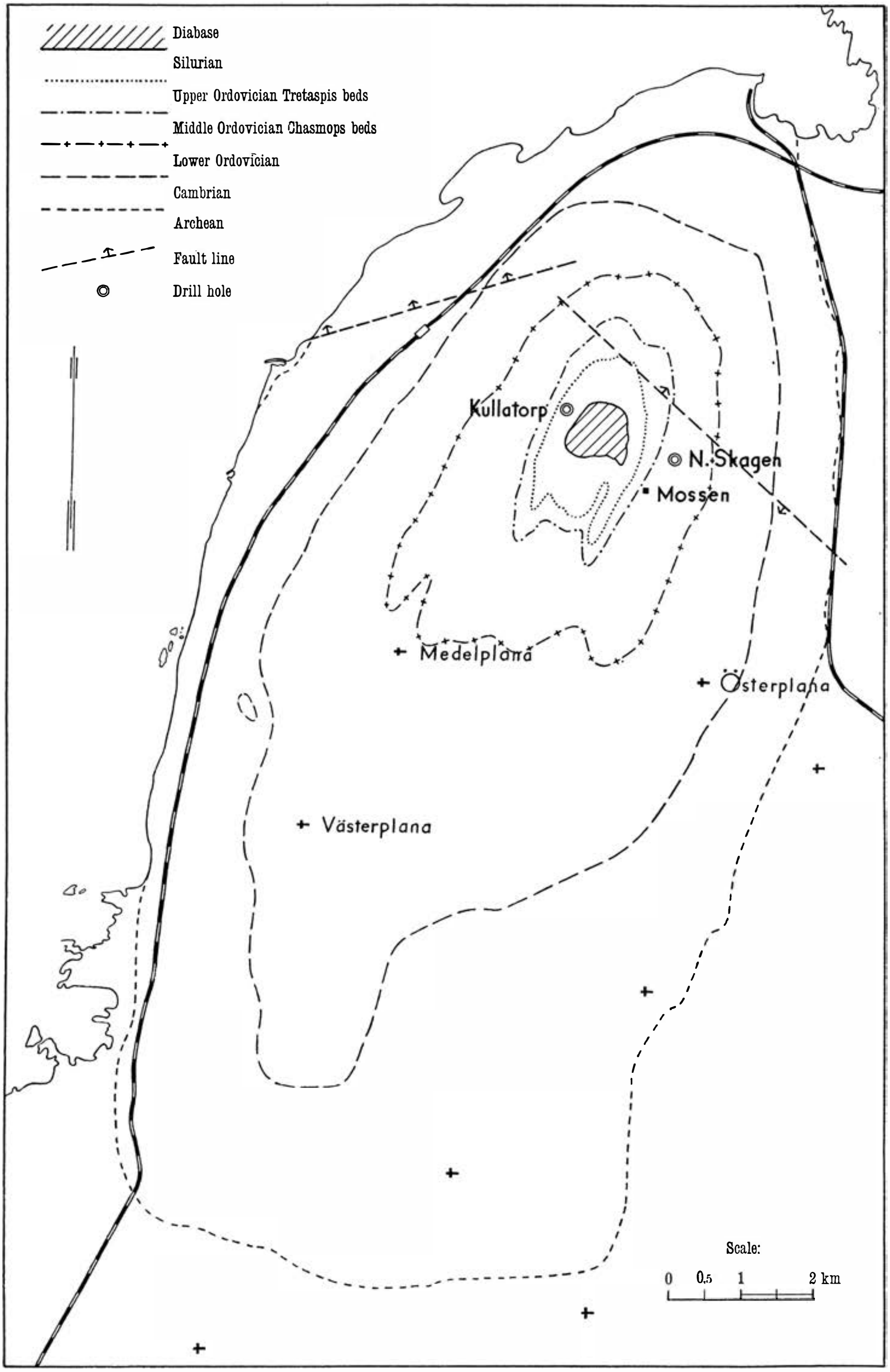

Fig. 1. Map of Kinnekulle, Vestergötland, showing the sites of the borings through Ordovician and Silurian.

According to HOLM (1901, p. 68) the beds in Kinnekulle dip towards NNW 0.23 m per 100 m, and this statement is thus confirmed by the above facts.

After completing all arrangements and erecting the derrick between May 30th and June 5th 1944, we began the drilling, which took till June 26th, whereupon the pulling down and loading was started and accomplished by June 29th. When no obstacles were encountered, about 6 m core could be pierced daily.

Diamond drilling was employed with a core diameter of 70 mm. Such a boring consumes much water flushing. As the Kullatorp spring could not supply all the quantities required (1000 litres per hour) steps were taken to collect the water which, mixed with boring mud, returned from the hole; after some clarifying in large barrels this water could be used again. The topmost metres of the rock contained many fissures, however, and at 6.25 the water disappeared completely. After cementing the hole the water could be regained. The rock was then more or less tight as far as 18.82—19.81, where a water-bearing level in the limestone diverted the water from the drill hole; also at 35.15, on the boundary between the basal limestone of the Dalmanitina beds and the topmost sandstone of the Tretaspis Series, the water disappeared again. The core had to be cemented at both these levels as well as at a certain level in the red Tretaspis Shale, but further down no cementation was done in order to regain the water which soon disappeared again. Therefore it can be said neither how many water-bearing levels there were encountered during the rest of the drilling nor their location. The decrease in the water-supply made it necessary to pump up water the whole time, which meant increased work with pumping. Owing to the limited water-supply the spring was often pumped dry during the drilling.

The drilling of the upper parts of the core was rendered rather difficult by the numerous fissures in the rock, especially by the vertical ones. The core was fairly crushed, and in order to facilitate its examination it had to be taken up in small portions only, *e.g.* 8 portions between 0.65—3.82. Lower down the core was in a somewhat better condition, though it was still crushed in some places and showed losses, though within reasonable limits: 10 % in the Rastrites beds and even less in the lower parts. The bentonite beds in the Chasmops Series were an exception, however, the losses in the core being considerable. The drilling itself in this sticky, heaving rock entailed certain difficulties, the water not always passing freely past the bit as the bentonite plugged up the space reamed by the diamonds. It was also technically difficult to do the drilling through the abrupt transition from soft bentonite to flint hard siliceous limestone. The lowest limestone produced 100 % core.

3. The Chasmops Series of the Kullatorp Core.

By

Per Thorslund

The Chasmops Series of Kinnekulle has hitherto been very incompletely known as it is mostly covered by Quaternary deposits, and only a couple of small outcrops of its upper part have been available for studies. Mainly owing to investigations made on boulders it has been possible to establish that there are, in the lower, never exposed half of the Series, beds of hard flinty limestone, less calcareous than those of gray or bluish gray limestone which have been suggested to form the top of the Series. The thickness has been estimated at 10 m at least.

On account of the limited possibilities of investigations the Chasmops Series of Kinnekulle, and of other Cambro-Silurian areas of Vestergötland as well, has not been subjected to a division into stratigraphical zones. Studies in some other districts demonstrate that the Series can be divided into two parts, each of them very likely corresponding to two graptolite zones. The lists of fossils published from Kinnekulle indicate that the Lower Chasmops Series is fairly complete from a stratigraphical point of view. The presence of the Upper Series has not been definitely established as it is connected with the validity of the statement by ANGELIN (1854, p. 9) that *Chasmops macroura* (Sjögren) occurs at Kinnekulle. LINNARSSON (1869, p. 33) has also recorded this species, though with a mark of interrogation, as found in boulders of Chasmops Limestone at Kinnekulle.

In the Kullatorp core the Chasmops Series includes the beds from 63.0 m to the bottom, 88.56 m, *i.e.* a thickness of 25.56 m. Lithologically it has a varying composition in different parts and therefore can be divided into the following portions.

62.96—63.08 m. Dark-gray, slightly argillaceous and glauconitic limestone with irregularly limited lenses of harder, bluish dark-gray, almost compact limestone, containing about 1% P_2O_5 (Pl. XXII, fig. 1). In the upper part of this bed the phosphatic limestone lenses form a layer rich in marcasite. Within and especially close above this layer the calcareous tests are quite white and porous as if they had been subjected to subaerial weathering — at all events there has been some sort of chemical decomposition and alteration.

This limestone bed is covered with black shale with a graptolite fauna belonging to the zone of *Climacograptus styloideus* of the Tretaspis Beds.

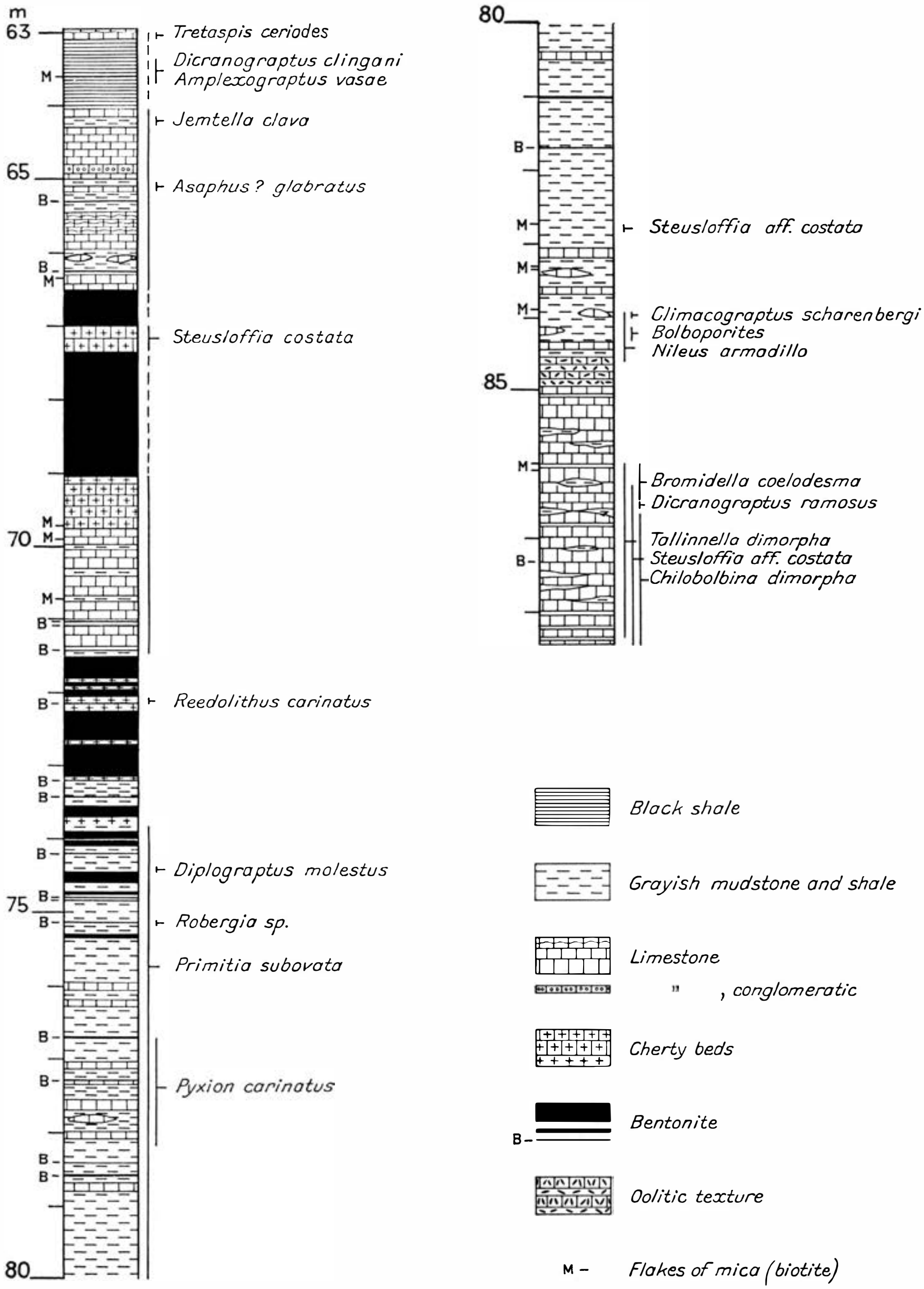

Diagram of the Chasmops series of the Kullatorp core.

The most basal part of this shale is calcareous and contains a shelly fauna, quite different from that of the limestone bed below, in the lower part of which *Tretaspis ceriodes* (Ang.) has been found together with *Euprimitia* aff. *locknensis* Thorsl., *Winchellatia* cf. *variolaris* (Bonn.) and a few species of *Conchoprimitia* and *Bothocypris*. Scattered valves of these ostracoda occur in the limestone close above the phosphatic layer in which they are associated with *Steusloffia* cf. *costata* (Linrs.) and fragments of very small, peculiar trilobites.

63.08—64.05 m. Chiefly black bituminiferous shale, towards the under- and overlying beds successively turning to grayish colour and becoming slightly calcareous. The black shale greatly resembles Upper Cambrian alum shale and like that it contains pyrite, but its calorimetric value is low. At about 63.60 m there is a conspicuous though thin, barely 1 mm thick layer containing sharp-edged grains of quartz and flakes of dark mica in a yellow brownish matrix.

This bed is fairly rich in graptolites and the following fossils were observed:—

Lonchodomas minutus n. sp.; *Primitia obesa* n. sp.; *Orbiculoidea? portlocki* (Gein.); *Dicranograptus clingani* Carr., *Climacograptus brevis* E. & W., *Diplograptus multidens* var. *compactus* (Lapw.), *Amplexograptus pulchellus* (Hdg.), *A. vasae* Tullb., *Corynoides curtus* Lapw.

64.05—65.43 m. Beds of gray to dark-gray limestone, compact to finely crystalline, and calcareous mudstone; mostly dark-gray mudstone in the lower third. Finely crystalline pyrite scattered throughout the whole length of the core portion, and zincblende at 64.10 m. An intraformational pebble conglomerate occurs between 64.81 and 64.90 m. The pebbles rounded or sub-rounded, occasionally indistinctly limited, consist of compact limestone, rarely of dark shale, and the limestone matrix is finely crystalline in the lower portion, coarser crystalline and glauconite-bearing in the upper one. A similar, more easily noticeable conglomerate (Pl. XXII, fig. 3), occurs at a corresponding stratigraphical level in a section at Mossen on the eastern slopes of Kinnekulle, 1.2 km SE of Kullatorp. At 65.29 m there is a very thin, about 1 mm thick layer, of dark bentonite clay and the underlying 4 cm are built up of very thin lenses of aragonite or calcite with interspaces of bentonitic or shaly material containing flakes of biotite and angular grains of quartz.

Except in small forms the tests of the fossils are mostly broken and fragmentary. The following fossils were collected:—

Jemtella clava Thorsl., *Lonchodomas* sp. (cf. p. 364), *Pharostoma* sp. (cf. p. 363), »*Odontopleura*» sp. (cf. p. 365), *Trinodus* sp., *Phillipsinella* cf. *parabola* (Barr.), *Platylichas* sp., *Remopleurides* sp., *Illaenus parvulus* Holm, *Asaphus? glabratus* (Ang.); *Steusloffia costata* (Linrs.), *Winchellatia variolaris* (Bonn.), *Winch. gunnari* n. sp., *Ulrichia* sp., *Biflabellum* sp., *Conchoprimitia* sp.; *Bothocypris* sp.; *Lepidocoleus* sp., and a few specimens of small brachiopods.

65.43—65.75 m. Three beds of limestone, each of them built up of a lower portion of mostly gray but partly dark, almost compact limestone, and an upper portion of darker, finely crystalline limestone with glauconite and with small lumps of dark or almost black phosphatic limestone (Pl. XXII, fig. 2). Pyrite present as concretions or as separate small crystals. The contact surface between the two portions is uneven, and the limestone close beneath it is distinctly darker than the main part of the lower portion. Fossils sparse. In the upper portion of the central bed there is an accumulation of graptolites, which — dissolved from the rock by hydrochloric acid — have proved to be very fragmentary preserved specimens of *Diplograptus* sp. and *Climacograptus* sp. Other fossils observed are *Remopleurides* sp., *Asaphus?* sp.; *Steusloffia costata* and *Winchellatia* sp.

65.75—66.50 m. Beds and lenses of gray almost compact limestone with slices of shaly matter, and grayish to dark shale, occasionally marly. In the dark shale between 66.25 m and 66.29 m there are plenty of flakes of biotite and also bentonitic material and lenses of aragonite or calcite in a thin core portion, which thus has a composition similar as that of the bed between 65.29 m and 65.34 m. In the limestone between 66.30 and 66.40 m there are also scattered flakes of biotite. The content of pyrite is almost as great as in the overlying beds. Fossils are relatively sparse and fragmentary:

Phillipsinella cf. *parabola*, *Remopleurides* sp.; *Steusloffia costata*, *Balticella oblonga* Thorsl., *Winchellatia variolaris*.

66.50—67.0 m. Mainly gray or pale-green bentonite, partly rich in biotite; the core is very incomplete and fragmentary. As the real sequence cannot be made out from it, reference is here made to the section at Mossen, described on pp. 350—352 and diagrammatically drawn in fig. 2.

67.0—67.35 m. Two beds of dark, hard, partly argillaceous limestone, towards the base increasingly flinty, containing about 68 % SiO_2. The fossils present are very difficult to clean out because of the hardness and splitting of the rock during clearing. On the upper surface, however, there are excellently preserved specimens of *Steusloffia costata.*

When weathered this rock gets a white crust, in which the fossils are easy to observe and to clean out. Samples of the corresponding beds in the Mossen section have yielded the following fauna, collected in the thin crust: *Trinodus* sp., *Remopleurides* n. sp. (aff. *latus* var. *kullsbergensis* Warburg), *Phillipsinella* cf. *parabola, Jemtella clava*, *Balticella oblonga*, and several other species of ostracoda, most of them belonging to the genus *Ctenentoma.*

67.35—69.05 m. Gray biotite-bearing bentonite with aragonite in the uppermost part. Core portion incomplete and fragmentary as is evident by a comparison with the sequence at Mossen.

69.05—71.50 m. Beds of gray to dark-gray, mainly finely crystalline limestone with mostly thin partings of dark-gray marly shale. In the upper portion, 0.7 m thick, the rock is very hard or flinty, the uppermost 10 cm mainly consisting of dark chert, containing 83.8 % SiO_2. Three very thin layers of light-gray bentonitic clay observed or traced at 71.03 m, 71.08 m and 71.42 m respectively. At the last level there are flakes of biotite, and such flakes also occur in the core portions 69.71—69.73 m, 69.87—69.90 m and 70.72—70.75 m. Close above 71.50 m there are plenty of striated slickensides and cone-like structures in the shale which is mixed with gray bentonitic material.

Other fossils than ostracoda are fragmentary or badly preserved. *Steusloffia costata* and *Euprimitia locknensis* are common and in addition there are found: *Chasmops* cf. *conicophthalmus* (Sars & Boeck), *Ampyx* sp., *Asaphus* sp., *Trinodus* sp.; *Haploprimitia* cf. *kogermanni* Öpik, *Winchellatia variolaris*, *Eurychilina suecica* n. sp.; *Bothocypris* sp.; *Sowerbyella* cf. *quinquecostata* (Sow.) sp.; *Climacograptus* cf. *kuckersianus* Wiman, *Climacograptus* sp. (cf. p. 369), ? *Dendrograptus* sp.

71.50—71.80 m. Bentonite, gray with a faint greenish tint. Very small black grains or lumps of bituminiferous matter are scattered in the bed.

71.80—71.83 m. Dark, hard and flinty shale or mudstone.

71.83—71.90 m. Gray bentonite with small flakes of biotite and grains or lumps of bituminiferous matter.

71.90—71.95 m. Dark, hard and flinty shale or mudstone, partly calcareous.

71.95—72.05 m. Gray bentonite with numerous dark grains or small lumps of bituminiferous matter and flakes of biotite.

72.05—72.25 m. Dark-gray, hard and flinty shale or mudstone with a probably thin layer of gray bentonite at the 72.15 m level, containing flakes of biotite. *Reedolithus carinatus* (Ang.).

72.25—73.15 m. The core sequence is very fragmentarily preserved, but seems to consist of bentonite beds with at least one intercalation, 5 cm thick, of dark flinty shale or mudstone. The bentonite above this layer is similar to that between 71.83 and 71.90 m, and the bentonite below it recalls that between 71.50 and 71.80 m. A thin layer of aragonite or calcite in the lower part of this core portion.

73.15—73.55 m. Argillaceous limestone or calcareous mudstone, dark or dark-gray, hard, in the uppermost part almost flinty. At 73.20 m a very thin layer or film of bentonitic clay in which was found a small fragmentary proximal part of *Climacograptus* sp.; abundant small flakes of biotite in the limestone close below. A very thin layer of gray bentonitic clay also at 73.43 m.

73.55—73.70 m. Greenish bentonite similar to that between 71.50 and 71.80 m. The uppermost portion of this layer is mixed with and grades into dark shaly matter, in which peculiar cone-structures and small cylinders or cones of calcite with striated surfaces are present. On horizontal surfaces of the dark shale there are also white flower-like precipitations of calcite or aragonite, each with a centre of a very small black grain of bituminiferous matter.

73.70—73.90 m. Limestone or mudstone similar to that between 73.15 and 73.55 m. *Corynoides* sp.; *Primitia subovata* n. sp., *Euprimitia* sp.; *Sowerbyella* sp.

73.90—74.10 m. Core portion fragmentary, mainly consisting of bentonite, probably with an intercalation of dark shale, about 2 cm thick. Above this layer grayish bentonite rich in biotite, below it pale-green bentonite.

74.10—74.45 m. Mainly dark, gray-spotted, hard, calcareous mudstone with a layer of pale-green bentonite, less than 1 cm thick, at 74.20 m. *Asaphus* cf. *ludibundus* Tqt, *Remopleurides* cf. *latus* Olin, *Cybele* sp., and *Sowerbyella* sp.

In the lower part of softer mudstone there are transverse slickensides, partly at least, covered with a film of calcite. In this part well preserved specimens of *Diplograptus molestus* n. nom. and *Primitia subovata* n. sp. were found.

74.45—74.60 m. Greenish dark-gray bentonite.

74.60—74.72 m. Dark, gray-spotted, hard, calcareous mudstone.

74.72—74.75 m. Pale-green bentonite.

74.75—75.30 m. Dark-gray marly shale or calcareous mudstone, in some parts with lighter gray spots, with thin layers of light-gray bentonitic clay at 74.78 m, 74.81 m and 75.14 m. At each of these levels the bentonitic clay upwards grades into dark mudstone traversed by slickensides of varying length and with abundant small flakes of biotite above the two upper levels. *Robergia* sp.; *Primitia subovata* n. sp.; *Sowerbyella* cf. *sericea* var. *resticta* Hdg; *Climacograptus* sp. (cf. p. 369).

75.30—75.34 m. Dark-gray bentonite.

75.34—78.58 m. Dark-gray calcareous mudstone with scattered beds or lenses of almost compact limestone. Thin bentonite layers at 76.71 (—76.73) m, 77.40 m and 78.42 m. The uppermost bentonite layer is 1—3 cm thick and dark-gray with a basal part which is lighter, faintly rust-coloured and harder. The layers at the other levels are very thin, each layer barely 1 cm thick, and mainly similar to the above basal part. Slickensides are present closely above those layers, and the mudstone contains grayish spots closely above 78.42 m. — Worm trails common, fossils sparse, fragmentary or badly preserved. *Asaphus* sp., *Stygina?* sp., *Nileus?* sp., *Ampyx* cf. *costatus* Ang., *Remopleurides* sp.; *Ulrichia reticulata* n. sp., *Pyxion carinatus* (Hadding), *P. kinnekullensis* n. sp.; *Nicolella* sp.; *Strophomena* sp.; *Climacograptus* sp., *Dicellograptus* sp.

78.58—78.61 m. Gray bentonite.

78.61—81.0 m. Dark-gray calcareous mudstone with gray, almost compact, argillaceous limestone between 78.69 and 78.81 m, and 80.41 and 80.50 m. Worm trails common (fig. 1), fossils very sparse. *Asaphus* sp., *Remopleurides* sp.; *Primitia subovata* n. sp.; *Strophomena* sp.; *Amplexograptus* sp.

81.0—81.04 m. Gray bentonite with flakes of biotite.

81.04—84.60 m. Dark-gray calcareous mudstone with beds or/and lenses of gray, compact, argillaceous limestone below 83.07 m. At 81.72 m a layer, less than 0.5 cm thick, of light-gray bentonite; flakes of biotite at

Fig. 1. Horizontal core section at the level 80.32 m. Worm trails in darkish mudstone. Nat. size.

82.76 m, 83.30 m, 83.35 m and 83.90 m, at the latter level also glauconite. Worm trails common from the top downwards to 83.7 m. Fossils sparse and mostly fragmentary: *Lonchodomas rostratus* (Sars), *Asaphus* sp., *Nileus armadillo* Dalm.; *Primitia subovata* n. sp., *Euprimitia* cf. *locknensis*, *Steusloffia* aff. *costata*, *Winchellatia* aff. *variolaris; Sowerbyella* cf. *quinquecostata* (M'Coy), *Sowerbyella* sp.; *Climacograptus scharenbergi* Lapw., *Dicellograptus* sp., *Leptograptus?* sp.; *Bolboporites*.

84.60—84.90 m. Darkish calcareous mudstone with lenses or layers of argillaceous limestone. Greenish iron oolites abundant, 0.2—1.5 mm in length. Fragments of trilobites and columns of pelmatozoan stems observed.

84.90—88.56 m. Beds of gray and dark-gray more or less argillaceous limestone intercalated with mostly thin irregular layers (or lenses) of dark-gray calcareous mudstone. Flakes of biotite at 86.0 m and between 86.14 and 86.16 m. At 87.35 m a very thin layer, less than 1 mm thick, of greenish gray bentonite with sparse small flakes of biotite; slickensides traverse the core portion close above this level.

Most of the fossils listed below occur in the mudstone layers: worm trails fairly common in the limestone below 86.50 m, *Remopleurides* sp., *Telephus* sp. (cf. p. 362), *Nileus armadillo*, *Pseudasaphus* sp., *Lonchodomas rostratus*, *Sphaerocoryphe* sp.; *Euprimitia* cf. *locknensis*, *Conchoprimitia* cf. *tolli integra* Öpik, *Winchellatia* aff. *variolaris*, *Chilobolbina dimorpha* n. sp., *Bromidella coelodesma* (Öpik), *Steusloffia* aff. *costata*, *Tallinnella dimorpha* Öpik; *Sowerbyella* sp. and some other small brachiopods; *Echinosphærites* sp.; *Climacograptus scharenbergi*, *Diplograptus* sp., *Orthograptus* cf. *calcaratus* var. *acutus* E. & W., *Dicranograptus ramosus* (Hall).

Lithology.

The most striking feature of the Kullatorp core sequence compared with that of known Chasmops Series in Central and Northern Sweden is the great content of argillaceous material. Pure limestone beds are almost absent, and the limestone is mainly concentrated in two parts of the core, a lowermost one — below the 85.0 m level — and an upper one — between the levels 64.05 m and 71.5 m —, the latter part including a central portion of intervening beds of altered volcanic materials, bentonite, together about 2.2 m thick. The sequence between these parts mainly consist of mudstone and shale, more or less calcareous, with very sparse intercalations of argillaceous limestone. The uppermost three metres of this sequence, however, contain numerous bentonite beds together about 1.9 m thick, and in the underlying part of it there are scattered thin bentonite layers.

Among the beds of argillaceous material those of bentonite hold a specific position as they are more numerous and display greater thickness in the Chasmops Series of Kinnekulle than elsewhere in the Cambro-Silurian strata in Scandinavia and in the areas round the Baltic. As pointed out above, however, the core sequence comprising these beds is very incomplete owing to circumstances connected with the boring and the bentonite beds themselves have suffered most. Thus the missing portions of the core have been assumed to have consisted of bentonite clay where such an interpretation has appeared reasonable. This reconstruction of the Kullatorp core section seems to represent the main features of the actual sequence of the Kinnekulle Chasmops Series as is evident by a comparison with a mined section at Mossen, a locality 1.2 km SE of Kullatorp. The Mossen section (fig. 2) was measured by Mr. H. RUDBERG in 1945, at that time Assistant Manager at the Hällekis Dept. of the Scanian Cement Co., and he has kindly placed a drawing of it to my disposal.

As is seen in both of these sections the thickest and most closely set bentonite beds are concentrated in two parts of the sequence, separated from each other by beds of almost the same thickness. The upper part mainly includes three different beds, the lowermost one probably being the

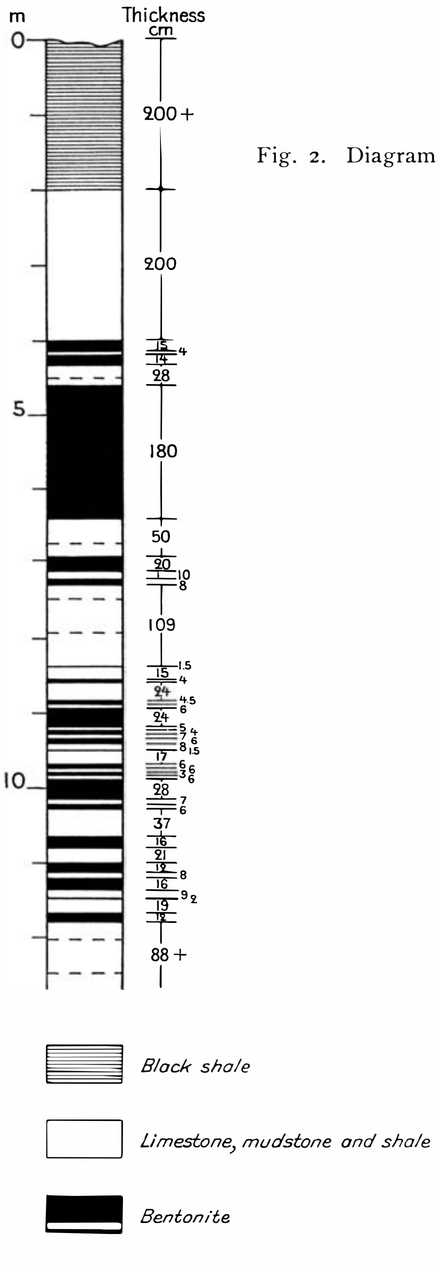

Fig. 2. Diagram of the section at Mossen.

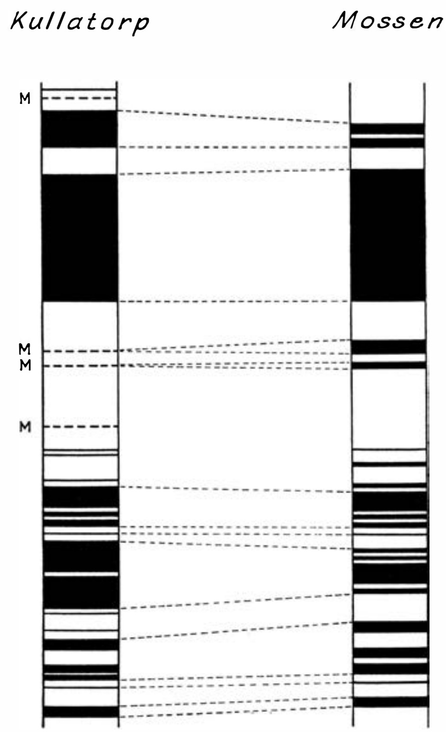

Fig. 3. Diagrams of the Kullatorp core and the Mossen section with tentative correlation of the bentonite beds (black). M = flakes of biotite in the intervening beds.

thickest Ordovician bentonite bed ever observed. Apparently it is a complex bed composed of several layers of somewhat different composition, as it at different levels varies in colour and in the content of biotite, the latter being very frequent in the lowermost and uppermost portions. The section at Mossen has revealed the mode of occurrence of aragonite in the upper part of this bed (see p. 356). In the lower half of it scattered though comparatively large lenses of pyrite have been observed in a section at Hoppet, a place about 0.5 km north of Mossen. As is seen at these localities the two upper beds, of about equal thickness, are separated by a thin layer of argillaceous limestone, the Kullatorp core being very incomplete in the corresponding part of the sequence.

A tentative correlation between the partly reconstructed sequence at Kullatorp and that measured at Mossen is shown in fig. 3. 0.5 m to 0.88 m below the thickest bentonite bed at the latter locality there are two layers of light-gray bentonite. At the corresponding levels of the Kullatorp core sequence the beds are rich in biotite, and no bentonite layer has been recognized. Thus, it seems reasonable to presume that some bentonite layers thin out to nothing in a comparatively short distance and that their occurrence at one locality may be traced by the presence of biotite-bearing beds at another. In the above instance an interpretation of the presence of biotite flakes as a result of redistribution from older deposits of bentonite seems unlikely; however, such a presumption might be valid in other cases.

The bentonite clays of the Kinnekulle Chasmops Series have so far not been subjected to a thorough examination as to their chemical and physical properties. What has been done in this and other respects shows, however, that they should be compared to the Ordovician bentonites of Eastern North America, described by several authors; for references see FOX and GRANT 1944. Further comments upon this subject will be published when the investigation of the Swedish materials is more complete. A sample, taken at the 68.90 m level of the Kullatorp core, has been analysed in the laboratory of the Geological Survey of Sweden (Table 1). For comparison this table also contains an analysis of bentonite from High Bridge, Kentucky. This analysis was published by NELSON (1922, p. 614), who states that the bentonite layer, at that place about 5 feet thick, occurs in the Middle Ordovician Lowville formation.

Table 1.

	1.	2.
SiO_2	55.99	54.56
TiO_2	0.14	
Al_2O_3	18.75	19.97
Fe_2O_3	0.76	0.69
FeO	1.85	1.28

	1.	2.
MnO	0.02	
CaO	2.30	1.08
MgO	3.92	5.08
K_2O	2.48	4 06
Na_2O	0.08	1.66
$H_2O < 110°$	6.90	6.62
$H_2O > 110°$	6.05	5.32
P_2O_5	0.05	0.15
CO_2	0.84	
S	nil	
F	0.02	0.13
BaO	nil	
	100.15	100.60

1. Bentonite from the 68.90 m level of the Kullatorp core, Kinnekulle, Sweden; A. M. BYSTRÖM, analyst.

2. Middle Ordovician bentonite from High Bridge, Kentucky; D. F. FARRAR, analyst.

Thin sections have been prepared from specimens of several bentonite beds. Dr. N. SUNDIUS, State Geologist of the Survey, has kindly examined some of the sections, and writes as follows:

»The microscopical investigations have been performed on four specimens taken from the 66.80 m, 68.73 m, 68.80 m and 71.97 m levels. The relations are in the main similar in them all, so they can be treated together.

The main part of the rock is made up of an intimately interwoven mass composed of one mineral with moderate birefringence and with a refraction somewhat lower than that of quartz. In the mass it is possible to distinguish lath-shaped sections, which display the highest birefringence (up to about 0.02), broader lath-shaped sections with lower birefringence and voluminous individuals, isotropic or with very low interference colours. In the lath-shaped sections γ is parallel with the elongation. In convergent light the voluminous sections with low interference colours show the picture of a negative acute bisectrice with small 2 V (about 10°—20°). These properties seem to agree with those of a montmorillonite poor in iron.

A fine pigment of non-transparent or brown translucent grains, possibly a Fe- or Ti-compound, is scattered in the clay-mineral. The latter may also contain minute sparse crystals or aggregates of a mineral with a high refraction and a fairly low birefringence. This mineral forms small, thick lamellae, idiomorphic and hexagonal with γ parallel to the direction of the lamellae. A weak greenish colour can be distinguished. The identification of this mineral is difficult. The refraction is higher than in kaolinite, and it does not agree with muscovite or illite. Possibly it is a member of the *chlorite group*. In any case the quantity present is inconsiderable.

In all the specimens studied sericite seems to be rare and in some instances it could not be found.

In the groundmass described there are always quite considerable quantities of *calcite*, evenly distributed as rather big individuals, and furthermore fragments or phenocrysts of *biotite*, *quartz*, *potash feldspar* and accessory grains of *apatite* and *zirkon*, the latter two minerals generally as idiomorphic and often fairly coarse crystals. In addition there are fragments of a very dense rock, which, judging from its appearance and refraction, seems to be a devitrified *quartz-porphyry*.

The biotite generally forms comparatively coarse laminæ of a deep brown colour, not seldom with idiomorphic hexagonal outlines on one side, more seldom on all sides of the laminæ. Generally it is fresh, but sometimes the laminæ are partly chloritized.

On the whole the quartz occurs as small, splintery grains but idiomorphic bipyramidal crystals can also be seen.

The feldspar, too, is generally fragmentary but thick tabular individuals after (010) are also found, though more seldom. The parallel extinction to the cleavage (010), the low refraction (distinctly lower than that of canada-balsam) and the low birefringence bespeak an orthoclase.

Considerable interest attaches to the rock fragments present. They are too dense to allow of a distinction of the mineral constituents. It is only possible to observe that they consist of low birefringent minerals and sometimes there is observed a thin lath-shaped development of part of the grains in the mineral mixture. The rough aspect of the surface, when the tube of the microscope is raised prompts the conclusion that it contains at least two colourless minerals, probably quartz and alkalifeldspar. In rare cases a micropoikilitic development is indicated by small quartz-sponges. The more highly refractive mineral has a refractive power similar to that of quartz, which causes the fragments to become visible with sharp boundaries when the tube of the microscope is raised. The rock fragments frequently have concave outlines.

The content of mineral and rock fragments in the slides studied varies somewhat, but generally they are sparse. Even when they are most abundant, they but rarely touch each other. The quantity of rock fragments is about equal to the whole quantity of mineral fragments.

No signs suggesting the earlier presence of ash fragments are discernible in the clay-mineral mass. If the original substratum from which the clay-mineral originated was a tuff, the texture of it must have been quite obliterated. On the other hand, the quartz-porphyry fragments would appear to be volcanic ash fragments in view of their frequently concave boundaries.

The mineral composition can only approximately be calculated from the analysis. In a thin section from the 68.80 level, quite neighbouring to that of the analysed specimen (68.90), the content of biotite and fragments of orthoclase, quartz and quartz-porphyry was estimated at about 5, 2—3, 4 and 10 per cent each. This makes the mineral composition:

Quartz (single fragments and in quartz-porphyry)	11.0
Orthoclase	7.2
Biotite	2.5
Calcite	1.9
Apatite	0.1
Bentonitic clay mineral	77.4

In this calculation the inconsiderable chlorite-like mineral was omitted. When the oxides of the clay mineral (77.4 per cent) are calculated on 100, its composition will be as follows:

SiO_2	50.8
Al_2O_3	22.8
Fe_2O_3	0.7
FeO	1.6
MgO	4.6
CaO	1.6
K_2O	1.4
H_2O	16.5.»

Most of the bentonite clays are gray, light-gray to darker gray, but some have a pale-green or almost green colour. The contrast with the »normal» beds below and above, which generally are much darker, is always distinct. The clays are stiff, readily fissile, and sometimes display a conchoidal cleavage. They have a waxy »feel» and lustre. Samples of them, immersed into water, always expand, sometimes comparatively slowly but sometimes rapidly and to several times their original volume; in the former case they disintegrate into a fluffy aggregate, in the latter they crack completely and break down into a very fine flour-like mass. In a few outcrops at Kinnekulle the clays have weathered into doughy masses, their colour has changed from gray or greenish to almost white or faintly yellow-brown.

Owing to its swelling property the bentonite clay material fills up fissures in the overlying strata and forms a compact bed, impermeable to water. As is seen at Kinnekulle and also in the other plateau mountains of the province Vestergötland there are many springs in the parts of the slopes where bentonite layers crop out or are hidden by thin coverings of loose deposits, most of the springs being located at the level of the uppermost clay beds of the Chasmops Series. In this connection it is of interest to note that the most conspicuous plateau of Kinnekulle is stratigraphically confined to that part of the Ordovician sequence, which follows close below the Chasmops beds containing bentonite beds.

The lower junction of the bentonite layers with the normal beds is always clear and sharply defined. The conditions are usually similar at the upper junction. However, when a bentonite layer is covered with dark shale, the shaly matter is sometimes intermingled with bentonitic material at and closely above the junction. This condition is probably due to slight movements of the waters over the sea-floor and to the slow rate of settlement of the finest bentonitic material.

The »normal» beds below the bentonite clays are frequently very hard or flinty, owing to their great content of silicious matter, and sometimes, *e.g.* above and below the thickest bentonite bed, they are clearly cherty. This is a common feature of a bed underlying bentonite, and it is recorded from several occurrences of Palaeozoic bentonite in America. According to WHITCOMB (1932) »the presence, in the rock immediately adjacent to the

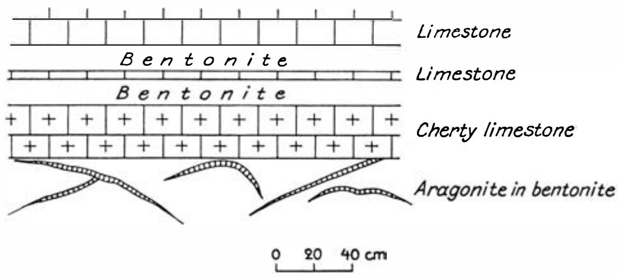

Fig. 4. Diagram showing the occurrence of aragonite in the uppermost part of thickest bentonite bed. Mossen.

bentonite bed, of a zone in which the lithology is distinctly different from the normal for the section» is one of the »methods which may be used in attempting to establish the identity of bentonite beds». And under this heading WHITCOMB writes (op. cit., p. 523): »When such a lithologic change is observed it may be of considerable value. One of the most common variations which is found associated with bentonite beds is the presence of chert in the underlying rock. The origin of this chert or silicified zone is open to debate, but the most probable cause is that the silica was leached from the overlying ash and redeposited in the underlying rocks or unconsolidated sediments.»

Aragonite forming thin, long, lense-like bodies, often somewhat curved, occurs in profuse quantities within the uppermost part of the thickest bentonite bed (fig. 4). It has been observed in the Kullatorp core and as well in exposures on the eastern and western slopes of Kinnekulle. Apparently the lense-like bodies are secondary, due to redeposition of calcium carbonate from the overlying calcareous beds in connection with the silicifying of these beds. A similar occurrence of aragonite has been observed in a sample of Middle Ordovician bentonitic clay from Bornholm (THORSLUND 1948) as well as at several levels of the Kullatorp core.

No fossils have been found in the bentonite beds, but on the basal surface or at the very base of such a bed there are often well preserved tests, sometimes occurring in abundance, indicating a sudden burial of the testaceous animals. This suggestion is also supported by the fact that the valves of the ostracoda are often lying in juxtaposition, which is very seldom the case in the rock below.

Sedimentation and Correlation.

As regards the upper boundary, the Chasmops Series of the Kinnekulle sequence is clearly defined in the core, as it can be drawn in the topmost portion of the partly phosphatic limestone bed above the black shale with *Dicranograptus clingani,* etc. The lithological conditions in this portion are suggestive of the existence of a break in the sedimentation after the deposition of the Chasmops Series. This is also supported by the fact that the dark, bedded limestone, almost 5 m thick, at the base of the Tretaspis Series in southwestern Mösseberg (abt. 42 km SSW of Kinnekulle) is quite missing in Kinnekulle as also in eastern Falbygden (cf. THORSLUND 1940, p. 124).

The investigation of the Kullatorp core has established the presence of beds of late Chasmops age, *i.e.* the Upper Chasmops Series, in the Kinnekulle sequence. The occurrence of *Tretaspis ceriodes* closely above the shale with *Dicranograptus clingani* corroborates the result gained by the present writer in Jemtland, that the zone of *Dicranograptus clingani* belongs to the Upper Chasmops Series.

Although there is nothing in the lithology of the core to support a suggestion of a real break in the sedimentation of the series investigated, there is, however, in the writer's opinion, evidence of changes of sea-level and of deposition in shallow waters. This evidence is the intraformational limestone conglomerate, the lithologically distinct change, that is repeated in the three consecutive limestone beds above the 65.75 m level, and possibly also the broken and fragmentary state of the fossils in the portion between 64.05 and 65.43 m.

The correlation of the Lower Chasmops Series with the graptolite zones of *Diplograptus molestus* and *Nemagraptus gracilis*, proposed by the writer in 1940 (p. 120), appears to be confirmed in the core sequence.[1]

No fossils found in the core appear to be useful for a correlation with the zone of *Amplexograptus vasae* which in Bornholm (HADDING 1915) and in Jemtland (THORSLUND 1940) comes next below the *Dicranograptus clingani* zone. However, some part of the core sequence between the shale with *Dicranogr. clingani* and that with *Diplogr. molestus* is very likely a correlative of the *Ampl. vasae* zone, and, according to the writer's suggestion, this part follows above the 65.75 m level. Thus, the boundary between the Upper and Lower Chasmops Series may tentatively be drawn at this level.

The fossils obtained in the lower Chasmops Series of the core are useful in attempting to establish the boundary between the portions of the sequence

[1] *Diplograptus molestus* n. nom. is a synonym of *Amplexograptus rugosus* (Hadding), as stated on page 370.

that correspond to the zones of *Nemagr. gracilis* and *Diplogr. molestus* resp. According to HADDING (1913, p. 68) *Pyxion carinatus* (Hadding) occurs in the zone of *Nemagr. gracilis* and the shale closely above this zone at Röstånga, Scania. This species is restricted to a certain portion of the Kullatorp core. Consequently, to judge from the occurrence of this species, the boundary between the two above zones is very likely situated within this portion or at least in the beds adjacent to it. This view is supported by the fossils occurring in the lower part of the core. As regards the graptolites, *Dicranograptus ramosus* (Hall) is a fairly common species in the *Nemagr. gracilis* zone and it has never been recorded from beds above this zone in Sweden. *Climacograptus scharenbergi* also occurs in that zone, but this species is of less stratigraphical importance as it has a great vertical distribution. At Kinnekulle it has also been found in boulders of flinty limestone, apparently from the zone of *Diplogr. molestus.* The ostracoda seem to be especially valuable for a correlation with strata in Estonia and Dalecarlia. According to ÖPIK (1937, pp. 25, 44) *Bromidella coelodesma* (= *Uhakiella coelodesma* Öpik) and *Tallinnella dimorpha* Öpik (cf. also JAANUSSON 1947, p. 48), which occur in typical specimens in the lowermost part of the core, are in Estonia restricted to the Uhaku formation. The latter species and *Steusloffia* aff. *costata* (Linrs.) have been recorded from the Flagkalk formation in Dalecarlia (JAANUSSON 1947, p. 46; see also this paper, p. 368).[1] The Uhaku has been considered equivalent in age, partly at least, with the *Nemagr. gracilis* zone (THORSLUND 1940; cf. JAANUSSON 1947), and the Flagkalk was correlated with this zone by TÖRNQUIST (1911) in his paper on the graptolite species *Diplogr.* (*Hallograptus*) *mucronatus* Hall var. *bimucronatus* Nich. and *Diplogr.* (*Glyptograptus*) *teretiusculus* (His.) var. from the Flagkalk in the Lake Siljan district.

Thus, the above statements involve substantial evidence for the correlation of a lower part of the Kullatorp core with the zone of *Nemagraptus gracilis.*

The above account and the data given by JAANUSSON (1945) in a paper on the Viru Series of Estonia[2] are summarized in Table 2, which presents a tentative correlation between the graptolite shale succession and the shelly facies represented by the Chasmops Series of Dalecarlia and the Esthonian

[1] The Flagkalk, built up of bedded argillaceous limestone with marly or shaly intercalations, constitutes the lowermost division of the Dalecarlian Chasmops Series (TÖRNQUIST 1883, p. 19), and has recently been described as the zone of *Illaenus crassicauda* (Wahl.) by Mr. V. JAANUSSON of Uppsala. In my paper on the Chasmops Series, etc. (1940), the Flagkalk was not considered, an oversight which I later became conscious of, and when I had an opportunity of discussing the matter with Mr. JAANUSSON during my investigation of the Kullatorp core in 1945, we found that our opinions on the age of the Flagkalk were consistent.

[2] According to an oral communication by Mr. JAANUSSON the Macrourus Limestone in Dalecarlia very likely includes strata corresponding in age to the Estonian Jõhvi and Keila formations.

Table 2.

		GRAPTOLITE SUCCESSION Bornholm, Scania	THE KULLATORP CORE	SHELLY FACIES Dalecarlia	SHELLY FACIES Esthonia[1]
CHASMOPS SERIES	Upper	Zone of *Dicranogr. clingani*	63.0—64.05 m	Macrourus Limestone	Keila D_2 Jõhvi D_1
		" " *Amplexogr. vasae*	64.05—65.75 "	— — ? — — ? — — Lower Chasmops " or	Jdavere C_3
	Lower	" " *Diplogr. molestus*	65.75—77.0 "	Cystoidean "	Kukruse C_{II}
		" " *Nemagr. gracilis*	77.0—88.56 "	Flagkalk (Zone of *Ill. crassicauda*)	Uhaku C_{1c}

[1] The Lasnamäe (= Tallinna) formation of the Estonian Viru series is not considered, as there are no faunistic data supporting a suggestion that this formation has correlative representatives in the Kullatorp core section; according to JAANUSSON 1947 (p. 49) it corresponds to the Swedish *Illaenus schroeteri* zone. Furthermore, strata corresponding to the Keila formation seem to be missing in Kinnekulle and in some other districts as well (cf. THORSLUND and WESTERGÅRD 1938, pp. 35, 36; THORSLUND 1940, p. 124).

Viru series. As pointed out above, it has not been possible to definitely determine the boundaries between the core portions corresponding to those of the graptolite zones, and it needs hardly be added that it is not very likely that the graptolite succession coincides in details with that of the shelly facies, zone fossils of the latter probably overlapping in time those of the graptolite shales and *vice versa*.

As far as can be read from a core drilled at Norra Skagen, a locality about 1.2 km ESE of Kullatorp, the lower boundary of the Chasmops series is not reached in the Kullatorp core. From the top downwards to 6.6 m the former core consists of slightly calcareous mudstone with indistinctly defined lenses and layers of limestone, these strata approximately corresponding to those between the 78.6 m and 85.2 m levels of the Kullatorp core (fig. 5). This correlation is also supported by some fossils, the occurrence of which in the Skagen core is given with remarks on their distribution below the top, denoted as zero: *Bromidella coelodesma* (Öpik) 8.06—8.1 m, *Tallinnella dimorpha* Öpik, 8.55—9.9 m, *Chilobolbina dimorpha* n. sp. 10.5—13.1 m, *Steusloffia* aff. *costata* (Linrs.) 3.6—23.5 m.

Valuable assistance for this correlation is also provided by the occurrence of biotite-bearing beds and bentonite layers. Thus, in the Skagen core the rock close above the 5.0 m level contains abundant flakes of biotite and a layer of pale-green bentonite occurs at the 8.7 m level, the corresponding levels of the Kullatorp core being 83.3 m or 83.9 m and 87.35 m respectively.

In the Skagen core there are small flakes of biotite in abundance between the 19.42 m and 19.45 m levels, but no bentonite layer has been observed below the 8.7 m level.

The investigation of the Skagen core will be treated in a subsequent paper and the following brief comments on that core merely serve to give an idea of the thickness of the Chasmops Series.[1] Judging from the lithology, no evidence of a break in the sedimentation is observed until the 26.56 m level is reached. The core portion 6.5 m—19.0 m mainly consists of grayish, argillaceous limestone, with occasional reddish portions; it is finely crystalline or almost compact, with thin partings or irregular intercalations of shaly matter, dark-gray to greenish, sometimes marly. The limestone material forms beds, thin lenses or irregular nodules. Between the 19.0 m and 26.56 m levels there is more shaly matter than limestone. — The fossils are sparse, mostly valves of ostracoda. Besides the above species the following ones affording information of stratigraphical value may be mentioned: *Chasmops* sp. 0.7 m, 8.1 m, *Trinucleus* cf. *foveolatus* Ang. 19.15 m, 23.45 m, *Remopleurides* cf. *circularis* Hadding 20.15 m, *Ctenentoma* cf. *polytropis* (Öpik) 8.1 m, 8.7 m, *Ceratopsis* aff. *perpunctata prominens* Öpik 21.15 m, 22.95 m, *Glyptograptus teretiusculus* (His.) var. 3.27—4.05 m, *Glyptograptus* cf. *teretiusculus* (distal fragments) 19.45 m, 20.6 m, *Climacograptus scharenbergi* Lapw. 3.2 m, 4.5 m, 11.33 m, 22.8 m.

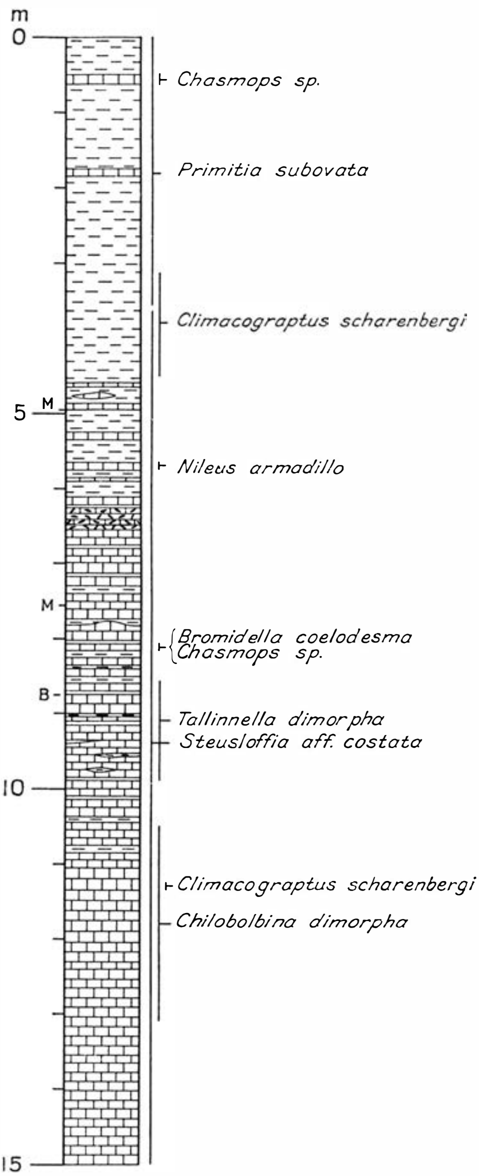

Fig. 5. Diagram of the uppermost portion of the core from N. Skagen, Kinnekulle, including Chasmops beds.

The occurrence of the above fossils in the Skagen core discloses that more than 13 m of the uppermost part of this core belongs to the Chasmops Series. This would mean that the entire thickness of this series in Kinnekulle may be estimated at 28—30 m at least. However, further investigations of the fossils occurring in the strata between the 13 m and 26.56 m levels of the Skagen core are needed to establish the lower boundary of the series. The beds with *Trinucleus* cf. *foveolatus*, *Remopleurides* cf. *circularis*,

[1] The Ordovician part of the core has been carefully examined for fossils by Messrs. V. Jaanusson and H. Mutvei of Uppsala; the Cambrian sequence of it was described by Westergård in 1943.

Glyptograptus cf. *teretiusculus*, etc. very likely lie below that boundary and belong to the zone of *Illaenus schroeteri* of the Asaphus series.[1] It is evident, however, that some upper part of the series of limestone beds which was formerly referred to that zone, *viz.* the »Upper Gray Orthoceras Limestone» or the »Leversten» (Liver-stone) according to HOLM (1901, p. 54), in reality belongs to the Lower Chasmops Series.

The present investigation has disclosed that the Lower Chasmops Series is more complete in Kinnekulle than in the autochthonous area of Jemtland, and very likely than in the Tvären area as well. In the series of strata in those areas the basal Chasmops beds consist of conglomerates, usually followed by sandstone, occasionally by limestone. At some localities in Jemtland the conglomerate contains fossils typical of the Lower Chasmops Limestone (THORSLUND 1940, pp. 67, 68). It rests on rocks of varying age (pre-Cambrian, Cambrian and Ordovician), all of them older than those of the *Nemagraptus gracilis* zone. Consequently, representatives of this zone may be entirely missing, as suggested by JAANUSSON (1947, p. 49) in the case of the autochthon in Jemtland. However, this gap is more or less completely filled in the overthrust sheets of the Jemtland area, where the Upper Ogygiocaris Shale belongs to the zone of *Nemagraptus gracilis*. Recent investigations have disclosed that the sandstone layers in this shale (cf. THORSLUND 1937, pp. 9—16) increase in a westerly direction within the area, and that the Chasmops Series of the westernmost sheet, which holds Ordovician strata, is built up of bedded graywacke and dark shales.

Looking for Middle Ordovician strata in Great Britain corresponding to those of the Chasmops Series, we find them in the Caradoc Series, according to the classification of the Ordovician used in the practice of the British Geological Survey (PRINGLE and NEVILLE GEORGE 1937, pp. 24, 26).[2] The lower boundaries of these two series appear to coincide, being drawn at the base of the zone of *Nemagraptus gracilis*. As regards the upper boundary, however, there are some differences, as the Caradoc Series includes the zone of *Pleurograptus linearis*, which forms the basal zone of the Upper Ordovician Tretaspis Series in Sweden.

It is a well-known fact that the Ordovician period, especially the Middle Ordovician epoch, included times of considerable volcanic activity in

[1] The borings at Kullatorp and Skagen now enable us to estimate the thickness of the Ordovician strata beneath the Tretaspis Series at about 84 m, of which the Asaphus Series (= »Orthoceras Limestone») in the Skagen core takes up less than 42 m, the Lower Didymograptus Shale 12 m and the Ceratopyge Limestone 0.3 m (cf. WESTERGÅRD 1943, p. 51).

[2] The Caradoc Series apparently corresponds to the subdivision Lower Bala in the classification proposed by O. T. JONES (1933).

various districts of Great Britain. Until recently no signs of a similar activity have been traced in Sweden. Mainly owing to the investigation of the Kinnekulle sequence in the Kullatorp core the occurrence of bentonite layers were discovered in the Chasmops series, and subsequently also in the Upper Ordovician and the Silurian strata. Thus, the Ordovician volcanic activity is traceable in Sweden in the same manner as in eastern North America.

The bentonite layers of the Swedish Chasmops Series mainly occur in that part of the series which lies above the zone of *Nemagraptus gracilis* and below the zone of *Dicranograptus clingani*. This occurrence implies that the chief volcanic outbursts, yielding the materials of these layers, took place during times coinciding with Caradocian periods of vulcanicity in some districts in Wales, for instance Snowdon and Llanwrtyd.

In Scandinavia quite thick rhyolitic tuffs of Caradocian age have been reported from the Trondheim region (VOGT 1945).

In the Chasmops Series the bentonite layers are thicker and more numerous in Kinnekulle than in the other Cambro-Silurian areas in Sweden, where such layers have so far been observed (Östergötland, Gotland, Scania, Dalecarlia and the Billingen-Falbygden district of Vestergötland as well). This mode of distribution seems to indicate that the volcanic materials were derived from sources located nearer to Kinnekulle than to the other areas in Sweden, and prompts a suggestion that the volcanoes were situated in some easterly part of the North Sea.

Description of Fossils.

1. Trilobita.

Telephus sp. Pl. XXI, fig. 10.

Remarks and *Occurrence:* Only the figured, small cranidium is available, found at the 86.50 m level. It is too badly preserved to permit a closer comparison with any known species. Its most prominent feature is the stout spine, projecting almost straight backwards from the occipital ring, which is prolonged backwards in the middle. The glabella seems to be almost as wide at the base as it is long, and the test displays no signs of ornamentation. It must be remembered, however, that the cranidium is poorly preserved.

As to the development of the occipital spine this species reminds of *Telephus* sp., figured by HADDING (1913, Pl. 2, fig. 24), although there are differences in other respects.

Asaphus ? glabratus (Ang.). Pl. XXI, figs. 7, 8.

1854 *Ptychopyge glabrata* ANGELIN p. 54, Pl. 29, figs. 3—3 a.
1906 » » OLIN » 60, » 2, » 19—23.

Remarks and *Occurrence:* Compressed fragments of this species have been obtained between the levels 65.05 m and 65.20 m. The largest is the cephalon figured, somewhat distorted and very broken. It closely agrees with the description and figures given by OLIN, who expressed some doubts whether this species should belong to the genus *Ptychopyge* or not. In the latter case it should be included in the genus *Asaphus*. One of his reasons for the reference to *Ptychopyge* is that the free cheeks are prolonged to spines. However, this feature does not seem to be of generic importance, since there are representatives of the genus *Asaphus*, e.g. *A. fennicus* Wiman, characterized by spine-bearing free cheeks. ANGELIN's diagnosis of *Pt. glabrata* was based on the pygidium, which, according to OLIN, appears to agree with that of *Asaphus* in having a comparatively narrow doublure. The labrum, too, is of the same type as that of *Asaphus* but for the oblique maculæ (cf. BRÖGGER 1886, p. 34). If the latter feature is not of generic importance — which the author is inclined to think — this species should very likely be referred to the genus *Asaphus*.

From the above it is evident that this species occurs at fairly high levels of the Chasmops series of the core, or in the part of it that has been correlated with the *Amplexograptus vasae* zone. Outside Vestergötland it has been recorded from Scania, where it seems to belong to the upper part of the Chasmops beds as well. Thus, according to FUNKQUIST (1919, pp. 25, 27) it occurs at Tommarp fairly close below the *Dicranograptus clingani* shale (FUNKQUIST 1919, p. 25), and accordingly, above the uppermost layer of bentonitic clay at this locality, and from other places it has been recorded (OLIN 1906) together with an association of trilobites, which indicates that it appeared in a relatively late period of the Chasmops age.

Pharostoma sp. Pl. XXI, figs. 4—6.

Remarks and *Occurrence:* The material available consists of an almost complete though compressed pygidium, a fragmentary, badly preserved cranidium and two fragmentary free cheeks found between the levels 64.24 m and 64.29 m of the core.

As far as can be seen from these parts, this small form is closely allied to *Pharostoma niezkowskii* Fr. Schmidt (SCHMIDT 1894, p. 29, Pl. 2, figs. 17—18; ÖPIK 1937, p. 22, text-figs. 1—3, Pl. XV, fig. 4, Pl. XVI) but owing to the poor state of preservation the identification with that species is not possible.

The pygidium seems to be about one and a half times as wide as long; its axis, occupying about one third of its width, is composed of 5 well defined rings and a comparatively large terminal piece not reaching the posterior outline of the pygidium. Each side lobe of the anterior edge has a pair of faceted half ribs, followed by 4 gently raised, flattened ribs, the two anterior ones with faint interpleural furrows. Test ornamented with tubercles of somewhat varying sizes.

Cranidium broadly rounded in front, with moderately raised anterior border. Preglabellar field comparatively short, apparently somewhat less than one fourth the length of glabella, which seems to be almost as wide at the base as it is long.

Free cheek sub-triangular in outline, with the lateral border broad, rounded and rather strongly raised above the lateral furrow; genal spine acutely pointed, its length being about one third that of the cheek. — Surface of test of free cheek and cranidium — except preglabellar field and furrows — ornamented with fairly closely set tubercles.

Approximate dimensions: Pygidium: length 1.3 mm, width 2.0 mm; glabella: length 1.7 mm, width at base 1.6 mm.

Lonchodomas minutus n. sp. Pl. XXI, figs. 1 a, b.

Specific characters: Cranidium small, slightly longer than half the width at base, sub-triangular, acutely pointed in front. Glabella diamond-shaped, somewhat longer than wide, and with greatest width across middle, moderately convex with greatest elevation along the middle line. Base of glabella truncated, not pointed, and about half the width of the broadest part. Front end of glabella freely projecting in front of cheeks and furnished with a long, straight, horizontal spine, more than twice the length of the glabella. Along the whole length of the spine runs a strongly marked keel both on its upper and lower side, thus giving the spine a cross-like section.

Fixed cheeks sub-triangular, almost flat but rapidly sloping downwards anteriorly. Posterior marginal furrows shallow and rather wide within, growing deeper but decreasing in width laterally and ending close to the postero-lateral angles of the cranidium.

Surface of test of glabella and free cheeks very finely granulated.

Dimensions: Cranidium: basal width 2.7 mm, length to base of spine (about) 1.5 mm; glabella: width at base 0.5 mm and across middle 1.1 mm. Length of spine (about) 3.4 mm.

Remarks and *Affinities:* The glabella of the specimen figured, the only one found, is compressed and slightly distorted in front. — As to the general shape of the cranidium this species displays quite a close resemblance to *Lonchodomas portlocki* (Barr.) and allied species, but differs from them all in having the fixed cheeks relatively much broader at base. The appearance of the spine with its cross-like section is another distinguishing character.

Occurrence: Black shale, zone of *Dicranograptus clingani*, at about the 63.35 m level.

Lonchodomas sp. Pl. XXI, fig. 11.

Remarks and *Occurrence:* A small pygidium found at the 65.05 m level displays resemblance to that of *Lonchodomas rostratus* (Sars; cf. STØRMER 1940, pp. 128—130, text-figs. 3 a—3 e, Pl. 2, figs. 2, 4), and it probably belongs to a species allied to that species. It is sub-triangular in outline, and about three and a half times as wide as long; axis indistinctly marked off from the side lobes in which there are three well defined pleurae with faint furrows in two pairs of them at least; posterior border narrow, steep and faintly striated. As the pygidium besides these features is very small, measuring 0.6 mm in length and 2.2 mm in breadth, it very likely belongs to a young adult.

The ratio between breadth and length in this pygidium is much greater than in that of (adult) specimens of *L. rostratus* in which there are only two furrows on each side lobe.

»Odontopleura» sp. Pl. XXI, fig. 9.

Remarks and *Occurrence:* The free cheek figured, found at the 64.25 m level, is available. Only the posterior part of the test is preserved, mainly in the long slender spine, which is gently curved downwards at the end, and in the long eye-stalk. From the latter it is evident that the eye is situated far back, near the base of the glabella, and that it is highly elevated. — No closer reference to some genus of the family Odontopleuridae is possible.

2. Ostracoda.

Primitia subovata n. sp. Pl. XX, fig. 5.

Specific characters: Valves almost one and a half times as long as high, highest in posterior part, hinge short; greatest convexity in anterior part and thickest round the muscle spot, which is situated at the ventral extremity of the straight short sulcus; undefined ridge-like swellings on both sides of the sulcus, the posterior one most elevated. Surface of test very finely granulated.

Dimensions: Length 1.3 mm, height 0.9 mm, hinge line 0.7 mm.

Occurrence: Common between the levels 73.8 m and 77.5 m.

Primitia obesa n. sp. Pl. XX, figs. 6, 7.

Specific characters: Similar to *Primitia subovata* but lacking real swellings on the sides of the sulcus and with greatest height in the middle part of the valve. Surface of test smooth.

Dimensions: Length 0.7 mm, height 0.6 mm, hinge line 0.55 mm.
» 0.75 » » 0.6 » » » 0.6 »

Occurrence: In black shale, zone of *Dicranogr. clingani*, between the levels 63.08 m and 64.05 m.

Ulrichia reticulata n. sp. Pl. XX, fig. 11 a, b.

Specific characters: Carapace moderately convex, almost twice as long as high; ends rounded, the anterior outline somewhat more convex than the posterior one, ventral edge uniformly rounded. Sulcus, between two prominent nodes, successively deepening and decreasing in width towards dorsal edge. Anterior node rounded, posterior node larger, transversally raised in dorso-anterior direction and slightly projecting over dorsal edge. Surface of test finely reticulated.

Dimensions: Length 0.8 mm, height 0.45 mm, greatest thickness of carapace 0.4 mm (across the posterior nodes).

Affinities: This species reminds of *Ulrichia morgani* (Jones, 1890, p. 5, Pl. IV, fig. 6) but differs from that in being comparatively longer and in having the nodes closer together.

Occurrence: In marly shale at 76.73 m level, close below a thin layer of bentonite.

Chilobolbina dimorpha n. sp. Pl. XX, fig. 14, Text-fig. 6.

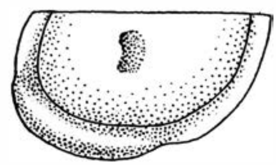

Fig. 6. Diagram of a female valve of *Chilobolbina dimorpha* n. sp., to show the extension of the brood-pouch. × 20.

Specific description: Like *Chilobolbina dentifera* (Bonn.) but without denticles on the edge of the sulcus, the posterior part of which is raised into a small node; false border or frill narrower, and brood pouch of greater extension.

	Dimensions			
	Length mm	Hinge line mm	Height mm	Height without frill mm
Male	0.8	0.65	0.5	0.4
»	1.0	0.9	0.7	0.55
»	1.3	1.05	0.8	0.65
Female	1.65	1.3	1.0	0.75

Remarks: Although badly preserved in all specimens obtained the test seems to be devoid of ornamentation but for the frill which is finely striated radially. As in *Ch. dentifera* the sulcus of fertilized females is sometimes much broader than in valves of males and unfertilized females, indicating a stronger development of the adductor muscle in females during the fertile period.

Occurrence: Between the 86.50 m and 88.50 m levels of the core.

Gen. **Pyxion** n. gen.

Diagnosis: Oblong valves with the marginal part along the free edge abruptly bent inwards, thickened and marked off by a more or less distinct furrow all round; posterior lobe elevated, conspicuous.

Genotype: Primitia carinata Hadding.

This genus reminds of *Polyceratella* or simple forms of *Ceratopsis, e.g. C. hastata* (BARR.), but for the absence of every kind of processes.

Two species are so far known, *Primitia carinata* Hadding and *Pyxion kinnekullensis* n. sp. from the Middle Ordovician Chasmops Series of Sweden.

Pyxion carinatus (HADDING). Pl. XX, figs. 1—2.

1913 *Primitia carinata* HADDING p. 68, Pl. VI, fig. 12.

Specific description: Valves oblong, depressed convex, somewhat more than one and a half times as long as high, hinge line straight; ends rounded, the posterior outline more convex than the anterior and with an oblique swing backwards; ventral side uniformly curved, forming an almost flat band, laterally thickened and raised into a ridge decreasing in width towards the ends, the width in the middle part being about one third the height of the valve. Sulcus in posterior part runs obliquely backwards and downwards, shallow in dorsal half but becomes more distinct ventrally. Posterior lobe swollen into a ridge-like node sub-parallel to posterior outline; anterior lobe large, elevated in dorsal part. Surface of test smooth.

Dimensions: Length 1.3 mm, hinge line 0.9 mm, height 0.85 mm.

Remarks: Several valves of this species were found in the Kullatorp core. They are not so well preserved as the genotype on which the above description is based, but agree in all essentials with it. The main difference observed concerns the anterior lobe which in the core specimens is almost flat and not so strongly raised in the dorsal part as in the genotype. Dimensions of the core specimen figured: length 1.4 mm, hinge line 1.0 mm, height 0.85 mm.

Occurrence: Between the levels 76.70 m and 78.20 m of the Kullatorp core. According to HADDING in the zone of *Nemagraptus gracilis* (Hall.) and close above it at Röstånga, Scania.

Pyxion kinnekullensis n. sp. Pl. XX, figs. 3, 4.

Diagnosis: Valves like those of *P. carinatus*, but the marginal part is broadly rounded laterally and marked off by a distinct furrow all round.

Dimensions: Length 1.2 mm, hinge line 1.0 mm, height 0.8 mm.
» 1.1 » » » 0.8 » » 0.75 »

Occurrence: Found in the Kullatorp core between the levels 76.70 m and 77.0 m.

Winchellatia gunnari n. sp. Pl. XX, figs. 12, 13.

Specific characters: This species seems to combine characters of *Winchellatia variolaris* (Bonn.) and *W. obliqua kuckersiana* (Bonn.), but differs from both of them in having a very coarse granulation. The general shape, especially the outline, is that of the former, and like the latter there is a lateral spinous elevation on the ventral half of the valve.

Dimensions: Length 1.1 mm, hinge line 0.9 mm, height 0.65 mm.

Occurrence: In marly limestone at the 65.05 m level.

Derivatio nominis: After Professor GUNNAR SÄVE-SÖDERBERGH, promotor of the investigations presented in this paper.

Eurychilina suecica n. sp. Pl. XX, figs. 8, 9.

Specific description: Valves moderately convex, oblong, almost twice as long as high, ends fairly strongly convex in outline, subequally rounded. Sulcus moderately broad and deep, situated behind the middle of the valve, running perpendicularly to dorsal edge and reaching from it about half the height of the valve; the posterior edge of sulcus slightly more raised than the anterior. False border radiately striated, probably running all round free margin. — Surface of test smooth or very finely granulous.

Dimensions:

	1.	2.
Length without border	1.05 mm	1.2 mm
Height	0.55 »	0.7 »
Height with border	0.7 »	0.85 »
Hinge line	0.8 »	1.0 »

Occurrence and *Remarks:* Only the two valves figured have been found, one at the 71.03 m level, the other at the 71.50 m level. Neither of them seems to have the border complete as it is very likely broken away at the anterior end of both valves. The larger valve probably belongs to a female as the frill is incurved in the posterior ventral part.

Steusloffia costata (Linrs.). Pl. XX, fig. 10.

For synonyms see THORSLUND 1940, pp. 176—178.

Remarks and *Occurrence:* This is a common species between the 64.05 m and 71.5 m levels of the core, where excellently preserved specimens are found especially on surfaces below bentonite layers. The characteristic features of these specimens are shown in the valve figured, and only small variations in the ornamentation have been observed. Thus, the bifurcation of the ribs below the median lobe is sometimes situated somewhat more ventrally, and the small node at the posterior angle is more or less pronounced.

At about the 62.98 m level or in the uppermost part of the limestone bed at the top of the Chasmops series there are several specimens obtained as casts — both natural and internal ones. Very likely they belong to *St. costata* but the state of preservation does not allow of a definite identification.

Below the 71.5 m level of the core no specimen of *Steusloffia* has been observed in a sequence of about eleven metres. Representatives of this genus are again found at 82.80 m and below 86.30 m. The valves obtained are not in a good state of preservation, however, as most of them occur in shaly material and the ornamentation is faint and sometimes almost obliterated. They are all of smaller size than the above specimens of *St. costata*, but the relative sizes of length and height seem to be comparable with those of that species. As to the development and course of the ribs there seem to be very small differences — if any — from those of the adult specimens of *St. costata* figured by the present writer in 1940 (in Plate 3). Generally, the bifurcation of the concentric crest-like ribs is placed below the median lobe or straight ventrally to it and never so far posteriorly as in the specimens of *St. costata* between the levels 64.05 m and 71.5 m. A partly testaceous and uncompressed valve at 82.80 m agrees with a specimen collected in »Flagkalk» (= zone of *Illaenus crassicauda*) at Fjecka, Dalarna, by Mr. V. JAANUSSON, who has kindly lent it to me for comparison. In these specimens the anterior dorsal rib running in a dorso-ventral direction towards the median lobe has a considerable length, and in this respect they bear a close resemblance to the specimen of *St. costata* figured by me in 1940, Pl. 3, fig. 6. However, they are much smaller and apparently also thicker. They very likely belong to a new species of *Steusloffia*, but as the material available is too incomplete for a diagnosis, the specimens of *Steusloffia* sp. found at 82.80 m and below that level have provisionally been referred to *Steusloffia* aff. *costata*.

3. Graptolithina.

Climacograptus sp. Pl. XX, fig. 15.

Remarks and *Occurrence:* A small specimen, 7 mm in length and found at the 70.25 m level probably belongs to a new species, though the state of preservation does not allow a complete diagnosis. The polypary is characterized by a very narrow proximal end, measuring 0.5 mm in width, and a rapid widening until a maximum breadth of 1.4 m is attained within 4 mm. Eight thecae in 5 mm.

A distal portion, about 1.3 mm long, of a polypary found at the 74.78 m level possibly belongs to the same species, or at any rate to a closely related one, as the thecae are of similar shape. The latter specimen widens from 1.2 mm to 2.0 mm and there are 14 thecae in 10 mm.

Diplograptus molestus n. nom. Pl. XXI, figs. 2, 3 a, b.

1915 *Climacograptus rugosus* HADDING, p. 19, Pl. XX, figs. 13—18.

1940 *Amplexograptus rugosus* (HADDING) THORSLUND, p. 82.

Remarks: This species was described by HADDING in 1915 on material from the Middle Dicellograptus Shale of Scania and Bornholm, and was then referred to *Climacograptus rugosus*, a species erected and briefly described by TULLBERG (1882, p. 19) but never figured by him. However, this reference was disputed by the present writer in 1940, since specimens of *Cl. rugosus*, labelled by TULLBERG and thus very likely syntypes, were found kept in the collections of the Geological Survey.[1] Studies on these specimens have proved that the thecae are of the *Climacograptus scharenbergi*-type and number 13—14 in 10 mm; the polypary is fairly wide in the proximal region and widens from 1 mm to attain its maximum breadth of 1.8 mm within 5 mm. This species is very closely related to *Cl. scharenbergi* Lapw. if it is not identical with that species.

Calling attention to HADDING's suggestion that the species under discussion might perhaps be referred to *Amplexograptus*, BULMAN has recently (1946, p. 50) pointed out that it most probably belongs to the genus *Diplograptus* s. str., and this opinion is shared by the present writer. As stated by BULMAN the specific name *rugosus* is preoccupied and therefore a new one must be proposed.

The material found in the Kullatorp core consists of three specimens, two of which are almost complete though compressed and partly somewhat obliquely compressed. The length of the smallest specimen is 1 cm, the longest is nearly 2 cm. The thecae number 14—16 in 10 mm. The polypary gradually widens from 0.9 mm at the proximal end till the maximum breadth of 1.3 mm is attained. Only the apertural part of the sicula is visible and it is provided with a slender virgella, about 0.4 mm long. A short sub-apertural spine is associated with each of th 1^1 and th 1^2. As far as can be observed in some distal portions of the large specimens (Pl. XXI, fig. 3) the existence of a median septum is very likely. A wiry virgula is seen almost throughout the whole length of the polypary and projects beyond the distal extremity.

Occurrence: At the 74.44 m level of the core. According to HADDING in the lowermost zone of the Middle Dicellograptus Shale of Bornholm and Scania.

[1] According to TULLBERG (1882, p. 19; 1883, p. 241) *Climacograptus rugosus* is associated with a number of other graptolite species, *e.g.* *Diplogr. foliaceus* Murch., *Leptogr. flaccidus* Hall and *Dicellogr. morrisi* Hopk., while the newnamed species is only found together with *Climacogr. scharenbergi* Lapw. (HADDING 1915, pp. 35, 37).

List of Species described.

These species have been found in the Kullatorp core. *Asaphus? glabratus, Pyxion carinatus,* and *Diplograptus molestus* also occur in Scania as well as *Steusloffia costata,* which has a wide distribution.	Upper Chasm. Series	Lower Chasm. Series	Page
Telephus sp.	+		362
Asaphus? glabratus (Ang.)	+		362
Pharostoma sp.	+		363
Lonchodomas minutus n. sp.	+		364
Lonchodomas sp.	+		364
Odontopleura sp.	+		365
Primitia subovata n. sp.		+	365
» obesa n. sp.	+		365
Ulrichia reticulata n. sp.		+	365
Chilobolbina dimorpha n. sp.		+	366
Pyxion carinatus (Hadding)		+	367
» kinnekullensis n. sp.		+	367
Winchellatia gunnari n. sp.	+		368
Eurychilina suecica n. sp.		+	368
Steusloffia costata (Linrs.)	+	+	368
Climacograptus sp.		+	369
Diplograptus molestus n. nom.		+	369

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Explanation of Plates.

All the specimens figured in these plates except that of Pl. XX, fig. 2, occur in the Chasmops beds of the Kullatorp core and belong to the Museum of the Paleontological Institute of Uppsala. (C. LARSSON phot., G. BIHL and P. THORSLUND ret.)

Plate XX.

Figs. 1—2. *Pyxion carinatus* (Hadding). 1 a, b. Right valve in lateral and ventral aspects. 2. Genotype in lateral view. Röstånga, Scania. Museum of the Min.-Geol. Inst. of Lund.

Figs. 3—4. *Pyxion kinnekullensis* n. sp. 3. Holotype. 4. Slightly distorted right valve.

Fig. 5. *Primitia subovata* n. sp. Holotype.

Figs. 6—7. *Primitia obesa* n. sp. 6. Holotype. 7. Right valve compressed and broken in anterior dorsal part.

Figs. 8—9. *Eurychilina suecica* n. sp. 8. Holotype. 9. Broken left valve, probably of a female.

Fig. 10. *Steusloffia costata* (Linrs.). Typical valve between 64 m and 71.5 m.

Fig. 11 a, b. *Ulrichia reticulata* n. sp. Holotype in lateral and dorsal views.

Figs. 12—13. *Winchellatia gunnari* n. sp. Right valves. 12. Holotype. 13. With badly preserved false border.

Fig. 14. *Chilobolbina dimorpha* n. sp. Small right valve of a male or unfertilized female. Holotype.

Fig. 15. *Climacograptus* sp. From the 70.25 m level.

Plate XXI.

Fig. 1 a, b. *Lonchodomas minutus* n. sp. Holotype without retouch (a) and retouched (b).

Figs. 2—3. *Diplograptus molestus* n. nom. 2. Small specimen obliquely compressed from the side. 3 a, b. Two specimes in different aspects.

Figs. 4—6. *Pharostoma* sp. 4 a, b. Imperfect cranidium in dorsal view and in cast. 5. Mainly exfoliated free cheek. 6. Somewhat distorted pygidium.

Figs. 7—8. *Asaphus? glabratus* (Ang.). 7. Compressed and broken cephalon. 8. Imperfect pygidium.

Fig. 9. »*Odontopleura*» sp. Free cheek, mainly in cast.

Fig. 10. *Telephus* sp. Badly preserved cranidium.

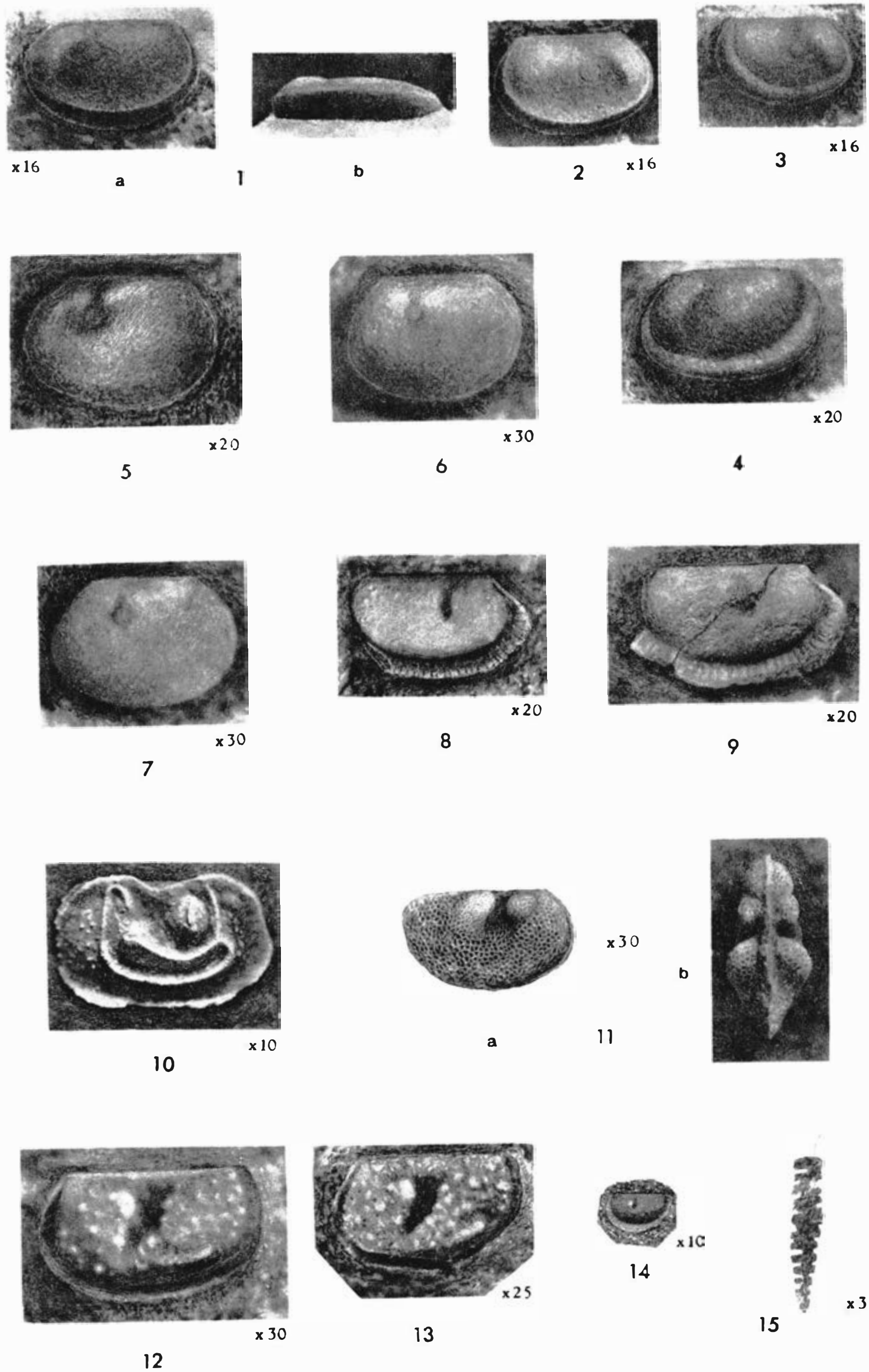
Fig. 11. *Lonchodomas* sp. Pygidium from the 65.05 m level.

Plate XXII.

Fig. 1. Core portion between the levels 62.96 m and 63.08 m. — × 3/4. Explanation on p. 343.

Fig. 2. Limestone bed between the levels 65.43 m and 65.51 m of the Kullatorp core. — × 3/4. Explanation on p. 346.

Fig. 3. Conglomeratic limestone from the suprabentonitic Upper Chasmops Series of the section at Mossen, Kinnekulle. — × 3/4.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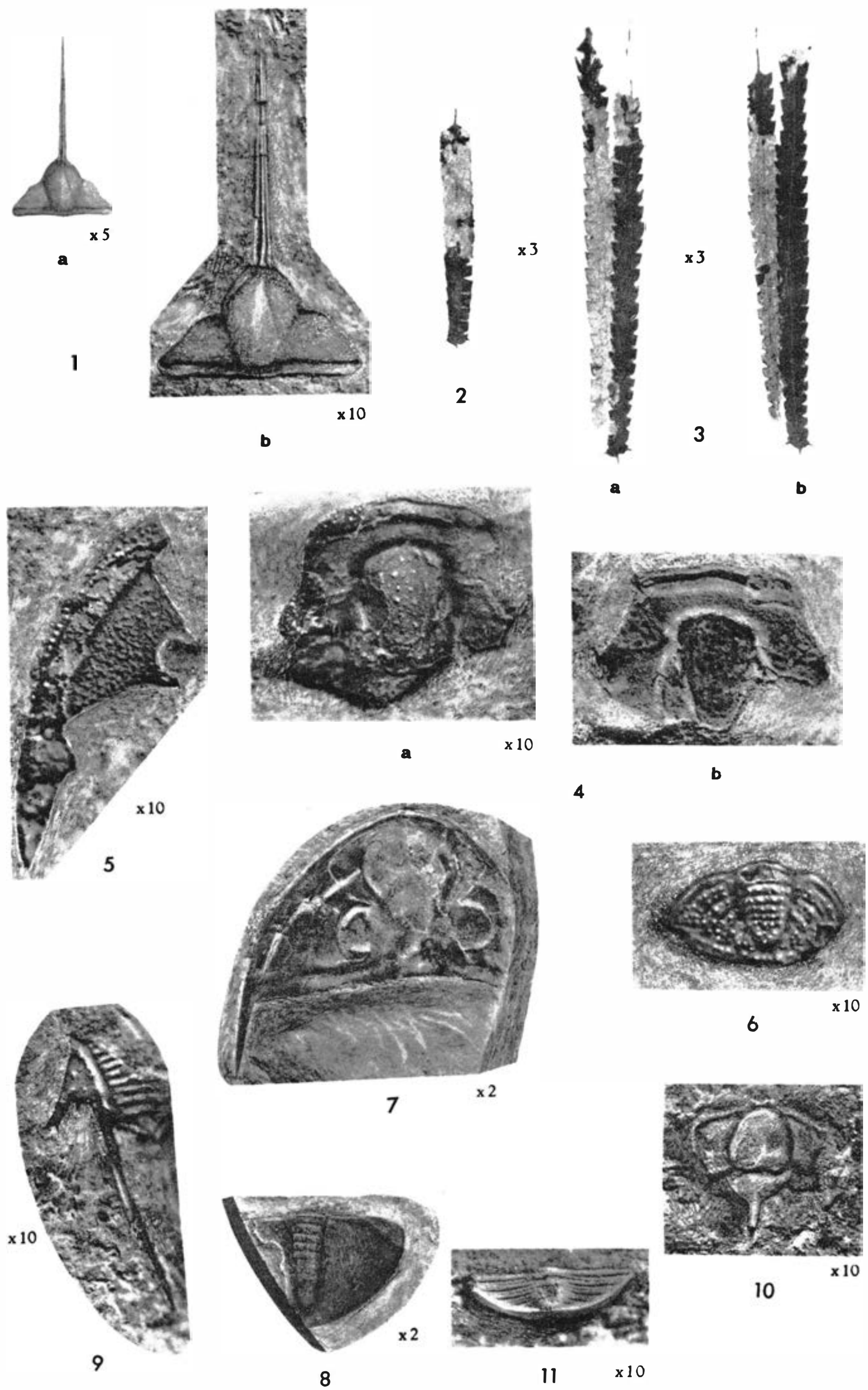
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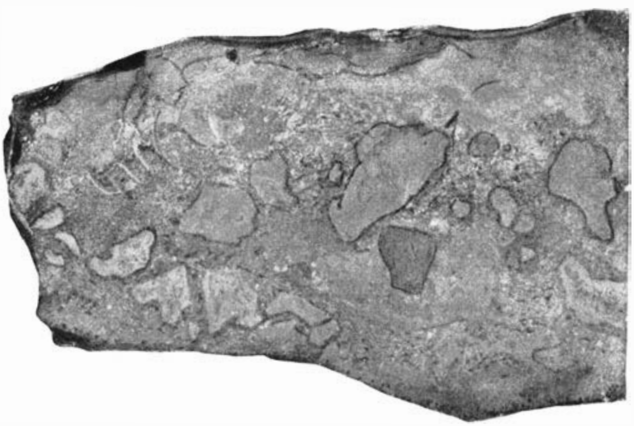

3

4. The Tretaspis Series of the Kullatorp Core.

By

Gunnar Henningsmoen (Oslo).

Abstract.

Investigations of the Tretaspis Series of Kinnekulle, Vestergötland, in the deep boring at Kullatorp have disclosed that this series, c. 27.85 m thick, is composed of five main lithological divisions (in ascending order): Black Tretaspis Shale 6.45 m, Green Tretaspis Shale 3.25 m, Masur Limestone about 1.2 m, Red Tretaspis Mudstone 14.3 m, and Grey or Top Sandstone 2.65 m.

These divisions were formerly regarded as belonging to the Tretaspis Series, except the Top Sandstone, which was then referred to the »Brachiopod Shale», together with the overlying conglomeratic limestone (of the

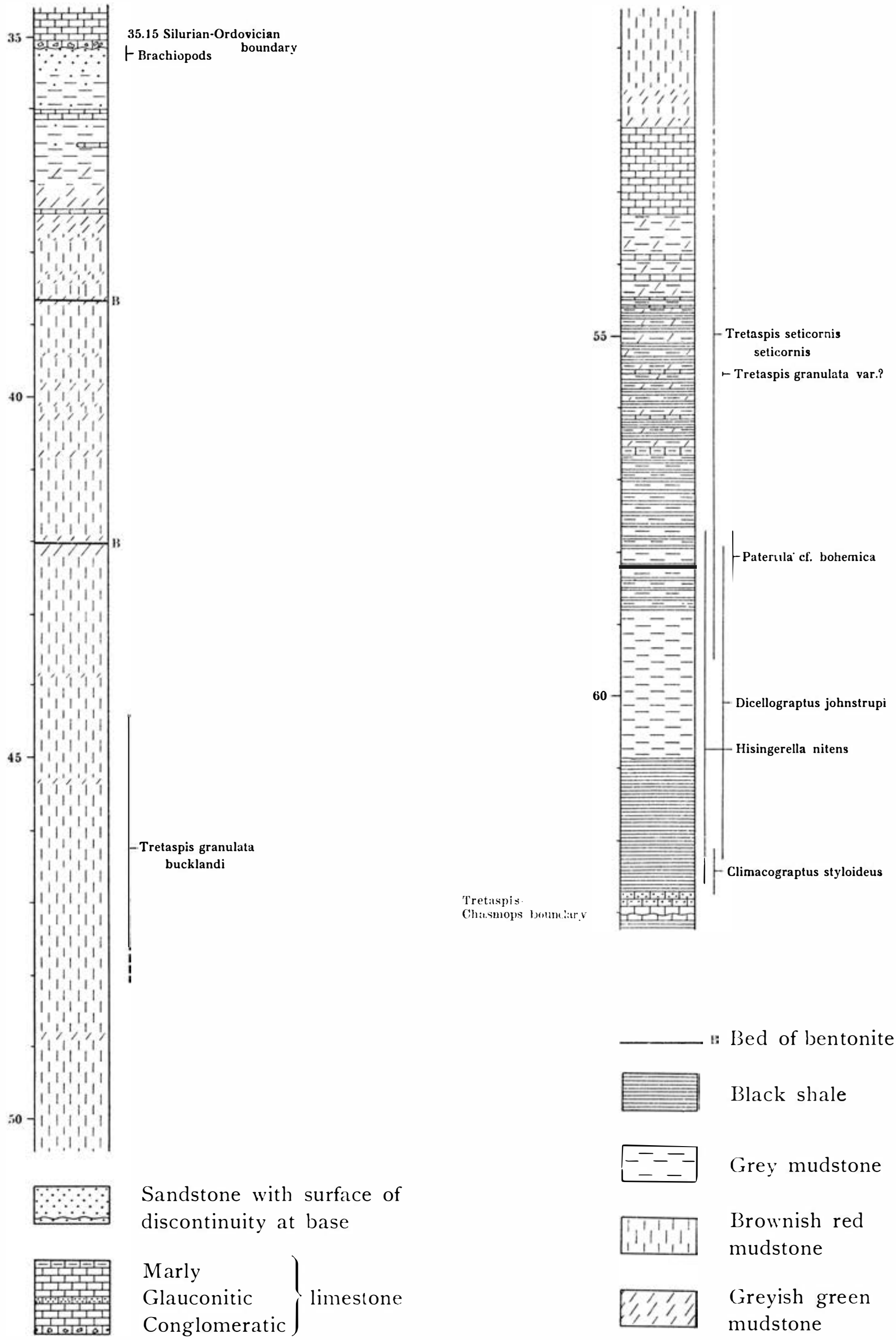

Diagram of the Tretaspis Series of the Kullatorp Core.

Dalmanitina beds). However, this sandstone grades from the underlying red mudstone and is sharply bounded at top. Since it contains *Dalmanitina mucronata* it probably is a representative of the Staurocephalus Zone, which constitutes the topmost part of the Tretaspis Series elsewhere in Vestergötland.

The graptolites obtained show that the Black Tretaspis Shale belongs to the zone of *Pleurograptus linearis* and *Climacograptus styloideus*, and that the lower boundary of the Tretaspis Series must be drawn in the uppermost part of an argillaceous, partly phosphatic limestone bed intercalated in black shales. As described by THORSLUND this limestone bed below the boundary contains *Tretaspis ceriodes* (a zone fossil of the Upper Chasmops Series), while the underlying black shale, which was formerly referred to the Black Tretaspis Shale, accordingly belongs to the Chasmops Series. [As pointed out by THORSLUND (above p. 357), this black shale contains graptolites of the zone of *Dicranograptus clingani*.]

During the earlier time of the deposition of the Black Tretaspis Shale stagnant and quiet conditions probably prevailed. The foul bottom waters excluded a benthonic fauna of any account. Later there were periodical alternations between ventilated and stagnant waters with a corresponding invasion and retreat of the shelly fauna, as shown by the numerous cycles of sediments and their fossils. These conditions lasted also during the earlier time of the deposition of the Green Tretaspis Shale, but later the stagnant conditions decreased. The Masur Limestone indicates a quiet and slightly stagnant period, when deposition of clastic material was recessive. At times the sedimentation was negative owing to corrosion. Life seems to have been scarce. The mud of the Red Tretaspis Mudstone was probably deposited under oxidation environments, though green bands probably tell of local reduction. The mud was probably deposited rather rapidly, and under quiet conditions. Two layers of bentonite found in the upper, unfossiliferous part of the Red Tretaspis Mudstone tell, however, of volcanic activity in Ashgillian time. The sparse and dwarfed fauna, as well as the absence of sessile benthonic forms indicate that the waters were muddy or contained a salinity different from the normal. The Top Sandstone is here interpreted as a regression sandstone.

A new conodont and several new species of ostracods and brachiopods are described. The species recorded from the Tretaspis Series of the core are listed on pages.

General Description.

(For chemical tests see table I p. 381.)

63.0—62.85 m. Dark and somewhat loose marlstone containing shaly matter and scattered grains of glauconite. The marlstone is rich in shell fragments and ostracod-valves; *Bromidella linnarssoni* n. sp., *Laccoprimitia nigra* n. sp. Conodont teeth (*Drepanodus altipes* n. sp.) are quite common.

62.85—60.85 m. Black, bituminous shale, finely laminated and dark when pulverized, — or dark-grey shale, not so finely laminated and light-grey when pulverized. Sometimes with speckles of a lighter colour (see below). Pyrite occurs as small concretions and as petrifying material in some fossils.

Graptolites are regularly met with, mostly several together in certain bedding planes. The following species have been observed: *Dicellograptus johnstrupi* HADDING, *Diplograptus* (*Orthograptus*) cf. *truncatus* LAPWORTH, *Diplograptus* (*Orthograptus*) *quadrimucronatus* (HALL), *Climacograptus* cf. *minimus* (CARRUTHERS), *Climacograptus styloideus* LAPWORTH (62.10 m) and *Leptograptus flaccidus macer* ELLES & WOOD (62.60 m). Of articulate brachiopods immature specimens of *Sowerbyella?* cf. *restricta* (HADDING) occur in great masses in some bedding planes, and also immature specimens of a dalmanellid (perhaps »*Orthis*» *argentea* HISINGER) is often met with. Inarticulate brachiopods occur abundantly: *Hisingerella nitens* (HISINGER) n. gen., *Paterula* cf. *portlocki* (GEINITZ), and others. Ostracods are common, but are often difficult to determine owing to the compressed state of the valves. *Laccoprimitia nigra* n. sp. is very common and *Primitiella tenera* (LINNARSSON) is quite usual. Trilobites are scarce. A few fragments have been found of *Caphyra* cf. *radians* BARRANDE, *Lonchodomas* sp., and *Triarthrus* sp. Other fossils are: *Lepidocoleus suecicus* MOBERG, *Drepanodus altipes* n. sp., *Hyolithus* sp., and undeterminable gastropods.

60.85—58.80 m. Grey, slightly marly mudstone, light grey when pulverized. Often faintly speckled due to the occurrence of slightly darker patches. In thin sections one can see that these patches contain small brown pigment-grains (0.01 mm and less), more or less closely packed. There is no distinct lower or upper lithological limit of this division.

Trilobites: *Tretaspis seticornis seticornis* (HISINGER), *Phillipsinella* cf. *parabola* (BARRANDE), *Trinodus* cf. *trinodus* (SALTER), *Lonchodomas* sp. Brachiopods: *Paterula* cf. *portlocki* (GEINITZ), *Sowerbyella?* cf. *restricta* (HADDING). Ostracods: *Bromidella linnarssoni* n. sp., *Biflabellum vestrogothicum* n. sp., *Primitiella tenera* (LINNARSSON), *Kinnekullea thorslundi* n. gen. & sp., *Kinnekullea waerni* n. gen. & sp., *Jonesina? modesta* n. sp. Plant-like or worm-trail-like fossils subparallel to the bedding planes are very common.

58.80—56.68 m. Alternating beds of dark, bituminous shale and slightly marly, grey mudstone, with transitional beds of a peculiar, speckled shale (Swedish: *spräcklig skiffer*), see p. 382. At two levels, 57.30 and 57.0 m, there is a very light-coloured, somewhat bluish, friable shale, rich in well-preserved, though very fragile, white shell fragments, mostly from trilobites. A few thin bands, probably nodules, of a rather finely crystalline limestone occur at different levels. Concretions of pyrite are not uncommon in the dark and speckled shales. The lower limit of this division is arbitrarily drawn, the upper limit is sharp.

Some fossils, such as graptolites, sponge-needles (?) and some of the inarticulate brachiopods only occur in the black and speckled beds, while others, such as *Tretaspis*, are only found in the grey or speckled beds. Graptolites: *Diplograptus* (*Orthograptus*) cf. *truncatus* LAPWORTH, *Diplograptus* (*Orthograptus*) *truncatus pauperatus* ELLES & WOOD (57.6 m), *Climacograptus* cf. *minimus* (CARRUTHERS), *Dicellograptus johnstrupi* HADDING. Trilobites: *Tretaspis seticornis seticornis* (HISINGER), *Trinodus* cf. *trinodus* (SALTER). Ostracods: *Laccoprimitia nigra* n. sp., *Primitiella tenera* (LINNARSSON), *Bromidella linnarssoni* n. sp., *Biflabellum vestrogothicum* n. sp., *Kinnekullea waerni* n. gen. & sp., *Kinnekullea thorslundi* n. gen. & sp., and others. Brachiopods: *Hisingerella nitens* (HISINGER) n. gen., *Paterula* cf. *portlocki* (GEINITZ), *Paterula* cf. *bohemica* BARRANDE, *Sowerbyella?* cf. *restricta* (HADDING), and a small dalmanellid. Other fossils are: *Lepidocoleus suecicus* MOBERG, *Hyolithus* sp., gastropods, sponge-needles (?). Plant-like or worm-trail-like fossils are very common.

56.68—56.55 m. Dark bituminous marlstone with angular silt grains, mostly of quartz. The fossils are calcareous. In thin section brown pigment grains are seen to occur abundantly in clusters in the rock, and in clusters or more isolated in the calcite of the fossils. At the top of the marlstone there is a band of calcite, 1 mm thick. Both the lower and upper boundary of this division are sharp.

The fossils consist of brachiopods, mostly in fragments; *Paterula* cf. *bohemica* BARRANDE, a strophomenid and a dalmanellid.

56.55—54.65 m. This division is similar to that below the marlstone, except that the grey material noted in the latter here becomes successively more greenish. Thus the speckled rock is here dark with grey-green speckles. Here, too, there are a few thin bands of grey limestone, probably concretions.

Poorly preserved graptolites, impossible to determine, have been found in this division. Trilobites: *Tretaspis seticornis seticornis* (HISINGER), *Tretaspis granulata* var.? (BARRANDE) (only at levels 55.55 and 55.20 m), *Lonchodomas* sp., *Phillipsinella* cf. *parabola* (BARRANDE), *Trinodus* cf. *trinodus* (SALTER), *Pseudosphaerexochus* sp. Brachiopods: *Sowerbyella?* cf. *restricta* (HADDING), *Christiania* sp., a small dalmanellid, and fragments of inarticulates. Ostracods: *Primitiella tenera* (LINNARSSON), *Kinnekullea thorslundi* n. gen. & sp., *Kinnekullea waerni* n. gen. & sp., *Bromidella linnarssoni* n. sp., *Biflabellum vestrogothicum* n. sp., and others. Other fossils are: *Lepidocoleus suecicus* MOBERG and plant-like fossils.

54.65—53.30 m. Greenish grey mudstone with layers or (probably) concretions of reddish and greenish grey limestone. The mudstone is sometimes very rich in leaf-thin fissure fillings of calcite, mostly subparallel to the bedding, but also vertical to these. The fossils are invariably covered by such calcite films. There is no sharp lower lithological limit of this division. The core was incomplete at the upper limit.

This division is rather poor in fossils, and owing to their state of preservation they are difficult to determine. *Tretaspis seticornis seticornis* (HISINGER) and *Primitiella tenera* (LINNARSSON) have been noted.

53.30—52.10 m. A grey to dark grey dense limestone, irregularly intersected by fissures filled with calcite. (So-called *Masur*[1] limestone.) The fissures were probably formed by contraction, as they do not seem to penetrate into the under- or overlying rock. Finely crystalline pyrite is not uncommon. The lower part of the limestone contains argillaceous partings, likewise the uppermost part. The limestone seems to consist of beds parted by irregular (corrosion?) surfaces. Unfortunately this division of the core was very crumbled. Hence the exact thickness of the limestone cannot be stated. This is the more to be pitied, as there are no out-crops of this limestone at Kinnekulle. It was known here only from boulders.

No macrofossils have been found in this limestone, but in a thin section a few microfossils (not determined) were observed.

52.10—37.80 m. Brownish red, sometimes (greyish-) green mudstone, more or less marly and containing a certain amount of angular silt grains ($\leqq$ 0.05 mm), mostly of quartz. The mudstone is strikingly uniform throughout the whole of this division. Limestone does not occur, but here and there are thin bands (probably fissure fillings) of calcite, one or a few mm thick. Leaf-thin fissure fillings of calcite, mostly subparallel to the bedding, are not unusual.

This division begins as green mudstone, with a fairly sharp boundary against the underlying limestone, the first red mudstone occurring at level 51.90 m. This is, however, only a 10 cm thick band, but after 20 cm of green mudstone the red mudstone is dominant throughout this division. Up to level 44.2 m, which is the upper limit of the fossiliferous part, only two green bands, 5 and 10 cm thick, occur. In the upper, unfossiliferous part there are about 12 green bands. Two of them contain a thin bed of bentonite.

The bentonite, occurring at levels 42.0 and 38.60 m, was crumbled by the boring, so that the exact thickness of the bentonite beds cannot be stated, though each of them is probably only 2—3 cm. The green mudstone has a greater thickness below the bentonite than above it, 12 cm : 4 cm and 5 cm : 1 cm respectively. Below the bentonite at 42.0 m there are several 1—2 cm thick bands of a matter which was first suspected to be aragonite, but

[1] *Masur* limestone is a name which was given by TÖRNQUIST (1883) to a limestone-bed below the Black Tretaspis Shale in Dalarne. The name refers to the characteristic veined appearance of this limestone. As proposed by THORSLUND (1943 p. 6 footnote 6) *Masur* limestone now denotes only a certain limestone facies (See *e.g.* WIMAN 1906 p. 128).

which W. MEIGEN's test showed to be calcite. The bentonite has a distinct violet colour. In thin sections the bentonite is seen as a greyish substance full of small opaque particles and biotite grains, while other mineral grains are scarce. A somewhat curved and lineate structure may perhaps be interpreted as glass relict structure. The bentonite shows the characteristic swelling in water.

Fossils. The upper part (44.20—37.80 m) of this division is without fossils. In the lower part fossils are common. Trilobites: *Tretaspis seticornis seticornis* (HISINGER) (only below level 50.60 m), *Tretaspis granulata bucklandi* (BARRANDE) (only above level 47.75 m), *Cybele verrucosa* DALMAN, *Lonchodomas tetragonus* (ANGELIN), *Illaenus megalophthalmus* (LINNARSSON), *Trinodus* cf. *trinodus* (SALTER), *Dionide euglypta* (ANGELIN). Ostracods: *Primitiella tenera* (LINNARSSON), *Bromidella linnarssoni* n. sp., *Biflabellum vestrogothicum* n. sp. (only below 50.30 m), *Kinnekullea thorslundi* n. gen. & sp., *Kinnekullea waerni* n. gen. & sp. (only below 50.30 m), *Laccoprimitia? binodosa* n. sp. (only above 46.2 m), and others. Brachiopods: *Christiania* sp. (only below 50.60 m), *Sowerbyella? rosettana* n. sp. (only above 50.60 m), a tiny dalmanellid (1—2 mm), and a few others. Plant-like or worm-trail-like fossils are common in some horizons.

37.80—35.15 m. The lower boundary of this division is arbitrarily drawn. The division begins as a slightly marly and slightly silty greyish green mudstone and ends as a grey, slightly brownish, marly coarse siltstone or very fine sandstone, the angular grains of the latter mostly having a diameter of 0.05—0.10 mm. The transition is gradual, both with respect to the colour of the rock and to the size and amount of the grains. The grains mostly consist of quartz, but also mica and other minerals are present. The upper part of this division is rich in brachiopods; the petrifying material is calcite. Small brown pigment grains often occur in clusters elsewhere in the rock. Bands of limestone occur, one being rich in plant-like remains.

Though the core is rich in brachiopods, more material than is obtainable from it must be collected to allow a reliable determination and description. Mr. V. JAANUSSON has kindly looked through the material and made the following preliminary determination: *Dalmanella* cf. *testudinaria* (DALMAN), *Hindella? cassidae* (DALMAN), *Cliftonia* (*Oxoplecia*) sp., *Schizoramma* sp., *Dolerorthis* sp., and others. Of other fossils, excluding the plant-like remains in the lower half of this division, only *Dalmanitina mucronata* (BRONGNIART) and poorly preserved ostracods have been found.

In the following the division 63.00—56.55 m will be referred to as the Black Tretaspis Shale, 56.55—53.30 m as the Green Tretaspis Shale, 53.30—52.10 m as the Masur Limestone, 52.10—37.80 m as the Red Tretaspis Mudstone, and lastly the division 37.80—35.15 m as the Grey or Top Sandstone. It should be kept in mind that these divisions are lithological divisions.

Table I.

Lithological Divisions of the Tretaspis Series in the Core	Lithological Character of Sample	Level m	Dissolved in cold diluted HCl. (Mainly $CaCO_3$) %	Loss by Ignition. (Mainly organic matter) %
Top Sandstone	Grey sandstone	35.40	23.4	3
	Greyish siltstone	36.30	16.4	3.6
	Greyish green mudstone .	37.30	14	4
Red Tretaspis Mudstone	Red mudstone	37.95	23.8	3.2
	Red mudstone	39.95	15.2	3.2
	Green mudstone	39.90	17.2	4
	Red mudstone	46.25	6	4.2
	Red mudstone	51.50	9.2	3.6
Masur Limestone	Grey limestone	52.70	90.0	1
Green Tretaspis Shale	Green mudstone	53.70	4	3.8
	Limestone, nodule	54.15	80.2	1
Black Tretaspis Shale	Dark marlstone	56.60	49.2	4.2
	Speckled shale: Grey substance .	57.10	7.6	4
	Speckled shale: Mostly dark subst.	57.10	3.0	8
	Grey mudstone	59.50	9.0	3.8
	Black shale	62.50	2.4	10.6
	Glauconitic marlstone . .	63.00	43.8	2.6

Analysts J. LUKINS and P. GRUNDULIS.

Lithological and Faunistic Problems.

Several interesting problems are connected with the lithology of the main types of sedimentary rocks found in the Tretaspis Series in the core, *viz.* the alternating beds of dark shale, speckled shale and grey mudstone, the *Masur* limestone and the red and green mudstone. A few more facts will be given here that may help to throw some light upon these problems.

The Speckled Shale.

The speckled shale of the core normally occurs between beds of black shale and grey or grey-green mudstone. The following cycle is often repeated in the Black and Green Tretaspis Shales in the core: Black shale — speckled shale — grey or grey-green mudstone — speckled shale — black shale. In order to obtain a better understanding of the speckled shale, the adjoining beds will here be described more in detail.

It is now generally assumed that black graptolite shales indicate a high degree of stagnation in the sea, at least near the bottom, at the time of their deposition. (See *e.g.* K. MÜNSTER STRØM 1936.) That the black shales of the Tretaspis Series in the core tell of foul water conditions is supported by the fact that they often contain great masses of immature brachiopods, as well as horizons full of graptolites at different astogenetic stages, indicating catastrophic death. Probably both the young brachiopods and the graptolites lived in the oxygen-bearing surface waters and perished when foul waters were lifted to the surface (See P. D. TRASK 1939 p. 99). In this connection it should be emphasized that the fauna of the dark shales in the core is mainly planktonic or pseudo-planktonic (cf. RUEDEMANN 1934), with graptolites, inarticulate brachiopods, immature articulate brachiopods and ostracods.

The grey or grey-green mudstone does not show such accumulations of fossils as the black shale, though fossils are not uncommon. In contrast to the black shale trilobites are rather numerous, and graptolites are absent. Both sediments have in common the lack of sessile benthonic forms. While pyrite concretions are common in the black shales, they are never found in the grey or grey-green mudstone. Table II (p. 384) furnishes further data for a comparison between the black shales and the grey mudstones. The percentages of organic matter and of sulphur are lower in the grey mudstone than in the black shales, and the percentage of carbonate is higher. These facts about the fauna and chemical conditions of the grey and grey-green mudstones seem to show that they were deposited under more ventilated conditions than the black shales.

As stated by J. E. MARR (1929 p. 187) the black graptolite shales are pigmented by finely disseminated iron sulphide, and partly by carbon. The degree of stagnation which may be illustrated by the percentage of sulphur and organic matter is thus also expressed by the colour of the sediment. The analysis seems to show that there is too little iron in the black shale in the core to allow of all the sulphur to occur as ferrous sulphide. The rest of the sulphur probably occurs in sulphates, in organic compounds, or possibly even as free sulphur.

The speckled shale (Swedish: *spräcklig skiffer*) is a dark shale with grey or grey-green lumps. The lumps have their greatest extension subparallel to the bedding planes. They have the form of small lenses, flat wormlike bodies and short, flat twigs. Their length varies from less than 1 mm to a few cm. The difference in colour between the dark and the grey substances may be more or less pronounced. The grey spots show, however, always a sharp outline against the darker surrounding, even under the microscope, and the outline is usually more or less convex. No traces of disparity in the mechanical composition of the grey and dark substance are seen macroscopically, but in thin sections it is seen that the dark rock, in contrast to the grey one, contains small, dark brown pigment grains, more or less closely packed. When most closely packed, the grains cannot be distinguished from one another, and in this case the dark areas appear to be black, both macro- and microscopically. These dark grains possibly consist of a bituminous substance, and in agreement with this chemical analyses show that the dark rock contains 2—3 times as much organic matter as the grey rock (Table II p. 384).

Following the core, upwards or downwards, from a bed of dark shale, one will discern that small isolated, grey lumps soon appear in the dark shale. These then become larger and lie closer and closer together, giving the rock quite an unusual speckled appearance. The lumps next become more or less connected with each other, and grey gradually becomes the dominating colour. Then the dark substance will only form thin contours of the grey lumps, and lastly the rock will consist of a homogenous, grey mudstone. The distance from one bed of non-speckled dark shale to the next usually varies from 10 to 30 cm. It is, however, not always that the dark shale is developed free from grey lumps, just as the grey mudstone is not always quite without dark substance (Plate XXIII).

The fauna in the speckled shale is a mixture of that found in the black shale and that seen in the grey mudstone. As in the black shale pyritic concretions occur, and a fairly large one is shown on Plate XXIII, fig. 1.

From the above it thus seems as if the sediments now found as speckled shales were deposited when conditions, at least near the bottom, were altering from stagnant to ventilated conditions or *vice versa*. It is noteworthy, too, that the core division containing the cycles with speckled shale as a whole occurs above black graptolite shales and below grey-green mudstone.

The fossils in the speckled shale, as well as in the adjoining beds, are more or less flattened, most so in the darkest beds. It is probably owing to their greater content of organic matter that the dark muds have been most compressed. The flattened character of the grey lumps is probably not primary, but due to the same compression, which has been caused by the weight of the overlying beds. According to ATHY (1929) there is a compaction in pure shales of roughly 25% at a depth of 1000 ft. and as much as 45% at 5000 ft. The core section with the pyritic concretion (Plate XXIII) is of special interest, as it seems to show how the compression has caused the bedding planes to bend around the concretion (which probably has been very little compressed), so that the grey lumps have been stretched out into thin, film-like bodies. Another possible explanation is that the pyritic concretion has pushed away the surrounding sediments by its growth. One would then, however, have expected to find a disturbance also at the sides of the concretion.

It seems most reasonable to believe the speckles to be of a primary character. It will not, however, be discussed here how the speckled character may have developed.

Speckled shale is common in the Staurocephalus Zone elsewhere in

Vestergötland. KING (1923 p. 495) mentions a speckled zone from the *Phillipsinella* Beds of the Berwyn Hills. He states that the beds of normal pasty grey-green mudstone become full of specks and blotches or dark-blue mudstone, and that this type of lithology has been found in the lower portions of the Ashgillian throughout the area on the East around Llanfyllin.

A modern sediment showing some resemblance to this rock is described by GRIPENBERG (1934 p. 95). Here, however, the lumps are black, sometimes greenish or bluish, and the surrounding substance grey. This reversion of the colours is sometimes seen also in the core. (See middle part of fig. 2, Plate XXIII.)

The rhythmic alternation between stagnant and ventilated conditions is perhaps only a local phenomenon, as the speckled shale does not seem to be common in corresponding layers outside Kinnekulle, where the black shales seem to dominate. One might think of a basin where renewal and aeration of water at times could cause more ventilated conditions. Considering that the foul water probably was overlaid by a layer of ventilated water, as indicated by the rich planctonic fauna, another possible explanation is that here the (somewhat oscillating) boundary between the two layers of water lay near to the bottom.

It would be of interest to know how persistent the beds of black shale, speckled shale, and grey mudstone are horizontally. Owing to lack of exposures of these layers at Kinnekulle, this is unfortunately not known.

Table II.

Lithological Character of Sample	Level m	% pyritic S	total % S	% Fe	Dissolved in cold diluted HCl. (Mainly $CaCO_3$) %	Loss by Ignition. (Mainly organic matter) %
Grey mudstone	59.5		0.53	4.75[2]	9.0	3.8
Speckled shale: Grey substance . .	57.1	0.053		4.5[1]	7.6	4
Speckled shale: Mostly dark subst.	57.1	2.76		4.25[1]	3.0	8
Black shale	62.5	3.50		5.78[2]	2.4	10.6

Analyst J. LUKINS.

[1] Diluted HCl used for this test. [2] Soda used for this test.

Table III.

Lithological Character of Sample	% Fe total	% Fe‴	% Fe″	Fe‴/Fe″
Red mudstone at 39.95 m	4.75	3.94	0.81	c. 5/1
Green mudstone at 39.90 m	2.75	1.81	0.94	c. 2/1

Analyst J. LUKINS.

The Tretaspis Limestone.

The Tretaspis Limestone, developed as compact *Masur*[1] limestone, and its rather sudden appearance and disappearance constitute another series of problems.

The limestone is fairly pure (90 % $CaCO_3$) and free from any coarse clastic material, thus indicating a deposition under quiet conditions.

The limestone contains no macrofossils. This is rather astonishing, as it is a compact limestone where conditions for preservation should be good. Some (undetermined) microfossils seen in a thin section are of interest, since they show that if macrofossils had been embedded, they would not have been dissolved later on — small fossils usually being dissolved first. There could hardly have been any macrofauna of importance here during the deposition of this limestone. Even microfossils seem scarce. The limestone does not show evidence of organic origin. Such limestones are often said to be chemical deposits, though micro-organisms are probably playing an important part in the precipitation of the carbonates. Such processes are known to occur now in shoal-water areas and in lagoons.

Scattered minute crystals of pyrite tell of somewhat stagnant conditions. In harmony with this there seem to be corrosion surfaces in the limestone, probably telling of times with even higher acidity of the waters.

The Red Tretaspis Mudstone.

The brownish-red mudstone with green bands constitutes the upper part of the Tretaspis Series in the core, with the exception of the top sandstone, into which it gradually passes. Regarding the relation between the red and green mudstone, a few facts will be summarized here. Although the mudstone starts and ends as greenish mudstone, the red colour definitely dominates throughout this division of the core. The green bands are not more than 20 cm thick, usually about 5 to 10 cm. Inside two of these green bands there is a thin layer of bentonite. In the field it is sometimes seen that the green bands after some meters thin out horizontally. In one case half the core only was penetrated by such a band. The boundary between the red and green mudstone is always sharp, as shown even when studied in thin sections under the microscope, with the exception of the somewhat diffuse boundary between the red mudstone and the greenish-grey mudstone at the top. With the exception of the colour, no disparity can be traced between the red and green mudstone, though small pyrite crystals are sometimes found in the green, never in the red mudstone. Chemical analyses (See table III p. 384) show that the proportions between $Fe^{\cdot\cdot\cdot}$ and $Fe^{\cdot\cdot}$ is c. 5 : 1 in the red and 2 : 1 in the green mudstone.

[1] See footnote page 379.

It seems from this as if the green mudstone represents a reduction facies of the red one, and it also seems possible that the colours are mainly due to iron compounds.

It is hardly possible that the green mud was »washed out» and deposited at the same time as the red mud. And the green mudstone would then not have a sharp outline towards the red one.

It has been suggested that the red mudstones have obtained their colour through oxidation after their deposition by having intermittently been laid dry (MOBERG 1904). In the case of the Red Tretaspis Mudstone, however, there are no mud-cracks or other indications of this. Worm-trail- or plant-like fossils in the red mudstone in the core are sometimes green, as well as their nearest surroundings. If the red colour should be due to a secondary oxidation, the green areas might have retained their colour owing to a greater amount of organic matter. In the case of the green layers, however, there is micro- or macroscopically no evidence of this, nor do chemical analyses support this view. (See table I p. 381.)

Most probably the red mudstone was deposited as red mud. Locally it may have been reduced to a green colour by decomposing organic matter. Layers might be formed similarly, though probably not the green layers in the core, as they show no extra amount of organic matter. They may have been deposited as green mud, in a more reducing milieu. The alternation between green and red mudstone would then recall that of black shale and grey mudstone described above. The reducing may, however, have occurred much later, due to reducing gases or solutions penetrating along zones of weakness (*e. g.* bentonite beds), f. inst. in connection with the intrusion of the Kinne-diabase.

The fauna of the red and green mudstones show little variation. Most common are small ostracods and trilobites. A few species of brachiopods are also regularly met with, though they are relatively scarce. No pelmatozoans, bryozoans, corals or other sessile benthonic forms have been met with. This may be due to the water having been too muddy and the bottom too loose. In this connection it is interesting to remember that, as pointed out by HOLM (1883 p. 32 footnote 2), some of the trilobites found here were blind forms (*Lonchodomas*, *Trinodus*) and to note that the nautiloideans seem to have shunned these waters. As more or less complete specimens of the fragile *Tretaspis* species are not too uncommon, it is probable that they lived in these waters. The same can be said about *Sowerbyella? rosettana,* whose valves sometimes are found in juxtaposition. This also shows that the waters have probably been quiet. MOBERG (1904 p. 140) seems already to have noticed that the fauna of the Red Tretaspis Mudstone consists mostly of small forms. Small forms, as well as the paucity of species often characterize the fauna in partly locked waters, especially where the salinity differs from that normal to the open sea, *e.g.* in brackish water. A low salinity could probably alone explain the absence of sessile benthonic forms. Another possible explanation of the absence of these forms as well as the occurrence of blind forms is that the red mudstone represents deep sea sediments. The uniform appearance of the red mudstone may support this view, though the constant amount of angular quartz-grains $\leqq$ 0.5 mm in diameter seems very suspicious. The variability of the thickness of the red mudstone from place to place in Vestergötland also seems to contradict this theory. This variability as well as the relatively great thickness of the Red Tretaspis Mudstone suggest a rather rapid deposition.

The Sediments of the Tretaspis Series as a Whole.

When discussing the lithology of the Tretaspis Series, one is constantly reminded of the Stockdale Shales, treated by MARR (1925). The vertical distribution of the predominating colours show great likeness. Stockdale Shales: dark — blue — green — red. Tretaspis Series: dark — green — red. Here the blue beds are missing, but two thin streaks of blue mudstone have been found at levels 57.3 and 57.0 m, that is in the upper part of the Black Tretaspis Shale.

In both series of sediments the detrital portion shows great uniformity. In both cases the muds are generally fine, though slightly coarser types of sediments occur near the top.

As MARR found in the Stockdale Shales, it is also found in the Tretaspis Series that beds of different character are welded together with no planes of discontinuity. The only planes of discontinuity found inside the Tretaspis Series are the corrosion surfaces in the Tretaspis Limestone, but these are probably of minor importance.

MARR suggests that the Stockdale Shales were deposited within the mudline and in quiet waters. This seems also to be the case with the sediments of the Tretaspis Series.

MARR further attributes the sparse benthonic fauna of the Stockdale Shales to the charging of the lower waters with deleterious substance (»poison»). This seems to be rather certain as regards the black graptolite shales in the core, but the absence of sessile benthonic forms, as well as the rather poor fauna in the Red Tretaspis Mudstone is more probably caused by abnormal salinity or possibly muddy waters. The conditions during the deposition of the red mud could hardly have been stagnant.

Signs of Volcanic Activity in the Tretaspis Series.

The two layers of bentonite in the Red Tretaspis Mudstone (p. 379) tell of volcanic activity in Ashgillian time. As yet, no other layers of bentonite have been recorded from the Swedish Tretaspis Series, nor is any other material of volcanic origin known from this period in Sweden.

It is interesting that in the Trondheim Region in Norway, the Grimsås Rhyolite or Quartz-porphyry, according to TH. VOGT (1945 p. 514), probably represents an effusive rock apparently of Ashgillian age. In Great Britain Ashgillian effusive rocks are known with certainty from different localities.

It thus seems possible that the bentonite layers in the Red Tretaspis Mudstone registrate the volcanic activity in the not too distant Caledonian geosyncline.

Description of Fossils.[1]

BRACHIOPODA.

Inarticulata.

The classification of the inarticulate brachiopods badly needs a revision, a revision in which due attention is paid to the internal characters. Unfortunately these characters are often very faintly developed or not at all discernible. W. C. BELL (1941) has, however, shown that detailed studies give valuable results. Only in respect to the genus *Paterula* BARRANDE can some new information regarding internal characters be added here.

The terminology is that proposed by W. C. BELL. Briefly, this involves applying the term *pseudointerarea* to the posterior slope of the subconical ventral valve in the neotremates and in the *Micromitra*-like species, and the flattened surfaces usually characterizing the thickened posterior margin in many neotremates, and both valves in the atremates. The term *proparea* is applied to each of the two smooth subtriangular surfaces that border the delthyrium and notothyrium in many of the *Micromitra*-like species, and which are delimited from the rest of the valve by ridges or grooves. The term proparea is also applied to each subtriangular half of the pseudointerarea where the pseudointerarea is divided medially by a groove, termed *intertrough* (WALCOTT: false pedicle groove). W. C. BELL further advises the use of the following terms in the description of inarticulates: *delthyrium*, *notothyrium*, *homoeodeltidium*, and *homoeochilidium*.

Genus ***Hisingerella*** n. gen.

Derivation of name: The genus is named in honour of W. HISINGER, who first described the genotype.

Genotype: *Hisingerella nitens* (HISINGER 1838).

Diagnosis:— A small inarticulate with *Micromitra*-like ventral valve (pseudoconical, with pseudointerarea and homoeodeltidium) and a low dorsal valve with an internal median ridge.

[1] When nothing else is stated, the specimen numbers refer to the catalogue of the Museum of the Palaeontological Institute of the University in Uppsala. Table IV pp. 422—424 shows the vertical range of the fossils.

Description: Outline subcircular to somewhat transversely subelliptical, posterior margin slightly truncated; line of valve junction shorter than greatest width of shell. Surface filate, in the genotype faint radiating ribs are present.

Ventral valve: Profile triangular, greatest height at pointed apex, which is situated behind the posterior margin. Delthyrial angle small. Homoeodeltidium continuous with the propareas and completely covering the delthyrium. No foramen observed. No internal features known.

Dorsal valve: Profile slightly convex. Notothyrium low, widely angular Homoeochilidium not observed. Interior with a median ridge.

Discussion: This genus is probably related to the *Micromitra-Paterina-Iphidella* group, the exterior of the ventral valve being the same, with a convex homoeodeltidium and no foramen. As maintained by W. C. BELL (1941) little can be gained by speculation regarding apparent affinities as long as the internal morphology of this group is so imperfectly known. The proposed genus differs, however, from the *Micromitra-Paterina-Iphidella* group in its long and well-defined internal median ridge in the dorsal valve. Such a ridge occurs often in species earlier referred to *Acrotreta*, now often referred to new genera. (One reason for separating new genera from *Acrotreta* has been that the internal characters of the genotype are unknown.) The species referable to *Hisingerella* can, however, not be referred to any of these new genera or to *Conotreta* WALCOTT 1889, all of which have a foramen and only have a median vertical groove (intertrough) across the interarea but no homoeodeltidium. WALCOTT (1912) already laid stress upon this difference between the species he referred to *Micromitra* and those he referred to *Acrotreta*.

In addition to *Acrotreta dubia* HADDING 1913, which should be regarded as a synonym for *Hisingerella nitens*, the closely related but stratigraphically slightly older *Acrotreta nana* HADDING 1913 should be assigned to *Hisingerella*.

Another Ordovician species, *Micromita (Paterina) davidsoni* REED (1917) from the Girvan district, may also belong to this genus. Only the ventral valve is described. On the other hand REED also describes several dorsal valves, resembling the dorsal valve of *Hisingerella*, without being able to associate them with certainty with any ventral valves. He tentatively refers them to *Acrotreta* (?) and *Acrothele* (?).

Hisingerella nitens (HISINGER 1838).

Pl. XXIV, figs. 3, 6—8.

1838 *Atrypa? nitens* — HISINGER, p. 77.
1867 *Orbicula? nitens*, HISINGER — TÖRNQUIST, p. 19.
1880 *Obolella? nitens*, HISINGER — ANGELIN-LINDSTRÖM, p. 21, pl. XIII, figs. 32—34.
1883 *Obolus nitens*, HISINGER — TÖRNQUIST, p. 22.
1913 *Acrotreta dubia* — HADDING, p. 61, pl. V, figs. 24, 25.
1915 *Acrotreta dubia*, HADDING — HADDING, p. 30, pl. IV, figs. 25, 26.

Lectotype:— HISINGER's original description of *Hisingerella nitens* was not accompanied by any illustrations, and he does not describe any individual specimens. A type specimen has been chosen from his original material. It seems the most appropriate to regard this as a lectotype.

The original material belongs to »HISINGER's collection» at the Palaeozoological Department of the Swedish Riksmuseum, Stockholm, and consists of several slabs from the type locality and stratum (as given in HISINGER's work) labelled *Atrypa? nitens*, each slab containing several specimens of *Hisingerella nitens*.

The lectotype chosen (Riksm. Palaeoz. Dep. — Br. 5041 a) is a rather small dorsal valve, measuring 1.3 mm (length) × 1.4 mm (width), but shows well the outline of the valve, as well as the median ridge as it so characteristically appears in compressed specimens. On the same slab (Br. 5041) there are several other dorsal valves of *Hisingerella nitens* of different sizes, as well as a few more or less damaged ventral valves.

Type locality:— Draggån, Rättvik, Dalarna.

Type stratum:— Black Tretaspis Shale.

Material:— A great number of compressed separate valves, also a few complete shells.

Description:— Outline transversely subelliptical to subcircular except for truncated posterior margin. Line of valve junction shorter than greatest width of shell. Greatest width somewhat behind the middle of the shell.

Ventral valve conical, about 0.5 mm high, the highest point being at the apex somewhat anterior to the hinge line. The pseudointerarea is thus steeply procline. The apex is slender and spine-like and is often bent backwards owing to compression. The homoeodeltidium is narrow and rather convex, covers the whole of the deltidium and is continuous with the propareas. The interarea is filate. Interiorly no other markings than reflections of the external sculpture. No foramen has been observed.

Dorsal valve almost flat. The rounded beak projects slightly behind the posterior margin, to fit into the sinus formed by the convex homoeodeltidium of the ventral valve. The pseudointerareal features are not clear, owing to the flatness of the valve. The notothyrium seems very wide, the propareas very narrow and a homoeochilidium has not been observed. The most striking feature in the dorsal valve is the interior median ridge, extending from the apex about 4/5 of the way to the anterior margin. Owing to compression of the thin valve, this ridge often appears as a dorsal external ridge. In complete specimens the compression has not caused such a deformation, but the position of the ridge is usually indicated externally by a faint furrow.

Discussion:— The core specimens agree with HISINGER's original description of *Atrypa? nitens* and the more detailed description in Fragmenta Silurica. Comparisons between specimens from the type locality (at Draggån, Dimensions:

Specimen	Length in mm	Width in mm	Valve	State of preservation	Stratum	Locality
1	1.8	2.0	Dorsal	Compressed	Black	Core 61.50 m
2	1.6	1.9	»	»	Tr. Shale	»
3	1.5	1.8	»	»	»	»
4	1.4	1.6	»	»	»	»
5	0.8	0.9	»	»	»	»
6	2.0	2.4	Ventral	»	»	»
7	1.7	1.9	»	»	»	»
8	1.5	1.8	»	»	»	»
9	1.5	1.8	Dorsal	Strongly compressed	»	Rättvik, Dalarna
10	1.4	1.5	»	»	»	»
11	1.4	1.8	Ventral	»	»	»

Rättvik, Dalarna) and the core specimens leave no doubt as to their representing the same species. Specimens from Hamra, Östergötland, a locality described in Fragmenta Silurica, also belong to the same form.

The core specimens also agree well with the description and figures of *Acrotreta dubia* HADDING (1913, 1915) from the zone of *Climacograptus styloideus* in Bornholm, and from the zone of *Dicranograptus clingani* as well as from older zones as far down as the zone of *Nemagraptus gracilis* in Scania. Specimens from these localities could not be distinguished from the core specimens.

Occurrence in core:— Very common in the Black Tretaspis Shale, 62.60—57.70 m. *Hisingerella nitens* is, in fact, the most common inarticulate brachiopod in the Tretaspis Series of the core.

Regional distribution:— Sweden: Dalarna, Östergötland, Västergötland. — Denmark: Bornholm.

Stratigraphic range:— Zone of *Nemagraptus gracilis* to (and including) zone of *Climacograptus styloideus*, the latter zone, at least partly, corresponding to the Black Tretaspis Shale.

Genus ***Paterula*** BARRANDE 1879.

Genotype:— *Paterula bohemica* BARRANDE 1879.

Diagnosis:— The outline is subcircular to elongate subelliptical. Both valves are slightly convex except for a flat marginal border. A pedicle fissure penetrates the margin posteriorly. In the interior a ring-like ridge separates the marginal border from the central disc. A corresponding groove is found in the dorsal valve. Two divergating furrows extend from the apex to the central region of the ventral interior.

Remarks:— To the genus *Paterula* species have been referred from Bohemia, Sweden, Scotland (REED 1917) and N. America (RUEDEMANN

1934 p. 79). All the species included in this genus seem to be closely related. When erecting the genus, BARRANDE (1879) states: »Les 2 valves, circulaires ou faiblement ovalaires, ne présentent qu'un bombement très peu prononcé vers l'extérieur. L'espace interne devait donc être très exigu. Ces 2 valves se rencontrent habituellement isolées. Cependant, nous figurons Pl. 152, 2 spécimens de valves juxtaposées, qui paraissent avoir appartenu à un même individu. Nous pouvons ainsi constater, qu'il n'existe aucune fissure, sur la surface ni de l'une, ni de l'autre valve. Ce fossile n'est donc pas une *Discina.* Mais nous observons, au contraire, la trace d'une perforation sur le bord. Elle est indiquée par un petit cylindre de la roche, qui l'a injectée et qui fait saille sur le contour.» A study of all the species now known permits a more precise diagnosis of the genus as given above.

Stratigraphic range:— Ordovician.

Paterula cf. ***bohemica*** BARRANDE 1879.

Pl. II, fig. 2.

1879 *Paterula Bohemica* — BARRANDE, Vol. V, p. 110, pl. 95, figs. I: 1—3, pl. 152, figs. I: 1—9.

1913 *Paterula Bohemica,* BARR. — HADDING p. 60, pl. V, figs. 16—19.

Material:— A small number of compressed separate valves.

Diagnosis:— A subcircular thick-shelled *Paterula* with strong internal submarginal ridge, making a sinus forward in front of the distinct pedicle fissure. Apex situated submarginally in both valves.

Description:— The outline is circular or slightly elongate elliptical. The greatest width of the shell is slightly behind the middle. Conspicuous growth lines and fila. Inconspicuous radiating lines are sometimes visible.

Ventral valve slightly and rather evenly convex (most so posteriorly), except for the depressed marginal border (0.3 mm broad anteriorly), only broken posteriorly by a conspicuous pedicle fissure. The apex is situated submarginally and is bluntly rounded. Interiorly a conspicuous ridge, representing a thickening of the shell, runs just inside the marginal border. In front of the fissure the ridge becomes lower and makes a shallow sinus forwards (inwards). At two more places, on each side of the valve, about one-third of the way from the posterior to the anterior end, the ring-like ridge shows minor irregularities. Here the ridge is faintly depressed and makes an inconspicuous sinus inwards as it sends off a ridge or fold-like elevation, obliquely backwards, pointing against the apex. From the apex two distinct furrows radiate to the middle of the shell. Here they embrace a smooth oval spot, partly divided by a short median furrow. At the end of each radiating furrow there is an indistinctly delimited, rough spot. In front of all the spots there are a number of short branch-like structures, probably representing vascular markings.

Dorsal valve. Also slightly convex, perhaps a little more than the ventral valve. The apex is situated submarginally and is bluntly rounded here too. The depressed margin corresponds to that of the opposite valve, but shows no notch. In the interior a groove opposes the ring-like ridge of the ventral valve. There is an oblique groove corresponding to each of the oblique ridges of the ventral valve. A number of faint furrows radiate from the apex halfway to the anterior and lateral margins.

Dimensions:

Length	Width	L/W
3.3 mm	3.3 mm	1.0
3.2 »	3.0 »	1.1
2.6 »	2.5 »	1.0
2.5 »	2.5 »	1.0
1.4 »	1.3 »	1.0
1.0 »	0.9 »	1.1

Discussion:— The core specimens agree well with BARRANDE's illustrations. Even the ratio length : width is the same as far can be judged from illustrations. As no Bohemian material of *Paterula bohemica* has been available for comparison, it is not advisable to refer the core specimens to *Paterula bohemica* with certainty, the more so as a renewed study of the Bohemian material may lead to the separating of new species, — the great vertical range (d1—d3—d5) pointed out by BARRANDE, being suspicious. A lectotype or neotype should be chosen from Bohemian material.

The specimens depicted by HADDING (1913) from Scania as *Paterula bohemica* seem similar to the core specimens. HADDING reports this species from as low down as in the zone of *Nemagr. gracilis*, as well as in the nearest overlying beds.

Occurrence in core:— Rather limited, 58.40—57.70 m in the Black Tretaspis Shale.

***Paterula* cf. *portlocki* (GEINITZ 1852).**

Pl. XXIV, figs. 4, 5.

1852 *Orbicula* (*Orthis*) *Portlocki*, GEINITZ p. 25, pl. I, fig. 31 (and 32?).
1890 *Discina Portlocki* (GEINITZ) — GEINITZ p. 27.
1915 *Discina Portlocki* (GEINITZ) — HADDING p. 30, pl. IV, figs. 21, 22.

Material:— A number of compressed, separate valves.

Diagnosis:— An ovate, thin-shelled *Paterula* with faint internal submarginal ridge. Apex situated nearly midway between posterior border and centre in ventral valve, slightly more posteriorly in dorsal. Pedicle fissure not very conspicuous.

Description:— Outline ovate, greatest width slightly behind middle of shell. Conspicuous concentric growth-lines and fila.

Ventral valve. Very low conical with depressed marginal border. Apex situated about midway between posterior margin and centre. Owing to mode of growth, the apex is relatively nearer the posterior margin in old shells than in young.

Interior of valve shows an inconspicuous submarginal ridge. A short groove posteriorly crosses this and the marginal border and ends in a shallow pedicle fissure. Two distinct but fine furrows radiate from the apex to the middle of the shell. A fainter system of radiating elements is occasionally seen. It is most conspicuous where it crosses the marginal growth-lines.

Dorsal valve. Very low conical with depressed margin. The apex is perhaps situated a little more posteriorly than in the ventral valve. Interiorly a faint system of radiating elements. In one case an inconspicuous and short median septum was observed.

Dimensions:

Length	Width	L/W
3.0 mm	2.6 mm	1.15
2.6 »	2.2 »	1.20
2.6 »	2.1 »	1.25
2.5 »	2.1 »	1.20
2.5 »	2.0 »	1.25
2.2 »	1.8 »	1.25
1.0 »	0.85 »	1.20

Discussion:— When erecting the species, GEINITZ only gives the following information about it: »durchschnittlich nur zwei Linien gross . . ., mehr oval-kreisrund, nicht kreisrund . . ., ziemlich randliche Lage des niedrigen Wirbels . . ., dicht an dem Rande vor ihrem Wirbel noch eine kleine leistenförmige Erhöhung . . .»

GEINITZ also states that this species occurs in Bornholm together with a certain graptolite that HADDING later has identified as *Diplograptus calcaratus robustus* HDG.

In spite of this not too detailed description, HADDING was able to find out which species GEINITZ meant of the several inarticulates occurring in the Middle Dicellograptus Shale of Bornholm, because only one showed the »little ridge-like elevation» behind the apex.

The core specimens agree well with HADDING's description, except for his remark that the dorsal valve (HADDING: ventral valve) has a low internal median ridge. His figures also show specimens more circular than the ovate core specimens.

Paterula cf. *portlocki* differs from *Paterula* cf. *bohemica* in the more central position of its apex, its more elongate elliptical outline, less pronounced pedicle fissure and internal ridge in the ventral valve, and in its thinner shell substance. The two radiating furrows in the ventral valve are, however, quite similar in these two forms. In shape and size *Paterula* cf. *portlocki* recalls some of the *Paterula balclatchiensis* specimens figured by

REED (1917), one even showing the same pair of radiating furrows. Just in these specimens the apex is, however, situated more marginally than in the others figured by REED. The constancy in the ratio length : width in each of the two core species of *Paterula* suggests that the specimens referred to *P. balclatchiensis*, some distinctly elongate elliptical, other subcircular, might belong to different species or subspecies.

Occurrence in core:— 64.5—56.7 m. This means that it occurs from the base of the black (Chasmops) shale below the Black Tretaspis Shale to the top of the latter. It is interesting to compare this vertical distribution with the small one of *Paterula* cf. *bohemica* (58.40—57.70 m). *Paterula* cf. *portlocki* occurs fairly regularly, though never in such great numbers as *Hisingerella nitens*.

Lingulellid, gen. et sp. ind.

A few more or less crushed separate valves of a *Lingulella*-like brachiopod have been met with in the lower part of the Black Tretaspis Shale (63.30—61.80 m). In size and shape the specimens agree very well with the description of the shell HADDING (1915) names *Lingula dicellograptorum* var. *pulla*, from the Middle Dicellograptus Shale of Bornholm and Scania. The interior is, however, quite unknown in the core specimens, as well as in the Bornholmian and Scanian specimens.

Articulata.

The determination of articulate brachiopods is more or less dependent on their internal characters. It has not always been possible to study these in the core material, and consequently the systematic position of several species described here is not certain. In some cases material collected in the field has given additional informations.

In addition to the brachiopod species described below from the Black, Green and Red Tretaspis Beds, also others occur in the core. A small strophomenid is met with in the Black Tretaspis Shale, or rather in the dark limestone lenses in the shale. Immature dalmanellid specimens (perhaps »*Orthis*» *argentea* HISINGER) occur in the Black and Green Tretaspis Shales. A tiny (1—2 mm) dalmanellid with a rather convex ventral and an almost flat dorsal valve is regularly met with in the Red Tretaspis Mudstone.

In the sandstone, here tentatively referred to the Tretaspis Series as its top bed, there are a number of brachiopod species, only represented by one or two shells each in the core. With the exception of one easily recognisable little *Schizoramma* sp., it has therefore not been advisable to give any description of these brachiopods until more material has been collected in the field, the more so as many species probably will prove to be new. To give an idea of the fauna, the following preliminary determination by Mr. V. JAANUSSON is given: *Dalmanella* cf. *testudinaria* DALMAN, *Hindella?* cf. *cassidae* DALMAN, *Cliftonia* (*Oxoplecia*) sp., *Dolerorthis* sp., and others.

The writer wishes to thank his friend Mr. V. JAANUSSON for most valuable help and advice regarding the study of the articulate brachiopods in the core.

Genus **Sowerbyella** JONES 1928.

Sowerbyella? cf. **restricta** (HADDING 1913).

1913 *Leptaena sericea* var. *restricta* HADDING, p. 62, pl. V, figs. 29—33.

Immature shells, usually less than 2 mm wide, occur in astonishing quantities at several levels in the Black and Green Tretaspis Shales. Most of them have only 5—6 radii developed. The radii often show a tendency to swell in the umbonal region. Shells belonging to stages transitional to the far less common adult specimens have also been found.

Adult shells agree very well with the description given by HADDING, having 11—13 radii and maximally 5 interradial costae. The primary 5 radii play a slightly more dominating rôle than the other radii. The shells in the core show no internal features other than that they are papillose. They reach a width of fully 5 mm and a length of just over 3 mm.

Remarks:— As long as the internal characters are not known, the systematic position of this shell is uncertain. In size and external ornamentation this shell recalls a species described as *Sowerbyella sericea* var. *albida* by REED (1917) from the Girvan district and referred to as *Leptelloidea? albida* (REED) by JONES.

Occurrence in core:— In the black shale at the top of the Chasmops division, and in the Black and Green Tretaspis Shale.

Occurrence elsewhere:— HADDING states that this form is found in the zone of *Nemagraptus gracilis* and the nearest younger beds, as well as in the corresponding Ogygiocaris Shale in Jämtland. He also reports it from the Chasmops and Tretaspis Series. Besides at Kinnekulle it also occurs in other localities in Vestergötland.

The **Sowerbyella subcorrugatella** Group. JONES 1928.

1880, ANGELIN-LINDSTRÖM (Fragmenta Silurica) p. 30, pl. XVII, figs. 1—4.
1916, HOLTEDAHL, p. 79, pl. XIV, figs. 6, 7.
1917, REED, p. 886, pl. XV, figs. 33, 34.
1928, O. T. JONES, pp. 463, 511, pl. XXIV, figs. 14, 15.

Sowerbyella? rosettana n. sp.

Pl. XXIV, figs. 9—12.

Derivation of name:— From Lat. *rosetta*, alluding to the fact that the two valves are often found in juxtaposition and give the fossil a rosette-like appearance.[1]

[1] It is a curious fact that even other brachiopods are not uncommonly found in juxtaposition in the Red Tretaspis Mudstone; in samples from Östergötland both a *Sampo* sp. and a small dalmanellid.

Holotype:— bp. 5276.
Type locality:— Jonstorp, Vestergötland.
Type stratum:— Red Tretaspis Mudstone.
Core material:— A number of separate valves, ventral moulds and complete shells.

Diagnosis:— A species reminding of the *Sowerbyella subcorrugatella* group. In the mid-region of the ventral valve four dominating primary radii border two radiating (paramedian) sulci, between which there is a low, flattened median fold. These features are reversed in the dorsal valve, which has two paramedian folds and a shallow median sulcus. The transverse rugae between the radii of the shell are non-continuous, concentric folds.

Description:— External features. The shell is concave-convex. The outline is subsemicircular, the greatest width at the hinge. The anterior part is often concealed by matrix, making the shell appear broader than it really is. The cardinal angles are slightly produced and about 70°, but they are often defective and then seem rectangular. The ventral valve is apsacline and the dorsal valve hypercline, the angle between the two interareas being negligible.

The surface of both valves is covered by radiating costae of two distinct sizes, the radii and threads of O. T. JONES. Between the radii there are conspicuous transverse wrinkles, concentrically arranged, each wrinkle being slightly convex posteriorly and terminating laterally at the radii.

There is no special alignment of the transverse rugae; one ruga (wrinkle) may be next its fellow in the adjacent series, or may be opposite a transverse stria between the rugae. The threads undulate over the wrinkles.

The median region of this shell is of special interest. In the ventral valve it is separated from the two lateral sectors by a pair of well-raised primary radii. Inside this pair of radii, there is another pair of equally well-raised primary radii. These four radii play a dominating rôle in the sculpture and will be termed the main radii (inner and outer pair). The space between the inner main radii will be termed the median sector, while the spaces between the inner and outer main radii will be called the paramedian sectors. In the median sector there are, in adult specimens, one secondary (median) radius and two tertiary radii, and in each of the paramedian sectors, also, there is one secondary radius. The total number of radii in the middle third (including the outer pair of main radii) is thus nine. Between every two of these radii there are from 2 to max. 5 threads.

Turning to the lateral sectors of the shell, these have each 4—5 radii, equal in strength but not in length. They correspond in strength to the secondary radii in the mid-region; though each lateral sector has one primary radius. The number of threads between the radii in the lateral thirds also number maximally five. The total number of radii in one valve is about 20.

In the dorsal valve the four main radii lie in the bottom of grooves, instead of being raised as in the ventral valve.

The ventral valve is convex, most so posteriorly. The two paramedian sectors are developed as sulci and the median sector is slightly fold-like. At the beak the fold of the median sector dominates anteriorly. In the concave dorsal valve these features are reversed. The anterior margin is thus biplicate.

Internal features. Furrows, corresponding to the radii and threads of the exterior, are well developed along the margin, but become fainter posteriorly. Transverse depressions, corresponding to the wrinkles, are more or less developed. The interior of the valves is coarsely papillose. The papillae are situated in rows between the furrows. Especially those on each side of furrows corresponding to radii are well developed. Papillae do not occur in the transverse depressions, but are often well developed just around these. The papillae become fewer and coarser posteriorly. They are, however, not developed in the muscular area of the ventral valve, nor in the corresponding part of the dorsal valve.

In the ventral interior the dental lamellae are well-defined, about 0.6 mm long in a shell of the average size, and enclose the two equally short muscle-impressions. The well-marked medium septum forks anteriorly after a short distance (0.3 mm). The branches make nearly a right angle with one another and form the inner boundaries of the muscle-impression. Each muscle-impression is divided radially by a furrow, which also continues in front of these. The furrows probably represent the pallial markings.

Dorsal interior. The hinge-line is not crenulated. The crural bases are straight and conspicuous, diverging at about 175°. They are connected with the cardinal process, which, unfortunately, is defective in the only specimen showing the dorsal interior. Anteriorly the cardinal process is seen to be divided by a short but conspicuous furrow. Two septa, ending in papillae, run from the cardinal region half way towards the anterior margin. There is no median septum and no so-called »Sowerbyellen-Grube» (ÖPIK).

Dimensions:— The shells in the core reach a size of 5 mm (length) × 11 mm (width), and shells of about this size are most common. The smallest specimen measures 2 × 4 mm.

Discussion:— The wrinkled or corrugated surface of this species suggests its place in the *Sowerbyella subcorrugatella* Group of O. T. JONES. The interior of the ventral valve, with the small muscle-impressions, clearly resembles that of *S. subcorrugatella* REED (probably from Upper Bala). In size and outline *S.? rosettana* reminds one especially of the *S. subcorrugatella* specimens originally described from Tyrone (probably Upper Bala) by PORTLOCK (1843 p. 450) as a variety of *Leptaena sericea*; these specimens being smaller and with more radii than the *S. subcorrugatella* specimens described by REED from the Girvan district, Whitehouse Group. (See O. T. JONES 1928 p. 463.) O. T. JONES does not state anything about the internal features of the dorsal valve of *S. subcorrugatella*. As long as these are unknown, the generic reference of the species remains uncertain. Unfortunately, neither the dorsal interior of *S.? rosettana* is fully known, but the »Sowerbyellen-Grube» is lacking. As this cavity is considered an important feature of the Sowerbyellinae by ÖPIK (1933 p. 48), it is possible that this species should not be referred to *Sowerbyella*. *S. subcorrugatella* REED may be congeneric with *S.? rosettana* n. sp.

Several specimens of *S.? rosettana* n. sp. belonging to the Palaeontological Institute of Uppsala were labelled »*Leptaena trabeata?* LINDSTRÖM». Examination of the original material used in the description of *Leptaena trabeata* in Fragmenta Silurica at the Riksmuseum, Stockholm, showed that this is quite another species. *Sowerbyella? trabeata* LINDSTRÖM is larger, has a finer and more regular concentric structure, and differs from *S.? rosettana* also in internal features. *S.? rosettana* agrees better in size with *Plectambonites trabeata* LINDSTRÖM var. *acuminata* HOLTEDAHL (1916) from the Tretaspis (Trinucleus) Division in Norway. Comparison with HOLTEDAHL's material shows that the wrinkles here, too, are finer and more continuous than in *S.? rosettana*. The development of the median region of *S.? rosettana* n. sp. differs, however, from that of all the other forms mentioned above.

Occurrence in core:— Commonly in the fossiliferous part of the Red Tretaspis Mudstone (50.60—44.20 m).

Regional distribution:— This shell is known from different localities for Red Tretaspis Mudstone in Vestergötland: Jonstorp (Mösseberg), Skogastorp (Plantaberget), Kungslena (Varvsberget), and from Red Tretaspis Mudstone at Rödbergsudden, Östergötland. Shells from the latter locality are smaller, the largest specimens found in the collections measuring 4 × 8 mm. Shells near to this size were commonest.

Sowerbyella? sp. ind.

A small shell with *Sowerbyella*-like exterior has been met with at different levels in the Red Tretaspis Mudstone. One complete shell measured 3.5 (length) × 6 (width) mm. Either owing to bad preservation or to faint development of the costae, little can be seen of the external ornamentation. There appear to be 5 primary radii and possibly some shorter radii. There are only scarce indications of threads. The mid-region of the ventral valve is slightly gibbous. The specimens are probably neanic. Nothing of the interior is known.

Genus ***Christiania*** DAVIDSON.

Christiania sp. ind.

A small *Christiania* species is regularly met with in the lowermost part of the Red Tretaspis Mudstone (50.90—50.60 m). Its dimensions varies between 7 mm (length) × 8.1 mm (width) and 6 mm × 6 mm. The valves have a slightly rough, only concentrically striated surface. A faint but conspicuous sulcus in the ventral valve reaches the anterior margin, making this appear slightly bilobate. No precise diagnosis of this species will be given as long as the interior of other *Christiania* species remains so incompletely known, and the exterior of the species differs so little. The same species as in the core has been found at various localities in Vestergötland and in Östergötland. *Christiania* specimens rather like those from the Red Tretaspis Mudstone have been found at level 57.50 and levels 56.20—56.80 m in the Green Tretaspis Shale. They seem to be proportionately slightly wider. A single *Christiania* specimen has been found in the Black Tretaspis Shale (58.80 m).

Genus ***Schizoramma*** FOERSTE 1912.

Schizoramma sp. ind.

Pl. XXIV, figs. 13—16.

Material:— Four ventral valves (only one from the core), showing the exterior only.

Description:— The ventral valve is subpyramidal. Outline transverse subelliptical, strongly truncated posteriorly. Cardinal angles rounded. Hinge wide and straight. Anterior commissure rectimarginate. Interarea plane and slightly procline. Beak not incurved. The delthyrium is open but constricted by lateral plates, making the opening narrow and almost parallel-sided for the greater part of its course. As a result of the development of lateral plates, the strong teeth are situated some distance laterally from the margin of the opening.

Surface multicostellate. New costellae arise by implantation. Both costellae and striae also cover the otherwise smooth interarea. Growth-lines are indicated by faint swellings of the costellae. Near the margin one or two growth-lines seem to be indicated by imbrication.

Dimensions of ventral valve:

Specimen	Length in mm	Width in mm	Height in mm	Locality	Collector
bp. 5332	4	6	3	Core 35.56 m	
bp. 5333	5	7	3.5	Kullatorp	G. HENNINGSMOEN
bp. 5334	5	7	3.5	»	»
bp. 5335	3	5	2.5	»	»

Occurrence in core:— Level 35.56 m.

GRAPTOLOIDEA.

It has not been possible to detect in the core the only graptolite mentioned by LINNARSSON (1871 p. 347) from the Tretaspis Series at Kinnekulle: *Diplograptus pristis* (HIS.).

The graptolites described below are, however, all from the Black Tretaspis Shale, while LINNARSSON records *Diplograptus pristis* (HIS.) from the Green Tretaspis Shale. Admittedly graptolites (probably a *Diplograptus* sp.) have been met with in the Green Tretaspis Shale of the core, but their state of preservation has been too bad for determination. Even in the Black Tretaspis Shale the graptolites have not always been possible to identify.

The greater part of the graptolites have been determined by Dr. P. THORSLUND.

Family ***Dicranograptidae*** LAPWORTH 1873.

Genus ***Dicellograptus*** HOPKINSON 1871.

Dicellograptus johnstrupi HADDING 1915.

1915 *Dicellograptus Johnstrupi* HADDING p. 24, pl. III, figs. 12—18.

Type data:— As lectotype is here chosen the larger of the four typical specimens on the slab from Risebæk, Bornholm, reproduced by HADDING (Pl. III, fig. 16) and belonging to the Geol.-Min. Institute in Lund.

The stipes.— For the first 5 mm the stipes diverge with an axillary angle of 330°—310°. Often this part only is found. Then the stipes make an outward bend with more conspicuous divergence. The upper part shows a gentle convex curvature. In one specimen the convex curvature starts right at the origin. In three specimens the stipes can be traced for fully 5 cm, and in one for 6.5 cm, though in most specimens the length varies from 0.5 to 1.5 cm. At the proximal end the stipes have a breadth of 0.4 mm or somewhat less. After 5 mm they have obtained a breadth of 0.8 mm. The longest specimens have a breadth of 1.3 mm at the distal end. The material is more or less compressed. The least compressed specimens are somewhat more slender (obtaining a breadth of only 0.7 mm after 10 mm). The longer stipes are usually twisted.

The proximal end:— Specimens showing both reverse and obverse aspects are commonly found. The sicula is not preserved in its full length in any of the specimens. The virgella is fairly short, but usually quite conspicuous just as the spines of th. 1^1, 1^2, 2^1 and 2^2. In one case what is probably the apertural spine of the sicula can be seen. The two proximal thecae grow almost horizontally, giving off a mesial spine not far below

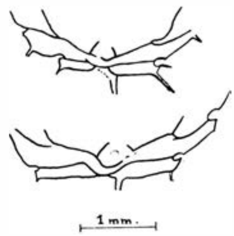

Fig. 2. *Dicellograptus johnstrupi* HADDING. Reverse view of the proximal end of two specimens, gr. 332 (above) and gr. 333 (below), from level 57.70 m.

the aperture (as do also th. 2^1 and 2^2). The distance between their apertures varies from 1.3 to 2 mm. The thecae develop as typical for *Dicellograpti.* Th. 2^1 is quite long for a theca in the proximal region (up to 1.5 mm).

The distal thecae:— There are about 12 thecae in the first 10 mm. In the larger specimens there are about 8 in 10 mm at the distal end. Each theca is 2.5 mm long and overlaps for nearly one half its length. The apertural excavation occupies about one third of the width of the stipe. The free ventral wall is curved, and the apertural portion is introverted.

Remarks:— The core specimens agree well with *Dicellograptus johnstrupi* described by HADDING from the zone of *Climacograptus styloideus* in Bornholm, but they often bear a somewhat greater resemblance to *Dicellograptus morrisi* HOPKINS in its general form. The earliest developed thecae are, however, characteristically slender, not wide as in *Dicellograptus morrisi.* (See text-fig. 2.) These two species are obviously closely related. *Dicellograptus morrisi* is reported from black Tretaspis shale in Dalarna (THORSLUND 1935 p. 48) and Jemtland (THORSLUND 1940 pp. 84, 87).

Occurrence in core:— In the Black Tretaspis Shale (62.20—57.90 m).

Family ***Diplograptidae*** LAPWORTH 1873.

Genus ***Diplograptus*** McCOY 1850 s. s.

Subgenus ***Orthograptus*** LAPWORTH 1873.

Diplograptus (***Orthograptus***) cf. ***truncatus*** LAPWORTH 1877.

1877 *Diplograptus truncatus* — LAPWORTH, p. 133, pl. VI, fig. 17.
1907 *Diplograptus* (*Orthograptus*) *truncatus*, LAPWORTH — ELLES & WOOD, p. 232, pl. XXIX, figs. 3 a—e.
1915 *Diplograptus truncatus*, LAPWORTH — HADDING, p. 14, pl. II, figs. 4—7.

Description:— Fragments, probably belonging to *Diplograptus truncatus* LAPWORTH, are not uncommon in the Black Tretaspis Shale. One rhabdosome could be traced for 2.5 cm. In 15 mm it widened from 1.2 to more than 3 mm. The thecae are never well preserved, but seem to widen at the edge of the aperture, overlapping for one half the total length. The apertural margin is slightly concave; excavation inconspicuous. The thecae have a length of almost 3 mm, and have a general inclination of more than 30°; 8—9 in 10 mm.

Remarks:— This form is somewhat smaller than the British one (zones of *Dicranograptus clingani* and *Pleurograptus linearis*), but agrees well with the form described from Bornholm and Scania (zone of *Climacograptus styloideus*).

Diplograptus (Orthograptus) truncatus pauperatus Elles & Wood 1907.

1907 *Diplograptus (Orthograptus) truncatus*, Lapworth var. *pauperatus* — Elles & Wood, p. 237, pl. XXIX, figs. 5 a—d.

1915 *Diplograptus truncatus* Lapw. var. *pauperatus*, Lapw. mscr. — Hadding, p. 15, pl. II, figs. 8—11.

The stipes:— All the specimens seem to be fragments only. The longest fragment with proximal end preserved measures 11 mm. The longest fragment without proximal end is 21 mm long. As full breadth, almost 2 mm, is obtained after 5 mm, the polypary may at least reach a length of 26 mm.

The proximal end:— This is preserved in three specimens, all showing the obverse side. The breadth is 1 mm. The sicula is free for fully 1 mm till it is concealed by th. 3^1. The virgella can be traced for nearly 1 mm. A short apertural spine can also be seen. The thecae 1^1 and 1^2 are developed as is normal in *Diplograpti*. Th. 1^1 gives off a spine some little distance below the aperture, while th. 1^2 gives off another where direct upward growth commences. These mesial spines could also be traced for about 1 mm. No septum makes its appearance until five thecae have developed on each side.

The thecae have a length of 1.8—1.9 mm and overlap for one half their extent. They widen throughout, somewhat abruptly immediately under the apertural margin, reaching a width of 0.6 mm. In bi-profile view they have an inclination of about 35°, and there are 10—13 thecae in 10 mm. The apertural margins are everted, slightly concave as they transgress a little upon the wall of the theca immediately above. The excavation is fairly inconspicuous. Growth-lines are well marked (about 17 in one theca).

Remarks:— This form agrees well with the British form from the zones of *Dicranograptus clingani* and *Pleurograptus linearis*, but seems to be somewhat larger than the specimens from the zone of *Climacograptus styloideus* in Bornholm.

Occurrence in core:— In the Black Tretaspis Shale. Level 57.6 m.

Diplograptus (Orthograptus) quadrimucronatus (Hall) 1865.

1865 *Graptolithus quadrimucronatus* — Hall, p. 144, pl. XIII, figs. 1—10.

1907 *Diplograptus (Orthograptus) quadrimucronatus*, Hall — Elles & Wood p. 223, pl. XXVIII, figs. 1 a—d.

1915 *Diplograptus quadrimucronatus*, Hall — Hadding, p. 12, fig. 3.

Description:— Rhabdosome more than 7 cm in length, widening gradually within 15 mm from 1.3 mm to a breadth of about 3 mm, which is then maintained. Sicula 1.5 mm long. Thecae 10—11 in 10 mm, having a length of 2 mm, and overlapping for somewhat less than half their extent. Apertural margins slightly lobate, both outer angles furnished with stiff projecting spines. In symmetrical view the thecae have a general inclination of fully 20°. In other views the spines are often invisible.

Remarks:— This form agrees well with the British form (zone of *Pleurograptus linearis*) as well as with the form from Bornholm and Scania (zone of *Climacograptus styloideus*).

Occurrence in core:— In the Black Tretaspis Shale (62.7—62.6 m).

Genus ***Climacograptus*** HALL 1865.

Climacograptus styloideus LAPWORTH 1878.

1878 *Climacograptus styloideus* — LAPWORTH, p. 330.
1906 *Climacograptus styloideus*, LAPWORTH — ELLES & WOOD, p. 205, pl. XXVII, figs. 9 a—e.
1915 *Climacograptus styloideus*, LAPWORTH — HADDING, p. 21, pl. II, figs. 20—27.

Description:— Rhabdosome, traced up to 2 cm, widens quickly from 0.8 mm at its origin to 1.8 mm. Sicula not observed. Virgella traced for more than 1 mm. Thecae overlap for a very small fraction of their extent, about 10 in 10 mm, fully 1 mm in length. The excavations are slightly oblique and inclined downwards and inwards.

Remarks:— The specimens in the core differ from the British form (zone of *Pleurograptus linearis*) through their smaller size, but agree very well with the Bornholmian form (zone of *Climacograptus styloideus*). The species is also reported from black Tretaspis shale in Dalarna (THORSLUND 1934 p. 48) and in Jemtland (THORSLUND 1940 p. 22).

Occurrence in core:— In the Black Tretaspis Shale (levels 62.8 and 62.1 m).

Climacograptus cf. ***minimus*** (CARRUTHERS 1868).

1868 *Diplograpsus minimus* — CARRUTHERS, p. 125, pl. V, figs. 12 a—b.
1906 *Climacograptus minimus*, CARRUTHERS — ELLES & WOOD, p. 191, pl. XXVII, figs. 1 a—g.

A tiny *Climacograptus* is met with at several horizons of the Black Tretaspis Shale. The longest rhabdosome reaches a length of 9 mm and a breadth of 1.4 mm. The rounded proximal end has a breadth of less than 1 mm, but widens in four mm to 1.3 mm. Sicula visible for 1 mm of length; virgella conspicuous; virgula distally prolonged. Basal thecae adorned with short spines somewhat below the apertures. Length of thecae about 1 mm. Owing to their unfortunately compressed state, little more can be said about the thecae. The apertures seem to be situated in deep excavations. The septum originates at once between th. 2^1 and th. 2^2.

Remarks:— The breadth of this form lies between the breadth of *Climacograptus minimus* CARR. (nearly 2 mm) and that of *Climacograptus brevis* E. & W. (up to about 1 mm, as a rule rather less). The compact and rounded-off appearance of the proximal end points towards *C. minimus*. *C. minimus* is found in the zone of *Dicranograptus clingani* and *Pleurograptus linearis* in Scotland, and is also reported from the black Tretaspis shale in Dalarna (THORSLUND 1934). *C. brevis* occurs in the zones of *Nemagraptus gracilis* and *C. peltifer* in Britain, but is reported from the zones of *Dicranograptus clingani* and *C. styloideus* in Bornholm by HADDING.

Family ***Leptograptidae*** LAPWORTH 1879.

Genus ***Leptograptus*** LAPWORTH 1873.

Leptograptus flaccidus macer ELLES & WOOD 1903.

1903 *Leptograptus flaccidus* var. *macer* — ELLES & WOOD, p. 110, pl. XV, figs. 2 a—i.
1915 *Leptograptus flaccidus* var. *macer,* ELLES & WOOD — HADDING, p. 25, pl. III, figs. 20—23.

Only fragments have been found. One stipe could be traced for more than 4 cm from its origin, its breadth here being c. 0.25 mm. The greatest breadth observed was 0.6 mm. The thecae are badly preserved and the sicula is broken off; but the characteristic oblique look of the proximal end, the wide angle (220°—190°) and the tenuity of the stipes permits one to place this form in *Leptograptus flaccidus macer* E. & W.

Remarks:— The British form occurs in the zone of *Pleurograptus linearis* and the Bornholmian and Scanian one in the zone of *Climacograptus styloideus*.

Occurrence in core:— In the Black Tretaspis Shale (level 62.6 m).

TRILOBITA.

Only the *Tretaspis* specimens in the core have been the object of a closer examination, in order to compare them with the subspecies established by STØRMER. The material is, however, not very good. This is even more the case with the other trilobites, and as these are scarce in the core, no detailed description of these species will be given here.

Besides the species occurring in the core the following trilobites have been found in the Green Tretaspis shale at Kinnekulle, according to LINNARSSON (1869): *Phacops recurvus* LINN., *Dindymene ornata* LINN., *Acidaspis* sp. and *Calymene* sp.

Genus *Tretaspis* McCoy 1849.

Tretaspis seticornis seticornis (HISINGER 1840), emend. STØRMER 1945.

1840 *Asaphus seticornis* — HISINGER, p. 3, pl. XXXVII, fig. 2.
1851—54 *Trinucleus seticornis,* HIS. — ANGELIN, p. 84, pl. XL, fig. 10.
1851—54 *Trinucleus affinis* — ANGELIN, p. 84, pl. XL, fig. 20, 21 e?
1930 *Tretaspis seticornis,* HISINGER — STØRMER, p. 55, fig. 27; pl. 7, figs. 1—15; pl. 8, figs. 1—6, pl. II, figs. 1—7.
1936 *Tretaspis seticornis,* HISINGER — ASKLUND, p. 4, pl. I, figs. 1—6.
1945 *Tretaspis seticornis* (HISINGER 1840), forma typica — STØRMER pp. 401, 406, text-fig. 4, pl. I, fig. 1.

Type data:— As stated by STØRMER (1945) a lectotype has to be chosen from HISINGER's cotypes, or from specimens deriving from the black Tretaspis Shale at Furdal or Draggå, Dalarna.

Material:— 12 more or less compressed and fragmentary cephala and a few fragments of the pygidium and thorax. Minute fragments probably belonging to this form are very common.

Description:— Cephalon. None of the 12 specimens are quite complete, even when the genal prolongations are not considered. The girder of the lower lamella is very prominent. In all specimens the glabella is badly preserved. The cheek lobes have lateral eye-tubercles that are but little elevated. The younger specimens have a reticulated surface both on glabella and cheek lobes. The width of the cephalon varies from 8—15 mm, though compressed specimens give the impression of having a width of up to 20 mm. The brim has radial sulci with two rows of pits. If I. denotes the number of pits along the posterior margin in the prolongation of the occipital segment, II. across the fringe along the median line in front and III. across the fringe in front of the dorsal furrow, the pit indices of the core material are: I = 6—7, II = 3, III = 4. In 1945 STØRMER established two varieties of *Tretaspis seticornis* beside the *forma typica.* All the specimens that allowed a study of the characteristic details belong to his *forma typica.*

Pygidium: Only two fragments of any considerable size have been found; a smaller one (complete probably 7 × 3 mm) and a larger one (complete probably 10 × 4 mm). The frontal part of the rachis is not preserved in the former, while the latter shows 7 pairs of muscle-scar anterior to the posterior band.

Occurrence in core:— 59.55—50.50 m, that is in the Black and Green Tretaspis Shale and in the lowermost beds of the Red Tretaspis Mudstone.

Occurrence elsewhere: *T. seticornis* is reported from all over the north of Europe. The subspecies *seticornis* is hitherto known from different localities in Vestergötland, from black Tretaspis shale in Dalarna, and in Norway from the Lower Tretaspis Shale (4 cα), Hadeland.

Tretaspis granulata bucklandi (BARRANDE 1852), emend. STØRMER 1930.

1852 *Trinucleus bucklandi* BARRANDE, p. 261, pl. 29, figs. 10—17.
1869 *Trinucleus Wahlenbergi* ROUAULT — LINNARSSON, p. 34.
1906 *Trinucleus bucklandi* BARR. — OLIN, p. 66, pl. 4, fig. 1.
— *Trinucleus elliptifrons,* OLIN, p. 68, pl. 4, fig. 2.
1930 *Tretaspis granulata* (WAHLB.) var. *bucklandi* (BARR.) — STØRMER, p. 70, figs. 30, 31.
1945 *Tretaspis granulata* (WAHLENBERG) var. *bucklandi* (BARRANDE), emend. STØRMER 1930 — STØRMER, p. 401.

Type data: As stated by STØRMER (1945) a lectotype has to be chosen from the Bohemian specimens (Bed D_5) described by BARRANDE.

Material:— More or less compressed fragments, especially of the cephalon.

Description:— Cephalon. Fringe narrow. Pits irregularly arranged. There are 3 rows of pits on the cheek roll, but in at least one specimen the inner row is divided into two rows of small pits in radial sulci. In the few cases where the pit indices could be determined, they agree with those given by STØRMER (1930 p. 77, 1945 p. 401). Owing to deformation, the size is difficult to tell, but one specimen indicates a width of 22 mm.

Pygidium and thorax. Only small fragments have been met with.

Occurrence in core:— 47.75—44.45 m in the Red Tretaspis Mudstone. An isolated occurrence of *Tretaspis granulata* possibly subsp. *bucklandi* (fragments of several specimens) was found as low down as at level 55.55 m in the Green Tretaspis Shale (see p. 378).

Occurrence elsewhere:— Sweden: Red Tretaspis Mudstone, different localities in Vestergötland; Tretaspis Shale, Scania. — Denmark: Tretaspis Shale, Bornholm. — Bohemia: D_5.

Other Recorded Trilobites.

Lonchodomas tetragonus (ANGELIN 1851). Several cephalae and pygidiae in the Red Tretaspis Mudstone. It has as yet not been proved that this species is the same as that which BARRANDE (1846) named *Ampyx Portlocki* from Bohemia. Poorly preserved fragments of *Lonchodomas* sp. have also been found in the Black and Green Tretaspis Shales.

Dionide euglypta (ANGELIN 1851). One complete, but poorly preserved specimen was found in the Red Tretaspis Mudstone at level 47.80 m.

Trinodus cf. *trinodus* (SALTER 1866). Cephalae and pygidiae occur in the Black, Green and Red Tretaspis Beds.

Triarthrus sp. A fragment of a cranidium was found in the Black Tretaspis Shale (level 62.10 m).

Caphyra cf. *radians* BARRANDE 1846. Parts of cephalae and of thoracic segments, finely preserved, were found in the Black Shale at level 61.90 m.

Illaenus megalophthalmus (LINNARSSON 1869). Cephalae and pygidiae are regularly met with in the Red Tretaspis Mudstone.

Illaenus sp. (Pl. II, fig. 1). A rather interesting pygidium from level

46.48 m in the Red Tretaspis Mudstone shows 4 well-defined pairs of muscle scars on the sides of the pygorachis. Length 6.5 mm, width 9.5 mm. A similar pygidium (Red Tretaspis Mudstone, Skogastorp, Vestergötland) belongs to the collections of the Palaeontological Institute in Uppsala.

Phillipsinella cf. *parabola* (BARRANDE 1846). Cephalae and pygidiae are regularly met with in the Black and Green Tretaspis Shales. They are usually rather small.

Cybele verrucosa DALMAN 1828. Fragments of this trilobite are characteristic for the Red Tretaspis Mudstone.

Dalmanitina mucronata (BRONGNIART 1822). A pygidium was found in the grey sandstone at level 35.45 m.

Pseudosphaerexochus sp. A fragment of a cephalon occurred at level 55.1 m in the Green Tretaspis Shale.

OSTRACODA.

Since LINNARSSON described two ostracods from the Tretaspis beds of Vestergötland in 1869, no ostracods from these beds have been studied. When the core was split up, it was soon found that ostracods occurred abundantly. 14 different species could be distinguished, among these LINNARSSON's *Primitia tenera.* The other species, which he described as *Primitia strangulata* SALTER, could not be found, though he reports it from Kinnekulle. Probably TROEDSSON is right when he states that *P. strangulata* had become a collective name for younger, primitia-like ostracods. In that case »*P. strangulata*» may have included such forms as *Bromidella linnarssoni* n. sp. The 14 species dealt with here do not represent all the ostracod-species occurring in the Tretaspis beds at Kinnekulle. Fragments and poorly preserved specimens seem to suggest at least three more species.

Orientation. This follows E. TRIEBEL 1941. In his thorough work he shows that it is most reasonable to assume that the sulcus (showing the site of the contraction muscles) is situated in front of the middle (p. 316) and that the great majority of the spines point backwards (p. 353). Moreover, the polarity of the marginal frills (p. 349) may be used as a support for determining the orientation.

In the following the central area is spoken of in opposition to the marginal area or border along the free margins. Sometimes the surface is markedly steepest in a narrow band just inside the depressed marginal border, thus making it possible to distinguish between a marginal border, a marginal slope, and a central area. In other cases the marginal border and central area are separated by a concentric groove (*Conchoprimitia*), a concentric ridge (*Drepanella* a. o.), or a velum (= false border, frill) as in *Bromidella.*

Taxonomy. This follows E. A. SCHMIDT 1941.

The writer wishes to thank his friend Dr. IVAR HESSLAND for his interest in and valuable advice regarding the description of these ostracods.

Superfam. ***Beyrichiacea*** ULRICH & BASSLER 1923.

Fam. ***Primitiidae*** ULRICH & BASSLER 1923.

Subfam. ***Primitiinae*** BASSLER & KELLETT 1934.

Genus ***Primitiella*** ULRICH & BASSLER 1923.

Primitiella tenera (LINNARSSON 1869).

1869 *Primitia tenera* — LINNARSSON, p. 85, pl. II, fig. 70.
1918 *Primitiella tenera* LNRSN. — TROEDSSON, p. 47, pl. II, figs. 1—3.

Type data:— It has not been possible to find any *Primitiella tenera* specimens collected by LINNARSSON from the type stratum and locality in the collections in Uppsala and Stockholm. A neotype should therefore be collected from Red Tretaspis Mudstone at Jettened, Mösseberg, Vestergötland.

Occurrence in core:— Separate valves of this ostracod are found in great numbers in the Black, Green and Red Tretaspis beds of the core. They agree well with the original description by LINNARSSON and also with the detailed description by TROEDSSON of his specimens from the Staurocephalus Shale and the Brachiopod Shale in Scania.

Genus ***Laccoprimitia*** ULRICH & BASSLER 1923.

Laccoprimitia? binodosa n. sp.

Pl. XXV, fig. 1.

Derivation of name:— The name refers to the fact that there are two nodes on each valve.

Holotype:— ar. os. 98 (a right valve).

Type locality:— Kinnekulle, Vestergötland.

Type stratum:— Red Tretaspis Mudstone. (Core level 44.4 m).

Material:— A number of separate valves.

Diagnosis:— An elongate primitian ostracod with a pit and two nodes on each valve; one node in front of the pit, the other postero-ventrally.

Description:— Valves elongate, about twice as long as high. Hinge straight. Dorsal margin straight; free margins regularly curved, ends subequal, ventral margin nearly straight, almost parallel to dorsal margin. Posterior part of valve slightly higher than anterior. Valves evenly and moderately convex. A distinct node in front of a well-defined pit. Another, slightly pointed node near the margin where the posterior and ventral free margins meet. Valves probably similar; contact seems plane. Surface in well-preserved specimens minutely granulate and slightly warty.

Dimensions:— Holotype: Length 1.2 mm, length of hinge 1.0 mm, height 0.65 mm.

Discussion:— The generic reference of this species is uncertain. The pit suggests *Laccoprimitia*, but according to the original diagnosis this should not have surface nodes. The absence of a border along the free edge of the valves points towards *Haploprimitia*, while the cutline of the shell is *Primitiella*-like. SWARTZ (1936 p. 368) describes a species, *Primitiella (?) ventricosa*, with a rather similar arrangement of the nodes. The position of the nodes in *Laccoprimitia? binodosa* n. sp. further reminds one of *Ctenobolbina rara* TROEDSSON (1918) from the Brachiopod Shale in Scania. *Laccoprimitia? binodosa* n. sp. differs, however, in having no signs of a second sulcus. TROEDSSON bases his species on one specimen only, a somewhat defective right valve. The secondary sulcus and the low elevation between the sulci in this specimen may be ascribed to compression. This is the more possible as TROEDSSON states that a furrow surrounding the anterior node has been caused by the depression of the node. It is thus possible that *Ctenobolbina rara* TROEDSSON and *Laccoprimitia? binodosa* n. sp. can be proved to be synonyms.

Occurrence in core:— Rather limited, between 46.2 and 44.6 m, that is at the top of the fossiliferous part of the Red Tretaspis Mudstone.

Laccoprimitia? nigra n. sp.

Pl. XXV, fig. 2.

Derivation of name:— From Latin *niger*, black, in view of its abundance in black shale.

Holotype:— ar. os. 99.

Type locality:— Kinnekulle, Vestergötland.

Type stratum:— Black Tretaspis Shale. (Core level 57.55 m.)

Material:— A great number of separate valves, more or less compressed.

Diagnosis:— A smooth ostracod with slightly leperditoid outline and a usually not very distinct pit in its lower end. The pit is better developed on internal moulds.

Description:— Outline truncate elliptical, slightly leperditoid. Hinge straight. Valve rather smoothly convex, though it is usually possible to discern a very shallow depression in front (?) of a (centrally situated) slightly elevated and rounded area. A thin depressed border is seen along the free margins. The interior mould often shows a fairly well-defined pit, though it may also be absent. In some cases this pit marks the lower end of a narrow sulcus-like depression. The position of the pit falls within the area of the depression of the exterior of the valve, and sometimes the pit is developed here, too. The surface seems to be smooth, but it is sometimes seen to be finely uneven. Shell rather thin. Valves probably similar.

Dimensions:—

	Length	Hinge	Height	L/H
Large specimen . . .	1.4 mm	1.0 mm	1.1 mm	1.3
Holotype	1.1 »	0.6 »	0.6 »	1.8
Smaller specimen . . .	0.9 »	0.45 »	0.45 »	2.0
Small specimen . . .	0.5 »	0.3 »	0.3 »	1.7

Discussion:— The generic position of this species is uncertain. The pit, though usually not developed on the exterior of the valve, but often on the internal mould, may be compared with the pit of *Laccoprimitia*. As the pit in *Laccoprimitia? nigra* n. sp. is situated in its lower end, this would involve that this end should be considered the anterior. Usually the sulcus or pit of the primitian ostracods is situated in the higher end. In the leperditians, however, the anterior end is the lower. *Laccoprimitia? nigra* n. sp. may be compared with *Laccoprimitia subcentralis* BOUČEK 1936, which has a dark-coloured muscular depression in the lower end of the valve.

Occurrence in core: — Very common in the Black Tretaspis Shale.

Fam. ***Drepanellidae*** SWARTZ 1936, emend. SCHMIDT 1941.

Subfam. ***Ulrichiinae*** SCHMIDT 1941.

Genus ***Ulrichia*** JONES 1890.

Ulrichia macronodosa n. sp.

Pl. XXV, fig. 3.

Derivation of name:— The name refers to the fact that, in relation to the shell, the two nodes are larger than usual.

Holotype:— ar. os. 94.

Type locality:— Kinnekulle, Vestergötland.

Type stratum:— Red Tretaspis Mudstone. (Core level 55.4 m.)

Material:— One left and one right valve.

Diagnosis:— Like *Ulrichia morgani* JONES 1890, but with the two nodes relatively much larger, so that they fill the greater part of the area inside the raised rim.

Description:— Outline truncate elliptical. Shell a little higher anteriorly than posteriorly. Hinge straight. Parallel to the free margin a swollen rim. Two oblong nodes fill most of the area inside this rim. The anterior node is slightly larger than the posterior. The upper, bluntly pointed ends of the nodes hardly protrude over the hinge. The anterior node points somewhat backwards, while the posterior is almost vertical. In one of the specimens a smaller node is situated between and partly below the bases of the two main nodes. Between the nodes there is an undefined central depression. Surface slightly granulate.

Dimensions:— Holotype: Length 0.6 mm, hinge 0.5 mm, height 0.45 mm.

Remarks:— Resembles such *Ulrichia* species as *U. morgani* JONES from the Bala Beds, North Wales.

Occurrence in core:— The left valve from 55.4 m level in the Green Tretaspis Shale, the right valve from the 50.50 m level in the Red Tretaspis Mudstone.

Subfam. ***Aechmininae*** BOUČEK 1936, emend. SCHMIDT 1941.

Genus ***Aechmina*** JONES & HOLL 1869.

Aechmina sp. ind.

Four poorly preserved *Aechmina* specimens have been found in the core. They are all of the type with a rather long and slender spine. The spine seems to incline a little. The valves are without ornaments and are highest in front of the spine. The length of the best preserved specimen seems to be 0.6 mm and the height (without spine) 0.3 mm. The spine is broken off in this specimen, but can be traced for 0.4 mm in another.

Occurrence in core:— Two specimens in the Black, one in the Green, and one in the Red Tretaspis beds.

Subfam. ***Drepanellinae*** ULRICH & BASSLER 1923.

Genus ***Kinnekullea*** n. gen.

Derivation of name:— The genus is named after Kinnekulle in Vestergötland.

Genotype:— *Kinnekullea waerni* n. gen. & n. sp.

Diagnosis:— Valves with straight hinge. No frill or »brood pouch». An arcuate ridge runs subparallel to and well inside the anterior free margin. In its dorso-anterior end it is more or less connected with a node or spine. Backwards the ridge may extend subparallel to the whole of the free margin. The ridge, sometimes connected with a marginal slope, always marks the boundary between the central and marginal areas. Where the ridge is missing, the marginal slope alone may separate these areas. The ridge may be well-defined or low and swollen.

Remarks:— This genus has a ridge, subparallel to the free margins, as has the genus *Drepanella*. The ridge in *Kinnekullea* does not, however, project beyond the hinge line as in *Drepanella*, nor has it a mainly ventral situation as in *Scofieldia*. While there are 2—7 nodes in the central and dorsal region in *Drepanella*, there are 2 or only one in *Kinnekullea*, the anterior showing a tendency to become spine-like and more or less connected with the ridge. The small size of the *Kinnekullea* species also differs from the typical species of *Drepanella* (carapace about 2.5 mm long). The ridge seems, however, to justify that *Kinnekullea* be placed in the Drepanellidae, more precisely in the Drepanellinae, which include *i.a. Drepanella*, *Scofieldia*, and *Jonesella*. When two nodes are present, the valve of *Kinnekullea* may produce an *Ulrichia*-like appearance. In this connection it is of interest to remember that SCHMIDT (1941) erects a new subfamily Ulrichiinae, which he places in the Drepanellidae.

Kinnekullea waerni n. gen. & n. sp.

Pl. XXV, fig. 4.

Derivation of name:— The species is named in honour of B. WÆRN.

Holotype:— ar. os. 96 (a left valve).

Type locality:— Kinnekulle, Vestergötland.

Type stratum:— Black Tretaspis Shale. (Core level 56.95 m.)

Material:— Several well-preserved separate valves.

Diagnosis:— A *Kinnekullea* with one spine-like node, and the ridge running subparallel to the whole of the free margins.

Description:— Outline truncate elliptical; hinge straight; dorsal margin straight, joining free margins with obtuse angularity; free margins regularly curved, ends subequal. A well-defined arcuate ridge, subparallel to free margins, separating steep and fairly broad marginal area from central area of valve. The ridge, representing a thickening of the shell, is not visible on interior moulds. Its place, however, is marked by a step between the central and marginal areas. In compressed specimens the ridge appears to have a more central position, owing to the flattening of the marginal area. The anterior end of the ridge rises into a slightly bulbous spine, pointing postero-dorsally and a little out from the valve, but hardly projecting beyond the hinge. An extremely faint node in the posterior half of the valve may sometimes be distinguished. The faint depression between this »node» and the bulbous spine may represent the sulcus. Valves probably similar; contact seems plane. Surface smooth.

Dimensions:— Holotype: Length 0.9 mm, length of hinge 0.7 mm, height 0.5 mm.

Occurrence in core:— In the Black, Green, and lowermost part of the Red Tretaspis Beds.

Kinnekullea hesslandi n. gen. & n. sp.

Pl. XXV, fig. 5, 6.

Derivation of name:— This species is named in honour of I. HESSLAND.

Holotype:— ar. os. 95 (a left valve).

Type locality:— Kinnekulle, Vestergötland.

Type stratum:— Glauconitic marlstone at the base of the Black Tretaspis Shale. (Core level 62.87 m.)

Material:— A small number of separate valves.

Diagnosis:— A *Kinnekullea* with two nodes, the ridge extending posteriorly subparallel to the ventral margin to a point below the posterior node.

Description:— Outline truncate elliptical; hinge straight; dorsal margin straight, joining free margins with obtuse angularity; free margins regularly curved, ends subequal. Two nodes near the dorsal margin with a sulcus-like depression between them. The posterior node is blunt and has almost a centro-dorsal position. The anterior node is bulbous and with a small spine pointing postero-dorsally. Just in front of the anterior spine, and sometimes connected with it, is the anterior end of the well-defined ridge which is subparallel to the free margins and runs as far back as to a point below the posterior node. The marginal area outside the ridge is rather steep, and so is the margin dorsally to the nodes. The sculpture of the valves is thus mainly confined to the anterior half; the posterior half being smoothly convex. Sometimes, apparently mostly in the larger specimens, the sculpture is somewhat effaced, especially the ridge, which becomes lower and more step-like, and at the same time broader. (As in the holotype.) The same is true of the interior moulds. Valves probably similar; contact plane. Surface finely pitted.

Remarks:— This species is rather like and probably closely related to the stratigraphically slightly younger *Kinnekullea waerni* n. gen. & n. sp., the difference mainly being the longer ridge, the more spine-like anterior node, and the lack of a distinct posterior node in the latter. It is of interest, however, that this node may sometimes be distinguished, though very faintly.

Dimensions:— Length 1.0 mm, length of hinge 0.6 mm, height 0.7 mm. (»Large» specimen: Length 1.1 mm, height 0.7 mm.)

Occurrence in core:— In the lowermost part of the Black Tretaspis Shale (62.90—61.90 m).

Kinnekullea thorslundi n. gen. & n. sp.

Pl. XXV, fig. 7—9.

Derivation of name:— This species is named in honour of P. THORSLUND who, in his studies of the Cambro-Silurian in Sweden, has paid due attention to the ostracods.

Holotype:— ar. os. 97.

Type locality:— Kinnekulle, Vestergötland.

Type stratum:— Red Tretaspis Mudstone. (Core level 54.40 m).

Material:— Several separate valves.

Diagnosis:— Valves with a sometimes spine-like node in front of an undefined sulcus. In the continuation of the node a more or less well-defined ridge subparallel to the anterior free margin. The ridge soon vanishes ventrally. Central area distinctly punctate.

Description:— Outline slightly leperditoid, greatest height in the posterior part. Hinge straight. In front of the undefined sulcus a well-defined node, sometimes more like a spine, attaining a length of 0.3 mm. The slope between the central and marginal areas swells up anteriorly to form a short ridge, which continues into the node. A faint indication of a node may sometimes be distinguished just behind the sulcus. Surface punctate in the central area only. Also the interior mould is pitted. It seems as if the ridge is most conspicuous in the stratigraphically older specimens.

Dimensions:

	Length	Hinge	Height
Holotype	1.4 mm	1.0 mm	0.9 mm
Large specimen	1.7 »	1.3 »	1.2 »
Small specimen	1.0 »	0.7 »	0.7 »

Remarks:— The anterior node and ridge suggest the inclusion of this species in *Kinnekullea.* It especially resembles those specimens of *K. hesslandi* where the sculpture is not so pronounced. It differs, however, from *K. waerni* and *K. hesslandi* by its higher and more leperditoid valve, as well as its rather coarse punctation. In these features *K. thorslundi* resembles Conchoprimitians of the type *Conchoprimitia tallinensis — C. tolli*, especially the groove-less *C. tolli integra* Öpik. This is especially true of the stratigraphically youngest specimens of *K. thorslundi.* It is possible that the ridge of *Kinnekullea* may be compared with the groove of *Conchoprimitia.*

Occurrence in core:— Fairly common in the Black, Green, and Red Tretaspis Beds.

Kinnekullea hofsteni n. gen. & n. sp.

Pl. XXV, fig. 10.

Derivation of name:— This species is named in honour of Professor N. von Hofsten, Rector of the University of Uppsala in 1943—47.

Holotype:— ar. os. 89 (a right valve).

Type locality:— Kinnekulle, Vestergötland.

Type stratum:— Green Tretaspis Shale (Core. level 50.55 m.)

Material:— Several separate valves.

Diagnosis:— Smooth valves with a well-defined spine, situated at the antero-dorsal corner and curved backwards.

Description:— Outline truncate elliptical with a postero-dorsally projecting spine; hinge straight; dorsal margin meeting free margins with slight angularity; free margins regularly curved, ends subequal. The dominating spine curves in an even continuation of the curvature of the anterior free margin till it points postero-dorsally and a little laterally. At least in some specimens a short and not well-defined ridge is seen below the spine. Sometimes also a slightly depressed marginal area is marked off from the central area, though usually these areas cannot be told apart. Valve rather convex, surface smooth. In a dorsal view the conture of a complete specimen would suggest an arrowhead, the spines forming the wings.

Dimensions:— Holotype: Length 0.9 mm, hinge 0.7 mm, height (without spine) 0.5 mm, length of spine 0.4 mm.

Remarks:— This species is rather different from the genotype of *Kinnekullea*, its spine, however, probably being equivalent to that of the other *Kinnekullea* species. When a short ridge and a depressed marginal area is developed, *K. hofsteni* reminds of *K. thorslundi*, the latter, however, being less convex, larger, with a shorter spine and distinctly punctate.

Occurrence in core:— In the Green Tretaspis Shale.

Fam. ***Hollinidae*** SWARTZ 1936, emend. SCHMIDT 1941.

Subfam. ***Hollininae*** SCHMIDT 1941.

Genus ***Bromidella*** HARRIS 1931.

(Synonym: ***Uhakiella*** ÖPIK 1937, see SCHMIDT 1941 p. 33.)

Bromidella linnarssoni n. sp.

Pl. XXV, fig. 11.

Derivation of name:— This species is named in honour of G. LINNARSSON, who first gave a detailed description of the Tretaspis Series in Vestergötland, and first described ostracods therefrom.

Holotype:— ar. os. 91 (a right valve).

Type locality:— Kinnekulle, Vestergötland.

Type stratum:— Black Tretaspis Shale. (Core level 59.45 m.)

Material:— A few complete shells and several separate valves, many of which with »brood-pouch».

Diagnosis:— Like *Bromidella* (»*Uhakiella*») *pumila* (ÖPIK 1937), but larger, with shorter »brood-pouch» and with reticular ornament.

Remarks:— The orientation is opposite to that used by ÖPIK. According to TRIEBEL (1941) the »brood-pouch» forms the anterior part of the marginal border. The function of the so-called »brood-pouch» is as yet not known for certain, but its presence in some specimens probably indicates a sexual dimorphism. TRIEBEL states (p. 365) that it is just as likely that it is characteristic of the males as of the females.

Description:— Outline truncate elliptical. Hinge straight. Dorsal margin straight; free margins evenly curved, ends subequal. Sulcus deep and open towards the hinge. Median lobe connected with posterior lobe by a swelling which surrounds lower part of sulcus. No ventral lobe can be distinguished. Posterior lobe hardly separated from median. Some specimens (ÖPIK: males) have a plane velum (false border) anteriorly and ventrally, situated 0.1—0.2 mm from the margin. The velum has a lineate structure parallel to the outline and broken by radiating striae. Other specimens (ÖPIK: females) have, instead, an anteriorly situated sausage-shaped »brood-pouch», formed by the convex vela of both valves meeting ventrally. Behind the »brood-pouch» the velum seems to continue as a low ridge only. The »brood-pouch» just fails to reach to a point below the sulcus, as in *Bromidella pumila*. All specimens are denticulate posteriorly, the denticles reaching a length of 0.1 mm. The surface is reticulate. Valves similar in size.

Dimensions:— Holotype: Length 1.6 mm, hinge 0.9 mm, height 1.2 mm, width 0.7 mm.

Discussion:— While the interior of the valve shows the velum as a narrow and deep groove, the internal mould shows hardly any traces of this or none at all. In fact, the smooth internal mould with its deep and simple sulcus would, if found alone, be interpreted as a *Primitia* sp. It is quite possible that the specimens LINNARSSON describes as *Primitia strangulata* SALTER (and reports also from Kinnekulle) are such moulds, the more so as it has not been possible to find any *Primitia* specimens in the core, in spite of several hundred ostracods having been examined. In the field, though not so when splitting up the core, the stone with *Bromidella linnarssoni* is apt to split so that one slab contains the interior mould and the other shows the interior of the valve. The moulds, mistaken for the shells, attract more attention in the field than the interior of the valve, mistaken for the external impression. This statement is easily proved by looking through collected material. Several such moulds have been found in the collections labelled *Primitia* sp. or *Primitia strangulata*. TROEDSSON (1918) is probably right when he states that »*P. strangulata*» in Sweden has become a collective name for younger Ordovician, primitia-like ostracods. It is thus not impossible that *Bromidella linnarssoni* will prove to be a synonym for a species earlier described as a *Primitia* sp. Several *Primitia* species described from blocks in Germany show likeness to the internal mould of *Bromidella linnarssoni*.

Occurrence in core:— Rather common in the Black, Green and Red Tretaspis Beds.

Genus *Biflabellum* Öpik 1937.

Biflabellum vestrogothicum n. sp.

Pl. XXV, fig. 12.

Derivation of name:— From Latin for Vestergötland.

Holotype:— ar. os. 90 (a left valve).

Type locality:— Kinnekulle, Vestergötland.

Type stratum:— Black Tretaspis Shale. (Core level 57.0 m.)

Material:— Several separate valves.

Diagnosis:— Like *Biflabellum crista* Öpik 1937, but more elongate and with the velum not extending so far posteriorly.

Description:— Shell somewhat elongate with straight hinge. Posterior angle ending in a spine-like process. The sulcus continues as a depression down to the velum, turning about 10° round a node in front of the sulcus. A short furrow below the node joins the sulcus, making this appear slightly bifurcate. The velum is radially striated. The posterior end, free from velum, is denticulate. Surface, appearing smooth, is minutely granulate.

Dimensions:— Holotype: Length 1.3, hinge 1.3, height 0.6 mm.

Occurrence in core:— In the Black, Green and lowermost part of the Red Tretaspis Beds.

Fam. *Kloedenellidae* Ulrich & Bassler 1908.

Genus *Jonesina* Ulrich & Bassler 1908.

Jonesina? modesta n. sp.

Pl. XXV, fig. 13.

Derivation of name:— The name is given in view of the rather simple sculpture of this species.

Holotype:— ar. os. 93 (a right valve).

Type locality:— Kinnekulle, Vestergötland.

Type stratum:— Black Tretaspis Shale. (Core level 59.6 m.)

Material:— A number of separate valves.

Diagnosis:— Like *Jonesina arcuata* Bean, but longer and with smaller sulcus, more anteriorly situated.

Description:— Valves strongly convex, except for the posterior end, oblong, approximating a parallelogram in outline. About twice as long as high. Sulcus, ending in a pit, reaches less than half the height from the dorsal margin. In front of the sulcus a round node. Posterior lobe almost uniformly convex and larger than the anterior, which is slightly bilobate. Marginal regions somewhat flattened out, especially posteriorly, though the transition into the convex lobes is successive. Outline of anterior free margin distinctly more convex than posterior. Hinge straight. Dorsal angles somewhat spine-like. Surface smooth.

Dimensions:— Holotype: Length 1.1 mm, hinge 0.85 mm, height 0.55 mm.

Remarks:— Only separate valves have been found, and it has not been possible to determine which is the larger valve. Owing to its likeness to simple types of *Jonesina*, this species has tentatively been referred to this genus. *J.? modesta* also recalls *Balticella oblonga* THORSLUND 1940, but in the latter the ventral side is incurved.

Occurrence in core:— Rather restricted, only in the lower half of the Black Tretaspis Shale.

Ostracods of unknown systematic position.

The two ostracod species briefly described below, would earlier have been placed under the heading: Superfamily Cypridacea ULRICH & BASSLER 1923, Family Bairdiidae SARS 1887, Genus *Bythocypris* BRADY 1880. As stated by SCHMIDT (1941 p. 72) the superfamily Cypridacea contradicts the taxonomy of recent ostracods. Further the family Bairdiidae is erected upon recent ostracods and should not be used for Paleozoic species. The same may be said about the genus *Bythocypris*.

Genus indet. sp. A.

A few separate valves, rather similar in size and outline to the Silurian species »*Bythocypris*» *holli* JONES 1887, have been found in the Green Tretaspis Shale.

Length 1.55 mm, height 0.85 mm.

Genus indet. sp. B.

A complete shell and some valves of a *Bythocypris*-like species have been found in the Top Sandstone, level 36.0 mm. Outline almost as in »*Bythocypris*» *phillipsiana* JONES & HOLL 1869, but relatively shorter. The right valve overlaps the left, but mainly posteriorly, ventrally and anteriorly. The shell is widest in its anterior half. Some valves found in the Black Tretaspis Shale are rather similar.

Length 0.5 mm, height 0.3 mm, width 0.3 mm.

MACHAERIDIA.

Fam. *Lepidocoleidae* WITHERS 1926.

Genus *Lepidocoleus* FABER 1887.

Lepidocoleus suecicus MOBERG 1914.

1914:1 *Lepidocoleus suecicus* — MOBERG p. 13, pl. II, figs. 1—11.
1914:2 » » MOBERG — MOBERG p 489
1918 » » MOBERG — TROEDSSON p. 46.
1926 » » MOBERG — WITHERS p. 27, pl. II, fig. 1.

Type data:— As lectotype WITHERS (1926) has chosen the specimen described by MOBERG (1914 page 15), and depicted by WITHERS (1926 Plate II, fig. 1). Brit. Mus. — I 14425. Coll. Dr. F. A. BATHER. The lectotype is from the Black Tretaspis Shale at Svälasgård, Skattungbyn in Dalarna.

Material:— Loose plates are found all through the Black Tretaspis Shale in the core. Their length varies from 2 to 5 mm. They are usually very well preserved, and quite agree with the detailed descriptions given by MOBERG and WITHERS, except that their inner surface is not smooth but finely granulate.

Regional and stratigraphic distribution:— *Lepidocoleus suecicus* was originally described from the Black Tretaspis Shale in Östergötland and Dalarna. TROEDSSON (1918 p. 46) reports it from the upper part of the Brachiopod Shale (= Dalmanitina Series) in Scania, and THORSLUND (1934 pp. 11—15) mentions a *L.* cf. *suecicus* from the zone of *Staurocephalus* and from the Dalmanitina Series in Dalarna. The core material shows that *L. suecicus* also occurs in Vestergötland. In Britain, WITHERS (1926) reports it from layers of Ashgillian and Caradocian age.

CONODONTA.

Genus *Drepanodus* PANDER 1856.

Drepanodus altipes n. sp.

Pl. XXV, fig. 14.

Derivation of name:— The name is given in view of the rather long (high) base of this species.

Holotype:— cd. 1.

Type locality:— Kinnekulle, Vestergötland.

Type stratum:— Base of the Black Tretaspis Shale. (Core level 62.87 m.)

Material:— A number of fairly well preserved but compressed specimens.

Diagnosis:— A *Drepanodus* with curved cusp and characteristic long base.

Description:— Tooth simple with curved cusp and markedly long base. The base is also well expanded. The cusp curves till its axis becomes almost parallel to the plane of the base. An anterior (convex) and a posterior (concave) keel shape a blade-like cusp, more or less flattened. A short lateral keel may sometimes be seen at the base. The apex of the conical basal cavity seems to be situated about midway between the margins.

Length:— c. 1 mm.

Occurrence:— Common in the glauconitic bed and regularly occurring in the lowermost part of the Black Tretaspis Shale (62.90—61.50 m).

OTHER FOSSILS.

Gastropoda.

A few specimens of a planospiral gastropod have been met with in the Black Tretaspis Shale. Diameter about 1 cm. They are strongly compressed, and the petrifying material is pyrite.

Hyolithida.

Fragments of Hyolithida are regularly met with in the Black Tretaspis Shale, one reaching a width of 2.5 cm.

Porifera.

Sponge-needles?

Small uniaxal spicules occur in great quantities at several levels in the Black Tretaspis Shale. They are straight and needle-shaped (pointed at one end only). Their length varies from 4 to 10 mm, and their diameter from 0.02 to 0.1 mm. The spicules are usually circular in cross-section and have a smooth surface; more seldom they are finely striated parallel to the axis. Some spicules have one or two distinct longitudinal furrows, in the latter case giving them an 8-like appearance in cross-section. These furrows are possibly due to compression and may indicate that an axial canal existed in the spicule. The needles are sometimes gathered in broad, worm-shaped clusters, but, as it seems, with no predominating orientation. The petrifying material is always pyrite.

Fossils of uncertain systematic position.

Plant- and worm-trail-like fossils.

Plant- and worm-trail-like fossils occur abundantly at several levels in the Black, Green and Red Tretaspis Beds. They are more or less flattened and usually form from 1 to 3 mm wide bands. They are imbedded sub-parallel to the bedding planes. They are sometimes of a green colour in the Red Mudstone; when not they are hardly distinguishable from the surrounding mudstone, having hardly any relief. In the Black and Green Tretaspis Shales they are always distinct, and consist of a brownish, earthy substance. The nearest surrounding matrix sometimes becomes stained, too, thus making the bands appear broader. The bands sometimes seem to branch, and this is at least the case in some very fine (c. 0.2 mm wide) plant-like fossils at levels 57.20—57.0 m. The latter occur together with wider bands (several transitional widths occur), the broadest being 3 mm wide. Here the substance of the bands and »twigs» may sometimes be dark blue instead of brown.

Table IV.

List of species described or reported from the Tretaspis Series in the core.

	Page	Pl.	Figs.	Black Tret. Shale	Green Tret. Shale	Masur Lime-stone	Red Tretaspis Mudstone			Top Sand-stone
							Lower 1.5 m	Next 6.5 m	Upper 6.5 m	
BRACHIOPODS.										
Hisingerella nitens (HISINGER) n. gen. . . .	389	XXIV	3, 6—8	+						
Paterula cf. *bohemica* BARRANDE	392	XXIV	2	+						
» cf. *portlocki* (GEINITZ)	393	XXIV	4, 5	+						
Lingulellid, gen. & sp. ind.	395			+						
Sowerbyella cf. *restricta* (HADDING)	396			+	+					
» ? *rosettana* n. sp.	396	XXIV	9—11, 12	.	.	.	.	+		
» ? sp. ind.	399			.	.	.	+	+		
Christiania spp. ind.	400			+	+	.	+			
Schizoramma sp. ind.	400	XXIV	13—16	.	.	.	.	.	.	+
Dalmanella cf. *testudinaria* (DALMAN)	395			.	.	.	.	.	.	+
Hindella? cf. *cassidae* (DALMAN)	396			.	.	.	.	.	.	+
Cliftonia (*Oxoplesia*) sp. ind.	396			.	.	.	.	.	.	+
Dolerorthis sp. ind.	396			.	.	.	.	.	.	+
Other brachiopods	395			+	+	.	+	+	.	+
GRAPTOLITES.										
Dicellograptus johnstrupi HADDING	401		2, p. 402	+						
Orthograptus cf. *truncatus* (LAPWORTH) . .	402			+						
» *truncatus pauperatus* E. & W.	403			+						
» *quadrimucronatus* (HALL) . . .	403			+						
Climacograptus styloideus LAPWORTH . . .	404			+						
» cf. *minimus* (CARRUTHERS) .	404			+						
Leptograptus flaccidus macer ELLES & WOOD	405			+						
Undeterminable graptolites	401			.	+					

TRILOBITES.										
Tretaspis seticornis seticornis (HISINGER) . .	406			+	+	.	+			
» *granulata bucklandi* (BARRANDE) .	407			.	?	.	.	+		
Lonchodomas tetragonus (ANGELIN)	407			?	?	.	+	+		
Dionide euglypta (ANGELIN)	407			.	.	.	.	1		
Trinodus cf. *trinodus* (SALTER)	407			+	+	.	+	+		
Triarthrus sp. ind.	407			+						
Caphyra cf. *radians* BARRANDE	407			+						
Illaenus megalophthalmus (LINNARSSON) . .	407			.	.	.	+	+		
» sp. ind.	407	XXIV	1	.	.	.	.	1		
Phillipsinella cf. *parabola* (BARRANDE) . . .	408			+	+					
Cybele verrucosa DALMAN	408			.	.	.	+	+		
Dalmanitina mucronata (BRONGNIART) . . .	408			.	.	.	.	.	.	+
Pseudosphaerexochus sp. ind.	408			.	.	.	1			
OSTRACODS.										
Primitiella tenera (LINNARSSON)	409			+	+	.	+	+		
Laccoprimitia? binodosa n. sp.	409	XXV	1	.	.	.	.	+		
» ? *nigra* n. sp.	410	XXV	2	+						
Ulrichia macronodosa n. sp.	411	XXV	3	.	1	.	1			
Aechmina sp. ind.	412			2	1	.	1			
Kinnekullea waerni n. gen. & n. sp.	413	XXV	4	+	+	.	+			
» *hesslandi* n. gen. & n. sp. . . .	413	XXV	5, 6	+						
» *thorslundi* n. gen. & n. sp. . .	414	XXV	7—9	+	+	.	+	+		
» *hofsteni* n. gen. & n. sp.	415	XXV	10	.	+					
Bromidella linnarssoni n. sp.	416	XXV	11	+	+	.	+	+		
Biflabellum vestrogothicum n. sp.	418	XXV	12	+	+	.	+			
Jonesina? modesta n. sp.	418	XXV	13	+						
»*Bythocypris*» sp. ind. A	419			.	+					
» sp. ind. B	419			.	.	.	.	.	.	+

Table IV. Cont.

	Page	Pl.	Figs.	Black Tret. Shale	Green Tret. Shale	Masur Lime-stone	Red Tretaspis Mudstone			Top Sand-stone
							Lower 1.5 m	Next 6.5 m	Upper 6.5 m	
MACHAERIDIA.										
Lepidocoleus suecicus MOBERG	419			+						
CONODONTS.										
Drepanodus altipes n. sp.	420	XXV	14	+						
OTHER FOSSILS.										
Undetermined microfossils	385			.	.	+				
Gastropods	421			+						
Hyolithids	421			+						
Sponge-needles?	421			+						
Plant-like and worm-trail-like fossils	421			+	+	.	+	+	+	+

1, 2 denote that only 1 or 2 specimens have been found.

Prof. T. G. HALLE at the Paleobotanic Department of the Naturhistoriska Riksmuseum, Stockholm, has kindly looked through this material. In his report he states that the fine twig-like fossils *might* be algae, and possibly even some of the coarser ones, found together with these.

Stratigraphical problems and results.

The succession of layers in the core in the boundary area between the Chasmops and Tretaspis Series is as follows: Above the uppermost limestone layer of the Chasmops Series, which according to THORSLUND (above p. 345) contains *Tretaspis ceriodes* there come 5 cm of glauconitic marlstone followed by black shale. Only 5 cm above the marlstone, and also 75 cm above it, the zone-fossil *Climacograptus styloideus* occurs. Later on beds containing graptolites of this zone (though not the zone-fossil itself) alternate with beds containing *Tretaspis seticornis seticornis*.

The graptolites found in the Black Tretaspis Shale in the core (Table V) thus show that this shale belongs to the zone of *Pleurograptus linearis* and *Climacograptus styloideus*. THORSLUND has already shown that this is the case as regards the Black Tretaspis Shale in Dalarna (1935 p. 48) and Jemtland (1940 p. 121).

Furthermore the graptolites in the core show that the boundary between the above-mentioned zone and the next older zone of *Dicranograptus clingani* should be drawn above the limestone layer a little above the base of the black shales on top of the Chasmops Limestone. As this boundary is also recognized as the boundary between the Chasmops and Tretaspis Series (Cf. THORSLUND 1940 p. 121), it means that the lowermost part of the black shale earlier as a whole referred to the Black Tretaspis Shale, should now be included in the Chasmops Series, the glauconitic bed marking the lower boundary of the Tretaspis Series.

Beds rich in glauconite often reveal the presence of gaps in the series of strata (See HADDING 1932 p. 159). In this case the break would probably not be a great one, but it is interesting that a break between the Chasmops and Tretaspis Series has been found in Gotland (Cf. THORSLUND & WESTERGÅRD 1938), and predicted by THORSLUND (1940 p. 122) very likely to exist also in Jemtland. In this connection it should also be remembered that RAYMOND (1916 p. 244) suggests the existence of a prominent break between the Upper Chasmops Limestone (4 bδ) and the Tretaspis Shale (4 cα) in the Oslo Region. STØRMER (1945 p. 395) shows that such a break most probably also occurs in other districts in Norway, and, as it seems at a successively higher level northwards from Oslo. In Bornholm HADDING (1915 p. 10) records a 2 cm »stark zersetzte, rostbraune Schicht» between black shale belonging to the zone of *Dicranograptus clingani* and black shale belonging to the zone of *Climacograptus styloideus*.

Table V.

Zonal Range of the Graptolites found in the Black Tretaspis Shale in the Core

In the Core, Kinnekulle	In Bornholm and Scania according to HADDING. B = Bornholm only			In Britain according to ELLES & WOOD			
Black Tretaspis Shale	Z. of *Dicr. cling.*	Z. of *Clim. styl.*	Z. of *Dicel compl.*	11. Z. of *Clim. wils.*	12. Z. of *Dicr. cling.*	13. Z. of *Pleur. lin.*	14. Z. of *Dicell. compl.*
Dicellogr. johnstrupi HADDING . .		+			(*Dic. morrisi*)		
Orthogr. cf. *truncatus* LAPW. . . .		+			+	+	
Orthogr. trunc. pauperatus E. & W.		+		+	+	+	+
Orthogr. quadrimucronatus (HALL)		+				+	
Climacogr. cf. *minimus* CARR. . .	(*Cl. brevis*)				+	+	
Climacogr. styloideus LAPW. . . .		B				+	
Leptogr. flaccidus macer E. & W. .		+				+	

Several of the fossils found in the Black Tretaspis Shale in the core were known earlier from the Dicellograptus Shale in Scania and Bornholm, thus showing the connection between these areas and Vestergötland. There are also close connection between these districts and others. Thus f. inst. it is now known that *Hisingerella nitens* (HISINGER) occurs in the Black Tretaspis Shale of Dalarna, Östergötland, Vestergötland, as well as in the Dicellograptus Shale of Scania and Bornholm.

The Masur Limestone at Kinnekulle was earlier only known from blocks, but the core shows that its stratigraphical position had been correctly assumed to be above the Green Tretaspis Shale and below the Red Tretaspis Mudstone.

As may be seen from table IV there seems to be a paleontological boundary between the lower 1.5 m and the rest of the Red Tretaspis Mudstone. Some forms only occur below this boundary, while others are only found above it.

STØRMER states (1930 pp. 76, 77) that apparently 3 zones exist in the Swedish Tretaspis Beds; a lower zone with *Tretaspis seticornis*, a middle zone with *T. granulata* and an upper zone with *T. latilimba*. In general the core material verifies this with regard to the two lower zones, where the uppermost occurrence of *T. seticornis* is at level 50.50 m (Red Tr. Mst.) and the lowermost occurrence of the main bulk of *T. granulata* at 47.75 m. There is, however, an isolated occurrence of *T. granulata* as low down as in the Green Tretaspis Shale at level 55.50 m, which is 5 m below the upper limit of *T. seticornis*, and nearly 8 m below the next appearance of *T. granulata*. Unfortunately the material at 55.50 m does not permit a subspecific determination, which could prove whether the subspecies found here is the same as the one occurring higher up, *viz. T. granulata buck-landi*. As to the upper zone, with *T. latilimba*, it is either not present in the core or probably more or less equalized by the upper, unfossiliferous part of the Red Tretaspis Mudstone.

The core shows that there is no sharp lithological boundary between the Red Tretaspis Mudstone and the overlying sandstone, rich in brachiopods. There seems, however, to be a break in the sedimentation between this sandstone and the overlying limestone, the latter containing bits of shale at its base. Unfortunately the upper 6.5 m of the Red Tretaspis Mudstone are unfossiliferous. The sandstone is here tentatively assigned to the Tretaspis Series as its top bed, and the break in sedimentation thus considered to mark the boundary between the Tretaspis Series and the Dalmanitina beds. The occurrence of *Dalmanitina mucronata* in the sandstone shows that if this sandstone belongs to the Tretaspis Series, it represents the Staurocephalus Zone, which contains a fauna with elements both from the Tretaspis Series and the Dalmanitina beds. This zone has hitherto not been recognized at Kinnekulle, but has been found at the top of the Tretaspis Series elsewhere in Vestergötland, as well as in Dalarna (THORSLUND 1935), Jemtland (THORS-LUND 1943), Scania, and in Bornholm (POULSEN 1936). POULSEN (1936) has shown that the Staurocephalus Zone corresponds to the British zone of *Dicellograptus anceps*. The Tretaspis Series thus corresponds to the three British graptolite zones of *Pleurograptus linearis, Dicellograptus complanatus* and *Dicellograptus anceps*.

The break between the Tretaspis Series and the Dalmanitina beds is of special interest, as it is also recognized as a break between the Ordo-vician and Silurian strata of Sweden. This boundary has, however, been treated in several earlier papers, and will not be discussed here. It should only be emphasized that this break is reported from all districts in Sweden where the Tretaspis Series and the Dalmanitina beds occur.

A comparison between the different developments of the Tretaspis Series in Scandinavia, as well as of the corresponding British and Anti-costian layers has recently been given by STØRMER (1945 pp. 395—398).

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Explanation of Plates.

Plate XXIII.

Diameter of core 7 cm.

1. Core section between 58.10 and 57.96 m. In the centre a pyritic concretion. Around this typical speckled shale. The lower part of the section consists of grey mudstone.
2. Core between 54.99 and 54.90 m showing speckled shale.

Plate XXIV.

Specimens figs. 1, 9—12 are from the Red Tretaspis Mudstone, figs. 2—8 from the Black Tretaspis Shale and figs. 13—16 from the Top Sandstone. If no other statement is made, the specimen belongs to the Palaeont. Inst. Univ. of Uppsala and is from the Kullatorp core. All specimens whitened. V. JAANUSSON and N. HJORT phot. A. NILSSON ret.

1. *Illaenus* sp. Pygidium. Level 46.48 m. ar. 3380. C. 6 ×.
2. *Paterula* cf. *bohemica* BARRANDE. Interior of ventral valve. Level 58.40 m. bp. 5303. 13 ×.
3. *Hisingerella nitens* (HISINGER). Posterior view of ventral valve. Apex damaged. Level 61.50 m. bp. 5336. 20 ×.
4. *Paterula* cf. *portlocki* (GEINITZ). Exterior of dorsal valve. Level 61.60 m. bp. 5324. 25 ×.
5. Same. Interior of ventral valve. Level 61.60 m. bp. 5323. 16 ×.
6. *Hisingerella nitens* (HISINGER). Dorsal valve. Draggån, Rättvik, Dalecarlia. Coll. HISINGER. Riksmuseum, Stockholm, Paleoz. Dept. — Br. 5041 a. Lectotype. 13 ×.
7. Same. Dorsal valve. From same stab as fig. 6. Rm. Paleoz. Dept. — Br. 5041 b. 13 ×.
8. Same. Inner side of dorsal valve. Level 61.5 m. bp. 5350. 13 ×.

9—11. *Sowerbyella? rosettana* n. sp. Fig. 9 anterior view; fig. 10 ventral view; fig. 11 posterior view. Skultorp, Vestergötland. bp. 5284. Holotype. 3.3 ×.

12. Same. Exterior of dorsal and ventral valves in juxtaposition. Jonstorp, Mösseberg, Vestergötland. Coll. JARVIK & THORSLUND 1935. bp. 5276. 3.3 ×.

13—16. *Schizoramma* sp. Ventral valve. Fig. 13 ventral view; fig. 14 lateral view; fig. 15 anterior view; fig. 16 posterior view. Level 35.56 m. bp. 5332. 6.6 ×.

Plate XXV.

The specimens figured are from the Kullatorp core and belong to the Palaeont. Inst., Univ. of Uppsala. Figs. 1—4, 7—14 drawn by Mrs LEPIKSAAR; figs. 5, 6 by E. STÅHL. Magn. 28 ×.

1. *Laccoprimitia? binodosa* n. sp. A right valve. Red Tretaspis Mudstone. Level 44.40 m. ar. os. 98. Holotype.
2. *Laccoprimitia? nigra* n. sp. A left valve. Black Tretaspis Shale. Level 57.55 m. ar. os. 99. Holotype.
3. *Ulrichia macronodosa* n. sp. A left valve. Red Tretaspis Mudstone. Level 55.40 m. ar. os. 94. Holotype.

4. *Kinnekullea waerni* n. gen. & n. sp. A left valve. Black Tretaspis Shale. Level 56.95 m. ar. os. 96. Holotype.
5. *Kinnekullea hesslandi* n. gen. & n. sp. A left valve. The anterior spine is missing. Black Tretaspis Shale. Level 62.87 m. ar. os. 95. Holotype.
6. *Kinnekullea hesslandi* n. gen. & n. sp. Anterior part of a left valve. Black Tretaspis Shale. Level 62.87 m. ar. os. 86.
7. *Kinnekullea thorslundi* n. gen. & n. sp. A right valve. Red Tretaspis Mudstone. Level 44.35 m. ar. os. 87. Holotype.
8. Same. A left valve. Red Tretaspis Mudstone. Level 54.40 m. ar. os. 97.
9. Same. A left valve. Black Tretaspis Shale. Level 59.55 m. ar. os. 88.
10. *Kinnekullea hofsteni* n. gen. & n. sp. A right valve. Green Tretaspis Shale. Level 50.55 m. ar. os. 89. Holotype.
11. *Bromidella linnarssoni* n. sp. A right valve. Black Tretaspis Shale. Level 59.45 m. ar. os. 91. Holotype.
12. *Biflabellum vestrogothicum* n. sp. A left valve. Black Tretaspis Shale. Level 57.0 m. ar. os. 90. Holotype.
13. *Jonesina? modesta* n. sp. A right valve. Black Tretaspis Shale. Level 59.60 m. ar. os. 93. Holotype.
14. *Drepanodus altipes* n. sp. Black Tretaspis Shale. Level 62.87 m. cd. 1. Holotype.

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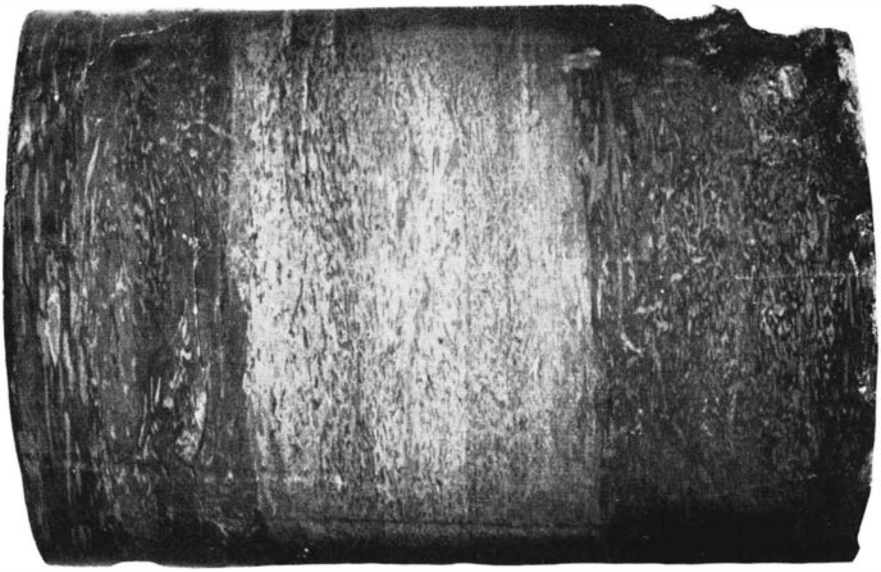
54.90  55.00

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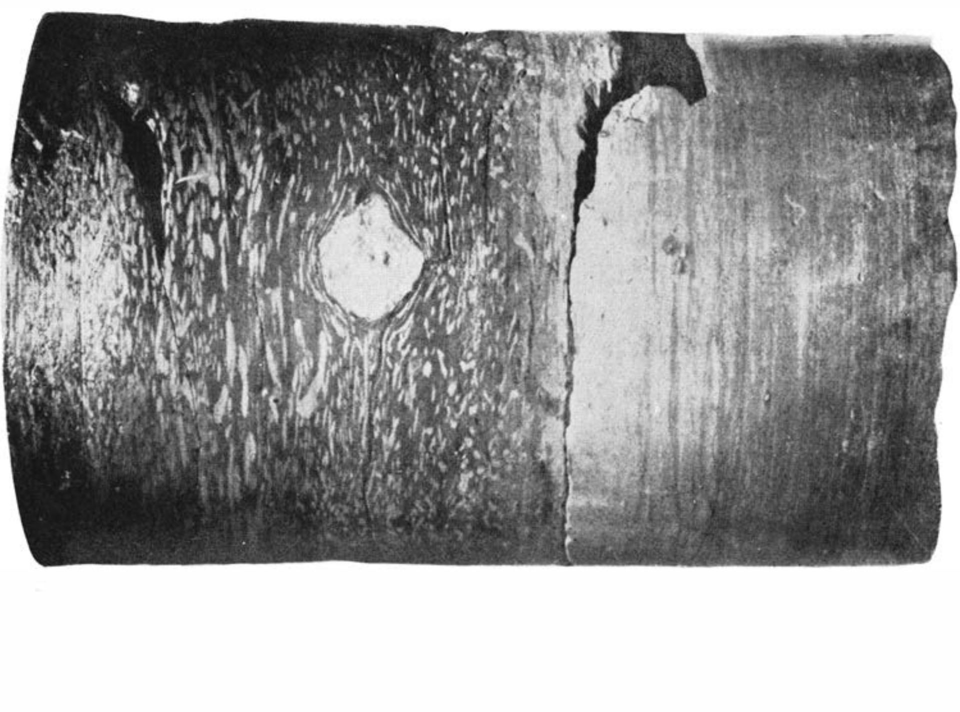
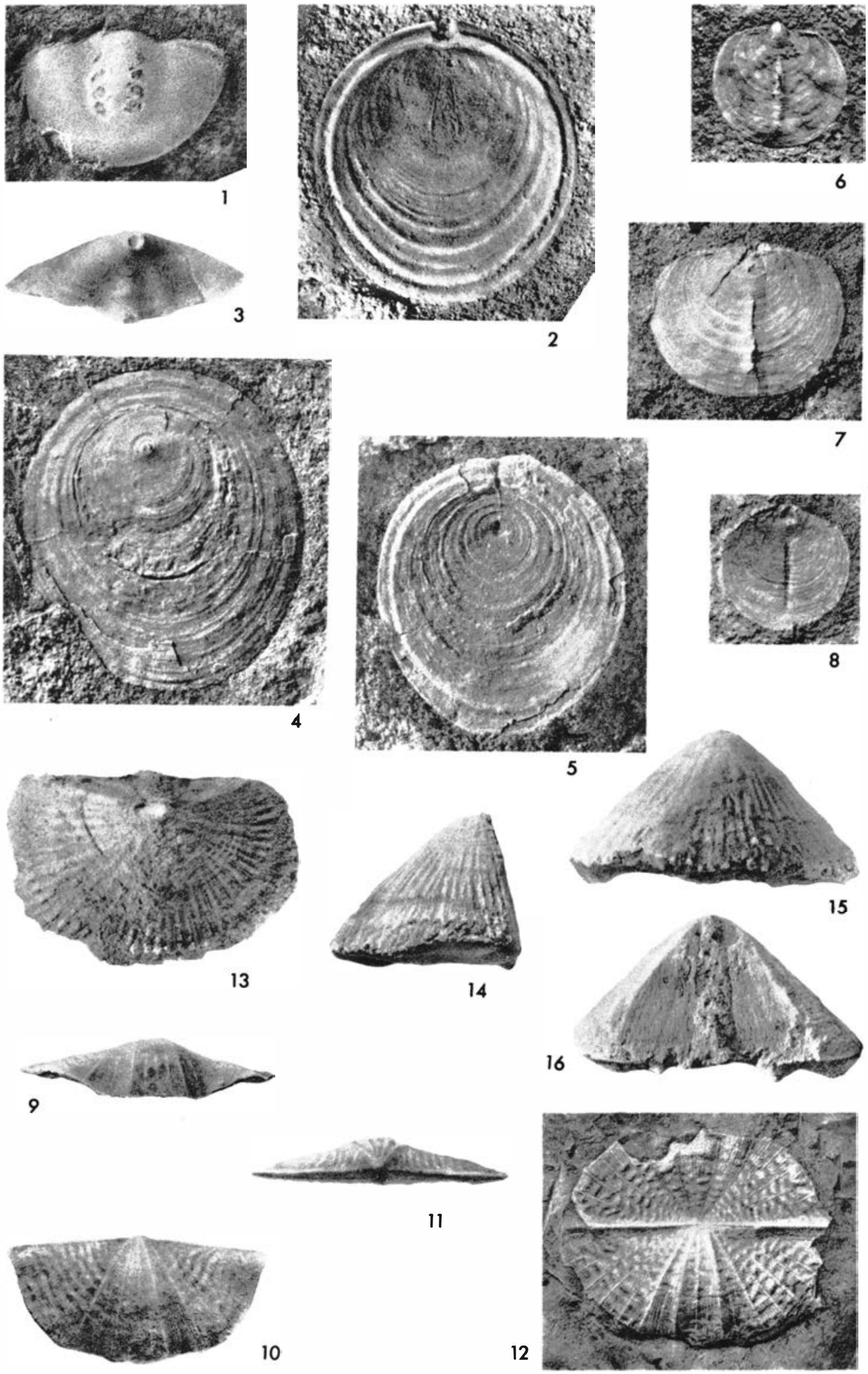
57.96  58.10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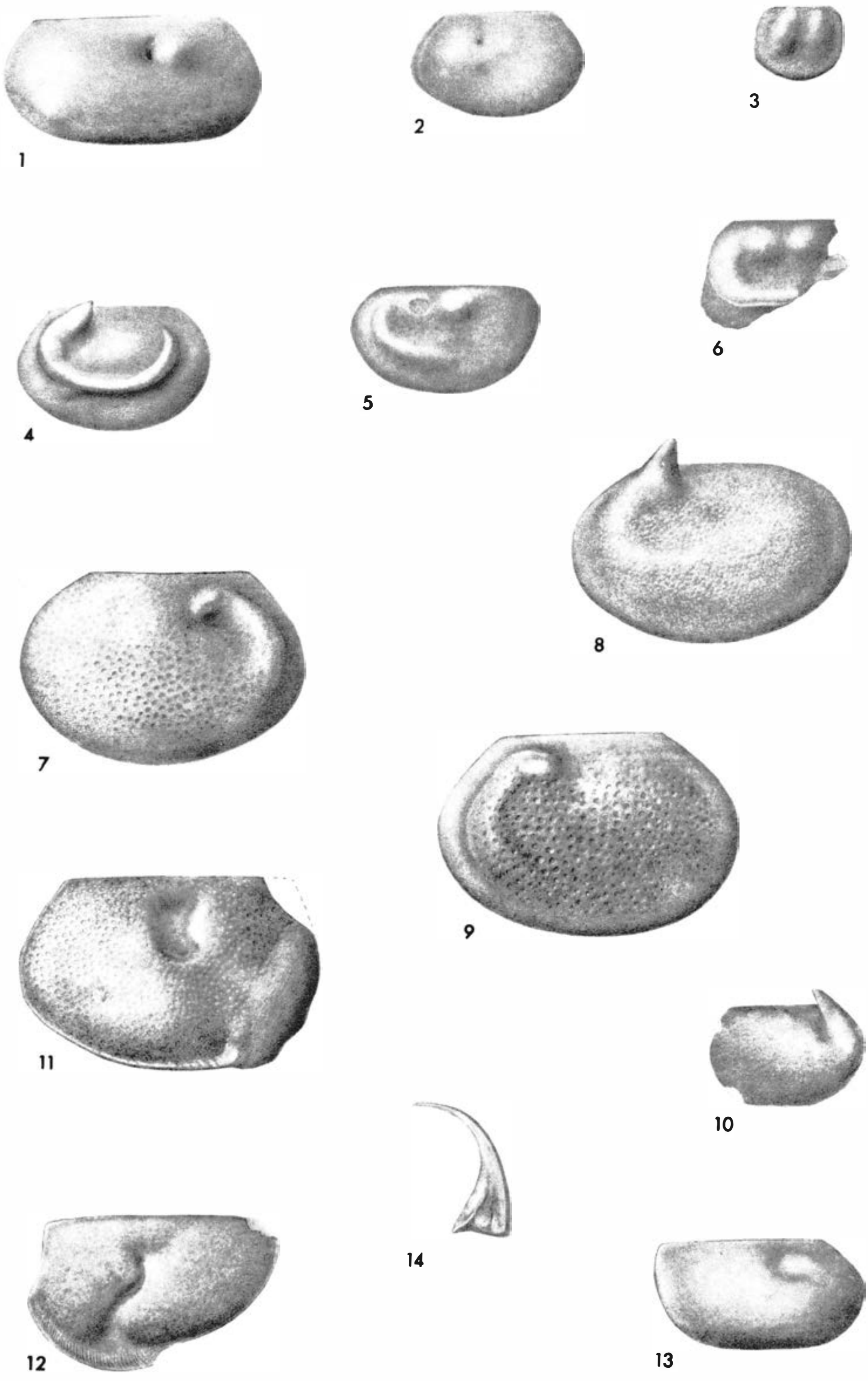
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5. The Silurian Strata of the Kullatorp Core.

By

Bertil Wærn.

I. Description of the Core.

At least the topmost 35.15 meters of the core belong to the Silurian, or, to be more exact, to the Llandovery. In ascending order, 2.38 m thereof belong to the Dalmanitina beds, 29.4 m to the Rastrites beds, and 3.3 m to the Retiolites beds. Above the zero point of the boring the section

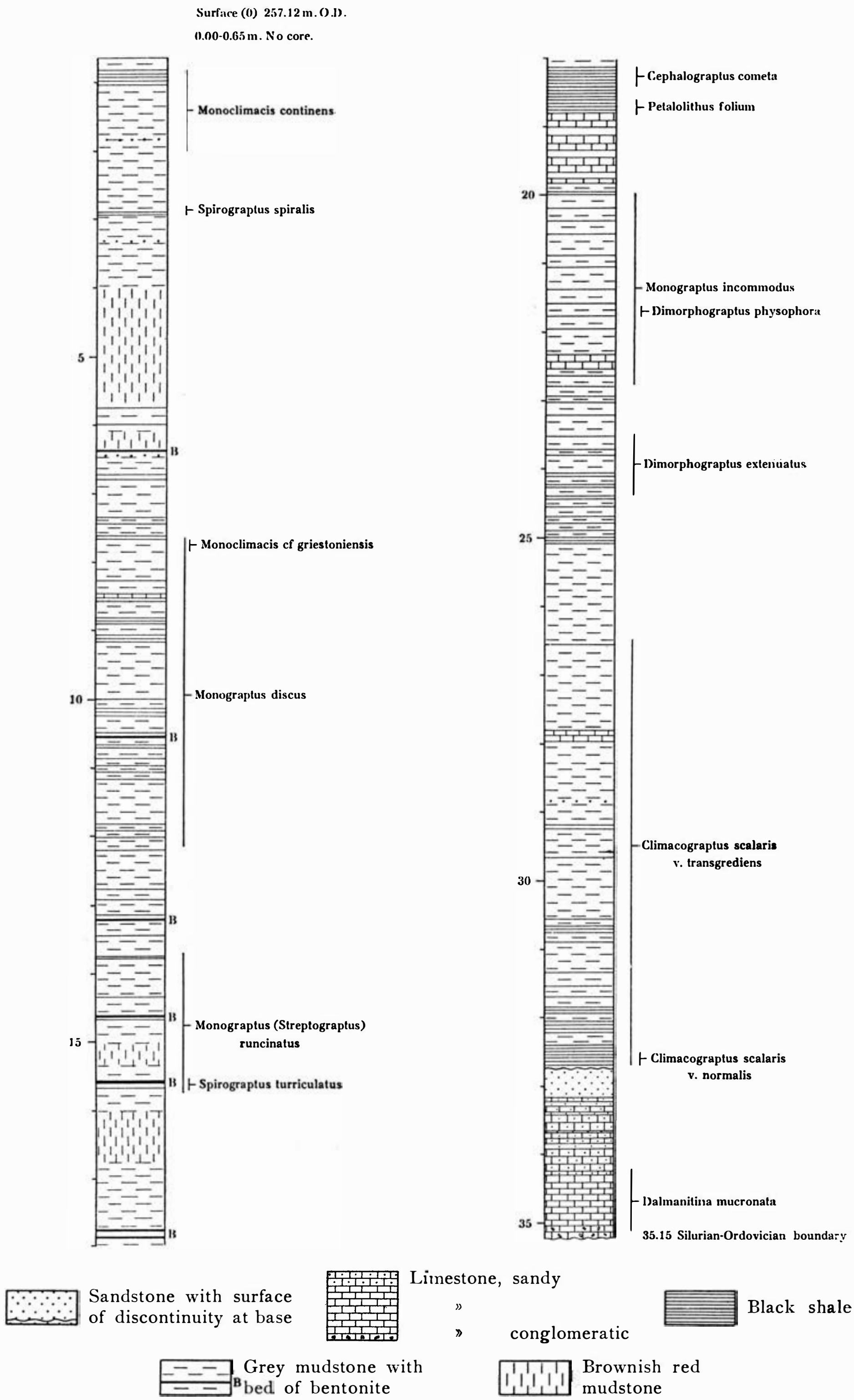

Diagram of the Silurian of the Kullatorp core.

extends for additional 22.7 m of mudstone belonging to the Retiolites Beds, followed by a 27 m thick cover of diabase. Sedimentary beds between the topmost Llandovery and the Quaternary are lacking in Vestergötland, at Kinnekulle as well as at the other mountains.

Dalmanitina Beds. 35.15—32.77 m.

A series of beds becoming upwards more and more sandy and following above the red Tretaspis mudstone possibly ought to be referred to the Dalmanitina beds, but more probably they represent the zone of *Staurocephalus clavifrons* in the Tretaspis Series (*Cf.* HENNINGSMOEN p. 427).

Above the top of these sandy beds follows limestone with *Dalmanitina mucronata* BRONGN., *etc.*, above a surface of discontinuity at 35.15 m. No angular unconformity has been observed but the boundary between siltstone and limestone is very distinct.

Numerous black fragments of shale are scattered in the crystalline limestone in the lowest part of the Dalmanitina beds. Most of them lie 3 cm or less from the base of the limestone, but single pieces occur up to 10 cm above the base. This crystalline limestone goes up to 34.13, *i.e.* it comprises 1 m. In its upper part there occur thin, sandy and marly beds dividing the limestone into several banks and lenses. The limestone is very rich in fossils, small strophomenids as well as rhynchonellids being especially abundant.

The preliminary list of species is as follows:

Homalonotus platynotus DALM. at several levels; fragments of cranidia, pygidia and thoraces.

Dalmanitina mucronata BRONGN. scattered.

Hindella ? cassidea (DALM.) at several levels.

Strophomenidae spp.[1] very numerous throughout the whole section. Both flat and arcuate types.

Rhynchonellidae small types not so very abundant as the preceding ones.

Fragments of brachiopods.

Graptodictya sp. grown in the shape of a flat disk with rounded holes, 34.48; 34.59.

Bryozoa, several different, staff-like types.

At 34.13 the crystalline limestone turns into a fine-sandy and calcareous, grey to greyish brown mudstone alternating with grey to greyish blue, fine-grained to dense, fine-sandy limestone in diffuse lenses and beds. This

[1] LINNARSSON and TROEDSSON report *Schuchertella pecten* from the Dalmanitina beds at Kinnekulle, but whether their determination is correct further investigations will have to prove.

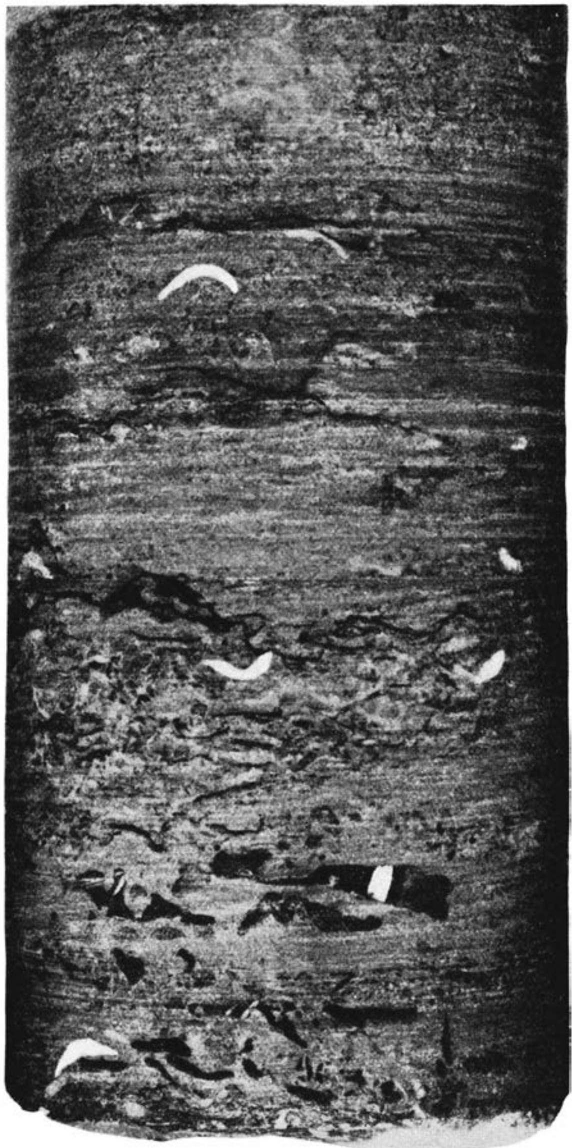

Fig. 1. Basal part of Dalmanitina Limestone 35.15—35.00 with scattered shale fragments in the lower part. Nat. size.

apparently barren rock passes into a grey, fine-grained, here and there somewhat rusty and scantily fossil-bearing calcareous sandstone or perhaps better siltstone at 33.06. Upwards the rock grows less calcareous. At the top, at 32.78, the calcareous sandstone is yellowish grey, rusty and weathered, and delimited from the overlying beds by an uneven denudation surface. Determinable fossils are found in the upper part only:

Proetus sp. (32.79); *Hyatidina* sp. (according to V. JAANUSSON) (32.84), Lingulide (32.94) and some fragments of other brachiopods; *Lepidocoleus suecicus* MBG (32.95; 32.78).

(I have encountered *Leonaspis centrina* (DALM.), *Plectambonites* sp., *Climacograptus* of the *normalis*-type at the rivulet Korsbäcken at this level.)

This sequence of limestone, sandy limestone and calcareous sandstone is thus bordered by denudation surfaces both below and above. It attains a total thickness of 2.38 m.

Rastrites Beds. 32.77—3.36.

The Rastrites beds can be subdivided into the following petrographic-stratigraphic sections from below upwards:

1) Alternating grey and greyish black mudstone with scattered limestone lenses. Total thickness 12.95 m. Zones of *Akidograptus acuminatus* (NICH.), *Dimorphograptus extenuatus* E. & W., and *Pernerograptus revolutus* (KURCK).
2) Grey limestone and mudstone. Thickness 1 m. No fossils.
3) Black shale (typical graptolite shale). Thickness 0.72 m. Zones of *Petalolithus folium* (HIS.) and *Cephalograptus cometa* (GEIN.).
4) Mostly grey but also at some levels red mudstone, with a number of graptolite-bearing black bands in the grey mudstone. Thin beds of bentonite at some levels. Together 14.75 m. Zones of *Spirograptus turriculatus* (BARR.), *Monograptus discus* TQT, and very likely also of *M. sedgwicki* PORTL.

1. Grey and Black Mudstone with Scattered Limestone Lenses.

Zones of ***Akidograptus acuminatus*** (NICH.), ***Dimorphograptus extenuatus*** E. & W., and ***Pernerograptus revolutus*** (KURCK). 32.77—19.81.

This section has a thickness of 12.95 m and consists of black mudstone, grey mudstone with black bands, and some layers or lenses of limestone. Apart from the alternation of lighter and darker layers of mudstone this section displays no real divergences in its various parts, the same types of sediment being met with throughout the section.

Above the yellowish grey siltstone of the Dalmanitina Series and separated from it by a surface of discontinuity follows mudstone. The lowest part of this mudstone, up to 7 mm, is mixed with washed-up debris from the substratum; it is yellowish grey with numerous rusty spots and with traces of fossils.

32.76—32.26 consists of black mudstone with only a few thin lighter layers. The rock is rather fine-bedded though not so as to laminate into thin smooth layers, the surfaces of the layers being uneven. The streak is usually grey, but at some levels it is black and the mudstone stains. Precipitates of ferric oxide at several levels. Graptolites in relief are filled both with ferric oxide and pyrite. At 32.74 there is a small concentration of granular pyrite. Also between 32.26 and 30.50 the dark mudstone occupies a considerable space in proportion to lighter grey types. Lighter grey mudstone predominates strongly still higher up.

The darker mudstone is usually more finely stratified while the lighter one is mostly thick-bedded, and often splits along other planes than the stratification planes. Here and there the lighter mudstone has lighter or darker spots, probably traces of digging animals. Rusty spots occur in some places while pyrite is only rarely met with (20.32). At 28.80 a fine-sandy layer has been encountered, and at 19.8 single round grains of quartz have been found in a dark brachiopod-bearing mudstone. Possibly also a thin bed of bentonite was deposited at this level. Unfortunately the core is here quite fragmentary. At 27.87—27.70 and at 22.55—22.35 the core consists of light grey and fairly dense limestone. It is impossible to determine whether the limestone appears in the shape of continuous beds or as lenses only.

Fossils are fairly numerous in the core, but nowhere do they cover the whole surface of the beds. Differences in facies as well as in the faunal sequence have been observed. Graptolites are quite predominant in the dark mudstones; they are, indeed, confined to them. In addition, there occur some lingulidae, *Paterula* sp. (29.2), single articulate brachiopods, gastropods, several ostracods, *etc.* In lighter mudstones the following species and groups have been found:

Lingula sp.
Sowerbyella sp.
Small smooth articulate brachiopods, abundantly.
Rhynchonellide (20.86).
Gastropods.
Hyolithids.
Ostracods (*Primitia* sp.).
Acidaspis centrina DALM. (26.3—19.83).
Calymene sp. (20.87).

Graptolites occur in the dark mudstone throughout the whole portion, though most numerously at 30.5—32.75; in some cases they are preserved in relief. In spite of their sparseness in the higher parts, it has nevertheless, thanks to them, been possible to divide the portion into three different zones, as demonstrated by the table below.

The lowest zone, the zone of *Akidograptus acuminatus*, is characterized mainly by forms which may be derived from *Climacograptus scalaris* HIS.

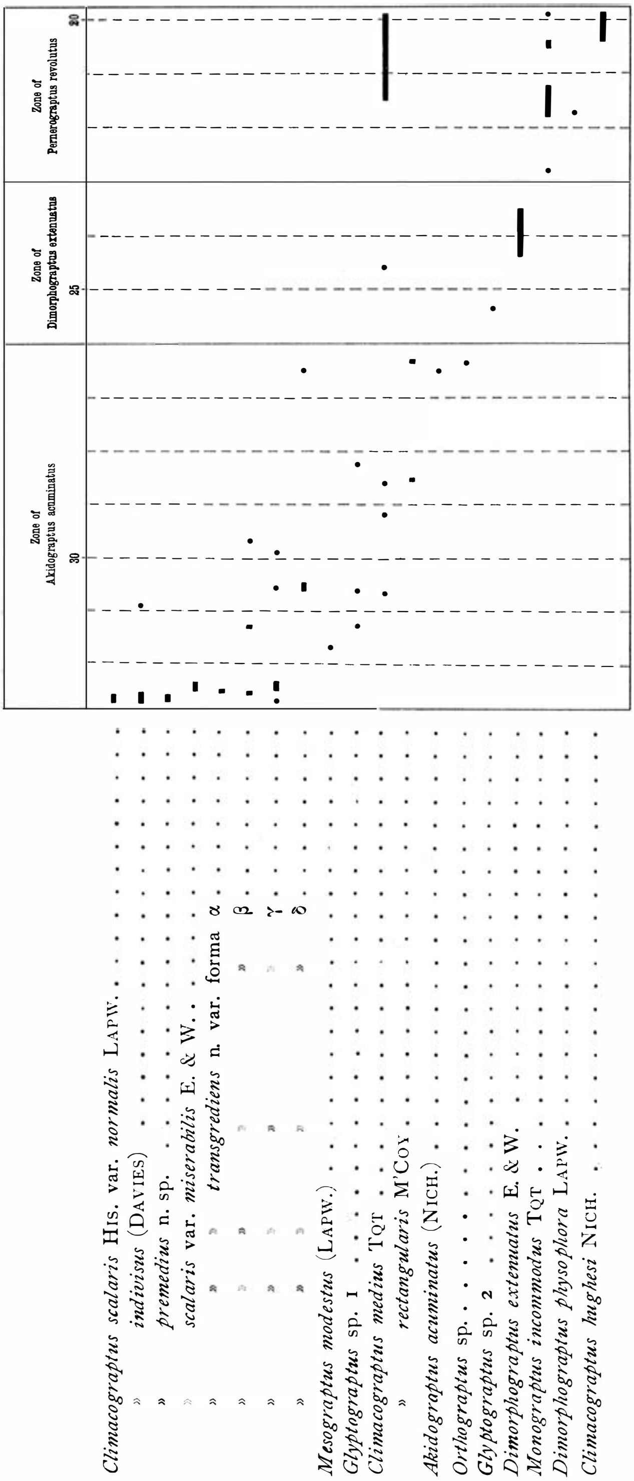

Fig. 2. Vertical distribution of the graptolites from Lower Llandovery in the Kullatorp core.

● = a single specimen; ■ = 2 or more specimens.

var. *normalis* LAPW., by transitional forms between this species and *Cl. medius* TQT, and by both these species. The middle zone, the zone of *Dimorphograptus extenuatus*, is but faintly pronounced and poor in species and individuals.

In the upper zone, the zone of *Pernerograptus revolutus, M. incommodus* TQT. and *Cl. hughesi* NICH. are the most common species.

2. **Grey Limestone and Mudstone.** 19.81—18.80.

This section of the core is quite badly crushed and has suffered great losses (50 %). It is probable that the mudstone beds have been subjected to stronger weathering than the limestone beds, and have been partly washed away. The surfaces of joints and beds in the impure limestone often have a yellow coating from weathering, showing that these beds are highly permeable so that the lime is dissolved from numerous surfaces of fissures and bedding planes.

Owing to the crushed and incomplete condition of the core nothing can be said with certainty regarding the mutual position, thickness, and alternation of the limestone and mudstone beds.

The limestone is light-grey to grey, dense, breaking with a conchoidal fracture, and partly so impure that it changes into calcareous marl. No distinct stratification can be seen though some tendency to banking is observed. Pyrite in the form of irregular lumps is met with in the upper part. Below the limestone borders on grey mudstone; this mudstone is also intercalated, thickness unknown, between the limestone banks. The upper boundary is very sharp but uneven as some limestone nodules penetrate through a topmost thin stratum of grey mudstone.

No fossils have been met with, though some small, irregular, oblong patches of oxidized ferriferous mud might be interpreted as trails and furrows left by animals.

3. **Black Shale.**

Zones of ***Petalolithus folium*** (HIS.) and of ***Cephalograptus cometa*** (GEIN.). 18.80—18.10.

This section consists almost entirely of black laminated shale. Lighter beds appear but very sparsely. Pyrite appears near the top in the form of small nodules, and the graptolite rhabdosomes, when preserved in relief, are filled with pyrite. At 18.50 there is a bed of pyrite up to 12 mm thick. The boundary of the black shale towards the substratum is distinct but uneven. The upper boundary has not been observed.

This section, surrounded by barren strata above and below, distinguishes itself by a remarkable abundance of graptolites. They are usually flat and consequently not very easy to determine, but at certain levels the graptolites are entirely or partly preserved in relief. A few brachiopods have been found in the highest and lowest parts of this graptolite-bearing section, in the lowest part also a single valve of an ostracod.

The following graptolite species occur more or less abundantly throughout this section of the core:

Climacograptus hughesi NICH.
Cl. scalaris HIS.
Glyptograptus tamariscus (NICH.)
Orthograptus bellulus (TQT)
Petalolithus palmeus (BARR.)
Demirastrites decipiens (TQT)
Monograptus lobiferus M'COY
Pernerograptus limatulus (TQT)
Pristiograptus leptotheca (LAPW.)
P. regularis (TQT)

Confined to the lower part, 18.80—18.40:

Petalolithus folium (HIS.)
Demirastrites convolutus (TQT)
Monograptus clingani CARR.
M. gemmatus BARR.
M. intermedius LAPW.
Rastrites approximatus f. *approximatus* PERNER
R. peregrinus BARR.
R. sp.
Spirograptus elongatus (TQT)

Only in the upper part, 18.40—18.10:

Cephalograptus cometa (GEIN.)
C. tubulariformis (NICH.)
Petalolithus cf. *ovato-elongatus* (KURCK)

The section 18.80—18.40 represents the zone of *Petalolithus folium*, while the section 18.40—18.10 falls within the zone of *Cephalograptus cometa*.

In order to understand the conditions of sedimentation of this shale it is very important to ascertain what is the explanation of its black colour. The relatively high content of organic matter (8.5 % as compared with about 5 % in the lighter grey shales) will but partly explain the colour. Rocks with high content of organic matter need not necessarily be dark and *vice versa*. However, the highest content of organic matter has been measured in the darkest rocks of the Rastrites beds; the lowest black shale of the Rastrites beds has 7.5 % of organic matter, while the content of the other samples analysed is 4.75—5 %. A thin, graptolite-bearing dark band in the discus-zone certainly had but 4.75 % of organic contents, but that may be explained by the dense alternation there of dark beds with lighter ones, so that an analysed sample is a mixture of the two.

Consequently, both the lighter and darker beds of the Rastrites beds demonstrate that the sea in which these sediments were deposited was rich in organic life, even if this does not appear in form of macro-fossils and »Lebensspuren» at all levels.

As can be seen by the zonal sequence, the black shale in spite of its limited thickness (0.7 m), was certainly deposited during a considerable time. Two different graptolite zones are represented. The accumulation of sediments was probably very slow and the sediments are far more highly organogene in origin than in the adjoining beds. The precipitates of pyrite indicate stagnant water saturated with sulphuretted hydrogen and with but little oxygen. Traces of bottom fauna are either very insignificant or entirely lacking, which circumstance, too, speaks of stagnated surroundings. Currents but rarely carried oxygen and sediments to this area of sedimentation. The fossils preserved in the shale are planktonic graptolites which were deposited in great numbers, either having been carried there by sea-currents but not washed away again, or they got into water poisoned by sulphuretted hydrogen and died there — or both these hypotheses may be true. Here and there their rhabdosomes cover the bedding planes.

P. E. RAYMOND has in 1942 discussed the problem of the pigment of black sediments. In that connection he deals with the abundant occurrence of black sediments in the older Paleozoic systems with graptolites, trilobites, *etc.*, and it is but exceptionally that he is inclined to consider them as sediments caused by stagnation. Instead, he emphasizes the wide-spread extension of those sediments and the world-wide occurrence of the fossils, especially of the graptolites. From this he concludes that neither the decomposition of organic remains under anaerobe conditions nor sulphuretted hydrogen in stagnated surroundings can be the main cause of the black colour of the sediments. RAYMOND maintains that animals with chitinous shells were of far greater importance in the seas of older Paleozoic times than in the seas of to-day. He mentions inarticulate brachiopods, trilobites and graptolites. Fragments of chitinous shells were, he says, concentrated into certain places, *e.g.* in mud-bottoms, where they were better protected against complete destruction by microbes breaking down the chitin, and so they brought about the black colour of the sediments. For in the course of time chitin turns black. Thus, according to the interesting and plausible explanation given by him, chitin will be the pigment in this black shale. Based on other arguments I nevertheless assert that it was deposited in rather stagnated surroundings, even if the actual colour of the sediments can not be considered conclusive evidence.

Furthermore, it is conceivable that it is the various layers, alternatingly rich and poor in chitinous sediments that produce the very dense black and grey-striped mudstones both occurring above and below this black shale. Graptolites prevail almost exclusively where the black component predominates in more or less homogeneous bands; in the lighter grey mudstones there are mostly brachiopods with calcareous shells, but no graptolites.

4. Grey and Red Mudstone with Black Bands and Beds of Bentonite.

Zones of ***Spirograptus turriculatus*** (BARR.), ***Monograptus discus*** TQT and very likely also of ***M. sedgwicki*** PORTL. 18.10—3.36.

This section consists of grey and greyish green, and of red and reddish brown mudstones, which pass one into another without any sharp boundaries. At a number of levels there appear in the grey mudstones dark beds and layers rich in graptolites, alternating with the grey beds. In addition, there are some single layers of limestone and several layers of bentonite.

The graptolite-bearing dark mudstone layers — »bands» according to British terminology — have no very great individual thickness. In some places the dark, a few mm thick layers alternate with lighter beds, in other places they attain a thickness of 2—10 cm. As a rule, dark and light beds follow closely upon each other, sometimes one type, sometimes the other predominates. The graptolite-bearing layers are mostly pure black but a few of them are more or less brown in colour.

Lighter mudstones without dark bands predominate. The colour is usually grey to light grey, yellowish grey or bluish grey, often with spots or thin streaks of darker rock. At 16.50—16.00, 15.30—15.03, 6.25—6.09 and 5.64—3.87 there is found reddish brown mudstone, which towards the upper and lower boundaries changes into pure brown and greyish brown, and which there alternates with grey and greyish green mudstone. The rock is generally very fine-grained. At 6.58 there occur a number of light yellowish grey, sandy concretions and spots in the grey mudstone. Spots and lines of light mudstone in dark mudstone or the reverse, *i.e.* dark mudstone in light mudstone, structures which may be explained as trails or burrows of worms or other animals, appear at several levels.

At 14.69 there occurs a clayey somewhat rusty greyish violet limestone forming a nodular bed up to 1 cm thick, which is overlain by bentonite.

Especially interesting are the beds of volcanic ashes which in the form of greenish grey and sometimes yellowish grey bentonite[1] with numerous micaceous scales have been deposited at several levels within the Upper Rastrites beds, as I have already reported on a previous occasion (THORS-

[1] Future petrographic examinations of Swedish beds of bentonite will show whether this is really bentonite or some other rock of a similar type.

LUND 1945). A specification of the levels as well as an estimate of the thicknesses of the beds follows below. In view of the easy destructibility of bentonite through drilling or water, this estimate is given with a certain reservation only.

17.80 3 mm;
17.72—17.70 about 16 mm (the bentonite is strongly intermingled with grains of biotite);
15.66—15.60 60 mm (this is the thickest bed. The colour is yellowish grey and the bentonite is strongly intermingled with mica. At the top, brownish yellow micaceous bentonite alternates with light grey mudstone. The bentonite here lies with a boundary as sharp as a razor-edge on black mudstone with *S. turriculatus*);
14.68 0—2 mm (on limestone);
13.23 about 10 mm (mixed with rusty grains);
10.55 some mm;
6.35 a few cm (the core having been badly crushed, it was not possible to determine the level; but as the water-level of the Kullatorp spring is at 6.33 and as levels of springs have been found in other places immediately on the beds of bentonite, it seems reasonable to locate the bentonite to the level stated above).

Thus 7 positive levels of bentonite have been observed.

It has already been pointed out before that the graptolites are mostly confined to the darkest mudstones while other fossils, brachiopods, trilobites, *etc.*, usually occur in lighter rocks. This is strongly pronounced in the upper zones of the Rastrites beds. We find a number of levels with finely bedded black mudstone, bands, often rich in graptolites and with single lingulida, intercalated by thick beds of light grey, greyish green or reddish brown mudstone showing but a sparse fauna consisting mainly of articulate brachiopods, but never of graptolites.

Apart from the brachiopods, which have not yet been fully determined, a conodont has been found at 11.68.

Above the black graptolite shale in the *C. cometa* zone follow some metres of greyish green and brownish red, but very sparsely fossil-bearing mudstone. *Favosites gothlandicus* LAMARCK forma *forbesi* EDWARDS & HAIME (17.25) and fragments of brachiopods with phosphatic shells are the only fossils found in the core. An exact determination of the stratigraphic level can not be based on these fossils. The beds of bentonite at 17.80 and 17.70, on the other hand, seem to indicate the zone of *M. sedgwicki*. This will be further discussed on p. 463.

At 15.66 there is a thin bed of black mudstone with graptolites. The species *Spirograptus turriculatus* (BARR.), *Monograptus* (*Streptograptus*) *runcinatus* LAPW., *Petalolithus palmeus* (BARR.) and *Plegmatograptus obesus*

(LAPW.) show that we have reached the *S. turriculatus* zone at this level. It extends at least up to 13.70 m and in addition to the species named above it contains also *Monograptus* (*Str.*) *exiguus* NICH., *M. marri* PERNER, *M. pandus* LAPW., *Spirograptus proteus* BARR., *S. tortilis* PERNER and *Glyptograptus tamariscus* (NICH.). The three bands belonging to this zone are thin; 1 cm at 15.66, 1 cm at 14.32 and 4 cm at 13.72—13.68. Above them there follow three bands: at 13.38—13.35, 13.18—13.15 and 12.58—12.55, which with some hesitation only may be referred to this zone as the graptolites in those bands are common to the *S. turriculatus* and *Monograptus discus* zones:

Glyptograptus tamariscus (NICH.)
Petalolithus tenuis (BARR.)
Monograptus marri PERNER
M. (*Streptograptus*) *becki* BARR.
M. (*Str.?*) aff. *dextrorsus* TULLB.
Pristiograptus nudus (LAPW.)
Spirograptus proteus (BARR.)

The *M. discus* zone begins at 12.20 with the appearance of the zone fossil *M. discus* TQT. About twenty bands contain a graptolite fauna, rich in species and individuals, characteristic for this zone. *M. discus* may be traced up to 7.60 and *Diversograptus sartorius* (TQT) still occurs at 6.70. Then, however, the beds with their reddish brown and grey mudstones are completely barren up to 2.87. In spite of the lack of fossils but in account of the facies I have chosen to extend this section, and consequently the *M. discus* zone too, to 3.36 m. Thereby the reddish brown mudstone beds between 6.30 and 3.85 are assigned to the same series as the reddish brown mudstones appearing earlier at 16 m, 15 m and outside the core South of the diabase cap at a level corresponding to about 13 m. At 3.36 there follow several sandy beds and at 2.87 the graptolites of the Retiolites beds.

With regard to the distribution of the graptolites in the core the *M. discus* zone is divisble into two parts, a lower part, 12.15—9.10, and an upper part, 9.0—6.7 (3.36).

In the lower part have been found:

Glyptograptus tamariscus (NICH.)
Petalolithus tenuis (BARR.)
Monograptus crispus LAPW.
M. discus TQT
M. marri PERNER
M. pandus LAPW.
M. priodon BRONN
M. (*Streptograptus*) aff. *dextrorsus* TULLB.
M. (*Str.*) *exiguus* NICH.
Pristiograptus nudus (LAPW.)
Spirograptus planus (BARR.)
S. proteus (BARR.)

With the exception of *M. crispus* and *M. discus* these species occur also in lower beds and most of them continue in the upper part of the zone.

At 9 m appear an additional number of species, most of them being typical for the *M. discus* zone; a couple of them, however, *Monoclimacis crenulata* (TQT) and *Retiolites geinitzianus* BARR., are forerunners of the Retiolites beds.

Of the species already met with at lower levels the following ones survive:

Petalolithus tenuis (BARR.)
Plegmatograptus obesus (LAPW.)
Monograptus crispus LAPW.
M. discus TQT
M. marri PERNER
M. priodon BRONN
M. (*Streptograptus*) *exiguus* NICH.
Spirograptus planus (BARR.)
S. proteus (BARR.)

The following are new for the level:

Retiolites geinitzianus BARR.
Demirastrites pragensis PRIBYL var.
Diversograptus sartorius (TQT)
Monoclimacis crenulata (TQT)
Monocl. cf. *griestoniensis* (NICHOL)
Pristiograptus pergratus PRIBYL
Spirograptus flagellaris (TQT)
S. sp.

Only by a comparison with deposits of the same age in other localities can it be settled how this increase in the fauna is to be explained: whether better conditions were the cause of the richer fauna or whether we have really found a stratigraphically valid boundary.

Retiolites Beds. 3.36—0.00.

The core comprises but little more than 3 m of the Retiolites beds. The boundary towards the Rastrites beds has in the profile on p. 434 been fixed to some sandstone lenses at 3.36 m.

The rock in the core is chiefly a dark grey to greyish brown and greyish green, hard mudstone, showing here and there light spots of siltstone or sandstone lenses. The crevices in the upper parts are usually bluish black owing to precipitates of iron. The rock is here strikingly harder and sandier than in the underlying *M. discus* zone. It is noncalcareous. From

2.87 m upwards there are sparse fossils throughout the whole core, the graptolites seeming to be confined to the dark types of mudstone, the brachiopods occurring both in those beds and especially in the lighter ones.

The following species have been found:

Monoclimacis continens (TQT) (0.80; 2.0)
Monocl. crenulata (TQT)
Monocl. aff. *griestoniensis* (NICHOL) (2.0)
Monograptus crispus LAPW. var.
M. priodon BRONN
Spirograptus spiralis (GEIN.) (2.87) and
Lingula sp., articulate brachiopods and ostracods (0.68; 0.70).

II. Retiolites Beds above the Core Sequence.

To the description of the sequence series of the core I should like to add some field observations regarding those portions of the Retiolites beds that lie above the zero point of the boring;· they comprise 22.7 m.

Above the top of the boring, 257.12 m above sea level, black and grey mudstones follow up to 279.8 m, where the sequence is interrupted by intrusive diabase. The rock is contact-metamorphically influenced by the diabase. Though this influence decreases with the distance from the contact surface, it is still discernible at a depth of 25 m below the diabase. Even on the boundary the fossils have not been extinguished, but they are badly preserved, being strongly crystallized. The general character of the fauna can, consequently, be established but it is rather difficult to undertake more detailed examinations. Up to about 270 m the beds are well accessible in road cuttings both on the eastern and western side of Högkullen, the local name of the top of Kinnekulle.

In the lowest part, the rock consists of distinctly slaty dark mudstone, while higher up it generally has a lighter colour. It is brownish grey at about 272 m, turning light greyish brown at 276 m. The superficial beds are very rusty. Some very light beds have been observed at a few levels. Thus, a bed of pale yellow mudstone about 10 cm thick occurs at 260.68 m in the road cutting immediately SSW of the boring place. The same bed is encountered in the quarry somewhat NE of the boring place at 261.09 m. On the eastern side of Högkullen, a similar bed has been observed at 267.32 m and a white rock, about one cm thick, with yellowish white grains at 270.73 m. Judging from its appearance, I consider it very probable that this last named bed consists of metamorphic bentonite. Also the other very light beds here discussed may be of the same origin, but lacking sufficient petrographical facts, I can only express this as a supposition.

Apart from very few sporadic brachiopods, the fauna consists almost exclusively of graptolites. At certain levels they are quite numerous, especially

Monoclimacis crenulata s. l., *Monograptus priodon* and *Spirograptus spiralis*. Thus, *e.g.* the following species have been found high up in the road cutting SSW of the boring place at about 260 m above sea level: *Monograptus priodon* BRONN, *Spirograptus planus* (BARR.), *S. spiralis* (GEIN.), *M.* (*Streptograptus*) *nodifer* TQT, *Monoclimacis sublinnarssoni* PRIBYL and *Diversograptus* sp.

In the western slope, a short distance south of the way up to the diabase cap 276.6 m above sea level, the following species could be identified with more or less certainty: *Monograptus priodon* BRONN (though with a slightly bent proximal end which recalls *M. riccartonensis* (LAPW.)), *Monoclimacis linnarssoni* (TULLB.) (numerous), *Spirograptus spiralis* (GEIN.) (1 specimen), *M.* sp., *Cyrtograptus* aff. *lapworthi* TULLB., *C.* sp. and *Retiolites geinitzianus* BARR. The determination is rendered difficult by the poor state of preservation of the fossils. They mostly appear as hollow spaces in the rock, filled with a partly crystallized rusty powder.

Graptolites could also be traced close to the diabase in the light yellowish brown and hard, rather fine-stratified mudstone; but it was impossible to identify them.

III. **Chemical Tests**

carried out by P. GRUNDULIS of the Palaeontological Institute of Uppsala.

	Dissolved in boiling diluted HCl (Mainly $CaCO_3$) %	Loss by ignition. Mainly organic matter %	Fe %	S %
1. Dalmanitina beds, limestone 34.53—34.57	81.25	1.25	1.25	0.0756
2. Dalmanitina beds, calcareous sandstone 33.53—33.57	60.5	2.0	1.375	—
3. Dalmanitina beds, sandstone 32.87—32.95	34.5	1.75	2.875	—
4. Rastrites beds, lowest black mudstone 32.55—32.62	2.5	7.5	4.5	—
5. Rastrites beds, lower grey mudstone 26.65—26.70	11.5	4.75	4.375	—
6. Rastrites beds, limestone, 18.94—19.44	76.76	1.4	—	—
7. Rastrites beds, C. cometa zone, black mudstone 18.55	4.75	8.5	4.375	0.397
8. Rastrites beds, M. discus zone, graptolite-bearing band 7.60—7.65	2.75	4.75	5.0	0.0
9. Rastrites beds, M. discus zone, grey mudstone 7.8	4.5	4.0	10.375	0.121
10. Rastrites beds, M. discus zone, red mudstone 5.0	1.0	5.0	7.125	0.0

IV. Remarks on *Climacograptus scalaris* His. var. *normalis* Lapw and some related species in the core.

In the lowest parts of the core a fairly rich fauna of often quite well preserved Climacograptidi has been observed. With this material some important results, both from a systematic and a stratigraphic point of view, have been achieved. I shall, therefore, give a survey of the species found and descriptions of some new species and forms. In this connection I wish to refer to DAVIES's account (1929) of some partly contemporaneous fossils in Great Britain, as well as to my discussion on the stratigraphic facts ascertained (pp. 461, 462).

Climacograptus scalaris v. *normalis*[1] has a very limited extension at Kinnekulle. The species occurs in the lower parts of the dark graptolite shale at the base of the Rastrites beds between 32.75 and 32.52.

Principal data: Sicula visible on the obverse side up to a length of 1.15 mm. Rhabdosome at th 1 0.70 mm broad (0.65—0.80), distally not exceeding 1.3 mm. Number of thecae in 5 mm 5.2—6 (distance between the apertures of th 1^1—5^1 = 3.25—3.6 mm). Septum begins at 1.2—1.35 and and 1.6—1.7 (measured in proportion to theca 1^1, 2^1, *etc.*, *cf.* p. 454).

From this species a number of other species and types as enumerated below may have originated:

Cl. scalaris HIS. v. *transgrediens* n. var. forma α—δ.
Cl. medius TQT.
Cl. premedius n. sp.
Cl. indivisus (DAVIES).
Cl. rectangularis M'COY.

Closely related to *Cl. scalaris* v. *normalis* is also *Cl. scalaris* v. *miserabilis* E. & W. It is a much more slender type, its breadth not exceeding 1.0 mm.

Cl. scalaris v. *transgrediens* occurs at Kinnekulle chiefly in the upper part of the dark shale at the base of the Rastrites beds and also a few metres higher up in the sequence. Regarding the distribution of the various forms *vide* fig. 2.

Principal data: The four forms of var. *transgrediens*, *viz.* α—δ, the subdivision based upon the beginning of the septum on the reverse side, show in most respects but little variation, though some trends may be traced.

Visible part of sicula 0.90 mm (in two early specimens 1.15 mm).

[1] There can be some doubt whether it is appropriate to designate this type as a variety of the much younger *Cl. scalaris* HIS. As I have as yet not been able to come to a definite conclusion regarding the details of *Cl. scalaris* I must here desist from drawing any systematical conclusions. HISINGER's holotype being in scalariform view is not of much help. Other specimens I have seen show a close resemblance to var. *normalis.* In contrast to British specimens (ELLES & WOOD 1918, p. 184, 185) they sometimes exceed a length of 20 mm being 30 mm and more.

Rhabdosome at th 1^1 0.60—0.75 mm broad, distally it attains a breadth of 1.5 mm, but probably not more. Number of thecae in 5 mm 6 in forma α and β, 6—6.2 in forma γ and δ (distance between the apertures of th 1^1—5^1 = 3.0—3.4 mm in forma α and β, 2.8—3.3 mm in forma γ and δ). Septum begins at 2.17 in α, 2.57—2.87 in β, 3.0—3.27 in γ and 3.53—3.80 in δ.

Cl. medius appears later than the types just described, and since the graptolite facies soon begins to recede, only some few widely scattered specimens have been observed. At Kinnekulle, the lowest level where it appears is at 30.6 m.

Principal data: Visible part of the sicula 0.85 mm.

Rhabdosome at th 1^1 0.75 mm (0.70—0.80) broad, distally the rhabdosome attains a breadth of 1.6 mm. Number of thecae in 5 mm 5.6—6.5 (distance between the apertures of th 1^1—5^1 = 2.8—3.5 mm). Septum begins at th 4 and higher up.

Cl. scalaris v. *transgrediens* forms a transition between *Cl. scalaris* v. *normalis* and *Cl. medius* with regard to the time of its appearance as well as to its anatomical characteristics. *Cl. scalaris* v. *transgrediens* occurs simultaneously with and somewhat later than *Cl. scalaris* v. *normalis*, first forma α appears, then forma β, γ and δ, and the last surviving specimens are contemporaneous with the earlier occurrences of *Cl. medius*.

Out of a material of 30 specimens (*Cl. scalaris* v. *normalis* 9, *Cl. scalaris* v. *transgrediens* 18, *Cl. medius* 3) the following tendencies in the development of *Cl. scalaris* v. *normalis* into *Cl. medius* may be traced:

The first thecae have a tendency to conceal more and more of the sicula; visible part = 1.15—0.85 mm. The proximal part of the rhabdosome seems to retain its breadth, or possibly to slightly diminish it; distally the maximum breadth increases from 1.3 mm to 1.6 mm, both figures indicating, however, rather the tendency than the maximum breadth. There are broader specimens, but the species could not be determined as the proximal end was missing. The frequency of the thecae (number of thecae in 5 mm) seems to increase (counted per 10 mm from 10.4—12 to 11—13). Often the measure for the distance between th 1^1 and th 5^1 gives a more exact and better expression for the same thing. The position of the beginning of the septum on the reverse side (on the obverse side the septum reaches the sicula) supplies the most important systematic characteristic. In this group of species there is a tendency on the part of an ever-increasing number of thecae, after growing out from their predecessors, to cross the middle line and open on the opposite side. Thus the stage is delayed when from one theca two fresh thecae bud out, each of them forming the origin of new thecae in two rows lying back to back and separated by a septum.

The septum of *Cl. scalaris* v. *normalis* begins at about 1.25 and 1.7; in *Cl. scalaris* v. *transgrediens* it begins at about 2.17, 2.7, 3.15 and 3.65, and in *Cl. medius* at 4 and 5.

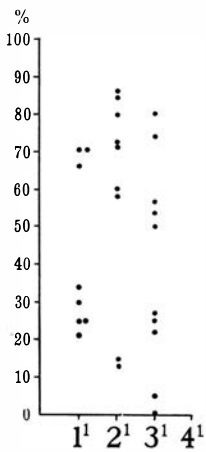

Fig. 3.

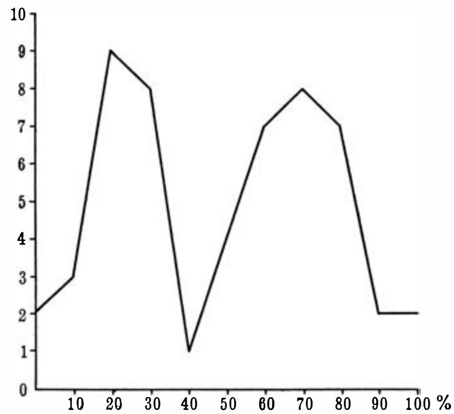

Fig. 4.

Fig. 3. Diagram showing the beginning of the septum on the reverse side in relation to the thecae of the right-hand row. Measures taken from the lower margin of the theca openings. The X-axis indicates the thecae 1^1—4^1 (right-hand row when seen from the reverse side). The Y-axis indicates the space between two consecutive theca openings. *E.g.* the uppermost dot in the middle row is to be read as 2.86 and means that the septum stretches down to a level between the openings of th 2^1 and 3^1 and ends quite near to the opening of th 3^1.

Fig. 4. Graph based upon fig. 3. The X-axis indicates the space between two consecutive theca openings no matter which. The distance from the lower theca opening to the upper one is given in percent. The plottings have been classed together: 01—20 under 10; 11—30 under 20 *etc.* The Y-axis indicates the number of specimens measured.

In order to show the connection between the beginning of the septum and the budding out of two thecae from one theca thus forming two rows of thecae, I have plotted down in a diagram the point marking the beginning of the septum (fig. 3). A curve based upon this diagram shows two maxima (fig. 4). One of the maxima represents the state when the two thecae have budded from a theca opening on the right side of the middle line, the other when they have budded from a theca opening on the left side.

Besides the types cited above some additional ones may derive from *Cl. scalaris* v. *normalis*, *viz.:*

Cl. premedius.
Cl. indivisus.
Cl. rectangularis.

Cl. premedius. Only two specimens are known from the Kullatorp core in the lowest black Rastrites shale between 32.62 and 32.52.

Principal data: Visible part of the sicula 0.8 mm.

Rhabdosome at th 1^1 0.50 mm broad, distally it attains a breadth of

1.65 mm. Number of thecae in 5 mm 4.7 (*i.e.* 9.5 th in 10 mm), distance between the apertures of th 1^1—5^1 = 4.4 mm). Septum begins at 3.2—4.

Thus it is the slender proximal part, the more widely spaced thecae, and the late appearance of the septum that distinguish this species.

Cl. indivisus occurs rarely in the lowest black Rastrites shale at 32.55, and 1 specimen at 30.88.

Principal data: Visible part of the sicula 0.9—1.0 mm.

Rhabdosome at th 1^1 0.65 mm (0.60—0.65) broad, distally a breadth of 1.9 mm has been measured. Number of thecae in 5 mm 5.8 (distance between the apertures of th 1^1—5^1 = 3.4 mm). Septum is entirely missing on reverse and obverse sides.

Cl. rectangularis. The lowest level at which it has been detected is 28.55; it then appears higher up, though only sparsely owing to the relatively unsuitable facies.

Principle data: Visible part of the sicula about 1 mm.

Rhabdosome at th 1^1 0.65 mm (0.65—0.75), distally a maximum breadth of 1.9 mm has been measured. Number of thecae in 5 mm 6.3 (distance between the apertures of th 1^1—5^1 = 3.2—3.6 mm). Septum begins at 1.3—1.6.

The early development of the septum and the rapidly increasing breadth are the characteristic features of this species.

While each of the three last named species, *Cl. premedius, Cl. indivisus*, and *Cl. rectangularis*, may be supposed to have originated from *Cl. scalaris* v. *normalis* or a closely allied type, none of them can be assumed to have originated from either of the other two.

Description of new Forms:

Climacograptus scalaris HIS. v. ***transgrediens*** n. var.

Pl. XXVI, fig. 2, 3.

1929 *Cl. scalaris—Cl. medius transient* DAVIES p. 7, figs. 28, 31.

Holotype: gr. 1223 b (forma β).

Material: A number of specimens from the Kullatorp core, Kinnekulle, Vestergötland.

Diagnosis: *Cl. medius—Cl. scalaris* v. *normalis*. Septum on the reverse side begins between th 2^1 and 4^1.

Description: The rhabdosome is straight, rarely exceeding 20 mm. Owing to the bend of th 1^1 the rhabdosome tapers somewhat towards the proximal end; it attains, however, a breadth of 0.7 mm at the aperture of th 1^1; at th 3^1 the breadth is about 0.9 mm. Distally 12 mm from the proximal end, a breadth of 1.5 mm has been measured. Thus the rhabdosome very slowly increases in breadth.

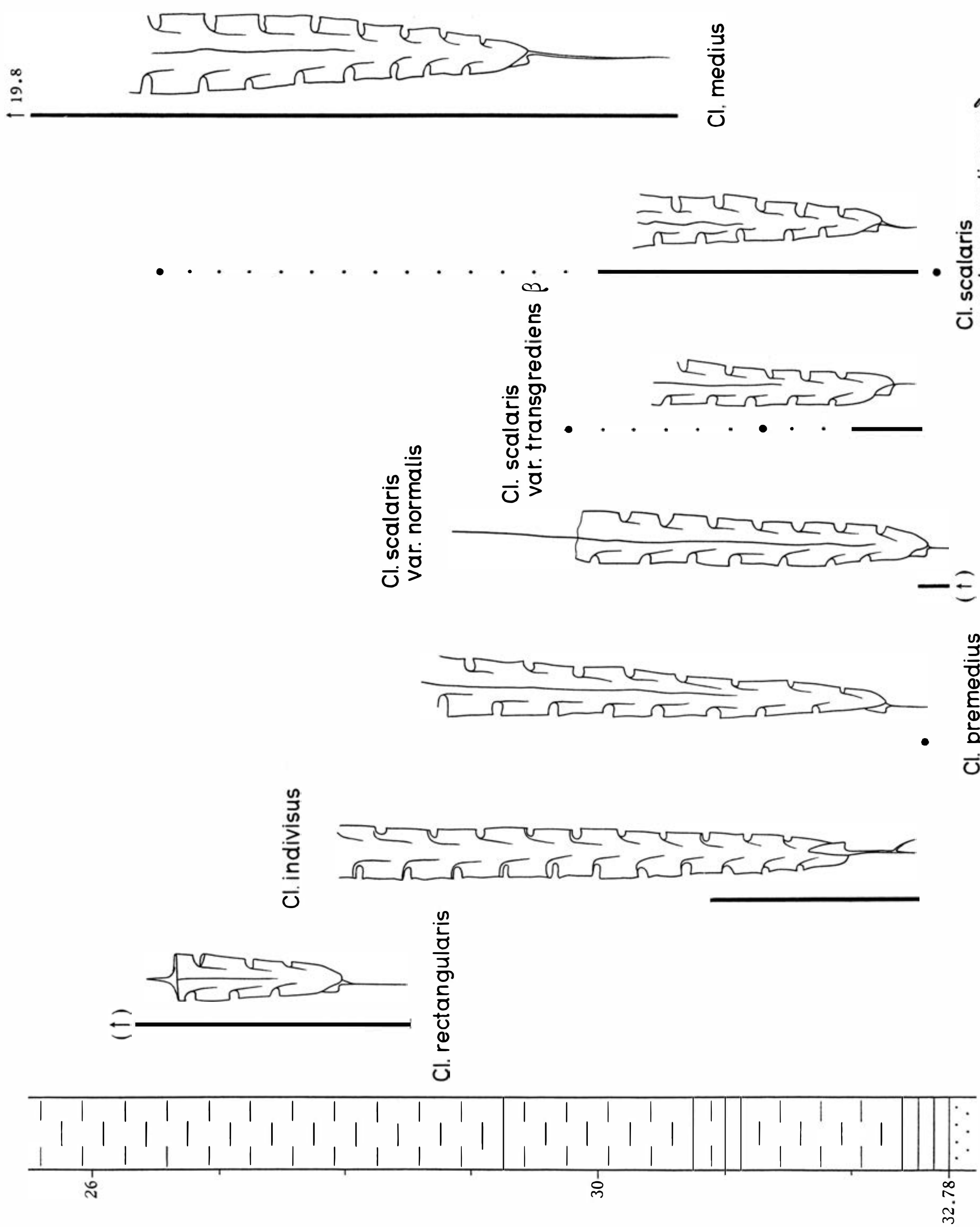

Fig. 5. The stratigraphical range of the Silurian Climacograptidi in the Kullatorp core.

On the reverse side most of the sicula is concealed by th 1^2. On the obverse side it can be traced somewhat farther, its proximal part, however, being partly covered. On two early specimens the length of the visible part has been ascertained to be 1.15 mm and on three other specimens 0.85—0.90 mm.

A virgella projects downwards from the sicula and — as is mostly true of specimens in relief — it is usually broken. In several cases it has, however, a length of 1.3—1.8 mm, in one case 3.1 mm. Theca 1^1 buds out rather high up on the wall of the sicula. It grows down the sicula, and then turns in a sharp bend at or somewhat below the aperture of the sicula, whereupon it grows upwards again and opens almost 1 mm above its lowest part. Th 1^1 gives rise to th 1^2, and that one grows obliquely upwards over the sicula on the reverse side. The inner walls of the thecae have a feebly sigmoid curvature, and highest up they run out to the border, forming a roof over the semicircular aperture. The outer walls, on the other hand, first run parallel with the inner walls of the preceding thecae but bend sharply on reaching the margin of the rhabdosome and then run almost parallel with the axis of the rhabdosome.

At the proximal end there are 6 to 6.2 thecae in 5 mm, which, with reference to a couple of specimens of the required length, may be interpreted as 12—12.4 th in 10 mm. By measuring the distance between the top of th 1^1 and the top of th 5^1, thus 4 thecae, I have obtained another measure for the closeness of the thecae. This measure varied between 3.0 and 3.4 in forma α and β, 2.8 to 3.3 in forma γ and δ. Thus the thecae of forma γ and δ seem to have been somewhat more closely set than those of forma α and β.

The septum is complete on the obverse side but incomplete on the reverse side. A tendency to delay the development of the septum has been observed, so that on ascending in the sequence one observes how its formation begins higher and higher up in the rhabdosome. There are four separate forms with different vertical extension.

Forma α and β: The septum begins between th 2^1 and 3^1, either at 2.16—2.18 or at 2.57—2.86.

Forma γ and δ: The septum begins between th 3^1 and 4^1 either at 3.0—3.27 or at 3.53—3.80.

The septum is straight or only slightly undulating. There is, however, a specimen (gr. 1196) from level 29.2 with a strongly undulating septum. According to the initial part of its septum it should be placed in forma β.

Discussion: As already pointed out by DAVIES (1929, p. 8), this variety seems to constitute a transition between *Cl. scalaris* v. *normalis* and *Cl. medius*. Thus it is open to discussion to which of those species it ought to be referred. *Cl. scalaris* v. *normalis* usually has a more complete septum.

DAVIES reports, however, forms from the zone of *Glyptograptus persculptus* in Wales which owing to the delaying of the septum lead to *Cl. medius*.

Cl. medius has an incomplete septum on the reverse side. It begins at the fourth or fifth thecal pair, *i.e.* according to the terminology given above, at (4) 4.2—5. *Cl. scalaris* v. *transgrediens* covers the shifting of the septum between 2.16 and 3.8.

Also as regards size this variety seems to lie somewhere between the species mentioned above. And this is the case, too, with regard to the development of the virgella. The latter seems to have been at least 2 mm long but no further development of the spina at the proximal end has been observed.

Judging from the position of the septum, the specimens figured by DAVIES (1929) seem to belong to forma α.

For the associated fauna I refer to my description of the core.

Horizon: The zone of *Akidograptus acuminatus*, Kinnekulle, Sweden. In the same zone and on the boundary towards the zone of *Glyptograptus persculptus* in Great Britain.

Climacograptus premedius n. sp.

Pl. XXVI, fig. 5.

Holotype: gr. 1230.

Material: 2 specimens gr. 1229 and gr. 1230 from the levels 32.54 and 32.63 in the Kullatorp core. The specimens are preserved in probably almost full relief and filled with pyrite. Only the reverse side has been observed.

Diagnosis: *Cl.* with slender proximal end. 4.7 th in 5 mm. Septum begins at 3.2—4 on the reverse side.

Description: The rhabdosome is long, slender and straight. The breadth at th 1 is 0.5 mm, at th 3 0.65 and 0.75 mm resp., at th 6 1.1 and 0.9 mm resp., and distally 1.8 and 1.5 mm resp. From a very slender proximal end the rhabdosome thus smoothly and continuously increases in breadth towards the distal end; it attains a length of 17.3 and 17.5 mm.

The sicula is but partly visible from the reverse side, its aperture being about on a level with the lowest part of th 1^1. The virgella attains a length of at least 1 mm.

It could not be observed whence th 1^1 emerges from the sicula. The theca first grows downwards and bends upwards at about the aperture of the sicula. It then grows upwards, to that its aperture lies 1 mm higher than its lowest part. Th 1^2 grows obliquely over the sicula, so that the first two thecae almost completely cover the sicula on the reverse side. The walls of the thecae run almost parallel with the axis of the rhabdosome. While the ventral or outer wall is quite straight, the dorsal wall shows a rather feeble sigmoid curvature. The highest part of the dorsal wall projects like a roof over the rounded aperture excavated to about a quarter of the rhabdosome's breadth. The feature last described can only be observed when the rhabdosome is preserved in full relief and can be seen in bi-profile view.

9 thecae in 10 mm on either side.

The septum begins on the reverse side on a level with the aperture of th 4 in gr. 1229 and at th 3 in gr. 1230. In gr. 1230 the sicula, and, then, each theca up to th 3^2, gives rise to one new theca, which, growing obliquely upwards, crosses the middle line of the rhabdosome, but th 4^1 gives rise to two thecae, th 4^2 and 5^1. Those, in their turn, and all the following ones, give rise to only one theca each.

It can, however, not be stated with absolute certainty whether it is really theca 4^1 that gives rise to two thecae, since the thecae cannot be traced into the interior of the rhabdosome unless it is sectioned. It seems to me, however, that the slight bend to the right, visible at the lower end of the septum, indicates that the last theca that crosses the middle line came from the right and ran obliquely to the left (*cf.*, moreover, BULMAN 1932, p. 15).

Discussion: The typical characteristics of this species are:

1) the slender rhabdosome, which slowly and continuously increases in breadth, the maximum breadth attained being, however, not very considerable;
2) the number of th in 10 mm (9 th) (less than the usual number);
3) the septum, which begins but on a level with the aperture of th 3^1, 4^1, resp.

Horizon: The base of the zone of *Akidograptus acuminatus* at Kinnekulle, Sweden. DAVIES reports similar forms from the same zone in Great Britain.

Climacograptus indivisus (DAVIES).

Pl. XXVI, fig. 6, 7.

1929 *Climacograptus scalaris* mut. *indivisus* DAVIES p. 7, figs. 26, 30.

Holotype: DAVIES 1929 fig. 26.

Material: Some few specimens from levels 32.48—32.55 and one specimen from level 33.88 in the Kullatorp core (Nos. gr. 1223 a, 1228 b, 1231 b, 1251, 1253 a and 1264 a).

Diagnosis: *Cl.* without visible septum. Outer end of virgella bifurcated.

Description: The rhabdosome is slender and straight. The breadth at th 1^1—1^2 is 0.6—0.7 mm and at th 6 1.0—1.1 mm, whereupon the rhabdosome does not seem to increase further in breadth. The rhabdosome tapers somewhat, though inconsiderably, towards the proximal end. Part of the sicula is discernible from the reverse side. Its aperture is on a level with the lowest part of th 1^1. The virgella can attain quite a considerable length (2.8 mm in gr. 1264 a). At a distance of about 1 mm from the aperture of the sicula the virgella forks. The two branches, which are somewhat more slender than the main part of the virgella, form an angle of 40—60° with one another. Their ends are slightly curved towards each other. I have observed a forked virgella in two specimens of this species (gr. 1223 a, 1264 a) but not in any other graptolite in the rest of the fauna. It is difficult to express an opinion regarding its function; possibly it served to facilitate the power of floating.

Th 1^1 may be observed to bud out high up on the sicula: it then runs down the sicula almost as far as the aperture, where it turns and grows upwards and opens somewhat above the highest visible part of the sicula. Th 1^2 emerges from th 1^1 and grows obliquely over the sicula on the reverse side, thereby covering most of it. The thecae do not differ in type and general appearance from those of closely related species.

11 thecae in 10 mm on either side.

No septum can be traced either on the reverse or the obverse side.

On studying the inner walls of the thecae, it is found that at the first 3 or 4 thecal pairs the walls begin near the middle line of the rhabdosome and then run obliquely outwards-upwards to the aperture. The inner walls of the more distal thecae, on the other hand, run almost parallel with the outer margin of the rhabdosome, the lowest part of the inner walls, however, being slightly curved towards the middle line. We know already that the first thecae to grow forth crossed the middle line. The distal thecae, too, may have grown in the same way, though the form of the inner wall of the thecae does not definitely favour this assumption.

Discussion: In spite of certain differences it seems to me that the specimens figured by DAVIES and my own should be comprised in the same species. DAVIES's forms seem to be somewhat slenderer (0.9 mm) and the thecae more widely spaced (5 th in 5 mm), but the actual shape of the rhabdosome and of the thecae does not appear to show any essential differences.

Horizon and localities: Lower part of the zone of *Akidograptus acuminatus* at Kinnekulle, Sweden. The zone of *Glyptograptus persculptus*, Great Britain.

V. **Historical Review.**

The Dalmanitina beds at Kinnekulle, by older authors also called the Brachiopod Shale, were first described by LINNARSSON in 1869. Subsequently, HOLM treated these beds in 1901, and TROEDSSON enumerates some fossils from them in 1921. The most recent account, principally taken from HOLM, is supplied by WESTERGÅRD in the description of the geological map Lidköping (1943). The beds are said to possess a thickness of 5.2 m and to be exposed in several places in the shape of a bank of calcareous sandstone and limestone.

HOLM, who had this bank levelled at two places SW and SE of the top, states (1901, pp. 67, 68) that the Dalmanitina beds dip 0.53 m per 100 m towards ENE. According to a new levelling at approximately the same places compared with the same level in the core I have found that the beds dip about 0.23 m per 100 m, this being the same dip as of other beds levelled at Kinnekulle. The upper boundary of the topmost red complex of the strata in the Rastrites beds lies E of the top at 254.97 m above sea level; in the core the same boundary lies at about 3.95 m (253.17 m above sea level). The distance between these places being about 800 m, the dip amounts to 0.225 m per 100 m.

The following fossils have been quoted by LINNARSSON, HOLM, TROEDSSON and WESTERGÅRD:

Dalmanitina mucronata BRONGN.
D. pulchella LINRS.
Homalonotus platynotus DALM.
Holometopus aciculatus ANG.
» *ornatus* ANG.
Orthis
Strophomena
Leptaena
Schuchertella
Meristella
Atrypa crassicostis DALM.
» *imbricata* SOW.
Discopora rhombifera SCHMIDT
Crinoidea

In the older literature, the strata above the Dalmanitina beds are embraced under the name of the Upper Graptolite Shale. Of those, only the Retiolites beds were originally known from Kinnekulle.

In 1869 LINNARSSON stated that the Dalmanitina beds were overlain by black shale with *Diplograptus*, but no further use was made of this statement.

Thus it was HOLM (1899) who for the first time with certainty established the Rastrites beds at Kinnekulle. He found in a road cutting 0.7 m black shale with a rich graptolite fauna which he refers to the zones of *Demirastrites triangulatus*, *Petalolithus folium*, and *Cephalograptus cometa*.

Between the top of the Dalmanitina beds and the black shale mentioned above appears a sequence of rocks attaining a thickness of 13 m which was not found accessible by earlier authors. HOLM estimates (1899, p. 307) the Rastrites beds to be at least 15 m thick, WESTERGÅRD states (1943, p. 84) 20 m »or maybe somewhat more».

TÖRNQUIST, who (1899) studied the road cutting mentioned above, found but the two higher zones and assumed that the species typical for the zone of *D. triangulatus*, *viz. Prist. gregarius* and *D. triangulatus* cited by HOLM, belonged to a level of the profile not accessible to him. On going through HOLM's material in the Museum of the Geol. Survey I was, however, not able to find them and I am consequently of opinion that there is no real evidence that the zone of *D. triangulatus* occurs at Kinnekulle. TÖRNQUIST also mentions shale with *i.a. Monograptus* (*Streptograptus*) *runcinatus* and *M. discus* lying higher up in the same road cutting. Above this there follow several metres of red barren mudstone, whereupon the Retiolites beds begin. Thus both the middle and the highest zones in the Rastrites beds have been established at Kinnekulle. HOLM in 1901 supplied a summary of TÖRNQUIST's and his own investigations, and so did WESTERGÅRD in 1943.

Unlike the Rastrites beds the Retiolites beds are exposed in many places. The beds were reported by LINNARSSON (1869) as well as by the other authors mentioned above. The fauna is said to be poor in species and no further subdivisions of the beds were made. The following graptolites were cited: *Monoclimacis crenulata*, *Monograptus priodon*, *M. cultellus*, *Spirograptus spiralis* and *Retiolites geinitzianus*; furthermore *Cheirurus* sp., *Bilobites* sp. and *Ortocerata* were found. No information regarding the thickness of the Retiolites beds was given; the total thickness of the Upper Graptolite Shales was estimated to 56 m.

VI. **Stratigraphical Review.**

Dalmanitina Beds.

Zone of ***Dalmanitina mucronata*** and ***Homalonotus platynotus.***

Above the red Tretaspis Shale, definitely determined as Ordovician, follows a sandy mudstone probably belonging to the Ordovician. Separated from it by a surface of discontinuity there appears in the profile at the level 35.15 a limestone belonging to the zone of *Dalmanitina mucronata* and *Homalonotus platynotus* in the Dalmanitina beds. Upwards this limestone passes into a fine-grained calcareous sandstone.

Apart from the trilobites already quoted the fauna in the limestone is principally characterized by a number of brachiopods, which, however, cannot be so closely determined as to be of any use for stratigraphical purposes. Consequently I must desist here from discussing the stratigraphical extension and situation of the beds with reference to their own fauna. I will, however, briefly elucidate the modern interpretation of the beds and especially their upper limit.

The Dalmanitina beds comprise certain limestones, mudstones, and sandstones with shelly facies within the Lower Llandovery in Sweden. The upper boundary of the beds has not been definitely fixed. Graptolite shale belonging to various zones of the Rastrites beds usually form the upper boundary. The beds assigned in literature to the Dalmanitina beds or considered comparable to it seem but partly to be of the same age. The hiatus proved to exist at the base of the Silurian seems to have had quite a different extension in different areas, and the date at which the facies of the Dalmanitina beds was more or less abruptly replaced by graptolite facies varies even within the same province. The appearance of the graptolite facies may be stated fairly exactly and thus, apart from any gaps that may occur in the sedimentation, it supplies a reliable upper limit for the Dalmanitina beds in various localities. In my opinion, the Dalmanitina beds may be considered an older Silurian shelly facies, probably partly contemporaneous with the graptolite facies of the Rastrites beds. We find a similar situation in the classification of the Swedish Ordovician, where the various sections of shelly and graptolite facies mostly but not always correspond, *e.g.* Didymograptus Shale—Orthoceras Limestone, Middle and Upper Dicellograptus Shale—Tretaspis Series, *etc.*

The character of the Dalmanitina beds as a transgression phase has been emphasized by several authors. Besides, they also represent a more permanent phase of pure water with a bottom fauna; apart from sandstone and sandy mudstone, the beds also comprise limestone and marl of fairly considerable thickness in some places (Östergötland, Dalarna). A comparison with districts with a more permanent Silurian bottom fauna than South and Central Sweden, *e.g.* the East Baltic, Gotland, the Oslo region, and Great Britain, would better contribute to the establishment of the boundary of the Dalmanitina beds and their importance as a stratigraphical unit than does a mere discussion about their transition into the graptolite facies.

The interpretation of the Brachiopod Shale—Dalmanitina Shale—Dalmanitina beds has been subjected to some modifications in the course of time; thus, the Staurocephalus Shale has been ascribed to the Tretaspis Series in the Ordovician while the Dalmanitina beds *s.s.* are now referred to the Silurian.

While TROEDSSON in 1918 stated that the Brachiopod Shale in Scania bordered upwards on the zone of *Clim. scalaris* var. *normalis* in the Rastrites beds, he, in 1936, made this zone the topmost one in the Dalmanitina beds. A fresh examination of the group of forms covered by the name of *Climacograptus scalaris* var. *normalis* might, if the material is tolerably well preserved, show with which graptolite zone in the Rastrites beds this one is contemporaneous. As to the so-called zone of »*Acidaspis*» *centrina* and *Clim. scalaris* which TROEDSSON (1933) after LINNARSSON (1869) establishes as an upper division of the Dalmanitina beds in Vestergötland, I have shown, with regard to Kinnekulle, that it may easily be subdivided and incorporated into the classification of the zones of the Rastrites beds.

Rastrites Beds.

In an endeavour to decide when during the Silurian period beds with graptolite facies reappear at Kinnekulle not only the constellation of species but also the evolutional stage that the species had reached is of importance for the dating. In the same bed fossil species do not only show a number of variations more or less closely resembling an average type, but upwards and downwards in the sequence new variations or modifications appear and old ones disappear, so that the average type may be completely changed. This is a well-known fact, the difficulty being only to obtain a sufficiently rich collection of tolerably well preserved fossils to cover the amplitude of variations and to be able to establish the levels of the occurrences correctly, so that the change of type can be established.

DAVIES (1929) studied this question when dealing with graptolites from the oldest Silurian. By careful studies of *Glyptograptus persculptus* (SALTER) he was able to prove that when sediments reappear after an interruption of the sedimentation in the topmost Ordovician, this occurs at different times within the zone of *Glypt. persculptus* at different places in Great Britain. The same author then shows how the development of different complexes of species may be followed through several zones within the Lower Llandovery. He establishes, *i.a.*, a number of stages in the development *Climacograptus scalaris miserabilis*—*Cl. scal. normalis*—*Cl. medius*, which are of special interest for the study of the corresponding forms at Kinnekulle (*vide* pp. 449—457).

Zone of *Akidograptus acuminatus.*

Above the upper sandy part of the Dalmanitina beds and above a surface of discontinuity there follows, as already mentioned, black graptolite-bearing mudstone, which higher up passes into grey mudstone with a more mixed fauna comprising, *i.a.*, forms of *Climacograptus scalaris* v. *normalis* and *Leonaspis centrina*. Beds containing those fossils occurring in other places (Billingen, Norra Falbygden, Scania) have been designated as »Acidaspis» Shale and have been considered a topmost zone of the Dalmanitina beds (TROEDSSON 1921, 1936). Since the graptolite fauna, however, shows affinities with several zones in the Rastrites beds, I shall separate the Leonaspis (= »Acidaspis») Shale from the Dalmanitina Series and use the term Leonaspis Shale as a designation of facies only and not as a stratigraphical unit.

At the base of the Rastrites beds appears *Climacograptus scalaris* v. *normalis*, which at that level (32.70—32.50) is the most abundant form. Besides, and especially from 32.55 and upwards, there appear some closely related forms, *viz.*, *Cl. indivisus* (DAVIES) and *Cl. premedius* n. sp., and a couple of likewise undescribed forms of *Cl. scalaris* v. *transgrediens*

n. var., which seem to constitute a transition to *Cl. medius*. *Cl. medius* first appears at 30.60, and then lives on for a long time. *Cl. scalaris* v. *normalis* has then already disappeared, and most of the other forms, with the exception of *Cl. rectangularis*, also disappear rapidly. Of other graptolites there occurs only a *Glyptograptus* sp. though not *G. persculptus,* and at 26.50 *Akidograptus acuminatus*.

With the support of the intermediate forms mentioned above as well as of the other forms, *i.a. Cl. indivisus*, which corresponds to DAVIES's mut. *indivisus*, the boundary between the zone of *Glyptograptus persculptus* and the zone of *Akidograptus acuminatus* can be located at 32.50, in accordance with DAVIES's establishment of that boundary line in Great Britain. On account of its fauna being poor in species it is difficult to fix the upper boundary. I put it at 26.0 m, not far above the occurrence of *Akidograptus acuminatus.* Though mainly confined to the zone of the same name, this species occurs also in the next higher zone in Great Britain.

Zone of **Dimorphograptus extenuatus.**

This zone, ranging between 26.0 and 23.0 m, contains but a poor graptolite fauna consisting of the following species: *Climacograptus medius*, *Dimorphograptus extenuatus*, and *Orthograptus* sp. Here I adopt TROEDSSON's (1933) denomination of the zone; it corresponds to the British zone of *Orthograptus vesiculosus*. In Great Britain *D. extenuatus* has not been met with outside that zone. From other animal groups *Leonaspis centrina* and *Primitia* sp. may be quoted.

Zone of **Pernerograptus revolutus.**

The zone extends from 23.0 m to 19.81 m. Apart from the longliving species *Cl. medius* also *Cl. hughesi*, *Dimorphograptus physophora* (21.7), and *Monograptus incommodus* have been found there.

The zone of *Demirastrites triangulatus* has not been established in the core. Between 19.81 and 18.80 the rock mainly consists of limestone. Neither in this nor in the accompanying mudstone have fossils been encountered.

Zone of **Petalolithus folium.**

This zone is situated at 18.80—18.40 and has a thickness of about 0.4 m. *Petalolithus folium* and *Monograptus clingani* are some of the fossils typical for this zone.

Zone of **Cephalograptus cometa.**

The zone lies at 18.40—18.10 and is about 0.3 m thick. *C. cometa* as well as *C. tubulariformis* (18.39) is typical for this zone. The latter species is an intermediate form between *Petalolithus folium* and *Cephalograptus cometa* and is confined to the lower part of the zone both here and in other places. The zones of *P. folium* and *Ceph. cometa* form together a black shale, 0.7 m thick and rich in graptolites, which has been described by HOLM (1899) and TÖRNQUIST (1899).

This black shale, laminated, dark, rich in fossils, exclusively graptolite-bearing, and containing pyrite, represents a typical so-called graptolite shale. Only near the upper and lower boundaries do some few brachiopods occur. The boundaries towards the over- and underlying mud- and limestone beds are sharp as regards the facies; however, the conditions of the boundaries do not indicate whether the deposition of this black graptolite shale was preceded or followed by an interruption of the sedimentation of any length. Nothing else can be said than that the preceding graptolite zone (the *Dem. triangulatus* zone) could not be found in the core and that the following zone (the *M. sedgwicki* zone) must be considered but poorly and incompletely developed.

Zone of **Monograptus sedgwicki.**

It has not been possible to establish the presence of this zone at Kinnekulle with the support of graptolites; instead, this has been done by correlating bentonite layers in this boring and in a boring in Östergötland. This latter boring was executed in 1945 at Smedsbygård, 4 km N of Motala, by the Geol. Surv. of Sweden, and I shall on some future occasion publish a more complete account of my studies of the Rastrites beds of this core. Here I shall only mention that a number of bentonite beds have been found in the richly fossil-bearing *M. sedgwicki*, *S. turriculatus* and *M. discus* zones. As at Kinnekulle the thickest bed lies in the *S. turriculatus* zone. In the Östergötland core, the bentonite beds lying immediately below belong to the *M. sedgwicki* zone, and in my opinion this is also the case at Kinnekulle. In such a case the zone of *M. sedgwicki* at Kinnekulle attains a thickness of max. 2 1/2 m.

Zone of **Spirograptus turriculatus.**

Spirograptus turriculatus and *Monograptus* (*Streptograptus*) *runcinatus* may be quoted as representative of this zone. The sequence characterized by these two species is 2.1 m thick. In addition, some higher graptolite-bearing strata up to 12.55 with a closely related fauna may advantageously be included in this zone, the thickness of which may thus be estimated to at least 3.1 m. In earlier Swedish literature the zone of *S. turriculatus* has been treated somewhat differently both with regard to its extension and denomination. My denomination as used here comprises graptolite-bearing beds with, *i.a.*, *Rastrites linnaei*, *S. turriculatus*, and *M.* (*Str.*) *runcinatus*. Below this zone lies the zone of *M. sedgwicki*. I cannot as yet advance any opinion as to the exact boundary between these zones. The upper boundary of the zone is characterized partly by the extinction of the species mentioned, possibly with the exception of *M.* (*Str.*) *runcinatus*, partly by the appearance of *M. discus*, the guide fossil of the next higher zone. I am quite aware that a richer fossil-bearing profile than the one here described may warrant the subdivision of the zone into several new ones, as has been done during the last decades in Bohemia (PRIBYL and BOUČEK) and in Great Britain.

Zone of *Monograptus discus*.

Monograptus discus is an especially good guide fossil for this zone. Of other typical species *Pristiograptus pergratus*, *Dem. pragensis* var., and *M. crispus* may be mentioned. I locate the lower boundary of the zone to the first appearance of *M. discus* and the upper boundary to a level below the appearance of *S. spiralis*. Neither here nor elsewhere have I ever come across *M. discus* and *S. spiralis* together. The zone attains a thickness of 9 m. In earlier Swedish literature it was sometimes united with the zone lying next below, designated as the zone of *M.* (*Str.*) *runcinatus*, sometimes it was treated as an independent zone with *M. discus*, *S. proteus* or *M. crispus* quoted as index fossils. In the British table this zone corresponds to the zone of *M. crispus* and, in all probability, also to the zone of *Monoclimacis griestoniensis*.

Retiolites Beds.

Zones of *Spirograptus spiralis* and *Cyrtograptus lapworthi*.

At Kinnekulle the series attains a thickness of 26 m, the lowest 3.36 m of which have been pierced by this boring. *Monocl. continens* is representative of the lowest part of the zone. This is also true of *M. cultellus*, which has been encountered at the Kullatorp spring 1 m beneath the top level of the boring. Higher up no guide species have been met with before 276.6 m above sea level, where the fauna appears to resemble that of the zone of *C. lapworthi*.

VII. Concluding Remarks on Stratigraphy and Paleogeography.

According to LINNARSSON 1869, TROEDSSON 1921, and the descriptions of the geological maps, *etc.*, the Dalmanitina beds show a highly varying development in Vestergötland. Generally they consist to a much higher degree of sandstone and mudstone in the other mountains of Vestergötland than at Kinnekulle, and their thickness is greater at most of the other localities than it is at Kinnekulle. However, mention must be made that the s. c. zone of »*Acidaspis*» *centrina* and *Climacograptus scalaris* v. *normalis* forms a great part of them. If we should include the Leonaspis-bearing strata at Kinnekulle in the Dalmanitina beds they would, being 15 m thick, exceed the Dalmanitina beds at all the other mountains ranging from 4.5 m at Ålleberg to 10 m at Skövde, Billingen. As I tried to show before, this zone has developed a more graptolite-bearing facies at Kinnekulle and I have, therefore, separated it from the Dalmanitina beds and united it with the Rastrites beds. A future investigation of my graptolite material from the »Acidaspis»-zone of the other mountains of Vestergötland will probably yield a similar result, *i.e.* that this zone may be incorporated into the Rastrites beds and subdivided into several graptolite zones.

Both at Kinnekulle and at the other mountains of Vestergötland, *Dalmanitina eucentra* ANG. (OLIN), typical for the oldest Dalmanitina beds of Scania, is missing. Thus the deposition of the Dalmanitina beds seems to have begun somewhat later in Vestergötland than in Scania.

THORSLUND (1935) distinguishes two divisions in the Dalmanitina beds of Dalarna; a lower one, not very thick, containing the »klingkalk» and called the zone of »*Meristella*» *crassa* (SOW.) and *Ptychophyllum craigense* M'COY; and an upper one, considerably thicker, marl- and limestone-bearing but poor in fossils, without a name. The lower division is juxtaposed to TROEDSSON's (1921) zone of *Homalonotus platynotus* and »*Meristella*» *crassa* in Vestergötland, the upper one to the zone of »*Acidaspis*» *centrina* and *Climacograptus scalaris* var. *normalis*. Since this upper division is overlain by the zone of *Pristiograptus gregarius* of Middle Llandovery age, it seems to belong to the middle and upper Lower Llandovery. It is, however, somewhat doubtful whether it is reasonable to designate such relatively young deposits as members of the Dalmanitina beds. In the other areas the Dalmanitina beds comprise only the lowest Lower Llandovery.

In Jemtland, the s. c. Brachiopod Shale with, *i.a.*, *Tretaspis latilimbus* (LINRS.) and *Dalmanitina mucronata* belongs to the Tretaspis Series (THORSLUND 1943). But at least the lower parts of the Kyrkås quartzite and the Phacops quartzite correspond to the Dalmanitina beds.

In the other mountains of Vestergötland, Lower Llandovery in graptolite facies has been reported from Bestorp on Mösseberg and Ållebergsände in Falbygden. From these places TÖRNQUIST (1884, 1899) and TROEDSSON (1921) mention the zone of *Pernerograptus revolutus*. The oldest sequence is, however, either not entirely exposed or no fossils of stratigraphical importance have been found there, or, as mentioned before, it is developed as Leonaspis Shale.

In Sweden it is only in Scania, apart from Kinnekulle, that the oldest graptolite zones in Llandovery have been established.

From Bornholm POULSEN (1922) reports a zone of *Monograptus acinaces* TQT, which may correspond to one or both of the British *O. vesiculosus*

Table VIII. Table of

Explanations and notes: ——— = Zonal boundary lines approximately syncronous or definitely Where the local duration of a zone is too

Great Britain		Scania
ELLES & WOOD 1918, JONES 1935		TÖRNQUIST 1913 TROEDSSON 1936
Wenlock	26 *Cyrtograptus murchisoni*	*Cyrt. murchisoni*
Upper Llandovery	25 *Monograptus crenulatus*	*Cyrt. lapworthi* *M. spiralis*
	24 *M. griestoniensis*	*M. exiguus*
	23 *M. crispus*	
	22 *M. turriculatus* *Rastrites maximus*	*M. turriculatus*
	21 *M. halli* *M. sedgwicki*	*M. sedgwicki*
Middle Llandovery	20 *Cephalograptus cometa*	*Ceph. cometa*
	20 *M. convolutus*	
	M. leptotheca	*Petalograptus folium*
	19 *Mesograptus magnus*	*M. triangulatus*
Lower Llandovery	19 *M. triangulatus*	
	18 *M. cyphus*	*M. revolutus*
	17 *M. acinaces*	*Dimorphograptus extenuatus*
	17 *M. atavus*	
	17 *Mes. modestus*	
	16 *Cephalograptus acuminatus*	*Cephalograptus acuminatus*
	16 *Glyptograptus persculptus*	Dalm. Beds: *Climacograptus scalaris*[1] 3 zones
	Hiatus	Hiatus
Ordovician	15 *Dicellograptus anceps*	Staurocephalus limestone[2]

[1] In an earlier work (1921) TROEDSSON named the zone after *Cl. scalaris* var. *normalis.* He has given no explanation for the alteration. *Cl. scalaris* var. *normalis* is still a valid form and *Cl. scalaris* is a species of Middle Llandoverian age (*cf.* p. 449 n. 1).

and *Prist. cyphus* zones. The lowest Rastrites beds, however, are not accessible. From the Bergen district in Norway, KIÆR cites (1930) the zone of *Orthograptus vesiculosus* (= zone 17 in Great Britain according to ELLES & WOOD 1918).

Stratigraphical Correlations.

stated. .... = Probable location of the boundary between shelly facies and graptolite facies. uncertain, no boundary line has been drawn.

Vestergötland: Kinnekulle	Vestergötland: Falbygden TQT 1899 TROEDSSON 1936	Dalarna: THORSLUND 1936	
Diabase *Cyrt. lapworthi* *Spirograptus spiralis*	Diabase	*M. spiralis*	Retiolites Beds
M. discus	?	*M. proteus*	Rastrites Beds
Spir. turriculatus	*M. turriculatus*	*M. turriculatus*	
? *M. sedgwicki*	*M. sedgwicki* (Kungslena)	*M. sedgwicki*	
Ceph. cometa	*Ceph. cometa* (Kungslena)	*Ceph. cometa*	
Petalolithus folium	*Petalograptus folium*	*M. leptotheca*	
?	?	*M. gregarius*	
Pernerograptus revolutus	*M. revolutus* (Åleberg, Bestorp)	Dalmanites	
Dim. extenuatus	Dalmanites Beds: *Acidaspis centrina* and	Series	
Akidograptus acuminatus	*Climacograptus scalaris*[1]		
Dalmanitina Beds	*Meristina crassa*		Dalmanitina Beds
Hiatus	Hiatus	Hiatus	
Tretaspis sh & ss	Staurocephalus limestone[2]	Staurocephalus shale	Tretaspis Series

[2] TROEDSSON's designation (1936, p. 496) is probably an error. In his earlier works he only speaks of Staurocephalus shale when treating these districts, and so do all other authors I have studied.

The zone of *Demirastrites triangulatus* has not been encountered in Vestergötland but both in Scania and Dalarna. The two next higher zones, the *P. folium* zone and the *C. cometa* zone, show several features common to the Middle Llandovery of Fennoscandia. Black, richly graptolite-bearing

Table IX.

Distribution of the Silurian graptolites of the Kullatorp core and of the Silurian beds above the core.

	Rastrites Beds										Retiolites Beds
	Lower		Middle Llandovery				Upper				
	Akidograptus acuminatus	*Dimorphograptus extenuatus*	*Pernerograptus revolutus*	(*Demirastrites triangulatus*)	*Petalolithus folium*	*Cephalograptus cometa*	(*Monograptus sedgwicki*)	*Spirograptus turriculatus*	*Monograptus discus*	*Spirograptus spiralis*	*Cyrtograptus lapworthi*
1	2	3	4	5	6	7	8	9	10	11	12
Akidograptus acuminatus (NICH.)	+										
Cephalograptus cometa (GEIN.)	.	.	.	.	.	+					
» *tubulariformis* (NICH.)	.	.	.	.	.	+					
Cyrtograptus aff. *lapworthi* TULLB.	.	.	.	.	.	.	.	.	.	.	+
» sp.	.	.	.	.	.	.	.	.	.	.	+
Climacograptus hughesi NICH.	.	.	+	.	+	+					
» *indivisus* (DAVIES)	+										
» *medius* TQT	+	+	+								
» *premedius* n. sp.	+										
» *rectangularis* M'COY	+										
» *scalaris* HIS.	.	.	.	.	+	+					
» » v. *miserabilis* E. & W.	+										
» » v. *normalis* LAPW.	+										
» » v. *transgrediens* n. v.	+										
Demirastrites convolutus (TQT)	.	.	.	.	+						
» *decipiens* (TQT)	.	.	.	.	+	+					
» *pragensis* PRIBYL var.	.	.	.	.	.	.	.	.	+		
Dimorphograptus extenuatus E. & W.	.	+									
» *physophora* LAPW.	.	.	+								
Diversograptus sartorius (TQT)	.	.	.	.	.	.	.	.	+		
» sp.	.	.	.	.	.	.	.	.	.	+	
Glyptograptus tamariscus (NICH.)	.	.	.	.	+	+	.	+	+		
» sp.	+	+									
Mesograptus modestus (LAPW.)	+										
Monoclimacis continens (TQT)	.	.	.	.	.	.	.	.	.	+	
» *crenulata* (TQT)	.	.	.	.	.	.	.	.	+	+	
» cf. *griestoniensis* (NICHOL)	.	.	.	.	.	.	.	.	+		
» aff. »	.	.	.	.	.	.	.	.	.	+	
» *linnarssoni* (TULLB.)	.	.	.	.	.	.	.	.	.	.	+

1	2	3	4	5	6	7	8	9	10	11	12
Monoclimacis sublinnarssoni (PRIBYL) . . .	.	.	.	.	.	.	.	.	.	+	
Monograptus clingani CARR.	.	.	.	.	+						
» *crispus* LAPW.	.	.	.	.	.	.	.	.	+		
» » var.	.	.	.	.	.	.	.	.	.	+	
» *discus* TQT	.	.	.	.	.	.	.	.	+		
» *gemmatus* BARR.	.	.	.	.	.	+					
» *incommodus* TQT	.	.	+								
» *intermedius* LAPW.	.	.	.	.	+						
» *lobiferus* M'COY	.	.	.	.	+	+					
» *marri* PERNER	.	.	.	.	.	.	.	+	+		
» *pandus* LAPW.	.	.	.	.	.	.	.	+	+		
» *priodon* BRONN	.	.	.	.	.	.	.	.	+	+	+
» (*Streptograptus*) *becki* BARR.	.	.	.	.	.	.	.	+			
» (» ?) *dextrorsus* TULLB.	.	.	.	.	.	.	.	+	+		
» (») *exiguus* NICH. . .	.	.	.	.	.	.	.	+	+		
» (») *nodifer* TQT . . .	.	.	.	.	.	.	.	.	.	+	
» (») *runcinatus* LAPW.	.	.	.	.	.	.	.	+			
Orthograptus bellulus (TQT)	.	.	.	.	+	+					
» sp.	+										
Pernerograptus limatulus (TQT)	.	.	.	.	+	+					
Petalolithus folium (HIS.)	.	.	.	.	+						
» cf. *ovato-elongatus* (KURCK) . .	.	.	.	.	.	+					
» *palmeus* (BARR.)	.	.	.	.	+	+	.	+			
» *tenuis* (BARR.)	.	.	.	.	.	.	.	+	+		
Plegmatograptus obesus (LAPW.)	.	.	.	.	.	.	.	+	+		
Pristiograptus leptotheca (LAPW.)	.	.	.	.	+	+					
» *nudus* (LAPW.)	.	.	.	.	.	.	.	+	+		
» *pergratus* PRIBYL	.	.	.	.	.	.	.	.	+		
» *regularis* (TQT)	.	.	.	.	+	+					
Rastrites approximatus f. *approximatus* PERNER	.	.	.	.	+						
Rastrites peregrinus BARR.	.	.	.	.	+						
» sp.	.	.	.	.	+						
Retiolites geinitzianus BARR.	.	.	.	.	.	.	.	.	+	.	+
Spirograptus elongatus (TQT)	.	.	.	.	+						
» *flagellaris* (TQT)	.	.	.	.	.	.	.	.	+		
» *planus* (BARR.)	.	.	.	.	.	.	.	.	+	+	
» *proteus* (BARR.)	.	.	.	.	.	.	.	+	+		
» *spiralis* (GEIN.)	.	.	.	.	.	.	.	.	.	+	+
» *tortilis* (PERNER)	.	.	.	.	.	.	.	+			
» *turriculatus* (BARR.)	.	.	.	.	.	.	.	+			
» sp.	.	.	.	.	.	.	.	.	+		

shales are preponderant. The *Petalolithus folium* zone is known from Scania, Vestergötland, Dalarna and Vesterbotten (KULLING 1925, p. 371), while the *Cephalograptus cometa* zone shows the widest extension of graptolite shale-facies in the Silurian of Fennoscandia. Besides in Bornholm and South and

Central Sweden the zone has been established below Gotland (THORSLUND and WESTERGÅRD 1938, p. 32, 39), Vesterbotten (KULLING 1925, p. 371) and in the Bergen area in Norway (KOLDERUP 1934, p. 375).

In Scandinavia the base of the Upper Llandovery (*M. sedgwicki* zone) has a graptolite facies in some places only. It has been found in Scania, but whether it is developed in Bornholm, which otherwise greatly resembles Scania, is not quite sure (POULSEN 1922, p. 13). From Vestergötland, TÖRNQUIST (1884) reports the *Monograptus sedgwicki* zone at Kungslena-Stommen on Varvsberget. There it introduces the series of grey mudstones which in the mountains of Vestergötland follows above the black shale in the *C. cometa* zone, where the sequence is preserved so high up and before it is cut off by the diabase. As will appear from this investigation, it has been possible to demonstrate this zone at Kinnekulle by correlation with bentonite beds in Östergötland but no graptolites have been found there. In Dalarna, I have found the zone to be somewhat better developed.

The two highest zones of the Rastrites beds, the zones of *Spirograptus turriculatus* and *Monograptus discus*, are, on the other hand, known from many places: Bornholm, Scania, Vestergötland, Östergötland, Dalarna, Jemtland and the Mjösen area in the Oslo region. As at Kinnekulle, they attain a fairly great thickness in some places, even up to some tens of metres They are usually developed as fairly light grey mudstones with scattered great limestone lenses. However, laminated black shales are also present, *e.g.* in Scania and Jemtland.

Also the lower part of the Retiolites beds, which belongs to the Llandovery, has a fairly wide-spread extension in Sweden. Besides at Kinnekulle, where both the zone of *Spirograptus spiralis* and the zone of *Cyrtograptus lapworthi* have been found, the base of the *S. spiralis* zone has been detected immediately below the diabase at Toran, on the north-western side of Billingen. In Scania and on Bornholm the graptolite facies persists up into Wenlock and Ludlow. In Östergötland the *S. spiralis* zone is known from loose boulders. On Gotland, where the shelly facies predominates, a find of *S. spiralis* (HEDSTRÖM 1923), indicates that the upper Visby marl and the *S. spiralis* zone are contemporary. The Retiolites beds of Dalarna show a richer graptolite fauna than at Kinnekulle and, moreover, with stronger features of brachiopod facies in their upper calcareous parts. They show great affinities to the development of the Mjösen area. In Jemtland, the lowest part of the Retiolites Beds have recently been proved by THORSLUND (1948).

From the above a certain periodicity in the extension of graptolite shale-facies and graptolite-bearing beds can be observed. At the beginning of the greater divisions the sequence is incomplete; the facies is in most places nongraptolite-bearing, or only sparsely graptolite-bearing: in Lower Llandovery we find the nongraptolite-bearing Dalmanitina beds and the but in few places graptolite-bearing *A. acuminatus* zone, in Middle Llandovery the

Prist. gregarius zone is mostly feebly developed, and in Upper Llandovery the *M. sedgwicki* zone is not everywhere to be seen with certainty. Between these strata, uncomplete or but sparsely graptolite-bearing, one can observe strata with more or less pronounced graptolite facies: in Lower Llandovery it can be seen more diffusely in several of the higher zones, in Middle Llandovery there is a strong advance of graptolite facies which culminates in the *C. cometa* zone, in Upper Llandovery a persistent graptolite facies in the *S. turriculatus-M. discus* zones slowly fades away in the *S. spiralis* zone. This is a rough outline of the development. The diverse areas vary strongly in their details, and the alternation between the different types of facies is contemporaneous in the various areas within rather wide limits only.

The search for the various bentonite beds in the various Cambro-Silurian areas of Sweden and their stratigraphical establishment is an important task. This concerns not only the creation of guide-levels for the areas but also the establishment of the age and frequency of the volcanism, probably in Western Norway, which caused those rains of ash.

The graptolite fauna of Vestergötland has much in common with that of Great Britain. As regards the thorough correlation of the lowest Llandovery in these two areas *vide* pp. 461, 462.

In Great Britain a boundary of great importance both with regard to the fauna and the facies has been drawn between Middle and Upper Llandovery. Below the boundary the graptolite-bearing sequence has a relatively inconsiderable thickness with a persistent quantity of Climacograptides and Diplograptides. Above the boundary, also graptolite-bearing beds attain a considerable thickness and Monograptides soon prevail over the weakened Diplograptide fauna. A similar development, not only faunistically but also regarding the facies, characterizes Kinnekulle and the other mountains of Vestergötland and, as far as I have seen, Dalarna as well.

Many common features closely connect the Silurian graptolite faunas of Sweden and Bohemia. Several of the new species erected in the last years by PRIBYL and BOUČEK certainly also occur in Sweden; so for instant *Pristiograptus pergratus* PRIBYL, an early species of the *Prist. dubius* group, and also *Demirastrites pragensis* PRIBYL var., a late relative of *D. denticulatus* TQT, have been found *i.a.* at Kinnekulle.

The elaborate stratigraphical zonal subdivision in Bohemia shows interesting parallels with Sweden, even if it seems to be too locally accentuated for a more detailed comparison between these two quite different areas.

X. **Summary.**

The author describes the Silurian part of a boring at Kullatorp at Kinnekulle, Vestergötland in Sweden. A plane of discontinuity separates the sequence from the Ordovician.

The sequence begins with limestone and sandstone with Dalmanitina mucronata *etc.*: The Dalmanitina beds.

The upper and greatest part of the sequence, the Rastrites and Retiolites beds, consists of grey, red, and dark mudstones and shales with graptolites.

With the exception of the zone of *Pristiograptus gregarius*, which could not be proved, the graptolite zones from the zone of *Akidograptus acuminatus* to the zone of *Spirograptus spiralis* have been encountered. Above the highest part of the boring, close below the diabase cap, the zone of *Cyrtograptus lapworthi* (topmost Llandovery) has been found. In the zones of *M. sedgwicki*, *Spir. turriculatus* and *M. discus*, beds of volcanic ash in the form of bentonite have been observed. In a special chapter several species of graptolites closely related to *Climacograptus scalaris* v. *normalis* are discussed, 2 new species and 1 new variety are described.

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Explanation of Plate XXVI.

All specimens are from the zone of *Akidograptus acuminatus* in the Kullatorp core, Vestergötland. Magnified 10 ×. The drawings are prepared by E. STÅHL from camera lucida drawings by the author.

Fig. 1. *Climacograptus scalaris* HIS. v. *normalis* LAPW. Mould of specimen in rock. Reverse view. gr. 1264 b, level 32.52.

Fig. 2. *Climacograptus scalaris* HIS. v. *transgrediens* n. var. forma β. Holotype. Reverse view. gr. 1223 b, level 32.43.

Fig. 3. *Climacograptus scalaris* HIS. v. *transgrediens* n. var. f. δ. Reverse view. gr. 1012, level 26.52.

Fig. 4. *Climacograptus medius* TÖRNQUIST. Reverse view. gr. 1203, level 30.6.

Fig. 5. *Climacograptus premedius* n. sp. Holotype. Reverse view. gr. 1230, level 32.63.

Fig. 6. *Climacograptus indivisus* (DAVIES) emend. Obverse view. gr. 1223 a, level 32.48.

Fig. 7. *Climacograptus indivisus* (DAVIES) emend. Mould of specimen in rock. Obverse view. gr. 1264, level 32.52.

Fig. 8. *Climacograptus rectangularis* M'COY. Young specimen. Reverse view. gr. 1186, level 26.35.


1


2


5


6


7


3


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8