SVERIGES GEOLOGISKA UNDERSÖKNING

SER. C. Avhandlingar och uppsatser. N:o 436.

ÅRSBOK 34 (1940) N:o 6.

ON THE CHASMOPS SERIES OF JEMTLAND AND SÖDERMANLAND (TVÄREN)

BY

PER THORSLUND

WITH 15 PLATES

Price 5 Kr.

STOCKHOLM 1940
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Preface.

The present paper is based on investigations carried out during several years, mainly field-work for the Geological Survey of Sweden. In 1928, when I was a student at the Palaeontological Institute of the University of Upsala, my special attention was attracted to the Chasmops series, for thanks to the courtesy of Dr. B. Asklund, at the time Reader at the University, I was then given the task to examine boulders of fossiliferous rocks discovered in 1927 on the coast of the province of Södermanland, SE of the bay of Tvären.

In 1931 the Geological Survey started investigating the Cambro-Silurian of Jemtland with a view to ascertaining the supply of rocks useful for industrial purposes. Dr. B. Asklund was put in charge of these investigations and I was engaged as his assistant. Since then I have been able to study the Chasmops beds on several occasions during my field-work in Jemtland and have devoted special interest to the beds in the area between the Bay of Brunflo and Lake Näckten.

The material collected has been worked up during different periods, first at the Palaeontological Institute of the University of Upsala, and later at the Geological Survey, the main part of this paper having been written since the year 1935, when I was engaged as a geologist of the Survey.

In now presenting the results of my investigations, I wish to tender my grateful thanks to the Director of the Geological Survey, Dr. A. Gavelin, thanks to whose courtesy and kindness it has been possible to complete the present work.

Dr. B. Asklund, under whose guidance I worked during my first four summers in Jemtland, has shown me great personal kindness and has followed my investigations with great interest. His initiative and support have been of the utmost value in my work, and I shall never forget his inspiring guidance during our work in Jemtland and Ångermanland.

Dr. O. M. B. Bulman of Cambridge has been kind enough to place his expert knowledge at my disposal and has spent much time and interest upon examinations of most of my collections of graptolites. I am greatly indebted to him for his contribution to the result of my work and for his kindness towards me.

I am pleased to have this opportunity of expressing my sincere gratitude to my teachers in palaeontology and geology at the University of Upsala. My thanks are especially tendered to Professor C. Wiman, whose stimulating teaching fostered my special interest in palaeontology and stratigraphy and whose great personal kindness has been of immeasurable assistance to me during my studies. Dr. Elsa Warburg deepened my knowledge of evertebrate palaeontology and has throughout my work placed her eminent knowledge of the Swedish trilobites at my disposal. I have had the advantage of being able to discuss with her any questions that arose in connexion with my investigations, and her criticism as well as her advice has been of great value. I also desire to thank Prof. H. Backlund and Dr. G. Frödin, who have given me valuable teaching in geology.

Dr. A. H. Westergård of the Geological Survey has given me much good advice and has facilitated my work in many ways, for all of which I beg to express my sincere gratitude.

Professor E. Stensiö most kindly placed the excellent equipment of the Palaeontological Department of the National Museum of Natural History at my disposal for the preparation and photography of fossils. I am greatly indebted to him for his kindness in this and other respects.

I beg to thank Professor G. Säve-Söderbergh for his valuable assistance and for the interest that he has always afforded my investigations.

Grants received from the C. F. Liljevalch, J. Letterstedt, and R. Otterborg foundations during my years of study at Upsala made it possible for me to study the Ordovician strata of most of the Cambro-Silurian areas in Sweden as well as in Norway, for which grants I am greatly indebted.

When photographing fossils and samples of rocks, I have been assisted by Mrs. M. Ferm, Messrs. J. W. Englund, C. Larsson, and G. Ahl, the retouch work having been carried out mainly by Messrs. S. Ekblom and J. W. Englund.

Certain parts of the translation, mainly the last three chapters, were made by me, the main part, however, having been made by Mr. B. Norbelie, who has also revised the whole manuscript and assisted in reading the proofs, in doing which he has displayed great interest and energy.

To the above-mentioned collaborators, as well as to those who have otherwise promoted the completion of this paper, I wish to express my sincere thanks.

Geological Survey of Sweden, Stockholm, April 1940.

Per Thorslund.

I. Introduction.

The name Chasmops Limestone was proposed by Linnarsson in 1871 (p. 345) for a subdivision of the Ordovician in Sweden. He intended it to denote a series of strata characterized by a common occurrence of species of the genus Chasmops, a genus that has its first representatives in this series. The strata completely or partly corresponding to this series in Sweden had previously had various names and it is evident that Linnarsson's idea was, if possible, to bring about a simplification of the comparisons between the Ordovician in Sweden and in Norway.

In his work of 1871, which aims at a comparison between the Ordovician-Silurian sequences of Dalecarlia and Västergötland, Linnarsson established the boundaries of the Chasmops limestone on the basis of his observations in the Lake Siljan district of the former province. Thus he stated that the substratum of the Chasmops limestone consists of Orthoceras limestone and that it is overlain by a grey limestone of a peculiar nodular structure. This limestone, subsequently called Masur limestone (Törnquist 1883), he referred to the Trinucleus beds, though he produced no palaeontological proofs to support his conception. The fossils that Linnarsson enumerated from the black shales resting on the Masur limestone include *Tretaspis seticornis* (HIS.) and *Diplograptus pristis* (HIS.).

Linnarsson made no subdivision of the Chasmops limestone of Dalecarlia. He merely stated that it must be considered to correspond to the limestone in Västergötland that he (1869) had called Beyrichia limestone and which he presumed probably to correspond to the lower part of Angelin's *regio Trinucleorum*. He did point out, however, that palaeontologically Beyrichia limestone agreed very well with the part of the Ordovician of Dalecarlia that Törnquist (1871) had called Cystidean limestone and which according to Linnarsson made up the lower part of the Chasmops limestone, but he also stated that the Cystidean limestone did not appear to have any sharp boundary, either palaeontologically or petrographically, towards the upper part of the Chasmops limestone.

In the explanation accompanying the geological map-sheet »Vreta Kloster» (Linnarsson and Tullberg 1882), the Chasmops limestone of Östergötland was divided — in accordance with Linnarsson's proposal — into two subdivisions or zones, a lower one, called Cystidean limestone, and an upper one especially characterized by the occurrence of *Chasmops macroura* (SJÖGREN). Leaving out of account Törnquist's attempt (1883) to divide the Chasmops limestone of the Lake Siljan district into three subdivisions, Linnarsson's classification has been generally accepted, though the names of the two subdivisions have varied. Tullberg (1882) thus divided the Chasmops limestone of Öland into Echinosphaerite limestone and Younger Chasmops limestone. Remelé proposed, in 1883, the name Macrourus limestone for the latter. In addition to the names mentioned above, the lower subdivision has been termed Older Chasmops limestone (Wiman 1906) and Lower Chasmops limestone (Thorslund 1938).

As implied by the name Chasmops limestone, its use has been limited to the strata where the part of the Ordovician in question is developed as a shelly limestone facies. When looking for strata corresponding to the Chasmops limestone in the sequences where a graptolite-bearing shaly facies is predominant, Swedish geologists have hitherto mainly concentrated their attention on the Middle Ordovician of Scania. It is not the writer's intention in this work to enlarge upon the various conceptions expressed on the basis of those investigations. An account of that kind, up to the year 1910, is, what more, available in the historical-stratigraphical review of the Cambro-Silurian of Sweden published by Moberg that same year. That review thus merely requires a supplement covering the time from 1910. Below follows such a supplement, mention only being made of such facts as are new and of importance.

In a table of the Ordovician of Sweden, Moberg in 1910 (p. 19) stated that the Chasmops beds in various districts include the following.

I. (Trilobite and Brachiopod facies). Västergötland, Dalarna, Öland	II. (Trilobite-bearing strata). Skåne	III. (Graptolite facies). Skåne	
Macrourus limestone (Öland)	Zone of *Ampyx rostratus* and *Calymene dilatata*	Zone of *Pleurograptus linearis*	Middle Dicellogr. shale
Echinosphaerite limestone (= Cystidean limestone)		Zone of *Dicranograptus Clingani* or *Climacograptus rugosus*	

The main part of this table is a copy of the one in which Olin (1906) summarized the results of his studies of the stratigraphy of the Scanian Chasmops and Trinucleus series. The novelty in Moberg's table was that the Chasmops limestone was by him at that time considered only to correspond to the middle Dicellograptus shale of Scania (cf. Moberg 1907, p. 80).

Examinations of the graptolite-bearing shales of the island of Bornholm led Hadding (1915) to the conclusion that the middle Dicellograptus shale could be divided into the following four zones:

zone of *Climacograptus styloideus* LAPW.
» » *Dicranograptus clingani* CARR.
» » *Amplexograptus vasae* (TULLB.)
» » *Climacograptus rugosus* TULLB.

It should be observed that the zone of *Cl. styloideus* is identical with the zone of *Pleurogr. linearis*, the index fossils of those zones occasionally having been found together (cf. Hadding 1915, p. 35).

In 1919, Funkquist stated that at Tommarp in southeastern Scania he had found a five-metre-thick series of strata which begins with a thin conglomerate resting on Orthoceras limestone and is overlain by shales with *Dicranograptus clingani*. This series of strata he considered to correspond to the two lower zones of the Bornholm middle Dicellograptus shale and, in addition, to part of the lower Dicellograptus shale.

In 1935, the present writer (p. 48) could state that *Climacograptus styloideus* occurs in the black Trinucleus shale of Dalecarlia, i. e. in the shale overlying the Masur limestone. His inference was that the Chasmops limestone must be older than the zone of *Pleurogr. linearis*, this zone thus probably corresponding to the lower part of the Trinucleus beds in Sweden.

It could be presumed, however, that also the Ordovician of Jemtland might yield some information regarding the correlation of the Chasmops limestone and the zones of the stratigraphic table based on the vertical range of the graptolites. Such a supposition seemed reasonable with special reference to the results that Hadding (1912, 1913) had arrived at upon examining the graptolite-bearing shales resting upon Orthoceras limestone on the island of Andersön in Lake Storsjön in Jemtland. Hadding could show that these shales, the Ogygiocaris shales of Jemtland, comprise two graptolite-zones which together with an underlying zone form the lower Dicellograptus shale of the Ordovician of Scania.[1] As was pointed out by Hadding, there are no Ogygiocaris shales in the Ordovician in the neighbourhood of Brunflo, about 24 km ESE of Andersön, the strata probably deposited contemporaneously with them there being developed as a limestone facies and belonging to the uppermost part of the Orthoceras limestone series.

As to the Chasmops limestone, the writer's investigations in Jemtland have fulfilled the expectations of obtaining data establishing the correlation mentioned though so far the writer has succeeded only partly to establish this correlation. Briefly, the results gained imply that the uppermost part of the Chasmops limestone was deposited contemporaneously with the shales of the *Dicranograptus clingani* zone. It should be emphasized that the results have been facilitated by collaboration with Dr. O. M. B. Bulman of Cambridge who has examined some of the writer's collections of graptolites. Most of the specimens of these collections were poorly preserved owing to pressure, and the assistance of a specialist was necessary for specific determinations.

[1] The upper one of these zones is that of *Nemagraptus gracilis*. Hadding stated that the index fossil of this zone occurred together with *Dicranograptus clingani* CARR. in the upper part of the shales examined on the island of Andersön. He concluded (1912, p. 601) that Chasmops beds were also represented on that island. That conclusion, however, has not been confirmed during my examinations of the area. In this connexion it should be mentioned that in the upper Ogygiocaris shales on the island of Frösön the present writer has found specimens of a species of *Dicranograptus* greatly resembling *D. clingani*, though presumably not identical with that species seeing that it occurs in a graptolite assemblage quite different from the one in which true *D. clingani* occurs.

A stratigraphical investigation of the kind mentioned above is certainly interesting in itself, but it obtains additional value when it contributes to elucidating the conditions under which the various sedimentary rocks were deposited. My stratigraphical investigation thus aims at results of a palaeogeographic character. But this does not only demand a detailed examination of a few sections but a regional investigation. As distinct from earlier reports on the Chasmops series of Jemtland, this paper is based on regional investigations of very large areas.

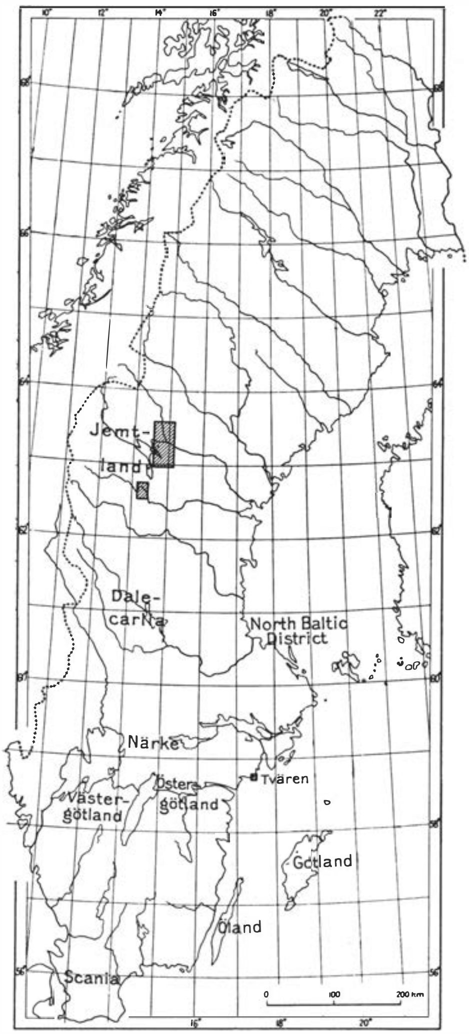

Fig. 1. Map showing location and extension of the areas investigated (see Pl. 13—15 and text-figs. 39 and 52). — The chief Cambro-Silurian districts in Sweden are indicated by their names.

This paper contains a continuation of the accounts of the investigations in Jemtland and Ångermanland carried out by the writer in collaboration with Dr. B. Asklund. It has been clearly evidenced by these accounts that the Cambro-Silurian of Jemtland forms a real and important part of the Caledonides of Sweden. A thorough investigation of the Chasmops series in this area thus requires that due regard be paid to the tectonic features. In order to explain these it has of course been necessary to submit information concerning also other parts of the sequence but the Chasmops series. This information, which also includes some new data, may be said to frame the picture of the formation of the Chasmops series of Jemtland, obtained by the writer during his investigations. For in the Cambro-Ordovician sequence upon which this series rests, the writer considers it possible to discern the main features of the conditions of sedimentation existing at the time when this series was deposited.

An account is also given of the sequence in a small area found to contain Chasmops beds and situated in the bay of Tvären in the province of Södermanland. It has only been possible to study the sequence in fragments within a boulder fan SSE of Tvären. In all probability the whole sequence belongs to the Chasmops series. The composition of its members is such as to make an account of it a valuable complement to the stratigraphical results gained in Jemtland.

In this paper the name Chasmops series is adopted as an equivalent to the name Chasmops limestone, proposed by Linnarsson. According to the writer's classification, the Ordovician of Sweden is thus composed of the following major divisions, in descending order,

Trinucleus series
Chasmops »
Orthoceras limestone series
Dictyonema-Ceratopyge series.

A special chapter is devoted to a description of species obtained in the areas investigated. Only two groups, *viz.* trilobites and ostracoda, are treated in this description, which does not even include all the species of these groups observed, this chapter being merely a small contribution to our knowledge of the fossils of the Chasmops series.

II. Jemtland.

A. Historical Survey of the Chasmops Series.

Linnarsson (1872, p. 43) was the first to report the occurrence of Chasmops beds in Jemtland. In the first place, however, he then referred to such deposits of dark shales with thin layers and lenticular intercalations of limestone as he had studied on the islands of Andersön and Utöarna in Storsjön, and which subsequently have been grouped under the name Ogygiocaris shales. It was probably on account of their stratigraphical position on top of the Orthoceras limestone that Linnarsson considered them to belong to the Chasmops series, for their assemblage of fossils — as reported by Linnarsson — cannot be said to bear out his conception. But Linnarsson was conscious of the faunistic as well as lithological difference between these strata and the ones that he called Chasmops limestone in Dalecarlia and Västergötland. This is also made evident by his statement regarding the find made in Jemtland, in the parish of Mörsil, of boulders of Chasmops limestone containing *Echinosphaerites aurantium* (GYLL.).

As a result of his study of fossil collections obtained from boulders, Wiman was able, in his report of 1893 on the Cambro-Silurian of Jemtland, to present satisfactory evidence of the presence of true Chasmops beds. The list of fossils does not cover many species, but includes representatives of the upper as well as the lower part of the Chasmops series. Outcrops of Chasmops beds, observed in the neighbourhood west of Lake Locknesjön and containing *Asaphus ludibundus* TQT and *Conularia pulchella* HOLM, were reported by Wiman in 1897. In that connexion Wiman gave some data regarding the stratigraphy of the so-called Loftarstone, a local name for a shallow water deposit, introduced into geological literature by A. G. Högbom (1886).[1]

[1] Wiman as well as A. G. Högbom seem to have understood the name Loftarstone to cover conglomerates from two different ages as well as sandstone. From information gathered among the oldest inhabitants of the village of Tand, the author, however, has gained the impression that Loftarstone chiefly refers to the sandstone that has been found to belong to the basal part of the Chasmops series. It has also been considered better to use the name in this limited meaning in this paper. Dr. Westergård has been kind enough to call the author's attention to a paper published in 1763 by Axel Fr. Cronstedt, »Rön och Anmärkningar Vid Jämtlands Mineral Historia» (»Observations and Comments on the Mineral History of Jemtland») (Kongl. Vetenskaps Academiens Handl. Vol. XXIV), in which the name Loftarstone in all probability appears for the first time in a scientific paper. Loftarstone is described as follows: »I Lockne var kalksten mörkgrå och hvitådrig utan petrificater, och fants där äfven en svartgrå hård sandstens art i skiffrige lager, som kallas i orten Loftersten och berömdes för sin fasthet mot eld och vatten, fast litet kalk var blandad i dess gluten» (»In Lockne the limestone was dark-grey and white-veined without petrifications, and there was also a blackish grey, hard, bedded sandstone, known locally as Lofterstone, and praised for its resistance to fire and water, although its gluten was mixed with a little lime»).

Wiman contributed greatly to our knowledge of the distribution of the Chasmops beds in his work »Eine untersilurische Litoralfacies bei Locknesjön in Jemtland» (1899), in which the complicated stratigraphy and tectonics of the Lockne field were dealt with. The investigations published in that work must be considered pioneer work. Wiman's interpretation of the stratigraphy therefore naturally differs in certain respects from the author's, but will not be subjected to a critical detailed scrutiny in this short historical survey. Wiman evidently was not aware of the unconformity and great break under the Chasmops beds, and this circumstance in all probability was the reason for his interpreting Loftarstone (*s. l.*) as a local littoral facies within various parts of the Orthoceras limestone series. Some of his tectonic results were subsequently criticized and corrected by G. Frödin (1920), who also published a report of great stratigraphical interest. Immediately east of the Lappgrubban farm he had observed ripple marks on bedding planes of fine-grained Loftarstone, directly superposed by Chasmops limestone and resting on basal breccias of granite.

Hadding (1927) also established the position of Loftarstone immediately below Chasmops limestone, and was the first to state that Loftarstone and its underlying conglomerate — by him called Loftarstone conglomerate — belong to the Chasmops series. Hadding (1927, p. 95) gave a description of this conglomerate, which he (1927, pp. 97, 148, 154) considered to belong to the group of conglomerates that were formed independent of the migration of the shoreline. Thus, it was interpreted as having been formed in direct connexion with strong tectonic disturbances, occurring in the Lockne field at that time. This conception was also maintained in a later paper (1929), in which Loftarstone was made the object of a petrological description. The four schematic profiles from the central part of the Lockne field are of special stratigraphical interest (*op. cit.*, figs. 88—91, p. 179). The reader should observe, however, that the limestone resting on the Loftarstone and denoted by the letter O, does not consist of Orthoceras limestone but of Chasmops limestone, which is clearly evident from Hadding's statement on the following page. Hadding (1927, p. 97) enumerated a few fossils from »the Chasmops-Trinucleus layers of the Lockne field», but gave no further specification of the assemblage of fossils in the limestones that he distinguished as Orthoceras limestone and Chasmops limestone. This was probably due to the rapid examination of the beds in question, which is evident from the fact that Hadding (cf. 1929, p. 179, fig. 88), as well as Wiman (1899, p. 143, fig. 5) before him, called a certain limestone Orthoceras limestone, although in reality it is Chasmops limestone rich in fossils (see p. 43). According to Hadding (1927, p. 93) this limestone rests on a conglomerate, described by him as »the Orthoceras limestone conglommerate of the Lockne field.»

The occurrence of Chasmops beds outside the Lockne area in Jemtland was not known of until the present writer in the summer of 1932 observed such beds on both sides of the Bay of Brunflo in the neighbourhood of the villages of Odensala (cf. Asklund 1933, p. 10) and Slandrom. The observations then made, and described in the following, resulted in an interpretation of the stratigraphy and tectonics of the Lockne field differing from Hadding's. A sequence in the Chasmops series similar to the one found at these two localities was discovered later in the same year at Hallen in the parish of Åsarna (cf. Asklund 1933, p. 34).

On various occasions during the following years, the author has observed other outcrops of Chasmops beds in Jemtland. These observations and the results gained will be presented in this paper.

In a paper written in 1938 and printed the following year, Asklund has mainly given a summary, in the German language, of the results obtained in the field work carried out by the Geological Survey of Sweden during the last decennium in the eastern border zone of the Caledonian mountain range in Jemtland, Ångermanland, and southern Västerbotten. In that paper (p. 91), Asklund reports his having observed Chasmops limestone resting on Ogygiocaris shales on the island of Frösön. The palaeontological evidence bearing out the age of the limestone is not presented, however. Moreover, in a table (Tabelle I) Asklund has given a survey of the classification and sediment-petrographic development of the post-Archaean sedimentary rocks of the region in question. Insofar as this table deals with the Chasmops beds — but also other fossiliferous deposits — the data given are partly based on statements by earlier writers, partly not proved by published observations.

According to investigations carried out during the last decade, the Cambro-Silurian deposits of Jemtland may, from a tectonic point of view, be divided into autochthonous and overthrust beds (cf. Asklund 1938). It has been found suitable to use this classification in the stratigraphical treatment of the fossiliferous beds. In the sequence of these beds the Chasmops series holds a central position, whichever sense the expression be given. A description of this series is the main theme of this paper, but, as will be clearly seen from the following, such a description demands that light also be thrown on other parts of the sequence. For this reason the following account may be said also to be a general survey of the stratigraphy and tectonics of the Cambro-Silurian in the eastern parts of the Storsjö area in Jemtland.

B. The Chasmops Series of the Autochthon.

1. Description of Areas and Sections.

The Autochthon of Jemtland comprises only Cambrian and Ordovician beds, covering a belt of varying width along the eastern border of the Cambro-Silurian rocks of the Storsjö area.

For many reasons it has proved easier to obtain information about the Chasmops series of the Autochthon than of the overthrust masses. This applies particularly to the boundary of this series towards underlying rocks. This boundary, as well as the development of individual parts of the series, has been found to vary in different parts of the Autochthon. In order to obtain as thorough a knowledge as possible of these variations and the reasons for them, the autochthonous belt has, in the following description, been subdivided into a number of parts that mutually border upon each other or lie close to each other. The most northern parts embrace

a. The Neighbourhood of the Bay of Brunflo.

The best opportunities of studying the autochthonous sequence in Jemtland are offered on both sides of the deep bay at the end of which the Brunflo community is located. This is due not only to the occurrence of a fairly large number of good exposures, but also to the fact that the beds are relatively intact, for which reason the mutual relationship between the various parts of the series can be established without very great difficulty. This is also facilitated by the fact that large parts of this series of strata display a general agreement or have many good points of comparison — with regard to lithological composition, stratigraphy, and fossil content — with corresponding well known series in other Palaeozoic areas in Sweden, for instance Öland, Östergötland, and Dalecarlia. A detailed scrutiny, however, discloses many differences and variations. The most palpable ones concern the development of the Chasmops series.

In the southeast, the Autochthon has a distinct limit of denudation. The substratum of the fossiliferous beds consists of pre-Cambrian igneous rocks, chiefly Revsund granite, but also of dolerite of the Åsby type. These rocks are thus denuded in the valley between the Bay of Brunflo and Lake Locknesjön and make up the rather hilly, fairly high country characteristic of the neigbourhood around Slåtte, southeast of Brunflo. There are also outcrops of Revsund granite in the fairly steep southwestern valley slope, N and NW of the church at Lockne.

The Autochthon around the Bay of Brunflo is bounded in the west and north by overthrust beds; the boundary in these directions is thus marked by the outcrop of an overthrust plane, cutting off the autochthonous sequence. This is most clearly visible in the neighbourhood of the village of Namn.

The Eastern Shore of the Bay of Brunflo. A summarized account of the observations so far made in the Autochthon on the eastern shore of the Bay of Brunflo discloses the following sequence under the Chasmops series, a sequence best accessible for study in the neighbourhood of Brunflo railway station. The pre-Cambrian rock, whose surface slopes fairly uniformly towards northwest, is followed by Cambrian beds which begin with a thin conglomerate (less than 0.5 m thick) containing *Torellella laevigata* (LINRS.) and thus of Lower Cambrian age. This conglomerate is succeeded by

Middle and Upper Cambrian beds, mainly consisting of alum shale with layers or lenses of stinkstone, but here and there also containing thin conglomerates representing certain zones. The lower Middle Cambrian, i. e. the Œlandicus beds, is thickest, at least 10 m, or more than half of the whole thickness of the Cambrian. The presence of middle Middle Cambrian, the so-called Tessini beds, has so far only been established by observations of a few boulders of stinkstone, while the upper Middle Cambrian beds, the Forchhammeri beds, are represented by a thin conglomerate, the Exporrecta conglomerate. The Upper Cambrian (cf. Westergård 1922) is comparatively incomplete and not so thick. The zone of *Parabolina spinulosa* and *Orusia lenticularis* always exists as a »normal» deposit. The basal zone, on the other hand, is sometimes lacking, sometimes also the one above, and according to Westergård's and Wiman's observations, the Exporrecta conglomerate is thus in different localities overlain by three different zones of Upper Cambrian. The zone of *Eurycare* and *Leptoplastus* is sometimes developed as a thin conglomerate, sometimes as stinkstone; in both cases the zone is represented in the upper part of a stinkstone bed, the lower part of which belongs to the zone of *Parabolina spinulosa.* The Upper Cambrian also contains the lower part of the zone of *Peltura, Sphaerophthalmus,* and *Ctenopyge.*

It should be pointed out that the Middle and Upper Cambrian conglomerates always occur in beds or — as in one case observed (Westergård 1922, p. 92) — in lenses of stinkstone.

Up to now, the boundary between the Cambrian and Ordovician has been observed in only one section where a thin (less than 0.1 m thick) glauconite-bearing Ceratopyge limestone with pebbles and granules of phosphatic and fossiliferous Cambrian stinkstone rests upon a corrosion surface of a stinkstone bed belonging to the zone of *Parabolina spinulosa* and *Orusia lenticularis* (Thorslund 1931). As stated above, the presence of layers belonging to two zones of the Upper Cambrian above this zone has been established in the neighbourhood of Brunflo railway station. Proof is thus obtained at Brunflo that the Ordovician rests upon different zones of the Upper Cambrian and consequently of the existence of an unconformity between the Cambrian and Ordovician.

The account above covers the main features of the development of the Cambrian and the Lower Ordovician in the neighbourhood of Brunflo, but applies with slight alterations — due to minor local deviations — also to corresponding parts of the sequence within the whole Autochthon. It thus portrays the general course of the sedimentation in the Autochthon during the periods in question. It is of special importance that this be emphasized, as corresponding parts of the sequence in the overthrust masses in the middle of the Storsjö area have proved to be more complete and thicker, and also, with the exception of the Lower Cambrian, seem to lack conglomeratic deposits.

In the above-mentioned section at Brunflo, the Ceratopyge limestone is overlain by dark-grey, stratified limestone, which belongs to the lower part of the *Megalaspis planilimbata* zone. The upper part of this zone has not been observed at Brunflo, but at the village of Bye, close to the western shore of the Bay of Brunflo, it consists of a greyish shale with a few limestone beds; it is represented by similar, although greatly disturbed and compressed deposits near Kolåsen fäb., a mountain dairy NNE of Brunflo.

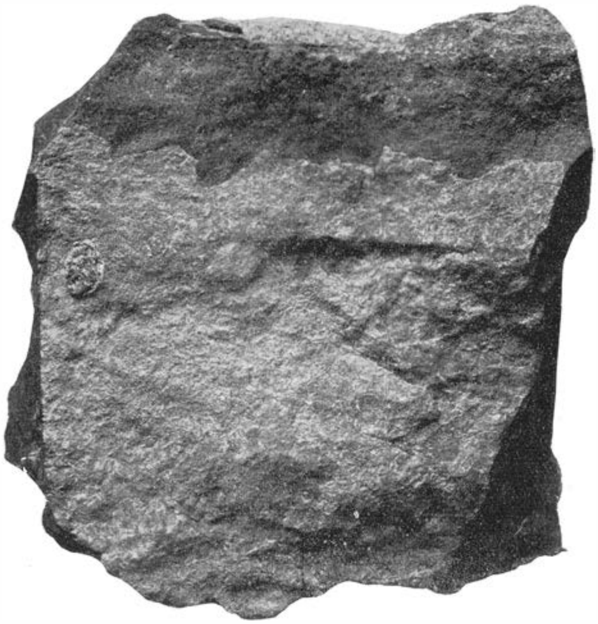

Fig. 2. Section of a bed of Orthoceras limestone showing the uneven contact between the Gigas and the Platyurus zones. The Gigas limestone is but slightly white-coloured. From the Gärde quarry, Brunflo. 3/4 of natural size.

The remainder of the Orthoceras limestone series, to which belongs the Planilimbata zone, is in the neighbourhood of the Bay of Brunflo composed of uniformly bedded limestone (cf. fig. 48, p. 98), varying slightly in colour in different parts. The thickness is estimated to be between 50 and 60 m, and the individual beds have a thickness varying from a few centimetres to 0.2 m, although most of them are about 0.1 m thick. The bedding planes are more or less shaly. The similarity to the development of the Orthoceras limestone series in other Cambro-Silurian areas in Sweden — except Scania — is striking. The Planilimbata zone is thus overlain by brownish red limestone, the *Megalaspis limbata* zone, which is followed by Asaphus limestone. The lower part of the latter, the *Asaphus expansus* zone proper, consists of grey limestone, whose basal beds contain glauconite; towards its upper part the Asaphus limestone becomes faintly reddish brown. This limestone is more or less exposed in the limestone quarries at Brunflo, as are also certain parts of the rest of the Orthoceras limestone series. This is divided into three zones, the two lower ones consisting of chiefly reddish brown limestone. They are the zones of *Megalaspis gigas* ANG. and *Asaphus platyurus* ANG., separated by a corrosion surface (fig. 2). This surface has been observed in the quarries at Lunne, Gusta, and Gärde. A similar surface separates the Gigas zone from its substratum, as can be seen in the two first-mentioned quarries. In all instances observed the corrosion surfaces are located in a lime-

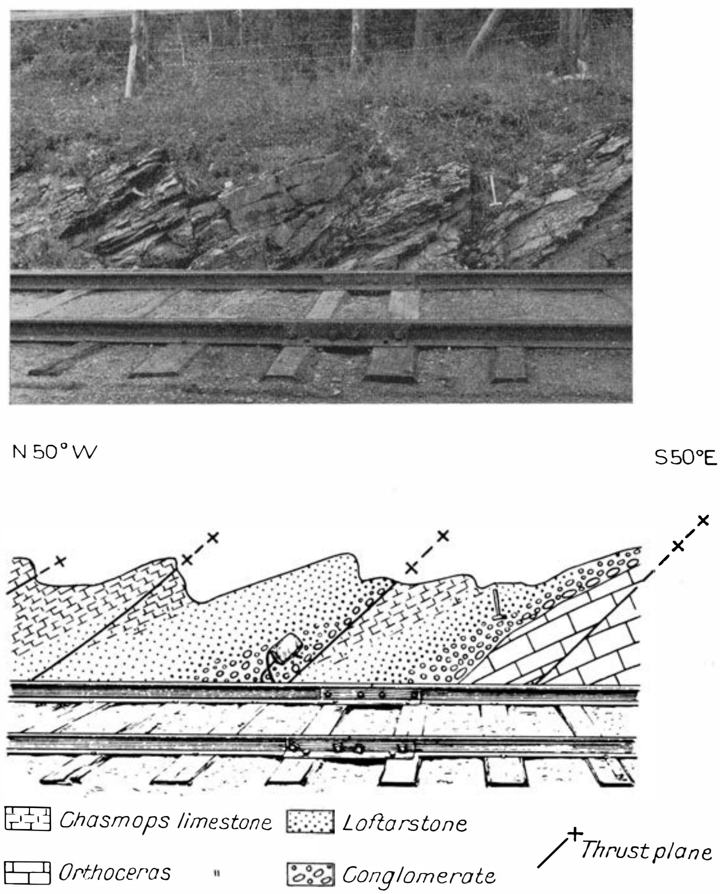

Fig. 3. The Torvalla railway-section, photo and diagram.

stone bed and do not coincide with the bedding planes. Schroeteri limestone[1] forms the uppermost zone of the series. It is mostly grey, but in certain parts has greenish tinges or darker hues. It is relatively thick, being estimated to make up at least half the entire series. Its basal layers have a characteristic appearance as they contain small dark oolites as well as scattered red portions. They are also highly fossiliferous. The list of fossils includes the following: *Illaenus schroeteri* (V. SCHLOTHEIM) (= *Ill. chiron* HOLM), *Nileus armadillo* DALMAN, *Asaphus plicicostis* TQT., *Pseudasaphus tecticaudatus* (STEINH.).

[1] Formerly called Chiron limestone, a name newly dropped (Westergård 1939, p. 42).

Ptychopyge rimulosa Ang., *Megalaspis patagiata* Tqt., *Ceraurus exsul* (Beyr.), and others.

Of the autochthonous Ordovician beds above the Orthoceras limestone there have only been observed such as belong to the Chasmops series, east of the Bay of Brunflo. They can best be studied in the Torvalla profile, a railway-section halfway between Torvalla and Odensala (fig. 3). The beds dip 20°—25° towards NNW and are in places greatly compressed and dislocated along several imbrication planes dipping towards northwest. The Chasmops series begins with a conglomerate resting upon grey Schroeteri limestone. It contains somewhat worn fragments (granules, pebbles, and rare cobbles[1]) of granite, dolerite, grey Orthoceras limestone, and Cambrian stinkstone. The granite and dolerite are among the types found in the solid rock E and SSE of Brunflo, where they constitute the substratum of the fossiliferous layers (p. 15). Two fragments of fossiliferous stinkstone have been obtained from two Upper Cambrian zones. One of them (a cobble) contains *Agnostus pisiformis* (L.), the other (a pebble) *Parabolina spinulosa* (Wahlnb.). The matrix consists of calcareous sandstone and the cement of calcite, which occasionally occurs in ample quantities and sometimes completely fills the space between the fragments. No fossils have been observed in the conglomerate, probably because of it being rather strongly compressed. It changes into a coarse sandstone of the appearance typical of Loftarstone. The total thickness of the conglomerate and the sandstone is 1.1—1.2 m, the sandstone composing slightly more than half. At this section the Chasmops series ends with a fairly pure, dark-grey, thin-bedded limestone, in which only fragments (transverse sections) of trilobites and brachiopods have been observed. A few metres above the sandstone is a bed rich in *Echinosphaerites aurantium* (Gyll.)

Loftarstone is a dark-grey, stratified calcareous sandstone, consisting mainly of the finer decomposition products of the rocks that occur as fragments in the underlying conglomerate. It is not even-grained and the grains are mostly sharp-edged or but slightly worn (fig. 4). The cement consists of calcite and, to a small degree, of calcareous mud. Immediately above the conglomerate the sandstone is coarse but becomes more and more fine-grained towards the top and also richer in calcareous matter, and in this manner grades into sandy limestone. It has a very typical weathered surface, light brownish grey with black spots, the latter caused by fragments of black shale. Thanks to the typical aspect of this surface, the rock is easily recognizable and is thus a good guide in stratigraphic field work. No identifiable fossils have been observed in the sandstone, but it contains fragments of shells, probably originating from the fossiliferous rocks which are part of the clastic material.

Also the Chasmops beds in all other outcrops observed on the eastern side of the Bay of Brunflo belong to the lower part of the series. Loftarstone has thus been denuded near a farm northeast of the road through Torvalla; and in a ditch a few hundred metres southwest of Vallmyra fäb., a mountain dairy, there is an outcrop of a few beds of dark-grey, somewhat argillaceous lime-

[1] The limiting sizes for these terms are those recommended by Twenhofel (1926, p. 155).

stone containing *Echinosphaerites aurantium* (GYLL.) and *Asaphus* cf. *ludibundus* TQT. — Near the shore between the Torvalla profile and the outlet of the Odensala brook, strongly compressed beds of conglomerate, Loftarstone, and limestone rich in shale, are exposed. Other small outcrops east of the brook consist of bedded dark-grey Chasmops limestone. Boulders from the lower part of the Chasmops series are found in great numbers on the banks

Fig. 4. Thin section of Loftarstone. Torvalla. Ord. light. × 9.

around the outlet of the brook. Among them are boulders of a conglomerate not deformed by pressure, resembling the basal Chasmops conglomerate at Öd described below. Its matrix contains fossils, not only fragments of trilobites but also of some of the ostracoda observed in the last-mentioned conglomerate. Boulders of dark-grey limestone have yielded, *inter alia, Illaenus scrobiculatus* HOLM, *Asaphus ludibundus* TQT., *Ampyx costatus* ANG., and *Echinosphaerites aurantium* (GYLL.). All these boulders must emanate from autochthonous Chasmops beds on the eastern side of the Bay of Brunflo.[1]

The Area around the Slandrom Rivulet. The Schroeteri limestone, forming the bed-rock on either side of the road between the

[1] Boulders of light-grey, thick-bedded limestone have been gathered on the shore about 0.5 km NW of the outlet of the Odensala brook. The limestone resembles the Masur limestone mentioned below and in all probability originates from the autochthonous Ordovician layers above the Orthoceras limestone. It contains a number of species of small trilobites (*Remopleurides* sp., *Ceraurus* sp., *Proetus* sp., etc.) and also ostracoda, but none of these have so far been encountered in solid rock in Jemtland. — These boulders as well as those originating from the autochthonous Chasmops series are here found on the outcrops of dark, strongly compressed shale with a few limestone lenses. Very probably this shale belongs to an overthrust mass, and a few fossils found (*inter alia*, a large specimen of *Isotelus* n. sp.) indicate that Trinucleus beds occur. At any rate this is the case with the strongly folded and dislocated beds — mostly dark shales — that are exposed here and there along the shore towards northwest.

villages of Öd and Slandrom, has its westernmost exposure immediately above the highway bridge across the Slandrom rivulet. About two metres vertically above, the Loftarstone is exposed in the rivulet. The thickness visible is about 0.5 m. At the base of the outcrop it is a very coarse sandstone with some large fragments (granules and rare pebbles) of dolerite, quartz, feldspar, limestone, and black shale. The grain-size of the arenaceous material diminishes successively upwards and the sandstone thus grades into a distinctly bedded dark-grey limestone, as was the case in the Torvalla pro-

Fig. 5. Upper Chasmops beds on the Slandrom rivulet.

file. The rock at Slandrom has not been deformed by pressure, and displays an originally bedded appearance, which is particularly evident in the more fine-grained parts. In each bed there is also a lamination, effected by the interstratification of very fine, dark and coarser, lighter material.

Very little of the Chasmops series immediately above the Loftarstone can be seen in the rivulet; a bed with an abundance of *Echinosphaerites aurantium* (GYLL.) has been observed a few metres above it. Farther up the rivulet there are minor exposures of bedded dark-grey limestone (the beds 0.1—0.2 m thick) with thin layers of dark shale between the beds. Larger outcrops appear about 300 m from the highway bridge, i. e. at a height of 18 m above the Loftarstone (fig. 5). Here the beds dip 10°—15° towards NW. Fossils were found in the dark-grey, finely crystalline, somewhat bituminous limestone, although the fauna does not seem to be rich in species. The list of fossils observed includes the following: *Triarthrus linnarssoni* n. sp., *Remopleurides* cf. *latus* var. *kullsbergensis* WARB., *Illaenus avus* HOLM (short and elongate types), *Calymene jemtlandica* n. sp., *Pharostoma*? sp., *Lonchodomas* cf. *affinis* ANG., *Ampyx* cf. *culminatus* (ANG.), *Chasmops extensa* (BOECK).

Similar strata are visible farther up the rivulet, but they are not easily accessible. They consist of bedded dark limestone interstratified with layers of black shale. 27 m above the Loftarstone they are overlain by a black, nodular, bituminous limestone, grey when weathered, about 5 m thick. The lower part of this limestone is thick-bedded, but towards the top the beds become thinner with thin layers of shale on the bedding planes. Its lithologic appearance and stratigraphical position greatly resemble those of the Masur limestone in Dalecarlia (and Östergötland), and this name will be adopted in this paper.

Measurements taken at the Slandrom rivulet indicate that the Chasmops series (below the Masur limestone) is here about 25 m thick.

The Masur limestone is the uppermost member of the Autochthon exposed in the Slandrom rivulet. Examinations of sections along the road and the shore northwest of the outlet of the Slandrom rivulet have yielded supplementary information regarding the autochthonous sequence. The bedded Chasmops limestone above the Loftarstone is thus visible on the shore 200 m northwest of the outlet of the rivulet. It seems rather poor in fossils and has only yielded *Illaenus sphaericus* HOLM, *Asaphus* sp., *Echinosphaerites aurantium* (GYLL.). The beds are denuded on either side of the Slandrom landing-stage and are gently folded.

Upper Chasmops beds have been observed on the shore 800 m northwest of the Slandrom rivulet, and consist of dark bedded limestone containing layers of dark-grey or black shale. Some graptolites were found there in a 0.2—0.3 m thick bed of black shale, but they are not very well preserved. According to Dr. Bulman the shale contains, ?*Amplexograptus vasae* (or ?? *Climacograptus pulchellus* HDG.), *Climacogr. brevis* E. & W., and *Corynoides* sp.. 1.5 m above this graptolite-bearing shale the limestone has yielded *Calymene jemtlandica* n. sp., which is the only fossil obtained from the limestone in this outcrop. 200 m farther northwest, the uppermost Chasmops beds are visible and consist of black, somewhat bituminous limestone with thin beds of black shale. The limestone only has yielded fossils, *Calymene jemtlandica* n. sp. and *Triarthrus linnarssoni* n. sp. These beds are here directly superimposed by Masur limestone. A few fragmentary cranidia of *Tretaspis seticornis* (HIS.) have been obtained from the upper part of that limestone, a part which is built up of a bedded dark, finely crystalline or almost compact limestone, interstratified with thin layers of shale.

By the road in the southeastern part of the village of Namn, a little more than 1 km northwest of the Slandrom rivulet, there is a section through the lower, thick-bedded, knobby Masur limestone. It is horizontal there, but towards northwest, on the other side of a little brook, it dips more and more steeply towards NW. Some ten metres NW of the brook, black shale containing limestone resembling stinkstone is exposed by the road. Fairly well preserved graptolites have been encountered in the limestone, e. g. *Climacograptus styloideus* LAPW., *Diplograptus* cf. *pristis* (HIS.), and *Dicellograptus* sp. (according to the writer's determinations).

About 500 m farther northwest along the road there is another exposure of black shale in which strongly compressed lenses of stinkstone have been observed, containing flattened specimens of *Olenus* spp. Olenus shale is also visible on the shore to the north, 50 m SE of the landing-stage at Namn. It seems to rest upon a grey limestone, destroyed beyond recognition by pressure. This limestone may possibly have been Orthoceras limestone. Towards SE there are found only folded Trinucleus beds, black shale with lenses of bituminous limestone containing *Climacograptus styloideus* LAPW., and *Diplograptus pristis* (HIS.)

NW of the Olenus shale at the Namn landing-stage comes a black, strongly compressed black shale, in which scattered graptolite fragments have been observed. They are far too destroyed by pressure to be more exactly identified, but in all probability belong to species of *Diplograptus* or *Climacograptus*. Towards the west, this shale is succeeded by a series of dark-grey shales, interbedded with grey limestone, dipping about 40° towards W. Fossils are rare and only sections of trilobite fragments have been observed. The beds being greatly compressed, it will certainly be difficult to obtain fossils that can be identified. A comparison with the overthrust beds between Skute and Stengärde, mentioned below, discloses, however, that this series belongs to the Trinucleus series and to the very part that rests on top of the black Trinucleus shale, containing, *inter alia*, *Diplograptus pristis* (HIS.). Observations and fossils found farther NW along the shore and the road indicate that there are solid rocks of the Trinucleus series only between Namn and Sandvik, and also farther west from the latter place, all the way to Digernäs (cf. Thorslund 1937, this paper p. 87).

The observations made thus give the following picture of the geology of the area bounded by the lower reaches of the Slandrom rivulet, the shoreline, and a line from the landing-stage at Namn towards SSE. The Chasmops series, deposited on grey Schroeteri limestone, begins with a conglomerate (not exposed) and sandstone, Loftarstone, and otherwise consists of bedded limestone, interstratified with layers of shales. The latter increase in thickness towards the upper part of the series, only to decrease slightly towards its top. Above the Chasmops beds comes Masur limestone, which at the base is built up of a thick-bedded, nodular limestone, but whose beds become thinner towards the top and interstratified by layers of dark shale. The upper part contains *Tretaspis seticornis* (HIS.). Then follows black Trinucleus shale with beds or lenses of black limestone, occasionally developed into stinkstone containing graptolites belonging to the zone of *Climacograptus styloideus* LAPW.

The main dip of this sequence is fairly small, being 5°—15° towards NW, but the beds are folded and the folding increases in strength towards NW, where the beds are cut by an overthrust plane. NW of Namn the overthrust mass mainly consists of folded and strongly compressed Trinucleus beds, largely consisting of shales, with occasional limestone beds or lenses. At Knytta, thin beds of dark quartzite have also been observed, probably belonging to the top of the sequence. Towards SSE and S, as is seen from exposures in the upper course of the Slandrom rivulet, there appears a wrinkled series of beds, consisting of Orthoceras limestone and black shales with limestone beds. As a result of certain observations in that succession of strata, which will not be gone into here, at least some of these latter beds should be considered to belong to the Chasmops series, although the fossils so far obtained have afforded no definite proof, this being due to their poor state of preservation.

The tectonic conditions in the front part of the nappe seem to be very complex. As is apparent from observations at Namn, large parts of the Ordovician are lacking above the Olenus shale; they are probably squeezed out. Under the

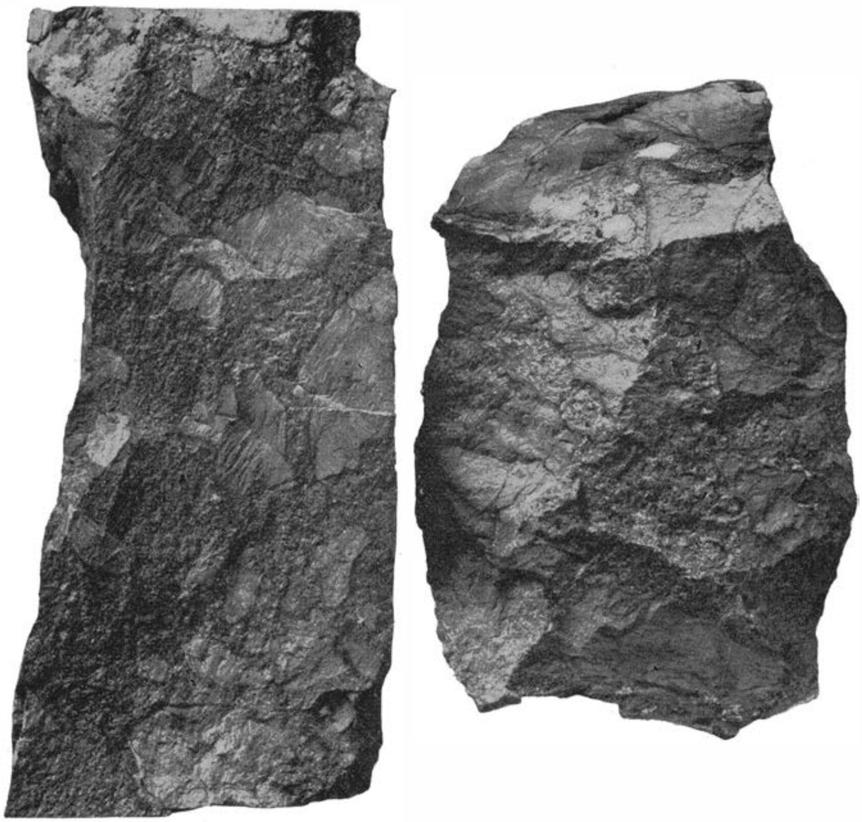

Fig. 6. Two samples of the Chasmops conglomerate at Öd. The visible pebbles consist of grey or dark-grey Orthoceras limestone. Lower Chasmops limestone at the top of the right sample. $^2/_3$ of natural size.

Olenus shale in the front, there is also a grey, not very thick limestone, the primary characteristics of which have been entirely effaced due to pressure. Except on the shore, it has also been observed in a small brook 700 m W of the outlet of the Slandrom rivulet. It may possibly be a detached patch in the front part of the nappe. On account of the covering of Quaternary deposits it is very difficult, however, and so far impossible, to give a satisfactory explanation of the complicated tectonic features in the front part of the nappe at Namn.

The Area between Slandrom and Lövåsen. Exposures of Orthoceras limestone are common between Slandrom and Överbyn, and in many places this limestone has been quarried. The largest quarry is near the shore by the village of Fugelsta, north of Marieby church, where limestone is still quarried. The limestone here belongs to the Asaphus and Gigas zones. The boundary between them is denoted by a corrosion surface, which can be followed along the entire quarry, or more than 200 m SE—NW. The corrosion surface is mainly in a limestone bed, but in one place it has been observed coinciding with a shaly bedding plane, and there appeared as a surface with cracks.

The Ordovician above the Orthoceras limestone is mostly covered and for that reason only a few exposures of Chasmops beds have been observed within the area in question. One of them is located at a farm in the southwestern part of Öd, where an outcrop of almost horizontal grey Schroeteri limestone, covered in spots by a conglomerate, can be seen inside the farm yard. Its contact with the limestone is sharp and almost smooth. The conglomerate is better exposed in some ditches about 100 m S of the farm, where a section discloses that it is directly overlain by thin beds of dark-grey Chasmops limestone (fig. 6). There is thus no Loftarstone.

The conglomerate, 0.4—0.5 m thick, is a polymict pebble conglomerate; the majority of the little worn fragments consist of grey Orthoceras limestone, while reddish brown Orthoceras limestone pebbles are rare. There are also pieces of black shales, small fragments of stinkstone, granite (Revsund granite), and dolerite (Åsby dolerite). The abundant matrix consists of a coarse to medium calcareous sandstone, which on weathering resembles Loftarstone. The cement consists of calcite, which sometimes is concentrated and then forms irregular, white fillings between the pebbles. Occasionally there is plenty of pyrite in the matrix, and fossils are not rare. Trilobites, however, mostly occur only as indefinable small fragments, while ostracoda generally have proved to be well preserved. Here follows a list of the fossils found:

Acidaspis sp. (fragmentary pygidium)
Remopleurides cf. *latus* OLIN (pygidium)
Illaenus cf. *parvulus* HOLM (pygidium)
Conchoprimitia elongata n. sp.
» cf. *leperditioides* n. sp.
Haploprimitia cf. *kogermani* ÖPIK
» » *inconstans* ÖPIK
Euprimitia aff. *bilabrata* ÖPIK
Primitia ? *locknensis* n. sp.
» ? *eutropis* ÖPIK
Uhakiella sp.
Ctenobolbina aff. *variolaris* (BONN.)
Steusloffia costata (LINRS.)
Sowerbyella sp. (cf. 5-*costata* M'COY).

On the shore north of this place there is also a small exposure of Chasmops beds, resting on grey Orthoceras limestone. The basal part of the Chasmops beds also here consists of a pebble conglomerate. Towards the top it grades into Loftarstone, on which rest thin beds of somewhat nodular, dark-grey limestone. The total thickness of the conglomerate and the Loftarstone is about 1.5—2.0 m. The beds are strongly compressed and disturbed and are lying in a depression, probably caused by faults.

Chasmops beds, consisting of dark-grey shale and limestone, have been observed in a ditch in a field about 800 m WNW of the southwestern farm in Öd.

Fig. 7. The Chasmops conglomerate exposed abt. 2.5 km W of Vålbacken brick-yard.

Near the site of an old dilapidated saw in the brook running through Vålbacken, about 2.5 km W of its outlet in Lake Storsjön, a coarse conglomerate is exposed (fig. 7). The thickness seems to be 6 m, but this figure is only approximate, the conglomerate being greatly disturbed, dipping 30° towards W 25° N, and intersected by planes along which dislocations have taken place. A distinct plane of that kind, covered with calcite, dips 40° towards NW and displays southeasterly striae. As mentioned above, the conglomerate is coarse and its main mass consists of rounded fragments. A few of them attain the size of boulders, many are cobbles, but most of them are pebbles. The majority of the fragments consist of grey or dark-grey Orthoceras limestone, but there are also pebbles of Cambrian stinkstone, granite, and dolerite, as well as pieces of shale. *Ctenopyge flagellifera*, *Ct. flagellifera angusta*, and *Peltura minor* have been found in one stinkstone pebble. The comparatively scanty matrix consists of sandstone, firmly cemented by calcite and limestone mud.

The rock around this exposure is covered with moraine. Beds of grey limestone and black shale, strongly folded and wrinkled, have been observed in the woods a few hundred metres to the west. Although these beds have yielded no fossils, they cannot belong to a lower part of the stratigraphic sequence than the Chasmops beds.

There are also solid Chasmops beds in the neighbourhood of Lövåsen. Near the farms there, only numerous boulders of Loftarstone and conglomerates have been observed, but NE of Lövåsen the beds are denuded. In the road leading to Vamleje there is thus a conglomerate and Loftarstone resting upon dark-grey Orthoceras limestone. The beds dip gently towards NE. Nearer

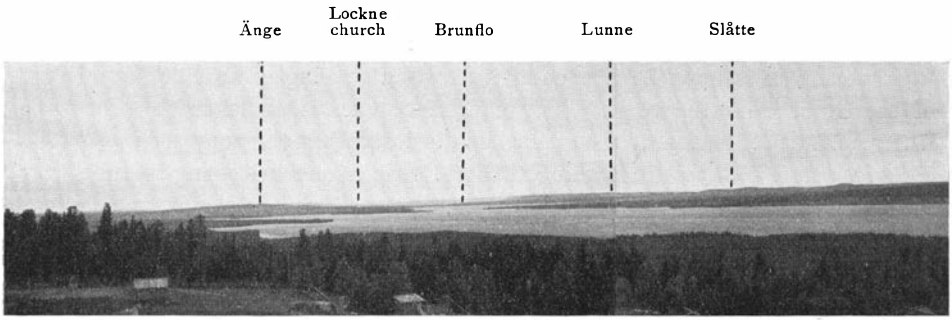

Fig. 8. View of the environs of Lake Locknesjön, seen towards the north from Bergböle.

Vamleje, by a small brook, there are boulders of dark-grey shaly Chasmops limestone, in which *Chasmops conicophthalma* (Sars & Boeck) has been observed. At Vamleje farm, black shale with thin beds of dark limestone appears as solid rock, probably upper beds of the Chasmops series, or Trinucleus beds.

About 1.2 km NW of Vamleje, Olenus shales and lower Didymograptus shales are exposed in two small road sections. Towards the north these shales have been dug through in two places in search for ore, the former some few hundred metres E of Bye fäb., the latter at Överbyns fäb. Immediately west of these localities strongly folded Orthoceras limestone has been exposed. This limestone has also been observed in ditches 1.5 km W of Lövåsen, here, too, strongly folded and overlain by black graptolite-bearing shale. These beds belong to an overthrust nappe in the front part of which Cambrian and Lower Ordovocian beds lie on autochthonous Chasmops beds in the neighbourhood of Lövåsen.

b. The Area East of Lake Locknesjön.

The bed-rock on either side of the middle part of Lake Locknesjön consists of fossiliferous formations, which, however, are often covered by Quaternary deposits. Where these beds occur, the shores are level (fig. 8), while the surrounding terrain of pre-Cambrian rocks, particularly around the southern part of the lake, presents steep slopes and is generally much hillier.

East of Lake Locknesjön the exposures are very few and mainly concentrated to the village of Haga. In the middle of that village there is a small road-section through an arkose-like breccia of granite. Such a breccia was also penetrated when sinking a well at a neighbouring farm. No outcrop of other rocks has been observed here, but the abundance of boulders of a conglomerate, and of coarse and fine Loftarstone is striking; it indicates that such solid rocks are present. 400 m NE of the exposure of the arkose-like breccia, red Orthoceras limestone, dipping 65°—70° towards SW, has been observed. A few metres NE, there is an exposure of arkose-like breccia. Although the contact between these rocks is not exposed, there is every reason to believe that the Orthoceras limestone there rests directly on the breccia.

Cambrian beds have been encountered when seeking ore about 300 m east of the breccia by the road. They consist of Olenus shales with stinkstone lenses. An examination of the latter has disclosed that the zones of *Parabolina spinulosa* and *Peltura* are developed there. Stinkstone belonging to the latter zone has yielded *Sphaerophthalmus major*, *Protopeltura praecursor*, and *Peltura scarabaeoides acutidens*.

c. The Area West of Lake Locknesjön.

The Northwestern Part. Exposures of bed-rock in the north-western part of the area west of Lake Locknesjön are fairly scarce, and therefore do not yield sufficient information for a detailed analysis of the geological features.

No observations of solid Cambrian beds have been made. Ordovician deposits, Orthoceras limestone and Chasmops beds, are found on either side of the belt of Archaean rocks that extends towards SW from the northern end of Lake Locknesjön to the western parts of the village of Tand. At the contacts towards the fossiliferous beds the Archaean rocks are covered by a crust of arkose-like breccia, which seems to be lacking only in a small area on the brook Musbäcken, where Cambrian beds probably occur as solid rocks immediately NW of an outcrop of Archaean rock.[1] The breccia is exposed in a number of railway-sections, most of them in the neighbourhood of Lassbyn. In the fairly deep railway-section N of Lockne church, the granite is but slightly brecciated throughout and thus seems to consist of large, angular fragments. As already stated by G. Frödin (1920, p. 36), it is here intersected by a number of vertical, or almost vertical fissure-fillings of dark-grey calcareous sandstone (fig. 9), which on weathering greatly resembles Loftarstone.[2] It is a coarse to medium sandstone with sharp-edged quartz and feldspar grains and small fragments of shale in a calcareous matrix (fig. 10); fossil fragments of calcareous shells are common. — In the area between the Bay of Brunflo and Lake Locknesjön the granitic and doleritic rocks do not display the above-mentioned breccia

[1] This is indicated in a section through a local moraine, which at the bottom mainly consists of fragments of lower Didymograptus shale and alum shale, the latter with stinkstone from the zone of *Parabolina spinulosa* and *Orusia lenticularis*.

[2] Similar fissure-fillings intersecting Revsund granite have been observed in new road-sections near the village of Österböle, 6 km ESE of Lockne church.

structure. As far as the granite is concerned, it has been possible to establish this in the neighbourhood of the village of Ede, and as regards the dolerite, in exposures near the railway about 1 km SSE of Brunflo station. In this connexion it may be mentioned that this is also true of the granite exposures near the boundary of the Cambrian beds between Lunne and Slåtte, NE of the northern end of Lake Locknesjön.

As to the fossiliferous beds resting on the arkose-like breccia of the Archaean along its southeastern border in the district W and SW of Lockne church, it may be mentioned that there are observations only of such as belong to the Chasmops series. Localities are the neighbourhood of Änge, Lassbyn, and the rivulet Musbäcken, the latter running in a southeasterly direction a few hundred metres SW from Lassbyn. The most complete section is exposed in this rivulet, where the arkose-like breccia towards SE is followed by a conglomerate, Loftarstone, and argillaceous beds of lower Chasmops limestone. The latter are also exposed on the road in the vicinity of the outlet of the rivulet. W of Lassbyn station there are some small hills, built up of the breccia, and partly covered and surrounded by beds similar to those of the rivulet section, following in the same order as there. At the road through the Änge farms there is an outcrop of argillaceous lower Chasmops limestone resting on Loftarstone not far from a fairly steep slope of breccia-covered Archaean; the Loftarstone in this exposure dips about 15° towards SE.

Fig. 9. Fissure-filling of calcareous sandstone in arkose-like breccia of granite. Railway-section N of Lockne church.

Upper Chasmops beds consisting of black shales with lenses or layers of black, stinkstone-like limestone have been observed in a well sunk at a farm a few hundred m W of Ångsta railway station. Similar beds are said to have been observed SSW of this place, near a railway-section through a thick-bedded, black, bituminiferous limestone, very likely belonging to the lower Chasmops series.

Outcrops of Orthoceras limestone are mainly met with only on the southern shore of the peninsula SE of Lassbyn, where strongly folded, occasionally crushed beds of Asaphus limestone, sometimes containing glauconitic, sometimes oolitic layers, can be studied, the fold-axis striking SE—NW. A low and narrow ridge of strongly disturbed red limestone running in the same direction and probably belonging to the Limbata zone, is exposed about 200 m further to the northeast. Brownish grey limestone, possibly the uppermost beds of the Asaphus zone, dipping gently towards E, has been observed at the farm 200 m SE of the railway-section with the black, thick-bedded limestone mentioned above. — Although these observations are not sufficient entirely to clear up the stratigraphical conditions, they indicate that the Chasmops beds of the district concerned are resting on rocks of different ages and that there are dislocations.

W and NW of the Änge farms, on the other side of the breccia-covered Archaean belt, there is a geologically very interesting terrain, the details of

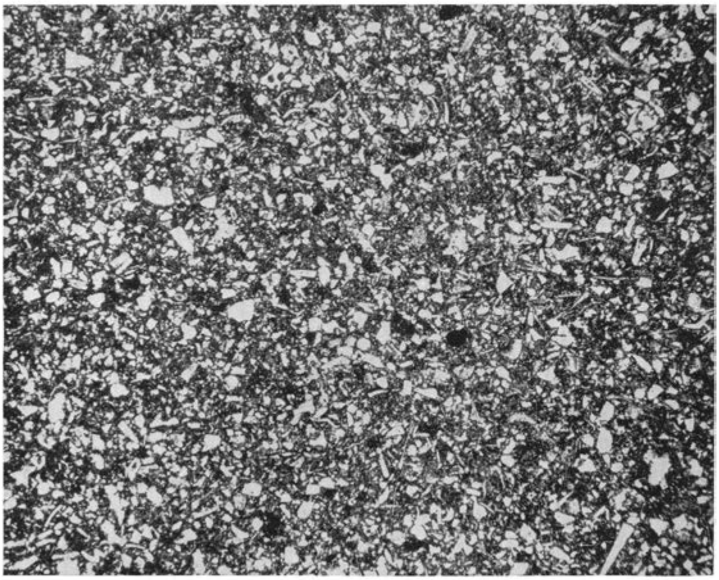

Fig. 10. Thin section of calcareous sandstone from the fissure visible in figure 9. Ord. light. × 9.

which, however, demand further investigation. Summing up the observations made, this district is built up of small hills of arkose-like breccias of Archaean rocks, granite and gneiss, or pre-Cambrian dolerite with more or less strongly folded Orthoceras limestone between them; in other words, disturbed beds of Orthoceras limestone are resting on an undulating surface of breccia-covered pre-Cambrian igneous rocks, which are here and there exposed. Along the road between Änge and Lövåsen there are many outcrops and small sections of brownish red (Gigas and Platyurus) limestone, and sometimes, as immediately NW of the northwestern Änge farm, of basal Schroeteri limestone. In these exposures the Orthoceras limestone either covers or is very close to the arkose-like breccia. In the valley south of this road, Asaphus limestone and, in one locality, also lower Didymograptus shale are observed, thus indicating that different parts of the Ordovician below the Chasmops series are resting on the breccia. Small outcrops of conglomerates, very likely of two different ages, are observed in a few localities. Thus, for instance, at the western end of the tarn

N of Nyckelberg fäb., there is a conglomerate built up of rounded fragments of brownish red limestone, evidently resting on grey and brownish grey Orthoceras limestone. This conglomerate probably corresponds to some part of the Gigas or Platyurus limestones. The coarsest conglomerate observed in the district is located about 0.9 km NW of the northwestern Änge farm. It contains large fragments of grey Orthoceras limestone and of Archaean rocks. As it is situated above the fossiliferous Schroeteri limestone of the vicinity, it very likely belongs to the Chasmops beds. A conglomerate exposed on the road abt. 0.7 km W of Nyckelberg fäb., is probably of the same age; it contains fragments of grey and red Orthoceras limestone, dolerite, and granite. Immediately W of this locality there is an outcrop of arkose-like breccia of granite. As mentioned above (p. 27), true Chasmops beds are found in the vicinity of Lövåsen and Vamleje in front af àn overthrust mass.

The Southwestern Part. The area of fossiliferous beds west of Lake Locknesjön is connected with the Central Lockne area, described below, by a comparatively narrow valley-like belt, in which Tandsbyn railway station is situated. The northern limit of its southwestern part is arbitrarily drawn along the lowermost reach of the rivulet Musbäcken. Pre-Cambrian rocks are present on both sides of the Tandsbyn valley, thus limiting this part to the west. In the NW these rocks rise dome-like above the surrounding fossiliferous beds and are but for a small area covered by arkose-like breccia; along the southwestern boundary they slope towards NE, the slope growing steeper from NW towards SE, and only a narrow strip of arkose-like breccia is here present along the boundary. Of the pre-Cambrian rocks, Archaean Revsund granite occupies large areas, but there are also, especially in the southeast, more or less metamorphic lavas and sediments, older than the granite, and dolerite of the Åsby type.

Cambrian beds, represented by strongly compressed and crimped alum shale have only been observed in trenches near the rivulet Öhntjärnsbäcken W of the village of Bleka. To the northeast these are overlain by lower Didymograptus shales with lenses and beds of dark or dark-grey limestone, containing, *inter alia*, *Megalaspis planilimbata*. Larger outcrops of these shales are seen in the slopes along the eastern side of the rivulet SW of Bleka, where, due to faulting, they are apparently resting on shaly Chasmops beds, exposed in the course of the rivulet. Between this and the Archaean in the southwest there are only Chasmops beds, usually dipping more or less steeply towards NE, though they are also (as in the NW) distinctly folded. They begin with a conglomerate mainly consisting of fragments of Archaean rocks emanating from the underlying arkose-like breccia. The conglomerate grades into Loftarstone overlain by beds of usually dark-grey limestone, in which more and more shaly matter appears towards the top so that the uppermost Chasmops beds of this area, as is evident in small sections at the rivulet, present dark-grey shales with layers of limestone lenses or nodules. Only in one locality, SW of the village of Loke, is there a lens-like intercalation of pure, light-grey limestone close above the Loftarstone. This limestone resembles the reef-like limestone facies of the Central Lockne area, described in the following chapter.

Fossiliferous lower Didymograptus shales, abt. 7 m thick, overlain by Orthoceras limestone are also recorded from the village of Loke (cf. Wiman 1899, p. 137), but large parts of the solid rock in the area NE of the rivulet Öhntjärnsbäcken are covered with thick Quaternary deposits. Probably these loose sediments rest on the lower zones of the Orthoceras limestone series, an opinion which seems to be confirmed by observations in the few outcrops available.

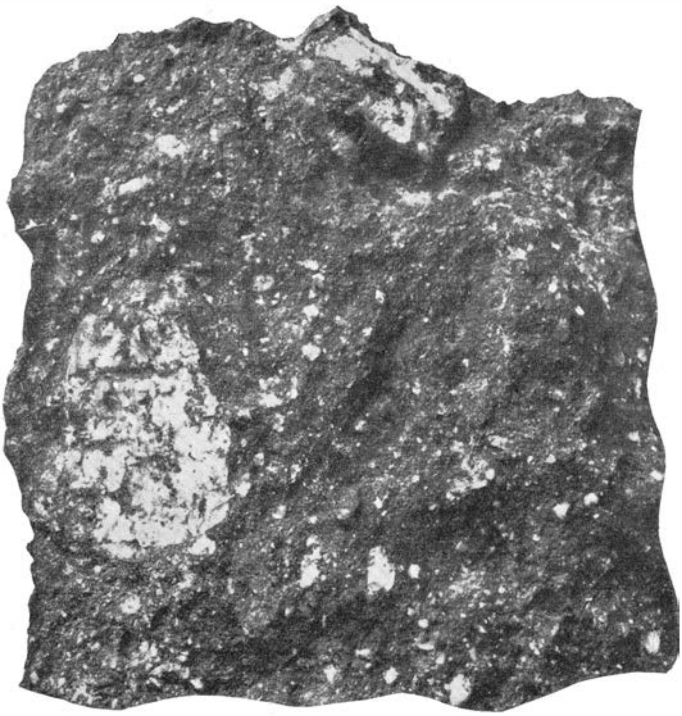

Fig. 11. Conglomeratic breccia, forming the immediate substratum of the Asaphus limestone NNW of Bergböle. Natural size.

Thus, in an old quarry between Loke and Bleka there is a red limestone, very likely belonging to the Limbata zone, dipping gently towards NE, and on the shore NNW of the village of Tramsta a brownish grey limestone of the Asaphus zone has been quarried.

Between the outlet of the rivulet Öhntjärnsbäcken and Bergböle no Cambrian beds are exposed; probably they are entirely lacking. Various parts of the Ordovician are here resting on the sometimes fairly thick arkose-like breccia that covers the Archaean rocks and the dolerite, or exposed near the arkose-like breccia.[1] In the small tongue-like area near Bergböle farm, Asa-

[1] The uppermost part of the breccia is conglomeratic with slightly rounded fragments in a sandy and argillaceous matrix, cemented by scanty calcareous mud hardly distinguishable from the matrix (fig. 11).

phus limestone seems to constitute the basal fossiliferous strata but towards northwest also Limbata limestone has been observed near the breccia. As seen in a road-section 1.4 km NNW of Bergböle farm, the basal Platyurus limestone at least is developed as a conglomerate built up of rounded fragments of Archaean rocks, dolerite, and Asaphus limestone. The Platyurus limestone is followed by the richly fossiliferous basal beds of the Schroeteri limestone. These beds form the uppermost part of the Orthoceras limestone series in the area under consideration. The unconformity between the pre-Chasmops and Chasmops beds is here clearly established, as the latter, mainly represented — in fairly common exposures — by the basal conglomerate and

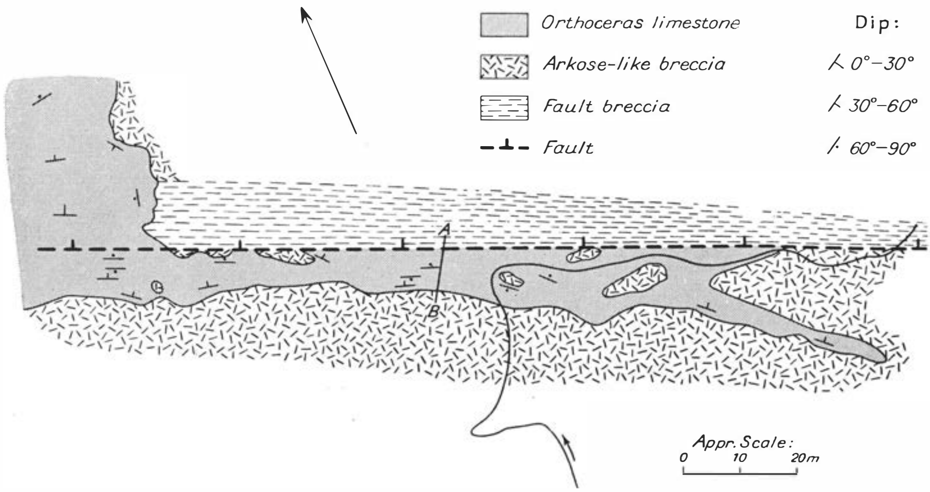

Fig. 12. Map of the tongue-like area near Bergböle farm.

the Loftarstone, are found to rest sometimes on the arkose-like breccia (as in the northwestern part of the area, and in the environs of Hällnäset fäb.), and sometimes on different zones of the Orthoceras limestone.

The tectonics of the small area under discussion display a fairly confused aspect as the beds dip more or less steeply in various directions. As a rule, the strike of the Ordovician strata near the pre-Cambrian rocks conforms to the direction of the contact lines, and the dip is here directed from those rocks. A very important tectonic feature is that a fault plane, dipping towards NNE, traverses the southwestern part and can be followed from here towards NW as well as SE. In the latter direction the fault is easily traced to the shore of Lake Locknesjön ESE of Ö. Berge, along a beautiful fault-breccia developed in the pre-Cambrian rocks. This breccia to a great extent limits the small tongue-like area N of Bergböle to the NNE, sometimes forming an overhanging wall, where fragments of the arkose-like breccia are occasionally visible. This is very likely due to the fact that the fault-breccia was partly developed in the arkose-like breccia, as there are also undisturbed parts of the latter observed in front of it (fig. 12). As seen in the section illustrated in fig. 13, the Orthoceras limestone — represented by the Asaphus limestone and the basal part of the Gigas limestone — is strongly folded between the fault and the fairly steeply descending slopes of the breccia-covered pre-Cambrian rocks in SW. In NW, at the entrance of the tongue-like area, it is harder to follow the fault-line, partly owing to covering, but it seems as if the basal beds of the Asaphus limestone were here thrust over the Platyurus limestone, this indicating the magnitude of the fault. Further towards NW the fault is marked by the crushed, arkose-like breccia, in a few localities partly overhanging small areas of Orthoceras limestone, which dips steeply towards NNE. On account of covering it has proved impossible to follow the fault-line a distance of about

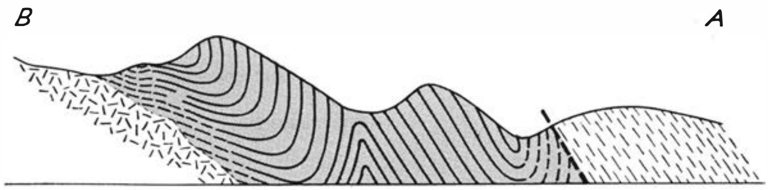

Fig. 13. Section in the area near Bergböle farm. For legend see fig. 12.

2 km towards NW, but in all probality there exists a connexion between it and the fault-line observed along the rivulet Öhntjärnsbäcken SW of the village of Bleka (p. 31). In the northwesterly continuation of this line, obviously crushed arkose-like breccia has been observed in several places in the village of Tand. It has not been possible to determine how far in this direction the fault may be traced, although there are indications of it further NW of Tand, for instance W of the tarn Mustjärn, where strongly disturbed Chasmops limestone strikes in the same direction as the presumed extension of the fault-line.

Crush breccia similar to that E of Bergböle mentioned above is also observed on the shore about 1.3 km SE of Hällnäset fäb., and like that it seems to denote the existence of a fold fault, though probably of smaller magnitude as no indications of it have been traced in the fairly good exposures along the road. In the forest a few hundred m WNW of the outcrop on the shore, a wall of crushed Archaean rocks partly overhangs Orthoceras (Asaphus) limestone dipping towards NNE. — There are also observations of similar crush breccias in the Archaean rocks on the east side of Lake Locknesjön half way between the villages of Valne and Börön, but the relation between the breccias just mentioned on either side of Lake Locknesjön will not be enlarged upon, as further investigations are necessary before this can be done.

d. **The Central Lockne Area.** (Pl. 13.)

The Central Lockne area refers to the district SW and W of Tandsbyn, which includes the valley traversed by the upper reaches of the rivulet Öhntjärnsbäcken. It has been given special attention on account of the great importance of this area for the study of the geology of the Chasmops beds in the Autochthon of Jemtland. An opportunity is here afforded in a comparatively limited area to make observations of the varying results of the changes of sea-level during the times that began with the deposition of the Chasmops series. In addition, the unconformity between this series and the pre-Chasmops beds is very clearly illustrated.

In the western part of the area as well as along the southern side of the valley system, there are large rock-surfaces practically covered by nothing but a thin humus layer. As explained by G. Frödin (1925), the absence of covering loose sediments is due to the fact that at the end of the Late-Glacial time this valley system constituted a temporary drainage eastwards for the ice-lake existing at that time in central Jemtland. It is only in the neighbourhood south of Storsved farm and in the northern part of the valley that the rocks are more generally covered with fairly thick Quaternary sediments. The good exposures and the numerous railway-sections have naturally greatly facilitated the geological mapping which has been considered desirable, for one thing to give an indication of the geological, and to some extent also of the topographical conditions prevailing at the time of the Chasmops transgression, and thus a support for the interpretation of the variations in the facies development characteristic of the Chasmops series.

No fossiliferous *Cambrian beds* have been observed. Strongly compressed and broken alum shale is exposed in road ditches near the rivulet SW of Tandsbyn station, but it seems to lack fossiliferous intercalations of limestone. In a small exposure close to the road the contact between the alum shale and a dark argillaceous shale is visible, but this contact is probably not primary. The latter shale is also deformed by pressure and this is probably the reason why no fossils have been found. Near the above-mentioned contact, however, it contains beds of grey limestone in which a deformed pygidium of *Megalaspis* sp. (probably *M. planilimbata*) has been observed. These beds thus in all probability correspond to the *lower Didymograptus shale.* They seem to be directly overlain by Chasmops limestone, which is exposed in road sections immediately SW of the rivulet.

Orthoceras limestone is present to the west of a line running N—S through Lappgrubban farm. Brownish red Orthoceras limestone (of the Limbata zone) has been quarried near the rivulet NNW of this farm. In the northern side of the small quarry, the limestone, dipping 25° towards N, is overlain by Chasmops beds, which become nearly horizontal some distance north of the quarry. The base of these beds consists of a conglomerate, mainly cobbles and pebbles of Asaphus limestone. The conglomerate grades into Loftarstone, and then follow beds of limestone and more or less marly shale. The quarry is located north of and at the foot of a hill in whose summit and southern slope Asaphus limestone is observed. The limestone beds in the hill dip in a manner indicating that they are folded. As is the case in this locality, the Asaphus limestone in outcrops nearer Lappgrubban also proves to be overlain by conglomerate and Loftarstone, the former composed of rounded fragments of Orthoceras limestone and Archaean rocks. About 200 m NW of Lappgrubban the Orthoceras limestone is brownish grey or reddish brown. No fossils having been found there, it cannot be determined whether this is the uppermost part of the Asaphus limestone or the lowest part of the Gigas limestone. It is horizontal, and as is seen from fig. 14, the basal Chasmops beds seem to rest concordantly upon it. In the nearby exposure close to the railway, the Orthoceras limestone forms a fold. It is a brownish grey limestone, partly conglomeratic. As no fossils have been found, it is uncertain whether this limestone belongs to the Asaphus limestone or the Gigas limestone. The conglomeratic limestone, exposed nearest the railway and overlain by coarse-

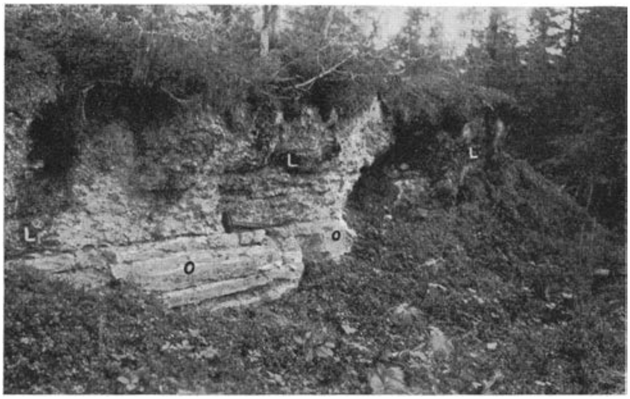

Fig. 14. Coarse-clastic basal Chasmops beds (L) seemingly resting concordantly on Orthoceras limestone (O). Outcrop abt. 200 m. NW of Lappgrubban.

clastic beds of the Chasmops series, may possibly correspond to the basal part of the Gigas limestone. Brownish red Orthoceras limestone of the Gigas or Platyurus zones is denuded in the western part of the mapped area, where it is visible in the anticline in the north and in the exposure south of it (fig. 15). In the latter the limestone is abruptly cut off approximately in a N—S direction, thus forming a steep wall towards the east. No conglomerate has been observed here, possibly due to only the upper part of the reddish Orthoceras limestone being exposed. In the above-mentioned anticline the highly fossiliferous basal beds of the Schroeteri limestone are overlain by the Loftarstone, which is conglomeratic at its base. In a locality south of Lappgrubban they occur close to a higher exposure of arkose-like breccia and have been found to contain, *inter alia, Illaenus schroeteri, Megalaspis patagiata, Asaphus plicicostis,* and *Ptychopyge rimulosa.* Schroeteri limestone is also visible WNW of Storsved, where there is an instructive railway profile (fig. 16). The limestone which in the south appears as almost horizontal beds close to a hill of arkose-like breccia of granite, seems to be gently folded near the railway. Its visible part there dips about 8° towards NW and is covered by the coarse-clastic Chasmops beds, the conglomerate filling a fissure in the limestone of the section. Towards SE the limestone forms a small cliff, at the foot of which Chasmops beds occur as demonstrated in fig. 17.

It will be seen from Pl. 13, that the *Chasmops beds* are of greater extension than any other sedimentary rock in the mapped area. As indicated in the beginning of this chapter, the development of the *lower Chasmops beds* varies in different parts of the area. Generally speaking we can here distinguish two main types, one that can be termed normal, and one that can be said to be typical of the Central Lockne area and its immediate vicinity towards the west.

The normal development displays a general agreement with the one characteristic of the Chasmops beds in the areas above described. This development is found in the neighbourhood around Lappgrubban and to the west, but also in the easternmost part of the mapped area, which bounds upon the area already described W of Lake Locknesjön. Within the parts concerned, the Chasmops beds thus begin with true clastic deposits, conglomerate and sandstone, and are overlain by bedded limestone with intercalations of more or less marly shale.

The conglomerate is polymict. Its appearance and composition varies in different localities. It is coarse in the neighbourhood of the arkose-like breccia of pre-Cambrian rocks, and there usually contains profuse quantities of more or less angular fragments of these rocks. This type can be studied, *inter alia*, in the vicinity of Lappgrubban, particularly in the lower slopes of the »islands» of the arkose-like breccia. In the southeastern wall of the largest railway-section through this breccia, however, there is a fissure-filling of the

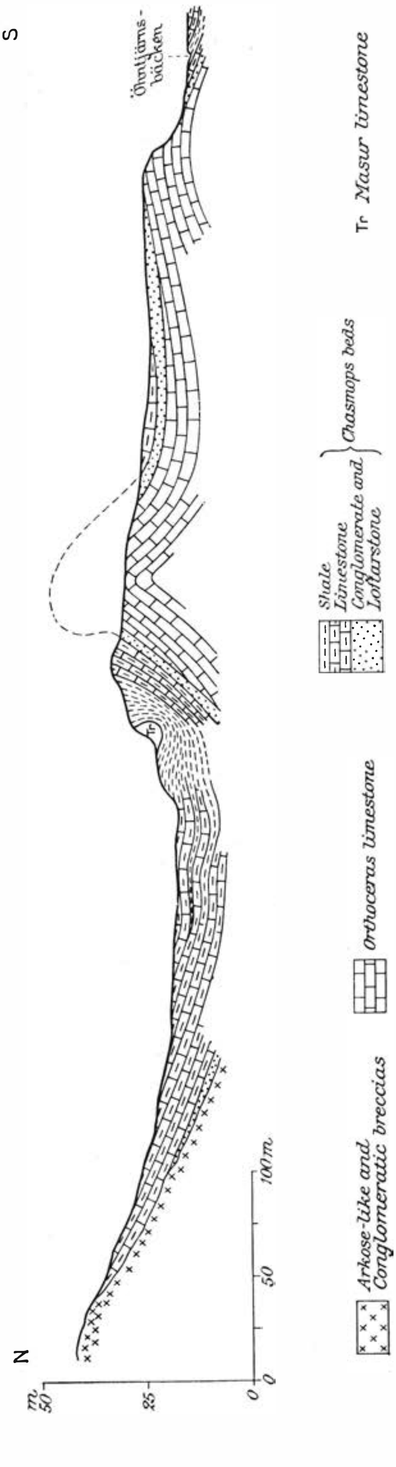

Fig. 15. Section A—B of the Central Lockne area. The location is seen in Pl. 13.

conglomerate containing a large quantity of rounded fragments of grey Orthoceras limestone (fig. 18). Such fragments are predominant in the conglomerate in other places, especially in the vicinity of occurrences of solid Orthoceras limestone. Fairly large pieces of black shale are not rare, but so far no fossils have been found in them. It should be mentioned that no fragments of Cambrian stinkstone have been encountered, and it is doubtful whether pieces of true alum shale occur. As Hadding (1927, pp. 93—97) has submitted exhaustive petrological descriptions of various types of the conglomerate, nothing

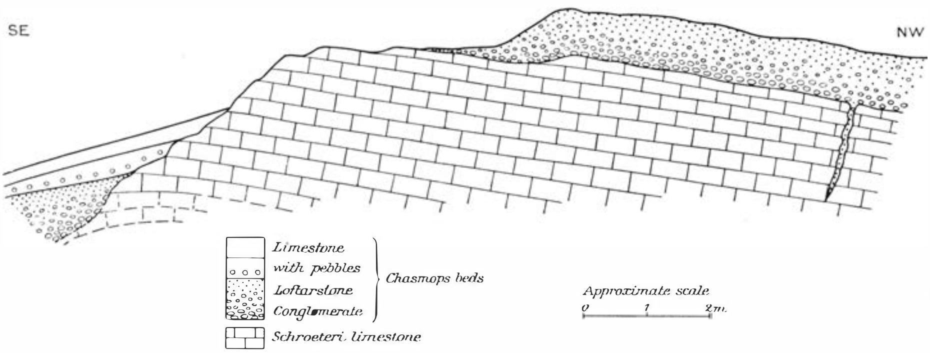

Fig. 16. Railway-section 400 m WNW of Storsved.

but a correction concerning the stratigraphy will be made here. Stratigraphically, Hadding has distinguished two conglomerates of different ages, an Orthoceras limestone conglomerate, which he considers to correspond to the lower part of the Orthoceras limestone series, and a Loftarstone conglomerate, or Lockne conglomerate, belonging to the Chasmops series. The former he supposes to be overlain by Orthoceras limestone, about 30 m thick. According to investigations made by the present writer, the fauna of this limestone in and around the locality mentioned by Hadding (*op. cit.*, p. 93), is typical of lower Chasmops limestone[1]. The Orthoceras limestone conglomerate described by Hadding is thus a type of the Chasmops conglomerate, or the Loftarstone conglomerate, if Hadding's term be used.

The thickness of the conglomerate varies greatly even in localities close to each other. The maximum thickness has been estimated to be between 1.5 and 2 m in the mapped area. The conglomerate seems to be thickest where the substratum, the pre-Chasmops surface, is very hilly, *i. e.* in the neighbourhood of the »islands» of arkose-like breccia of pre-Cambrian rocks cropping out of the fossiliferous beds.

As to fossils, it may be mentioned that usually nothing but fragments have been observed in the conglomerate, chiefly fragments of trilobites. Hadding

[1] It should be mentioned in this connexion that the limestone in question generally rests on a sedimentary rock, which does not resemble the specimen of the conglomerate illustrated by Hadding. In the present writer's opinion, Hadding's illustration gives a good idea of the appearance of the Chasmops conglomerate when it contains an abundance of Orthoceras limestone fragments. The writer has never observed this type of conglomerate under the limestone in question.

mentions an eye of a *Chasmops* species and a hinge portion of an *Orthis* sp. The present writer has found a large fragment of an *Echinosphaerites* sp. in a section near the railway, 1.1 km SW of Tandsbyn station.

What has been said above demonstrates that the conglomerate rests upon rocks of varying ages, a fact that also can be seen from the map.

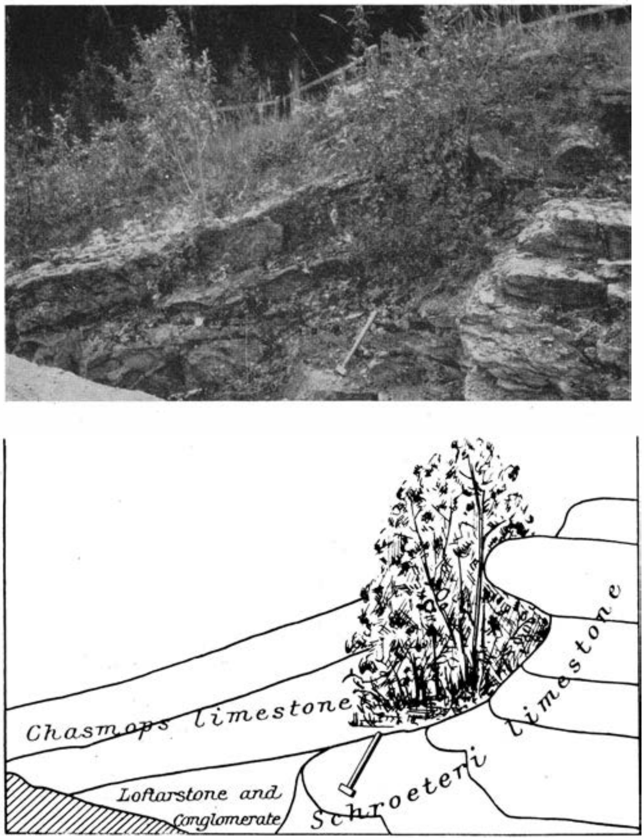

Fig. 17. Photo and diagram of the southeastern part of the section, fig. 16.

The conglomerate is overlain by Loftarstone, which may be characterized as a sandstone consisting of the finer products of the rocks that make up the conglomerate. Hadding (1929, p. 179) has published a petrological description of this sandstone, applicable parts of which are quoted below. »The Loftarstone proper is a highly calcareous sandstone or arenaceous limestone, usually darkgray, almost black, though sometimes lighter gray. On weathering it assumes a light grayish brown tint. It occurs in thinner or thicker beds, sometimes unstratified, sometimes with a fine stratification, specially pronounced on the weathering of the rock. — Under the microscope the rock proves to consist of angular grains of quartz and felspar together with chloritic scales derived from the granite. A great deal of the material, however, consists of dark calcareous mud with fragments of shales, limestone and fossils from the disintegrated (or suspended) sediments. The bulk of the mud is derived from unconsolidated Orthoceras limestone.[1] Secondary aggregates of calcite are

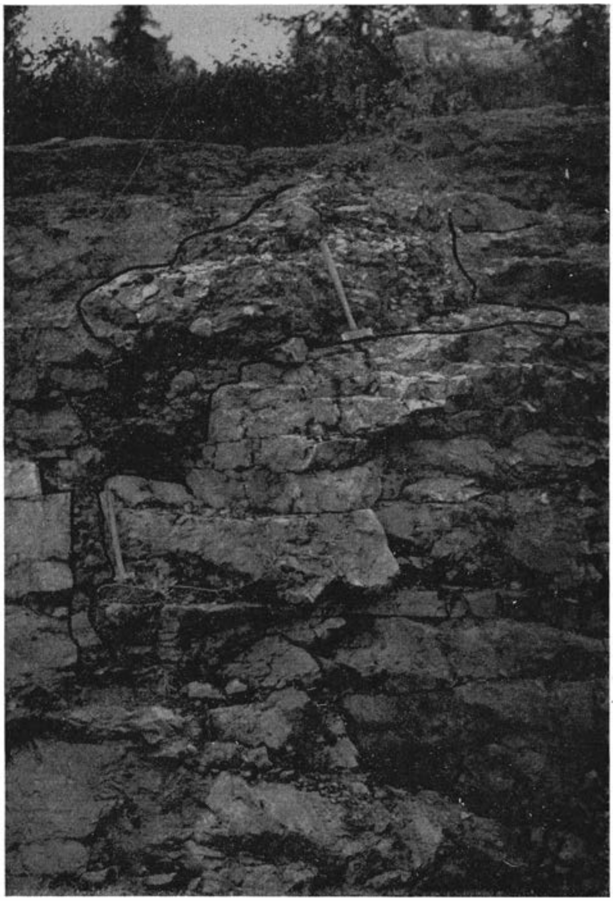

Fig. 18. Fissure-filling of Chasmops conglomerate in arkose-like breccia of granite. Railway-section 1.2 km SW of Tandsbyn station.

sometimes abundantly present. — The variations shown by the rock are partly due to the varying quantity of granitic material and partly to the character

[1] Hadding's statement that the bulk of the calcareous mud is derived from unconsolidated Orthoceras limestone is not proved by actual facts, but is evidently connected with his idea of the origin of the Loftarstone (cf. p. 13). He thus defines (1929, p. 180) the Loftarstone as »a marine, clastic rock formed essentially by disintegration of sedimentary rocks under formation. The rock forms an anomaly in an otherwise normal series of strata. The disturbance in the sedimentation has been caused by tectonic movements, which have thus led directly to the formation of the rock.» In the author's opinion, the presence of more or less worn fragments of Orthoceras limestone in the Loftarstone as well as in the underlying conglomerate, indicates that this limestone was a consolidated rock before the deposit of the Chasmops beds. For other reasons the writer cannot share Hadding's view concerning the conditions of sedimentation during the development of the Loftarstone.

of the sediments that have been shifted and form an essential part of the rock. Consequently we cannot expect that a Loftarstone formed at one place .... will be exactly like one formed at another place ...., even though the mode of formation has been the same. However, the variations are not great.»

In older sections where the surface is weathered, thin conglomerates can be observed in the Loftarstone. This is clearly demonstrated in the ditch near

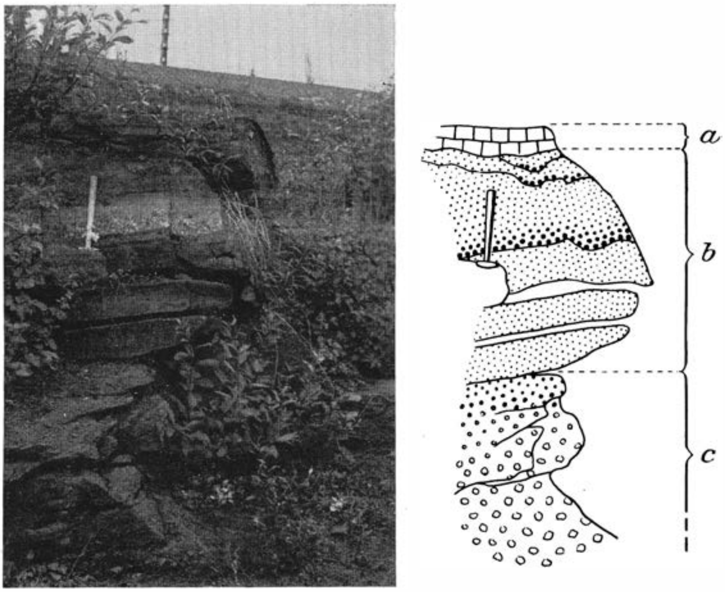

Fig. 19. Photo and diagram of a section 1.1 km SW of Tandsbyn station. a = arenaceous limestone, b = Loftarstone with intraformational conglomerates, c = basal Chasmops conglomerate.

the railway 1.1 km SW of Tandsbyn station (fig. 19). There the Chasmops beds slope from a hill of granitic breccia cropping out of them. They begin with a coarse conglomerate, the lower part of which contains a comparatively large number of rounded fragments of grey Orthoceras limestone, granite, and pieces of black shale. The content of granite fragments increases upwards and finally becomes predominant, these fragments simultaneously becoming more and more sharp-edged. The conglomerate changes almost abruptly into coarse Loftarstone, which becomes finer and more calcareous towards the top (fig. 20). Some distance above the basal conglomerate a new conglomerate appears, containing sharp-edged fragments of granite. That conglomerate sharply borders on the substratum whose surface appears to be uneven in the section. Two similar conglomerates, although thinner and finer, are developed in the uppermost part of the Loftarstone, about 0.27 m and 0.35 m, respectively, above the base of the former. They mainly fill pockets in distinct surfaces of the Loftarstone, which is overlain by impure, somewhat arenaceous limestone, apparently cutting the two surfaces mentioned.

As stated in Hadding's description, the Loftarstone contains fragments of fossils, but no identifiable specimen has been found.

The Loftarstone is usually succeeded by dark-grey, bedded limestone, never more than a few dm thick. As the vertical distance from the Loftarstone increases, the limestone contains successively thicker layers of shale at the bedding planes. The middle part of each bed consists of fairly pure, crystalline limestone, but towards the bedding planes the limestone becomes impure, richer in argillaceous material. Pebbles and granules of granite are occasionally found in the limestone beds immediately above the Loftarstone; they appear in the middle of the beds. Most of the Chasmops series above the Loftarstone, however, consists of dark shale with lenses of various sizes, sometimes nodules of dark-grey limestone, with an occasional limestone layer. The development of the series varies from place to place, but the rule is that where the series includes Loftarstone the higher parts usually contain a large quantity of shaly material (fig. 21). Facies types, transitional to the pure or non-argillaceous limestone facies, described below, are also found here and there outside the immediate neighbourhood of this limestone, and are noted in various parts of the lower Chasmops series. They can best be studied in the vicinity of Lappgrubban and in railway-sections between that place and Tandsbyn stn.

Fig. 20. Basal Chasmops conglomerate with sharp-edged fragments of granite at the top and overlain by Loftarstone. The hammer is standing on arkose-like breccia. Section 1.1 km SW of Tandsbyn station.

The pure limestone facies of the lower Chasmops beds which forms the second, more special, facies type — in contrast distinction to the »normal» facies development described above — is best seen near the Archaean SSW of Tandsbyn station, where we also observe its largest occurrence in the area. Earlier authors have considered this limestone to correspond to some part of the Orthoceras limestone series, probably mainly

Fig. 21. Railway-section 1.25 km SW of Tandsbyn station. The left hammer is standing at the contact between the Chasmops conglomerate and the arkose-like breccia of granite. Lower Chasmops limestone in a shaly facies follows above the Loftarstone (L).

due to it being rich in fossil cephalopods in one of the most accessible localities, about 0.7 km from Tandsbyn station. A closer scrutiny of its fossils, however, has disclosed that this stratigraphic determination cannot be correct. As indicated above, the limestone instead represents a facies development of the lower Chasmops series, a fact that completely changes our conception of the geological development of the whole area both as regards its stratigraphy and tectonic features, and thus necessitates a revision of the geological theory which — more or less expressly — has been associated with the old interpretation (cf. p. 108).

The limestone in many places rests on a sedimentary rock, which Wiman (1899, p. 146) called a sedimentary breccia. As will be seen on Wiman's map, he regarded it partly as a fault-breccia, for instance in the region about 500 m SSW of Tandsbyn station. Hadding (1927) has described this basal bed from the region east of Lappgrubban farm, where the two main types of lower Chasmops beds meet and merge, and looks upon it as a conglomerate, the Loftarstone conglomerate. Although Hadding (cf. 1927, pp. 97, 163) clearly states that it should be classed amongst the conglomerates, he adds, however, that it would be justifiable to call the rock a sedimentary breccia. In Pl. 13 of this paper, it has been mapped as a conglomeratic breccia, but the writer has no objection to the designation breccia-like conglomerate. The difference between these two terms would be that the former refers to the appearance of the rock, and the latter to its formation.

In its typical development the basal bed in question consists of an unsorted clastic rock with cobbles, pebbles, and granules of Archaean rocks, cemented by calcite (fig. 22), in the upper part by limestone mud. In the latter part there is

Fig. 22. Secondarily weathered surface of the conglomeratic breccia forming the substratum of the pure limestone facies of the lower Chasmops series. 300 m E of Lappgrubban. 1/2 of natural size.

no other matrix, and upwards the rock rapidly grades into a fragment-bearing limestone. Towards the base, the conglomeratic breccia contains a matrix of sandy material, the quantity of which increases more and more downwards, thus gradually reducing the quantity of calcite cement. There is no sharp boundary towards the underlying arkose-like breccia, which forms a crust of varying thickness above the Archaean rocks. In the mapped area, the latter chiefly consist of granite (of the Revsund type), but there are also small parts consisting of older, metamorphic rocks (of the leptite formation), as for instance at the »corner» south of Tandsbyn station. There is an intimate connexion between the occurrence of these various types as solid rock and as fragments in the breccias.

In the area SE of Lappgrubban, and in the vicinity of the »corner» south of Tandsbyn station, the uppermost part of the conglomeratic breccia successively contains more filling material of argillaceous mud, and obtains the composition and appearance described by Hadding (1927, p. 95, fig. 28).

It resembles the conglomeratic rock illustrated in fig. 11 (p. 32), which constitutes the substratum of the Orthoceras limestone. At the same time the strata covering it begin to change into Loftarstone or Chasmops limestone rich in shale. The latter is true in the upper parts of some fairly high hills of arkose-like breccia, as illustrated at the small »island» south of Lappgrubban farm.

The formation of the typical conglomeratic breccia in all probability took place in the manner indicated by Wiman (1899, p. 146). Thus, it may be

Fig. 23. The light rock to the left consists of pure reef limestone of the lower Chasmops series. Close below the white paper it rests on the conglomeratic breccia; outcrops of arkose-like breccia in the fore-ground and to the right. Compare fig. 21. 0.8 km SSW of Tandsbyn station.

considered a redeposited uppermost part of the arkose-like breccia which had been exposed to weathering and, to some degree, to disintegration, its fine filling material having partly been carried away before or during submergence. As to its correlation, it may be suggested that most probably it was formed contemporaneously with the deposition of the Loftarstone and of the uppermost part of the »normal» conglomerate described above.

The appearance of the limestone covering the conglomeratic breccia varies slightly in different places. To a certain degree it resembles Orthoceras limestone, but lacks its distinct and regular bedding. In many places, particularly in its lower part, there are no distinct bedding planes, and in this respect as well as others the limestone resembles the reef-like limestones of Dalecarlia. It is a very pure limestone[1], generally distinctly crystalline, sometimes rather coarsely crystalline, though there are parts that are almost com-

[1] Consisting of about 96 % $CaCO_3$ (cf. Wiman 1899, p. 138, analysis IV).

pact. It is mostly light-grey with slight variations; but occasionally an abundance of bituminous material darkens its colour.

This limestone was deposited directly on the conglomeratic breccia (fig. 23) and at the base often contains angular fragments of Archaean rock, mostly pebbles but occasionally also cobbles. Such pebbles can also be observed above this basal part. A limestone bed about 1.5 m above the base, containing several granite fragments, can thus be studied in a profile near the boundary of the limestone east of Lappgrubban.

Sideways as well as upwards the limestone grades into Chasmops beds rich in shaly material. This is clearly illustrated in the railway-sections between Lappgrubban and Tandsbyn. The transition towards the sides is effected by distinctly bedded limestone, superficially very similar to Orthoceras limestone, but the individual layers, separated by more or less thin strata of shale, usually consist of distinctly crystalline limestone, which is not characteristic of Orthoceras limestone. This transitional type is well exposed close to the limestone quarry a couple of hundred metres east of Lappgrubban farm.

In the railway-section about 1 km SSW of Tandsbyn station there are tongues of the pure limestone facies interstratified with the »normal» type of Chasmops beds rich in shale (figs. 25—27). The observations made are of interest, as they seem to indicate that there were changes of sea-level during the time when the elements of the series under discussion were deposited. We can study certain beds of grey, apparently pure and homogeneous limestone in the section, and between them more or less irregularly bounded lenses or thin layers of dark-grey limestone in shale. The thickness of the same bed varies within a fairly small distance. On weathering, the limestone appears conglomeratic, and upon closer investigation, small, angular granite pebbles are found in the central parts of the two lowest limestone beds. In addition, fresh surfaces show that the limestone contains subrounded pebbles of limestone in a groundmass of crystalline limestone, this being the chief component of the bed. Structurally as well as with regard to colour, the fragments distinctly differ from the matrix, as they consist of darker, finely crystalline or almost compact limestone. Its appearance and the fragments of fossils observed indicate that the pebbles originate from beds of lower Chasmops limestone, which emerged and became disrupted.

In this connexion it should be mentioned that the breccia-covered Archaean surface SE of the section in question has a comparatively steep dip towards NW.

About 0.6 km ENE of Lappgrubban there is an old quarry in pure limestone, only parts of which display a distinct bedding. Here, too, beds of intraformational conglomerates have been observed containing an abundance of limestone fragments, thus resembling the conglomeratic limestone beds in the railway-section.

No fragments of Archaean rocks or limestone have been observed in the shaly layers in which the above-mentioned beds are intercalated. The pure limestone seems to dissolve and grade into these layers in such a manner that first very thin, but gradually thicker strata of shaly material appear there, dividing it into small units, sometimes to begin with into fairly thick beds, sometimes directly into more or less elongate lenses. This is fairly well illustrated in the upper part of fig. 27, and seems to be the general mode of transition between the two facies of the lower Chasmops series. This transition within the section of the area under consideration is mainly confined to the direction SE—NW, which is the direction of the dip of the pre-Chasmops surface. The development and spread of the two facies types seem chiefly to depend upon the morphology or configuration of this surface, this prompting the conclusion that the purer limestone was deposited in more agitated water than the impure, argillaceous beds. The shaly facies is thus developed in the depressions between the islands of brecciated granite near Lappgrubban, but NE of the islands, in the coastal area exposed towards the west in early Chasmops time, the pure limestone facies becomes successively predominant throughout the lower Chasmops series. At the »corner» SSW of the railway station, this facies is thus almost directly covered by the upper Chasmops beds rich in shale, the transition being effected by only a few beds of somewhat impure, dark-grey limestone, interstratified with thin layers of shale. On the other, eastern side of the »corner», the shaly facies is predominant, and the transition from one facies to the other is very rapid.

The lower Chasmops beds above the Loftarstone and the conglomeratic breccia are generally very fossiliferous, and should contribute considerably to our knowledge of the fauna at the time they were deposited. The collections so far made by the writer are fairly small, however, having been made mainly with a view to obtaining proof of the correlation of larger units and to facilitate an interpretation of the geological development of the area.

As to the fossil content of the pure limestone facies, whose development and composition the writer considers to indicate its being a kind of reef limestone, many circum-

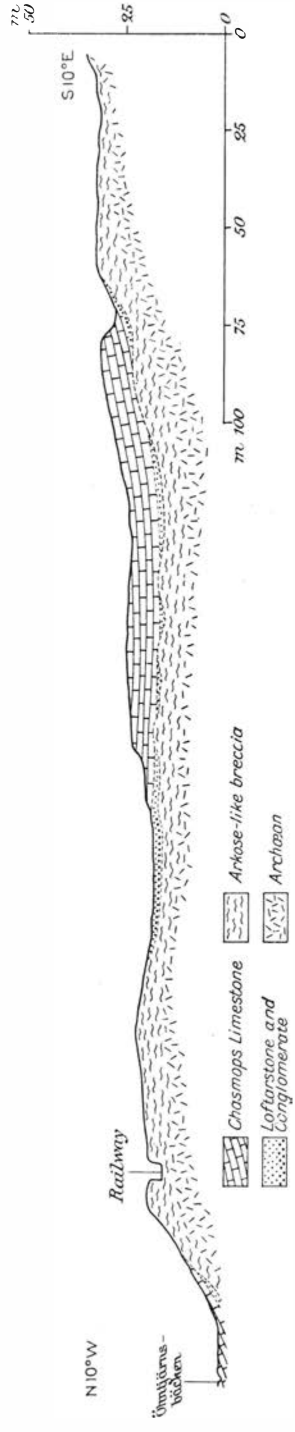

Fig. 24. Section C—D of the Central Lockne area. The location is seen in Pl. 13.

stances may be adduced apparently promising a rich and interesting result in several respects, upon a more careful investigation than those hitherto made. In some places the limestone is crowded with fossils, in others it is poor in fossils or actually lacks them entirely. There also seems to be a kind of »qualitative» difference, a certain group of animals, or even a certain species, sometimes appearing to be predominant in one accumulation of fossils,

Fig. 25. Two beds of conglomeratic limestone intercalated in shaly facies of lower Chasmops limestone. A rucksack is standing on one of them, the other is marked by a paper, a hammer, and a satchel. Section 1 km SW of Tandsbyn station.

another group or species in others. The abundance of cephalopods is thus striking in certain places, particularly in the vicinity of the railway about 0.7 km SSW of the station, and this condition is probably responsible for the fact that earlier writers misinterpreted the age of the limestone. In a few places the writer has observed beds filled with fragments of trilobites; in one place they are mainly of *Illaenus avus* HOLM, in another of *Asaphus ludibundus* TQT. Close above the conglomeratic breccia, in the limestone quarry at Lappgrubban, there are thin layers of crystalline limestone on whose bedding planes there are large numbers of brachiopods (mainly Orthids) and bryozoans. In another exposure not far NE from there, the writer has observed a limestone bed rich in a species of *Sowerbyella*.

These examples indicate that the fossils in the pure limestone facies occur in about the same manner as in the reef-like limestones of Dalecarlia (cf. Warburg 1910, Isberg 1917, Thorslund 1936). Also lithologically and in its relation to and transition into the facies rich in shale, the limestone resembles the latter (cf. Thorslund 1935, p. 25). As these have proved to contain fossils, useful in a correlation with distant formations of the same age (Warburg 1925), there is every reason to assume that future, large collections of fossils in the above limestone of the Central Lockne area will be found valuable for similar purposes.

Although the reef-like limestone seems to contain several species, which according to investigations so far made occur there only, there are also such as have a wider distribution. For the time being the following can be mentioned: *Chasmops conicophthalma* (SARS et BOECK), *Asaphus ludibundus* TQT., *Ampyx costatus* (BOECK), and *Steusloffia costata* (LINRS.), which may be looked upon as an assemblage of index fossils of the lower Chasmops limestone.

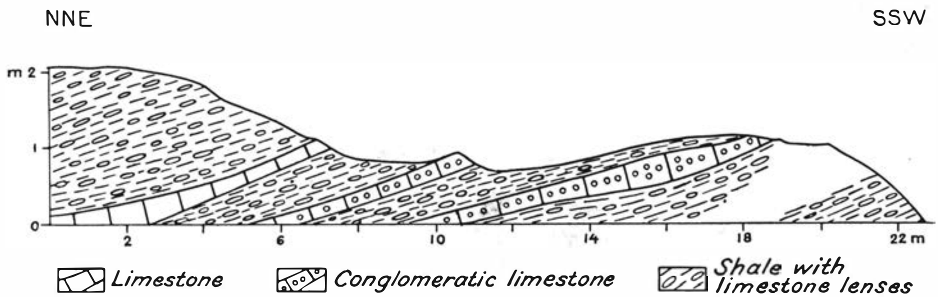

Fig. 26. Diagram of the section seen in fig. 25.

The reef-like limestone is rich in ostracoda, which is not true of the shaly facies, where only *Steusloffia costata* seems to be common. With regard to the abundance of species in this group, it can — among corresponding deposits in Sweden — be compared with the limestone from Tvären, Södermanland. Species common to these districts are: *Primitia troedssoni* n. sp., *Chilobolbina decumana* (BONN.), *Platychilina kapteyni* (BONN.), *Steusloffia costata* (LINRS.), *Hesperidella globifera* (KRAUSE), *Balticella oblonga* n. sp., *Ctenobolbina suecica* n. sp., *Ct. obliqua* (KRAUSE). A few of these species also occur in the Kuckers formation of Esthonia.

These brief data regarding the fossil content are given to prove the age of the reef-like limestone, and as an indication of its correlation. For further information, see list on p. 184. Other occurrences of the pure limestone facies, more or less directly overlying arkose-like breccias of Archaean rocks, are found in the northwestern part of the mapped area. They consist of light-grey, sometimes dark and bituminous crystalline limestone, often displaying a distinct bedding, although its content of shaly material is extremely small or entirely lacking at the bedding planes. SW from the breccia-covered Archaean area, where the village of Tand is located, the quantity of the argillaceous material increases, and in the anticline between the branches of the rivulet Öhntjärnsbäcken the shaly facies is predominant. This is schematically illustrated in fig. 15.

In the southeastern part of the railway-section (fig. 16) about 400 m WNW of Storsved, the fairly thin Loftarstone is covered by bedded, somewhat impure limestone rich in cephalopods. It is mentioned here as it may be looked upon as an example of an intermediate between the two types of facies of the lower Chasmops series. Its basal beds contain pebbles and granules of granite. As indicated in the illustration, the limestone partly rests directly on Schroeteri limestone.

The continuation of the reef-like limestone SSW of Tandsbyn station is visible in folds to the west of the railway (fig. 28). The appearance of this limestone is different to that of the limestone on the eastern side, but the

Fig. 27. Weathered surface of a limestone bed showing the conglomeratic structure. The arrow points at a pebble of granite. Detail (= right portion) of the section illustrated in fig. 25.

change can be followed step by step. It is darker, sometimes almost black, generally very bituminous. It is finely crystalline or almost compact and closely interwoven with fissures filled with calcite, giving it the appearance of a breccia, probably acquired in connexion with the folding. It closely resembles Masur limestone, and it is hardly possible to distinguish between samples of these two limestones. Like Masur limestone it contains very thin, irregular layers of black shale, which are nearly always glossy on account of sliding.

No fossils have so far been observed in the limestone, but its stratigraphic position is established, as it is overlain by the upper Chasmops series.

This limestone is exposed by the road on either side of the lower Didymograptus shale on the Öhntjärnsbäcken and in a small quarry 0.8 km WSW of the station. By the rivulet it occurs close to that shale, but their contact is not visible; it may be secondary, caused by a short thrust. No traces of coarse-clastic deposits, conglomerates, or Loftarstone have been observed near the boundary between the shale and the limestone.

The *upper Chasmops beds* are exposed on either side of the railway, from the station to the locality 0.7 km SW of it. They also occur in the northeastern part of the anticline in the northwestern corner of the mapped area, although the exposures there are very incomplete. They mainly consist of black shale with large stinkstone-like lenses of limestone. Sometimes, as is the case in the basal part, there are also beds of dark-grey or black limestone, which form an unnoticeable transition from the upper part of the lower Chasmops series. It is thus hardly possible to draw a definite lithological boundary between the two subdivisions of the Chasmops series.

The intercalations of limestone in the shale are fairly fossiliferous, although most of the fossils are poorly preserved, having suffered from pressure. This is particularly true of the graptolites, which occur abundantly in a section at

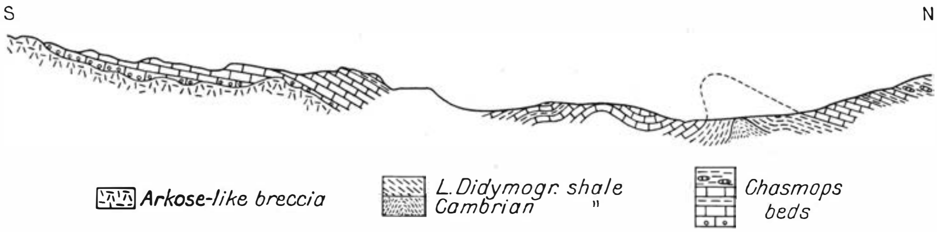

Fig. 28. Section E—F of the Central Lockne area. The location is seen in Pl. 13.

Tandsbyn station. According to Dr. Bulman's examination, the following graptolites have been obtained:

Glyptograptus cf. *teretiusculus* var. *euglyphus* (LAPW.)
Amplexograptus cf. *vasae* (TULLB.)
? » *pulchellus* (HDG)
? *Dictyonema* sp.
Desmograptus sp.
Dendrograptus spp.

The most common brachiopod in the limestone lenses is »*Orthis*» cf. *argentea* (HIS.), whose valves sometimes cover the bedding planes. Bryozoans and spicules of sponges are also fairly common. The following trilobites and ostracoda have been observed:

Remopleurides wimani n. sp.
Illaenus sp.
Proëtus sp.
Otarion sp.
Cryptolithus discors (ANG.)
Tretaspis cerioides (ANG.)
Uralichas ? sp.
Chasmops extensa (BOECK)
Triarthrus skutensis n. sp.
Trinodus sp.
Apatochilina aff. *ubjaensis* ÖPIK.
Steusloffia costata (LINRS.)
Piretella öpiki n. sp.

The youngest Ordovician rock of the Central Lockne area consists of the limestone, earlier quarried for lime production, in the northeastern side of the anticline SW of Tand. It is a black, bituminous limestone, resembling the facies of the lower Chasmops limestone described above from the vicinity of the rivulet Öhntjärnsbäcken SSW of Tandsbyn station. Lithologically it also agrees with *Masur limestone* and seems to hold the same stratigraphic position, overlying the Chasmops series, as is clearly seen at this locality. Immediately below the limestone, the Chasmops beds consist of black shale with thin layers or lenses of black, almost compact limestone. The layers are strongly squeezed and no fossils have so far been found in them, but it must be admitted that they have not been examined very carefully for fossils.

As regards the tectonics of the Central Lockne area, it must first be pointed out that the beds almost everywhere bear witness to their having been exposed to pressure. This is apparent from the observations of the dip which are given on the map. Even in the rare places where the beds seem to be horizontal, there are distinct traces of deformation by pressure, in the shape of slide-surfaces and fine fissures filled with calcite. The latter feature is particularly noticeable in such limestone beds as are fairly free from shaly material, while for instance in the Chasmops beds rich in shale the movements mostly took place outside the limestone intercalations. The thick-bedded limestones are usually strongly compressed and sometimes contain recrystallized parts, for which reason it is not easy to obtain well-preserved fossils from them.

The dip of the sedimentary rocks seems chiefly to depend upon movements in the rocks themselves, while the crystalline substratum has remained practically intact. This is explained by the difference in resistance to pressure of the rocks in question. It need hardly be mentioned that the resistance is dependent upon the constitution of the rocks, their composition, homogeneity, hardness, and rigidness. This is clearly seen in the sedimentary rocks of the area, in which the shaly beds more easily have become folded than the more compact limestones, which instead often display more or less distinct imbrication structures. These tectonic features are demonstrated in the comparatively narrow passage between the Archaean rocks near Tandsbyn station. The general dip of the pure Chasmops limestone east of the railway seems to have originated out of a co-ordination of movements along a number of fairly short imbrication planes, each dipping more or less steeply towards NW. The majority of these movements have taken place within the limestone, which has, as it were, been piled up against a wall, in this case consisting of the breccia-covered Archaean rocks. The limestone seems to have been split into blocks of varying size by fissure planes running almost at right angles to the dips, which planes in the present exposures are denoted here and there by crevices with steep walls towards W and NW. Although there are traces of movement also in the underlying arkose-like breccia, it is evident that the dip of the limestone immediately above the breccia-covered Archaean is conformable to the configuration of the substratum.

As intimated above, there are also traces of movement in the substratum of the Chasmops beds, although it is generally not possible to observe them. A couple of examples can be given. At the eastern boundary of the limestone about 600 m SSW of the railway station, the arkose-like breccia is distinctly crushed about one metre under the base of the limestone. Here the thrust plane probably dips steeply, as the limestone dips almost 60° towards NW. —

In the large railway-section ENE of Lappgrubban, steep dislocation planes are distinctly visible in the arkose-like breccia of granite (fig. 29). They dip in various directions, for instance 86° N 15° W, 75° W 40° N, and 60° W 25° N, in the NW side of the section. Other directions are represented in other parts of the section, and on the whole the steep dislocation planes are most obvious in the periphery of the »island» of breccia, where they seem to run more or less

Fig. 29. Section through arkose-like breccia 1.2 km SW of Tandsbyn station, showing steeply dipping (fairly dark) displacement planes, and almost horizontal joints.

parallel to its boundary. There are also joints dipping but slightly towards the north, separating the arkose-like breccia into banks, thus making it appear more or less bedded (figs. 18 and 29). That the dislocating in the breccia took place after the deposition of the Chasmops beds is apparent from the fact that more or less crushed pieces of conglomerate and Loftarstone are found by the steep dislocation planes, as seen in the southwestern part of the section.

We thus find that the breccia-covered Archaean rocks have not remained entirely intact under the pressure that caused such distinct dislocations in the adjoining fossiliferous deposits. Nevertheless, there is no reason to assume that the movements within them were so great as to contribute vitally to the origin of the tectonic features now characteristic of the bedded rocks. The present morphology of the breccia-covered Archaean rocks may thus in all probability be considered to be very much the same as the one existing prior to the deposition of these beds. Its influence upon the development of the tectonic features of the latter should thus be ascribed to the comparatively great resistance of the Archaean rocks. This influence is very clearly demonstrated by the course of the fold running about W—E through the Central Lockne area and closely following the largest depression in the pre-Ordovician topography, which generally speaking must be considered to coincide with the sub-Cambrian.

The interpretation of the tectonic development of the area as outlined above is in accordance with opinions expressed by G. Frödin (1920, pp. 35—37), who in his work on the quartzite-sparagmite formation of the southern mountains of the Caledonides in Sweden also briefly dealt with some geological problems of the Lockne area.

e. The Neighbourhood W, SW, and S of the Central Lockne Area.

This chapter will summarily deal with the district between the northern part of Lake Näckten and the Central Lockne area, where autochthonous fossiliferous Cambrian and Ordovician beds occur. From a purely stratigraphical point of view it has practically nothing new to offer beyond what has already been related from other areas, but certain features seem to be more pronounced here, and they can easily be studied thanks to the fact that the rock is fairly well exposed or in other ways made accessible for studies in one or two parts of the area. This applies to the neighbourhood of Lake Öhntjärn and Kloxåsen, representing two parts which mutually differ with regard to the completeness of the sequence.

The Surroundings of Öhntjärn. Stratigraphically, the parts west of the Central Lockne area are characterized by the absence of Cambrian beds. Lower Ordovician beds, Planilimbata limestone, lower Didymograptus shale, and Limbata limestone, also seem to be lacking; at any rate it has not been possible to find them so far. Here, as around Rosåsen fäb. and Nyckelberg fäb., the Orthoceras limestone is directly deposited on pre-Cambrian rocks (mostly Archaean granite but also dolerite) covered by arkose-like breccia. Their surface has been very uneven and there are indications that they have been in contact with different zones of the Orthoceras limestone series and also with the basal Chasmops beds. In this respect there is thus a similarity to adjacent eastern areas.

The indications alluded to above consist of shallow water deposits, chiefly conglomerates with fragments of pre-Cambrian rocks. One of these conglomerates appears in the Orthoceras limestone, which is clearly demonstrated in a railway-section 250 m W of the southern end of Lake Öhntjärn (fig. 30). This conglomerate which mainly contains fragments of Orthoceras limestone, is interstratified in the upper (red) Orthoceras limestone series and probably corresponds to the basal part of the Platyurus limestone. Coarse and sometimes fairly thick conglomerates are intersected along the railway west of this locality, but due to considerable tectonic disturbances it has not been possible definitely to determine their stratigraphic standing. Since they contain large boulders of red Orthoceras limestone, they must be assumed to correspond to some part of the upper Orthoceras limestone series (possibly parts of the Platyurus limestone) or — which seems most plausible — constitute the basal part of the Chasmops series. In this connexion it should be added that fossiliferous basal beds of Schroeteri limestone without conglomerates have been observed to overlie Platyurus limestone. With regard to the occurrence of Archaean fragments, it may be mentioned that they are generally found in great abundance in the upper part of the conglomeratic beds, this indicating the progress of the denudation in the area that yielded material to these beds.

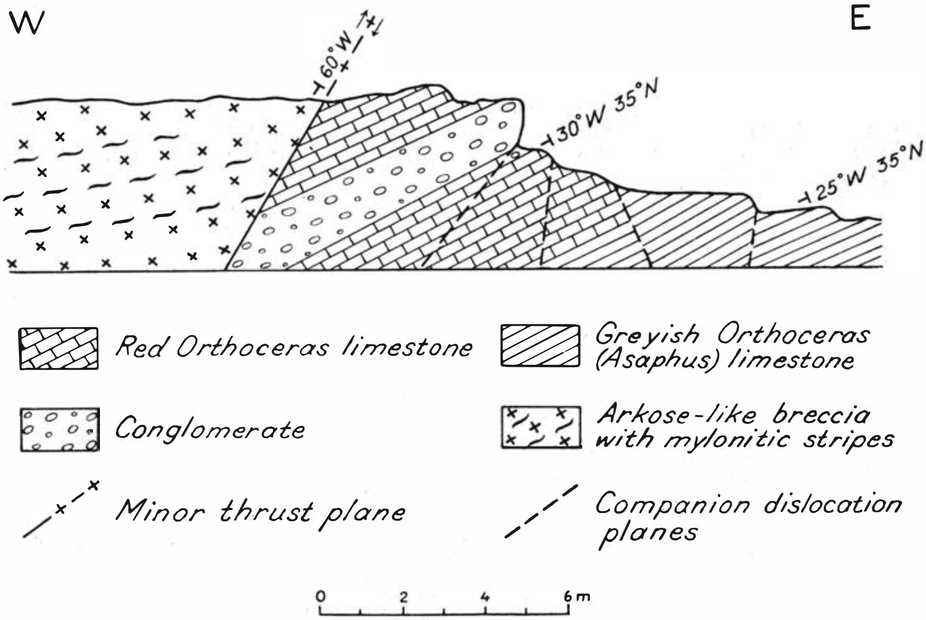

Fig. 30. Railway-section 250 m W of Lake Öhntjärn.

Generally speaking, the Chasmops beds are developed in the same manner as in the neighbouring Central Lockne area. They thus begin with a conglomerate containing fragments of granite, dolerite, and Orthoceras limestone, this conglomerate grading upwards into Loftarstone. Where the basal beds have been observed in their original position, they always rest upon Orthoceras limestone, although on different parts of this limestone in different localities. The pure limestone facies seems to be predominant in the lower Chasmops series. Sometimes, as in the old quarries west of Lake Öhntjärn, it consists of thick-bedded, black, bituminous limestone, towards the top grading into beds richer in shales. Bedding is at times hardly visible, this at least to some extent being a primary feature. In the railway-section about 400 m W of Lake Öhntjärn (fig. 33), the Loftarstone is overlain by grey crystalline limestone in comparatively thin layers, some of which are rich in *Haplosphaeronis* sp. In the first railway-sections 900 m E of Skute station, we find the primary bedding best preserved. Here the appearance of the limestone is similar to that of the limestone in the section just mentioned, but towards N it grades into more thick-bedded, black, bituminous limestone, which has been quarried about 100 m from the railway. Upwards the Chasmops limestone here becomes more shaly and thus successively grades into the upper Chasmops beds, which consist of black shale with concretions or scattered layers of dark limestone. They constitute the uppermost autochthonous beds, towards W being abnormally superposed by Cambrian shales, which form the front of the first overthrust mass.

As mentioned above, the tectonics in the vicinity of Lake Öhntjärn are very complicated, and it has proved impossible to analyse them in detail. The dis-

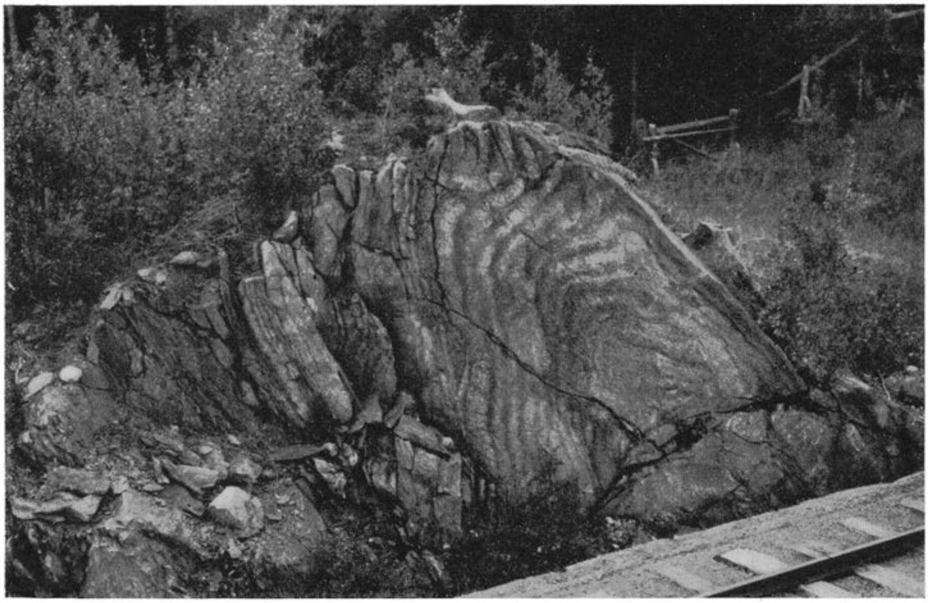

Fig. 31. Overturned fold in front of the Skute Nappe; Orthoceras limestone to the right, crushed basal Chasmops beds to the left.

locations definitely increase in magnitude and the deformations of the rocks likewise become more intense from east to west.

The present tectonic features should be explained by folding and thrusts in connexion therewith. The complications, illustrated by differences in the strikes of the sedimentary rocks and of the thrust planes, are undoubtedly due to the heterogeneous composition of the dislocated rocks. As far as the reaction to pressure is concerned, they may be said to consist of two different components, the fossiliferous, more or less shaly limestones, which have folded easily (fig. 31), and the pre-Cambrian rocks covered by arkose-like breccias, whose resistance has been fairly good. The latter having formed a broken topography in which the former have been deposited, it is not difficult to imagine that the tectonic result of a one-sided pressure, in this case from NW, on a bed-rock of this kind, has produced a confused and broken area.

A few observations must be mentioned here to supplement and explain the more or less schematic profiles in figs. 30, 32, and 50.

The Orthoceras limestone in railway-sections east and southeast of Lake Öhntjärn displays but slight dislocations except folding. The first (break-) thrust of any considerable magnitude has been observed about 300 m E of the lake. Its plane dips steeply, about 75° W 10° N. Asaphus limestone is driven up on the basal Chasmops conglomerate, which is crushed. This conglomerate rests upon Orthoceras limestone which strikes S 20° W—N 20° E. — In the

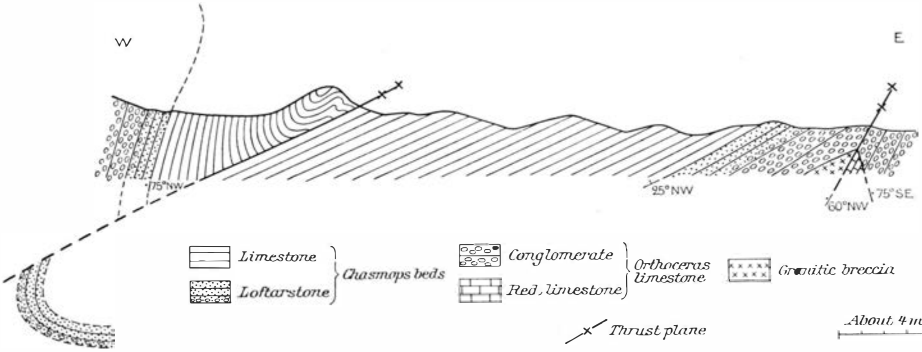

Fig. 32. Railway-section about 350 m W of Lake Öhntjärn.

western part of the large »island» SE of the lake, the arkose-like breccia is distinctly crushed along lines running chiefly in a N—S direction and cut by thrust planes dipping towards NW.

On the western side of Lake Öhntjärn minor thrusts gradually become more common the closer we come to the first overthrust mass. The granite hill close to the western shore of Lake Öhntjärn is partly driven up on Chasmops beds. The plane along which this movement took place can be traced in the Chasmops limestone of the quarry immediately north of the hill. In the railway-section 250 m W of the lake the arkose-like breccia of granite is driven up on red Orthoceras limestone (probably of the Platyurus zone), as shown in fig. 30. The thrust plane dips 60° W. The arkose-like breccia is partly crushed and contains thin slices of mylonite. About 100 m farther west there is another thrust plane, dipping 60° NW; here, too, crushed granite is driven up on Orthoceras limestone. Still farther to the west there are two sections presenting almost completely mylonitized dolerite driven up on Orthoceras limestone. The thrust planes are not so steep here, dipping 35°—45° towards NW. We are now in the area immediately in front of the first nappe, and we find a large number of overthrust planes. In a field bare of wood we here observe a number of large blocks of brecciated granite on top of dislocated Orthoceras limestone, which manifestly are quite rootless (fig. 49, p. 99). They constitute severed and overthrust, probably hilly parts of the substratum of the Ordovician sequence. The folds usually strike N 35° E—S 35° W, and their axis-planes thus form an acute angle to the thrust planes.

The Kloxåsen Area. No Chasmops beds are preserved in the district around the villages of Kloxåsen and Åsan, S of the Central Lockne area and Lake Öhntjärn. The Cambrian series, on the other hand, is well represented, and greatly resembles the one at Brunflo. It begins with a thin conglomerate like that at Brunflo and Mon, probably Lower Cambrian, although no fossils have been observed. The remainder chiefly consists of shales with limestone lenses or beds. In the Middle Cambrian the Œlandicus beds are very thick. At the top of the Middle Cambrian beds there is a thin Exporrecta conglomerate

Fig. 33. Part of the railway-section, drawn in fig. 32. L = Loftarstone.

constituting the uppermost part of a stinkstone bed containing *Lejopyge laevigata* (DALM.). Besides pebbles and granules of phosphatic stinkstone the conglomerate also contains rounded quartz grains in fair quantities. The Upper Cambrian sequence is described by Westergård (1922, pp. 91—93).

The boundary between the Cambrian and Ordovician has the same appearance as at Brunflo. It has been possible to study it in two road-sections at the western farm in Kloxåsen and 0.7 km NE of Åsan. In the former locality the beds are almost vertical, and in the latter overturned. The Ordovician begins with a thin Ceratopyge limestone, rich in glauconite. It is 0.10—0.15 m thick. Its basal part, which chiefly consists of glauconite grains, pebbles and granules of phosphorite, and pebbles of stinkstone from the substratum, cemented with calcite, also contains quartz grains which are generally well rounded. It fills superficial pits of the substratum, this being a bank of stinkstone. At Kloxsåen the latter contains *Peltura minor*, *Protopeltura praecursor*, *Ctenopyge tumida*, *Ct. flagellifera*, and *Ct. flagellifera angusta;* at Åsan *Protopeltura praecursor* and *Ctenopyge flagellifera* have been observed.

The Ceratopyge limestone is covered by greyish green and dark shale with thin layers of limestone. The shale presents the fauna of the lower Didymograptus shale. With one exception the succeeding Orthoceras limestone is of the same appearance as at Brunflo. The exception is the development of the upper red Orthoceras limestone (Gigas + Platyurus zones). Its basal part is replaced by a conglomerate, which mainly consists of fairly well rounded fragments (pebbles and cobbles) of Orthoceras limestone, but also granite and dolerite fragments. At Kullstaberg the conglomerate is 0.7 m thick; 500 m W from there its thickness has been estimated at 4.5 m (Thorslund 1935a, p. 15). The Gigas limestone seems to be lacking here or is possibly partly replaced by the conglomerate.

The Ordovician ends with the Schroeteri limestone, of which only the basal, very fossiliferous beds have been observed.

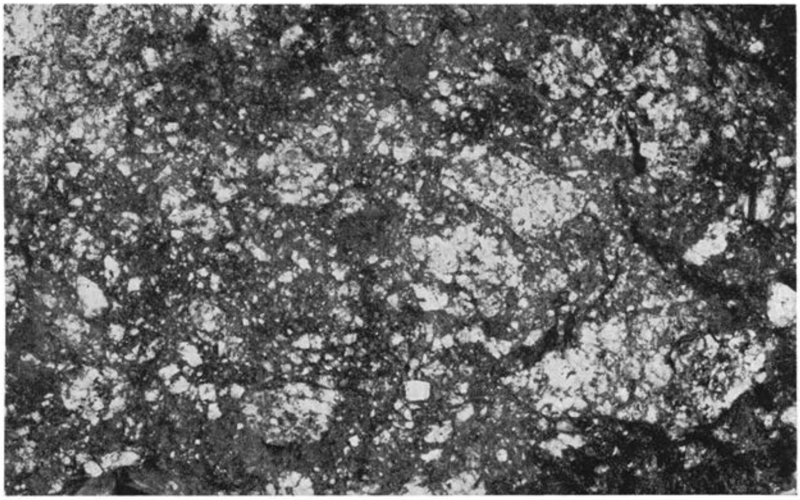

Fig. 34. Section through the arkose-like breccia of granite forming the substratum of the Orthoceras limestone. Kloxåsen. $^{2}/_{3}$ of natural size.

The Cambrian and Ordovician series have been deposited in an island landscape of pre-Cambrian, mostly Archaean rocks, which towards the E and NE form a fairly high precipice, rising above the Cambro-Ordovician beds. Towards the south, these beds form a steep slope, at the foot of which the pre-Cambrian continues as a slightly uneven surface, gently sloping towards NW. Standing on the ridge of pre-Cambrian rocks in the east, it is thus possible to look down upon the Cambrian and Ordovician beds around Kloxåsen, from where there is a view towards the south of a surface of the pre-Cambrian rocks spreading at the foot of the sedimentary rocks.

Where the pre-Cambrian is covered by Orthoceras limestone, it is always covered by arkose-like breccia. A fragment of such a breccia of granite is illustrated in fig. 34 (cf. also Frödin 1920, p. 35, fig. 10). Immediately below the Orthoceras limestone the breccia is often conglomeratic, the fragments being somewhat rounded and the filling material calcareous.

No similar breccia has been observed anywhere under the Cambrian series (cf. Wiman 1899, p. 136). If there is an arkose-like rock under the bottom-conglomerate of the Cambrian, it is probably very thin, as exposures of pre-

Cambrian rocks near Cambrian shales always display fresh surfaces with primary structures. This is clearly demonstrated in the eastern part of the village of Kloxåsen in the valley of Djupdalen, a drainage for a Late-Glacial ice-lake.

The fossiliferous beds are greatly disturbed and folded between the pre-Cambrian »islands». Movements have undoubtedly taken place also in the latter, although it has not been possible to establish this, there being no large sections through them. These movements are no doubt evinced in the same manner as described from the railway-section NE of Lappgrubban. The Ordovician and Cambrian beds on the E—S sides of the »islands» often dip towards these islands, which indicates that displacements of an overthrust type have taken place, even though each of them was of no great magnitude.

N and NW of Kullstaberg, the area in front of the first nappe consists of a very hilly, wood-clad terrain. In the ridges and hills there are here and there exposures of compressed Orthoceras limestone, dipping in various directions. In the hollows, often filled with water with no off-flow, there are probably shales (lower Didymograptus shale and alum shale). They presumably indicate anticlines. The tectonic features are probably similar to those in the neighbourhood of Lake Öhntjärn, but the soil covering has permitted no detailed examinations.

f. The Area between Viken and Mon.

There is little to be said of the stratigraphy of the Autochthon. *Torellella laevigata* (LINRS.) has been found in a thin Lower Cambrian conglomerate at Mon (Thorslund 1931). Middle and Upper Cambrian strongly folded shales are exposed here and there in the slopes around the heights, particularly in the west and south. Autochthonous Ordovician beds occur at least along the road between Sinnberg and Gäle, where they largely consist of lower Didymograptus shale and the lower part of the Orthoceras limestone. Ceratopyge beds have also been observed at Gäle. As is seen in a road-section immediately NW of this village, the autochthonous sequence is partly repeated by an overthrust (fig. 35). Immediately above the overthrust plane, which is indicated by a very thin layer of crumbled alum shale, crushed glauconite shale occasionally occours, containing lens-like lumps of grey glauconite-bearing limestone, which except fragments of trilobites (*Megalaspis?* sp., *Niobe?* sp.), has yielded *Lycophoria laevis* STOLLEY.

Most of the Ordovician series in this area seems to belong to an overthrust mass, although it has not yet been possible to fix its exact limits. This is particularly true of the western part of the area. In the eastern slope the tectonic features are quite distinct. At Blekmyrsved, about 0.7 km NE of Mon, a strongly compressed black shale with lenses of dark limestone rests upon crushed and kneaded alum shale containing lenses of stinkstone, most of which are so greatly deformed that fossils that may have existed are entirely obliterated, but one of them has yielded *Olenus* cf. *truncatus* and *Agnostus* (*Homagnostus*) *obesus*. The black shale contains graptolites, although most of them are very poorly preserved. A fairly good specimen of a *Climacograptus* seems to resemble

Cl. brevis ELLES and WOOD. There are also specimens of *Neurograptus* sp., either *N. fibratus* (LAPW.) or *N. margaritatus* (LAPW.), possibly both.

The presence of these graptolites implies that the black shale corresponds to some part of the upper Chasmops series as it is developed in the first overthrust mass (cf. p. 94). At this locality the shale is about 12 m above Archaean granite, exposed barely 300 m towards SE. It has not been possible to determine whether or not any part of the Upper Cambrian alum shale belongs to the overthrust mass. At any rate it is evident that the overthrust plane here cuts

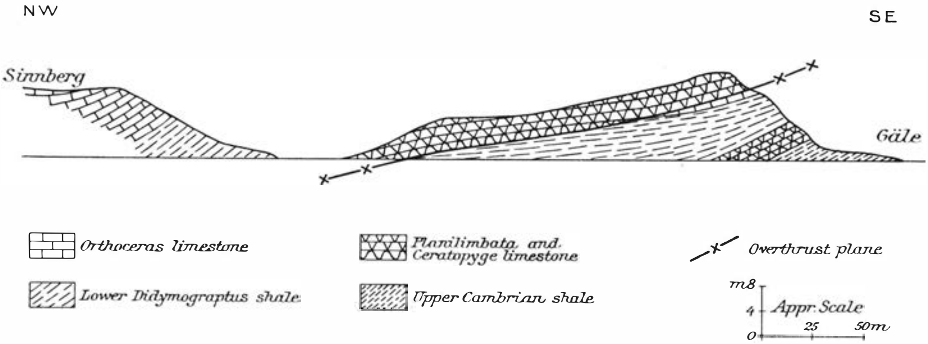

Fig. 35. The road-section between the villages of Sinnberg and Gäle, E of Lake Näckten.

off the autochthonous Cambrian series, as the latter must have been more than 12 m thick. The Middle Cambrian alone probably has this thickness. At a new road-section at Kangsberget, 0.5 km SW of Mon, Œlandicus shale has been penetrated about 8 m, without its upper part being exposed.

In the slope about 300 m NNE of the graptolite-bearing shale at Blekmyrsved there is a small exposure of dark-grey, bedded lower Chasmops limestone, and 100 m SE of that there is an occurrence of Masur limestone, which towards the south and southeast is followed by black, strongly compressed and kneaded shale with large limestone lenses, probably black Trinucleus shale, although no fossils have been found. At the boundary of the Cambro-Ordovician, this shale occurs slightly above Archaean granite cropping out in the bogs in the NE front of the hill. It is thus probable that the overthrust plane at least somewhere goes down as far as the sub-Cambrian surface (fig. 36).

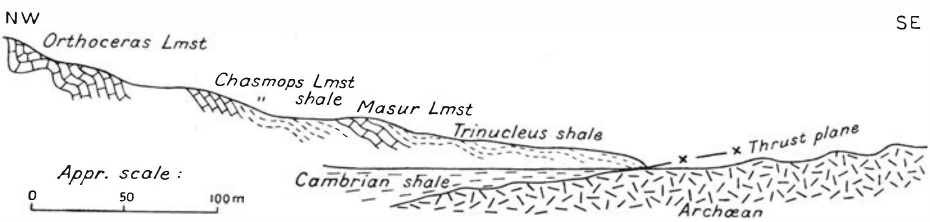

Fig. 36. Schematic profile from the vicinity of Blekmyrsved, 1 km NE of the village of Mon.

In slopes near Mon and also at that locality, Orthoceras limestone occurs directly on the Cambrian shales. The presence of an overthrust plane under the Orthoceras limestone is indicated, *inter alia*, by the absence of Ceratopyge beds and lower Didymograptus shale, and also by the apparent absence of the upper part of Upper Cambrian. — In the slope NE of Gäle the tectonic features are very confused and cannot readily be analysed. The overthrust plane seems to run immediately above the lower Didymograptus shale, on top of which there is much crushed and disrupted Orthoceras limestone. The slope on the other side of the hill, 1.5—2.0 km SE of Viken, presents similar features.

g. **Flon—Målingen—Näckten** (fig. 37).

Along the western shore of Lake Näckten south of the bay of Månstaviken to the village of Näcksta, there is a narrow belt of autochthonous Cambrian beds, whose main part consists of Middle Cambrian Œlandicus shale. This belt becomes wider SE of Näcksta, where also Ordovician beds are preserved. On Lake Målingen they are represented by Chasmops beds; otherwise Orthoceras limestone is the only Ordovician rock observed.

On the shore of Näckten N of Högtjärn there is an exposure of Œlandicus shale, overlying a thin conglomerate, about 0.2 m thick. It rests upon granite, but in the immediate proximity there is a dolerite dike running N—S. South of this locality there is folded Orthoceras limestone in a hill in whose southeastern slope Olenus shale is exposed. About 200 m to the south the contact between the granite and the Cambrian has also been observed. NW of Högtjärn there is another hill consisting of folded Orthoceras limestone.

Rather considerably disturbed Cambrian and Ordovician beds are well exposed along the outflow of the rivulet Lillån at Lake Flon. In the section on the northeastern side of the rivulet, Cambrian beds are seen in contact with the Ordovician, and the contact conditions look exactly the same as at Kloxåsen. The Ordovician thus begins with a glauconite limestone filling corrosion pits in stinkstone containing *Protopeltura praecursor* and *Ctenopyge flagellifera*. Greenish grey shales containing limestone layers are found here and there above the glauconite limestone, and are then followed by reddish and grey Orthoceras limestone. The beds are folded and faulted and seem to be pressed into a depression in the granite, which rises quite steeply, particularly towards NE, in a ridge whose crest is very much higher than the surface of the Orthoceras limestone. Œlandicus shale rests upon this granite, as is seen in a quarry by the road. The shale and the bed immediately below it, a thin conglomerate rich in pyrite and adhering to the granite, dip 30° towards W. The granite is compressed and partly brecciated. A loose-cemented breccia (probably subjected to secondary weathering) is visible by the road about 100 m W of Lillå farm.

By the road north of Lake Flon there is an old lime-kiln standing in Orthoceras limestone which is covered by a conglomerate containing fragments (pebbles and cobbles) of grey Orthoceras limestone (Asaphus limestone).

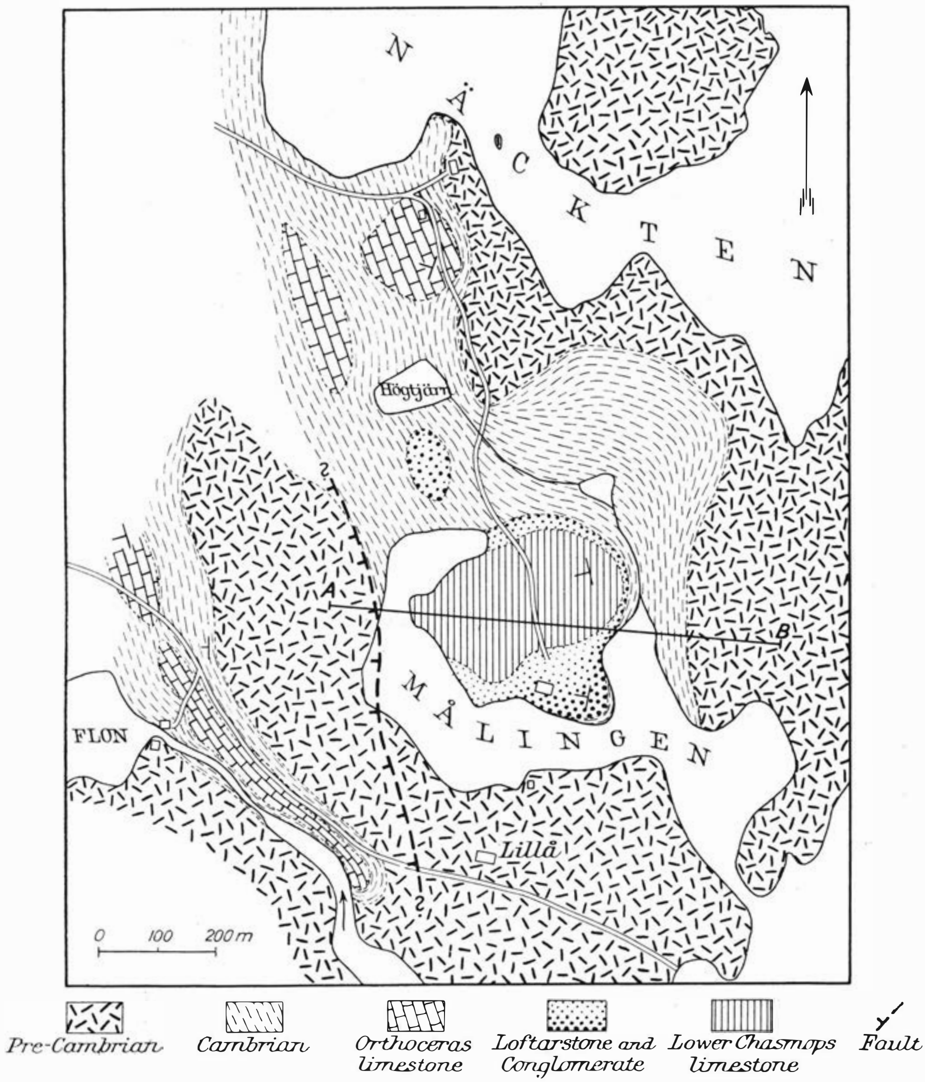

Fig. 37. The area around Lake Målingen.

Megalaspis limbata and *Nileus* sp. have been found in reddish grey limestone about 1 m below the base of the conglomerate. This conglomerate possibly corresponds to the one at the base of the Platyurus limestone at Kullstaberg and at other localities.

The Chasmops beds on Lake Målingen begin with a conglomerate 2--2.5 m thick, mainly built up of pebbles and cobbles of grey and reddish grey Orthoceras limestone and pieces of shale. There are also pebbles of Cambrian stinkstone, one of which contains *Ctenopyge flagellifera* and *Protopeltura* sp., another *Parabolina spinulosa*. Fragments of pre-Cambrian rocks are not common but do occur at least in the uppermost part of the conglomerate, which grades into Loftarstone rich in calcareous matter. That in turn similarly grades into shaly Chasmops limestone. The conglomerate rests upon Œlandicus shale, which is best seen in the southeastern point of the promontory in Lake Målingen. There are numerous boulders of a thin conglomerate by the outcropping Archaean rock on the other side of the bay. It resembles the conglomerate under the Œlandicus shale at other localities in the neighbourhood.

The Chasmops beds apparently lie in a syncline, probably bounded towards the west by a fault. This is indicated, *inter alia*, by the fact that the granite west of Lake Målingen rises steeply above the upper surface of the Chasmops

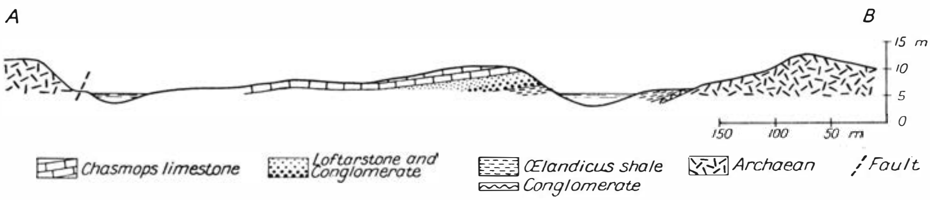

Fig. 38. Profile (A—B) from the Lake Målingen area. The location is indicated in fig. 37.

beds, and that it is greatly fissured and at least in some places distinctly crushed (cf. above). The Cambrian and Ordovician beds on Lake Flon and Lake Målingen may thus be said to lie in synclines on either side of a faulted anticline, in this instance represented by the granite ridge between the two waters.

h. Åsarna.

SSW of Lake Målingen autochthonous Chasmops beds are found in the parish of Åsarna, where they have been observed in three places, about 2 km NNW of Åsarna church, at the village of Hallen, and in the mountain Gammelboberget (fig. 39). In all three places they occur immediately below an overthrust mass mainly consisting of Vemdal quartzite.

The first observations of Chasmops beds in this parish were made in 1932 during investigations superintended by Dr. B. Asklund. On that occasion only the surroundings of the village of Hallen were visited. Subsequent examinations by the writer have resulted in some supplementary observations, but they afford little information beyond what is already included in Asklund's report (1933) on the geological conditions at Hallen.

The Chasmops beds rest everywhere upon the Orthoceras limestone series which is developed similar to the one at Brunflo. The lower part of the Ordovician consists of a thin Ceratopyge limestone rich in glauconite, and lower Didymograptus shale above it. As is seen in a road-section in the SE part of the village of Hallen and in the southern slope of Gammelboberget, the Orthoceras limestone is dislocated and in places fairly strongly folded. Its upper part consists of Schroeteri limestone, which in the central part of the village of Hallen and NNW of Åsarna church is almost horizontal, with a maximum dip of 5° towards W. According to measurements carried out by Dr. J. Öster in 1933, the Schroeteri limestone is about 32 m thick at the latter locality.

The best locality for a study of the Chasmops beds is in the slope east of the central part of Hallen. In a road running eastwards from the village, outcrops of Orthoceras limestone are seen here and there, and above them *in situ* blocks

Fig. 39. Geological sketch-map of the Åsarna area. Examined outcrops indicated; A = Cambrian beds, O = Orthoceras limestone, Ch = Chasmops beds. Scale 1 : 200 000.

of conglomerate, typical Loftarstone and lower Chasmops limestone. The conglomerate contains rounded fragments of limestone and Revsund granite, one of the latter measuring 15 cm. About 5 m above the conglomerate there is an outcrop of mylonitized granite, this being a small enclosure in the overthrust quartzite mass and situated at the base of it. This enclosure is probably a severed portion of the primary substratum of the Vemdal quartzite (Asklund 1933, p. 52). An uppermost thin part of the Chasmops limestone is bluish-black, hard, jointed, and silicified, thus showing signs of having been exposed to great pressure, but remaining parts of the Chasmops beds are quite »normal» and contain well-preserved fossils. In a profile exposed by digging immediately south of the road the sequence is as follows, in descending order:

Flat lenses of impure, dark-grey limestone with thin interstratifications of shale, thickness	> 0.5 m
Bedded, fairly pure, dark-grey limestone, each bed 5—6 cm . .	abt. 0.4 m
Very thin-bedded dark-grey calcareous sandstone or arenaceous limestone	0.08—0.1 m
Conglomerate	0.2—0.22 m.

Dark-grey, fairly pure limestone in beds or elongate lenses with thin layers of shale. This limestone greatly resembles the Chasmops limestone above the calcareous sandstone. Towards the bottom of the section it becomes richer in shaly material, and 0.6 m below the conglomerate the limestone is light-grey, nodular, and resembles a somewhat weathered Orthoceras limestone.

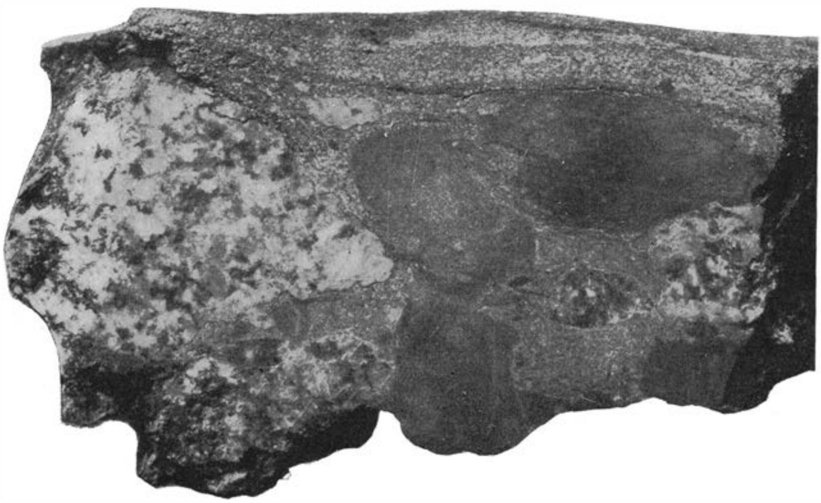

Fig. 40. Chasmops conglomerate with pebbles of Revsund granite and dark-grey Orthoceras limestone, overlain by typical Loftarstone. Partly polished section of a loose block from Hallen, Åsarna. Natural size.

The Chasmops limestone is comparatively poor in fossils, but as mentioned above, those that do exist are well preserved. Generally, trilobites and scattered brachiopods are the only fossils found, the first-mentioned including: *Chasmops conicophthalma* (SARS & BOECK), *Asaphus ludibundus* TQT., *Illaenus* cf. *parvulus* HOLM, *Stygina* ? *nitens* (WIMAN), *Remopleurides* sp., and *Ampyx* sp.

The calcareous sandstone in the profile is a very fine Loftarstone sometimes displaying cross-lamination. Coarser Loftarstone in its typical development (fig. 40) occurs in the vicinity in much thicker beds, max. 0.4 m. These variations must probably be explained as being due to current conditions during sedimentation, and they may also indicate that the Chasmops beds were deposited on a somewhat uneven surface, developed by denudation.

The calcareous sandstone and the conglomerate occur together in one bank which thus is about 0.3 m thick (fig. 41). The conglomerate is polymict and the rounded fragments vary in size. Most of them consist of Orthoceras limestone, grey, light-grey, and sometimes faintly reddish brown. Fragments of granite are next in number. They are concentrated to the upper part of the conglomerate, where they sometimes attain considerable sizes (cf. above).

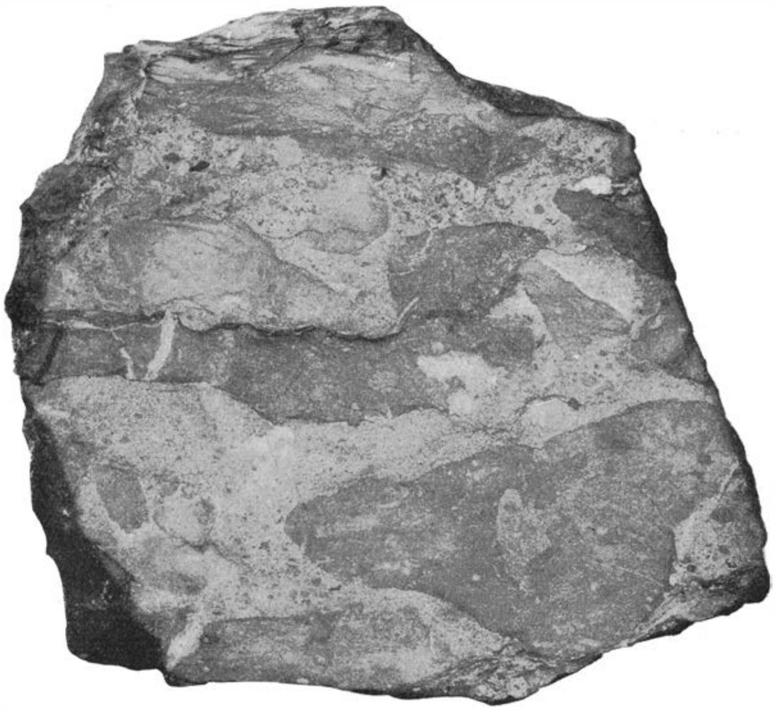

Fig. 41. Part of the Chasmops conglomerate in the Hallen section, showing the abundance of calcareous matrix. Large pebbles of grey and dark-grey Orthoceras limestone. Small pebbles and granules of granite and black Cambrian stinkstone in the upper part, close below the arenaceous limestone at the top. Polished vertical section. 1/2 of natural size.

Small fragments of granite are found, however, throughout the whole conglomerate, also at its base. Pieces of black shale are rarer and only one pebble of Cambrian stinkstone has been found. It contains *Agnostus* (*Homagnostus*) *obesus* and fragments of *Olenus* sp. The matrix makes up about one-third of the rock and consists of grey, crystalline limestone with scattered grains of the same rocks as in the large fragments. It is rich in fossils, particularly ostracoda and fragments of trilobites occurring in large numbers. The list of fossils includes the following: *Asaphus ludibundus* TQT, *Illaenus warburgae* n. sp., *Illaenus parvulus* HOLM, *Remopleurides* cf. *latus* OLIN, *Pseudosphaerexochus* sp., *Ceraurus* sp., *Cybele* sp., *Lonchodomas rostratus* (SARS); *Steusloffia costata* LINRS., *Conchoprimitia leperditioides* n. sp., *Conchopr. elongata* n. sp., *Primitia ? eutropis* ÖPIK, *Pr. ? locknensis* n. sp., *Rafinesquina dorsata* BEKKER, *Sowerbyella* sp., *Echinosphaerites* sp. This fauna thus embraces representatives typical of the lower Chasmops limestone and in addition a couple of ostracod species otherwise only met with in the conglomerate at Öd.

The limestone immediately below the conglomerate contains but few fossils. Indefinable fragments of trilobites and *Conchoprimitia hallensis* n. sp. (similar to *Conchopr. leperditioides* n. sp. and very likely closely related to it) have been observed and also *Echinosphaerites* sp., the latter common in limestone about 0.1 m below the conglomerate. The more shaly limestone in the lower part of the profile contains a large number of ostracoda, but they seem to represent other forms than those occurring in the conglomerate.

NW of this locality there are Chasmops beds, at times represented by conglomerate and Loftarstone only, immediately below Vemdal quartzite, which is separated from them by a bed of mylonite about 1 m thick. Similar conditions prevail in the precipice 2 km NNW of Åsarna and in the southern slope of Gammelboberget. In the first-mentioned locality Chasmops limestone (with *Echinosphaerites aurantium* and *Asaphus ludibundus*) has an observed thickness of 3 m under the quartzite precipice. In Gammelboberget the quartzite lies like a cap on top of the Ordovician beds, which are exposed in the southern slope. Most of the Orthoceras limestone series seems to be intersected and in certain parts it contains a fair quantity of shaly material. The limestone beds thus alternate with beds of shale, which may reach the same thickness as the former. The thickness is very great; by means of barometric levelling it has been estimated at 88 m. The basal part of the Orthoceras limestone series not being exposed, however, and there also being small dislocations in the exposed series, this figure is not exact, but is only a rough estimate. As is the case at Hallen, the Orthoceras limestone is here overlain by conglomerate, Loftarstone (0.2—0.3 m), and Chasmops limestone.

2. Summary Account of the Autochthonous Chasmops Series.

The object of this stratigraphical investigation mainly being the Chasmops series, the above description may possibly appear too extensive. The question may arise, for instance, what connexion there is between the stratigraphy of the Cambrian and the pre-Chasmops part of Ordovician on the one hand, and the development of the Chasmops series on the other. The writer has found, however, that in order to acquire definite knowledge of the latter, it is necessary to study the former. In other words, the conditions under which the Chasmops series was deposited are considered linked up with and to a great degree explained by the geological development during the Cambrian and Lower Ordovician epochs. This statement will be further explained below on the basis of the evidence contained in the above description and in earlier literature. It will be found that such an account also throws light upon other geological problems and contributes to their solution.

a. Distribution.

The distribution of the autochthonous Chasmops series in Jemtland is fairly limited. Its northern boundary runs immediately north of the middle of the Bay of Brunflo; the southernmost isolated occurrences are met with in the parish of Åsarna. It is most extensive, however, between the Bay of Brunflo and Lake Locknesjön on one side and Lake Näckten on the other. Chasmops beds also occupy a small area on the western shore of Lake Näckten.

Only on rare occasions has the series been found overlain by autochthonous beds. It generally forms the uppermost part of them, or it is covered by overthrust masses, sometimes fossiliferous beds, sometimes — as in the parish of Åsarna — by Vemdal quartzite with comparatively small portions of Archaean rocks immediately above the overthrust plane.

b. Stratigraphy and Development.

From a faunistic point of view the Chasmops series may be divided into two zones, comprising the upper and lower Chasmops series. *Chasmops conicophthalma* (SARS & BOECK) and closely related species may be mentioned as zone fossils of the former, and *Chasmops extensa* (BOECK) and *Ch. macroura* SJÖGREN[1] of the latter. This classification corresponds to that proposed by Linnarsson in 1882 (see p. 7). Although the classification may be considered fairly rough, it is impossible to make a further subdivision on the basis of the fossil material so far available. It should also be pointed out that a division of this series into a greater number of zones might be facilitated by investigations in areas where the beds are less disturbed than in Jemtland.

The Middle Ordovician of Jemtland has earlier been very little known both with regard to stratigraphy and development. This is apparent from the fact, among others, that certain parts of the Chasmops series were earlier classed amongst the Orthoceras limestone series, and were looked upon as facies developments of certain parts of that series. Moreover, no reports have earlier been made of observations of upper Chasmops beds. Even though the writer's investigations do not occasion a new subdivision of the Chasmops series, they do involve a number of corrections of earlier misconceptions and a more specific definition of what should be included in that series.

The lower Chasmops beds begin with true shore deposits. There is usually a polymict conglomerate at the base, generally with rounded fragments of Ordovician, Cambrian, and pre-Cambrian (mostly igneous) rocks. It has often been observed that the fossiliferous fragments are most plentiful in the lower part of the conglomerate, while the pre-Cambrian fragments are concentrated at the top. The conglomerate is followed by and successively grades into a sandstone of characteristic appearance, the so-called Loftarstone. This con-

[1] It has not yet been established if *Chasmops macroura* is identical with *Ch. extensa*, although the identity seems probable (cf. Störmer 1940, p. 138).

sists of finer products of the rocks that make up the conglomerate, cemented by calcareous mud and calcite. The thickness of the conglomerate and of the Loftarstone varies from place to place. This variation may be explained by reasons that will be discussed below. No identifiable fossils have been found in the Loftarstone, only fragments of valves. In the matrix of the conglomerate, on the other hand, especially where it is profuse, a fairly rich fauna has been encountered containing elements that may be said to constitute index fossils of the lower Chasmops limestone (see p. 67).

The Chasmops beds sometimes rest upon an arkose-like breccia of pre-Cambrian rocks. This is the case in the Central Lockne area, where they sometimes begin with a conglomeratic rock, called conglomeratic breccia on the map, Pl. 13. This sedimentary rock, which should be interpreted as a redeposited upper part of the arkose-like breccia, consists of sharp-edged or slightly worn fragments of the same rocks as in the underlying breccia, towards which it has a diffuse boundary (see p. 44). It is superposed by limestone, the basal part of which contains scattered fragments of pre-Cambrian rocks. It wedges out towards high parts of the arkose-like breccia, which thus occasionally is directly covered by fragment-bearing limestone. The maximum thickness of the conglomeratic breccia, which stratigraphically corresponds to the basal Chasmops conglomerate and Loftarstone, is estimated at 0.5 m.

Above these basal beds comes a series of strata rich in limestone, the lower Chasmops limestone. It displays local variations in its composition, especially in the Central Lockne area. It is usually developed as a bedded, grey, or dark-grey limestone with shaly material or thin layers of shale at the bedding planes. The lowest beds, immediately above the Loftarstone, are argillaceous, and the usual sequence is thus Loftarstone — argillaceous, bedded limestone — pure, bedded limestone. This transition takes place within 0.5 m.

Here and there the bulk of the lower Chasmops limestone contains much shaly material in which the limestone chiefly forms small lenses or nodules arranged in layers. This is specially the case in the Central Lockne area. There we find two facies developed, one rich in shale and one of pure limestone, between which transitions exist. The shaly facies always overlies Loftarstone, while the pure limestone facies follows immediately on top of the conglomeratic breccia, or sometimes directly on top of the arkose-like breccia (cf. above). In the border area between the two facies we find more or less thick beds of pure, sometimes conglomeratic limestone, interstratified with shaly beds. A schematic description of the stratigraphy of the lower Chasmops series will thus be as follows:

Limestone facies, rich in shale, 15—20 m	Pure limestone facies, abt. 20 m
Loftarstone, Conglomerate } max. 4 m	Conglomeratic breccia, max. 0.5 m

The fossils found in the lower Chasmops beds are listed on p. 00. The difference in the composition of the fauna of the pure limestone facies and the shaly facies of the lower Chasmops limestone of the Central Lockne area has been touched upon on p. 49. In order better to illustrate this difference, however, more material is required than that so far collected, also of other groups than trilobites and ostracoda.

The autochthonous upper Chasmops beds seem to form an uninterrupted continuation of the lower Chasmops limestone. They are characterized by the fact that they contain graptolite-bearing black shales. In the two areas where they can be studied, their development differs somewhat. In the Central Lockne area they thus consist chiefly of black shales with subordinate intercalations of black limestone in the form of beds or stinkstone-like lenses. Between Slandrom and Namn, on the other hand, limestone seems to be predominant in the upper Chasmops beds, and there we find them built up of bedded dark-grey and (at the top) black limestone, interstratified with more or less thick layers of black shale.

The thickness of the upper Chasmops series has been estimated at 10—15 m. No exact statement of the thickness can be given, for one thing because it has not been possible to establish the lower boundary. Between beds containing fossils typical of the lower Chasmops series and beds with a true upper Chasmops fauna, there are passage beds, consisting of dark-grey, bedded limestone with thin layers of shale. From these beds, which are exposed for instance in a railway-section about 500 m SSW of Tandsbyn station, only a few fragmentary fossils have so far been obtained (*Asaphus* sp., *Remopleurides* sp., *Steusloffia costata*), which do not afford sufficient information to determine in which subdivision these beds may be included.

A list of fossils found in the upper Chasmops series will be found on pp. 184—187. In addition to the ones mentioned there, many brachiopods and bryozoans have been observed in the Central Lockne area. Among the first-mentioned »*Orthis*» cf. *argentea* (HIS.) is very plentiful. Graptolites have been found only in the lower half of the upper Chasmops series. Unfortunately they have suffered much from pressure, for which reason it is hardly possible definitely to identify the species.

The upper Chasmops series is followed by Masur limestone, the lower part of which consists of black, bituminous, nodular, hard, thick-bedded limestone, in which no fossils have been found. Its upper part, consisting of dark-grey, bedded limestone with thin layers of dark shale, has been found to contain *Tretaspis seticornis* (HIS.), which intimates that at least this part should be included in the Trinucleus series, and probably the boundary between it and the Chasmops series should be drawn at or near the base of the Masur limestone, possibly in its lowest limestone bed.

c. Conditions Prevailing during the Formation of the Chasmops Series.

A study of the composition and development of the autochthonous Chasmops series in different areas allows us to form a fairly good opinion of the conditions prevailing during the deposition of the series. In this respect the Chasmops series in many ways offers better possibilities than most other subdivisions of the Cambro-Silurian of Jemtland.

The above description presents facts indicating that the autochthonous Chasmops series of Jemtland may on the whole be said to have been formed during a transgression. This also seems to be true at least of the lower Chasmops series in other parts of Sweden, and there are indications that this is the case in corresponding Ordovician series of certain other countries.

The Eastern or Southeastern Coastal Region. In order to obtain a complete picture of the conditions at the time when the series in question was formed, due consideration should be given to the earlier geological development, as it can be deduced from the underlying Cambro-Ordovician deposits.

Earlier investigations (Wiman 1894 and 1899) have shown that in several places in the eastern Storsjö area the Cambrian begins with a basal conglomerate. It has later been disclosed (Thorslund 1931) that this conglomerate belongs to the Lower Cambrian and that the fossiliferous Lower Cambrian series becomes thicker towards the west. The latter condition indicates the direction of the transgression during the Lower Cambrian inundation. This is a fundamental feature in the Cambro-Ordovician history of Jemtland, stratigraphical investigations having disclosed that an eastern coast was repeatedly denuded in connexion with changes of sea-level and thus confirming the general suppositions of Th. Vogt (1924) and Asklund (1929).

The evidence proving the existence in central Jemtland of an eastern shore of the sea during Cambrian and Ordovician times is thus chiefly of a stratigraphic character. In the autochthonous Middle and Upper Cambrian series conglomerates are occasionally found, while the corresponding parts of the sequences in the overthrust masses in the middle Storsjö area lack such conglomerates and are more complete, consisting as they do of dark or black shales with limestone lenses. In these series it is only the Forchhammeri beds that indicate that the pre-Cambrian substratum has been exposed, these beds being represented in the Autochthon by the Exporrecta conglomerate, containing quartz grains. Similar conditions can be traced in the basal Ordovician beds, where the Dictyonema-Ceratopyge series in the eastern exposures consists of a thin, partly conglomeratic limestone with a small content of quartz-grains (Ceratopyge limestone), but towards the west in the overthrust masses (e. g. on the island of Frösön) is built up of Dictyonema shale as well as nonconglomeratic limestone.[1] The autochthonous Orthoceras limestone series supplies positive proof that it was deposited off a coast of pre-Cambrian rocks and also that the deposition took place during changes of sea-level. In the areas S and SW of Brunflo we could thus see that different zones of this limestone series rest on a substratum of weathered pre-Cambrian rocks. The changes of sea-level are there evinced by the fact that certain zones are at least partly developed as conglomerates in the neighbourhood of outcropping parts of this substratum; on the Bay of Brunflo they are proved by the presence of corrosion surfaces between different zones and sometimes (as between the Asaphus and Gigas zones at Fugelsta) these corrosion surfaces contain mud cracks.

Other clear proofs of changes of sea-level during the Ordovician period emanate from the time when the Chasmops beds began to be deposited. A fairly long period of denudation must have preceded this sedimentation. This is shown partly by the fact that the basal Chasmops beds rest upon different zones of the Cambrian and Lower Ordovician sequence and on weathered pre-Cambrian rocks, partly by their containing an abundance of fragments from the underlying rocks, which fragments are spread over a large area. It is actually possible to form a general opinion of the probable appearance of the eastern coastal land at the time of the inundation by the Chasmops sea, and as regards one part it is even possible to make a fairly accurate reconstruction of the morphological picture.

It is probably safe to state that the coastal zone in the east during the time in question was of the same general form and morphological development as the area next to the present boundary of the Cambro-Ordovician. We must assume that this area was liberated from its covering of fossiliferous beds in relatively recent times, and we here find fissure fillings of Ordovician sediments, probably of Chasmops age (cf. p. 28). The coastal zone thus generally speaking coincided with the western border zone of the mountain region of present-day Inner Norrland, built up of pre-Cambrian rocks. These rocks formed a landscape of small hills, large areas of which displayed a fairly uniform and distinct slope towards NW or WNW. This was in all probability the case in the area east of the present boundary of the Cambro-Silurian, which runs E and NE of the Bay of Brunflo, and also in the similarly situated area SE—SW of the northern part of Lake Näckten. Scattered heights towered here and there above the general slope in the coastal zone. Such a height is now denoted by the present mountain Gålberget (see fig. 39).

In the surroundings of Lake Locknesjön there was a portion protruding from the highlands of Inner Norrland, a peninsula gashed by small bays, in the upper parts of which the pre-Cambrian rock was exposed above the fossiliferous pre-Chasmops deposits remaining in the depressions. The coastal line can even to-day be followed fairly accurately in the Central Lockne area

[1] As regards the development of this series, it must be considered remarkable that so far no Obolus conglomerate has been found in the east, there being reason to assume that the pre-Cambrian rock was exposed close to the present eastern boundary of the Cambro-Ordovician at the beginning of the Ordovician period.

(Pl. 13) and immediately southeast of that area. Outside this coastline scattered parts of the pre-Cambrian rock appeared as islands cropping out of the Orthoceras limestone. We can here form a conception of the appearance of the coastal zone also in areas farther away from the present boundary of the Cambro-Ordovician, from where the fossiliferous beds have now been removed.

The area immediately NE of Lake Locknesjön in all probability constituted the northern part of the peninsula in question. Here we see an example of the part of the coastal zone that is located near the present boundary of the Cambro-Ordovician, but nevertheless lacks remains of covering fossiliferous deposits. The upper part (the Schroeteri limestone) of the Orthoceras limestone at

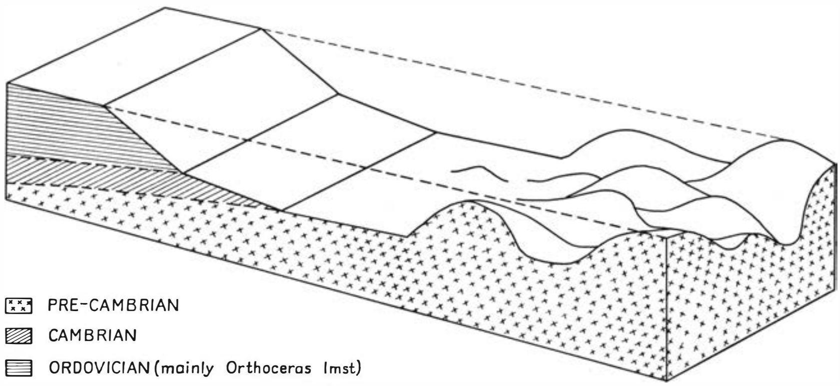

Fig. 42. Diagram of the morphologic elements in the boundary region between the Cambro-Ordovician strata and the Pre-Cambrian rocks (after Hjulström 1936).

Lunne is to-day on a level with the heights around Lake Hornsjön which are built up of pre-Cambrian rocks. The schematic picture of the present morphological state of this area, as outlined by Hjulström (fig. 42), also shows how we should imagine the appearance of the coastal zone in early Chasmops times. We must naturally imagine that pre-Chasmops deposits then at least partly filled the depressions in the pre-Cambrian rock.

As pointed out above, stratigraphical investigations have disclosed that the Cambro-Ordovician deposits under the Chasmops beds wedge out towards E or SE in Central Jemtland and that they sometimes are partly replaced by conglomerates. There thus existed an eastern coast already at the time when the oldest Cambrian beds were deposited. This was first suggested by Th. Vogt (1924) and the conception was adopted by Asklund (1929), who in subsequent works has been able to throw more light upon this question, according as evidence has been obtained thanks to stratigraphical examinations of fossiliferous strata. It was earlier believed that the sub-Cambrian surface along the present eastern boundary of the Cambro-Silurian continued towards E and SE above, or possibly (e. g. near the boundary) in the peaks of the highland of Inner Norrland. This interpretation was further elaborated and illustrated by G. Frödin (1920), who pointed out, however, that the broken Archaean ground of the Lockne area must be considered to have been part of the sub-Cambrian denudation relief, and not to have been caused by subsequent movements (faulting, etc.). At that time, however, the fairly common occurrence of the coarse-clastic basal strata of the Chasmops series outside the actual Lockne area was not known; neither was it known why these strata were lacking in the Ordovician towards the north. It was also taken for granted that the slope of the sub-Cambrian surface towards W and NW had had the same gradient outside as inside the areas that are now covered by Cambro-Silurian sediments. In other words, it was assumed that the regional Caledonian deformation which was believed to have caused the slope of the sub-Cambrian surface in the eastern belt of the present Cambro-Silurian area, had had the same influence throughout considerable areas E and SE of this belt.

According to Asklund (cf. 1938, p. 12) a sub-Cambrian peneplain with Monadnocks spreads out with practically intact relief like a belt of varying width along the present eastern boundary of the Cambro-Silurian. This peneplain is said to have a distinct boundary towards E and SE, where the pre-Cambrian landscape rises one hundred and even several hundred metres above the sub-Cambrian base-levelled plain.

Some observations have been made, however, that modify Asklund's picture briefly sketched above. By a combination of the stratigraphical facts available and morphological studies of the areas of Central Jemtland concerned, Hjulström (1936) found that the picture must be considered far too schematic. The same conception is reached upon making a closer study of a few new stratigraphical observations.

In the basal Chasmops conglomerate, where it covers the uppermost part of the Schroeteri limestone in localities outside the Lockne area proper, there are also some fragments of fossiliferous stinkstone from Cambrian beds. They are sometimes fairly common, for instance in the railway-section at Torvalla, where they are represented, *inter alia*, by stinkstone from the lowest zone of the Upper Cambrian (p. 19). They must have come from the east, or, as far as the Torvalla section is concerned, probably from SE, and they occur together with fragments of such pre-Cambrian rocks (Revsund granite, Åsby dolerite) as now form the solid rock towards E and SE. Their presence in the conglomerate cannot be explained but by the fact that in early Chasmops times Cambrian beds had such a high position in the coastal area towards E and SE that material from them could be broken loose and carried out above deposits that were stratigraphically higher. This can hardly have been the case if we accept Asklund's explanation of the appearance of the costal area in sub-Cambrian and early Cambrian times. A more plausible explanation of this circumstance is that no real sub-Cambrian peneplain was developed, but that the undulating substratum of pre-Cambrian rocks on which the fossiliferous sediments were deposited, had a generally uniform and decided slope towards W and WNW. But even with this interpretation we cannot very well avoid the assumption that epeirogenic movements occurred, placing the Cambrian beds in a position explaining the presence of the stinkstone fragments in the basal Chasmops beds. If this assumption be correct, the unconformity between the Chasmops beds and the underlying Ordovician and Cambrian deposits actually indicates the presence of a nonconformity or angular unconformity (fig. 43). It has not been possible to establish this nonconformity directly, however, maybe due to it having been effaced by subsequent (Caledonian) orogenic movements, and furthermore because the angle between the beds in question very possibly is so small that it cannot be discerned in the small scattered sections.

On Lake Näckten and SE of its northern part, the undulating sub-Cambrian surface rises almost continuously towards SE from the boundary of the Cambro-Ordovician. Immediately N of the rivulet Lillå the basal Chasmops conglomerate rests upon Middle Cambrian shale a few metres thick (cf. p. 64). The

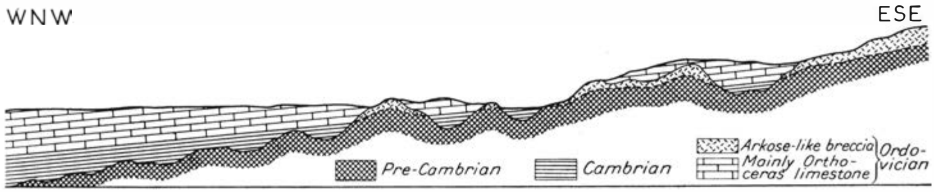

Fig. 43. Profile through the eastern coastal region of Central Jemtland, according to the writer's conception of its appearance in early Chasmops times. The uppermost line denotes the surface on which the Chasmops beds were deposited.

conglomerate contains, *inter alia*, fragments of pre-Cambrian igneous rocks. The Cambrian begins with a thin conglomerate in which no fossils have been found. Nor have any been found in the very thin conglomerate (about 0.1 m thick) that separates Œlandicus shale from granite in the section by the road immediately W of the Lillå. This conglomerate very likely forms the base of the Middle Cambrian. — By the rivulet through Mon there is an exposure of Lower Cambrian conglomerates containing *Torellella laevigata* (LINRS.). The hill Kangsberget rises a few hundred metres S of this locality, and is built up of Cambrian shales with Orthoceras limestone at the top, the latter probably overthrust. Here the sub-Cambrian surface is at least 10 m above the conglomerate at Mon, and the Middle Cambrian rests directly upon intact granite, as seen in a new road-section in the southern slope of the hill.

These observations from the area around Lake Näckten also disclose facts which do not go well with the conception of a true sub-Cambrian peneplain being developed in front of the present boundary of the Cambro-Silurian, and yet the data have been collected in an area that earlier was looked upon as a typical part of such a peneplain (cf. Frödin 1920, p. 33, Asklund 1933, p. 45).

Even though, as pointed out above (p. 73), we must imagine that the pre-Cambrian rock in its present aspect in front of the Cambro-Ordovician boundary is generally similar to the one existing at the time of the Chasmops transgression, this is no rule without exception. Subsequent movements, probably Caledonian, have modified the picture, and in many instances undoubtedly intensified the relief. Good examples can be quoted from the area around Lake Locknesjön, where the contact between the pre-Cambrian rocks and the Chasmops beds is now at such different levels that it must be secondary and caused by faulting or overthrusts in post-Chasmops time. A modification of the topography of the area by denudation may certainly also have occurred, particularly in the Quaternary, but that can hardly have had any great influence on the general morphological features.

The fact that the basal Chasmops beds contain profuse quantities of fragments of pre-Cambrian rocks implies in itself that the appearance of the eastern coastal zone in early Chasmops time was partly different from its appearance at the time of the Cambrian inundation. The conglomerate in the Orthoceras limestone contains similar fragments, although more scarce and only occurring in the coastal zone and there where pre-Cambrian rocks were exposed. Fragments of Cambrian rocks have never been observed in this conglomerate. Where the autochthonous Ordovician beds do not rest upon Cambrian deposits, their substratum everywhere consists of an arkose-like breccia of pre-Cambrian rocks. In the neighbourhood of Lake Locknesjön we thus find such a breccia, partly under the Chasmops beds and partly under different zones of the Orthoceras limestone. It is sometimes very thick, as for instance under the Asaphus limestone at Bergböle, where it seems to be at least 40 m. Its thickness is also considerable in many places under the Chasmops beds (for instance at Tand, the rivulet Musbäcken by the railway, Änge). It is seen in many sections that this breccia grades into the underlying rock (mostly consisting of granite, but also dolerite and leptitic rocks). It may be considered formed as a sedentary arkose, probably under the influence of cold climatic conditions. As it never occurs beneath Cambrian deposits, its age must be Ordovician. — The arkose-like breccia formed in pre-Chasmops times and the arkose, which probably also was formed by disintegration in early Chasmops time, apparently yielded much material during the transgression of the Chasmops sea, as evidenced by the widely spread coarse-clastic basal Chasmops beds. We must imagine that the Cambrian coastal region also changed appearance in this manner. On account of subsequent deformation and denudation it is not possible definitely to determine whether facets were then also created in that region, but this does seem plausible (cf. Hjulström 1936, p. 356).

Topographical Conditions for the Facies Formation. The Chasmops deposits, except their coarse-clastic basal part, are usually distinctly bedded. This can be seen in all sections located some distance from the eastern coastal region, where pre-Cambrian rocks were exposed at the time of the Chasmops transgression. The conditions at Slandrom offer the best examples, the lower Chasmops limestone — at least in certain parts — there having an appearance and a bedding that make it very similar to the Orthoceras limestone.

Unstratified or indistinctly bedded limestone deposits belonging to the lower Chasmops series are found in the Central Lockne area and its immediate vicinity where the deposition took place in a topographically more broken part of the eastern coastal region. The different facies existing there have been described above (pp. 37—50). In the Central Lockne area proper it is possible to establish that they are dependent upon topographical conditions. The limestone that has been denoted as shore-reef limestone is here found to rest either directly or almost directly upon the arkose-like breccia of Archaean rocks. In the latter case it is generally separated from the Archaean only by a conglomeratic breccia, which grades into the underlying breccia. The typical basal Chasmops conglomerate and the Loftarstone are lacking, as in the locality SSW of Tandsbyn station, although these deposits do occur in the immediate vicinity, where they are on a level with the basal part of the limestone, or are even above it. If sediments of these kinds were deposited where the reef-like limestone now occurs, they must largely have been transported from there simultaneously with the deposition of similar sediments in the neighbourhood. Whether or not this was the case, the lack of these deposits indicates that the conditions of sedimentation varied within areas close to each other. In this case the variations must have been due to differences in the water conditions, expressed in varying ability to transport the sedimentary material. We must actually consider the possibility that so strong currents existed within the hilly coastal area that it was impossible for sediments to become deposited or — if they already were deposited — that they would later be transported away for redeposit elsewhere. Topographical conditions allowing such an interpretation of the conditions of sedimentation, as they are now mirrored in the sequence, prevailed in the Central Lockne area during the time of the formation of the lower Chasmops series. Between the large island (peninsula?) on which the villages of Tand, Gottand, and Änge are now located, and the peninsula protruding from SE to the vicinity of Lappgrubban farm, there was then a narrow sound, which acted as a sort of funnel, receiving the water which flowed from the west into a bay now occupied by Lake Locknesjön and its immediate neighbourhood.

This picture may appear to be the product of a far too vivid imagination. However, due attention being paid to the contact of the Chasmops beds with underlying rock, it will be found, *inter alia*, that in the narrow sound SW of the village of Tandsbyn no coarse-clastic basal formations have been traced between the Chasmops limestone and underlying Lower Ordovician (Didymograptus) shales, and that along the shores of the sound the Chasmops beds rest directly on the arkose-like breccia of Archaean rocks.[1] This is also the case in large areas in the surroundings of Lake Locknesjön, where, too, the Chasmops beds generally do not rest upon higher parts of the Ordovician than the Asaphus limestone, but occasionally on lower parts. It is only north of Bergböle that they lie so high as to rest on top of the basal beds of the Schroeteri limestone.

[1] Here the contact surface goes up to the basal beds of the Schroeteri limestone, or even higher. This may be concluded from the location of these beds in the small exposure S of Lappgrubban farm.

These observations may be said to constitute sufficient presumptive evidence to bear out this interpretation, and the presence of the reef-like limestone also supports it. This limestone is very pure, richly fossiliferous, and its fauna generally seems to be of a local character. All these factors can be accounted for by assuming that it originated during intense water circulation, i. e. under the influence of currents.

Similar limestone, although often with fairly distinct bedding, occurs here and there in the western part of the Central Lockne area and immediately west of it. A small occurrence has also been observed northwest of the village of Tand. In these localities the limestone usually rests on coarse-clastic basal Chasmops beds, which in turn often rest upon different zones of Orthoceras limestone, as for instance west of Öhntjärn. There, too, the limestone was formed within a hilly coastal area, which is indicated by the presence of »islands» built up of arkose-like breccia of pre-Cambrian rocks. The westernmost, fairly extensive limestone occurrence in all probability represents a deposition along the western slope of the coast.

In the neighbourhood of Lake Locknesjön the shaly facies is predominant in the Chasmops beds above the Loftarstone. SE of Tandsbyn there is a smaller, lens-shaped occurrence of pure, fossiliferous limestone by the slope of the Archaean rock SW of Loke. This limestone is fairly distinctly bedded. NE of Tandsbyn, dark, bituminous limestone has been observed in one place only, and it probably belongs to the lower Chasmops series.

A Swedish parallel to the development of the lower Chasmops series of the Lockne area is found in the Cretaceous deposits of the Kristianstad area in Scania. They consist of a Senonian series of strata, built up of more or less coarse-clastic basal sediments and limestone deposits, formed during the transgression of the Cretaceous sea over the hilly Archaean surface of the area (cf. Lundegren 1934). This surface was covered with kaolin to varying depths, which partly explains the difference in the development of the basal deposits during the Senonian transgression (in southern Sweden) and of the corresponding ones during the Chasmops transgression (in Jemtland). The basal part of the Senonian series in question is thus mainly developed as a pure quartz-sandstone. Direct comparisons can be made between the limestone deposits of the Kristianstad area, which have been characterized as shell-bed facies (Lundegren 1934, p. 286), and the reef-like Chasmops limestone. This applies both to the conditions for and the manner of their formation.

The fossil content has proved that the reef-like limestone belongs to the lower part of the Chasmops series. It is thus here that the variation of facies is clearly evidenced. Generally speaking the upper Chasmops series has a uniform development in the two separate parts of the Autochthon where it has been possible to study it. It is more shaly in the Lockne area than at Slandrom, however, the limestone beds there regularly intercalating more or less thick layers of shale throughout the Chasmops series above its basal part. The greatest change in the conditions of sedimentation must thus have taken place in the Lockne area, and this change was probably influenced by the topographical conditions at the beginning of the Chasmops transgression. Due to the limited quantity of observation material, it has not been possible to determine whether or not there also existed local variations in the development of the upper Chasmops beds of the Lockne area.

In this connexion observations of changes of sea-level during the deposition of the Chasmops series should be touched upon. The evidence of these changes is only found in the Central Lockne area, i. e. where the topographical conditions were favourable for their expression. This also indicates that we are not here concerned with great changes of sea-level. The evidence referred to consists mostly of fairly thin conglomerates of limited distribution in the lower Chasmops series (Loftarstone and covering limestone). These are described in the chapter dealing with the geological observations in the Central Lockne area (pp. 41, 46); they indicate that the Chasmops transgression, as is usually true of transgressions of a eustatic character, was no continuous rise of the sea-level, but an oscillatory inundation and that some of the oscillations were of sufficient magnitude to be clearly mirrored in the sediments.

It should be stated that the limestone beds of the Chasmops series usually seem to be shallower water deposits than the shaly beds. This is evident from the circumstance, *inter alia,* that fragments of granite and consolidated limestone occasionally occur in the limestone beds, while such fragments are lacking in the shaly strata in which these beds are intercalated. It seems to be the rule that the lower Chasmops beds deposited near the shore line during early Chasmops time are more calcareous than those formed farther away from there. The pure limestone facies in the Central Lockne area thus rests directly upon the arkose-like breccia or the upper, redeposited part of it, while the shaly facies has never been observed in a similar position. It may also be stated that the matrix of the basal Chasmops conglomerate sometimes — as is the case at Hallen and Öd — consists of fairly pure, fossiliferous limestone, also when this conglomerate is followed by Loftarstone.

It is not only in the Chasmops series that such conditions of sedimentation can be found but also in many parts of the rest of the Ordovician. The autochthonous Ordovician, separated from the Cambrian by a considerable stratigraphical gap, thus begins with a limestone, *viz.* Ceratopyge limestone. — Observations of conglomeratic beds in the Orthoceras limestone series have been made in many localities. These conglomerates indicate that changes of sea-level have taken place, exposing an eastern coastal zone and subjecting it to denudation. None the less their corresponding strata are made up of bedded limestone at other localities where the changes of sea-level can be traced only by the presence of corrosion surfaces.

This paper does not purport to go into the details of this question, no matter how important it must be considered to be in connexion with stratigraphical investigations. But it must be added that also the Cambrian sequence offers many examples of limestone having to be regarded as a deposit in shallower water than the shale. The conglomerates of the Middle and Upper Cambrian are thus confined to limestone beds, and fossils of a number of successive zones sometimes occur within the same limestone bed, as for instance at Tossåsen in Jemtland (cf. Westergård 1922, p. 90). In thicker and more complete zones conglomerates are lacking and the limestone is usually represented only by scattered lenses in the shale.

C. Chasmops Beds of the Overthrust Region.

Fossiliferous beds belonging to the Chasmops series have been observed in a number of places in the overthrust region of the Cambro-Silurian of Jemtland. Most of these localities, however, are found in the first, easternmost overthrust mass. Here we also find profiles through the Ordovician sequence by the aid of which a fairly detailed comparison with the sequence of the Autochthon can be made. In addition these profiles have supplied information of value for a more general correlation of the Chasmops series.

1. Description of Areas and Sections.

a. The Skute Nappe.

The first overthrust mass west of the Lockne area has been called the Skute Nappe. It contains Cambrian, Ordovician, and Silurian strata. The Ordovician sequence can best be studied W and NW of Skute station, particularly in the immediate vicinity of the railway, where there are several sections. The Orthoceras limestone series is on the whole built up in the same manner as in the autochthonous sequence, although no conglomerates exist and the series seems to be somewhat thicker. The Orthoceras limestone presents the characteristic bedding. It is mostly grey, but occasionally reddish brown in the part most likely corresponding to the Gigas and Platyurus zones. Fossils appear to be fairly scarce, and where they have been observed it is difficult to obtain them in an identifiable state, this due to pressure. Fossils have thus only been obtained from the Asaphus zone, which is partly exposed in a road-section about 0.7 km W of Skute, and from the basal part of the Schroeteri limestone. Among the latter we observe *Megalaspis patagiata* TQT and *Ceraurus exsul* (BEYR.).

Outcrops of Chasmops beds are visible in a few places. The best exposures are found by the railway half-way between Skute and Stengärde stations and on Storgårdsbäcken, south of the road at Stengärde. On account of covering it has not been possible to study the contact between the Orthoceras limestone series and the Chasmops beds, nor has it been possible to study much of the lower Chasmops series. The extensive research in the area, however, has disclosed nothing indicating the presence of coarse-clastic Chasmops beds corresponding to the basal Chasmops conglomerate and the Loftarstone of the autochthonous series.

In the above-mentioned locality between Skute and Stengärde, the exposed Chasmops beds consist chiefly of limestone and overlying black shale. The beds are folded and strongly compressed. The limestone is dark-grey and bedded. Between the limestone beds there are layers of dark-grey shale which increase in thickness towards the top of the series. This limestone is also exposed by the road immediately south of the railway. It has yielded a few, poorly preserved fossils: *Asaphus* sp. (pygidia), *Lonchodomas* cf. *affinis* Ang. and *Remopleurides* cf. *wimani* n. sp. By the railway the shale immediately above the limestone is exposed to a depth of abt. 2 m. At the bottom it is hard, somewhat calcareous and dark-grey, but otherwise black and rusty. Fragmentary specimens of *Amplexograptus* sp. and *Climacograptus* sp. occur there, but cannot be definitely identified.[1] In the next exposure some 20 or 30 m W of that locality, black shale with lenses and thin layers of dark limestone is visible for a distance of about 20 m along the railway. This shale dips 5°—10° W 30° N and is covered by dark, partly nodular, hard limestone, Masur limestone, exposures of which are visible in several places from there over to the rivulet Storgårdsbäcken. In the outcrop nearest the shale it dips 10°—15° W 30° N. Fossils have been found in the surface contacting the shale. They are *Tretaspis cerioides* (Ang.), *Triarthrus* cf. *skutensis* n. sp., and *Remopleurides* or *Caphyra* sp. (cranidium), intimating that the very lowest part of the limestone belongs to the Chasmops series. Immediately below the Masur limestone the shale contains *Triarthrus linnarssoni* n. sp. and poorly preserved graptolites, while its limestone intercalations have yielded profuse quantities of *Calymene jemtlandica* n. sp.

The above-mentioned limestone, containing *Lonchodomas* cf. *affinis*, etc., by the road, is visible in a small exposure on the southern side of the road. Black shale has been exposed in the ditch on the northern side. At the bottom it consists of rusty shale with fragmentary graptolites (*Amplexograptus* and *Climacograptus* spp. indet.). Above follows shale with scattered beds of black, somewhat bituminous limestone, containing *Triarthrus skutensis* n. sp. and *Tr. linnarssoni* n. sp. and unidentifiable fragments of graptolites.

About 0.7 km W of this place, Chasmops beds and Masur limestone are exposed on the rivulet Storgårdsbäcken (fig. 44). Below the road, the rivulet has cut a channel through the shales of the upper Chasmops series. In the wall and at the bottom of an old quarry east of the rivulet there is a bedded, dark-grey, strongly compressed limestone, from which unidentifiable fragments of trilobites (*Asaphus* sp. and *Chasmops* sp.) and *Echinosphaerites* sp. have been obtained. This limestone is overlain by a black, rusty shale,

[1] According to Dr. Bulman they include a species which he has called ? *Amplexograptus rugosus* (Hadding). In this connexion it should be mentioned that *Amplexograptus rugosus* (Hdg) is not identical with *Climacograptus rugosus* Tullberg. This has been established by a comparison between two of Hadding's original specimens of *Climacograptus rugosus* (Hadding 1915, Pl. I, figs. 13—14) and a few specimens of the latter species, labelled by Tullberg (»*Climacograptus rugosus*, Fågelsång 7, 1880, S. A. Tullberg») and kept in the collections of the Geological Survey. The latter are probably syntypes. They represent a true *Climacograptus*, which very much resembles *Cl. scharenbergi* Lapw., as pointed out by Tullberg in his description. In the same slabs from Fågelsång 7, there are specimens of a *Diplograptus* sp., which probably is the species mentioned by Linnarsson (1878, p. 243) from that locality.

about 1.1 m thick, followed above by a somewhat softer, dark shale. Only a few fragmentary graptolites have been observed in these shales. In the channel there is black, strongly compressed shale, displaying schistosity in some parts and containing beds of black, somewhat bituminous limestone on the western side. *Triarthrus* spp. are encountered in the shale as well as in the limestone. There are plenty of graptolites in the shale interstratifying

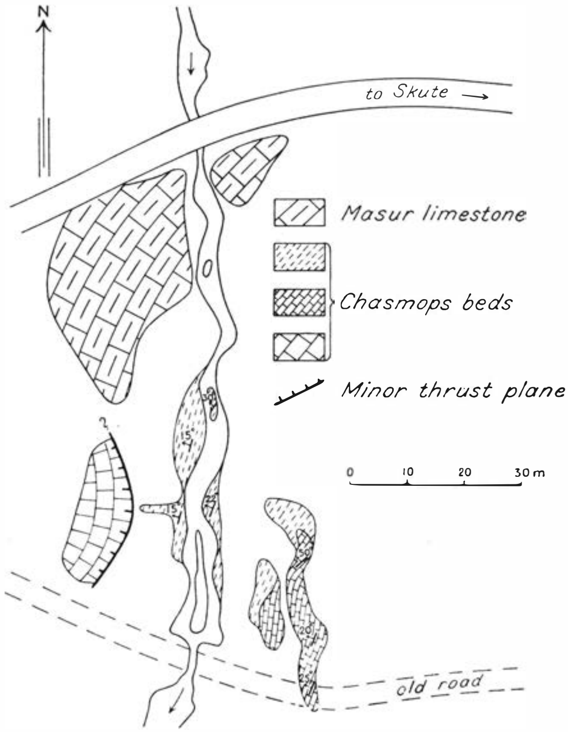

Fig. 44. Showing the exposures around the brook Storgårdsbäcken immediately south of the main road between Skute and Grönviken.

the limestone beds, which according to Dr. Bulman's identifications include *Amplexograptus* cf. *vasae* (Tullb.), *Amplexograptus pulchellus* (Hdg), ? *Orthograptus truncatus* var. *intermedius* E. & W., *Dicranograptus clingani* Carr., *Corynoides* sp. — Immediately below the bridge across the brook there is a dark, almost black Masur limestone. A grey, partly light-grey, strongly compressed limestone follows on top of the graptolite-bearing shale in its southernmost exposure on the western bank of the brook. Intensive searching has disclosed fragments of trilobites in this limestone, *inter alia*, *Platylichas* sp., which, judging from the ornamentation of the test, is *Pl. validus* (Linrs.), and a couple of ostracoda (*Conchoprimitia* ? sp. and *Cytherellina* sp.). The limestone probably belongs to the lower Chasmops series and manifestly overthrusts younger strata.

E and ESE of this locality, close to the old road, there are small exposures of grey and dark-grey limestone, probably belonging to the lower Chasmops series. There the limestone approaches the upper part of the Orthoceras limestone, but it has not been possible to find the contact between them.

Masur limestone and underlying graptolite-bearing shales have been observed in a couple of places north of the railway. One of them is 0.4 km from the section described above. Black shale with poorly preserved graptolites (? *Climacograptus brevis* E. & W.,? *Glyptograptus* cf. *teretiusculus* var. *euglyphus* (LAPW.), ? *Amplexograptus pulchellus* (HDG), and *Corynoides* sp., according to Dr. Bulman's identifications) is visible in a small brook, an eastern tributary to the rivulet Storgårdsbäcken. Immediately west of this shale and probably on top of it, there is an occurrence of black, bedded limestone with layers of black shale. In these beds the writer has observed *Triarthrus* cf. *skutensis* n. sp. and graptolites, *inter alia*, *Neurograptus margaritatus* (LAPW.). Immediately to the west there is an occurrence of thick-bedded, black, nodular Masur limestone.

Finally, something must be said about the Ordovician sequence above the Chasmops series in the Skute Nappe. Illustrative profiles through the Trinucleus series are found by the railway near and in the rivulet Storgårdsbäcken. Upwards the thick-bedded Masur limestone grades into thin-bedded dark limestone with layers of shale. Then follows black shale, the lower part of which contains large, stinkstone-like limestone lenses. In the latter as well as in the shale there are large quantities of graptolites, *Dicellograptus morrisi* HOPK., *Climacograptus* sp., and *Diplograptus* cf. *pristis* (HIS.). Its thickness has been estimated at 6 to 10 m. Above it comes the following sequence, visible in two railway-sections (1 and 2) west of the rivulet, given below from east to west, i. e. in ascending order:

1.	Dark-grey shale with layers or lenses of dark limestone; visible thickness . . . A few fragments of fossils have been found in the limestone, among them a fragmentary cheek of *Tretaspis* sp.	abt. 11 m.
2.	Thin-bedded, dark, almost compact limestone; thickness of the exposed part . .	2 m.
	Reddish brown, partly greenish grey shale with scattered thin lenses or layers of dark, almost compact limestone; thickness	abt. 7 m.
	Dark-grey marly shale with limestone lenses containing *Tretaspis latilimbus* (LINRS.); visible thickness	2 m.
	Hard, grey and dark-grey arenaceous limestone; thickness of the exposed part .	> 1 m.
	Section 2 is about 70 m west of section 1.	

The beds of section 2 apparently belong to the upper part of the Trinucleus series and correspond to the red Trinucleus shale of Dalecarlia; the uppermost part in all probability corresponds to the Staurocephalus shale.

b. The Bjerme Nappe.

The second overthrust mass west of Lockne has been called the Bjerme Nappe, its boundary towards the Skute Nappe being best visible in the neighbourhood of the village of Bjerme. South of the island of Frösön it contains

Cambrian and Ordovician strata. It has not yet been possible to make out the sequence of its Middle Ordovician part, this on account of the exposures being few and small and usually consisting of sections in ditches, etc. It is also difficult to obtain identifiable fossils, particularly from the limestone, as the beds have been subjected to great pressure and therefore are strongly folded, sometimes corrugated, and also display schistosity in some parts. The determination of the sequence is also rendered difficult by the fact that certain parts of it are developed differently to the facies characteristic of corresponding parts of the sequence in the Autochthon and partly also in the Skute Nappe. On the whole the Ordovician of the Berme Nappe is thus much richer in shales than the Ordovician east of it.

The Schroeteri zone of the Orthoceras limestone in the Bjerme Nappe seems to a large extent to be developed as a shaly facies. This is indicated by observations at the brook near the road NW of Bjerme. There we find the northwesternmost exposure of Orthoceras limestone in its typical facies. Above (i. e. W of) its uppermost part, which consists of a dark limestone containing, *inter alia, Megalaspis patagiata* TQT, are black shales with thin-bedded dark limestone. Then follows shale with fairly large limestone lenses. One of the latter has yielded *Triarthrus freji* n. sp., which is a common species in the Ogygiocaris shales of Jemtland, e. g. on the island of Frösön (cf. p. 129).

About 1 km N of this locality there are several small outcrops of black shale by the brook and east of it, here and there containing large limestone lenses near the brook. The latter generally lack fossils, but in a small exposure of shale, 100 m E of the brook, graptolites have been observed, e. g. *Orthograptus* cf. *whitfieldi* (HALL), *Amplexograptus* sp. (cf. *arctus* E. & W.), *Corynoides* sp. and ? *Nemagraptus* sp.

Between Bleka and Öf. Måläng the bed-rock consists of dark or black shales and limestone. Generally the beds strike N—S and are strongly folded. Sometimes, as at Bleka and other places by the brook, which runs alongside the road at Blädäng, the exposures consist of thin-bedded black limestone with thin layers of shale between the limestone beds. To the west, black shales are predominant, here and there containing intercalations of more or less thin-bedded black limestone. Fossils are rare. The trilobites observed are only poor specimens of a small *Triarthrus* sp., in the shale as well as in the limestone. *Climacograptus bicornis* (HALL) occurs in shale with thin-bedded limestone on the western side of the road in southern Blädäng. At the farms about 0.6 km NNW of this locality, the southernmost exposure has yielded *Triarthrus* sp., *Climacograptus bicornis* (HALL), and *Corynoides* sp. About 200 m to the north, the beds contain *Orthograptus truncatus* var. *intermedius* E. & W. and *Corynoides* sp. The first-mentioned graptolite has also been collected from shale which, near the road 1.1 km N of Blädäng, contains beds of black limestone with *Triarthrus* sp. and *Climacograptus* sp.

In a ditch 0.5 km west of the last-mentioned locality, a small section has been observed containing black, fairly thick-bedded limestone covering dark-grey, calcareous shale. The limestone has yielded *Telephus* sp. and the shale *Climacograptus bicornis* (HALL). In a small brook to the west, black shale with lenses of black limestone is seen by the road. Another exposure by the brook a couple of hundred metres south of the road discloses black shale with scattered beds of black limestone. *Tretaspis* sp., *Triarthrus* sp., *Telephus* sp., *Climacograptus* sp., *Diplograptus* sp., and cf. *Pleurograptus linearis* (CARR.) have been found in the shale, indicating the presence of the zone of *Pleurogr. linearis.* — North of the road and immediately west of the brook there is dark-grey shale with intercalations of dark limestone. Petrographically these beds resemble the part of the Trinucleus series that lies immediately on top of the black Trinucleus shale in the Skute Nappe (p. 84).

The above-mentioned observations make it seem plausible that between Bleka and Öf. Måläng there are beds belonging to the Chasmops series. They thus seem to be hemmed in between beds of the Orthoceras limestone series in SE and beds representing the lower part of the Trinucleus series in NW, this also being indicated by the presence of *Climacograptus bicornis* (HALL) and *Orthograptus truncatus* var. *intermedius* E. & W.

Fossiliferous Chasmops beds have been observed S and SE of the Rasten farms. They lie at the sides of an anticline, in the middle of which the Orthoceras limestone hill at Brattås is located. The strike of the axis seems to be SE—NW and the dip towards NW. In the Slandrom rivulet, 2.7 km SW of its outlet, there is a section through lower Didymograptus shale and Orthoceras limestone, dipping towards NE. In the direction of the strike, 0.5 km NW of this section, the Orthoceras limestone is exposed in a ditch. It is here overlain by black shale with scattered lenses of black limestone. This shale, intersected about 70 m NNE of the Orthoceras limestone, contains *Climacograptus* cf. *caudatus* LAPW., *Glyptograptus teretiusculus* (HIS.) cf. var. *euglyphus* LAPW., and *Amplexograptus perexcavatus* (LAPW.). 0.4 km NW of this locality there is another ditch in which strongly folded beds of shale and dark, thin-bedded limestone have been cut through. *Triarthrus* sp., *Dicellograptus* cf. *forchhammeri* (GEINITZ), *Climacograptus* cf. *brevis* E. & W., and *Orthograptus truncatus* var. *intermedius* E. & W. have been collected from the shale in one place, and about 30 m NE of that locality *Climacograptus* cf. *bicornis* (HALL) and *Diplograptus* sp. were found on limestone bedding planes.

At Bonäset fäb., 1.2 km SSW of Brattås the following profile has been observed in a ditch running E—W and cutting the vertical beds at right angles:

Farthest east: Dark limestone in beds and flat lenses, interstratified with thin layers of shale.
No exposure abt. 3.5 m.
Black shale with limestone lenses visible 3 m.

The last-mentioned beds have yielded *Triarthrus* cf. *linnarssoni* n. sp. and fairly well preserved graptolites, which according to Dr. Bulman's identification belong to the following species:[1]

[1] Most of this material was obtained from pieces of shale thrown up from the ditch. A small limestone lens containing *Triarthrus billingsi* (LINRS.), *Triarthrus jemtlandicus* LINRS., and *Diplo-*

Dicranograptus clingani CARR.
Orthograptus truncatus var. *intermedius* E. & W.
? *Diplograptus multidens* var. *compactus* LAPW.
Amplexograptus pulchellus (HDG).
Neurograptus margaritatus (LAPW.)
Corynoides curtus LAPW.

By the road through the village of S. Rasten there are small sections through black shale with beds of black limestone, containing poorly preserved specimens of *Triarthrus* sp. and of species of graptolites. E, NE, N, and NW of this locality, fossil finds have established the existence of Trinucleus beds only in the Ordovician of the overthrust mass. Black shales with large limestone lenses have thus been exposed in a ditch 1.3 km E of the outlet of the rivulet Slandrombäcken. Some of the limestone lenses contain graptolites: *Dicellograptus* cf. *morrisi* HOPK., *Climacograptus* sp., and *Diplograptus* sp. A limestone lens originating from the shale has yielded *Tretaspis seticornis* (HIS), *Dionide euglypta* (ANG.), and *Remopleurides* or *Caphyra* sp. (cf. Asklund 1936). — Between the road and the shore at Knytta there is a dark-grey shale with beds of grey limestone and also quartzite. *Tretaspis* sp. and *Dionide* cf. *euglypta* (ANG) have been observed in the limestone there. — On the shore 1.7 km WNW of Knytta there are exposures of dark shale with lenses of dark-grey limestone containing *Tretaspis* cf. *latilimbus* (LINRS.), and in the brook Fillstabäcken NW of Rasten there is black shale with *Dicellograptus morrisi* HOPK. and *Climacograptus* sp. Along the shore W of the outlet of the Fillstabäcken there are also exposures of Trinucleus beds, and fossiliferous beds of that kind have been found in the height west of the brook.

These observations of the distribution of the Trinucleus beds are of value in judging the tectonics as they corroborate the above interpretation (p. 86) of their main features in the area S of Rasten.

c. The Overthrust Region NE of Lake Storsjön.

With the exception of a small area on the Bay of Brunflo, SE of Östersund (p. 19), all the Chasmops beds N and NE of Lake Storsjön belong to the overthrust region. Large areas of the beds of the Chasmops series are here covered by Quaternary deposits and only appear in a few sections near brooks or in exposures along the roads. The best information about them has been obtained from the parish of Häggenås, about 30 km NE of Östersund.

The Profile on the Brook Öran. This locality, situated immediately below the road 6.5 km W of Storhögen, was mentioned by Wiman

graptus sp., was also obtained from the easternmost part of the western exposure. It is not quite certain whether it comes from the graptolite-bearing shale, as it probably was of a loose boulder. — In a small exposure 0.6 km SW of this locality, black shale with lenses of black limestone has been observed, containing, in addition to the species just mentioned, *Triarthrus* n. sp. (very similar to *Tr. linnarssoni* n. sp.) and *Dicellograptus* sp. This fauna is found in the Ogygiocaris shale on the island of Frösön, together with *Triarthrus freji* n. sp., *Climacograptus bicornis* (HALL), *Dicranograptus* sp., and *Corynoides* sp. (cf. Thorslund 1937, p. 15).

(1896, p. 282). He expressed the opinion that the beds exposed there consist of Orthoceras limestone covered by black, graptolite-bearing shale, and that due to inversion the former appears in its present position on top of the shale.

The present writer has visited this locality on several occasions, and has collected material and made observations which show that the beds are not inverted and that they belong to the Masur limestone and the upper part of the Chasmops series. The exposures begin by an old saw-mill, 80 m south of the road, and extend from there about 140 m towards SSW along the brook (fig. 45). The lowest beds, consisting of dark-grey, somewhat calcareous, non-fossiliferous shale, are found east of the brook, about 60 m south of the saw-mill. Above, towards NW, comes black shale with graptolites; according to Dr. Bulman's determinations:

Climacograptus brevis E. & W. (HDG),
Cl. bicornis HALL,
Climacograptus or *Amplexograptus* sp. indet,
Orthograptus truncatus var. *intermedius* E. & W.,
Amplexograptus cf. *vasae* (TULLB.),
? *Amplexogr. pulchellus* (HDG).

This shale has been observed only on the eastern side of the brook about 50 m below the saw-mill. On the western side there is black shale, which to a depth of about 2.5 m below the Masur limestone contains beds of black fine-crystalline limestone and, under that, beds of calcareous shale or argillaceous limestone. *Triarthrus linnarssoni* n. sp. and *Tr. skutensis* n. sp. occur abundantly in the limestone, but particularly in the shale. The beds containing these species are about 6 m thick. Graptolites are profuse in the shale and are fairly well preserved in its calcareous beds. In the profile line, about 1 m below the Masur limestone, the following species have been collected, all according to Dr. Bulman's determinations:

Dicranograptus clingani CARR.,
Climacograptus bicornis (HALL),
Orthograptus truncatus var. *intermedius* E. & W.,
Amplexograptus vasae (TULLB.),
? *Amplexogr. pulchellus* (HDG),
Neurograptus margaritatus (LAPW.),
Neurograptus fibratus (LAPW.),
Corynoides sp.

Most of these species have also been collected in the southernmost exposure on the eastern side of the brook. In addition, the shale there, to a depth of about 2.5 m below the Masur limestone, has been found to contain the following species, according to Dr. Bulman:

Climacograptus caudatus LAPW.,
Orthograptus truncatus LAPW.,
Orthogr. calcaratus var. *vulgatus* LAPW. MS.

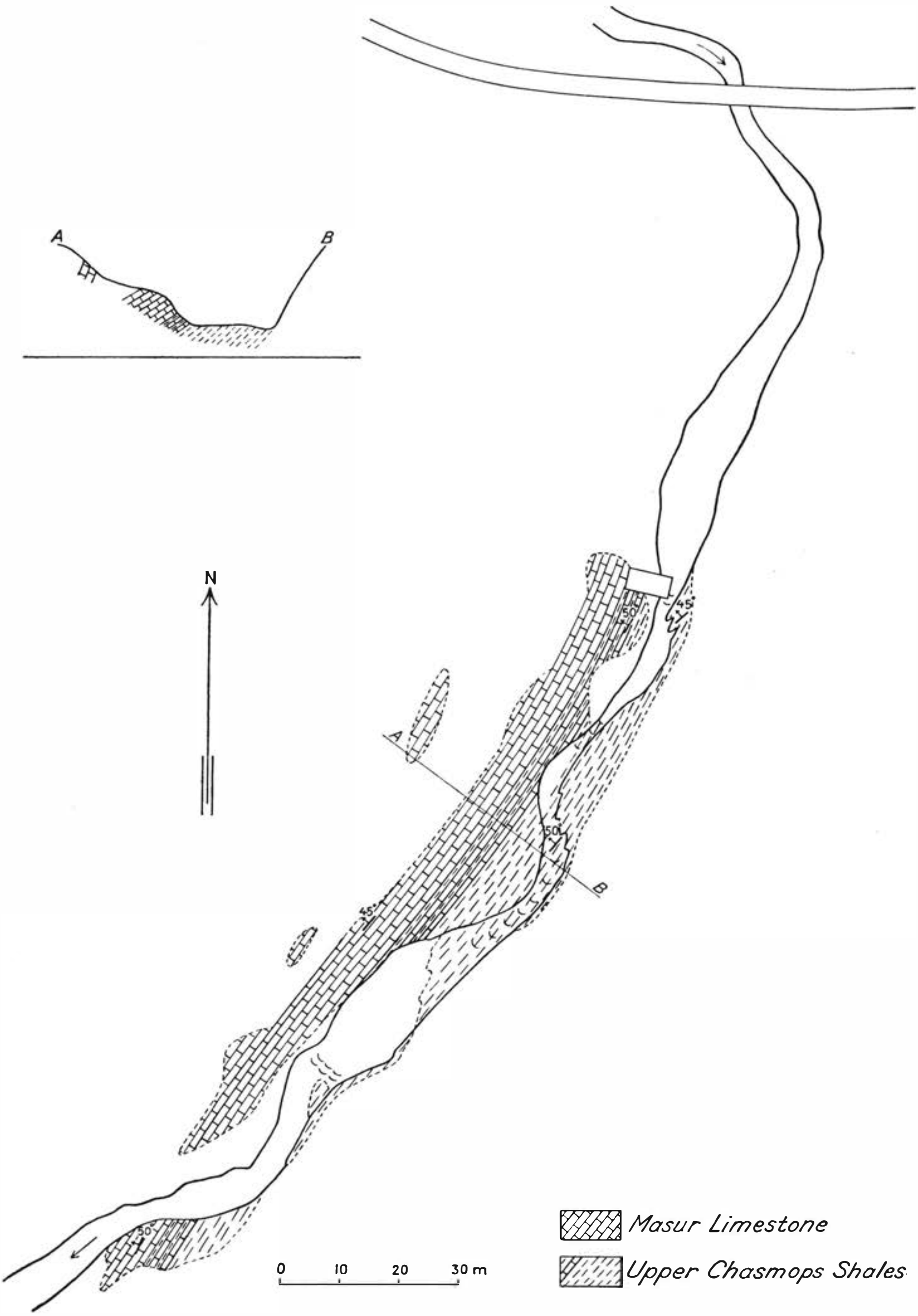

Fig. 45. Showing the exposures on the brook Örån south of the main road between Häggenås and Storhögen.

At the last-mentioned place, a bed in the Masur limestone, about 2 m above the contact towards the Triarthrus-bearing shale, has yielded *Stygina* sp. (a small pygidium), *Flexicalymene* cf. *planimarginata* (REED), *Ctenobolbina* sp. and »*Orthoceras*» sp. The following sequence in the Masur limestone has been established at the old saw-mill in the direction E 35° S—W 35° N, i. e. in ascending order:

1.	Bed of black, compact, somewhat nodular limestone	0.55—0.60 m
2.	Black shale	0.12—0.15 »
3.	Bed of limestone, similar to No. 1, dip 62° W 35° N. From its upper part small fragmentary cranidia of *Tretaspis* cf. *seticornis* (HIS.) have been collected, and a pygidium of *Calymene* sp.	0.35—0.40 »
4.	Black shale	0.15—0.17 »
5.	Dark, impure limestone	0.10 »
6.	Black shale	0.25—0.27 »
7.	Dark, fine-crystalline limestone	0.08 »
8.	Black shale	0.04 »
9.	Limestone like No. 7	0.07 »
10.	Black shale	0.015 »
11.	Limestone like No. 7	0.07 »
12.	Black shale	0.10 »
13.	Limestone, dark-grey, almost compact	0.06 »
14.	Black shale	0.03 »
15.	Limestone, black, compact	0.05 »
16.	Shale with two thin beds of nodular, greyish limestone	0.12 »
17.	Limestone bed, containing *Calymene* sp. and »*Orthoceras*» sp.	0.10 »
18.	Thin beds of black, fine-nodular limestone	0.62—0.65 »
19.	Bed of black, bituminous, fine-nodular limestone	0.43—0.45 »
20.	Grey limestone, rich in shaly material	0.18—0.20 »
21.	Bed of dark-grey and black, bituminous, partly nodular limestone	0.20—0.22 »
22.	No exposure	0.60 »
23.	Grey shaly limestone	0.10 »
24.	Bed of black, bituminous, nodular limestone	0.35 »
25.	No exposure	0.80 »
26.	Limestone like No. 24, dip 65° W 35° N	0.40—0.42 »
27.	Grey shaly limestone	0.10 »
28.	Limestone like No. 24	0.32—0.35 »
29.	Limestone with shaly bedding planes	0.01 »
30.	Limestone like No. 24	0.26—0.28 »
31.	Black shale	0.04—0.05 »
32.	Limestone like No. 24	0.43—0.45 »

The Masur limestone in this exposure thus seems to be 7.3 m thick; the thickness of the underlying shale has been estimated at 15 m. It is impossible, however, to obtain an exact figure as the shale is greatly compressed and imbricated.

The beds described above from the Örån belong to the eastern limb of a syncline. This is evident from the following observations. About 0.9 km south of the road and by the brook, there is a section through dark-grey shale with layers of grey, argillaceous limestone, which has yielded *Orthograptus truncatus* var. *socialis* LAPW. and *Climacograptus* cf. *scalaris* var. *miserabilis*

E. &. W.; immediately towards SSW there are outcrops of dark-grey and brownish grey sandstone of the Kyrkås group. Farthest north, the sandstone dips 35° W 20° S. There are outcrops of quartzite in several places along the stream; the dips vary, indicating the presence of a composite fold; in the southernmost exposure, about 2 km south of the road, the dip is 60° NW. Folded Trinucleus beds have been observed at Lappgård, 1.5—2 km W of the Örån.

By the road 1.2 km W of the Örån there is a small exposure of upper Chasmops beds, consisting of black shale with layers of black limestone. *Triarthrus*

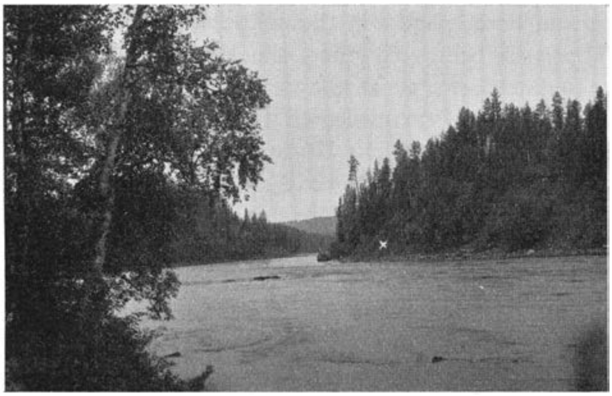

Fig. 46. View of the river Hårkan towards SW, as seen from a locality 0.5 km SSW of Högbron highway-bridge. Outcrops of Chasmops limestone in the stream, of Cambrian shales to the right (×) and on the bank to the left in the back-ground.

skutensis n. sp. is fairly common in the latter, and *Ampyx* ? *aculeatus* Ang. has also been found. Poorly preserved specimens of graptolites (*Climacograptus* cf. *caudatus* Lapw.) are also present in the limestone.

1.1 km up the brook Örån, counting from the road, the visible rock consists of thin layers of dark-grey, argillaceous limestone interbedded with thin marly layers of shale. These layers dip 65° N 35° W and rest upon a greyish limestone resembling Orthoceras limestone. 100—150 m farther up the brook there is another section through beds dipping 60° towards NW and beginning with grey limestone resembling Orthoceras limestone. In the direction of the dip it is overlain by dark-grey, bituminous limestone, which first (a distance of about 1 m) is thin-bedded and then (about 2 m) consists of thicker beds, the thickness of which varies between 0.1 and 0.3 m. The following part of the section consists of dark-grey, thin-bedded limestone with thin layers of shale, which increase in thickness towards the northwestern end of the section. In that part, where the beds have a total thickness of 2.5 m, *Haplosphaeronis* sp. and unidentifiable fragments of trilobites have been observed. It seems probable that the beds in the above-mentioned part of the profile, which is about 5.5 m thick, belong to the lowest part of the Chasmops series, and in this connexion it should be mentioned that neither a conglomerate nor Loftarstone have been observed.

The Profile on the River Hårkan. True lower Chasmops limestone is exposed on the river Hårkan. By the rapids at Högfors the river has cut a fairly deep, canyon-like channel through Orthoceras limestone dipping slightly towards W. Where the rapids end, about 0.3 km SW of the highway-bridge, the limestone has a somewhat steeper dip and the bed-rock is then covered with moraine. Another exposure is seen on the eastern bank of the river, about 0.5 km SSW of the bridge. There the rock consists of a strongly compressed, grey limestone, in which small Cystideans and fragments of Pelmatozoan stems have been observed. Another 100 m SW from there, greyish limestone occurs in beds, partly in the shape of irregular lenses in the dark-grey shale. The rock brings to mind the lower Chasmops limestone of the autochthonous sequence (e. g. at Slandrom) and contains fossils, of which it has only been possible definitely to identify *Echinosphaerites aurantium* (GYLLENH.) and *Illaenus sphaericus* HOLM. In its southwesternmost exposure, the limestone dips 20° W 10°—15° S. About 70 m SW of this exposure the high sections of black shales begin that surround the river on both sides a long distance down the stream, and which thanks to their fossil content have been established to belong to the Middle and Upper Cambrian. These shales form the front part of a more westerly overthrust mass than the one to which belong the Ordovician and Silurian series described above. Judging from the investigations so far made, the overthrust plane of the latter seems to run east of a line Nyby—Storhögen. This nappe thus extends far to the east and no observations of Chasmops beds have been made in its front section in the parishes of Häggenås and Lit north of the river Indalsälven, those beds probably being completely squeezed out there.

The Area around the Village of Byom. There are few sections through Chasmops beds by the road through the village of Byom in northern Lit. The beds are part of the overthrust mass whose plane crops out on the river Hårkan SW of Högfors. In the southern part of Byom there is a section through dark-grey and black shale with layers of dark-grey limestone, brownish on the weathering. The strike is NE—SW, and the beds, which have a visible thickness of somewhat more than 10 m, are vertical. Only a poorly preserved specimen of *Amplexograptus* or *Climacograptus* sp. has been observed in the shale, and in the limestone, fragments of trilobites (*Remopleurides* sp. and *Asaphus* ? sp.). Along the road SE of this section there are small exposures of strongly compressed dark-grey limestone with intercalations of shaly material. Sometimes the limestone is slightly nodular and dark-brown on the weathering. Only unidentifiable fragments of fossils have been observed in this limestone, which in all probability corresponds to the lowest part of the Chasmops series. Between the southeastern part of Byom and the rivulet Gällsån there are several sections through greyish Orthoceras limestone.

Along the road in the middle and northern parts of the village, there appear folded beds of black, graptolite-bearing shale, sometimes having layers of black limestone and above them Masur limestone, the latter visible in several places between Byom and Ringsta. In one place a large number of specimens of *Orthograptus truncatus* LAPW., *O. truncatus* var. *intermedius* E. & W., and *Climacograptus caudatus* LAPW. were collected from the shale. Limestone beds in shale not far below the Masur limestone have yielded *Triarthrus skutensis* n. sp., *Tr.* cf. *linnarssoni* n. sp., and *Climacogr.* cf. *caudatus* LAPW. These observations indicate that the development of the upper Chasmops series is here similar to that at the Örån.

It may also be mentioned that the Masur limestone at Ringsta is superposed by black shale with large stinkstone-like limestone lenses. This shale is intersected in a pit near the old road running through the village, and *Dicellograptus* sp., probably *D. morrisi* HOPK., has been observed in its limestone lenses. Otherwise the Trinucleus beds are covered by another nappe, the front part of which at Ringsta consists of Ogygiocaris shale, exposed in the northern part of the village. At Husås it consists of Orthoceras limestone covered by Ogygiocaris shale.

The Area around the Village of Åskott. Chasmops beds have been observed immediately south of the village of Åskott and E and N of Granbo. In the first-mentioned place they are exposed in a brook 0.7 km S of the road running through the village. They consist of dark-grey bedded limestone with thin layers of calcareous shale between the beds. *Asaphus ludibundus* TQT and *Echinosphaerites aurantium* (GYLLENH.) have been found in them, indicating the occurrence of lower Chasmops limestone. These beds occupy the northwestern part of the brook section, where the dip is steep towards NW. Towards SE, and visibly connected with them, there is an occurrence of greyish bedded limestone, resembling Orthoceras limestone, the dip of which diminishes more and more towards NW and towards the southeastern part of the section. The exposure in the brook has a length of about 36 m from NW to SE, but no sharp boundary between the fossiliferous limestone and the underlying limestone has been observed.

At the rapids in the river Indalsälven N of Granbo, grey Orthoceras limestone is exposed along the banks and also on the island in the river. Towards the west, where the rapids begin, the limestone is succeeded by dark-grey marly shale with thin layers or lenses of grey limestone. These beds, which dip 45° WNW, are strongly compressed and only fragments of Pelmatozoan stems have been observed in them. Towards the west they grade into a dark-grey calcareous rock, resembling mudstone, although the bedding can be followed by the occurrence of brownish weathering limestone in the shape of scattered thin layers or rows of small lenses. About 200 m to the W, black graptolite-bearing shale occurs, resembling the one described from the Örån. The following fossils have been observed:

Triarthrus linnarssoni n. sp.,
Tr. cf. *skutensis* n. sp.,
Climacograptus cf. *brevis* E. & W.,
Cl. cf. *caudatus* LAPW.,
Orthograptus truncatus var. *intermedius* E. & W.,
Neurograptus margaritatus (LAPW.).

Beds similar to the ones by the river have been observed in small outcrops in the slope E and SE of Granbo. There Masur limestone also makes its appearance and on top of it black shale with large limestone lenses. Near the railway immediately N of Åskott station there are good sections of the latter beds. North of them and also in the hill on which the village of Granbo lies, the rock consists of strongly compressed Orthoceras limestone, which overthrusts the Trinucleus beds and forms the front of a new nappe.

2. Summary of the Stratigraphy of the Overthrust Chasmops Series.

The above will have shown that it has not been possible to obtain a complete profile through the overthrust Chasmops series of the eastern Storsjö area, but the observations of different parts of that series combine to give a general view of the development and stratigraphy of the series.

In the *Skute Nappe and NE of Lake Storsjön* we find that the Chasmops series probably rests upon Orthoceras limestone, although it has not been possible to establish the actual boundary between them. As the Chasmops series seems to begin with bedded limestone, there is the possibility that the boundary towards the Orthoceras limestone is represented by a corrosion surface, as is the case in the Gotland sequence at File Haidar (cf. Thorslund and Westergård 1938). However this may be, the occurrence of lower Chasmops beds in a limestone facies has been established thanks to a few fossils: *Asaphus ludibundus* TQT, *Illaenus sphaericus* HOLM, *Stygina ? nitens* (WIMAN), and *Echinosphaerites aurantium* (GYLL.). Towards the top the series becomes successively richer in shaly material, and its upper part consists of black shales rich in graptolites. The uppermost part of these shales contains a graptolite assemblage indicating the presence of the zone of *Dicranograptus clingani* CARR. The fact that this zone must be correlated with the upper Chasmops beds of the autochthonous sequence is borne out by a few trilobites in common, *Triarthrus linnarssoni* n. sp., *Calymene jemtlandica* n. sp., and *Ampyx ? aculeatus* ANG., the last-mentioned certainly not having been found previously in Sweden, but occurring in Norwegian Chasmops beds corresponding to the upper part of the Swedish Chasmops series. Moreover, the Masur limestone is an important factor in establishing the correlation.

The thick-bedded, mostly nodular Masur limestone thus covers the autochthonous Chasmops series, its upper part (at Slandrom) containing *Tretaspis seticornis* (HIS.), then being followed, towards the top, by black shale with limestone lenses, whose graptolite fauna indicates the presence of the zone of *Climacograptus styloideus* LAPW. The zone of *Dicranograptus clingani* in the overthrust series (in the Skute Nappe and NE of Lake Storsjön) is overlain by a similar limestone, which in turn is covered with black shale with limestone lenses, probably representing the zone of *Cl. styloideus.*[1]

[1] A limestone lens containing *Dicellograptus* sp., *Climacograptus* sp., *Diplograptus* sp., and *Flexicalymene trinucleina* (LINRS.) has been found in such shales about 0.6 km NE of Häggenås church. The last species, which greatly resembles *Flexicalymene onniensis* SHIRLEY (1936, p. 405,

Tretaspis cerioides (ANG) has been found at the base of the Masur limestone in the Skute Nappe. As this species may be considered an index fossil of the upper Chasmops beds, it is evident that the most basal part of the Masur limestone is closely related to the Chasmops series.

The main result of the investigation of the overthrust Chasmops series is the confirmation of the fact that the zone of *Dicranograptus clingani* belongs to the upper part of this series and thus corresponds to the upper Chasmops beds of the autochthonous series. The graptolite-bearing shale which at the Örån locality (cf. p. 88) lies under the shale containing *D. clingani*, must in all probability be included in the upper Chasmops series. This is indicated by the presence of such graptolites as *Amplexograptus* cf. *vasae* (TULLB.) and ? *A. pulchellus* (HDG), which occur in the upper Chasmops beds of the Lockne area and at Slandrom. Possibly this shale represents a graptolite zone of its own, which may be correlated with the zone of *Amplexograptus vasae* on the island of Bornholm (cf. Hadding 1915). The faunistic difference between this shale and the overlying shale containing *Dicranogr. clingani* is not great, however, as all species of graptolites that can be identified in the former also occur in the latter. The main difference is thus that some species occurring in the true Clingani shale, among them the index fossil and *Neurograptus margaritatus* (LAPW.), are lacking in the underlying graptolite-bearing shale.

Above the bedded Orthoceras limestone in the *Bjerme Nappe* west of the Lockne area, we find a series characterized by its richness in shaly material. Although further investigations will be required before the stratigraphy of this series can be established, the observations so far made give some help. Its lowest part, immediately on top of the bedded Orthoceras limestone and consisting of black shale with lenses containing *Triarthrus freji* n. sp., thus probably corresponds to some (upper) part of the Schroeteri zone of the autochthonous Orthoceras limestone. Then follow above it black, partly graptolite-bearing shales, which must be considered to be passage beds to the Chasmops series. The latter is built up of dark, bedded limestone and black shales; the shales apparently predominate in the upper part of the series, while the limestone is predominant in the lower part. Among the few fossils observed, *Climacograptus bicornis* (HALL) and *Orthograptus truncatus* var. *intermedius* E. & W. indicate the presence of Chasmops beds. No typical Masur limestone limiting the series towards the top, has been observed. Possibly the limestone at Måläng, in which *Telephus* sp. has been found, corresponds to the Masur limestone, as it seems to be covered by black shale whose fossils indicate the presence of the zone of *Pleurograptus linearis* or the zone of *Climacogr. styloideus*.

Fossiliferous black shale belonging to the zone of *Dicranograptus clingani* has been observed in the part of the Bjerme Nappe that is located west of the upper course of the Slandrombäcken. Black shales with limestone lenses con-

Pl. 30, figs. 5—7), is common in the black Trinucleus shale of Dalecarlia, where it occurs together with the following graptolites, according to Dr. Bulman's identifications: *Dicellograptus morrisi* HOPK., *Climacograptus minimus* (CARR.), *Cl. styloideus* LAPW., and *Diplograptus pristis* (HIS.).

taining fossils that occur in the upper Ogygiocaris shale have been found there close to the deposits of the Clingani zone. There is thus reason to believe that information might be obtained there contributing to the solution of the stratigraphical problem offered by the relation between deposits included in the so-called Ogygiocaris shale and deposits belonging to the Chasmops series. This question was touched upon by the writer in an earlier paper (Thorslund 1937) and will be briefly dealt with in the following (p. 121).

It only remains to state that no clastic deposits (conglomerate or sandstone) have been observed in the overthrust Chasmops series, and it may be added that boulders of Chasmops conglomerate and Loftarstone are entirely lacking in the overthrust area E and NE of Lake Storsjön.

D. Tectonic Features.

Much has been said above of autochthonous and overthrust sequences, and the Chasmops series has been dealt with in different chapters according as it belongs to either of these sequences. We have then found that this series displays different developments, intimately connected with the tectonic classification. It now remains to comment upon the principles of this classification, or, in other words, to present a survey of the main features of the tectonic development of the area under discussion. In the main this survey agrees with the one recently published by Asklund (1938), which is chiefly based on our investigations during the first half of the past decade. As a result of subsequent field-work by the writer, it has been possible to supplement the picture presented by Asklund and also to modify certain details.

1. The Autochthon.

The autochthonous sequence is limited to a belt of varying width, though usually quite narrow, along the eastern boundary of the Cambro-Silurian area of Jemtland. Cambrian and Ordovician beds are found in this sequence, the youngest beds belonging to the lower part of the Trinucleus series. They appear immediately below the first nappe on the Bay of Brunflo (at the village of Namn), where the Autochthon is widest, or about 17 km SE—NW. NNE of Brunflo the belt is very narrow and chiefly embraces Cambrian deposits only, while SW of the Bay of Brunflo it varies in width, the width, however, successively diminishing towards the northern part of Lake Näckten. No part of the autochthonous sequence higher than Chasmops beds has been observed SW of Lake Näckten.

It is apparent from the description of the various areas in front of the first overthrust plane that the beds of the autochthonous sequence are not intact. They are in reality folded and dislocated in many ways. As a rule the manifestation of the pressure is more distinct near the first nappe than farther away from it, but this is no rule without exceptions. The best opportunities of studying the dislocations where they are not too great, are offered in the

Orthoceras limestone quarries at Brunflo. Generally the large folds are not visible there, the sections in most cases being superficial. Numerous dislocations can be seen in them, however, in the shape of small overthrusts, the lengths of which vary between a few cm and 3—4 m. Most of the overthrust planes of this kind dip between 25° and 45° towards NW. In the large quarry at Berge (figs. 47—48), we find, however, that these small dislocations mainly appear in the upper parts of the sequence, while the sequence as a whole is more or less steeply folded. The minor thrust planes seem to cease at a certain

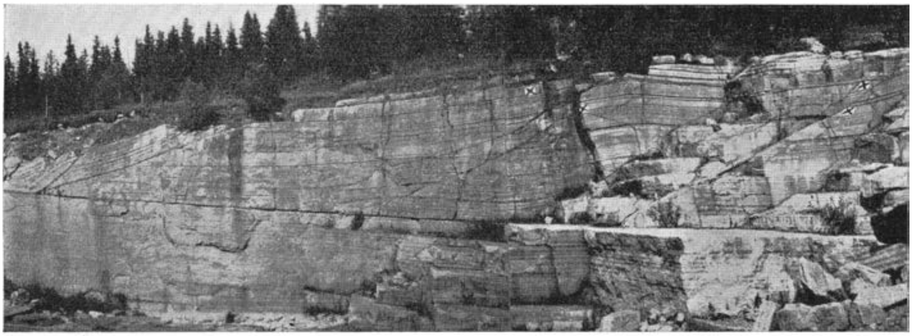

Fig. 47. View of the Berge quarry showing the bedding and the tectonic features of the Orthoceras limestone. The letter × indicates the location of one bed. Photo from the southwest.

depth; in the quarry at Berge they do so at a slickensided bedding plane which thus is a slide surface.

The Orthoceras limestone along the shore NW of Fugelsta displays a more intense folding, and in the railway-section at Torvalla the imbrication structure is accentuated (fig. 3). On the Bay of Brunflo the strike of the fold-axis is usually NE—SW, although sometimes a tendency towards transversal folding can be observed, as for instance in the shore exposures at Ope and immediately in front of the first overthrust mass north of Brunflo, in which latter place it is particularly evident.

As would be expected, the beds of the overthrust mass are far more strongly compressed, more intensely folded, and mutually more dislocated than the beds of the Autochthon. This difference in the tectonic structures is clearly demonstrated on the Bay of Brunflo.

The tectonic features of the area in front of the first nappe west of Lake Locknesjön are more complicated than on the Bay of Brunflo. This seems to be due to the fact that there is greater variety in the composition of the bed-rock. The strong pressure from northwest which occasioned the formation of an overthrust mass now found almost as far southeast as the present boundary between the Cambro-Ordovician strata and the pre-Cambrian rock, struck rocks whose resistance to pressure varied quite considerably. As pointed out before, the more or less distinctly bedded Cambro-Ordovician deposits have suffered most, and their folding and displacement of other kinds have been influenced by the configuration of their pre-Cambrian substratum. The strike of the fossiliferous beds thus displays great variations. Near the boundary line towards the pre-Cambrian, and also at some distance from it, it is usually conformable to the boundary line, and the dip is generally directed from the pre-Cambrian rock. When the pre-Cambrian surface displays long depressions, the fold-axes adhere quite closely to their longitudinal direction. For this reason we sometimes find distinct transverse folds, as in the Central Lockne area, in the valley running northwest from the westernmost bay of

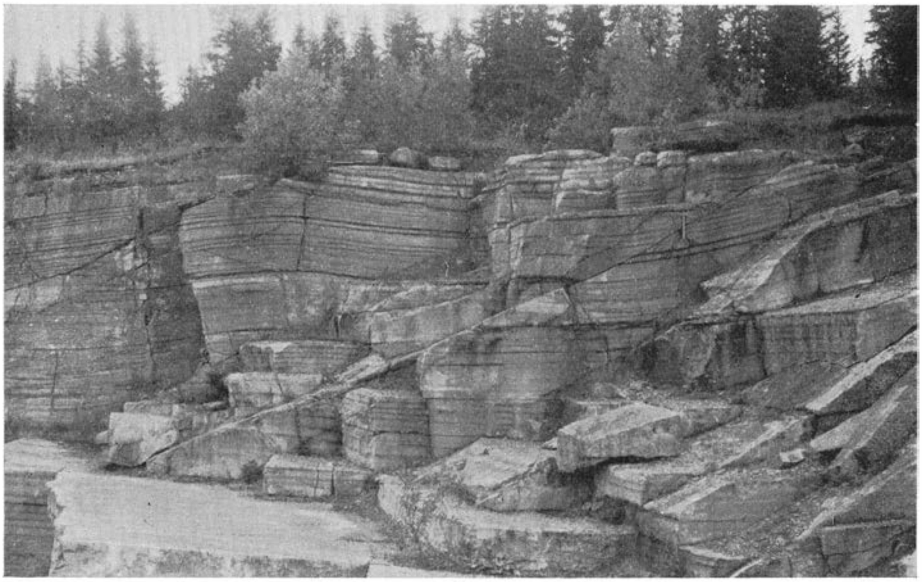

Fig. 48. Southeastern part of the Berge quarry. Photo Professor J. Frödin, 8. 9. 1937.

Lake Locknesjön, and in the area west of the middle part of that lake. Faulting occurred in connexion with this folding, this being particularly evident in the latter area, and there the dislocated limb has been thrust in the direction where the greatest resistance was encountered.

In the pre-Cambrian rock near the boundary of the Cambro-Ordovician beds the movements are denoted by fault-breccias. There are thus beautiful fault-breccias along lines which can be traced to coincide with outcrops of fault- or thrust-planes in the Cambro-Ordovician (for instance NE of Bergböle and Ö. Berge, at Tand, and near the Lillå). In addition, breccias have been observed along lines having other directions. There is one striking WSW—ENE, half-way between the villages of Valne and Börön; on the shore of Lake Locknesjön the breccia cuts through leptitic rocks and rests upon a distinct thrust-plane, dipping 35° W 40° N; on the road to the north the breccia runs through granite. Similar breccias in granite have been observed in a couple of places (at the southern end of Lake Djupsjön, SW of Ö. Berge, and in a railway-section on the northern part of Lake Svänglingen), but further investigations of the pre-Cambrian rocks of the area immediately E and SE of the Cambro-Silurian are necessary before it is possible to establish the magnitude of the movements of which these scattered observations bear witness. The occasionally steep dip of the Cambro-Ordovician beds where they directly overlie pre-Cambrian rocks (such as SSW of Tandsbyn and at Kloxåsen) also indicates that movements have taken place in the latter. There is every reason to assume, however, that the dislocations of the pre-Cambrian rock that can be linked up with the Caledonian orogeny, as it

Fig. 49. The light rock embraced by the broken lines consists of a root-less mass of arkose-like granite, overthrust and resting on steeply dipping Orthoceras limestone, which is exposed in the railway-section. Photo from the southwest, about 1 km E of Skute station.

is expressed in the Cambro-Ordovician sequence of the Autochthon, have not been very great. They are probably only of local character, for presumably they are limited to the areas that in early Chasmops time formed part of the exposed coastal zone, that part extending relatively far towards the west and being cut up due to denudation, i. e. the Central Lockne area and its immediate neighbourhood.

In front of the first nappe west of the Central Lockne area we find an area whose rock is intensely dislocated. In all probability this is due to the fact that the Ordovician series were there deposited on a very undulating surface of pre-Cambrian rocks and that the influence of the one-sided pressure varied, as stated above, in the case of these two components. The former are intensely folded and there are numerous thrust-planes, along which the latter have been thrust up on them. The dips of the overthrust planes are steep in the east, but their angles become more and more acute towards the Skute Nappe. Severed parts of the substratum of the fossiliferous beds have been transported along these planes, and lie as large boulders inside the fossiliferous beds (fig. 49). While the thrust-planes usually dip towards NW, the strikes of the axial planes vary, and have been influenced by the configuration of the surface of the pre-Cambrian rocks. The tectonic features are thus very complex and confused. Fig. 50 is but an attempt at an interpretation of them as they appear immediately in front of the Skute Nappe, based on observations in the railway-sections between Lake Öhntjärn and Skute station. The contrast is striking between the effect of the pressure on this area and the effect characterizing the tectonic features of areas where the location in relation to the front of the first nappe is similar, but where the substratum of the Autochthon is more even, as on the Bay of Brunflo and in the parish of Åsarna.

2. The Overthust Region.

a. The Skute Nappe.

The first overthrust mass west of Lake Locknesjön, the Skute Nappe, is built up of Cambrian, Ordovician, and Silurian strata. Its greatest width is west of the Central Lockne area, and it can best be studied in the immediate vicinity of the railway. Its front follows the valley in which the Skutebäcken flows. Towards the north it can be traced to the southern neighbourhood of Lövåsen, but then seems to be cut or concealed by the Bjerme Nappe. Towards SSW it can be followed to Lake Näckten.

About 0.7 km E of Skute station we find strongly folded and crushed Middle Cambrian shales by the overthrust plane, which shales rest on black shale belonging to the upper part of the autochthonous Chasmops series. Upper Cambrian shales follow towards the west, nearer Skute, and above them the strongly compressed and dislocated Ordovician sequence.[1]

Going westward along the railway towards Skute, the Autochthon is thus replaced by the Skute Nappe. Thus, within a short distance one passes from an area entirely lacking Cambrian beds to a fairly large field of Cambrian rocks only.

Nothing more of importance can be said in this connexion regarding the Ordovician series of the Skute Nappe. The Silurian, represented by the Kyrkås group and by Pentamerus limestone covers a small belt running northeast from the railway at Bjerme to the vicinity of Lövåsen. Towards SW as well as NE it seems to be cut off by the overthrust plane of the following nappe. The Kyrkås group consists of beds of dark-grey quartzite and grey and black

[1] In the Paradoxides beds, exposed along the road NE of Skute station, there has been observed a limestone layer with phosphorite nodules; it has yielded *Micromitra* (*Iphidella*) cf. *ornatella princeps* Wgd. Limestone lenses in shales have yielded *Paradoxides* cf. *torelli* Holm MS, *Dorypyge* n. sp., *Ellipsocephalus polytomus* Linrs., and *Agnostus gibbus praecurrens* Wgd. This assemblage indicates the presence of Œlandicus beds. — Various lenses of stinkstone from the Olenus shale have yielded: *Parabolina spinulosa* (Wahlnb.), *Eurycare angustatum* Ang., and *Ctenopyge* sp.

shales. This is not its characteristic development, as it contains more shale than usual. Slightly fossiliferous shales seem to be predominant in its middle part. The upper part of the group, which mainly consists of bedded dark quartzite, becomes calcareous towards the top and grades into Pentamerus limestone. This is a fairly pure limestone, strongly compressed and partly crushed. In certain places profuse quantities of fossils have been observed, mostly *Halysites* sp. and *Favosites* sp., but also brachiopods (*Pentamerus, Atrypa, Leptaena,* etc.), trilobites (*Proëtus, Calymene*), and a few ostracoda. Towards NW it is covered by Cambrian shales belonging to the next overthrust nappe.

The heights Kangsberget and Sinnberg east of the northern part of Lake Näckten consist partly of autochthonous beds, partly of overthrust masses (cf. p. 60). The latter, mainly making up the upper parts of the heights, are probably isolated remains of the Skute Nappe.

Is there any possibility to estimate the distance the Skute Nappe has been thrust? As far as the writer can see, a comparative study of the Chasmops beds of the Autochthon and of the Skute Nappe may possibly supply an answer.

As already described, the basal Chasmops beds of the Autochthon at Slandrom and Odensala consist of conglomerates and Loftarstone, and they contain an abundance of fragments of rocks from districts SE of the present boundary of the Autochthon. These observations in-

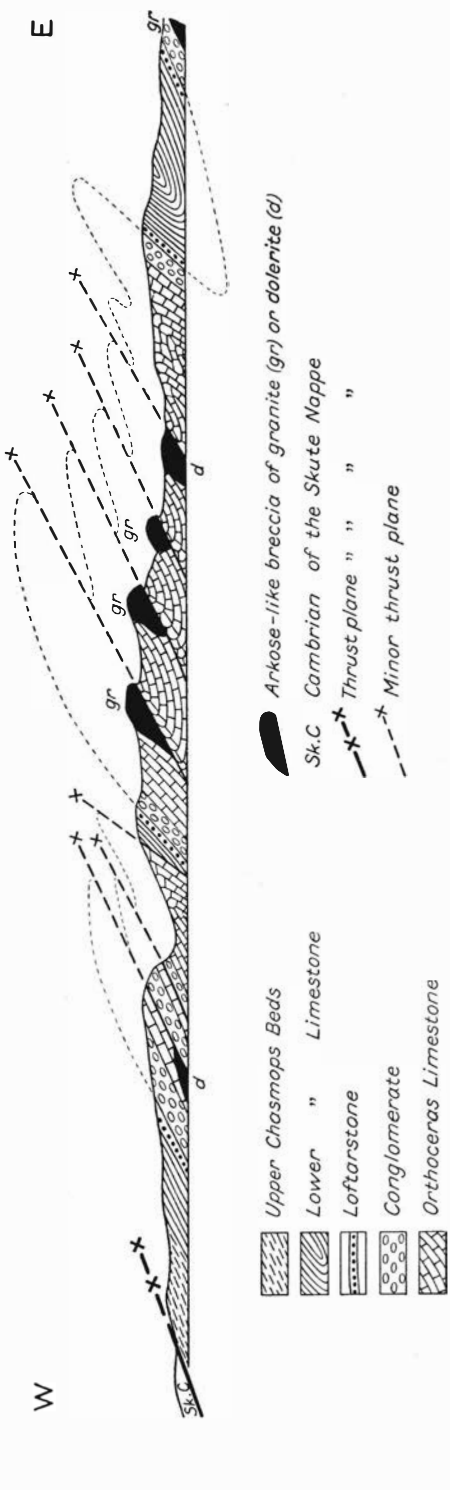

Fig. 50. Schematic profile through the area in front of the Skute Nappe. Based on observations along the railway. Length about 350 m.

dicate the minimum distance these fragments were transported in early Chasmops time. The fragments of pre-Cambrian rocks (granite, dolerite) were thus transported at least 11 km. The presence of fragments of Cambrian stinkstone in the Chasmops conglomerate denotes, however, that the distance was greater (cf. fig. 43). — The nearest source of the large granite boulders in the Chasmops conglomerate at Hallen (in the parish of Åsarna) may be supposed to be Gålberget, 10 km E of Hallen. In this conglomerate, too, there are fragments of Cambrian stinkstone, which undoubtedly originated farther east than the granite fragments that may be assumed to have come from Gålberget. — The source of the pre-Cambrian material found in the basal Chasmops beds in the southern slope of Gammelboberget may be assumed to be at least 13 km from that mountain.

Immediately in front of (E of) the overthrust plane of the Skute Nappe the basal Chasmops beds present a typical development and are fairly thick. In a few localities W of the village of Tand, the Chasmops beds, too, rest directly upon an arkose-like breccia of such pre-Cambrian rocks as form fragments in the Chasmops conglomerate.

Under such circumstances it is remarkable that no signs of coarse-clastic basal Chasmops beds have been observed in the Skute Nappe, although sediment-producing (pre-Cambrian) rocks for such beds exist within about 2 km east of the Chasmops series of this nappe. The explanation seems to be that this series was deposited so far west from the eastern coastal region in early Chasmops time that no shallow deposits could be developed in the shape of conglomerates or sandstone. As the above examples from the Autochthon of neighbouring parts have proved that such deposits are distinctly observable at least 10—13 km from outcropping pre-Cambrian rocks in this coastal region, one is inclined to assume that the Chasmops beds of the Skute Nappe were overthrust a considerable distance, probably more than ten km.

b. The Bjerme Nappe.

As mentioned above, the Silurian series of the Skute Nappe is covered by Cambrian shales belonging to the front part of another nappe, this being clearly visible in the neighbourhood of Bjerme. South of the island of Frösön this nappe contains Cambrian and Ordovician beds. The former have been observed only in a belt of varying width along the eastern part of the nappe, where they rest upon various parts of the sequences of the Skute Nappe and the Autochthon. Along the western shore of Lake Näckten they thus overthrust autochthonous Cambrian beds, in the district north of Lövåsen they probably rest on Chasmops beds, and at Namn on Trinucleus beds. In most localities where the Cambrian of the Bjerme Nappe is exposed it has been possible to establish the presence of Olenus shale only; at the northern end of Lake Näckten, ESE of Fåker railway station, there is also Œlandicus shale, and in a railway-section NE of that locality, a lens of stinkstone with *Hyp-*

agnostus parvifrons (TULLB.) has been found. The fauna of the Upper Cambrian beds W of Stengärde station has been examined by Westergård (1922, p. 91).

The Ordovician sequence seems to begin with a limestone rich in glauconite (probably Ceratopyge limestone) and then follow lower Didymograptus shale and Orthoceras limestone. This sequence can be studied in a number of sections at the villages of Fåker and Bjerme. Lower Didymograptus shale has also been observed at Öfverbyn fäb. — Lower Ordovician beds seem to be lacking between Slandrom and Namn; at Namn the front part of the nappe is thus chiefly made up of Trinucleus beds, which directly overlie strongly compressed Cambrian shales, these shales evidently having acted as a kind of lubricant when the overthrust took place.

The presence of a large anticline in the Bjerme Nappe west of the line Namn —Slandrom has been mentioned earlier (cf. p. 86). Its axis dips towards NW. The overthrust plane appears to cut through the eastern limb of this fold. This seems to explain the fact that younger and younger Ordovician beds appear next to the overthrust plane as Namn is approached from the Slandrom area.

Westwards (outside the mapped area, Pl. 15) the Bjerme Nappe is covered by another nappe, whose overthrust boundary runs through the village of Digernäs and from there towards the south slightly east of the villages of Åkeräng, Svedje, and Stackris (cf. Thorslund 1937, fig. 9). Farther south it has been possible to trace this boundary in the central part of the village of Hackås.

c. The Overthrust Region E and NE of Lake Storsjön.

The investigations so far carried out in the mapped area N of Lake Storsjön (see Pl. 15) disclose that most of the Cambro-Silurian rocks of this area are overthrust. Only east of the Bay of Brunflo is there a fairly wide field of autochthonous Cambro-Ordovician beds. Between this field in the south and the river Indalsälven by Lit in the north, the Autochthon forms a comparatively narrow belt, which seems mainly to consist of Cambrian beds. As far as the writer has been able to ascertain in this very little exposed area, the overthrust beds belong to one nappe, which probably is a continuation of the Bjerme Nappe.

The village of Lundkälen, about 12 km NE of Brunflo, is the only place where the overthrust contact is directly visible. In a small brook-section, very strongly compressed grey Orthoceras limestone, being the front part of the nappe, can be seen superposing autochthonous Middle Cambrian shale, mainly Œlandicus beds with well-preserved fossils. The overthrust plane itself is denoted by a thin, argillaceous layer of crushed alum shale.

NW of this locality, beds belonging to the Chasmops series seem to form the front of the nappe. Investigations made between Lundkälen and Bjerme have disclosed that the Chasmops series and the lower Trinucleus beds are developed similarly to those of the Skute Nappe. No signs of Chasmops conglomerate or Loftarstone have been observed, which affords an indication of the distance of the overthrust.

The largest area in the district in question between the Bay of Brunflo and the river Indalsälven is occupied by Upper Ordovician Trinucleus beds and rocks of the Silurian Kyrkås group, the latter consisting of more or less quartzitic sandstones, slightly varying in colour and coarseness. They lie in a syncline which broadens at Fjäl, south of the river Indalsälven. It is bounded on the west by an anticline whose axis dips towards SSW. The central part of this anticline is denoted by outcrops of Orthoceras limestone in a belt running from the northern part of the town of Östersund (Lugnvik) practically north through the villages of Kännåsen and Åskott to the river Indalsälven. In the western limb of the anticline Trinucleus beds are covered by another nappe, whose

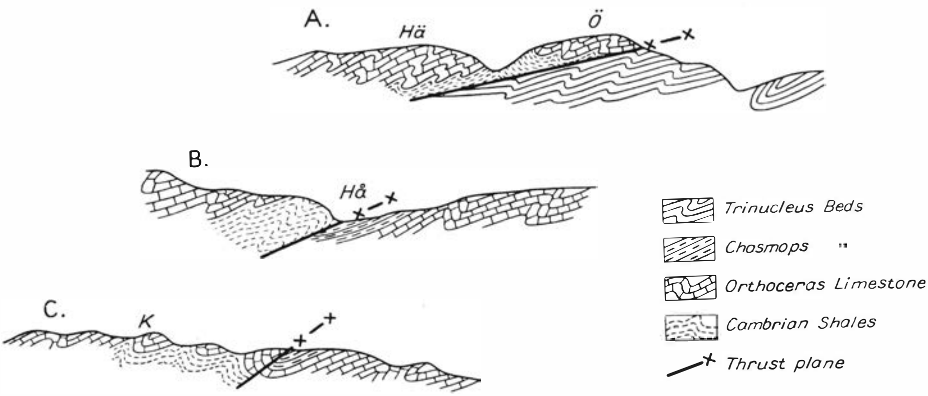

Fig. 51. Schematic W—E sections through the overthrust region between Lit and Häggenås. A = section through Häggenås (Hä) and Österåsen (Ö); B = section about 0.6 km SW of Högbron (Hå = the river Hårkan); C = section through the village of Korsta (K).

eastern boundary runs mainly N—S through the parish of Ås, and is connected in the south, via the island of Frösön, with the overthrust boundary which towards the west cuts off the Bjerme Nappe (p. 103).

North of the river Indalsälven, large parts of the Ordovician sequence are lacking in the eastern front of the overthrust area. Between the villages of Källåsen and Nyby, Masur limestone and Trinucleus shales thus come next to the overthrust plane where it crops out. The presence of autochthonous Cambrian beds in the field, sloping slightly towards SE, between the overthrust boundary and the Archaean rocks exposed at Källåsen, is evinced by the abundance of shaly material at the bottom of the moraine and of boulders of stinkstone with well-preserved Middle and Upper Cambrian fossils.

The overthrust sequence is strongly folded, deep synclines being denoted by the presence of rocks of the Kyrkås group. The overthrust whose boundary can be followed from the river Indalsälven at Lit along the southern course of the river Hårkan, north of Högbron turning east to the village of Österåsen, in all probability denotes a break-thrust in the fold that south of the river Indalsälven reveals itself in the strongly folded Orthoceras limestone, particularly at Halåsen. It has not been possible to trace the overthrust south of the river. About 2 km N of the bridge at Lit, Orthoceras limestone is found on top of Chasmops limestone at the overthrust plane[1]; on the river Hårkan, SW of Högbron, Cambrian shales probably superpose Chasmops beds (cf. p. 92), and at Österåsen Cambrian and Lower Ordovician beds cover Trinucleus shale. The overthrust thus seems to increase successively in magnitude NNE of the river Indalsälven (fig. 51). At Häggenås the overthrust mass makes a distinct bend towards the east, which also is evident from the strike of its individual components. The facies development, of these components shows no great difference from that of the corresponding beds east of the overthrust boundary. This is shown, *inter alia*, by the examination of the Chasmops series and the lower Trinucleus beds, and denotes that the overthrust in question is of no considerable magnitude.

d. The Ås-Husås Nappe.

It seems justified in this connexion to say a few words about this nappe, which towards the west limits the overthrust area north of the Bay of Brunflo and Östersund, described above. Besides at Granbo in the parish of Ås, it has been possible to establish its overthrust boundary at Ringsta and Husås (p. 93). Orthoceras limestone or Ogygiocaris shale usually seem to form its front part, as is the case at the localities mentioned, where the overthrust plane rests on Trinucleus beds. NNE of Husås this plane occasionally cuts the Kyrkås group in the preceding nappe. This is thus probably the case NW of Norderåsen; north of the mapped area (Pl. 15) it has been possible to follow the overthrust boundary up to Lake Gåxsjön immediately west of outcrops of Kyrkås quartzite at Höljebohöjden, Klumpen, and Brattåsen (Thorslund and Asklund 1935, Tavl. 3). On the north as well as the south side of Frösön, the Kyrkås quartzite is covered by the front part of the nappe, in which the presence of Cambrian shale and lower Didymograptus shale has been established on that island.

A comparison between the development of the Middle Ordovician of this nappe and the development of the corresponding part of the nappe north of the Bay of Brunflo and Östersund indicates that the former nappe has probably been thrust a long way from the west. This is indicated particularly by the occurrence of the so-called Ogygiocaris shale, which is fairly thick in the Ås-Husås Nappe, but the typical development of which is lacking in the sequence immediately east of it. In part it corresponds to the upper section of the Orthoceras limestone of the latter; it is the lower part of the Ogygiocaris shale, earlier called the zone of *Climacograptus putillus* (HALL).[2] A certain middle part of the Ogygiocaris shale probably forms passage beds between

[1] In a road-section here *Echinosphaerites aurantium* (GYLL.) and *Stygina ? nitens* (WIMAN) have been observed in the Chasmops limestone..

[2] The Swedish *Climacograptus* species earlier identified with *Climacograptus putillus* (HALL) cannot be identical with the American species, nor with any of the types of the *Cl. putillus* group described by Ruedemann (1925, pp. 60—64), all of which occur in formations that are younger than the lower part of the Ogygiocaris shale.

the Orthoceras limestone series and the Chasmops series.[1] In the upper Ogygiocaris shale, which in the Ås-Huså Nappe mainly consists of black shale with limestone lenses containing *Triarthrus billingsi* (LINRS.) and *Climacograptus bicornis* (HALL), there are also layers of dark, calcareous, fine sandstone, observed along the shore SW of Ås church. As the writer attempted to demonstrate in an earlier paper (1937), this shale should probably be included in the zone of *Nemagraptus gracilis*, for the index fossil of this zone occurs in the uppermost Ogygiocaris shale on the island of Andersön in a sequence that belongs to a more western overthrust mass than the Ås-Huså Nappe, and which in this very part of the Ogygiocaris shale contains sandstone layers. Somewhat coarser, mostly greywacke-like sandstone occurs in a corresponding part of the sequence in a still more western nappe, the overthrust boundary of which runs through the northern part of the island of Norderön, and a large part of the Middle Ordovician of the area W and NW of Lake Storsjön is mainly built up of beds of such sandstone with intercalations of dark shales. This indicates that the material of the sandstone beds in the uppermost Ogygiocaris shale was transported from the west, and it seems probable that this transportation took place in connexion with the changes of sea-level, the results of which can be traced in the autochthonous sequence by the presence of more or less coarse-clastic deposits in the basal Chasmops series.[2]

It may be added that, excepting *Climacograptus bicornis* (HALL), which has a wide vertical distribution, the sequence of the Ås-Huså Nappe has been found to contain no species common to the Chasmops series of the Autochthon and the overthrust region north of the Bay of Brunflo and Östersund.

A study of the sequence of the Autochthon as well as of each of the overthrust masses shows that the change of facies generally takes place very slowly in a horizontal direction, and that the stratigraphical succession remains unchanged within large areas. If these observations are co-ordinated with the above account of the difference between the Middle Ordovician sequence of the ÅsHuså Nappe and the corresponding sequence of the area north of the Bay of Brunflo and Östersund, the impression is produced that the Ås-Huså Nappe must have been thrust a very long distance.

3. Summary.

No beds of the Cambro-Silurian of Jemtland are absolutely intact. Although the Autochthon, which occupies a comparatively small eastern part of the

[1] There is probably no parallel to these passage beds in the Autochthon and the overthrust region north of the Bay of Brunflo and Östersund. They mainly consist of thin-bedded dark limestone intercalated in black shales with limestone lenses.

[2] As regards the conditions of sedimentation in the Middle Ordovician epoch, we must thus in Jemtland count with a transport of material both from the east and from the west. The western origin of the clastic material of the Ås-Huså Nappe, which must be considered to represent an eastern part of the whole geosyncline in Jemtland, denotes that much more material was transported from the west than from the east. This conclusion is also supported by the circumstance earlier pointed out, *viz.* that no conglomerates or sandstones have been observed in the Middle Ordovician series of the easternmost overthrust masses. — Predominant transports of material from the west in the Middle Ordovician epoch have earlier been established to have occurred in the Mjösen field in Norway (cf. Holtedahl, 1909).

Cambro-Silurian field of Jemtland, is not dislocated in a body, it bears more or less distinct evidence of movements caused by tangential pressure chiefly from NW. The dislocations reveal themselves as folds and overthrusts, the lengths of which vary though they are always of small magnitude. The thrusts seem to be limited mainly to the upper parts of the sequence and are numerous also within small areas. The configuration of the substratum of the Cambro-Ordovician sequence has played an important part in the development of the tectonic features of the Autochthon. A comparative study of the Autochthon around the Bay of Brunflo and in the area between Lake Locknesjön and the northern part of Lake Näckten shows this very distinctly. The tectonic features of the latter area are thus much more complicated than of the former, which is mainly due to the fact that the autochthonous beds west of Lake Locknesjön were deposited within a very hilly terrain of pre-Cambrian rocks, while the sub-Cambrian surface on the Bay of Brunflo generally speaking seems to have sloped smoothly towards NW.

The fossiliferous overthrust beds of Jemtland are divided into a number of nappes, the easternmost ones being represented in the mapped area, Pl. 15. They are:

a. The Skute Nappe, the first overthrust mass west of Lake Locknesjön. It covers a fairly small area and NE as well as SW it seems to be overridden or cut by

b. The Bjerme Nappe, which is the second nappe west of Lake Locknesjön but otherwise forms the front of the overthrust region of the Cambro-Silurian of the Lake Storsjön area. — c. The probable continuation of the Bjerme Nappe north of the Bay of Brunflo and Östersund is very broad and is limited towards the west by the overthrust plane of

d. The Ås-Husås Nappe. This nappe continues towards the south via the island of Frösön. There, farthest west (in Bynäset), it is superposed by a new nappe, whose eastern boundary line runs along the eastern part of the island of Andersön and from there towards SSE (»the Karlsvågen—Österänge Nappe» according to Thorslund 1937, p. 23).

In each nappe the beds are strongly compressed into folds of varying size. The folding is often characterized by a dome-structure, which is clearly seen in those parts of the sequences where shales follow directly on top of or underlie more resistant rocks (limestone or quartzite). The Orthoceras limestone thus occurs in several places in the shape of long ridges which rise like domes above the surrounding, covering shales, while the quartzite of the Kyrkås group sometimes occurs in the shape of outlying lenses in underlying Trinucleus shales. Usually the fold-axes appear to be parallel to the outcrop of the nearest overthrust plane.

The tectonic features of the nappes do not consist of folding only, overthrusts being equally common. The distances of the overthrusts vary, though they are mostly short, as in the Autochthon. Contrary to the conditions there, however, there are also overthrusts in the nappes, the length of which is probably quite considerable. One such example is found in the continuation of the Bjerme Nappe in the area north of the Bay of Brunflo and Östersund, where the overthrust (break-thrust) in the neighbourhood of Häggenås appears to have a length of several km. Another example is afforded in the Ås-Huså s Nappe and is very distinct in the middle part of the island of Frösön and south of it (»the Torptjärn-Fanbyn Nappe» according to Thorslund 1937). Farther west in the Lake Storsjön area, imbrications of this kind are so numerous that it is difficult to distinguish them from tectonic units of greater magnitude.

A comparison between the development of the Middle Ordovician series of the Autochthon and that of the nappes has been found to be of value when endeavouring to ascertain the distance the latter have been thrust. Ten km has been estimated to be the probable minimum distance that the Skute Nappe was thrust. The same is probably true of the probable continuation of the Bjerme Nappe north of the Bay of Brunflo.

Each nappe represented in the mapped area on Pl. 15, presents a sequence comprising Cambrian, Ordovician, and Silurian beds. Generally the Silurian is represented by the Kyrkås group only, but the Skute Nappe also contains a limestone corresponding to the Pentamerus limestone of the middle and western Lake Storsjön area.[1] This indicates that the movements that resulted in the transportation of the nappes and the dislocations of the Autochthon took place after the deposit of the Silurian beds of the Lake Storsjön area.

It may be mentioned in this connexion that according to an opinion adopted by several authors, and most clearly expressed by Hadding (1929, pp. 176—180), the movements that gradually originated the Caledonian mountain range started in pre-Silurian time; proof of strong disturbances, bearing out this opinion, have been said to be evident, *inter alia*, in the autochthonous Ordovician sequence of the Lockne area. The present writer, however, has not been able to find any such evidence. As already indicated in this paper (pp. 40, 43), the writer is of opinion that their supposed existence depends upon a misinterpretation of the stratigraphy of the Ordovician sequence. The coarse-clastic beds of the Ordovician of the Lockne area thus did not arise as a result of local dislocations, but in connexion with changes of sea-level, whose influence it has been possible to trace far beyond the field in question, and which at least are reflected in the Jemtland part of the Caledonian geosyncline (cf. p. 106).

[1] For reasons which will not be stated in this paper, this limestone should be considered to correspond to the lower zones of the Rastrites shales of Scania.

III. Södermanland (Tvären).

1. Introduction.

Tvären is a bay of the Baltic on the coast of the province of Södermanland, about 25 km E of Nyköping and 72 km SSW of Stockholm. Its surface is almost triangular and its boundary line towards SE is denoted by the large islands of Ringsö and Långö. Narrow sounds connect it with the open sea. The depths of the bay are seen in the map, fig. 52.

Boulders of fossiliferous Ordovician rocks, mainly limestone, are fairly abundant in a limited area in the neighbourhood of Tvären. Before 1927 this occurrence was not known, or at any rate not mentioned in geological literature. The description accompanying the geological map »Björksund» (Stolpe 1874) does not mention it. The discovery was made by Dr. B. Asklund and Dr. A. H. Westergård, who were carrying out investigations that year on the island of Ringsö. These investigations were made at the suggestion of Dr. Asklund, who nursed the opinion that there ought to be a Cambro-Silurian area in that district, depressed due to faulting.

Asklund studied the boulder fan in detail and found that the boulders must emanate from solid beds in Tvären, from where they must have been transported southeast by the inland ice. He also sketched the approximate limits of the boulder fan. The collectors were kind enough to let the writer have the material gathered in 1927 for an examination of the fossils. It consists of several boulders of crystalline and marly limestone, a few boulders of a conglomerate, and one of calcareous sandstone. The writer visited the Tvären district in 1928 and 1931 in order to supplement this material, and examined boulders with a view to obtaining a representative fossil collection and more of the conglomerate. A preliminary report on the probable sequence in Tvären was published in 1930 (Thorslund 1930).

2. Occurence of Boulders.

The area within which the boulders in question are scattered grows distinctly narrower towards NNW. Its extended boundary lines towards the east and west enclose a sectoral area whose apex lies immediately north of Tvären. The beds from which the boulders emanate must thus lie in Tvären, which is further evidenced by the fact that no beds or boulders of this kind have been encountered anywhere else along the shores of this bay. As shown by the

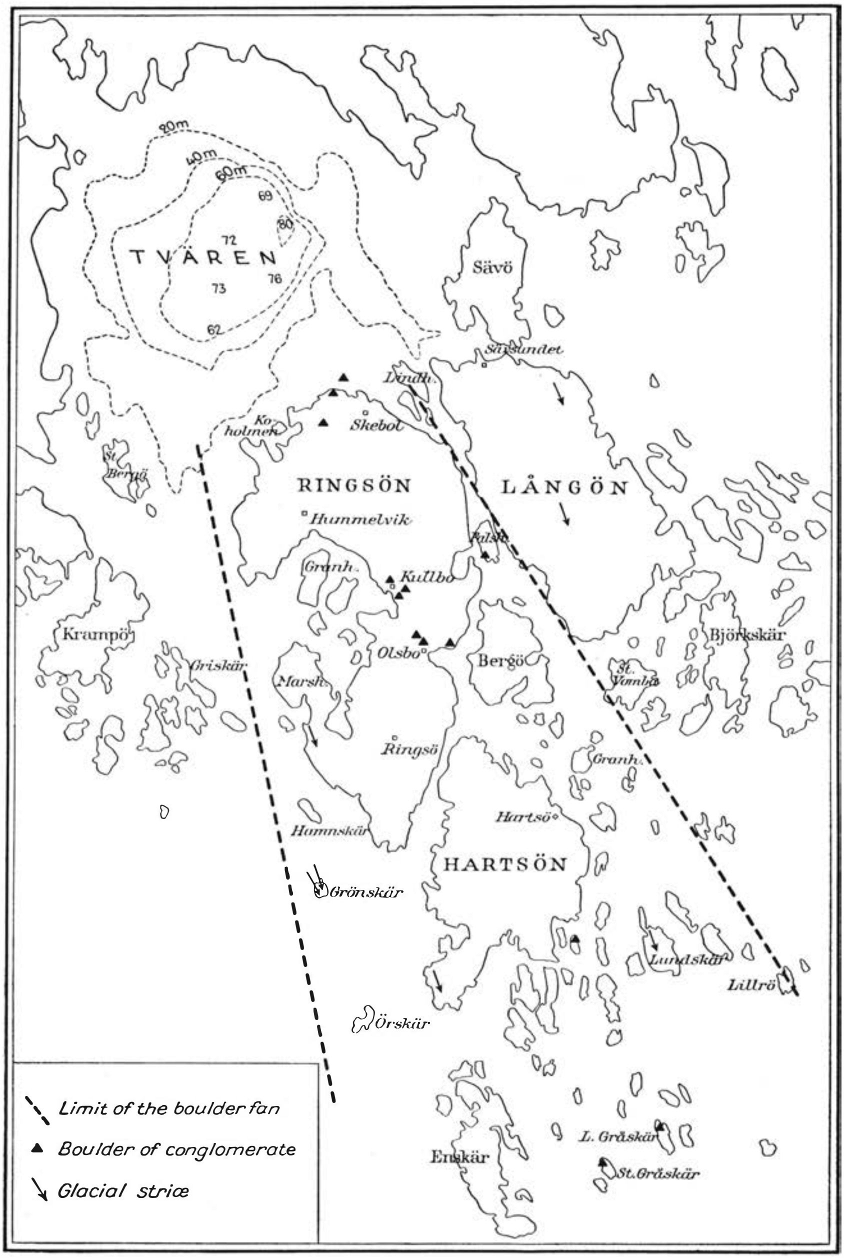

Fig. 52. Map of the Tvären district in the province of Södermanland. The depths of the bay are given in metres.

nautical chart, the depth increases fairly continuously towards the middle, where the depth curves are almost concentric, although the greatest depth found, 80 m, has an eccentric location. The boundaries of the boulder fan clearly indicate that the boulders issue from the deeper part of Tvären, or, more exactly, from the area within the 60 m curve.

The direction of the boulder drift is also indicated by the glacial striae. Around Tvären they run in directions varying from N 15° W to N 25° W. It has been possible to make out two systems of striae on the island of Grönskär. One runs N 20°—25° W, and the other, which is older, N 15° W.

As mentioned above, limestone boulders are most common, and these have served as a guide in establishing the boundaries of the boulder fan. They are most frequent along the shore of the island of Ringsö between Skebol farm and the island of Koholmen and in the continuation towards SSE around the bisector of the fan. The conglomerate boulders are all located in the eastern half of the sector, most of them, and the largest, however, in the vicinity of the line mentioned. Only a few small boulders of calcareous sandstone have been found along the shore NW of Skebol.

The beds from which the boulders originate lie in a depression, caused by dislocations in post-Silurian time. These dislocations no doubt resulted in a cauldron being formed (see Asklund in Ramsay 1931, p. 372). This interpretation is supported by the configuration of the bottom of the bay and the presence of breccias in the local Archaean rocks.

3. The Sequence in Tvären.

Chasmops Limestone. The examination of the boulders collected indicates that the Tvären beds probably belong to the Chasmops series exclusively and represent the lower part of that series. This is certainly true of the limestone boulders, several hundred of which have been examined. This result has been reached chiefly thanks to the fact that the limestone boulders are rich in ostracoda, most of which are characteristic, easily recognized types. For this reason and also because the Ordovician ostracoda are known to be good index fossils, no list of the fossil content of each individual boulder has been considered necessary.

Although the limestone occasionally occurs in fairly large boulders, it never displays quite distinct bedding.

The limestone is grey, light-grey, or faintly brownish grey. In most of the boulders it is crystalline and medium-coarse. More seldom it is marly and compact, but there are a number of variations between these two types. The crystalline limestone is often somewhat bituminous, particularly when it is of a deeper colour, and easily breaks under the blows of a hammer. In a few boulders observed it is very hard, due to it being partly silicified, but no true cherts have been seen. Sometimes the fossil fragments — particularly valves of brachiopods — are somewhat silicious, and it has thus been possible to liberate them from the limestone with acid.

The content of terrigenous material is characteristic of the limestone, this material consisting of pebbles, granules, and grains of the Archaean rocks that form the bed-rock in the neighbourhood of Tvären. Such fragments are found also in the purely marly limestone, though they mainly consist of scattered quartz grains, small fragments of feldspar, or mica flakes, the last-mentioned being common in all limestone boulders. In the crystalline limestone the Archaean fragments are mostly sharp-edged or display slight signs of wear

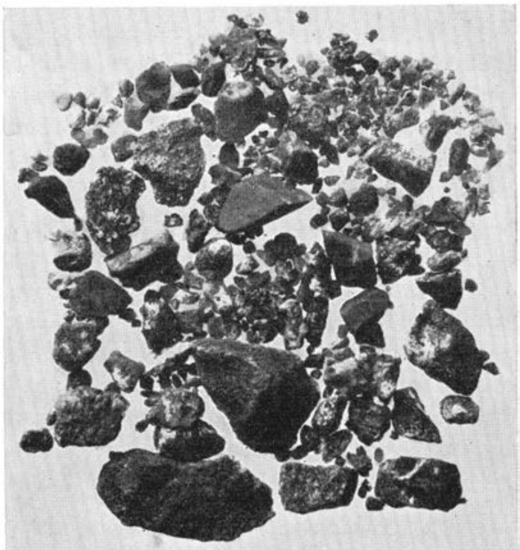

Fig. 53. Fragments of Archaean rocks dissolved from a boulder of crystalline limestone. Ringsön, SE of Tvären. Natural size.

(fig. 53). They are often so profuse that the rock resembles a conglomerate or sedimentary breccia (fig. 54).

Limestone containing fragments of Archaean rocks is no common occurrence in the Ordovician of Sweden. Actually such limestone is known only from the Ceratopyge series of Dalecarlia in Central Sweden. For this reason and also on account of the fact that such fragments have been observed in practically all the boulders examined from Tvären, they may in this instance be considered to indicate that the boulders emanate from one and the same sequence.

The fossils occur scattered in the limestone. There is thus hardly any accumulation of a certain species or representatives of a special group. It is true, of course, that a fair quantity of well preserved graptolites has been encountered only in one boulder of grey, compact, but little marly limestone, from which they could readily be liberated. However, the same species do occur, though they are not so frequent, in crystalline as well as marly limestone, but in these rocks they are fragmentary. In the crystalline limestone rich in boulders there are usually only fragments of pelmatozoan stems and fairly well preserved valves of brachiopods belonging to the genera *Hesperorthis*, *Nicolella*, and *Platystrophia*.

With regard to the occurrence of fossils, it has been said above that ostracoda are common, and they are actually the group of fossils that is best represented. Besides the species described in this paper, there are many others, which, however, lack test ornamentation and other characteristics by means of which it would be easy to identify the species. — The brachiopods come next in

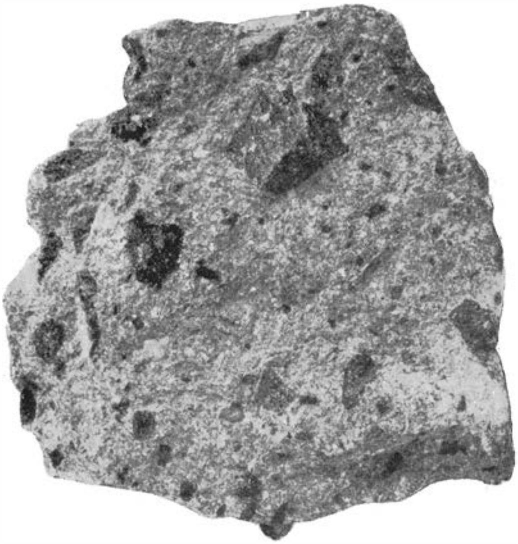

Fig. 54. A boulder of light-grey crystalline limestone rich in dark fragments of Archaean rocks. Ringsön, SE of Tvären. $^1/_2$ of natural size.

order. Most numerous are species belonging to the family *Orthidae*. The following list, including only such species as are earlier known or very closely related to known species, gives an idea of the composition of the brachiopod fauna. It also illustrates the great faunistic agreement with the corresponding part of the Ordovician sequence of Esthonia:

Tvären:	Vertical range in Esthonia[1]
Orbiculoidea cf. *mickwitzi* (HUENE)	(the main species: C_2—C_3)
Hesperorthis inostrancefi (WYSOG.)	C_2—C_3
Nicolella salme ÖPIK	C_2
» *moneta* (EICHW.) »mut.» WYSOG.	$C_{2\alpha}$
» » » var.	C_2—D_1
Platystrophia lynx (EICHW.)	C_3—D_1
» *dentata* (PANDER) var.	D_1
» *biforata* (SCHLOTH.)	$C_{1\beta}$—$C_{2\beta}$

[1] According to A. Öpik. In 1930 Professor Öpik was kind enough to examine, and in a couple of instances to correct, the writer's identification of several species from Tvären. The valuable information he then submitted regarding the distribution of these species in the Esthonian Ordovician is used in the above list.

Leptelloidea musca ÖPIK	$C_{2\beta}$—D_1
Sowerbyella sp. (*quinquecostata*-group)	
» » (*liliifera*-group)	
Leptaena trigonalis FR. SCHM. var.	C_2
» aff. *minuta* KIAER	
Rafinesquina dorsata BEKKER	$C_{1\delta}$—D_1
Christiania semiglobosa (PANDER)	$C_{1\beta}$—$C_{1\gamma}$

Trilobites are rarer. They always occur as fragments, more or less cracked and broken. The breakage evidently took place during the sedimentation or induration, for the limestone displays no signs of having been exposed to pressure. Besides the species mentioned in the description of the fossils, scattered fragments have been encountered of: *Platylichas bottniensis* (WIMAN), *Conolichas peri* WARB., *Chasmops* sp. — a fragment of a small cranidium, ? *Ch. odini* EICHW., *Pterygometopus exilis* (EICHW.) — pygidium, *Ceratocephala* sp. — a fragmentary pygidium, possibly belonging to *C. kuckersiana* (FR. SCHM.). A few small pygidia have also been obtained, whose generic references are uncertain, however.

Several species of bryozoans have been collected; a few of them are identical with species described by Bassler (1911) from the Kuckers formation.

The graptolite material, examined by Dr. Bulman, comprises the following species:

Dicellograptus sp.,
Climacograptus bekkeri (ÖPIK) (= *Cl. haljalensis* BULMAN),
Climacograptus aff. *kuckersianus* HOLM MS, WIMAN,
Diplograptus (? *Glyptogr.*) *uplandicus* WIMAN,
Dendrograptus sp. (= *Temnograptus* ÖPIK 1928),
Acanthograptus suecicus (WIMAN)[1].

A few small gastropods, one lamellibranchiate, a few scattered plates and a fragmentary calyx of *Echinosphaerites* sp., conodonts and spicules of sponges have also been found.

The fossils in the boulders indicate that the limestone belongs to the lower part of the Chasmops series in Sweden (the lower Chasmops limestone) and that in Esthonia it corresponds to a sequence that comprises the Kuckers formation (C_2) and the Itfer formation (C_3), possibly also the lowermost part of the Jewe formation (D_1).

The abundance of fragments of Archaean rocks in the limestone shows that it was formed near a coast consisting of such rocks. In all probability that coast was fairly steep, at least parts of it. This seems to be the explanation why the sharp-edged fragments of Archaean rock occur scattered in the limestone. It must thus be imagined that they have incessantly been transported to the calcareous deposits during the sedimentation, for instance by downfall from cliffs, by the action of the waves or the wind.

[1] cf. O. M. B. Bulman. The structure of *Acanthograptus suecicus* and the affinities of *Acanthograptus*. Geol. För. Förhandl., Vol. 59, Stockholm 1937.

Redeposition of material probably took place during the sedimentation of the limestone. This is indicated by the absence of distinct bedding in the sometimes fairly large boulders, and the fragmentary, often broken and occasionally also worn state of the fossils.

Lithologically, the limestone brings to mind certain parts of the pure limestone facies of the Central Lockne area, and it was formed contemporaneously with that limestone and under similar conditions. In this connexion it is natural to refer to the comparison (p. 79) made between this limestone facies and the Senonian limestone deposits in Scania. If we were to attempt to visualize the deposits now represented by the Chasmops limestone of Tvären, this would undoubtedly be greatly facilitated by a study of the Mammillatus beds of the Ivö quarry in the Kristianstad area. The picture presented by them at this locality would probably need but little retouching to be applicable to the Tvären beds. Apart from a reduction in proportions, the alterations necessary would mainly be of the details that may be attributed to the different climatic conditions under which the two deposits were formed.

Calcareous Sandstone. The few boulders of this rock found consist of grey, fairly hard, coarse to very fine sandstone. In most of the boulders the sandstone is only a few cm thick, but in one boulder, which illustrates the transition from medium to very fine sandstone, the thickness is almost 0.1 m. The sandstone bears a certain resemblance to the Loftarstone, as it has black spots, but these spots do not consist of pieces of shales, as is generally the case in the latter, but of flakes of mica. The number of these flakes is so great that the rock may be called a micaceous sandstone.

Most of the grains are sharp-edged or split (fig. 55). They consist mainly of quartz, feldspar, and dark mica, but there are also scattered grains of other minerals, for instance garnet. The sandstone is not even-grained. There are thus scattered grains of very coarse sand and also a few granules and even small pebbles (of red gneiss) in one boulder of coarse sandstone. The cement consists chiefly of calcite. The sandstone displays no distinct bedding, but the stratification is clearly denoted by the orientation of the flakes of mica.

The sandstone is fossiliferous, but the fossils obtained give no direct indication of its stratigraphy. A small fragment of *Climacograptus* sp., several poorly preserved specimens of a brachiopod, which it has not been possible to identify with any known species, and one conodont, have been observed. The presence of *Climacograptus* sp. indicates that the sandstone is of Ordovician age, and in all probability it belongs to the basal part of the Chasmops series of Tvären.

The Conglomerate. The location of the boulders of conglomerate that have been observed is shown in the map, fig. 52. It must be stated that the few occurrences marked on the map along the shore northwest of Skebol farm represent actual finds of a number of small boulders. Large boulders, 0.5 — abt. 0.9 m in diam., have been found at Kullbo (fig. 56), Olsbo, and on the small island south of the island of Hartsö.

The conglomerate is polymict. The bulk of the material consists of Archaean rocks, grey and red gneiss, pegmatite, and other fragments of the migmatitic rocks represented in the bed-rock around Tvären, as well as small pebbles and granules of minerals, mainly quartz and feldspar. There are also rare boulders of Orthoceras limestone.

The conglomerate is unsorted. True boulders are rare, cobbles are fairly common, but the bulk of the fragments consists of pebbles and granules.[1] The Orthoceras limestone mostly occurs as pebbles, but a few small or medium-sized cobbles have been obtained.

Fig. 55. Thin section of a boulder of calcareous sandstone found on the northwestern coast of the island of Ringsön. Ord. light. × 9.

Most of the fragments have well worn edges. Sometimes they are well rounded, particularly those consisting of limestone, or gneiss rich in mica. But there are also fragments that are but little worn or have sharp edges.

The sandy matrix is usually scarce. Where it is somewhat more plentiful it greatly resembles the coarse sandstone described above. The cement consists mainly of calcite but also of calcareous mud. Sometimes white calcite fills the space between the fragments, sometimes it covers the walls of fairly large hollows in which beautiful crystals often are developed.

No fossils have been observed in the matrix of the conglomerate. As the conglomerate was not found together with any sedimentary rock whose stratigraphical position is known, it is only the fragments that can supply information about its age. The fossils in the limestone fragments are then of very great importance.

The limestone in the fragments is grey or greenish grey. Some fragments have a brownish zone of varying thickness around the grey nucleus, which

[1] As to the limiting sizes for the terms used, see Twenhofel 1926, p. 155.

indicates that the limestone was subjected to weathering before being deposited. A distinct corrosion surface is visible in one fragment; under this surface the limestone is brownish grey, and above it greenish grey. The following fossils have been observed in this fragment, obtained from a boulder at Olsbo:

Nileus armadillo DM — fragmentary free cheek and pygidium of a small specimen,
»*Agnostus*» sp. — pygidium of a new species,
Acrotreta sp.

Several fragments of fossiliferous limestone have been obtained from a large boulder at Kullbo. Some of them contain glauconite; in one of these

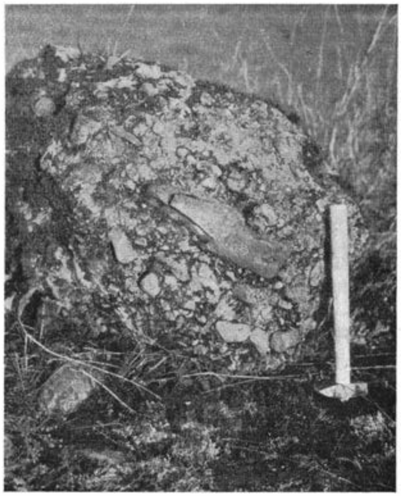

Fig. 56. Showing a boulder of the conglomerate from Tvären. Kullbo, Ringsön.

Orthis callactis DM occurs in large quantities, in another — also cut by a corrosion surface — there is a pygidium of *Ampyx* sp., probably *A. nasutus* DM. — *Ampyx nasutus* DM (cranidium), *Eurychilina* n. sp., and a couple of other ostracoda have been found in some other fragments of non-glauconitic limestone.

The fossils obtained and to some degree the appearance of the limestone would seem to indicate that the fragments originate from the Asaphus zone of the Orthoceras limestone series. This means that the conglomerate is younger than the Asaphus limestone and that it was deposited after that limestone had been denuded. Definite information regarding the age of the conglomerate can not be obtained from the fragments of fossiliferous rocks found in it.

No doubt the conglomerate belongs to the Chasmops series and forms its basal part. This is intimated partly by the absence, in the fan, of boulders from the upper zones of the Orthoceras limestone series, partly by the presence of boulders of Chasmops limestone containing Archaean fragments. Judging from the abundance of Archaean fragments in the conglomerate, it is probable that it rests upon Archaean rock.

As mentioned above, the matrix of the conglomerate is sometimes similar to the sandstone found in boulders. The transition from conglomerate to sandstone can also be observed in a small boulder, thus showing the mutual stratigraphic relation.

Tentative conclusions may be drawn regarding the sequence from which the fossiliferous fragments in the conglomerate originate. Since no fragments from Ordovician beds older than Asaphus limestone have been observed, it seems probable that the Ordovician of this sequence began with the Asaphus zone, as is the case with the Ordovician of Gotland as demonstrated in the deep-borings (cf. Thorslund and Westergård 1938), and in certain parts of the area west of Lake Locknesjön in Jemtland. The absence of fragments of fossiliferous Cambrian rocks seems to indicate that at least Middle and Upper Cambrian beds were also lacking in this sequence. It may also be questioned whether or not it contained Lower Cambrian beds. No fragments of such beds have been found in the conglomerate, but in the fan there are several boulders, sometimes fairly large, of a greyish sandstone which is probably of Lower Cambrian age. In this connexion it should be pointed out that boulders of reddish grey Jotnian sandstone, sometimes displaying ripple marks, have also been encountered. In the writer's opinion, however, there is no reason to assume that the sandstone boulders originate from Tvären, nor does it seem feasible to connect them with the sequence that supplied material for the conglomerate. Very likely they are erratic boulders from fairly distant localities.

4. Summary and Conclusions.

A boulder fan SSE of the Bay of Tvären on the coast of Södermanland contains three components of sedimentary Ordovician rocks. The boulders originate from Tvären and thus picture the sequence there. The beds are located in a depression, caused by faulting in post-Silurian time. The components are limestone, calcareous sandstone, and conglomerate.

The limestone is mostly crystalline, but sometimes it is more or less argillaceous. It contains sharp-edged fragments of Archaean rocks. Its fossils demonstrate that it belongs to the lower part of the Chasmops series.

The calcareous sandstone is grey, and fine to coarse. The grains are mostly sharp-edged and consist of the minerals of which the solid Archaean rocks around Tvären (chiefly gneisses) are composed. Scattered granules and small pebbles of these Archaean rocks are sometimes found in the sandstone. Flakes of dark mica are especially numerous, and their orientation indicates the bedding. *Climacograptus* sp. is one of the few, poorly preserved fossils obtained.

The bulk of the conglomerate consists of rounded or worn fragments of Archaean rocks. There are also scattered pebbles of grey, sometimes glauconite-bearing limestone with fossils, indicating the presence of fragments from the Asaphus zone of the Orthoceras limestone series. No evidence has been found proving that older Ordovician beds or Cambrian rocks are represented in the conglomerate. The matrix consists of calcareous sandstone, sometimes similar to the sandstone encountered in boulders.

Apart from the fact that the sandstone has been found adhering to the conglomerate in a small boulder, it has not been possible to establish the mutual stratigraphy of the three components. There is presumptive evidence, however, that the boulders emanate from a sequence which, in descending order, is built up of the limestone — the sandstone — the conglomerate, and that the whole of this sequence belongs to the Chasmops series.

The abundance of Archaean fragments in a few boulders of crystalline limestone seems to indicate that the limestone partly rests directly upon Archaean rocks.

The stratigraphy of the sequence and the appearance of its components indicate that it was formed during a transgression over an Archaean coast. This transgression was preceded by a regression, during which existing fossiliferous rocks were broken down. Small denudation remnants of Orthoceras limestone, probably resting directly on Archaean rocks, existed at the time of the Chasmops transgression and yielded material for the conglomerate. This is proved by the presence of scattered fragments of Asaphus limestone in the conglomerate. The presence of these fragments in the conglomerate is also an indication of the magnitude of the changes of sea-level preceding the deposition of the Chasmops beds.

The presence of Archaean fragments in all three components, particularly of sharp-edged fragments in the limestone, tells us that the sedimentation took place on a hilly Archaean coast, which continually yielded material during the formation of the lower Chasmops series.

There is a great similarity between the sequence in Tvären and the corresponding part of the Chasmops series of the Central Lockne area. This similarity shows that the sedimentary conditions were analogous in these two areas, so far from each other. This is particularly apparent from the great similarity between the limestone from Tvären and the pure limestone facies of the Lockne area, and in this connexion it may be mentioned that palaeontological evidence proves that these limestones were formed contemporaneously.

Palaeontologically, the agreement is great also between the limestone from Tvären and the Esthonian sequence represented by the Kuckers and Itfer formations.

IV. Survey of the Chasmops Series in Sweden and a few Comments on its Correlation with Strata in Foreign Countries.

Summing up the stratigraphical results obtained in the areas investigated, we find the following data useful for a correlation of the different facies of the Chasmops series.

The zone of *Dicranograptus clingani* CARR. belongs to the upper Chasmops series.

Amplexograptus vasae (TULLB.), which Hadding considered to be an index fossil of a graptolite zone below the zone of *Dicranogr. clingani*, appears to occur, in Jemtland as well as in Bornholm, in the Clingani zone proper as well as in the shale close below that zone. According to observations made in Jemtland, this shale, too, may be considered to belong to the upper Chasmops series.

The list of graptolites obtained from the Tvären area includes species that are earlier known from two other districts in the Baltic region. *Acanthograptus suecicus* (WIMAN) has thus been reported from the lower Chasmops limestone of the North Baltic district, while *Climacograptus bekkeri* (ÖPIK) and *Dendrograptus* sp. (= *Temnograptus* sp. ÖPIK 1928) are described from the Esthonian C_2—C_3. According to Öpik (1927, p. 29), *Cl. bekkeri* is a fairly common species in these formations, which should be correlated with the lower Chasmops limestone in Sweden. Several specimens of it have also been found in that limestone from Tvären. *Cl. bekkeri* may thus be regarded as an index fossil of the lower Chasmops limestone.

In Bornholm the zone of *Amplexograptus vasae* rests on graptolite-bearing shales, which Hadding (1915) proposed calling the zone of *Climacograptus rugosus* TULLB. The index fossil of this zone not being indentical with *Cl. rugosus* TULLB., the name *Amplexograptus rugosus* (HADDING) has been proposed for it (see foot-note on p. 82). The stratigraphical position of this zone indicates that it probably belongs to the lower Chasmops series, although its relation to the lower Chasmops limestone cannot be definitely established.

The above data are noted in the following table, which also includes the boundary beds of the Chasmops series.

Table of the Chasmops Series showing correlation between different facies.

Series		Shelly facies	Graptolite facies
Trinucleus Series		Black Trinucleus shale (with *Tretaspis seticornis*, *Flexicalymene trinucleina*, etc.).	Zone of *Pleurograptus linearis* and *Climacograptus styloideus*
		Masur limestone	
		Hiatus?	Hiatus?
Chasmops Series	Upper	Upper Chasmops limestone	Zone of *Dicranograptus clingani*
			Zone of *Amplexograptus vasae*
	Lower	Lower Chasmops limestone (with *Climacograptus bekkeri*)	? Zone of *Amplexograptus rugosus*
		Sandstone (Loftarstone)	Zone of *Nemagraptus gracilis*
		Basal conglomerate	
		Hiatus	Hiatus in Sweden[1]
Orthoceras limestone series		Schroeteri limestone	Zone of »*Climacograptus putillus*»[2]

It is suggested in this table that an upper part of the zone of *Nemagraptus gracilis* be considered equivalent in age to the basal Chasmops series, instead of to the uppermost part of the Schroeteri limestone, i. e. the so-called Ancistroceras limestone (cf. Hadding 1913, p. 83). However, no palaeontological evidence can as yet be presented supporting this opinion. The argument for this tentative correlation is a conclusion that may be drawn from the presence of arenaceous layers in the zone of *N. gracilis* (cf. p. 106). If we accept this correlation we find an interesting analogism between the Chasmops series and the Dictyonema-Ceratopyge series, as illustrated by the following data. The lower Dictyonema-Ceratopyge series was deposited during a transgression by the Ordovician sea, as was the lower Chasmops series. In some districts (e. g. in Dalecarlia and the North Baltic district), it consists of a basal conglomerate, the Obolus conglomerate, and Obolus sandstone; in other districts (e. g. in Västergötland, Östergötland, S. Öland, and Scania), it is made up of alum shale with *Dictyonema flabelliforme*. In Östergötland this shale contains sandstone beds and, according to a personal communication from Dr. Westergård, also thin conglomerate beds. As shown by Westergård (1917), the Dictyonema shale, at least part of it, was deposited contemporaneously with the Obolus beds.[3] In the Chasmops series, the basal

[1] cf. p. 125.
[2] cf. foot-note p. 105.
[3] In Esthonia, beds of Obolus sandstone and Dictyonema shale alternate (cf. Öpik, 1929 p. 12).

beds, composed of conglomeratic breccia or conglomerate and sandstone (Loftarstone), hold a stratigraphical position similar to that of the Obolus beds in the Dictyonema-Ceratopyge series, and investigations in Jemtland give good reasons to presume that their relationship to the Nemagraptus gracilis shale is analogous to that of the Obolus beds to the Dictyonema shale. There are indications that further examinations of the N. gracilis zone may result in a division of this zone into several subzones, as is the case with the Dictyonema zone (cf. Thorslund 1937, p. 15). Such an examination might possibly also disclose what part of the N. gracilis zone corresponds to the above-mentioned Chasmops beds.

Very likely there exists a stratigraphic gap between the Chasmops and the Trinucleus series, though it has not been possible to demonstrate the existence of this gap in Jemtland. The writer is of opinion that the Masur limestone in the base of the Trinucleus series was formed during changes of level. Corrosion surfaces in limestone prove that breaks have occurred in the sedimentation in connexion with changes of sea-level (cf. Thorslund 1937 a). If there is a surface of that kind indicating the boundary in question, it is probably at or close above the base of the Masur limestone, but it has not yet been observed in Jemtland. The break under consideration, however, is distinctly indicated in the Ordovician sequence of Gotland (cf. Thorslund and Westergård 1938). In addition it may be noted that the uppermost Chasmops series of that sequence contains arenaceous layers and also several corrosion surfaces, indicating oscillations during the withdrawal of the sea in late Chasmops time.

Coarse-clastic deposits at the base of the Chasmops series have been observed in no other Cambro-Silurian areas than those of Jemtland and Södermanland (Tvären). The unconformity between this series and the pre-Chasmops beds is demonstrated, however, in the deep-boring core from File Haidar, Gotland, in which there is an uneven contact (a corrosion surface) between the lower Chasmops limestone and the Schroeteri limestone (Thorslund and Westergård 1938, Pl. IV, figs. 2—2 a). No similar contact surface, separating the Chasmops series from its substratum, has so far been observed in other districts, probably owing to the absence of good exposures.

The Chasmops series of other Palaeozoic districts in Sweden than those of Jemtland, Södermanland, and Scania, is on the whole developed in a limestone facies. In most cases it is built up of bedded limestone containing mostly thin layers of argillaceous shale at the bedding planes, occasionally strata of thin lenses or nodules of limestone in marly shale. In the Lake Siljan district of Dalecarlia, a reef-like limestone, the Kullsberg limestone, which forms a few large lenticular intercalations in the »normal» Ordovician deposits (cf. Thorslund 1936, p. 22, fig. 8), is partly of the same age as the Chasmops series. Thus, as demonstrated by a palaeontological investigation (Warburg 1925), the lower Kullsberg limestone was mainly formed contemporaneously with the upper Chasmops limestone, although the possibility certainly exists that its formation began a short time before the deposition of the latter. The upper Kullsberg limestone belongs to the Trinucleus series, having been formed contemporaneously with the Masur limestone, and like that it is overlain by black Trinucleus shale containing, *inter alia*, *Climacograptus styloideus* LAPW. In 1935 (p. 40) the writer expressed the opinion that the Kullsberg limestone was probably formed during a transgression. Having subsequently studied the Chasmops series in other districts of Sweden, however, the writer has arrived at the conclusion that the lower Kullsberg limestone was on the whole deposited during a regression of the sea, the upper Kullsberg limestone during a subsequent transgression. This interpretation implies that the Kullsberg limestone was formed during changes of the bathymetrical conditions similar to those occurring during the formation of the Boda limestone, which is indicated by the shape of these occurrences. — The Chasmops series of Dalecarlia is abt. 25—30 m thick.

Lithologically as well as faunistically there seems to exist a close agreement between the Chasmops series of the North Baltic district, of Öland, and of Gotland. Information of the series in the first mentioned district has been gained from examinations of boulders (Wiman 1906 a, pp. 105—122). Only in northern Öland does the series occur as solid rock of lower Chasmops limestone, being mainly exposed in the vicinity of the village of Böda. In southern Öland the upper Chasmops series is represented by boulders of Macrourus limestone, some of which attain a considerable size (cf. Hedström and Wiman 1905, p. 110). The Chasmops series of Gotland is known from two deep-borings only (cf. Thorslund and Westergård 1938). — The lower Chasmops series of these districts consists of bedded, grey limestone, lithologically similar to the underlying Schroeteri limestone, though generally purer and harder than that. The upper Chasmops series is also built up of limestone but of a somewhat different type to that of the lower series, being light-grey, fine-grained, and occasionally more or less arenaceous. It seems to be sandier and thinner in northern Gotland than in the sequence represented by boulders in Öland. — In the North Baltic district there is apparently also a limestone formation of the same geological type and age as the Kullsberg limestone of Dalecarlia (cf. Warburg 1925, p. 419).

The Chasmops series of Östergötland is very little known as there are but few exposures. The observations made indicate, however, that on the whole it agrees with the series of Dalecarlia where the latter presents a »normal» development, i. e. in localities some distance from occurrences of Kullsberg limestone (as for instance in the rivulet section at Fjecka). Also in Östergötland the series is overlain by Masur limestone.

The Chasmops series of Västergötland, too, is not very much known, and so far it has been observed in small outcrops only. Generally it consists of bedded limestone with intercalations of more or less marly shale, but the development varies in different sections of the series as well as in different parts of the province. Thus, in Kinnekulle (cf. Holm 1901, p. 54) most of it consists of a greenish shale with beds or lenses of a dark, almost compact limestone which is flinty (silicious) and very hard; at the top it contains limestone that is lighter and purer. In Billingen and Falbygden the series is richer in limestone than in Kinnekulle. According to the writer's observations in the Falbygden area, the content of shaly material as well as the thickness of the series seem to increase from the east (Plantaberget) towards the west (Mösseberg). In Gisseberg the upper Chasmops series consists of a fairly pure, slightly bituminous bedded limestone, containing, *inter alia, Triarthrus linnarssoni* n. sp., described in this paper. In most cases this series is overlain by greenish or dark Trinucleus shale, but in Mösseberg, at least in its southwestern slopes, the lowermost Trinucleus series is made up of a thick-bedded, dark limestone with a thickness exceeding 4.7 m. This limestone, which stratigraphically corresponds to the Masur limestone, is quite lacking in eastern Falbygden, this indicating the existence of a break in the sedimentary record, between the Chasmops and Trinucleus series. — The thickness of the Chasmops series in Västergötland is comparatively small, being estimated at abt. 10 m in Kinnekulle and 6—8 m in Billingen and Falbygden.

It is not intended in this paper to fully discuss a correlation of the Chasmops series with formations of foreign countries, as the solution of this problem is largely a corollary of the correlation of the shelly facies of this series and the graptolite sequence. It should be pointed out, however, that the fauna of the shelly facies allows of a fairly detailed comparison with the Middle Ordovician strata of Esthonia and Norway, while some graptolites of the graptolite facies are helpful for a correlation over large distances (cf. table on p. 183).

The works of several palaeontologists (Fr. Schmidt, Holm, Wiman, Warburg, Öpik, and others) have resulted in the list of species common to the Chasmops series and the East Baltic formations lettered C_2—D_1 becoming longer and longer. Thus there exists a substantial fund of faunistic evidence for a correlation of the lower Chasmops series with the Kuckers and Itfer formations (C_2—C_3), and in this correlation the Uhaku formation ($C_1\delta$) must also be included, that formation probably being equivalent in age to the basal coarse-clastic Chasmops strata in Södermanland and Jemtland. In this connexion it may be mentioned that, according to Öpik (1937, p. 3), there evidently is a stratigraphical break between the Uhaku formation and its substratum at Tallinn, its basal strata being without correspondence there. The upper Chasmops limestone (the Macrourus limestone) has generally been correlated with the Jewe and Kegel formations (D_1—D_2), this correlation being mainly based on the occurrence of the species *Chasmops maxima* FR. SCHM., which according to Warburg (1925) is probably identical with *Chasmops macroura* SJÖGR. The writer is of opinion that this correlation is definitely proved as regards the correlation of the upper Chasmops limestone with the Jewe formation. Whether or not an uppermost part of the Chasmops series may be correlated with the Kegel formation, must, however, as yet be left an open question. In the Ordovician sequence at File Haidar in Gotland, at least, there are evidently no strata corresponding to the Kegel formation (cf. Thorslund and Westergård 1938, p. 38).

In Norway the strata correlatable with those of the Chasmops series in Sweden are found in the Chasmops beds and the Ampyx limestone of the Oslo region, the subdivisions lettered 4bδ—4aβ (cf. the stratigraphical table given by Störmer 1934, p. 331). The fauna of the upper Chasmops limestone (4bδ) in the Oslo district is closely related to that of the upper Chasmops series in Sweden, and they have several species in common, e. g. the following trilobites: *Ampyx ? aculeatus* ANG., *Cryptolithus discors* (ANG.), *Platylichas laxatus* (MCCOY), and *Chasmops extensa* (BOECK). The correlation of the lower Chasmops limestone + the lower Chasmops shale (4bβ + 4bα) with the lower Chasmops limestone in Sweden is also clearly established by palaeontological evidence. The occurrence of *Ampyx costatus* (BOECK), *Ptychopyge glabrata* ANG., *Echinosphaerites aurantium* (GYLL.), and others (cf. Störmer 1934, p. 331, and 1940, p. 132), in the Ampyx limestone (4aβ) indicates that this limestone should be correlated with some basal part of the Chasmops series in Sweden. In the shelly facies of that series, however, there are possibly no strata corresponding to the lower part of the Ampyx limestone. As to the lithological development of the Norwegian Chasmops strata, it should be pointed out that there is a closer resemblance to the Autochthon of Jemtland in the Oslo district than in the Mjösen district, the corresponding strata in the latter district mainly consisting of shales with beds of fine, calcareous sandstone (cf. Holtedahl 1909).

The reference of the zone of *Nemagraptus gracilis* to the Chasmops series and the fact that the zone of *Pleurograptus linearis* forms the base of the Trinucleus series thus enable us to be brief with regard to the correlation of this series with Ordovician strata in Great Britain and N. America. The basal Caradocian and probably also the upper Llandeilian of England were formed contemporaneously with the Chasmops series. The Benan conglomerate in the Girvan district of Scotland is probably the chronological equivalent to the basal Chasmops conglomerate in Jemtland and Södermanland. As clearly stated by several authors, it rests on mudstones containing *Nemagraptus gracilis*, this probably being the reason why it has been considered to correspond to the zone of *Climacograptus peltifer* which follows next above the zone of *Nemagr. gracilis* in the British stratigraphical table based on the succession of the graptolite zones (cf. Pringle 1935, p. 18)[1]. However, Elles (1937, p. 489) seems to place it between these zones, and if we regard the graptolite assemblage encountered in the mudstones underlying it, we find, besides *Nemagr. gracilis*, such species as *Didymograptus superstes* LAPW., *Glossograptus hincksi* (HOPK.), and *Cryptograptus tricornis* (CARR.), which all occur below the zone of *Nemagr. gracilis* in Sweden (cf. Hadding 1913). The writer considers this to imply that *Nemagr. gracilis* appeared earlier in Scotland than in Sweden, where a hiatus is supposed to occur below the known part of the zone of

[1] *Climacograptus peltifer* (LAPW.) also occurs in Jemtland. This has been disclosed by Dr. Bulman's examination of an old collection made by Prof. C. Wiman in the neighbourhood of Nälden railway station, abt. 27 km NW of Östersund. According to the writer's observations around that locality, the present exposures there consist of Ogygiocaris shale and the strata immediately above it.

Nemagr. gracilis and that the Benan conglomerate as well as the Chasmops conglomerate in Sweden should be correlated with an upper part of the zone of *Nemagr. gracilis*[1]. This is further substantiated by the statement (Elles 1937, p. 488) that in the Girvan district the Knockgerran shales (= lower Ardwell flags) contain graptolites of the zone of *Cl. peltifer.* The Balclatchie beds, lying between these shales and the Benan conglomerate, are fairly rich in trilobites, most genera of which are also represented in the lower Chasmops limestone, by closely related forms. The upper Ardwell flags must be correlated with the upper Chasmops beds in Sweden, for they contain graptolites of the zone of *Dicranogr. clingani* and are overlain by the Whitehouse beds with graptolites of the zone of *Pleurogr. linearis.*

In attempting a correlation of the Chasmops series with American formations, we find that the Trenton of New York may on the whole be of the same age as this series. Evidence supporting this correlation is supplied by the fact that beds of upper Trenton age are followed by the Utica shale with fossils of the Pleurogr. linearis zone, e. g. the zone fossil, and *Leptograptus flaccidus* (Hall), this zone following above the Chasmops series (cf. p. 9). The stratigraphical standing of the Rysedorph conglomerate, discussed by Ruedemann on several occasions, seems to be similar to that of the Benan conglomerate in Scotland. Ruedemann has changed his opinion of its relation to the Normanskill shale (zone of *Nemagr. gracilis*), which is clearly stated in his last comprehensive account of its stratigraphy; he writes (1930, p. 113): »In the first paper ('01) dealing with this conglomerate, we placed it within the Normanskill shale, seeing in the Trenton fauna of the conglomerate evidence of the Trenton age of the Normanskill shale. With the recognition of the fact that the typical Normanskill shale is older than the Trenton, it became necessary to assume that the Rysedorph conglomerate either is intercalated in the upper division of the Normanskill (Magog shale) of Black River and perhaps earliest Trenton age or rests entirely on the series. The relative position of the conglomerate to the shales gives no indication of its age, except that, as at the Moordener kill, it is undoubtedly interfolded with Normanskill shale, which yet must be considerably older. We are now placing the Rysedorph conglomerate at the top of the whole Normanskill shale and below the Snake Hill shale, correlating it with the lower Trenton.»

The above correlations suggest that the changes of sea-level which are evinced in the strata of the lower Chasmops series in Sweden are also traceable in the Ordovician of other parts of the world, and that the crustal movements causing these oscillations had more than a local effect.

[1] In this connexion it should be pointed out that *Nemagr. gracilis* (Hall) has never been reported from Sweden, only its variety *remotus* E. and W. being observed here (cf. Hadding 1913).

V. Description of Species.

1. Trilobita.

Fam. ***Agnostidae*** M'Coy.

Trinodus armatus n. sp. Pl. 9, fig. 9.

Specific characters. Cephalon subquadrate in outline, slightly wider than long, widest across frontal end of glabella, strongly convex in transverse direction, its posterior margin furnished with a pair of short, pounce-like spines. Glabella strongly raised above the cheeks, highest posteriorly, gently sloping to frontal end, broadly rounded posteriorly, measuring three fifths the length of cephalon; (as seen in cast) furnished with a low median tubercle, surrounded (at least in front and laterally) by a weak furrow from which three pairs of very faint furrows run in the following manner: 1st pair directed obliquely forwards and outwards, apparently dying out before reaching axial furrows; 2nd pair short, directed straight outwards; 3rd pair (hardly traceable) running obliquely backwards and outwards; basal lobes small and low. Axial furrows strong, increasing in depth and slightly diverging posteriorly. Cheeks of approximately uniform width throughout, coalescing anteriorly, sloping fairly steeply downwards with gently convex surface in front of glabella, gradually more steeply bent down posteriorly. Marginal rim with convex surface, at the sides decreasing in width posteriorly, marked off from the cheeks by a comparatively strong and broad furrow. Surface of test smooth.

Dimensions. Cephalon: length 3.3 mm, greatest width 3.6 mm; glabella: length 2 mm, width at base 1.3 mm.

Affinities. Only the cephalon of this species has been found. It bears a close resemblance to that of *Agnostus tardus* Barrande (1852, p. 913, Pl. 49), and the only distinctive feature between them seems to be that the latter has much smaller and more slender cephalic spines. The glabella of *T. tardus* lacks a median tubercle, which possibly is traceable in wholly testiferous specimens of *T. armatus.*, though such a specimen is not yet available. Disregarding the absence of cephalic spines, the cephalon of *Agnostus lentiformis* Angelin (1854, p. 7, Pl. VI, fig. 7) appears to be very like that of the new species.

Occurrence. Lower Chasmops limestone, Central Lockne area, Jemtland.

Fam. ***Olenidae*** BURMEISTER.

Triarthrus linnarssoni n. sp. Pl. 12, figs. 4—12.

1869, *Triarthrus Becki* LINNARSSON p. 70, Pl. I, fig. 27.

Specific characters. Cranidium sub-semielliptical in outline, rather strongly convex transversally. Glabella broadly rounded in front, slightly wider than long, widest across the »anterior» (the true third) pair of lateral lobes, nearly flat in the median portion (behind the pair of pits), moderately convex at the sides and sloping fairly steeply anteriorly. Four pairs of lateral glabellar furrows discernible in well-preserved specimens; 1st pair placed far forward on the frontal slope of glabella, marked as short, faintly depressed straight lines; 2nd pair very short, mainly represented by oblong pits and located at a distance from the occipital furrow equal to about three fifths the length of glabella; 3rd and 4th pairs sub-parallel, deep and narrow, curving inwards and slightly backwards from their beginning in axial furrows, extending from there more than one third across the glabella on either side. Basal lateral glabellar lobes slightly longer (in longitudinal direction) than the preceding ones; »frontal lobe» short, occupying less than half of glabella. Axial furrows distinct, narrow, sub-parallel outside posterior part of »frontal» glabellar lobe, then curving slightly outwards and converging posteriorly. Occipital furrow strong, transverse in the middle portion, curving forwards laterally. Occipital ring of moderate, almost uniform width throughout, gently convex transversally, with an oblong, median tubercle near posterior margin. Anterior border narrow, indistinctly projecting in the middle, gently arched transversally, marked off by a strong preglabellar furrow.

Fixed cheeks sloping steeply downwards with gently convex surface, gradually widening posteriorly, their greatest width equal to two fifths the width of glabella. Palpebral lobes situated approximately opposite the interspace between the 2nd and inner extremities of the 3rd pair of glabellar furrows, with flattened surface, gently arched longitudinally, marked off by shallow furrows. Anterior branches of facial sutures curving forwards and inwards; posterior branches running in slightly convex curves from eyes to posterior border furrows, then almost straight backwards to cut posterior margin of cephalon at slightly obtuse angles.

Surface of free cheeks with minute punctae, glabella smooth.

Dimensions. Length of cranidium 6 mm; length of glabella 4.7 mm, its greatest width 5 mm.

Remarks. The above description is mainly based on the cranidium, which Linnarsson (1869, p. 70, Pl. I, fig. 27) referred to *Triarthrus Becki* GREEN and collected in »Beyrichiakalk» at Gisseberg, Västergötland. According to the writer's collections, it is a rare species at the type locality where it is associated with a fauna of upper Chasmops age. In Jemtland it is sparse in autochthonous beds of a corresponding age, but abundantly met with in the zone of *Dicranograptus clingani* of the easterly nappes. Only detached parts of the carapace have been obtained, in the clingani-zone occurring together with such of *Triarthrus skutensis* n. sp., described below. Owing to distortion by compression it is often impossible to discriminate between cranidia of these species. In such cases the presence of two different species is evident from the fact that there are free cheeks of two different types, one of them furnished with a long posterior spine, the other lacking a spine. Cheeks of both types are sometimes found in the same slab of shale. Comparisons between several free cheeks of these types and cranidia of the two species indicate that the spine-bearing cheek very likely belongs to *Tr. linnarssoni*. The probability of this inference is enhanced by the fact that only free cheeks of the other type have been obtained in a lens of limestone containing typical cranidia of *Tr. skutensis*.

The free cheek, thus referable to *Tr. linnarssoni*, has a broad rounded marginal border marked off by a shallow, comparatively broad border furrow and proceeds backwards and slightly outwards from the postero-lateral angle into a straight, long and slender spine, which seems to attain a length almost equal to that of the cheek; aperture of the eye large, its diameter being about half its distance from posterior margin.

The dimensions given above refer to Linnarsson's original specimen. The following measurements (in mm) may be added to show the ratio between length and width of glabella of some cranidia obtained from limestone in Jemtland: 1.8 : 1.9 (Slandrom), 2.7 : 2.9 (Örån), 4 : 4.9 (compressed from above, Stengärde).

Affinities. As far as can be learnt from Ruedemann's critical treatment and figures of *Triarthrus becki* GREEN (RUEDEMANN 1926, p. 115, Pl. 21, figs. 10—12), which occurs in beds of Trenton age, i. e. at a stratigraphical position approximately corresponding to that of *Tr. linnarssoni*, cranidia of these two species show a very close resemblance to each other. It seems as if the main difference between them is that the palpebral lobes (and eyes) of the former species are smaller and placed somewhat farther forward. Further, the surface ornamentation is different, as fine tubercles are noticed in *Tr. becki*. There are no description and figures of the free cheeks of the latter species, but probably these were not spine-bearing.

In the Jemtland Ogygiocaris shales several species of *Triarthrus* are met with, but all are easily distinguished from the species mentioned above, and they also occur in older beds than those. As pointed out by Ruedemann (op. cit. p. 119), the form described by Hadding (1913, p. 69, Pl. VI, figs. 18—19) as *Tr. becki* var. *humilis* agrees in some characters with *Tr. becki*, but the glabella is relatively longer, the posterior two pairs of lateral glabellar furrows are shorter and more weakly impressed, the anterior one of these pairs being more strongly curved. Although apparently closely related to *Tr. becki* var. *humilis*, the form recently described by Asklund as *Triarthrus beckii* GREEN (Asklund 1936a, p. 3, Pl. I, figs. 1—5) is quite distinct from the species to which it is referred and also from *Tr. linnarssoni*. The glabella is as long as wide, its posterior two pairs of lateral furrows scarcely impressed (in testiferous specimens usually marked only as dark lines), comparatively strongly curved backwards and relatively short, the anterior border of cranidium distinctly projects in the middle. The holotype of this species, for which the name *Triarthrus freji* n. sp. is herewith proposed, is the cranidium figured by Asklund on Pl. I, figs. 1—2. The cranidium (probably also the pygidium) on fig. 4 of the same plate also belongs to that species.

The form (a cranidium) described by Reed (1903, p. 28, Pl. IV, fig. 10) as *Triarthrus becki* var. is probably not identical with *Tr. Becki* LINRS. (= Tr. *linnarssoni*) as suggested by Reed. A comparison with Reed's description supplies the following distinctive features. In the unnamed variety the glabella is comparatively longer (»nearly as broad as long»), the axial furrows are straight, parallel, the occipital furrow is arched forward in the middle and the facial sutures meet the posterior margin at acute angles (»about 75°»). It seems to bear a closer resemblance to the following species than to *Tr. linnarssoni*.

Occurrence. Upper Chasmops beds in Västergötland (Gisseberg) and Jemtland (autochthonous strata at Slandrom); zone of *Dicranograptus clingani* in Jemtland (common in black shales with limestone lenses of overthrust beds at Örån and Stengärde).

Triarthrus skutensis n. sp. Pl. 12, figs. 13—18.

Specific characters. Glabella subquadrate in outline, with sides parallel, truncate in front, at least as long as wide; lateral glabellar furrows as in *Tr. linnarssoni*. Axial furrows strong, straight, parallel. Fixed cheeks sloping rather steeply from axial furrows with convex surface, gradually widening posteriorly; palpebral lobes small, located far forward or opposite the middle portion of the »frontal» lobe. Facial sutures running backwards from the eyes in curves that run slightly outwards to cut the posterior margin at almost right angles.

Dimensions. The specimens obtained from limestone lenses are usually smaller but better preserved than those occurring in the shales. The cranidia figured on Pl. 12 show the following measurements:

	Fig. 13	Fig. 14	Fig. 16
Length of cranidium	4.5 mm	3.6 mm	5.9 mm
» » glabella	3.6 »	2.8 »	4.6 »
Width » »	3.1 »	2.8 »	4.6 »

Remarks. As mentioned above, this species occurs in Jemtland in the zone of *Dicranograptus clingani*, where it is associated with *Tr. linnarssoni*. Besides, a fragmentary though otherwise well preserved cranidium has been obtained from dark limestone of the upper Chasmops beds in the Central Lockne area. In the free cheeks, very likely belonging to this species, the eyes are placed far forward, their aperture being small, not longer than one third the distance to posterior margin of cephalon along the suture line.

Affinities. Cranidia of this species and *Tr. linnarssoni* agree in many characters and are usually not distinguishable when occurring as compressed specimens in shales. Two distinctive features are otherwise to be noted. The palpebral lobes are smaller and placed farther forward in *Tr. skutensis* and the length of its glabella is relatively greater.

As suggested above (p. 130), this species seems to bear a close resemblance to the Scottish form described by Reed as *Tr. becki* var. The differences between their cranidia appear to be small and mainly concern the manner in which the facial sutures meet the posterior margin and the relative length and shape of the occipital ring. Judging from the additional descriptions and figures of *Triarthrus eatoni* (HALL) given by Ruedemann (1926, p. 119, Pl. 21, figs. 7—9) and Foerste (1924, p. 240, Pl. XLV, fig. 13) the cranidium of this species closely resembles that of *Tr. skutensis* except that the palpebral lobes are placed farther backwards and that the fixed cheeks are more contracted close behind them in the American species.

Occurrence. Zone of *Dicranograptus clingani* in the easterly nappes of Jemtland (Örån; in outcrops near Stengärde railway station). Upper Chasmops limestone of the Autochthon (Central Lockne area, abt. 0.7 km SW of Tandsbyn railway station).

Fam. ***Remopleuridae*** CORDA.

Remopleurides nanus elongatus FR. SCHMIDT. Pl. 7, figs. 17—20.

1894 *Remopleurides nanus* v. LEUCHT. var. *elongata* FR. SCHMIDT, p. 89, Pl. 6 fig. 36.
1925 » » » » » » ÖPIK, p. 16, Pl. 2, figs. 11, 17.

A few more or less fragmentary cranidia found in boulders of lower Chasmops limestone from Tvären seem to agree with that of *R. nanus* var. *elongata* SCHMIDT.

Description. Glabella slightly convex, five sixths as long as wide, widest just behind the middle; tongue strongly bent down, moderately convex, parallel-sided, twice as wide as long (high), about two fifths the length of posterior part of glabella, as wide as the constricted basal part of glabella, antero-lateral parts flattened, marked off by short furrows, which do not meet. Lateral furrows and palpebral lobes as in *R. latus kullsbergensis* WARB. (cf. Warburg 1925, p. 83, Pl. 1, fig. 1), surface of glabella smooth. Occipital furrow deep; occipital ring flattened, tapering towards the sides, middle part moderately arched from side to side, lateral parts strongly bent down, near anterior margin provided with a minute median tubercle; surface close behind this tubercle finely striated (usually two parallel, transverse striae present, in one specimen only one, but distinct); lateral parts of posterior edge serrate.

Remarks and *Affinities.* A couple of fragmentary thoracic segments and a labrum[1] of a *Remopleurides* have been found in boulders from Tvären and may possibly belong to this species. The segments display a rather great general resemblance to those of *R. validus* n. sp., the surface, however, being but finely striated and the posterior edges of the axial rings denticulated only in their lateral parts. The labrum differs but slightly from that of *R.*

[1] Labrum is used in the same sence as hypostoma.

validus; the body is somewhat more convex, its grooves at the anterior edge are shallower and the ridge between them more prominent; furthermore, the postero-lateral corners are raised into short points.

The cranidia of the two species under consideration suggest a close affinity between them. The only difference seems to be a slightly more circular outline of the posterior part of glabella and a slightly wider tongue in *R. nanus elongatus* than in *R. validus*. Öpik (1925) has figured and briefly described a pygidium and a part of a thorax of a form which he refers to *R. nanus elongatus*. As pointed out by him the thorax is suggestive of that of *R. dorsospinifer* PORTL., though it is not quite clear from his description and figure if the spine-bearing axial ring belongs to the 8th segment or not. The pygidium he compares with that of *R. latus* OLIN and, as far as can be ascertained from the figure, it is clearly different from that of *R. validus*, owing to the long spine of the 2nd pair of pleurae. Among the specimens of *Remopleurides* sp. found in boulders of North Baltic Chasmops limestone and mentioned by Wiman (1906 a, p. 108), which I have had an opportunity to examine, there are a few cranidia (very likely those compared by Wiman with *R. latus* OLIN) in the Upsala Palaeontological Institute, which agree so closely with the cranidia from Tvären that I have not hesitated to refer them to the same species.

Occurrence. As mentioned above this species has been found in boulders of lower Chasmops limestone from Tvären and from the North Baltic district. It occurs in the Kuckers formation of Esthonia.

Remopleurides validus n. sp. Pl. 7, figs. 1—9.

Diagnosis. Cephalon sub-semicircular in outline. Glabella about two thirds as long as wide with a broad and rather short tongue, arched strongly downwards; palpebral lobes very narrow; spine of free cheek short, not reaching beyond posterior margin of the cheek. Labrum subquadrate, surface flattened; body subreniform, bigrooved at anterior edge, raised into a prominent ridge between the grooves.

Thoracic segments gradually and regularly decreasing in width posteriorly, axial rings traversed by rather coarse and slightly sinuous striae, posterior edges serrate; on one segment (very likely the 8th) a long median spine; side lobes narrow, pleurae striated, gradually directed (more) backwards posteriorly.

Pygidium with very short spines, twice as wide as long, with distinct axial furrows, lacking a post-axial portion; 1st pair of pleurae directed almost straight backwards; 2nd pair strongly arched inwards, their inner and posterior margins forming a reversed U-shaped figure.

Description. Glabella in dorsal view subelliptical in outline, gently convex in anterior part, flattened posteriorly, about two thirds as long as wide, widest close behind the middle; tongue strongly arched down, slightly convex, parallel-sided, four fifths as wide as glabella at base and somewhat less than one third as long as posterior part of glabella; antero-lateral parts of tongue with narrow borders, marked off by furrows interrupted in the middle; 3 pairs of lateral furrows present (though barely visible in the specimens available), located at about the same distance from each other; anterior pair very short, its inner ends situated about two thirds the distance from the occipital furrow to the tongue of the glabella; middle pair almost straight, directed inwards and rather slightly backwards; basal pair more curved, especially in their inner parts, which are arched rather strongly backwards. Palpebral lobes separated from glabella by strong furrows, narrow, widest posteriorly, gradually decreasing in width anteriorly, almost filiform at sides of tongue. Test of glabella smooth. Occipital ring flattened, tapering towards the sides, furnished with a minute median tubercle close to the occipital furrow, lateral parts (at least) of posterior edge finely denticulate.

Free cheeks with large, semicircular eyes, which slightly increase in width (or height) towards base of glabella. Beneath the eye there is a narrow, sharply raised rim or eye-lid marked off from the eye and the outer part of the free cheek by strong furrows. Outside the latter (lower and posteriorly deeper) furrow the posterior part of the cheek is raised into a ridge, from which the cheek gently slopes outwards and downwards. Anteriorly the outer part of the cheek becomes narrower, forming a narrow border along the eyelid. Cheek-spine arising in front of the rounded genal angle, slender, rapidly tapering, directed backwards and slightly outwards, not reaching beyond posterior border, forming acute angles with the hindmost portion of the lateral margin of the cheek. Posterior marginal furrow deep; posterior edge close to the dorsal furrow with a deep notch to receive the articulating process of the anterior thoracic pleura. Surface of the broadest, flattened portion of the cheek finely striated. Doublure broad, gently arched, furnished with rather coarse striae, parallel to the edge of the dorsal part of cheek.

Labrum subquadrate in outline, widest in anterior part, slightly wider than long; posterior margin straight, parallel with the middle of anterior margin, the lateral parts of which are directed outwards and somewhat backwards; sides gently arched, almost lyrate in outline. Body subreniform, gently convex, indistinctly bilobate, all round limited by conspicuous though rather shallow furrows (which are flat and wide at the post-lateral corners), in the anterior part of the middle line strongly raised into a ridge, which gradually widens and becomes higher towards its end at the anterior margin; this ridge having a rather deep groove or pit on either side. Surface of body ornamented with very delicate lineation within the lobes, and somewhat coarser, sinuous striae at the postero-lateral sides of the pits, in the middle line and on the ridge. Anterior border narrow, elevated, in the middle connected with the anterior end of the ridge, laterally prolonged into the short anterior wings which are directed straight outwards. Lateral borders narrow in front, widening posteriorly, gently arched from front to back, bent obliquely upwards and outwards. Posterior border fusiform with thickened rim. Surface of lateral and posterior borders ornamented with coarse, almost ridge-like striae, running parallel to the margins.

Thorax (probably composed of eleven segments as in other species of *Remopleurides*) gradually and regularly diminishing in size posteriorly. Axis moderately convex, tapering towards pygidium (4th or 5th axial ring being once and a half as wide as the 11th). Rings flattened, surface ornamented with transverse, rather coarse, sinuous striae, posterior edge denticulate. 8th (or 9th) ring provided with a strong median spine, directed upwards and backwards, about as long as the width of the ring. Side lobes narrow; pleurae gradually decreasing in size posteriorly, falcate, directed downwards and rather straight outwards in anterior part of thorax, being gradually arched more strongly backwards posteriorly; pleural furrows oblique, deep and broad, tapering outwards, terminating before reaching margin; anterior pleural band close to axial furrow with a strong, projecting fulcral knob; posterior edge of pleura with a corresponding notch, the margin of which is elevated all round. Surface of pleura traversed by few and coarse striae, subparallel to margin.

Pygidium subrectangular, about twice as wide as long. Axis half as long as pygidium, sub-semicircular in outline, composed of two segments. Axial furrows very distinct, becoming slightly broader posteriorly, ending blind. 1st axial ring widening towards the sides, here being about twice as long as in the middle; posterior part ornamented similar to the axial rings of thorax; articulating half-ring well defined with a rather wide excavation in middle part, thus leaving an open strip between pygidium and posterior edge of the last axial-ring of thorax. Posterior part of axis consisting of two subelliptical, rather coarsely granular swellings, marked off from each other by a distinct furrow in the middle line of pygidium. Side lobes composed of two pairs of pleurae. 1st pair like those of the thoracic segments, directed almost straight backwards, with short free posterior ends; anterior edge with fulcral tubercles directed almost straight outwards. 2nd pair of pleurae strongly curved inwards, leaving a reversed U-shaped area open between their posterior portions, separated from 1st pair by short interpleural furrows in outer part, inner part confluent with them; surface of test finely granular.

Remarks. The material on which this description is based was found in the same piece of rock. Besides the parts figured, there were observed several more or less fragmentary cranidia, thoracic segments, labra, pygidia, and one fragmentary free cheek. It is beyond doubt that they all belong to the same species, so much the more as no traces of any other species of *Remopleurides* have been observed in the rock.

As to the number of the thoracic segment, the axial ring of which is provided with a spine, it is very probably the 8th. This is demonstrated by a comparison between the last thoracic segment and that posterior to the spine-bearing one. The difference in the backward swings of the pleurae of these segments indicate that there must be one segment between them. Thus, if the thorax is composed of 11 segments (as it in all probability is), the spine-bearing axial ring belongs to the 8th.

Affinities. This new species is easily distinguishable from all species of *Remopleurides* previously described by the short spine of the free cheek and the short and wide pygidium. The thorax appears to show a great resemblance to that of *R. dorsospinifer* PORTL. (Salter, 1853, Pl. 8, figs. 3, 4), and, as is the case in the latter, the 8th segment very likely has a median spine.

Our species also seems to agree in some characters with *R. nanus* var. *elongata* SCHMIDT, but on account of our rather scanty knowledge of the latter, it is as yet impossible to decide how closely allied they are (cf. above).

Occurrence. Lower Chasmops limestone, Central Lockne area, Jemtland.

Remopleurides wimani n. sp. Pl. 7, figs. 10—13.

Specific characters. Glabella very slightly convex, subelliptical in outline, about three fourths as long as wide, widest in the middle of the posterior part; tongue as wide as long, rather strongly arched downwards, slightly convex, two fifths as long as posterior part of glabella and one third the width of that at base. Surface of glabella ornamented with fine sinuous striae approximately subparallel to the margins in the lateral portions of the posterior part, U-curved in the middle of it and transverse on tongue. 3 pairs of lateral glabellar furrows, indistinctly marked off by interruptions in the striation, similarly directed and placed as in the species described above. Palpebral lobes marked off by strong furrows, narrow, widest at base, rather rapidly decreasing in width anteriorly; surface of test finely striated, subparallel to margins. Occipital ring flattened, slightly narrowing towards the sides, moderately arched, with a minute median tubercle near the occipital furrow and fine denticles on the lateral parts of posterior edge.

Remarks. In the same beds and locality as the cranidium upon which the above description is based, there were found two small pygidia and a fragmentary free cheek. Very likely they belong to this species.

The pygidia agree in all essential features with that described and figured by Olin as *Lichas quadrispinus* ANG. (Olin, 1906, p. 54, Pl. I, fig. 29), which, as pointed out by Wiman (1906 a, p. 134) and Warburg (1925, p. 86), probably belongs to *Remopleurides latus* OLIN. But for the cranidium the writer would not have hesitated to refer them to this species. The only, slight difference from the pygidium figured by Wiman (1906 a) on Pl. 8, fig. 26, and by that author referred to *R. latus* [according to Warburg (1925, p. 86) possibly belonging to var. *kullsbergensis* WARB.] seems to be a somewhat broader postaxial portion, which is marked off by very indistinct furrows, confluent with the axial furrows. In one of the specimens available, fine, transverse striae are visible all over the surface of the test. — The two pygidia are of equal sizes, measuring in width and length 4/3 mm.

The free cheek appears to be very like that of *R. latus* var. *kullsbergensis* WARB. (Warburg, 1925, p. 84, fig. 15). As in that form the posterior part in front of the genal angle is produced into a slender spine which reaches beyond the posterior edge of the cheek (this spine is broken off in the specimen available). As far as can be ascertained, considering the poor state of preservation, the posterior margin seems to be slightly convex outside the notch, rather than straight or slightly concave as in *R. latus* var. *kullsbergensis*.

Affinities. This species is apparently closely allied to *R. latus* var. *kullsbergensis* WARB. The cranidium differs, however, from that of the latter species in having a comparatively longer and narrower tongue and possibly also with regard to the ornamentation of the surface of the test.

Occurrence. Upper Chasmops beds of the Central Lockne area, about 300 m SW of Tandsbyn railway station.

Remopleurides cf. *latus* OLIN. Pl. 7, figs. 14—16.

Occurrence and *Remarks.* The materiala vailable consists of three small fragmentary pygidia and an almost complete free cheek found in the Chasmops conglomerate, one pygidium at Öd, the other parts at Hallen, Jemtland.

As far as can be seen from the parts preserved, this form is at least closely allied to *R. latus* OLIN (1906, p. 55, Pl. II, figs. 5—9) and possibly identical with that species. The pygidium seems to agree with that described and figured by Olin (1906, p. 54, Pl. I, fig. 29) as *Lichas quadrispinus* ANG. which probably belongs to *R. latus* (cf. p. 135). The free cheek very much resembles that of *R. latus* var. *kullsbergensis* WARBURG (1925, p. 84, fig. 15), except that the posterior portion outside the eye is somewhat narrower and the spine is more slender and directed a little more outwards.

Fam. ***Asaphidae*** BURMEISTER.

Asaphus nieszkowskii FR. SCHMIDT. Pl. 5, figs. 8—13.

1938 *Asaphus nieszkowskii* P. SIEGFRIED, p. 7, Pl. II. (For synonyms see Siegfried.)

Remarks. This form evidently caused Fr. Schmidt much trouble, and was first proposed by him as a new species though he later referred it to different species (*ludibundus* TQT and *lepidus* TQT) on different occasions. Finally, it was regarded as a distinct species, an opinion now shared by Siegfried.

It is apparently closely related to *A. ludibundus* TQT, which, however, appears to be more robust and to attain larger dimensions. The head-shield displays distinctive features. In *ludibundus* the eyes are comparatively larger and lower (being about as high as long, while in *nieszkowskii* about half as high as long), and the fixed cheeks are relatively much broader at the sides of the frontal part of glabella. As already pointed out by Schmidt (1907, p. 72), the labrum of *nieszkowskii* differs from that of *ludibundus* in having the lateral »notches» more sharply set off and somewhat deeper; in addition, in the former species the width across the middle part is about as great as the length, while the labrum of *ludibundus* is comparatively much longer and is furnished with larger anterior wings.

The resemblance between *A. nieszkowskii* and *A. lepidus* TQT was pointed out by Schmidt, who once suggested that the former might be identical to the latter. The originals of *A. lepidus* TÖRNQUIST (1884, Pl. II, figs. 16—17) in the collections of the Geological Institution of Lund have been examined by the writer, who considers them too imperfect (and too badly preserved), however, to permit any decided opinion as to the relationship between *A. lepidus* and other species of the genus. Perhaps they are small specimens of *A. praetextus* TQT.

The material available consists of several detached pygidia, thoracic segments and labra, and a few cranidia and free cheeks; they were collected in loose blocks.

Occurrence. Lower Chasmops limestone, Tvären; C_{1b}—C_3 in Esthonia (according to Schmidt and Siegfried).

Asaphus sp. Pl. 9, fig. 4.

Occurrence and *Remarks.* Two fragmentary cranidia of a small species were found in boulders of lower Chasmops limestone from Tvären. Their distinctive features are a pair of low, comparatively large lateral glabellar lobes, located opposite the eye lobes. In casts these lateral lobes are rather distinctly marked off by furrows. Fixed cheeks in front of them very narrow, but widening anteriorly as in *Asaphus ludibundus* TQT. Preglabellar field narrow, hardly discernible when cranidium is seen in straight dorsal view, pointed in the median line. Surface of anterior portion of cranidium ornamented with fine terraced lines.

The material available is too imperfect to allow a more complete diagnosis of this form, which probably represents a new species, distinguished from other members of the genus *Asaphus* hitherto known from the corresponding beds by the distinct lateral glabellar lobes mentioned above.

Dimensions of the figured specimen; length of cranidium 4 mm, length of glabella 3.4 mm, its width across anterior part 2.8 mm.

Pseudasaphus cf. *tecticaudatus* var. *laurssoni* ÖPIK Pl. 9, figs. 7—8.

Occurrence and *Remarks.* Two fragmentary labra have been found in boulders of lower Chasmops limestone from Tvären. They appear to agree with the labrum of *Pseudasaphus tecticaudatus* var. *laurssoni* ÖPIK (1927, Pl. III, fig. 1), occurring in the Kuckers formation of Esthonia.

Fam. ***Styginidae*** RAYMOND.

Stygina? nitens (WIMAN) Pl. 6, figs. 1—10.

1906a *Holometopus nitens* WIMAN, p. 112, Pl. VII, figs. 19—20.
1925 *Stygina nitens* WARBURG, p. 72, 95.

Remarks. The original description of this species was founded on a single cephalon and two pygidia occurring in boulders from the North Baltic district. The writer's collection includes several cranidia and pygidia, but for one of the latter found in solid rocks. The new material appears to disclose that this species is variable in some characters and, moreover, that its generic reference is questionable.

In large specimens the glabella is almost flat in front and but gently convex between the eye lobes; when the surface is well preserved, three pairs of lateral glabellar pits or depressions are traceable; the first two pairs sub-circular, very faint and almost obsolete, basal pair larger and a little deeper; a glossy muscle spot corresponds to each pit; the glabella is usually slightly raised along the middle line between the pits into a keel-like ridge, which is rather conspicuous in casts; surface of test smooth or furnished with very fine striae on the anterior part of glabella.

In small specimens (= young adults) the glabella is more highly raised above the cheeks and its posterior portion is rather strongly convex transversally; lateral glabellar pits indistinguishable, their places marked by indistinct, non-ornamented (muscle) spots; surface of test finely granular, and, in addition, furnished with minute striae on the frontal slope of glabella.

As seen in the cephalon figured by Wiman (Pl. VII, fig. 19) the inner, convex portion of the free cheek is marked off from the outer, flattened portion by a shallow groove running sub-parallel to margin. In the specimens examined by the writer, the continuation of this groove on the fixed cheeks is also traceable at the sides of the anterior part of glabella.

In small pygidia the axis is rather strongly convex from side to side and gradually decreases in width and becomes obsolete posteriorly, without having a terminal piece clearly set off. A narrow pointed post-axial ridge of somewhat variable length, but never reaching posterior margin, is always to be seen in larger pygidia, in which the axis is more or less flattened, and some (anterior) pleurae of the side lobes are usually traceable (at least in casts). Surface of test of small specimens with minute granulation, in larger ones it is only striated.

Affinities. As pointed out by Reed (1914, p. 27) there are many points of resemblance between *Holometopus nitens* WIMAN and the species described by him as *Bronteopsis armadillanensis* (Reed 1904, p. 92, Pl. XIII, figs. 1—4; 1914, p. 26, Pl. IV, fig. 7). In fact, these species seem to be very closely related and, judging from the figures of the latter species, the differences between them mainly concern the shape of the free cheek and the test ornamentation of the glabella; possibly the pleurae of the pygidium are more strongly marked in the latter species.

As to interpretations of the relation between different species of »*Holometopus*», *Stygina*, and *Bronteopsis*, reference is here made to the discussion in Warburg's memoir of 1925 (pp. 93—96), in which the opinion is expressed that judging from the material available at that time, *inter alia*, *Holometopus nitens* should be referable to the genus *Stygina*. The new material, on which the above remarks are based, does not positively contradict this view but it enables us to draw special attention to some characters in this species which are also present and more strongly marked in the genus *Bronteopsis*, as represented by the genotype *Br. scotica* SALTER (REED 1904, p. 94, Pl. XIII, figs. 5—13, 1914, p. 26, Pl. IV, fig. 6) and *Ogygia? concentrica* LINNARSSON (1869, p. 75, Pl. II, figs. 37—40), the latter species from the Swedish Chasmops beds. These characters concern the longitudinal, ridge-like elevation in the middle of the posterior portion of the glabella, the paired lateral glabellar markings, the subconcentric grooves of the cheeks, and the pleural ridges of the pygidium. As to the cephalon, the features distinguishing *Holometopus nitens* from the representatives of *Bronteopsis* just mentioned are restricted mainly to differences in the width of the fixed cheeks and the shape of the free cheeks, which are comparatively broader and less acutely pointed posteriorly in the latter, but these differences can hardly be considered of generic importance. The details of the pygidia, however, appear to display greater differences, though there is a general agreement. The close resemblance between *H. nitens* and representatives of the genus *Stygina*, on the other hand, is striking and undeniable (cf. Warburg 1925), and pygidia of the former species can hardly be distinguished from some of those referred to *Stygina latifrons* SALTER by Wiman (1901, p. 171, Pl. V, figs. 17, 19). Thus, summing up the results of the comparisons, it appears evident that *Holometopus nitens* WIMAN represents a transition form between *Bronteopsis s. str.* and *Stygina*, and the reference of it to either of these genera merely seems to be a matter of subjective conception. The »transitional» relation is in this case quite as obvious as that represented by *Bronteopsis scotica* SALT. between *Bronteus* and the form named *Bronteopsis armadillanensis*, a relation suggested by Warburg (1925, p. 72).

Occurrence. Lower Chasmops limestone; found in solid rocks in Jemtland (Central Lockne area; Hallen; overthrust beds at Lit) and Dalecarlia (Fjecka), in boulders from the North Baltic district and from Tvären, in the deep-boring at File Haidar, Gotland.

Bronteopsis concentrica (LINRS.) Pl. 6, fig. 11.

1869 *Ogygia? concentrica* LINNARSSON, p. 75, Pl. II, figs. 37—40.
? 1919 *Ogygiocaris concentrica* FUNKQUIST, Pl. II, fig. 10.

Remarks. A small pygidium measuring 3.3 mm in length and 6.0 mm in width agrees in all essential characters with Linnarsson's original specimen. It belongs to a young adult, and owing to this circumstance it differs from Linnarsson's specimen in having the axis somewhat more convex and the test ornamented with a minute granulation. (Compare the above remarks on *Stygina? nitens* (WIMAN), in which similar differences between small and large pygidia are observable.)

Affinities. As suggested by Reed (1904, p. 95) this species is closely allied to *Bronteopsis scotica* SALTER (Reed 1904, p. 94, Pl. XIII, figs. 5—13, 1914, p. 26, Pl. IV, fig. 6). In fact, the distinctive features between them appear to be small. Judging from the figures given by Reed, the pygidium of the latter species differs from that of the former in having the terminal piece more distinctly set off from the axis and the pleurae less strongly marked off at the sides. As to the cephala, the basal pair of lateral glabellar pits seems to be deeper in *Br. scotica* than in the present species, also being of a somewhat different shape, but other differences are hardly traceable in the material available. The affinities to *Stygina? nitens* have been discussed above.

Occurrence. Pure limestone facies of the lower Chasmops beds, Central Lockne area, Jemtland; Chasmops limestone in Västergötland; ? Middle Ordovician beds in Scania.

Fam. ***Illaenidae*** CORDA.

Illaenus minor n. sp. Pl. 6, figs. 12—13.

Diagnosis. Small species with cranidium bent down very strongly anteriorly, relatively narrow glabella and a shallow occipital furrow.

Description. Cranidium very strongly arched from back to front, its projected length about seven tenths the width between the eyes; posterior portion relatively flattened, middle portion strongly convex in all directions, anterior portion bent down vertically. Glabella moderately convex from side to side, raised above the cheeks, extending less than half the length of cranidium, slightly contracted between the eyes, where it is about two fifths as broad as the width of cranidium. Axial furrows moderately depressed, deepening posteriorly, in cast rather broad and deep, gently concave outwards. A shallow, in cast rather broad and distinct, occipital furrow is present. Occipital ring narrow, of the same width in longitudinal direction in all parts.

Fixed cheeks outside middle and posterior portions of axial furrows gently convex. Palpebral lobes long and narrow, hardly projecting laterally, situated about two thirds their own length from posterior margin. Anterior branches of facial sutures slightly converging anteriorly, almost straight as far as the anterior edge, where they turn rather abruptly inwards; posterior branches at first directed straight backwards, near margin turning somewhat outwards.

Test smooth but for the anterior portion of cranidium, where the surface is ornamented with fine terraced lines parallel to margin.

Dimensions. Width of cranidium between the eyes 1.85 mm
» » glabella » » » 0.72 mm

Remarks. The material on which the above description is based consists of the figured cranidium. It differs from all species of the genus hitherto known in having an occipital furrow and an occipital ring. As pointed out by Holm (1880, p. 9), an occipital ring is indicated in *Ill. crassicauda* (WAHLNB.), where it seems to be formed by the somewhat raised posterior edge of glabella, but in this species no occipital furrow is marked off.

Occurrence. Lower Chasmops limestone, Central Lockne area, Jemtland.

Illaenus fallax HOLM.

1882 *Illaenus fallax* HOLM, p. 82, Pl. 2, figs. 1—13, 15—20; Pl. 5, figs. 15—24; Pl. 6, fig. 16.
1925 *Illaenus fallax* WARBURG, p. 111. (For synonyms see Warburg.)

Occurrence. This species was found together with the form below, which is regarded as a variety of it, in the lower Chasmops limestone of the Central Lockne area.

It occurs most abundantly in the Kullsberg limestone in Dalecarlia, where it has been found (at Amtjärn) also in the lowest part of the Trinucleus beds (in a grey shale approximately corresponding to the lower part of the Masur limestone of that district).

It is further recorded from the Chasmops limestone at several localities in Dalecarlia, Västergötland, and Öland, and in boulders of that limestone from the North Baltic district. According to Holm (op. cit. p. 88), it is found in Norway in beds belonging to Kjerulf's Etage 4.

Illaenus fallax HOLM var. *elongatus* nov. Pl. 8, figs. 7—10.

Remarks. This form is very like *Ill. fallax* HOLM and differs from that species mainly in the following respects. Cranidium less convex from back to front, being in projection as long as the width between the eyes; posterior part of glabella somewhat more raised, not forming an evenly curved arch together with the fixed cheeks but with independent convexity.

Pygidium slightly more elongate, being nearly four fifths as long as wide.

As already pointed out by Holm (1882, pp. 81, 87; 1886, p. 123), *Ill. fallax* is closely allied to *Ill. oblongatus* (ANG.) (Angelin, 1854, p. 41, Pl. 24, figs. 3, 3 a; Holm, 1882, p. 78; 1886, p. 117, Pl. 8, figs. 10—13) and this can be said to be still more true of var. *elongatus*. The cranidium of this form rather much recalls that of *Ill. oblongatus*, though the latter is more evenly and strongly arched from back to front. As to the pygidia, the difference between *Ill. oblongatus* on the one hand and *Ill. fallax* with var. *elongatus* on the other is obvious (cf. Holm 1886, p. 123).

The material on which this variety is based consists of two fragmentary carapaces and several cranidia and pygidia.

Dimensions. Cranidium (Pl. 8, fig. 7): projected length and width between the eyes 19 mm; pygidium (Pl. 8, fig. 10): length 26 mm, width about 33 mm, (Pl. 8, fig. 9): length 19 mm, width 24 mm.

Occurrence. *Ill. fallax* var. *elongatus* occurs in the lower Chasmops limestone of the Central Lockne area and has been found in solid rock near the railway SSW of Tandsbyn and on the rivulet Öhntjärnsbäcken WSW of that village.

Illaenus avus (HOLM) WARBURG. Pl. 8, figs. 11—12.

1886 *Illaenus Linnarssoni* forma *avus* HOLM, p. 150, Pl. 10, figs. 10—13.
1925 » *avus* WARBURG, p. 125, Pl. 2, figs. 28—35; Pl. 11, figs. 35—37. (For other synonyms see the latter author.)

Remarks. Thanks to the thorough investigations carried out by Warburg, the great variability in some characters of this species has been clearly established. Thus, *Ill. avus* embraces one long and one short type, between which there are intermediate forms. The whole scale of types is represented in the lower Chasmops limestone of the Lockne area, where detached parts of the carapace of the species have been found in considerable abundance in the solid rock about 0.7 km SSW of Tandsbyn railway station.

According to Warburg (1925, p. 131), the elongate type was previously only known from the Kullsberg limestone (= »Lower Leptaena Limestone») in Dalecarlia. Cranidia of that type, however, have also been found at the above-mentioned locality and at Slandrom in Jemtland.

Occurrence. *Ill. avus* is a species with very long vertical range. It occurs in the Chasmops beds, the Boda Limestone (= »Upper Leptaena Limestone»), and in strata between these two formations (cf. Warburg 1925, p. 133). In Jemtland found in lower Chasmops limestone near Tandsbyn and in upper Chasmops limestone at Slandrom.

Illaenus warburgae n. sp. Pl. 8, figs. 1—6.

Diagnosis. Glabella moderately raised, almost three fourths as long as its width between the eyes; axial furrows extending half the length of cranidium. Eyes about four times as long as wide (high), laterally bounded by sub-cresentiform, rather deep grooves. Pygidium sub-semicircular in outline, strongly bent down posteriorly; axis triangular, extending about half the length of pygidium; axial furrows distinct and rather broad; doublure broad, increasing in width posteriorly, in the middle forming a broad protruding tongue, which almost reaches the extremity of the axis. Surface of test ornamented with terraced lines and shallow pits, pygidium punctate.

Description. Cranidium strongly convex from back to front, gently convex from side to side, the distance between anterior and posterior margins a little more than four fifths the width in front of the eyes. Glabella moderately raised, with the sharpest bend (from side to side) in posterior part; nearly three fourths as long as the width between the eyes, where it is rather strongly contracted; extending half the length of cranidium. Axial furrows rather broad and shallow, concave outwards and with the anterior and posterior portions meeting at obtuse angles. Palpebral lobes comparatively long and narrow. Eyes distant about one third their own length from posterior margin, their distance from the axial furrows somewhat more than half the width of glabella. Anterior branch of facial suture curved S-fashion; posterior branch gently arched outwards, meeting posterior margin of cranidium at a very acute angle.

Free cheeks rather large, sub-quadrangular, (when seen from above) almost as wide as their mean length, slightly convex. Lateral margin straight, posterior margin also nearly straight, lateral angle strongly and evenly rounded. Eyes sub-cresentiform, about four times as long as wide (high), laterally bounded by sub-cresentiform, rather deep grooves. Doublure extending comparatively far inwards underneath cranidium, under lateral angle furnished with a very well marked area to receive anterior part of border of pygidium.

Thorax unknown, probably composed of 10 segments.

Pygidium sub-semicircular in outline, about three fifths as long as wide in the single specimen found, with the inner anterior part flattened, the lateral and especially the posterior parts rather strongly bent down. Axis comparatively long, flattened, triangular, a little less than half the length of pygidium; at the front it seems to be somewhat more than one third the width of pygidium. Axial furrows relatively deep and broad. Doublure rather wide, increasing in width posteriorly towards the middle, where it forms a protruding broad tongue with obtuse-angled point; inner part convex, outer part concave; shallow but rather broad median furrow dying out before reaching posterior margin.

Surface of cephalon ornamented with closely set, shallow pits of various sizes, especially well marked on the free cheeks. As far as can be judged from an internal cast, the surface of pygidium is ornamented with minute punctae, some of which form sub-parallel, slightly sinuous, transverse lines. Terraced lines occur on the surface of cephalon.

Dimensions. *Ill. warburgae* seems to attain rather large dimensions and may possibly reach the same size as *Ill. gigas* HOLM. The largest free cheek found has a mean length (and width) of 21 mm; length of pygidium about 28 mm, width about 46 mm; width of cranidium (between the eyes) 38 mm, length apparently somewhat more than 25 mm.

Remarks. No entire specimen of this species has as yet been found, but the parts of the carapace figured assuredly belong to the same species. The above diagnosis and description are also based on a broken cranidium and a few free cheeks from Tvären and a fragmentary pygidium from Jemtland.

Affinities. As to the cephalon, this new species shows a great resemblance to *Ill. gigas* HOLM (Holm, 1882, p. 67, Pl. 1, figs. 1—11; Pl. 6, figs. 9—10; Warburg, 1925, p. 102) and its allied species. The great length of the dorsal furrows and the large eyes distinguish it, however, from them all. The pygidium is more rounded in outline than that of *Ill. gigas*, the posterior portions of its axial furrows are more strongly marked, and the protruding tongue of its doublure is broader and anteriorly less pointed than that of *Ill. gigas*. The ornamentation of the surface of the test, especially that of the free cheeks, seems to be very charactaristic of *Ill. warburgae*.

The cranidium has also several points of resemblance to *Ill. cf. gigas* HOLM, described and figured by Warburg (1915, p. 104, Pl. 1, figs. 19, 20) but that species is as yet too little known to permit a closer comparison.

Occurrence. In boulders of lower Chasmops limestone from Tvären; Chasmops conglomerate at Hallen, Jemtland.

Illaenus oblongus kuckersianus HOLM Pl. 8, fig. 13.

1886 *Illaenus oblongus* forma *kuckersiana* HOLM, p. 121, Pl. 8, figs. 5—7, 9.

Remarks. Two small cranidia and a slightly fragmentary free cheek have been found in boulders of limestone from Tvären. The free cheek quite agrees with that of this species, according to the description and figures given by Holm. Very likely the cranidia are also referable to it. — Glabella rather strongly raised above the cheeks, slightly broader anteriorly than at posterior margin, contracted between the eyes. Axial furrows rather deep and narrow, (in cast) extending about two thirds the length of cranidium. Palpebral lobes comparatively long and narrow, their distance from posterior margin about one half their own length and from the axial furrows about half the width of glabella between them. Posterior branch of facial suture straight and directed almost straight backwards or very slightly outwards; anterior branch almost straight, slightly curved inwards in anterior portion. Surface of test ornamented with rather fine terraced lines in front of glabella parallel to the anterior margin.

Occurrence. Found in boulders of lower Chasmops limestone from Tvären. According to Holm this species occurs in the Kuckers formation of Esthonia.

Fam. ***Calymenidae*** MILNE-EDWARDS.

Pharostoma similis n. sp. Pl. 11, figs. 1—14.

Diagnosis. Cranidium like that of *Pharostoma nieszkowskii* FR. SCHMIDT. Pygidium seven tenths as long as wide, furnished with 8 to 10 axial rings and 7 to 8 pairs of pleural ribs. Pleural ends of thoracic segments pointed.

Remarks and *Specific characters.* As far as can be learnt from descriptions and figures of *Ph. nieszkowskii* FR. SCHMIDT (Schmidt 1894, p. 29, Pl. 2, figs. 17—18; Öpik 1937, p. 37, text-figs. 2—3, Pl. XV, fig. 4, Pl. XVI) the features of the cranidium of this species are similar to those of *Ph. similis*, the only difference between the cranidia of these two species apparently being that the latter can attain greater sizes than the former. The pygidia are, however, different. According to Öpik (op. cit., text-fig. 1) the pygidium of *Ph. nieszkowskii* has an axis composed of 5 rings + a terminal piece, and the side-lobes are furnished with 6 pleural ribs separated by strong furrows. The following description of the pygidium of *Ph. similis* may thus supply distinguishing specific characters.

Pygidium sub-triangular in outline, about seven tenths (in a small specimen nearly half) as long as wide. Axis rather narrow, width at anterior margin about one fourth (in a small specimen one third) that of entire pygidium, strongly convex, rather slightly descreasing in height and gently tapering posteriorly, with rounded extremity not reaching posterior margin; composed of 8 to 10 axial rings, the posterior one being very incompletely defined behind. Ring furrows almost straight across the median portion of axis, the first one slightly arched forwards, the two posterior ones somewhat bent backwards; their lateral portions at first slightly arched forwards, and then, halfway to axial furrows, rather abruptly and successively more strongly curved backwards. Axial furrows rather strongly marked. Side lobes flattened adjacent to axis, outermost portions steeply and rather abruptly bent down to slightly incurved edge. Each side lobe on anterior edge has a pair of faceted half ribs, followed by 7 to 8 gently raised, flattened regular ribs without (in a small specimen with traces of) interpleural furrows; pleural furrows narrow and deep, the anterior ones almost reaching the margin, the posterior ones dying out at a somewhat greater distance from the margin, a narrow, unfurrowed border thus being formed, increasing in width posteriorly. 8th pair of ribs, not recognizable in all specimens, very short, directed nearly straight backwards, very indistinctly defined within, as sometimes also the 7th pair. — Surface of test, except in the furrows and on the facets, ornamented with small rounded tubercles of various sizes, the larger ones produced into fine spines. (The spines are usually broken off, but their places are marked by small rounded pits in centre of tubercles.)

From the same locality and rock as the cranidia and pygidia discussed above, there are several detached, more or less fragmentary free cheeks, labra, and thoracic segments, which very likely belong to this species.

The free cheek is sub-triangular in outline, moderately convex, produced backwards and outwards into an acutely pointed genal spine, the length of which is a little less than one fourth that of the cheek; lateral border rounded, rather strongly raised above the lateral furrow, its edge ornamented with a row of rather coarse and closely placed spines, which become shorter and finer posteriorly.

Labrum subquadrate in outline, with fairly large anterior and posterior wings, slightly longer than wide, widest in front. Width behind anterior wings about seven ninths the length. Anterior margin gently arched forwards; lateral margins subparallel, diverging very slightly posteriorly; posterior margin reversed U-shaped. Central body sub-semioviform, strongly raised, somewhat compressed from the sides, rounded, slightly tapering posteriorly, near the posterior end marked at the sides by a pair of short, rather indistinct, shallow grooves or furrows. Anterior furrow narrow, gently arched forwards, deepening towards the sides and then becoming obsolete backwards; lateral furrows very deep, becoming shallower backwards. Anterior wings strongly bent down laterally, on each side near postero-lateral margin with a rather deep pit. Lateral border narrow, strongly raised, rounded, continuing backwards into the posterior wings. Posterior border rounded, rather strongly raised; middle portion (behind the central body) almost straight, lateral portions arched and directed obliquely forwards and outwards, separated from lateral borders by shallow furrows. Posterior wings large, depressed outside lateral parts of posterior border, each wing laterally produced into four spines, the anterior of which is very short. Surface of posterior part of central body ornamented with small tubercles.

Thorax with strongly convex axis and narrow but distinct axial furrows. Axial rings slightly arched forwards in the middle, without lateral nodes. Pleurae horizontal, straight, and of the same width to fulcrum, situated half way out from axis, then curving abruptly downwards and somewhat backwards to lateral margins; extra-fulcral portions slightly decreasing in width for about two thirds the length out from knee, then slightly widening (in longitudinal direction) but immediately tapering again to pointed end; each pleura marked by strong furrow, running almost straight outwards to fulcrum and slightly in front of the median line of pleura, becoming obsolete a little inside extremity; extra-furrowed portion of pleura flattened, with the posterior margin slightly convex. Surface of test, except in the furrows and on the articulating half ring, ornamented with tubercles of various sizes, the larger ones apparently produced into fine spines, and between the tubercles minute granules.

D i m e n s i o n s.

		Length	Width
a.	Cranidium	18.3 mm	—
b.	»	10.5 »	20.8 mm
c.	»	6 »	—
a.	Glabella	11 »	14.3 »
b.	»	6.2 »	7.5 »
c.	»	3.7 »	2.9 »
1.	Pygidium	14 »	20 »
2.	»	8.8 »	11.8 »
3.	»	4 »	5.8 »

A f f i n i t i e s. From the above it is evident that *Ph. similis* has very close affinities to *Ph. nieszkowskii*, and these forms are hardly specifically separable by means of the cranidia when the former species is represented by small specimens. However, *Ph. similis* seems to attain greater sizes and its pygidium differs in many respects from that which Öpik has referred to *Ph. nieszkowskii* (cf. above).

Ph. similis also appears to be rather closely allied to *Pharostoma foveolata* (TÖRNQUIST) from the Kullsberg limestone in Dalecarlia, which, apart from attaining greater dimensions, differs from it mainly in the following respects: somewhat longer cranidium in relation to the width at base, comparatively much longer preglabellar field (being one third to more than half the length of glabella, in *similis* only about one fourth as long as glabella); thoracic pleurae increasing in width (in longitudinal direction) laterally from axial furrows, and with truncate extremities; pygidium comparatively (though slightly) longer and furnished with a larger number of axial rings and pleural ribs.

The cranidium of *Ph. similis* also bears a fairly strong resemblance to that of *Pharostoma oelandicum* ANG., very briefly described and badly figured in Palaeontologia Scandinavica (1854, p. 62, Pl. 33, fig. 15) . According to my observations on Angelin's original specimen in the State Museum of Natural History it differs from *similis* mainly in having a comparatively much shorter preglabellar field and a lower anterior border.

O c c u r r e n c e. Common in boulders of lower Chasmops limestone from Tvären.

Flexicalymene jemtlandica n. sp. Pl. 12, figs. 19—22.

Specific characters. Glabella trapezoidal in outline, slightly rounded in front, moderately convex and sloping gently forward to preglabellar furrow, reaching as far forward as the fixed cheeks, width at base five thirds the width between the antennary pits and somewhat greater than the length. Basal pair of lateral glabellar lobes relatively large, measuring about one third the width of glabella, irregularly quadrilateral in outline, marked off from the median portion of glabella by shallow grooves (which are fairly deep in casts); preceding pair much smaller, sub-rectangular in outline and with slight independent swelling; anterior pair small, incompletely marked off in front. 3 pairs of lateral glabellar furrows or impressions discernible; basal pair deep, running in curves obliquely inwards and backwards, their inner portions slightly bifurcate; preceding pair relatively deep, directed obliquely inwards and backwards, inner extremities becoming shallow and curving backwards; anterior pair comparatively weak, short, not reaching axial furrows, straight.

Axial furrows converging anteriorly, almost straight, bent inwards posteriorly and slightly curved outwards outside second lobes; deep outside basal lobes, shallow in front of them but ending in very deep antennary pits at the antero-lateral angles of glabella. Occipital furrow with a slight forward swing in its median portion, where it is moderately deep, growing deeper laterally. Occipital ring (badly preserved in all specimens available) rather strongly arched from side to side, probably flattened in the central portion but rounded at the sides, broadest (longitudinally) behind central part of glabella. Preglabellar furrow or groove scarcely impressed. Frontal field wide (longitudinally), flattened, turned up at a high angle. Anterior border with rounded edge.

Cheeks rather strongly convex, rising from all sides to the eye lobes, which almost reach the same height as the glabella and stand opposite the second glabellar lobes. Palpebral lobes strongly turned upwards. Posterior border narrow and raised at the axial furrow, becoming somewhat broader and flatter laterally; border furrow strong and deep. Anterior branches of facial sutures running from the eyes straight forwards and slightly inwards, curving somewhat inwards at the sides of the frontal border; posterior branches running from the palpebral lobes at first straight outwards for a short distance, then curving rather strongly backwards and downwards to meet posterior margin of cephalon at slightly acute angles. Free cheek sloping steeply with gently convex surface to lateral border furrow, which is broad and shallow; lateral border rounded and relatively broad.

Pygidium parabolic to suboval in outline, a little more than twice as wide as long. Axis strongly convex, narrow, occupying less than one third the width of pygidium in front, composed of 4 distinct axial rings and a short terminal piece, which does not reach posterior margin. Side lobes first sloping moderately steeply, the marginal portion then being curved down more steeply with the edge slightly curved inwards; each lobe with a half rib on anterior edge followed by four ribs, which are rather strongly raised near axis but become flattened and wider towards margin. Pleural furrows strong, extending to inclined marginal portion of pygidium; interpleural furrows distinct on the outer portions of the lobes, becoming fainter and finally obsolete near axis.

Surface of test, except in the furrows, ornamented with small rather closely placed tubercles.

Dimensions. In the type cranidium from Stengärde, the distance between the anterior and posterior margins is 10 mm, the length of glabella measures 7 mm and the width across the basal lobes 7.5 mm. In another cranidium from Slandrom the glabella measures 4.6 mm in length and 5 mm in width. A pygidium from the latter locality is 3 mm long and 6.2 mm wide.

Remarks and *Affinities.* The above description is based on several cranidia and pygidia, all more or less fragmentary owing to the impossibility of getting them complete from the limestones in which they occur. In one of the cranidia the left free cheek is attached. Thorax is unknown.

This species is a typical *Flexicalymene* SHIRLEY (1936, p. 395) and it seems to be closely allied to *Calymene caractaci* SALTER (cf. Shirley 1931, p. 26, Pl. II, figs. 4—6). The frontal (preglabellar) field of the cranidium is bent upwards in the same manner as in that species, and the pygidia appear to agree in most respects, except that there are 5 axial rings in the British species. As to the cranidia there are some differences; thus in *Fl. jemtlandica* there is no pair of »supplementary» grooves on the sides of the frontal glabellar lobe, which is less rounded in front and does not project further forward than the fixed cheeks. The palpebral lobes seem to be more strongly upturned in our species.

Occurrence. Both in autochthonous and overthrust beds, Jemtland. It occurs in the upper Chasmops limestone of the former (at Slandrom) and in the zone of *Dicranograptus clingani* of the latter (at Stengärde).

Fam. ***Cyphaspidae*** SALTER.

Törnquistia reedi n. sp. Pl. 10, figs. 14—19; Pl. 11, fig. 15.

Specific characters. Cranidium about four fifths as long as wide at base (in projection). Glabella moderately convex, as long as wide, widest at base, slightly tapering anteriorly, rather broadly rounded in front, surrounded by strong axial and preglabellar furrows. Two pairs of short and faint lateral glabellar furrows recognizable; they are mainly visible as fairly large spots with smooth, non-ornamented surfaces; basal pair slightly depressed, directed backwards and inwards, incompletely marking off small, sub-triangular basal glabellar lobes. Occipital furrow almost transverse, strong, becoming deeper and narrower laterally. Occipital ring slightly protruding outside base of glabella, broad in the middle, narrowing and strongly arching down towards the sides, furnished with a small median tubercle. Preglabellar field sloping steeply to anterior border furrow, with gently convex surface, in median line somewhat longer than one third the length of glabella, widening laterally;

median groove represented mainly by a deep pit in the preglabellar furrow; lateral furrows rather indistinct, short and shallow. Anterior border narrow, with rounded surface, marked off by a strong furrow; its margin gently arched backwards laterally.

Fixed cheeks between axial and palpebral furrows forming regularly swollen, narrow rolls. Palpebral lobes about three fifths as long as glabella, bent rather steeply upwards from comparatively strong palpebral furrows. Posterior border furrow narrow and deep, directed straight outwards. Posterior borders raised and rounded, narrow near axial furrows, increasing in width laterally. Anterior branches of facial sutures running straight forwards and downwards; posterior branches curving almost abruptly outwards and slightly backwards from palpebral lobes.

Surface of cranidium, except in the furrows and on the anterior border, ornamented with closely placed, small, low tubercles. On anterior border there are faint striae sub-parallel to margin.

Dimensions. Cranidium: length 2.5 mm, width at base 3 mm; length of glabella 1.6 mm.

Remarks. The above description is based on three imperfectly preserved cranidia. From the same locality and bed as these there is a pygidium, which very likely belongs to this species. It is semi-elliptical in outline, somewhat more than twice as wide as long (length 1.2 mm, width 2.8 mm). Axis almost reaching posterior border, rather strongly convex in anterior portion where it occupies one third the width of pygidium, decreasing in convexity and somewhat in width posteriorly; composed of strong articulating half ring and two distinct rings separated by rather strong furrows. Rings provided with small knobs at the sides, distinctly marked off in the anterior ring. Side lobes nearly flattened, with two indistinctly tuberculated ridges on each side, separated by a strong furrow; anterior ridge cut off by a relatively large, sharply marked off facet. Border wide, flattened and smooth, sharply set off from the side lobes and rather steeply sloping obliquely downwards and backwards; its upper edge close behind the axis very slightly raised into a faint, indistinctly marked off ridge, probably corresponding to an almost obsolete axial ring.[1]

Affinities. This species displays a rather close resemblance to *Törnquistia nicholsoni* REED (cf. Warburg 1925, p. 200, Pl. V, figs. 40—44), but differs from this in having narrower fixed cheeks, indistinct and much shorter preglabellar furrows. Compared with the imperfectly known *Törnquistia* cf. *depressa* WARBURG (1925, p. 205, Pl. V, fig. 46) from the Kullsberg limestone, it appears to have a more convex and raised glabella, the anterior border of the cranidium also being somewhat less arched backwards laterally.

Occurrence. Pure limestone facies of lower Chasmops limestone; Central Lockne area, Jemtland.

[1] In an incomplete cranidium (Pl. 11, fig. 15) a third axial ring is clearly discernible, marked off by a rather distinct furrow behind.

»*Törnquistia*» *parvula* n. sp. Pl. 6, figs. 15—16; Pl. 10, figs. 20—22.

Specific characters. Cephalon strongly convex, semi-circular in outline. Glabella sub-equally rounded at the ends, its width about four fifths the length, strongly convex and swollen, sloping downwards and overhanging anteriorly, steeply raised posteriorly, bounded by strong axial and preglabellar furrows; lateral glabellar furrows obsolete and untraceable externally, marked as three pairs of small dark spots without ornamentation on white-weathered test in internal view. Occipital furrow broad and relatively deep, growing somewhat deeper laterally, terminating in small rounded pits. Occipital ring of moderate width, almost parallel-sided, transverse in the middle, curving slightly forwards and strongly bent down at sides, protruding outside base of glabella, strongly convex longitudinally, especially at sides. Preglabellar field narrow in the middle, widening and becoming rather strongly convex laterally, sloping steeply down to anterior border; no median and lateral grooves or notches present. Anterior border rather narrow, almost parallel-sided and very slightly diminishing in width laterally, marked off by a relatively broad and shallow furrow, strongly bent down anteriorly and furnished with a row of short spines, directed forwards. Fixed cheeks very strongly convex, sloping steeply down to axial, palpebral and posterior furrows, thus forming node-like elevations laterally to posterior part of glabella, about half as high as that. Palpebral lobes narrow and raised, strongly convex in longitudinal direction, apparently about half as long as glabella, and situated at about their own length from posterior margin of cranidium; palpebral furrows distinctly marked off, rather strong but becoming shallower towards anterior extremities. Posterior border raised and rounded, narrow adjacent to axial furrows, here furnished with small knobs, widening laterally and bending rather strongly downwards; posterior margins gently curved backwards towards the sides; posterior border furrow directed straight outwards, narrow at inner end, increasing in width and depth laterally. Anterior branches of axial sutures directed almost straight forwards and downwards; posterior branches running obliquely backwards; outwards, and downwards.

Surface of glabella, occipital ring, and fixed cheeks ornamented with rather closely set tubercles of somewhat different sizes, the larger ones apparently terminating in points (broken off in all specimens); lateral portions of posterior borders of fixed cheeks provided with two pairs of comparatively large pointed tubercles or knobs.

Dimensions of the holotype. Cranidium: length 1.6 mm, width 2.2 mm; glabella: length 1 mm, width 0.8 mm. (The largest cranidium observed has a length of about 3.5 mm).

Remarks. The above description is based on examinations of several more or less incomplete, mostly exfoliated cranidia. They occur in two small pieces of medium crystalline limestone, in which there are also found several fragments of free cheeks and a few detached fragmentary thoracic segments very likely belonging to this species. Judging from the former, the cheeks are bent strongly downwards to border furrow, with convex surface, sloping somewhat more abruptly anteriorly than laterally. Eyes strongly convex in both directions, almost as high as long at base, surrounded by a shallow lower lid furrow. Lateral border rather narrow in front, increasing considerably in width posteriorly; lateral furrow strong, widening and curving inwards posteriorly. Genal spine comparatively long and stout. Surface ornamented as that of the fixed cheeks. — Two kinds of thoracic segments are observed. They differ in regard to the axial rings, one of them being furnished with a median spine. Axis wide, in the segment just mentioned somewhat more than one third the width of thorax, strongly arched from side to side, with deep articulating furrows. Axial furrows scarcely depressed. Inner horizontal part of pleurae as long as outer part, which is very strongly bent down, slightly widening towards the lateral margin, and very gently arched backwards in the outermost portion. Facet distinctly set off. The spine of the above-mentioned segment is stout and long, its length being somewhat less than twice the width (from side to side) of the ring, from which it runs almost straight backwards and slightly upwards. Surface of ring ornamented with small tubercles; surface of each pleura furnished with three small knobs or relatively large tubercles, one (the largest) situated at the knee, the others placed on either side of the knee and at about equal distances from it.

Affinities. This species is closely allied to *Sphaerexochus minutus* NIESZK. (= *Menocephalus minutus* FR. SCHMIDT, 1894, p. 60, Pl. IV, figs. 46—49, and *Törnquistia ? minuta* ÖPIK, 1937, p. 29, Pl. II, figs. 3—6, Pl. III, figs. 1—2) which seems to differ from it mainly in the following respects. The glabella is more abruptly truncate at base — not rounded and raised as in our species —, its posterior two pairs of lateral furrows are (though faint) observable in external view; the fixed cheeks are more evenly convex; the knobs (»Knötchen») situated adjacent to the occipital ring are more conspicuous and more distinctly marked off; the outline of the anterior border of cranidium is different, being comparatively much longer in the middle than at the sides.

»*T.*» *parvula* is apparently also related to *Törnquistia altifrons* WARBURG (1925, p. 202, Pl. V, figs. 47—48), which, however, occurs in much younger strata, being found in the Boda limestone (= »Upper Leptaena Limestone») in Dalecarlia. Distinctive features are found, *inter alia*, in the preglabellar field, which is relatively longer (in longitudinal direction) and more steeply bent down to anterior border in *T. altifrons*, and in the shape of the fixed cheeks.

From the above it is evident that »*Törnquistia*» *parvula* belongs to the same group of species as *Sphaerexochus minutus* NIESZK. and *Törnquistia altifrons* WARB. As far as can be judged from the material available at present this group differs from the genus *Törnquistia*, with which it appears to be closely related, in having the cranidium provided with a swollen glabella, overhanging anteriorly, and lacking median and lateral grooves or notches in the preglabellar field adjacent to front end of glabella. As to the two latter of the above-mentioned species, these distinctive features have previously been pointed out by Öpik (1937), who, in addition, has suggested further differences based on observations in *Törnquistia ? minuta* (NIESZK.). However, these differences seem mainly to be of specific value.

Owing to the following circumstances a new name for this group (genus or sub-genus) cannot be proposed at present. *Sphaerexochus minitus* NIESZK. and *Dimeropyge minuta* ÖPIK (1937, p. 32, Pl. IV, fig. 5; Pl. XII, figs. 1—2; Pl. XIX, fig. 1) both occur in the Kuckers formation. The latter species was described by Nieszkowski (1857, p. 593, Pl. III, fig. 15) as *Cheirurus octolobatus* ? M'COY, but it has recently been proposed by Öpik as the type of a new genus, being the only species known. Only the pygidium has been found. According to Öpik, there is a possibility that it belongs to the same species as the cranidia and free cheek described by him as *Törnquistia ? minuta* (= *Sphaerexochus minutus* NIESZK.). Although Öpik has other alternatives, this assumption seems very likely to the present writer but the material available is not sufficient to warrant a definite opinion.

Occurrence. In boulders of lower Chasmops limestone from Tvären.

Fam. ***Harpedidae*** CORDA.

Harpes concavus n. sp. Pl. 11, figs. 16—18.

Specific characters. Cephalon sub-circular in outline, only slightly wider than long, with a broad concave brim produced posteriorly into rather stout horns, which are gradually curved inwards. — Central body of cephalon (inside brim) slightly more than half as long as wide at base, strongly convex, somewhat more steeply raised from the brim at the sides than in front. Glabella occupying barely more than half the length of cephalon inside brim and (at the base) somewhat less than one third its width, apparently with comparatively small basal lobes. Cheek-lobes rather indistinctly marked off from the cheek-rolls — at least posteriorly — by weakly impressed lateral line; cheek-rolls with very slight independent convexity. — Brim rather strongly concave, widest at the sides, here measuring on each side slightly less than half the width of cephalon (minus brim) at base, gradually and very slowly decreasing in width anteriorly to about three fourths its greatest width. — Surface of brim and cheeks seems to be ornamented in the same manner as in *Harpes youngi* REED (1914, p. 6, Pl. I, figs. 4—6).

Dimensions of the figured specimen.

Length of cephalon to extremities of horns abt.	32.5	mm
Width » » (including brim)	34.0	»
Length of central body of cephalon (without brim)	10.0	»
Width of brim in front	6.0	»
» » » at sides	8.0	»

Affinities. This species seems to bear a close resemblance to *Harpes youngi* (cf. above), the brim of which is also wider at the sides than in front, and the horns curving inwards. It differs from that species essentially in having the upper surface of the brim rather strongly concave instead of gently convex and the glabella comparatively smaller.

Occurrence. The figured specimen and a few fragmentary brims have been found in pure limestone facies of lower Chasmops limestone; Central Lockne area, Jemtland.

Fam. ***Raphiophoridae*** ANGELIN.

Ampyx? aculeatus ANG. Pl. 9, figs. 10—11.

1854 *Ampyx? aculeatus* ANGELIN, p. 81, Pl. XL, fig. 5.

Remarks. The most characteristic feature of this species is the glabellar ridge running along the middle line and continuing forward into the long, horizontal frontal glabellar spine. Its surface is rounded on the very glabella but becomes successively flattened towards the spine, the cross-section of which is trapezoidal with slightly concave sides. Although gradually lower posteriorly, this ridge is traceable to the occipital furrow. Occipital ring strongly arched transversally, with a long, strongly upturned median spine.

3 pairs of short lateral glabellar furrows discernible (at least in large specimens); the two posterior pairs seemingly lying in slightly depressed, comparatively large, smooth areas on the slopes of the basal portion of glabella; basal pair ending in axial furrows, incompletely marking off a pair of somewhat swollen basal lobes; preceding pair very short, not reaching axial furrows, limiting the depressed areas in front; anterior pair very small and faint, almost obsolete, located close to the axial furrows and just behind the antennary pits. The latter are rather deep and placed in the axial furrows at the antero-lateral angles of glabella. On either side of glabella there is a small oblong tubercle or knob, situated near the axial furrow behind the anterior glabellar furrow or impression.

The above additional notes to Angelin's brief diagnosis of this species are based mainly on material from Norway in the collections of the State Museum of Natural History. With a view to making comparisons with the specimen figured in this paper, this material, very likely including the originals of Angelin's figures, has been examined, as well as some comparatively large cranidia, kindly sent me by Dr L. Størmer of Oslo. The latter were collected in upper Chasmops limestone (4 b δ) at Nakkholmen near Oslo.

It should be added that the fixed cheeks of Angelin's figures are far from accurately rendered, as, in reality, they are much longer, being about three fifths the length of the glabella behind the frontal spine.

Occurrence. Zone of *Dicranograptus clingani* in Jemtland; the figured specimen obtained from a limestone lens in black shale in a small outcrop by the road, 1.2 km E of the rivulet Örån. — Upper Chasmops limestone of the Oslo area, Norway.

Fam. ***Trinucleidae*** EMMRICH.

Cryptolithus discors (ANG.). Pl. 12, figs. 1—3.

1930 *Cryptolithus discors* STØRMER, p. 40, Pl. VI, figs. 1—12.

Remarks and *Occurrence.* A few small, more or less fragmentary cephala have been obtained from limestone lenses in dark shales of the upper Chasmops beds in a road-section located about 300 m SW of Tandsbyn railway station, Jemtland. Apart from the small sizes, they agree with the description and figures of *Cr. discors* in Størmer's paper, in which synonyms are given and affinities discussed.

The largest cephalon available is about 3 mm long and 7.5 mm wide. The cephalic spines are fairly long, straight and directed obliquely backwards and outwards.

This species is not previously recorded from the Swedish Ordovician, but typical specimens have been found in the upper Chasmops beds of Dalecarlia (at Vikarbyn). According to Størmer it occurs in the upper Chasmops beds at a few localities in S. Norway, and probably also in England.

Fam. ***Odontopleuridae*** BURMEISTER.

Ceratocephala asklundi n. sp. Pl. 6, fig. 14.

Specific characters. Glabella sub-trapezoidal in outline, gently convex in transverse direction, truncate in front, about two thirds as long as wide, widest across basal lateral lobes. Two pairs of lateral glabellar lobes present, coalescing laterally, depressed below central lobe of glabella and indistinctly marked off from this by faint longitudinal furrows, which begin a little in front of occipital furrow and converge but slightly anteriorly; basal lobes large, with slightly convex surface sloping steeply downwards, obliquely outwards and backwards; the other lobes small, occupying about one third the length of bi-composed lobes. Basal lateral glabellar furrows forming deep pits inside coalescing parts of the lateral lobes. Axial furrows narrow, distinct, growing deeper and curving steeply downwards posteriorly. — Occipital furrow moderately deep and narrow, transverse occipital ring very long along the median line, here measuring nearly four fifths the length of glabella, furnished with a large median tubercle or spine-bearing boss (broken off in the specimen available) near occipital furrow, and two comparatively stout, diverging occipital spines (only proximal portions preserved) which seem to curve somewhat downwards posteriorly. From the median tubercle or boss, the occipital ring is strongly arched downwards laterally and slopes rather steeply towards posterior margin. — Fixed cheeks inside eye-ridges sub-triangular, with gently convex surface, curving steeply downwards posteriorly and sloping more gently towards axial furrows. Eye-ridges bounded by distinct narrow furrows, almost straight, prominent, directed obliquely outwards, backwards and somewhat upwards from antero-lateral projections of frontal glabellar end.

Surface of cranidium, except in the furrows, rather closely covered with small, low tubercles.

Dimensions. Length of glabella 2.3 mm, its greatest width about 3.3 mm, length of occipital ring 1.8 mm.

Affinities. This species is obviously closely related to *Acidaspis furcata* LINNARSSON (1869, p. 65, Pl. I, fig. 18) and *A. kuckersiana* SCHMIDT (1885, p. 4, Pl. I, figs. 2—3; Öpik 1937, p. 47, Pl. XXIV, figs. 3—4), from which both it differs mainly in having a much smaller anterior pair of bi-composed lateral glabellar lobes, the ornamentation of the surface also being finer.

Occurrence. Pure limestone facies of lower Chasmops limestone, Central Lockne area, Jemtland.

Fam. ***Lichadidae*** CORDA.

Platylichas validus (LINRS.). Pl. 9, figs. 1—3.

1869 *Lichas validus* LINNARSSON, p. 66, Pl. I, figs. 19—20.
1939 *Platylichas* » WARBURG, p. 132, Pl. 14, figs. 2—8.

Remarks. Unfortunately the specimen available is rather badly preserved as it cannot be completely cleaned of the hard limestone in which it occurs. This concerns the important antero-lateral parts of the cranidium. Notwithstanding, it undoubtedly belongs to *Pl. validus* as is apparent from a comparison with Linnarsson's original specimen and Warburg's figures of specimens from the type locality. In the present cranidium the tongue-like marginal extension of the anterior border is almost entirely preserved. It measures about three fifths the length of glabella, and across the middle two thirds its own length; it is almost parallel-sided, rounded in front and directed obliquely forwards and upwards; compared with that of *Pl. lingua* WARBURG (cf. Warburg 1939, p. 127, Pl. 13, figs. 10 a—b), which it resembles, it is a little shorter in relation to the length of the glabella, much narrower and more strongly upturned.

Affinities. The affinities of this species have been subjected to a detailed discussion by Warburg (1925, p. 272), and, with reference to the above comparison, nothing need be added.

Occurrence. Uppermost part of lower Chasmops limestone (shaly facies), Central Lockne area, Jemtland; Chasmops limestone at Jonstorp, Vestergötland; Kullsberg limestone, Dalecarlia.

Fam. ***Cheiruridae*** SALTER.

Pseudosphaerexochus elongatus n. sp. Pl. 10, figs. 1—2.

Material. One almost complete and three fragmentary cranidia.

Specific characters. Cephalon semi-elliptical in outline, three fourths as long as wide, strongly convex. — Glabella oblong, narrowly rounded in front, truncate at base, bordered laterally and posteriorly by narrow and deep furrows, strongly arched longitudinally, overhanging anteriorly, three fourths as wide as long, widest between the eye lobes which are situated opposite second lateral glabellar lobes, and extending a little behind these. Anterior two pairs of lateral glabellar furrows faintly marked (stronger in casts), subparallel; second pair extending nearly half-way up sides of glabella from axial furrows, where they begin half-way between occipital furrow and front end of glabella; anterior pair somewhat shorter, beginning in axial furrows, the distance from the front of glabella being almost once and a half the distance to second pair. Basal pair of lateral furrows strongly marked, beginning in axial furrows half-way between preceding pair and occipital furrow, curving obliquely inwards and backwards, not reaching occipital furrow but connected with this by shallow grooves or depressions (rather distinct in casts). — Occipital ring comparatively wide, almost parallel-sided, strongly arched transversally, surface flattened or slightly rounded longitudinally.

Cheeks sloping steeply to lateral border furrows, convex or, rather, ridge-like between palpebral furrows and inner extremities of posterior border furrows. These are deep and fairly narrow but increase in width towards genal angles, where they curve forwards to meet the shallower and broader lateral furrows. Posterior borders raised and rounded, increasing in width laterally. Lateral borders pointed outside the connecting curves between the posterior marginal and lateral furrows. Genal spines comparatively stout and short, their length being about one third the distance to axial furrows, directed obliquely backwards, outwards and downwards. Palpebral lobes of moderate width, bent strongly upwards from comparatively deep palpebral furrows. Facial sutures in front of them sub-parallel to axial furrows, running obliquely forwards and inwards; posterior branches of facial sutures running sub-parallel to posterior borders, gently curving backwards laterally, cutting margins just where the lateral borders seem to be pointed.

Surface of cranidium, except in the furrows, closely covered with small tubercles of various sizes; portions of fixed cheeks inside the bounding furrows having relatively large pits between the tubercles.

Dimensions. The holotype has the following measurements. Cranidium: length 7.2 mm, width 9.6 mm; glabella: length 6.2 mm, greatest width 4.8 mm.

Affinities. Ps. elongatus differs from all previously described species of *Pseudosphaerexochus* by its elongate cranidium and its relatively long frontal lobe of glabella.

Occurrence. Pure limestone facies of lower Chasmops limestone; Central Lockne area.

Pseudosphaerexochus tvaerensis n. sp. Pl. 10, figs. 3—5.

Material. Two fragmentary cranidia, one of which is almost complete, though crushed and divided into several dislocated parts.

Specific characters. Glabella slightly longer than wide, widest across second pair of lateral furrows, broadly rounded in front, rather gently convex longitudinally, curved downwards anteriorly, here overhanging, strongly convex transversally, bounded all round by distinctly impressed narrow furrows. Anterior two pairs of lateral glabellar furrows faint, subparallel, gently curved; second pair extending half-way up sides of glabella from axial furrows and beginning in these somewhat nearer front end of glabella than occipital furrow; anterior pair shorter, situated half-way between second pair and front end of glabella; basal pair of furrows much stronger than the others, as long (in projection) as the second pair, beginning in axial furrows half-way between these and occipital furrow, at first running almost straight and perpendicular to axial furrows, then curving strongly backwards, not connected with occipital furrow; the distance between their inner extremities longer than twice the distance from these to axial furrows. Occipital ring of moderate width, slightly narrower near axial furrows than in centre, strongly arched transversally, with the surface flattened or very gently rounded longitudinally.

Fixed cheeks with rather evenly convex surface, sloping steeply downwards laterally. Posterior and lateral furrows and borders, situation of palpebral lobes and run of facial sutures as in *Ps. elongatus.* Genal spine somewhat shorter than in that species, stout.

Test of cranidium, except in the furrows, ornamented with rather sparsely distributed small tubercles of somewhat various sizes — the larger ones being sub-conical — and between the tubercles minute granules; portions of cheeks in front of border furrows having, in addition, small pits between the tubercles.

Dimensions. The smallest specimen (the holotype) has the following measurements; glabella: length 5.1 mm, greatest width 4.9 mm, width at base 3.5 mm.

Affinities. This species is apparently closely allied to *Ps. granulatus* (ANG.) but differs from that by its shorter genal spines and its somewhat longer glabella.

Occurrence. Lower Chasmops limestone; found in boulders from Tvären.

Nieszkowskia cephaloceras (NIESZK.) var. *longispina* n. var. Pl. 10, fig. 8.

Diagnosis. Like *Nieszkowskia cephaloceras* (NIESZK.) but the glabellar spine is considerably longer.

Material. A fragmentary cranidium with the anterior part of the glabella obliquely cut off and only the inner portion of the right cheek left.

Description. But for the length of the spine, the glabella of this variety seems to agree in all essentials with that of *N. cephaloceras*, as described and figured by Schmidt (1881, p. 186, Pl. IX, figs. 9—11, Pl. XVI, fig. 36). Thus, it is sub-rectangular in outline, slightly broader at base than anteriorly, somewhat longer than the width at base and highly raised between the eyes, where it bears a vertical spine, which, however, arches gradually backwards. This spine

— rather distinctly set off at base — is slightly longer than the height of the glabella when seen from the side; its section at base is circular but becomes gradually more oblong towards the top, which is situated straight above the occipital furrow. Cranidium strongly arched in longitudinal direction, the inner cheek portions on each side of the eye lobes forming almost right angles. Anterior branch of facial suture parallel to the deep and narrow axial furrow. Base of basal lateral glabellar furrow situated opposite anterior part of palpebral lobe. This lobe is strongly raised above the cheek and about twice as long as the distance between the axial furrow and the palpebral furrow. — Occipital furrow deep and narrow; occipital ring comparatively broad, almost parallel-sided, strongly arched transversely. — Surface of cranidium furnished with closely placed tubercles of various sizes, ending in short spines, largest in the posterior part of glabella and on the glabellar spine.

Dimensions. Length of glabella (about) 9 mm, width (between the eyes) 8 mm.

Affinities. As seen in a figure of *N. cephaloceras* given by Schmidt (1881, Pl. IX, fig. 10; reproduced by Öpik, 1928, text-fig. 2 e), the glabellar spine of that species is barely as long as half the height of the glabella, and as stated by Öpik (1928, p. 28), its section is circular throughout. On the basis of these differences, the specimen described above has been referred to a variety of that species. It is apparently closely allied to *N.* cf. *cephaloceras* (NIESZK.) from the Kullsberg limestone as described and figured by Warburg (1925, p. 365, Pl. X, figs. 30, 31), but as the single specimen available of this form is also very imperfect, it is not possible to enter into a close comparison. However, there are some small though obvious differences as to the shape of the glabella, especially its spine-bearing part.

Occurrence. Pure limestone facies of the lower Chasmops limestone; Central Lockne area, Jemtland.

Nieszkowskia sp. Pl. 9, figs. 5, 6.

Occurrence and *Remarks.* Several fragments of an apparently large species of *Nieszkowskia* have been found in boulders of lower Chasmops limestone from Tvären. The test is thin and furnished with bosses of various sizes, and its surface is covered with small granules. Judging from these characters the fragments very likely belong to a species referable to the *variolaris*-group of the genus *Nieszkowskia* (cf. Öpik 1928, pp. 25—27).

Sphaerexochus cf. *hisingeri* WARB. Pl. 10, figs. 9, 10.

Remarks. Three imperfectly preserved cranidia are available. They agree in all essential features with those of *Sphaerexochus calvus* McCOY and *Sph. hisingeri* WARB. As stated by Warburg (1925, p. 384) these species are hardly distinguishable from each other by means of their cranidia only. Since the former occurs in the Boda Limestone (= the Upper Leptaena Limestone of

Dalecarlia) and corresponding strata, it appears convenient to compare the present species with *Sph. hisingeri* from the Kullsberg Limestone (= the Lower Leptaena Limestone of Dalecarlia), which was, partly, deposited contemporaneously with the Chasmops beds. As no pygidium is available, however, the reference to that species is merely tentative.

Occurrence. Pure limestone facies of lower Chasmops limestone; Central Lockne area, Jemtland.

Hemisphaerocoryphe sulcata n. sp. Pl. 10, figs. 6, 7.

Diagnosis. Similar to *Hemisphaerocoryphe granulata* (ANG.) but differs from that species in having all glabellar furrows distinctly marked and the glabella less swollen posteriorly.

Material. An imperfect cranidium with the glabella in cast and only the inner portion of the left fixed cheek preserved.

Description. Glabella — except the basal lateral lobes — sub-elliptical in outline, evenly swollen into a sub-semiglobular mass, highest in the middle portion, somewhat steeper in anterior part than posteriorly. Anterior two pairs of lateral furrows of uniform length and width, comparatively broad and deep, situated on either side of the middle of glabella, running subparallel from the axial furrows and reaching somewhat less than half the height of the glabella. Basal lateral furrows strong, oblique, plainly visible when the cranidium is seen in dorsal view; basal glabellar lobes narrowly triangular in outline, distinctly raised, each occupying almost one third the width of the glabella at base, separated by the basal middle portion of the glabella. Occipital furrow comparatively narrow and deep; occipital ring narrow, rather strongly arched transversally. Surface of glabella tuberculate.

Fixed cheeks appear to be rather strongly convex; palpebral lobes situated opposite second pair of lateral glabellar furrows; surface pitted.

Dimensions. Length of glabella 7 mm, greatest width 6 mm.

Affinities. The features distinguishing the glabella of this species from that of *H. granulata* (ANG.) have been pointed out above. As the latter species, it seems to be closely related to *H. pseudohemicranium* var. *dolicocephala* (FR. SCHMIDT). Judging from the figures of that variety, given by Schmidt in 1881, the specimens figured by him on Pl. VIII, fig. 15, and Pl. XVI, fig. 21, can hardly be distinguished from *H. granulata* (cf. WARBURG, 1925, p. 389). The other specimens (Pl. VIII, figs. 9, 10, Pl. XI, fig. 29, Pl. XVI, fig. 20) appear to be more like *H. sulcata* and the difference between them and our species mainly refers to the appearance of the anterior two pairs of lateral glabellar furrows, which — as stated by Schmidt (op. cit. p. 164) — in the Esthonian form are developed as rounded pits above the axial furrows, with which they are not confluent.

Occurrence. Pure limestone facies of lower Chasmops limestone;Central Lockne area, Jemtland.

Genus *Jemtella* n. gen.

Diagnosis. Cranidium similar to *Oedicybele*, but lacking a preglabellar field. — Genotype: *Jemtella clava* n. sp.

Jemtella clava n. sp. Pl. 10, figs. 11—13.

Specific characters. Cephalon strongly convex, sub-semicircular in outline; its length along median line almost four fifths the width at base; genal angles produced into short, rather stout spines.

Glabella strongly convex from side to side, sloping steeply anteriorly, subclavate in outline, expanding anteriorly to about three times its width at base; frontal lobe greatly swollen, sub-oval in outline, its width nearly equal to twice its length and slightly less than the length of glabella; posterior, furrowed part of glabella raised above the cheeks, sub-semicylindrical, gradually and but slightly widening anteriorly from the base, marked off from frontal lobe by a pair of comparatively broad and shallow furrows, which are directed obliquely upwards and forwards from axial furrows and do not meet in the median line of glabella. Just behind these lateral furrows the glabella is somewhat raised into a ring-like wall. Posterior two pairs of lateral glabellar furrows marked as rounded pits. Axial furrows strong and rather deep, deepening anteriorly, strongly divergent in front of second pair of lateral glabellar furrows. Occipital furrow transverse, rather narrow and deep. Occipital ring of moderate width, slightly narrowing towards the sides, strongly arched transversally, strongly convex longitudinally and somewhat elevated above adjacent part of glabella.

Fixed cheeks curving steeply downwards laterally and anteriorly, with moderately convex surface adjacent to axial furrows, nearly flattened laterally; proximal parts of their posterior margins directed straight outwards, distal parts curving gently backwards to genal spines. Eye lobes small, situated comparatively far forward, opposite anterior lateral glabellar furrows; palpebral lobes narrow, marked off by distinct furrows. Posterior borders narrow and strongly raised, slightly widening laterally from axial furrows, marked off by strong and deep furrows. Genal spines (imperfectly preserved) short, rounded, directed backwards and outwards, somewhat curved upwards. Anterior branches of facial sutures running vertically downwards, slightly converging to antero-lateral corners of glabella, then curving inwards and slightly upwards to unite in front; posterior branches at first directed straight outwards from the eye lobes, then curving backwards to cut lateral margins a little in front of bases of genal spines.

Surface of glabella ornamented with stout spine-like tubercles or protuberances arranged in rows in the following manner: 1st row, numbering 6 »spines», situated near anterior »margin» and sub-parallel to that, 2nd row, 4 »spines», sub-parallel to the preceding one and located at some distance from it on the frontal slope of glabella, 3rd row, 2 »spines», situated in the space between the 2nd row and the inner extremities of the anterior lateral glabellar furrows; probably there is a pair of low tubercles on the ring-like wall behind these furrows. Surface of fixed cheeks inside border furrows closely covered with relatively small, rounded pits.

Material. The above description is based on two small cranidia, one of which is fragmentary, the other rather imperfectly preserved.

Dimensions. The dimensions of the larger cranidium examined are: length 3.6 mm, width across bases of genal spines 5.6 mm, length of glabella 3.2 mm, width of its frontal lobe 3 mm; the small specimen: length of cranidium 1.8 mm, length of glabella 1.4 mm, its greatest width 1.2 mm.

Affinities. This curious form seems not only to represent a new species but a new genus as well. However, the classificatory reference must as yet be left undecided as the material available is too imperfect to permit a more complete diagnosis. Possibly *Jemtella clava* is referable to the family Phacopidae, since, *inter alia,* the anterior branches of its facial sutures unite in passing round the front of glabella. The fixed cheeks appear to be rather like those of *Josephulus gracilis* WARBURG (1925, p. 408, Pl. XI, fig. 21). The glabella recalls that of *Staurocephalus,* having a greatly swollen frontal lobe and a narrow, almost semi-cylindrical posterior portion, but there is no deep transverse furrow abruptly cutting off the frontal lobe behind as in that genus.

In many features (*viz.* outline, general shape and furrows of glabella) *Jemtella clava* seems to agree with *Oedicybele kingi* WHITTINGTON (1938, p. 446, Pl. XXXVIII, figs. 4, 5) from the Phillipsinella parabola beds of the Ashgillian in the Llansantffraid Ym Mechain district, Montgomeryshire. The latter species is regarded as the type of a subgenus of the genus *Cybele.* It has some important characters of that genus which are lacking in *Jemtella;* these are a preglabellar field, which »appears to show spinose fringe», and an eye-line, »probably represented by a very short ridge running out at right angles from the frontal lobe of the glabella, across the extreme anterior edge of the fixed cheek.» It cannot be denied, however, that as to the ornamentation of the glabellar surface, *Jemtella* bears a close resemblance to this species as also to other related representatives of the family Encrinuridæ, for instance some East Baltic species of the subgenus *Atractopyge* CORDA (cf. Öpik 1937, p. 121).

Occurrence. Lower Chasmops limestone, Central Lockne area, Jemtland

2. Ostracoda.

Fam. ***Primitiidae*** ULRICH and BASSLER.

Gen. *Conchoprimitia* ÖPIK.

Conchoprimitia leperditioides n. sp. Pl. 4, figs. 14, 15; Pl. 5, fig. 1.

Diagnosis. Carapace inflated, its length less than once and a half the height. Sulcus shallow, straight. Valves with a very narrow concentric marking or depressed line, usually visible at the posterior end, sometimes traceable also in the central part. Surface smooth or without distinct punctation.

Dimensions. Length 2.9 mm, height 2.0 mm, hinge line 1.95 mm, thickness 1.25 mm.

Remarks and *Affinities.* As to the unequal sizes of the valves, the overlapping of the left valve is very pronounced and greatest along the middle of the ventral edge, thus giving the outline of the carapace a leperditiod aspect (cf. Pl. 4, fig. 15). However, in *Leperditia* the left valve is the smaller one.

Only in one specimen is there observed a faintly marked punctation, located as in *Conchoprimitia tolli* (BONN.) in the posterior part of the valve. Even upon preparing the valve with NH_4Cl this punctation is scarcely visible. However, in the same specimen, the holotype, another concentric depressed line is then traceable, though it is very faintly marked. It is situated dorsally to the line commonly visible and observed at the anterior end, and can then be followed on the lateral side beyond the ventral extremity of the sulcus (and the muscle spot). As pointed out by Öpik (1935, p. 5), the depressed lines, also developed in other species of *Conchoprimitia*, should not be regarded as true growth lines though they do resemble such.

This species is apparently closely related to *Conchoprimitia tolli* (BONN.) but differs from that mainly with regard to the relative sizes, the latter according to measurements given being longer in relation to the height. The punctation also appears to be more conspicuous in that species.

Occurrence. Common in the Chasmops conglomerate at Hallen in the parish of Åsarna, Jemtland.

Conchoprimitia hallensis n. sp. Pl. 5, figs. 2—4.

Diagnosis. Like *Conchoprimitia leperditioides* but less inflated and lacking concentric depressed lines; surface non-punctate.

Dimensions. Length 2.8 mm, height 1.85 mm, hinge line 1.75 mm, thickness 1.1 mm.

Remarks. Length of carapace about once and a half the height. The overlapping of the left valve is less conspicuous than in *Conchoprimitia leperditioides.* The only feature of concentric marking is a shallow groove at the anterior end of the valves.

Occurrence. In dark-gray limestone about 0.1 m below the base of the Chasmops conglomerate at Hallen in the parish of Åsarna, Jemtland.

Conchoprimitia elongata n. sp. Pl. 4, figs. 12, 13.

Diagnosis. Length more than once and a half the height, lacking concentric depressed lines, a faint shallow groove traceable at the anterior end of the valves; surface smooth, without punctation.

Dimensions. Length 3.15 mm, height 1.95 mm, hinge line 2.0 mm, thickness 1.3 mm.

Occurrence. Basal Chasmops conglomerate, Jemtland (Öd, Hallen).

Gen. *Primitiella* ULRICH and BASSLER.

Primitiella elongata (KRAUSE).

1891 *Primitia elongata* KRAUSE, p. 494, Pl. 30, figs. 4a, b.
1892 » » » , p. 386, » 21, fig. 16.
1896 » » » , p. 933, » 25, fig. 9.
1934 *Primitiella elongata* BASSLER and KELLETT, p. 461 (pars.).

Occurrence. Several valves obtained from lower Chasmops limestone of the Lockne area, Jemtland. Outside Sweden found in loose blocks of Ordovician »Beyrichien-Kalk» in North Germany and Holland.

Primitiella (?) *carinata* n. sp. Pl. 4, fig. 8.

Specific characters. Valves oblong, moderately convex, somewhat less than twice as long as high; outline of the valve-body in lateral view seemingly ovate with the anterior end highest, in reality it is subrectangular with almost equally rounded ends; no median sulcus but a slight depression in the dorsal half close behind the middle of the valve; behind this a conspicuous tubercle located somewhat dorsally. Muscle spot circular, with glossy surface, situated ventrally to the depression. Ventral side of the valve provided with a keel-like flange, gradually increasing in breadth towards the posterior end.

Surface of valve finely reticulate.

Dimensions. Length 1.04 mm, hinge line 0.82 mm, height 0.56 mm, breadth of border 0.13 mm.

Occurrence. Lower Chasmops limestone; Central Lockne area, Jemtland.

Gen. *Laccoprimitia* ULRICH and BASSLER.

Laccoprimitia reticulata n. sp. Pl. 1, fig. 17.

Diagnosis. General shape similar to that of *Primitiella elongata*. Differs from that species in having a small, round, subcentral pit and a minute reticulation of the surface instead of small tubercles.

Dimensions. Length $^2/_3$ mm, height $^1/_3$ mm.

Occurrence. In a boulder of lower Chasmops limestone from Tvären.

Gen. *Primitia* JONES and HOLL.

Primitia troedssoni n. sp. Pl. 1, figs. 13—15.

Specific characters. Valves elongate, about twice as long as high, highest in posterior part, moderately convex. The undefined depression is in the middle part of the dorsal half of the valve; close behind it a small node-like elevation. A narrow false border runs from the postero-dorsal corner round the ventral side to the anterior end. Beneath it the valve is bent abruptly inwards. Surface finely reticulate or smooth.

Dimensions. Length 0.7 mm, hinge line 0.64 mm, height 0.37 mm.

Remarks. The valve on Pl. I, fig. 15, is probably from a female specimen, being slightly more convex than the holotype and having a pouch-like swelling of the border at the postero-ventral end.

Affinities. This species recalls *Primitia elongata obliqua* STEUSLOFF (1894, Pl. LVIII, fig. 12) which, however, seems to attain greater sizes and to be ornamented with small tubercles, also being provided with a striated frill. The latter species is recorded from loose blocks of Borkholm limestone.

Occurrence. Lower Chasmops limestone; the holotype in a boulder from Tvären, the female valve from Lockne, Jemtland.

Primitia granulosa n. sp. Pl. 1, fig. 16.

Specific characters. Valves long-hinged, elongate, about twice as long as high, relatively strongly and evenly convex. Sulcus narrow and shallow, rather undefined, with a hook-like swing backwards near the dorsal edge; posterior lobe somewhat more raised than the anterior. Free margin provided with a simple border or frill, which is broadest in ventral part of the valve. Surface of test relatively coarsely granular.

Dimensions. Length 0.75 mm, hinge line 0.7 mm, height 0.39 mm, border about 0.1 mm.

Affinities. This species recalls, in some features, *Primitia* (?) *extraria* ÖPIK, a valve of which has also been obtained from the same locality, but it differs from that in its greater convexity and in lacking a node.

Occurrence. Found in boulders of lower Chasmops limestone from Tvären.

Gen. *Euprimitia* ULRICH and BASSLER.

Euprimitia minor n. sp. Pl. 1, figs. 11, 12.

Specific characters. Carapace rather strongly convex, thickest in median part, subrectangular in outline with subequally rounded ends; posterior dorsal angle slightly more obtuse than the anterior. Valves seemingly equal, but one valve probably overlaps the other round the free edge; flattened at the dorsal margin, ventral side tumid, a thickened rim or narrow false border runs along the ventral side near the edge. Sulcus subcentral, deep, not reaching half the height of the valve from dorsal margin, posteriorly and ventrally surrounded by a slightly raised ridge. Surface of test finely reticulate.

Dimensions. Length 0.7 mm, hinge line 0.59 mm, height 0.41 mm
» 0.81 », » » 0.64 », » 0.48 »,
thickness $^1/_3$ mm.

Remarks. This species resembles *Primitia bursa* KRAUSE (1889, Pl. I, fig. 8) but lacks the false border at the ends and its sulcus is shorter, occupying approximately only one third the height of the valve. It is smaller than *Euprim. plena* ÖPIK and the ornamentation is different.

Occurrence. Found in boulders of lower Chasmops limestone from Tvären.

Euprimitia (?) *locknensis* n. sp. Pl. 4, fig. 7.

Specific characters. Valves moderately convex, oblong, somewhat less than twice as long as high, highest in anterior part; ends semicircular in outline, posterior end slightly more convex than the anterior. Sulcus broad and rather deep, situated behind the middle of the valve, running perpendicularly to the dorsal edge, thence traversing more than half the height of the valve and bounded by a conspicuously raised ridge round its ventral and posterior part. A false border on the ventral side lengthened into a keel-like flange, which gradually becomes broader towards the posterior end.

Surface of test finely reticulate and furnished with a few fine tubercles in the dorsal part.

Dimensions. Length 1.31 mm, hinge line 0.92 mm, height 0.72 mm, breadth of border 0.14 mm.

Affinities. This species is evidently closely related to *Primitia* (?) *eutropis* ÖPIK, a species also obtained from the basal Chasmops conglomerate at Hallen, Åsarna, Jemtland, but differs from that, *i. a.*, in the shape of the false border and the surface ornamentation. It should be pointed out, however, that the specimen of that species figured by Öpik (1937) on Pl. XIII, fig. 1, appears to be very like *Pr. locknensis*, at all events more like it than the holotype of the same species seems to be.

Occurrence. Lower Chasmops limestone of the Central Lockne area; Chasmops conglomerate at Hallen, Åsarna, Jemtland.

Gen. *Chilobolbina* ULRICH and BASSLER.

Genotype. *Primitia dentifera* BONNEMA.

Ulrich and Bassler (1923, p. 304) give the following diagnosis: »Like Coelochilina in many respects, but a long ovate brood pouch is developed in the posterior three fifths of the ventral part of frill»; and in the same paper (p. 515) a more detailed one: »Carapace with the broad striated frill characteristic of the subfamily, a simple, short, more or less deeply impressed median furrow or spot, the median lobe barely elevated above general convexity of surface, the male closely resembling the older, simply sulcate section of *Eurychilina*. The females differ in having a prominent, long, ovate brood pouch that covers approximately the posterior three-fifths of the ventral part of the frill and laps slightly onto the convex part of the valve.» The first, more comprehensive diagnosis is cited by Bassler and Kellett (1934, p. 22).

A careful examination of specimens of the genotype (and of other species very likely belong'ng to this genus) creates the impression that these diagnoses are too wide, at least in one respect, and too narrow in another. Certainly *Coelochilina, Eurychilina,* and *Chilobolbina* display resemblances *e. g.* as regards the bodies of the valves, their general shape, the form and situation of the sulcus, and so on. But primarily (in male and probably also in unfertilized or unproductive females) the border of the free margin of *Chilobolbina* was not bent inwards or »curved on its under side so as to form a concave area around the true contact edges of the valves» as in *Coelochilina* and *Eurychilina* (Ulrich and Bassler 1923, p. 303). In reality this feature is restricted to certain specimens

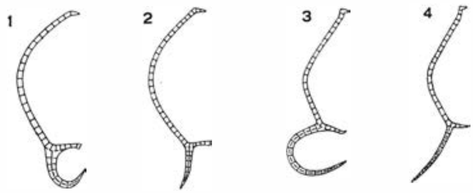

Fig. 57. Vertical sections of females (1,3) and males (2,4).
1—2. *Chilobolbina decumana* (BONN). 3—4. *Ch. dentifera* (BONN).

of species of *Chilobolbina.* As has been pointed out by several authors we are in these cases concerned with females in which a brood space is developed. Transverse sections (fig. 57) have proved that the walls of this chamber are formed by the false border, bent inwards, and the ventral part of the valve inside the border. Very likely there is no direct communication with the inner cavity of the shell, although the exterior might be read to indicate the existence of an opening between the contact edges of the valves.

Thus in *Chilobolbina* the marginal expansion itself is nothing but a simple flat false border, and the swellings under discussion must be regarded only as alterations in order to form a brood space in fertilized females.[1] In this connection reference should be made to Bonnema (1909, p. 28) who suggested this interpretation for *Primitia decumana* BONN. and *Prim. kuckersiana* BONN. The writer is of opinion that both these species may be referred to the genus *Chilobolbina,* not only the latter as was first proposed by Ulrich and Bassler (1923, p. 516).[2] The size and convexity of the brood space do not seem to be of generic importance as, *inter alia,* these features very likely are only due to the extension of the swellings along the ventral part of the valves. There being a minor extension, one might thus expect such a pouch-like form as that developed in *Ch. dentifera.*

[1] Recently, this was pointed out by A. Öpik (1937, p. 22).
[2] These species were provisionally referred to the genus *Eurychilina* by Öpik (1937, p. 20), who considers them to be representatives of a new genus.

Chilobolbina dentifera (BONNEMA). Pl. 1, figs. 1, 2, text-fig. 57.

1909	*Primitia dentifera*		BONNEMA pp. 25—26, Pl. II, figs. 1—5.
1923	*Chilobolbina*	»	ULRICH and BASSLER, p. 303, text-fig. 16.
1933	»	»	BONNEMA, p. 36, figs. 34—35.
1934	»	»	BASSLER and KELLETT, pp. 21, 244, text-fig. 7.
1937	»	»	ÖPIK, p. 22. Pl. VII, figs. 1—3.

Description. Valves sub-semielliptical in outline, moderately convex, with a small flat area in each corner at the dorsal margin; hinge line forming right angles with the anterior edge, posterior edge semicircularly rounded. Sulcus well-defined, oblong, situated in posterior part of the valves, its edge furnished with at least eight (probably nine) denticles. False border or frill bent outwards, almost as broad as the height of the valve, evidently broadest in ventral and anterior part, slightly tapering towards the postero-dorsal edge, with radiate and very fine concentric striations.

Valves of fertilized females provided with a prominent ovate brood pouch lying within the false border, its dorsal and central portion slightly overlapping the adjacent ventral part of the valve.

Excepting the small flat areas at the dorsal corners, the surface of the test is very finely reticulate.

Dimensions. Male: Length and height without frill 1.25 mm and 0.7 mm, respectively; breadth of frill 0.5 mm. Female: Length and height without frill 1.45 mm and 0.85 mm, respectively; brood pouch: 0.7 mm long, 0.45 mm high.

Remarks. When there is a brood pouch, the sulcus seems to have a somewhat extraordinary shape. In such individuals it is distinctly broader than in valves of males (cf. Bonnema 1909 Pl. II, figs. 1—4), and sometimes, as in the specimens examined by the writer (cf. Pl. 1, figs. 1, 2), its outline, too, is somewhat altered, falciform with posterior edge concave rather than elliptical, as is commonly the case. This alteration of the sulcus possibly indicates a stronger development of the adductor muscle in fertilized females.

The reconstructions of this species given by Ulrich and Bassler (1923), later reproduced by Bassler and Kellett (1934), are not quite satisfactory. The border, for instance, is broader along the posterior part of the valve than along the anterior, which is contrary to the actual fact. Furthermore, the brood pouch seems to form an appendix separated from the border instead of being part of it.

Occurrence. Found in boulders of lower Chasmops limestone from Tvären and of grey limestone (probably from Chasmops beds) near the village of Lerkaka in Öland. — Outside Sweden the species occurs in the Kuckers formation of Esthonia.

Chilobolbina decumana (BONNEMA). Pl. 3, figs. 8—10, text-fig. 57.

1909 *Primitia decumana* BONNEMA, p. 26, Pl. II, figs. 10—14.
1923 » » KUMMEROW, p. 440.
1934 *Eurychilina* » BASSLER and KELLETT, p. 314.
1937 » » ÖPIK, p. 21, Pl. XII, fig. 8.

Description. Valves subelliptical in outline, rather convex. Dorsal margin forming obtuse and about equal angles with posterior and anterior edges. Close to the dorsal corners there are small ridges forming facets similar to though not so strongly developed as those seen in *Öpikella tvaerensis* (cf. Pl. 2, figs. 1—6). Sulcus well-defined and crescent-shaped in outline, its posterior edge somewhat raised into a small but rather indistinct node. False border or frill moderately broad, anteriorly partly developed as or replaced by (9—12) fine spines. Surfaces of test ornamented with small tubercles of somewhat different sizes.

In fertilized females the complete frill — besides a small postero-dorsal part of it — is bent inwards to form a long sausage-shaped brood space. Other specimens have a flat or slightly concave frill.

Dimensions:

	1	2	3	4
Length	1.84 mm	2.23 mm	2 mm	2.1 mm
Hinge line	1.18 »	1.28 »	1.2 »	1.25 »
Height	1.15 »	1.33 »	1.2 »	1.28 »
Breadth of border	0.3 »	0.3 »	0.34 »	—

Nos. 1, 2, and 3 are males (according to Bonnema); No. 4 is a valve of a fertilized female.

Occurrence. Lower Chasmops limestone of Sweden; very common in boulders from Tvären and in solid rock of the Central Lockne area, also found in beds of thin-bedded limestone and shale in the parish of Lönsås, Östergötland. Kuckers formation of Esthonia. Boulders in North Germany.

Chilobolbina cf. *kuckersiana* (BONNEMA). Pl. 3, fig. 11.

cf. 1909 *Primitia Kuckersiana* BONNEMA, p. 27, Pl. III, fig. 25, Pl. V, figs. 7—21.
» 1923 *Chilobolbina* » ULRICH and BASSLER, p. 516.
» 1933 *Eurychilina* » KUMMEROW, p. 49, text-fig. 8.
» 1934 *Chilobolbina* » BASSLER and KELLETT, p. 245.
» 1937 *Eurychilina* » ÖPIK, p. 20, Pl. I, fig. 9; Pl. XI, figs. 1—6.

Description. Carapace similar to that of *Chilobolbina decumana* but with a complete false border all round the free margins, with a smaller subcentral pit or sulcus. Brood space of quite the same shape as in that species. Surface of valve covered with small rounded tubercles of somewhat different sizes.

Dimensions. Length of valve with border 1.5 mm, hinge line 0.87 mm, breadth of border in antero-ventral part 0.15 mm.

Remarks. Only the figured valve has been obtained and unfortunately its posterior part is somewhat fragmentary. Close behind the sulcus there was probably a node as in *Ch. kuckersiana*, but it is entirely missing in our specimen. The resemblance to this species is very great and the only difference seems to be the surface ornamentations. In the present case it is, however, questionable whether this difference is of any specific importance as it may be explained by different states of preservation.

In Bonnema's description of *Primitia kuckersiana* the following statement is noticed. »Ein sehr charakteristisches Kennzeichen ist es, dass die Lateralfläcke in der Mitte ein schönes Netzwerk besitzt mit verdickten Knoten. Nach den Rändern zu werden die Maschen feiner und undeutlicher, zuletzt sind nur die Knoten in der Gestalt von kleinen Tuberkeln übrig.» According to Kummerow (1933), the shell of the Ordovician and Silurian ostracoda is built up of three layers comparable with those of the pelecypod shell. An external layer usually conceals the underlying prismatic layer, but in many species the former is very thin and in such cases the reticulate structure of the latter may be more or less distinguishable. When the shell is weathered or worn, the reticulation appears clearly. Thus in the case under consideration it would seem very likely that the surfaces of the valves of *Ch. kuckersiana* figured and described by Bonnema acquired their reticulate ornamentation by weathering. This opinion seems to be corroborated by the figures recently published by Öpik, which show a granular ornamentation. According to Öpik, *Primitia kuckersiana* has a small node near the posterior dorsal angle. However, this node does not seem to be developed in all specimens (cf. Öpik 1937, Pl. XI, figs. 4 and 6). The shape of the brood space in Öpik's specimens differs slightly from that of the specimen figured in this paper.

Occurrence. Found in a boulder of lower Chasmops limestone from Tvären.

Gen. *Platychilina* KUMMEROW.

Diagnosis. Similar to *Chilobolbina*, but lacking a well-defined sulcus, instead having a conspicuous, subcentral muscle spot.

Genotype. *Primitia distans* KRAUSE (1889, p. 6, Pl. 1, fig. 3).

Platychilina kapteyni (BONN.). Pl. 1, figs. 8—10, Pl. 5, fig. 7.

1892 *Primitia distans* KRAUSE, p. 386, Pl. 21, fig. 16.
1896 » » » , p. 933, » 25, figs. 8, 7.
1909 » *Kapteyni* BONNEMA, p. 29, Pl. 6, fig. 31.
1923 *Chilobolbina* » ULRICH and BASSLER, p. 516.
1934 » » BASSLER and KELLETT, p. 245.
» *Coelochilina distans* » » » , p. 246 (pars).

Dimensions. Valve on Pl. 1, fig. 8: Length 1.15 mm, hinge line 0.95, height 0.82 mm.

Remarks. The valves available agree with Bonnema's description and figure in all essential features. In most of them, however, the surface of the test is smooth and only one valve shows a distinct but minute reticulation, obviously not due to weathering. Two kinds of valves are present; thus in fertilized females a brood space is formed by the frill being curved inwards as in *Chilobolbina decumana* (BONN.).

Affinities. *Pl. kapteyni* shows a great resemblance to *Pl. distans* (KRAUSE). The differences between them have been pointed out by BONNEMA (1909, pp. 29, 30). The test of the latter species is granular, and furthermore that species occurs in a stratigraphically higher formation of Esthonia.

Occurrence. Fairly common in lower Chasmops limestone of the Lockne area, Jemtland, and in boulders from Tvären; Kuckers formation of Esthonia, and in glacial drift boulders in North Germany and Holland.

Gen. *Apatochilina* ULRICH and BASSLER.

Apatochilina aff. *ubjaënsis* ÖPIK. Pl. 4, fig. 6.

Description. Valve oblong, sub-rectangular in outline with subequally rounded ends, moderately and uniformly convex, slightly less than twice as long as high; along ventral margin provided with a narrow, somewhat incurved false border, which in the valve available seems to run from one end approximately to half the height of the other.

Dimensions. Length 0.92 mm, hinge line 0.85 mm, height 0.5 mm.

Remarks. Only the figured, somewhat fragmentary and weathered valve has been found. As regards the general shape and the marginal border it recalls *A. ubjaënsis*, especially the specimen figured by Öpik (1937) on Pl. XV, fig. 8, which he, though with some hesitation, considers to belong to a female carapace of that species. On account of the poor state of preservation of the valve available it is not possible to give any detailed description and satisfactory diagnosis of this species.

Occurrence. Found in upper Chasmops beds of the Central Lockne area, Jemtland.

Fam. ***Beyrichiidae*** JONES.

Gen. *Ceratopsis* ULRICH.

Ceratopsis obliquejugata (FR. SCHMIDT). Pl. 3, fig. 13.

1858 *Beyrichia obliquejugata* FR. SCHMIDT, p. 193.
1909 *Ceratopsis Schmidti* BONNEMA, p. 39, Pl. VI, figs. 1—6.
1937 » *obliquejugata* ÖPIK, p. 25, Pl. II, figs. 3—4, XIV, fig. 6.

Dimensions. Length 1.23 mm, hinge line 1 mm, height 0.65 mm.

Remarks. Only the figured valve has been found. It differs from most of the figured specimens of this species by its short and flat but fairly coarse horn-like process at the postero-dorsal end. In this respect it agrees, however, with the female specimen figured by Öpik on Pl. XIV, fig. 6. The minute reticulation of the surface mentioned by Bonnema is also visible in the valve pictured in this paper.

Occurrence. In a boulder of lower Chasmops limestone from Tvären. A badly preserved specimen probably belonging to this species, from lower Chasmops limestone at Fjecka, Dalecarlia, is included in the collections of the National Museum of Nat. History, Stockholm. — According to Öpik common in the Uhaku and Kuckers formations of Esthonia.

Gen. *Polyceratella* ÖPIK.

Diagnosis. Similar to *Ceratopsis*, but with a more or less raised marginal ridge and a usually well defined posterior lobe.

Genotype. *Ulrichia Kuckersiana* BONNEMA (1909, p. 51, Pl. VI, figs. 10—15).

General description. Carapace small, less than 2 mm long, compressed-convex, oblong, subrectangular to subovate in outline; hinge line long and straight, ventral side subparallel to the dorsal edge, postdorsal angle obtuse, antero-dorsal angle acute but almost right. An elevated ridge runs near the free edge of the valve; it usually projects over the edge at the dorsal corners. Anterior lobe relatively large, subtriangular in outline, its ventral extremity confluent with the marginal ridge; posterior lobe isolated. Surface usually granular. — Brood pouch unknown, probably wanting.

Polyceratella bonnemai n. sp. Pl. 4, fig. 11.

Diagnosis. Like *P. kuckersiana* (BONN.), but lacking the horn-like protrusions of the marginal ridge at the dorsal corners.

Description. Valves oblong with an oblique swing backwards, depressed-convex, about twice as long as high, highest in posterior part; outline subparallelogramic, postdorsal angle obtuse, antero-dorsal angle acute, almost 90°. Marginal ridge ending at the dorsal corners, not protruding over the dorsal edge, slightly depressed ventrally to the posterior lobe. Anterior lobe large and low, broadest at the dorsal edge, confluent with the ventral part of the marginal ridge in the middle of the valve; posterior lobe ovate, raised above the adjacent surface of the valve, isolated by comparatively deep furrows. Along the free edge there is a narrow flange, extending to the ventral part of the anterior end. Surface of valve coarsely granular.

Dimensions. Length 1.15 mm, hinge line 0.95 mm, height 0.56 mm.

Affinities. As suggested in the diagnosis this species is closely related to *P. kuckersiana.* Apart from the differences pointed out there, the latter appears to be more robust, its marginal ridge being broader and the surface ornamentation more conspicuous.

Occurrence. In a boulder of lower Chasmops limestone from Tvären.

Gen. *Uhakiella* ÖPIK.

Uhakiella coelodesma ÖPIK. Pl. 1, figs. 6, 7.

1889 *Bollia granulosa* KRAUSE, p. 14. Pl. II, fig. 1.
1937 *Uhakiella coelodesma* ÖPIK, p. 43, Pl. III, figs. 1—3.

Dimensions. Length 1.5 mm, height 0.95 mm.
» 1.75 », » 1.1 ».

Remarks. The two measured and figured valves are the only ones available. They agree in all essential features with the male specimens figured by Öpik though — probably on account of the poor state of preservation — the ventral lobe observed by that author is not clearly discernible in them.

Fine spines derivable from the free margin are occasionally observed, in lateral view visible at the ends, but as they become successively more bent inwards on the ventral side, they are there hidden by the narrow, strongly convex rim or false border outside the concentric groove of the valve.

The affinities are given by Öpik. According to him *Primitia* aff. *jonesii* KRAUSE (1891, Pl. XXXI, fig. 6) is referable to this species, but this is not a very likely assumption.

Occurrence. Found in boulders of lower Chasmops limestone from Tvären; according to Öpik rare in the Caryocystites limestone of Esthonia; recorded from boulders of »Beyrichien-Kalk» in North Germany.

Gen. *Ctenobolbina* ULRICH.

Ctenobolbina suecica n. sp. Pl. 2, figs. 13, 14, Pl. 3, fig. 14.

Specific characters. Carapace subovate, rather strongly convex, ends subequally rounded, highest anteriorly. Sulcus primitoid, hardly curved, restricted to the dorsal half of the valve, located behind the middle, round its ventral part defined by a distinct, slightly raised edge, which becomes node-like posteriorly. Valves along ventral side provided with a narrow false border or flange, running somewhat obliquely so that it is nearer to the free edge anteriorly than at the postero-ventral end. Surface of test ornamented with a minute granulation.

Dimensions. Holotype: Length 1.7 mm, height 1 mm.

Specimen on Pl. 2, fig. 13: Length 1.72 mm, height 1.05 mm. Hinge line 1.28 mm, thickness 0.66 mm.

Remarks. The flange is scarcely discernible in many specimens; but in fertilized females it is comparatively broad and convex along the posterior ventral part of the valve, which here, beneath the flange, is strongly concave, thus, together with the flange, forming a sausage-shaped brood pouch.

Affinities. In spite of the presence of a comparatively short primitian sulcus, this species is a true *Ctenobolbina* species of the unisulcate group of that genus. It is closely allied to *Ct. kuckersiana* BONNEMA (1909, Pl. IV, figs. 19—25) from which it differs mainly in having a ventrally well-defined sulcus and a more truncate shape, being somewhat higher in relation to length than that species.

Occurrence. Common in lower Chasmops limestone of the Lockne area, Jemtland, and in boulders from Tvären.

Ctenobolbina variolaris (BONN.). Pl. 3, figs. 15—17.

1909 *Entomis variolaris* BONNEMA, p. 68. Pl. 5, figs. 10—11.
» » *oblonga* var. *kuckersiana* BONNEMA, p. 67 (*pars*), Pl. 5, fig. 9.
1937 » *variolaris* ÖPIK, p. 35, Pl. XI, fig. 11.

Dimensions:

Valve on Pl. 3, fig. 15,	length 0.8 mm,	hinge line 0.67 mm,	height 0.45 mm.
» » » » » 16	» 0.64 »	— — —	» 0.35 »
» » » » » 17	» 0.7 »	— — —	» 0.36 »

Remarks. Below the false border or flange, the ventral part of the valve is bent abruptly inwards, thus concealed in lateral view. According to Bonnema, valves provided with such a false border may be regarded as belonging to females, those with only a simple and narrow marginal border at the free edge to males.

This species shows a great resemblance to *Ct. oblonga kuckersiana* (BONN.), and it seems doubtful whether they in reality are specifically distinguishable. Both are, however, clearly separable from *Ct. kuckersiana* (BONN.), referred to *Ct. oblonga kuckersiana* by Bassler and Kellett (1934, p. 252). The latter name ought to be dropped, as according to Kummerow's examination of Steusloff's originals (Kummerow 1923, p. 407), *Ct. obl. kuckersiana* (BONN.) is most likely identical with *Ct. oblonga* (STEUSL.).

Occurrence. Common in boulders of lower Chasmops limestone from Tvären, and in the Kuckers formation of Esthonia.

Ctenobolbina obliqua (KRAUSE). Pl. 1, figs. 21—23.

1892 *Entomis obliqua* KRAUSE, p. 388, Pl. 22, fig. 10.
1934 *Dilobella obliqua* BASSLER and KELLETT, p. 287.

Description. Valves subrectangular in outline, about twice as long as high, strongly convex. Sulcus oblique, extending in a slightly S-shaped curve from the dorsal margin to the flange on the ventral slope, broadest and deepest in dorsal part, rather indistinct ventrally. Posterior lobe subquadrate in outline, smaller than the anterior, furnished with a small prominent node close to the deepest part of the sulcus. Ventral part of posterior lobe raised into an oblong node, like a rifle-bullet, extending in postero-anterior direction from the ventral extremity of the sulcus somewhat more than half the length of the lobe. Flange narrow, running obliquely from the postero-dorsal end to the antero-ventral side. Ventral part of the valve bent abruptly inwards beneath the flange. A narrow marginal border surrounds the valve at the free edge. Surface with a minute granulation.

Dimensions.

Valve on Pl. 1, fig. 21, length 0.9 mm, hinge line 0.82 mm, height 0.45 mm.
» » » » » 23, » 1 », » » 0.9 », » 0.5 »

Remarks. This species was figured and briefly described in 1892 by Krause, who referred it to the genus *Entomis.* No doubt it is a true *Ctenobolbina,* but not identifical with *Ctenobolbina obliqua* ULRICH (1900, p. 180, Pl. 8, fig. 4). As this latter species was described some years later, it must be given a new name, and *Ctenobolbina ulrichi* is hereby proposed.

Occurrence. Lower Chasmops limestone. Central Lockne area, Jemtland, and in boulders from Tvären. — Outside Sweden it is recorded from glacial drift boulders in North Germany.

Ctenobolbina mammillata n. sp. Pl. 2, figs. 8, 9.

Diagnosis. Like *Ctenobolbina obliqua* (KRAUSE) in many respects, but the anterior lobe is swollen into a subcentrally located bulbous node, terminating in a pap-like protuberance.

Description. Valves strongly convex, subrectangular in outline; ends subequally rounded, the posterior slightly more convex than the anterior. Sulcus gently curved and oblique, deepest in dorsal part, reaching the narrow false border or flange on the ventral slope. Posterior lobe occupying about one third of the valve. Middle part of the valve (within the anterior lobe) swollen into an indistinctly defined bulb, which terminates in a process directed outward (broken off in the specimen available).

Surface of test displays a minute granulation.

Dimensions. Length 1.18 mm, hinge line 0.97 mm, height $^2/_3$ mm.

Occurrence. Lower Chasmops limestone, Lockne area of Jemtland.

Ctenobolbina jemtlandica n. sp. Pl. 4, figs. 9, 10.

Specific characters. Valves with a broad and deep sulcus, extending from the posterior half of the dorsal margin to about three fourths the height of the valve, gently curved in dorsal part, rather strongly arched backwards in ventral part. A narrow, crest-like false border conceals, in lateral view, the ventral part of the free edge. Surface of test granular and furnished with a large, probably spiny tubercle on the anterior lobe in front of the ventral curve of the sulcus.

Dimensions.

Length 1.46 mm, hinge line 1.34 mm, height 0.8 mm.
» 1.05 », » » 0.97 », » 0.62 ».

Affinities. *Ct. jemtlandica* bears a rather great resemblance to *Primitia curva* STEUSLOFF (1894, p. 780, Pl. 58, fig. 10). If accurately figured, that species differs in having a shorter sulcus and a broad, plicated frill, which seems to be located at the ventral margin.

Occurrence. — *Ct. jemtlandica* is fairly common in the lower Chasmops limestone of the Central Lockne area, Jemtland.

Fam. *Piretellidae* ÖPIK.

Gen. *Piretella* ÖPIK.

Remarks. Öpik has recently proposed the name *Piretellidae* for a family to which — besides *Piretella* — the genera *Steusloffia, Rigidella, Pseudostrepula* and *Hesperidella* are referred. The genus *Piretella* is described as the type of this new family. However, his diagnosis of this genus can hardly be regarded as adequate to the family for there are features in *Piretella* lacking in all other genera included by him in *Piretellidae, inter alia,* the general outline of the carapace, the structure of the false border, and the presence of a brood pouch in fertilized females. Thus, the present writer is of the opinion that the selection of *Piretella* as a type of a family including the other genera mentioned above is open to discussion.

Piretella öpiki n. sp. Pl. 4, figs. 1—5.

Diagnosis. Very like *P. margaritata* ÖPIK (1937, p. 49, Pl. IV, fig. 5, XIV, figs. 10, 11) but having a well defined brood pouch and lacking prominent granules along the dorsal margin; shape of crest slightly different, being approximately a reflected image of that of *P. margaritata.*

Description. Carapace sub-elliptical in outline, rather strongly convex; sulcus in posterior part, mainly forming a deep pit, falciform in outline. Posterior part of valve raised into a prominent rounded node close behind the pit. Marginal border as in *Chilobolbina decumana* (BONN.) but obviously broader, replaced by six to eight long spines in anterior part. Productive females with a well-developed brood pouch of a shape and position similar to that in *Chilobolbina dentifera* (BONN.).

Surface of carapace finely reticulate, traversed by a thin, crest-like and U-shaped ridge with the ends at the dorsal margin, enclosing the sulcus and the node, touching the latter.

Dimensions.

Specimen on Pl. 4.	fig. 2	fig. 3	fig. 4
Length	1.5 mm	1.26 mm	1.45 mm
Hinge line	1.2 »	1.1 »	1.2 »
Height	0.85 »	0.77 »	0.8 »
Breadth of border	0.4 »	0.35 »	—

Brood pouch of specimen on Pl. 4, fig. 4, length 0.9 mm, height 0,38 mm.

Affinities. This species appears to be closely related to *P. margaritata* (cf. above) and *P. reticulata* (KRAUSE) (Krause 1891, p. 498, Pl. XXXI, fig. 13, cf. Öpik 1937, p. 48). The latter seems to have a larger and elongate node, and the posterior branch of its crest meets the dorsal margin nearer the posterior dorsal corner.

Occurrence. Upper Chasmops beds of the Central Lockne area.

Gen. *Steusloffia* ULRICH and BASSLER.

Genotype. Beyrichia costata LINNARSSON (1869).

Remarks. As pointed out by Öpik (1937, p. 46) the diagnosis of this genus given by Ulrich and Bassler (1923, p. 308) is too wide, as no brood pouch is developed. According to Öpik (*op. cit.*, p. 49) »the most important generic features are 1) the well developed anterior and median lobes, 2) a small posterior lobe in the posterior dorsal angle, 3) one or more concentric crests, and 4) a very conspicuous tubercle on the anterior lobe». Number 2 of these features is, however, of no generic importance, and as shown below it is hardly of specific value.

Since Ulrich and Bassler (1908) proposed the name *Steusloffia* for a subgenus of *Beyrichia*, *Strepula linnarssoni* KRAUSE has been regarded as the genotype of this genus. However, Linnarsson's description of *Beyrichia costata* is somewhat erroneous, and the figures given by him are not quite satisfactory. The result was that Krause (1889, p. 17) could suggest some differences between it and specimens found in boulders of »Backsteinkalk» in North Germany, for which he then proposed the name *Strepula linnarssoni*. This species and *Beyrichia costata* LINRS. are, however, identical, and *Beyrichia costata* must thus be regarded as the type of the genus *Steusloffia*.

Steusloffia costata (LINRS.) Pl. 2, figs. 10—12; Pl. 3, figs. 1—7, Pl. 5, fig. 5, text-fig. 58.

1869 *Beyrichia costata* LINNARSSON, p. 85, Pl. II, figs. 67—68.
1889 *Strepula linnarssoni* KRAUSE, pp. 16—17. Pl. II, figs. 4—5.
1908 *Beyrichia (Steusloffia) linnarssoni* ULRICH and BASSLER, pp. 282, 296, text-figs. 8, 34; Pl. XXXVIII, fig. 1.
1923 *Steusloffia linnarssoni* ULRICH and BASSLER, p. 308, text-fig. 5.
1924 » *(Strepula) linnarssoni* KUMMEROW, p. 413, text-fig. 1.
1934 » *linnarssoni* BASSLER and KELLETT, p. 475.
» *Strepula?* » » » » p. 477.
1937 *Steusloffia* » ÖPIK, p. 50, text-fig. 7.

Description. Valves about three fifths as high as long, subelliptical in outline, the hinge line long and straight, ventral side gently convex, ends subequal, dorsal angles slightly differing. Median furrow oblique, broad and flat at dorsal edge, tapering and becoming deeper ventrally, reaching scarcely more than half the distance to ventral margin; posterior furrow narrow and weak. Median lobe subcircular to subovate in outline, situated in posterior half of the valve. Anterior lobe large, ovate, running diagonally along the antero-ventral side of the median furrow, at the top furnished with a pointed large tubercle. Close below posterior angle a small rounded node is sometimes developed.

Valves (at least of adult specimens) provided with a relatively narrow false border all round, broadest at posterior and ventral sides, becoming rib-like

Fig. 58. Showing different stages of test ornamentation in *Steusloffia costata* (LINRS.). Drawn after figs. 2—4 in Pl. 3.

at the anterior end. The dorsal, somewhat undulating part of this border is usually broken off.

Surface of valves ornamented with tubercles of somewhat different sizes and traversed by ribs or crests as demonstrated in the figures of Pl. 2 and 3 (cf. below).

Dimensions.

No. of specimen on Pl. 2 and 3	fig. 1	fig. 2	fig. 3	fig. 5	fig. 10
Length	2.0 mm	1.5 mm	1.72 mm	1.82 mm	1.95 mm
Hinge line	—	1.2 »	1.38 »	1.4 »	1.56 »
Height	1.18 mm	0.82 »	1.0 »	1.07 »	1.15 »
Breadth of border	0.3 »	—	0.16 »	—	0.35 »

Remarks. As to the surface ornamentation, it seems as if the ribs and the dorsal part of the false border were developed, at least to some degree, by a confluence of tubercles during the ontogeny. In small valves (ephebic specimens, cf. Pl. 3, figs. 2 and 3) these ribs are relatively incomplete and parts of those present have a rather granulous appearance. The rib running subparallel to the ventral and anterior margins, joining the posterior rib ventrally to the median lobe, seems to be entirely missing in these specimens, but its way is marked by more or less closely lying tubercles. The development of the ornamentation in question is suggested in text-figure 58, drawn and reconstructed after the specimens figured on Pl. 3, figs. 2—4.

Apart from this development, the ornamentation of the valves is seemingly subjected to rather great variations, especially that of the ribs. It is the writer's opinion, however, that in most cases this can be explained by differences in the state of preservation. Thus in specimens from the hard Chasmops limestone of Västergötland — weathering similar to »Backsteinkalk» — the marginal border or crest along the dorsal edge has never been observed. In this respect they quite agree with *Strepula linnarssoni* KRAUSE. As seen in the figures on Pl. 3, the small anterior dorsal rib running in dorso-ventral direction towards the anterior lobe, varies in length and as regards its relation (angle, contact) to the anterior branch of the concentric rib. Sometimes (Pl. 2, fig. 10) it is scarcely developed. The bifurcation below the median lobe is occasionally (cf. Pl. 2, figs. 11 ,12) situated somewhat more posteriorly than in the majority of the specimens figured, and the angle between the branches varies slightly. — In some specimens tubercles are fairly common, in others — as for instance in valves obtained from marly limestone in Dalecarlia — they are quite missing. In the former case they are sometimes arranged in a concentric manner, forming ribs outside the ordinary ones (Pl. 2, fig. 10). A great resemblance to *Steusloffia multimarginata* ÖPIK (1937, p. 52, Pl. IV, fig. 4) is thus developed and the latter probably ought to be regarded merely as a variety of our species. — The small node below the posterior dorsal angle has been observed in specimens from Chasmops limestone of the Lockne area, Jemtland, and of Västergötland. The valve figured on Pl. 3, fig. 6, was obtained from a piece of limestone also containing other specimens, some of which were furnished with an indistinct node, others lacking it.

Affinities. This species is closely related to the *Steusloffia* species of the Kuckers formation in Esthonia described by Öpik (1937). The differences mainly concern the ornamentation of the valves. As pointed out above, the agreement with *St. multimarginata* is very great but for the spiny anterior border in that species. However, this feature is observed in a large specimen from the Jemtland lower Chasmops limestone, which, besides, has a very distinct node at the posterior end. The fine spines are easily broken off. *St. rigida* ÖPIK mainly differs in having the rib on the median lobe prolonged towards the dorsal crest or marginal border and the branches of the concentric ribs kneed; a posterior node is permanently developed in that species. From the Chasmops limestone of the deep-boring core at File Haidar, Gotland, a small valve was obtained which the writer recently found to be identical with *St. rigida*. *St. humilis* ÖPIK seems to hold an intermediate position between *St. rigida* and *St. costata*.

Occurrence. *St. costata* is a very common species in the Chasmops beds of Sweden and seems to have a wide distribution. Owing to its abundant occurrence in the strata between the Orthoceras limestone and the Trinucleus shales in Västergötland, Linnarsson (1869, p. 5) proposed the name Beyrichia Limestone for these beds. This name has subsequently been dropped.

St. costata occurs in the lower Chasmops beds of Dalecarlia, Västergötland, Östergötland, and Jemtland (also in the basal conglomerate at Hallen, Åsarna), and in boulders of lower Chasmops limestone from Tvären. Rare in upper Chasmops beds of the Lockne area, Jemtland. — According to Funkquist (1919, p. 39) it also occurs in the »Orthisskiffer» of Scania. — Outside Sweden found in boulders of »Backsteinkalk» and (Ordovician) »Beyrichienkalk» in North Germany.

Gen. *Hesperidella* ÖPIK.

Remarks. Öpik (1937, p. 49) suggests that this genus is closely related to *Piretella*. As pointed out above (p. 175), this opinion cannot be shared by the writer, who considers its affinity with *Steusloffia* more obvious.

The type of this genus is *Primitia* (*Ctenobolbina?*) *globifera* KRAUSE, very likely identical with *Primitia Esthonica* BONNEMA (cf. below).

Hesperidella globifera (KRAUSE) Pl. 3, fig. 12, Pl. 5, fig. 6.

1892 *Primitia* (*Ctenobolbina?*) *globifera* KRAUSE, p. 389, Pl. 22, fig. 9.
1909 » *Esthonica* BONNEMA, p. 32, Pl. 6, fig. 30.
1934 *Kloedenia globifera* BASSLER and KELLETT, p. 362.
» *Eurychilina esthonica* » » » , p. 314.
1937 *Hesperidella* » ÖPIK, p. 49, Pl. XI, figs. 14—15.

Remarks. The features mentioned by Bonnema (1909) distinguishing *Prim. globifera* KRAUSE from *Prim. Esthonica* BONNEMA are merely superficial. As to the general shape, a comparison between the measurements given by these two authors (cf. below) is sufficient to establish the close agreement. The differences in the ornamentation reported by Bonnema are very likely due to the varying state of preservation of the specimens described. When weathered or worn, the surface of the test appears reticulate, when well preserved it is granulous with some slightly coarser tubercles. The rib-like crests and the false border of this small species are easily broken off during preparation, thus changing the appearence of the valves. In lateral view the dorsal crests conceal most of the dorsal edge.

Dimensions.

The figured specimen, length 0.85 mm, height 0.5 mm, breadth of border 0.07.
According to Krause, » 0.93 » » 0.53 »
» to Bonnema, » 0.95 » » 0.56 » breadth of border 0.08.

Occurrence. Fairly common in lower Chasmops limestone, Central Lockne area, Jemtland, and in boulders from Tvären. According to Öpik it is rare in the Kuckers formation but common in higher formations in Esthonia.

Fam. ***Kloedenellidae*** ULRICH and BASSLER.

Gen. *Balticella* n. gen.

Diagnosis. Valves with long and straight hinge line, a primitioid sulcus somewhat behind the middle, the right valve overlapping the left, at least along the ventral side.

Genotype. *Balticella oblonga* n. sp.

The genotype is the only species of this genus so far known.

Balticella oblonga n. sp. Pl. 1, figs. 18—20.

Specific characters. Valves strongly convex, oblong, almost twice as long as high; ends rounded, the anterior outline somewhat more convex than the posterior; ventral side incurved, its edge moderately convex. Sulcus gently curved, reaching slightly more than half the height from the dorsal edge. Anterior lobe larger and more convex than the posterior, in lateral view slightly concealing the dorsal edge; posterior lobe with a well-defined, large, ovate node, close to the sulcus. Surface of test ornamented with very small tubercles, sometimes with a larger one on the antero-dorsal slope.

Dimensions. Length 1.8 mm, height 0.95 mm.
» 4/3 » , » 0.69 mm.

Remarks. The incurved ventral side with its convex edge indicates that this species is unequivalved. But as only a few separate valves have so far been found, it is difficult to determine which valve is the overlapping one. As far as the writer has been able to ascertain, the right valve is the larger, being less incurved on the ventral side than is the left, and provided with a small process at the postdorsal angle. Thus, if this interpretation of the relative sizes of the valves coincides with the actual facts, there would appear to be little difficulty in distinguishing this genus from *Jonesina* Ulrich and Bassler (1908, p. 324), though there seems to exist a rather great resemblance between *B. oblonga* and simple types of *Jonesina*, especially for inst. *J. arcuata* (Bean).

Occurrence. *B. oblonga* occurs in lower Chasmops limestone and is found in the Lockne area and rather commonly in boulders from Tvären.

Fam. ***Kirbyidae*** Ulrich and Bassler.

Genus *Macronotella* Ulrich.

According to Ulrich and Bassler (1923, p. 316) and Bassler and Kellett (1934, p. 32) the diagnosis of this genus is as follows. »Shell semicircular or semiovate with a long, nearly straight hinge; valves equal, inflated centro-dorsally, without ridges or sulcus but exhibiting a smooth, subcentral spot where the reticular ornament is omitted.»

This diagnosis differs in no essential respect from that previously given by Ulrich (1894, p. 683) although Bonnema in 1909 pointed out that — besides the genotype *M. scofieldi* Ulrich — nearly all the species up to that time referred to the genus have a subcircular outline and a short straight hinge line. And it is hardly necessary to stress that Bonnema's statement is still valid, as all the species subsequently referred to *Macronotella* (cf. Bassler and Kellett 1934, p. 407) show those features.

Thus the reference of the two following species to the same genus as *Macronotella scofieldi* ULRICH is only tentative.

Macronotella (?) *kuckersiana* BONN.

1909 *Macronotella Kuckersiana* BONNEMA, p. 55, Pl. 3, figs. 1—9.

Dimensions. Length 1.03 mm, hinge line 0.55 mm, height 0.76 mm.

Remarks. The valve found agrees in all respects with the description and figures of this species given by Bonnema.

Occurrence. Found in a boulder of lower Chasmops limestone from Tvären; Kuckers formation of Esthonia.

Macronotella (?) cf. *elliptica* KUMMEROW.

cf. 1923 *Macronotella elliptica* KUMMEROW p. 432, Pl. 21, fig. 11.

Dimensions. Length 1.44 mm, hinge line 0.6 mm, height 1.12 mm.

Description. Similar to *M. elliptica* in outline, convexity, ornamentation, and location of the muscle spot. The valve observed smaller than those measured by Kummerow and furnished with a slightly longer hinge line, being somewhat more than one third the length of the valve. Perhaps these features are of no specific importance.

Occurrence. Found in a boulder of lower Chasmops limestone from Tvären. *M. elliptica* KUMMEROW was obtained from a boulder of gray Ordovician limestone in North Germany.

Gen. *Öpikella* n. gen.

Diagnosis. Similar to *Macronotella,* but valves subelliptical in outline with straight hinge and lacking a centrodorsal inflation. Surface usually with minute punctation instead of reticulate.

Genotype. Öpikella tvaerensis n. sp.

Besides the two species described in this paper, this genus includes *Isochilina canaliculata* KRAUSE (1892, p. 385, Pl. 21, fig. 1), *Macronotella bonnemai* ÖPIK (1937, p. 23, Pl. 1, figs. 7—8) and *Macronotella* (?) sp. *a* ÖPIK (1937, p. 23, Pl. XV, fig. 6).

Öpikella tvaerensis n. sp. Pl. 2, figs. 1—7.

Specific characters. Carapace strongly convex, ventricose, thickest in the posterior part, length slightly less than once and a half the height, sharply bevelled at the dorsal corners. Valves subelliptical in outline, ends subequally rounded, anterior outline slightly more convex than the posterior. Surface of test finely punctate, the ornamentation being slightly coarser round the large, glossy, subcentral muscle spot.

Dimensions.

Length	1.77 mm,	hinge line	4/3 mm,	height	1.2 mm,				
»	2.03 »,	»	» 1.5 »,	»	1.35 ».				
»	2.56 »,	»	» 1.9 »,	»	1.72 »,	thickness	1.61 mm		
»	2.95 »,	»	» 2.05 »,	»	2.05 »,	»	1.87 mm		

Affinities. This species is closely related to *Isochilina canaliculata* KRAUSE. It differs from that by its greater convexity and by having somewhat larger and more sharply marked facets at the dorsal corners. Furthermore, the latter species is comparatively longer, its length being more than once and a half the height, a specimen from a boulder of Macrourus limestone in Öland having the following dimensions: length 2.38 mm, hinge line 1.82 mm, height 1.5 mm, thickness 1.39 mm.

Occurrence. Common in boulders of lower Chasmops limestone from Tvären.

Öpikella asklundi n. sp. Pl. 1, figs. 3—5.

Diagnosis. Like *Öpikella tvaerensis,* but its length more than once and a half its height; provided, furthermore, with a broad, finely and radially striated frill on the ventral side, reaching half the height of the valve at the posterior end and becoming successively more incurved posteriorly.

Dimensions.

Length	2.0 mm,	hinge line	1.54 mm,	height	1.23 mm,	breadth of border	1/3 mm.
»	2.3 »,	»	» 1.9 »,	»	1.4 »,	» » »	0.41 »
»	3.2 »,	»	» 2.45 »,	»	2.05 »,	» » »	0.54 »

Occurrence. In boulders of lower Chasmops limestone from Tvären.

Table of tentative correlation of the Swedish Chasmops series with corresponding strata in certain districts of foreign countries.

Sweden: Graptolite succession	Sweden: Lockne, Jemtland	Esthonia	Norway	Great Britain: Girvan	Great Britain: Graptolite succession		N. America (New York)	
Z. of *Pleurograptus linearis*	Black Trinucleus shale Masur limestone	Wesenberg (E) Kegel (D_2)	Lower Trinucleus shale (4cα)	Whitehouse group	Z. of *Pleurograptus linearis*	Caradocian	Utica shale	
Z. of *Dicranograptus clingani*	Upper Chasmops beds	Jewe (D_1)	Upper Chasmops limestone (4bδ)	Upper Ardwell group	Z. of *Dicranograptus clingani*	Caradocian		
Z. of *Amplexograptus vasae*			Upper Chasmops shale (4bγ)	Middle Ardwell group	Z. of *Climacograptus wilsoni*	Caradocian		
Z. of *Amplexograptus rugosus*	Lower Chasmops limestone	Itfer (C_3) Kuckers (C_2)	Lower Chasmops limestone (4bβ) Lower Chasmops shale (4bα)	Lower Ardwell group Balclatchie group	Z. of *Climacograptus peltifer*	Llandeilian	Snake Hill shale	Trenton
Z. of *Nemagraptus gracilis*	Loftarstone Conglomerate	Uhaku ($C_{1\delta}$)	Ampyx limestone (4aβ)	Benan conglomerate	Z. of *Nemagraptus gracilis*	Llandeilian	Rysedorph conglomerate	
	Hiatus	Hiatus	?	Mudstone w. *N. gracilis*, *Glossogr. hincksi* etc.		Llandeilian	Normanskill shale	Black River
Z. of »*Climacograptus putillus*» (with *Glyptograptus teretiusculus* etc.)	Schroeteri limestone	»Baukalk» ($C_{1\gamma}$)	Ogygia shale (4aα)		Z. of *Glyptograptus teretiusculus*	Llandeilian		

VI. Palaeontological Survey of the Chasmops Series.

List of species of trilobites, ostracoda, and graptolites observed in Jemtland and Södermanland, and their distribution in the Scandinavian-Baltic region.

( ) indicates that the identification is somewhat uncertain.
± ╪ indicate that the specimens in question have (in Jemtland) either (±) been found only in the basal Chasmops conglomerate, or (╪) both in this and in the lower Chasmops limestone.
* indicates that the species in question occurs in the reef-like limestone of the Central Lockne area.

	Lower Chasmops Series	Upper Chasmops Series	Jemtland	Södermanland	Dalecarlia	North Baltic Distr.	Östergötland	Västergötland	Öland	Gotland	Scania	Norway (Oslo)	Esthonia	Register of described species. Page	Plate	Fig.
Trilobites.																
**Trinodus armatus* n. sp.	+		+											127	9	9
Triarthrus linnarssoni n. sp.		+	+					+						128	12	4—12
» *skutensis* n. sp.		+	+											130	12	13—18
Remopleurides cf. *latus* Olin	+		±											136	7	14—16
» » » var. *kullsbergensis* Warb.		+	+													
» *nanus elongatus* Fr. Schm.	+			+		+							+	131	7	17—20
* » *validus* n. sp.	+		+											132	7	1—9
» *wimani* n. sp.		+	+											135	7	10—13
**Asaphus ludibundus* Tqt.	+		╪		+	+		+					(+)			
» *nieszkowskii* Fr. Schm.	+			+									+	136	5	8—13
» sp.	+			+										137	9	4
Pseudasaphus cf. *tecticaudatus* var. *laurssoni* Öpik	+			+										137	9	7—8
**Stygina? nitens* (Wiman)	+		+	+	+	+				+				137	4	1—10
**Bronteopsis concentrica* (Linrs.)	+		+					+			(+)			139	4	11
**Illænus avus* Holm	+	+	+		+		+		+			(+)	+	141	8	11—12
* » *fallax* Holm	+	+	+		+	+			+			+		140		
* » » var. *elongatus* n.	+		+											141	8	7—10
» *gigas* Holm		+	+		+		+	+								

**Illænus minor* n. sp.	+		+											140	6	12—13
» *oblongatus kuckersianus* HOLM	+			+									+	143	8	13
» *parvulus* HOLM	+		±	(+)	+	+				+						
» *scrobiculatus* HOLM	+		+		+											
» *sphæricus* HOLM	+		+		+			(+)					+			
» *warburgae* n. sp.	+		±	+					(+)					142	8	1—6
Pharostoma similis n. sp.	+			+										144	11	1—14
Flexicalymene jemtlandica n. sp.		+	+					(+)						147	12	19—22
**Törnquistia reedi* n. sp.	+		+											148	10; 11	14—19; 15
»*Törnquistia*» *parvula* n. sp.	+			+										150	6; 10	15—16; 20—22
**Harpes concavus* n. sp.	+		+											152	11	16—18
**Ampyx costatus* ANG.	+		+		+			+	+			+				
» *culminatus* (Ang.)		+	(+)					+								
» *?aculeatus* ANG.		+	+									+		153	9	10—11
Lonchodomas rostratus (SARS)	+		±			+		+	+		+	+				
» *affinis* ANG.		+	(+)									+				
Cryptolithus discors (ANG.)		+	+		+							+		154	12	1—3
Tretaspis cerioides (ANG.)		+	+					+				+				
**Ceratocephala asklundi* n. sp.	+		+											154	6	14
» *kuckersiana* (FR. SCHM.)	+			(+)									+			
Platylichas bottniensis (WIMAN)	+	?		+	+	+										
» *validus* (LINRS.)	+	?	+		+			+						155	9	1—3
Conolichas peri WARB.	+			+												
**Pseudosphaerexochus elongatus* n. sp.	+		+											155	10	1—2
» *tvaerensis* n. sp.	+			+										156	10	3—5
**Niezkowskia cephaloceras* (NIESZK.) var. *longispina* n.	+		+											157	10	8
» sp.	+		(+)	+				(+)						158	9	5—6
**Sphaerexochus* cf. *hisingeri* WARB.	+		+											158	10	9—10
**Hemisphaerocoryphe sulcata* n. sp.	+		+											159	10	6—7
Pterygometopus exilis (EICHW.)	+			+	+	+			+	(+)			+			
**Chasmops conicophthalma* (SARS & BOECK)	+		+					(+)				+				
» *odini* (EICHW.)	+			(+)				+					+			
» *extensa* (BOECK)		+	+									+				
» *macroura* (SJÖGREN)		+	(+)		+	+	+	+	+	+	(+)		(+)			
**Jemtella clava* n. sp.	+		+											160	10	11—13

( ) indicates that the identification is somewhat uncertain.
± ∓ indicate that the specimens in question have (in Jemtland) either (±) been found only in the basal Chasmops conglomerate, or (∓) both in this and in the lower Chasmops limestone.
* indicates that the species in question occurs in the reef-like limestone of the Central Lockne area.

	Lower Chasmops Series	Upper Chasmops Series	Jemtland	Södermanland	Dalecarlia	North Baltic Distr.	Östergötland	Västergötland	Öland	Gotland	Scania	Norway (Oslo)	Esthonia	Register of described species. Page	Plate	Fig.
Ostracoda.																
Conchoprimitia leperditioides n. sp.	+		±											161	4; 5	14—15; 1
» *elongata* n. sp.	+		±											162	4	12—13
Laccoprimitia reticulata n. sp.	+			+										163	1	17
**Primitiella elongata* (Krause)	+		+											163		
* » (?) *carinata* n. sp.	+		+											163	4	8
Haploprimitia kogermani Öpik	+		±										+			
» *inconstans* Öpik	+		±										+			
Primitia granulosa n. sp.	+			+										164	1	16
* » *troedssoni* n. sp.	+		+	+										163	1	13—15
» ? *extraria* Öpik	+			+									+			
Euprimitia bilabrata Öpik	+		±										+			
» *minor* n. sp.	+			+										164	1	11—12
» ? *eutropis* (Öpik)	+		±										+			
* » ? *locknensis* n. sp.	+		∓										?	165	4	7
**Chilobolbina decumana* (Bonn.)	+		+	+			+						+	168	3	8—10
» *dentifera* (Bonn.)	+			+					+				+	167	1	1—2
» cf. *kuckersiana* (Bonn.)	+			+										168	3	11
**Platychilina kapteyni* (Bonn.)	+	(+)	+	+					(+)				+	169	1; 5	8—10; 7
Apatochilina aff. *ubjaënsis* Öpik		+	+											170	4	6
Ceratopsis obliquejugata (Fr. Schm.)	+			+	(+)								+	170	3	13
Polyceratella bonnemai n. sp.	+			+										171	4	11
Uhakiella coelodesma Öpik	+			+									+	172	1	6—7
**Ctenobolbina jemtlandica* n. sp.	+		+											174	4	9—10

**Ctenobolbina mammillata* n. sp.	+		+											174	2	8—9
* » *obliqua* (KRAUSE)	+		+	+									?	173	1	21—23
* » *suecica* n. sp.	+		+	+										172	2; 3	13—14; 14
* » *variolaris* (BONN.)	+		+	+									+	173	3	15—17
Piretella öpiki n. sp.		+	+											175	4	1—5
**Steusloffia costata* (LINRS.)	+	+	+	+	+		+	+			+		(+)	176	2; 3; 5	10—12; 1—7; 5
**Hesperidella globifera* (KRAUSE)	+		+	+									+	179	3; 5	12; 6
**Balticella oblonga* n. sp.	+		+	+										180	1	18—20
Macronotella (?) *kuckersiana* BONN.	+			+									+	181		
» » cf. *elliptica* KUMMEROW	+			+										181		
Öpikella asklundi n. sp.	+			+										182	1	3—5
» *tvaerensis* n. sp.	+			+										181	2	1—6
Graptolites.																
Acanthograptus suecicus (WIMAN)	+			+		+										
Dendrograptus sp.	+			+									+			
Desmograptus sp.		+	+													
Dicranograptus clingani CARR.		+	+								+					
Dicellograptus sp.	+			+												
Climacograptus bekkeri (ÖPIK)	+			+						(+)			+			
» *bicornis* HALL		+	+								+					
» *brevis* E. & W.		+	+								(+)					
» *caudatus* LAPW.		+	+													
» aff. *kuckersianus* HOLM MS, WIMAN	+			+						+						
Orthograptus calcaratus var. *vulgatus* LAPW.		+	+													
» *truncatus* LAPW.		+	+								+					
» » var. *intermedius* E. & W.		+	+													
Glyptograptus teretiusculus var. *euglyphus* LAPW.		(+)	(+)													
» ? *uplandicus* (WIMAN)	+			+		+				+						
Diplograptus multidens var. *compactus* LAPW.		+	(+)								+					
Amplexograptus pulchellus (HADDING)		+	+								+					
» *rugosus* (HADDING)	(+)		(+)								+					
» *vasae* (TULLB.)		+	+								+					
Neurograptus fibratus (LAPW.)		+	+													
» *margaritatus* (LAPW.)		+	+													
Corynoides curtus LAPW.		+	+								+					

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PLATES.

The following abbreviations are used:
S. G. U. = Musem of the Geological Survey of Sweden.
U. M. = Museum of the Palaeontological Institute of Upsala.

Plate 1.

All specimens figured in this plate occur in lower Chasmops limestone and except fig. 15 belong to U. M. (Figs. 1—6, 8—14, 16—19, 21—23, P. THORSLUND, M. FERM phot., S. EKBLOM ret.; figs. 7, 15, 20, J. W. ENGLUND phot. & ret.)

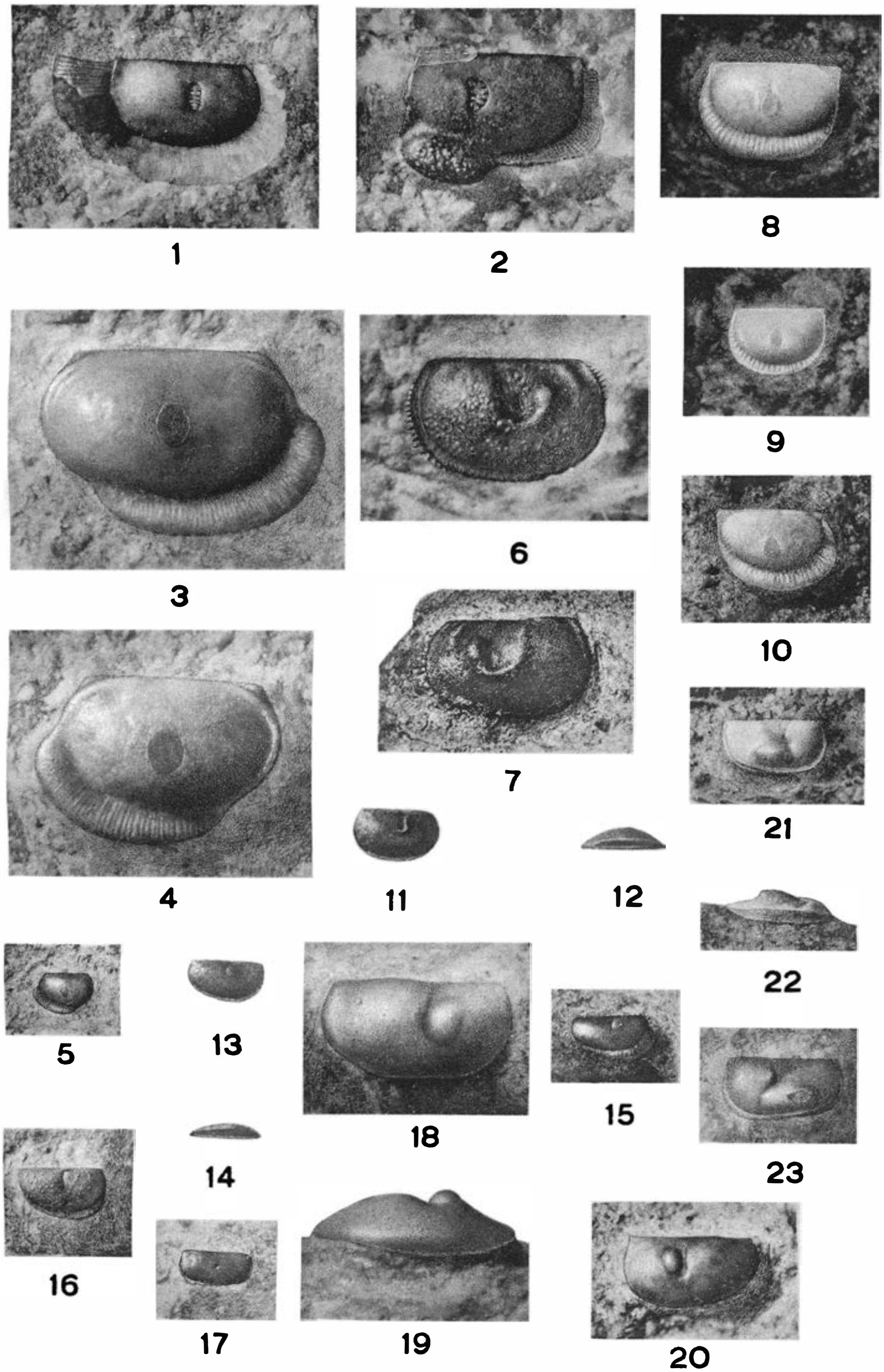

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Plate 2.

All specimens figured in this plate except fig. 11 occur in lower Chasmops limestone. (Figs. 1—7, 10, 14, P. Thorslund and M. Ferm phot., S. Ekblom ret.; figs. 8, 9, 11, 13, J. W. Englund phot. & ret.; fig. 12, C. Larsson phot.)

			Page
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		1—2. Large right valve in lateral and posterior views × 14. 3—6. Holotype in lateral, posterior, ventral, and dorsal aspects × 13. 7. Left valve in ventral view × 15. Tvären. U. M.	
»	8—9.	*Ctenobolbina mammillata* n. sp. Holotype in lateral and ventral aspects × 13. Central Lockne area. S. G. U.	174
»	10—12.	*Steusloffia costata* (LINRS.)	176
		10. A multi-tuberculate right valve (cf. *St. multimarginata* ÖPIK) × 15. Tvären. U. M. 11. Left valve × 10, Upper Chasmops beds. Central Lockne area. S. G. U. 12. White-coloured right valve × 10. Central Lockne area. S. G. U.	
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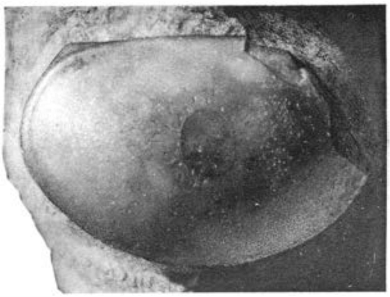
		13. Probably a male seen from the right × 14. Tvären. U. M. 14. Right valve of a female × 12. Holotype. Central Lockne area. S. G. U.	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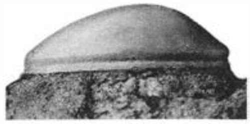
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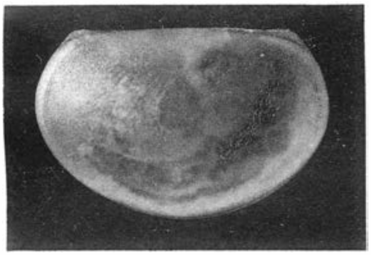
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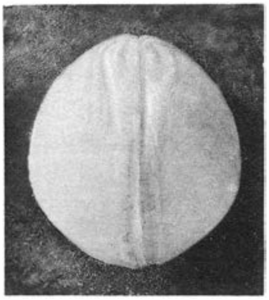
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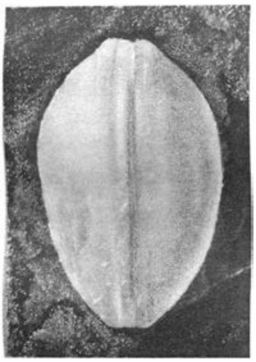
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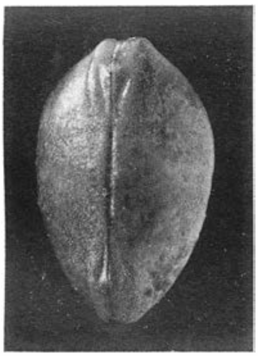
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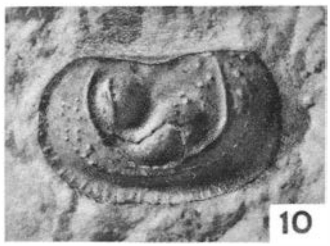
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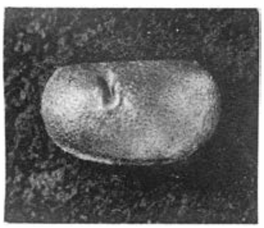
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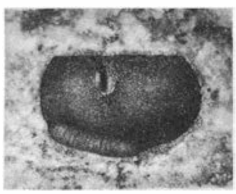
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Plate 3.

All specimens figured in this plate occur in lower Chasmops limestone. Except that in fig. 6 they are from Tvären and belong to U. M. (Figs. 1—5, 7—10, 12—17, P. Thorslund and M. Ferm phot., S. Ekblom ret.; figs. 6, 11, J. W. Englund phot. & ret.)

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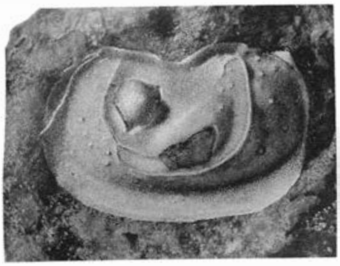
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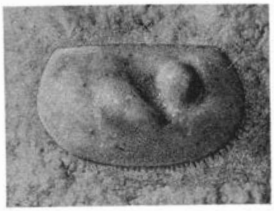
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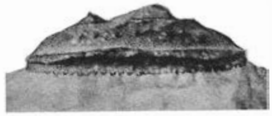
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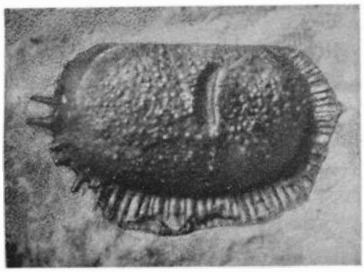
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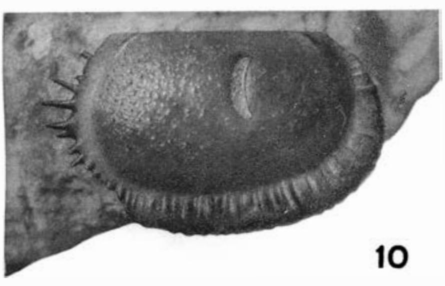
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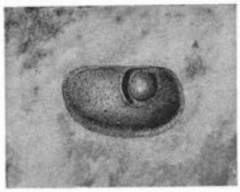
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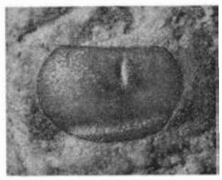
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Plate 4.

All specimens figured in this plate — except fig. 11 — belong to S. G. U. (Figs. 1—7, 9—11, J. W. Englund phot. & ret.; figs. 8, 12—15, C. Larsson phot., P. Thorslund ret.)

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»	12—13.	*Conchoprimitia elongata* n. sp. Nearly complete specimen in lateral aspects × 10. Holotype. Chasmops conglomerate. Hallen. Jemtland	162
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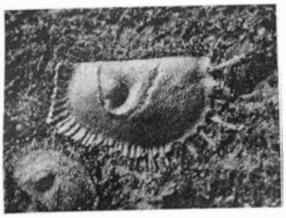
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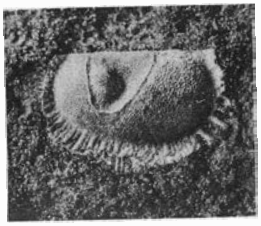
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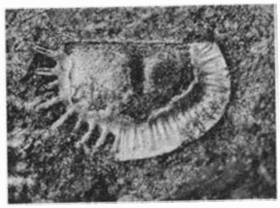
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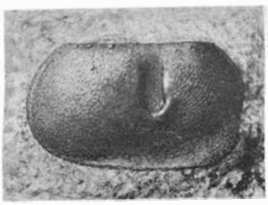
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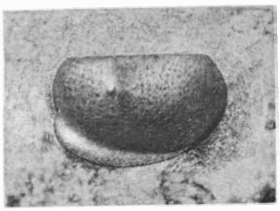
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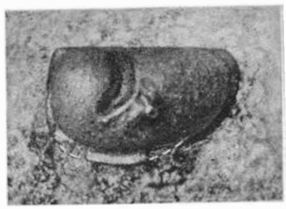
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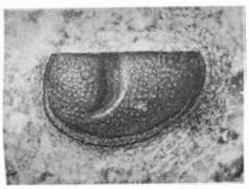
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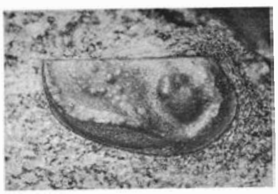
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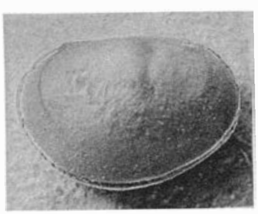
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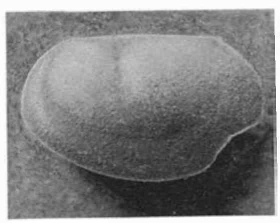
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Plate 5.

(Figs. 1—6, C. Larsson phot., P. Thorslund ret.; figs. 7, J. W. Englund phot. & ret.; figs. 8—13, P. Thorslund and M. Ferm phot., S. Ekblom ret.)

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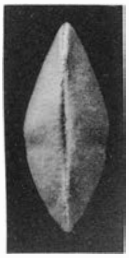

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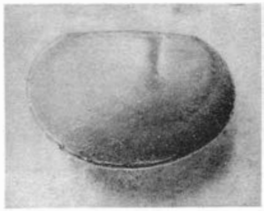

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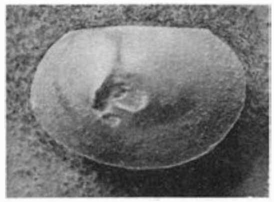

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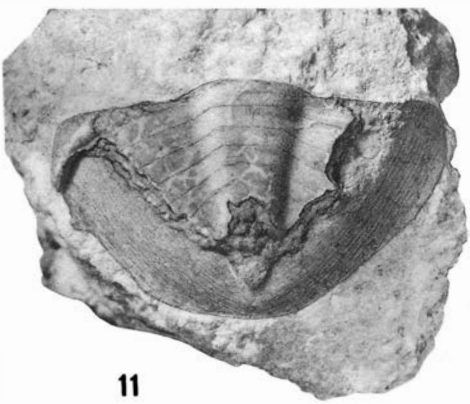

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Plate 6.

All specimens figured in this plate have been obtained from lower Chasmops limestone. (Figs. 1, 2, 5, 6, 8—14, J. W. Englund phot. & ret.; figs. 3, 4, 15, 16, C. Larsson phot., P. Thorslund ret.; fig. 7, P. Thorslund phot., S. Ekblom ret.)

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Figs.	1—10.	*Stygina ? nitens* (Wiman) 1. Cranidium, retouched to show the location of the glabellar muscle spots, × 2. 2. The same specimen prepared with ammonium chloride. Part of a free cheek (with the point of the spine broken off) juts out to the right in front of the cranidium, × 2. Hallen, Jemtland, S. G. U. 3—4. Small cranidium × 2 and × 10, respectively. 5. Labrum probably belonging to this species × 10. 6. Pygidium, partly exfoliated × 2. (3—6) Central Lockne area. S. G. U. 7. Internal cast of fragmentary pygidium × 1. Tvären. U. M. 8—9. Pygidium and enlarged right part of it × 2 and × 5, respectively. 10. Small pygidium × 5. (8—10) Central Lockne area. S. G. U.	137
»	11.	*Bronteopsis concentrica* (Linrs.). Pygidium × 5. Central Lockne area. S. G. U.	139
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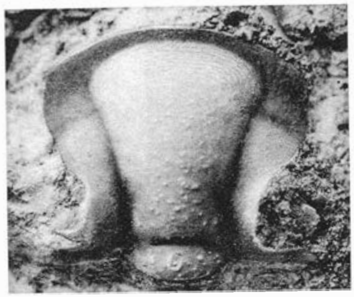
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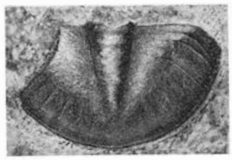
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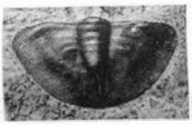
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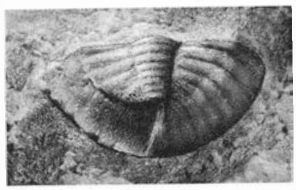
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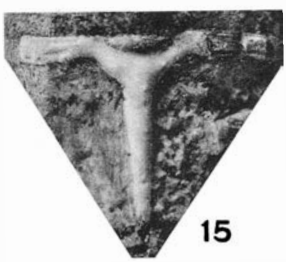
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Plate 7.

(Figs. 1—13, J. W. Englund phot. & ret.; figs. 14—16, C. Larsson phot., P. Thorslund ret.; figs. 17—20, P. Thorslund and M. Ferm phot., S. Ekblom ret.)

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Figs. 1—9.	*Remopleurides validus* n. sp.	132
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» 10—13.	*Remopleurides wimani* n. sp.	135
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» 17—20.	*Remopleurides nanus elongata* FR. SCHMIDT	131
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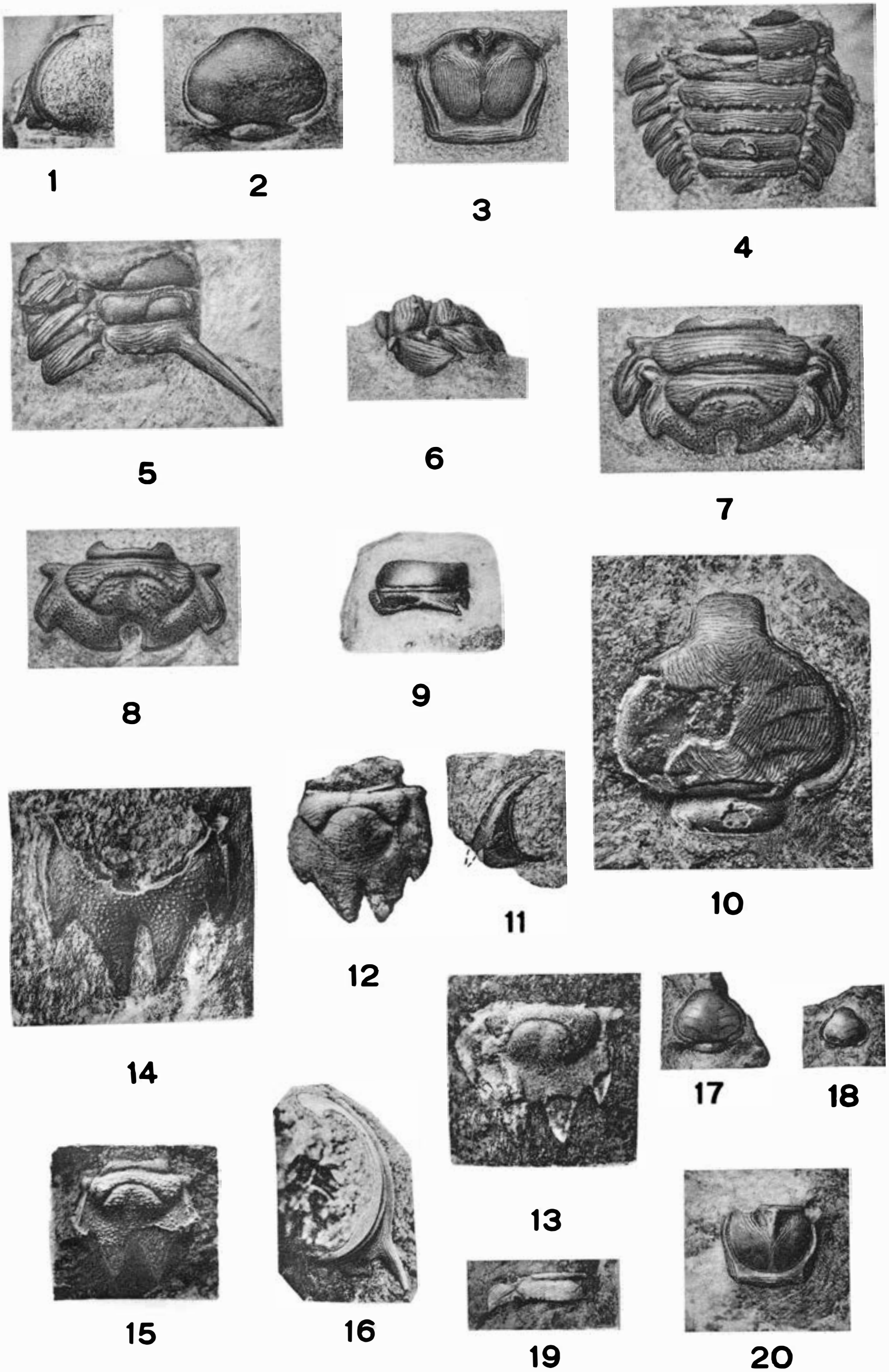

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Plate 8.

All specimens figured in this plate occur in lower Chasmops limestone. (Figs. 1—6, 13, P. Thorslund and M. Ferm phot., S. Ekblom ret.; figs. 7—12, J. W. Englund phot. & ret.)

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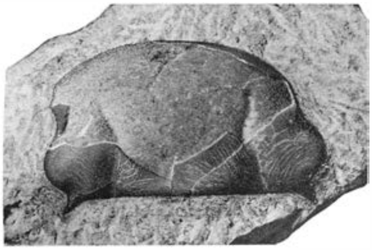
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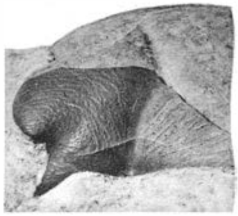
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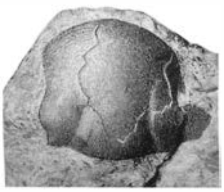
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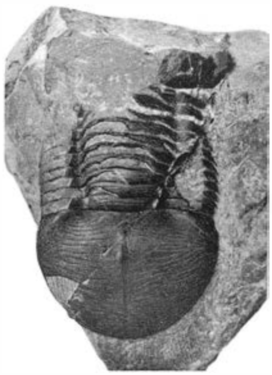
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Plate 9.

(Figs. 1, 10, 11, G. Ahl phot., S. Ekblom ret.; fig. 3, C. Larsson phot.; figs. 4—8, P. Thorslund and M. Ferm phot., S. Ekblom ret.; fig. 9, J. W. Englund phot. & ret.)

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»	7—8.	*Pseudasaphus* cf. *tecticaudatus* var. *laurssoni* ÖPIK. Imperfect hypostomata × 1. Lower Chasmops limestone. Tvären. U. M.	137
»	9.	*Trinodus armatus* n. sp. Cephalon × 4. Holotype. Lower Chasmops limestone. Central Lockne area. S. G. U.	127
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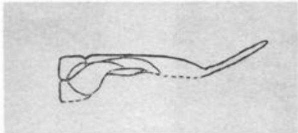

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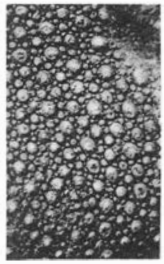

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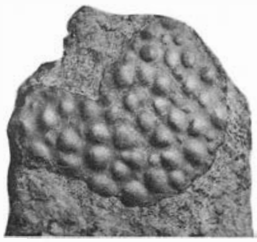

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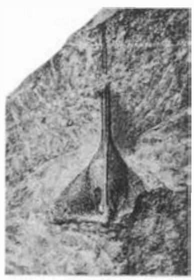

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Plate 10.

All specimens figured in this plate occur in lower Chasmops limestone. (Figs. 1—13, 22, C. Larsson phot., P. Thorslund ret.; figs. 14—19, J. W. Englund phot. & ret.; figs. 20, 21, P. Thorslund phot., S. Ekblom ret.)

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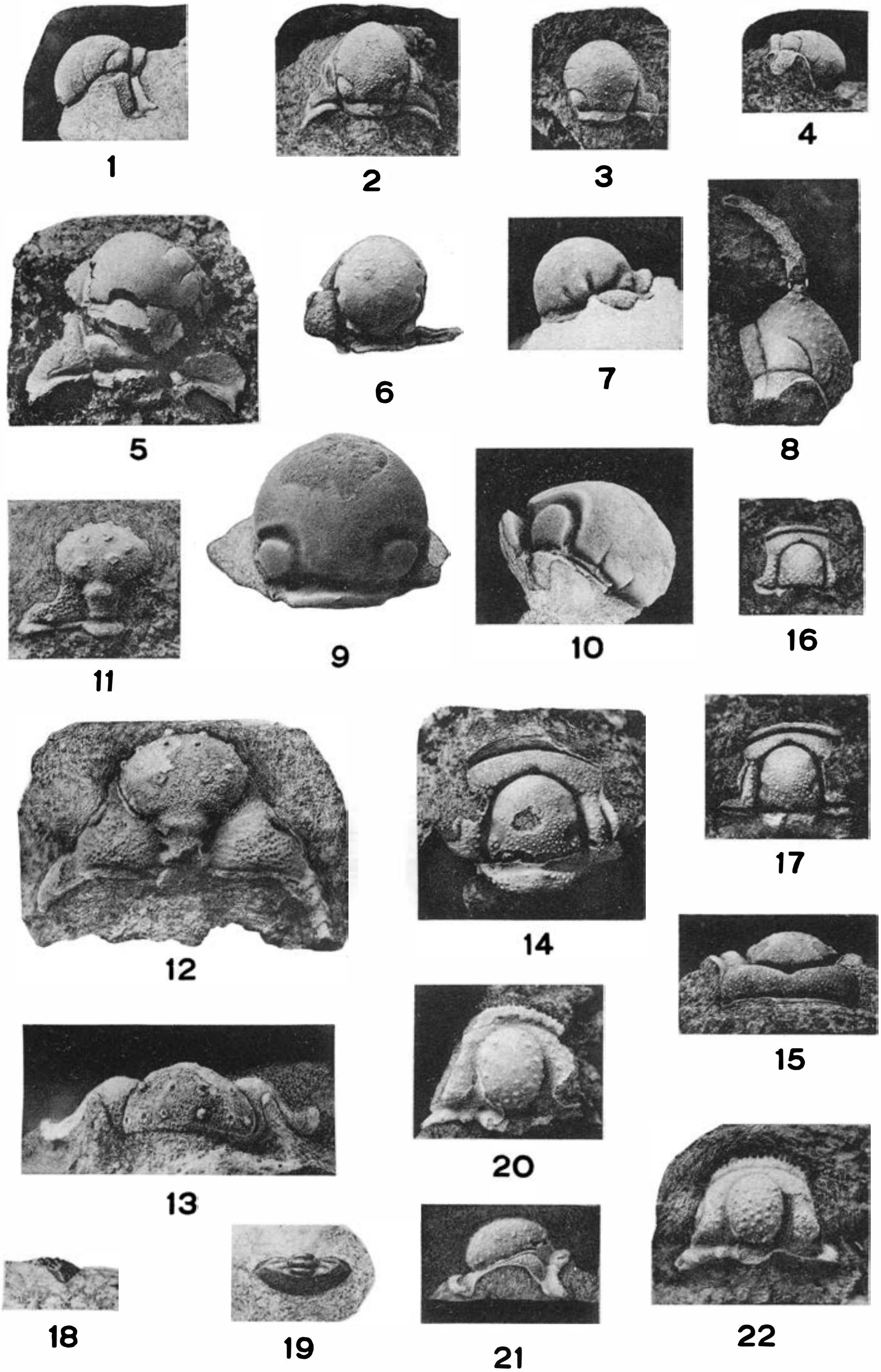

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Plate 11.

All specimens figured in this plate occur in lower Chasmops limestone. (Figs. 1—11, P. Thorslund and M. Ferm phot., S. Ekblom ret.; figs. 12—18, C. Larsson phot., P. Thorslund ret.)

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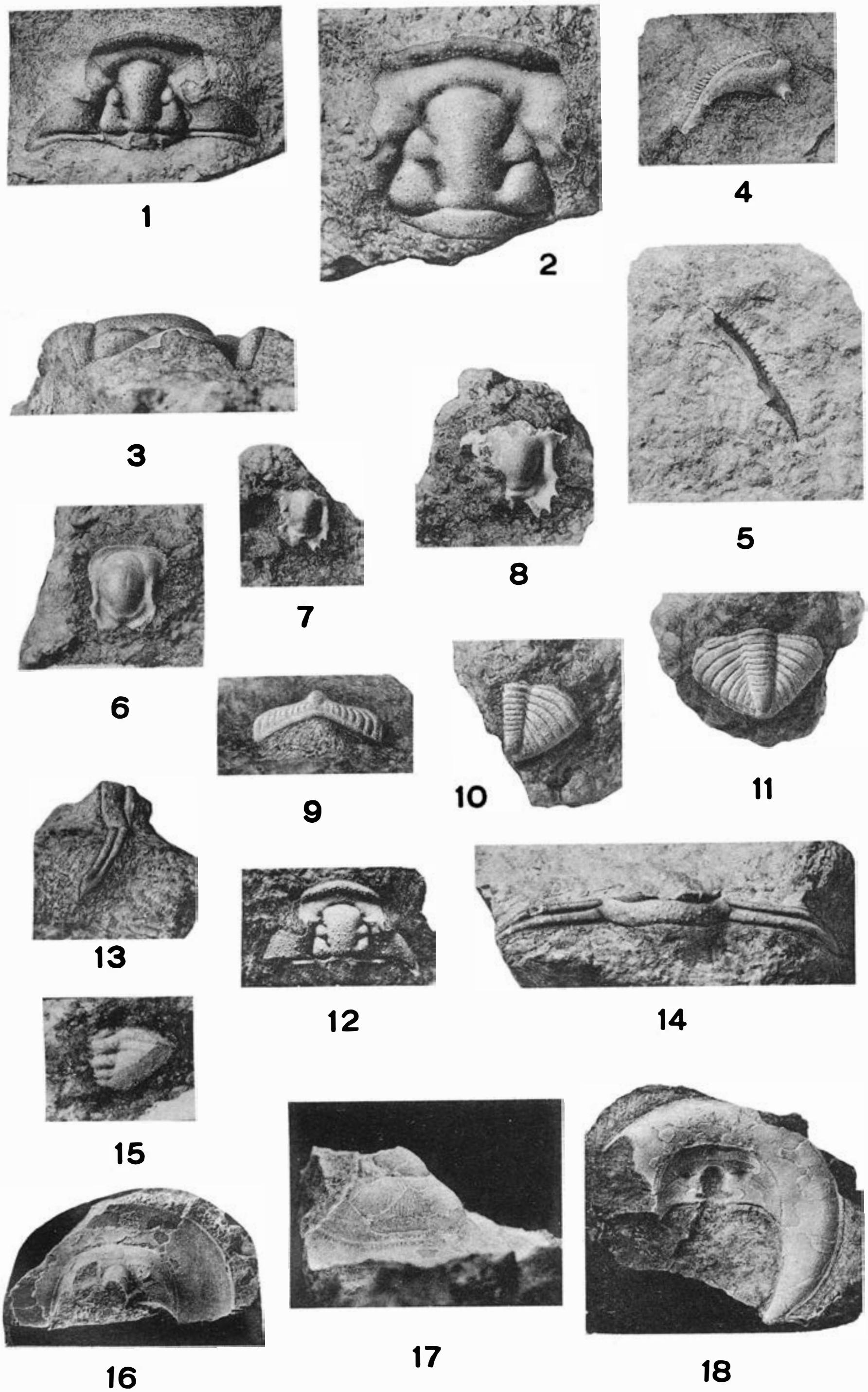

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Plate 12.

All specimens figured in this plate belong to S. G. U. (Figs. 1—3, 17, J. W. Englund phot. & ret.; figs. 4—8, 11—13, 15, G. Ahl phot., S. Ekblom ret.; figs. 9, 10, 14, 16, 18—21, C. Larsson phot., P. Thorslund ret.)

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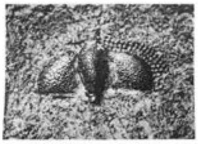
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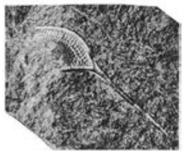
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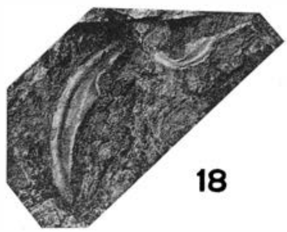
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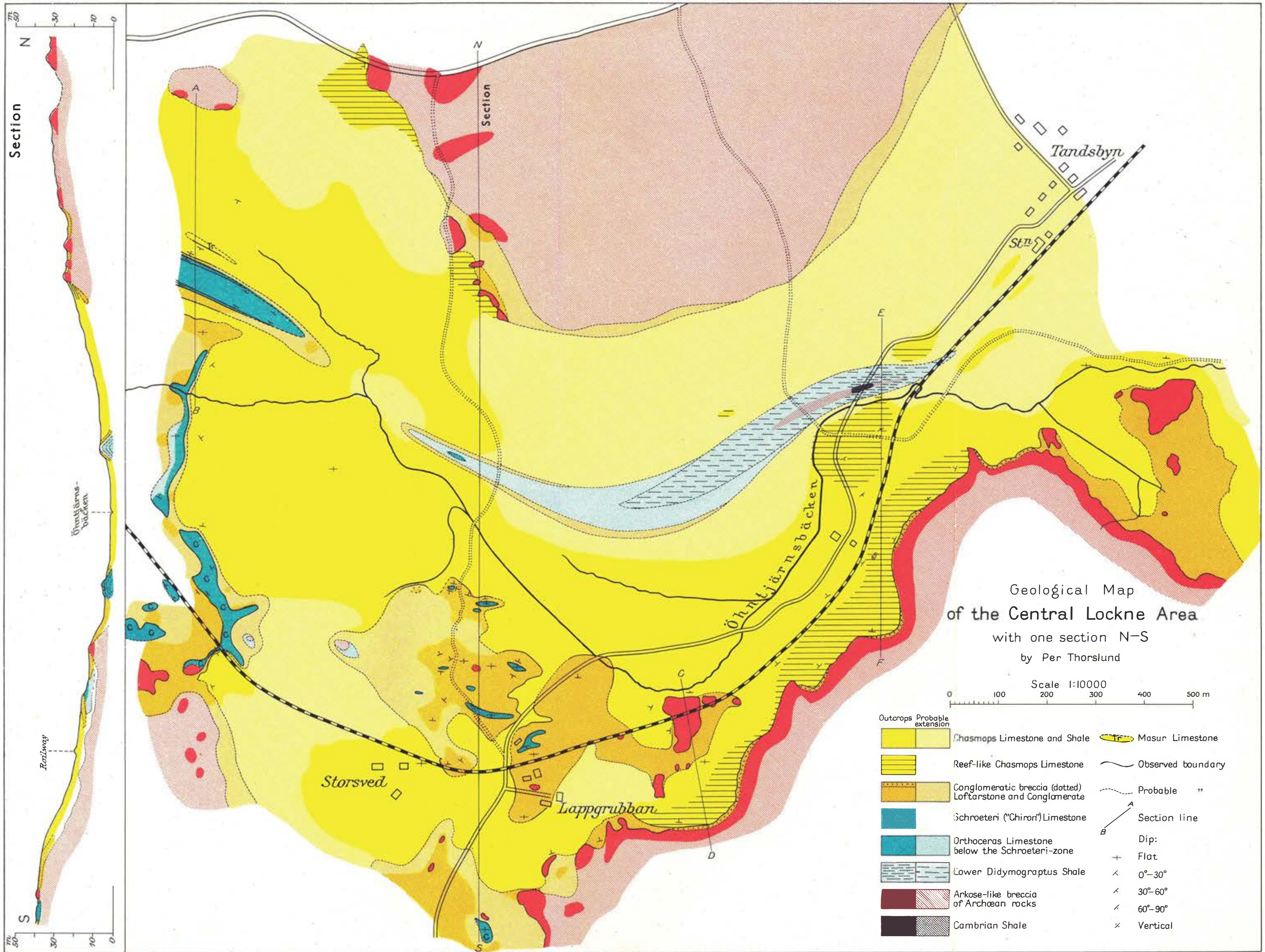

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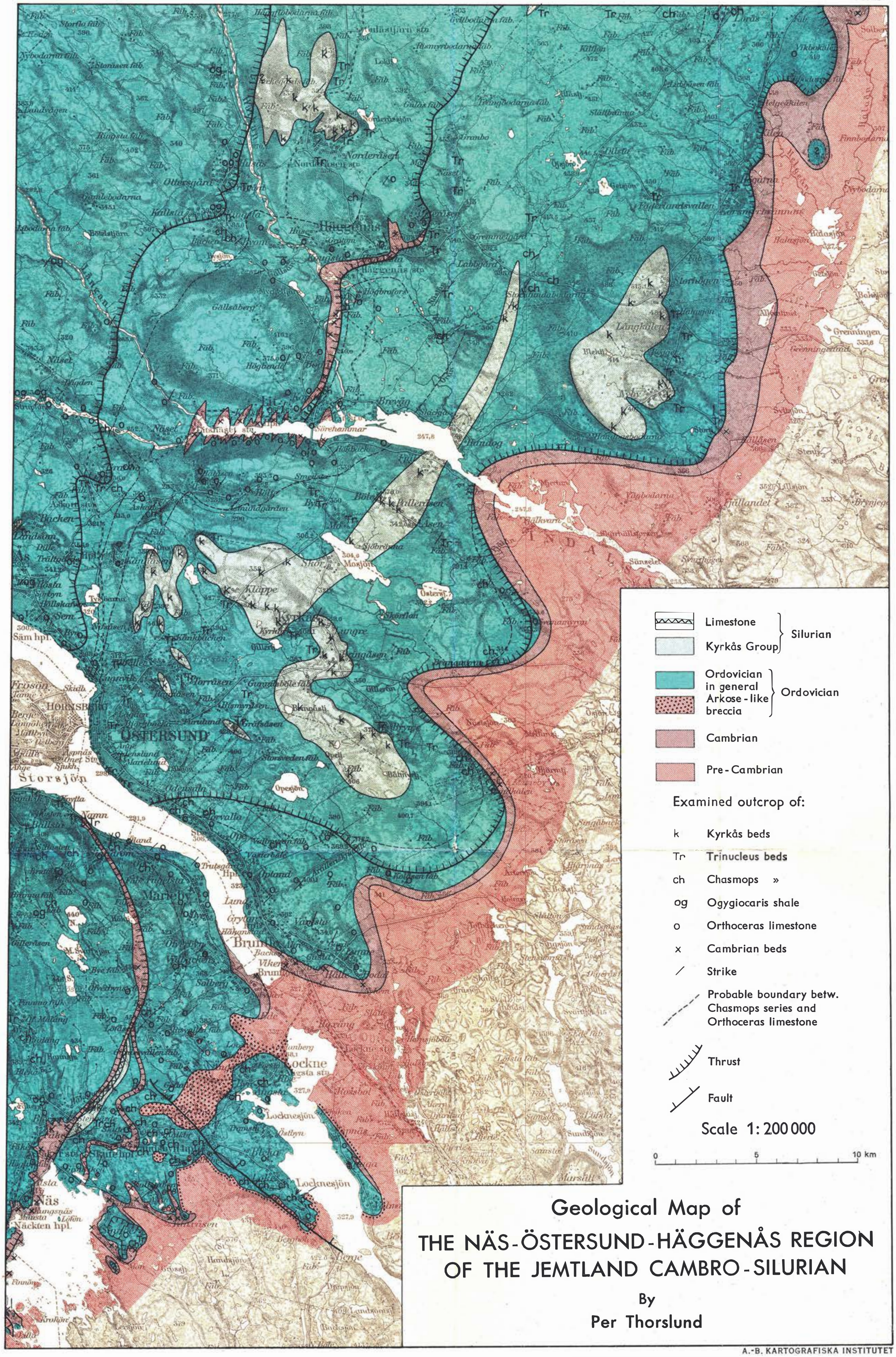

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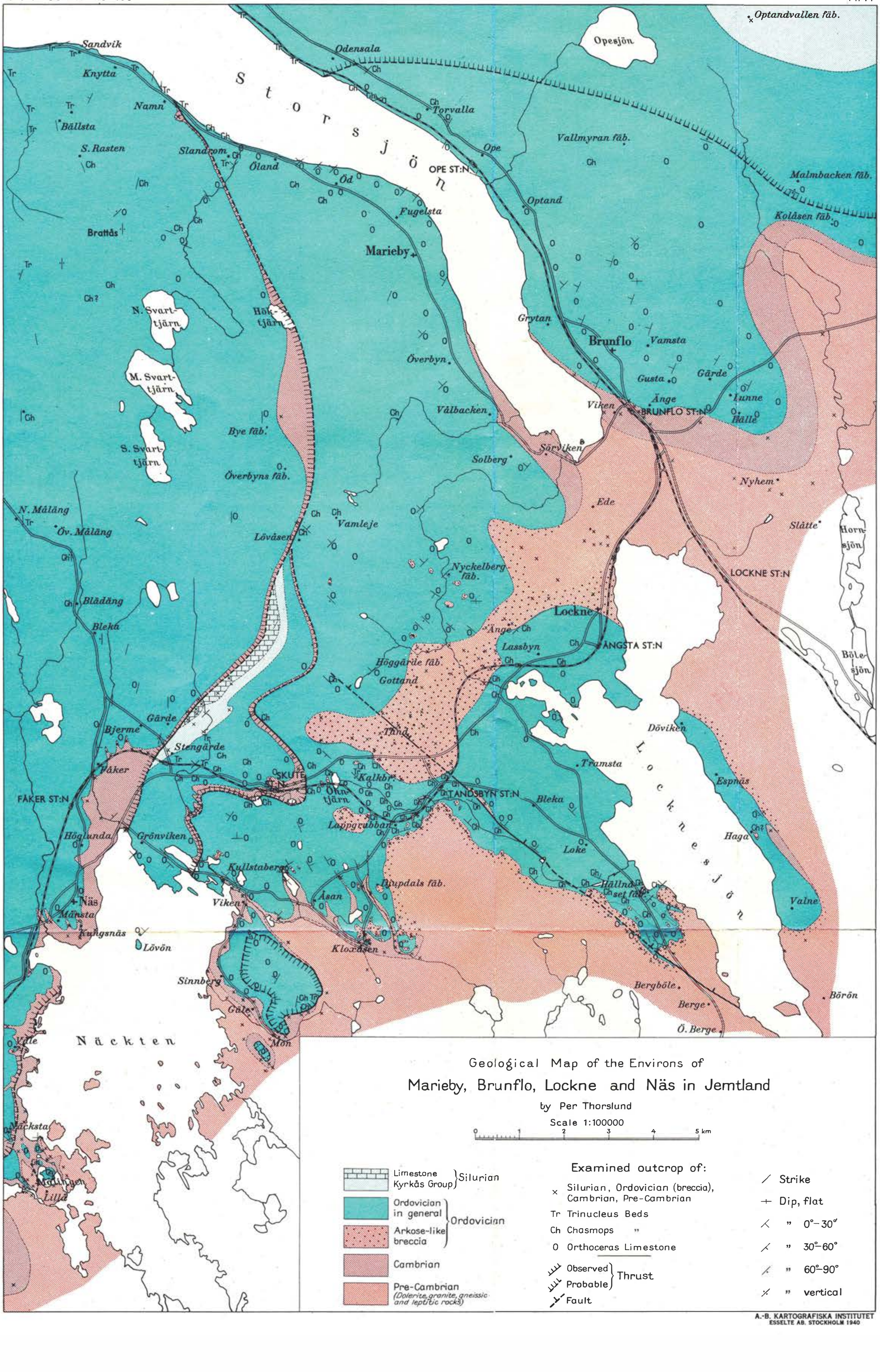

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Errata

in The Chasmops Series of Jemtland and Södermanland

by *Per Thorslund.*

Page 71. Line 1: p. 00. read pp. 184—187.
Page 85. Line 10: Berme read Bjerme.
Page 92. Line 2: Högfors read Högbrofors.
Page 103. Fourth passage, line 4: fig. 9 read fig. 6.
Line 5 from below: Bjerme read Brynje.
Page 111. Line 8 from below: More seldom it is read is it.
Page 136. Line 8: materiala vailable read material available.
Page 139. Line 18: *Bronteus* read *Scutellum.*
Page 143. Line 11 from below: charactaristic read characteristic.
Page 144. Fourth passage, line 3: p. 37 read 22.
Page 145. Line 2: a pair of faceted half ribs read a faceted half rib.
Page 148. Fam. ***Cyphaspidae*** SALTER read ***Otarionidae*** R. et E. RICHTER.
Page 149. Foot-note: cranidium read pygidium.
Page 150. Line 16 from below: axial read facial.
Line 14 » » : backwards; read backwards,
Page 152. Line 5: *minitus* read *minutus.*
Fam. ***Harpedidae*** read ***Harpidae.***
Page 154. Line 12 from below: transverse occipital read transverse; occipital.
Page 155. Fam. ***Lichadidae*** read ***Lichidae.***
Page 165. Sixth passage, line 6: *Pr. locknensis* read *Eupr.* (?) *locknensis.*
Page 173. Line 5 from below: posterior lobe read anterior lobe.
Page 179. Line 1, below *Dimensions:* The figured specimen add in Pl. 3, fig. 12.
Page 180. Line 6 from below: besides read except.
Plate 1. Line 9: One male (9) two read and two.
Plate 5. Line 1: figs. 7 read fig. 7.
Plate 7. Line 5 from below: *elongata* read *elongatus.*
Plate 8. Line 2 from below: *kuckersiana* read *kuckersianus.*
Plate 10. Line 14: *Longispinus* read *longispinus.*

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